Permit

Environmental Protection Act 1994

Environmental authority EPML00853413

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML00853413

Environmental authority takes effect on 26 February 2024

Environmental authority holder(s)

Name(s)	Registered address
QCT MINING PTY. LTD.	Level 16 480 Queen Street BRISBANE CITY QLD 4000 Australia
QCT Resources Pty Limited	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
QCT INVESTMENT PTY. LTD.	Level 16 480 Queen Street BRISBANE CITY QLD 4000 Australia
BHP COAL PTY LTD	Level 14, 480 Queen Street BRISBANE CITY QLD 4000 Australia
BHP Queensland Coal Investments Pty Ltd	Level 14, 480 Queen Street BRISBANE CITY QLD 4000
Mitsubishi Development Pty Ltd	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
Umal Consolidated Pty Ltd	Level 14, 480 Queen Street BRISBANE CITY QLD 4000

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Schedule 3 13: Mining black coal	ML70287 ML70494 ML1763 ML70288 ML70469 ML70421 ML70478 ML70479 ML70468 ML1802 ML70121 ML70493 ML1764 ML70289 ML70194 ML1900 ML700003 ML70193
Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)	ML70468 ML1802 ML70121 ML70493 ML1764 ML70289 ML70194 ML1900 ML700003 ML70287 ML70193 ML70494 ML1763 ML70288 ML70469 ML70421 ML70479 ML70478

Queensland Government

Environmentally relevant activity/activities	Location(s)
Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t	ML70468 ML1802 ML70121 ML70493 ML1764 ML70289 ML70194 ML1900 ML700003 ML70193 ML70287 ML70479 ML70494 ML1763 ML70288 ML70469 ML70421 ML70478 ML70479
Ancillary 56 - Regulated Waste Storage Receiving and storing regulated waste	ML70289 ML70194 ML1900 ML700003 ML70193 ML70287 ML70494 ML1763 ML70288 ML70469 ML70421 ML70478 ML1764 ML70479 ML70468 ML1802 ML70121 ML70493
Ancillary 60 - Waste disposal 2: Operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b) (h) more than 200,000t	ML1763
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (c) more than 1,500 but not more than 4,000EP	ML1802 ML70121 ML70493 ML1764 ML70289 ML70194 ML1900 ML700003 ML70193 ML70287 ML70494 ML1763 ML70288 ML70469 ML70421 ML70478 ML70468

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days) that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise- one the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Planning Act 2016* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

Juliana Mccosker
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

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Date Issued: 26 February 2024

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Other permits required

This permit only provides an approval under the *Environmental Protection Act 1994*. In order to lawfully operate you may also require permits / approvals from your local government authority, other business units within the department and other State Government agencies prior to commencing any activity at the site. For example, this may include permits / approvals with your local Council (for planning approval), the Department of Transport and Main Roads (to access state controlled roads), the Department of Natural Resources, Mines and Energy (to clear vegetation), and the Department of Agriculture and Fisheries (to clear marine plants or to obtain a quarry material allocation).

Conditions of environmental authority

Schedule A: General	
Condition number	**Condition**
A1	This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
A2	**Prevent and /or minimise likelihood of environmental harm** In carrying out the environmentally relevant activities, the environmental authority holder must take all reasonable and practicable measures to prevent and/or to minimise the likelihood of environmental harm being caused. Any environmentally relevant activity, that, if carried out incompetently, or negligently, may cause environmental harm, in a manner that could have been prevented, shall be carried out in a proper manner in accordance with the conditions of this environmental authority.
A3	**Maintenance of measures, plant and equipment** The environmental authority holder must ensure: a) that all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority are installed; b) that such measures, plant and equipment are maintained in a proper condition; c) that such measures, plant and equipment are operated in a proper manner; and d) that all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.
A4	**Monitoring and records** Except where specified otherwise in another condition of this environmental authority, all monitoring records and reports required by this environmental authority must be kept for a period of not less than **five (5) years**.
A5	Monitoring and determinations required under any condition of this environmental authority must be conducted by an appropriately qualified person(s).
A6	Upon request from the administering authority, copies of monitoring results, records, registers, management plans and reports required by the conditions of this environmental authority must be made available and provided to the administering authority within **ten (10) business days** or an alternative timeframe agreed between the administering authority and the environmental authority holder.
A7	**Notification of emergencies, incidents and exceptions** The environmental authority holder must notify the administering authority by written notification within **twenty-four (24) hours** after becoming aware of any emergency or incident that results in the release of contaminants not in accordance, or reasonably expected to be not in accordance, with the conditions of this environmental authority.

A8	Within **ten (10) business days** following the initial notification under condition **A7**, or the receipt of monitoring results associated with the notification made under condition **A7**, whichever is the latter, the environmental authority holder must provide further written advice to the administering authority, including the following: a) results and interpretation of any samples taken and analysed; b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and c) proposed actions to prevent a recurrence of the emergency or incident.
A9	**Complaints** The environmental authority holder must record all environmental complaints received about the mining activities, including: a) name, address and contact number for of the complainant; b) time and date of complaint; c) reasons for the complaint; d) investigations undertaken; e) conclusions formed; f) actions taken to resolve the complaint, including the use of appropriate dispute resolution if required; g) any abatement measures implemented; and h) person responsible for resolving the complaint.
A10	A register of alternative arrangements must be established and maintained by the environmental authority holder. The register must include: a) the location to which the alternative arrangement applies; b) the period of the alternative arrangement; c) details about the particular environmental nuisance impact or impacts the arrangement is for; and d) details about the mitigation measures, where relevant.
A11	**Monitoring on request** When requested by the administering authority, the environmental authority holder must investigate any nuisance, or contaminant release, or environmental harm, or complaint that is neither frivolous nor vexatious in the opinion of the authorised person, by: a) undertaking the monitoring specified by the administering authority; b) undertaking the monitoring in the timeframe nominated or agreed to by the administering authority; c) completing an analysis and interpretation of the monitoring results; and d) implementing abatement measures, where required.

A12	The results of the investigation undertaken in accordance with condition **A11** must be provided to the administering authority within **twenty (20) business days** of completion of the monitoring timeframe in accordance with condition **A11(b)**, or a longer timeframe agreed to by the administering authority.
A13	No mining to be undertaken on ML70478 and ML70479.

Schedule B: Air	
Condition number	**Condition**
B1	**Odour nuisance** The release of noxious or offensive odour or any other noxious or offensive airborne contaminant resulting from the mining activities must not cause an environmental nuisance, at any sensitive place or commercial place.
B2	If the administering authority determines odour released from the mining activities to constitute an environmental nuisance, the environmental authority holder must immediately implement abatement measures so that emissions from the mining activities do not result in further environmental nuisance.
B3	**Dust nuisance** The release of dust or particulate matter or both resulting from the mining activities must not cause an environmental nuisance, at any sensitive place or commercial place.

B4	Monitoring of dust and particulate matter resulting from the mining activities, undertaken in accordance with condition **A11**, must be carried out at a place relevant to the potentially affected sensitive place or commercial place and must not exceed the following levels when measured at any sensitive place or commercial place: a) dust deposition, measured as total insoluble matter, of 120 milligrams per square metre per day, averaged over one month, when monitored in accordance with the most recent version of Australian Standard *AS3580.10.1 Methods for sampling and analysis of ambient air – Determination of particulate matter – Deposited matter – Gravimetric method*. b) a concentration of particulate matter with an aerodynamic diameter of less than 10 micrometre (PM10) suspended in the atmosphere of 50 micrograms per cubic metre over a 24-hour averaging time, when monitored in accordance with the most recent version of either: i. Australian Standard *AS3580.9.6 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 high volume sampler with size selective inlet – Gravimetric method*; or ii. Australian Standard *AS3580.9.8 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 continuous direct mass method using a tapered element oscillating microbalance analyser*; or iii. Australian Standard *AS3580.9.9 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 low volume sampler – Gravimetric method*; or iv. Australian Standard *AS3580.9.11 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 beta attenuation monitors*. c) a concentration of particulate matter suspended in the atmosphere of 90 micrograms per cubic metre over a 1 year averaging time, when monitored in accordance with the most recent version of either: i. Australian Standard AS3580.9.3 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – Total suspended particulate matter (TSP) – High volume sampler gravimetric method; or ii. any alternative method of monitoring TSP that may be permitted by the Air Quality Sampling Manual as published from time to time by the administering authority. *NOTE: Exceedances due to events that cannot be managed by the environmental authority holder, such as bushfires, fuel reduction burning for fire management purposes or dust storms, would not be considered to be in breach of condition **B4** if the environmental authority holder can demonstrate that the exceedance was caused by such events.*
B5	If monitoring, undertaken in accordance with condition **A11**, indicates exceedance of the relevant limits in condition **B4**, the environmental authority holder must immediately implement abatement measures so that emissions from the mining activities do not result in further environmental nuisance.

Schedule C: Noise and Vibration	
Condition number	**Condition**
C1	**Noise nuisance** Noise from the mining activities must not cause an environmental nuisance, at any sensitive place or commercial place.
C2	Noise is not considered an environmental nuisance under condition **C1** if monitoring shows that noise does not exceed the limits in **Table C1 (Noise Limits)**, at any sensitive place or commercial place.
C3	**Noise monitoring** Noise monitoring, undertaken in accordance with condition **A11**, must comply with the most recent version of the administering authority's *Noise Measurement Manual*, and must include the following descriptors, characteristics and conditions: a) $L_{A10, adj, 10 mins}$; b) $L_{A 1, adj, 10 mins}$; c) the level and frequency of occurrence of impulsive or tonal noise; d) atmospheric conditions including wind speed and direction; e) effects due to extraneous factors such as traffic noise; and f) location, date and time of recording.
C4	If monitoring, undertaken in accordance with condition **A11**, indicates exceedance of the relevant limits in **Table C1 (Noise Limits)**, the environmental authority holder must immediately implement abatement measures so that emissions from the mining activities do not result in further environmental nuisance.

Table C1 (Noise Limits)

Noise Level dB(A)	**Monday to Saturday**			**Sundays and Public Holidays**		
	Day (7am to 6pm)	**Evening (6pm to 10pm)**	**Night (10pm to 7am)**	**Day (9am to 6pm)**	**Evening (6pm to 10pm)**	**Night (10pm to 9am)**
Sensitive Place						
$L_{A10, adj, 10 mins}$	B/g + 5	B/g + 5	B/g + 0	B/g + 5	B/g + 5	B/g + 0
$L_{A1, adj, 10 mins}$	B/g + 10	B/g + 10	B/g + 5	B/g + 10	B/g + 10	B/g + 5
Commercial Place						
$L_{A10, adj, 10 mins}$	B/g + 10	B/g + 10	B/g + 5	B/g + 10	B/g + 10	B/g + 5
$L_{A1, adj, 10 mins}$	B/g + 15	B/g + 15	B/g + 10	B/g + 15	B/g + 15	B/g + 10

C5	**Vibration nuisance** Vibration from the mining activities must not cause an environmental nuisance, at any sensitive place or commercial place.
C6	Vibration is not considered an environmental nuisance under condition **C5** if monitoring shows that vibration does not exceed the limits specified in **Table C2 (Vibration Limits)**.
C7	**Airblast overpressure nuisance** The airblast overpressure level from blasting operations on the mining leases must not cause an environmental nuisance, at any sensitive place or commercial place.
C8	Airblast overpressure is not considered an environmental nuisance under condition **C7** if monitoring shows that airblast overpressure does not exceed the levels specified in **Table C3 (Airblast Overpressure Level)**.
C9	**Vibration and/or airblast overpressure monitoring** Vibration and/or airblast overpressure monitoring, undertaken in accordance with condition **A11**, must comply with the most recent version of the administering authority's *Noise Measurement Manual*, and must include the following descriptors, characteristics and conditions: a) location of the blast(s) within the mining area (including which bench level); b) atmospheric conditions including temperature, relative humidity and wind speed and direction; and c) location, date and time of recording.
C10	If monitoring, undertaken in accordance with condition **A11**, indicates exceedance of the relevant limits in **Table C2 (Vibration Limits)** or **Table C3 (Airblast Overpressure Level)**, the environmental authority holder must immediately implement abatement measures so that emissions from the mining activities do not result in further environmental nuisance.
C11	The environmental authority holder cannot undertake any blasting on ML70478 and ML70479.

Table C2 (Vibration Limits)

Location	Vibration Measured
Sensitive place or commercial place	5 mm/s peak particle velocity for nine (9) out of ten (10) consecutive blasts and not greater than 10 mm/s peak particle velocity at any time.

Table C3 (Airblast Overpressure Level)

Location	Airblast Overpressure Measured
Sensitive place or commercial place	115 dB (Linear peak) for nine (9) out of ten (10) consecutive blasts and not greater than 120 dB (Linear peak) at any time.

Schedule D: Waste	
Condition number	**Condition**
D1	**Waste management** A Waste Management Plan must be developed by an appropriately qualified person and implemented. The Waste Management Plan must include, but is not limited to: a) a description of the mining activities that may generate waste; b) a description of all waste activities being carried out; c) the location/s (including GPS coordinates) of where all waste activities are, or have been, carried out, including: i. the type of waste disposed of, treated, or reprocessed; and ii. the volume of waste disposed of, treated, or reprocessed; d) identification of the potential risks to the environment from all waste activities carried out; e) control measures to be implemented to minimise the potential for environmental harm associated with carrying out of the waste activities, including but not limited to: i. segregation of the wastes; ii. storage of the wastes; iii. transport of the wastes; and iv. monitoring and reporting matters concerning the wastes; f) how the waste will be managed with in accordance with the waste management hierarchy (that is, avoid, reuse, recycling, energy recovery, disposal); g) the hazardous characteristics of the wastes generated including disposal procedures for hazardous wastes; h) procedures for reprocessing waste in accordance with condition **D4**; i) procedures for managing accidents, spills and other incidents; j) the indicators or other criteria on which the performance of the waste management plan will be assessed; k) staff training; and l) reference to the Groundwater Monitoring and Management Program for the general waste landfill.
D2	The environmental authority holder must submit the Waste Management Plan required by condition **D1** to the administering authority prior to commencing a new process, or varying an existing process, for reprocessing any waste.
D3	**Waste receipt** The only waste permitted to be received is: a) the types of waste specified in conditions **D5** to **D8** (inclusive); and b) sewage and sludge for treatment in accordance with **Schedule H: Sewage Treatment**; and c) from a BHP Billiton Mitsui Coal (BMC) or BHP Mitsubishi Alliance (BMA) site in Queensland.

D4	**Waste reprocessing** The only waste permitted to be reprocessed is: a) spoil or overburden; b) vegetation; c) water or sediment containing hydrocarbons; d) fuels, oils, lubricants and coolants; e) bulk rubber; f) inert waste; g) poly-pipe and other plastic; h) fibreglass; i) treated and untreated timber; and j) asphalt.
D5	**Waste disposal** Unless otherwise specified in conditions **D6** to **D8** (inclusive), waste, other than spoil or overburden or vegetation removed as part of the mining activity, must not be disposed of within the mining leases listed on this environmental authority and must be taken to a facility that is lawfully allowed to accept such waste under the provisions of the *Environmental Protection Act 1994*.
D6	The following types of waste are permitted to be disposed of within the specified features for the waste type: a) rejects and sediment containing hydrocarbons: i. in spoil emplacements; and ii. in regulated structures in accordance with **Schedule G: Structures** of this environmental authority; and iii. in pits or voids; and iv. in dedicated rejects emplacements; and b) tailings and water or sediment containing hydrocarbons: i. in regulated structures in accordance with **Schedule G: Structures** of this environmental authority; and ii. in pits or voids that are not regulated structures, provided a consequence category assessment in accordance with condition **G1** has been completed.

D7	The following types of waste are permitted to be disposed of within the mining leases listed on this environmental authority: a) bulk rubber; a) inert waste; b) poly-pipe and other plastic; c) fibreglass; d) treated and untreated timber; e) asphalt; and f) asbestos. These types of waste may be disposed of: a) in pits or voids; b) in spoil emplacements; and c) left insitu below ground level.
D8	General waste can only be disposed of into the general waste landfill on ML1763 and identified in **Figure 1 (General Waste Landfill Location)**, which must be operated in accordance with the Waste Management Plan as described by condition **D1**.

Schedule E: Land	
Condition number	**Condition**
E1	**Topsoil** Topsoil must be strategically stripped ahead of mining in accordance with a Topsoil Management Plan.
E2	A topsoil inventory, which identifies the topsoil requirements for rehabilitation and availability of suitable topsoil on site, must be provided with any Estimated Rehabilitation Cost application.
E3	**Rehabilitation landform criteria** Unless otherwise permitted under the conditions of this environmental authority, all areas significantly disturbed by mining activities must be rehabilitated in accordance with **Table E1 (Rehabilitation Requirements)**.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Cattle grazing	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
		Rehabilitation is erosionally stable	Extent, slope gradient and groundcover	1. Groundcover >50% 2. 70% of slopes ≤20%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation is suitable for sustainable cattle grazing	Land suitability assessment for cattle grazing	Land suitability class ≤3 or not different from pre-mining class if ≥4. Assessment completed in accordance with *LSA Framework for Open-Cut Coal Mine Rehabilitation 2018 (A rule-set for land suitability assessment of sustainable beef cattle grazing on land rehabilitated after open-cut coal mining in the Bowen Basin Queensland)* unless otherwise agreed in writing between the administering authority and the environmental authority holder.
			Leucaena stem density	<250 stems >2m height per ha (1 per 40m^2), mean total area

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Dryland cropping	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
		Rehabilitation is erosionally stable	Percentage of cultivation at >1% slope gradient with functional contour banks	100% of rehabilitated areas
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation is suitable for sustainable dryland cropping	Land suitability assessment for dryland cropping	Land suitability class ≤3 or not different from pre-mining class if ≥4. Assessment completed in accordance with the *Regional Land Suitability Frameworks for Queensland 2013* unless otherwise agreed in writing between the administering authority and the environmental authority holder.
Woodland habitat	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5 unless an alternative is justified by an appropriately qualified person
		Rehabilitation is erosionally stable	Groundcover (steep slopes, >15%)	80%
			Groundcover (lesser slopes, ≤15%)	50%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-	Native bushland characteristics	Species richness Trees Shrubs Grasses	 ≥2 ≥3 ≥4

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
	mining land use		Tree canopy cover	≥16%
Water Storage	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of Safety	≥1.5
		Rehabilitation is erosionally stable (banks and immediate surrounds)	Groundcover	>50%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation retains water that is a potential resource for cattle grazing, with quality according to ANZECC guidelines version October 2000	TDS Calcium Magnesium Nitrate Nitrite Sulphate	≤5,000mg/L ≤1,000mg/L ≤2,000mg/L ≤400mg/L ≤30mg/L ≤1,000mg/L
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

E4	Progressive rehabilitation must commence within **two (2) years** when areas become available within the mining leases.
E5	Complete an investigation into rehabilitation of disturbed areas and submit a report to the administering authority proposing acceptance criteria for Department review and comment. The investigation report must be reviewed and updated every **three (3) years**, commencing on **30 June 2008**. The Rehabilitation Management Plan must include, at a minimum: a) map existing areas of rehabilitation; b) develop design objectives for rehabilitation of disturbed areas and post mining land uses across the mine; c) specify spoil characteristics, soil analysis, soil separation for use on rehabilitation; d) detail rehabilitation methods applied to areas; e) contain landform design criteria including end of mine design; f) detail how landform design will be consistent with the surrounding topography; g) identify success criteria for areas and itemize revegetation criteria; h) explain planned native vegetation rehabilitation areas and corridors; i) identify at least a minimum of three (3) reference and three (3) rehabilitation sites to be used to develop rehabilitation success criteria; j) describe rehabilitation indicators and the monitoring program to be used; k) develop a contingency plan for rehabilitation maintenance or redesign; l) describe end of mine landform design plan and post mining land uses across the mine; and m) include a cost benefit analysis / triple bottom line assessment (or an alternative assessment method) of the proposed final landform design criteria and alternatives.
E6	**Residual void outcome** Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.

E7	Complete an investigation into residual voids and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in condition **E6** and landform design criteria in **Table E2 (Rehabilitation Design Parameters)** and must be reviewed and updated every **three (3) years**, commencing on **30 June 2008**. The investigation must include the following, at a minimum: a) a study of options available for minimising final void area and volume; b) a void hydrology study, addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term; c) a pit wall stability study, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events; d) a hydrological study into the long-term risk of the Isaac River / final void interaction, including erosion of the banks and spoil and extreme hydrological events, and the consequences of such interaction to the long-term stability of the final voids; e) a study of void capability to support native flora and fauna; f) proposal/s for end of mine void rehabilitation success criteria and final void areas and volume; and g) the recommendations of these studies are to be followed during the life of the mine, and will include detailed research and modelling.

Table E2 (Landform Design Parameters)

Rehabilitation Area	Design Criteria	Qualifications
Final high walls: Competent rock Incompetent rock	 <65° slope <17° slope	Competency certified by an appropriately qualified professional accredited by a credible third party
Low walls	<17° slope	Angle of repose / benched / graded

E8	**Preventing contaminant release to land** Contaminants must not be released to land in manner that constitutes a nuisance, material harm or serious environmental harm.
E9	**Storage and handling of chemicals and flammable or combustible liquids** All chemicals and flammable or combustible liquids must be stored and handled in accordance with the most recent version of an Australian Standard where such is applicable. Where no relevant Australian Standard exists, store such materials within an effective on-site containment system.
E10	**Infrastructure** All infrastructure, constructed by or for the environmental authority holder during the mining activities including water storage structures, must be removed from the site prior to surrender, except where agreed in writing by the post mining landowner/ landholder. *NOTE: This is not applicable where the landowner/ landholder is also the environmental authority holder.*

E11	**Exploration** The environmental authority holder must rehabilitate in accordance with this environmental authority, any disturbance from mining activities which were undertaken under: a) this environmental authority; or b) any other environmental authority that applied to the land that is the subject of this environmental authority.
E12	**Subsidence** The post mining land use for areas affected by subsidence as a result of underground mining, except for watercourse subsidence that is subject to **Schedule H: Watercourse Subsidence**, must be: a) if agricultural land use prior to mining – agricultural land use; or b) if a land use other than agricultural use – the same land use as existed prior to mining.
E13	Subsidence management procedures must be developed and implemented during the continuation of the environmental authority, except for watercourse subsidence that is subject to **Schedule H: Watercourse Subsidence**. The subsidence management strategies must be detailed in the Subsidence Management Plan and must at a minimum include: a) subsidence modelling prior to mining; b) rehabilitation methodology; and c) land management practices pre and post subsidence.
E14	No subsidence permitted on ML70478 and ML70479.
E15	**Impacts to Prescribed Environmental Matters** No impact on State Significant Biodiversity Values (SSBV) or Matters of State Environmental Significance (MSES) on ML70478 and ML70479.
E16	Impacts to Matters of State Environmental Significance (MSES) on ML1763 that are associated with Red Hill Mine are only authorised to occur in accordance with the conditions of the Red Hill Mine Environmental Authority EPML03337715.

Schedule F: Water	
Condition number	**Condition**
F1	**Contaminant Release** Contaminants that will or have the potential to cause environmental harm must not be released directly or indirectly to any waters as a result of the mining activities, except as permitted under the conditions of this environmental authority.
F2	Unless otherwise permitted under the conditions of this environmental authority, the release of mine affected water to waters must only occur from the release points specified in **Table F1 (Mine Affected Water Release Points)**.
F3	The release of mine affected water to internal water management infrastructure that is installed and operated in accordance with a Water Management Plan that complies with conditions **F28** to **F29** inclusive is permitted.

Table F1 (Mine Affected Water Release Points)

Release Point (RP)	Easting (GDA94)	Northing (GDA94)	Mine Affected Water Source and Location	Monitoring Point	Receiving Waters Description
RP1	602621	7588947	GS4a Dam (Eureka Creek)	Upstream of spillway (MP1)	Isaac River

F4	The release of mine affected water to waters in accordance with condition **F2** must not exceed the release limits stated in **Table F2 (Mine Affected Water Release Limits)** when measured at the monitoring points specified in **Table F1 (Mine Affected Water Release Points)** for each quality characteristic.

Table F2 (Mine Affected Water Release Limits)

Quality Characteristic	Release Limit	Monitoring Frequency
Electrical Conductivity (µS/cm)	10,000	Real time telemetry for EC and pH with grab samples at commencement and weekly thereafter when safe to do so and access permits Daily grab samples if telemetry not available (the first sample must be taken as soon as practicable)^
pH (pH units)	6.5 (minimum) 9.0 (maximum)	
Sulphate (SO_4^{2-}) (mg/L)	N/A (correlated with EC)	Commencement of release and weekly thereafter during release when safe to do so and access permits

NOTES:^ Generally during daylight hours only

F5	The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table F1 (Mine Affected Water Release Points)** for each quality characteristic and at the frequency specified in **Table F2 (Mine Affected Water Release Limits)** and **Table F3 (Release Contaminant Trigger Investigation Levels)**. *NOTE: the administering authority will take into consideration any extenuating circumstances prior to determining an appropriate enforcement response in the event condition **F5** is contravened due to a temporary lack of safe or practical access. The administering authority expects the environmental authority holder to take all reasonable and practicable measures to maintain safe and practical access to designated monitoring locations. When there no temporary safe or practical access to the monitoring point, a representative alternative site or monitoring point can be used.*

Table F3 (Release Contaminant Trigger Investigation Levels)

Quality Characteristic	Trigger Level (µg/L)	Comment of Trigger Level	Monitoring Frequency
Aluminium	1530	Based on 80th percentile of 4 background sites and comparison with upstream values.	Commencement of release and weekly thereafter during release, when safe to do so and access permits.
Chromium	3	Based on 80th percentile of 4 background sites and comparison with upstream values.	
Copper	3	Based on 80th percentile of 4 background sites and comparison with upstream values.	
Iron	970	Based on 80th percentile of 4 background sites and comparison with upstream values.	
Nickel	11	For aquatic ecosystem protection, based on SMD guideline	
Zinc	8	For aquatic ecosystem protection, based on SMD guideline	
Molybdenum	34	For aquatic ecosystem protection, based on low reliability guideline	
Selenium	10	For aquatic ecosystem protection, based on LOR for ICPMS	
Uranium	1	For aquatic ecosystem protection, based on LOR for ICPMS	
Vanadium	10	For aquatic ecosystem protection, based on LOR for ICPMS	
Nitrate	1100	For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for TN	
Petroleum hydrocarbons (C6-C9)	50	Based on LOR for P&T/GC/FID/MSD	
Petroleum hydrocarbons (C10-C36)	200	Based on LOR for C15-C28 fraction using GC/FID	
Total Nitrogen	500	For aquatic ecosystem protection, based on Isaac River Sub-basin Environmental Values and Water Quality Objectives (September 2011)	
Total Phosphorus	50	For aquatic ecosystem protection, based on Isaac River Sub-basin Environmental Values and Water Quality Objectives (September 2011)	

NOTES:
1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.
3. SMD – slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).
4. LOR – typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.

F6	If quality characteristics of the release exceed any of the trigger levels specified in **Table F3 (Release Contaminant Trigger Investigation Levels)** during a release event, the environmental authority holder must compare the downstream results in the receiving waters to the trigger values specified in **Table F3 (Release Contaminant Trigger Investigation Levels)** and: (1) where the trigger values are not exceeded then no action is to be taken; or (2) where the downstream results exceed the trigger values specified in **Table F3 (Release Contaminant Trigger Investigation Levels)** for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites and; (a) if the result is less than the background monitoring site data, then no action is to be taken; or (b) if the result is greater than the background monitoring site data, complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: i. details of the investigations carried out; and ii. actions taken to prevent environmental harm. *NOTE: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with condition **F6(2)(b)**, no further reporting is required for subsequent trigger events for that quality characteristic.*
F7	If an exceedance in accordance with condition **F6(2)(b)** is identified, the environmental authority holder must notify the administering authority within **twenty-four (24) hours** of receiving the result.
F8	**Mine Affected Water Release Events** The environmental authority holder must ensure a stream flow gauging station(s) is installed, operated and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table F4 (Mine Affected Water Release During Flow Events)**.
F9	Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with condition **F2** must only take place during periods of natural flow events in accordance with the receiving water flow criteria for discharge specified in **Table F4 (Mine Affected Water Release During Flow Events)** for the release point(s) specified in **Table F1 (Mine Affected Water Release Points)**.
F10	Notwithstanding condition **F9**, releases from RP1 may occur during periods of no flow in the Isaac River, provided: a) a surface flow has been recorded in Eureka Creek at Monitoring Point 2 within the **twenty-four (24) hour** period prior to release; and b) the release serves only to allow for the total volume of inflow into GS4a Dam resulting from natural flows in Eureka Creek to be conveyed through GS4a Dam into the Isaac River during periods of no flow in the Isaac River.

F11	The 80th percentile of electrical conductivity (EC) values recorded at the downstream monitoring points listed in **Table F6 (Receiving Waters Upstream Background and Downstream Monitoring Points)** must not exceed 2000uS/cm at any time during the release influence period. The 80th percentile must be calculated using all EC values recorded by the monitoring station during the release influence period. *Note: The release influence period is the period during which the downstream monitoring points are influenced by mine affected water includes both the duration of release and any lag time between release point/s and downstream monitoring points*
F12	The daily quantity of mine affected water released from each release point must be measured and recorded at the monitoring points in **Table F1 (Mine Affected Water Release Points)**.
F13	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in such waters.

Table F4 (Mine Affected Water Release During Flow Events)

Receiving waters	Release Point (RP)	Gauging Station	Gauging Station Easting (GDA94)	Gauging Station Northing (GDA94)	Receiving Water Flow Criteria for Discharge* (m^3/s)	Receiving Water Flow Recording Frequency^
Isaac River	RP1	Upper Isaac River	605183	7596105	≥ 3	Daily

^ Assumes access to real time telemetry monitoring is available. Where real time telemetry is not available, daily records will be calculated.
*# When the downstream flow gauge falls below the minimum flow trigger, the 6 week tail flow period commences. Tail flow restricted by trigger limits in receiving waters (**Table F5**).*
** Receiving water minimum flow requirements at the time of commencement apply to the entire release event, where the release period changes.*

F14	**Notification of release event** The environmental authority holder must notify the administering authority via WaTERS as soon as practicable and no later than **twenty-four (24) hours** after commencing to release mine affected water to the receiving environment. The release commencement notification must include the submission of written advice to the administering authority of the following information: a) release commencement date and time; b) expected release cessation date and time; c) release point(s); d) release rate; e) receiving water(s) including the natural flow rate; and f) any details (including available data) regarding likely impacts on the receiving water(s).

F15	The environmental authority holder must notify the administering authority via WaTERS as soon as practicable and no later than **twenty-four (24) hours** after cessation of a release event notified under condition **F14**. The release cessation notification must include the submission of written advice to the administering authority of the following information: a) release cessation date and time; b) receiving water(s) including the natural flow rate; and c) volume of water released. *NOTE: Successive or intermittent releases occurring within **twenty-four (24) hours** of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with conditions **F14** and **F15** and **F16**, provided the relevant details of the release are included within the notification provided in accordance with conditions **F14** and **F15** and **F16**.*
F16	Within **twenty-eight (28) days** of notification under condition **F15**, the environmental authority holder must provide the administrating authority via WaTERS the following information in writing: a) confirmation of: i. the release commencement date and time; ii. the release cessation date and time; iii. receiving water(s) including the natural flow rate; iv. volume of water released; b) all in-situ and laboratory water quality monitoring results; c) details regarding the compliance of the release with the conditions of **Schedule F: Water** of this environmental authority (i.e. contamination limits, natural flow, discharge volume); d) whether the release of water resulted in any impacts to the receiving environment; and e) any other matter(s) pertinent to the water release event.
F17	**Notification of release event exceedance** If the release limits defined in **Table F2 (Mine Affected Water Release Limits)** are exceeded, the environmental authority holder must notify the administering authority within **twenty-four (24) hours** of receiving the results.
F18	The environmental authority holder must, within **twenty-eight (28) days** of the notification provided in accordance with condition **F17**, provide a report to the administering authority via WaTERS detailing: a) the reason for the release; b) the location of the release; c) the total volume of the release and which (if any) part of this volume was non-compliant; d) the total duration of the release and which (if any) part of this period was non-compliant; e) all water quality monitoring results; f) any general observations; g) all calculations; and h) any other matters pertinent to the water release event.

F19	**Receiving Environment Monitoring and Contaminant Trigger Levels** The quality of the receiving waters must be monitored at the locations specified in **Table F6 (Receiving Water Upstream Background and Downstream Monitoring Points)** for each quality characteristic and at the monitoring frequency stated in **Table F5 (Receiving Waters Contaminant Trigger Levels)** and **Table F3 (Release Contaminant Trigger Investigation Levels)**.
F20	If quality characteristic(s) of the receiving water at the downstream monitoring point exceed any of the trigger levels specified in **Table F5 (Receiving Waters Contaminant Trigger Levels)** during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and: (1) where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or (2) where the downstream results exceed the upstream results, complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: (a) details of the investigations carried out; and (b) actions taken to prevent environmental harm. *NOTE: Where an exceedance of a trigger level has occurred and is being investigated in accordance with **F20(2)** of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*

Table F5 (Receiving Waters Contaminant Trigger Levels)

Quality Characteristic	Trigger Level	Monitoring Frequency
pH (pH units)	6.5 to 9.0	Real time telemetry for EC and pH with grab samples at commencement and weekly thereafter when safe to do so and access permits Daily grab samples if telemetry not available (the first sample must be taken as soon as practicable)^
Electrical Conductivity (µS/cm)	2000 – cease the release	
Sulphate (SO_4^{2-}) (mg/L)	1000	Commencement of release and weekly thereafter during release when safe to do so and access permits^

NOTES: ^ Generally during daylight hours only

Table F6 (Receiving Waters Upstream Background and Downstream Monitoring Points)

Monitoring Point (MP)	Receiving Waters Location Description	Easting (GDA94)	Northing (GDA94)
Upstream Background Monitoring Points [a]			
MP2	Eureka Creek upstream	595792	7592251
MP3	Isaac River upstream of confluence with Eureka Creek	604898	7590685
Release Point Monitoring Points			
MP1	Eureka Creek Diversion (GS4a Dam)	602621	7588947
Downstream Monitoring Points			
MP4	Isaac River downstream (Railway Bridge)	600545	7582923

NOTES: (a) The data from background monitoring points must not be used where they are affected by releases from other mines.

F21	**Receiving Environment Monitoring Program (REMP)** The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. For the purposes of the REMP, the receiving environment is the waters of the Isaac River and connected or surrounding waterways within **ten (10) kilometres** downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water.
F22	The REMP must: a) assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); b) be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; c) include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in **Table F6 (Receiving Water Upstream Background and Downstream Monitoring Points)**); d) specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the *Queensland Water Quality Guidelines 2009*. This should include monitoring during periods of natural flow irrespective of mine or other discharges; e) include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in **Table F2 (Mine Affected Water Release Limits)** and **Table F3 (Release Contaminant Trigger Investigation Levels)**); f) include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments); g) include, where appropriate, monitoring of macroinvertebrates in accordance with the AusRivas methodology, h) apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; i) describe sampling and analysis methods and quality assurance and control; and j) incorporate stream flow and hydrological information in the interpretations of water quality and biological data.
F23	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions **F21** and **F22** must be prepared annually. This report must include the following: a) an assessment of background reference water quality; b) the condition of downstream water quality compared against water quality objectives; and c) the suitability of current discharge limits to protect downstream environmental values.

F24	**Water reuse** Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party for the purpose of: a) supplying stock water subject to compliance with the quality release limits specified in **Table F7 (Stock Water Release Limits)**; or b) supplying irrigation water subject to compliance with quality release limits in **Table F8 (Irrigation Water Release Limits)**; or c) supplying water for construction and/or road maintenance in accordance with the conditions of this environmental authority.

Table F7 (Stock Water Release Limits)

Quality Characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	5000

Table F8 (Irrigation Water Release Limits)

Quality Characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	Site specific value determined in accordance with ANZECC & ARMCANZ (2000) Irrigation Guidelines

F25	Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as dams or tanks, for the purpose of supplying water to any operation licensed for either ERA13 (mining black coal) or ERA31 (mineral processing). The volume, pH and electrical conductivity of water transferred must be monitored and recorded.
F26	If the responsibility for mine affected water is given or transferred to another person in accordance with conditions **F24** or **F25**: a) the responsibility for the mine affected water must only be given or transferred in accordance with a written agreement (the third party agreement); and b) the third party agreement must include a commitment from the person utilising the mine affected water to use it in such a way as to prevent environmental harm or public health incidents and specifically make the persons aware of the General Environmental Duty (GED) under section 319 of the *Environmental Protection Act 1994*, environmental sustainability of the water disposal and protection of environmental values of waters; and c) the third party agreement must be signed by both parties to the agreement.

F27	**Water general** All determinations of water quality and biological monitoring must be: a) performed by a person or body possessing appropriate experience and qualifications to perform the required measurements; b) made in accordance with methods prescribed in the latest edition of the administering authority's *Monitoring and Sampling Manual*; c) collected from the monitoring locations identified within this environmental authority, within ten hours of each other where possible; d) carried out on representative samples; and e) analysed at a laboratory accredited (e.g. NATA) for the method of analysis being used. *Note: Condition **F27** requires the Monitoring and Sampling Manual to be followed and where it is not followed because of exceptional circumstances this should be explained and reported with the results.*
F28	**Water Management Plan** A Water Management Plan must be developed by an appropriately qualified person(s) and implemented for all mining activities. The Water Management Plan must address, the following: a) provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity carried out under this environmental authority; and b) be developed in accordance with administering authority's guideline *Preparation of water management plans for mining activities* and include: i. a study of the source of contaminants; ii. a water balance model for the site; iii. a water management system for the site; iv. measures to manage and prevent saline drainage; v. measures to manage and prevent acid rock drainage; vi. contingency procedures for emergencies; and vii. a program for monitoring and review of the effectiveness of the Water Management Plan.
F29	The Water Management Plan must be reviewed each calendar year by an appropriately qualified person(s).
F30	**Stormwater and water sediment controls** An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.
F31	Stormwater, other than mine affected water, is permitted to be released to waters from: a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition **F30**; and b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with conditions **F28** to **F29** inclusive, for the purpose of ensuring water does not become mine affected water.

RR1	Conditions F21 to F23 do not apply if the environmental authority holder is a participant of the FRREMP.
RR2	The environmental authority holder must notify the administering authority in a written statement within twenty (20) business days of ceasing to be a participant of the FRREMP. The written statement must detail how the environmental authority holder is going to fulfil the requirements of conditions F21 to F23.

Schedule G: Structures	
Condition number	**Condition**
G1	**Assessment of consequence category** The consequence category of any structure must be assessed by a suitably qualified and experienced person, in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*, at the following times: a) prior to the design and construction of the structure, if it is not an existing structure; or b) prior to any change in its purpose or the nature of its stored contents.
G2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
G3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*.
G4	**Design and construction of a regulated structure** Conditions **G5** to **G9** inclusive do not apply to existing structures. *NOTE: Construction of a dam includes modification of an existing dam – see definitions.*
G5	All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*. *NOTE: Certification of design and construction may be undertaken by different persons.*
G6	Construction of a regulated structure is prohibited unless the environmental authority holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this environmental authority.
G7	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*, and must be recorded in the Register of Regulated Structures.

G8	Regulated structures must: a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*; b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: viii. floodwaters from entering the regulated dam from any watercourse or drainage line; and ix. wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) for regulated dams associated with a failure to contain – seepage, have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.
G9	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; and b) construction of the regulated structure is in accordance with the design plan.
G10	**Operation of a regulated structure** Operation of a regulated structure, except for an existing structure, is prohibited unless the environmental authority holder has submitted to the administering authority: a) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition **G6**; b) a set of 'as constructed' drawings and specifications; c) certification of those 'as constructed drawings and specifications' in accordance with condition **G9**; d) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; e) the requirements of this environmental authority relating to the construction of the regulated structure have been met; f) the environmental authority holder has entered the details, required under this environmental authority, into the Register of Regulated Structures; and g) there is a current operational plan for the regulated structures.

G11	For existing structures that are regulated structures: a) where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the environmental authority holder must submit to the administering authority within **twelve (12) months** of the commencement of this condition a copy of the certified system design plan including that structure; and b) there must be a current operational plan for the existing structures.
G12	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
G13	**Mandatory Reporting Level** Conditions **G14** to **G17** inclusive only apply to regulated structures which have not been certified as low consequence category for 'failure to contain – overtopping'.
G14	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that, during routine inspections of that dam, it is clearly observable.
G15	The environmental authority holder must, as soon as practical and within **forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
G16	The environmental authority holder must immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
G17	The environmental authority holder must record any changes to the MRL in the Register of Regulated Structures.
G18	**Design Storage Allowance** The environmental authority holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to **1 July** of each year.
G19	By **1 November** of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems).
G20	The environmental authority holder must notify the administering authority as soon as possible and within **forty-eight (48) hours** of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year.

G21	The environmental authority holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.
G22	**Annual inspection report** Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
G23	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.
G24	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*.
G25	The environmental authority holder must: a) within **twenty (20) business days** of receipt of the annual inspection report, provide to the administering authority: i. the recommendations section of the annual inspection report; and ii. if applicable, any actions being taken in response to those recommendations; and b) if, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the environmental authority holder, provide this to the administering authority within **ten (10) business days** of receipt of the request.
G26	**Transfer arrangements** The environmental authority holder must provide a copy of any reports, documentation and certifications prepared under this environmental authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.
G27	**Decommissioning and rehabilitation** Dams must not be abandoned but be either: a) decommissioned and rehabilitated to achieve compliance with condition **G28**; or b) be left in-situ for a beneficial use(s) provided that: i. it no longer contains contaminants that will migrate into the environment; and ii. it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii. the administering authority, the environmental authority holder and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).

G28	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least three (3) years; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated d) not allowing for acid mine drainage; or e) there is no ongoing contamination to waters (including groundwater); f) rehabilitation is undertaken in a manner such that any actual or potential acid sulphate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the *Instructions for the treatment and management of acid sulfate soils (2001)*; g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; h) for land that is not being cultivated by the landholder: i. groundcover, that is not a declared pest species is established and self-sustaining ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the mining activity(ies). i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of mining activities being completed.
G29	**Register of Regulated Structures** A Register of Regulated Structures must be established and maintained by the environmental authority holder for each regulated structure.
G30	The environmental authority holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority.
G31	The environmental authority holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition **G10** and **G11** has been achieved.
G32	The environmental authority holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.
G33	All entries in the Register of Regulated Structures must be approved by the chief executive officer for the environmental authority holder, or their delegate, as being accurate and correct.
G34	The environmental authority holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.

G35	**Transitional arrangements** All existing structures that have not been assessed in accordance with either, the Manual or the former *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*, must be assessed and certified in accordance with the Manual within **six (6) months** of amendment of the environmental authority adopting this schedule.
G36	All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table G1 (Transitional Requirements for Existing Structures)**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure.
G37	**Table G1 (Transitional Requirements for Existing Structures)** ceases to apply for a structure once any of the following events has occurred: a) it has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or b) it has been decommissioned; or c) it has been certified as no longer being assessed as a regulated structure.
G38	Certification of the transitional assessment required by **G35** and **G36** (as applicable) must be provided to the administering authority within **six (6) months** of amendment of the environmental authority adopting this schedule.

Table G1 (Transitional Requirements for Existing Structures)

Transition period required for existing structures to achieve the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*			
Compliance with Criteria	**High**	**Significant**	**Low**
>90% and a history of good compliance performance in last 5 years	No transition required	No transition required	No transitional conditions apply. Review consequence assessment every 7 years.
>70% to ≤90%	Within 7 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 10 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	No transitional conditions apply. Review consequence assessment every 7 years.
>50 to ≤70%	Within 5 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 7 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Review consequence assessment every 7 years.
≤50%	Within 5 years or as per compliance requirements (e.g. TEP timing)	Within 5 years or as per compliance requirements (e.g. TEP timing)	Review consequence assessment every 5 years.

Schedule H: Sewage Treatment	
Condition number	**Condition**
H1	**Treated sewage effluent** The cumulative total daily peak design capacity of the sewage treatment plant/s must not exceed 4000 equivalent persons (EP). Small package plants and/or septic systems, each with a daily peak design capacity less than 21EP, are not included in the cumulative total daily peak design capacity.
H2	Treated sewage effluent must not be directly released from the sewage treatment plant/s to any waters. *Note: 'waters' does not include structures associated with the mine affected water management system.*
H3	Treated sewage effluent may be: a) released to the mine affected water management system for mixing with other mine affected water; b) released to land via a sub-surface infiltration trench; c) irrigated or sprayed for dust suppression or firefighting or evaporation; or d) removed as waste.
H4	Treated sewage effluent that is released in accordance with condition **H3(a)** and has mixed with other mine affected water must be managed as mine affected water in accordance with the conditions of this environmental authority.
H5	Treated sewage effluent that is released in accordance with condition **H3(b)** or **H3(c)** must be carried out in a manner such that: a) vegetation is not damaged; b) there is no surface ponding of effluent; and c) there is no run-off of treated sewage effluent to waters.
H6	Treated sewage effluent released in accordance with condition **H3(a)** or **H3(b)** or **H3(c)** from any sewage treatment plant that has a daily peak design capacity of greater than 21EP must be monitored: a) at the point where the treated sewage effluent is released from the sewage treatment plant/s; b) for the quality characteristics specified in **Table H1 (Treated Sewage Effluent Monitoring Requirements)**; and c) at the frequency specified in **Table H1 (Treated Sewage Effluent Monitoring Requirements)**.

Table H1 (Treated Sewage Effluent Monitoring Requirements)

Quality Characteristic	Units	Monitoring Frequency
5-day Biochemical Oxygen Demand (uninhibited)	mg/L	Monthly
pH	pH units	Monthly
Thermotolerant coliforms	Colonies per 100mL	Monthly
Total nitrogen	mg/L	Monthly
Total phosphorus	mg/L	Monthly

H7	If treated sewage effluent is being released in accordance with condition **H3(c)**: a) the results of monitoring in accordance with condition **H6** must not exceed the release limits specified in **Table H2 (Treated Sewage Effluent Contaminant Release Limits)**; and b) the release must not cause spray drift or over spray to any sensitive place or commercial place.
H8	If the release limits specified in **Table H2 (Treated Sewage Effluent Contaminant Release Limits)** are exceeded in accordance with condition **H7(a)**, the environmental authority holder must notify the administering authority in accordance with conditions **A7** and **A8**.

Table H2 (Treated Sewage Effluent Contaminant Release Limits)

Quality Characteristic	Release Limit	Units	Limit Type
5-day Biochemical Oxygen Demand (uninhibited)	50	mg/L	Maximum
pH	6.0 to 9.0	pH units	Range
Thermotolerant coliforms, based on the average of a minimum number of five samples collected	1000	Colonies per 100mL	Maximum

Schedule I: Groundwater	
Condition number	**Condition**
I1	**Groundwater Monitoring and Management Program** A Groundwater Monitoring and Management Program to detect and manage risk from the landfill authorised by condition **D8** must be developed, documented and implemented by an appropriately qualified person prior to the landfill receiving waste.
I2	The Groundwater Monitoring and Management Program required by condition **I2** must: a) identify potential sources of contamination to groundwater from the landfill; b) ensure that all potential groundwater impacts due to the landfill are identified, mitigated and monitored; c) document sampling and monitoring methodology; d) ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives: i. detect any impacts to groundwater levels due to the landfill; ii. detect any impacts to groundwater quality due to the landfill; and iii. determine trends in groundwater quality; e) include an appropriate quality assurance and quality control program; f) include a conceptual groundwater model; g) be provided to the administering authority for review at least **six (6) weeks** before being finalised; and h) include a review process to identify required improvements to the program and address any comments provided by the administering authority.
I3	The construction, maintenance and decommissioning of groundwater monitoring bores must be undertaken in a manner that: a) prevents contaminants entering the groundwater; b) ensures the integrity of the bores to obtain representative groundwater samples from the target aquifer; and c) maintains the hydrogeological environment within the aquifer.
I4	A bore drill log must be kept for each reference, compliance and observation groundwater monitoring bore which includes: a) bore identification reference and geographic coordinate location; b) specific construction information including but not limited to depth of bore, depth and length of casing, depth and length of screening and bore sealing details; c) standing groundwater level and water quality parameters including physical parameters and results of laboratory analysis for the possible trigger parameters; d) lithological data, stratigraphic interpretation by an appropriately qualified person to identify important features associated with groundwater monitoring; and e) target aquifer formation of the bore.

Schedule J: Watercourse Subsidence	
Condition number	**Condition**
J1	**Authorised subsidence** Subject to the conditions of this environmental authority, specifically conditions **J1** to **J14** inclusive, the environmental authority holder is authorised to subside the Isaac River within ML1763, as depicted in **Figure 2 (Authorised Subsidence Extent)**. This subsidence is authorised to occur as a result of underground longwall mining activities.
J2	This environmental authority does not authorise the use of top coal caving (or thick seam mining) methods where it would result in subsidence of the bed or banks of the Isaac River.
J3	**Subsidence Management Plan** A Subsidence Management Plan must be developed to the satisfaction of the administering authority, in accordance with the administering authority's guideline "Watercourse Subsidence – Central Queensland Mining Industry" or any subsequent versions, or any other relevant guideline as directed by the administering authority. The Subsidence Management Plan must include at least the following components: a) the condition of the existing watercourse (including a baseline assessment); b) the objectives and outcomes of the subsidence management plan; c) a risk assessment that identifies all potential impacts on the watercourse and associated floodplain resulting from subsidence of the watercourse; d) the measures to be implemented to avoid, minimise and mitigate each potential impact; e) a monitoring, maintenance and evaluation program that: i. details the level of effectiveness of the measures using indicators and success criteria; ii. includes the annual review of success and appropriateness of measures; and iii. details how improvements will be implemented where success criteria are not met. f) consideration of cumulative impacts on the Isaac River from upstream activities; g) consideration of impacts on groundwater as a result of subsidence of the watercourse; h) a rehabilitation plan for subsided areas of the Isaac River including: i. rehabilitation objectives; ii. completion criteria; and iii. schedule for progressive rehabilitation; and i) an action plan to address the outcomes and recommendations from annual inspections.
J4	The Subsidence Management Plan must be assessed and certified by an independent, third party, suitably qualified and experienced person, that the plan is compliant in all respects with this environmental authority.

J5	Subsidence of the Isaac River within longwall panel LW11 onwards must not commence until: a) the administering authority has received a copy of the certified subsidence management plan; and b) the subsidence management plan has been implemented.
J6	The administering authority may, within **twenty-eight (28) days** of receiving the certified Subsidence Management Plan as required by condition **J5**, provide comments in respect to the submitted plan.
J7	All comments made by the administering authority under condition **J6** must be considered and incorporated into the Subsidence Management Plan within **twenty-eight (28) days** of receipt of the comments, and the plan be re-submitted to the administering authority.
J8	**Annual inspection** Each subsided longwall panel and the full extent of the Isaac River must be inspected annually by a suitably qualified and experienced person in accordance with the following minimum requirements: a) report on the condition of the bed and banks of the watercourse; b) report on ground cover (%) and pasture biomass (kg/ha) in the riparian zone; c) a comparison of the bed depths, and bank widths from the previous inspection, to determine the overall soil loss from the subsided areas of the Isaac River, and the mitigation measures to be implemented to minimise further soil loss; d) assess the structural, geotechnical and hydraulic adequacy of the subsided longwall panels; e) assess the adequacy of all mitigation measures with respect to the subsidence management plan and any previous annual inspection; and, f) detail any recommended mitigation measures or rehabilitation requirements to be undertaken.
J9	After each annual inspection, a copy of a report including any recommendations, certified by an independent, third party, suitably qualified and experienced person, must be provided to the administering authority within **two (2) months** of completion.
J10	Any recommended mitigation measure, as identified in the annual inspection, must be implemented prior to **1 November** of the year that the recommendation was given, unless otherwise agreed to by the administering authority.
J11	If the mitigation measures recommended in the annual inspections are not implemented, no further subsidence of the Isaac River is permitted until the measures are completed, unless otherwise agreed to by the administering authority.
J12	The Subsidence Management Plan must be reviewed and updated to address any recommendations detailed in the annual inspection reports.

J13	**Rehabilitation of watercourse subsidence** All areas of the Isaac River that have been affected by subsidence must be rehabilitated to a standard consistent with items a) through e) below, and certified by a suitably qualified person; a) incorporate pre-existing natural features of the watercourse (including geomorphic and vegetation); b) attain the pre-existing hydrologic characteristics of surface water and groundwater systems for the area in which the watercourse is located; c) attain the hydraulic characteristics of the watercourse that are equivalent to other local watercourses, and are suitable for the subsided areas of the Isaac River, without using artificial structures that require on-going maintenance; d) attain sediment transport and water quality regimes that allow the watercourse to be self-sustaining, while minimising any impacts to upstream and downstream water quality, geomorphology and/or vegetation; and e) attain equilibrium and functionality in all substrate conditions at the location of the watercourse.
J14	Rehabilitation of the subsided areas of the Isaac River must be undertaken progressively in accordance with the Subsidence Management Plan.

END OF CONDITIONS

Definitions

Key terms and/or phrases used in this document are defined in this section. Environmental authority holders should note that where a term is not defined, the definition in the *Environmental Protection Act 1994*, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

Acceptance criteria means the measures by which the actions implemented to rehabilitate the land are deemed to be complete. The acceptance criteria indicate the success of the rehabilitation outcome or remediation of areas which have been significantly been disturbed by the mining activities. Acceptance criteria may include information regarding:

a) vegetation establishment, survival and succession;

b) vegetation productivity, sustained growth and structure development;

c) fauna colonisation and habitat development;

d) ecosystem processes such as soil development and nutrient cycling, and the recolonisation of specific fauna groups such as collembola, mites and termites which are involved in these processes;

e) microbiological studies including recolonisation by mycorrhizal fungi, microbial biomass and respiration;

f) effects of various establishment treatments such as deep ripping, topsoil handling, seeding and fertiliser application on vegetation growth and development;

g) resilience of vegetation to disease, insect attack, drought and fire; and

h) vegetation water use and effects on ground water levels and catchment yields.

Acid rock drainage means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture as a result of mining activity.

Administering authority is the agency or department that administers the environmental authority provisions under the *Environmental Protection Act 1994*.

Airblast overpressure means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

Alternative arrangement in relation to a sensitive place or a commercial place, means:

a) A written agreement:
   i. between the environmental authority holder and a third party;
   ii. that identifies a particular type(s) of environmental nuisance;
   iii. about the way in which the particular environmental nuisance impact(s) will be dealt with;
   iv. at a particular location; and
   v. for a defined period of time.

b) An alternative arrangement must make clear to the third party that by entering in to the agreement that:
   i. their place will be excluded as a sensitive place or commercial place; and
   ii. the consequences of exclusion as a sensitive place or commercial place.

Note: An alternative arrangement may include, but is not limited to, details of the nuisance abatement measures to be implemented, provision of alternative accommodation, or agreement between the parties that the location will not be considered a sensitive place or commercial place for the purposes of the Environmental Authority, for the duration of the alternative arrangement. The written agreement may be in any form, with some examples being a lease, or an agistment, or a conduct and compensation agreement under the *Mineral Resources Act 1989*.

Annual exceedance probability or AEP means the probability that at least one event in excess of a particular magnitude will occur in any given year.

Annual inspection report means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan):

a) against recommendations contained in previous annual inspections reports;

b) against recognised dam safety deficiency indicators;

c) for changes in circumstances potentially leading to a change in consequence category;

d) for conformance with the conditions of this authority;

e) for conformance with the 'as constructed' drawings;

f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems); and

g) for evidence of conformance with the current operational plan.

ANZECC means the Australian and New Zealand Guidelines for Fresh Marine Water Quality 2000

Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

Assessed or assessment by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

a) exactly what has been assessed and the precise nature of that determination;

b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

Associated works in relation to a dam, means:

a) operations of any kind and all things constructed, erected or installed for that dam; and

b) any land used for those operations.

Authority means an environmental authority or a development approval.

Bed and banks for a waters, river, creek, stream, lake, lagoon, pond, swamp, wetland or dam means land over which the water of the waters, lake, lagoon, pond, swamp, wetland or dam normally flows or that is normally covered by the water, whether permanently or intermittently; but does not include land adjoining or adjacent to the bed and banks that is from time to time covered by floodwater.

Beneficial use in respect of dams means that the current or proposed owner of the land on which a dam stands, has found a use for that dam that is:

a) of benefit to that owner in that it adds real value to their business or to the general community;

b) in accordance with relevant provisions of the *Environmental Protection Act 1994;*

c) sustainable by virtue of written undertakings given by that owner to maintain that dam; and

d) the transfer and use have been approved or authorised under any relevant legislation.

Biosolids means the treated and stabilised solids from sewage.

Blasting means the use of explosive materials to fracture:

a) rock, coal and other minerals for later recovery; or

b) structural components or other items to facilitate removal from a site or for reuse.

Bulk rubber means tyres, conveyor belt, and other similar rubber waste.

Certification in relation to regulated structures, means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* or this environmental authority, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A).

Certifying, certify or certified have a corresponding meaning as 'certification' in relation to regulated structures.

Chemical means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994 (Commonwealth)*; or

b) a dangerous good under the dangerous goods code; or

c) a lead hazardous substance within the meaning of the *Workplace Health and Safety Regulation 1997*; or

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth; or

e) any substance used as, or intended for use as:

   i. a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product; or

   ii. a surface active agent, including, for example, soap or related detergent; or

   iii. a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or

   iv. a fertiliser for agricultural, horticultural or garden use; or

f) a substance used for, or intended for use for:

   i. mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or

   ii. manufacture of plastic or synthetic rubber.

Commercial place means:

a) A work place that is used as:
   i. an office; or
   ii. a place of business; or
   iii. a place used for commercial purposes.
b) Despite paragraph (a), the following places are not commercial places:
   i. subject to paragraph (c), a place that is the subject of an alternative arrangement; or
   ii. places that are part of the mining activity; or
   iii. employees accommodation or public roads; or
   iv. a property owned or leased by one or more of the environmental authority holders, or a related company, whether or not it is subject to an alternative arrangement.
c) A place that is the subject of a current alternative arrangement in relation to a particular type(s) of environmental nuisance, is not a commercial place for the purposes of that type(s) of environmental nuisance, however remains a commercial place for the purpose of other types of environmental nuisances.

Consequence in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

Consequence category means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*.

Construction or constructed in relation to a dam includes building a new dam and modifying or lifting an existing dam, but does not include investigations and testing necessary for the purpose of preparing a design plan.

Contaminate means to render impure by contact or mixture.

Contaminated means the substance has come into contact with a contaminant.

Contaminant can be

a) a gas, liquid or solid; or
b) an odour; or
c) an organism (whether alive or dead), including a virus; or
d) energy, including noise, heat, radioactivity and electromagnetic radiation; or
e) a combination of contaminants.

Control measure means any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level.

Dam means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works.

Dam crest volume means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

Design plan is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

Design storage allowance or DSA means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an annual exceedance probability (AEP) specified in that Manual.

Designer for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

Disturbance of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth;

b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;

c) carrying out mining within a watercourse, waterway, wetland or lake;

d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be removed after the mining activity has ceased; or

f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of disturbance:

a) areas off lease (e.g. roads or tracks which provide access to the mining lease);

b) areas previously disturbed which have achieved the rehabilitation outcomes;

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be left by agreement with the landowner; or

e) disturbance that pre-existed the grant of the tenure.

Dwelling means any of the following structures or vehicles that is principally used as a residence:

a) a house, unit, motel, nursing homer or other building or part of a building; or

b) a caravan, mobile home or other vehicle or structure on land; or

c) a water craft in a marina.

Effluent means treated waste water released from sewage treatment plants.

Emergency action plan means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

End of pipe means the location at which water is released to waters or land.

Environmental authority means an environmental authority granted in relation to an environmentally relevant activity under the *Environmental Protection Act 1994*.

Environmental authority holder means the holder of this environmental authority.

Environmentally relevant activity means an environmentally relevant activity as defined under section 18 of the *Environmental Protection Act 1994*.

EPBC means the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

ERC decision means a decision made by the administering authority under section 300 of the *Environmental Protection Act 1994* about the estimated rehabilitation cost for a resource activity.

ERC period for the estimated rehabilitation cost for a resource activity, means:

a) if a PRCP schedule applies for the activity, the period of between 1 and 5 years stated in the application for an ERC decision under section 298(2)(b); or

b) if the activity is a petroleum activity that is an ineligible ERA, other than a petroleum activity to which a plan of operations applies, or the activity relates to a 1923 Act petroleum tenure granted under the *Petroleum Act 1923*, the period of between 1 and 5 years stated in the ERC decision about the estimated rehabilitation cost; or

c) if a plan of operations applies for the activities, the plan period for the plan of operations; or

d) otherwise, the total period during which the resource activity is likely to be carried out under the environmental authority for the activity.

Estimated rehabilitation cost (ERC) for a resource activity, see section 300(2) of the *Environmental Protection Act 1994*.

Existing authority has the meaning in section 94 of the *Environmental Offsets Act 2014*.

Existing structure means a structure that was in existence prior to 24 October 2014.

Extreme storm storage means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* published by the administering authority.

Floodwater means water overflowing, or that has overflowed, from waters, river, creek, stream, lake, pond, wetland or dam onto or over riparian land that is not submerged when the watercourse or lake flows between or is contained within its bed and banks.

Flowable substance means matter or a mixture of materials that can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

Foreseeable future is the period used for assessing the total probability of an event occurring. Permanent structures and ecological sustainability should be expected to still exist at the end of a 150 year foreseeable future with an acceptable probability of failure before that time.

FRREMP means a Fitzroy Basin Receiving Environment Monitoring Program for the region in which the EA is located, that has been endorsed in writing by the administering authority.

General waste means waste other than regulated waste.

Hazardous waste means a substance, whether liquid, solid or gaseous that, if improperly treated, stored, disposed of or otherwise managed, is likely to cause environmental harm.

Holder, for a mining tenement, means a holder of the tenement under the *Mineral Resources Act 1989*, and the holder of the associated environmental authority under the *Environmental Protection Act 1994*.

Hydraulic performance means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*.

Inert waste means bricks, pavers, ceramics, concrete, glass, steel, or similar waste that does not biodegrade or decompose.

Infrastructure means water storage dams, roads and tracks, buildings and other structures built for the purpose of mining activities but does not include other facilities required for the long-term management of mining impacts or the protection of potential resources. Such other facilities include dams, waste rock dumps, voids, or ore stockpiles and buildings as well as other structures whose ownership can be transferred and which have a residual beneficial use for the next owner of the mining leases or the background land owner.

$L_{A10, adj, 10 mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 10% of any 10 minute measurement period, using Fast response.

$L_{A1, adj, 10 mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 1% of any 10 minute measurement period, using Fast response.

Lake includes:

a) lagoon, swamp or other natural collection of water, whether permanent or intermittent; and

b) the bed and banks and any other element confining or containing the water.

Land in the "land schedule" of this document means land excluding waters and the atmosphere.

Land use describes the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

Landfill means land used as a waste disposal site for lawfully putting solid waste on the land.

Levee means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of water or flowable substances at any other times.

Low consequence dam means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635).*

Mandatory reporting level or MRL means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* published by the administering authority.

Manual means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* published by the administering authority.

Matters of state environmental significance or MSES has the meaning in schedule 2 of the *Environmental Offsets Regulation 2014*.

Maximum extent of impact means the total, cumulative, residual extent and duration of impact to a prescribed environmental matter that will occur over a project's life after all reasonable avoidance and reasonable on-site mitigation measures have been, or will be, undertaken.

mbgl means metres below ground level.

mg/L means milligrams per litre.

Mechanically reprocessing waste includes mechanically crushing, milling, grinding, shredding or sorting waste, whether or not for the purpose of recycling the waste.

Mine affected water means the following types of water:

a) pit water, tailings dam water, processing plant water;

b) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity;

c) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage runoff containing sediment only, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;

d) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;

e) groundwater from the mine's dewatering activities; or

f) a mix of mine affected water (under any of paragraphs (a) to (e)) and other water.

Mineral means a substance which normally occurs naturally as part of the earth's crust or is dissolved or suspended in water within or upon the earth's crust and includes a substance which may be extracted from such a substance, and includes:

a) clay if mined for use for its ceramic properties, kaolin and bentonite;

b) foundry sand;

c) hydrocarbons and other substances or matter occurring in association with shale or coal and necessarily mined, extracted, produced or released by or in connection with mining for shale or coal or for the purpose of enhancing the safety of current or future mining operations for coal or the extraction or production of mineral oil there from;

d) limestone if mined for use for its chemical properties;

e) marble;

f) mineral oil or gas extracted or produced from shale or coal by in situ processes;

g) peat;

h) salt including brine;

i) shale from which mineral oil may be extracted or produced;

j) silica, including silica sand, if mined for use for its chemical properties; or

k) rock mined in block or slab form for building or monumental purposes;

But does not include:

a) living matter;

b) petroleum within the meaning of the *Petroleum Act 1923*;

c) soil, sand, gravel or rock (other than rock mined in block or slab form for building or monumental purposes) to be used or to be supplied for use as such, whether intact or in broken form; or

d) water.

Mining activities means the activities:

a) authorised as per the definition in section 110 of the *Environmental Protection Act 1994*; and

b) all environmentally relevant activities authorised under this environmental authority; and

c) waste activities.

Modification or modifying (see definition of 'construction').

Natural flow means the flow of water through waters caused by nature.

Notice of election has the meaning in section 18(2) of the *Environmental Offsets Act 2014*.

Noxious means harmful or injurious to health or physical wellbeing.

Offensive means causing reasonable offence or displeasure; is disagreeable to the sense; disgusting, nauseous or repulsive, other than trivial harm.

Operational plan includes:

a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance); and

b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

Participant of the FRREMP means an environmental authority holder that is identified as a current participant by the organisation carrying out the Regional REMP.

Peak particle velocity or ppv means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

Prescribed environmental matters has the meaning in section 10 of the *Environmental Offsets Act 2014*, limited to the matters of State environmental significant listed in schedule 2 of the *Environmental Offsets Regulation 2014*.

Protected area means

a) a protected area under the *Nature Conservation Act 1992*; or

b) a marine park under the *Marine Parks Act 1992*; or

c) a World Heritage Area.

Progressive rehabilitation means rehabilitation (defined below) undertaken progressively or a staged approach to rehabilitation as mining operations are ongoing.

Receiving environment, in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

a) a watercourse;

b) groundwater;

c) land; and

d) sediments.

Receiving waters means the waters into which this environmental authority authorises releases of mine affected water.

Reference site (or analogue site) may reflect the original location, adjacent area or another area where rehabilitation success has been completed for a similar biodiversity. Details of the reference site may be as photographs, computer generated images and vegetation models etc.

Register of Regulated Structures includes:

a) date of entry in the register;

b) name of the dam, its purpose and intended/actual contents;

c) the consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)*;

d) dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;

e) name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;

f) for the regulated dam, other than in relation to any levees –

i. the dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

ii. coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

iii. dam crest volume (megalitres);

iv. spillway crest level (metres AHD).

v. maximum operating level (metres AHD);

vi. storage rating table of stored volume versus level (metres AHD);

vii. design storage allowance (megalitres) and associated level of the dam (metres AHD);

viii. mandatory reporting level (metres AHD);

g) the design plan title and reference relevant to the dam;

h) the date construction was certified as compliant with the design plan;

i) the name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) details of the composition and construction of any liner;

k) the system for the detection of any leakage through the floor and sides of the dam;

l) dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) dates when recommendations and actions arising from the annual inspection were provided to the administering authority; and

n) dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

Regulated dam means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (Version 4, 10 April 2014) (EM635)* published by the administering authority.

Regulated structure includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

Regulated waste is defined in the *Environmental Protection Regulation 2008*.

Rehabilitation means the process of reshaping and revegetating land to restore it to a stable landform and in accordance with the acceptance criteria set out in this environmental authority and, where relevant, includes remediation of contaminated land.

Rejects means:

a) breaker rejects; or

b) coarse rejects; or

c) mid/fine size rejects; or

d) tailings that have been dewatered; or

e) any combination of rejects (under any of paragraphs a to d).

Representative means a sample set that covers the variance in monitoring or other data due to either natural changes or operational phases of the mining activities.

Reprocessing includes:

a) recycling; or

b) mechanical treatment; or

c) thermal treatment; or

d) biological treatment; or

e) chemical treatment.

Residual void means an open pit resulting from the removal of ore and/or waste rock that will remain following the cessation of all mining activities and completion of rehabilitation processes.

Resource activity is an activity that involves

a) a geothermal activity; or

b) a GHG storage activity; or

c) a mining activity; or

d) a petroleum activity.

Saline drainage is the movement of waters, contaminated with salt(s), as a result of the mining activity.

Scheme fund means the scheme fund established under section 24 of the *Mineral and Energy Resources (Financial Provisioning) Act 2018*.

Self-sustaining means an area of land which has been rehabilitated and has maintained the required acceptance criteria without human intervention for a period nominated by the administering authority.

Sensitive place means:

a) Any of the following:

i. a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or

ii. a motel, hotel or hostel; or

iii. an educational institution; or

iv. a medical centre or hospital; or

v. a protected area; or

vi. a public park or gardens.

b) Despite paragraph (a), the following places are not sensitive places:

i. subject to paragraph (c), a place that is the subject of an alternative arrangement; or

ii. a mining camp (i.e. accommodation and ancillary facilities for mine employees or contractors or both, associated with the mine the subject of the environmental authority), whether or not the mining camp is located within a mining tenement that is part of the mining project the subject of the environmental authority. For example, the mining camp might be located on neighbouring land owned or leased by the same company as one of the environmental authority holders for the mining project, or a related company; or

iii. a property owned or leased by one or more of the environmental authority holders, or a related company, whether or not it is subject to an alternative arrangement.

c) A place that is the subject of a current alternative arrangement in relation to a particular type(s) of environmental nuisance, is not a sensitive place for the purposes of that type(s) of environmental nuisance, however remains a sensitive place for the purpose of other types of environmental nuisances.

Sewage means the used water of persons to be treated at a sewage treatment plant.

Significant residual impact has the meaning in section 8 of the *Environmental Offsets Act 2014*.

Spillway means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.

Stable in relation to land, means land form dimensions are or will be stable within tolerable limits now and in the foreseeable future. Stability includes consideration of geotechnical stability, settlement and consolidation allowances, bearing capacity (trafficability), erosion resistance and geochemical stability with respect to seepage, leachate and related contaminant generation.

Stormwater means all surface water runoff from rainfall.

Structure means dam or levee.

Suitably qualified and experienced person in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

a) for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.

b) for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

Suitably qualified and experienced person in relation to watercourse subsidence means one who holds relevant professional qualifications to the satisfaction of the administering authority and the administering authority is satisfied that person has knowledge, suitable experience and demonstrated expertise in relevant fields, as set out below:

a) knowledge of engineering principles related to the structures, hydrology, hydraulics and environmental impact of watercourse subsidence; and

b) a total of five years of suitable experience and demonstrated expertise in the following categories:

   i. hydrology with particular reference to flooding, estimation of extreme storms or water management;

   ii. hydraulics with particular reference to sediment transport and deposition and erosion control;

   iii. hydrogeology with particular reference to seepage, groundwater.

System design plan means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

Tailings means fines from mineral processing that have not been dewatered.

The Act means the *Environmental Protection Act 1994*.

Void means any constructed, open excavation in the ground.

Waste as defined in section 13 of the *Environmental Protection Act 1994*.

Waste activities means receiving, storing, disposing, treating, or reprocessing wastes, and does not include composting.

Waste and resource management hierarchy has the meaning given by section 9 of the *Waste Reduction and Recycling Act 2011*.

Water quality means the chemical, physical and biological condition of water.

Watercourse has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently:

a) in a natural channel, whether artificially improved or not; or

b) in an artificial channel that has changed the course of the watercourse.

Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

Waters includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

WaTERS means the Water Tracking and Electronic Reporting System.

Wet season means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination, this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

µg/L means micrograms per litre.

µS/cm means microsiemens per centimetre.

END OF DEFINITIONS

Figure 1 (General Waste Landfill Location)

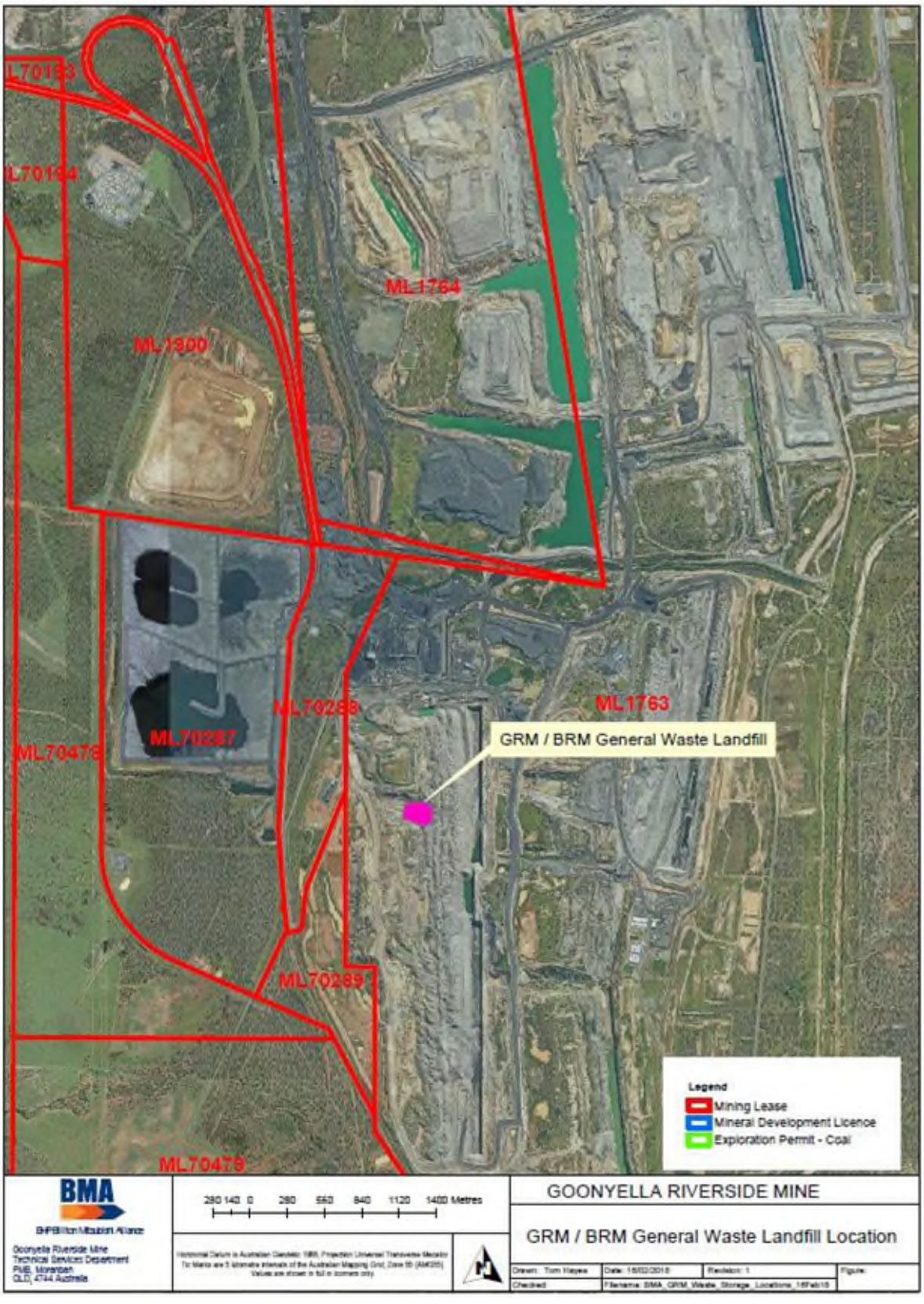
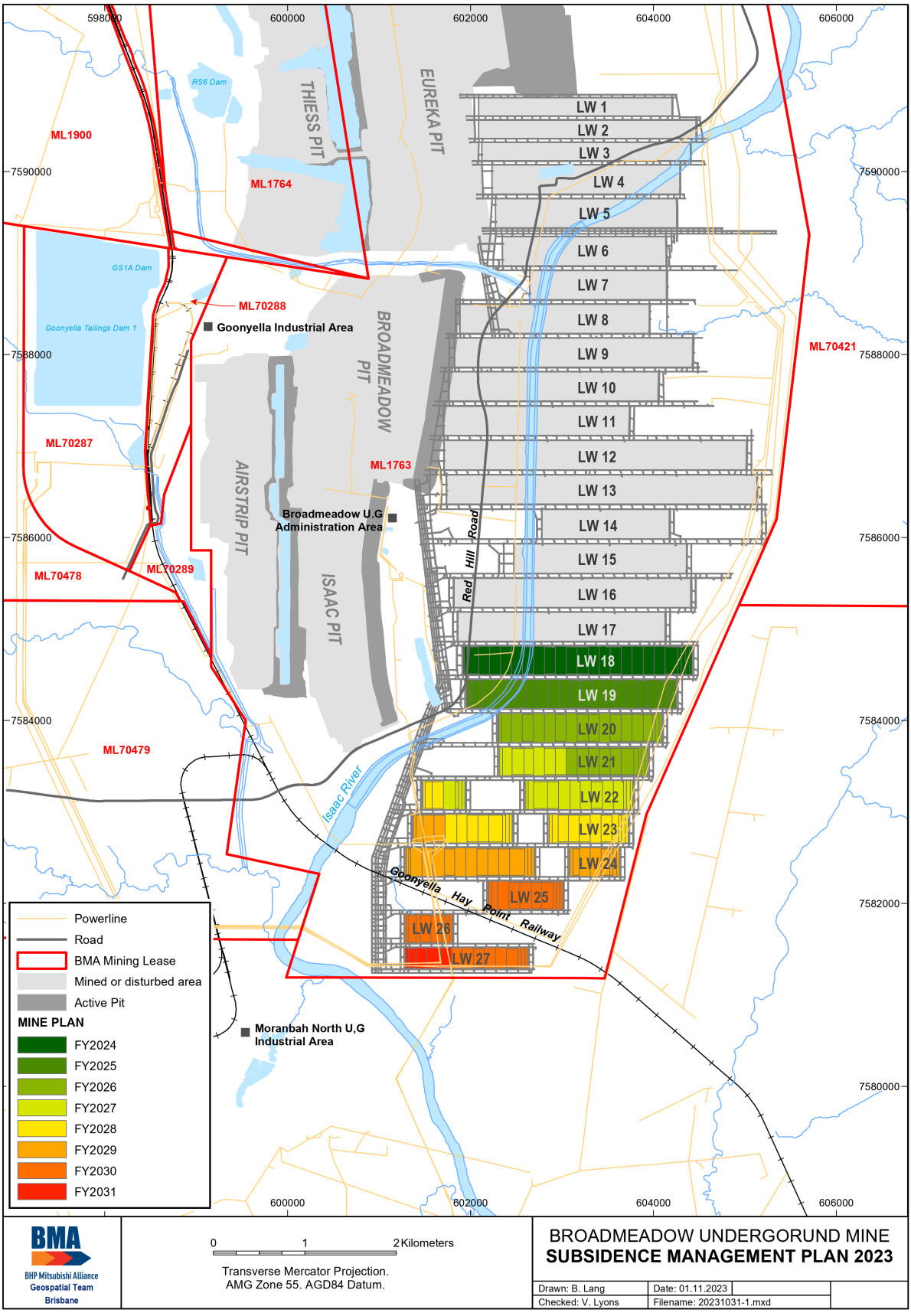


Figure 2 (Authorised Subsidence Extent)



END OF ENVIRONMENTAL AUTHORITY

Notice

Environmental Protection Act 1994

Progressive rehabilitation and closure plan transition notice

This statutory notice is issued by the administering authority[1] under section 754 of the Environmental Protection Act 1994 *to advise you that you must submit a proposed Progressive rehabilitation and closure plan (PRC plan).*

BHP Coal Pty Ltd
Level 14, 480 Queen Street,
Brisbane City, QLD 4000

Craig.lockhart@bhp.com; Trudy.mazucco@bhp.com

Attention: Craig Lockhart & Trudy Mazucco

Our reference: EPML00853413

Transition Notice for a PRC plan

1 Environmental authority details

Environmental authority EPML00853413 dated 25 June 2020 issued to BHP Coal Pty Ltd, Mitsubishi Development Pty Ltd, QCT MINING PTY. LTD., Umal Consolidated Pty Ltd, QCT INVESTMENT PTY. LTD., BHP Queensland Coal Investment Pty Ltd and QCT Resources Pty Limited.

Land description: ML1763, ML1764, ML1802, ML1900, ML700003, ML70121, ML70193, ML70194, ML70287, ML70288, ML70289, ML70421, ML70468, ML70469, ML70478, ML70479, ML70493 and ML70494

2 Required action

The holder(s) of environmental authority EPML00853413 must submit a proposed PRC plan that meets the requirements in sections 126C and 126D of the *Environmental Protection Act 1994,* pursuant to section 754 of the *Environmental Protection Act 1994*. The holder(s) must submit the proposed PRC plan to the administering authority, by **29 November 2024**.

3 Transitional provisions

Pursuant to the transitional provisions in section 754(3) of the *Environmental Protection Act 1994*, the holder(s) of the environmental authority are not required to comply with the requirements under section 126C(1)(g) or (h), or 126D(2) or (3) of the *Environmental Protection Act 1994* if –

[1] The Department of Environment and Science is the administering authority under the *Environmental Protection Act 1994*.

Queensland Government

(a) an outcome for the land has been identified under a land outcome document; and

(b) the outcome for the land is the same as, or substantially similar to, the outcome for the land if it were a non-use management area under a PRCP schedule.

A land outcome document is defined under section 750 of the *Environmental Protection Act 1994*.

Section 126C(1)(g) or (h), or 126D(2) of the *Environmental Protection Act 1994* require reasons and evidence to be provided to support a proposed non-use management area.

Section 126D(3) of the *Environmental Protection Act 1994* provides for any void that is contained wholly or partly in a flood plain to be rehabilitated to a stable condition.

In accordance with section 754(4) of the *Environmental Protection Act 1994*, if a land outcome document does not state sufficient detail to identify either the location or area of the land to which the outcome relates, the proposed PRC plan must state–

(a) if the area is not identified — how the total area of the land to which the outcome relates will be minimised; and

(b) if the location is not identified — how the mining environmental authority holder will ensure the location of the land to which the outcome relates minimises risks to the environment.

4 Supporting information

As detailed in section 2 of this notice, your PRC plan and associated PRCP schedule is required to address the relevant legislative requirements.

Please refer to the guideline Progressive Rehabilitation and Closure Plans (ESR/2019/4964) for more information about the requirements of the PRC plan and associate PRCP schedule, and the assessment process.

5 Consultation

The administering authority recommends that you request a pre-lodgement meeting to discuss the requirements of the proposed PRC plan in more detail. To request a pre-lodgement meeting, please complete and lodge the form ‘Application for pre-lodgement services’ (ESR/2015/1664) to arrange a meeting.

Should you have any questions in relation to this notice, contact Business Centre Coal via the below details.

Signature

13/12/2021

Date

Chris Wake
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Coal Business Centre
Department of Environment and Science
PO Box 3028, Emerald QLD 4720
Phone: (07) 4987 9320
Email: CRMining@des.qld.gov.au

Memorandum

Date	29 November 2021
To	Chris Wake, Manager Environmental Services, Department of Environment and Science
From	Trudy Mazucco, Principal Closure Planning Minerals Australia
CC	Craig Lockhart, Manager Closure Planning Minerals Australia
Subject	Progressive Rehabilitation and Closure Plan – Goonyella Riverside / Broadmeadow Mine Complex (v2)

Purpose

The purpose of this memo is to provide context and background information for the purpose of completing a Progressive Rehabilitation and Closure Plan (PRC Plan) and associated PRCP Schedule for the Environmental Authority (EA) noted below (Goonyella Riverside / Broadmeadow Mine Complex). This information is intended to facilitate the issuing of a notification for the PRC Plan and associated PRCP Schedule for this EA.

Environmental Authority Number: EPML00853413 (19 December 2019)

Environmental Authority Holders: BHP Billiton Mitsubishi Alliance (BMA) equity holding, comprising:

- QCT Mining Pty Ltd
- QCT Resources Pty Ltd
- QCT Investments Pty Ltd
- BHP Coal Pty Ltd
- BHP Queensland Coal Investments Pty Ltd
- Mitsubishi Development Pty Ltd
- Umal Consolidated Pty Ltd

BHP Group Limited ABN 49 004 028 077, BHP Group Plc. registration number 3196209 and their respective subsidiaries are members of the BHP Group. The BHP Group is headquartered in Melbourne, Australia.

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
Introduction	The Goonyella Riverside Mine Complex (GRBM Complex) comprises the open cut Goonyella Mine (GRM) and the underground longwall Broadmeadow Mine (BRM). The mine is located 30km north of the town of Moranbah, Queensland. Environmentally relevant activities are authorised on mining leases (MLs) ML1763, ML1764, ML1802, ML1900, ML70121, ML70193, ML70194, ML70287, ML70288, ML70289, ML70468, ML70469, ML70478, ML70479, ML70493, ML70494, and ML700003. Mining operations commenced at Goonyella in 1971 and the mine merged with the Riverside Mine in 1989.	-
Project Planning		
Project description	GRM is a conventional open cut strip mine with a north-south coal seam strike. Mining involves the removal and stockpiling of topsoil, drilling and blasting of overburden, and use of draglines and truck/shovel to remove the overburden to expose the coal seams (Goonyella Upper, Goonyella Middle and Goonyella Lower). The underground operations at BRM utilise longwall mining. Mining operations commenced with access from the GRM Eureka Pit, with current access from Broadmeadow Pit. Access to future underground panels may be established from other GRM pits. Product coal is transported by rail to the Hay Point Coal Terminal for export. Mining activities primarily occur within ML1763, with a small portion of mining occurring on the south-eastern portion of ML1764.	-
Mining activities	The current mining activities at GRBM include: • Open cut mining (GRM); • Underground mining (BRM); • Spoil dumps and reject dumps; • Tailings storage facilities (TSFs);	-

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PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
	• Two coal handling and preparation plants (CHPPs); • Mine water dams; • Coal stockpile areas; • Run-of-mine (ROM) area; and • Haul roads and laydown areas.	
Existing rehabilitation	Rehabilitation has been completed routinely at GRBM each year.	-
PMLUs	The predominant pre-mining land uses at GRBM were cattle grazing and woodland. As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, BHP has transitional arrangements for GRBM for the post-mining land uses (PMLUs) listed in Table E1 of the EA, which include: • Cattle grazing; • Dryland cropping; • Woodland habitat; • Water storage; and • Watercourse. The completion criteria in Table E1 will also be transitioned to milestone criteria in the PRC Plan. The location, extent and viability of these PMLUs will be detailed in the PRC Plan.	-
NUMAs	As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, BHP has transitional arrangements for residual voids as NUMAs for GRM. Void wall stability will determine the extent of a NUMA as it may extend past the mined void crest if necessary to allow for management of wall instability. This will be detailed in the PRC Plan for GRM. As the EA does not state the area or location of the proposed NUMAs, the PRC Plan will include detail on how the total area of land as NUMAs will be minimised, as well as how the location will minimise risk to environment, as required in the guideline.	-

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
	The PRC Plan will also demonstrate how environmental harm will be managed beyond the transitioned NUMAs	
Voids in floodplains	As the location and size of the transitioned NUMAs are not identified in land outcome documents, flood modelling in accordance with the *BHP PRCP Flood Modelling Position – 23072020 memo* will be completed.	-
Community consultation	As a transition site, there is no requirement for community consultation prior to submission of PRC Plan. However, BHP will follow an engagement plan over the life of the operation, in line with current internal stakeholder engagement frameworks.	-
Rehabilitation and Management Methodology		
Hydrogeology	GRBM comprises deep voids, and underground workings which extend under the Isaac River. The groundwater regime in the mine area comprises Quaternary alluvial aquifers associated with the creeks and rivers in the area, Tertiary sediment and basalt aquifers, and Permian sedimentary rock aquifers. The aquifers generally yield low flow volumes of poor quality groundwater and generally have limited beneficial use in the area. GRBM is a large, complicated hydrogeological site, with limited groundwater data and no current groundwater model. To allow the delivery of the PRC plan in November 2024 the PRC plan groundwater assessment and modelling work will need to commence by mid-2023, which will also represents the cut-off date for the collection of additional groundwater data. The reduced timeline, will limit BMA's capacity to collect additional site-specific information to close out data gaps. This is particularly relevant where shallow groundwater is hosted in alluvial and tertiary geology. Historical limited groundwater data collection for the site has been focused on the Permian geological units and as such only limited information is held characterising shallower groundwater units. To achieve the proposed timelines, groundwater inputs into the PRC plan will rely more heavily on available regional models, data sharing agreements, existing data held for the sites and more conservative assumptions/uncertainty analysis. The delivery of the PRC plan in November 2024 will not provide for: • Closing out any data gaps/uncertainties identified during the assessment of groundwater;	As documented in the DES memo Groundwater Scope of Work to Satisfy PRCP requirements, dated 25 September 2020, it is noted that delivery of the PRCP on 1 November 2024 will be based on the groundwater data held at the time. Additional groundwater data may be required post-2024 to assess seasonal trends, provide greater data definition, and to reduce uncertainties. The delivery of a PRCP for GRBM by 1 November 2024 will need to rely on the initial rounds of contaminated land investigations. These initial rounds of investigation are unlikely to achieve delineation of plumes and coverage across the entire mine site. This will limit the understanding of contaminant fate-and-transport modelling. Contaminated land investigations will be on-going post-2024 based on potential risks identified.

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
	• Completion of contaminated land investigation data sets that will allow for predicative modelling of contaminant transport; • Collection of complete data sets for all shallow/confined groundwaters to provide confirmation of existence, condition and depth; and • Modelling to higher levels of resolution if required/relevant for specific locations to inform other technical studies.	
Flooding	The GRBM Complex is located within the headwaters of the Isaac-Connors sub-catchment of the greater Fitzroy Basin. The Isaac River is the main watercourse traversing the mine site. The Isaac River and tributaries (Eureka, Goonyella, Cleanskin, Platypus, Holding Paddock, Fischer and Ceil Creeks) in and around the GRBM Complex are ephemeral. As per the *BHP PRCP Flood Modelling Position – 23072020* memo, BHP will use a risk-based approach to flood modelling. Where the risk-based approach identifies a flood modelling requirement, the modelling will be completed using criteria identified as appropriate for the location.	-
Soil and capping material	As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, the soil and capping assessment at GRBM will include: • Topsoil quality, quantity, treatments and management; • Availability, quality and quantity of any other capping material required; and • Strategies to address any deficits including development of alternative growth media to support appropriate PMLUs.	As contaminated land detailed site investigations and fate-and-transport modelling for the entire site are unlikely to be completed by 1 November 2024, this will impact the level of certainty on site-wide capping material balances.
Waste characterisation	Mine waste at GRBM includes: • Overburden / interburden; • Coarse rejects; and • Tailings. Historic geochemical and physical (for sodicity and dispersivity) characterisation test work will represent the bulk of the data utilised to assess the geochemical risk posed by key mine waste domain and landforms.	On-going contaminated land investigations are envisaged to be required post-2024, which may impact on the understanding of impacts associated with waste materials. Therefore, additional data collected as part of the contaminated land investigations may require updates to

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
	As detailed in *BHP PRCP Geochem DES Update 26082020*, site specific and data collected from other BHP sites extracting coal from the Moranbah Coal Measures (*PRCP memos – comments and feedback 25092020*) will be used to assist with defining the environmental geochemical properties of key material domains at GRBM. In addition to the historic samples listed in *BHP PRCP Geochem DES Update 26082020*, the following additional data are currently available: • Core drilling of 6 holes (totalling 1277m) completed in October 2021. Overburden and seam samples currently being collected for analysis in early 2022. Estimate minimum 850 samples. These data were not included in the *BHP PRCP Geochem DES Update 26082020*. • 159 tailings and rejects samples collected from drilling conducted at the GS1 TSF in 2021. These data were not included in the *BHP PRCP Geochem DES Update 26082020*. • 127 tailings and rejects samples collected from drilling conducted at the RS1 TSF in 2021. These data were not included in the *BHP PRCP Geochem DES Update 26082020*. • 26 coarse reject samples from GY and RV CHPPs + ongoing routine sample collection. Commenced July 2021. These data were not included in the *BHP PRCP Geochem DES Update 26082020*. • 110 tailings samples from GY and RV CHPPs + ongoing routine sample collection. Commenced February 2017. • Ongoing tailings and reject sampling testing will be conducted to augment geochemical knowledge for these materials type (*BHP PRCP Geochem DES Update 26082020*). Sample prep and analytical tests varied slightly between the different sampling programs (and between drill-hole samples vs reject samples). However, the fundamental geochemical and physical (i.e. sodicity and dispersivity) characterisation methodology was the same or similar between programs. Therefore, all data is relevant and will be used in the assessment. Lab-work generally undertaken in stages: • Stage 1 (screening – typically all samples): pH & EC (1:5 water extracts on pulps); total sulfur (S); acid neutralising capacity (ANC).	the interpretations made as part of the waste characterisations studies. Groundwater data gaps may not be closed out for PRCP submission on 1 November 2024. Therefore, source, pathway and receptor linkages associated with waste characterisation studies may need to be updated on closing out of any hydrogeological data gaps.

<table>
<tr><th rowspan="2">PRCP Requirement</th><th colspan="2">BHP information submission for review</th></tr>
<tr><th>29 November 2024 submission</th><th>Post-2024 submission considerations</th></tr>
<tr><td></td><td>

Stage 2 (typically selected samples): sulfur speciation; net acid generation (NAG); total metals; soluble metals (1:5 water extracts on pulps); exchangeable cations; Emerson Aggregate.
Stages 3+ (selected samples): acid buffering characterisation curves (ABCC); Extended Boil NAG; Sequential NAG; Kinetic-NAG; Quantitative XRD; OxCon; free draining column leach tests.

Historic and new data for all mine waste will be reinterpreted to provide a consistent understanding and definition of the geochemical and physical risk (i.e. AMD and salinity/dispersivity, as applicable) across key material domains including pit wall geochemical stability.

One of the outcomes of the geochemical and physical characterisation will be a classification system that will confidently identify beneficial and problematic waste from a chemical and physical stability perspective.

The PRC Plan will detail the waste categories to ensure problematic waste, based on both chemical and physical behaviour, is managed at GRBM. Conceptual waste categories at GRBM are shown in the table below but modification may be made in the PRC Plan submission once the final assessments have been completed:
<table>
<tr><th>Waste Category</th><th>Characteristics</th><th>Recommended Management</th></tr>
<tr><td>Tertiary/ Weathered Permian waste</td><td>Non-carbonaceous
Fine textured, often saline and sodic</td><td>• Place on lower slopes or not on the outside of higher slope dumps where possible
• If used on the outside of the landforms, ameliorants to be considered for sodic materials to limit dispersion and landforms to be designed accordingly</td></tr>
<tr><td>Permian waste</td><td>Non-carbonaceous
Rockier, lower in salinity and sodicity</td><td>• Place on the outside of higher slope dumps where possible</td></tr>
<tr><td>Rock</td><td>Non-carbonaceous
Basalt and competent sandstone</td><td>• Can be used on outside slopes to achieve steeper, more stable landforms (rock mulching)</td></tr>
<tr><td>AMD potential</td><td>Coaly and carbonaceous material (carbonaceous overburden/ interburden, thin partings)</td><td>• Co-mingle dumping with other waste</td></tr>
</table>
A risk based approach will be used to determine what work is required to characterise existing waste dumps if issues are identified.
</td><td></td></tr>
</table>

DRAFT

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
Landform design	The main structures of the GRBM final landform include spoil dumps, rejects dumps, final voids, tailings storage facilities and subsidence. The PRC Plan will include the detail for landform design as per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*.	As contaminated land detailed site investigations and fate-and-transport modelling for the entire site are unlikely to be completed by 1 November 2024, this will impact the level of certainty on site-wide remediation requirements and closure-related landform designs.
Cover design	A risk-based approach will be used to determine areas that may require a cover design.	As contaminated land detailed site investigations and fate-and-transport modelling for the entire site are unlikely to be completed by 1 November 2024, this will impact the level of certainty on site-specific cover designs.
Water management	Water management planning will integrate the results of other technical studies such as contaminated land, waste characterisation, TSF closure, diversions, groundwater assessments and landform design, to provide an understanding of the post mining water management requirements and potential risks. Water management planning will identify requirements for any ongoing dewatering or treatment and how this is to be achieved. The design of the final landforms will include, where required, infiltration and seepage intervention and collection controls, where these measures are deemed to be required. There are four creek diversions at GRBM: • Isaac River Creek; • Eureka Creek Holding; • Holding Paddock Creek; and • Fischer Creek. The creek diversions undergo routine monitoring as part of the operations, and this monitoring will be completed throughout the LoA as part of the operations and closure. The PRC Plan will define the approval regime and status of each diversion i.e. temporary or permanent. In addition, BHP will assess the performance of all watercourse diversions and this assessment will be used to inform subsequent relinquishment and final landform outcomes for each diversion. Forward work plan based on the outcomes of the assessment of the watercourse diversion will be included in the PRCP schedule.	On-going contaminated land investigations are envisaged to be required post-2024, which may impact on the understanding of sources, pathways, receptors and their potential linkages. Water management considerations within the 2024 PRC plan will be based on available information and take a conservative approach.

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
Revegetation	The PRC Plan will include the detail for revegetation as per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*. The Revegetation Plan will be consistent with the revegetation planning requirements of the PRCP guideline and existing BHP rehabilitation management plans. The Revegetation Plan will describe the works for establishing and managing the revegetation as it relates to the intended PMLUs as listed in Table E1 of the EA (e.g. cattle grazing, woodland habitat, watercourses, water storage and dryland cropping).	-
TSFs	Current GRBM TSFs include: GS1 TSF, RS1 TSF, Ramp 32 and Dragline 5 TSF. These facilities comprise the following: • Central decant turkey's nest dams (RS1 and GS1): these are above ground facilities with partial or complete perimeter embankments (RS1 is bounded by a waste dump of coarse rejects on its western side). These facilities have a central decant using an embankment or pontoon-mounted pump. In addition to requiring additional fill materials to promote drainage to the external embankments, softer tailings in the vicinity of the central decant will result in differential settlement that will require additional fill materials to maintain the drainage. • In-pit TSF (Ramp 32): this is a disused mining void that has been partially filled with tailings. The relatively level pit floor will result in small differential settlement. • In-void TSF (Dragline 5): this is a disused mining void that has been partially filled with tailings. The relatively level pit floor will result in small differential settlement. The PRC Plan will include the detail for TSFs as per the *BHP Coal Tailings PRCP Final 30062020 memo*. This includes site and material characterisation which will inform conceptual closure designs of TSFs where applicable. The closure design schedule will be driven by availability and risk profile of individual facilities.	-
Voids	Voids at GRM are progressively backfilled with overburden and mine waste as mining advances during the operational stage. At closure, only the final voids (location of final cuts) will remain. BHP will use a risk-based approach to assess representative final voids at GRM. The PRC Plan will include the detail for voids as per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*. Void closure planning relating to water resources will include:	As previously mentioned, contaminated land detailed site investigations and fate-and-transport modelling for the entire site is unlikely to be completed by 1 November 2024. As the results of these investigations may impact on the water quality within the void, the void water

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
	• An update of the hydrogeological model where appropriate; • Void water balance; • Void water quality prediction for electrical conductivity; • Hydrologic conceptual site model; and • A risk based approach to assess the potential impacts of flooding and the need for any additional flood modelling.	quality predictions may be incomplete and require additional development post-PRC Plan and Schedule submission. Where void hydrology is impacted by shallower groundwaters, for which limited data is currently held, amendment of the Void Closure Plan may be required upon collection of additional data and any updating of the hydrogeological model.
Underground mining	The requirements of the PRCP Guideline will be compiled for the BRM workings.	Ongoing groundwater data collection and any update to the hydrogeological model undertaken after 1 November 2024 may improve the understanding of hydrogeological conditions. Therefore, updates to the underground mining PRCP considerations may be required post-2024.
Infrastructure	The main on-site infrastructure at GRBM includes: CHPPs, train load-out facility, permanent and temporary buildings, bitumen roads and car parks, mine industrial area (MIA) (workshops, sheds etc.), ROM pad and coal stockpiles (conveyors, stackers, etc.) and water dams. As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, all required information on decommissioning or retainment of infrastructure will be included as part of the PRC Plan.	-
Risk assessment		
Risk assessment	To be completed as part of the PRC Plan.	Due to the limited datasets pertaining to the hydrogeological and contaminated land outcomes, the level of certainty of occurrence of potential risk events identified as part of the 1 November 2024

PRCP Requirement	BHP information submission for review	
	29 November 2024 submission	Post-2024 submission considerations
		GRBM submission, and their potential consequences and required controls and/or mitigations will only be at a conceptual level of understanding. Ongoing data collection and analysis after 1 November 2024 will enable improved risk analysis.
Rehabilitation trials and monitoring and maintenance	Rehabilitation trials will be undertaken, if required, to verify alternate rehabilitation treatments such as alternative growth media and landform requirements. Where appropriate, concepts requiring further investigation in a trial will be included in the PRC Plan. Monitoring and maintenance will be based on current BHP processes. As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, all required information will be included.	-
PRCP Schedule		
Rehabilitation milestones, and milestone criteria	To be completed based on the content of the PRC Plan.	-
PRCP Submission		
As discussed with the DES team on Monday, 29 November 2021: **GRBM PRCP submission date: 29 November 2024**		

Recommendations

Review and consider the above information as a basis for PRCP compilation for the GRBM complex.

Yours sincerely

Trudy Mazucco
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BHP Group Limited ABN 49 004 028 077, BHP Group Plc. registration number 3196209 and their respective subsidiaries are members of the BHP Group. The BHP Group is headquartered in Melbourne, Australia.

Appendix 1: Goonyella Riverside / Broadmeadow Mine Complex: Supporting Maps

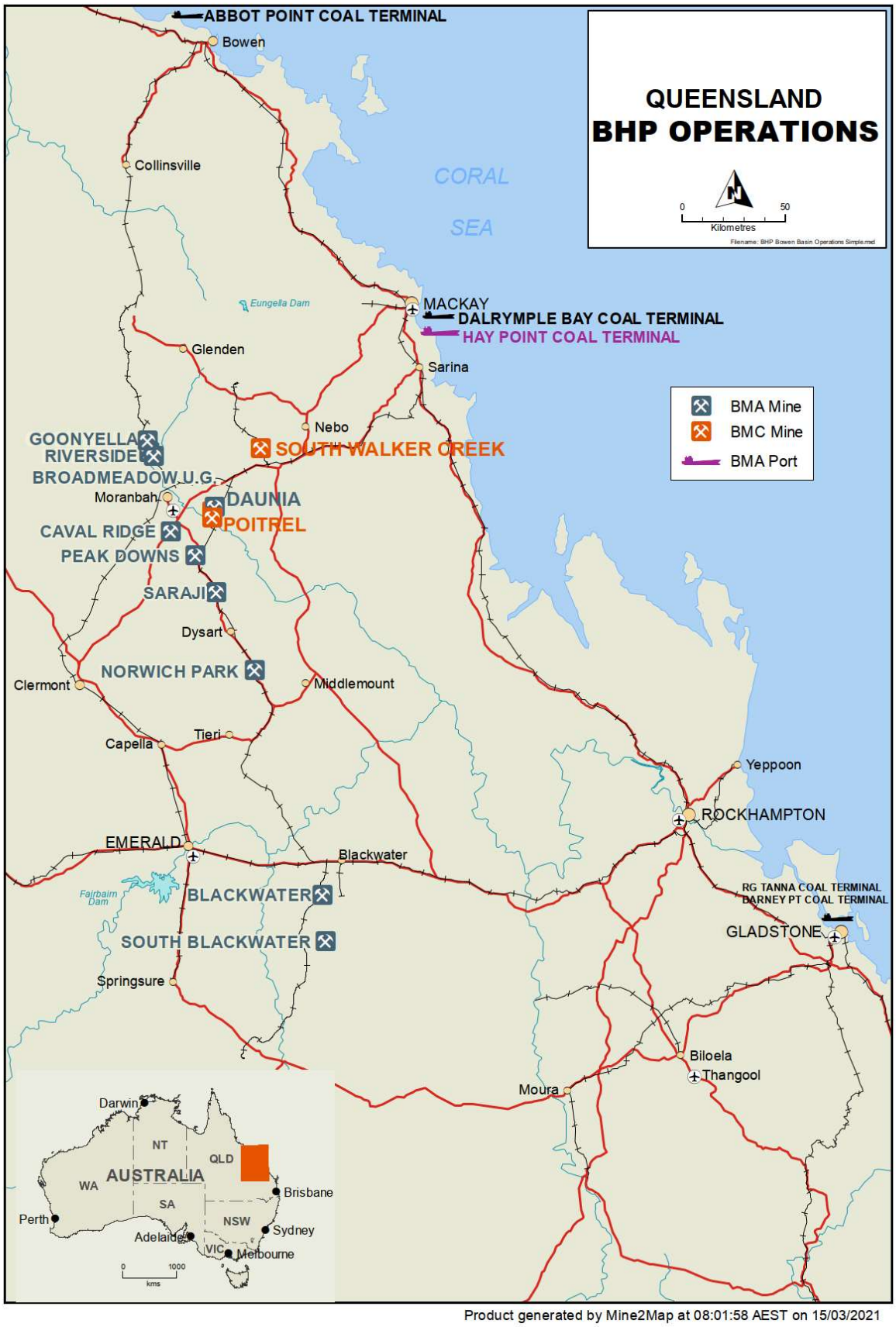

Figure 1: BHP Operations in Queensland

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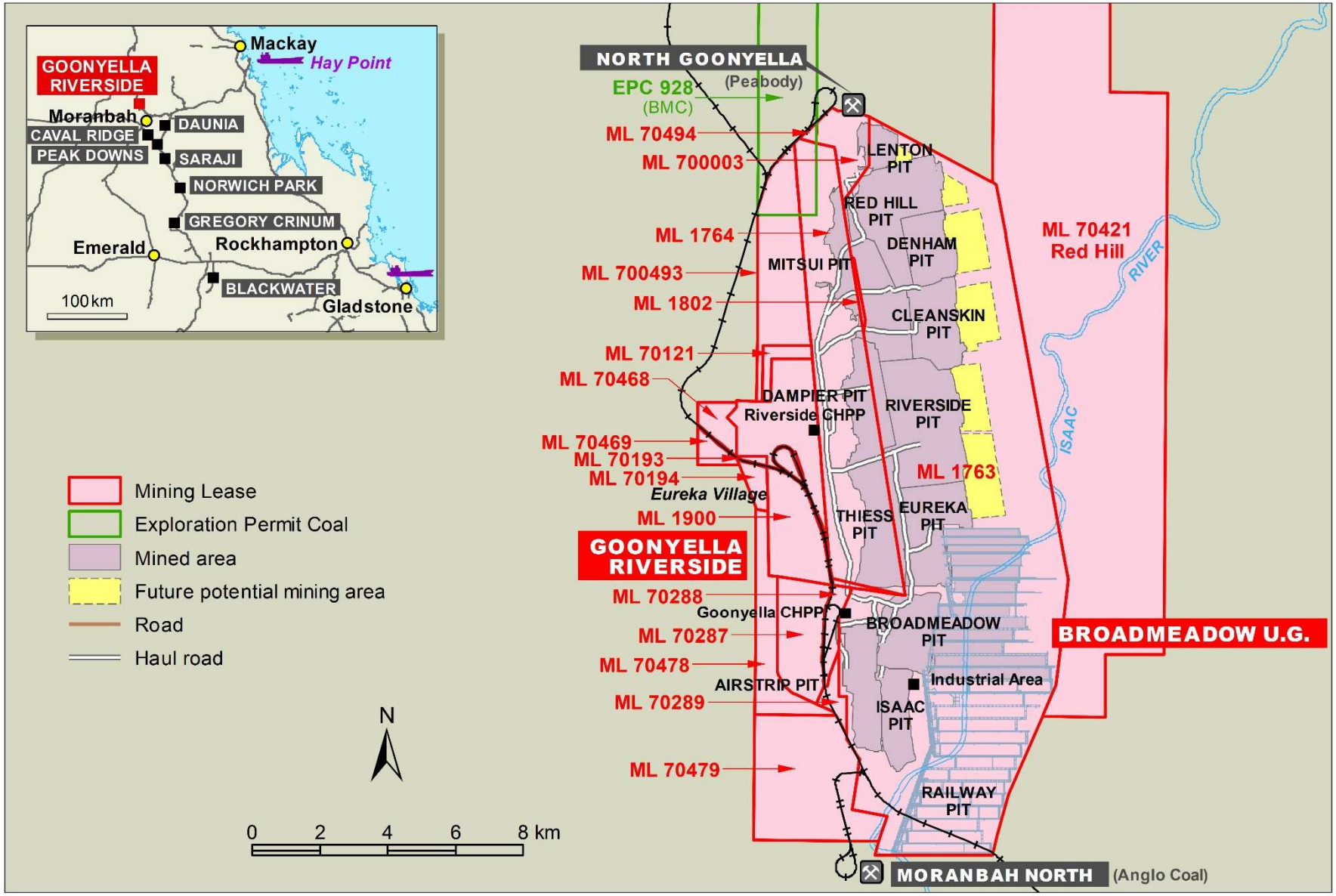

Figure 2: GRBM Complex mining tenements and operational land

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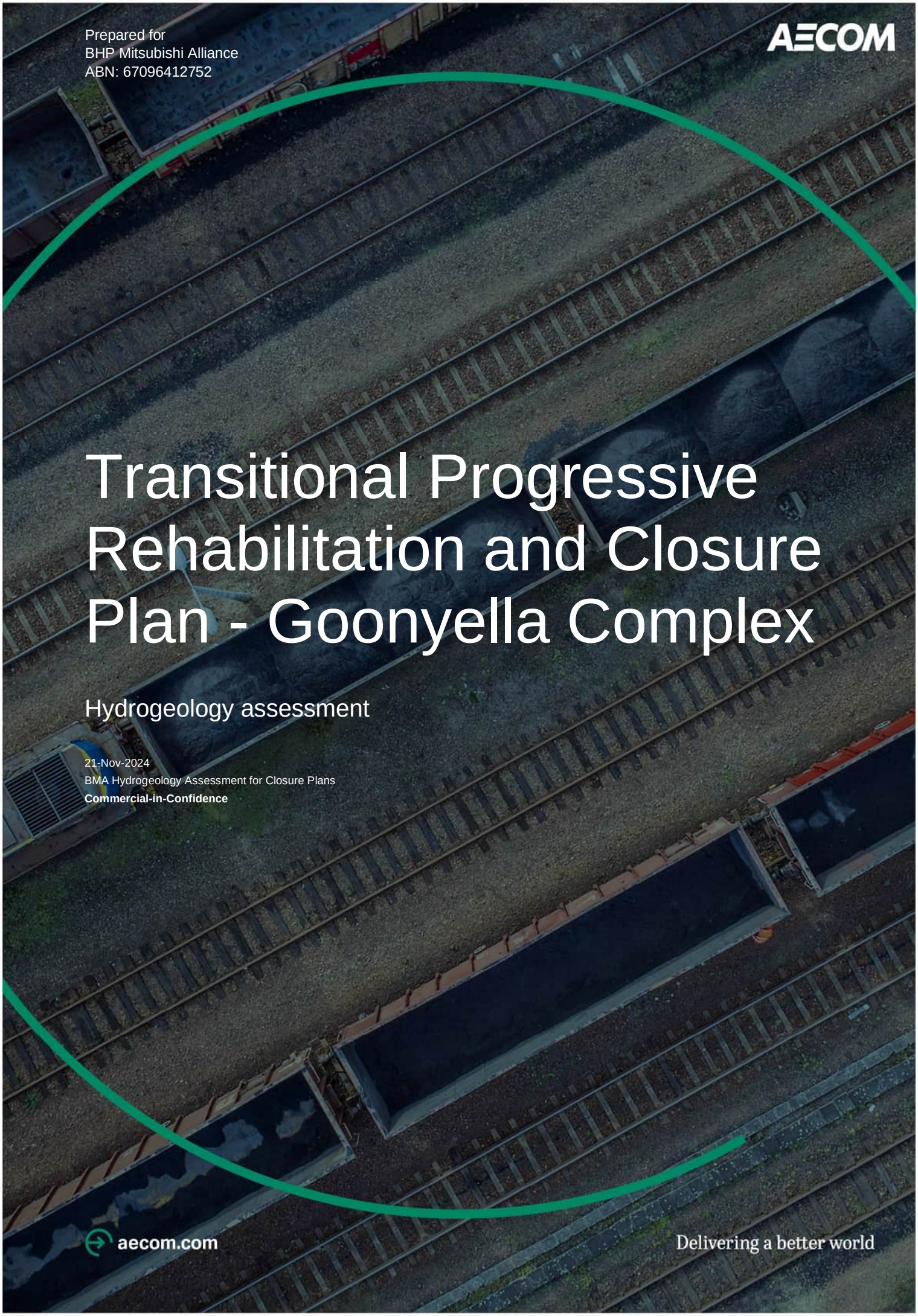
Prepared for
BHP Mitsubishi Alliance
ABN: 67096412752

AECOM

Transitional Progressive Rehabilitation and Closure Plan - Goonyella Complex

Hydrogeology assessment

21-Nov-2024
BMA Hydrogeology Assessment for Closure Plans
Commercial-in-Confidence



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Transitional Progressive Rehabilitation and Closure Plan - Goonyella Complex

Hydrogeology assessment

Client: BHP Mitsubishi Alliance

ABN: 67096412752

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1.0 Introduction

BHP Mitsubishi Alliance Pty Ltd (BMA) appointed AECOM Australia Pty Ltd (AECOM) to undertake hydrogeological assessments to support the transitional Progressive Rehabilitation and Closure Plan (PRC Plan) for the Goonyella Complex (GRB). The GRB comprises of the Goonyella, Riverside, and Broadmeadow mines, located about 30 kilometres (km) north of Moranbah, Queensland (see Figure 1).

The GRB metallurgical coal mining complex includes both open cut (Goonyella Riverside Mine) and underground (Broadmeadow Mine) operations, across eighteen (18) Mining Lease (ML) tenures within the geological Bowen Basin. Existing operations at GRB are executed under the conditions of Environmental Authority (EA) EPML00853413, for the extraction of coal via open cut strip mining from the Goonyella Riverside Mine and underground extraction of coal from the Broadmeadow Mine.

Mine workings of relevance for the Project are located primarily on ML 1763 and ML 1764, which include existing open cut pits: Thiess Pit, Airstrip Pit, Isaac Pit, Broadmeadow Pit, Red Hill Pit, Denham Pit, Cleanskin Pit, Riverside Pit, and Eureka Pit as depicted on Figure 2. This hydrogeological assessment was undertaken in accordance with the relevant requirements of the Queensland Department of Environment and Science (DES) Guideline – Progressive Rehabilitation and Closure Plans (PRC Plans), reference ESR/2019/4964, Version 3.1 (16 September 2024), 'the Guideline'. The groundwater assessment will be utilised to assist in the development of rehabilitation strategies and selection of post-mining land uses (PMLUs) and non-use Management Areas (NUMAs) within the GRB PRC Plan.

The BMA Red Hill Mine (RHM), an undeveloped hard coking coal underground mine, is located immediately adjacent and down dip of the GRB. The mine will be accessed through the open cut pit highwall of the GRB and utilise existing disturbance areas and infrastructure. The RHM is designed to be an extension of the GRB operational life and capacity of operations at the GRB. RHM is operated under a separate EA (EPML03337715) from the GRB and, as such, will have a separate PRC Plan. However, it is noted that, due to the interconnectivity of the hydrogeology, this groundwater input into the GRB PRC Plan incorporates both the GRB and RHM.

The terms 'GRB', 'Goonyella Complex', and 'Project area' throughout this report are defined as:

- GRB and Goonyella Complex are both defined as the collective Goonyella Riverside and Broadmeadow mines and the terms are interchangeable
- The Project area is defined as the regional area surrounding the GRB considered in detail within this assessment, to inform the understanding of the local and more regional scale groundwater system/s.

Figure 1 Project locality plan

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423058S m | 2426765S m | 2430472S m | 2434190S m

ML 700003
ML 70493
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
ML 70421

Mabbin Road
Ellensfield Road
Red Hill Road
Pasha Road
Riverside Mine Road
Goonyella Road

Isaac Western Uplands
Upper Isaac River
Isaac River
Isaac River
Isaac River
Isaac River
Upper Isaac River
Isaac Northern and Central Floodplain

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Locality Plan

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

Mackay

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1.1 Background

The Goonyella open pit coal mine commenced operations in 1971, while the adjacent Riverside underground longwall mine was brought into production in 1982. The mines were merged into a single operation in 1989. The open pit mine targets three coal seams of the overall late Permian-aged Moranbah Coal Measures (MCM): the Goonyella Upper (GUS), Goonyella Middle (GMS), and Goonyella Lower (GLS) seams. The average thicknesses of these target coal seams are 3.9 m, 7.5 m, and 8.5 m, respectively. Comprising sandstones, siltstones, mudstones, claystone, and coal, the MCM extends more than 300 m below ground surface.

Operations began at Broadmeadow Mine as an underground longwall mine, which now includes top coal caving mining (TCC) methods, in 2005 under the ownership of BHP Billiton Mitsubishi Alliance. The TCC mining method is defined as “a special type of longwall mining applicable to very thick seams”. This method reduces the amount of good quality coal that can be left using ‘conventional’ longwall equipment. Implementing this method at Broadmeadow increased productivity and offers safety advantages.

The introduction of the longwall top coal caving method, alongside an expansion of the Broadmeadow Mine eastwards, increased the productive capacity at the mine from 0.4 million tonnes per annum (Mtpa) to a new total capacity of 4.8 Mtpa and extended the life of the mine by 21 years. This expansion began producing coal in 2013 as part of the Goonyella Riverside Mine Expansion Project.

The neighbouring Goonyella Riverside mine has two coal handling and processing plants (CHPP) where mined coal is sorted and washed. Coal from Broadmeadow mine utilises these CHPPs. After being processed, the coal is transported by rail to the BMA-owned Hay Point Terminal.

Figure 2 GRB Mine areas (source: BMA)

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BMA

BHP Mitsubishi Alliance

GOONYELLA RIVERSIDE & BROADMEADOW MINES

0 1 2 km

Projection: AGD66 AMG Zone 55

Scale 1:25000

Filename: GRM_Photomap_Monthly.mxd

LEGEND

- Mining Leases
- Mineral Development Licence
- Exploration Permit - Coal
- Surface Areas

MINING TENURES

ML 1763	Goonyella Mine	10274ha
ML 1764	Riverside Mine	2162.63ha
ML 1802	Riverside Extended	19.22ha
ML 1900	Riverside West	1163ha
ML 70121	Riverside Tailings	90.24ha
ML 70193	Williams' Dam North	14.04ha
ML 70194	Williams' Dam South	79.73ha
ML 70287	Goonyella Tailings	458.85ha
ML 70288	Goonyella Industrial Area	99.6ha
ML 70289	West Airstrip Pit	80.08ha
ML 70421	Red Hill	8841.28ha
ML 70468	Riverside West Ext. 1	120.3ha
ML 70469	Riverside West Ext. 2	74.1ha
ML 70478	Goonyella West 1	426.52ha
ML 70479	Goonyella West 2	1138.5ha
ML 70493	Riverside Northwest	746.15ha
ML 70494	Riverside North	15.66ha
ML 700003	Mabbin	261.4ha
EPC 928	Wards Well Infrastructure	8 sub-blocks

Product generated by Mine2Map at 11:19:28 AEST on 17/05/2024

2.0 Final Landform #2.3

The post-mining final GRB landform relevant to this hydrogeological assessment was provided by BMA (denoted Landform #2.3) and is shown as Figure 3. The final landform comprises six planned residual final voids: Goonyella Pit (comprising Redhill Void, Denham Void, Cleanskin Void, Riverside Void), Thiess / Ramp 21 Pit, Ramp 32 East, Ramp 32 South, Broadmeadow Pit, and Isaac Pit (Plate 1). Ramp 32 East and Ramp 32 South are residual voids derived from the airstrip pit (Figure 2), where airstrip pit will be backfilled and rehabilitated for cattle grazing.

It is noted that Landform #2.3 was utilised in the predictive modelling included in the groundwater study, as reflected in Figure 21.

The final landform was a (2nd iteration) final landform provided by BMA to assess the suitability of BMA's intended post mining land use (PMLU) at GRB, that includes 'Cattle grazing', 'Woodland habitat', Water storage' and 'Watercourse' as defined within Table E1 of the EA.

Plate 1 GRB final landform residual voids

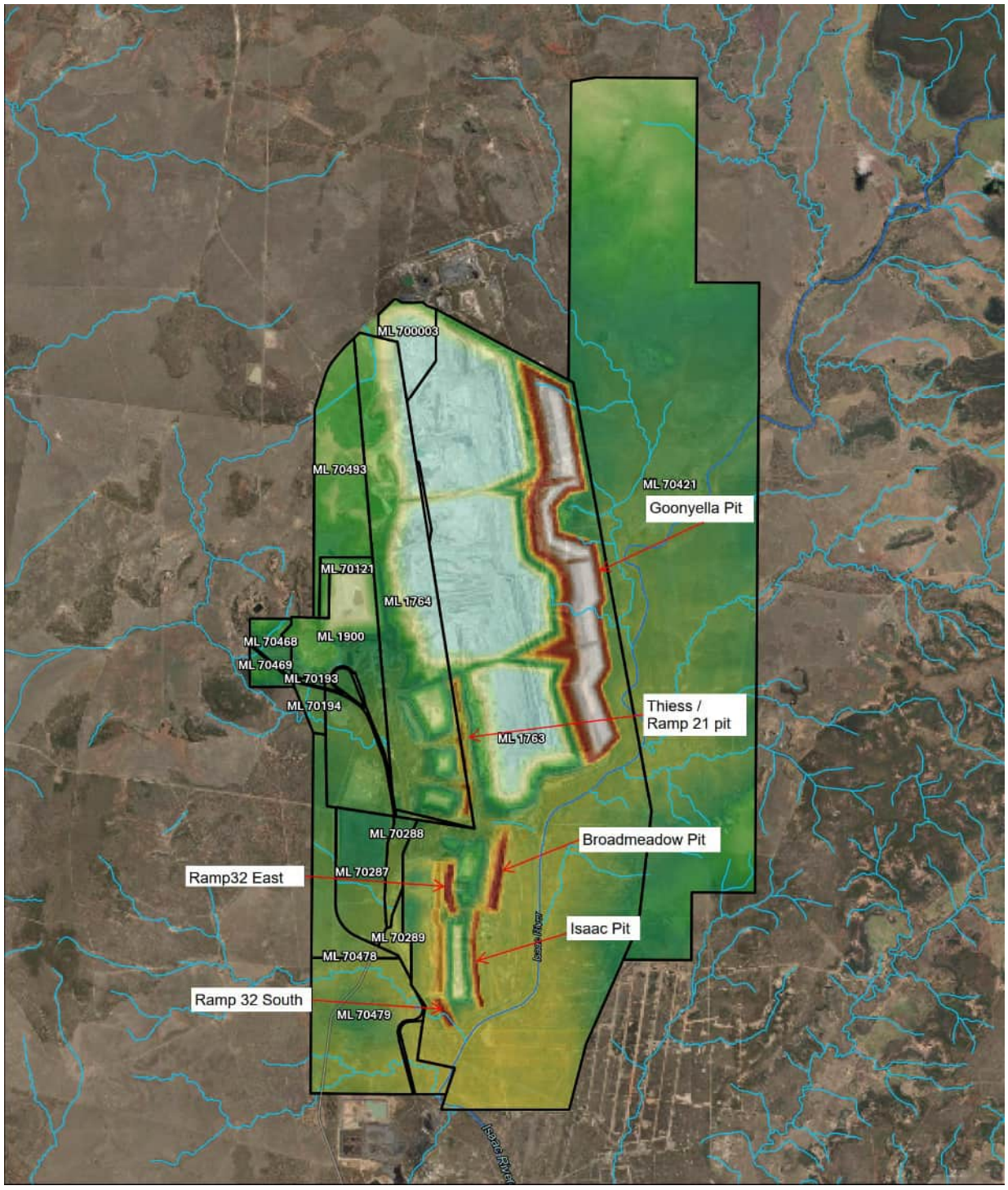

Figure 3 Landform #2.3

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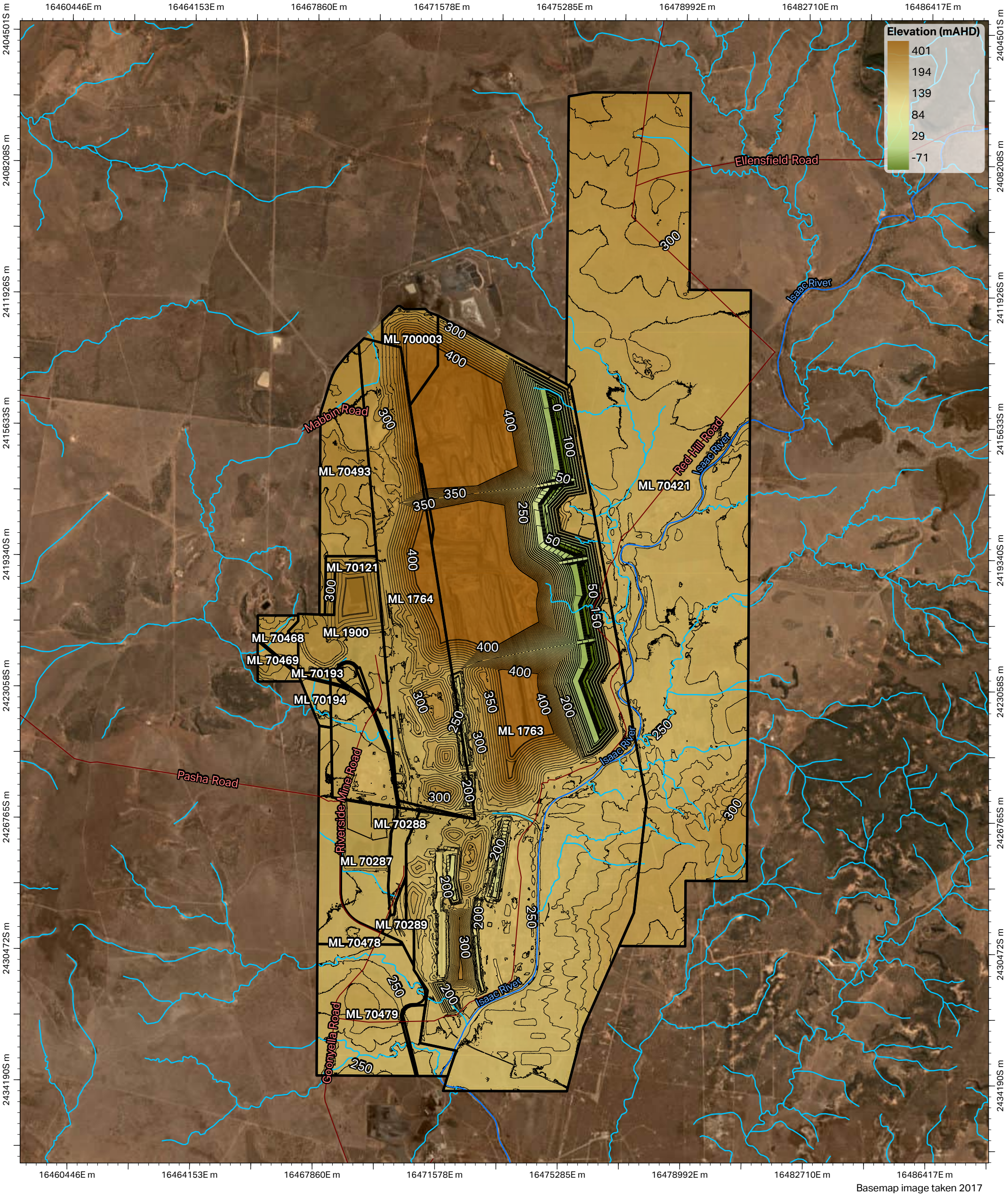


Goonyella, Riverside and Broadmeadow Mines

Post Mining Landform (Landform #2)

GDA 1994 MGA Zone 55

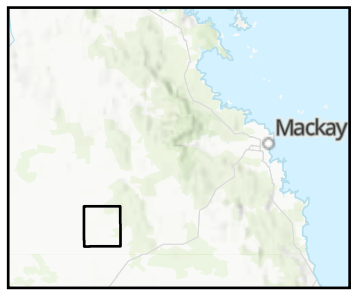
0 1 2 3 km

1:100,000

Mine Lease

Watercourse (Major)

Watercourse (Minor)



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3.0 Objectives

The main objective of the hydrogeological assessment is to assess the potential groundwater related impacts at GRB at completion of mining and until conditions stabilise post rehabilitation (i.e. groundwater equilibrium).

A focus of the hydrogeological assessment is demonstrating suitability of the landform for the intended PMLUs with respect of the GRB groundwater system. As such, the key specific objectives adopted in this assessment to demonstrate this suitability include:

- That the final landform is non-polluting with respect to groundwater:
  - The Goonyella Pit (final void) is recognised, through predictive groundwater and water balance modelling, to act as sink for groundwater, including groundwater contained within spoil.
  - The residual void pit water levels within the Goonyella Pit remain below groundwater bearing units, (i.e. there is sufficient freeboard to negate risk of void water discharge off site within a groundwater system).
- That there are minimal (little or no) additional impacts to groundwater receptors post-closure caused by the final landform that have not already occurred as a result of approved mining:
  - Little to no additional groundwater drawdown at potential groundwater dependant ecosystem (GDE) locations.
  - Little to no additional groundwater drawdown at anthropogenic bore users.

3.1 Guideline Criteria

A Progressive Rehabilitation and Closure Plan (PRC Plan) is a crucial component of ensuring that an Environmental Authority (EA) holder plans progressive rehabilitation of the land properly and provides conditions to which the land will be rehabilitated before surrendering the EA.

This hydrogeological assessment is undertaken in accordance with the relevant requirements of the Queensland Government Department of Environment and Science (DES) Guideline: Progressive Rehabilitation and Closure Plans (DES Reference: ESR/2019/4964, version 3.01, 16 September 2024).

Note: Guideline section 3.6.4 requires an assessment of groundwater interactions and potential lowering of groundwater levels that includes: consideration of the potential exposure of previously saturated geological formations to air - leading to AMD generation. Potential AMD generation and migration potential is not discussed in the hydrogeological assessment report, as a geochemical assessment has been compiled separately.

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Table 1 Statutory guidelines requirements addressed in the PRC Plan groundwater study

Guideline Section 3.6.1 Hydrogeology Requirements	Report Sections
Determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	Section 7.0
Locating groundwater recharge and discharge locations locally and regionally	Sections 7.3, 11.0, 13.0, and 17.0
Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	Section 8.0
Current and potential future uses of groundwater including existing groundwater extraction bores	Section 9.1
Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	Section 7.2 and Section 13.0
The development of potentiometric mapping and hydro stratigraphic cross sections	Sections 7.3, 6.0,11.0, and 17.0
Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage	Section 13.0, 14.0, 15.0, and 16.0
Guideline Section 3.6.3 Voids Requirements	**Report Sections**
Groundwater modelling to determine whether the void is acting as a sink or a source for groundwater	Section 15.0
A water balance study including an assessment of void surface and groundwater interactions such as:	
• groundwater lowering/reduction in hydraulic head	Section 15.4.3
• cones of depression and associated impacts	Sections 15.4.3, 15.6, and 15.7
• a conceptual model that incorporates all projected inflows, outflows, and recharge rates	Section 11.0, Section 15.4
• each of the major water fluxes into and out of the void	Section 16.3.1
Guideline Section 3.6.4 Underground Mining Requirements	**Report Sections**
• the development of a hydrogeological conceptual model	Section 11.0 and Section 17.1
• changes to the hydrogeological regime as a result of new cracks in the rock mass which can provide new flow paths in what could have previously been impermeable rock	Section 7.3.4
• potential for vertical connections between previously separated aquifers	Section 7.3.4

4.0 Project area description

The GRB complex is located within the Isaac River sub-basin of the Fitzroy Basin. The Isaac River sub-basin spans an area of about 22,000 square kilometres (km^2). Several tributaries join the Isaac River around the Project.

Eureka and Goonyella creeks are located immediately west and east of the GRB, respectively, and drain into the Isaac River. The Eureka Creek was modified with a man-made diversion drain and weir just upstream of where it joins the Isaac River. Eureka Creek is a partially regulated system for runoff from mining activities and is authorised as a discharge point to the Isaac River.

The Isaac River diversion is detailed in Section 5.2.

4.1 Climate

The climate around the Project area is sub-tropical, characterised by high variability in rainfall, temperature, and evaporation. Summer is between December and February and Winter is between June and August. The maximum daily temperature averages between 29.8 and 30.7 °C.

Climate data has been collected from two Bureau of Meteorology (BoM) weather stations around the project site. The weather stations used are:

- Moranbah Airport, QLD (Station 034035) – this station is situated about 36 km south of the project site. The station has been in operation since February 2012 to present day.
- Wentworth, QLD (Station 034015) – this station is situated approximately 43 km southwest of the project site. The station has been in operation since January 1963 to present day.

Average annual rainfall around the Project area is between 500 mm and 560 mm. High rainfall and evaporation occur in the summer months (December to February). Monthly evaporation rates are higher than monthly rainfall amounts throughout the year, indicating a net loss due to evaporation (i.e., a negative climate balance which has implications for final void water levels).

Summary of the average temperature and rainfall from the Moranbah Airport and Wentworth weather stations are presented in Table 2 and Table 3, respectively. Evaporation data was only available from the Wentworth weather station.

Table 2 Moranbah Airport (Station 034035) Temperature and Rainfall Averages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Min Temp (°C)	21.5	21.4	20.3	16.9	12.8	10	8.8	8.9	12.7	16.3	18.9	20.6	15.9
Mean Max Temp (°C)	34.5	33.7	32.8	30.3	26.9	24.4	24.3	26.8	30.1	33.2	34.5	34.9	30.7
Mean Rainfall (mm)	103.1	82.6	76.8	25.7	30.6	23.1	38.7	12.2	14.5	22.8	66.3	64.3	560.8

Table 3 Wentworth (Station 034015) Temperature and Rainfall Averages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Min Temp (°C)	21.7	21.5	20.0	16.7	12.8	9.4	8.1	9.5	12.9	16.7	19.3	21.0	15.8
Mean Max Temp (°C)	33.8	33.0	32.0	29.7	26.4	23.8	23.6	25.8	29.2	32.1	33.6	34.3	29.8
Mean Rainfall (mm)	88.6	77.0	50.2	28.8	28.6	18.4	19.6	18.3	9.9	25.9	54.8	82	499.3
Mean Evaporation (mm)	226.6	185.1	189.1	150.7	119.3	95.7	104.7	138.5	181.3	226.5	235.7	246.9	2,085.2

Rainfall data for the Project area were examined for rainfall patterns. Rainfall data was collected across the GRB for the period from 2014 to 2024. The coordinates for the rain gauges are provided in Table 4.

Table 4 Rainfall Stations Provided by BMA

Gauge Name	Commenced	Easting (GDA94)	Northing (GDA94)
GRM North AWS 2014 - 2024	2014	599688	7601004
BRM AWS 2014 - 2024	2014	602574	7588265
Eureka Village TEOM 2015 - 2024	2015	596976	7591840
GRM South AWS 2016 2024	2016	601182	7583820

The rainfall data indicates an average annual rainfall ranging from 510 to 560 mm, similar to the more regional weather stations.

Table 5 Average Rainfall Data (GRB)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GRM North AWS 2014 - 2024	108.5	66.9	62.9	16.6	36.1	18.9	35.3	11.3	19.	21.7	45.8	73.9	517.2
BRM AWS 2014 - 2024	100.0	63.9	64.3	21.1	30.7	19.5	40.8	12.6	40.9	19.4	60.1	82.4	555.9
Eureka Village TEOM 2015 - 2024	85.6	86.6	90.9	21.4	38.1	25.1	44.6	9.78	17.5	28.8	54.5	73.0	575.8
GRM South AWS 2016 2024	94.2	64.7	75.3	19.1	42.0	13.1	39.6	6.7	14.7	15.2	41.9	87.6	514.0

4.2 Topography

The Project area comprises undulating with gently sloping valleys influenced by three main topographic controls. These include the sloping terrain in the northeast which is controlled by the Burton Range, the low-lying Isaac River floodplains in southwest, and the subtle hills and ridgelines in the west.

Elevation across the Project area ranges from approximately 520 m around the Burton Range to approximately 230 m south of the mines.

Figure 4 provides the topography and drainages across the Project area.

Figure 4 Topography and drainage

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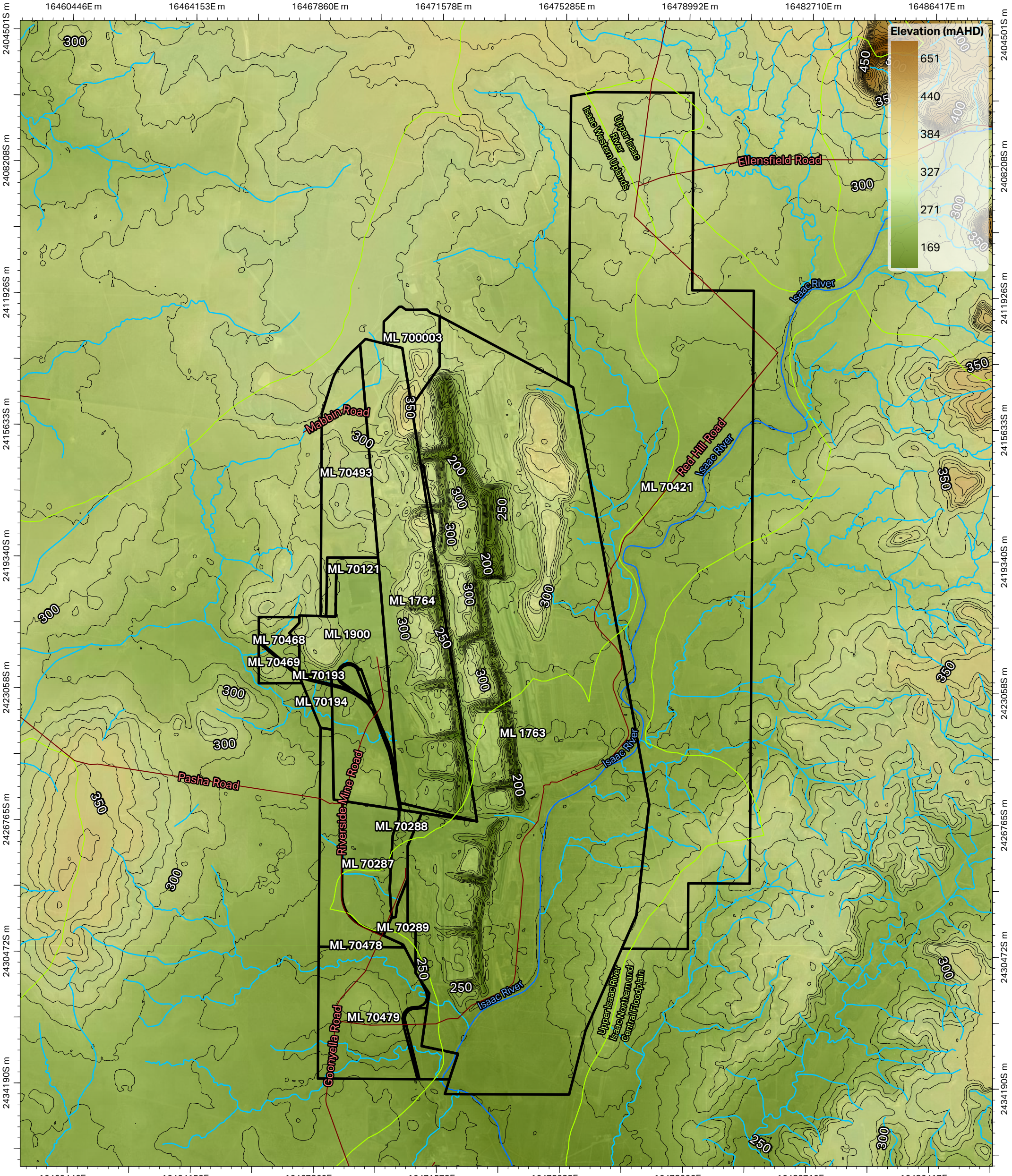

Goonyella, Riverside and Broadmeadow Mines

Topography and Drainage

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

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- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

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4.3 Cumulative Rainfall Departure

Cumulative rainfall departure (CRD) from long-term monthly rainfall records from the Moranbah and Wentworth weather stations are presented in Figure 5. The trends in this plot may provide an indication of water level response to rainfall recharge. A positive trend indicates periods of above average rainfall where increased groundwater recharge can occur. A negative slope indicates periods of below average rainfall where decreased groundwater recharge may occur.

Historic rainfall data from Wentworth, from 1964 to 1972, indicates a period of decreased rainfall. This was followed by a period of above-average rainfall (wet cycle) that lasted until 1991. After that, a period of below-average rainfall occurred until 1998, marking a dry cycle. There was an above the average level from 1998 to 2000, indicating an increase in rainfall. Rainfall levels fell below the average from 2000 to 2006 and then increased to above average from 2006 to 2012. A period of low rainfall was observed from 2012 to 2020. Since 2020, rainfall levels have remained above average rainfall.

Both CRD curves, for Moranbah and Wentworth, from 2016 to 2020, indicate a decrease in monthly rainfall in the Project area, leading to a reduction in groundwater recharge. The period from 2020 to 2024 saw a resurgence of wet weather, with rainfall levels surpassing the average and leading to an increase in groundwater recharge (Figure 5).

The CRD data during the period from 2016 to 2024 indicates similar rainfall patterns recorded for both Wentworth and Moranbah weather stations (Figure 5).

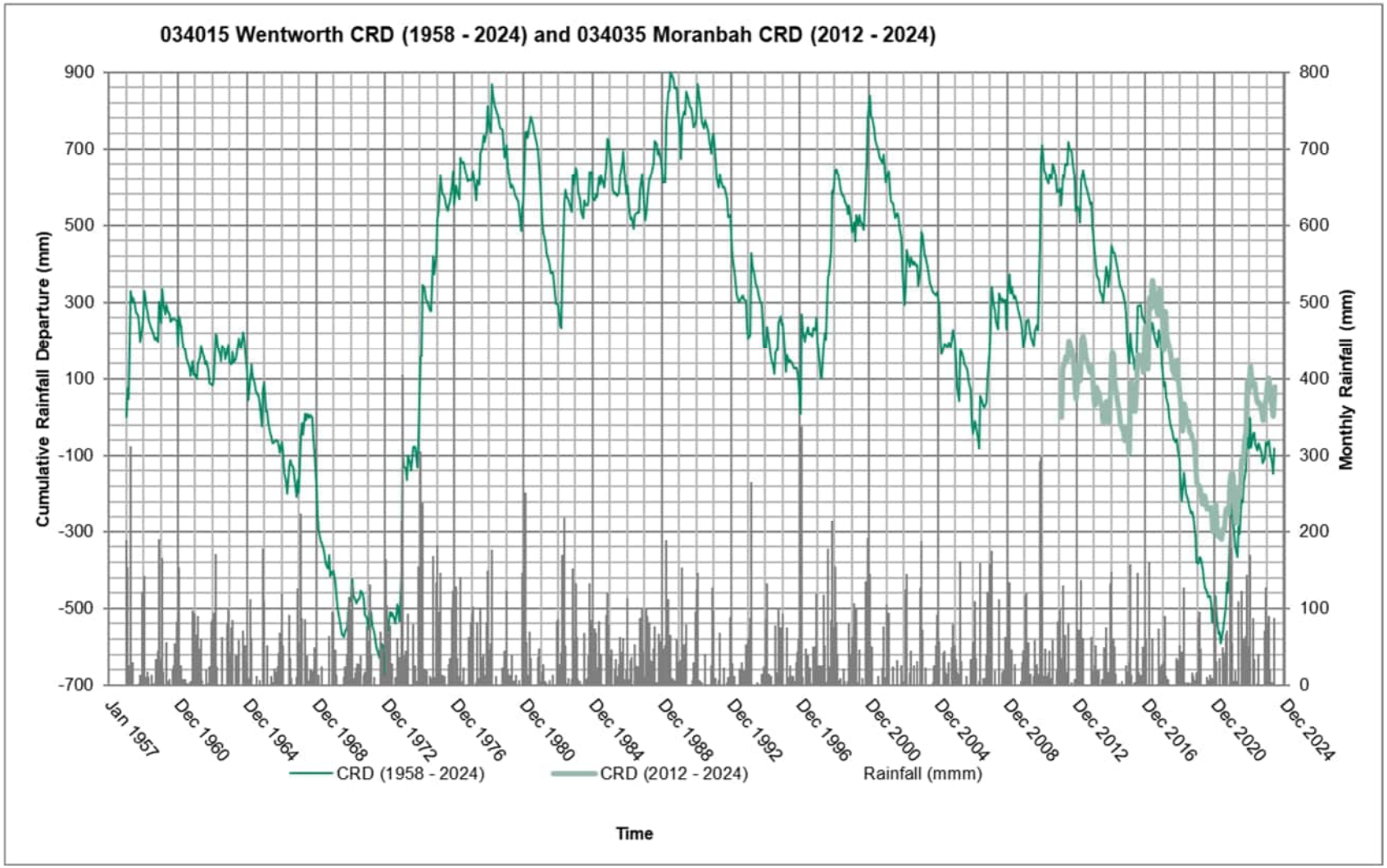


Figure 5 Wentworth (Station 034015) 1958 to 2024 and Moranbah Airport (Station 034035) 2012 to 2024 Cumulative Rainfall Departure curves

5.0 Surface Water and drainage

5.1 Overview

The Project area includes the headwaters of the Isaac-Connors sub-basin of the Fitzroy Basin. The mining activities span from near Eureka Creek to just west of Goonyella Creek and Isaac River. The Isaac River bisects the southwestern Project area, across the Goonyella and Broadmeadow mines, in a north-south direction (Figure 4). Other tributaries located south of the Project site include the Fisher Creek and the Eureka Creek. All these tributaries are considered to be ephemeral and drain into the Isaac River (Plate 2).

Plate 2 Tributaries across the Project area (Qglobe)

Drainage and surface water runoff mimic topography and flow from northeast to southwest across the project area, flowing into the Isaac River and tributaries, within and around the project. Baseflow originates from water stored in bedrock, valley soils, and riparian zones rather than distinct groundwater as water levels recede rapidly after rain events. Baseflow is typically limited to a few days up to approximately one or two weeks after surface runoff (quick flow) has drained from contributing sub-catchments (URS, 2013).

The Isaac River is an ephemeral sand bed stream that is largely alluvial downstream of the Burton Gorge. Geomorphologically, the Isaac River has a channel that is moderately winding and is primarily composed of sand and sediment, with minimal bedrock. Flooding has created a narrow alluvial terrace next to the channel, followed by a larger floodplain that is often flooded during major events.

Goonyella Creek is an ephemeral, slightly-to-moderately winding channel located largely at the Isaac River terrace-valley margin. The channel is relatively narrow and deep and features some bedrock upstream of Red Hill Road. Downstream, the channel merges with the Isaac River

Eureka Creek is also ephemeral and moderately winding (Plate 2).

A number of drainage lines feed into the waterways. Drainage lines consist of narrow channels and broader overland flow, and a series of ponds that remain as flows recede. These water bodies are temporal for short periods after flow.

5.2 Isaac River Diversion

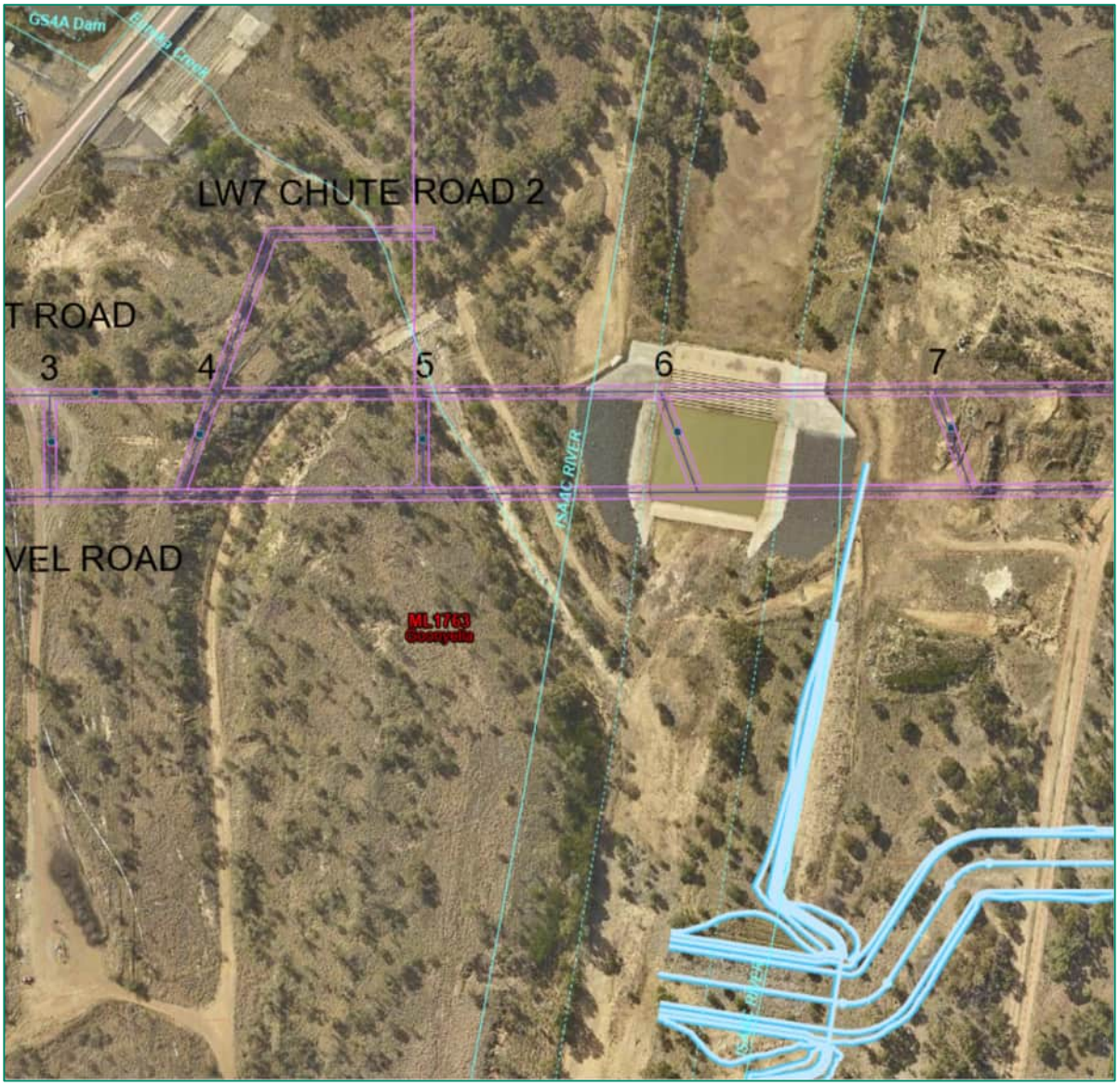
The Isaac River was diverted between 1985 and 1987 to allow access to coal deposits by open cut mining in the Project area. The diversion begins at the same location as Broadmeadow long wall panel, LW105, and replaces approximately 11 km of river channel with 7.8 km of diversion channel including two drop structures of around 2 m in height each, which were designed to manage the bed grade due to shortening of the channel. One drop structure is located immediately upstream of Eureka Creek confluence (Plate 3).

The diversion has bends at its upstream and downstream ends, however, the majority of the diversion is a near linear north-south channel. The diversion is largely cut through the Isaac River terrace, it is presently typically 8 to12 m deep with a top width of 80 to 100 m.

The Isaac River channel is incised into its floodplain by four to eight metres; the floodplain is inset within the broader terrace by a further two to four metres. The terrace, which is essentially a paleo-floodplain, is the dominant feature within the Project area. It has low relief with a gentle slope often away from the channel and in a downstream direction. The Isaac River diversion has been constructed within the Isaac River terrace and has no contemporary floodplain around the channel.

The excavated sediment from the diversion channel forms an embankment up to six metres above the surrounding terrace along the western bank of the diversion channel. To the east of the terrace, smooth hill slopes of reasonably low gradient rise up to a local catchment boundary near the eastern extent of the GRB mining area. There are only a few incised gully systems toward the upper limit of the local catchment. Two minor tributaries from beyond the mine plan area toward the upstream end of the mine plan, only the southern of these two will be over the mine footprint of GRB.

Plate 3 Drop structure



6.0 Geology

6.1 Regional Geology

6.1.1 Introduction

The Project area is located on the western flank of the northern part of the Bowen Basin, a sedimentary basin that covers an area of approximately 60,000 km^2. The Bowen Basin is a north-northwest to south-southeast orientated basin which extends from Collinsville in the north to beyond the New South Wales border in the south. It is overlapped by the Surat Basin in the southern region. The Bowen Basin a sedimentary sequence of Permian to Triassic age clastics, which attain a maximum thickness of 9,000 m in the depocentre of the Taroom Trough.

The Bowen Basin is divided into a number of tectonic units that comprise of platforms or shelves trending in the NNW to SSE direction, and are separated by sedimentary troughs. The main geologic feature of the project site is the Collinsville Shelf, which is a stable tectonic environment with sediment accumulation that gently dips and thickens towards the east.

Folding in the basin tends to be gentle and was largely a result of compression by thrust faults along the eastern margin. The area where the Collinsville Shelf meets the Nebo Synclinorium, an extension of the Taroom Trough, is defined by the Jellinbah Thrust Fault Zone. The lack of significant structures distinguishes the Collinsville Shelf sediments from the more disturbed formations of the Nebo Synclinorium.

The regional stratigraphic sequence of the geology can be summarised as Permian to Triassic sedimentary rocks that are overlain by Tertiary age deposits of the Duaringa and Suttor Formations that are separated by olivine-rich basalt remnants. The thin unconsolidated Quaternary alluvium and colluvium overlie the tertiary deposits.

The Permian age Back Creek Group, which generally comprise of fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is unconformably overlain by the Blackwater Group, which include the Rangal Coal Measures (RCM), the Fort Cooper Coal Measures (FCCM), and the Moranbah Coal Measures (MCM). The Permian deposits outcrop in the eastern and western margins and are unconformably overlain by the Triassic age sedimentary rocks of the Rewan Group. The RCM are the shallowest seams; they have been extensively mined along the eastern and western flanks.

The regional stratigraphy is summarised in Table 6 and presented in Figure 6, which depicts the solid geology as complied in 1:100,000 scale geological maps as downloaded from QSpatial. Figure 7 presents the surface geology mapped across the Project area (Queensland Government, 2024).

6.1.2 Crustal Extension

Development of the Bowen Basin initiated during the early-Permian as East-West extension generated a series of half graben sub-basins. Subsequent partial filling of the sub-basins occurred in the form of volcanic and sedimentary (lacustrine and fluvial) deposits (i.e. the Reid's Dome Beds (Esterle et al 2002).

6.1.3 Thermal Subsidence

Rapid subsidence due to continued thermal sag and continental erosion led to a marine transgression. From this point onwards, deposition within the basin became dominated by coastal and shallow marine sedimentation (e.g. the Back Creek Group).

6.1.4 Foreland Loading

Evolution of the Bowen Basin continued into the Late Permian, as further basin opening occurred with uplift and renewed volcanism in the east of the basin. During this period the half graben sub-basins became interconnected with continuing burial by a series of transgressive and regressive events.

Table 6 Regional Lithostratigraphy

Age	Stratigraphic Unit	Lithology	Typical Thickness (m)	Occurrence
Quaternary	Alluvium	Clay, silts, sand, gravel, and floodplain alluvium	15 - 35	Confined to present day stream alignments, floodplains, alluvial fans, high terraces and paleochannels. Localised along the Isaac River, Eureka and Goonyella Creeks, and floodplains
Tertiary	Undifferentiated Tertiary sediments	Clay, silt, sand, gravel, colluvium, fluvial, and lacustrine deposits including cross-bedded.	15 m	Underlying alluvium or as surficial cover
	Suttor Formation	Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt.	0 - 120	Most extensive in the mine areas and to the east. Sparsely distributed around the Project area
	Basalt	Olivine-rich weathered basalt remnants, moderately weathered and fresh basalts	0 - 80	Isolated outcrop and subcrop/s, inferred dykes, and flow remnants in the norther regions of the Project site
	Duaringa Formation	Mudstone, sandstone, conglomerate, siltstone, some oil shale, lignite, and basalt	0 - 50	The formation does not outcrop in the area of the Project site
Triassic	Moolayember Formation	Mudstone, lithic sandstone, interbedded siltstone, mudstone, sandstone, and thin coal seams	0 - 200	Outcrop farther east of the Project site
	Clematis Sandstone	Quartz sandstone, some quartz conglomerate, minor reddish brown mudstone	0 - 300	Isolated outcrops/subcrop/s in the east and north
	Rewan Formation	Lithic sandstone, pebbly sandstone, conglomerate, red and green mudstone, siltstone, quart sandstone, and shale	200 - 800	Outcrops east of the Project site; increasing in thickness as it proceeds east
Late Permian*	Rangal Coal Measures	Coal seams, carbonaceous shale and mudstone, tuff, siltstone, and mudstone	25 - 200	Isolated outcrops in the east and north
	Fort Cooper Coal Measures	Coal, brown and green sandstone, labile sandstone, quartzose sublabile sandstone, calcareous and tuffaceous sandstone, mudstone, siltstone, conglomerate, carbonaceous shale, tuff, volcanic conglomerate	100 - 600	Isolated outcrops in the east and north
	Moranbah Coal Measures	Coal, quartzose to sublabile, locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone	100 - 700	Underlies the Project site
Middle Permian	Back Creek Group	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal, and sandy coquinite	400 – 1,200	Outcrop west and extends under mined areas to the east

*Three coal-bearing formations are recognised in the Blackwater Group: the Moranbah, Fort Cooper, and Rangal Coal Measures

Figure 6 Solid Geology

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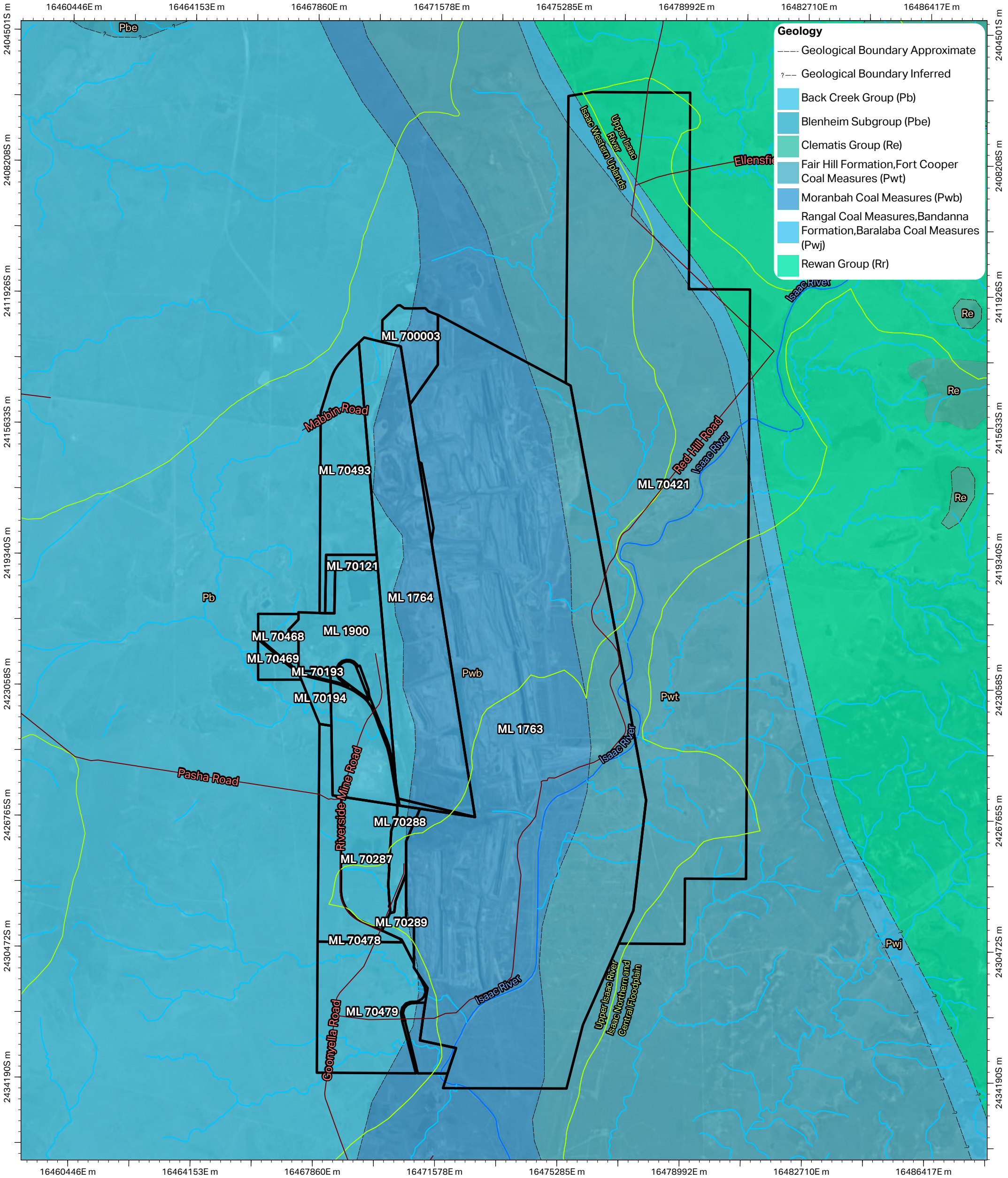

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines

Solid Geology

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

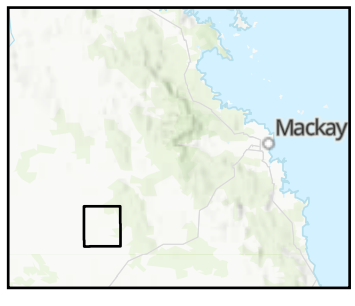

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Figure 7 Surface geology

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423058S m | 2426765S m | 2430472S m | 2434190S m

ML 700003
ML 70493
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
ML 70421
Mabbin Road
Pasha Road
Riverside Mine Road
Goonyella Road
Red Hill Road
Isaac River
Upper Isaac River
Isaac Western Uplands
Upper Isaac River Isaac Northern and Central Floodplain

Geology

- Geological Boundary Approximate
- Geological Boundary Inferred
- Back Creek Group (Pb)
- Back Creek Group,TQr-QLD (Pb,TQr)
- Clematis Group (Re)
- Fort Cooper Coal Measures (Pwt)
- Moranbah Coal Measures (Pwb)
- Qa-QLD (Qa)
- Qa\f-QLD (Qa\f)
- Qhh-QLD (Qhh)
- Qpa-QLD (Qpa)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- Qr\s-QLD (Qr\s)
- Qr\s-QLD,Qf-QLD (Qr\s,Qf)
- Rangal Coal Measures (Pwj)
- Rewan Group (Rr)
- Suttor Formation (Tu)
- Suttor Formation>Back Creek Group (Tu>Pb)
- TQa-QLD (TQa)
- TQr-QLD (TQr)
- TQr-QLD,Back Creek Group (TQr,Pb)
- TQr-QLD>Back Creek Group (TQr>Pb)
- TQr-QLD>Suttor Formation (TQr>Tu)
- TQr-QLD>Tb-QLD (TQr>Tb)
- TQr\f-QLD (TQr\f)
- TQr\f-QLD>Back Creek Group (TQr\f>Pb)
- TQr\f-QLD>Fort Cooper Coal Measures (TQr\f>Pwt)
- TQr\f-QLD>Suttor Formation (TQr\f>Tu)
- Tb-QLD (Tb)
- Tb-QLD,TQr\f-QLD (Tb,TQr\f)
- Td\f-QLD (Td\f)

Basemap image taken 2017

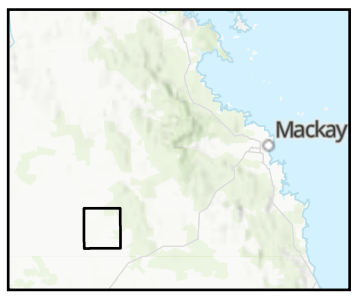
Goonyella, Riverside and Broadmeadow Mines
Surface Geology

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000



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6.1.5 Basin Closure

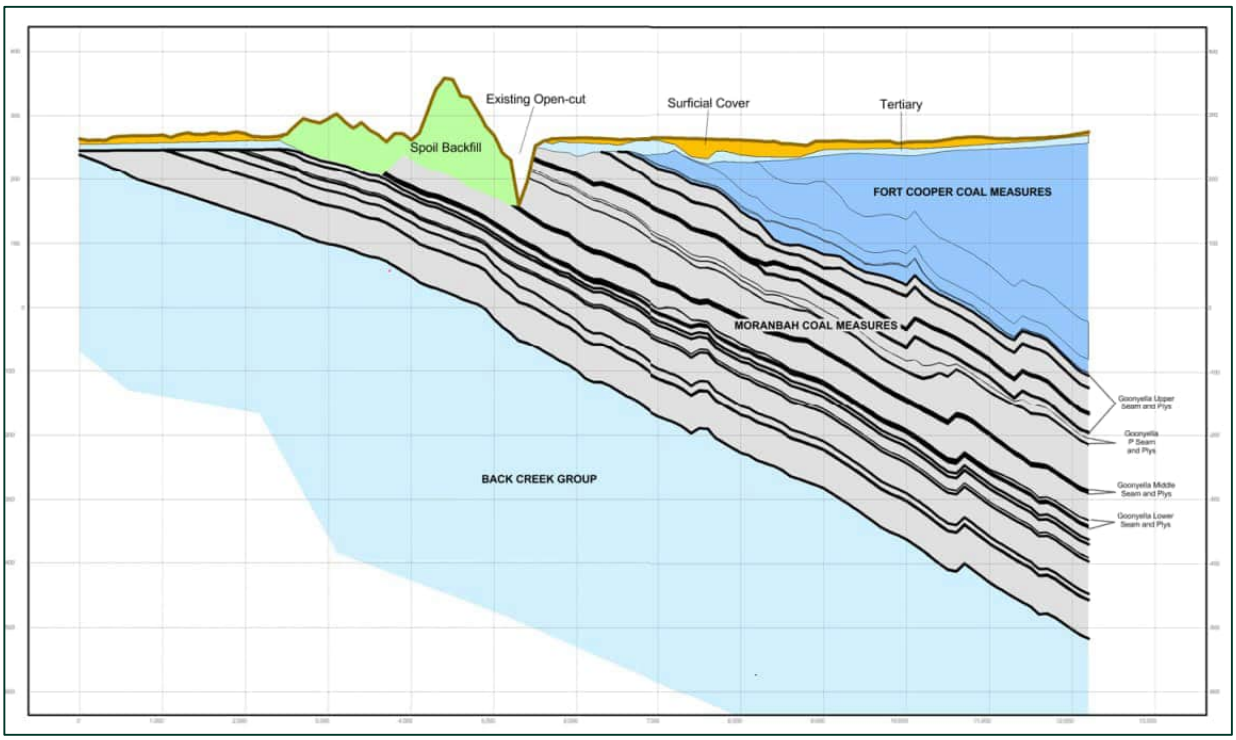
A period of tectonic compression in the Middle to Late-Triassic terminated any further sedimentation within the basin resulting in gentle folding and regional faulting (e.g. The Jellinbah Thrust). The regional area is mantled by an irregular cover of poorly consolidated Tertiary sedimentary strata and basalt (fresh and weathered). The Tertiary cover unconformably overlies the sediments and main coal-bearing units of the Late Permian Blackwater Group.

6.2 Local geology

The geology in the Project area, as included in the geological section, includes (from youngest to oldest):

- Quaternary Alluvium
- Tertiary Suttor Formation
- Tertiary Basalt
- Triassic Rewan Formation
- Permian Coal Measures (RCM, FCCM, MCM)
- Permian Back Creek Group.

Geological section through GRB



6.2.1 Structural description

The regional tectonic setting is mainly characterised as a compressive environment, which led to the development of thrust faults and folds, particularly along the eastern margin. Majority of the thrust faults dip towards the east and propagate into the Permian sediments. The thrust fault system aligns with the northwest-trending synclinal axis of the Basin, as most fault segments trend in a northwest direction, indicating the continuation of earlier basement structures.

The Project area is located on the Collinsville Shelf in the north-west of the Bowen Basin. The Collinsville Shelf is an area that has undergone a period of major deposition and is characterised by low

structural disturbance. Formations dip east at approximately 5° with small-scale and wide-spaced normal and reverse faulting showing small displacement.

The Project area is located approximately 30 km west of the Jellinbah Fault system (also known as the Isaac Thrust Fault system). Jellinbah Fault system represents a major regional structure that extends along a northwest – southeast orientation. The fault is typically steeply dipping, with a significant vertical displacement of throws that range from 100 to 500 m. Individual faults are typically 10 to 80 km long. The vertical displacement has resulted in contact of significantly different geological units.

Approximately 16 km east of the active mines are fault splays that are from the Jellinbah Fault system. These splays have north and northwest orientations. The Jellinbah Fault system splays have resulted in throws within the Permian coal measures of approximately 50 and 100 m.

Igneous intrusions present as dykes and sills are rarely found intruded through coal seams, causing coking and heat-affected coal.

6.2.2 Quaternary Alluvium

The Quaternary alluvial deposits unconformably overlie the Suttor Formation, Tertiary Basalt, and Rewan Formation in places (Figure 7). Quaternary alluvium is comprised of irregular sequences of clay, silt, sand and gravel that have been unconformably deposited in an eroded, valley-fill setting. Alluvium exists predominantly around rivers, creeks, and floodplains. The composition of the alluvium reflects a depositional environment that is dominated by meandering and braided river. The typical thickness of the alluvial deposits is between 15 and 35 m.

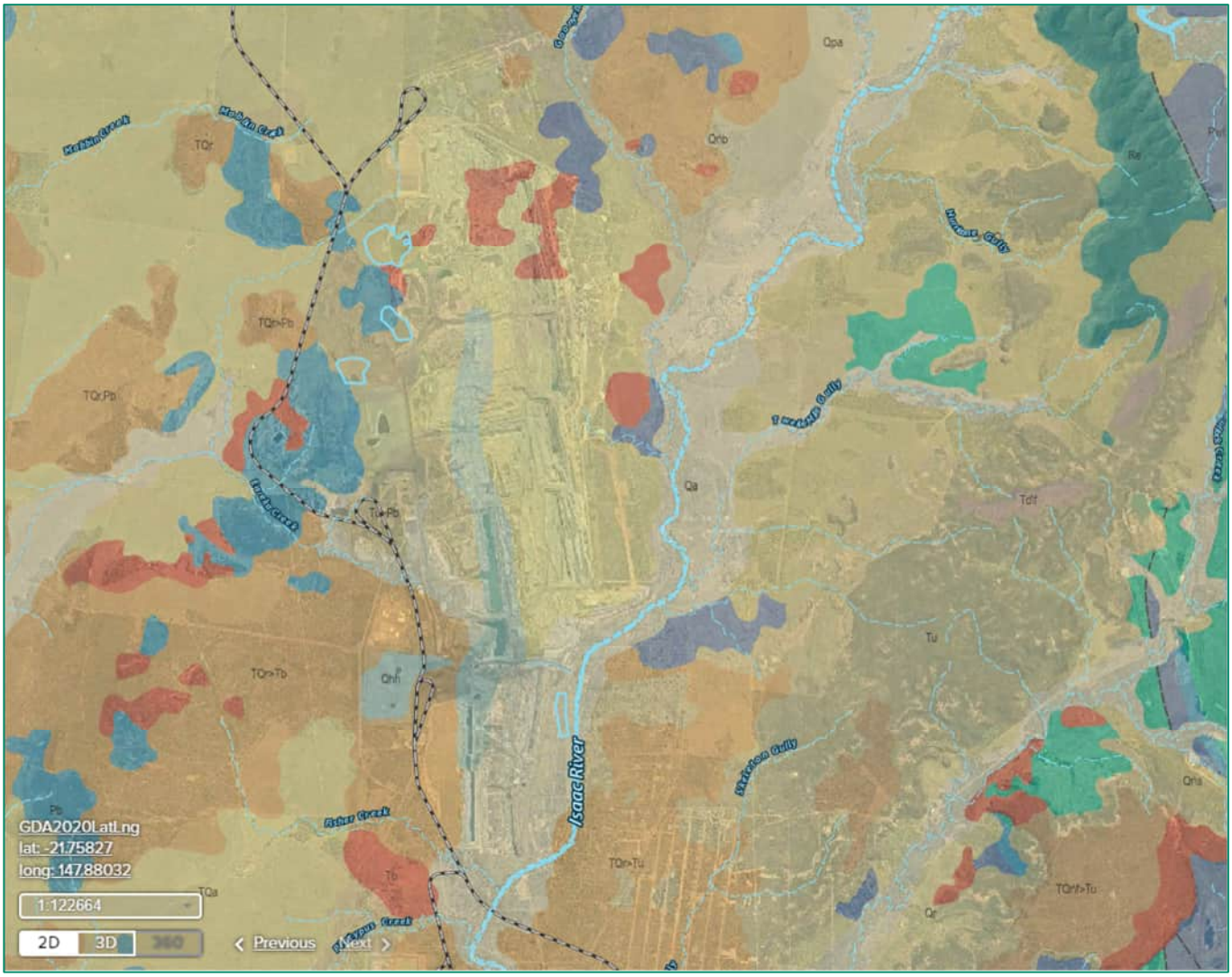
6.2.3 Tertiary age units

Tertiary age units mapped across the Project area (Figure 7) include the Suttor Formation (Tu), which comprises quartz sandstone, conglomerate, and sandy claystone, and the undifferentiated Tertiary sediments. These sediments consist of clay, silt, sand, gravel, colluvium, fluvial, and lacustrine deposits including cross-bedded.

The Tertiary age sediments, mainly colluvium, overlie Permian-Triassic bedrock. The thickness of the Tertiary sediments have an average thicknesses of 15 m. The Suttor Formation is mapped to the east adjacent to the Jellinbah Fault system (Plate 4).

Minor Tertiary age basalt (Tb) is mapped within or adjacent to the Project, as included in Plate 4.

Plate 4 Tertiary basalt (Tb) and Suttor Formation (Tu) within the Project area



6.2.4 Permian Coal Measures

The Permian coal measures comprise, from youngest to oldest, the RCM, FCCM, and MCM. The Blackwater Group is the collective term for these coal bearing units.

6.2.4.1 Rangal Coal Measures

The RCM are comprised of up to 200 m of lithic sandstones, mudstones and at least two discrete coal seams of economic importance. The low ash upper-most Leichhardt seam displays few stone bands and generally lies up to 50 m above the Vermont seam, the latter seam distinct due to the presence of the Yarrabee Tuff, which separates the upper and lower plies. The Yarrabee Tuff is a basin-wide geo-chronological marker; the top of which is often regarded as the base of the RCM formation. Both the Leichhardt and Vermont Seams are subject to splitting and merging.

The RCM sub-crop to the eastern side of the area and dip east to a maximum depth, of approximately 400 m where the formation is juxtaposed the Burton-Jellinbah Fault Zone. Locally net coal thicknesses for the formation can be up to 8.0 m with the Leichhardt seam containing up to 4.0 m.

The RCM overlie the FCCM and comprise both fractured and well-cleated coal seams. The RCM outcrops and subcrops strike generally in a north-south direction, and dip at a shallow angle to the east. The transition between the RCM and FCCM is generally indicated by the Yarrabee Tuff.

The RCM are separated by fine to medium grained sandstone, siltstone, carbonaceous shale, and mudstone layers. These units are competent and effectively limit vertical seepage between coal seams. The FCCM has a thickness range from 25 to 200 m, with the average estimated at 150 m.

6.2.4.2 Fort Cooper Coal Measures

Comprising up to 450 m of interspersed sandstones, mudstones, tuff-bands, and high-ash coaly packages. The coal measures comprise at least seven main seam intervals of variable resource potential. These packages can be up to 80 m gross thickness and consist of a series of thin, high-ash coal bands, stone bands, and carbonaceous units with a low net-to-gross coal ratio.

The FCCM lie directly below the RCM and are contiguous across the Project area. The maximum depth to the top of the formation is approximately 800 m with the Fairhill seam showing most local potential with up to 57 m gross coal thickness.

The FCCM is made up of alternating layers of coal seams, with thin vitrinite-rich coal seams mixed with carbonaceous shale, and are interspersed with tuffaceous sandstone, lithic sandstone, and mudstone. The measures overly the MCM and are regarded as laterally continuous. Outcrops and subcrops of the FCCM are found in the east of the Project area and extend underground, dipping beneath the RCM.

6.2.4.3 Moranbah Coal Measures

The MCM subcrop to the west of the Project area and are contiguous eastwards. The maximum depth to the top of the formation is approximately 700 m. Comprised of Permian sandstones, mudstones and tuffs interspersed with at least six discrete coal seams, the MCM form a 250 m to 350 m thick formation underlying the FCCM. Coal resources relate to regionally continuous GU, P, GM, and GL seams. Together these seams can total a net coal thickness approaching 30 m, with the GM capable of contributing in excess of 10 m.

The MCM are the lowermost coal-bearing sequence of the Blackwater Group and form the key coal resource targeted by BMA. The lithic sandstone, siltstone, mudstone, conglomerate, and coal of the MCM overly the Back Creek Group.

The MCM contains thick coal seams interspersed with several thin minor seams. The main target seams, along with their plies, include the following:

- Goonyella Upper (GU) Seam - The GU seam and its associated splits range in thickness from 2 – 7 m with an average of approximately 3 m in the Project area. It is the equivalent to the Q-seam.
- P Seam - Formed of three main plies, the GP1, GP0, and the GP4, the P-seam package averages approximately 5 m in net coal thickness. The package is rich in tuff bands, most notably the P-tuff, which is recognisable across the basin by its distinctive gamma signature.
- Goonyella Middle (GM) Seam - The GM seam is the thickest coal seam in the MCM averaging 8 m in thickness locally. Thinning of the GM seam is seen to the southeast of the Project area due to seam splitting. The lower half of the seam hosts two tuff bands – the Penny and Tonstein bands.
- Goonyella Lower (GL) Seam - The GL seam is located approximately 50 m below the GM seam. The GL seam has an average thickness of 6 m with characteristic thinning to the south of the exploration area.

6.2.5 Back Creek Group

The Back Creek Group underlies the Blackwater Group, and outcrops immediately west of the Project area. This unit consists of quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite. The consolidated fine-grained sedimentary rocks are considered semi-permeable, acting as a confining layer to the overlying the Blackwater Group.

7.0 Hydrogeology

Based on the understanding of the geological setting presented in Section 6.2, the hydrogeological regime relevant to GRB comprises the following key hydrostratigraphic units with enhanced groundwater potential:

- Quaternary alluvium – unconfined aquifer (sporadic discontinuous water-bearing strata of permeable unconsolidated sand or gravel) localised at and near to GRB along the Isaac River, Eureka Creek, and Goonyella Creek, and more regionally along the Isaac River where it is particularly well developed
- Permian age coal measures:
  - Low permeability interburden units with aquitard properties
  - Coal seams that exhibit water bearing properties associated with secondary porosity through cleats and fracturing.

The coal seams within the MCM are the primary aquifer at GRB. The coal seams can be characterised as confined aquifers (above and below by low permeable interburden), with the GUS, GMS, and GLS forming the main hydrostratigraphic units locally. The MCM overburden and interburden function as aquitards and are typically dry, or low yielding.

This section discusses hydrogeological units, which are recognised to be relevant to GRB closure planning, covering hydraulic properties, groundwater occurrence, hydraulic gradients, recharge, discharge, groundwater quality, and water use.

7.1 Groundwater monitoring network

The GRB groundwater monitoring network comprises a total of 46 monitoring sites. Water levels in 18 of the monitoring bores have not been measured since 2023.

The monitoring network was established in 2012 as part of the Red Hill mining project approvals study (URS, 2013) the context of supporting further environmental approvals. The network's monitoring bores intersect a range of hydrostratigraphic units, including:

- Alluvium
- Tertiary
- MCM
- Back Creek Group

Groundwater monitoring data compiled between 2012 and 2020 has been lost due to monitoring data corruption. Groundwater monitoring data across the monitoring bore network, augmented and revised overtime, has been compiled regularly since 2020. The locations of the current monitoring bore network are shown on Figure 8.

It is noted that the RHM groundwater model was constructed and calibrated based on available geological and groundwater data available up to 2013. The resultant model report is included in **Appendix A** to provide additional details of the available data used for the RHM groundwater model. The model report includes the location of bores used for geological and hydrogeological data.

The PRC Plan refinement of the model, using transient data from 2020 to 2024, allowed for the conceptualisation of groundwater conditions, influence of approved mining, and the transient calibration of the model. The model was then, with the use of uncertainty analysis, used to predict post-closure groundwater conditions.

Figure 8 GRB groundwater monitoring bore network

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423056S m | 2426765S m | 2430472S m | 2434190S m

Groundwater Monitoring Network

- Alluvium
- Back Creek
- FCCM
- GLS
- GMS
- GPS
- GUS
- Permian - Moranbah Overburden
- Permian: Interburden
- Tertiary

ML 700003
ML 70493
ML 70121
ML 1764
ML 1900
ML 70468
ML 70469
ML 70193
ML 70194
ML 1763
ML 70421
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479

MB20GRM08P
MB21GRM83P
MB21GRM80T
MB20GRM05T
MB20GRM10T
GRM_MB104
GRM_MB_104_01
GRM_MB_105_01
MB21GRM03P
GRM_MB02_02
MB20GRM11T
MB21GRM81P
MB21GRM82T
GRM_BH1
MB21GRM89C
GRM_MB_120_02
GRM_MB_121
GRM_BH3A
GRM_MB_123
GRM_BH11
MB21GRM93C
GRM_MB_102_02
GRM_MB_103_02
DR-BH01
DR-BH02
DR-BH04
MB20GRM15T
MB20GRM16P
GRM_MB03_03
MB20GRM07P
MB20GRM06A
GRM_MB01_02
GRM_MB01_03

Mabbin Road
Ellensfield Road
Red Hill Road
Pasha Road
Riverside Mine Road
Goonyella Road
Isaac River
Upper Isaac River
Isaac Western Uplands
Upper Isaac River
Isaac Northern and Central Floodplain

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Groundwater Monitoring Network

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

GDA 1994 MGA Zone 55
0 1 2 3 km
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7.2 Hydraulic conductivity

GRB groundwater hydraulic testing included slug (rising and falling head) tests, packer tests and stress and permeability tests performed on monitoring network bores across the Project area. This section presents a summary of the available site-specific hydraulic data.

7.2.1.1 Quaternary alluvium

Aquifer hydraulic properties of Quaternary alluvium material (Isaac River bed sands) and flood plain deposits were obtained from investigations undertaken at Moranbah North mine (JBT Consulting 2010). These hydrogeological investigations determined that permeability of the alluvium ranged from 8.9 to 45.4 metres per day (for some investigation sites water dissipated so rapidly that measurements could not be taken, indicating permeability higher than this range).

These investigations also found that the Quaternary flood deposits (river bank sediments) were generally finer grained than the bed sands, and returned permeability values between 0.01 and 10 metres per day. This testing indicated that the river bank sediments were less permeable than the bed sands, and would be regarded as being of low to moderate permeability, compared to the higher permeability of the bed sands.

Onsite, hydraulic testing of the Quaternary alluvium associated with the Eureka Creek provided a hydraulic conductivity value of 0.001 metres per day, typical for silty clay (URS, 2013).

The most recent tests across the Project area were undertaken between 2022 and 2024, and involved rising and falling head slug tests. Testing revealed a hydraulic conductivity range between 5×10^{-8} to 0.12 m/day.

7.2.1.2 Tertiary sediments

A review of bore logs within the RHM footprint showed that the Tertiary sediments are dominated by low permeability clays and sandy clays with isolated areas of loose more permeable sand.

The interpreted hydraulic conductivity value of 6.6×10^{-4} metres per day (m/day) obtained from the variable (falling) head test at the Airstrip Pit (IESA 2001a) is low, indicating predominantly clay intersected within this area (URS, 2013).

Past tests performed in the sandstone/siltstone, sands and clays of the Tertiary Formation indicated a hydraulic conductivity range of 2×10^{-7} to 24.6 m/day. The hydraulic conductivity of 24.6 m/day is atypical, as it was the sole one that was exceedingly high.

7.2.1.3 Permian coal measures

Interpreted hydraulic conductivity values estimated from the MCM aquifer testing results indicate that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability. WDS (2011) conducted an engineering study for coal seam degassing required prior to mining of the RHM, using data derived from packer testing in 31 seam/site combinations in the MCM and FCCM. This study found a relationship for permeability variation with depth, ash, and gas content as part of this study that resulted in the ranges of hydraulic conductivity to be (URS 2013):

- GMS 0.009 to 0.1 m/day
- GLS 0.06 to 0.82 m/day
- Interburden 9×10^{-7} to 9×10^{-5} m/day.

Note: No GUS testing was conducted by WDS in 2011.

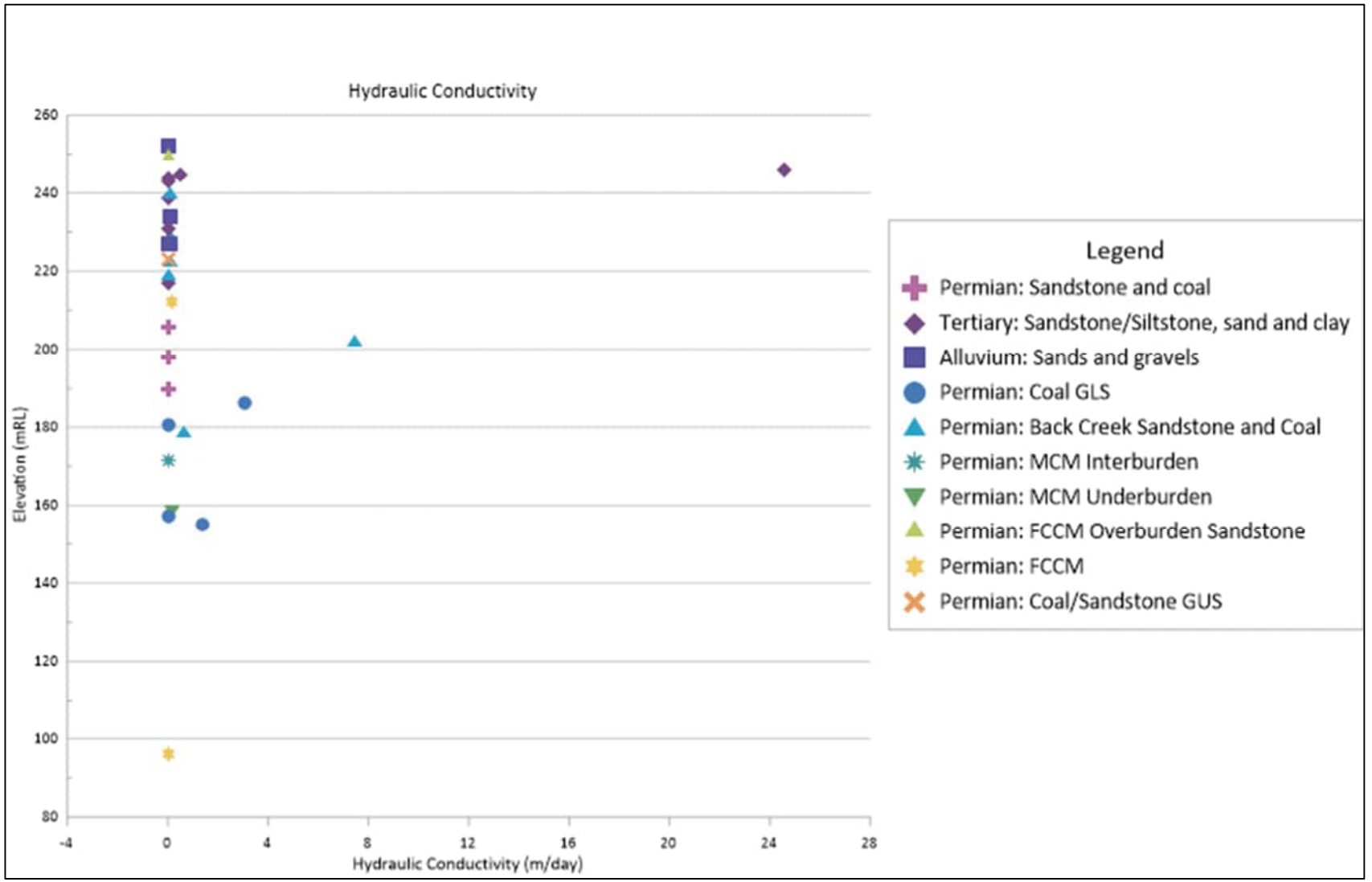
The hydraulic conductivity of the MCM that were tested between 2020 and 2024 across the Project area was variable and indicating a decrease with increasing depth, corroborating previous studies conducted in the MCM coal seams.

The MCM testing revealed hydraulic conductivity estimates:

- Overburden between 6 x 10^{-4} and 5 x 10^{-2} m/day
- GUS and GMS were estimated at 0.02 m/day
- GLS ranged from 7x10^{-7} and 3 m/day.
- Interburden and underburden at 1 x 10^{-5} and 2 x 10^{-2} m/day, respectively.

Testing data from 2020 to 2024 is summarised in Figure 9.

Figure 9 Summary of hydraulic data



7.3 Groundwater distribution, flow, recharge, discharge

7.3.1 Quaternary alluvium

7.3.1.1 Distribution and flow

Quaternary alluvial deposits in the survey area occur predominantly within the Isaac River floodplains as shown in Figure 7 (labelled Qa-QLD). Along the Isaac River these deposits consist of clay, silt, sand and gravel, to a depth of up to 37 metres, as historically recorded in monitoring bore GW1 and exploration bore 43840 (Plate 5).

Investigations into the Isaac River alluvium at the Moranbah North Mine (located immediately to the south of GRB) indicated that the thickness of bed sands in the Isaac River was two to three metres (JBT Consulting 2010).

The alluvium associated with Eureka Creek consists of approximately nine metres of silty sand and poorly sorted sand and gravel at monitoring well GW8, with no alluvium present at GW7. The historic monitoring and exploration bores are included in Plate 5.

The Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round. Limited groundwater resources may, however, occur in the deeper and relatively narrow parts of the channel.

Due to the generally shallow saturated thickness and the lack of continuity of the more permeable gravel and sand sections, the Quaternary alluvium is not considered a significant aquifer as it has limited sustainable yield. However, during periods of creek or river flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams or other underlying aquifers.

Drilling and monitoring on site indicates that, where groundwater does occur, depth to groundwater in the Quaternary alluvium is approximately 3 to 13 metres below ground level (mbgl). The groundwater level in the alluvium, measured in a study by Thatcher (1976), was about 20 metres above the piezometric (confined) water level in the coal at the same location. These groundwater levels indicate a marked separation between the alluvium water table and the piezometric levels associated with the deeper coal seam aquifer groundwater (i.e., there is no hydraulic connection between the alluvium groundwater and the confined aquifers). It is, thus, unlikely that changes in piezometric levels in the coal would markedly impact on the water table associated with the alluvium.

Owing to the paucity of data for the Quaternary alluvium (Figure 10 and Figure 11), limited information exists regarding groundwater flow. However, regionally groundwater flow within the alluvium follows topography and drainage patterns.

Plate 5 Historic monitoring and exploration bores

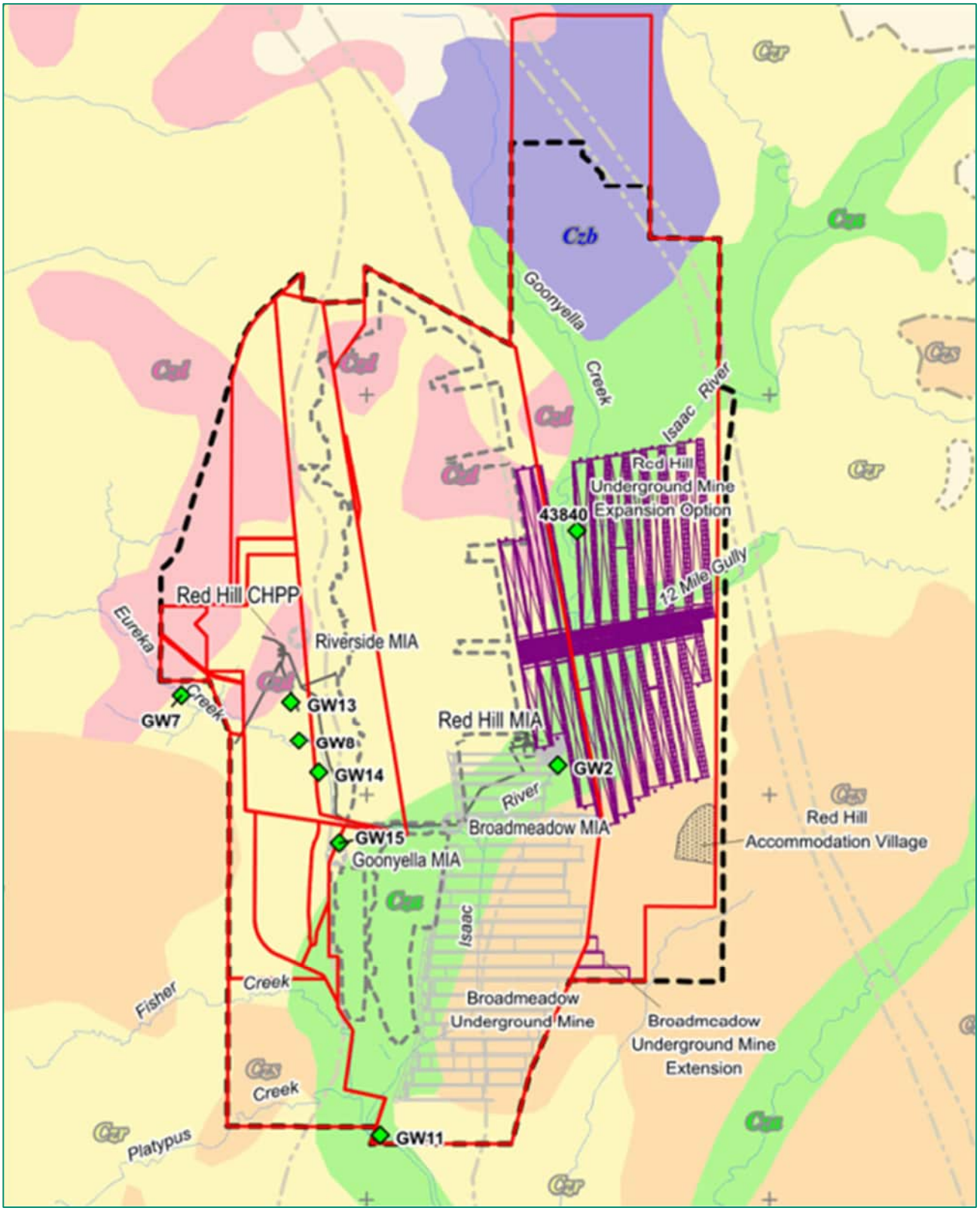
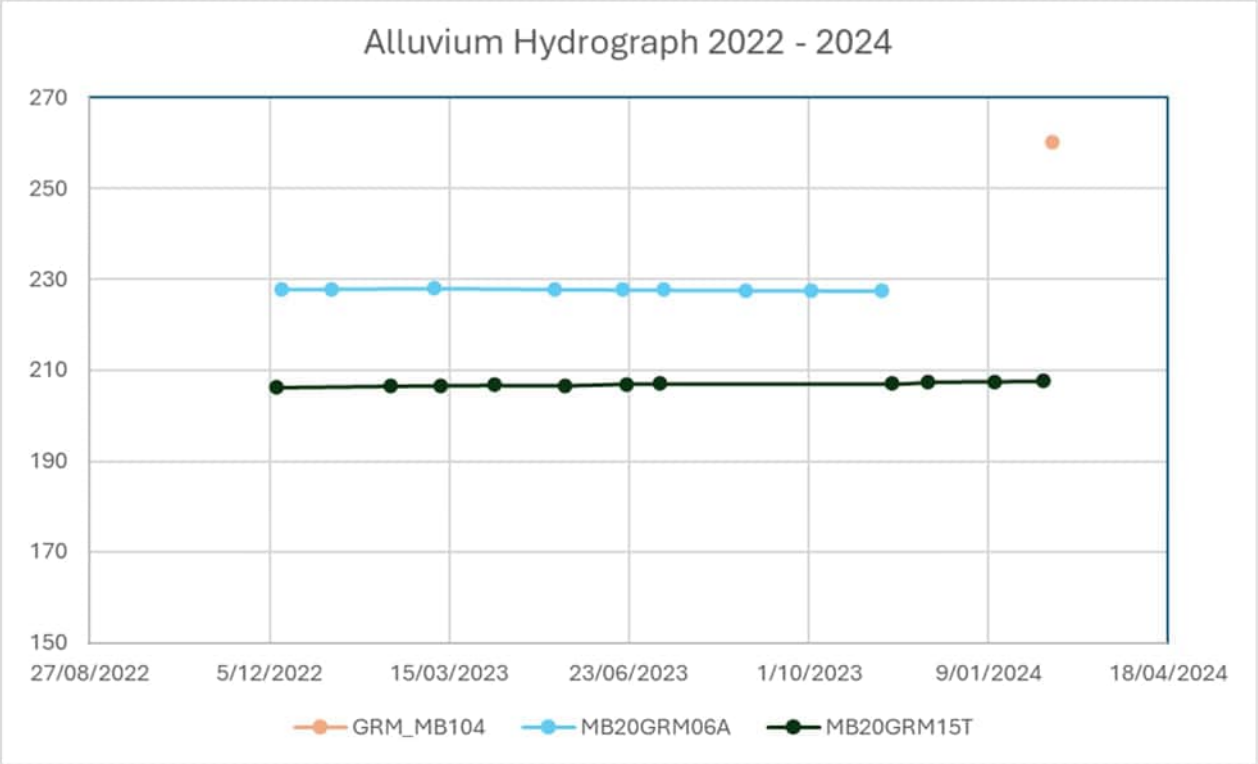


Figure 10 Hydrograph of alluvial groundwater trends



Notes:
GRM_MB104 water level is 8.86 mbgl
MB20GRM06A water level is around 9.5 mbgl, bore is 13.35 m deep
MB20GRM15T water level is on average 4.5 mbgl, bore is 7 m deep

Figure 11 Alluvium groundwater elevations

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423058S m | 2426765S m | 2430472S m | 2434190S m

Isaac Western Uplands
Upper Isaac River
Ellensfi
ML 700003
Mabbin Road
ML 70493
ML 70421
Red Hill Road
Isaac River
ML 70121
ML 1764
ML 1900
ML 70468
ML 70469
ML 70193
GRM_MB104
256.3 mRL
13/02/2024 15:10
ML 70194
ML 1763
Pasha Road
Riverside Mine Road
ML 70288
ML 70287
ML 70289
ML 70478
MB20GRM15T
235.9 mRL
8/02/2024 14:55
ML 70479
MB20GRM06A
227.6 mRL
10/11/2023 16:40
Isaac River
Goonyella Road
Upper Isaac River Isaac Northern and Central Floodplain

Geology

- Geological Boundary Approximate
- Geological Boundary Inferred
- Back Creek Group (Pb)
- Back Creek Group,TQr-QLD (Pb,TQr)
- Clematis Group (Re)
- Fort Cooper Coal Measures (Pwt)
- Moranbah Coal Measures (Pwb)
- Qa-QLD (Qa)
- Qa\f-QLD (Qa\f)
- Qhh-QLD (Qhh)
- Qpa-QLD (Qpa)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- Qr\s-QLD (Qr\s)
- Qr\s-QLD,Qf-QLD (Qr\s,Qf)
- Rangal Coal Measures (Pwj)
- Rewan Group (Rr)
- Suttor Formation (Tu)
- Suttor Formation>Back Creek Group (Tu>Pb)
- TQa-QLD (TQa)
- TQr-QLD (TQr)
- TQr-QLD,Back Creek Group (TQr,Pb)
- TQr-QLD>Back Creek Group (TQr>Pb)
- TQr-QLD>Suttor Formation (TQr>Tu)
- TQr-QLD>Tb-QLD (TQr>Tb)
- TQr\f-QLD (TQr\f)
- TQr\f-QLD>Back Creek Group (TQr\f>Pb)
- TQr\f-QLD>Fort Cooper Coal Measures (TQr\f>Pwt)
- TQr\f-QLD>Suttor Formation (TQr\f>Tu)
- Tb-QLD (Tb)
- Tb-QLD,TQr\f-QLD (Tb,TQr\f)
- Td\f-QLD (Td\f)

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines

Alluvium Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - Alluvium

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

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Mackay

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7.3.1.2 Recharge and discharge

The alluvial aquifer is classed as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The volume of groundwater associated with the alluvium depends on the interconnection of permeable units, saturated thickness, and the ability to store groundwater, (i.e., effective storage allowing for baseflow to creeks and rivers during the dry season). The alluvial aquifers are considered to be strongly linked (recharged during flow events) to surface water (SKM 2009).

The Isaac River and creeks at the Project are ephemeral and recharge of the alluvium is by:

- Losses from surface water flow or flooding (losing system)
- Direct rainfall and overland flow recharge, where alluvium is exposed, and no substantial clay barriers occur in the shallow sub-surface.

Available hydrologic data suggests that water infiltrates / drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. The available transient groundwater level data, Figure 11, indicates saturation is sporadic and can produce semi-permanent, localised, thin, aquifers. The groundwater level data does not indicate marked variation in dry/wet seasons (noting limited manual data measurements), which could indicate isolated pockets of water not readily recharged or discharged.

Groundwater discharge from the alluvium occurs through:

- Evapotranspiration from vegetation where depth-to-groundwater is shallow, such as in the creek beds and along the banks
- Short duration baseflow from the permeable sands and gravels within the alluvium material.

Infiltration and recharge to the underlying older formations underlying the creeks is not evident based on the marked hydraulic disconnect between the depth to water in the alluvium and the confined piezometric levels associated with the confined coal seam aquifers (Section 7.3.1.1).

Surface water loss, via the alluvium, to the longwall mining panels (goaf and subsidence related) is discussed in Section 13.3.6.1.

During a ground penetrating radar survey of the Isaac River at Moranbah North Mine, accessible during the dry season, it was noted that all test pits dug for the GPR survey within the bed sands were dry, or only damp in the base layer. This indicates that the Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round.

7.3.2 Tertiary Formation

7.3.2.1 Distribution and flow

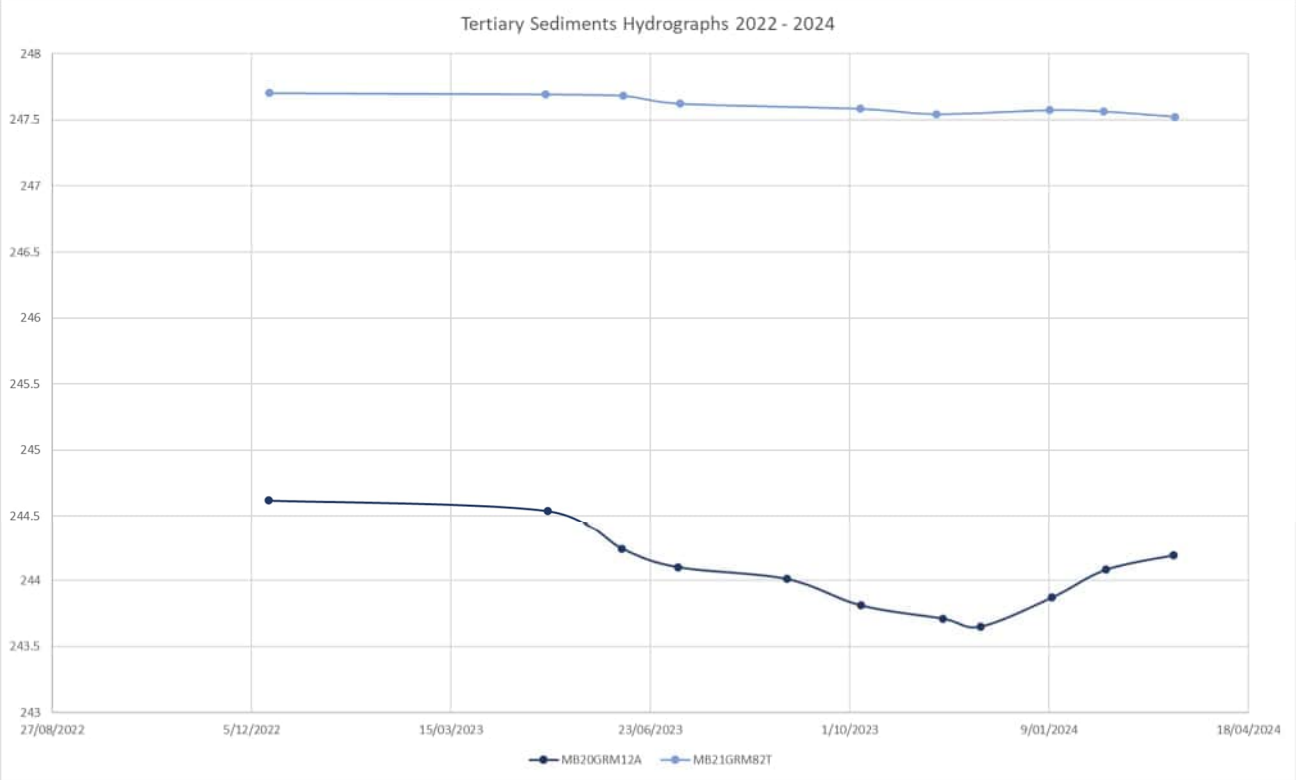
The undifferentiated Tertiary sediments and Suttor Formation is mapped across the Project area, noting that the mapped outcrop is not continuous. In areas where the Tertiary units are eroded inliers of older Permian rocks are mapped. In other locations the Tertiary units are concealed by younger alluvium.

The undifferentiated Tertiary sediments can occur as lenses of paleochannel gravels and sands separated by sandy silts, sandy clays and clays. A review of the borehole logs showed the undifferentiated Tertiary sediments vary in thickness up to approximately 80 metres with a typical thickness of up to 15 m.

Groundwater level in the Tertiary deposits was measured to be around 10 mbgl, deeper and hydraulically disconnected from the alluvium (as detailed in Section 7.3.1). There is also a distinction between the semi-confined to confined Tertiary and the coal measures potentiometric levels indicating a separation (hydraulic disconnect) between these hydrostratigraphic units.

In the Tertiary units, groundwater flow mimics topography and drainage systems.

Figure 12 Hydrographs of Tertiary Formation groundwater elevation



MB20GRM12A has an average depth-to-water of 9.4 mbgl, bore depth 18 m
MB21GRM82T has an average depth-to-water of 10.9 mbgl, bore depth 29.3 m

Additional groundwater level data for the Tertiary sediments was obtained from monitoring bores constructed across the Project area. These bores have limited geological data but bore depths and locations, plus the use of geological contact data, allowed for the identification of monitoring bores constructed within the Tertiary sediments. These monitoring bores plus groundwater elevation data is included in Figure 13.

Figure 13 Tertiary groundwater elevations

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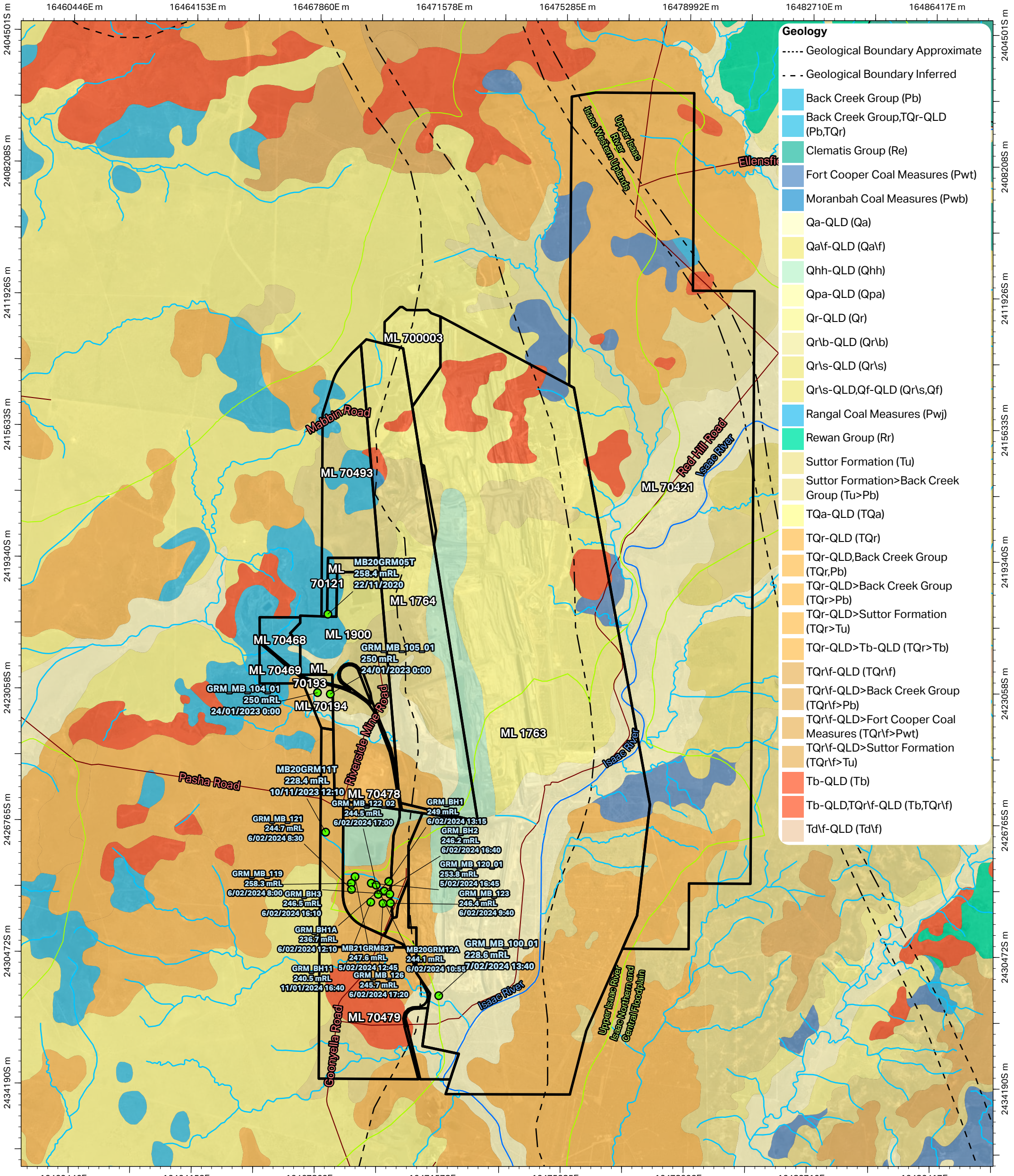


Goonyella, Riverside and Broadmeadow Mines

Tertiary Groundwater Elevations

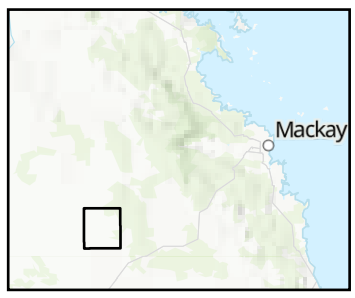
- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - Tertiary

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

AECOM



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7.3.2.2 Recharge and discharge

Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments, and represents a semi-confined to confined aquifer depending on location, degree of weathering, the nature of the overlying alluvium, and clay content, as recognised in the transient groundwater level data included in Figure 12.

Recharge mechanisms include:

- Direct infiltration of rainfall
- Overland flow / ponding where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface

Little or no recharge from overlying Quaternary alluvial aquifers is identified. Groundwater elevation data for MB20GRM15T at 235.9 mAHD (Figure 11) and GRM_MB_100_01 at 228.6 mAHD (Figure 13), located in proximity to each other, indicates a marked separation (7.3 m) between the two hydrostratigraphic units (i.e., no hydraulic connection between the alluvium water table and the semi-confined Tertiary sediments).

Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- Through flow
- Evapotranspiration
- Groundwater extraction.

7.3.3 Permian – Triassic strata

The Permian-Triassic formations within the Project area comprise the two Permian formations, which are the Blackwater Group (which contains the MCM, FCCM, and RCM) and the Back Creek Group. These units are included on Figure 6. As with the rest of the Bowen Basin, the coal seams are the main aquifers within the Permian sequences, with the overburden and interburden rocks in most mines being described as essentially impervious to groundwater movement (AGE 2008). The MCM coal seams, GLS, GMS and GUS, constitute the most extensive aquifers at the Project.

The coal seam aquifers are confined above and below by low permeability geological formations (Section 7.2.1.3) and movement of water through the aquifer (transmissivity) is likely to be through the more permeable (cleats) coal rather than the confining units. The confining units also have low vertical hydraulic conductivity (leakance), such that water flows into the aquifer (recharge) is limited.

Groundwater occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable (either due to high clay content or significant cementing) and form aquitards. The Permian and Triassic strata may, therefore, be categorised into the following hydrogeological units:

- Hydrogeologically ‘tight’ and hence very low yielding to essentially dry claystone, mudstone, sandstone, siltstone and shale that comprise the majority of the strata.
- Low to moderately permeable coal seams, which are the primary water bearing strata within the Permian sequence.
- Localised fracture or fault systems which are open and have not been infilled by clay/carbonate deposition.

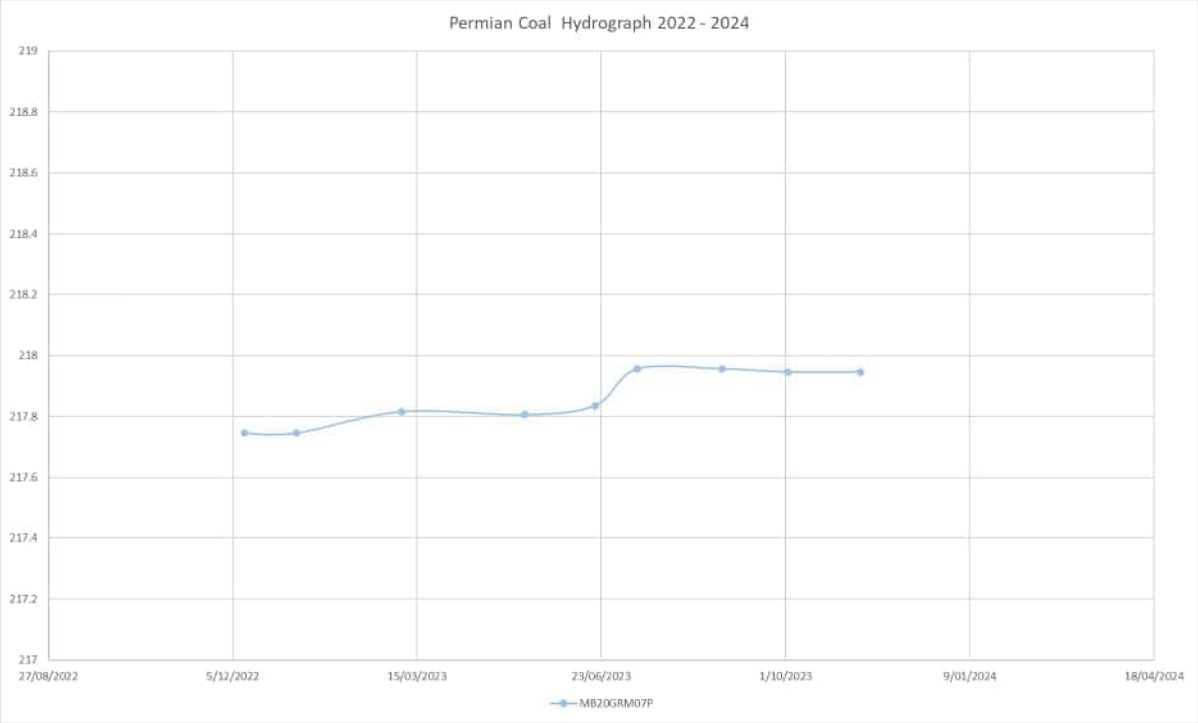
Groundwater levels in the Permian formations have historically been measured during hydrogeological investigations at the Project and used for assessing potential inflows to pits and underground workings. Other studies included the establishment of boxcut or pit dewatering bores for mine design and production purposes (AECOM, 2013). Evidence from piezometric observations for the coal seam aquifers during these previous investigations suggests the groundwater levels were different for each seam, with the GUS seam being one to two metres higher than the GMS seam, and the GLS seam being up to 14 metres lower than the GMS seam at the same location (i.e., no hydraulic connection between the coal seams due to interbedded aquitards). This variation in hydraulic heads between coal

seams indicates limited potential for induced flow. The piezometric levels in the coal seams varied from 15 to 69 mbgl.

Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers in inferred to have been from the north and west to the south and east across the site. This flow direction is based on recharge to the coal seams occurring at the subcrops in the west and north of the site and discharge occurring downgradient in the Isaac River sub-basin. The current (2020 to 2024) groundwater flow patterns have been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation.

Recent transient groundwater level data for Permian coal within the Project area is available for MB20GRM07P, included in Figure 14. The average groundwater depth was 18.1 mbgl (±0.2 m) and the bore depth is 85 m.

Figure 14 Transient groundwater level data for Permian coal



The most recent available groundwater level elevation data for the Permian GMS and GLS, across the Project area, are included in Figure 15 and Figure 16, respectively.

Groundwater elevation data in the area containing the Quaternary alluvial monitoring bore MB20GRM15T indicates the following:

- Alluvium water table at 235.9 mAHD (Figure 11)
- Tertiary sub-artesian potentiometric level of 228.6 mAHD at GRM_MB_100_01 (Figure 13)
- Permian GMS groundwater elevation of 187.5 mAHD in GRM_MB_102.02 (Figure 15)
- Permian GLS groundwater elevation of 215.7 mAHD in MB20GRM18P (Figure 16).

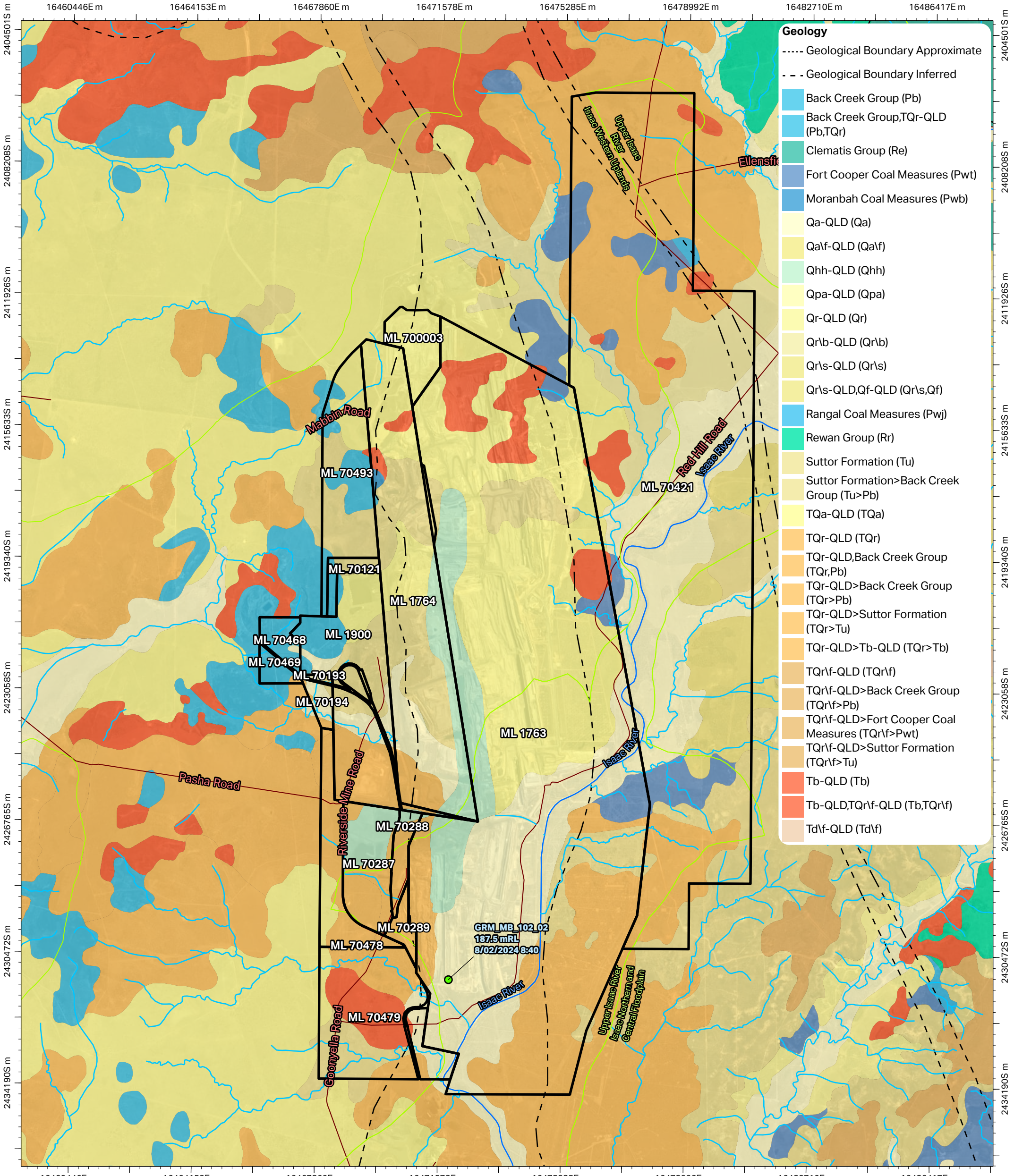
These data indicate:

- No hydraulic connection between the different hydrostratigraphic units
- Confining aquitards above and below the coal resulting in different potentiometric levels associated with the coal seams
- Upward vertical groundwater gradients from GLS to GMS
- Vertical downward groundwater gradients from alluvium, to Tertiary, to Permian coal

- Marked separation between the Tertiary and the Permian units, even with an upward vertical groundwater gradient within the coal seams.

Figure 15 GMS groundwater elevations

See overleaf for Figure 15



Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines

GMS Groundwater Elevations

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - GMS

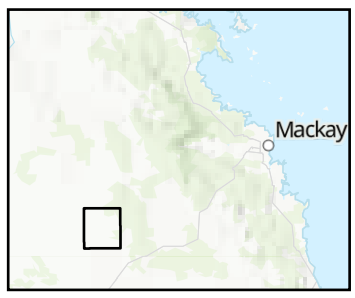


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Figure 16 GLS groundwater elevations

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423058S m | 2426765S m | 2430472S m | 2434190S m

ML 700003
ML 70493
ML 70121
ML 1764
ML 1900
ML 70468
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70478
ML 70289
ML 70479
ML 70421

Mabbin Road
Pasha Road
Riverside Mine Road
Goonyella Road
Red Hill Road
Isaac River
Upper Isaac River
Isaac Western Uplands
Upper Isaac River Isaac Northern and Central Floodplain

MB21GRM93C
192 mRL
11/07/2023 12:10

GRM_MB_100_02
205.4 mRL
2/12/2023 14:15

MB20GRM18P
215.7 mRL
15/11/2023 9:55

MB20GRM07P
218.2 mRL
10/11/2023 15:15

Geology

- Geological Boundary Approximate
- Geological Boundary Inferred
- Back Creek Group (Pb)
- Back Creek Group,TQr-QLD (Pb,TQr)
- Clematis Group (Re)
- Fort Cooper Coal Measures (Pwt)
- Moranbah Coal Measures (Pwb)
- Qa-QLD (Qa)
- Qa\f-QLD (Qa\f)
- Qhh-QLD (Qhh)
- Qpa-QLD (Qpa)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- Qr\s-QLD (Qr\s)
- Qr\s-QLD,Qf-QLD (Qr\s,Qf)
- Rangal Coal Measures (Pwj)
- Rewan Group (Rr)
- Suttor Formation (Tu)
- Suttor Formation>Back Creek Group (Tu>Pb)
- TQa-QLD (TQa)
- TQr-QLD (TQr)
- TQr-QLD,Back Creek Group (TQr,Pb)
- TQr-QLD>Back Creek Group (TQr>Pb)
- TQr-QLD>Suttor Formation (TQr>Tu)
- TQr-QLD>Tb-QLD (TQr>Tb)
- TQr\f-QLD (TQr\f)
- TQr\f-QLD>Back Creek Group (TQr\f>Pb)
- TQr\f-QLD>Fort Cooper Coal Measures (TQr\f>Pwt)
- TQr\f-QLD>Suttor Formation (TQr\f>Tu)
- Tb-QLD (Tb)
- Tb-QLD,TQr\f-QLD (Tb,TQr\f)
- Td\f-QLD (Td\f)

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines

GLS Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - GLS

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

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7.3.3.1 Distribution and flow

Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers appears to have been from the north and west to the south and east across the site. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the north and west and discharge occurring downgradient in the Isaac River sub catchment in the Bowen Basin. The current groundwater flow pattern has been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation.

The occurrence of groundwater in the interburden is limited. Aquifers in the interburden are discontinuous with heterogeneous hydraulic properties creating isolated, lens-like aquifers. Due to the heterogeneity and discontinuity of the interburden aquifers within the Permian strata, the groundwater flow direction cannot be determined on a regional scale for these aquifers.

7.3.3.2 Recharge and discharge

Groundwater recharge in the coal seam aquifer occurs from:

- Infiltration of rainfall and overland flow in outcrop and sub-crop areas
- Leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

Downward seepage or vertical flow from overlying alluvial or tertiary aquifers is not recognised, based on vertical groundwater elevation data, to occur.

Primary discharge mechanisms in the Permian-Triassic strata include:

- Dewatering for mine progression
- Downgradient flow within the Permian-Triassic strata away from the outcrop areas
- Possible movement to other hydrostratigraphic units / coal seams via structural discontinuities.

7.3.4 Underground mining influencing groundwater flow

Underground mining using the thick seam mining method (longwall top coal caving) will result in subsidence of the overlying strata in the mined-out areas behind the longwall, resulting in aquifer alteration due to the goaf. This caving and subsidence can cause fractures and joints in the overlying strata.

AGE (2002) state that following the passage of longwall panels and stabilisation of subsidence, fracturing in the bulk of the strata will generally close up, allowing strata permeability to return to near to the pre-mining levels.

Within the zones above and adjacent to the longwall panels the vertical and horizontal strata permeability will be markedly and permanently altered due to sub-surface fracturing. The vertical extent of these fractures is dependent on numerous factors, such as mine design, geological conditions, surface topography, and the distance between the mine workings and the ground surface.

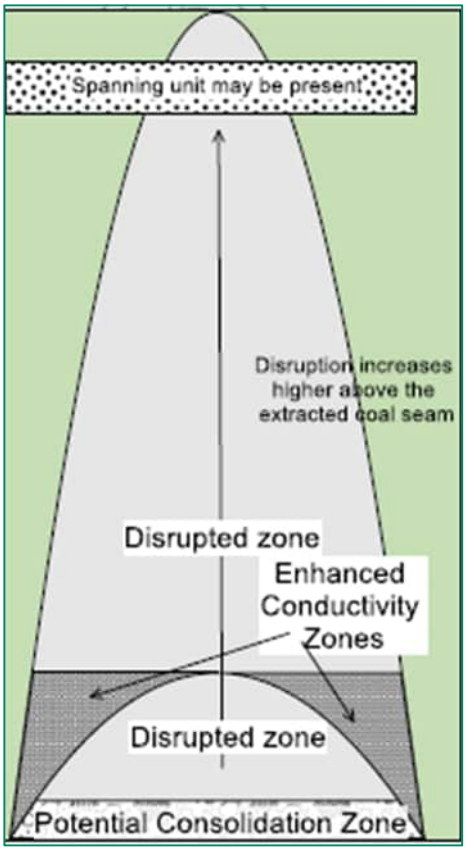
Unfortunately, the location of existing bores with groundwater level data, included in Figure 8, are not within or immediately adjacent to the Broadmeadow underground mine panels. The lack of alluvium, Tertiary and Permian groundwater level data at the Broadmeadow underground mine does not allow for the evaluation of possible vertical hydraulic connection due to longwall mining. The influence of the longwall mining was, however, assessed using geotechnical modelling.

7.3.4.1 Longwall modelling

BMA appointed Byrnes Geotechnical to undertake a geotechnical study is required to provide assessment of possible hydraulic conductivity and porosity changes due to BMA longwall and pillar extraction mining (Byrnes Geotechnical, 2024). This draft study reviewed historic approaches to estimating alteration to aquifer hydraulic properties based on geotechnical modelling, a review of previous studies and finds, allowing for a revised conceptualisation of alteration. The report is included in **Appendix B**.

The resultant geotechnical model derived from the Byrnes Geotechnical study, depicted in Plate 6, indicates differing zones of alteration above the panels. The shape and extent of these zones is markedly different to previous simulations of alteration adopted in groundwater modelling.

Plate 6 BMA longwall and pillar extraction mining geotechnical model



The BMA longwall and pillar extraction mining geotechnical model considers:

The simple triangular shape(Plate 7) of the disrupted zone is replaced by a parabolic shape following some numerical analysis of failure in bedding rock masses.

It is noted that:

- The height of the disrupted zone is a function of the average thickness of the bedded units in the overburden. The default height is two times the extraction width which is equivalent to the panel geometry that represents the step from subcritical to supercritical.
- The enhanced conductivity zone (ECZ) geometry is based on the D zone angles (Figure 17), with overall shape defined by two parabolas. The ECZ is the locus for high inflows.
- If the surface subsidence developed between adjacent chain pillars was more than 400 mm, then there would be a fracture connection, albeit possibly tortuous, between the surface and the underground workings.

Plate 7 Triangular conceptual inflow model (Younger, 2011)

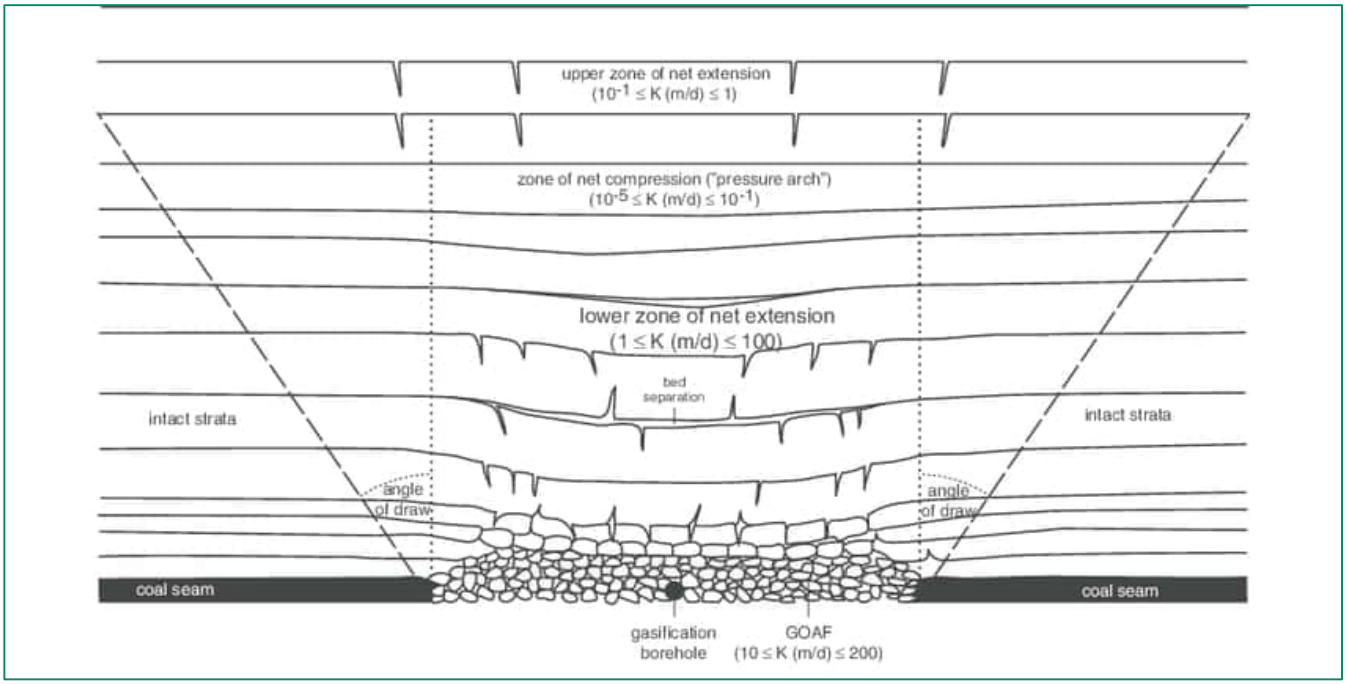
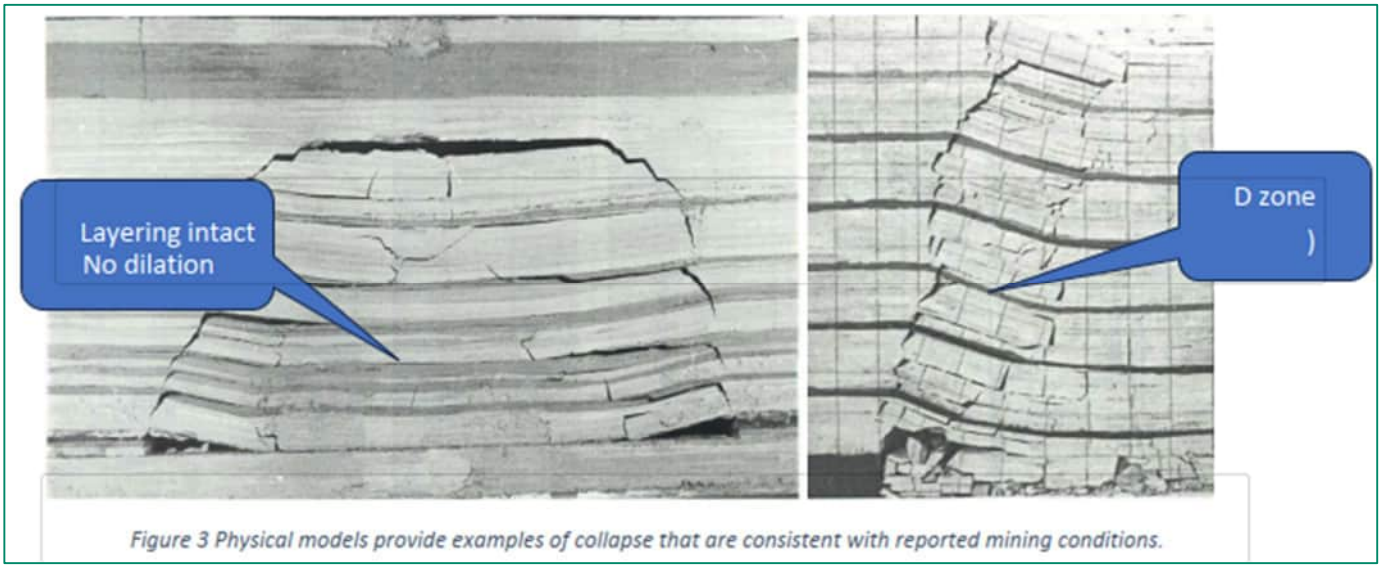


Figure 17 Physical model showing alteration shape and collapse



7.3.4.2 Alteration due to longwall mining

The Geotechnical model provides a basis for the prediction of hydraulic conductivity associated with the supercritical longwall geometry of the BMA longwall operations. It's important to note that there is no validation of the method available and Brynes geotechnical notes that is would be difficult to undertake given the large volume of longwall mining.

Mine inflows are not useful in this context as they are most likely related to the ECZ and not the larger disrupted zone and there is the problem of the low conductivity in the potential consolidated zone (PCZ).

The Geotechnical model is applicable to the Permian and Tertiary sequences but does not include the possible role of Quaternary alluvium and surficial cover.

Output from the Geotechnical Model includes the conductivity changes up to twice the excavation width, such that it can be sliced at any actual mining depth.

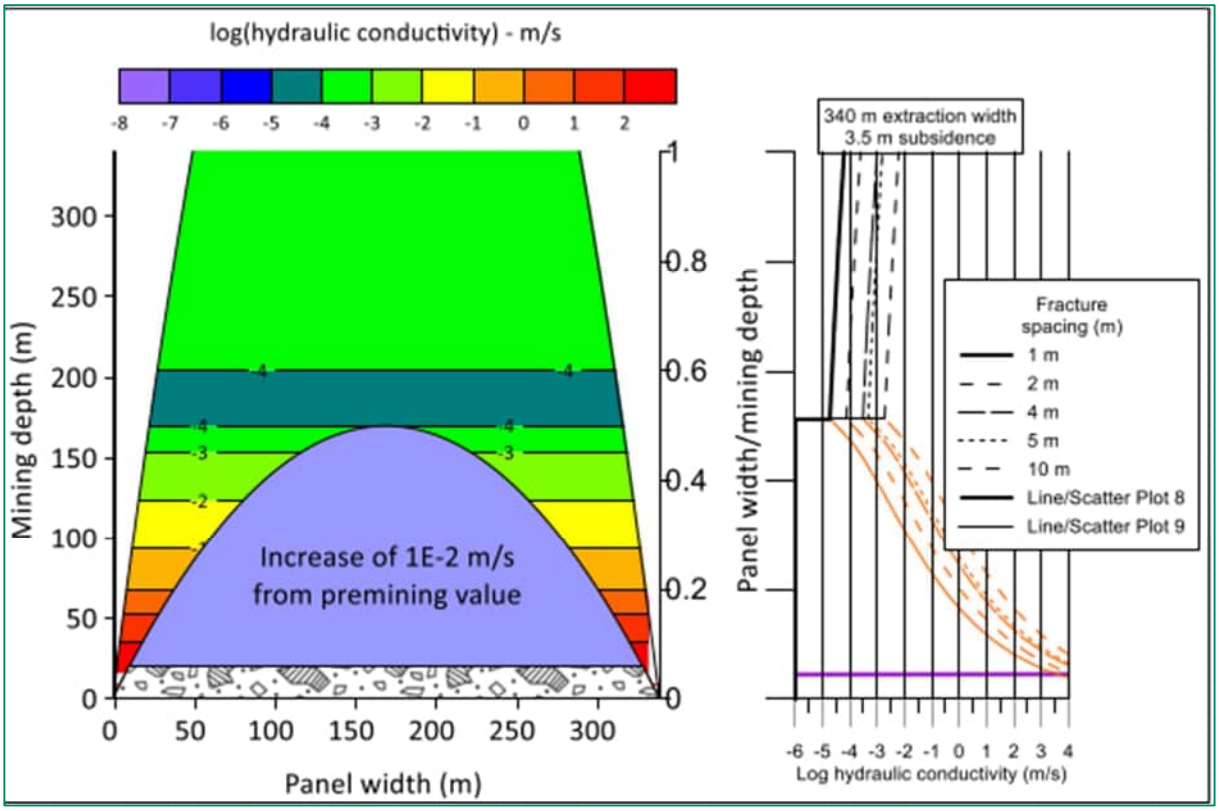
The input variables to the Geotechnical model are:

- Maximum vertical subsidence, or more precisely the difference in the maximum subsidence at /near the panel centreline relative to the subsidence above the chain pillars.
- The extraction width.
- The spacing of the cracks, where these may be mining-induced or the natural geological joints. This is a highly uncertain parameter, and its selection will require substantial judgement.

An example is presented in Figure 18, which also includes a sensitivity study on the choice of fracture spacing.

Note: The Byrnes Geotechnical report (**Appendix B**) is still in draft and was not finalised at the time of writing.

Figure 18 Example of hydraulic conductivity prediction for Broadmeadow underground mine with sensitivity to fracture spacing



7.3.4.3 Groundwater modelling approach

The alteration due to longwall mining, as conceptualised and modelled by Byrnes Geotechnical, predicts a complex heterogeneous hydrostratigraphic unit/s within, adjacent, and above the longwall panel post mining. It is also noted that Mine inflows are most likely related to the smaller more permeable ECZ at the edge of the panels rather than the larger disrupted zone.

The approach adopted to include for the alteration of the longwall mining was to assess the historic groundwater ingress into Broadmeadow GMS underground and simulate the altered target coal seam and overlying aquitards as an equivalent porous medium (EPM).

The EPM is a porous medium of a continuous solid matrix and pore-inclusions with an equivalent porosity that is higher than the porosity of the initial medium was used. Thus, an equivalent permeability across the entire mine panel was used in lieu of complex parametrisation within each panel to simulate high permeable areas (ECZ) and low permeable zones (PCZ).

Model calibration to match the actual groundwater extraction from the Broadmeadow GMS underground mining (Plate 8), allowed for the refinement of alteration to be adopted at all longwall mining panels across the Project.

The model calibration is detailed in Section 13.0. The model calibration using the groundwater extraction results plus the EPM approach indicated alteration resulting in hydraulic properties as follows:

- GMS goaf Horizontal hydraulic conductivity (Kh) = 1.1 m/day
- GMS goaf Vertical hydraulic conductivity (Kv) = 5E-05 m/day
- GMS goaf Specific capacity (Sc) confined storage = 1.5E-03
- GMS goaf Specific yield (Sy) unconfined storage = 0.15

The Kv in the overlying model layer (interburden aquitard) was 0.0005 m/day after longwall mining. The goaf K and S parameters were adjusted by comparing computed extracted groundwater volumes from the goaf areas to the measured and recorded groundwater ingress pumped from the underground between 2018 and 2023.

The yellow highlighted areas in Plate 8 are the GMS underground longwall panels included in the original (RHM Model) mine plan (2010 to 2023).

Plate 9 includes the goaf aquifer hydraulic parameters included after longwall mining was complete.

Goaf Kv in model layer 10 (GMS) is similar to the pilot point estimates (Section 14.3) and the Kv in model layer 9 (MCM interburden) was increased to 5 E-5 m/day.

Specific yield, as a result of longwall mining, increased from 0.001 to 0.15, and the storage coefficient increased from 1E-5 to 0.0015.

Plate 8 Historic GMS mine panels (2010 to 2023) in yellow - overleaf

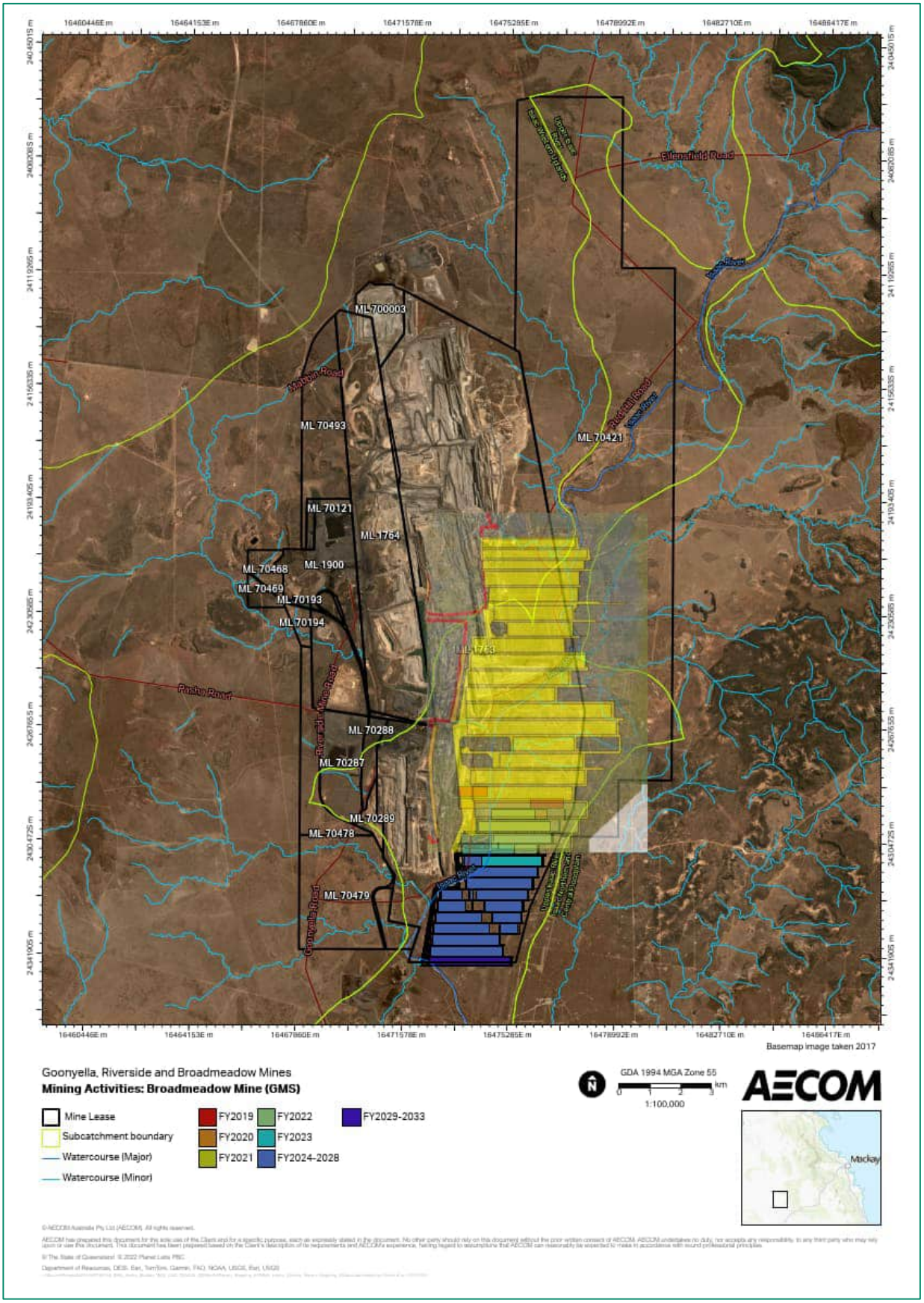
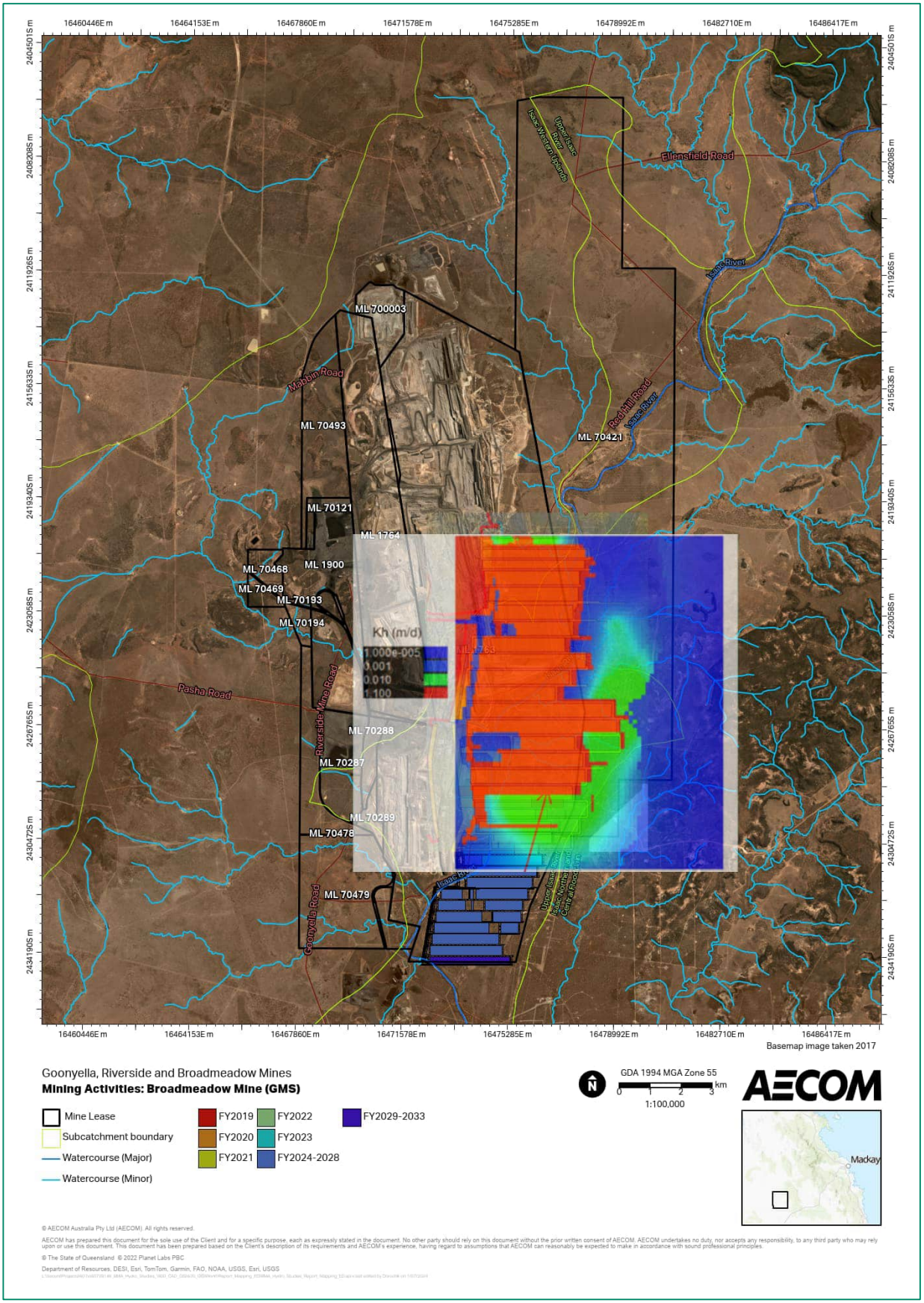

ML700003
ML 70493
ML 70421
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
Basemap image taken 2017
Goonyella, Riverside and Broadmeadow Mines
Mining Activities: Broadmeadow Mine (GMS)
Mine Lease
Subcatchment boundary
Watercourse (Major)
Watercourse (Minor)
FY2019
FY2020
FY2021
FY2022
FY2023
FY2024-2028
FY2029-2033
GDA 1994 MGA Zone 55
1:100,000
Mackay

Plate 9 Representation of hydraulic conductivity distribution at the GMS mine panels after mining alteration - overleaf


16460446E m
16464153E m
16467860E m
16471578E m
16475285E m
16478992E m
16482710E m
16486417E m
2404501S m
2408208S m
2411926S m
2415633S m
2419340S m
2423058S m
2426765S m
2430472S m
2434190S m
Ellensfield Road
Isaac River
Upper Isaac River
Isaac Western Uplands
ML 700003
Mabbin Road
ML 70493
ML 70421
Red Hill Road
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
Kh (m/d)
1.000e-005
0.001
0.010
1.100
ML 1763
Pasha Road
Riverside Mine Road
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
Goonyella Road
Basemap image taken 2017
Goonyella, Riverside and Broadmeadow Mines
Mining Activities: Broadmeadow Mine (GMS)
Mine Lease
Subcatchment boundary
Watercourse (Major)
Watercourse (Minor)
FY2019
FY2020
FY2021
FY2022
FY2023
FY2024-2028
FY2029-2033
GDA 1994 MGA Zone 55
0 1 2 3 km
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Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

8.0 Water Quality

8.1 Baseline groundwater quality

Available hydrochemistry data for the key hydrostratigraphic units across the Project area included data from 2001 to 2020, which was used to describe the historic conditions. More recent data, from 2020 to 2024, allowed for the evaluate of current groundwater quality and a comparison to historic data. This allowed for the evaluation of possible alteration due to approved mining activities at the Project.

8.1.1 Historic data

Groundwater quality data from previous investigations at GRB and RHM, from 2001 to 2010 (Table 7) have informed this section and from RHM from 1998 to 2011.

Groundwater chemistry is typically neutral to weakly alkaline (pH) for all formations.

The groundwater from the Quaternary alluvium is dominated by sodium and bicarbonate ions. The alluvial aquifer has variable salinity as the depth of the aquifer and its distance from the area of recharge are likely to influence the result at a given sample point and appears to increase with depth and the distance from the area of recharge (i.e., residence time increases the salinity of the groundwater). Generally, the alluvial groundwater has lower salinity than the Permian age confined formations.

The Tertiary and Permian age formations have variable salinity (measured as electrical conductivity), ranging from brackish to saline.

The Permian MCM and Back Creek Group has moderate to high salinity principally due to elevated levels of sodium and chloride ions. The Back Creek Group groundwater contains a relatively higher proportion of sulphate due to marine influence during deposition compared to the MCM (URS 2013).

Table 7 Groundwater quality results (2001 – 2010)

Lithology	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Alluvium	2	521 – 561		6.88 - 7.55	
Tertiary Basalt	3	2,670-15,384	13,100	8.19 – 8.67	8.38
Tertiary Sediments	1	5,060		9.3	
Permian Interburden	6	7,030 – 18,800	12,805	7.38 - 8.38	8.06
GMS coal seam	5	2,450 – 16,127	9,110	6.65 – 7.9	7.12
GLS coal seam	30	387 – 31,300	24,050	2.71 - 8.76	7.99
Back Creek Group	3	4,530 – 24,030	22,660	5.98 – 6.79	6.74
Undifferentiated samples from airlift during exploration	75	100 – 30,000	12,593	6.89 – 9.18	7.68
EPP (Water) - 50th Percentile					
Shallow groundwater (<30 m)		2,150		7.75	
Deep groundwater (>30 m)		6,100		7.8	

Notes:

- Electrical Conductivity value based on TDS value for livestock (EC [µS/cm] = 1.67 × TDS [mg/L])
- EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34.

8.1.2 Recent data

Groundwater quality monitoring results, compiled between 2020 and 2024, show that the alluvium indicated high variability, with salinity varying from fresh to highly saline.

Tertiary sediments have salinity that ranges from moderate to highly saline. The GMS coal seam salinity ranges from brackish to highly saline. The GLS coal seam and Back Creek Group samples indicate high salinity.

Table 8 Groundwater quality results (2020 – 2024)

Geology	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Alluvium	27	492 – 41,000	696	5.25 – 8.1	7.42
Tertiary Sediments	57	11,400– 42,200	21,700	5.52 - 8.33	6.59
FCCM	6	167 – 36,500	22,300	7.24 – 8.99	7.65
Permian Interburden	28	2,120 – 17,800	3,305	6.22 - 8.47	7.62
GMS coal seam	13	6,720 – 26,100	9,610	7.15 - 8.32	7.68
GLS coal seam	4	14,900 – 42,200	24,400	6.34 - 8.54	7.50
Back Creek Group	2	17,200 – 24,452	24,700	6.37 – 8.08	7.62
EPP (Water) - 50th Percentile					
Shallow groundwater (<30 m)		2,150		7.75	
Deep groundwater (>30 m)		6,100		7.8	

8.1.3 Water quality data review

Historic data

Alluvium major ions and nutrients minimum values from the 1998 to 2011 monitoring data:

- Did not exceed the EPP (Water) 50th percentile water quality objectives for the shallow (<30 m depth) groundwater
- All the maximum concentrations and several median values exceeded the 50th percentile water quality objectives.

The maximum analysis concentrations for the MCM major ions were above the 50th percentile water quality objectives for both the shallow and deep groundwater. The MCM sodium and chloride median values exceeded the 50th percentile water quality objectives for shallow groundwater.

The median and maximum values for the Back Creek Group major ions were greater than the shallow and deep groundwater 50th percentile water quality objectives, except for bicarbonate. Sodium, chloride, and sulphate of the Back Creek exceeded water quality objectives for shallow groundwater (Table 9).

Recent data

During the 2020 to 2024 monitoring, the minimum and median values for groundwater samples from the alluvium major ions remained below the shallow groundwater 50th percentile water quality objectives. However, the maximum values were found to be above the 50th percentile water quality objectives except for chloride, which was slightly below the objective.

MCM analyses indicated exceedance of the 50th percentile water quality objectives for the median and maximum values of the major ions, with the exception of the bicarbonate. Minimum values were all below the objectives.

All Back Creek Group major ions exceeded the water quality objectives for both the shallow and deep groundwater water quality objectives, with the expectation of the bicarbonate which was below the objectives for all geological units (Table 10).

	Water Quality Objectives		Alluvium				MCM				Back Creek Group			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP(Water) – 50th Percentile, Deep (>30 m depth)[1]	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)
Parameter														
Major Ions														
Sodium	747	1,100	13	40	1,096	3,560	3	824	3,470	4,400	2	40	-	94
Calcium	84	145	13	<0.01	49	469	3	34	214	422	2	13	-	39
Magnesium	108	115	13	<0.01	25	570	3	86	542	805	2	7	-	20
Potassium			13	1.4	6	28	3	29	35	38	2	3	-	3
Chloride	1,309	1,900	13	64	2,024	7,510	3	1,390	7,000	9,750	2	10	-	71
Bicarbonate	536	330	13	85	497	5,656	3	10	417	774	2	180	-	293
Sulphate	140	138	13	0.2	4	626	3	223	692	763	2	6	-	26
Fluoride	0.28	0.155	11	<0.1	0.2	1.2	3				2	0.2	-	0.4
Nutrients														
Nitrite + Nitrate as N	0.95	2.15	13	0.02	0.2	0.9	3	0.05	0.09	0.33	2	0.125	-	0.315
Total Phosphorous as P			13	0.03	0.5	5.08	3	0.78	1.49	1.56	2	0.47	-	0.75

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater.

Table 9 Groundwater quality results (1998 – 2011)

	Water Quality Objectives		Alluvium				MCM				Back Creek Group			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP(Water) – 50th Percentile, Deep (>30 m depth)[1]	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)
Parameter														
Major Ions														
Sodium	747	1,100	27	49	116	8,140	89	293	2,450	8,770	24	3,160	4,115	4,540
Calcium	84	145	27	11	23	290	89	40	211	662	24	160	276	358
Magnesium	108	115	27	8	18	915	89	41	425.5	1,230	24	403	458.5	558
Potassium			27	1	3	64	89	3	14	34	24	13	15	37
Chloride	1,309	1,900	27	24	75	13,000	89	414	7,460	16,900	24	6,420	7,710	8,320
Bicarbonate	536	330	27	1	256	492	89	166	469	1,360	24	313	478	520
Sulphate	140	138	27	13	30	3,400	89	36	555	2,160	24	438	552	655
Fluoride	0.28	0.155	27	0.1	0.1	0.7	89	0.1	0.2	400	24	0.1	0.4	400
Nutrients														
Nitrite + Nitrate as N	0.95	2.15	27	0.01	0.125	2.42	89	0.01	0.035	0.44	24	0.01	0.04	0.67
Total Phosphorous as P			27	0.01	0.06	0.34	89	0.01	0.055	19,000	24	0.09	0.16	0.44

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater.

Table 10 Groundwater quality results (2020 – 2024)

The comparison of water quality data, to the relevant water quality objectives, does not readily indicate a marked difference in water quality over time. The variation in data is considered related to differing groundwater monitoring locations (reflecting the heterogeneous nature of the sediments across the Project), the number of samples, and the difference in residence time (different recharge / climate conditions).

8.2 Groundwater Environmental Values

Water plans have been developed by the State regulators, under the Water Act to sustainably manage and allocate water resources in Queensland. The Project is located within the Isaac Connors Groundwater Management Area (GMA) as defined in Schedule 3 of the Water Plan (Fitzroy Basin) 2011 (current as of 2 September 2022). Plate 10 indicates the Isaac Connors GMA and the approximate Project location.

Plate 10 Water Plan (Fitzroy Basin) 2011 Schedule 3 Groundwater Management Areas (Project is red dot)

GRB lies within or in proximity to the Isaac Connors Groundwater Management Area (GMA – Zone 34) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011 (Plate 11). Within the GMA, alluvial groundwater is managed as Groundwater Unit 1 and water within the hard rock aquifers as Groundwater Unit 2 (sub-artesian aquifers). Volumetric limits apply to extraction of groundwater within the GMA for non-stock and domestic purposes.

Groundwater resources in the GRB are also scheduled under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 as Isaac Groundwaters of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1310). The legislated environmental values (EVs) for these groundwaters are:

- Biological integrity of aquatic ecosystems.
- Human use EVs:
    - Suitability of water supply for irrigation
    - Farm water supply/use
    - Stock watering
    - Primary recreation
    - Drinking water supply
    - Cultural and spiritual values.

The WQ1310 WQOs for groundwater at GRB are shown in Table 11.

The EPP Water and Wetland Biodiversity provides water quality objectives (WQOs) for the scheduled EVs in WQ1310. WQOs are long-term goals for water quality management and the purpose of the WQOs is to support and protect EVs. They are numerical concentration levels or narrative statements of indicators established for receiving waters to support and protect the designated EVs for those waters. They are based on scientific criteria or water quality guidelines but may be modified by other inputs (e.g. social, cultural, economic). Where groundwater quality analysis results exceed a particular WQO for a particular EV, it is considered indicative that the groundwater may be unsuitable for supporting that particular EV.

The EPP Water and Wetland Biodiversity also provides limited WQOs specifically for underground aquatic ecosystem protection in Fitzroy Basin groundwaters. These WQOs vary across the Fitzroy Basin and are defined on the basis of groundwater Chemistry Zones. The applicable Chemistry Zone for the GRB is Isaac Groundwater (Zone 34; Sodic Sequence - Saline: Na, Cl). These WQOs are classified by groundwater depth (‘shallow’ being <30 m depth, and ‘deep’ being >30 m depth) and are summarised in Table 12. The management intent of Zone 34 WQOs is to “maintain each of 20th, 50th and 80th percentile values”, i.e. that there should be no change to existing water quality (no statistical change in the natural range of values) (DES, 2022).

Plate 11 Fitzroy Basin Groundwater Zones (Project red dot)

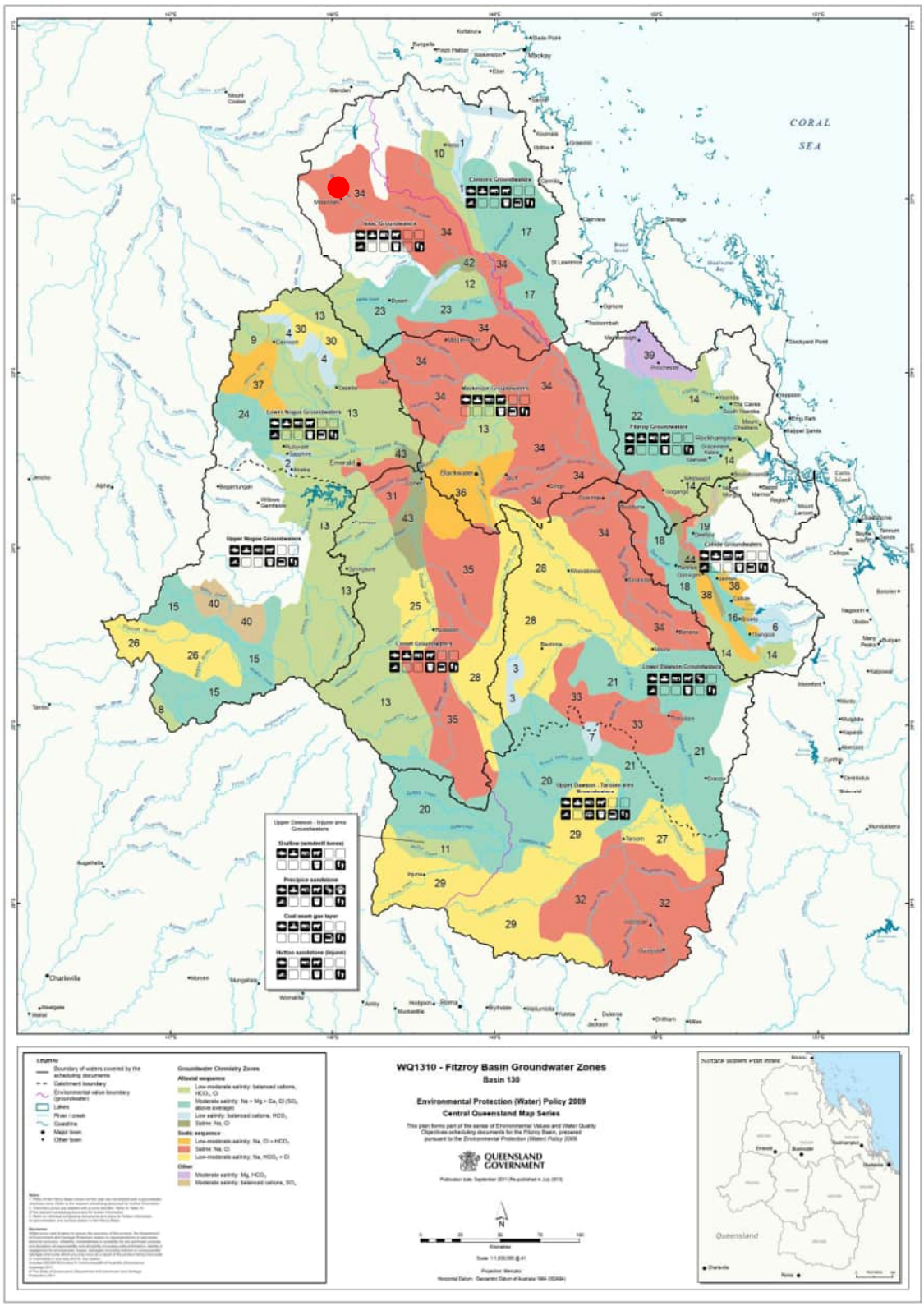

Table 11 WQOs for Isaac River sub-basin EVs

Water quality indicator	Unit	ADWG Guidelines[1]		Isaac River Sub-basin EVs[2]		
		Health	Aesthetic	Irrigation	Stock	Aquatic 95% spp[3]
pH	pH units	6.5 – 8.5				6.5 – 8.5
Al	mg/L		0.2		5	0.055
Ca	mg/L				1,000	
Cl	mg/L		250			
Mg	mg/L				2,000	
Mn	mg/L	0.5	0.1	10		1.9
Na	mg/L		180			
SO_4	mg/L				1,000	
Zn	mg/L		3			0.008
As	mg/L	0.01		2	0.5	0.024
Cd	mg/L	0.002			0.01	0.0002
Cr	mg/L	0.5			1	0.001
Co	mg/L			0.1	1	
Cu	mg/L	2	1		1	0.0014
Pb	mg/L	0.01			0.1	0.0034
Hg	mg/L	0.001			0.002	0.0006
Ni	mg/L	0.02			1	0.011
Se	mg/L	0.01			0.02	0.005
Ag	mg/L	0.1				0.05

Table notes:
1. Table 4 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Drinking water EV.
2. Table 2, Table 9, Table 10 and Table 11 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed.
3. Table 3.4.1 of Australian and New Zealand Guidelines for Fresh and Marine Water Quality: trigger values for slightly - moderately disturbed systems (95% level of protection).

Table 12 Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection)

Water quality indicator	Unit	Shallow groundwater (<30m) percentile			Shallow groundwater (>30m) percentile		
		20th	50th	80th	20th	50th	80th
EC	µS/cm	498	2,150	8,910	3,419	6,100	16,000
Hardness	mg/L as $CaCO_3$	163	674	2,228	359	919	3,208
pH	pH units	7.1	7.75	8.1	7.4	7.8	8.03
Alkalinity	mg/L	154	435	752	156	275	536
Ca	mg/L	18	84	215	46	145	442
Mg	mg/L	27	108	389	35	115	491
Na	mg/L	135	747	1,500	480	1,100	2,565
Cl	mg/L	171	1,309	3,185	753	1,900	5,905
SO_4	mg/L	12	140	318	25	138	398
HCO_3	mg/L	187	536	878	188	330	650
NO_3	mg/L	0	0.95	5.3	0.01	2.15	14.92
SiO_2	mg/L	21	36	52	16	25	36
F	mg/L	0.1	0.28	0.5	0.02	0.155	0.4
Fe	mg/L	0	0.03	0.14	0	0.05	0.246
Mn	mg/L	0	0.01	0.16	0	0.05	0.291
Zn	mg/L	0	0.015	0.06	0.01	0.025	0.317
Cu	mg/L	0	0.01	0.03	0.017	0.03	0.03
SAR	-	4.37	10.85	18.21	10.5	15.6	24.65
RAH	meq/L	0	0	2.3	0	0.24	6.25

In order to understand the groundwater resources within the GRB area, available water quality data Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater have been compared to the:

- Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011)
- ANZG (2018) guidelines for irrigation (long-term and short-term), stock water supply, and 95% level of protection for aquatic ecosystems in slightly - moderately disturbed systems
- Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) for deep and shallow groundwater.

8.2.1 Groundwater quality comments

Median groundwater salinity values were greater than the 50th percentile WQOs nominated in the (Water) for groundwaters in the Isaac River Sub-basin. The available dataset does, however, indicate that groundwater results cover a wide range for each hydrostratigraphic unit (due to depth, distance from recharge, and age of water). The lower end of the range of results are within the WQOs.

Alluvium

- Major ion concentrations for alluvial groundwater are less than the EPP (Water) 50th percentile water quality objectives for shallow (<30 metre depth) groundwater.
- The maximum concentration of zinc recorded is above the ANZG (2018) water quality guideline for aquatic ecosystems.

MCM

- The median concentration of sodium for groundwater from the MCM is less than the EPP (Water) 50th percentile water quality objective for deep (>30 m depth) groundwater.
- The median concentrations of chloride and bicarbonate were above their respective water quality objectives.
- The median concentration of manganese was above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (chromium, copper, and zinc) are all above the ANZG water quality guidelines for aquatic ecosystems.
- The median concentrations of manganese and iron are above the relevant water quality objectives, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (boron, cadmium, chromium, copper, nickel, selenium, and zinc) are above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

Based on the historic and more recent groundwater quality data for the Project area, the groundwater quality does not readily comply with the guideline WQOs. The limited variation over time, considering the historic and recent water quality sample results, indicate the natural groundwater quality reduces the suitability for use (Isaac Connors Groundwater Management Area EVs) and aquatic ecosystems.

9.0 Groundwater Receptors

9.1 Groundwater Bores

A search of the Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Bore Database (GWBD) was carried out for registered bores within and adjacent to the Project. The search, across the mine lease areas and a 5 km buffer around the mine leases, indicated that there are 238 registered bores (Figure 19). These registered bores, summarised in Table 13, include:

- Sixteen (16) bores are abandoned and destroyed, with the rest are reported as existing on the GWDB bore cards.
- 190 of the registered bores are reported as used for groundwater monitoring.
- Six (6) are used for water supply, with three reported as no longer being used.
- 20 are recorded as exploration bores.
- Six (6) are reported as use unknown.

Table 13 Registered groundwater bores in proximity to GRB

Use	Number of bores	Percent total
Groundwater monitoring (mine monitoring, water resource investigation,etc.)	190	85
Water supply	6	3
Exploration	20	9
Unknown	6	3
Total		100

A search of the Queensland Water Entitlement Database showed that none of the 224 existing registered groundwater bores located within 10 km of GRB had water licences (i.e., there are no licensed water users identified within the GRB mine area) This indicates that the bores reported as water supply bores (on the bore cards) are entitled to be used for stock and domestic purposes, which do not require a water licence and allocation.

Table 14 Registered water supply bores in proximity to GRB

RN	Easting	Northing	Name	Depth	Comment
182313	604240	7594890	Cleanskin Gully	25.34 mbgl	No longer used Water level 14.02 mbgl
81696	608182	7586081	Skeleton Bore	63.7 mbgl	No details Water level 28.41 mbgl Yield 1.3 L/s
81700	591815	7587788	Harvey's Bore	No data	No data
182311	599005	7610760	Old Mill Bore	117.1 mbgl	No details Water level 90.66 mbgl Yield 1.9 L/s
182312	596795	7610020	Tex's bore	118.9 mbgl	No longer used Water level 34.13 mbgl Yield 4.5 L/s
132496	586258	7611031	?	79.6 mbgl	Back Creek Group Water level 50 mbgl Yield 1.1 L/s

The water supply bores, included in Figure 65, are discussed in detail in Section 15.8.1, which includes an assessment of potential long term (closure) impacts to the water supply bores.

Figure 19 Registered groundwater bores

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16460446E m 16464153E m 16467860E m 16471578E m 16475285E m 16478992E m 16482710E m 16486417E m

2404501S m 2408208S m 2411926S m 2415633S m 2419340S m 2423056S m 2426765S m 2430472S m 2434190S m

Isaac Western Uplands
Upper Isaac River
Ellensfield Road
Isaac River
ML 700003
Mabbin Road
ML 70493
ML 70421
Red Hill Road
Isaac River
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
Isaac River
Pasha Road
Riverside Mine Road
ML 70288
ML 70287
ML 70289
ML 70478
Isaac River
Upper Isaac River
Isaac Northern and Central Floodplain
ML 70479
Goonyella Road

16460446E m 16464153E m 16467860E m 16471578E m 16475285E m 16478992E m 16482710E m 16486417E m

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Registered Bores

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- GWDB registered bores

GDA 1994 MGA Zone 55
0 1 2 3 km
1:100,000

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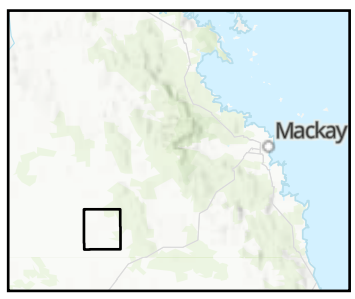

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Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

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9.2 Groundwater Dependent Ecosystems

A groundwater dependant ecosystem (GDE) is a natural ecosystem that requires “access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services” (Richardson, S., et al., 2011). GDEs can require access to groundwater on a permanent (obligate) or intermittent (facultative) basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Doody et al., 2019).

GDEs can be classified as either:

- Aquatic GDEs (i.e. ecosystems dependent on the surface-expression of groundwater, such as aquatic species that inhabit groundwater-fed surface pools).
- Terrestrial GDEs (i.e. ecosystems dependent on the sub-surface presence of groundwater, including some riparian vegetation communities with rooting depths that intersect the groundwater table).
- Subterranean GDEs (aquifer and cave ecosystems, such as stygofauna that can live within aquifer systems).

Broad-brush national scale desktop mapping of potential GDEs is available in the Bureau of Meteorology (BoM) National Atlas of GDEs (GDE Atlas). The GDE Atlas classifies ecosystems based on the potential for dependence on groundwater through desktop collation of multiple lines of scientific evidence. Ecosystems have been mapped as either:

- High potential for groundwater dependence (indicating a strong possibility the ecosystem is interacting with groundwater).
- Moderate potential for groundwater dependence.
- Low potential for groundwater dependence (indicating it is relatively unlikely the ecosystem will be interacting with groundwater and will include ecosystems that are not interacting with groundwater).

The broadbrush GDE Atlas mapping of potential aquatic and terrestrial GDEs indicates that areas with possible high, moderate, and low potential for groundwater interaction occur in the vicinity of the Project area (Figure 20).

Figure 20 indicates moderate and high potential Aquatic GDEs and moderate and low potential Terrestrial GDEs are mapped within the GRB mine lease. There are isolated areas of high potential Aquatic and Terrestrial GDEs, where aquatic GDEs are associated with rivers and tributaries. The only high potential Terrestrial GDEs are identified approximately 10 km north of the northern boundary of the mine.

It is noted that the potential aquatic GDEs, mapped at GRB in Figure 20, are tailings dams, mine water storages and mining voids. Thus, the mapping is recognised to identify potential GDEs only.

The remaining potential Aquatic and Terrestrial GDEs outside of the GRB mine leases fall between moderate and low potential GDEs, with low potential GDEs identified predominantly around the GRB boundaries. The groundwater study for the PRC Plan considers post mining conditions as the risks and management of these potential GDES has been assessed as the mining activities are approved and licensed activities. These mined areas will not be present (rehabilitated) during closure.

Sampling for stygofauna was undertaken as part of the Red Hill Mining Lease EIS; no stygofauna were found in any of the accessible groundwater bores on site (URS 2013).

Figure 20 Mapped GDEs

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16460446E m | 16464153E m | 16467860E m | 16471578E m | 16475285E m | 16478992E m | 16482710E m | 16486417E m

2404501S m | 2408208S m | 2411926S m | 2415633S m | 2419340S m | 2423058S m | 2426765S m | 2430472S m | 2434190S m

ML 700003
ML 70493
ML 70121
ML 1764
ML 1900
ML 70468
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
ML 70421
Mabbin Road
Pasha Road
Riverside Mine Road
Goonyella Road
Red Hill Road
Ellensfield Road
Isaac Western Uplands
Upper Isaac River
Isaac River
Upper Isaac River Isaac Northern and Central Floodplain

Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines

Potential GDEs (Aquatic, Terrestrial, and Springs)

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

Terrestrial GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

GDA 1994 MGA Zone 55

0 1 2 3 km

1:100,000

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Mackay

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10.0 Mining activities

10.1 Mine plans

Goonyella, Riverside, Broadmeadow, and Red Hill mining is through both open pit and underground methods. Drill and blast/truck and shovel are the employed mining process for the open pit. The open pit depth will range from approximately 60 m below ground level to greater than 300 m; depth is controlled by the target coal seams.

The underground operations are an extension of the open pits. It allows for mining of the coal further down dip. Mining is mechanised and is conducted by longwall. Once the coal has been removed from the mines, it is conveyed to the preparation plant for processing, sorting, and then distribution.

Mining at the GRM will continue until 2059 and the target seam for this mine is the GLS, with the final void used to access the underground RHM. The void will stay dewatered until end of mining at RHM.

The underground operations for the Broadmeadow GMS will continue until 2031, and will stay dewatered to allow for the mining of Broadmeadow GLS. Mining is planned to continue from 2031 until 2055 within the Broadmeadow GLS. Access to the GLS will be through the Broadmeadow GMS portal.

RHM underground mining is planned to commence in 2063 and will last until 2091. Access into the mine will be through the GRM void.

Predictive modelling to predict groundwater level, flow patterns, and potential for ingress into the residual voids adopted the mine plan schedules and decommissioning activities as detailed in Table 15.

Table 15 Mine plans and decommissioning activities until end-of-mining for PRC Plans

Mine	Planned start / Continued mining	End-of-mining	Closure	Comments
Goonyella / Riverside open cut mining	Prior to 2019	2059	2092	Target GLS Figure 21
Existing / residual pits Broadmeadow Isaac Ramp 32 East Thiess Ramp 32 South	 n/a n/a 2025 n/a 2033	 2009 1997 2026 2031 2036	 2053 2053 2032 End of mining End of mining	
Broadmeadow underground - GMS	2007	2031	2053	GMS seam continued longwall mining Figure 22
Broadmeadow underground - GLS	2031	2055	2056	Same portal as Broadmeadow GMS, mining below the GMS longwalls Figure 23
Broadmeadow underground	2057 2058, 2059, 2060			Decommissioning Injection of water to fill workings
Red Hill underground mine - GMS	2063	2091	2092	Access through Goonyella / Riverside highwall GMS (50 m above GLS) Figure 24
RHM	2093 2094, 2095, 2096			Decommissioning Injection of water to fill workings
Recovery	2097 onwards			All mining complete

Figure 21 Goonyella / Riverside open cut mining plan (plus Ramp 32)

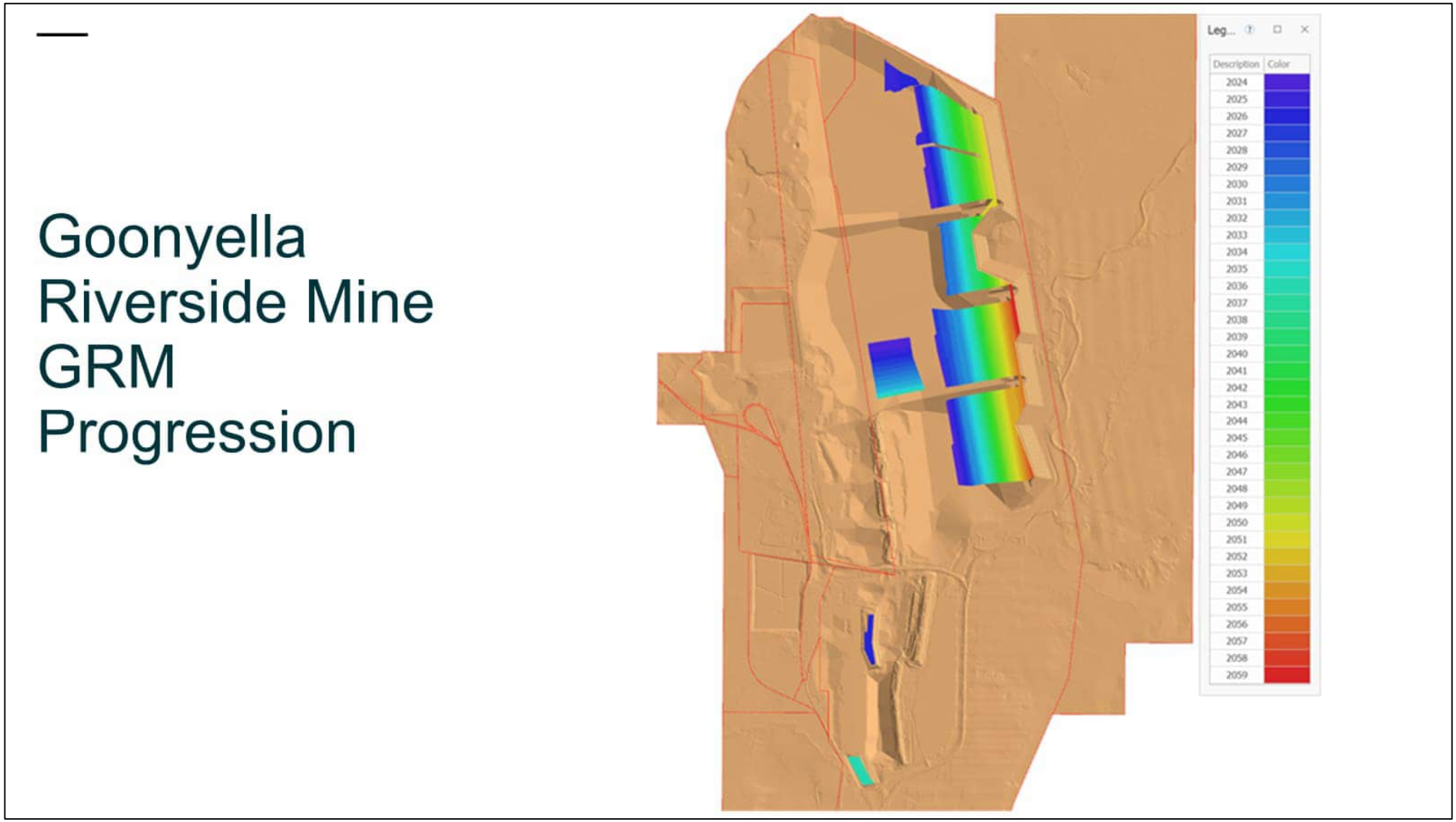


Figure 22 Broadmeadow underground mine plan – GMS

Figure 23 Broadmeadow underground mine – GLS

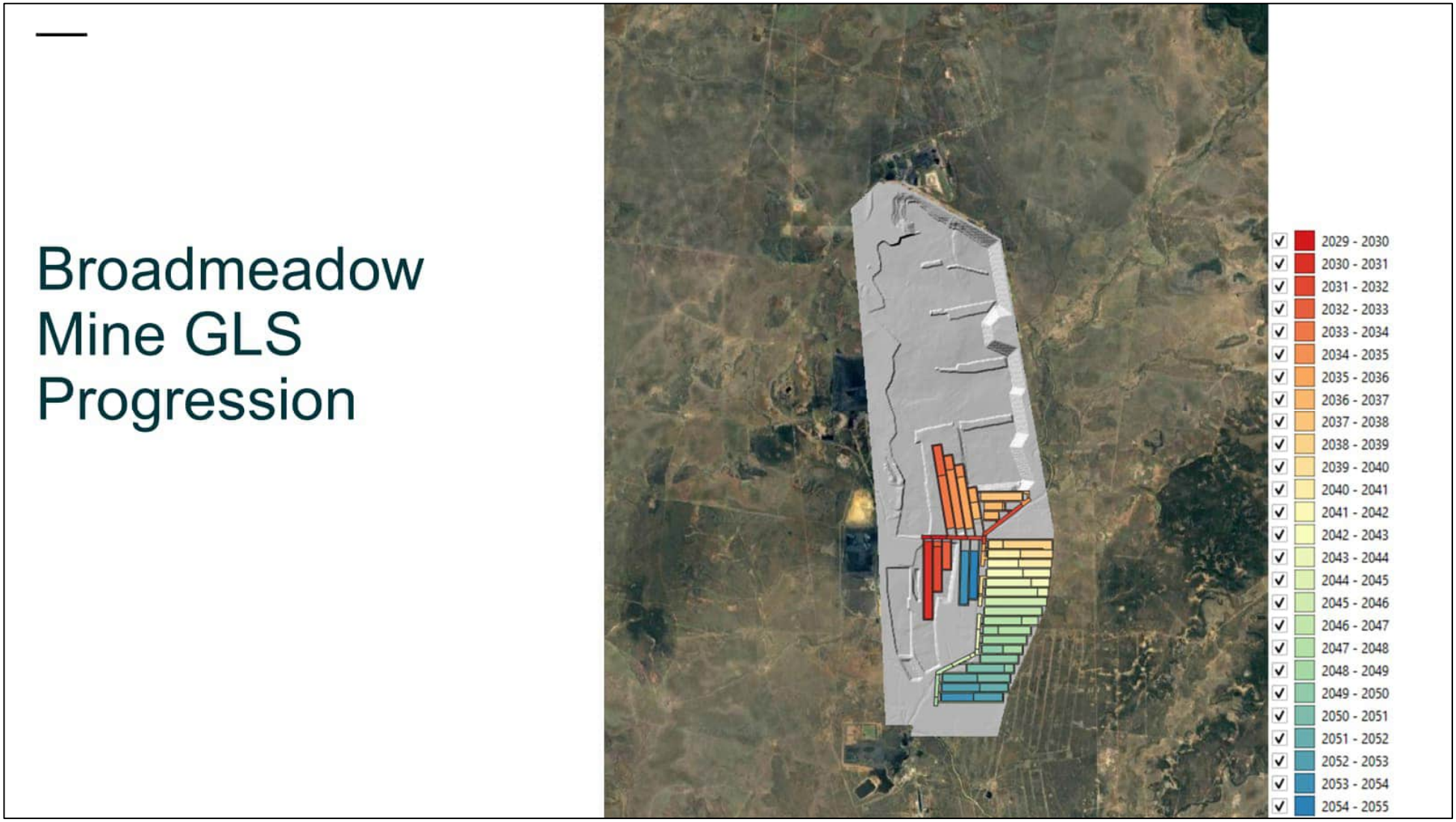


Figure 24 Red Hill underground mine plan

10.2 Mine Pit Inflows

Groundwater inflows from the Permian coal measures to GRB's active and residual pit voids are generally small in volume and do not typically need to be actively managed via advance dewatering or other groundwater management methods, with evaporation from the pit void walls and floors accounting for most of the groundwater. Small volumes of groundwater inflow, when they occur, are generally managed via the use of in-pit sumps to capture water that is then used for dust suppression purposes or circulated via the mine water management system for use in coal washing.

Groundwater inflow estimates for GRB for a typical year (2020 – 2021) are provided in Table 16 below based on BMA's annual Associated Water Take reporting to the Queensland Department of Resources (DoR). Estimates are based on BMA's site water balance calculations using site climate data, pit void storage, and pumped outflow data in accordance with the DNRME (2020) Associated Water Take Guideline, and as such inflow estimates are considered conservative. Refer to Figure 2 for pit locations.

Table 16 Estimated groundwater inflow at GRB (2020 – 2021)

Open Cut Pits	Annual estimate (ML/year)
Dampier Pit	0 (0)
Red Hill Pit	26 (±5)
Denham Pit	63 (±11)
Cleanskin Pit	67 (0)
Riverside Pit (Ramp 8)	11 (±2)
Riverside Pit (Ramp 6)	255 (±30)
Broadmeadow Pit	27 (0)
Isaac Pit	0 (±1)
Eureka Pit	79 (±4)
Airstrip Pit	0 (±45)
Lenton Pit	2 (0)
Broadmeadow underground	60 (±7)

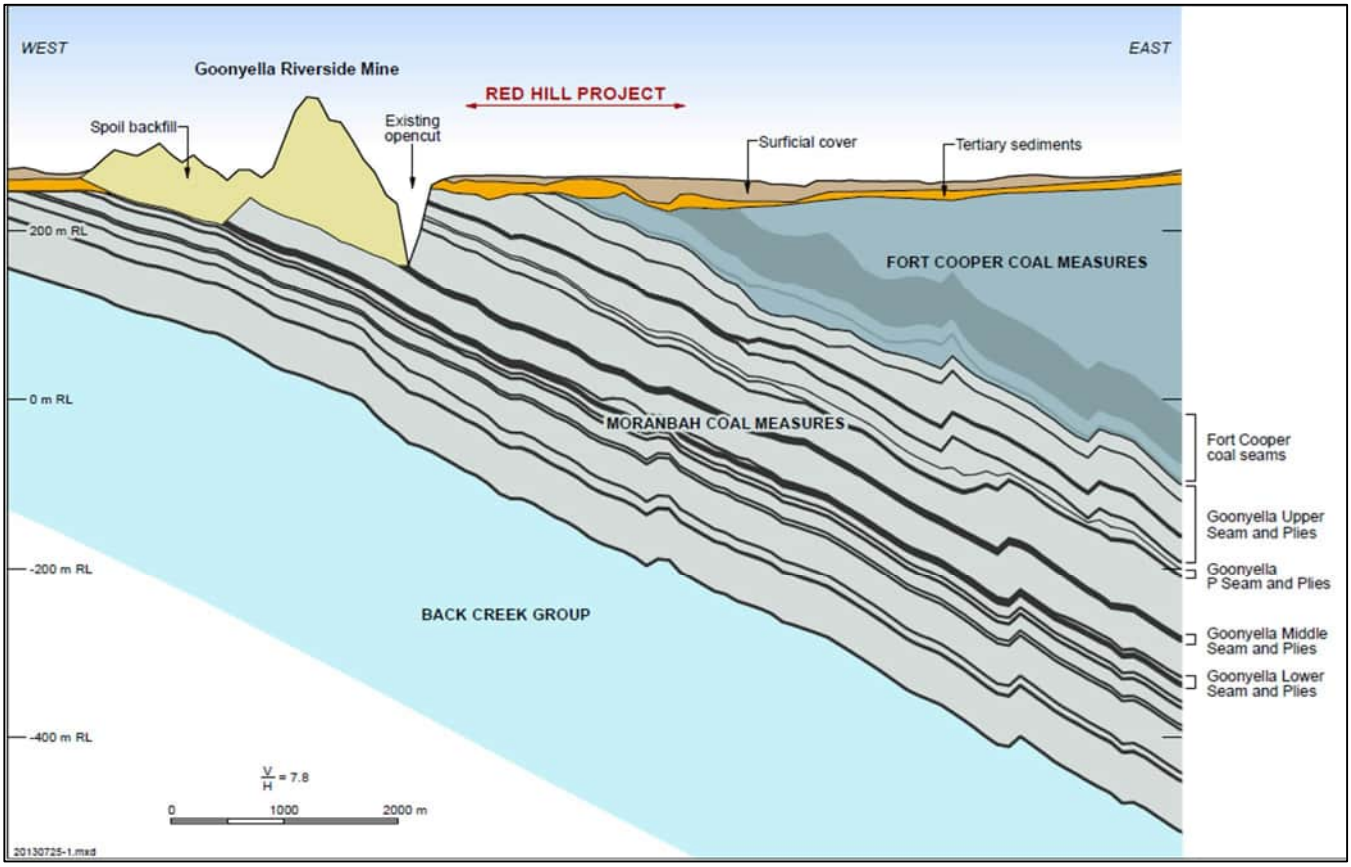
11.0 Conceptualisation – End of Mining

Conceptualisation of the groundwater regime/s has been developed based on the review of the hydrogeological information for GRB presented in the above report sections. Hydrogeological conceptual models (HCMs) are presented as conceptual cross-sections.

11.1 Overview

The geology of Project area comprises the stratified sequences of the MCM at the westernmost extent of the syncline that dip towards the east. Mining at GRB targets the coal seams of the MCM, that occur at subcrop, and increase with depth towards the east. Surficial cover at GRB includes alluvium associated the Isaac River floodplains and tributaries, primarily Eureka Creek. Surficial cover at GRB outside of these water lines consists of Quaternary to Tertiary age sediments (Plate 12).

Plate 12 Lithological cross section



The primary hydrogeological features at GRB include:

- Cainozoic sediments:
  - Quaternary alluvium – unconfined
  - Tertiary unconsolidated sediments of the Suttor Formation – unconfined / semi-confined.
- Permian – Triassic coal measures with
  - Low permeability interburden aquitards
  - Coal seams have higher groundwater potential due to secondary porosity through cleats.

Surficial cover

Groundwater within the alluvium is recorded at depths of 4.5 to 9.5 mbgl (Figure 10). Regionally, groundwater flow within the alluvium is a subdued reflection of topography, with groundwater flowing in an east-south-easterly direction.

Losing conditions from water courses to the underlying alluvium are evident during flow periods. Recharge to the alluvium is considered to be primarily from stream flow or flooding. Direct infiltration of rainfall also occurs where there are no substantial clay barriers in the shallow sub surface.

On a regional scale, discharge is via evapotranspiration from riparian vegetation growing along creek beds and minor short duration baseflow events after significant rainfall/flooding.

The Tertiary Suttor Formation and undifferentiated Tertiary sediments comprise unconsolidated sediment aquifer/s, which has a depth to groundwater in monitoring wells at RHM around 10 mbgl (Figure 12). The clean sand and gravel lenses in the Tertiary sediments are permeable but are of limited lateral and vertical extent.

Coal seams

Regionally, groundwater within the Permian-Triassic coal measures flows in a south-easterly direction, but the flow system is modified on a local scale by mining activities in the region with ongoing discharge to mine workings, including at GRB.

Review of water quality data indicates water within the Permian coal measures is generally saline at GRB but can range between brackish to highly saline. Groundwater within the coal measures at GRB exceeds guideline criteria for irrigation, drinking water, and protection of aquatic ecosystems, and only variably meets the guideline criteria for stock water supply with guideline exceedances for salinity and sulfate.

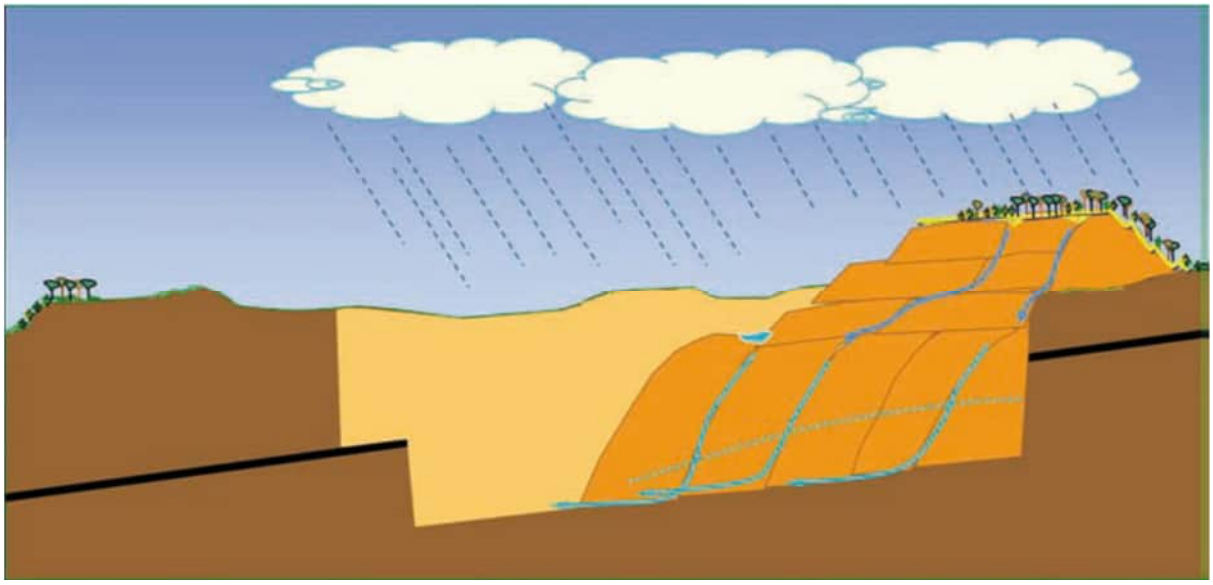
11.2 Hydrogeological conceptualisation

For the conceptualisation of groundwater response to mining, the recharge and discharge mechanisms at several (mine area) locations across the GRB were considered. These conceptual cross sections include the envisaged end-of-mining groundwater conditions. These conceptual models were considered when undertaking the predictive groundwater modelling.

Recharge mechanisms include:

- Rainfall recharge.
- Enhanced recharge through spoil (loose, unconsolidated).
    - Discrete ingress flow patterns and intermittent saturation within the spoil (as conceptualised by NSW Department of Primary Industries included in Plate 13, noting this is a fully backfilled mine void which has been rehabilitated).

Plate 13 Conceptual model of movement of water in a typical rehabilitated mine void and spoil pile



- Possible induced flow from over- and under-lying hydrostratigraphic units towards the dewatered target coal seams.
- Vertical groundwater movement (in response to vertical groundwater gradients and longwall alteration).
- Surface water losing systems.

Discharge mechanisms include:

- Mine dewatering resulting in groundwater drawdown into open cut and underground workings.
- Groundwater flow into the open cut workings where the pits intersect saturated hydrostratigraphic units (including the surficial cover).
- Evaporation from pits resulting in groundwater drawdown and local groundwater flow into open cut workings.
- Evapotranspiration.
- Groundwater extraction.

11.3 End of Mining

The potential impacts to the groundwater system at end of mining, as relevant to the hydrogeology assessment for the transitional PRC Plan/s, relate to how the groundwater system is dewatered, artificially recharged (through reinjection into the underground workings), and then recovers after all active mining ceases (Table 15). Therefore, it is important to understand the nature of the groundwater system/s at the conclusion of mining immediately prior to the closure period.

A visual representation of the end of mining HCMs for GRB is provided in a series of conceptual cross sections. These cross sections depict the different mining activities across the GRB. The location of the cross-sections is included in Figure 25.

Key features relevant to groundwater conditions at the end-of-mining include:

- Groundwater drawdown within the MCM, associated with passive dewatering into the GRB residual voids, results in inwards hydraulic flow gradients in the coal measures.
- Drawdown in the MCM at the end of mining is at, or close to, the maximum expected to occur as a result of GRB.

- Residual voids capture seepage from spoil emplacements
- Residual voids capture seepage from TSFs
  - Runoff from the spoil and TSFs is directed down ramps into the residual voids.
- Little to no impact on surficial aquifers, which is intermittently saturated, including the Isaac River Alluvium.
- Little to no impact on environmental receptors.
- No impact on anthropogenic receptors (i.e., private groundwater users).

11.4 Continual mining

The timing and extent of mining, at Goonyella / Riverside Mine, Broadmeadow Mine (both GMS and GLS), and Red Hill Mine, is envisaged (for the purposes of the PRC Plan) to continue sequentially leading to continued groundwater extraction during mining within the Project area. Section 10.1 presents the mine plans, including the end-of-mining dates.

The HCMs consider groundwater drawdown at the end-of-mining at different time periods, corresponding with different mine end dates. Based on the proximity of mines and continuous sequencing plus mine locations (such as Broadmeadow GLS underneath GMS), little or no groundwater recovery (and thus contribution to the final voids at GRB) is envisaged until all mining ceases or when underground workings are artificially filled with water.

The prediction of groundwater response to continuous mining, spatial and overtime, will be included in the predictive groundwater modelling.

Figure 25 GRB cross section locations

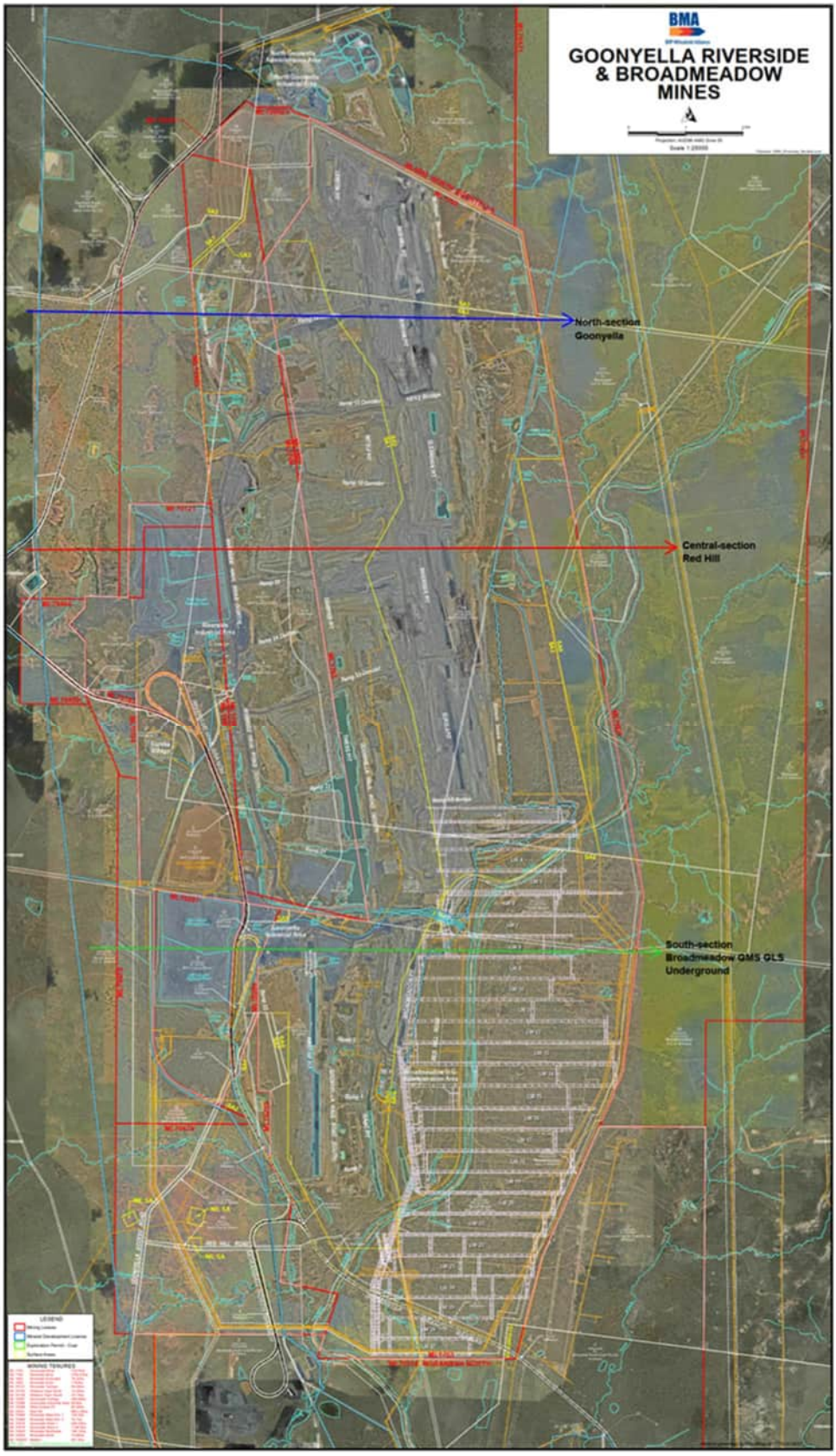


Figure 26 Goonyella open cut mining – North cross-section west to east at end of mining

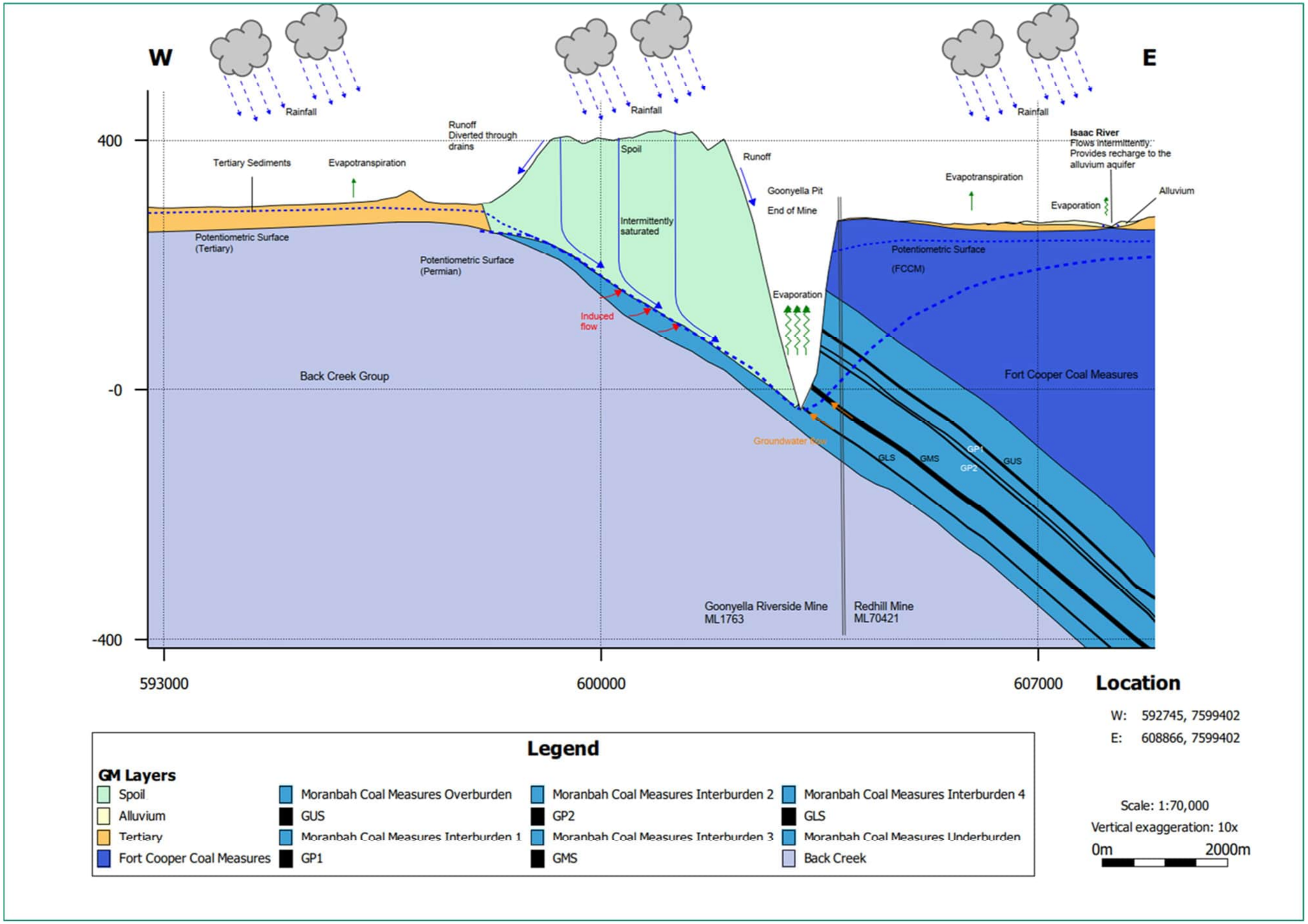


Figure 27 Goonyella open cut and Red Hill underground mines – Central cross-section west to east at end of mine

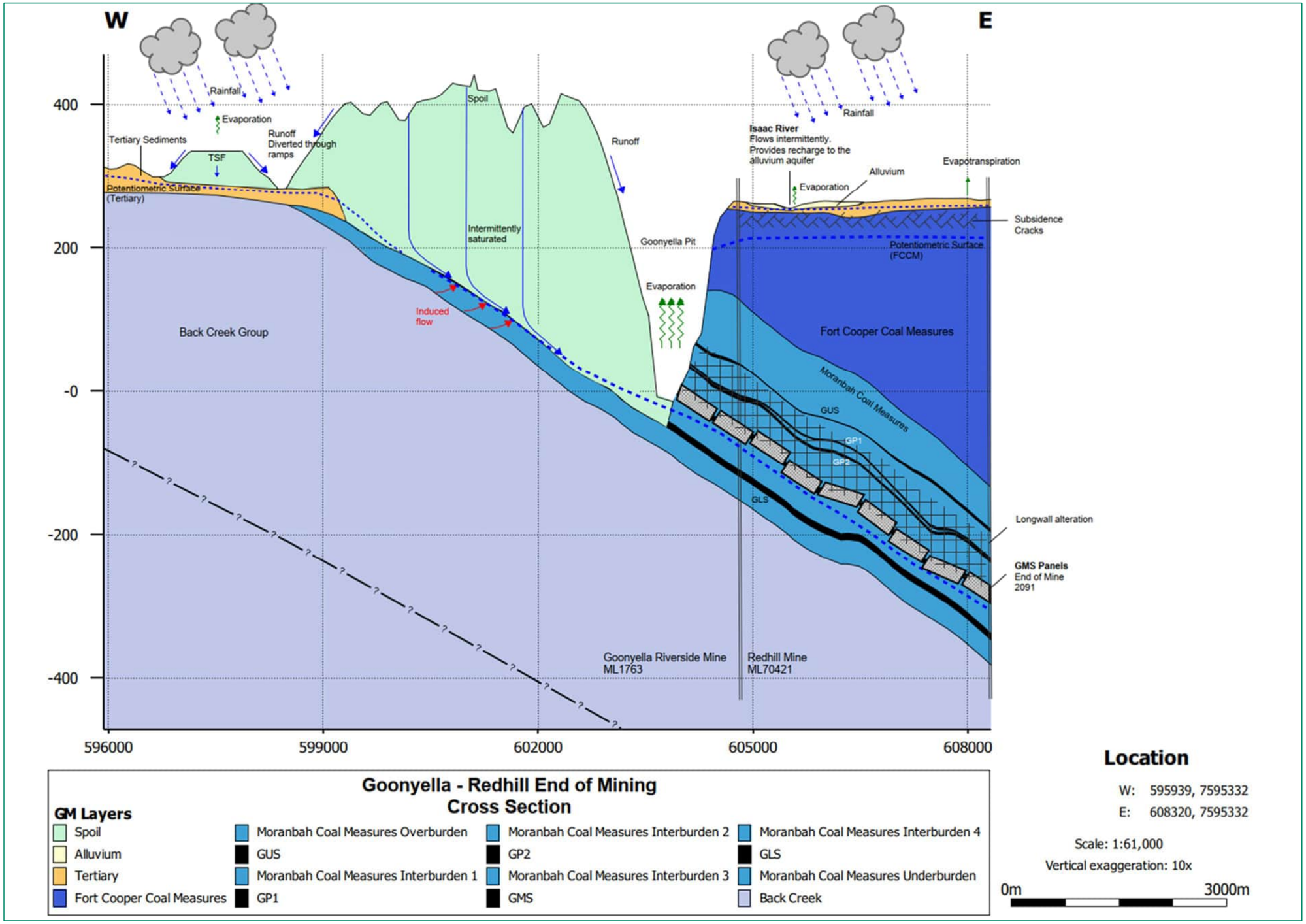
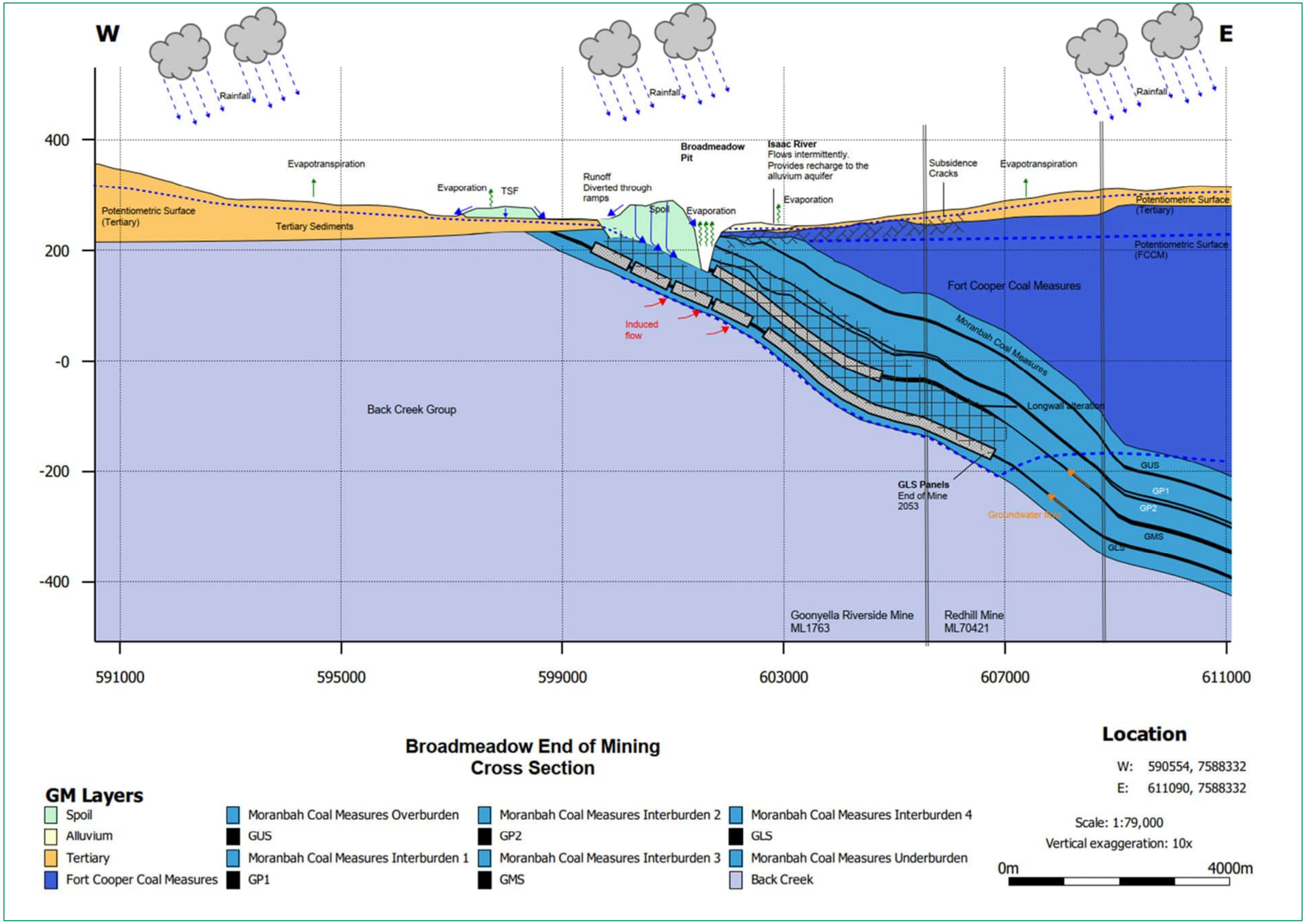


Figure 28 Broadmeadow longwall mining GMS and GLS – South cross-section west to east at end of mining



12.0 Potential Impacts

Potential impacts associated with shallow sources of potential groundwater contamination at GRB are being assessed for the PRC Plan by a separate Contaminated Land Assessment. Therefore, this hydrogeology assessment focuses on the larger scale impacts to the GRB groundwater system. However, the movement of potential contaminants in groundwater that might be associated with seepage from spoil dumps is considered within this hydrogeological assessment.

Predictive groundwater modelling is to include particle tracking simulations, where particles were included in the saturated model cells and the migration over time mapped. Particles moved in response to groundwater head differences, aquifer hydraulic properties, and evaporation from the final voids (acting as groundwater extraction).

These predictions through the generation of hydrographs for hypothetical observation points within and adjacent to the residual voids plus drawdown contours, allowed for the evaluation of the residual voids acting as source or sinks to the groundwater system. This then allowed for the evaluation of the risk of residual void water migrating from the mine leases during closure.

12.1 Groundwater System Post-Mining

The potential impacts to the groundwater system at the end-of-mining, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining including the groundwater flow regime that results from the final landform. Therefore, it is important to understand the nature of the groundwater system at the conclusion of mining immediately prior to the closure period.

The nature of the GRB groundwater system at the end of mining, and potential groundwater system impacts that may have arisen at the end of mining, can be summarised as:

- Groundwater level drawdown of the Permian coal measures, associated with passive dewatering into the active GRB mine pit voids.
    - The magnitude of this drawdown will be most significant in the immediate vicinity of the pit voids, but extend northwards, eastwards and southwards of GRB by several kilometres and interact with drawdown from nearby mining activities.
- Little to no groundwater level drawdown of the alluvium away from GRB due to limited hydraulic connection between the hydrostratigraphic units (Section 7.3.3). The conceptualisation cross sections (plus predictive modelling) indicate:
    - No groundwater-related effect on surface water flows of the Isaac River
    - Low potential for groundwater level drawdown impacts to potential GDE’s
- One of the six water supply bores, located in proximity to the Goonyella residual void, will be impacted (dewatered) as a result of approved mining (Section 15.8.1).
- The comparison of historic and recent groundwater quality data does not readily indicate impacts associated with spoil dumps and TSFs.

12.2 Groundwater System Post-Closure

The potential impacts to the groundwater system at the end-of-mining, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining including the groundwater flow regime that results from the final landform. Therefore, it is important to understand the nature of the groundwater system recovery and pseudo-steady state conditions post closure.

The predictive groundwater modelling allows for the assessment of groundwater level recovery, groundwater flow patterns, and the influence of residual voids (included in the final landform) on the groundwater resources and receptors.

The post-closure conceptualised groundwater can be summarised as:

- There will be limited recovery in groundwater levels post-closure, with groundwater recovery characterised as ‘slow’ within the Bowen Basin. Limited recovery of groundwater levels naturally was considered due to:
  - Limited rainfall recharge
  - Long term mine dewatering across a large area and several mining areas, which has resulted in groundwater being removed from storage which needs to be replaced before marked changes in groundwater levels will be observed
  - High evaporation over large final void areas (particularly the Goonyella Pit)
  - Low permeability within the sediments surrounding the residual pits.
- Consideration of the climate data, limited runoff (catchment around pits) and limited groundwater ingress would result in the high probability of the residual pit water levels being below pre-mining groundwater levels (i.e., residual voids likely to act as groundwater sinks post-closure).
  - The residual void water level recovery is expected to be below the base of weathering or any shallow Cainozoic aquifers (i.e., limited potential for discharge into the surrounding surficial units, including alluvium).
- Ongoing groundwater discharge to the residual voids driven by the inwards hydraulic gradient between the void lakes and the surrounding groundwater system will be maintained by ongoing evaporative discharge from the voids.

The predicted post mining conditions, considering the residual voids, are presented after Section 13.0, the groundwater modelling. These predictions indicate the likelihood for impacts to receptors, other than one water supply bore in proximity to the Goonyella residual void, is low.

13.0 Groundwater Modelling

The existing RHM predictive groundwater model (**Appendix A**) was adopted for the PRC Plan's hydrogeological assessment (Figure 29). The refinement of the existing model, including increasing the model domain and model boundary conditions, was used to promote efficiencies in the delivery of the outputs for the PRC plan/s.

Figure 29 Extent of the existing RHM model domain

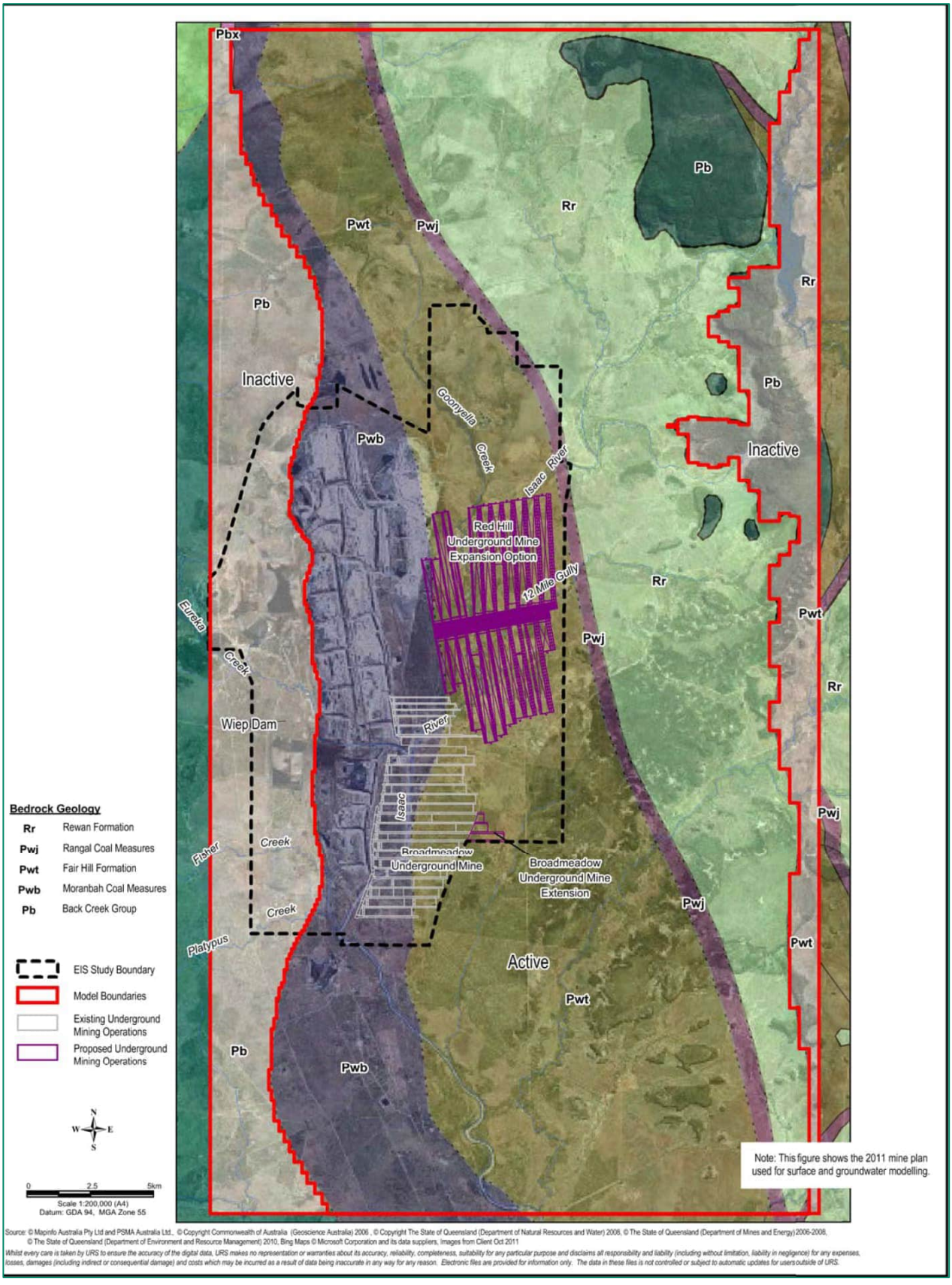
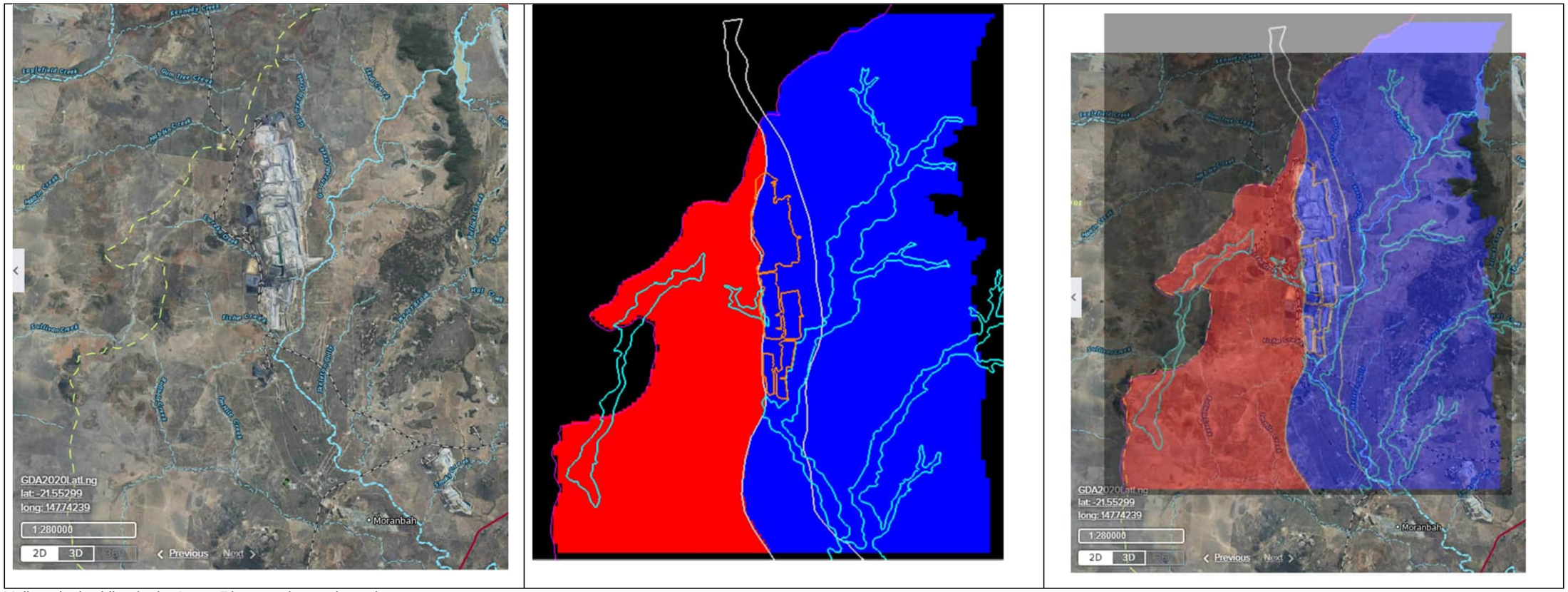


Figure 30 Extent of the refined GRB and RHM model domain



Yellow dashed line is the Isaac River catchment boundary

The red area of the model domain includes the Back Creek Group subcrop, the blue area indicates the coal bearing Permian age sediments. The contact between the two areas illustrates the GLS coal seam subcrop.

13.1 Model Details

AECOM utilised the existing RHM numerical (MODFLOW-SURFACT) groundwater – surface water interaction model with refinement from data compiled since the existing model was constructed and calibrated in 2013.

The use of the existing MODFLOW-SURFACT model, after review of the available more recent geological and hydrogeological data compiled in the report above, was considered suitable based on the following:

- Selection of the model software package
    - The MODFLOW-SURFACT model software package is suitable for dewatering and recovery model simulations in the open cut and underground mine workings. It converts from saturated flow to an unsaturated flow equation as the groundwater elevation drops below the base of the model cell. The key point of MODFLOW-SURFACT is that the cell does not go dry, is never excluded from the numerical calculations, and as heads rise again the model switches the cell back to saturated flow.
- The model allows for the refinement of model grid cell size to ensure the correct relationship between the key features (residual voids) and the model cell sizes (for accurate modelling / predictions).
- The model can simulate possible contaminant migration within groundwater using particle tracking during predictive groundwater modelling.
    - The fate and transport of residual void water can be depicted using particle tracking, where flow directions, extent of migration within groundwater, and variation in flow during the post-mining rebound of groundwater levels and the saturation of sediments in the footwall and hanging wall overtime.
- Model boundary conditions, type and location (sufficiently far from the mine workings to not influence model predictions), were assessed and revised. Noting the eastern model boundary remains as a no flow boundary at the outcrop/subcrop of the Back Creek Group, uplifted along the Burton Fault (Figure 29 and Figure 30).
- The cumulative impacts of the differing mine workings, timeframes, and decommissioning across the Project.

13.2 Model Objectives

The groundwater modelling, as required for input into the PRC Plan, aimed to:

- Assess the potential groundwater related impacts at completion of mining and until conditions stabilise post rehabilitation (Section 15.0).
- Assist in demonstrating the suitability of the final landform for the post mining land uses (i.e., evaluate the residual voids included in the final landform to determine influence on groundwater resources) (Section 15.0 and 17.0).
- Demonstrate that the final landforms are non-polluting with respect to potential poor quality water leaving the mine leases within groundwater (Section 15.6 and 15.7).
- Demonstrate that there are minimal additional impacts to groundwater receptors post-closure caused by the final landforms (Section 15.8).

The predictive groundwater modelling aimed to provide understanding, for Landform Design #2.3 (as included in Section 10.1 Figures 19 to 22), of:

- Groundwater interactions with the residual voids (Section 15.4, 15.6, and 15.7).
- Changes in hydrogeological conditions (including groundwater levels) from the active mining to stable post-mining conditions (Section 15.4.3).

- Impacts to water quality off lease through migration within groundwater.
    - The prediction of potential off lease water quality impacts from mining activities was included to determine appropriate measures for the containment and management of potential contaminant impacts on EVs should these contaminants migrate within the groundwater system (Section 15.6 and 15.7).
- Long term influence on alluvial and Tertiary age hydrostratigraphic units that may host GDEs or future land users (e.g., stock water and/or non-potable domestic use) (Section 15.8).
- Influence of groundwater on surface water resources (Section 13.3.6, 15.8.2, and 17.2).
- Possible on-going water management and reduction requirements (Section 16.0).

AECOM developed a modelling approach methodology to meet the modelling objectives to inform the PRC plan/s, ensure alignment with the guideline, and consideration to address uncertainty in predicted outcomes.

13.3 Model Design

13.3.1 Approach

AECOM utilised the MODHMS (Hydrogeologic Inc., USA) groundwater modelling package to construct the required groundwater model. MODHMS is based on the standard MODFLOW groundwater modelling code. The MODFLOW code was developed by the United States Geological Survey (McDonald and Harbaugh 1984) for three-dimensional, finite-difference, modular, groundwater flow modelling.

The MODFLOW code is the most widely used code for groundwater modelling and is considered an industry standard. MODHMS incorporates additional computational modules to enhance the simulation capabilities and robustness. MODHMS was selected as it allowed for:

- The modelling of variable saturation conditions, allowing for unsaturated and saturated conditions thus avoiding dry-cell problems
- Coupled flow and mass transport simulations (if required)
- The inclusion of discrete features, such as the backfill area of open cuts
- Integrated groundwater and surface water modelling (if required).

An existing numerical groundwater model was refined based on the more recent (since 2013) available data to represented current groundwater flow conditions (2020 to 2024) due to the existing GRB mine complex dewatering. The outcome of this transient modelling of the existing approved GRB mine complex impacts (drawdown extent) was used as initial conditions for the predictive model, which undertook four predictive scenarios capturing the different mine plans, decommissioning, injection, and recovery after mining ceased. The four predictive scenarios are summarised in Table 17, and discussed in the prediction Section 15.0.

Table 17 Prediction phases incorporated in the groundwater modelling

Prediction periods	Mining activities
Phase 1: 2024 to 2056	Existing Broadmeadow and Isaac pits remain dewatered Thiess, R32 South, and R32 East have pit water levels Broadmeadow GMS underground mining continues to 2031 Broadmeadow GLS underground mining 2031 to 2055 Broadmeadow underground workings remain dewatered in 2056 Goonyella open cut mining is ongoing
Phase 2: 2057 to 2060	Broadmeadow GMS underground mining altered by goaf Broadmeadow GLS underground mining altered by goaf #-years of water injection into Broadmeadow underground workings
Phase 3: 2061 to 2092	Red Hill Mining conducted 2063 to 2091 Remains dewatered during decommissioning in 2092
Phase 4: 2093 to 2199	RHM changed to goaf 3-years of water injection into RHM Recovery post 2097

The modelling approach comprised the following:

- Simulations of dewatering cones (drawdown contours) and extent at the end of mining (over time in response to different mine plans).
- Groundwater extraction volumes with time into residual voids and mine dewatering activities
    - Groundwater ingress estimates to include in residual void water balance modelling (coupled water balance).

13.3.2 Model conceptualisation

Every numerical groundwater model has a conceptual model as it's foundation. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

The conceptualisation(Section 11.0) of the groundwater resources across the Project area was developed based on geological and hydrogeological data, including topographical maps, geological information from coal exploration bores drilled across the GRB mine complex and RHM footprint areas, geological modelling developed by BMA, results from previous hydrogeological investigations in the Bowen Basin, relevant data from hydrogeological and gas drainage studies conducted by BMA, and groundwater monitoring data.

The conceptual model, which formed the basis of the predictive model, included for the upper units of the Back Creek Group, the Blackwater Group (MCM and FCCM), and the overlying Tertiary and surficial cover units of the Bowen Basin.

The conceptualisations (as included in the Section 11.0 cross sections) allowed for the groundwater model construction to include for:

- The outcrop/subcrop of the Back Creek Group to the west of the Project (Figure 30).
- A system of thrust faults, approximately 10 kilometres (km) to the east of the RHM footprint, that result in the Back Creek Group having been uplifted against the Rewan Formation (Figure 29).
- An arbitrary distance of approximately 25 kilometres to the north and south of the GRB and RHM mines that was judged to be beyond the influence of potential mine dewatering (Figure 29).

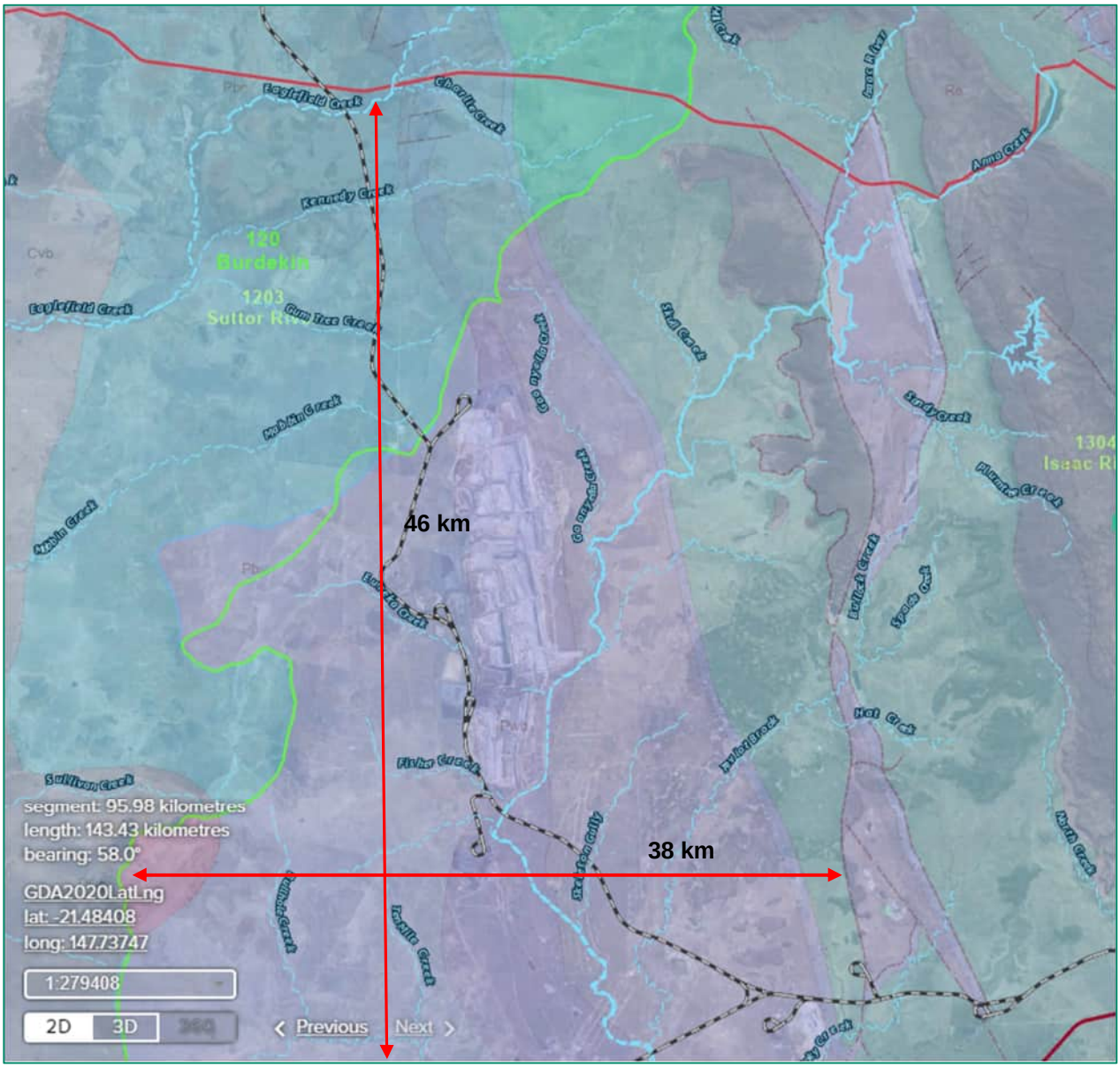
69oy56The model domain for the PRC Plans, considering the conceptualisation based on data assessment, was increased to the west, corresponding to the Isaac River catchment and further north and south, to ensure:

- The model boundaries encompassed all mine activities
- Includes for possible seepage / contaminated groundwater migration
- The model boundaries were sufficiently far from the mine activities so as not to impact on predictions (Figure 30).

13.3.3 Model extent and grid

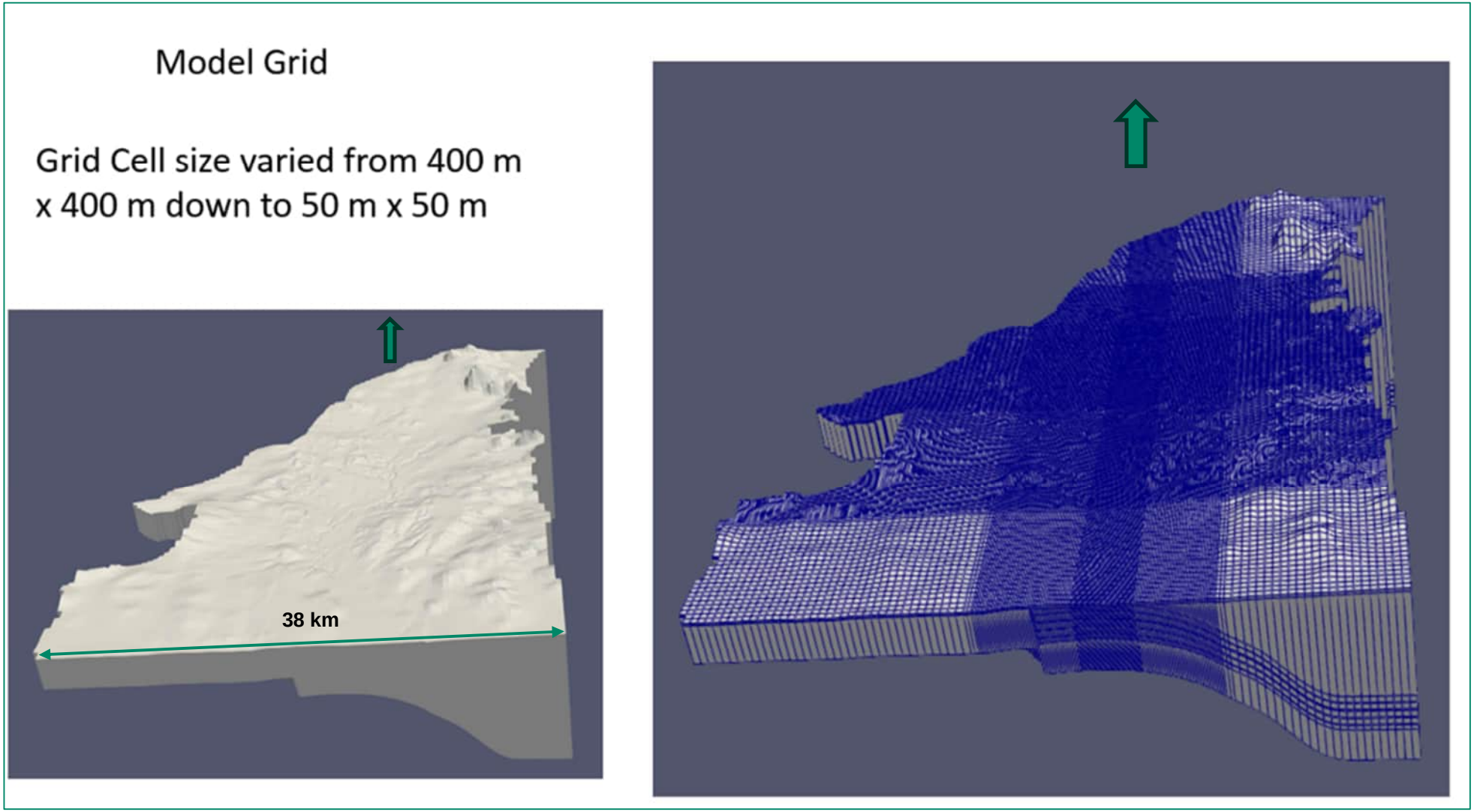
The refined numerical groundwater model was constructed across an area of 46 km by 38 km as shown in Plate 14 and Figure 30, with the Project area situated towards the centre of the model domain based on boundary conditions.

Plate 14 Catchment and geological structure boundaries



The model was constructed with a refined grid of 50 by 50 metres for the mining areas and with grid spacing of 100 x 100 meters up to 400 by 400 metres outside the mining areas, as shown in Plate 15.

Plate 15 Depiction of the 3D groundwater model and cells, showing dip and strike of the lithology



The finite difference model comprised:

- A model area of 1,748 square kilometres
- 422 rows and 223 columns
- 1,117,410 active cells for a fourteen-layer model.

13.3.4 Boundary conditions

Model boundaries, included on Plate 13, which indicates the active model cells (white) and the inactive model cells (black), were based on the model refinement to simulate groundwater conditions. The boundaries include:
Top inflow boundary comprising recharge and evaporation. Available precipitation and evaporation data was reviewed / verified.

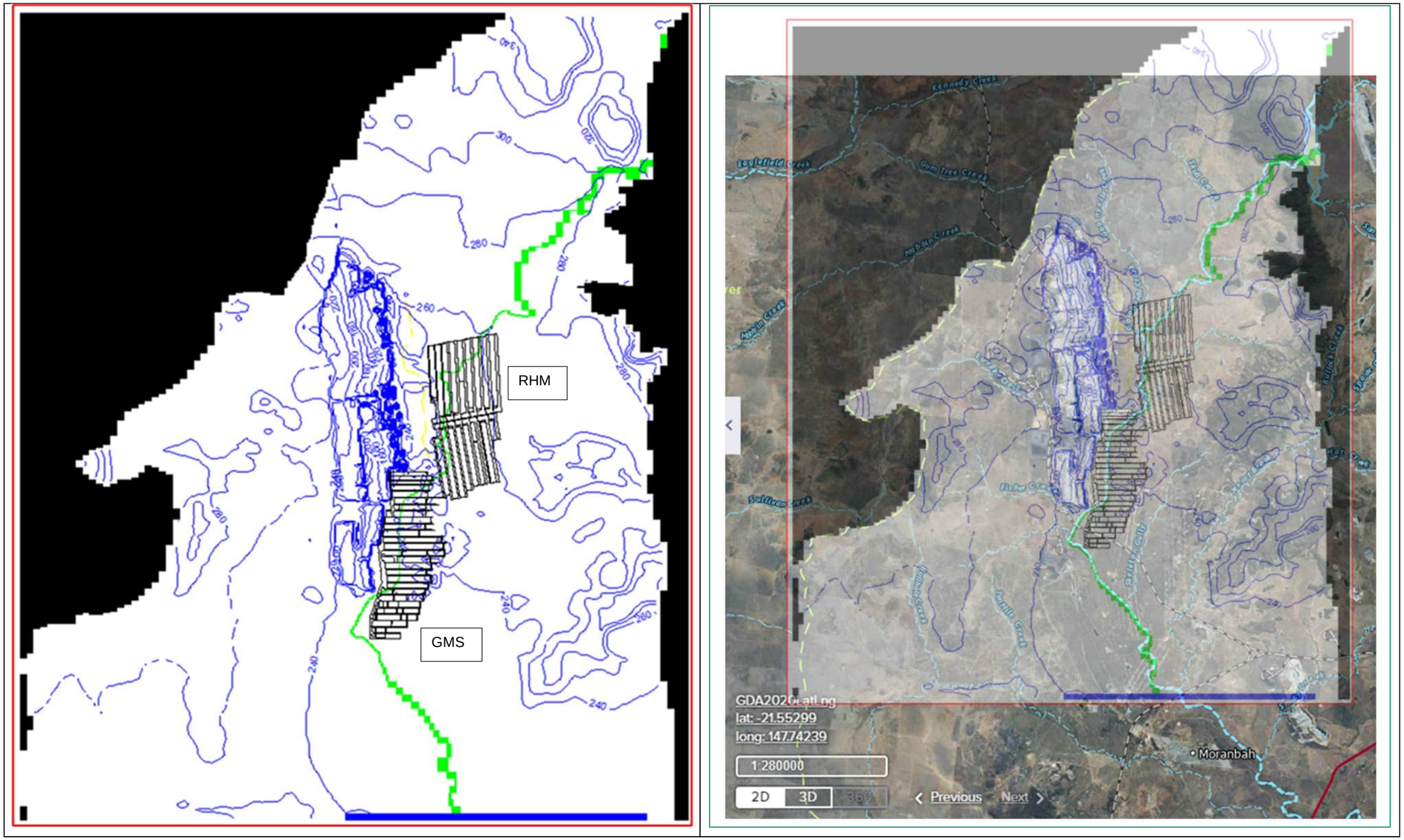
Horizontal inflow boundary based on groundwater level data, which is used to determine the model's east, west, north, and south boundary conditions. Geological log data and groundwater level information was used to set up representative prescribed head boundaries, sufficiently far from the GRB and RHM footprints as follows:

- Eastern boundary – No flow boundary due to thrust faults (Rewan Formation – Back Creek Group contact at surface)
- Western boundary – No flow boundary at the Isaac River catchment boundary, both the Back Creek Group and Tertiary units
- Northern boundaries (northwest corner) – No flow boundary for Tertiary sediments, and a range of constant head boundaries for the MCM
    - 20 mbgl for GUS
    - 25 mbgl for GP1 and GP2
    - 30 mbgl for GMS
    - 40 mbgl for GLS

    No flow the rest of the layers
- Southern boundaries – Constant head for the alluvium and Tertiary (part) at 10 mbgl (blue section along southern boundary Plate 16)
    - Similar no flow and constant heads to northern boundary
    - Since few head observations were available near the boundaries, topographic elevations were used as reference elevations relative to groundwater levels. The groundwater levels were 20 to 40 mbgl for the northern and southern boundaries based on average depth to groundwater from available observations across the survey area.

Bottom inflow boundary considered below the site. Model bottom elevations were determined from floor and roof elevation data supplied by BMA. The no-flow boundary was assumed sufficiently far below the base of any mining (GMS and GLS) elevation based on available geological data.

Plate 16 Model Boundaries



LEGEND

Green model cells indicate the Isaac River
RHM – Red Hill Mine
GMS – Broadmeadow GMS mine (historic footprint)

13.3.5 Model layers

Publicly available digital elevation data with a 90 by 90 metre grid spacing was used to represent the ground surface in the model outside of the refined area (400 metre grid area in Plate 15), and BMA topographical data was used to represent the ground surface within the refined area (100 metre grid in Plate 15). The model layer elevations in the refined-grid area were generated based on the BMA geological model; while the layer elevations outside the refined area were extrapolated based on available data (Bowen Basin digital geology, Bowen Basin regional contouring of the top of the MCM on 50 metre intervals, and coal seam gas well logs) and assumptions.

These data sets were used to create layer elevations throughout the model domain. Fourteen layers, representing the different lithological units across the survey area (Plate 15), were included in the model (Table 18).

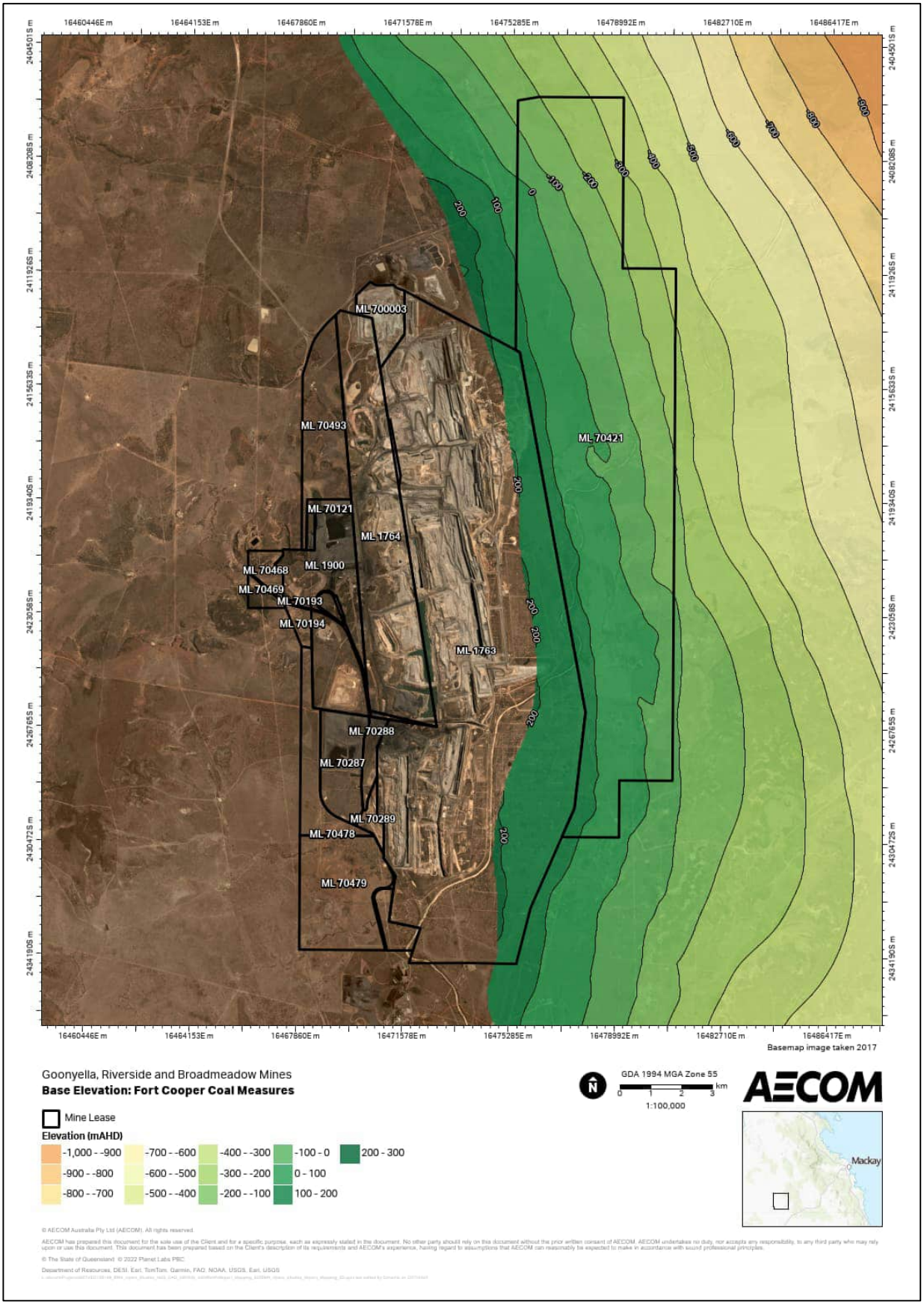
An example of the FCCM floor elevations extrapolated from west (subcrop) to east is include in Plate 17.

Table 18 Model layers

Layer	Unit
1	Tertiary, alluvium
2	FCCM[1]
3	Overburden
4	GUS coal seam
5	Interburden
6	GP1 coal seam
7	Interburden
8	GP2 coal seam
9	Interburden
10	GMS coal seam
11	Interburden
12	GLS coal seam
13	Underburden
14	Back Creek Group

[1] The FCCM is depicted in the PRC Plan model as a single model layer, including for coal seams and interburden. This simplification of this layered seam and aquitard formation was adopted to facilitate the running (calibration and predictions) of the large model domain and cell size. The use of bulk hydraulic parameters allowed for the inclusion of the FCCM in the model.

Plate 17 FCCM subcrop and floor elevation example


16460446E m
16464153E m
16467860E m
16471578E m
16475285E m
16478992E m
16482710E m
16486417E m
2404501S m
2408208S m
2411926S m
2415633S m
2419340S m
2423058S m
2426765S m
2430472S m
2434190S m
ML700003
ML 70493
ML 70421
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
Basemap image taken 2017
Goonyella, Riverside and Broadmeadow Mines
Base Elevation: Fort Cooper Coal Measures
Mine Lease
Elevation (mAHD)
-1,000 - -900
-900 - -800
-800 - -700
-700 - -600
-600 - -500
-500 - -400
-400 - -300
-300 - -200
-200 - -100
-100 - 0
0 - 100
100 - 200
200 - 300
GDA 1994 MGA Zone 55
km
1:100,000
AECOM
Mackay

13.3.5.1 Faults

It is important to note that faults can act as both conduits for groundwater flow and, in the case of coal seams, barriers to flow. The eastern boundary of the model is along the Burton Fault, where the Rewan Formation and Blackwater Group units are significantly offset, and is considered a no flow boundary.

Within the Project area, the MCM have undergone some minor to moderate faulting that may interrupt the continuity of the aquifer and act as boundaries to groundwater flow. In the model domain, the coal seams were simplified to allow continuous groundwater flow and to tie in with the interpolated levels beyond the Project area where data is limited. The effect of this simplification was to remove barriers to groundwater flow, which effectively extends the predicted drawdowns and increases groundwater inflows to the workings. The model is, therefore, considered to be conservative and allowed for the assessment of impacts over a larger area.

13.3.6 Rainfall Recharge

Recorded site specific climate data is summarised in Section 4.1. The average annual rainfall around the Project area is between 500 mm and 560 mm. High rainfall and evaporation occur in the summer months (December to February). Monthly evaporation rates are higher than monthly rainfall amounts throughout the year, indicating a net loss due to evaporation (i.e., a negative climate balance which has implications for final void water levels). The average evaporation rate is approximately 2 m per year.

Through a review of available data and previous modelling), recharge rates were determined to be less than one per cent of mean annual average rainfall, and evapotranspiration was not considered due to the depth to groundwater observed for the deep aquifers.

13.3.6.1 Alluvium recharge and discharge

Variation in rainfall recharge, to assess sensitivity of rainfall recharge in the model, was included during modelling to assess recharge to alluvium. As the majority of alluvium monitoring bores were dry, allowing additional recharge to facilitate saturated conditions in the alluvium and flow towards the creeks and Isaac River. The groundwater model was used, allowing for differences in rainfall recharge, to assess the potential loss from the alluvium to the underlying hydrostratigraphic units (and resultant reduction in surface water contribution).

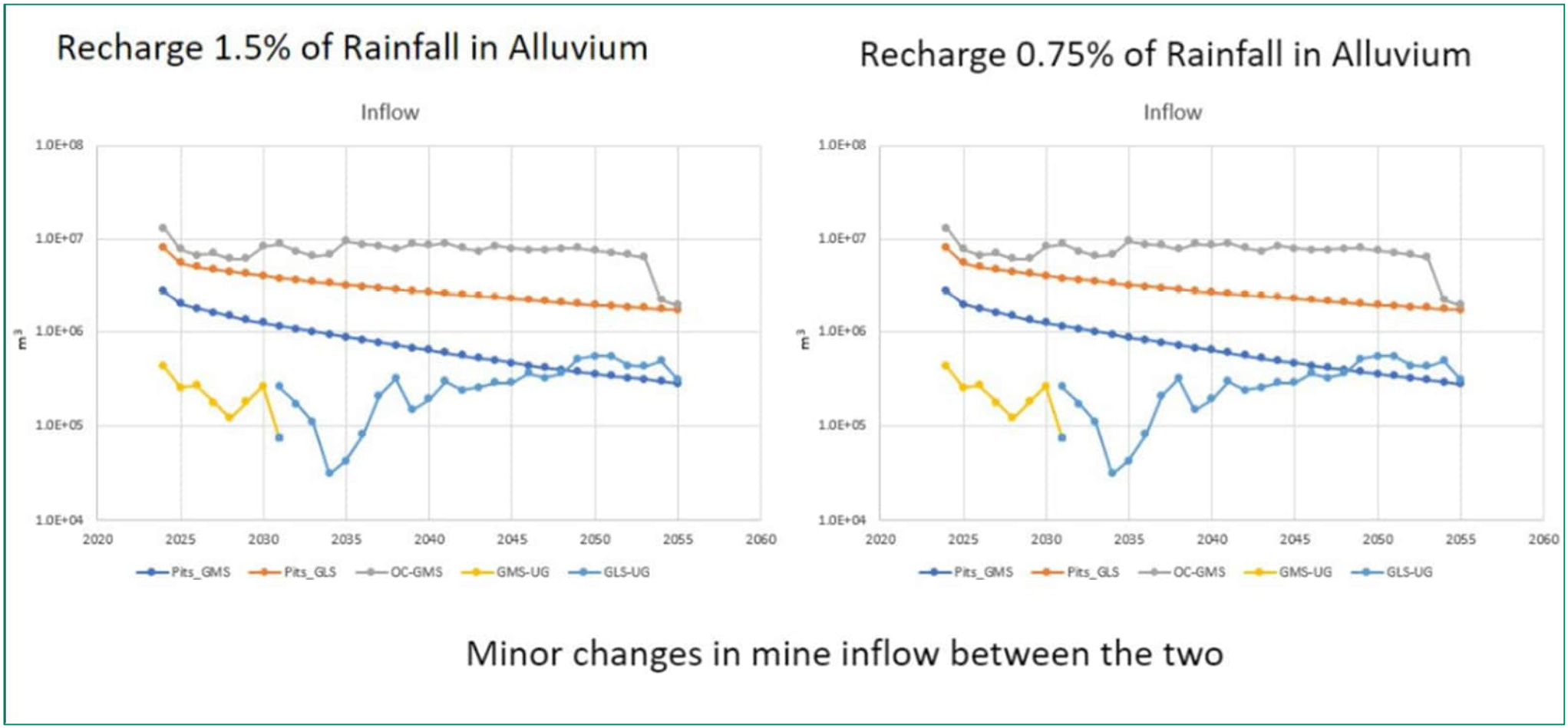
Recharge rates of 1.5 per cent (wet conditions) and 0.75 per cent (dry conditions) of annual rainfall was included in the model calibration and assessed through the model water budget (Section 14.4).

The mine inflow predictions, for the period to the end of the Broadmeadow underground mining, is included in Figure 31. This figure presents the estimates of groundwater ingress into the different mine pits, the ongoing Goonyella open cut mining, and the GMS and GLS underground mining.

The modelled inflows, allowing for wet and dry rainfall conditions to the alluvium, does not indicate increased ingress into the mine workings under the two simulations of recharge (i.e., 1.5% or 0.75% of mean annual rainfall acting as recharge).

The alluvium water table (discontinuous unconfined conditions) and the piezometric levels (confined conditions) associated with the deeper coal seam aquifer groundwater data indicate a marked separation (i.e., based on available data presented and assessed in Section 7.3.3 there is no hydraulic connection between the alluvium water table and the confined aquifers). Thus, the vertical movement from the alluvium, when saturated, is limited even taking possible subsidence alteration into account (i.e., the limited groundwater resources associated with the alluvium remains separated from the confined piezometric levels even if additional water is added to the alluvium (as recharge) or the separation between the water table and the piezometric levels are increased (due to mine dewatering leading to larger vertical groundwater gradients).

Figure 31 Groundwater ingress considering recharge variation to the alluvium (ingress in m^3per year versus years)



Pits_GMS - Inflow estimates into residual voids which target the GMS seam
Pits_GLS – Inflow estimates into residual voids which target the GLS seam
OC_GMS – Inflow estimates for continued open cut GMS mining
GMS_UG – Inflow estimates for the GMS underground mining
GLS_UG – Inflow estimates for the GLS underground mining

13.3.7 Hydraulic parameters

The ranges of hydraulic conductivity (K) and storativity values, included in the original RHM model were derived from aquifer hydraulic testing and literature values where onsite data was not available. These aquifer hydraulic properties are included in Table 19 and were refined during model calibration (Section 14.3).

Table 19 Summary of calibrated parameters in the original RHM model

Model Layer	Unit	Kh (m/day)	Kv (m/day)
1	Tertiary, alluvium	0.49	0.049
2	FCCM	1.00 E-03	1.00E-04
3	Overburden	1.08E-04	1.08E-05
4	GUS coal seam	Distribution*	Distribution* x 0.1
5	Interburden	1.08E-04	1.08E-05
6	GP1 coal seam	Distribution*	Distribution* x 0.1
7	Interburden	1.08E-04	1.08E-05
8	GP2 coal seam	Distribution*	Distribution* x 0.1
9	Interburden	1.08E-04	1.08E-05
10	GMS coal seam	Distribution*	Distribution* x 0.1
11	Interburden	1.08E-04	1.08E-05
12	GLS coal seam	Distribution*	Distribution* x 0.1
13	Underburden	1.08E-04	1.08E-05
14	Back Creek Group	1.08E-04	1.08E-05

*K distribution derived from regression formula

The calibrated aquifer hydraulic parameters plus method used to derive the parameters are include in Section 14.3.4.

13.3.7.1 Simulation of mine dewatering using drains

In order to simulate mine dewatering, the MODHMS drain package was utilised. Using drains involved the setting of a reference (drain target) elevation (base of the target coal seam) and a conductance (leakage) term.

The bottom elevations of the drains were set at the base of the GLS or GMS coal seam to be mined. Groundwater levels in the model were compared to the elevation of the bottom of the drain in each model cell. When the groundwater level was above the bottom of the drain water was removed from the model domain at a rate determined by the head difference (within and adjacent to the workings) and the drain hydraulic conductance.

The drains were activated according to the Project mine plans (schedule and progression). Drain conductance was set at a high rate to ensure the groundwater level was lowered to the drain level (to simulate dry workings as required for mine safety).

This approach was adopted in order to:

- Estimate the total volume of groundwater to be removed at the end of mining
- Determine the groundwater drawdown / groundwater elevation heads prior to decommissioning and closure activities.

These data were used as initial inputs into the residual water balance modelling (Section 15.0).

Drains were then converted to constant head boundaries (MODHMS CHD package) in the model, to level predicted in the (surface water and groundwater) residual void water balance model (Section 15.4). .

The introduction of the residual void water levels (as CHD) resulted in reduced groundwater gradients, around the residual voids. Using the CHD elevations allowed for evaluation of drawdown and long term groundwater conditions when the water levels in the residual voids reach pseudo-steady state.

These closure groundwater conditions allowed for the assessment of groundwater flow, potential contaminant migration in groundwater, and impacts post-closure (Section 15.6).

13.3.7.2 Simulation of mine dewatering considering goaf alteration

To further estimate groundwater ingress during mining activities, consideration and simulation of aquifer alteration (due to longwall mining (goaf)) was undertaken. The use of EPM, as detailed in Section 7.3.4, was included to alter aquifer parameters after longwall mining was complete.

14.0 PRC Plan Landform #2.3 Model

The post-mining final GRB landform relevant to this hydrogeological assessment was provided by BMA (denoted Landform #2.3) and is shown as Figure 3. The final landform contains six residual (final) voids:

- Goonyella Pit
- Thiess / Ramp 21 Pit
- Ramp 32 East,
- Ramp 32 South,
- Broadmeadow Pit, and
- Isaac Pit.

14.1 Existing conditions

Open cut and underground mining at GRB has been ongoing since the 2013 groundwater model was constructed, as described in Section 1.1. The RHM original model was refined to include for the open cut mining, placement of backfill (referred to as spoil), the various pits plus the Broadmeadow GMS mining panels, which had been mined since the original model set-up.

The model was constructed using the historic mine plans to replicate the mine conditions for 2020 (the start of the transient groundwater calibration period), including the location of pits, spoil, and longwall panels (Plate 18).

The pits, highlighted in blue on Plate 18, are labelled in Figure 2.

The spoil, for use in the zone budget (refer to Section 14.2) required to estimate groundwater ingress sources (spoil or natural, for example), was further refined in the model set-up. Plate 19 indicates the subdivisions of the spoil as follows:

- Red outlined areas – Historic spoil areas in 2020
- Yellow highlight areas – GMS open cut mining between 2012 and 2019 (backfilled with spoil)
- Pink areas – surface areas to be mined (open cut), 2019 to 2059).

The Broadmeadow mine areas, included as goaf in the model set-up, are shown in Plate 20.

The GMS mining is delineated as:

- Yellow areas – GMS underground mining (2010 to 2019) based on historic mine plan
- Green areas- future GMS longwall panels post 2019.

Plate 18 2020 pit locations and spoil locations (red areas)

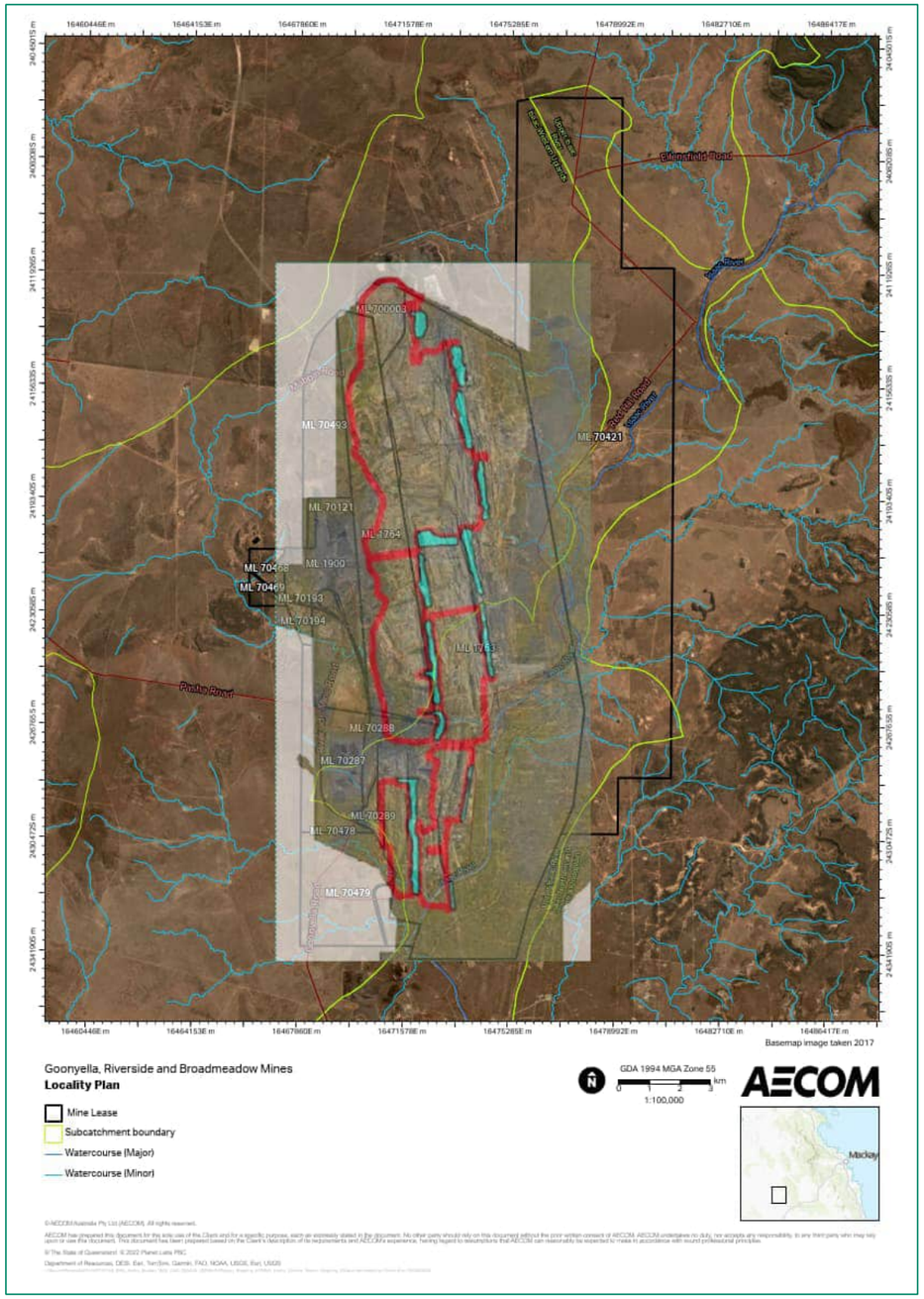


Plate 19 2020 spoil subdivisions

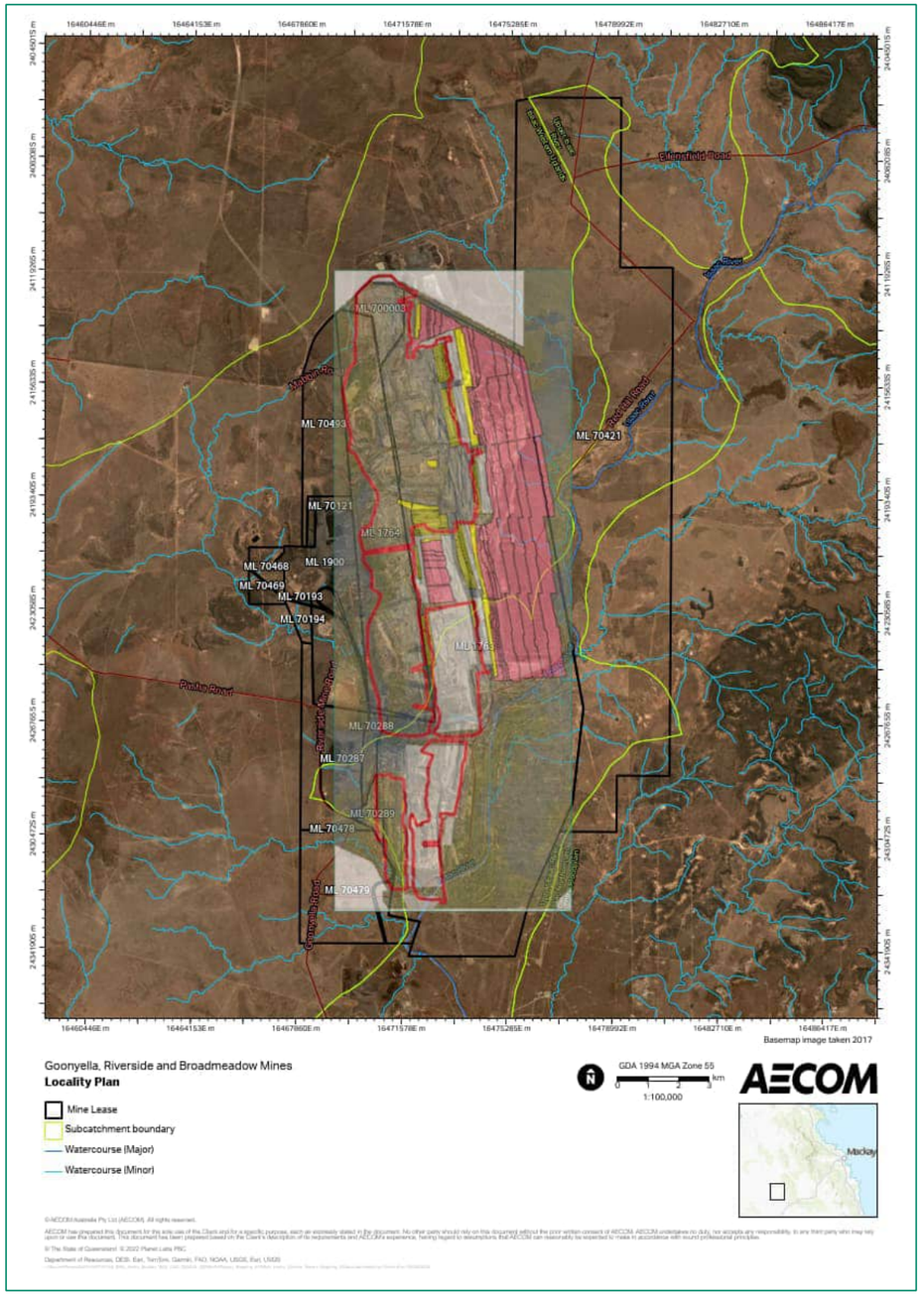


Plate 20 Goaf areas in 2019

BMA
BHP Mitsubishi Alliance
GOONYELLA RIVERSIDE & BROADMEADOW MINES
Projection: AGD66 AMG Zone 55
Scale 1:25000
North Goonyella Administration Area
North Goonyella Industrial Area
Riverside Industrial Area
Eureka Village
Goonyella Industrial Area
RED HILL ROAD
Ramp 14 Corridor
Ramp 12 Corridor
Ramp 10 Corridor
Ramp 25
Ramp 24 Corridor
Ramp 23 Corridor
Ramp 21
Ramp 45 Bridge
10/12 Bridge
LENTON PIT
GOONYELLA PIT
MEGHU PIT
CLEANDON PIT
RIVERSIDE PIT
EUREKA PIT
THERESA PIT
RIVERSIDE HAUL ROAD (NORTH)
RIVERSIDE HAUL ROAD (SOUTH)
GOONYELLA HAUL ROAD (NORTH)
GOONYELLA HAUL ROAD (SOUTH)
Goonyella Service Road
Eureka Service Road
Ring 1
Ring 2
Ring 3
LW 17
LW 21
LW 22
LW 23
LW 24
LW 25
LW 26
LW 27
ML70121
ML70464
ML70465
ML70287
ML70288
ML70289
ML70290
ML70291
ML70292
ML70293
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ML70314
ML70315
ML70316
ML70317
ML70318
ML70319
ML70320
ML70321
ML70322
ML70323
ML70324
ML70325
ML70326

14.2 Model Setup

The mine plan/s (Plate 21) schedules (overlapping and continual over time), decommissioning, and alteration of geology and groundwater (aquifer hydraulic parameters) required the model to be set-up to simulate mine dewatering, water injection into the underground workings, and alteration (goaf and spoil backfill areas).

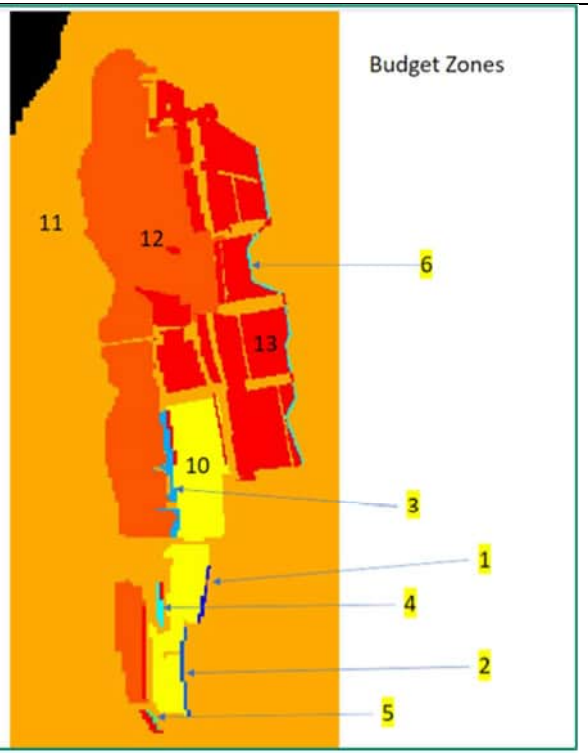
The objective of the groundwater modelling was to provide input (predictions of groundwater ingress into the residual voids post closure) to the water balance model, which considers all inputs and outputs from the residual voids. Long term pit water levels can then be estimated.

To provide the groundwater contribution, from spoil and natural geology, the model was set-up to include zones. The predictive model can then be used to assess ingress or outflow from the residual voids using a model zone budget.

The water budget zones, corresponding to mine areas (pits, spoil, or natural / undisturbed geology), are included in Figure 32.

Figure 32 Budget zones

Water Budget Zones	Starting date	Down to Layer	Zone
Broadmeadow	2009	10 (GMS)	1
Issac	1997	10 (GMS)	2
Thiess & Ramp 21	2016	12 (GLS)	3
R32 East	2037	12 (GLS)	4
Ramp 32 South	2026	12 (GLS)	5
Goonyella	2060	12 (GLS)	6
GW		All layers	11
Spoil to Layer 10	2020	10 (GMS)	10
Spoil to Layer 12	2020	12 (GLS)	12
Spoil in Goonyella Open cuts	2060	12 (GLS)	13



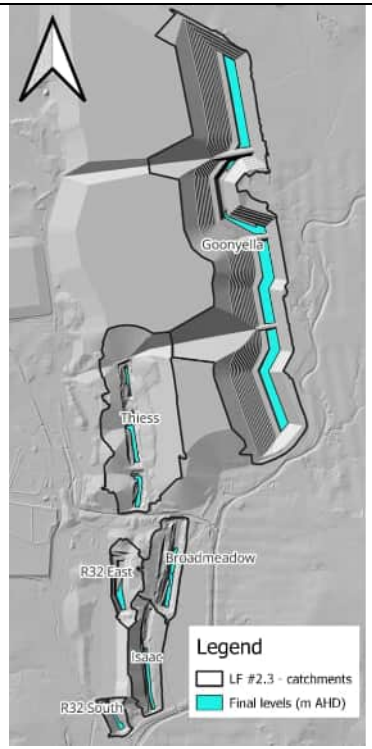
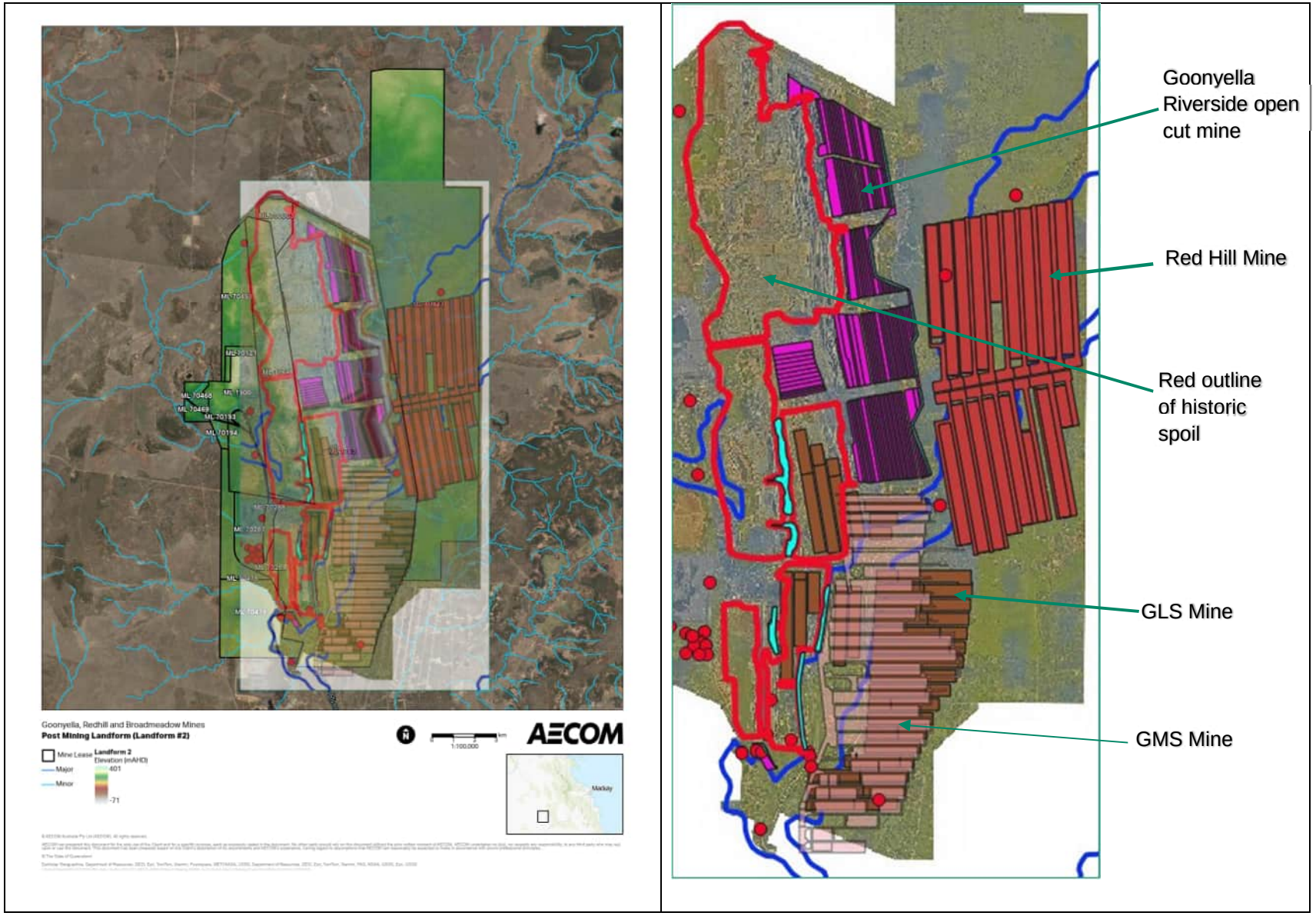


Plate 21 Mine areas historic and future



14.2.1 Introduction of water into the underground workings

Geotechnical assessments at the Project recommended the filling of the underground workings with water to ensure long term stability. The introduction of water into the underground workings, as part of the decommissioning (Table 15), was included in the modelling.

Options to simulate the introduction of water included changing the mine workings drain cells to constant head boundaries (based on the portal entrance elevations), injection down the portals, or simulating injection via vertical bores.

BMA, based on historic groundwater volumes removed from the Broadmeadow GMS workings and mine plans, provided estimates of water to be introduced into the underground workings over three (3) years.

The Broadmeadow underground mining areas received 5.34 GL over a 3 year period. Red Hill Mine received 4.94 GL over a 3 year period. This approach was adopted to aid with the PRC Plan assessment, it is considered that the timing of the introduction of water may lengthen based on water availability.

To best simulate this volume of water over a three year period the model was set-up to allow for the injection of water into the model cells across the mine footprints.

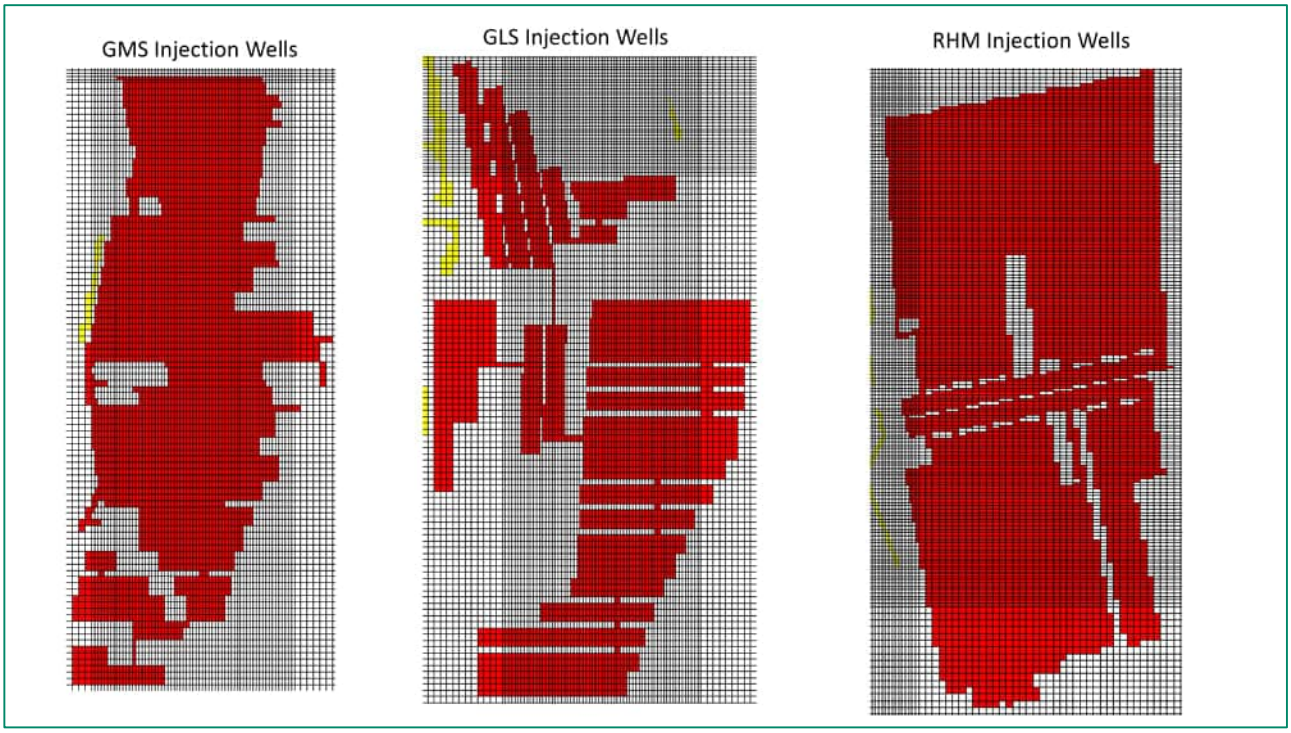
The introduced water was divided up between the two Broadmeadow underground mines based on size.

- The Broadmeadow GMS mine plan covered an area which contained 4,171 model cells. Injection was simulated by introducing 6.22 m^3/day into each of the model cells for 3 years.
- The Broadmeadow GLS mine plan covered an area which contained 3,684 model cells. Injection was simulated by introducing 6.18 m^3/day into each of the model cells for 3 years.

The RHM mine plan covers 6,005 model cells, the injection into each model cell was 7.51 m^3/day for 3 years.

Areas at the underground workings, which will receive the introduced water, are included on Plate 22.

Plate 22 Red model cells allowing for the introduction of water in the model



14.3 Calibration

The refined numerical groundwater includes a transient calibration (2020 to 2024) based on the most recent groundwater monitoring data. The initial conditions were derived from the prior pseudo-steady conditions covering the period from 1996 to 2009 plus the historic mining (2010 to 2019), and average climate conditions during these periods.

The calibration used 260 target heads for 50 bores at GRB (Figure 8). The transient calibration captured the historical mining at GRB. Mining was represented in the model using the MODFLOW drain package, with the drain cells set to the base of the target coal seam for each pit, and within the target GMS coal seam for the Broadmeadow underground mine.

Calibration of the model was carried out with the objective being to replicate the groundwater levels measured at and adjacent to GRB, as well as some registered bores, in accordance with Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The calibration targets, datasets and monitoring points, plus corresponding model layers are included in **Appendix C**.

14.3.1 Approach

The calibration approach included:

1. Model calibration to depict the hydrogeological framework, aquifer hydraulic properties, and boundary conditions.
2. Achieve correlation between the model output and measured/observed field data.
3. Determine optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The calibration targets included:

- Transient Head Targets, for data available from 2020 to 2024 (Q1).
- Aquifer test data (hydraulic conductivity parameter constraints).

The modelling tools used included PEST++ with the Iterative Ensemble Smoother algorithm, referred to as PESTPP-IES.

The calibration results were assessed through the evaluation of calibration criteria, including:

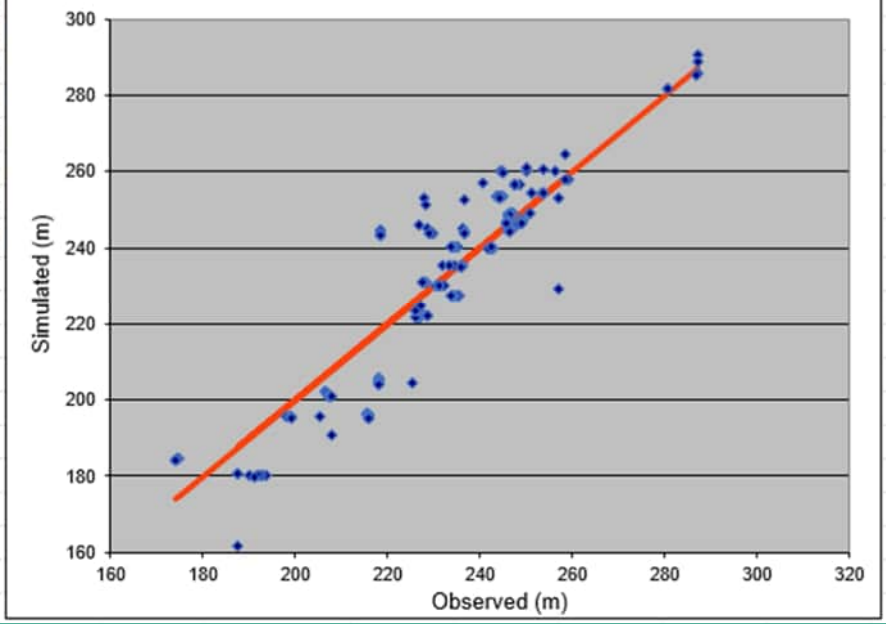
- The root mean square error (RMSE)
- The mean error (ME)
- Coefficient of determination (R^2).

14.3.2 Calibration statistics

Calibration for the model (Plate 23) achieved the following statistics: a 9.55 m root mean square (RMSE) error, equating to an 8.4% scaled root mean square (SRMSE) error, which is within the recommended range (i.e. 10%) in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Plate 23 Calibration results (entire dataset)

Mean Error	-0.23
RMSE	9.55
SD	9.57
Head range	113.27
Scaled ME	-0.20%
Scaled RMSE	8.4%
Scaled SD	8.4%
R^2	0.85



Two groundwater monitoring bores, GRM_BH2A and GRM_BH3A, located immediately adjacent to a mine water dam (Plate 24), could not readily be calibrated. The water levels within these bores were markedly lower than the surround monitoring bores and there is no obvious mine dewatering impacts (within the Tertiary sediments above the Back Creek Group basement lithology).

Removal of these two anomalous groundwater elevation data points (possibly related to poor bore construction grouting) allowed for an improvement in the transient groundwater model calibration statistics (Plate 25).

The revised calibration statistics (Plate 25) included an 8.66 m root mean square (RMSE) error, equating to a 7.6% scaled root mean square (SRMSE) error.

Plate 24 GRM_BH2A and GRM_BH3A bores

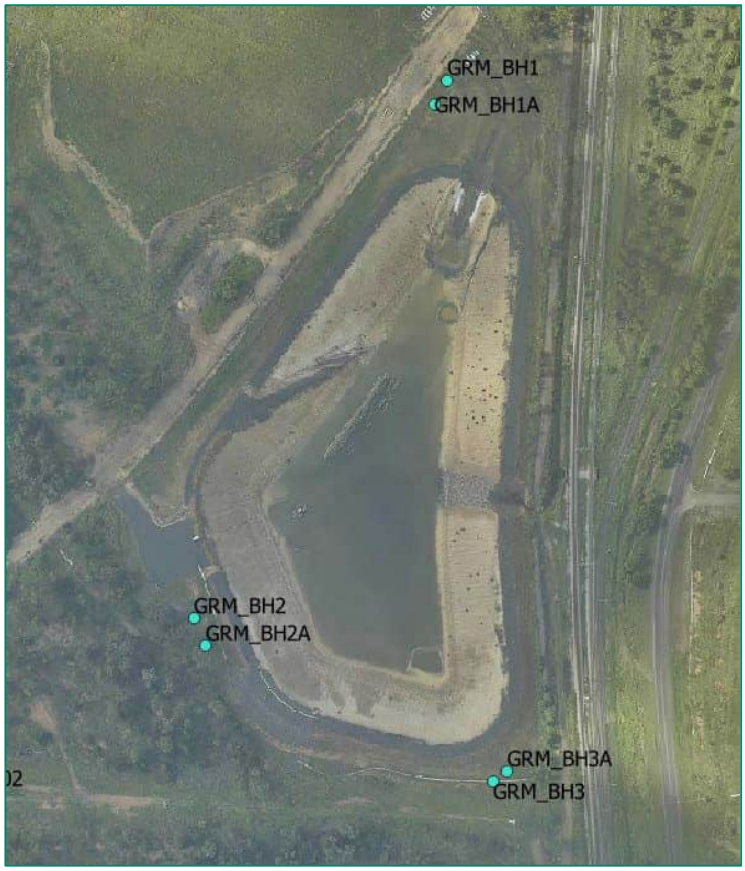
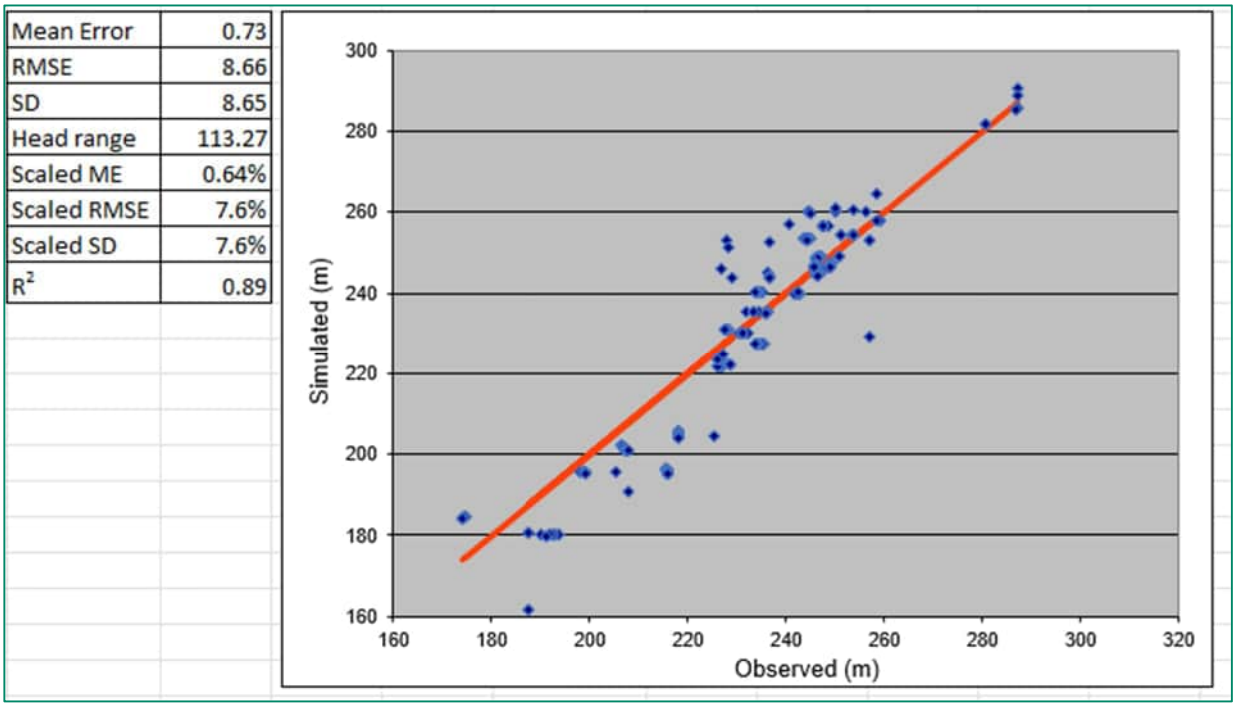


Plate 25 Edited dataset calibration results



14.3.3 Transient data hydrographs

The transient water level data recorded between 2020 to 2024 is presented in hydrographs with the model simulation results. The hydrographs indicate trend matching across the model domain (Figure 33).

14.3.4 Calibrated aquifer hydraulic parameters

The calibration approach, Section 14.3.1, using the parameter estimation software (PEST) allowed for the estimation of aquifer parameters for each of the model layers. Table 20 presents the parameters, hydraulic conductivity and storage, plus the depth range for each layer across the model domain.

The method for deriving the aquifer hydraulic properties included:

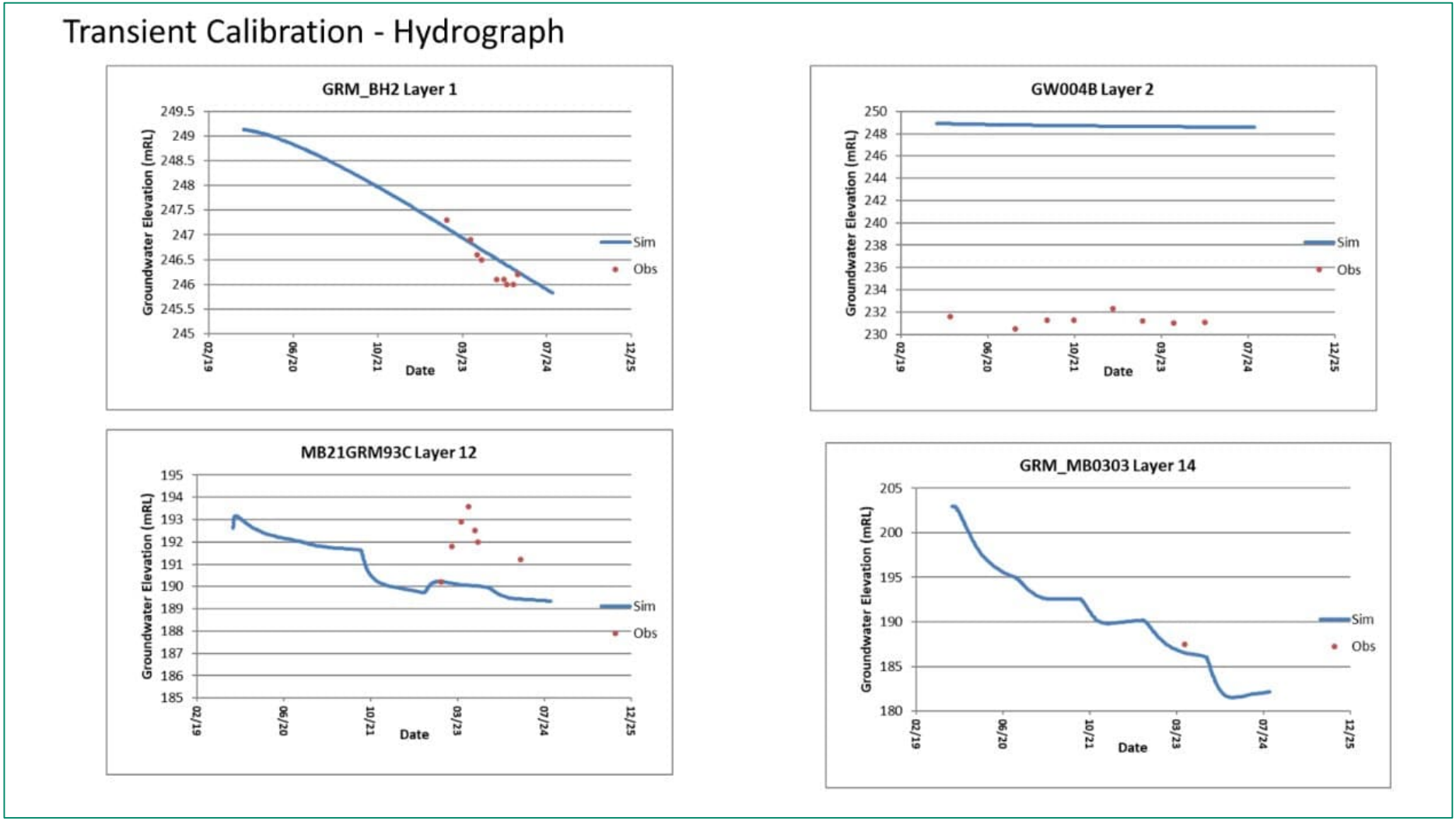
- Pilot – Using pilot points within the model domain
- Uniform – Homogeneous distribution in the aquitard layers
- Pilot plus regression, where the cut-off depth for switching between pilot point and regression estimates is determined by PEST.
    - Noting that for depths shallower than the cut-off then the pilot pointe estimate is adopted, if deeper than the cut-off then the value from the regression equation is adopted.

The regression equation is aa*exp(-bb*depth), where:

aa = 0.2703
bb = 0.016

Layer	Kx_Max	Kx_Min	Cut-off depth (m)	
4	0.025	1.00E-05	500	
6	0.025	1.00E-05	267.49	
8	0.025	1.00E-05	0	Only regression, no pilot point estimates
10	0.025	1.00E-05	336	
12	0.025	1.00E-05	435.64	

Figure 33 Groundwater model calibration transient hydrographs examples



Blue line – simulated (sim) model water level hydrograph

Obs – Available transient groundwater level measurements

Table 20 Summary of hydraulic parameters in the PRC Plan model

Model Layer	Unit	Kh / Kv (anisotropy)	Kh min (m/day)	Kh max (m/day)	Sy min	Sy max	Sc min	Sc max	Thickness From (m)	Thickness To (m)	Method
1	Tertiary, alluvium	10	1.0E-02	1.0E+01	5.0E-02	2.0E-01	1.0E-06	1.0E-04	15	20	Pilot
2	FCCM	10	1.0E-05	1.0E-01	5.0E-03	1.0E-01	1.0E-06	1.0E-04	42	880	Pilot
3	Overburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	50	Uniform
4	GUS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Pilot+Reg.
5	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	25	40	Uniform
6	GP1 coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	4	Pilot+Reg.
7	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	15	40	Uniform
8	GP2 coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Regression
9	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	40	Uniform
10	GMS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	8	Pilot+Reg.
11	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	50	Uniform
12	GLS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Pilot+Reg.
13	Underburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	40	Uniform
14	Back Creek Group	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	200	500	Pilot

Pilot + Reg. - Pilot plus regression

The resultant distribution of the aquifer parameters within the model layers and spatially across the model domain is presented in Figure 34, the horizontal hydraulic conductivity included in the model.

The horizontal hydraulic conductivity values included in the surficial sediments (model layer 1), GMS (model layer 10), and GLS (model layer 12) is included in Figure 35, Figure 36, and Figure 37, respectively.

These figures include the Isaac River (black line) and mine footprints (light blue or brown as hydraulic conductivity changes with depth) and show the heterogeneity of the sediments, after all mining activities (at the end of P4), included in the model.

14.3.4.1 Aquifer hydraulic parameters for historic spoil and goaf

As per Section 14.1, the model was set-up to include for historic mine workings prior to model predictions (2024 Q2 onwards) and for inclusion in the transient calibration period (2020 to 2024 Q1).

The location and extent of spoil within the model set-up is shown in Figure 38. The areas of historic goaf within the model are as included in Plate 20.

The aquifer hydraulic parameters for the goaf, are as detailed in Section 7.3.4.3, included:

- GMS goaf Horizontal hydraulic conductivity (Kh) = 1.1 m/day
- GMS goaf Vertical hydraulic conductivity (Kv) = 5E-05 m/day
- GMS goaf Specific capacity (Sc) confined storage = 1.5E-03
- GMS goaf Specific yield (Sy) unconfined storage = 0.15

The Kv in the overlying model layer (interburden aquitard) was also increased to 0.0005 m/day.

For the spoil, using model parameters supplied by BMA as used in the Saraji Mine PRC Plan (SLR, 2023), was assigned the following aquifer hydraulic parameters:

- Spoil Horizontal hydraulic conductivity (Kh) = 1.0 m/day
- Spoil Vertical hydraulic conductivity (Kv) = 0.1 m/day
- Spoil Specific capacity (Sc) confined storage = 1.5E-04
- Spoil Specific yield (Sy) unconfined storage = 0.15

The recharge across the spoil was increased to 1.0% of the mean annual rainfall.

These hydraulic parameters are included in the model layers 1 to 10 (if mining targeted the GMS) or model layers 1 to 12 (GLS), where the lithology has been mined and replaced with backfill.

Figure 34 Depiction of the hydraulic conductivity distribution spatially and with depth across the model

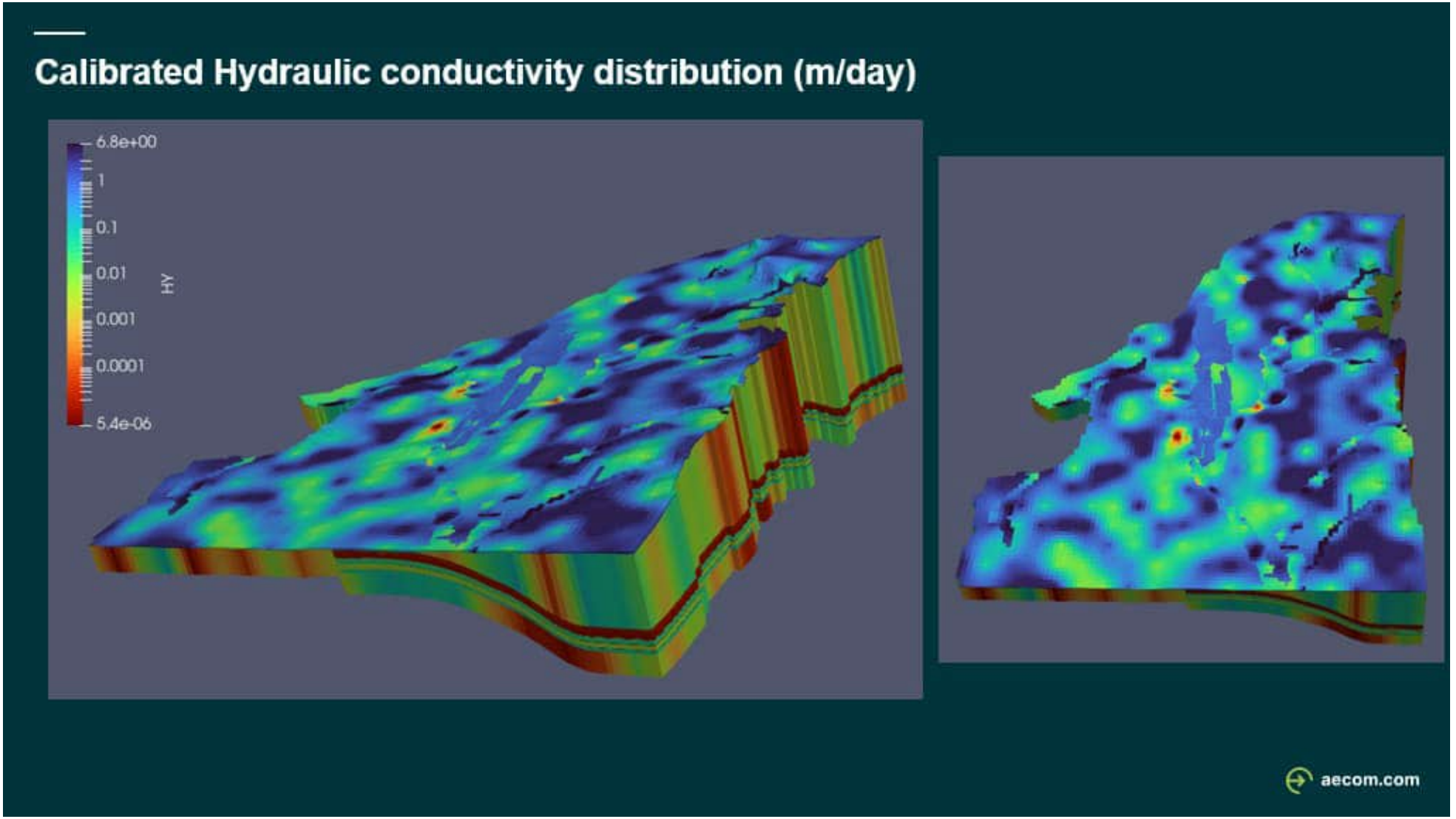


Figure 35 Hydraulic conductivity within the surficial sediments

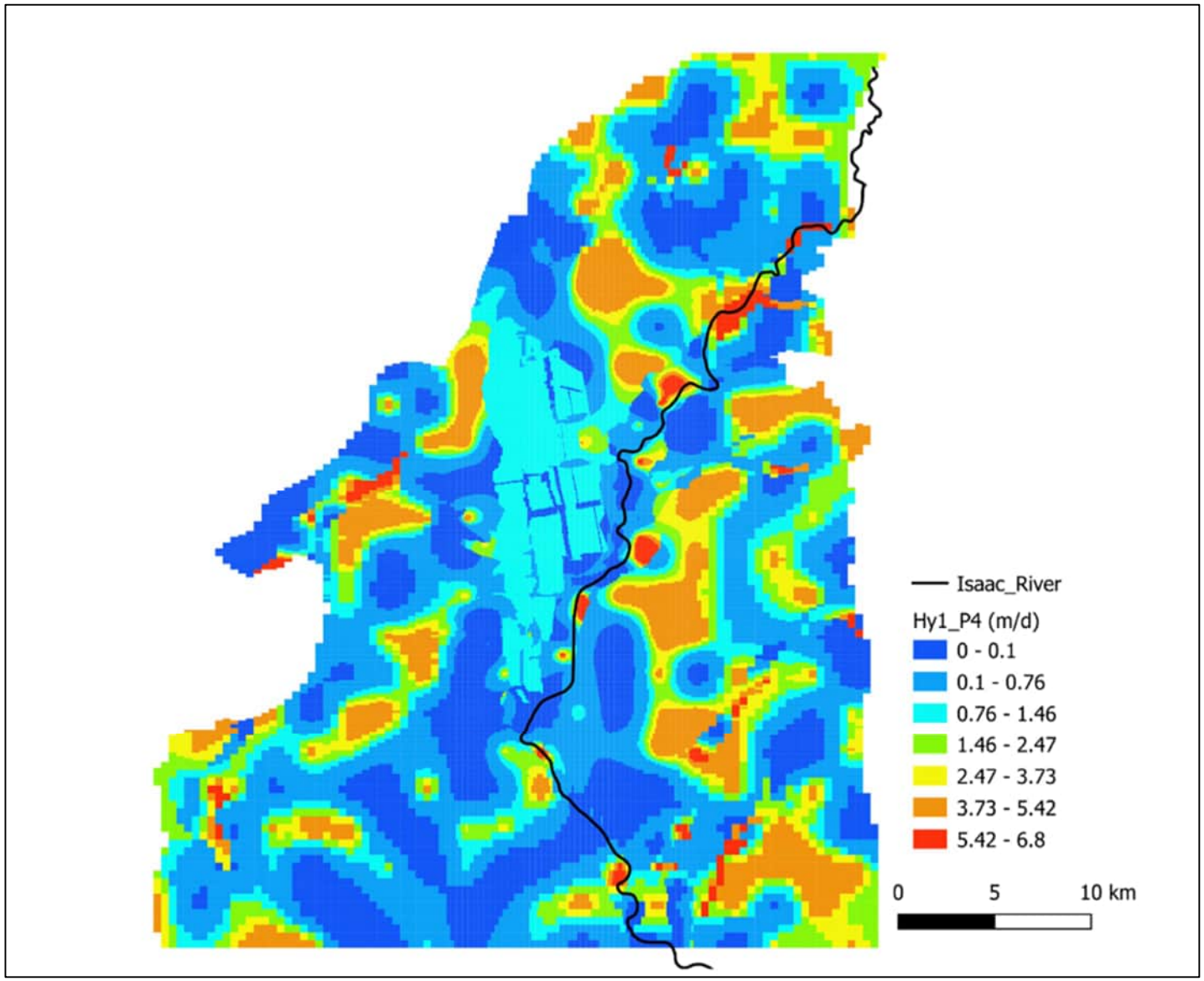


Figure 36 Hydraulic conductivity within the GMS model layer 10

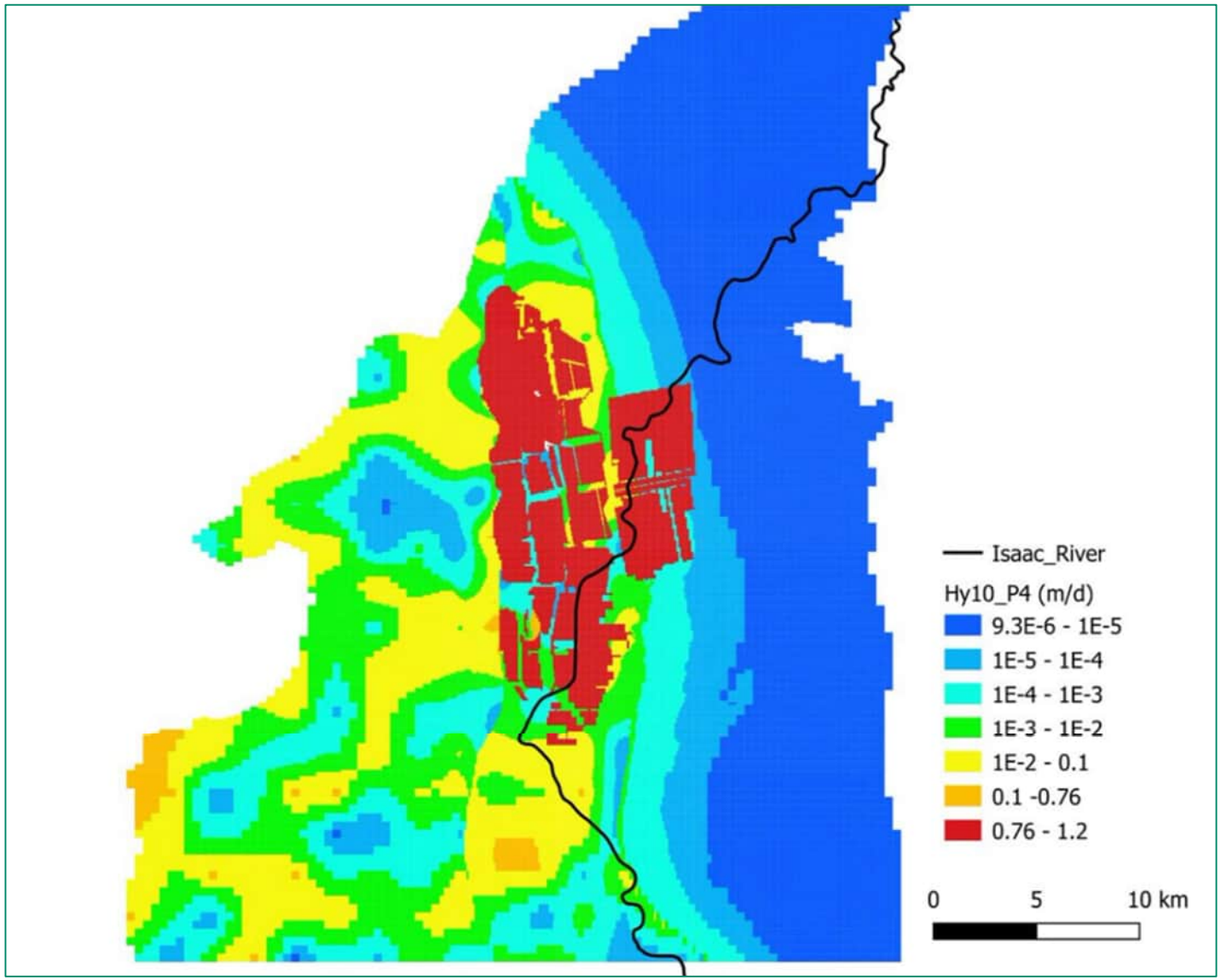


Figure 37 Hydraulic conductivity within the GLS model layer 12

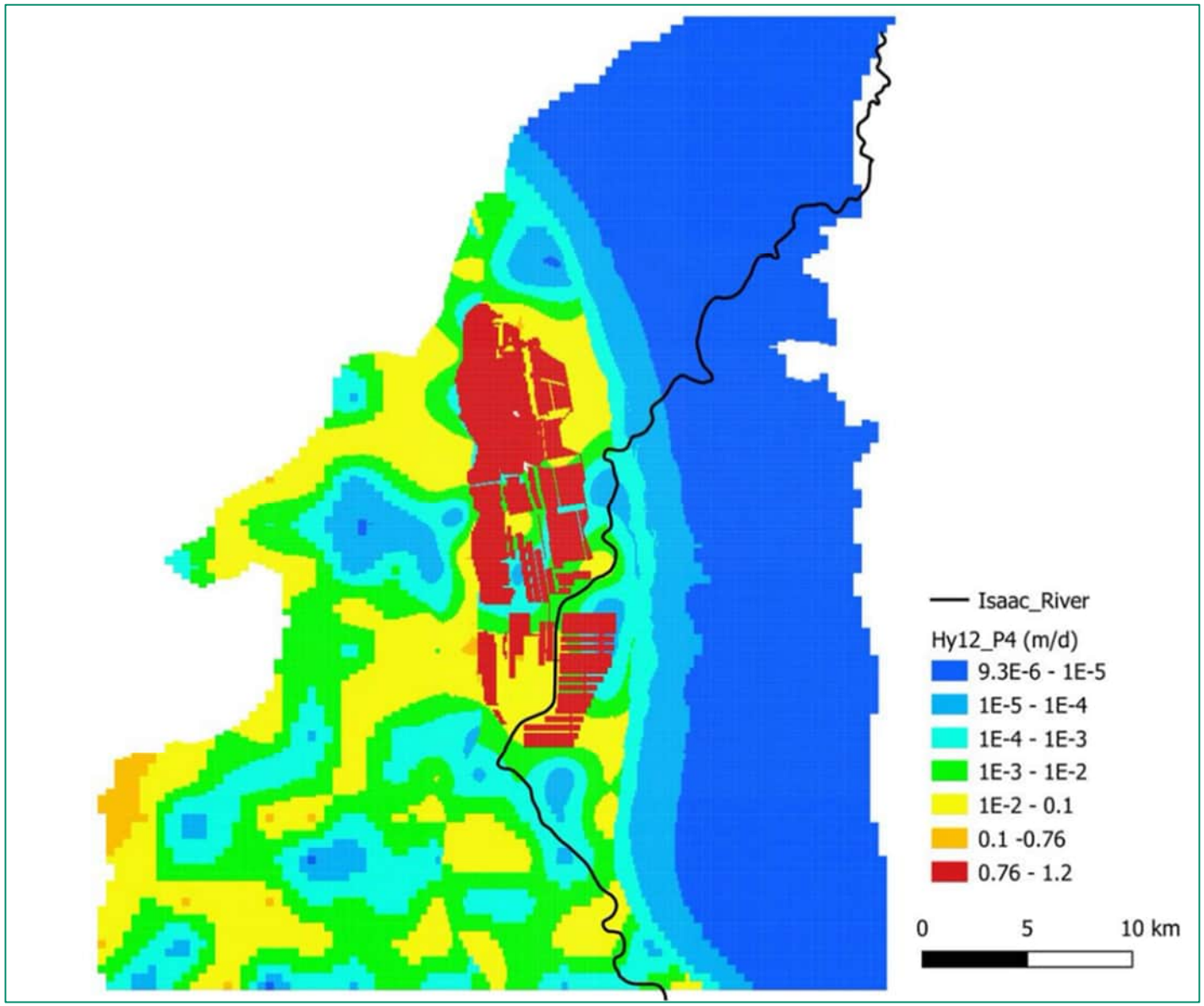
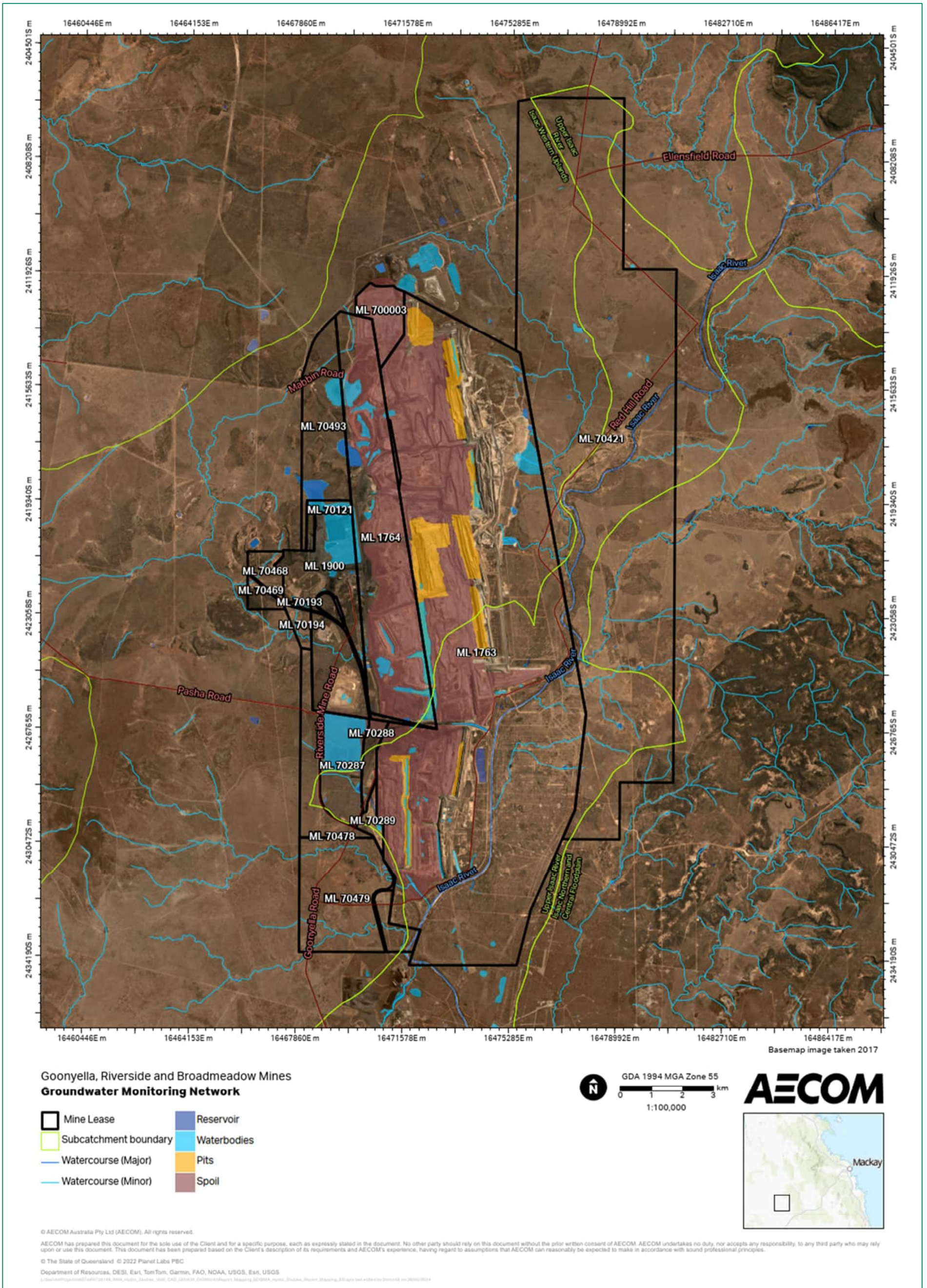


Figure 38 Historic spoil included in the model for the start of predictions in 2024



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Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

14.4 Model Water Budget

A model water budget was compiled for the calibration period 2020 to end of 2023 (actual Q1 2024), considering the inflows and outflows from the model.

The resultant model water budget is included in Table 21.

Table 21 Calibration model water budget (2020 to 2023)

Cumulative Volumes	IN (m^3)	OUT (m^3)
Storage	80,040,064	31,753,570
Constant Head	1,715,496	189,055
Drains	0	52,179,584
Recharge	14,250,555	0
Evaporation	0	10,426,460
River leakage	0	1,547,646
TOTALS	96,006,115	96,096,315
IN - OUT	-90,200	
Percent discrepancy	-0.09	

The predictive groundwater model included four different phases of prediction, as discussed in Section 15.0. A model water budget was generated for a predictive run, which included the underground mining and continued open cut mining (at Goonyella Pit). This predictive run, 2024 to 2055, allowed for the evaluation of alluvium recharge (discussed in Section 13.3.6.1) as well as an assessment of in and out flows in the numerical model. These results are included in Table 22.

The percent discrepancy is close to 0% for the calibration water budget and approximately 0.1% for the predictive water budget, indicating good model convergence. The inflow storage (IN storage) is a significant inflow to the groundwater system, contributing a major portion to mining dewatering (drains), which indicates substantial extractions from aquifer storage.

Table 22 Prediction model water budget (2024 to 2055)

Cumulative Volumes	IN (m^3)	OUT (m^3)
Storage	4.46E+08	1.11E+08
Constant Head	8,439,281	999,161.9
Drains	0	3.82E+08
Recharge	90,986,808	0
Evaporation	0	47,265,681
River leakage	0	4,635,597
TOTALS	5.45E+08	5.46E+08
IN - OUT	-599,647	
Percent discrepancy	-0.11	

14.5 Model Performance and Limitations

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), the Murray Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) and the released IESC Explanatory Note for Uncertainty Analysis (IESC, 2018). **Note:** These are mostly generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The 2012 Australian Groundwater Modelling Guidelines has replaced the model complexity classification of the previous MDBC guideline by a "model confidence level" (Class 1, Class 2, or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design and construction.
- Calibration procedures that are undertaken during model development.
- Consistency between the calibration and predictive analysis.
- Level of stresses applied in predictive models.

The model confidence level for a transitional PRC Plan is not readily identified, as the model will be revised on a regular basis in response to additional data compilation, changes in mine activities and mine schedules, plus ongoing remediation and decommissioning activities and plan changes. It is noted that the 2012 Australian Groundwater Modelling Guidelines state that a Class 2 model may be used for assessing impacts associated with mine dewatering (Barnett et al. 2012).

The subjective qualitative criteria allowing model classification, per Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines is compiled in Table 23. The classification of the PRC Plan model was assessed subjectively by the groundwater modeller and reviewed by a Technical Director level hydrogeologist, whereby:

1. The classification table was subjectively reviewed, and the specialists mutually decided, in their professional opinion, which box most appropriately describes the various characteristics of the model.
2. Thereafter, the assessors assigned an overall classification class for the model based on the characteristics selected, i.e. which class has the most selected characteristics.

The assessment shown in Table 23 indicates that, overall, the GRB-RHM groundwater model can be classified as primarily Class 2 using the 2012 Australian Groundwater Modelling Guidelines classification system. This is considered an appropriate level for this transitional PRC Plan context.

The PRC plan model is considered to contain components of Class 1, Class2 and Class 3, which is typical of groundwater models.

Table 23 Groundwater Model Classification Table

Class	Model Characteristics					
	Data		Calibration		Prediction	
1		Few or poorly distributed data points		Not possible		Predictive timeframe >> calibration timeframe
		Unavailable or sparse data in areas of greatest interest		Unacceptable levels of error		Temporal discretisation is different to calibration
		No metered groundwater extraction data	X	Inadequate distribution of data		Transient prediction but steady state calibration
		Remote climate data		Targets incompatible with model purpose		Unacceptable validation
		Little or no useful data on land-use, soils, or river flows and stage elevations				
2	X	Some data but may not be adequate throughout domain	X	Reasonable calibration statistics with errors in parts of the model	X	Predictive timeframe > calibration timeframe
	X	Some metered groundwater extraction data	X	Long-term trends not replicated in all parts of domain	X	Long stress periods compared to calibration
	X	Streamflow and stage measurements are available at some points		Transient calibration not extending to present day		New stresses not in calibration
		Reliable irrigation application data available in part		Weak seasonal replication		Poor validation
				No use of calibration targets compatible with model purpose		
			X	Validation not undertaken		
3		Spatial and temporal distribution of data adequate	X	Scaled RMS error or other calibration statistics are acceptable		Predictive timeframe ~ calibration timeframe
	X	Clearly defined aquifer geometry	X	Long-term trends adequately replicated where important	X	Temporal discretisation in predictive model consistent with transient calibration
		Reliable metered groundwater extraction data		Seasonal fluctuations adequately replicated	X	Similar stresses to those in calibration
	X	Rainfall and evaporation data is available	X	Transient calibration is current		Steady state prediction consistent with steady state calibration
	X	Aquifer testing data to define key parameters	X	Model is calibrated to heads and fluxes		Model validation suggests calibration is appropriate
	X	Good quality and adequate spatial coverage of DEM	X	Key modelling outcomes dataset used in calibration		Steady-state predictions when the model is calibrated in steady-state
		Streamflow and stage measurements are available at many points				

Class	Model Characteristics					
	Data		Calibration		Prediction	
		Reliable land-use and soil-mapping data available				
		Reliable irrigation application data available				

Notes: Based on Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines (Barnett et al. 2012)2.
Grey highlighted cells = model has been subjectively assessed to meet the classification criteria for that Class

15.0 Predictions

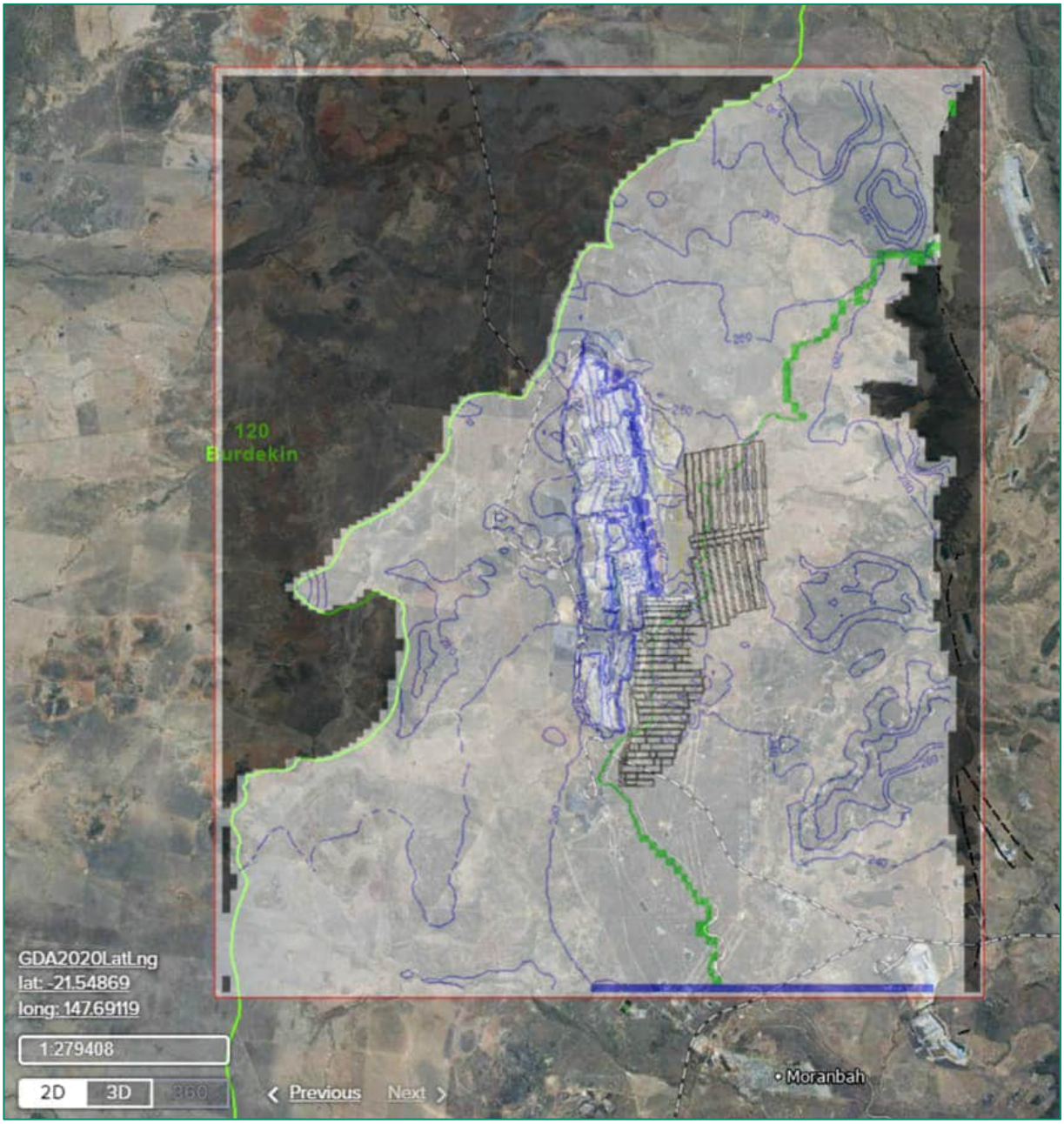
15.1 Prediction Conditions

As per Section 14.3 the refined numerical groundwater model included initial groundwater conditions based on prior pseudo-steady conditions covering the period from 1996 to 2009 plus the historic mining (2010 to 2019). The model included transient calibration using data from 2020 to 2024.

This allowed for the establishment of groundwater heads (elevations) across the model domain, including drawdown as a result of active (mine dewatering) and passive (seepage ingress into pits) plus artificial recharge from residual pits which contain or store water.

Examples of the head contours, for alluvium, GMS, and GLS (target coal seams), at the start of model predictions are included in Figure 39.

For reference the layout of the head contours across the model domain are as included in Plate 16 and as included below.



15.2 Prediction Periods

To capture the complex interaction between the different mine plans, decommissioning, and injection, activities, as detailed in Table 15 and summarised in Table 17, four distinct periods were included in the predictive modelling.

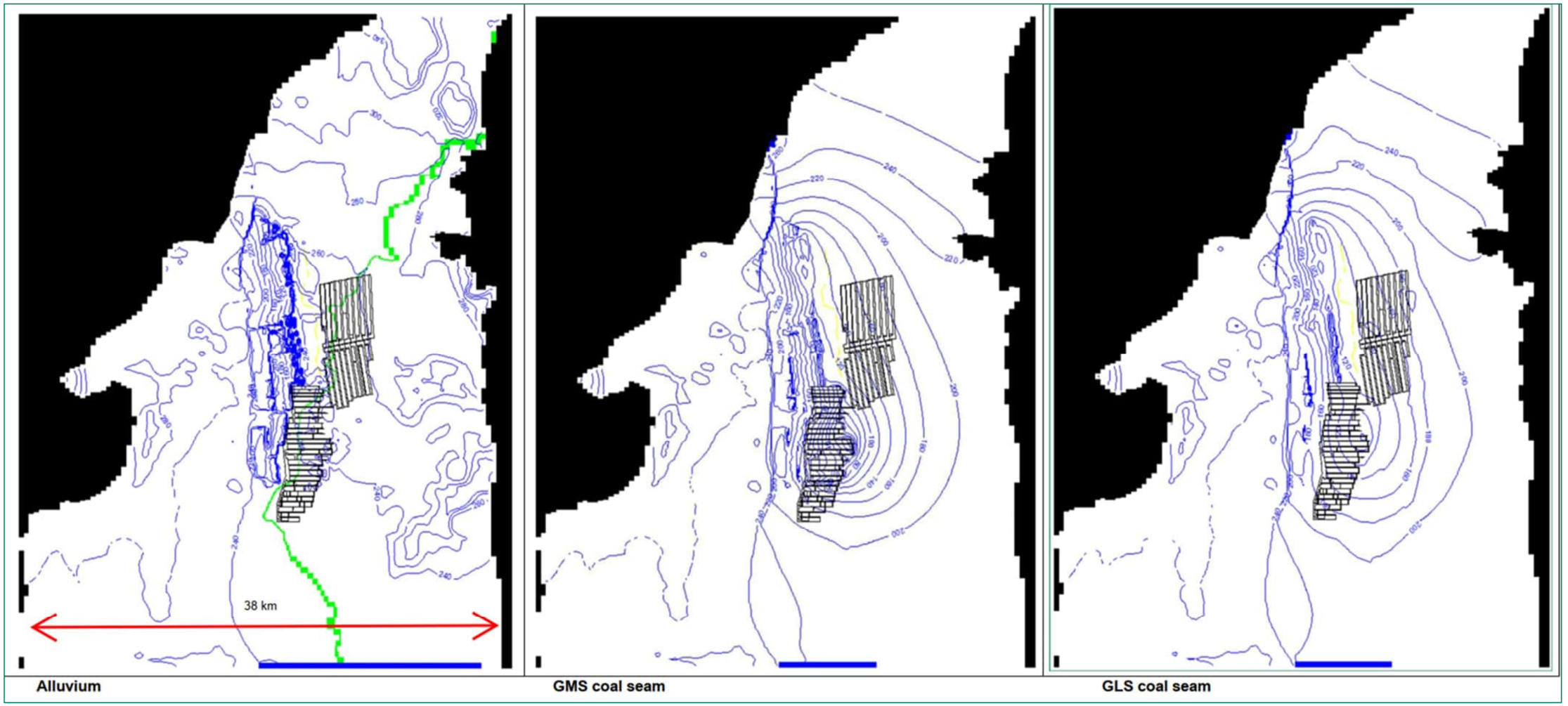
The activities and changes in the model for each prediction period were made to accurately capture:

- The cumulative impacts of the different mining (target seams, schedules, mining methods, and locations).
- The periods of decommissioning and introduction of water into the underground workings.
- The areas and timing of rehabilitation (backfilling of open cuts with spoil).
- The incorporation of residual voids (historic and over time).

The prediction phases are summarised as:

- **Prediction phase 1 (2024 to 2056)**
  - Broadmeadow and Isaac pits (GMS) remain dewatered to facilitate Broadmeadow underground mining (2024 to 2056)
  - Ramp 32 East is mined from 2027 to 2031 (drain model cells then converted to CHD, as per Section 13.3.7)
  - Ramp 32 South is mined up to 2036 and converted to CHD in 2037
  - Thiess Pit is included as CHD from 2024
  - Broadmeadow GMS underground includes historic goaf 2007 to 2023, continues longwall mining to 2031, and then remains dewatered till 2055 (to accommodate GLS underground mining)
  - Broadmeadow GLS underground occurs between 2031 to 2055
  - Broadmeadow GMS and GLS, in 2056, remain dewatered during decommissioning
  - Goonyella pit open cut mining continues (2024 to 2059) and includes historic spoil (2012 to 2023).
- **Prediction phase 2 (2057 to 2060)**
  - 2057, change Broadmeadow GLS underground (2031 to 2055) to goaf (parameters as per Section 7.3.4)
  - 2057, change Broadmeadow GMS underground (2007 to 2031) to goaf
  - 2057, change Goonyella open cut mining (2024-2056) to spoil
  - 2057, drain cells at both Broadmeadow GLS and GMS underground removed (1-yr decommissioning)
  - 3-yr injection into both Broadmeadow GLS and GMS underground workings.
  - Broadmeadow and Isaac pits and Goonyella Pit (GLS) have drain cells and remain dewatered
  - CHD for residual void water levels in Thiess (2057-2060), Ramp 32South (2057-2060), and Ramp 32East (2057-2060).
- **Prediction phase 3 (2061 to 2092)**
  - 2061, change Goonyella open cut mining (2057 to 2059) to spoil
  - 2061, CHD included in Broadmeadow, Issac, Thiess, Ramp 32 East, Ramp 32 South (2061-2092) pits
  - 2063 to 2091, Red Hill Mine mining (drain cells) included, finishing in 2091, Goonyella pit remains dewatered to facilitate RHM mining
  - 2092, Red Hill Mine completion year, stay dewatered during decommissioning.
- **Prediction phase 4 (2093 to 2199)**
  - 2093, 1-year decommissioning (drain cells in RHM removed, only Goonyella pit remain), change RHM to goaf (parameters as per Section 7.3.4)
  - Drain cells in Goonyella pit (2093-2096)
  - CHD in Broadmeadow, Issac, Thiess, Ramp 32 East, Ramp 32 South (2093-2199)
  - CHD in Goonyella Pit (2097 to 2199)
  - 2094 to 2096, 3-years injection into RHM
  - 2097 to 2199 all mining activities ceased, recovery period.

Figure 39 Head contours at the start of Prediction Modelling (2024)



15.3 Initial Ingress Estimates

For the closure plan input, the predictive model aimed to assess groundwater ingress into the mine voids that will remain post-closure. These pits are as included in Section 14.2, Figure 32 as incorporated in the model set-up and zones.

The estimate of groundwater ingress, adopting drains in all of the residual mine pits, during the entire prediction period/s, allowed for the evaluation of **maximum groundwater extraction** and evaluation of the influence of reinjection, plus input into the residual mine water balance.

The estimates of groundwater ingress, as m^3/year, for each pit are included below.

Plate 26 Broadmeadow Pit initial estimates of ingress

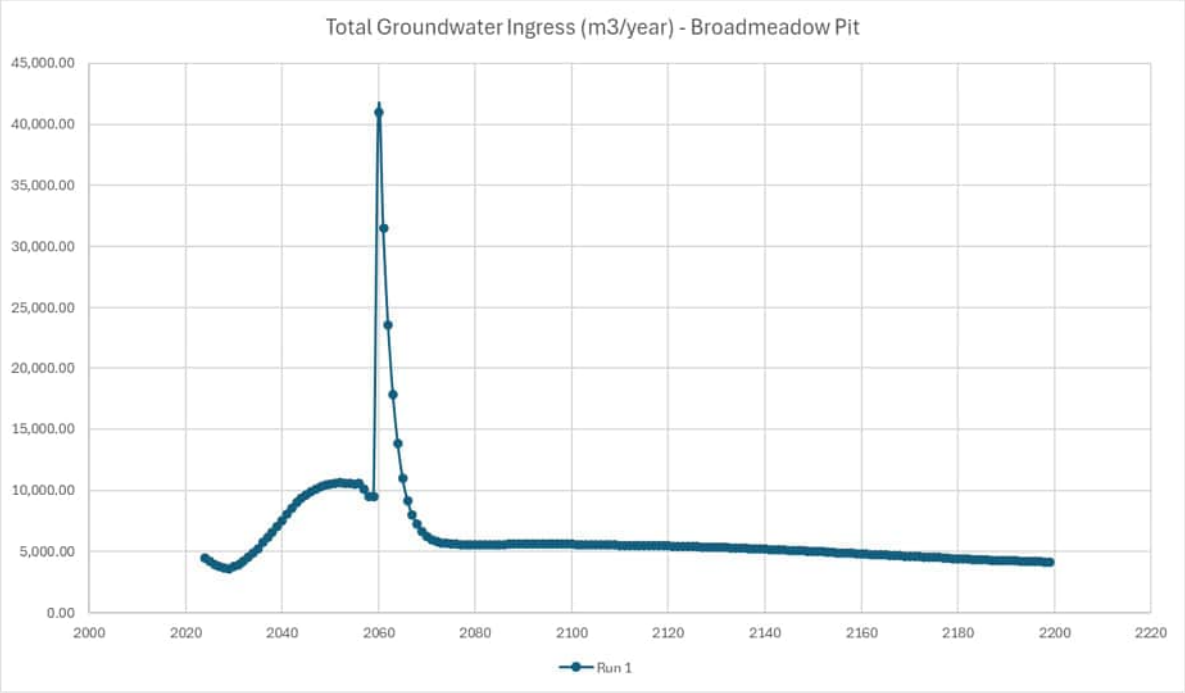


Plate 27 Isaac Pit initial estimates of ingress

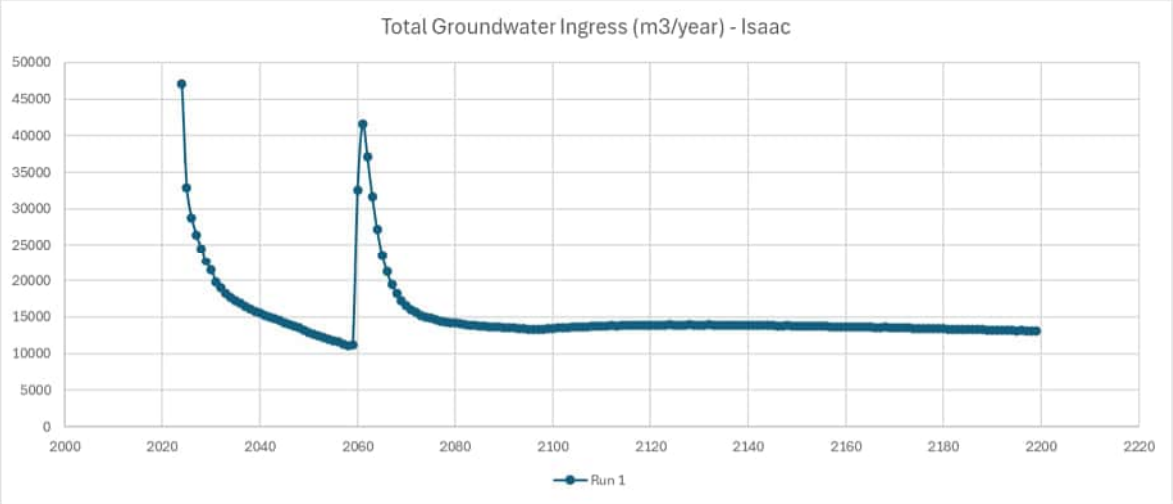


Plate 28 Thiess Pit initial estimates of ingress

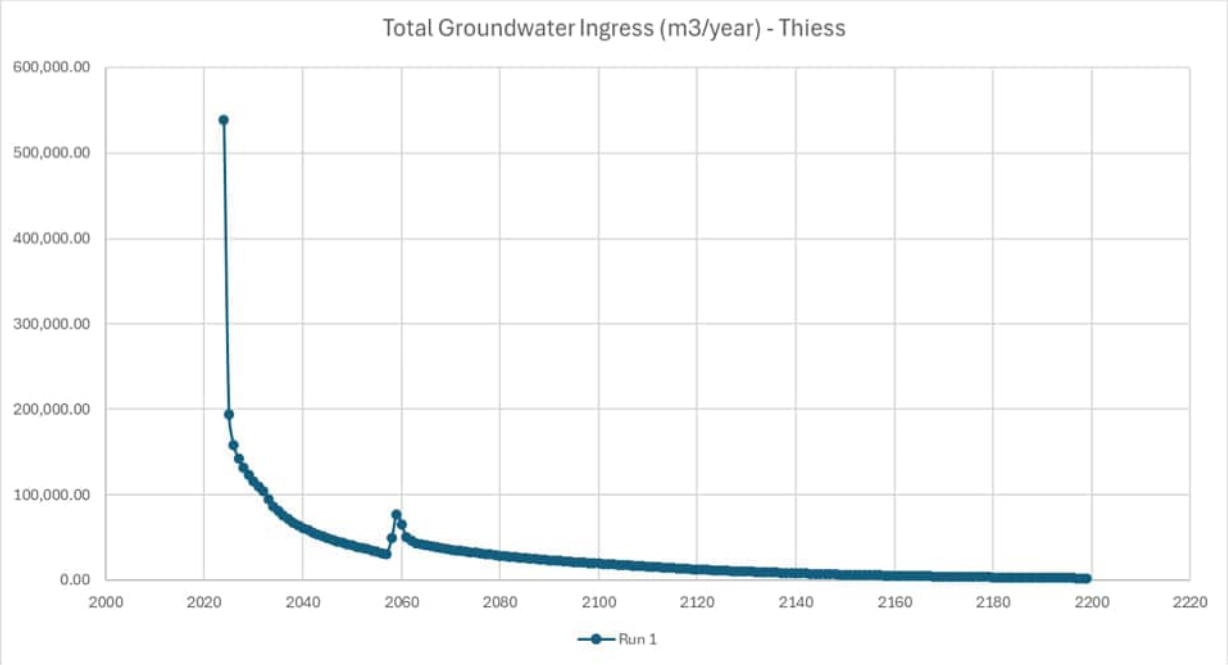


Plate 29 Ramp 32 East Pit initial estimates of ingress

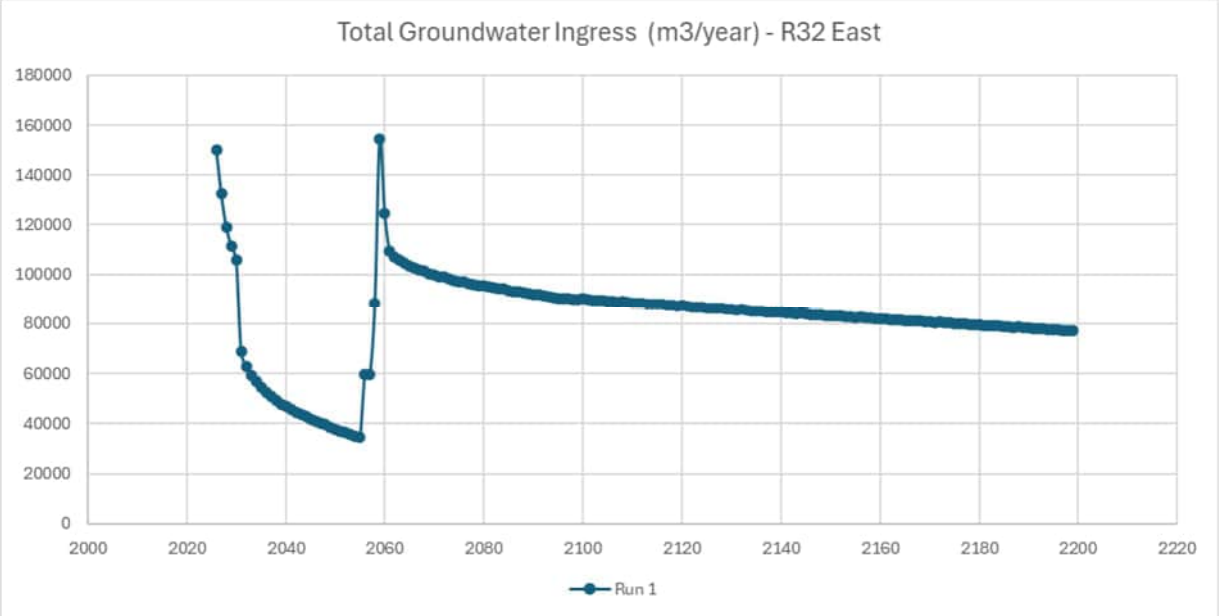


Plate 30 Ramp 32 South Pit initial estimates of ingress

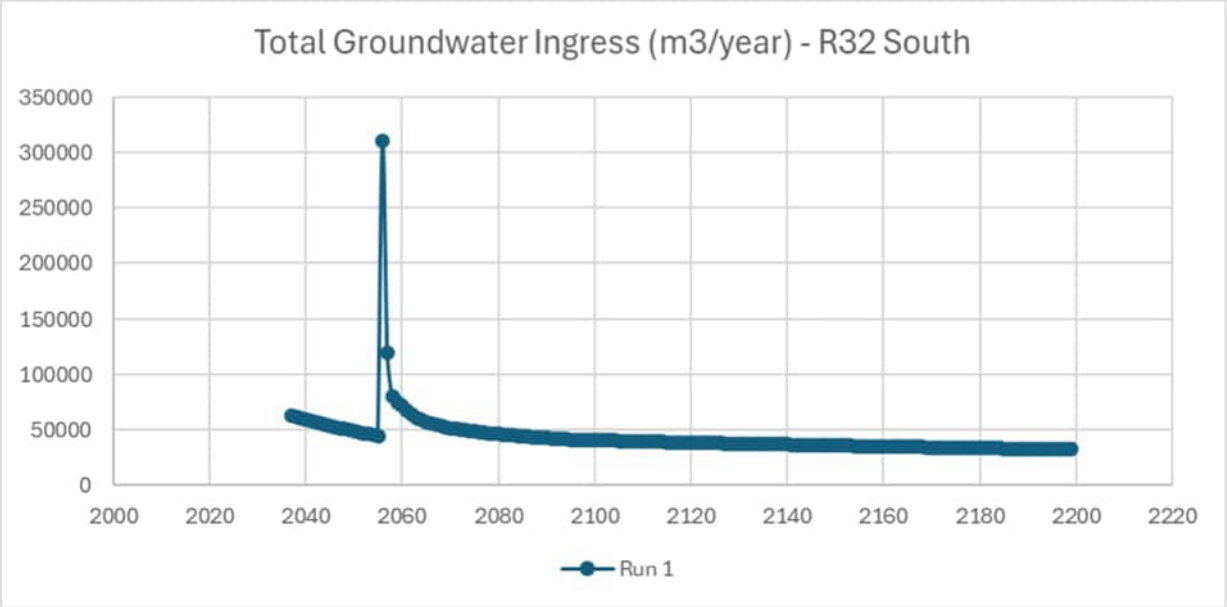
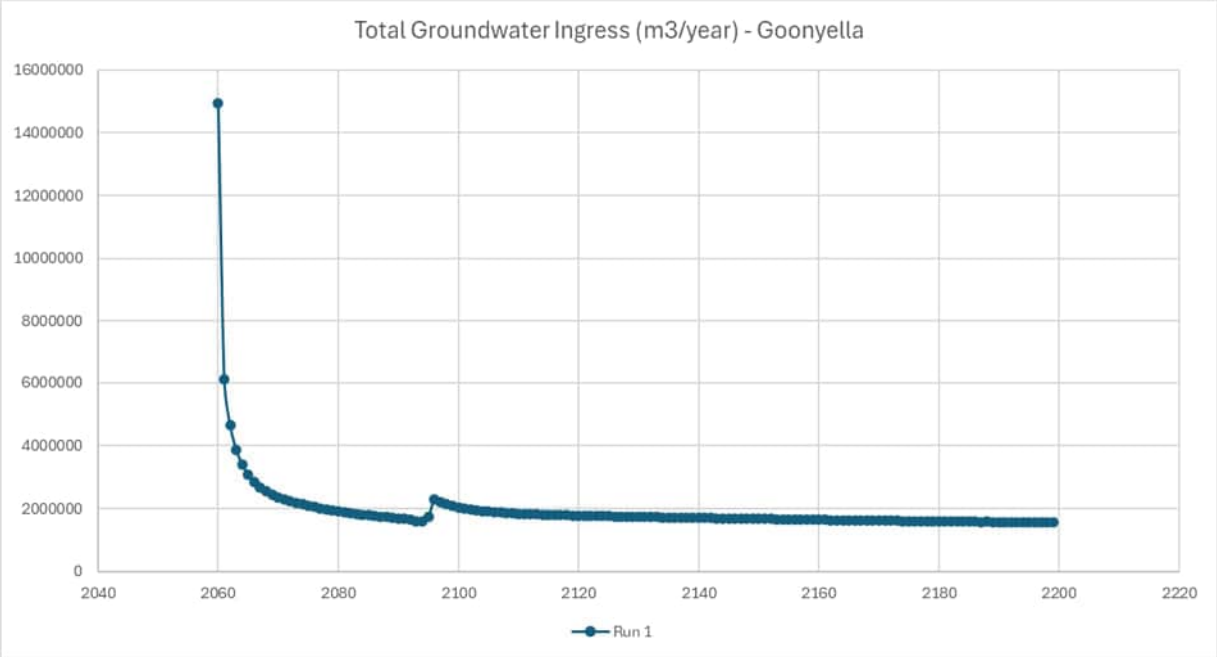


Plate 31 Goonyella Pit initial estimates of ingress



Note: These initial ingress estimates were based on the open cut pits being drained to base of the pits, such that the ingress estimates are based on surrounding groundwater levels and the permeability of the host material containing and adjacent to the open cut pits (where spoil has higher hydraulic conductivity to the natural rock). Thus, these estimates of ingress are maximum expected ingress rates and do not readily compare to the estimates in Section 10.2.

15.4 Integration with Residual Void Water Balance Model

The hydrogeological assessment was provided to the specialists commissioned to undertake the residual void/s water balance modelling.

The approach adopted followed the process detailed in the approach of mining closures compiled in the Review of current approaches to model residual mine voids for rehabilitation planning, technical paper 11 (Tomlin et al, 2023).

The approach consisted of coupled water balance and groundwater models, allowing for the capture and assessment of the key aspects of residual void water balances. The groundwater flow model ingress predictions were used with the surface water balance predictions, as a method referred to as 'quasi-coupling', to predict residual void water levels.

The coupled water balance approach allowed for:

- Iterative approach, which allowed for the refinement of the residual void water levels through including pit water levels in the groundwater model, revising the groundwater ingress rates (m^3/year), which was then used to generate the next set of pit water levels.

  Predictions from the transient groundwater flow model includes the use of a high conductance to simulate the 'lake'. This allows for the production of groundwater inflow predictions for the estimation of residual void water elevation (during rebound and to the pseudo-steady state residual void water level).

  It is noted that the surface water modelling allowed for the evaluation of climate (rainfall and evaporation) plus runoff on a daily basis across the prediction periods. Due to the large data sets, large groundwater model (117,410 active cells for a fourteen-layer model), and limited variation (groundwater ingress versus surface water contributions reliant on climate), the average annual residual void water levels (derived from the surface water balance modelling) were included in the groundwater modelling.

- Validation stage, the re-running of the groundwater model using the revised set of pit water levels was conducted for four iterations. Once the model simulations closely matched the previous ingress (surface water and groundwater predictions) as reflected in the pit water levels (i.e., converging data) no further iterations were necessary.

- Consistency Between Models – The model outputs exhibited good agreement in terms of water balances, fluxes, and water levels at these interfaces such that the interactions between the two systems were deemed adequately represented.

15.4.1 Iterations

Four iterations of ingress and pit water levels were included in the residual water balance modelling, these included:

- Pit water levels (Rev A) and groundwater Model Run 1 using drain cells predictions (Section 15.3 data), which produced Pit water levels (Rev B)

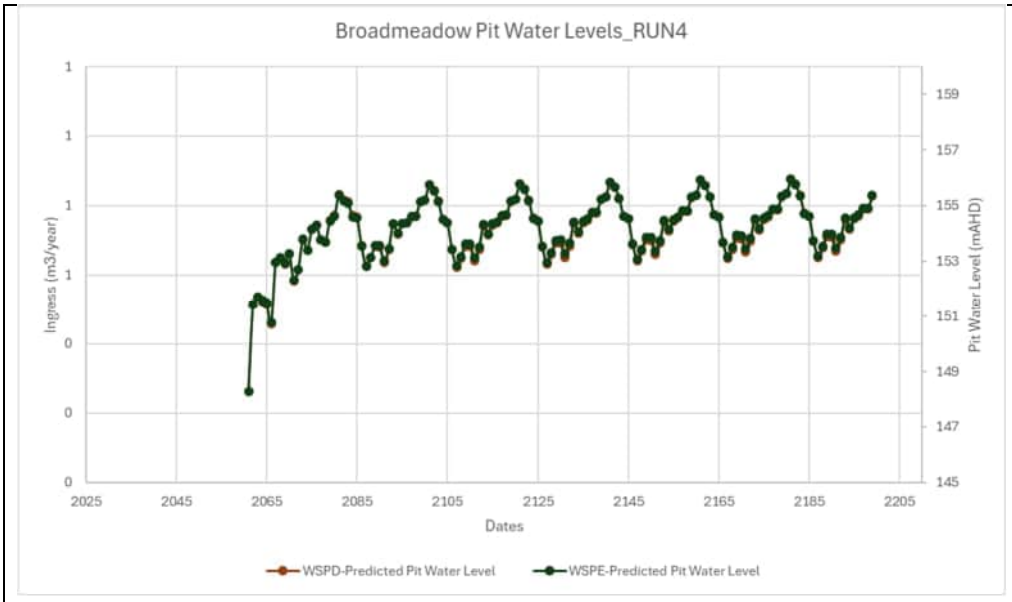
- Pit water levels (Rev B) and groundwater Model Run 2 using CHD cells predictions, which produced Pit water levels (Rev C)

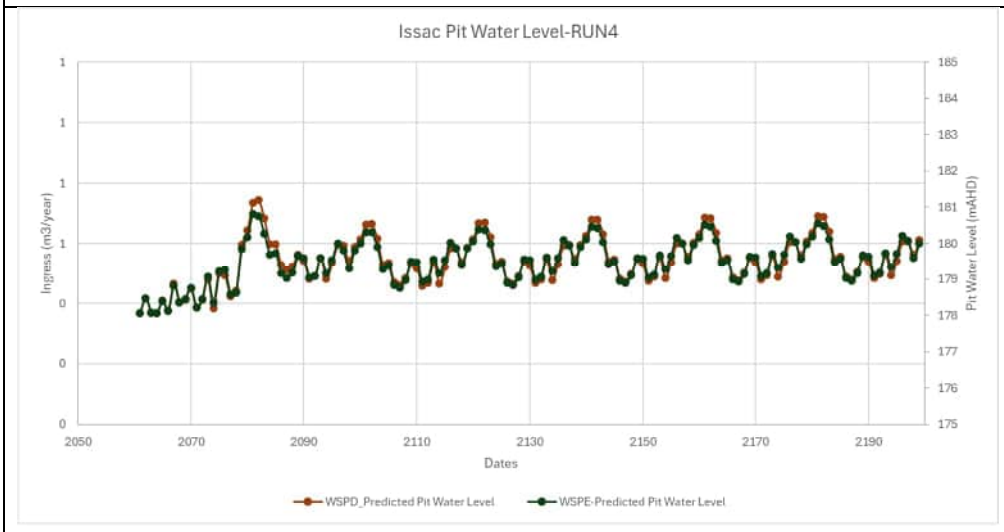
- Pit water levels (Rev C) and groundwater Model Run 3 using CHD cells predictions, which produced Pit water levels (Rev D)

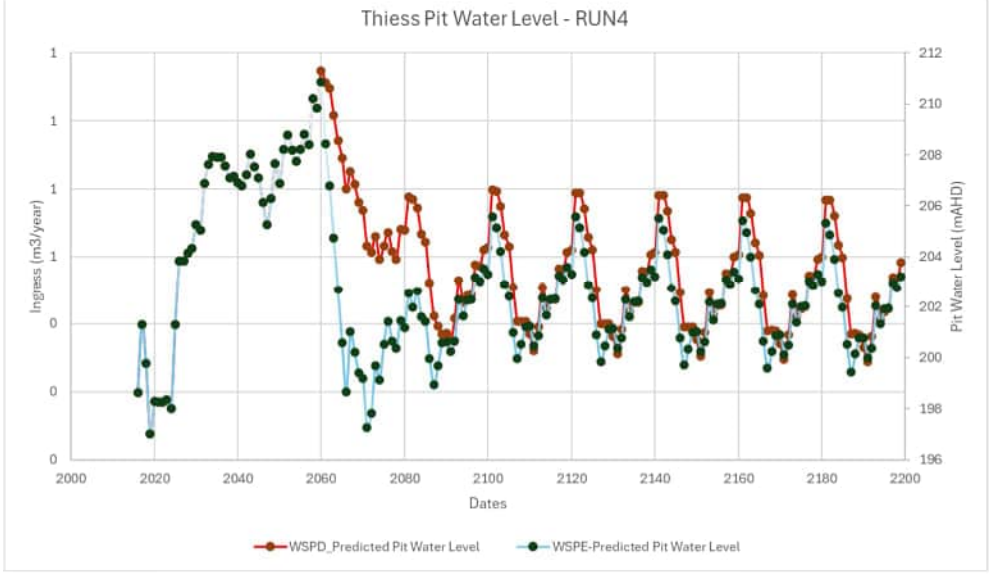
- Pit water levels (Rev D) and groundwater Model Run 4 using CHD cells predictions, which produced Pit water levels (Rev E).

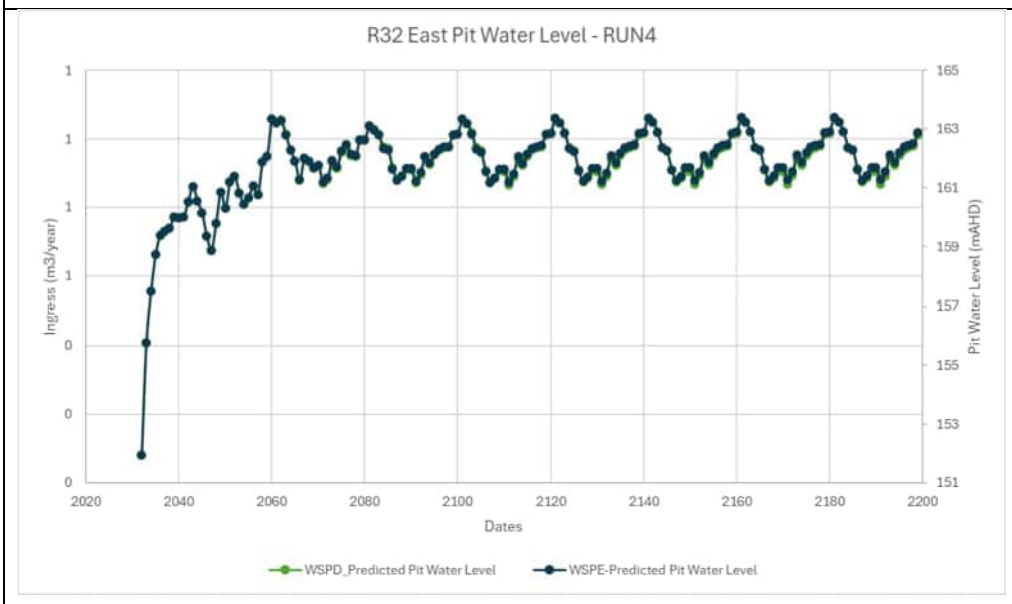
The Pit water levels Rev D and Rev E were closely matched, as included below (Plate 32).

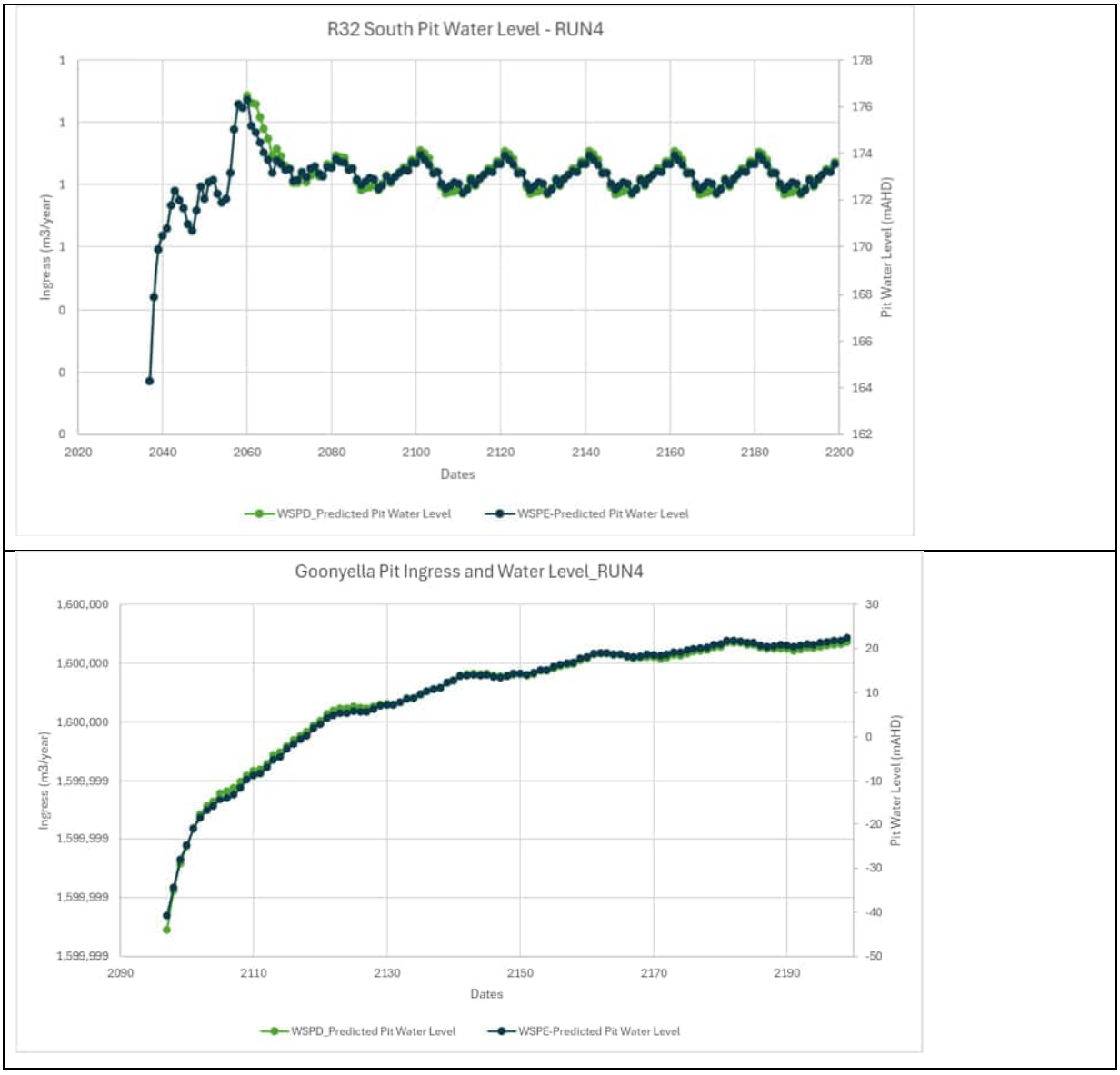
Plate 32 Residual void water levels Rev D and Rev E






Thiess Pit Water Level - RUN4
Ingress (m3/year)
Pit Water Level (mAHD)
Dates
WSPD_Predicted Pit Water Level
WSPE-Predicted Pit Water Level


R32 East Pit Water Level - RUN4
Ingress (m3/year)
Pit Water Level (mAHD)
Dates
WSPD_Predicted Pit Water Level
WSPE-Predicted Pit Water Level



15.4.2 Residual Void Groundwater Inflow

The final predicted groundwater inflows to the residual voids from the groundwater model, using the Model Run 4 predictions. The net groundwater flux into or out of the residual voids, using the Model Run 4 predictions, were assessed using the groundwater model zone budget. This allowed for the evaluation of contribution from (or to) the spoil and natural / unmined geology, as detailed in Section 14.2.

The pit water levels from Rev D / Rev E compared to the groundwater elevation surrounding the residual voids determined the flow direction in or out of the surrounding saturated hydrostratigraphic units, including the spoil (installed to GMS or GLS depending on the historic mining).

It is noted that the residual void water balance modelling included consideration of wet, dry and mid climate conditions on a daily basis. The groundwater modelling adopted the average residual void levels from these three climate condition simulations. This approach, plus undertaking uncertainty analysis (Section 16.0), was adopted for the ingress predictions. This was done due to:

- The large groundwater model domain
- Long prediction periods,

- Complex alteration of the model to match mining activities during each prediction period.

Thus, the groundwater model (zone budget) provided annual groundwater flux estimates in or out of the different zones (spill, natural geology, etc,).

15.4.2.1 Broadmeadow Pit

The groundwater model zone budget indicates that ingress into this pit occurs predominantly from the spoil to the west of the pit (refer to Figure 32). Groundwater from the unmined geology to the east (down dip of Broadmeadow Pit) is limited with the potential for pit water to move towards the east (Plate 33).

Initial ingress into the Broadmeadow Pit is related to the change of the pit from drain cells (water level drawdown down to the base of the pit) and then including a CHD to simulate the pit water levels (including fluctuations). This change in the water level relates to the model requiring water from the surrounding model cells to fill the residual voids (from the drain elevation to the CHD residual void level instantaneously in the model) until gradients stabilise. This would occur over time once the mine dewatering ceases, and groundwater and surface water can enter the residual void. This is included in the model to facilitate the assessment of groundwater flux post-closure.

It is noted that ingress from the spoil into the Broadmeadow residual void will occur in perpetuity, driven by evaporation from the residual void. Groundwater from the surrounding natural (unmined) formations will flow into the residual void when groundwater elevations are higher than the residual void water level. Predictions indicate that the pit water will also flow into the natural formation due to lower groundwater levels after mining.

Hydrographs of hypothetical water level observation points in the model were generated to assess the residual void water level and groundwater 100 m up and down dip (west and east) of the Broadmeadow Pit. The full hydrographs, across the entire prediction phases, are included in **Appendix D**. These water level hydrographs (Figure 40) indicate:

- The hydrographs reflect the mine decommissioning and water introduction activities in P4 prediction period (Section 15.2).
- The residual void water level fluctuates around 154 mAHD
- Groundwater levels in the GMS to the west (up dip) are some 160 mAHD (flow towards the pit)
- Groundwater levels in the GMS to the east (down dip) are some 143.5 mAHD (flow away from the pit).

These data plus groundwater drawdown contours (Section 15.4.3) are considered when evaluating flow path simulations (Section 15.6).

Plate 33 Broadmeadow groundwater flux predictions

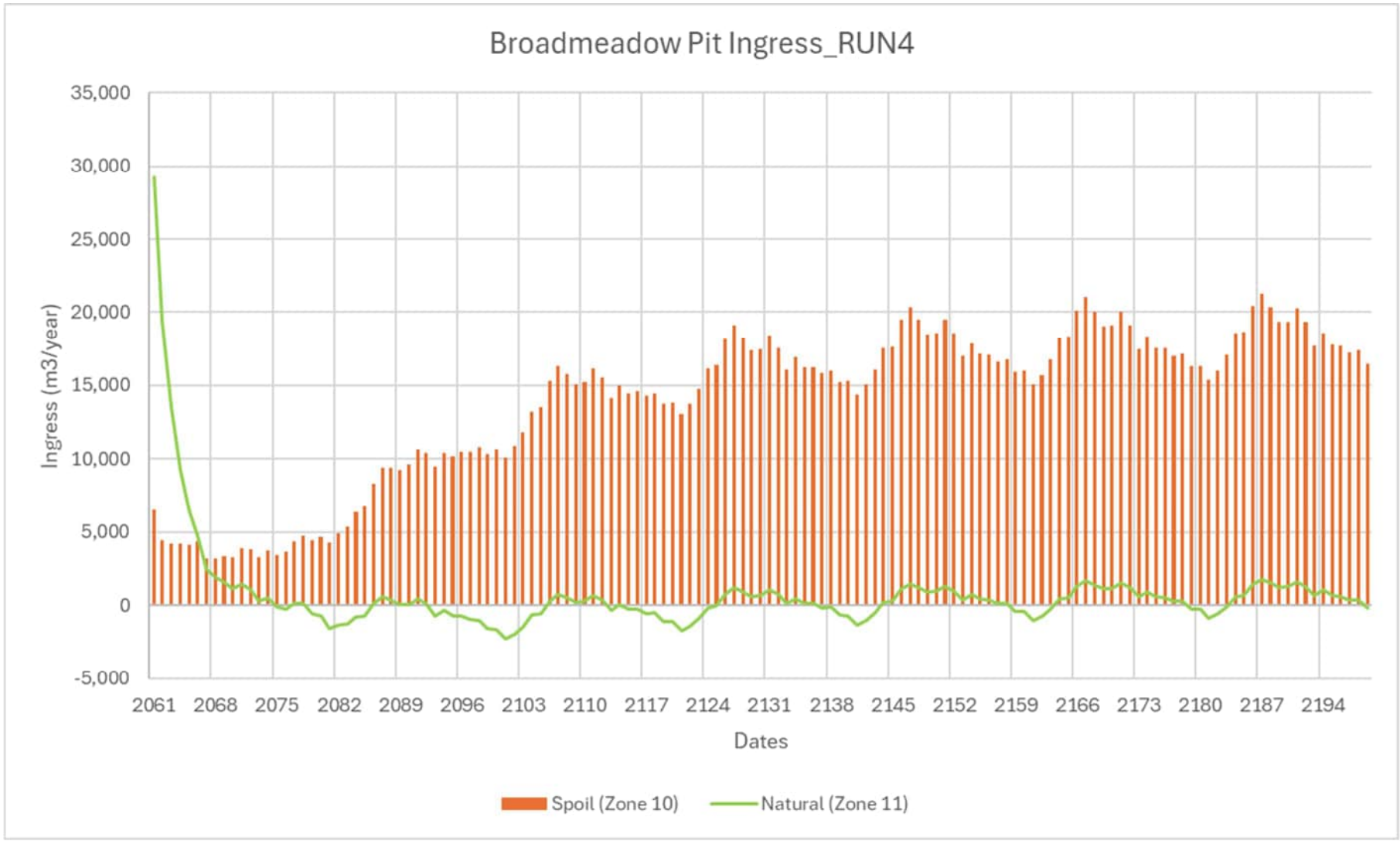
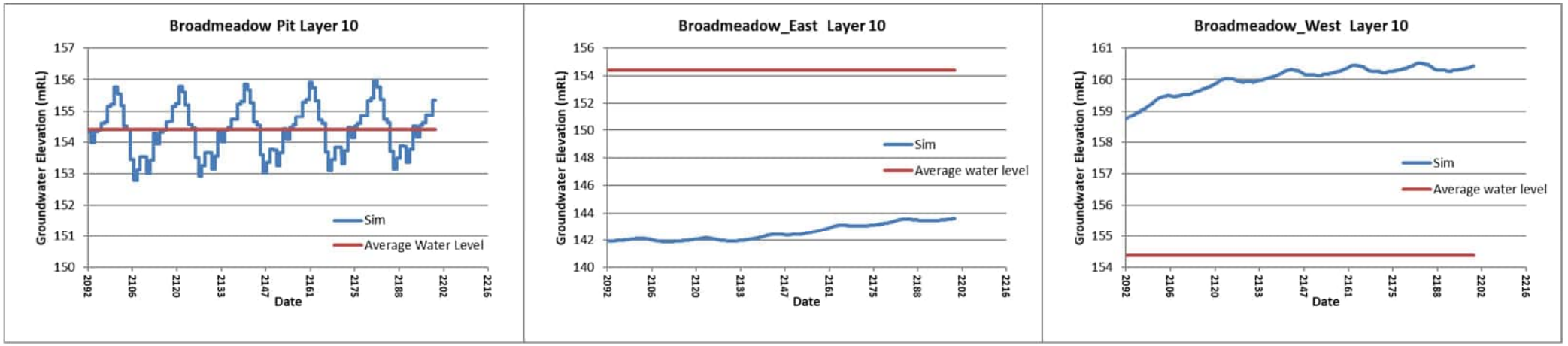


Figure 40 Broadmeadow Pit simulated water level hydrographs (2093 to 2199)



Where:

Broadmeadow Layer 10 provides predictions of residual void water level (red line is the average pit water level for reference)

Broadmeadow_East Layer 10 provides (simulated (sim)) groundwater levels in the GMS seam down dip of Broadmeadow Pit

Broadmeadow_West Layer 10 provides (simulated (sim)) groundwater levels in the GMS seam up dip of Broadmeadow Pit

15.4.2.2 Isaac Pit

The groundwater model zone budget indicates that water from within Isaac Pit flows into both the spoil to the west of the pit and the natural surrounding units (Plate 34). Groundwater flux into the pit is minimal and no ingress from the unmined geology to the east is predicted.

Hydrographs of hypothetical observation points in the model (as per Broadmeadow Pit) were generated to assess the water levels in the pit and in groundwater 100 m up and down dip (west and east) of the pit. These water level hydrographs (Figure 41) indicate:

- A pseudo-steady residual void water level of 179.5 mAHD
- Groundwater levels in the GMS to the west (up dip) are some 179.5 mAHD (potential for flow in and out of the pit, albeit net flux is outward)
- Groundwater levels in the GMS to the east (down dip) are some 177 mAHD (facilitating flow outward from the pit).

Plate 34 Isaac pit net groundwater flux predictions

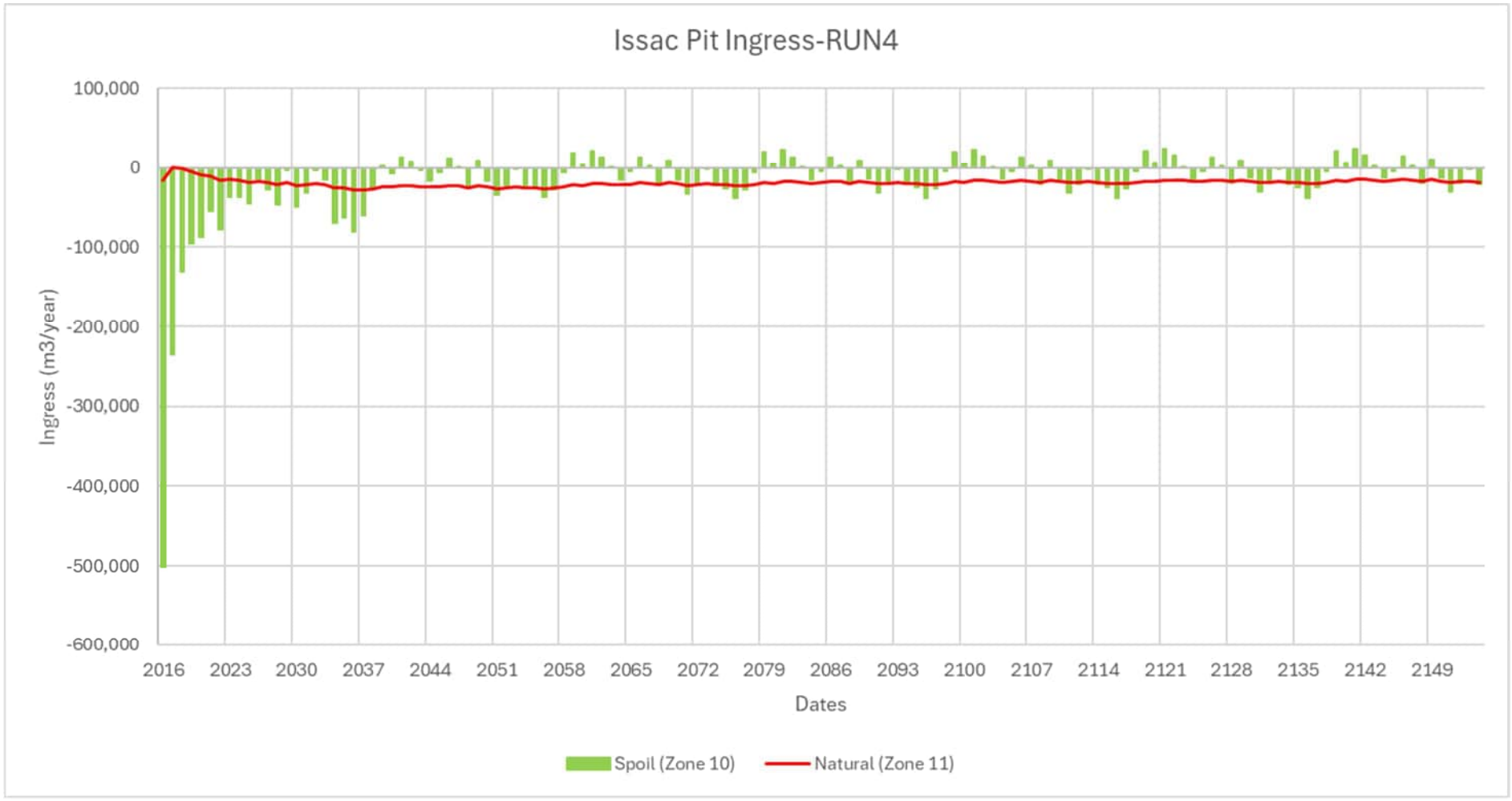
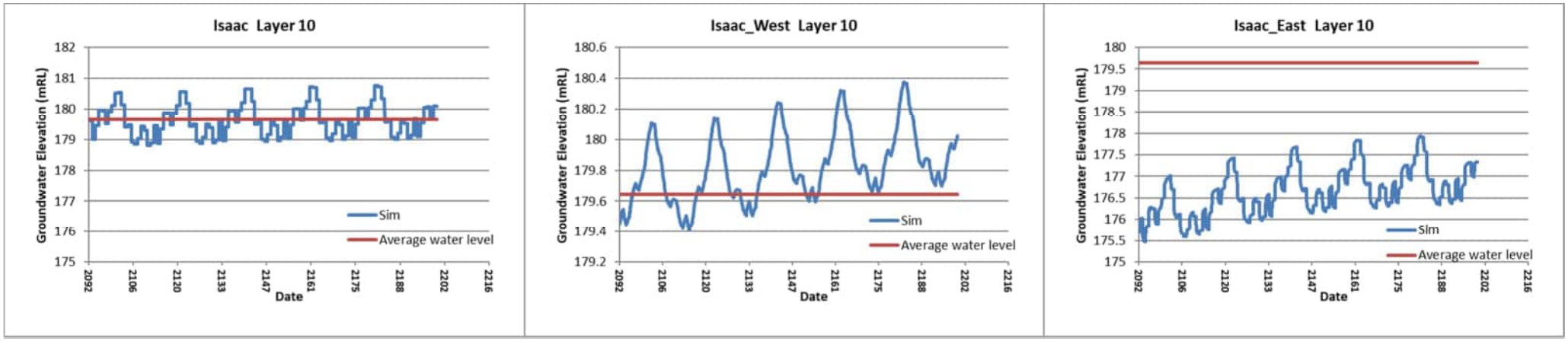


Figure 41 Isaac Pit simulated water level hydrographs (2093 to 2199)



Where:

Isaac Layer 10 provides predictions of residual void water level (red line is the average pit water level for reference)

Isaac_West Layer 10 provides predicted groundwater levels in the GMS seam up dip of Isaac Pit

Isaac_East Layer 10 provides simulated groundwater levels in the GMS seam down dip of Isaac Pit

15.4.2.3 Thiess Pit

The groundwater model zone budget indicates that water from within this pit flows into both the spoil to the west (up dip) of the pit and the surrounding natural units (Plate 35). Groundwater flow into the pit is minimal and no ingress from the unmined natural geology to the east is predicted.

Hydrographs of hypothetical observation points in the model were generated to assess the groundwater elevations 100 m up and down dip (west and east) of the pit and pit water levels. Due to the large extend of Thiess Pit, three locations along the large pit were selected for the inclusion of hypothetical observation points were included in the model to obtain simulated water level data. These water level hydrographs (Figure 42) indicate:

North

- Pseudo-steady residual void water level at 203 mAHD
- Groundwater levels to the west (up dip) are some 201 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 203 mAHD (flow in and out of the pit albeit net flux is outward).

Central

- Pseudo-steady water level in the residual void is predicted to be around 203 mAHD
- Groundwater levels to the west (up dip) are some 193 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 192 mAHD (facilitating flow out of the pit).

South

- Pseudo-steady water level in the residual void is predicted to be around 203 mAHD
- Groundwater levels to the west (up dip) are some 194 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 187 mAHD (facilitating flow out of the pit).

Plate 35 Thiess pit net groundwater flux predictions

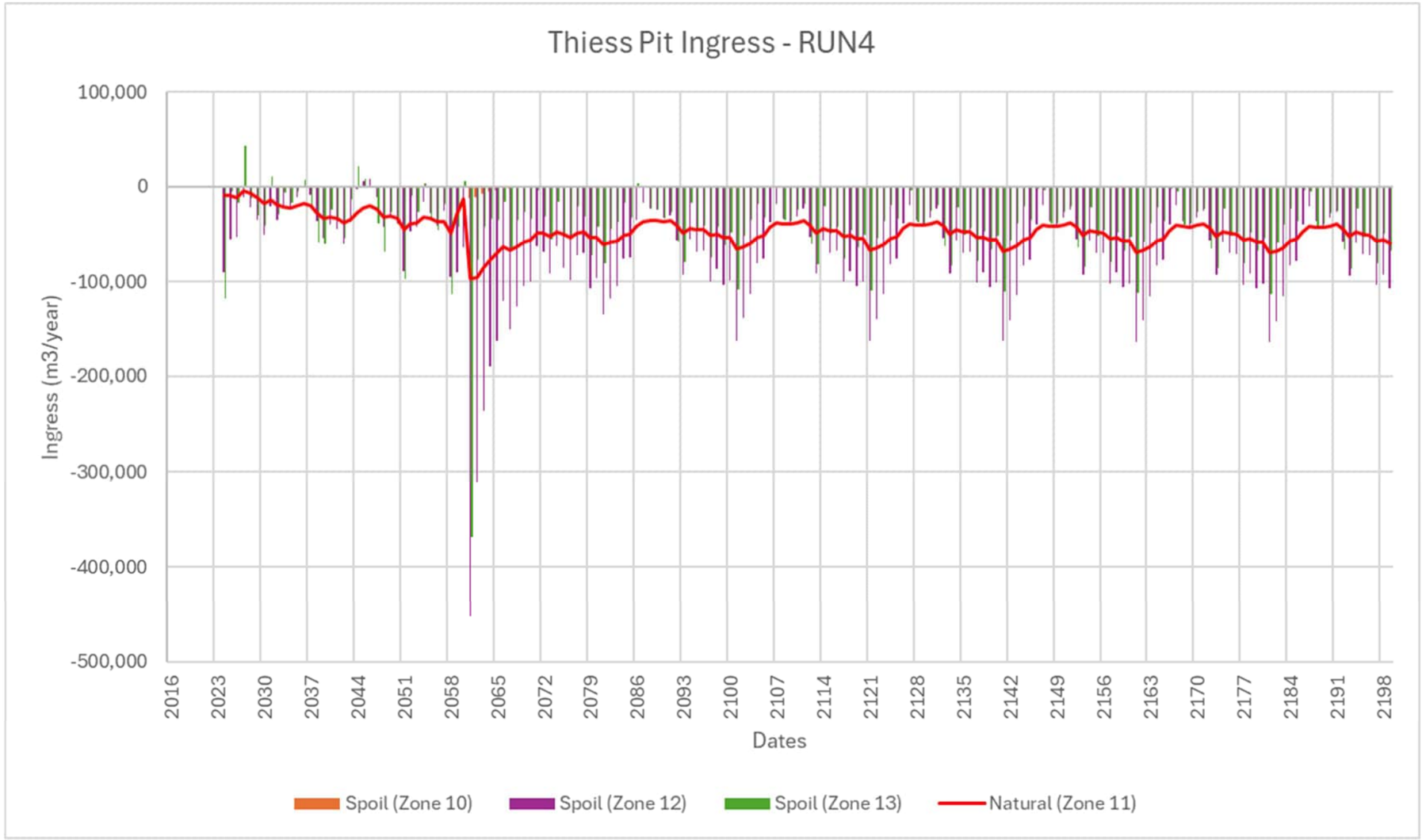
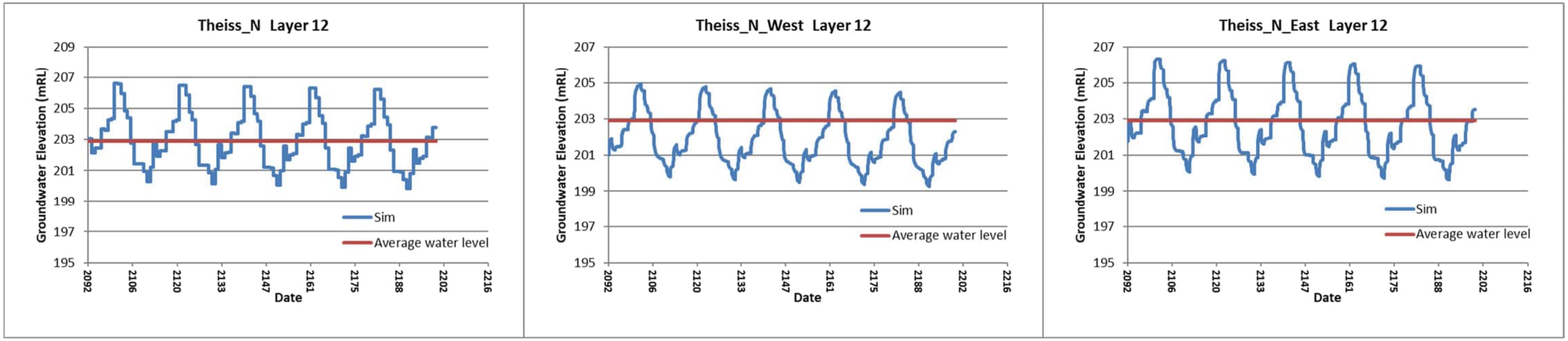
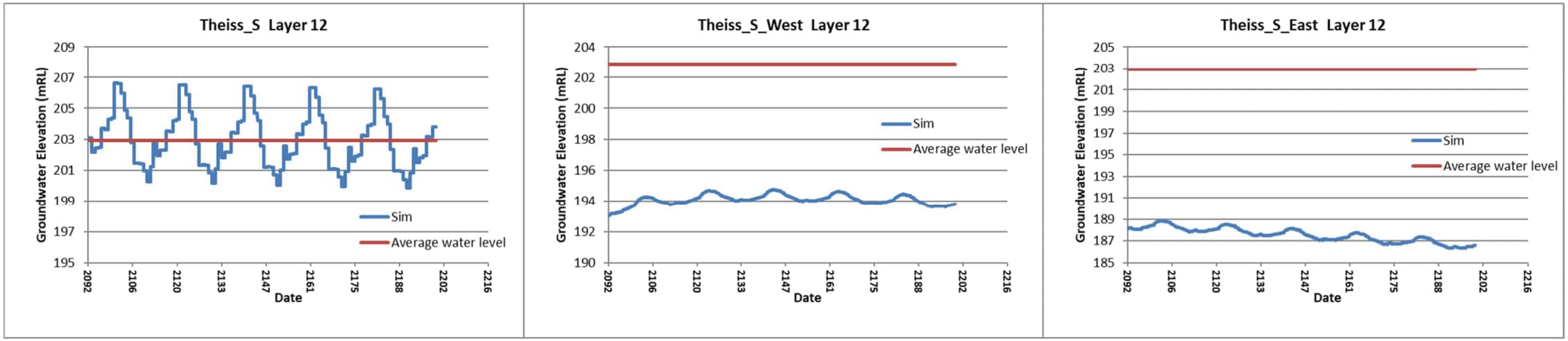


Figure 42 Thiess Pit hydrographs (2093 to 2199) north, central and south





Where:

Theiss N, Theiss C, and Theiss S provide predictions of residual void water level in the north, central, and southern portions of Thiess Pit, respectively

Theiss N West, Theiss C West, and Theiss S West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Thiess Pit in the north, central, and southern portions of Thiess Pit, respectively

Theiss N East, Theiss C East, and Theiss S East Layer 12 provides predicted groundwater levels in the GLS seam down dip of Thiess Pit in the north, central, and southern portions of Thiess Pit, respectively

The red line is the average pit water level for reference

15.4.2.4 Ramp 32 East Pit

The groundwater model zone budget indicates that this pit acts as a groundwater "sink", where groundwater from the surrounding natural rock flows into the residual void (Plate 36). Groundwater out of the pit is minimal and no ingress from the surrounding spoil is predicted.

Hydrographs of hypothetical observation points in the model were generated to assess the water levels in the pit and 100 m up and down dip (west and east) of the pit. These water level hydrographs (Figure 43) indicate:

- Pseudo-steady water level in the residual void is predicted to be around pit water 162 mAHD
- Groundwater levels to the west (up dip) are some 169 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 162.5 mAHD (facilitating flow into the pit).

Plate 36 Ramp 32 East pit groundwater flux predictions

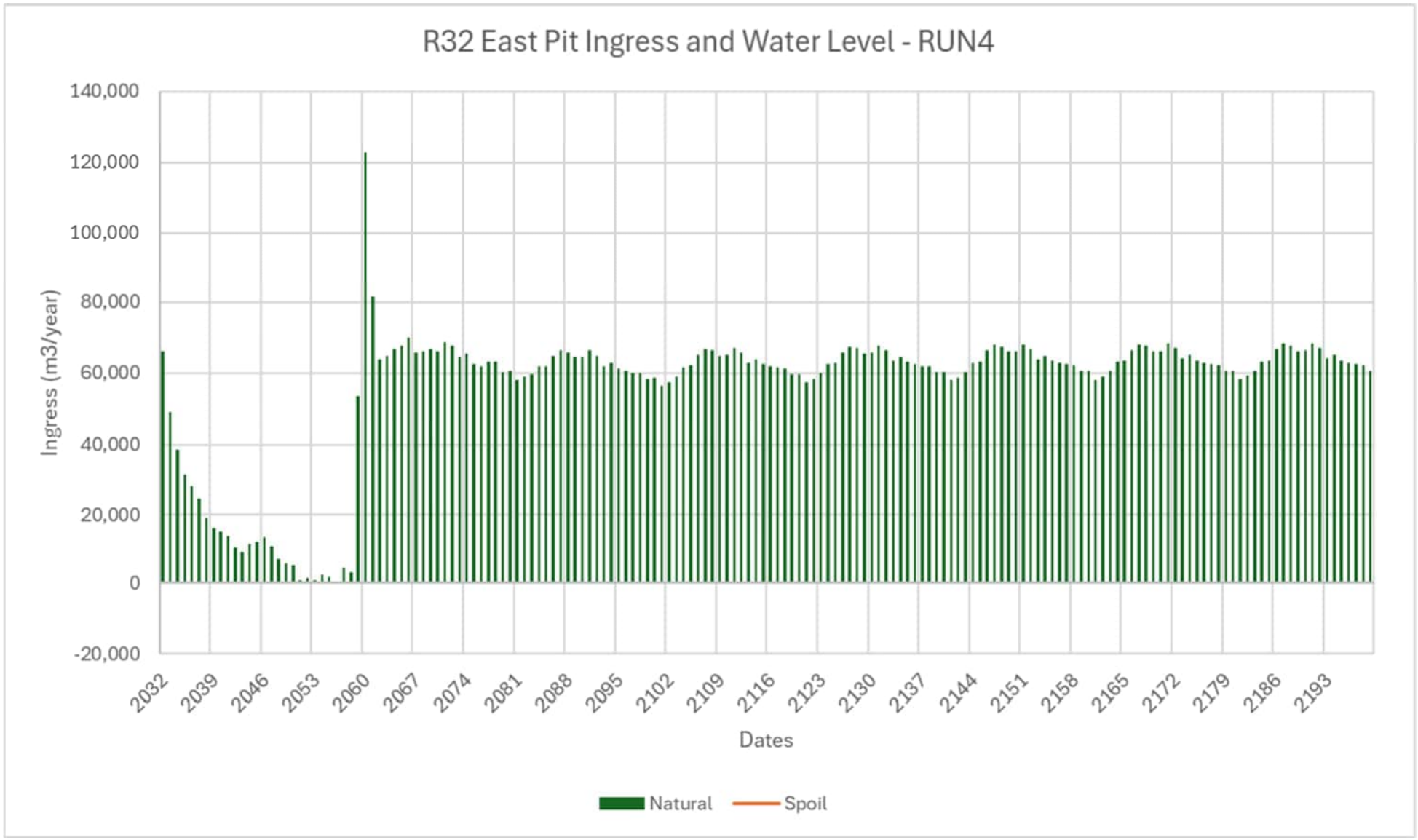
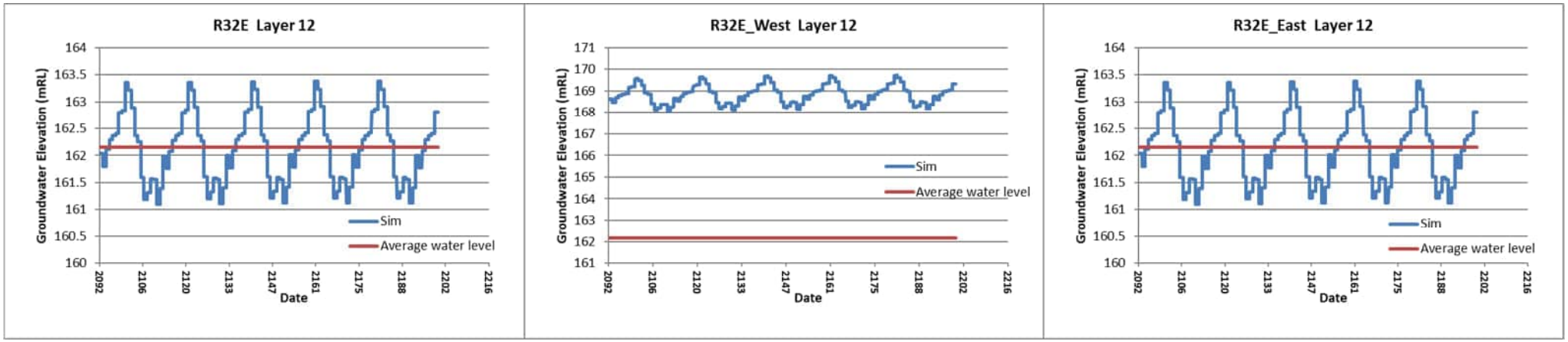


Figure 43 Ramp 32 East Pit hydrographs (2093 to 2199)



Where:

R32E Layer 12 provides predictions of Ramp 32 East residual void water level

R32E_West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Ramp 32 East Pit

R32E_East Layer 12 provides simulated groundwater levels in the GLS seam down dip of Ramp 32 East Pit

The red line is the average pit water level for reference

15.4.2.5 Ramp 32 South Pit

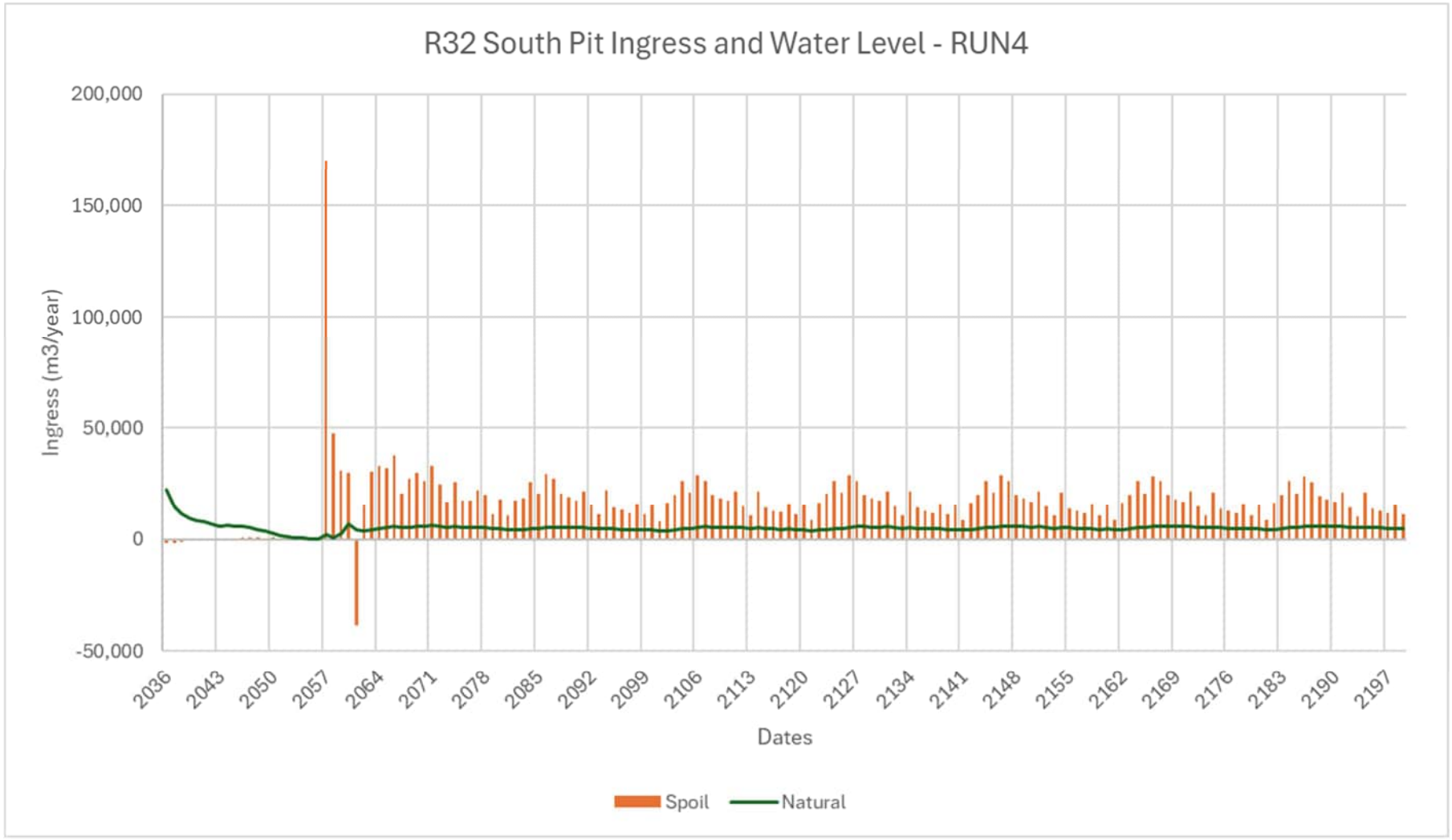
The groundwater model zone budget indicates that this pit acts as a groundwater “sink”, where groundwater from the surrounding natural rock flows into the residual void (Plate 37). Groundwater flow out of the pit is limited with ingress from the surrounding spoil and natural geology predicted.

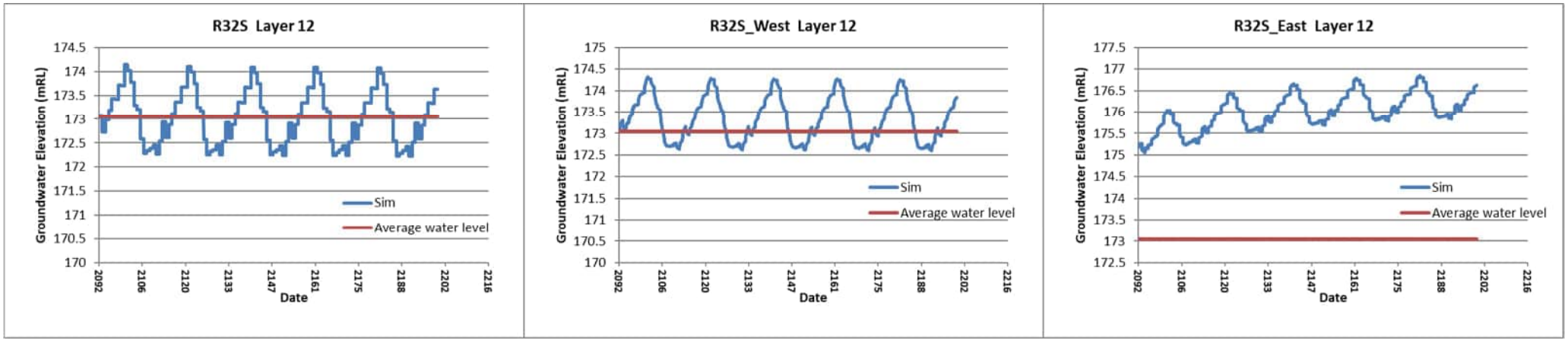
Hydrographs of hypothetical observation points in the model were generated to assess the water elevations in the pit and 100 m up and down dip (west and east) of the residual void.

These water level hydrographs (Plate 37) indicate:

- Pseudo-steady water level in the residual void is predicted to be around pit water 173 mAHD
- Groundwater levels to the west (up dip) are some 173.5 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 176 mAHD (facilitating flow into the pit).

Plate 37 Ramp 32 South pit groundwater flux and hydrographs





Where:

R32S Layer 12 provides predictions of Ramp 32 South residual void water level

R32S_West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Ramp 32 South Pit

R32S_East Layer 12 provides simulated groundwater levels in the GLS seam down dip of Ramp 32 South Pit

The red line is the average pit water level for reference

15.4.2.6 Goonyella Pit

The residual void at the end of the Goonyella open cut mining extends along the eastern mine lease boundary and includes the deepest mining voids in GRB (some 325 m deep).

The groundwater model zone budget output indicates that this residual void acts as a groundwater "sink", where groundwater from the surrounding backfilled mine areas, residual voids (where outflow is predicted), and natural rock flow into the Goonyella residual void (Plate 38).

Hydrographs from hypothetical observation points east, west and within the void were generated at regular intervals along the length of the residual void, as indicated in Plate 39.

All of the water level hydrographs confirm that the Goonyella residual void acts as a groundwater sink and indicate that the pit water (compared to the surrounding groundwater levels) are markedly lower than the water level depths across the Project, as included in the hydrographs presented for all the other residual voids above.

<u>North</u>

- Pseudo-steady residual void water level is around 20 mAHD (> 100 m deeper than other residual void water levels)
- Groundwater levels to the west (up dip) are some 22 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 30 mAHD (facilitating flow into the pit).

Note: The pit floor is some -35 mAHD at this location, the pit floor adopted in the residual void (surface water) water balance model is set at a uniform -45 mAHD (it is assumed that the specialist modellers used the deepest pit floor elevation in their water balance model).

This results in the water level dip or decrease at the start of the water level hydrographs when the groundwater model drain cells (at bottom of pit) are changed to CHD and adopt the predicted water balance model pit water levels (Section 15.4.1). This dip in the water level hydrographs is recognised in all of the hypothetical observation point hydrographs. This is particularly evident in the middle set of hydrographs where the Goonyella open cut mine only extends to a depth of around 25 mAHD in this area (mining is shallower in this area due to environmental constraints in this area).

The predictive groundwater model recovery over the long term allows for the prediction of pseudo-steady state water levels over time. This allows for the evaluation of post-closure conditions (groundwater levels, residual void levels, and groundwater flow patterns). This indicates that the difference in the start (depth of pit water level) does not influence the Goonyella residual void acting as a sink in the long term.

Plate 38 Goonyella Pit groundwater flux

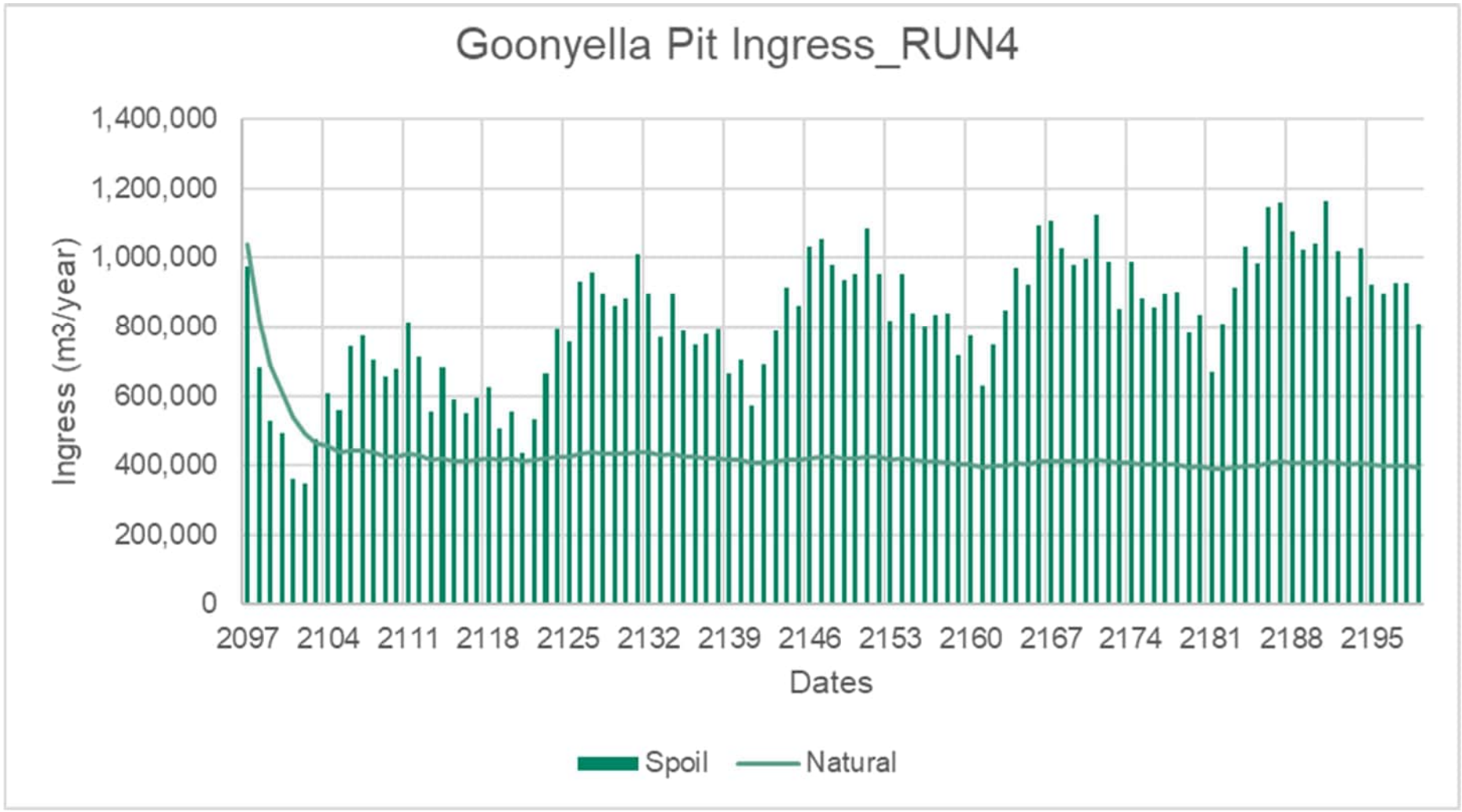
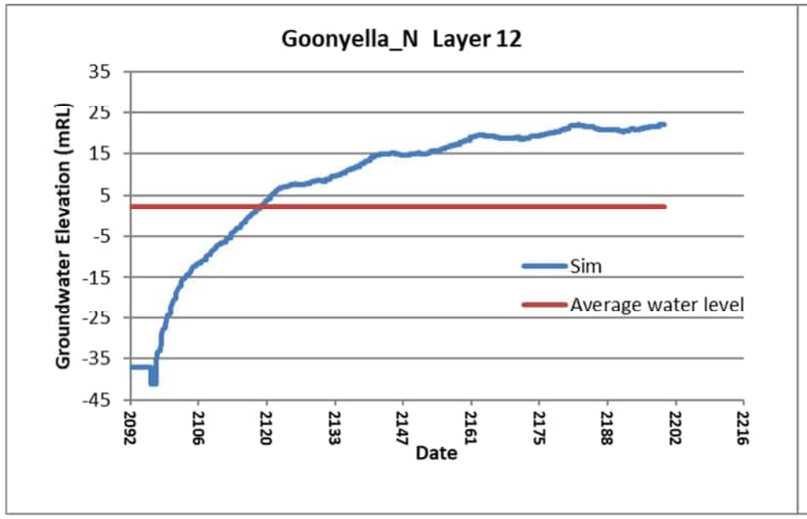
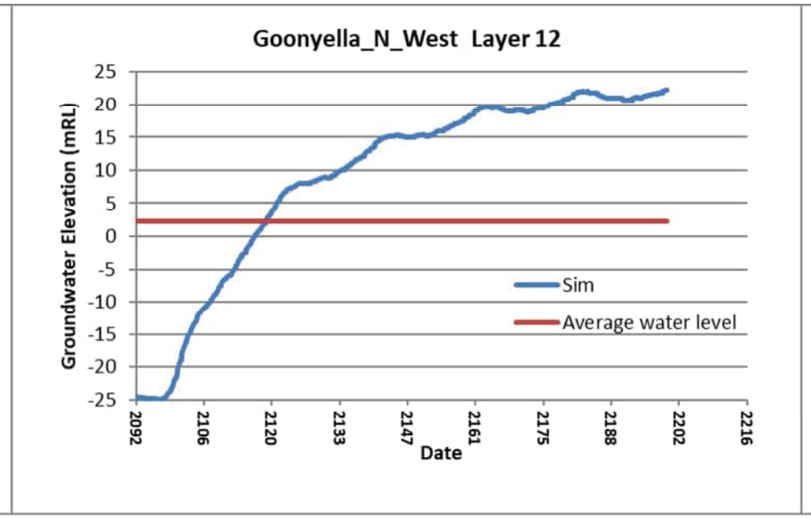
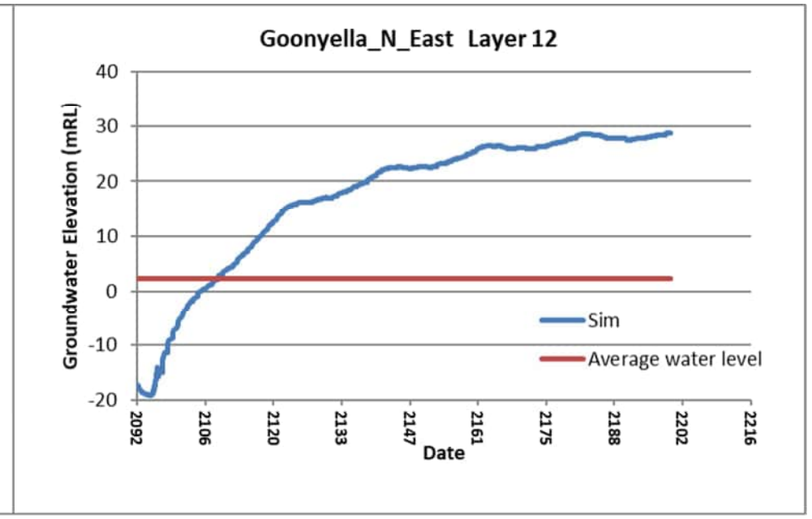
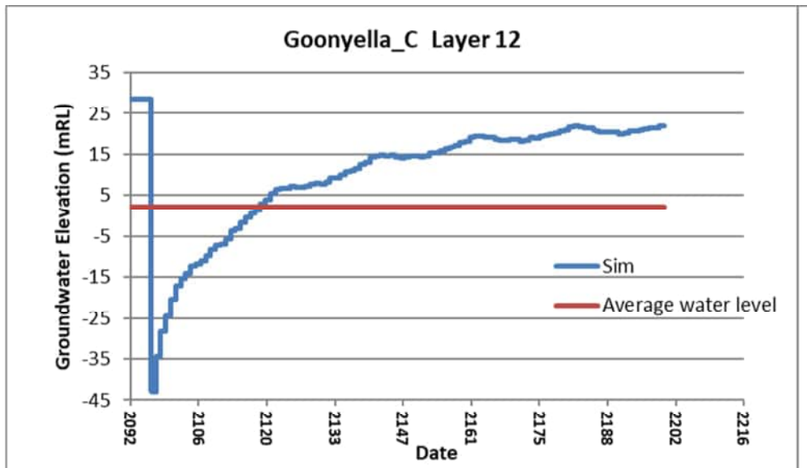


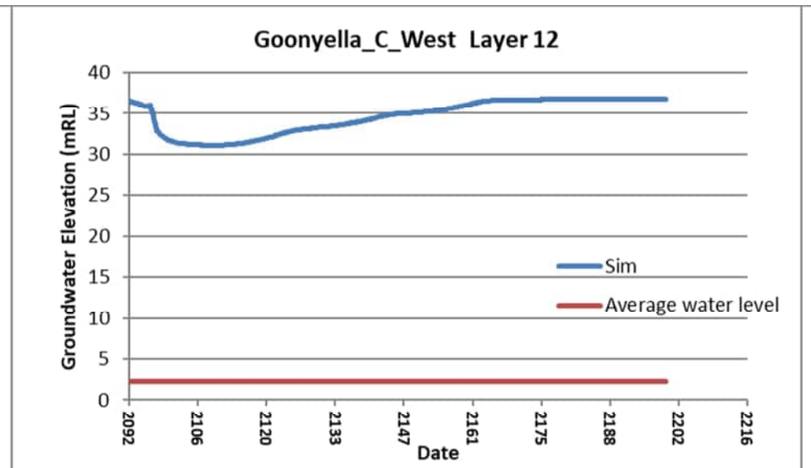
Plate 39 Goonyella pit hydrographs

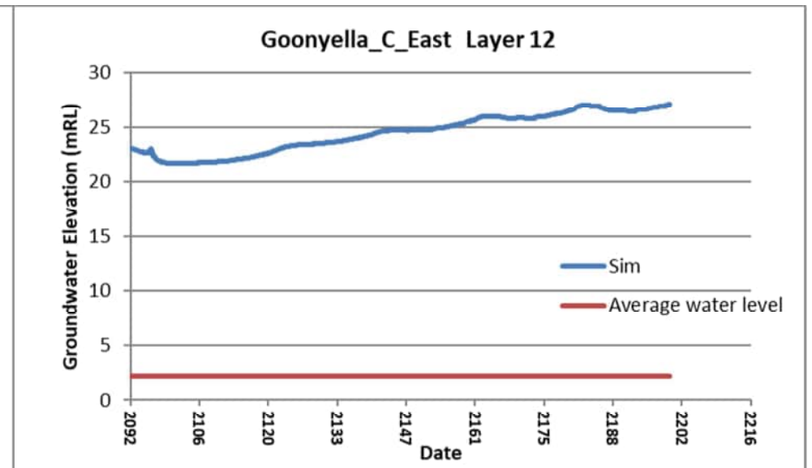


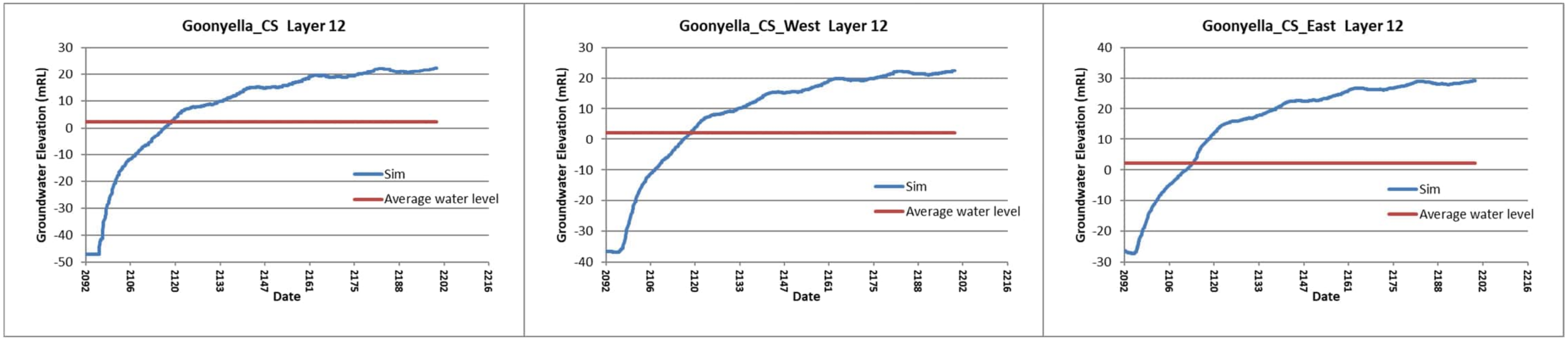












Where:
Goonyella_N (north), Goonyella_C (middle), Goonyella_CS (central), and Goonyella_S (south) Layer 12 provide predictions of water levels in the north, middle, central, and south portions of the Goonyella residual void, respectively
Goonyella_N West, Goonyella_C West, Goonyella_CS West, and Goonyella_S West Layer 12 provide predictions of water levels up dip of the north, middle, central, and south portions of the Goonyella residual void, respectively
Goonyella_N East, Goonyella_C East, Goonyella_CS East, and Goonyella_S East Layer 12 provide predictions of water levels down dip of the north, middle, central, and south portions of the Goonyella residual void, respectively
The red line is the average pit water level for reference

Middle

- Pseudo-steady residual water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 36 mAHD (flow into the pit)
- Groundwater levels to the east (down dip) are some 27 mAHD (flow into the pit).

Note: The change from actual drawdown in the shallower portion of the Goonyella Pit in this area and the adopting of the CHD to match the residual void water balance pit levels (Section 15.4.1) results in the decrease in water levels to the west and east of the pit, due to sudden dewatering (dropping the level to match the uniform -45 mAHD obtained from the residual void water balance model). This will not occur in reality. As per the statement included above the difference in the start (depth of pit water level) does not influence the Goonyella residual void acting as a sink in the long term.

Central

- Pseudo-steady residual void water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 20 mAHD (flow into the pit)
- Groundwater levels to the east (down dip) are some 30 mAHD (facilitating flow into the pit).

South

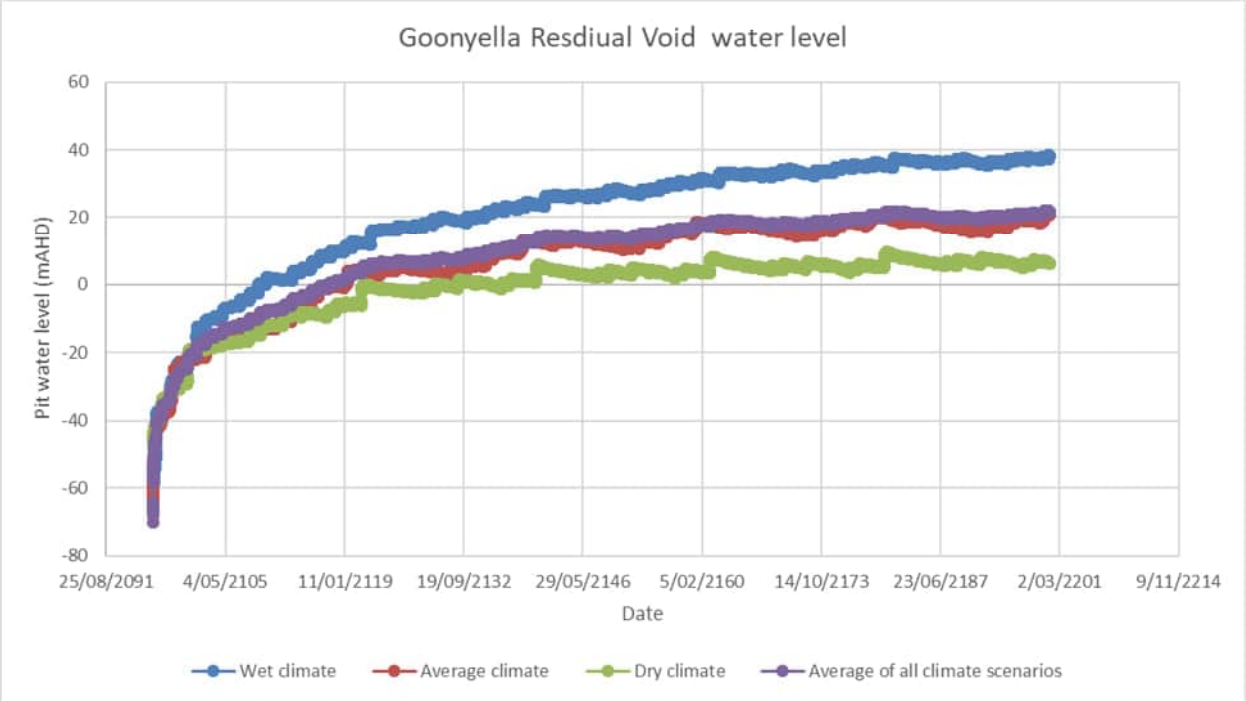
- Pseudo-steady pit water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 35 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 33 mAHD (facilitating flow into the pit).

15.4.3 Residual void water levels

The residual void water balance modelling included for wet, average, and dry climate conditions as inputs into the model predictions, this allowed for an assessment of variability in the residual void water levels and assessment of potential for decant and void water migration.

An example of the variation in the residual void water level, for the Goonyella residual void, is included in Figure 44.

Figure 44 Goonyella residual void predicted water level (WSP water balance model)



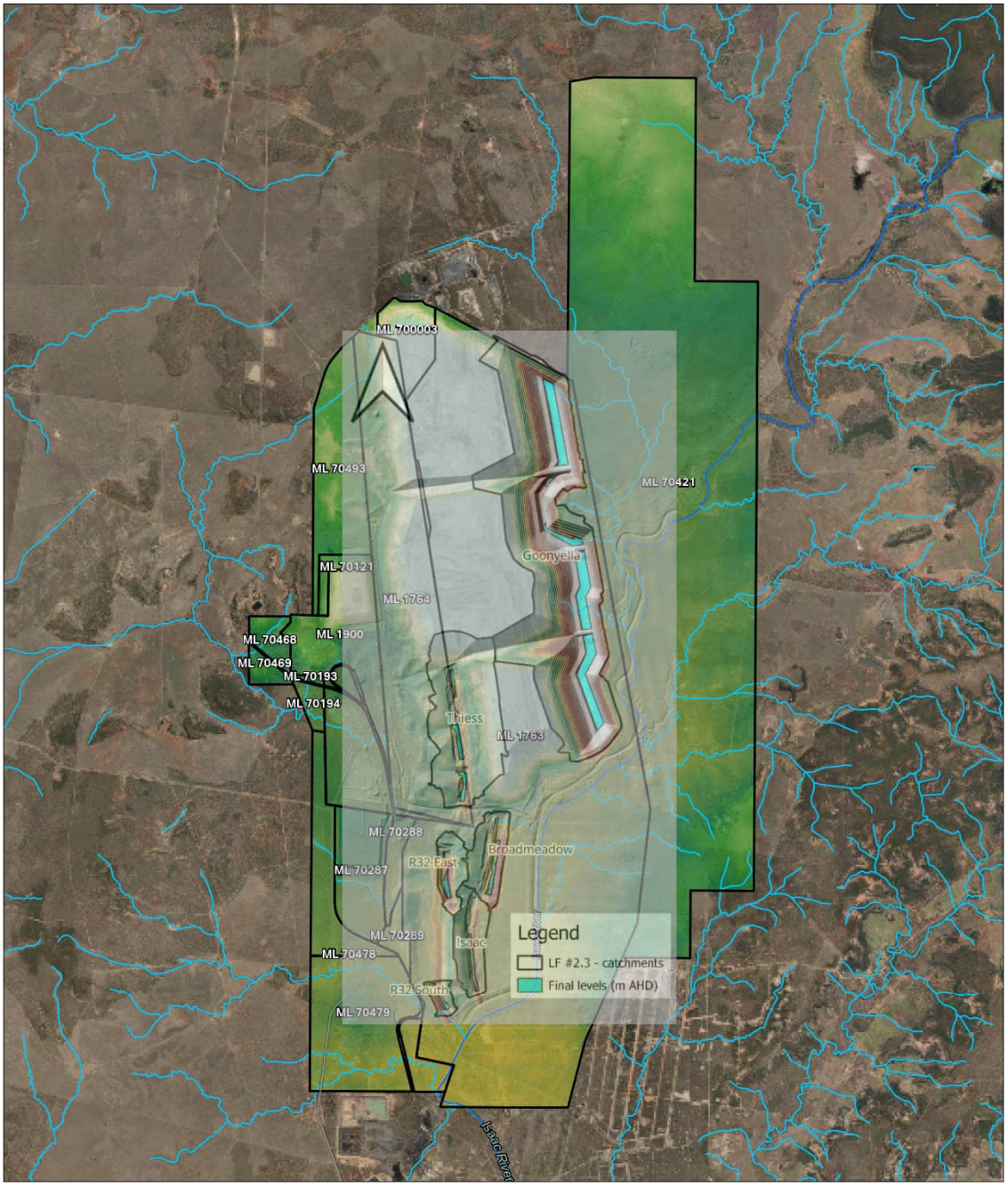
The void water level resulting from the average of the climate scenarios was adopted for the groundwater model predictions.

To allow for the potential variability of the residual void water levels with regards to the groundwater flux component an assessment of groundwater contribution into the water balance was conducted (Section 16.3.1).

An uncertainty analysis of the groundwater flux predictions was then conducted to allow for a validation of residual voids acting as sources or sinks as well as a more detailed evaluation of potential for void water migration within the groundwater. These groundwater flux assessments are included in Section 16.3.

A depiction of the residual void water levels post-closure associated with Landform #2.3 is included in Figure 45.

Figure 45 GRB residual voids containing water post-closure (source: WSP, 2024)


ML 700003
ML 70493
ML 70421
Goonyella
ML 70121
ML 1764
ML 1900
ML 70468
ML 70469
ML 70193
ML 70194
Thiess
ML 1763
ML 70288
Broadmeadow
R32 East
ML 70287
ML 70289
Isaac
ML 70478
R32 South
ML 70479
Isaac River
Legend
LF #2.3 - catchments
Final levels (m AHD)
Goonyella, Redhill and Broadmeadow Mines
Post Mining Landform (Landform #2)
Mine Lease
Major
Minor
Landform 2
Elevation (mAHD)
401
-71
0 1 2 3 km
1:100,000
Mackay
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15.5 Predicted Groundwater Levels

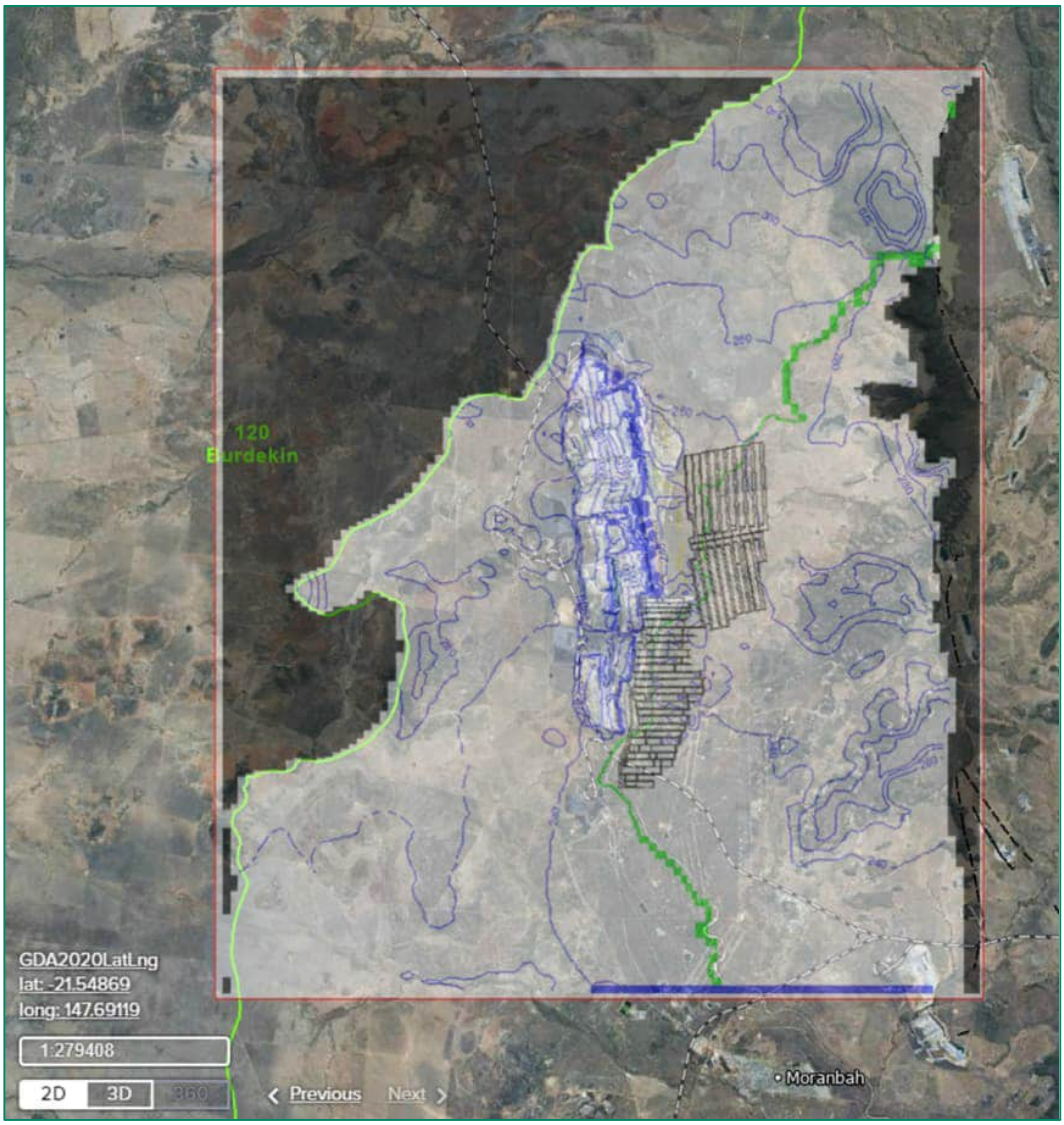
Groundwater level changes during the predictions periods were compiled and assessed to understand the change in groundwater flow patterns and gradients as a result of active (mine dewatering), the introduction of water into the underground workings, and passive (seepage ingress into) plus artificial recharge from residual pits which contain pit water.

Groundwater contours over time assisted with flow path simulations (using particle tracking) in Section 15.6 and understanding changes at receptors (Section 15.8).

Section 15.1 describes the groundwater elevation estimated for the start of model predictions in 2024. The groundwater elevation data indicates the groundwater contours, flow patterns and gradients that are predicted to occur across the model domain in 2024.

Complex mine activities detailed in Section 15.2 indicate the dewatering and recharge activities over time that will determine the groundwater levels at the end of mining activities, in 2097. The closure (end of all mining activities at GRB and RHM) groundwater levels and flow patterns are predicted post 2097 within prediction period P4 (Section 15.2).

Note: As reference the modelled contours include for the entire model domain as included in Plate 16 and Section 15.1 and presented below.



15.5.1 Water level change in the surficial cover

The drawdown and recovery of the groundwater levels in Model Layer 1 (Table 18), which includes surficial cover either alluvium or Tertiary sediments, was predicted based on the calibration groundwater elevations at the start of prediction period P1.

The changes at the end of each of the prediction phases including the end of P4 (considered representative of closure after an extended period of recovery, 2199) are included in Figure 46.

The water level change from 2024 over time indicates:

- Limited change over time (limited expansion or contraction of the extent of drawdown around the residual voids from P2 to P4)
- No change to the zero (no drawdown) contour across the Issac River (green model cells)
- The extent of drawdown in Model Layer 1, when comparing groundwater drawdown contours (location and extent) in 2024 (derived from calibration for start of predictions) reduces and then is recognised to stabilise over time (end of P3 and end of P4).

15.5.2 Water level change in the GMS target coal seam

The drawdown and recovery of the groundwater levels in the GMS (Model Layer 10, Table 18), was assessed based on the change in groundwater levels relative to levels derived at the start of P1.

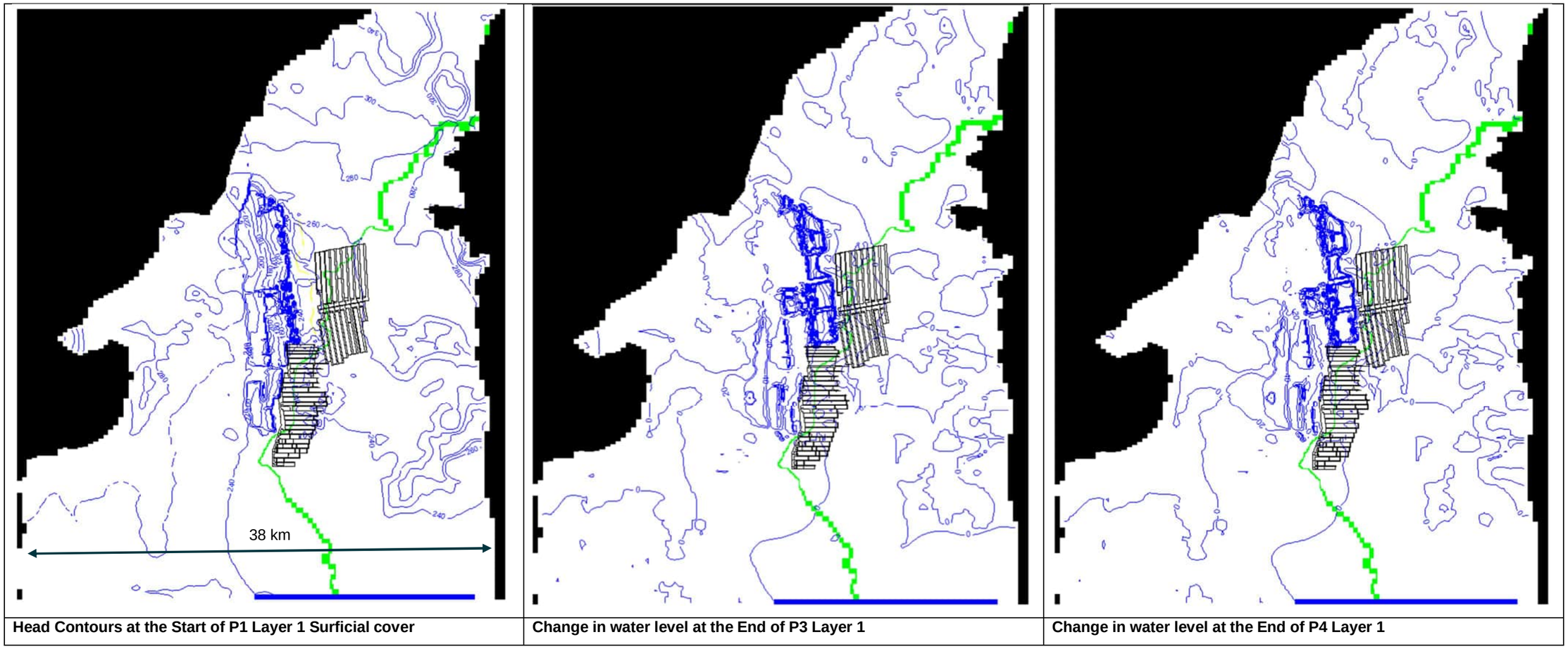
The changes at the end of each of the prediction phases including the end of P4 (considered representative of closure after an extended period of recovery, 2199) are included in Figure 47.

The water level change over time indicates:

- The influence of RHM is evident in P3 water levels, resulting in larger drawdown
- Water introduced into the underground workings reduces the RHM drawdown to the east, as evident in P4 drawdown contours
- Water levels in portions of the Broadmeadow GMS workings do not recover to the 2024 (P1) levels, even after the introduction of water, due to the proximity to the Broadmeadow, Isaac, and Goonyella residual voids, which continue to remove water from the system
- The GMS dewatering is not predicted to result in induced flow from the Tertiary and Back Creek Group to the west of the mining areas.

To assist in comparing the change in water levels from mining activities (mining, rehabilitation, decommissioning, and water introduction during the prediction periods) to post-closure the difference in water level (rise and fall) is included in Plate 40.

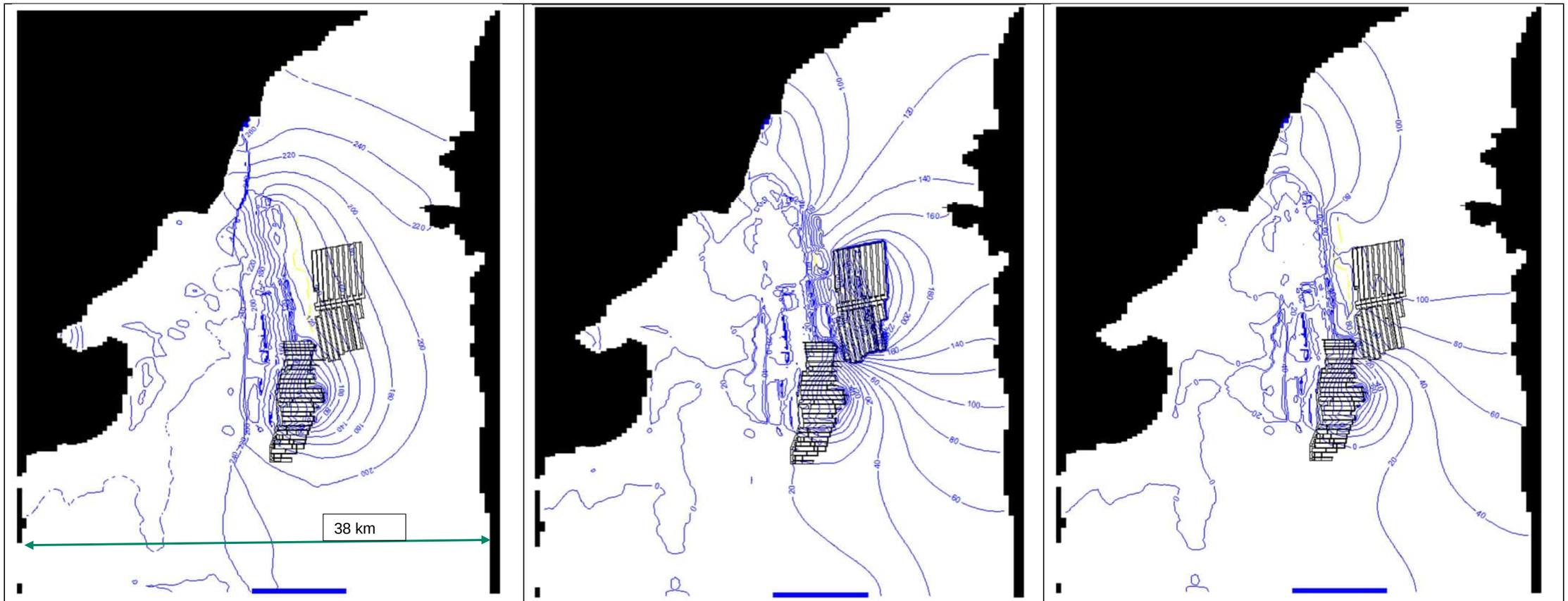
Figure 46 Initial groundwater elevation at start of P1 and change in water level (in m) at end of P3 and P4 in Model Layer 1



Head Contours at the Start of P1 Layer 1 Surficial cover	Change in water level at the End of P3 Layer 1	Change in water level at the End of P4 Layer 1

Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

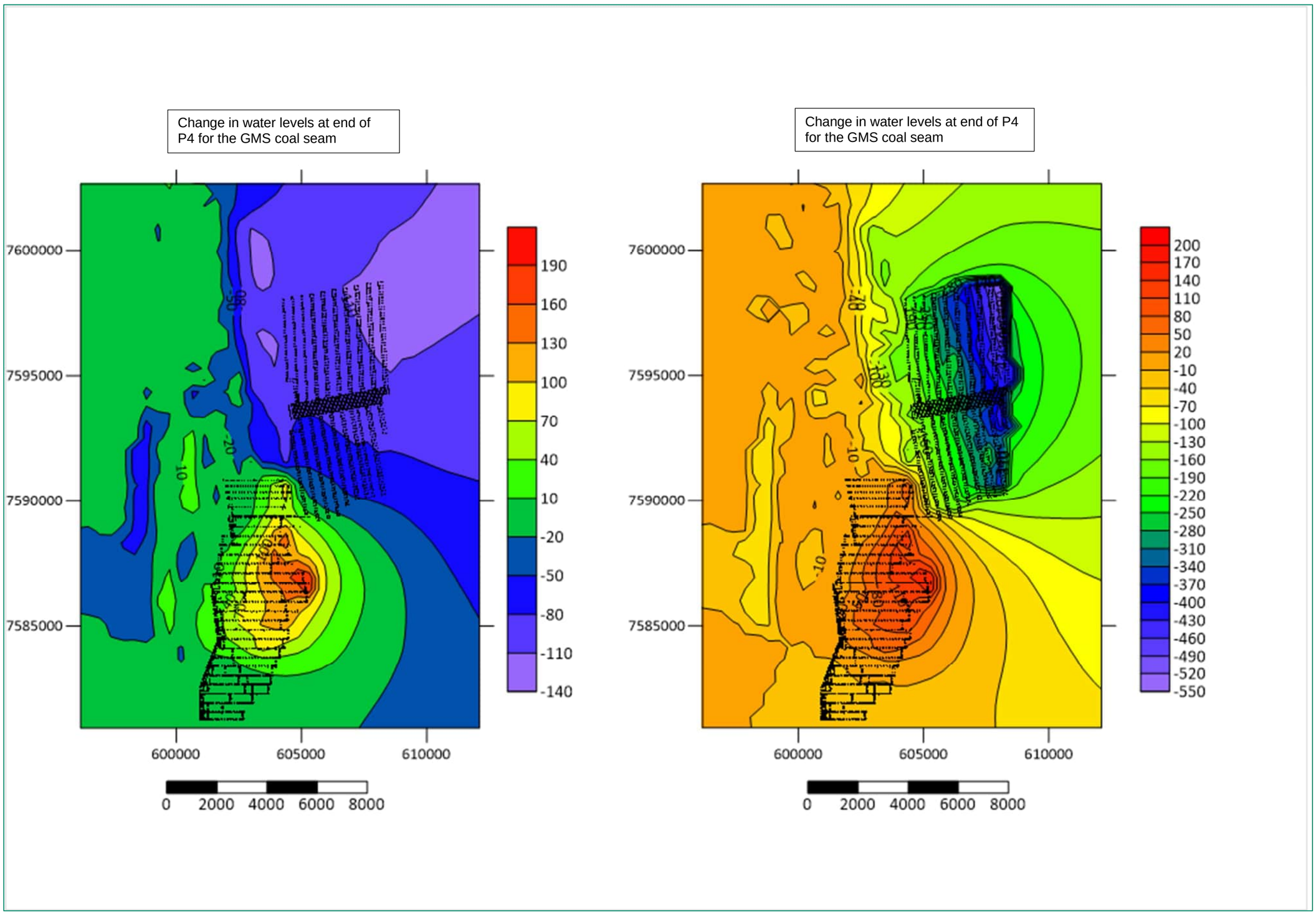
Figure 47 Groundwater elevations at start of P1 and water level change end of P3 and P4 (in m)in Model Layer 10 GMS

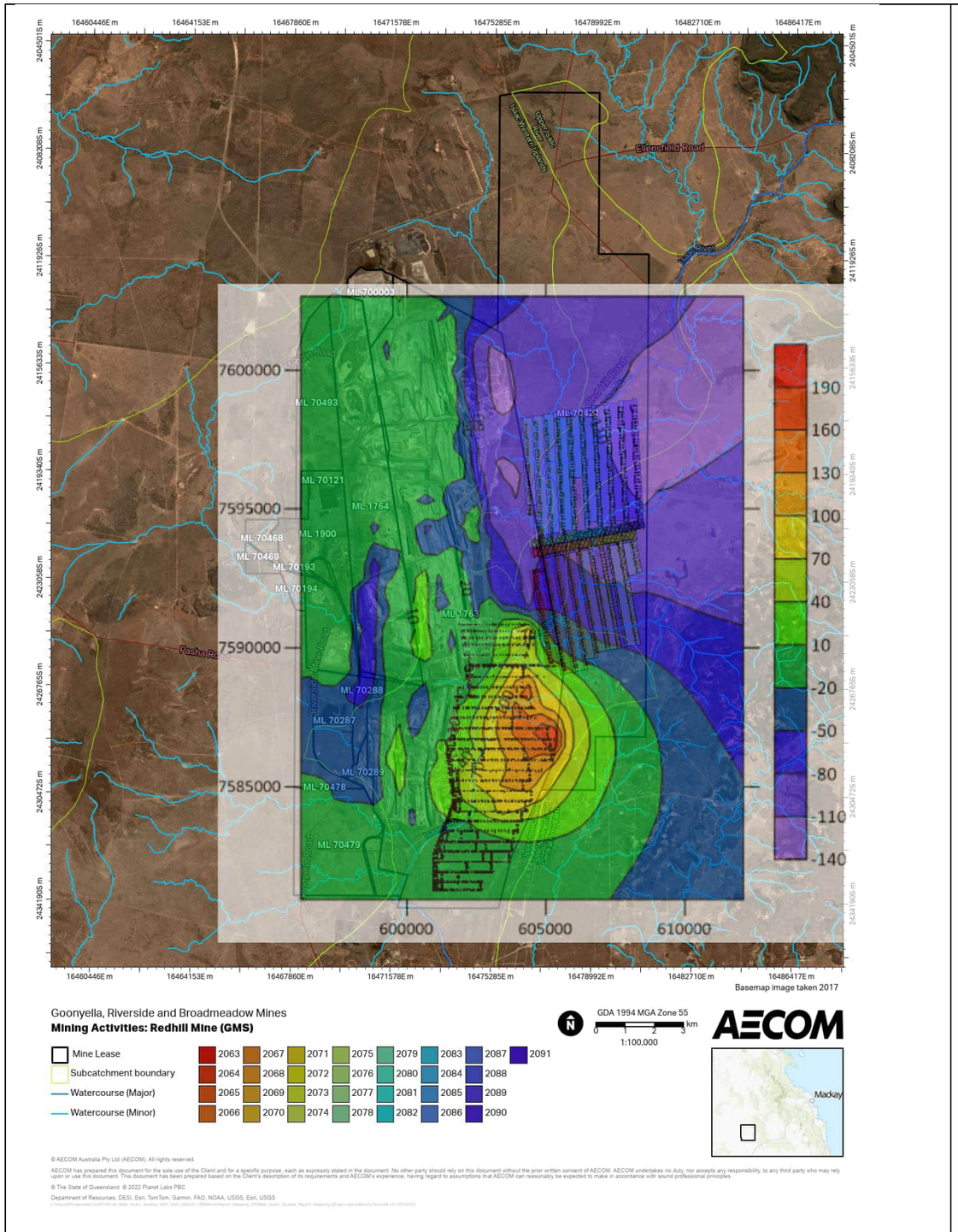


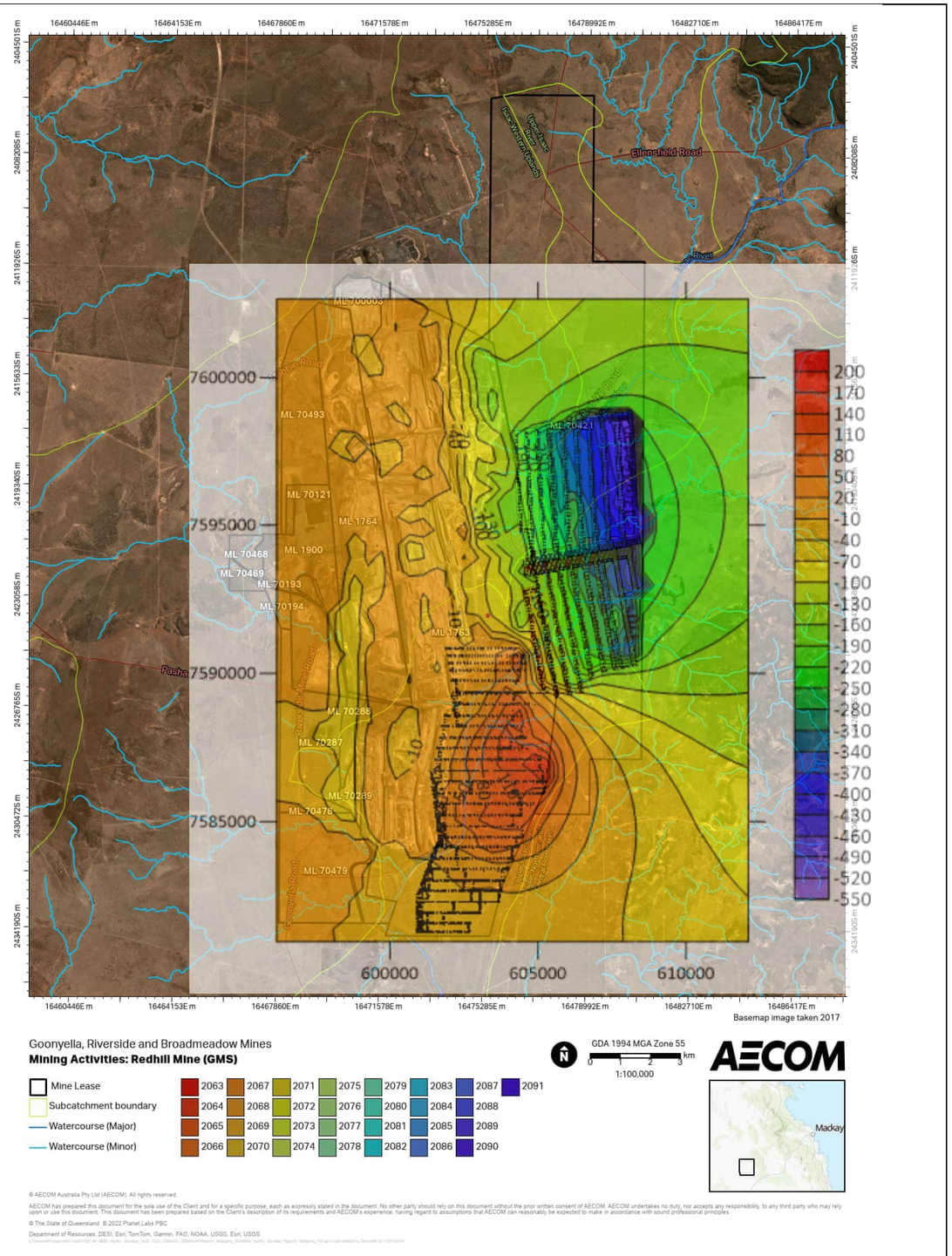
Head Contours at the Start of P1 Layer 10, GMS	Change in water level at the End of P3 Layer 10, GMS	Change in water level at the End of P4 Layer 10, GMS

Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

Plate 40 GMS water level difference from the initial groundwater heads at start of P1 (water level change in m)







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The predictive modelling, considering change in groundwater levels from the 2024 initial calibrated elevations, indicate:

- The drawdown in GMS at the end of P3 2092, at the end of Red Hill Mine mining, is up to 550 m at the deepest part of the Red Hill Mine (Plate 40).
    - The drawdown below the initial groundwater levels (P1) ranged from +200 m (water introduced into Broadmeadow GMS) and – 550 m (deepest mine workings in RHM) at the end of P3.
- During P4 the Red Hill Mine is filled with water plus recovery and groundwater stabilisation occurs, as included in the P4 predictions at the end of 2199 (Figure 47).
- The water level change from P1 levels in GMS at the end of P4 2199 (prolonged recovery and stabilisation after mining and the introduction of water) range from +190 m (water introduced into Broadmeadow GMS) and -140 m (in proximity to the Goonyella residual void).
    - Water introduced into the Broadmeadow GMS underground workings caused a 200 m change (rise) in 2092, which decreased slightly to 190 m in 2199. This reduction is related to the Goonyella residual void.

15.5.3 Water level change in the GLS target coal seam

The drawdown and recovery of the groundwater levels in the GLS (Model Layer 12, Table 18), was predicted based on changes relative to the initial groundwater levels and contours derived during model calibration and included at the start of prediction period P1.

The water level changes at the end of each of the prediction phases including the end of P4 (considered representative of post-closure after an extended period of recovery, 2199) are included in Figure 48.

The water level comparison to start of P1 over time indicates:

- The influence of RHM is evident in P3 water level change
- The introduction of water reduces the RHM drawdown to the east, as evident in P4 drawdown contours
- Broadmeadow GLS is not readily drawn down after water introduced into the underground workings, even due to the proximity to the Goonyella residual void
- GLS dewatering is not predicted to result in induced flow from the Tertiary and Back Creek Group to the west of the mining areas (0 m water level change contours).

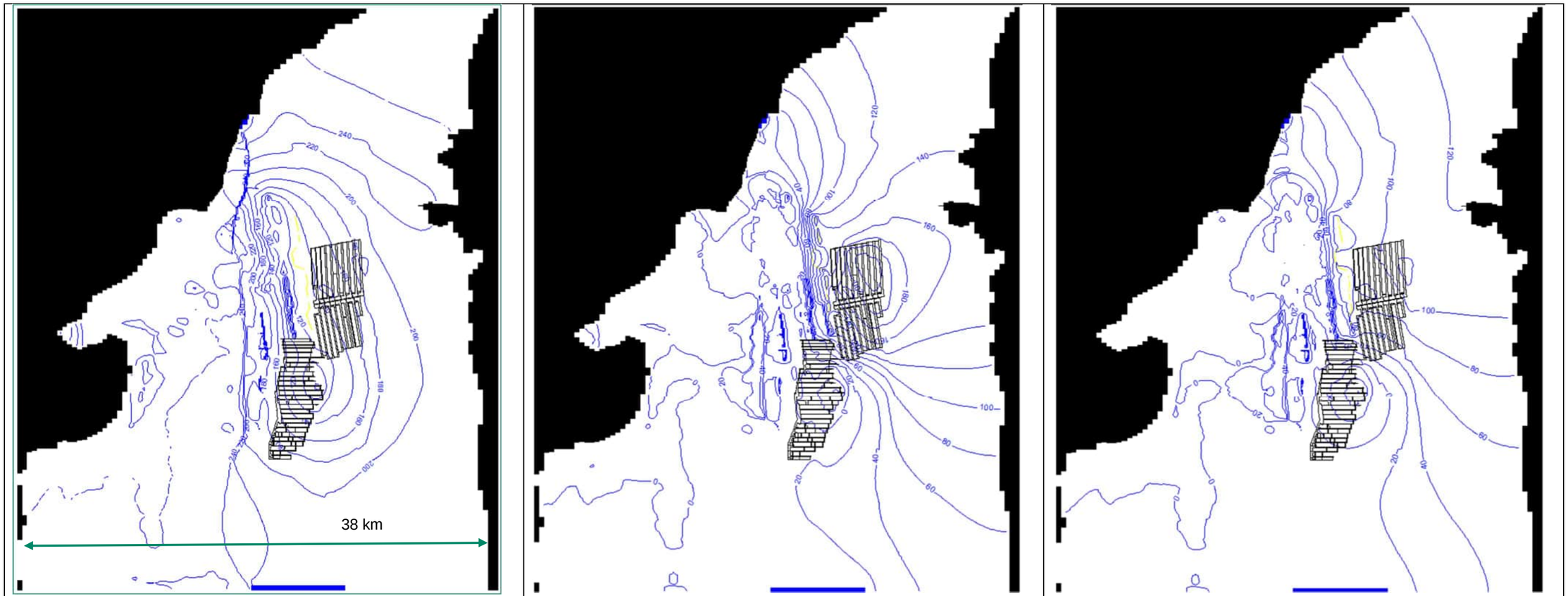
To assist in comparing the change in water levels from mining activities (mining, rehabilitation, decommissioning, and water introduction during the prediction periods) to post-closure the difference in water level (rise and fall) is included in Plate 41.

The predictive modelling, considering change in groundwater levels from the 2024 initial calibrated elevations, indicate:

- The drawdown in GLS at the end of P3 2092, at the end of Red Hill Mine mining, is up to 240 m centred around the Red Hill Mine (Plate 41).
    - The drawdown below the initial groundwater levels (P1) ranged from +60 m (water introduced into Broadmeadow GLS) and – 240 m (RHM) at the end of P3.
- During P4 the Red Hill Mine is filled with water and recovery and groundwater stabilisation occurs, as included in the P4 predictions in 2199 (Plate 41).
- The water level change from P1 levels in GLS at the end of P4 2199 (prolonged recovery and stabilisation after mining and the introduction of water) range from +50 m (water introduced into Broadmeadow GLS) and -240 m (in proximity to the Goonyella residual void).

- Water introduced into the Broadmeadow GLS underground workings caused a 60 m change (rise) in 2092, which decreased slightly to 50 m in 2199. This reduction is related to the Goonyella residual void.

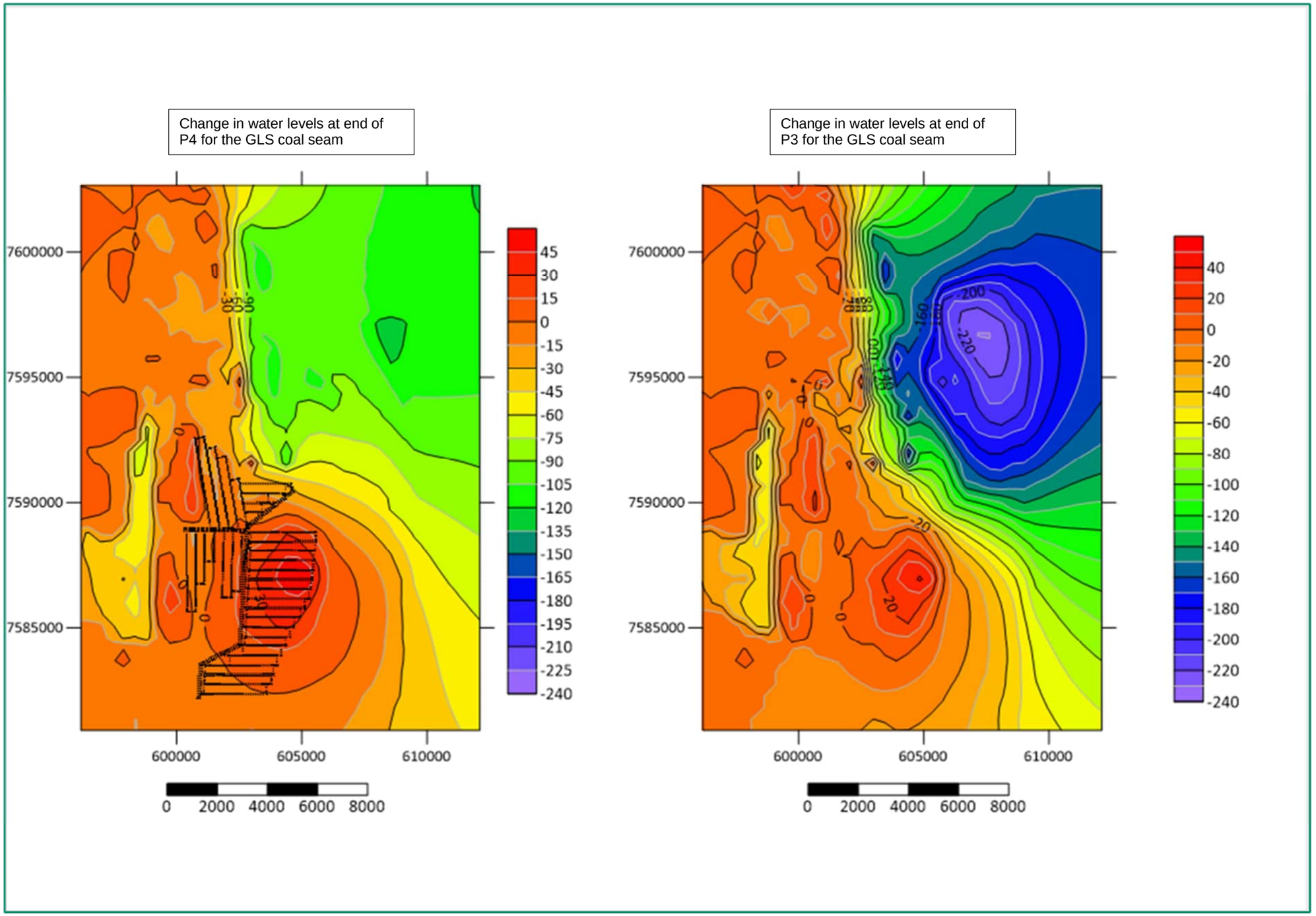
Figure 48 Groundwater elevation in GLS at start of P1 and water level change (in m) at the end of P3 and P4 for in Model Layer 12 GLS

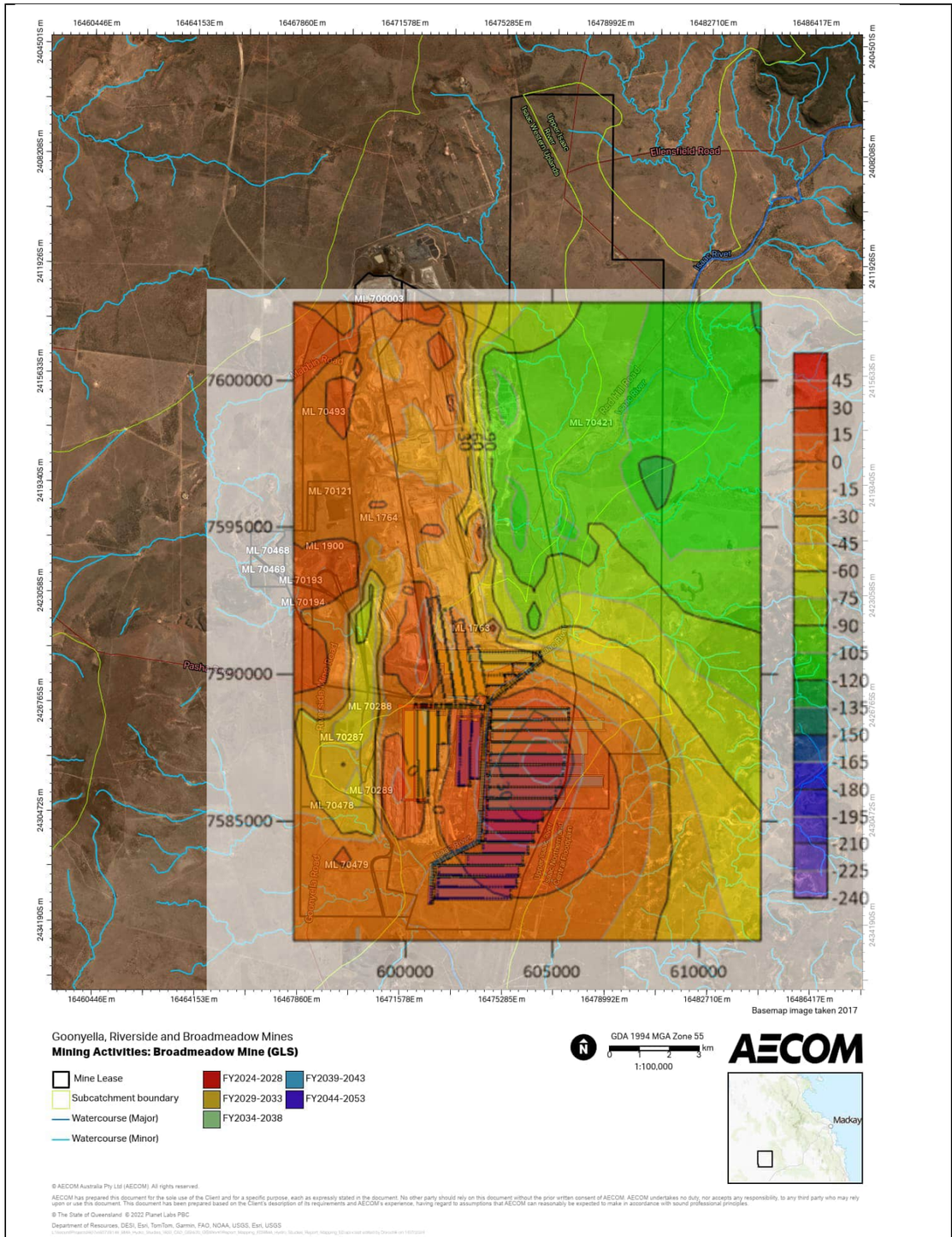


Head Contours at the Start of P1 Layer 12, GLS	Change in water level at the End of P3 Layer 12, GLS	Change in water level at the End of P4 Layer 12, GLS

Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

Plate 41 GLS water level difference from the initial groundwater heads at start of P1 (water level change in m)




16460446E m
16464153E m
16467860E m
16471578E m
16475285E m
16478992E m
16482710E m
16486417E m
2404501S m
2408208S m
2411926S m
2415633S m
2419340S m
2423058S m
2426765S m
2430472S m
2434190S m
Isaac River
Isaac River Diversion
Ellensfield Road
Peak River
Peak River
ML 700003
ML 70493
ML 70421
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
Goonyella Road
Red Hill Road
Peak Downs Mine
Peak Downs Mine Coal Allocation
7600000
7595000
7590000
7585000
600000
605000
610000
45
30
15
0
-15
-30
-45
-60
-75
-90
-105
-120
-135
-150
-165
-180
-195
-210
-225
-240
Basemap image taken 2017
Goonyella, Riverside and Broadmeadow Mines
Mining Activities: Broadmeadow Mine (GLS)
Mine Lease
Subcatchment boundary
Watercourse (Major)
Watercourse (Minor)
FY2024-2028
FY2029-2033
FY2034-2038
FY2039-2043
FY2044-2053
GDA 1994 MGA Zone 55
0 1 2 3 km
1:100,000
Mackay
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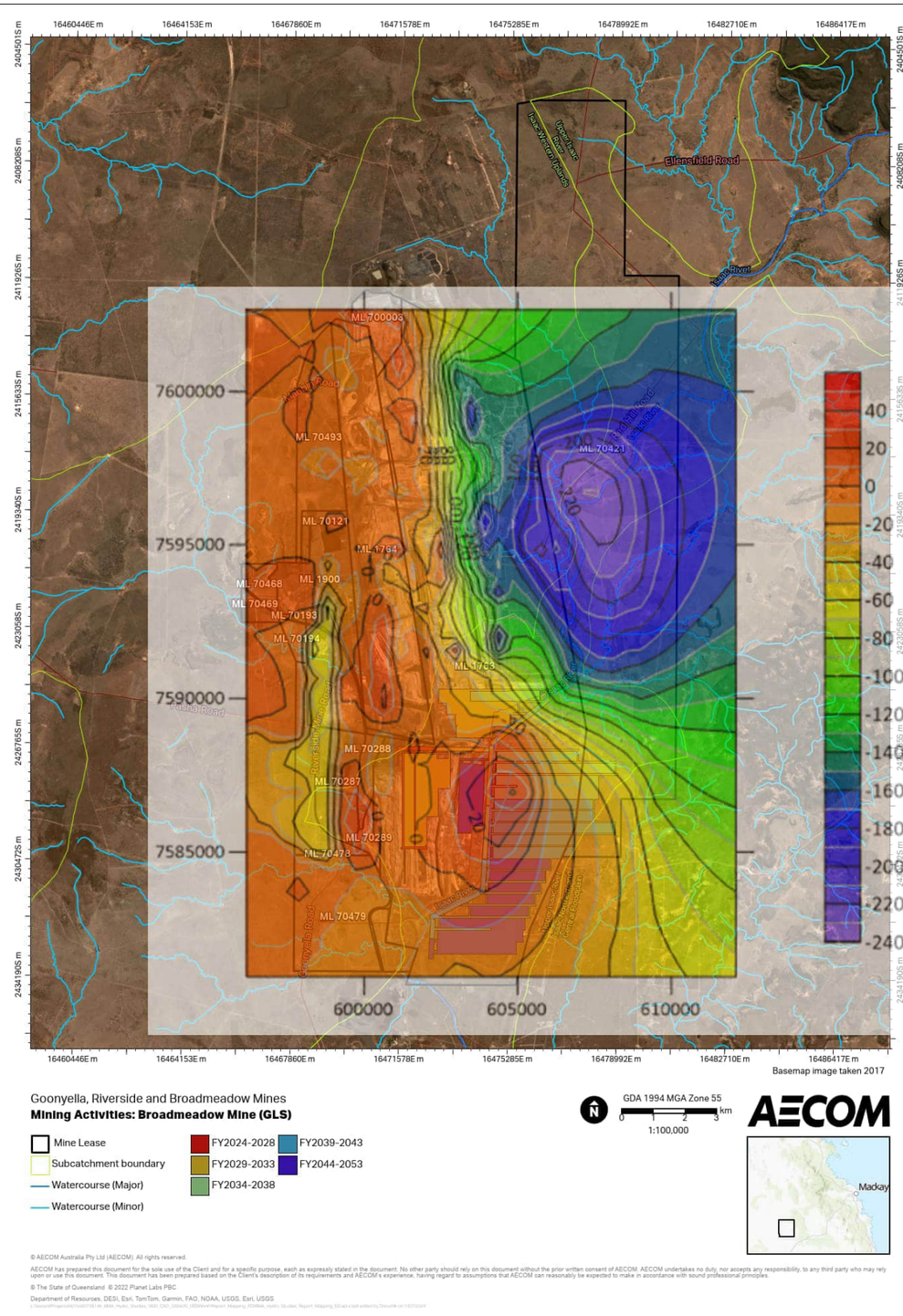
16460446E m
16464153E m
16467860E m
16471578E m
16475285E m
16478992E m
16482710E m
16486417E m
2404501S m
2408208S m
2411926S m
2415633S m
2419340S m
2423058S m
2426765S m
2430472S m
2434190S m
Isaac River
Isaac River Diversion
Ellensfield Road
Peak River
ML 700003
ML 70493
ML 70421
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70287
ML 70289
ML 70478
ML 70479
Goonyella Road
Red Hill Road
Peak Downs Mine
Peak Downs Mine Coal Allocation
7600000
7595000
7590000
7585000
600000
605000
610000
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
Basemap image taken 2017
Goonyella, Riverside and Broadmeadow Mines
Mining Activities: Broadmeadow Mine (GLS)
Mine Lease
Subcatchment boundary
Watercourse (Major)
Watercourse (Minor)
FY2024-2028
FY2029-2033
FY2034-2038
FY2039-2043
FY2044-2053
GDA 1994 MGA Zone 55
0 1 2 3 km
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15.6 Flow Path Simulation

The groundwater model zone budget approach allowed for the evaluation of the groundwater flow either into or out of the residual voids (Section 15.4.2). In addition, the evaluation of the hydrographs generated for hypothetical water level observation points, provided an indication of residual voids acting as sinks or sources within the groundwater system post closure based on relative long term water level predictions (in the residual voids and up and down dip of the residual voids).

The migration of the void water was further assessed using particle tracking, to evaluate flow directions, extent of migration within groundwater, and variation in flow during the post-mining stabilisation of groundwater levels overtime.

Particles were introduced into the saturated model cells at different times during the model prediction phases, to assess migration to or from the residual voids. These data were then considered with groundwater contours (as described in Section 15.4.3), plus the groundwater model zone budget and hydrograph lines of evidence, to assess potential for transport of the void water from the mine leases over time.

The initial particle tracking, based on the large model domain and active cells, was conducted for a 10 year period during prediction periods P3 and P4, to obtain an understanding of groundwater flow patterns and influence of mining activities (mining, rehabilitation, decommissioning, and water introduction during the prediction periods). Long duration post-closure particle tracking were conducted (Section 15.7) based on the 10-year results (i.e., targeted particle tracking was conducted for residual voids were migration from the residual voids were identified to allow for the assessment of potential contaminant migration within the groundwater to be further assessed).

15.6.1 Residual voids (excluding Goonyella Pit)

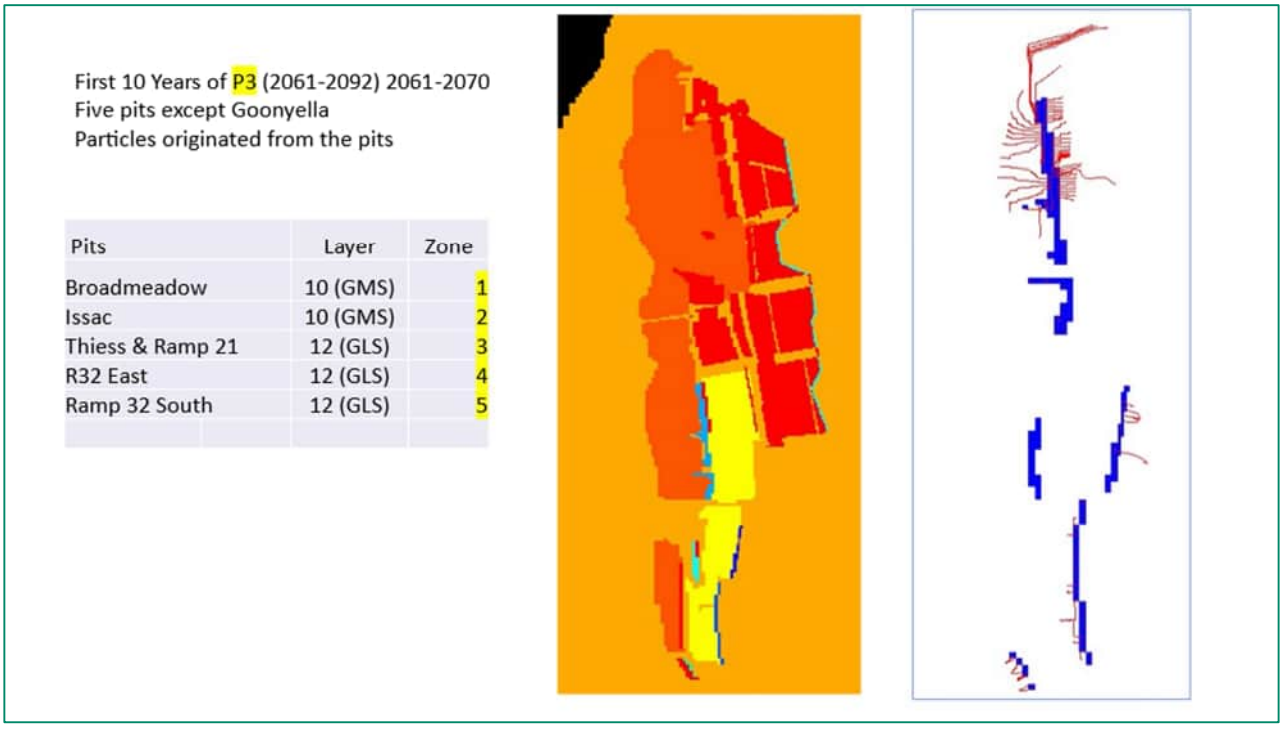
Particle tracking was conducted at the five (5) residual voids to assess possible void water migration within groundwater. The particle tracking was limited to 10 year running times to allow for the evaluation of possible particle movement and to provide validation of the groundwater flow predicted during the post-mining using groundwater contours and flow patterns, model zone budget (in or out) ingress, and pilot hole/s hydrographs.

15.6.1.1 First 10 Years of P3 (2061-2070)

This Prediction Period includes for the residual voids to include CHD, the start of RHM, and Goonyella Pit dewatering (drain cells).

Figure 49 indicates the particle tracking (red lines) where particles originated in the five residual voids. For ease of assessment and to better evaluate the influence of the large deep Goonyella residual void, this residual void was assessed (particles added within and adjacent to Goonyella residual void) separately as presented in Section 15.6.2.

Figure 49 First 10 Years of P3 – 5 residual voids



Blue model cells are the residual voids

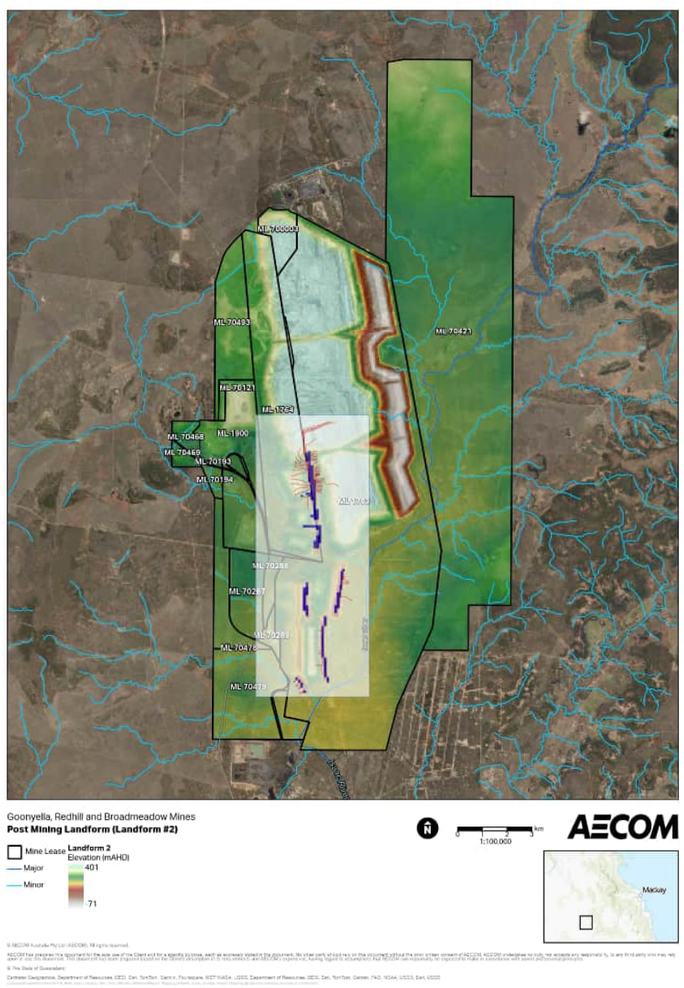
Red lines are particle flow tracks over the 10 year run

The particle pathways, running for 10 years, were included on groundwater head contours for selected years during the particle tracking simulation. These contours for Model Layer 12 (GLS) and Model Layer 10 (GMS) allow for the identification of groundwater flow patterns and gradients in the saturated target coal seams or spoil (backfill) adjacent to the 5 residual voids (Figure 50 to Figure 52).

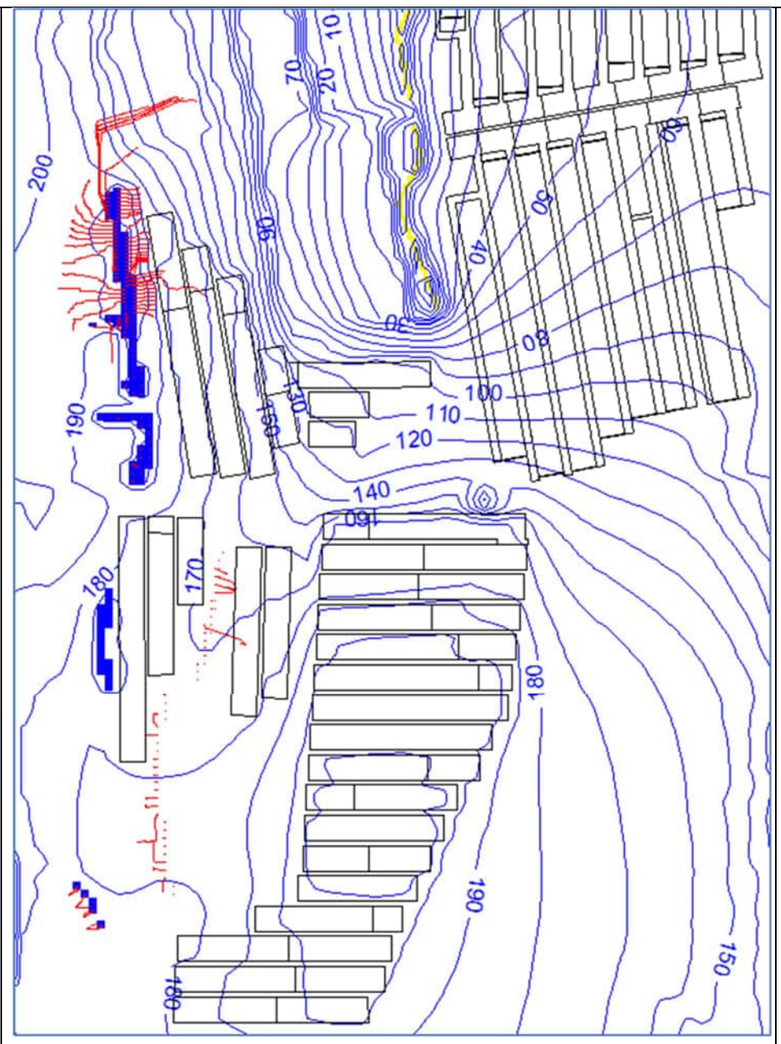
Due to the changing groundwater elevations, in response to mining activities during each prediction period, and the 10 year particle tracking, the groundwater elevation contours at different years were included to illustrate the influence on particle migration.

Note the mining in the five residual voids target different coal seams, as included in Figure 49, this is reflected in the Figure 50 to Figure 52.

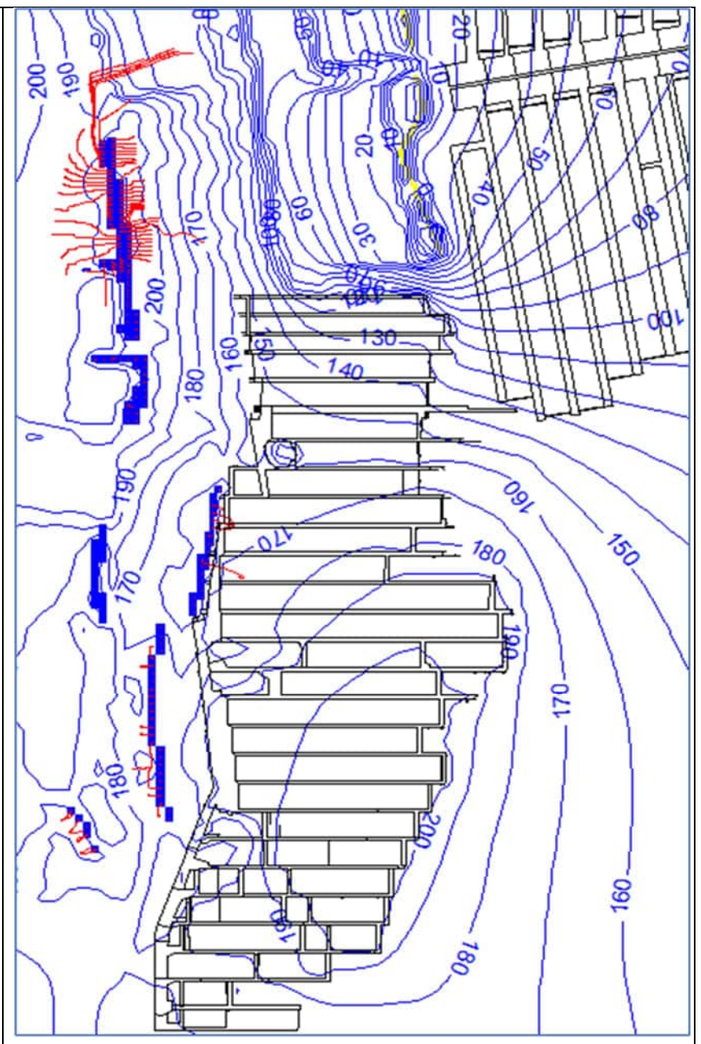
Figure 50 First 10 Years of P3 for 5 residual voids – Year 2061groundwater contours



Particles originating in each of the five residual voids



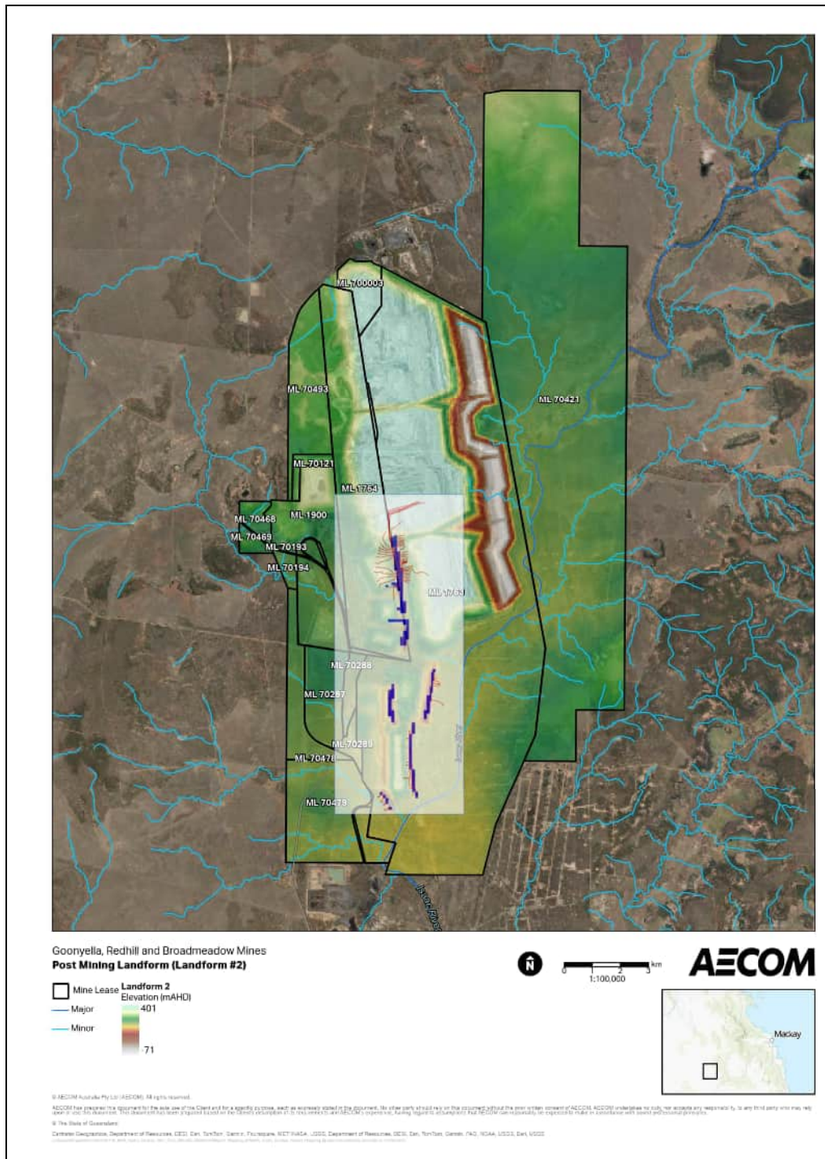
Year 2061 GLS groundwater elevations (mAHD)



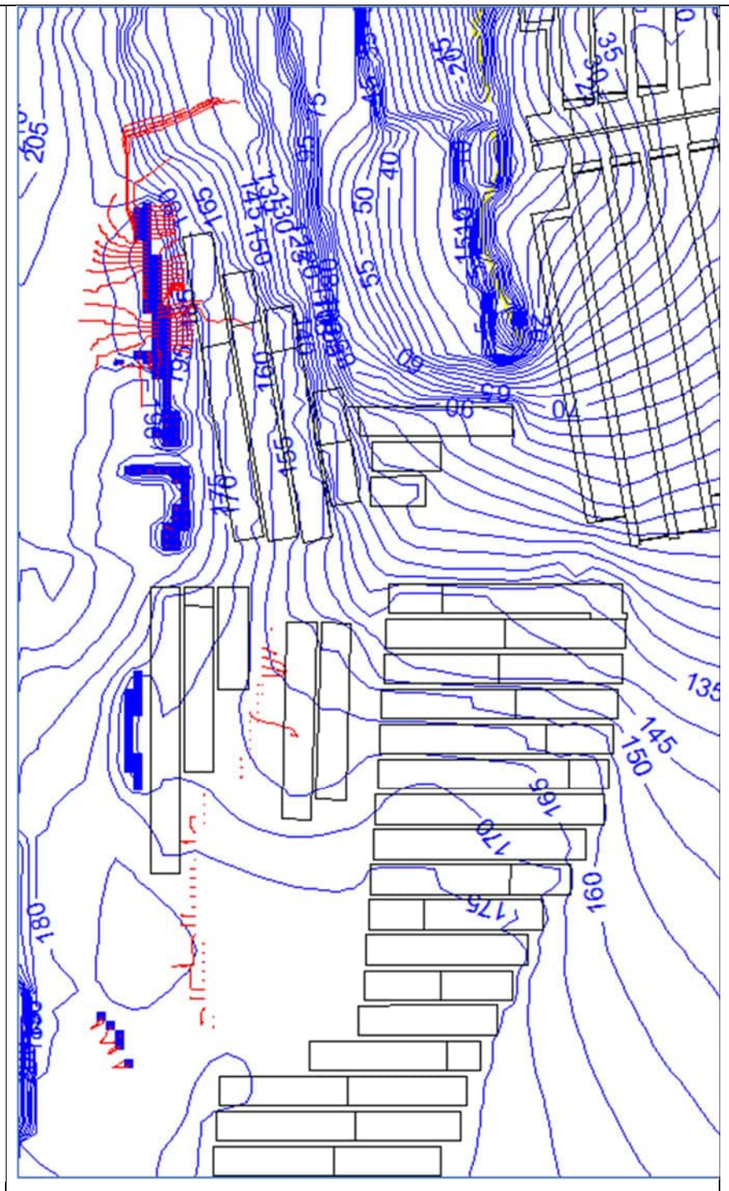
Year 2061 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells are the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

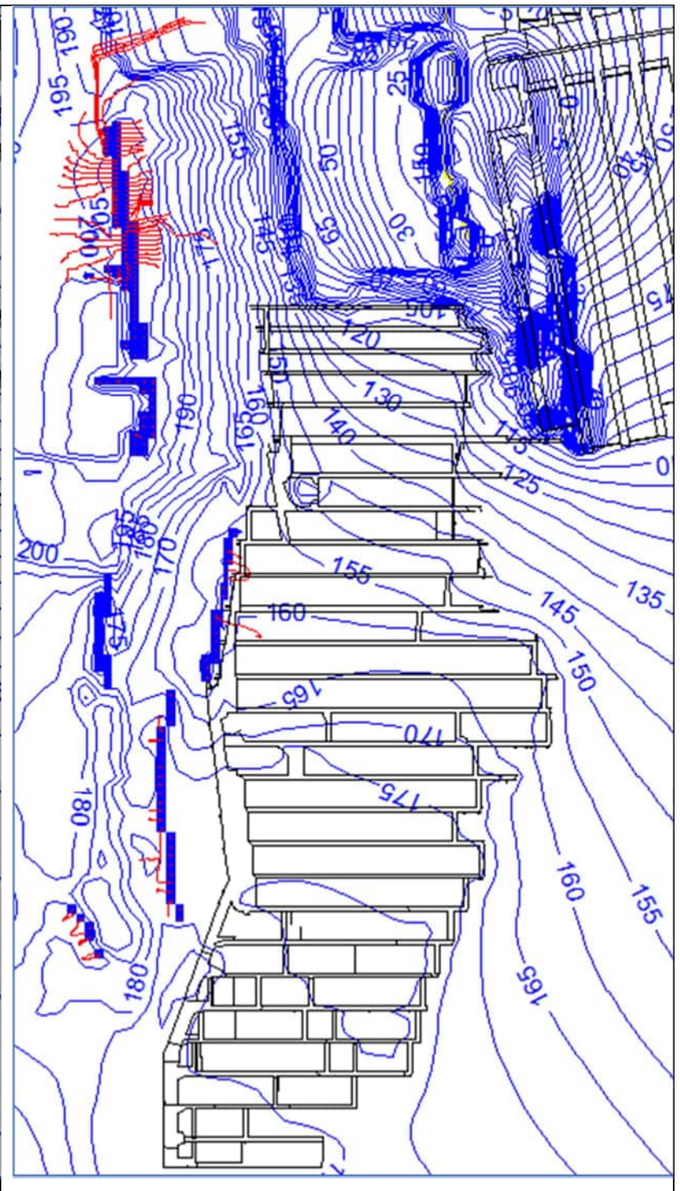
Figure 51 First 10 Years of P3 for 5 residual voids – Year 2063 contours



Particles originating in each of the five residual voids



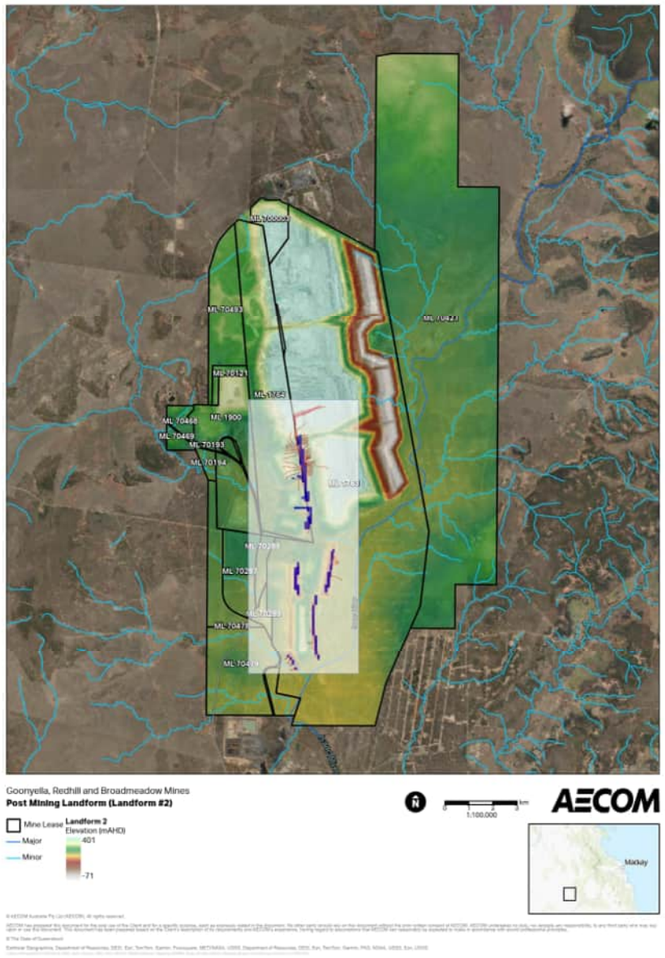
Year 2063 GLS groundwater elevations (mAHD)



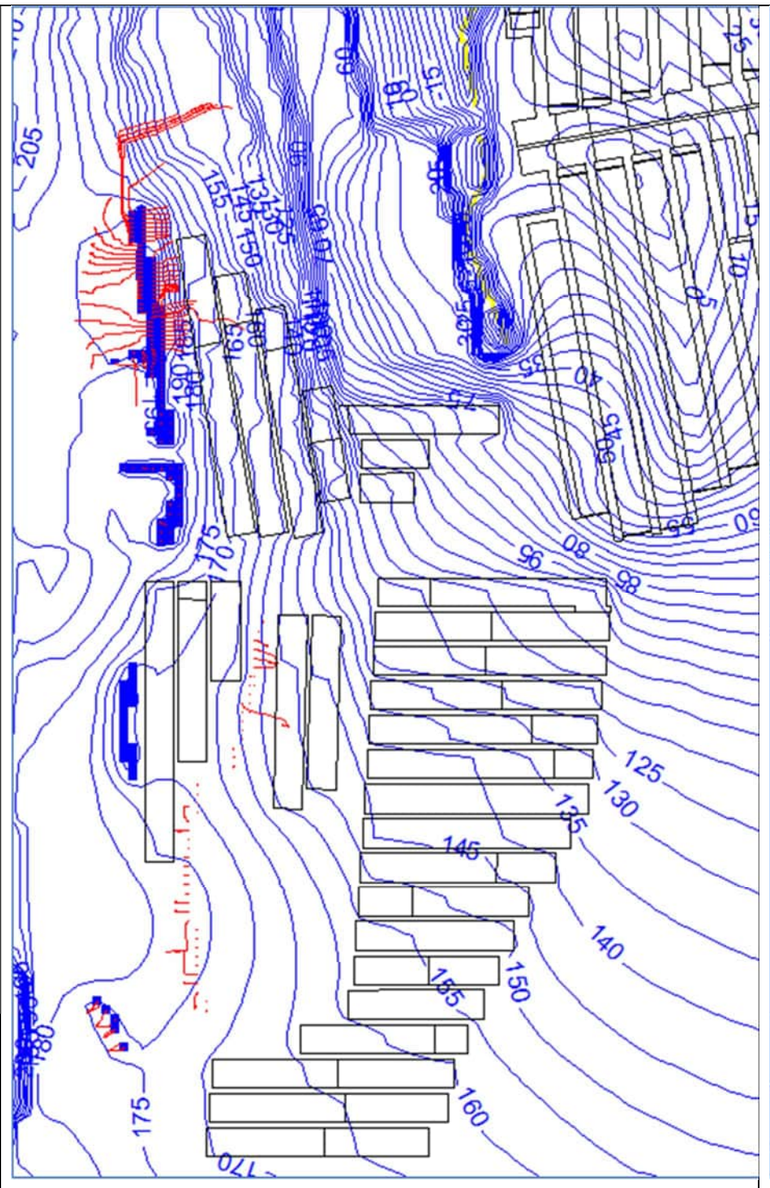
Year 2063 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells represent the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

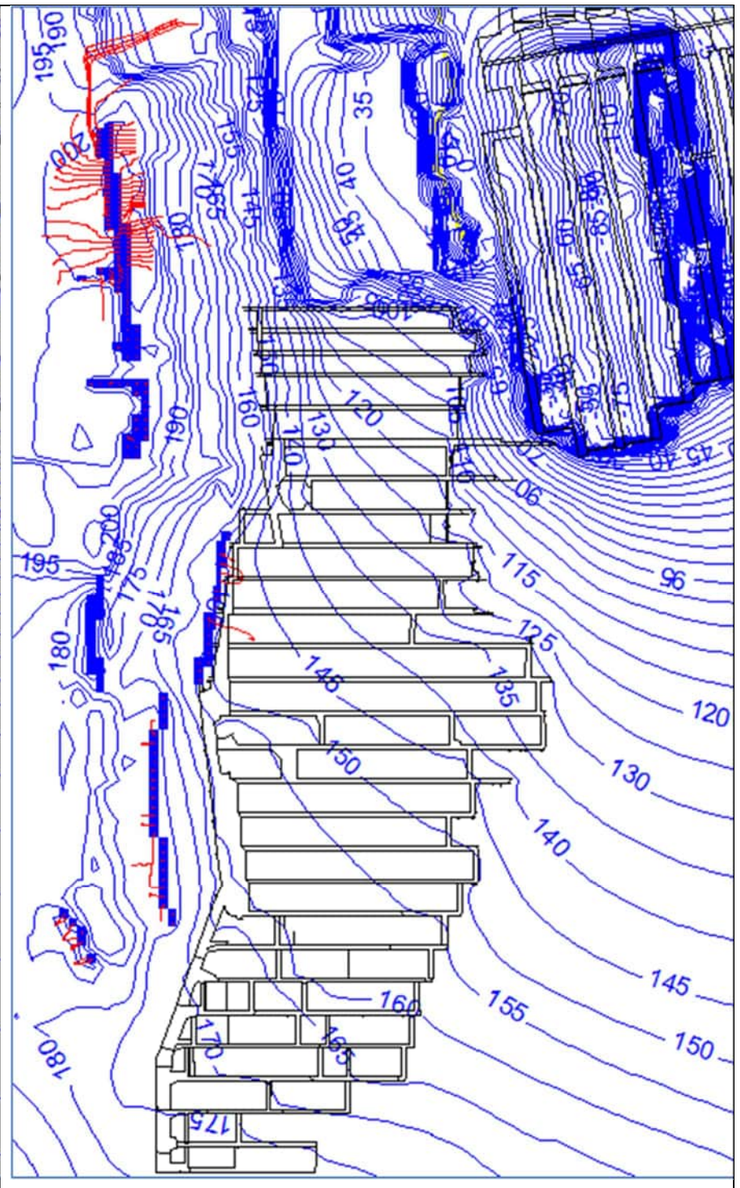
Figure 52 First 10 Years of P3 for 5 residual voids – Year 2070 contours



Particles originating in each of the five residual voids



Year 2070 GLS groundwater elevations (mAHD)



Year 2070 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

Figure 50 to Figure 52 indicate the influence of the RHM on the GMS groundwater contours during P3, even with the introduction of water into the Broadmeadow underground (Figure 50).

Residual void water, considering the GLS and GMS groundwater elevation contours and particle tracking, is considered to:

- Migrate within groundwater (saturated groundwater model cells) from Isaac Pit, Ramp 32 South, and Thiess Pit towards the west, into the spoil / backfill areas
- Residual void water migration to the west is limited with particles returning to these residual voids, in response to ongoing mine dewatering at Goonyella Pit and RHM
- Residual void water from Thiess Pit and Broadmeadow Pit is recognised to migrate towards the east (down dip)
- Thiess Pit, which acts as a source (high residual void water level compared to surrounding groundwater), indicates residual void water flow away from the residual void initially then migrating to the north and west in response to mine dewatering (Goonyella Pit and RHM).

15.6.1.2 First 10 Years of P4 (2093-2102)

The prediction period (P4) includes water levels within the residual voids to be represented by CHD (including Goonyella Pit), the end of RHM mining, introduction of water into RHM, and recovery (no mining activities from 2097).

Figure 53 indicates the particle tracking (red lines) where particles originated in the five residual voids. Due to the fluctuation in the residual void water levels, particles were also included immediately adjacent to Broadmeadow Pit and Isaac Pit to further assess possible pit water migration (Figure 54).

The particle tracking during this P4 10 year simulation indicates continued residual void water loss from Thiess Pit, which is migrating within groundwater towards the drawdown caused by the deep Goonyella Pit residual void water levels.

Residual void water migration from Broadmeadow Pit can occur where the particles are predicted to migrate towards RHM GMS dewatering even though water has been introduced into RHM GMS mine workings.

Particles immediately adjacent to Broadmeadow Pit indicate potential for residual void water migration. This is not predicted for the Issac Pit residual void.

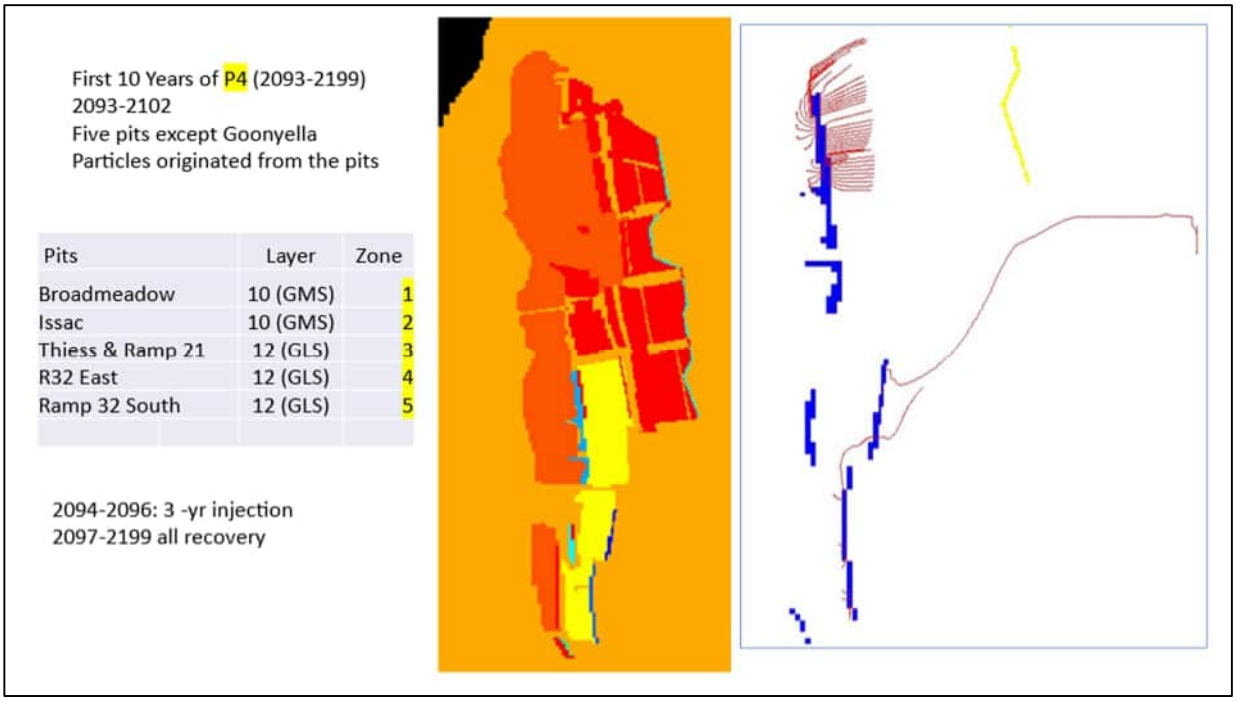
The particle pathways, running for 10 years at the start of P4, were included on groundwater elevation contours for selected years during the particle tracking simulation. These contours for Model Layer 12 (GLS) and Model Layer 10 (GMS) allowed for the identification of groundwater flow patterns and gradients in the saturated target coal seams or spoil (backfill) adjacent to the 5 residual voids.

Figure 55 to Figure 57 indicate flow from Broadmeadow Pit towards the dewatered RHM flooded underground (Figure 56), as the underground workings do not flood entirely when adopting the volumes supplied by BMA (Section 14.2.1).

The long particle travel path from Broadmeadow is recognised to reach the RHM and then change direction to the northeast, towards Goonyella Pit.

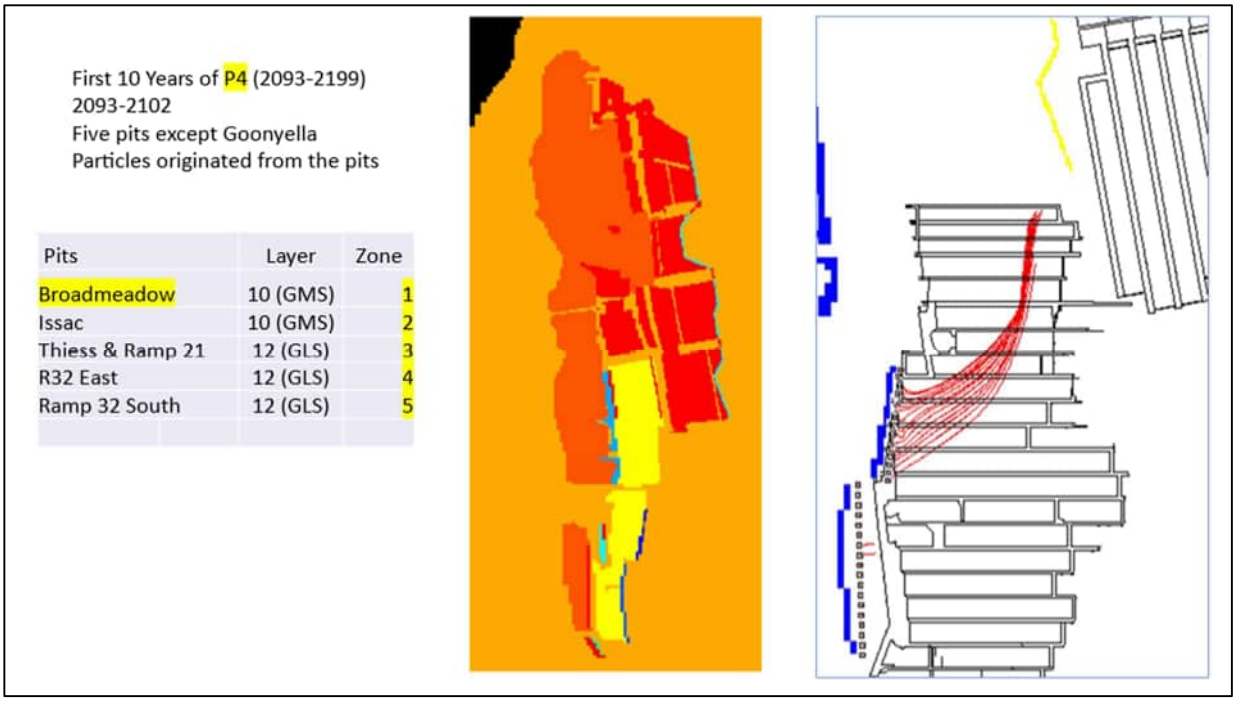
Note: The particles migrate for a period of 10-years, the groundwater elevations change over time based on mining activities which vary over time (as detailed in the prediction periods, Section 15.2), hence the need to illustrate the groundwater contours in and adjacent to the residual voids (including Goonyella Pit) to aid with evaluating the particle tracking.

Figure 53 First 10 Years of P4 – 5 residual voids



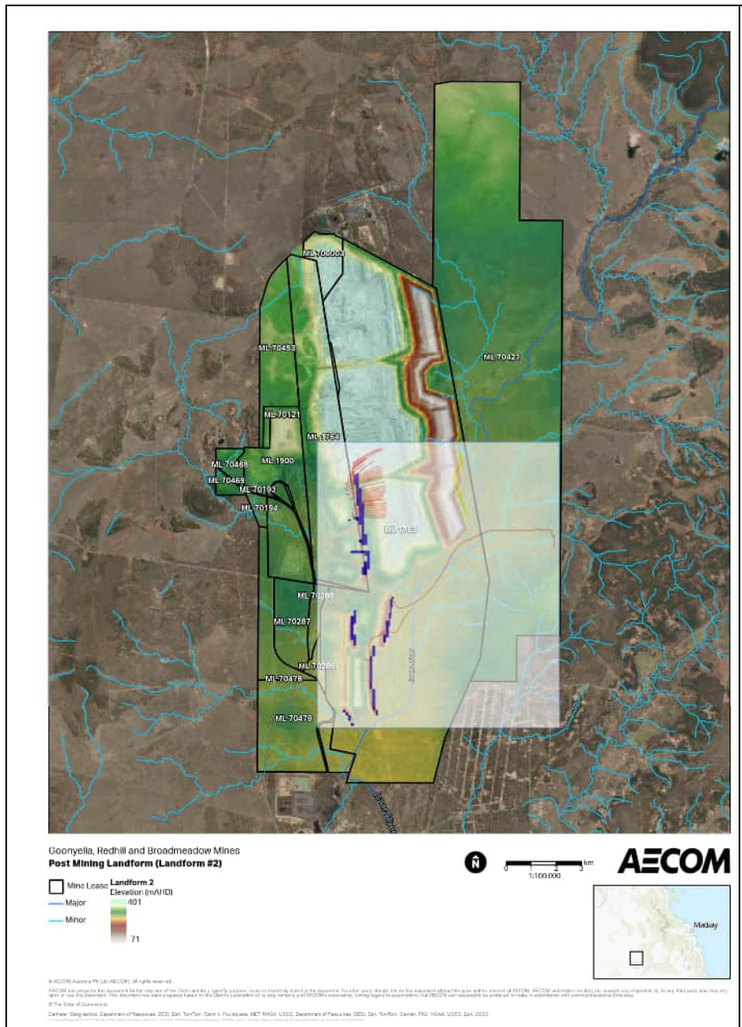
Blue model cells are the residual voids
Red lines are particle flow tracks over the 10 year run

Figure 54 First 10 Years of P4 – 5 residual voids (particles outside Broadmeadow and Isaac Pits)

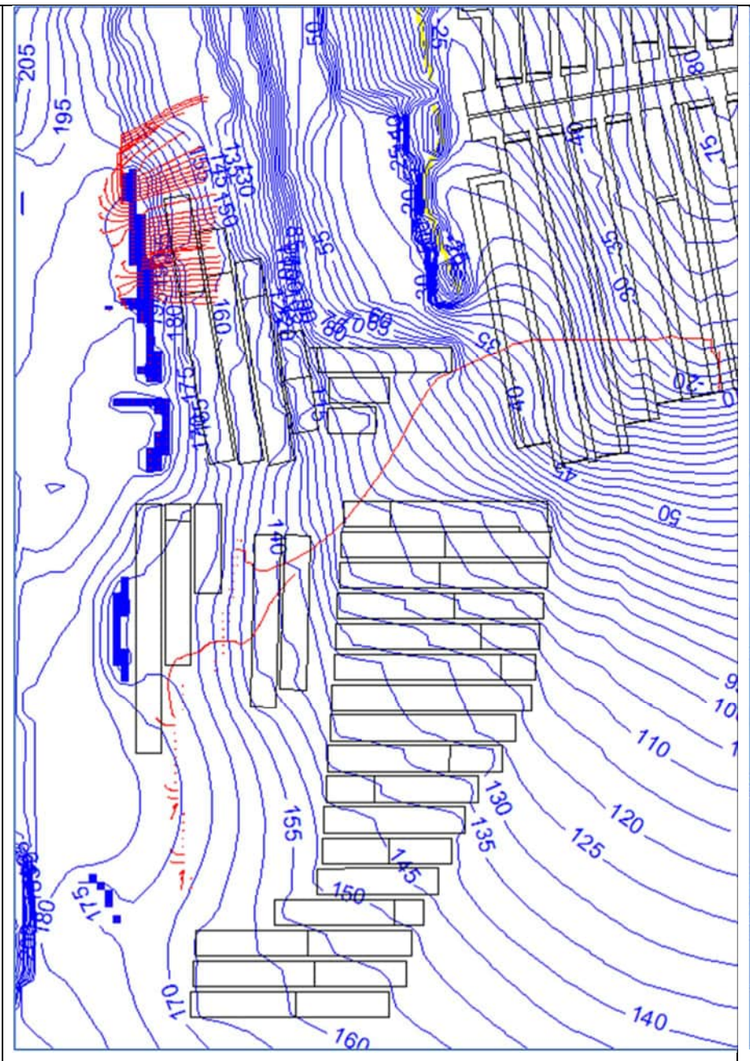


Blue model cells are the residual voids
Red lines are particle flow tracks over the 10 year run

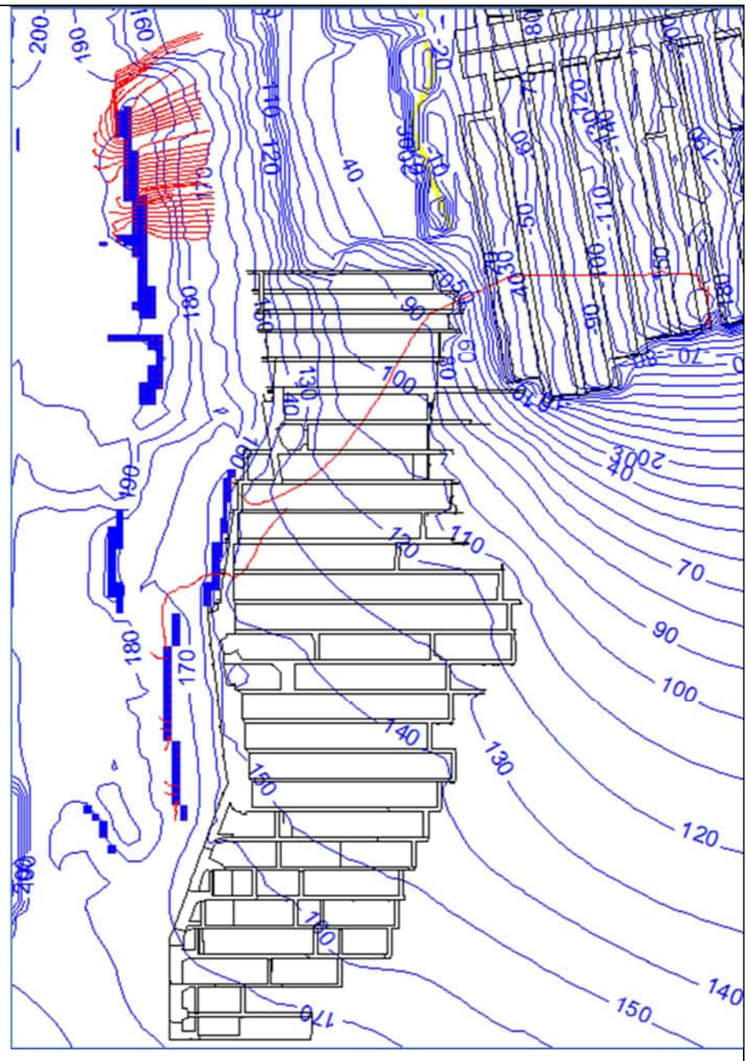
Figure 55 First 10 Years of P4 for 5 residual voids – Year 2093 contours



Particles originating in each of the five residual voids



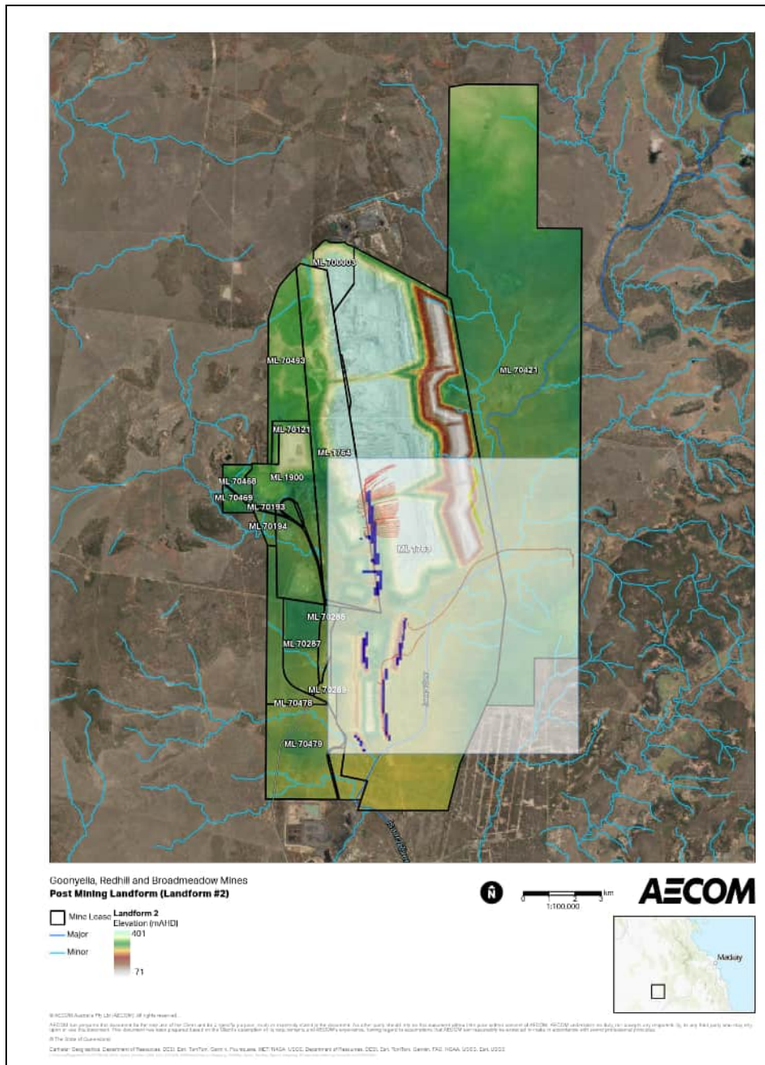
Year 2093 GLS groundwater elevations (mAHD)



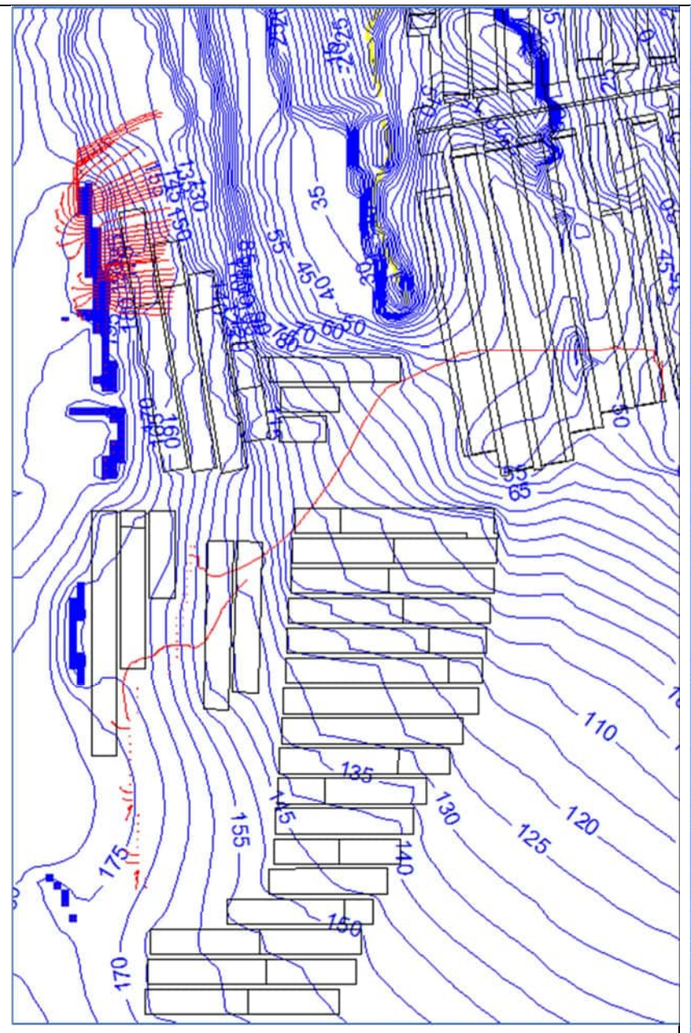
Year 2093 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

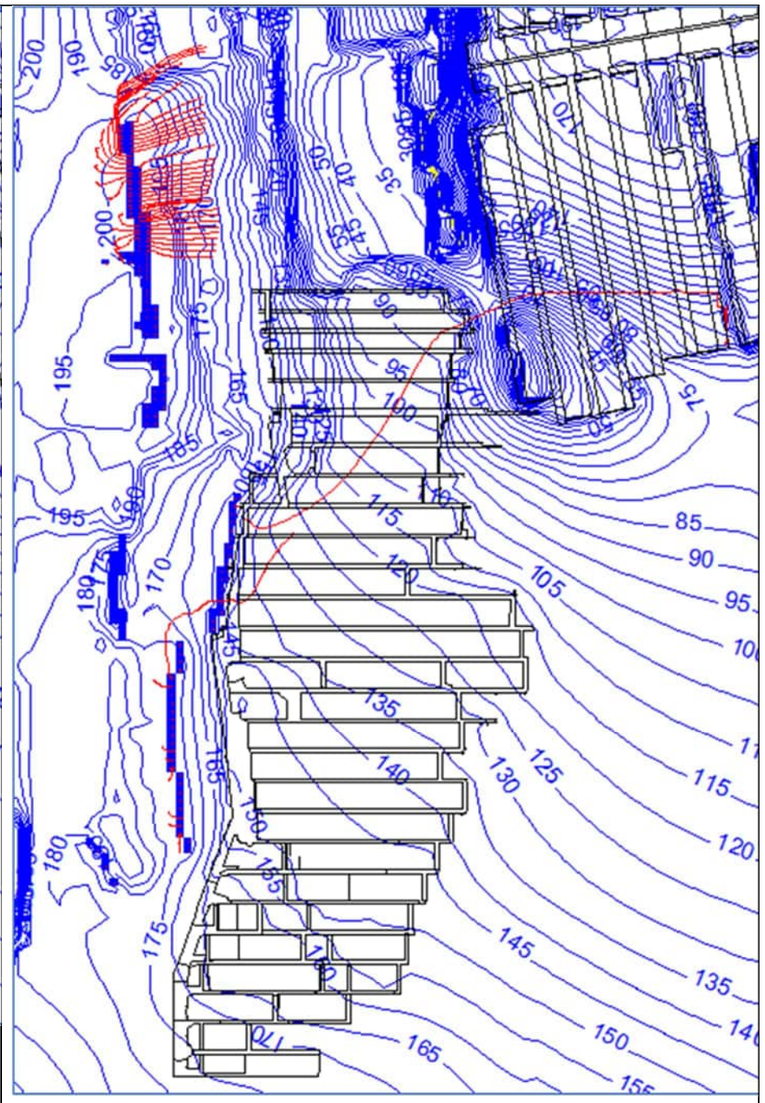
Figure 56 First 10 Years of P4 for 5 residual voids – Year 2096 contours



Particles originating in each of the five residual voids



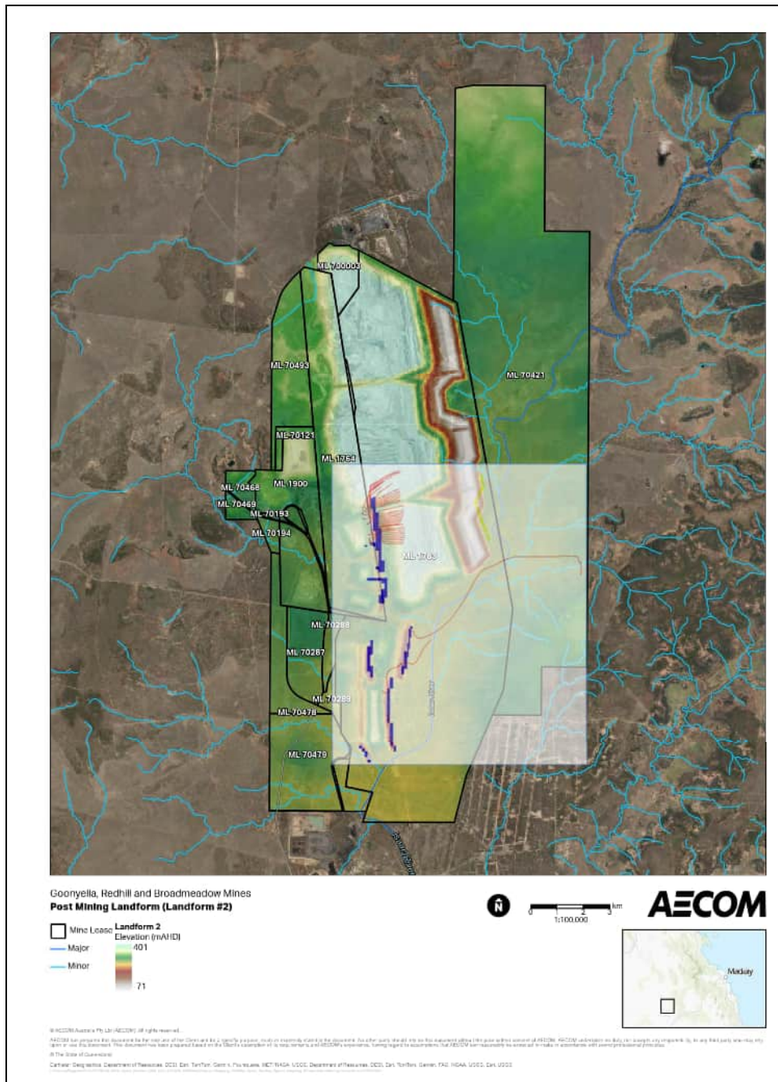
Year 2096 GLS groundwater elevations (mAHD)



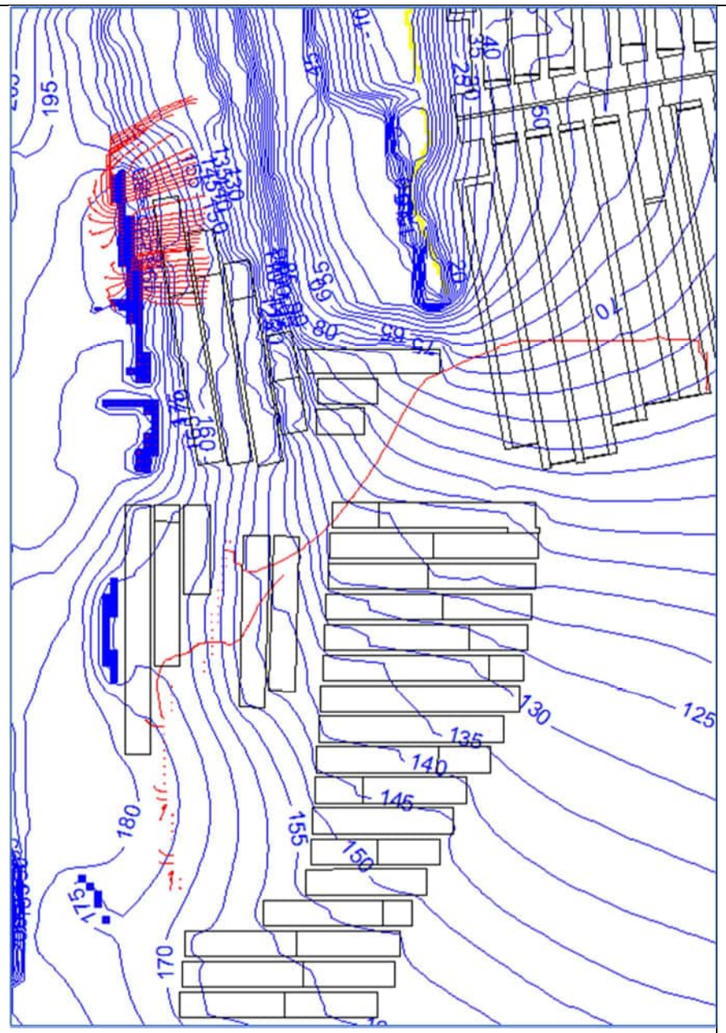
Year 2096 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

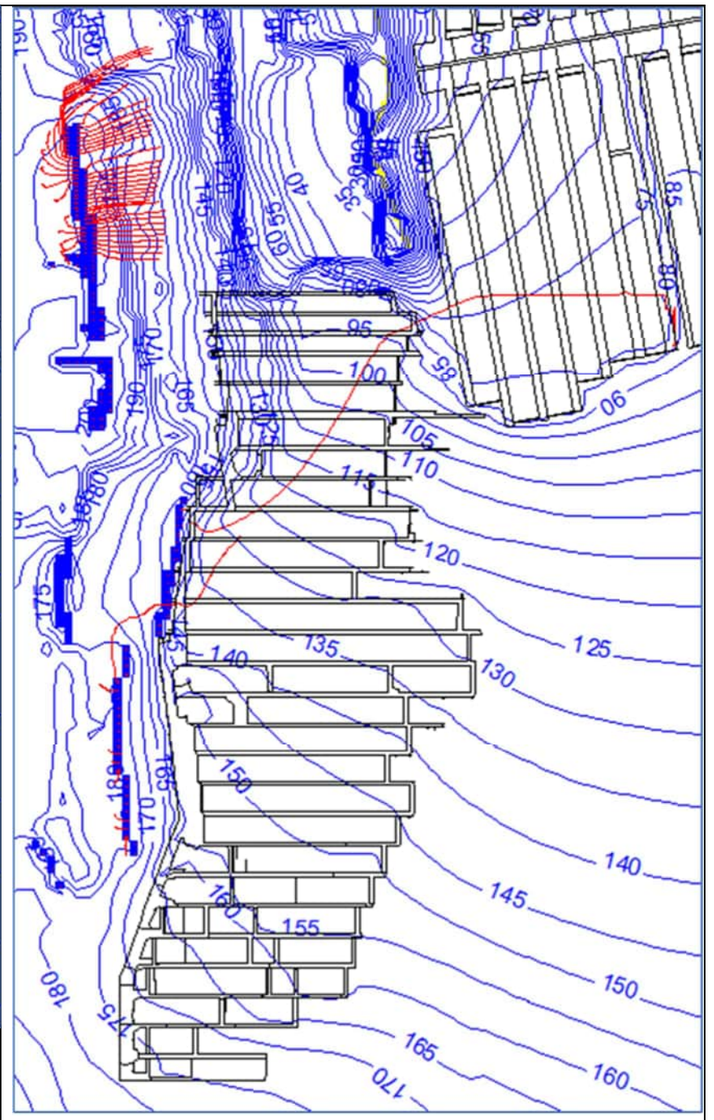
Figure 57 First 10 Years of P4 for 5 residual voids – Year 2102 contours



Particles originating in each of the five residual voids



Year 2102 GLS groundwater elevations (mAHD)

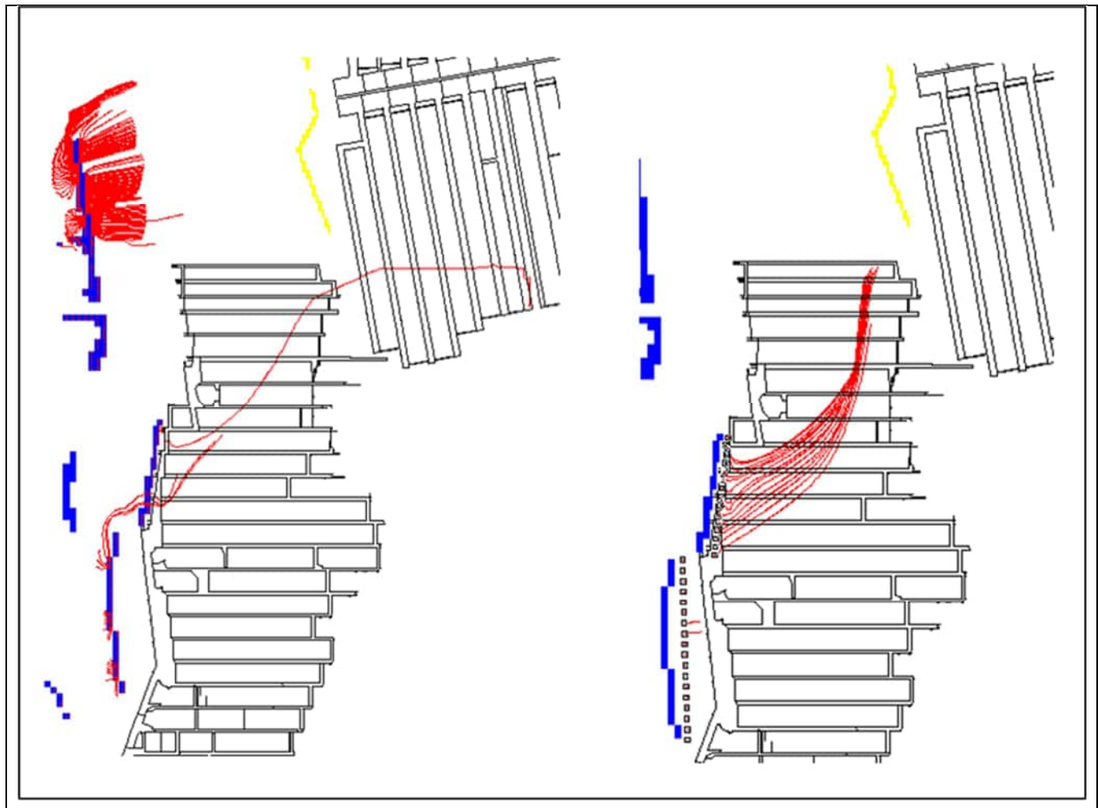


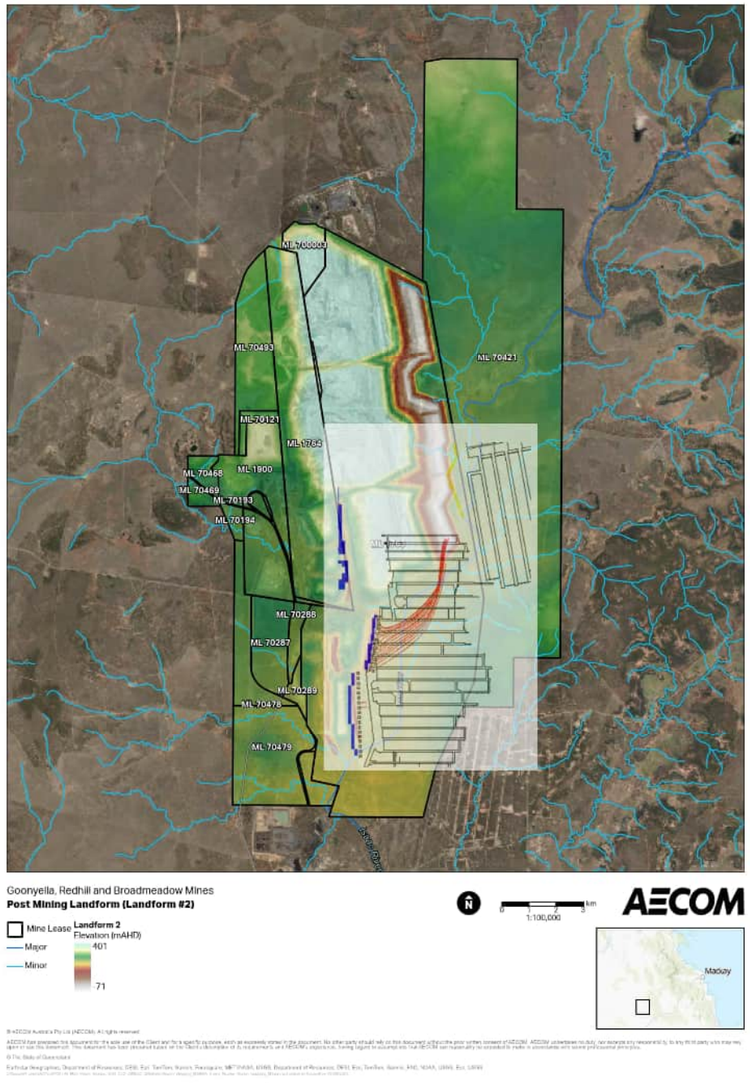
Year 2102 GMS groundwater elevations (mAHD)

Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

Figure 58 presents the particle tracking from inside and outside the residual voids at a higher resolution. Migration away from the residual voids is recognised to be influenced by the Goonyella Pit dewatering, such that particles move away and then return to the voids or change direction towards the north, due to the drawdown at Goonyella Pit.

Figure 58 First 10 Years of P4 for 5 residual voids – higher resolution particle tracking





Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS mine footprint s are included as reference locations

15.6.2 Goonyella Pit residual void

To aid with the assessment of each residual void and to allow for ease of evaluation and discussion, the particle tracking for the five residual voids (Section 15.6.1) included the mining activities associated with Goonyella Pit (mine dewatering and residual void water levels) but did not include particles for particle tracking around the Goonyella residual void.

Particle tracking for the Goonyella Pit required the inclusion of particles adjacent to the residual void, to allow for evaluation of pit water migration. This was done as any particle included within the residual void, based on the depth and surrounding groundwater levels (Section 15.4.2.6), would not migrate within groundwater.

The particle tracking, similar to the five residual voids, included 10 year simulations for prediction periods P3 and P4.

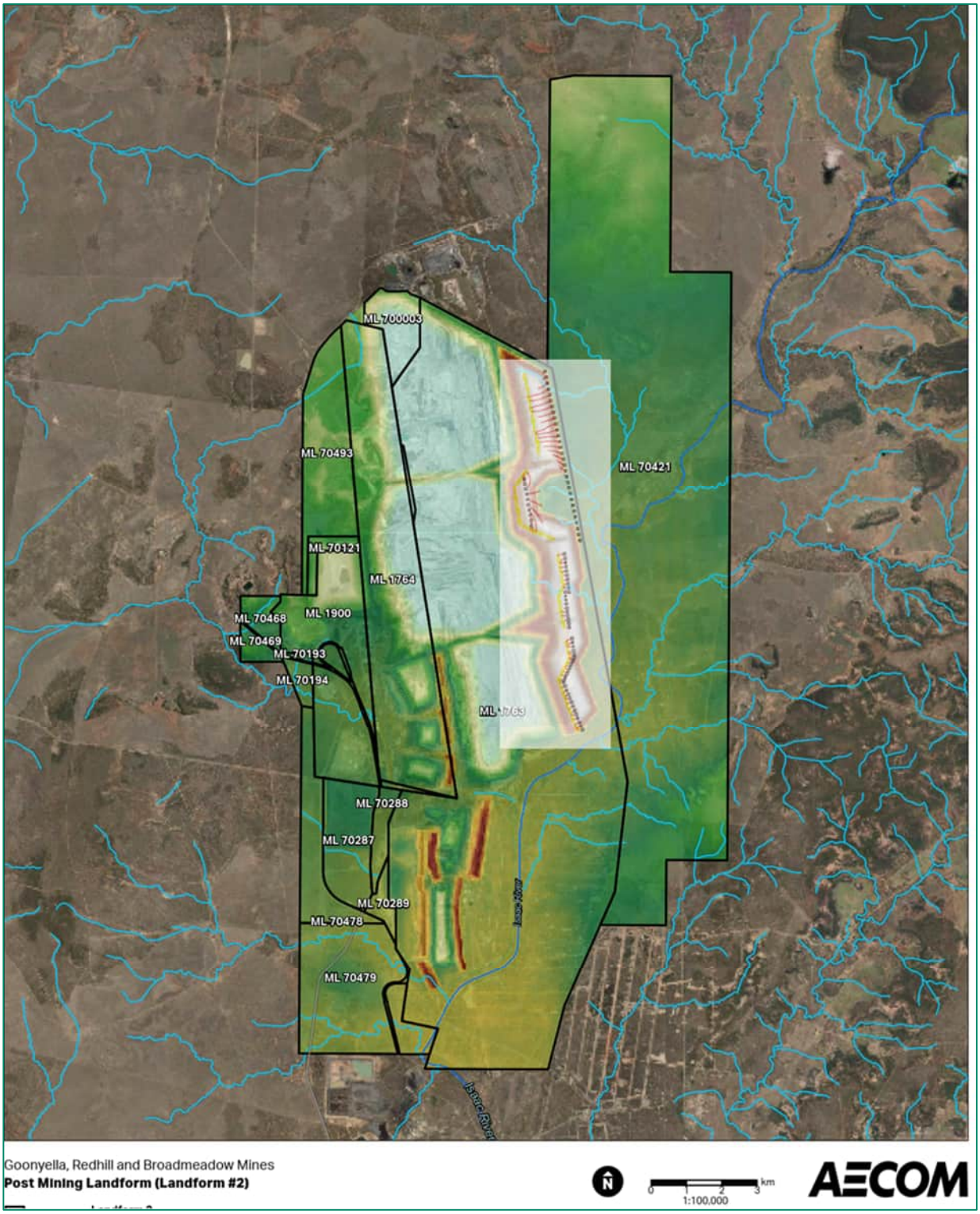
15.6.2.1 First 10 years of P3 (2061 – 2070)

The particle tracking during this time period is included in Plate 42, and indicate flow into the deepest Goonyella Pit locations.

The particles adjacent to the shallowest central portion of Goonyella Pit, as detailed in Section 15.4.2.6, are at higher groundwater elevations than the surrounding dewatered (deeper groundwater elevations) areas associated with the Goonyella Pit and RHM. Particles are recognised to initially migrate from this section of the Goonyella Pit during P3 and then migrate towards the Goonyella Pit dewatering as evident in Plate 42.

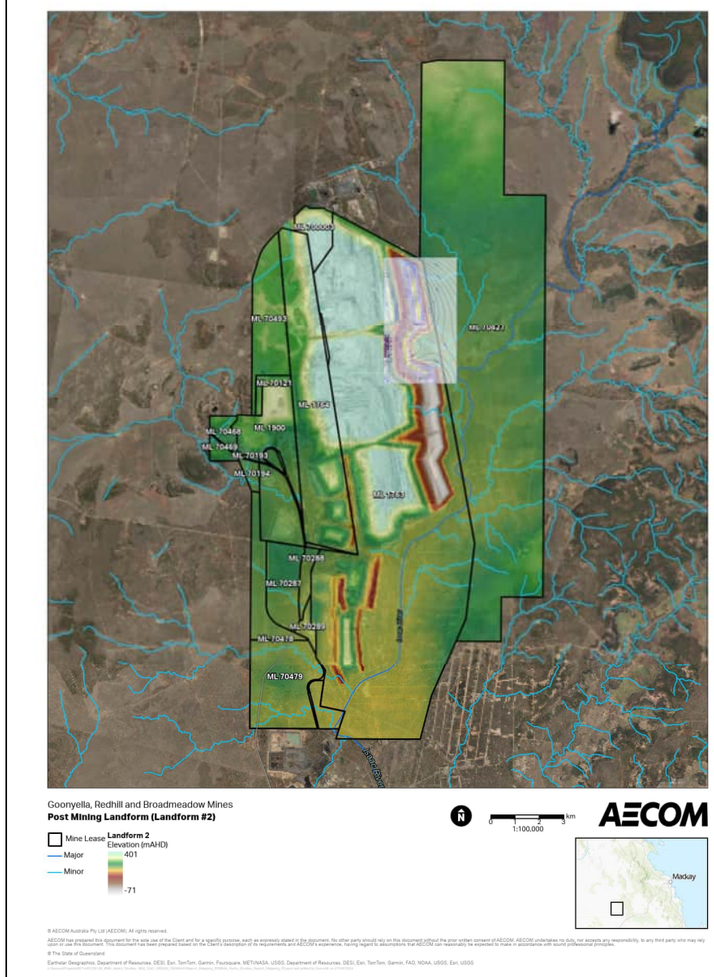
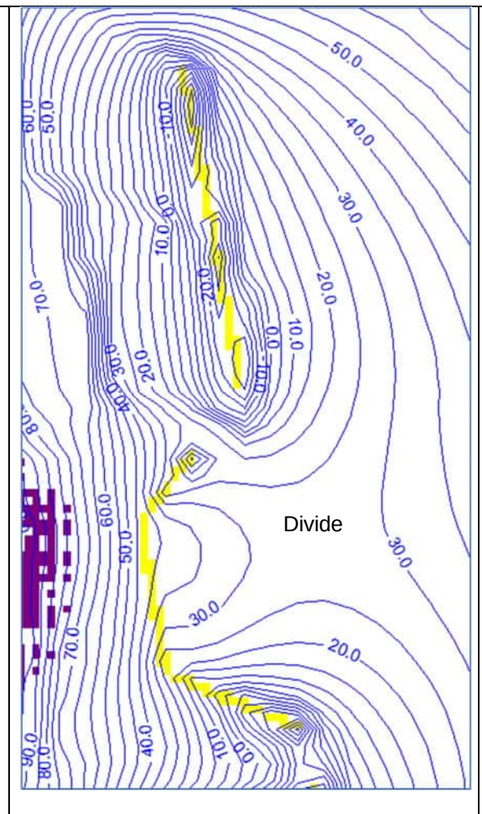
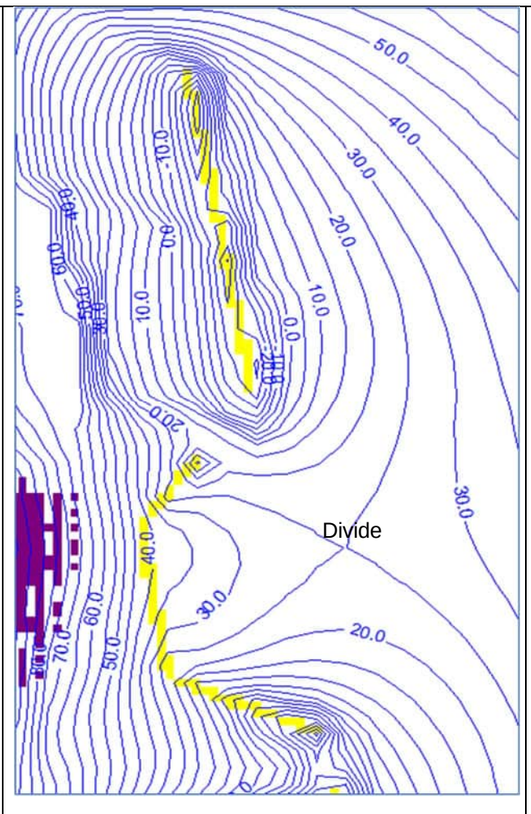
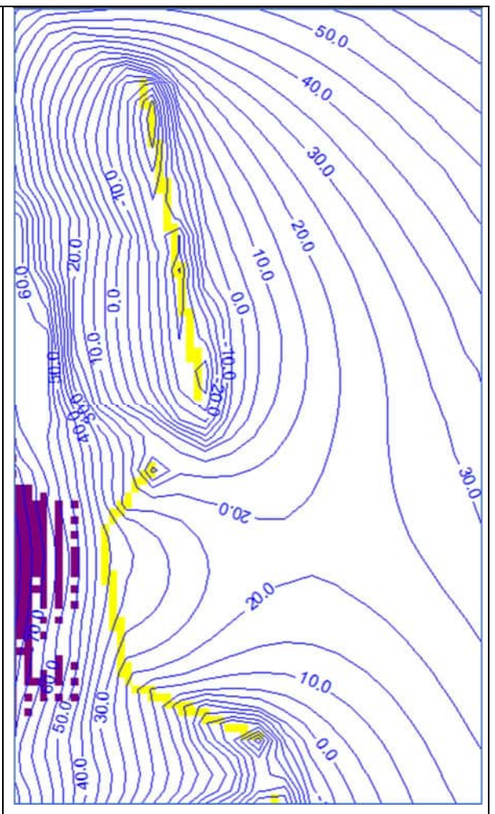
Groundwater flow contours for the P3 years 2061, 2063, and 2070, spilt into a northern and southern portion (to accommodate the long pit length), are included in Figure 59.

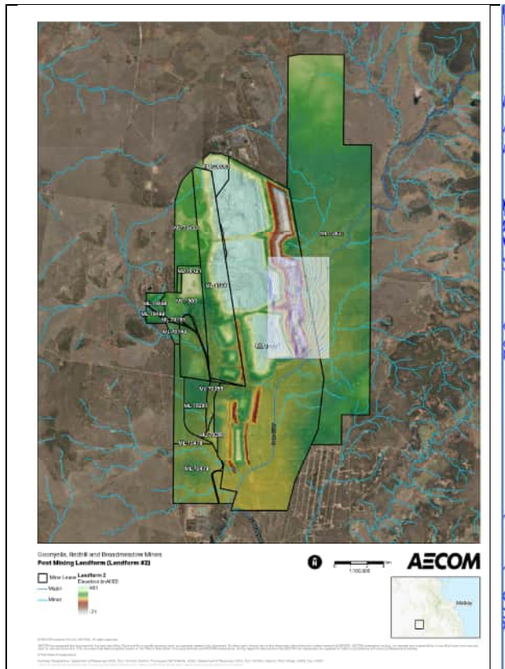
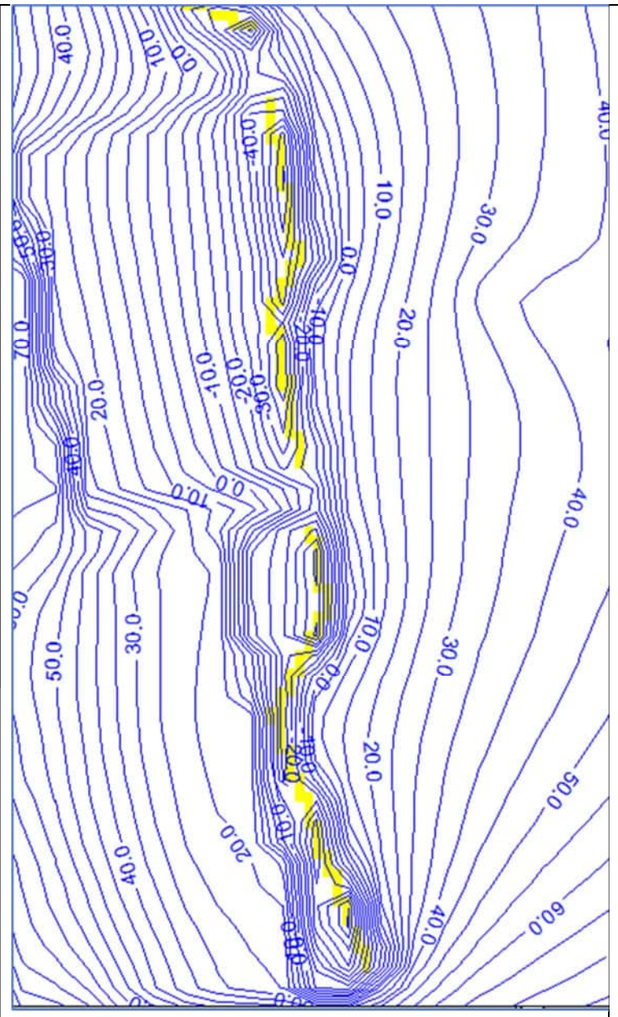
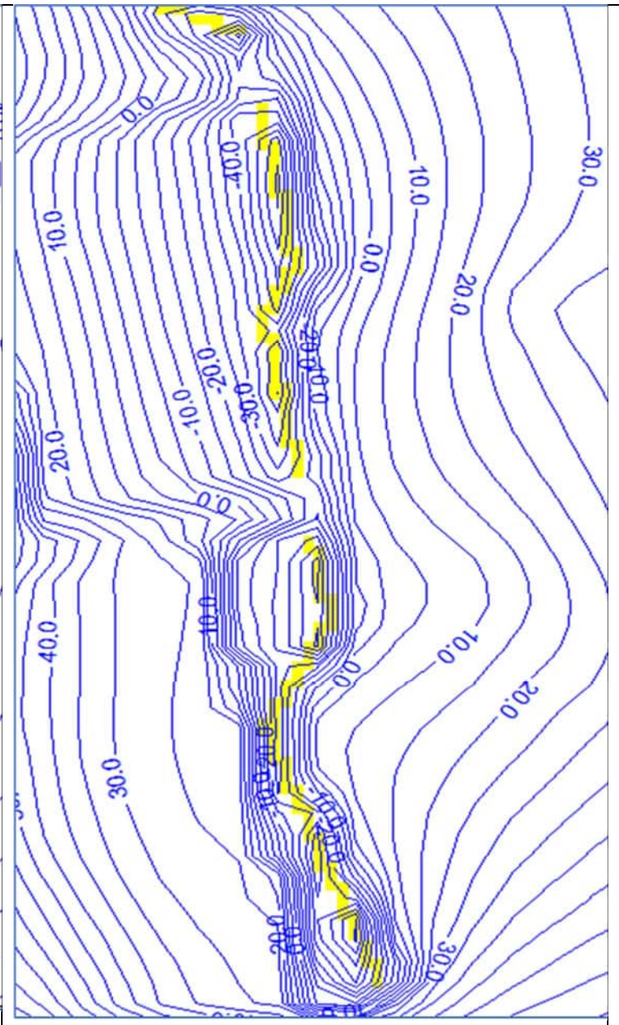
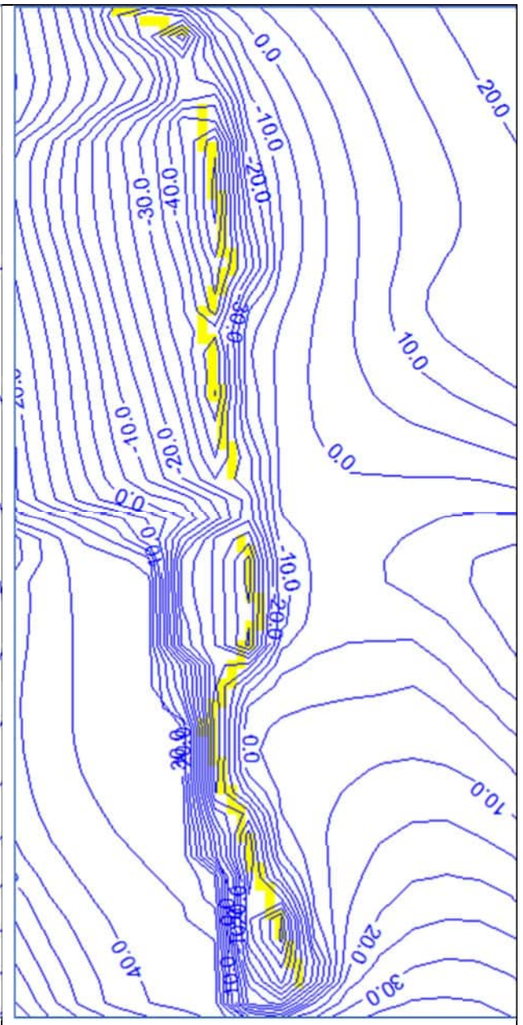
Plate 42 Goonyella residual void particle placement and tracking first 10 years of P3



Yellow model cells are the Goonyella residual void
Grey model cells are cells used for the Goonyella residual void particle tracking

Figure 59 Groundwater flow contours for P3 years 2061, 2063, and 2070 – Goonyella Pit (GLS contours)

Location	2061 (North)	2063 (North)	2070 (North)
			

			
Location	**2061 (South)**	**2063 (South)**	**2070 (South)**

Yellow model cells depict the Goonyella residual void
Purple model cells are dry (unsaturated)

The GLS groundwater flow pattern shows the groundwater contours in 2061 and 2063 facilitate flow towards a groundwater depression along the East-West direction, as well as form a groundwater divide in the North-South direction, east of the shallow central portion of Goonyella Pit (divide on Figure 59). This explains how particles are predicted to move away from the portion of the Goonyella Pit and then turn north and south, due to the influence of the groundwater divide.

Groundwater contours in 2070 indicates the developed groundwater divide adjacent to Goonyella Pit in response to RHM mining.

15.6.2.2 First 10 years of P4 (2093 – 2102)

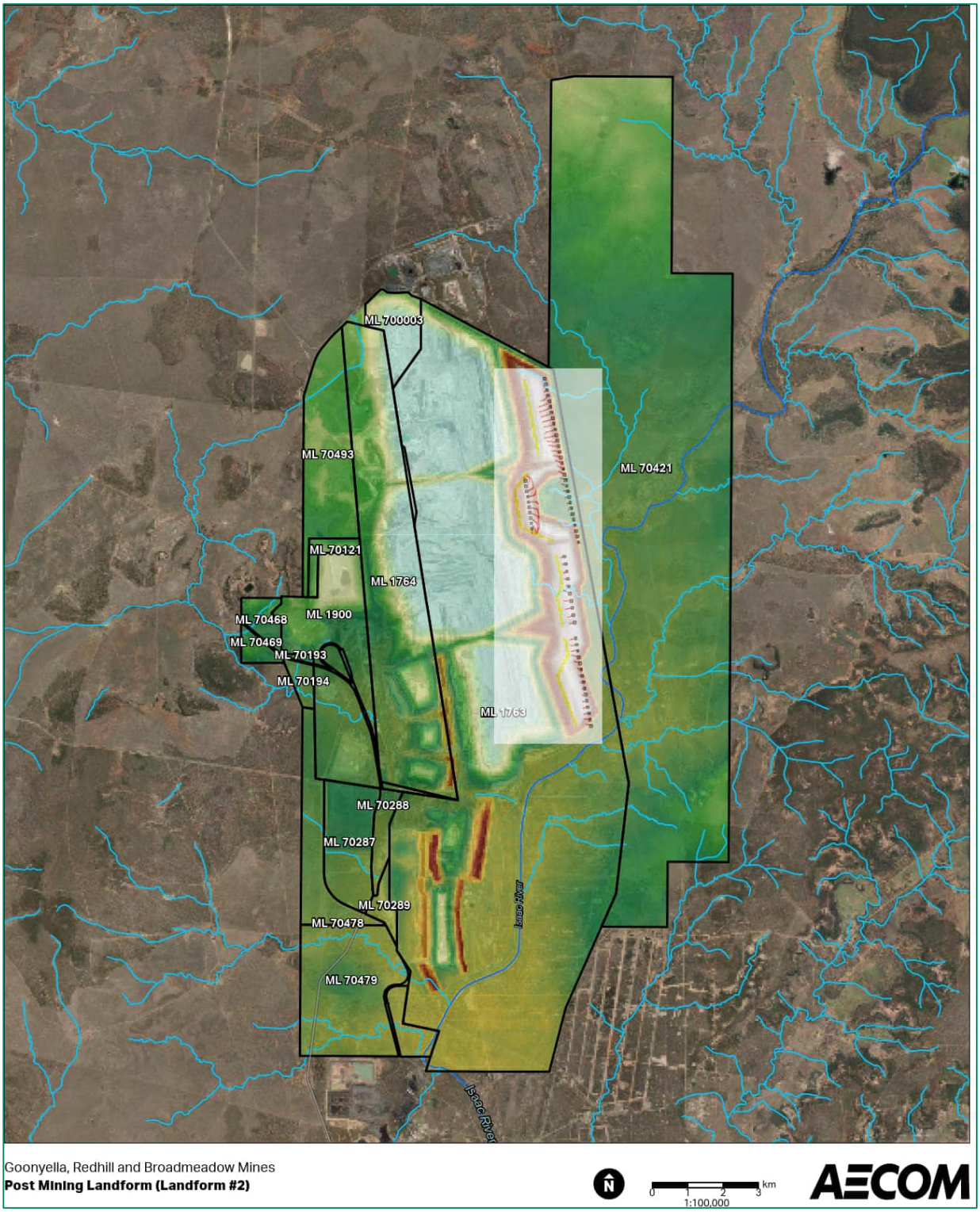
The particle tracking during this time period is included in Plate 43, and indicate flow into the deepest Goonyella Pit locations.

The particles adjacent to the shallow central portion of Goonyella Pit, are recognised to migrate back towards the Goonyella Pit during this phase of prediction. This relates to the reinjection of RHM and the stabilisation of flow patterns around Goonyella Pit, which dominates the groundwater flow pattern, as included in Figure 60.

The groundwater flow pattern indicates steep groundwater gradients around Goonyella Pit in 2102. The purple model cells are dry in Figure 60, including immediately west (up dip) of the central shallow section of the Goonyella Pit, indicating the particles from this section of the pit can only flow east due the dry conditions to the west.

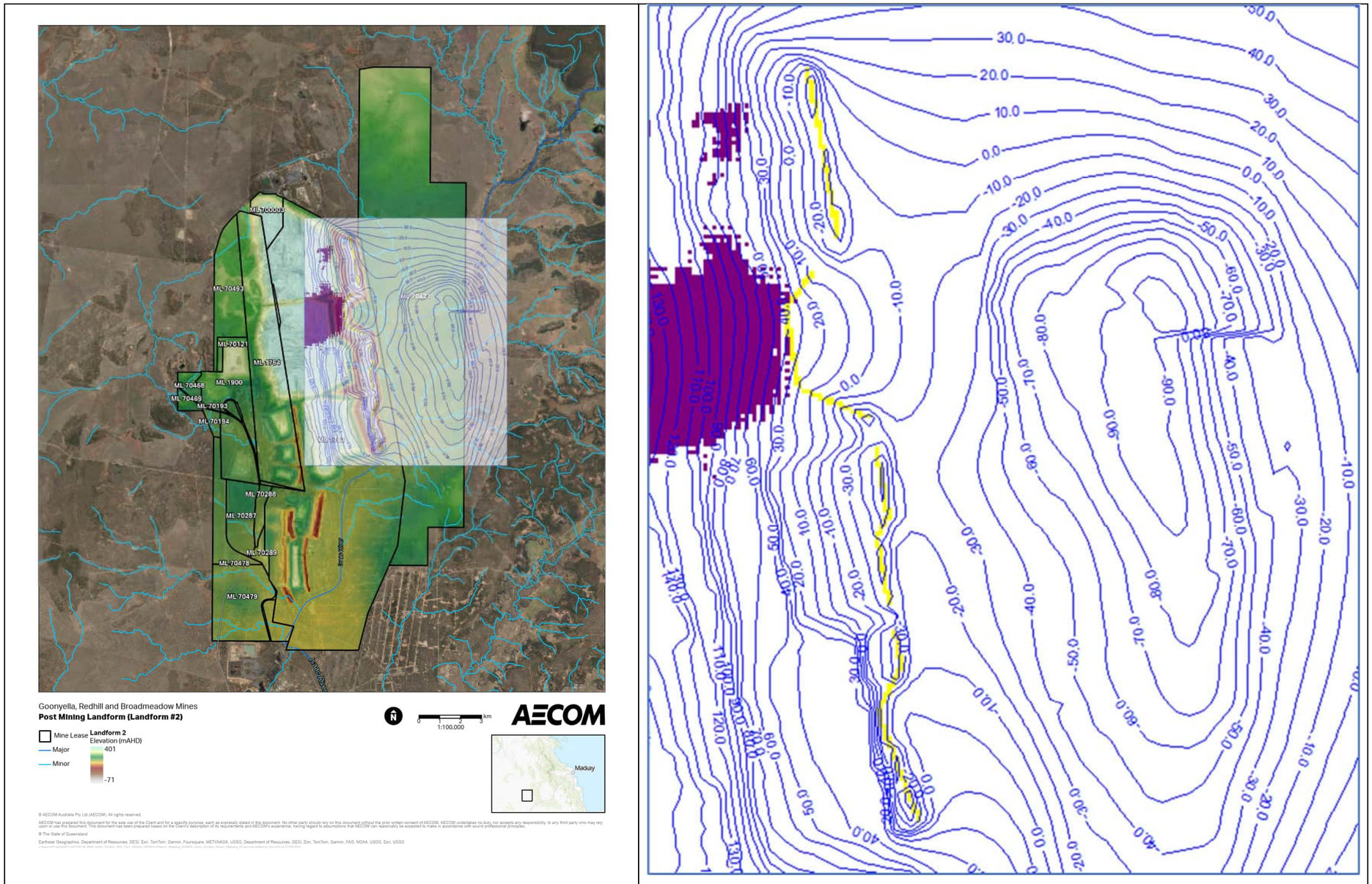
These varying groundwater flow patterns, saturated and unsaturated model cells, plus predicted long term pseudo-steady water levels across the Project was assessed to allow for the evaluation of all residual voids post-closure (i.e., particle tracking for all residual voids was conducted from 2199 (post P4 prediction period) to 2299, a 100-year particle tracking simulation in Section 15.7.

Plate 43 Goonyella Pit particle tracking first 10 years of P4



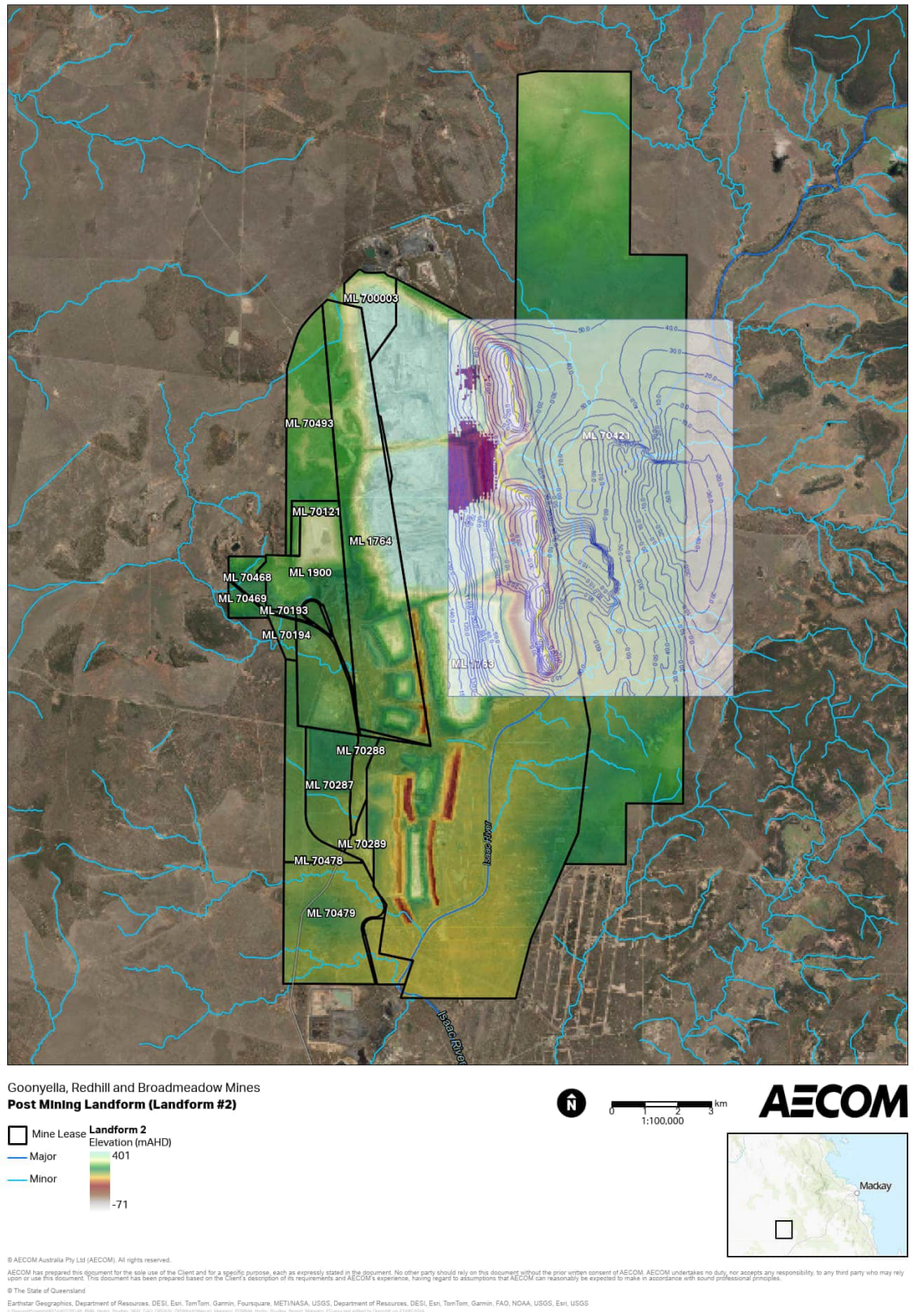
Yellow model cells are the Goonyella residual void
Grey model cells are cells used for the Goonyella residual void particle tracking

Figure 60 Groundwater flow contours for P4 years 2093, 2096, and 2102 – Goonyella Pit (GLS contours)

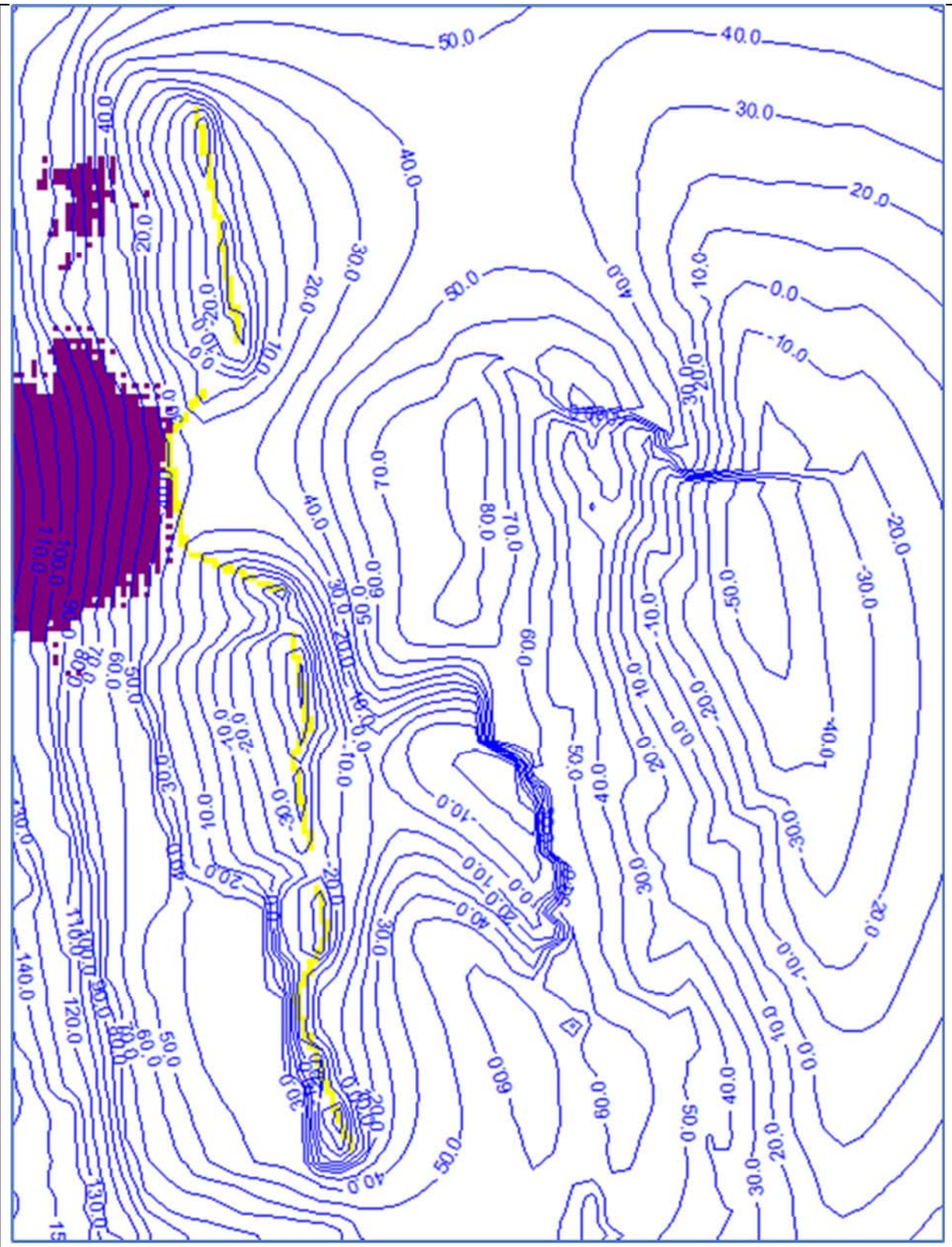


Location	2093

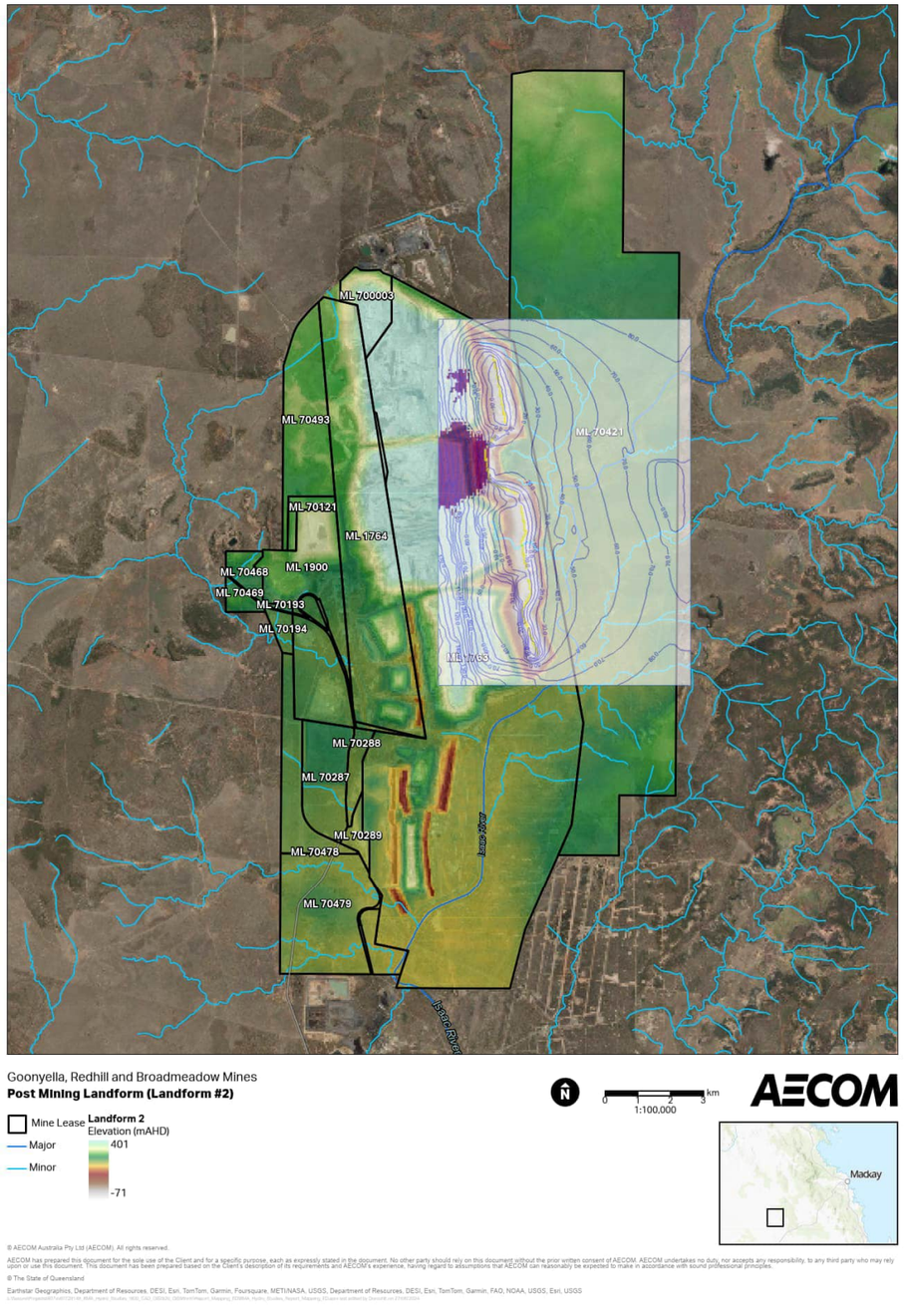
Yellow model cells depict the Goonyella residual void
Purple model cells are dry (unsaturated)



Location



2096 (3-year water introduced 2094 to 2096)



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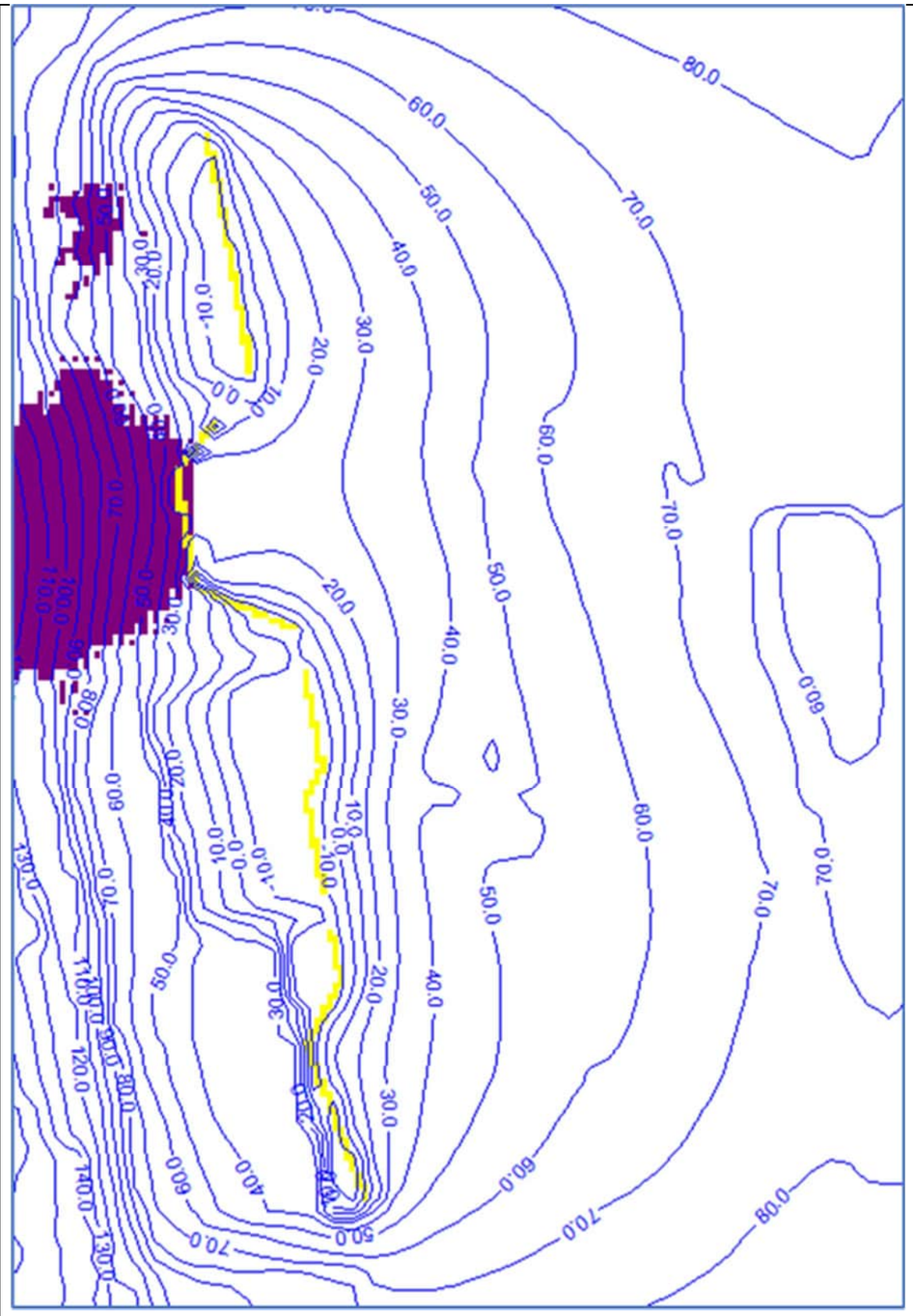

80.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
70

15.7 Long-term assessment

Utilising particle tracking and the predicted groundwater elevations in the long-term, after 2199, the assessment of potential pit water migration within groundwater was conducted. The long-term assessment also considered potential migration from rehabilitated mine waste storage areas located across the model domain.

15.7.1 Particle tracking 2199 to 2299

As per Section 15.6 particles were included both within and immediately next to the residual voids as included in Figure 61. The particles, per year, were simulated within the predictive groundwater model to provide an indication of post-closure flow patterns.

The long term stabilised groundwater flow patterns in the GMS coal seam (in 2299) are included in Figure 61, which shows the Goonyella Pit (yellow model cells) acts as a groundwater “sink” in the long term. Particles included in and immediately adjacent to the Broadmeadow and Isaac pits plus particles within the Thiess, Ramp 32 East, and Ramp 32 South, were predicted to migrate over time. The travel times, in days, indicates that all particles will reach the Goonyella Pit within the 100 year (36500 days) particle tracking timeframe.

The Goonyella Pit influences localised flow within the Project area.

Particle tracking for the Goonyella Pit plus the predicted 2299 GLS groundwater elevation contours are included in Figure 62. Particles included in the model cells immediately adjacent to the Goonyella Pit final void indicate flow into the residual void.

The Goonyella Pit influences localised flow within the GLS at the Project.

15.7.2 Particle tracking for mine waste storage areas

To further assess the potential for water, associated with mine waste storage facilities, to migrate post-closure, particle tracking simulations were conducted.

The mine waste storage facilities and Goonyella and Riverside Mine Industrial Areas, which can act as potential sources of artificial recharge post closure, were included in the predictive groundwater model. The potential sources (identified to have been included in the final landform and will be rehabilitated) are included in Plate 44 (below),and include (refer to Figure 2) RS1 North and South tailings storage facility (TSF)

- GS1 North and South TSF
- Thiess TSF
- Riverside Rejects dump
- R32/Airstrip TSF
- Goonyella Mine Industrial Area (MIA)
- Riverside MIA.

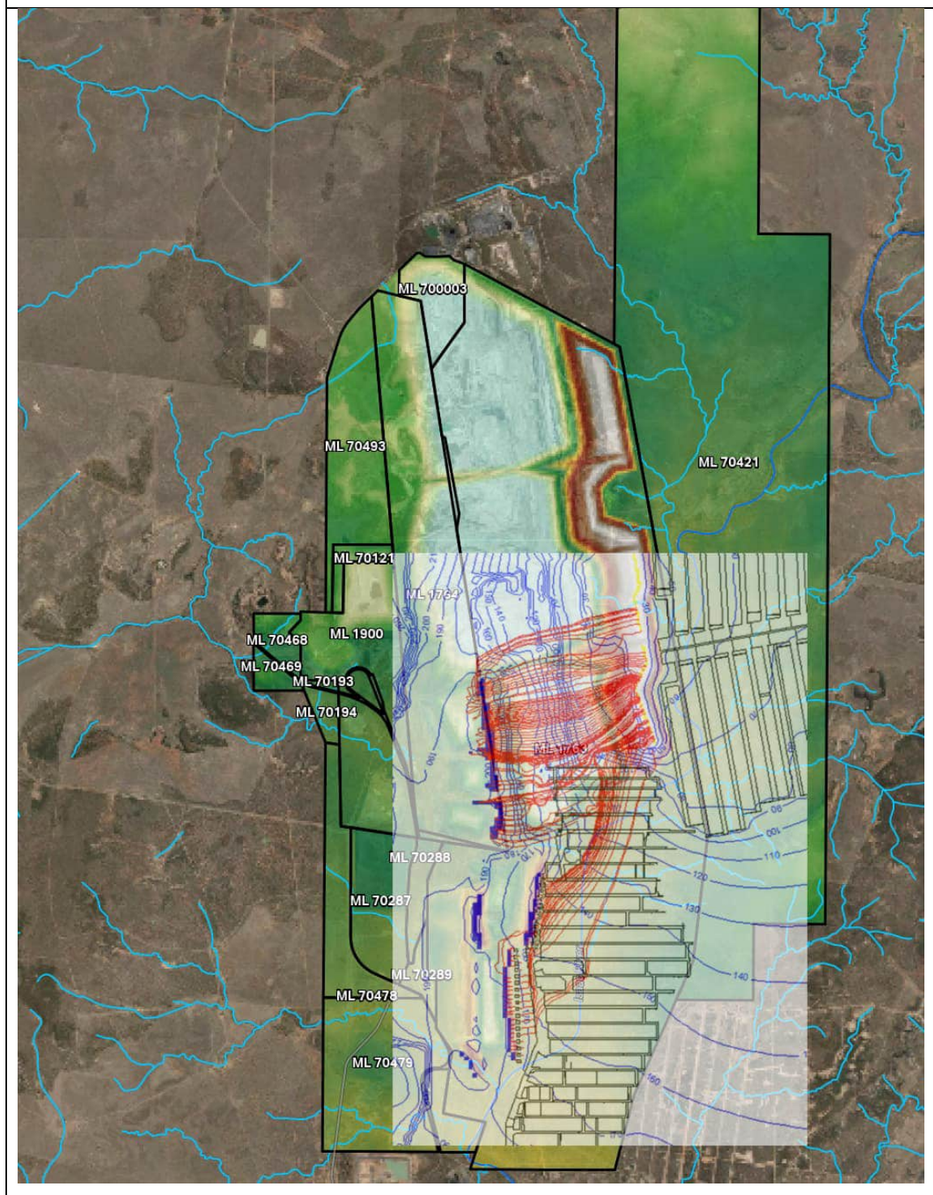
Particles were included within each of these mine waste source areas in model layer 1, simulating possible seepage from these locations post-closure, for 100 years from 2199 to 2299. The resultant particle tracking indicates limited saturation in model layer 1 (purple model cells in Figure 63 are dry during the 2199 to 2299 simulation) resulting in migration from only the southern portion of GS1 TSF, the Riverside MIA, and the Riverside Rejects.

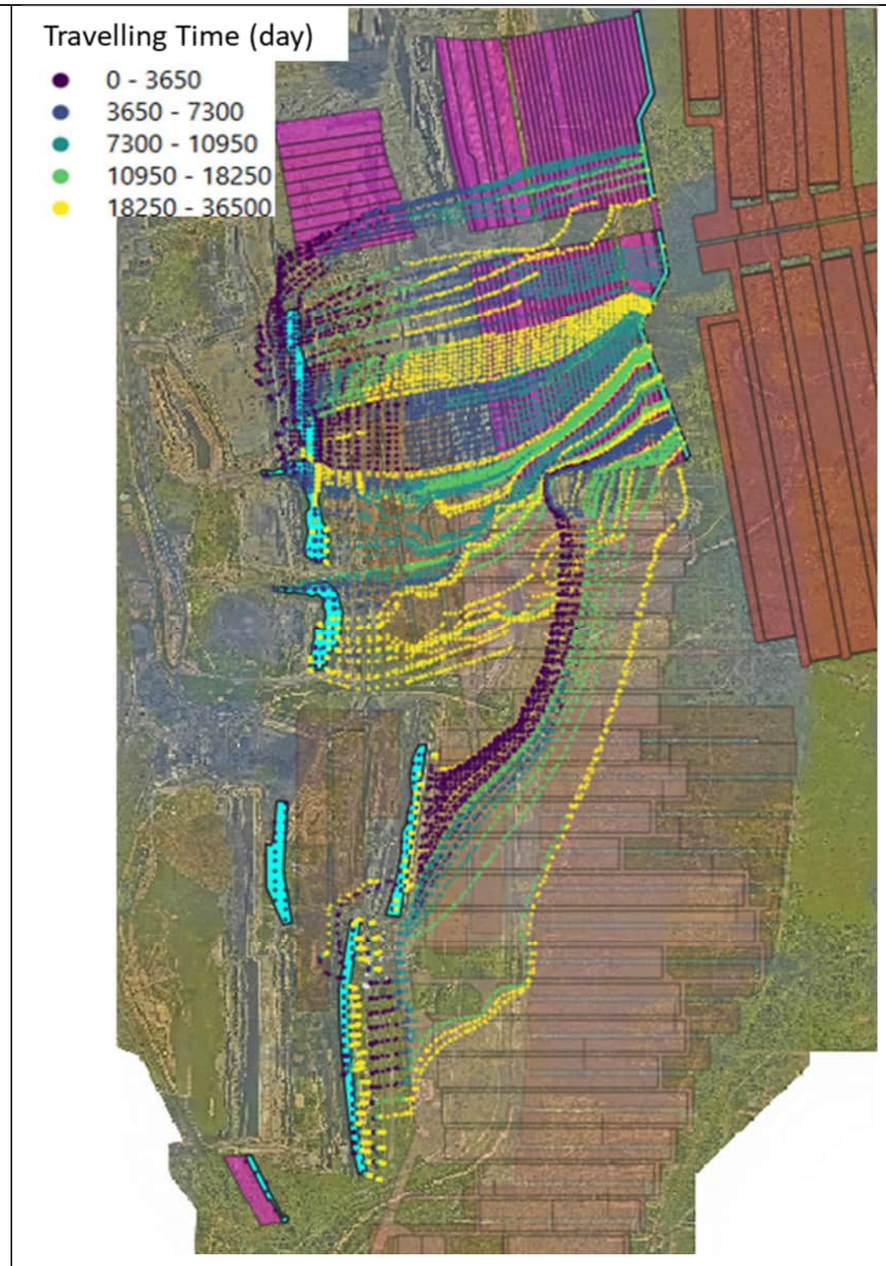
The 100 year particle migration is influenced by the Goonyella Pit; however, the possible migration will take over 100 years to reach the residual void.

Due to the limited saturation in model layer 1, which limits migration assessment, an evaluation of the depth-to-water below these mine waste storage facilities was conducted to evaluate the risk of artificial recharge from these facilities to the groundwater post-closure.

Figure 61 Long-term particle tracking for the residual voids except Goonyella Pit

Particle tracking for 100 years (2199 to 2299) for the five residual void except Goonyella Pit, particles include in the 5 pits plus outside of Broadmeadow and Issac pits





GMS groundwater elevation contours in 2299

Figure 62 Long-term particle tracking for the Goonyella Pit residual void

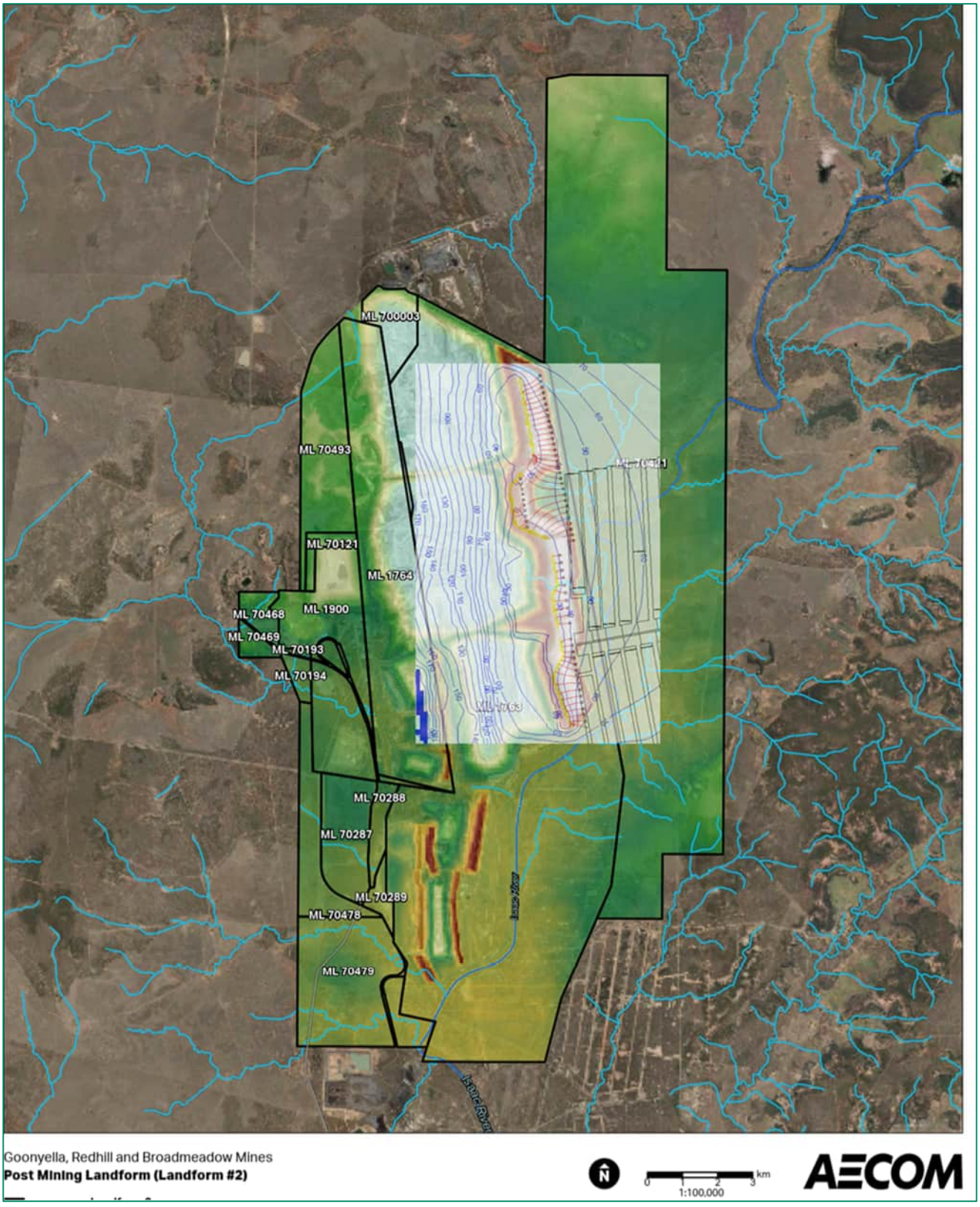


Plate 44 TSFs, MIAs, and the Riverside Rejects locations

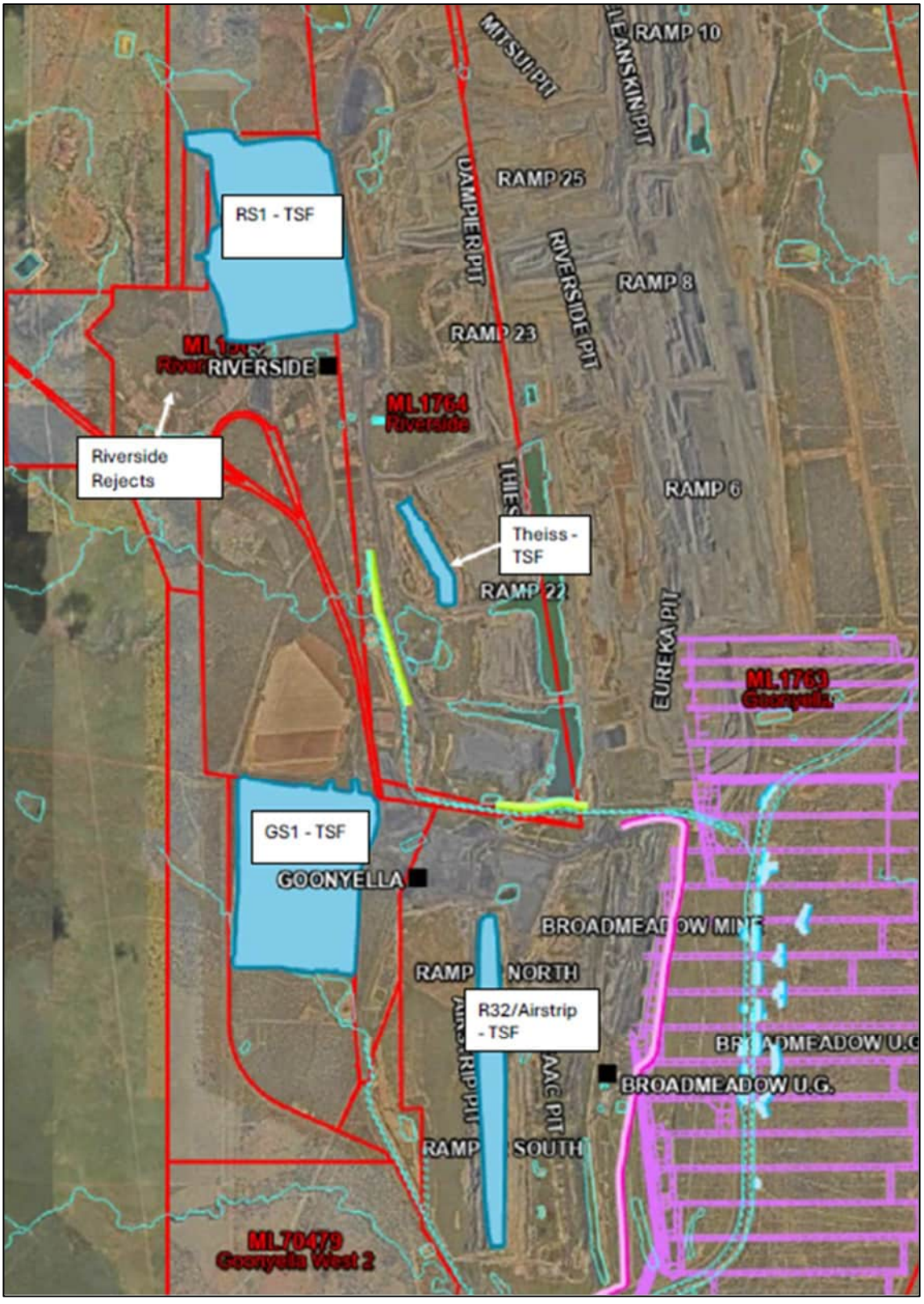
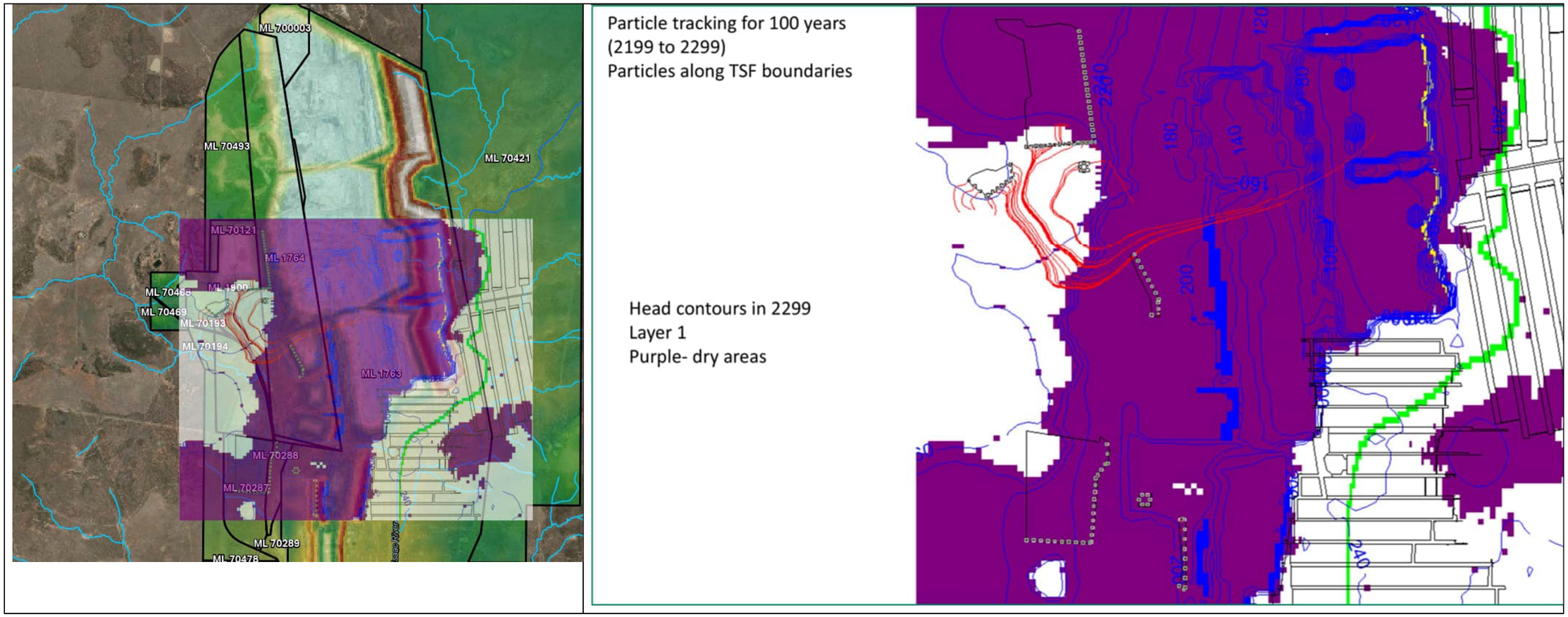


Figure 63 Particle tracking from mine waste storage facilities

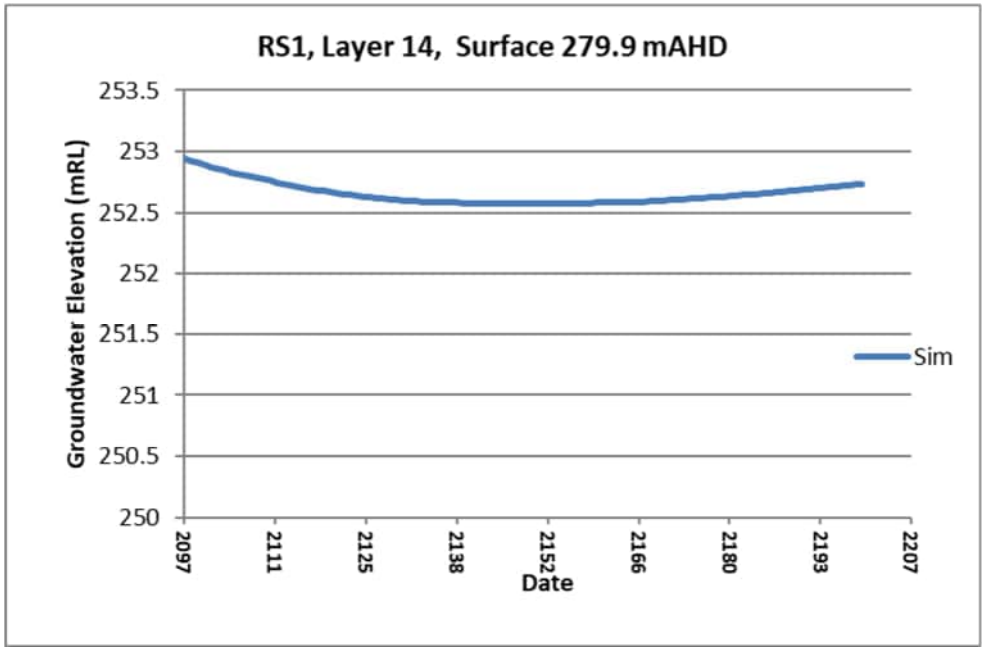


Purple model cells in the surficial sediments (model layer 1) are dry
White model cells are saturated
Green model cells represent the Isaac River

Mine closure when all mining and decommissioning activities have ceased is recognised to be 2097. This is considered to include the rehabilitation of all mine waste storage facilities, included in the particle tracking simulation above. Hypothetical water level observation points were included within the predictive groundwater model within the footprints of these mine waste storage areas, MIAs, and rejects dump. The water level hydrographs allowed for the assessment of groundwater elevations (depth-to-water) at these locations from 2097 to 2199.

The resultant water level hydrographs provided the depth-to-water at each site at the start of the post-closure particle tracking simulation 2199 to 2299 (Figure 63). The hypothetical observation points water level hydrographs indicate:

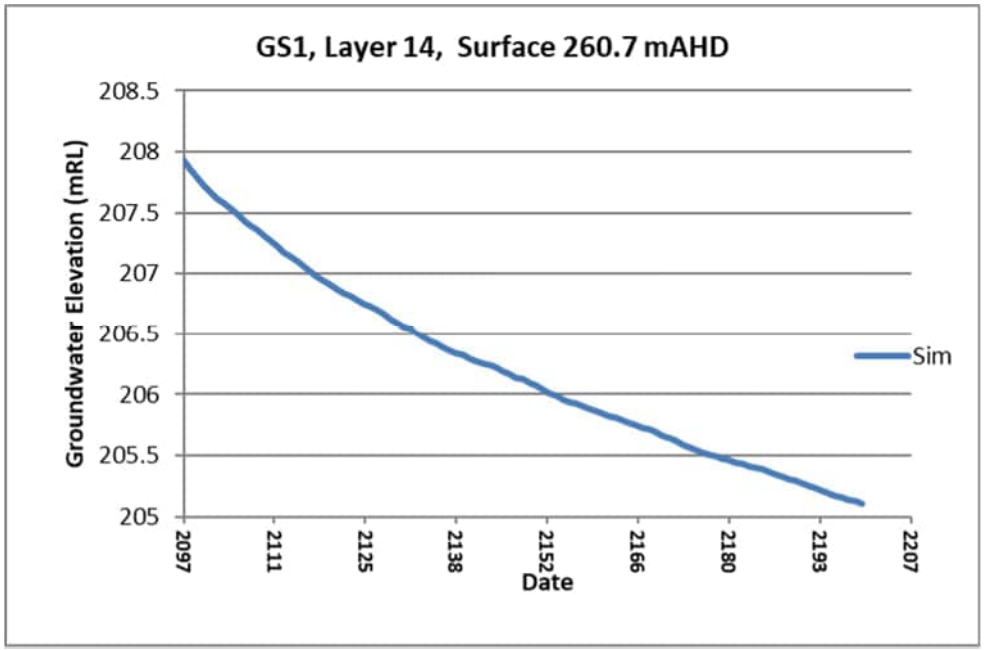
- RS1 North and South TSF



Sim – simulated groundwater elevation in mAHD

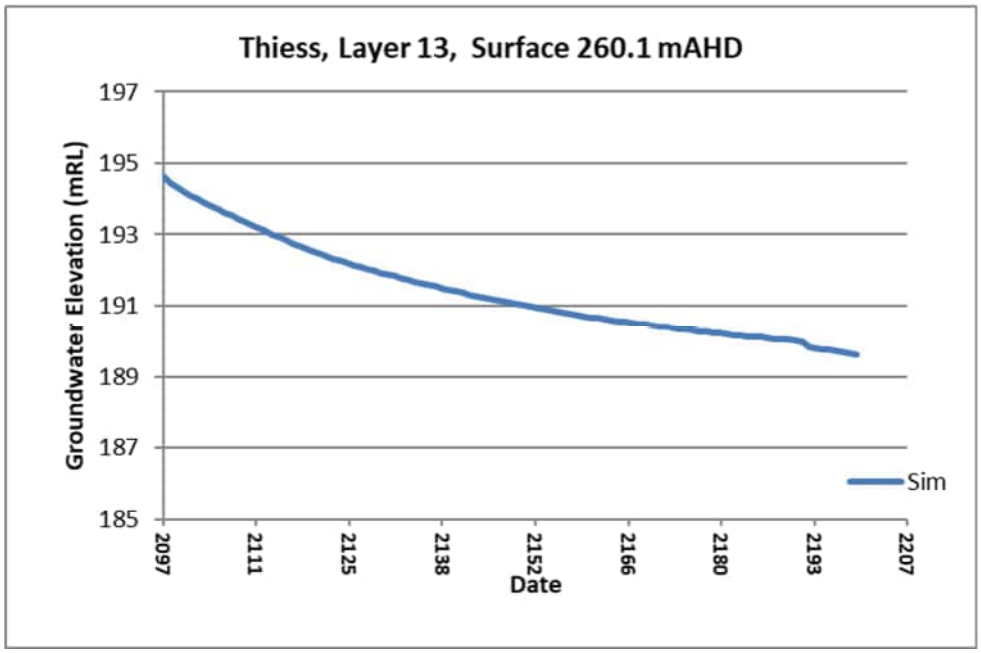
- The saturated model layer below the RS1 TSF is the Back Creek Group, and the depth-to-water at the centre of the TSF is some 27 m below surface.
- The aquitard nature of the Back Creek Group (Table 20) indicates limited vertical seepage migration potential below the TSF.
- Particles were included in the south of the TSF were the surficial cover (model layer 1) is predicted to be saturated.

- GS1 North and South TSF



  - The saturated model layer below the GS1 TSF is the Back Creek Group, and the depth-to-water is some 55 m below surface in 2199.
  - The aquitard nature of the Back Creek Group negates the risk of vertical migration from surface to the saturated Back Creek Group in this location.

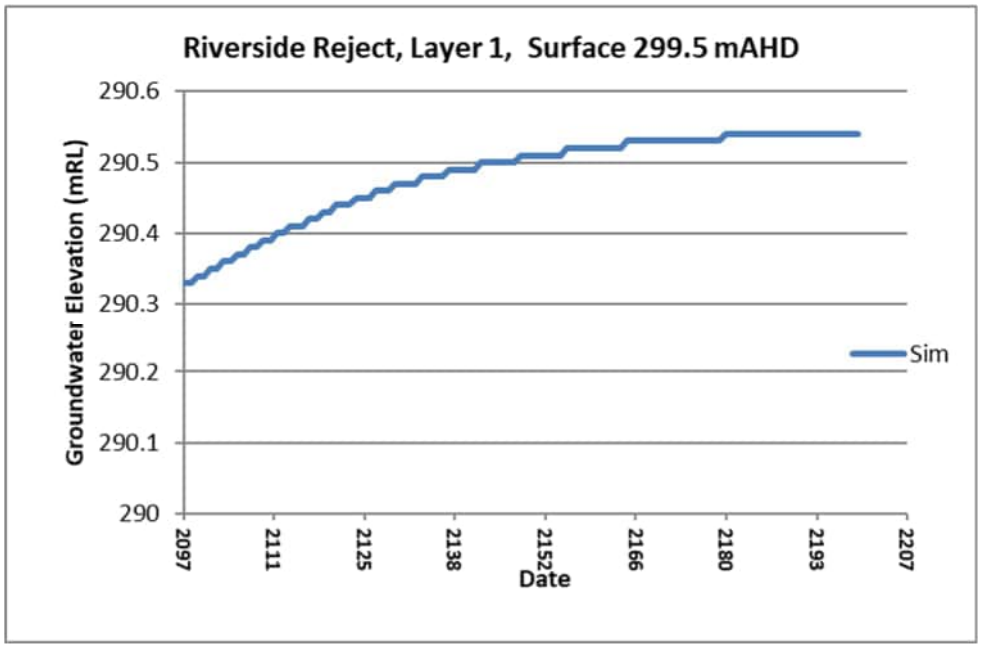
- Thiess TSF



  - The saturated layer below the Thiess TSF is model layer 13, the underburden below the GLS coal seam.
  - The depth to the groundwater in 2199 at this TSF is 70 m.
  - The thick unsaturated zone reduces potential for artificial recharge (if possible after rehabilitation) to enter the saturated hydrostratigraphic units and migrate within the

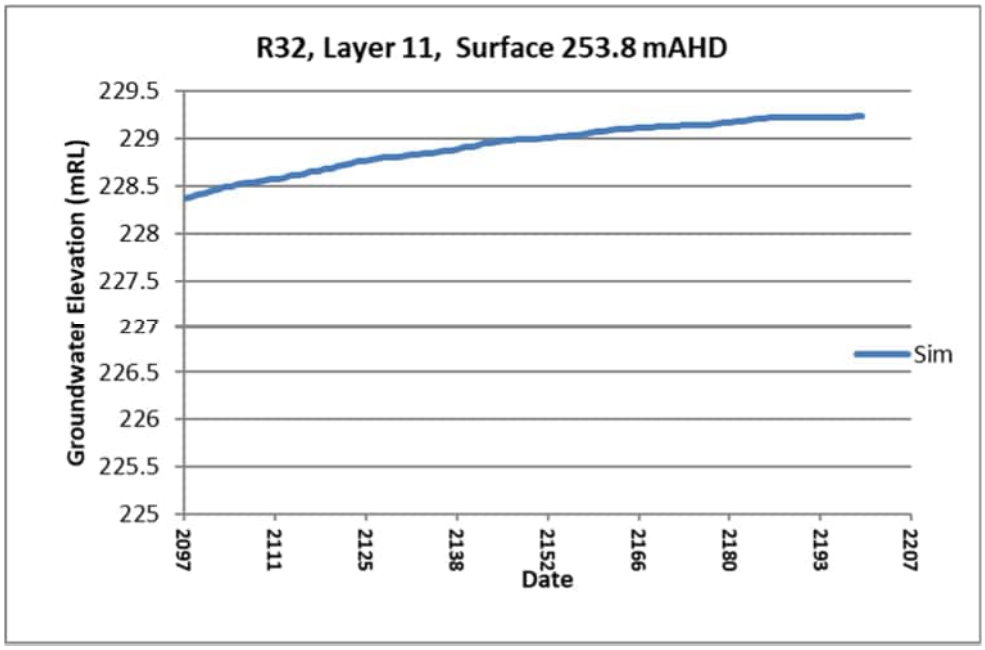
groundwater. Noting that any possible artificial recharge migration would ultimately end at the Goonyella Pit.

- Riverside Rejects dump



  - The surficial cover is saturated within the Riverside Reject area, with groundwater approximately 9 m below surface.
  - Particle tracking for this waste storage facility is included in Figure 63.

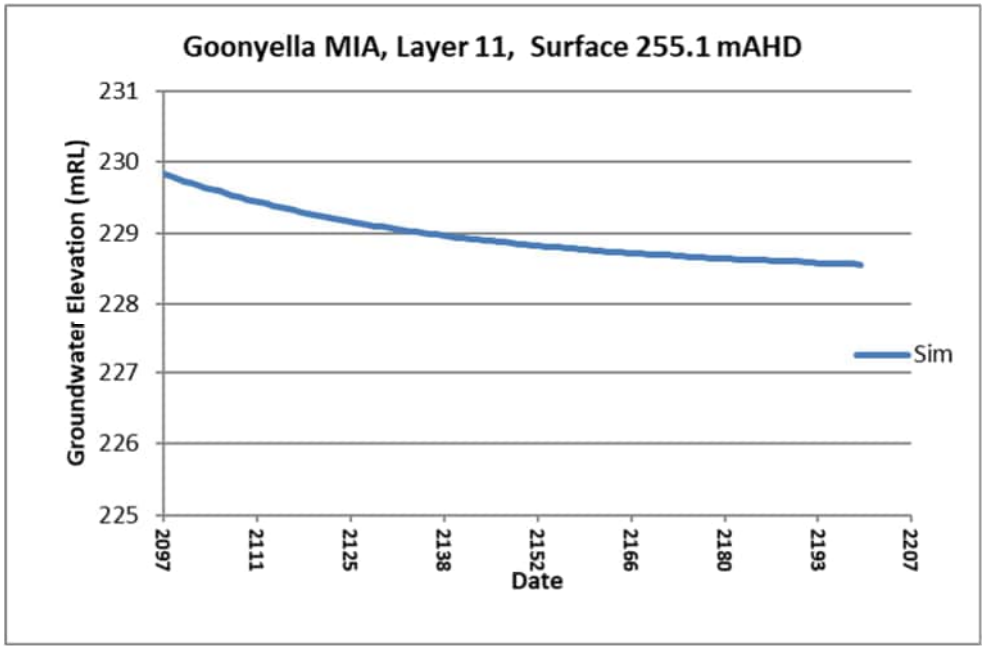
- R32/Airstrip TSF



  - The saturated layer below the Airstrip TSF is model layer 11, the interburden between GMS and the GLS coal seams. Note: The GMS subcrop is predicted to be dry post-closure (Section 15.7.3).
  - The depth to groundwater in 2199 in this location is 25 m.

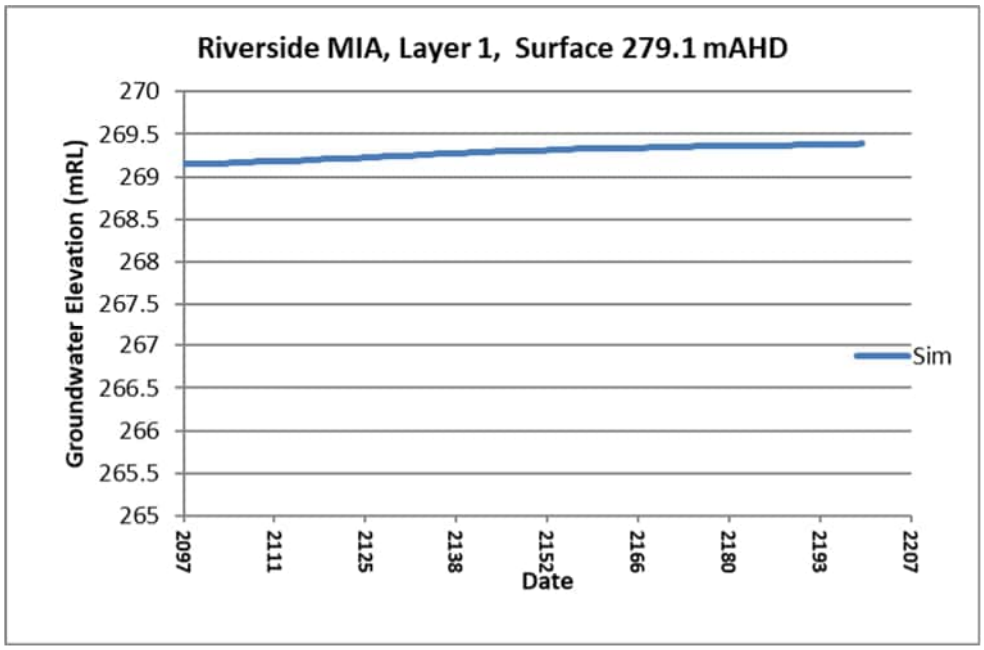
- Possible artificial recharge (if possible after rehabilitation) resulting in vertical migration to the saturated hydrostratigraphic units and migration within the groundwater is limited in this area. Noting that any such migration would report to the Goonyella Pit.

- Goonyella Mine Industrial Area (MIA)



- The saturated layer below the Goonyella MIA is model layer 11, the interburden between GMS and the GLS coal seams. Note: The Goonyella MIA is located to the west of the GMS outcrop.
- The depth to groundwater in 2199 in this location is some 25 m.
- Possible artificial recharge (if possible after rehabilitation) resulting in vertical migration to the saturated hydrostratigraphic units and migrate within the groundwater is limited in this area. Noting that any such migration would end at the Goonyella Pit

- Riverside MIA.
  - The depth-to-water at the Riverside MIA is some 9 m below surface in the surficial cover (Model Layer 1).
  - Particle tracking from this facility is included in Figure 63



The depth-to-water at these facilities indicate the limited risk to groundwater post-closure, based on:

- The thickness of the unsaturated zone below each site
- The limited aquifer hydraulic properties, particularly the vertical hydraulic conductivity, of the underlying units
- The resultant long-term groundwater flow patterns all locally influenced by the deep Goonyella Pit water level (possible water migration from mine storage facilities would end at the Goonyella Pit).

15.7.3 GMS long term saturation

The assessment of particle tracking and predictive groundwater elevations for the GMS indicate that the GMS would remain unsaturated in sections of the Project area post-closure. Groundwater elevations for the GMS after calibration (at the start of prediction phase P1), Figure 39, indicates the influence of historic Broadmeadow GMS underground mining. Water is introduced into the Broadmeadow underground workings between 2057 and 2060 (Section 15.2). An evaluation of groundwater contours for the GMS over time is included in Figure 64.

Figure 64 indicates the influence of Red Hill Mine, the introduction of water into Red Hill Mine, and the Goonyella Pit on the groundwater elevations and flow patterns in the GMS. The groundwater elevations and depth of GMS (bottom of coal seam elevations) allowed for the identification of saturated and unsaturated conditions of the GMS in the model. The purple model cells in Figure 64 indicate dry cells.

The northwest portion of the Broadmeadow GMS underground workings are identified to be unsaturated, after the introduction of water into the underground, over time due to the influence of the Goonyella Pit in this area.

The underground workings are planned to be filled with water to facilitate geotechnical stability. It is noted that mitigation and management of this portion of the GMS workings may be required in the future subject to further geotechnical assessment.

The portion of the Project area presented in Figure 64 is as included below.

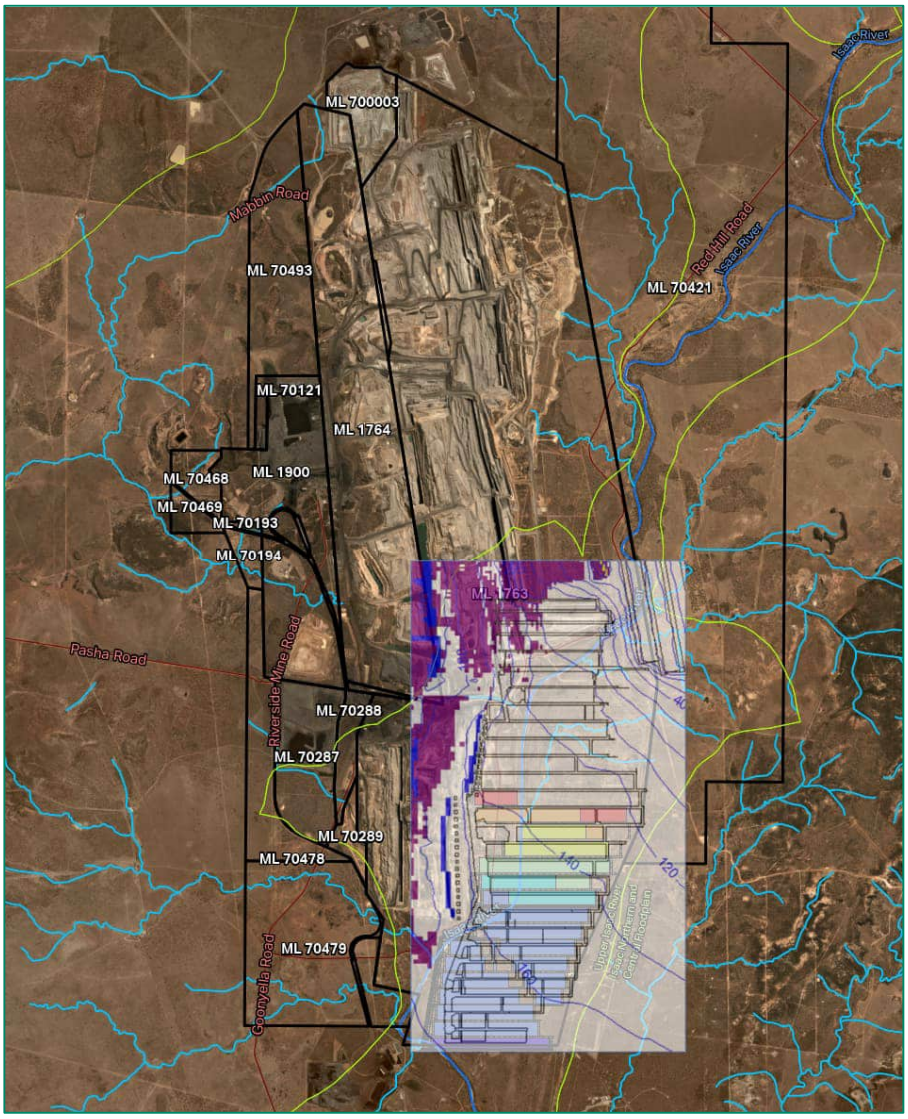
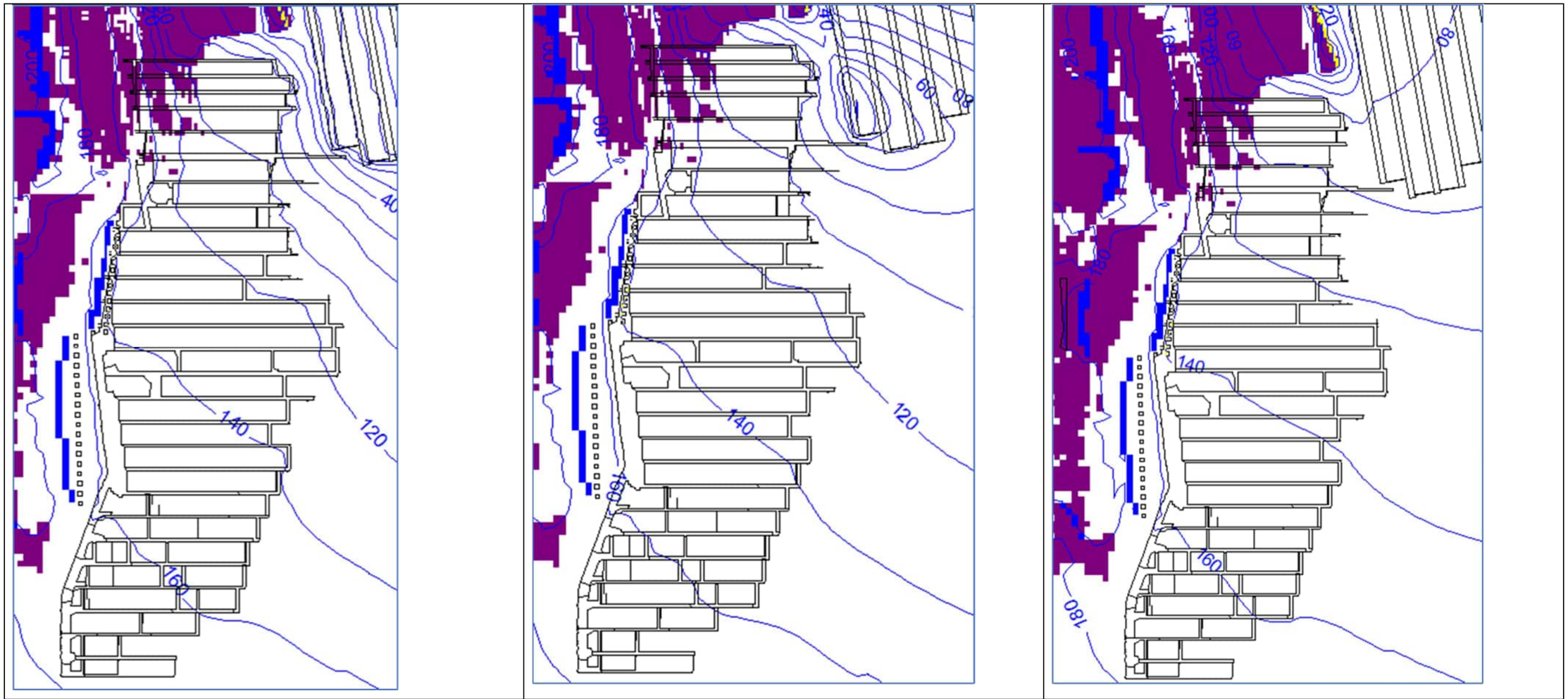
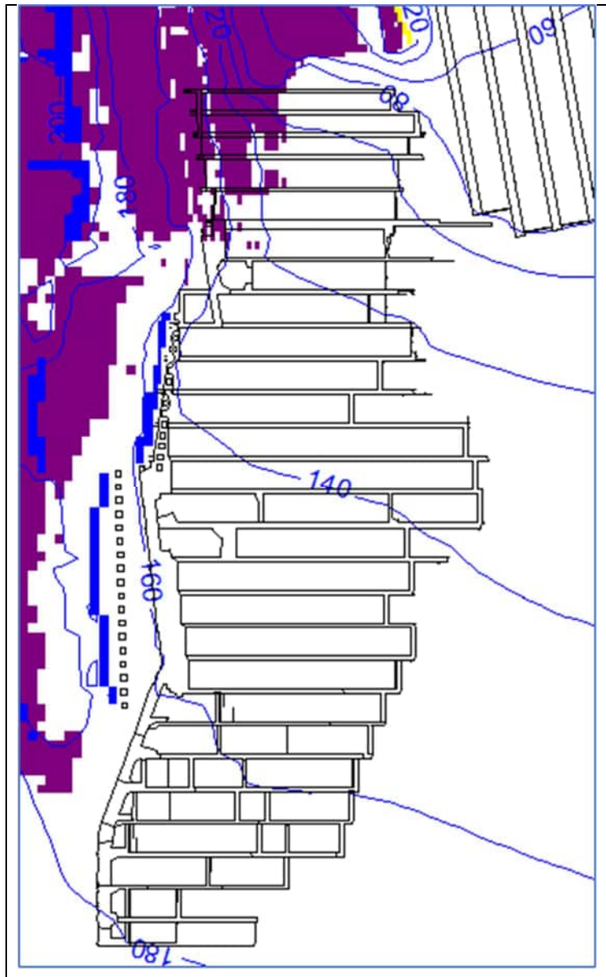
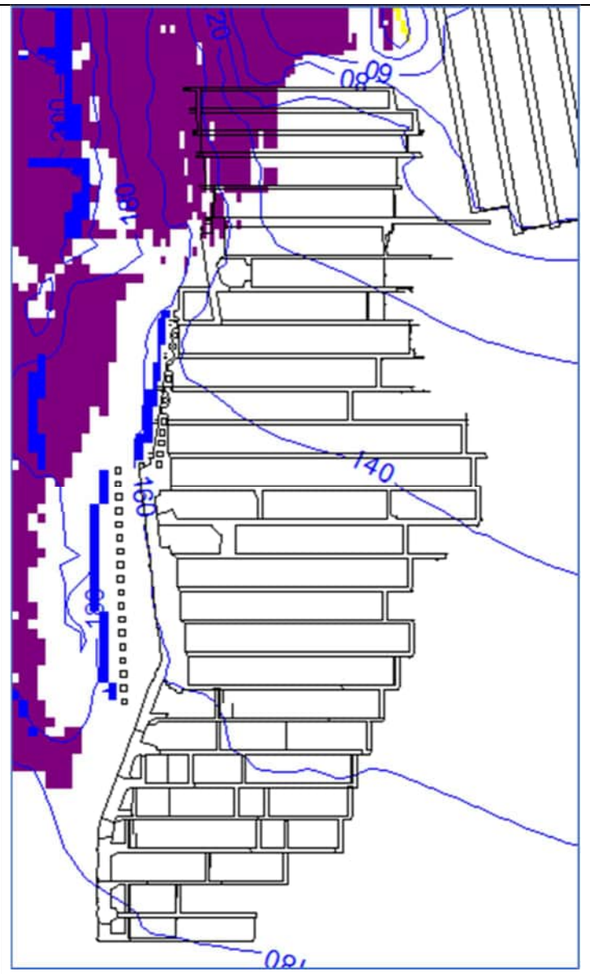
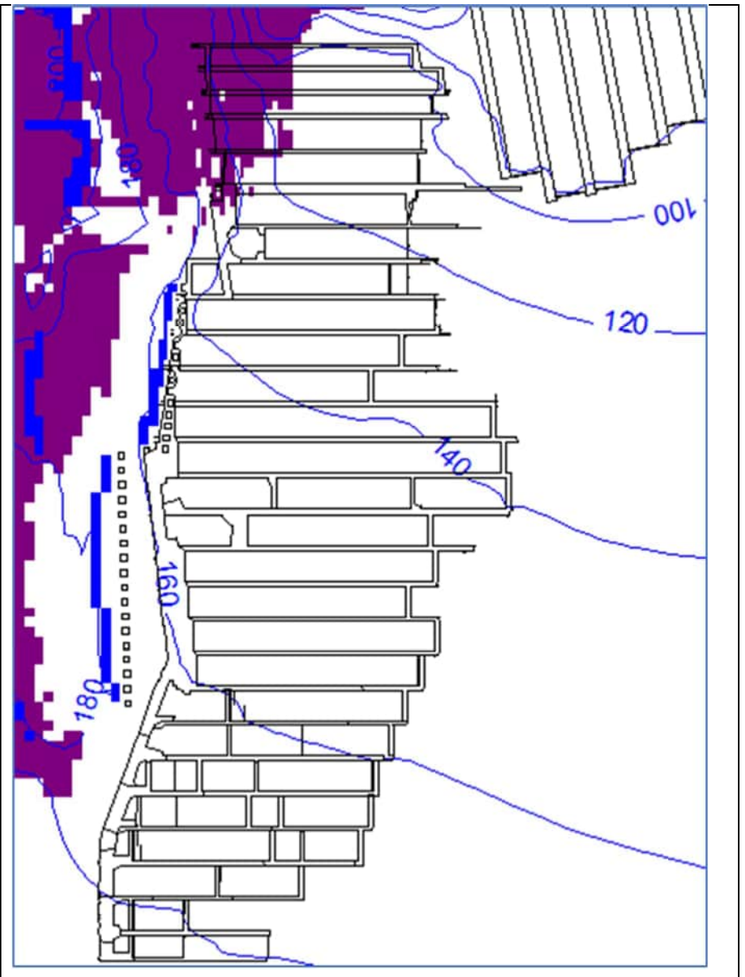


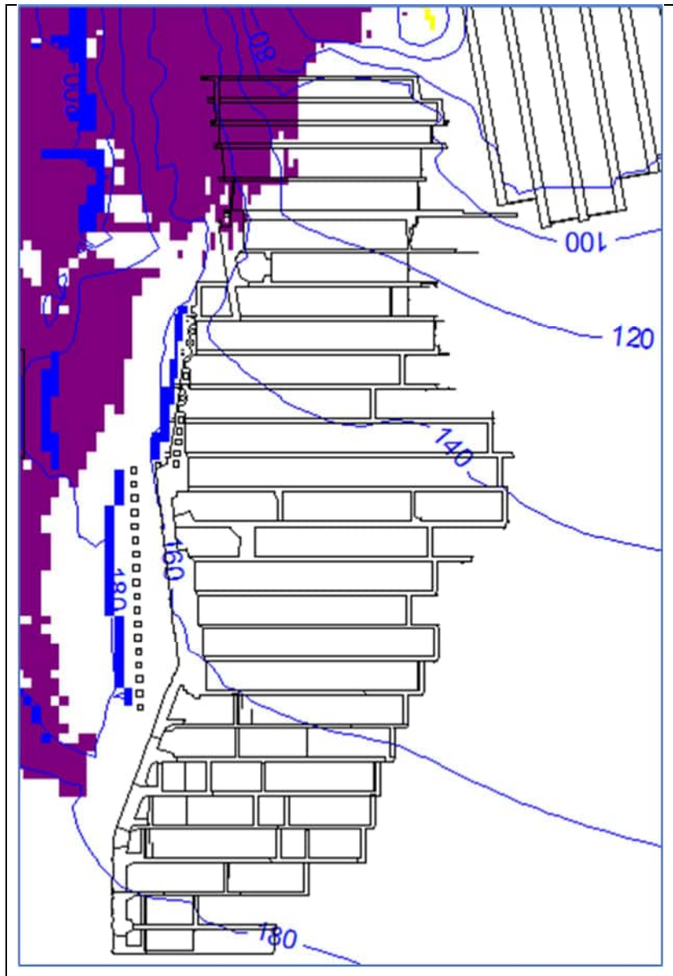
Figure 64 GMS saturated and unsaturated conditions over time



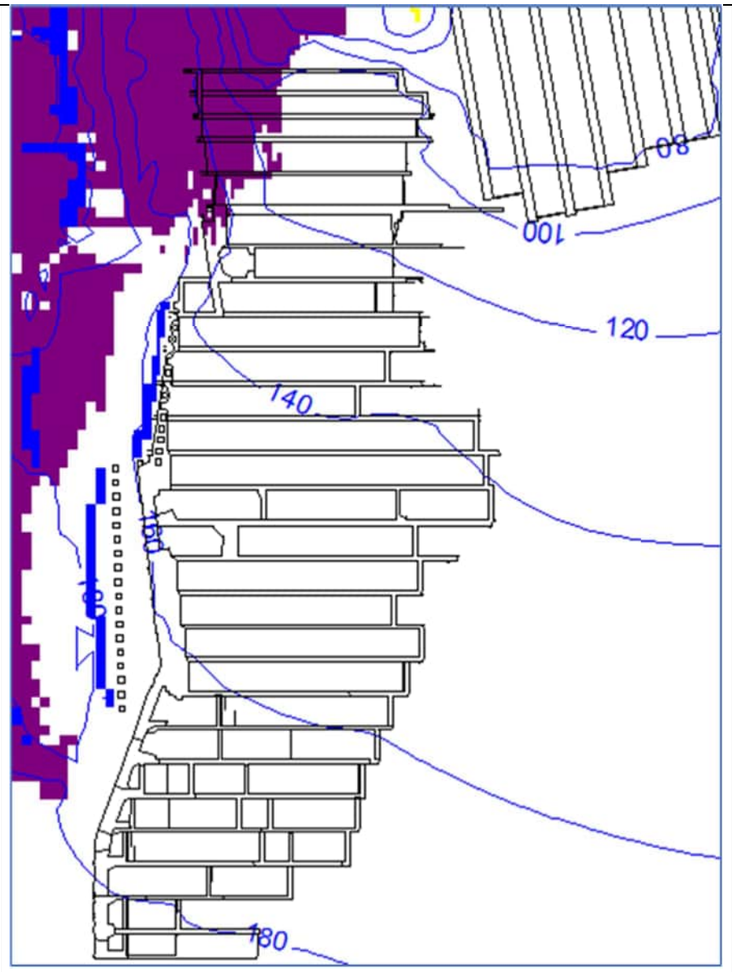
2093	2096 (after RHM water introduced)	2100

Purple model cells are dry
Yellow model cells are Goonyella residual void
Blue model cells are the other five residual voids

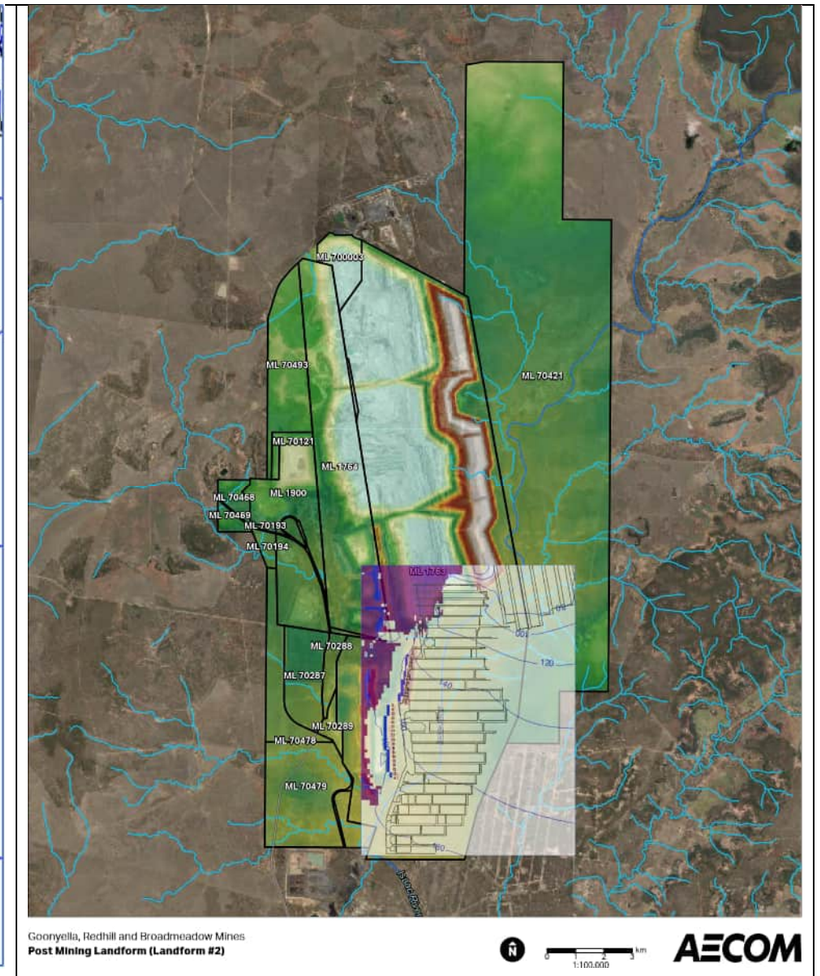
		
2120	**2140**	**2160**



2180



2199



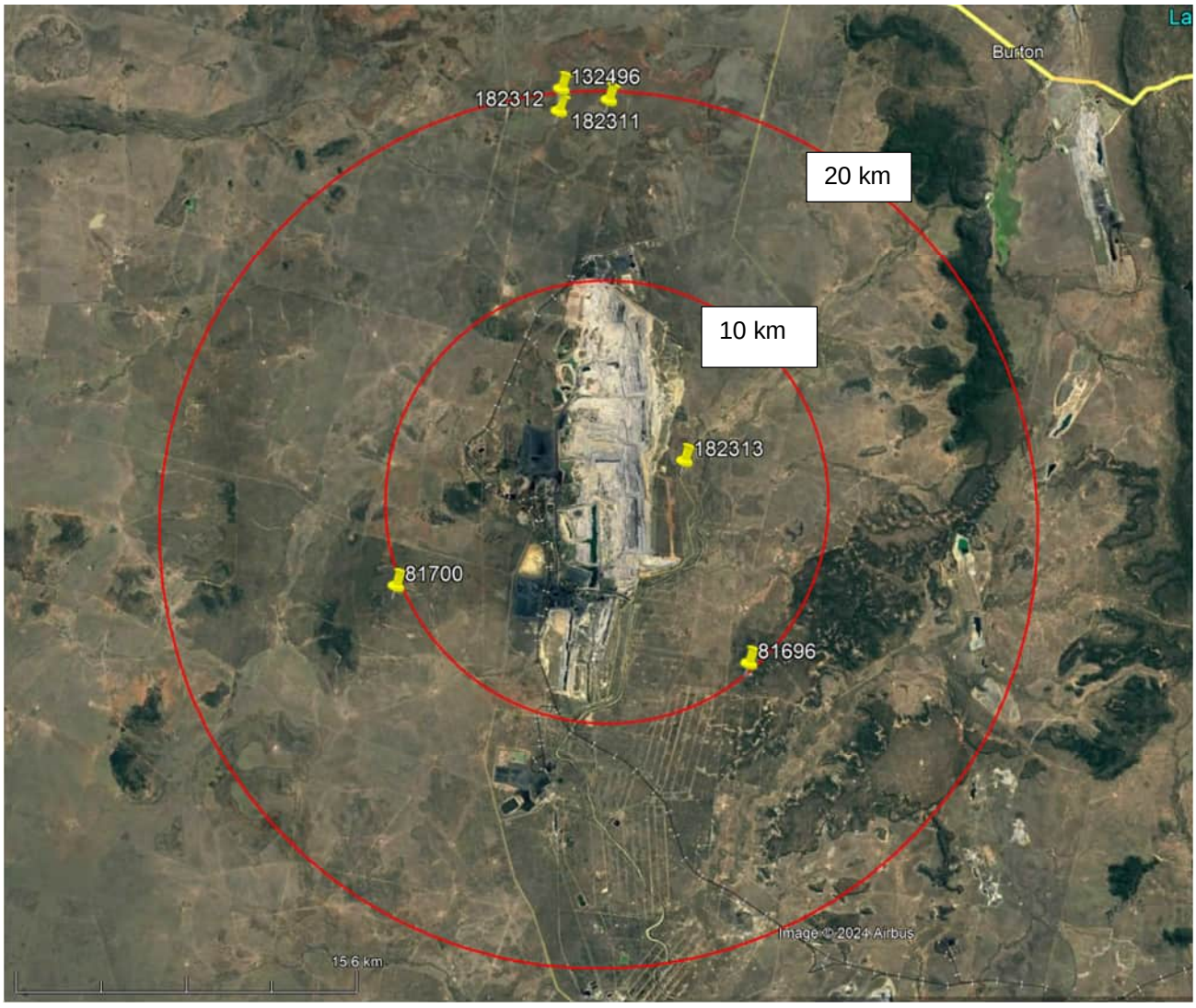
2199 reference

15.8 Potential Groundwater Level Impact to Receptors

15.8.1 Water supply bores

Six water supply bores were identified within the assessment of registered bores, as discussed in Section 9.1. The six water supply bores, as included in Table 14, were located up to 20 km from the GRB mining area, as shown in Figure 65.

Figure 65 Water supply bores identified adjacent to GRB



Groundwater level hydrographs were compiled for each of these registered bores to assist in assessing the potential change in groundwater levels, due to approved mining and post-closure, overtime.

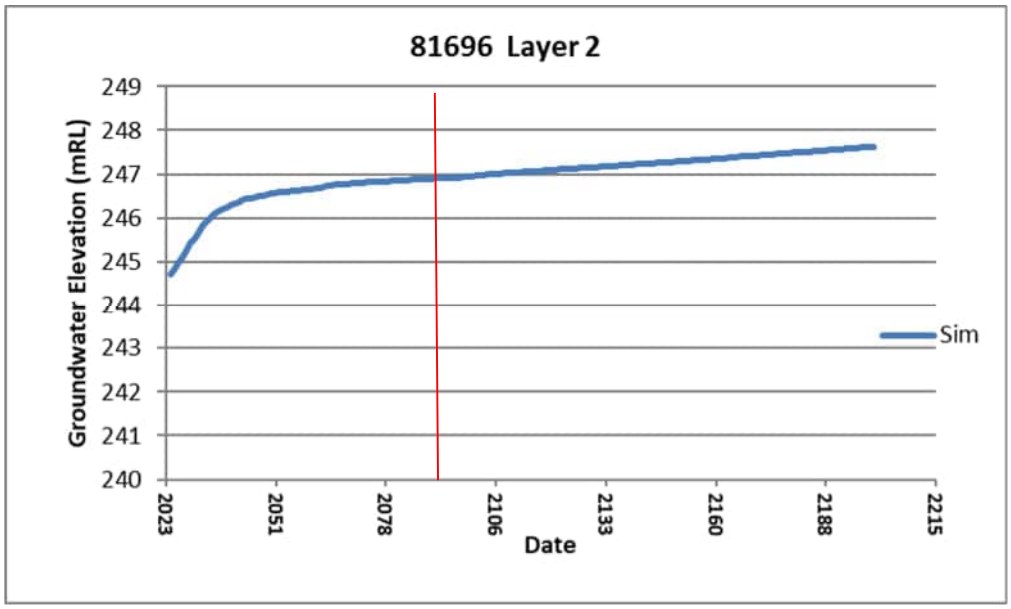
Three water supply bores, at or within 10 km from the current GRB footprint include:

- RN182313, Cleanskin Gully bore, which was drilled to 25.34 m, and based on depth intersects FCCM (model layer 2)
- RN81696, Skeleton Bore, which was drilled to 63.7 m in model layer 2
- RN81700, Harvey's Bore, has no data but assumed to be in model layer 2 (same as the other two water supply bores).

The water supply bores were included in the groundwater model domain and the groundwater levels were simulated during all four prediction phases (Section 15.2), from 2024 to 2199. The resultant hydrographs are discussed below.

The hydrographs include 2097 the date when mine closure is recognised, when all mining and decommissioning activities are complete.

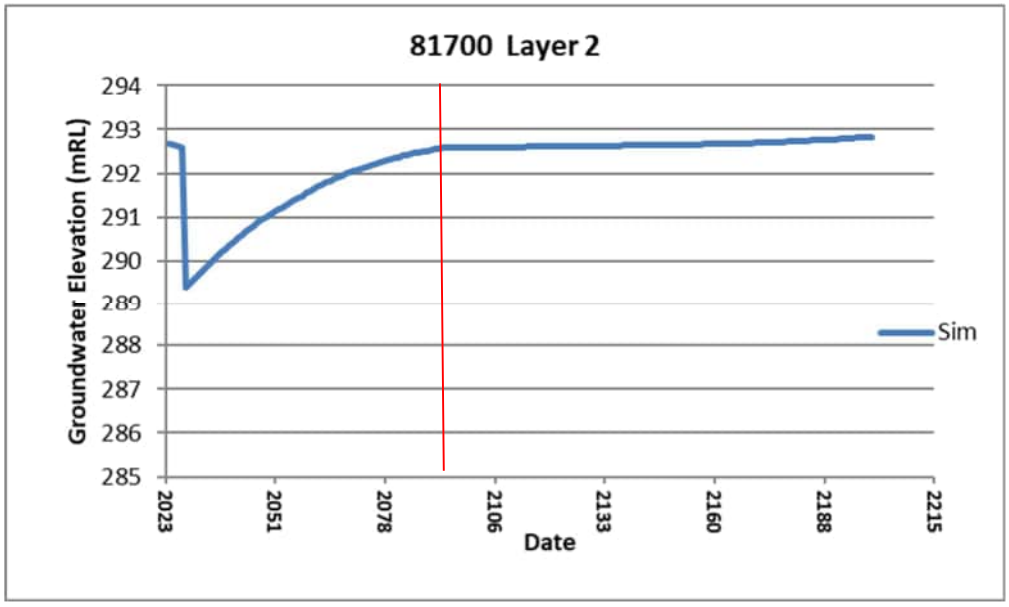
RN81696 Skeleton Bore



Sim – simulated groundwater level within the water supply bore
Red line – 2097 closure date

The bore, located some 10 km to the south west of GRB is recognised to recover over time, indicating no predicted alteration due to GRB during and post-closure in this location.

RN81700 Harvey's Bore

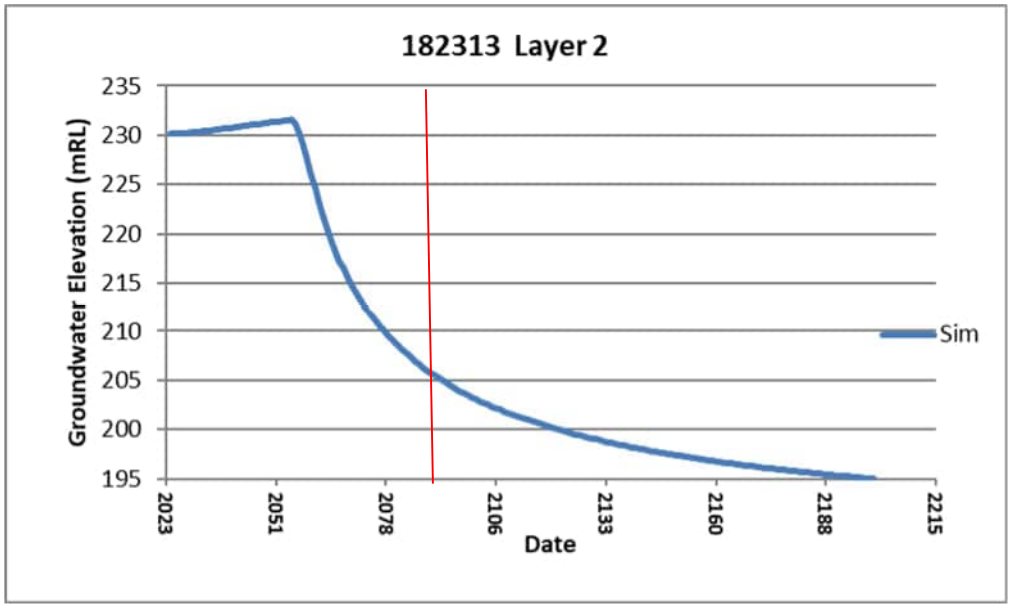


Sim – simulated groundwater level within the water supply bore
Red line – 2097 closure date

Note: Harvey's Bore is located to the west of the GRB mining, on Back Creek Group sediments. The Model Layer 2 to 13 in this area are dummy layers as required in the MODFLOW model. The surficial sediments, alluvium and Tertiary, are 10 m thick in the model to the west of the Permian coal bearing units. This bore is assumed, based on the other water supply bores, to be deeper than 10 m and thus included in the underlying model layer.

The groundwater drawdown for RN81700 is predicted at the start of the prediction period P1 (2024 – 2056), which includes the Broadmeadow underground mining. This change in groundwater level possibly relates to matching calibration levels for the Back Creek Group rather than mine related drawdown (i.e., the mine dewatering activities are not predicted to impact on Back Creek Group sediments to the west). The groundwater level then recovers back to 2024 (start of P1) groundwater elevations.

RN182313 Cleanskin Gully Bore



Sim – simulated groundwater level within the water supply bore
Red line – 2097 closure date

This bore, down dip and in proximity to the residual Goonyella Pit void, is predicted to be dewatered overtime and remain dewatered post-closure. This bore is located in proximity to the Goonyella residual void high wall on BMA operated area. Therefore, it is reasonably assumed not to be used for supply purposes.

A drawdown of some 35 m will, based on the bore depth of 25.34 m, become dry with time. It is considered that the approved mining activities will result in the dewatering of the bore and has been assessed and managed under approval conditions.

15.8.1.1 Remaining water supply bores

Based on the limited impact of the mining post-closure at 10 km from the Project, the three registered bores, 182311, 182312, and 132496, are located some 20 km from GRB and thus are sufficiently far from the mining activities to not be impacted. These water supply bores are located outside the active model domain (Plate 16) (i.e., these bores are beyond the northern model boundary, which is based on the Isaac River catchment).

15.8.2 GDEs

The mapped potential GDEs (aquatic and terrestrial) are included in Figure 20. The mapping indicates low potential terrestrial GDEs adjacent to the Isaac River with the river channel itself identified as having high potential aquatic GDEs. Mine water storages across the GRB are mapped as high and moderate potential GDEs. It is noted that these storages, including the RS and GS TSFs (Plate 44) will be rehabilitated at closure. As per Section 9.2 it was noted that the potential aquatic GDEs, mapped in Figure 20, included areas containing tailings dams, mine water storages, and mining voids. Thus, the mapping is recognised to identify potential GDEs only.

Groundwater elevations derived during the groundwater model at the end of 2023 (Q1 2024) are included in Figure 66. These groundwater levels and flow patterns were representative of the influence of approved mining activities within the Project area. The modelling identified where saturated sediments, which can provide groundwater for GDEs, have been dewatered due to approved mining activities.

The extent of groundwater drawdown in the surficial sediments (Model Layer 1) as discussed in Section 15.5.1, is identified to be limited to the proximity of the mine workings. This is due to:

- The discontinuous nature of the surficial sediments
- The thin saturated thickness of the surficial cover
- The discontinuous nature of saturated sediments
- The restricted aquifer hydraulic properties.

Groundwater elevation contours from north (upstream) to south (downstream) along the Isaac River (green model cells) do not indicate any drawdown influence in 2024 (start of prediction periods in the groundwater model).

The mapped potential GDEs, a portion of Figure 20, is included in Figure 67. This figure includes the mapped GDEs within the mine footprint. Groundwater drawdown, compared to the initial groundwater elevations in Model Layer 1 in 2023/2024, is included in Figure 66.

The post-closure change in groundwater compared to current (2024) conditions resultant from approved mining, indicates:

- Zero (0) change along the Isaac River (green model cells)
- Drawdown immediately adjacent to the Goonyella residual void post-closure is not predicted to extend to the Isaac River
- Marked reduction in extent of drawdown around the closed mine workings due to decommissioning activities, introduction of water, and recovery of groundwater levels, which reduce the extent of drawdown.

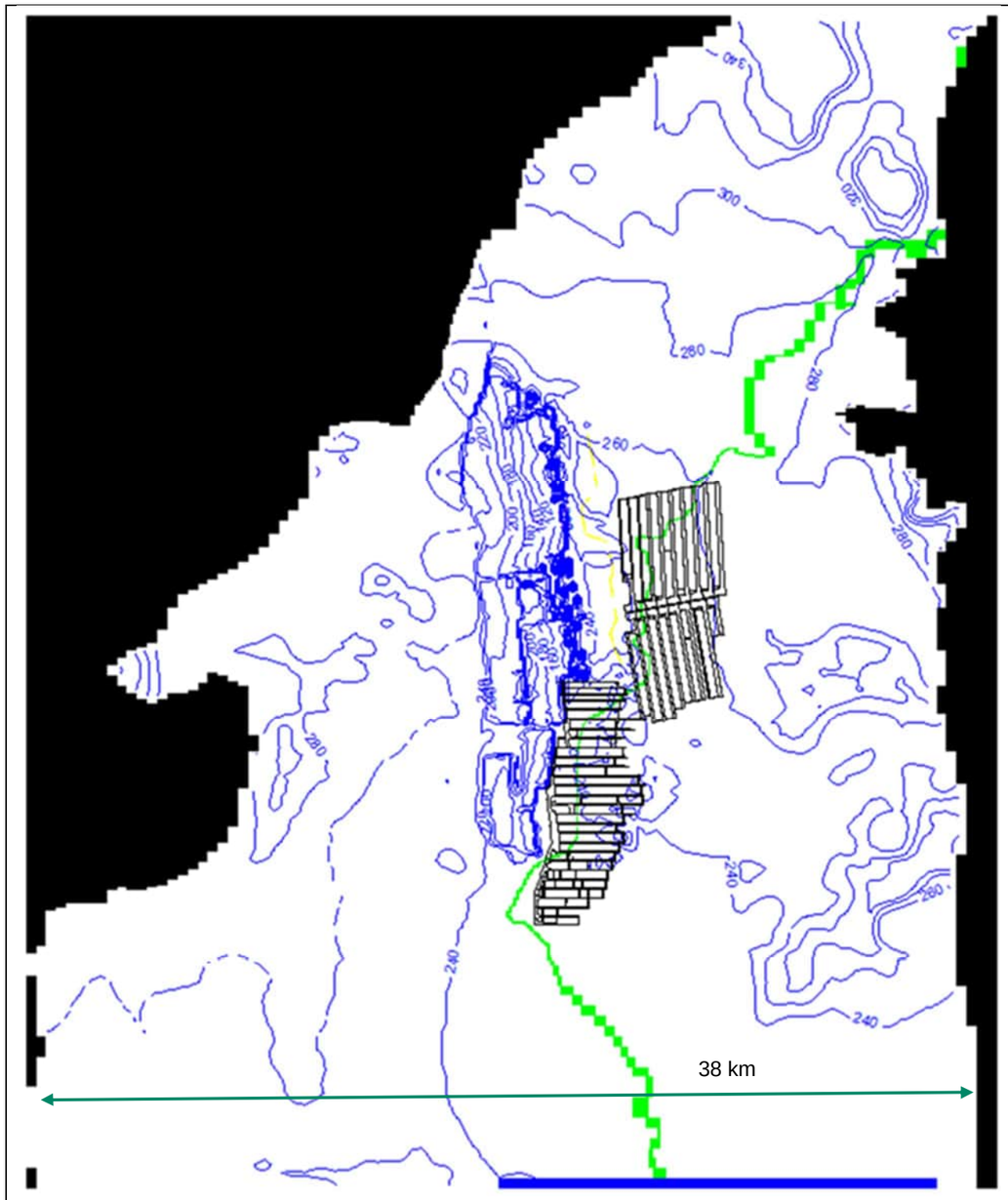
The post-closure groundwater conditions are not predicted to impact on the Isaac River GDEs and have reduced impact to potential GDEs compared to mining operations

Hypothetical water level observation points were included in the predictive model, model layer 1, along the Isaac River and at potential high potential aquatic GDEs, to aid in the assessment of water level change. The hypothetic observation points, GDE1 to GDE4, are included on Figure 67.

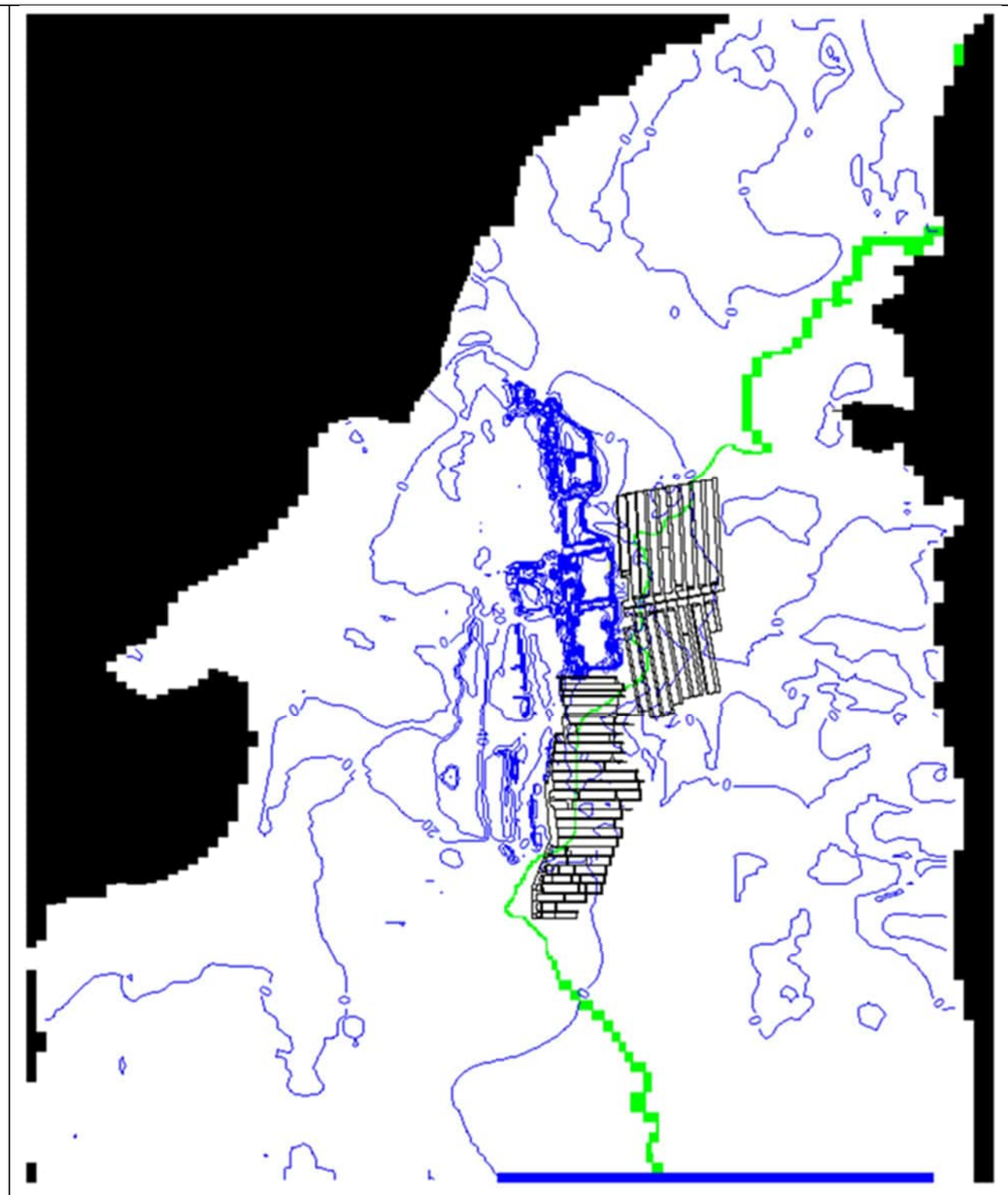
The hydrographs included in Plate 45 indicate:

- Stable or increasing groundwater elevation at these locations post-closure indicate no predicted impacts to the potential aquatic GDEs
- Limited natural fluctuation in groundwater levels over time (narrow range of groundwater levels)
- Water level recovery at GDE3 relates to initial water level derived during 2024 calibration correcting during the prediction periods in response to mining activities.

Figure 66 Water level change from the 2024 groundwater elevations post-closure



Initial groundwater level contours in the surficial sediments in 2024



Change in water level from the initial 2024 levels in 2199 (in m)

Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void

Figure 67 Mapped GDEs within the groundwater drawdown extent Model Layer 1

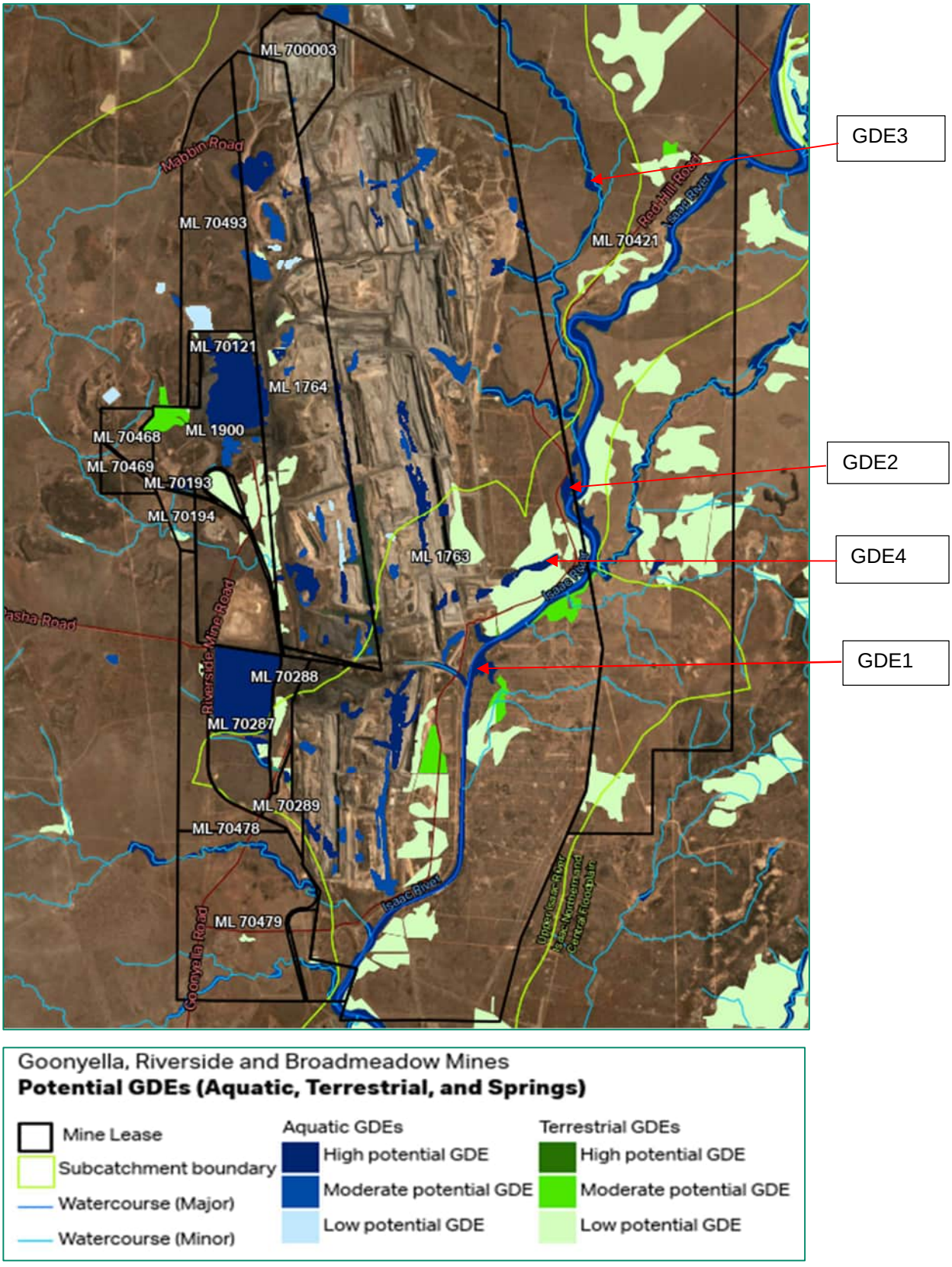
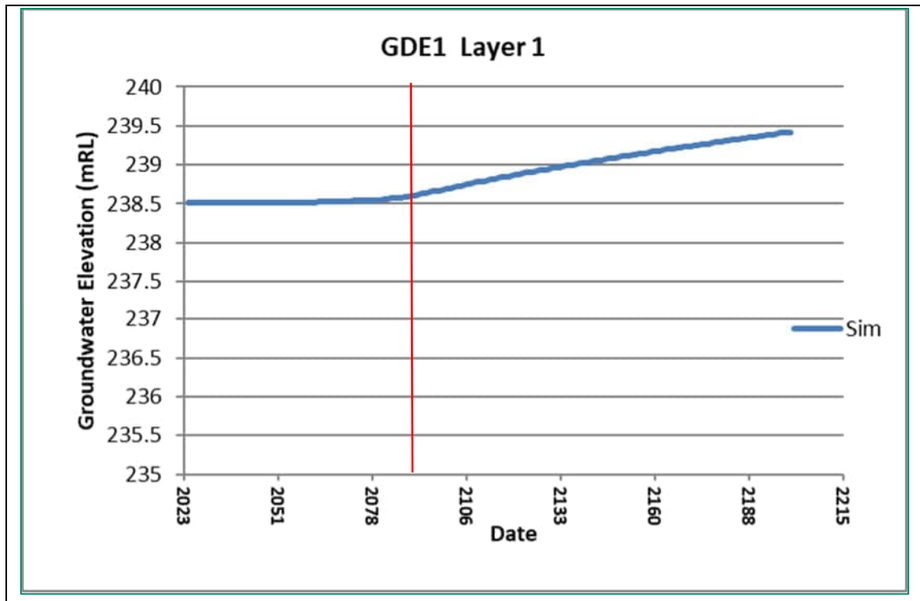
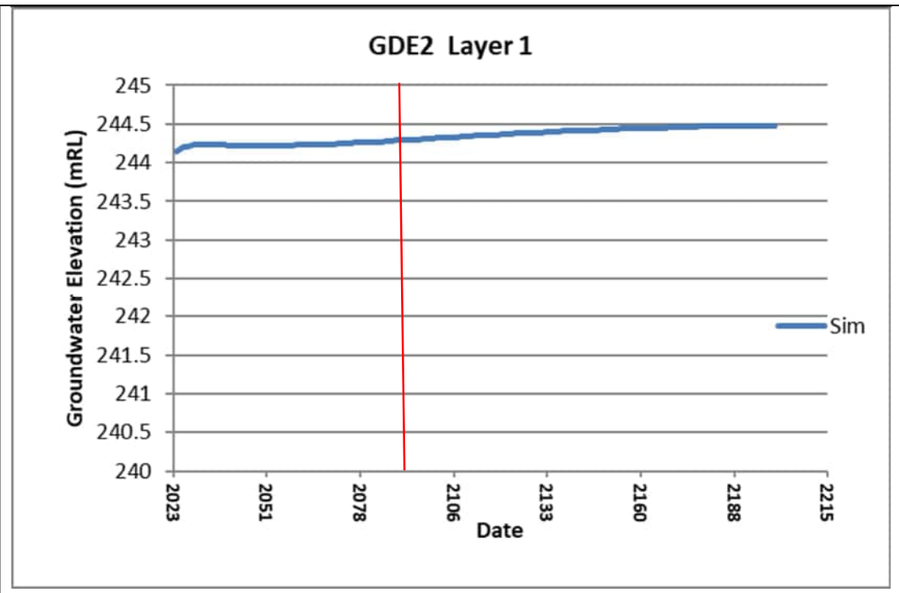


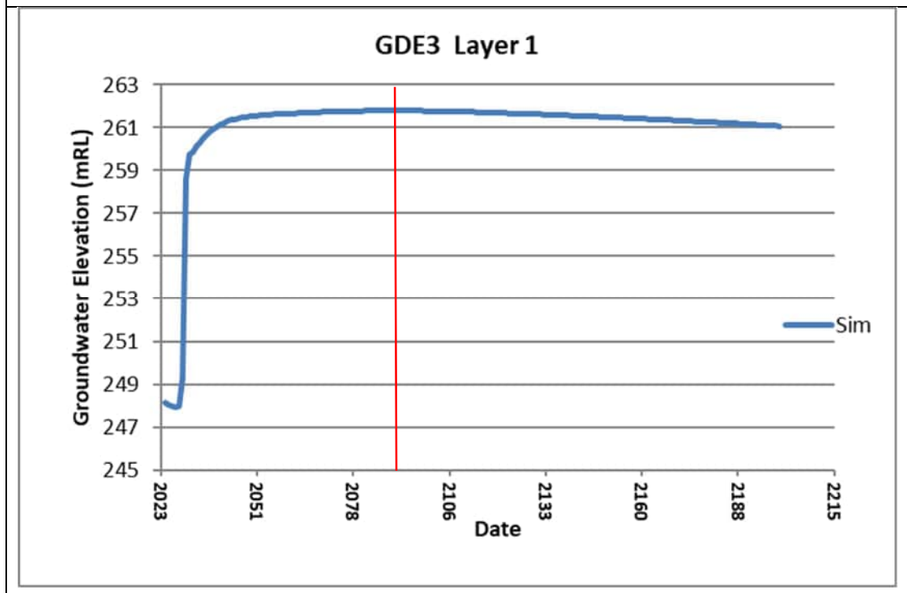
Plate 45 Hydrographs of groundwater elevation at high potential aquatic GDEs



Simulated (sim) groundwater elevation at GDE1 in the surficial cover (model layer 1)
Closure (red line) date 2097



Simulated (sim) groundwater elevation at GDE2 in the surficial cover (model layer 1)
Closure (red line) date 2097



Simulated (sim) groundwater elevation at GDE3 in the surficial cover (model layer 1)
Closure (red line) date 2097

Simulated (sim) groundwater elevation at GDE4 in the surficial cover (model layer 1)
Closure (red line) date 2097

16.0 Uncertainty analysis

16.1 Prediction uncertainty

Groundwater models are simplifications of complex natural systems and are inherently subject to uncertainty. Prediction uncertainty in groundwater modelling arises from various sources, including uncertainties in model conceptualization and parameter estimation. These uncertainties can significantly impact the reliability of model predictions and, consequently, the decision-making processes that rely on these predictions.

The conceptual model represents the understanding of the aquifer system, including its hydrogeological framework, flow processes, and interactions with surface water. Simplifications and assumptions made during the conceptualization phase can introduce uncertainty. However, the effects of alternative conceptualizations on the calibrated model were not explored in this study because the alternatives were considered limited. The current model has been built based on the best available information, including geological and hydrological data, which were deemed sufficient to represent the system conceptually.

Parameter uncertainty is a critical aspect of groundwater modelling that can significantly influence model predictions. Parameters such as hydraulic conductivity, porosity, and recharge rates are often estimated from limited field data, leading to inherent uncertainties. The spatial and temporal variability of these parameters further adds to the complexity. Given the inherent nature of parameter uncertainty, it is essential to incorporate this uncertainty into the model predictions and quantify the potential range of these predictions.

16.2 Approach to parameter uncertainty analysis

This section describes the methodology used to analyse parameter uncertainty in the groundwater model, employing PEST++ in conjunction with the Iterative Ensemble Smoother (IES) algorithm. This approach aligns with the Australian IESC guidelines for robust uncertainty assessment.

This approach provides a comprehensive analysis of parameter uncertainty by estimating posterior parameter distributions that yield an acceptable fit to the historical observations under the Bayesian framework. This method allows for the incorporation of prior knowledge and observational data to refine parameter estimates iteratively. During the iterative process, it employs ensemble-based sampling methods, similar to Monte Carlo simulations, to explore the parameter space and estimate parameter uncertainty. By generating multiple realizations of the model with different parameter combinations, it can assess the sensitivity of model predictions to parameter variations.

This process provides insights into quantifying the range of possible parameter values and assessing the uncertainty of model predictions. The results of this analysis can be used to inform decision-making processes, guide further data collection efforts, and improve the overall reliability of the groundwater model.

16.3 Ingress variation

The model calibration process, utilizing PEST++ IES, yielded multiple model realizations, each representing a unique set of parameter values that achieved a satisfactory fit to the historical observations. The goodness-of-fit for each realization was assessed using the standardized root mean squared error (SRMS), with all realizations achieving values below 10%. This indicates that the calibrated models are capable of replicating the observed data within a reasonable margin of error, providing confidence in the parameter values and the resulting predictions.

These accepted model realizations were then employed to explore the potential range of groundwater ingress into six mine pits: Broadmeadow, Issac, Thiess, R32 East, R32 South, and Goonyella. The ensemble of model predictions generated from these realizations provides a distribution of predicted ingress values for each pit. To interpret the probabilistic nature of these predictions, percentiles were calculated for each pit in every stress period (year) following the guidelines outlined in the Australian

IESC (2018) report. These percentiles translate the predicted ingress values into a likelihood of exceedance:

- <10th percentile indicates it is very likely the outcome is larger than this value
- 10th – 33rd indicates it is likely that the outcome is larger than this value
- 33rd - 67th indicate it is as likely as not that the outcome is larger or smaller than this value
- 67th - 90th indicates it is unlikely that the outcome is larger than this value
- > 90th percentile indicates it is very unlikely the outcome is larger than this value.

16.3.1 Groundwater contribution

Water balance modelling was conducted to predict pit water levels over time, the predictive groundwater modelling allowed for the estimate of groundwater contribution as detailed in Section 15.4. The groundwater contribution, compared to the surface water runoff inputs (derived from residual void water balance modelling Rev D, Section 15.4.1), was conducted based on the mean data compiled for the last 20 years. These statistics, allowing for runoff from different catchments and landcover, plus pit size (direct rainfall) is included in Table 24.

The data indicates the groundwater contribution into the mine pits has historically been around 30% or less of the total influx into the pits.

The contribution for the end of water balance modelling (31 December 2199), using the results of the coupled surface water and groundwater water balance modelling provided an estimate of groundwater contribution in 2199, as included in Table 25.

The contributions, after adopting the Landform #2.3, reduces surface water contribution. This results in the major contributor to the water balance is the groundwater ingress. The ingress contribution indicate that four of the residual voids will function as groundwater sinks. The Isaac and Thiess residual voids, with no groundwater ingress, function as sources, as recognised in Figure 58.

The daily water balance data in Table 25 indicate evaporation at each residual void is orders of magnitude higher than the total ingress during post-closure (end of 2199). This indicates that, allowing for different climate conditions and ingress uncertainty, the influx contributions to the residual voids are unlikely to exceed the evaporation outflux.

The surface water contributions over time are climate (seasonal) related and are markedly higher than the evaporation rate (a daily) basis (see examples for Goonyella Pit influx and outflux in Plate 46 and Plate 47, respectively). This, plus the depth of the residual voids (shade), allows for the development of residual void water levels and not dry residual voids.

Note: Figure 68 indicates that Landform #2.3 includes for limiting natural surface water runoff into the Goonyella Pit, where the final landform diverts clean surface water away from Goonyella Pit (as evident in the small natural catchments). This further reduces surface water ingress at closure resulting in the large change in contribution, such that groundwater comprises the majority of the influx post-closure.

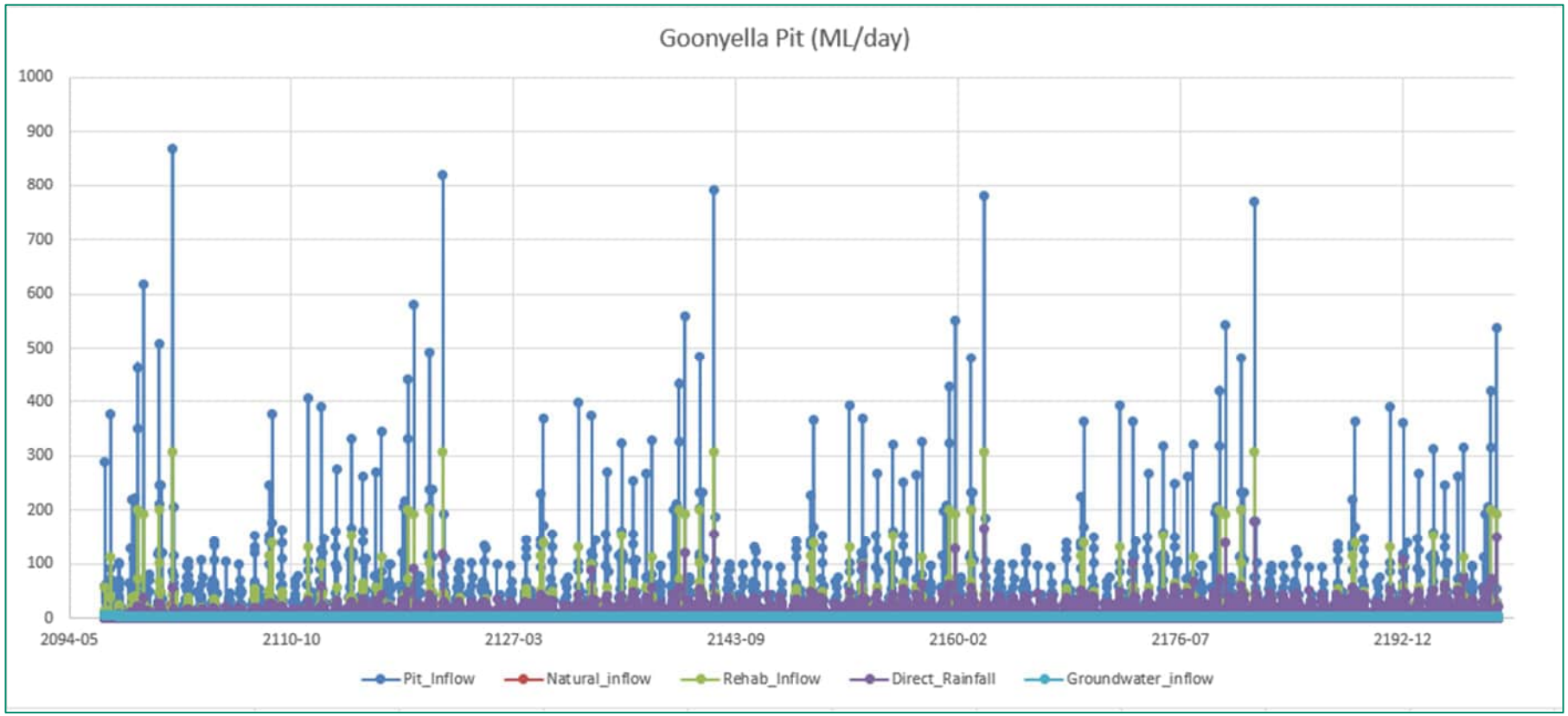
Table 24 GRB mine pit water balance data – mean for last 20 years

Mean for last 20 years	Goonyella	Broadmeadow	Isaac	R32South	R32East	Thiess
Pit Inflow (ML/day)	0.17	0.011	0.005	0.005	0.007	0.018
Natural inflow (ML/day)	0.005	0	0	0	0	0
Rehab Inflow (ML/day)	0.049	0.008	0.012	0.001	0.005	0.045
Direct Rainfall (ML/day)	0.147	0.008	0.007	0.003	0.008	0.016
Groundwater inflow (ML/day)	0.178	0.002	0	0.003	0.008	0
Groundwater outflow (ML/day)	0	0	0.002	0	0	0.0215
Evaporation Actual (ML/day)	0.53	0.029	0.022	0.012	0.029	0.058
Sum (ML/day)	**1.08**	**0.06**	**0.049**	**0.024**	**0.058**	**0.158**
%GW contribution (influx)	32.5	8.5	0.06	25	29	0

Table 25 GRB mine pit water balance data – 31 December 2199

End of P4	Goonyella	Broadmeadow	Isaac	R32South	R32East	Thiess
Pit Inflow (ML/day)	0.0287	0.0019	0.0009	0.0008	0.0012	0.0031
Natural inflow (ML/day)	0.0002	0	0	0	0	0
Rehab Inflow (ML/day)	0.0048	0.0008	0.0011	0.0001	0.0005	0.0043
Direct Rainfall (ML/day)	0.4119	0.0164	0.0223	0.0075	0.0200	0.0192
Groundwater inflow (ML/day)	3.3354	0.0474	0	0.0411	0.1647	0
Groundwater outflow (ML/day)	0	0	0.0594	0	0	0.5242
Evaporation Actual (ML/day)	15.0441	0.9299	0.6100	0.3639	0.8996	1.7333
Sum (ML/day)	**3.7809**	**0.0664**	**0.0243**	**0.0495**	**0.1865**	**0.0266**
%GW contribution (influx)	88	71	0	83	88	0

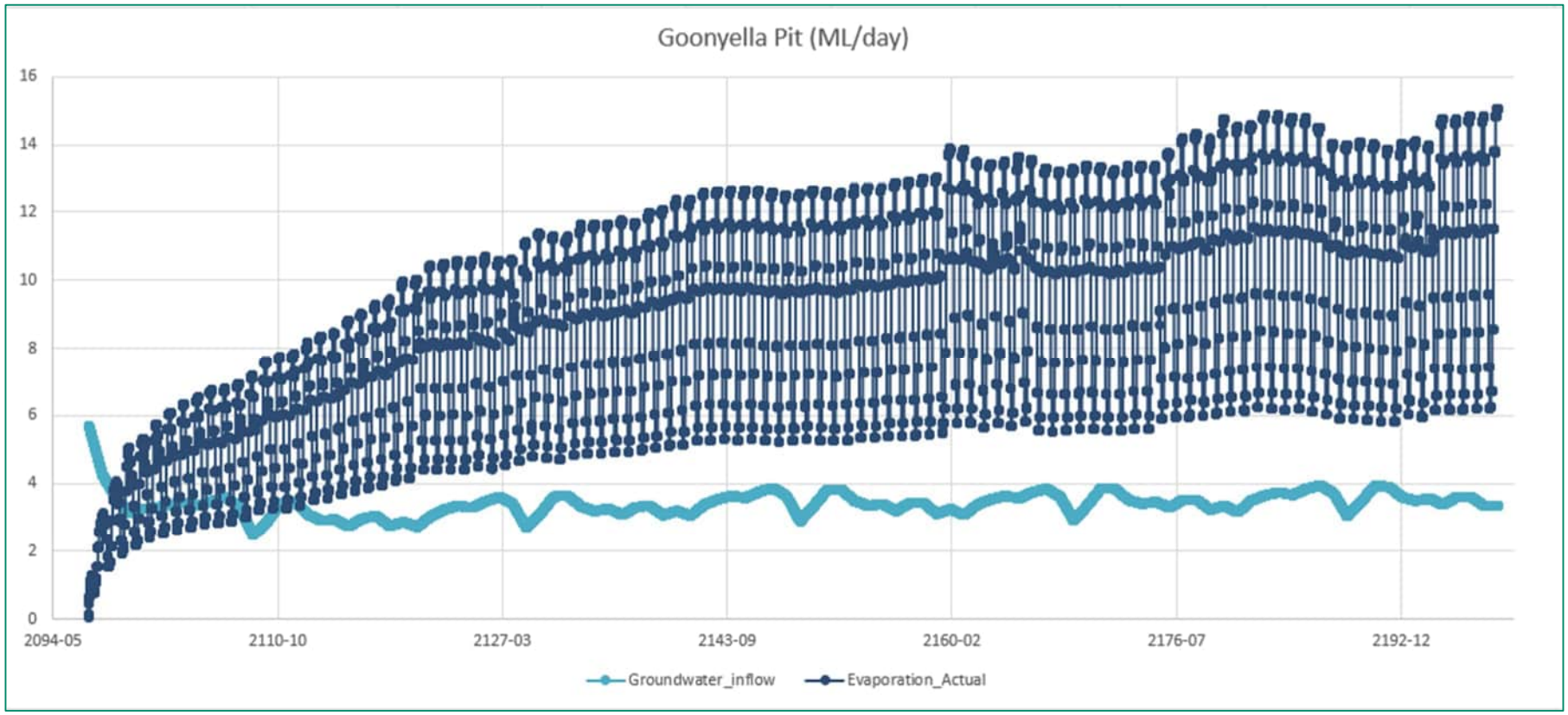
Plate 46 Goonyella Pit influx values in ML/day



The surface water influx is split into catchment areas as included in Figure 68:

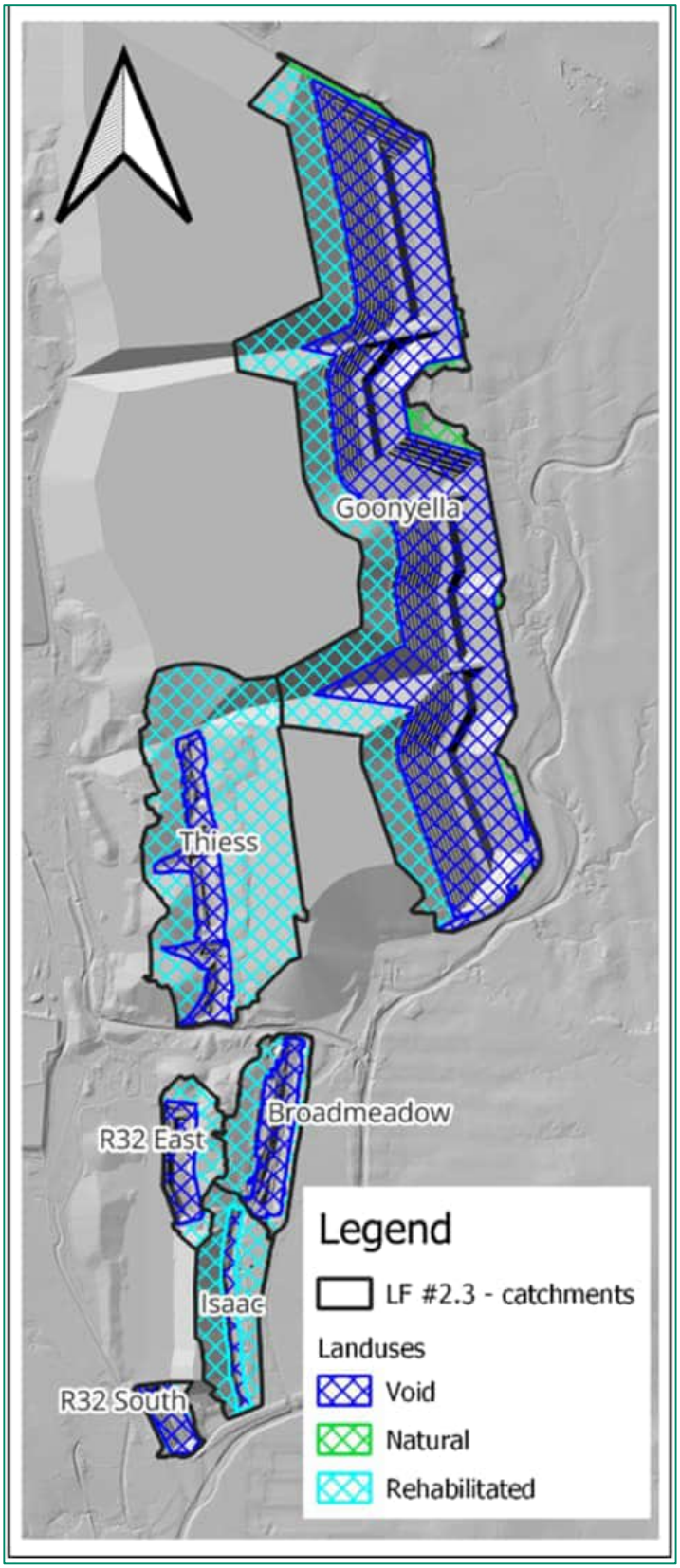
- Pit inflow from void catchments
- Natural inflow from unmined natural catchment areas
- Rehabilitated area inflow from rehabilitated catchments
- Direct rainfall into the residual voids

Plate 47 Goonyella Pit evaporation and groundwater ingress estimates on a daily basis (in ML/day)



Evaporation losses range from 0.005 to 15 ML/day

Figure 68 Catchment delineation for each catchment zone included in the water balance modelling (WSP, 2024)



16.3.2 Broadmeadow Pit

Adopting the uncertainty approach as described above in Section 16.0 a range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations (while the model remains within the acceptable calibration criteria). These percentiles of ingress estimates across the stress periods for Broadmeadow Pit, as included in the model, are included in Plate 48.

The base case (set of model parameters) ingress predictions fall between the 10th percentile (very likely the outcome is larger than this value) and the 90th percentile (very unlikely the outcome is larger than this value), and matches well between the narrow band of estimates derived by the 33rd and 67th percentiles. This narrow band is included in Plate 48.

The ingress estimates, leading to the estimate of the Broadmeadow Pit water level is considered suitable for input into the water balance modelling, as the base case allowed for an estimate that (between 33rd and the 67th percentiles) is not likely to be larger or smaller than these ingress estimate values.

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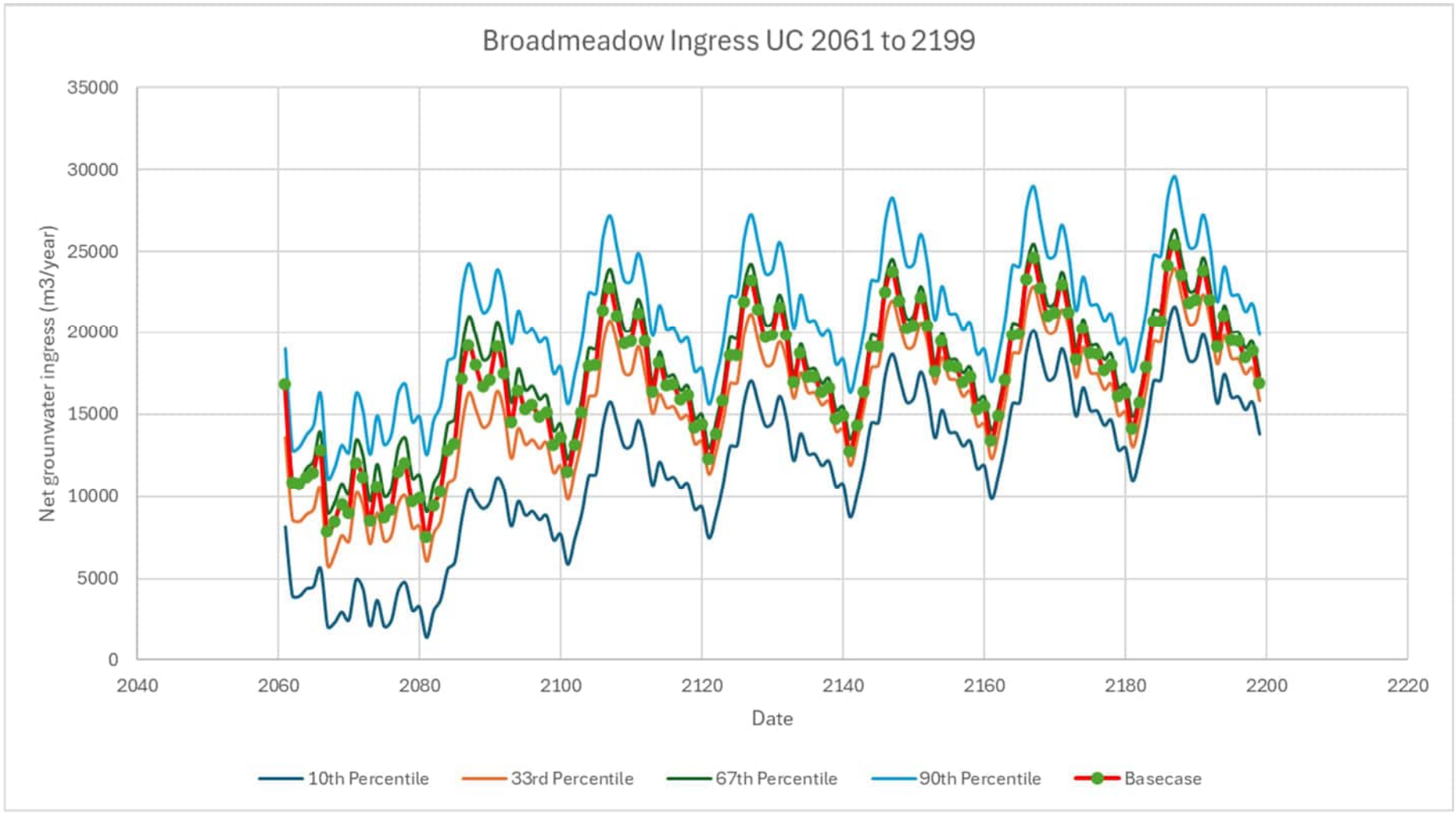
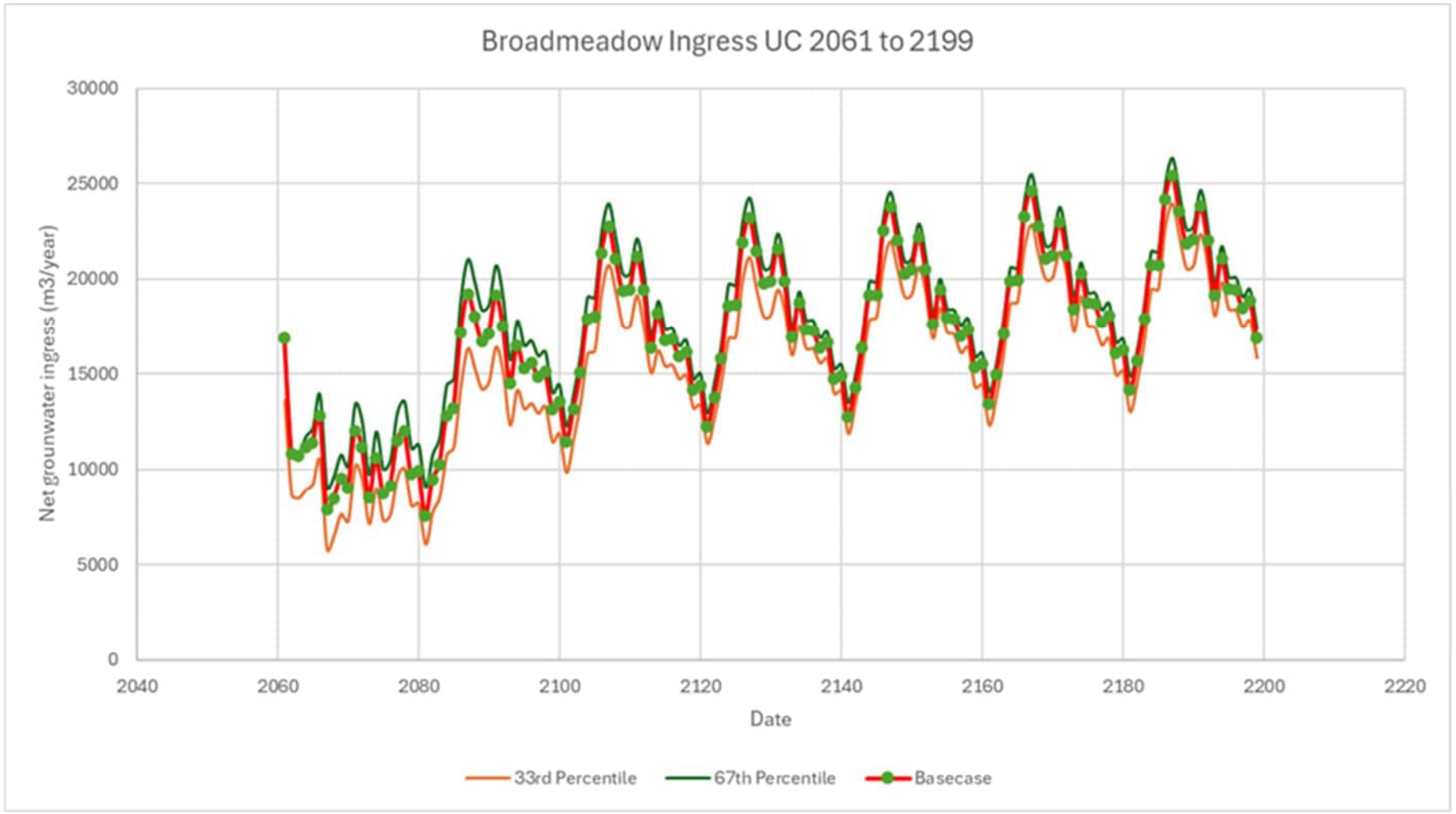
Plate 48 Uncertainty graph for Broadmeadow Pit




Broadmeadow Ingress UC 2061 to 2199
Net grounwater ingress (m3/year)
30000
25000
20000
15000
10000
5000
0
2040
2060
2080
2100
2120
2140
2160
2180
2200
2220
Date
33rd Percentile
67th Percentile
Basecase

16.3.3 Isaac Pit

Groundwater is predicted to flow out from Isaac Pit during mining, decommissioning, and post-closure, as included in Plate 49, as evident from the base case estimates using the parameters adopted in the predictive model.

The multiple realizations of the model using different parameter combinations indicated the predictions were not sensitive to the parameter changes for Isaac Pit, as evident in the narrow band of estimates (considering the 33rd and 67th percentiles).

The base case and 90th percentile are similar indicating that the groundwater outflow from the pit is likely to be lower than included in the water balance model for the Isaac Pit water level predictions.

16.3.4 Thiess Pit

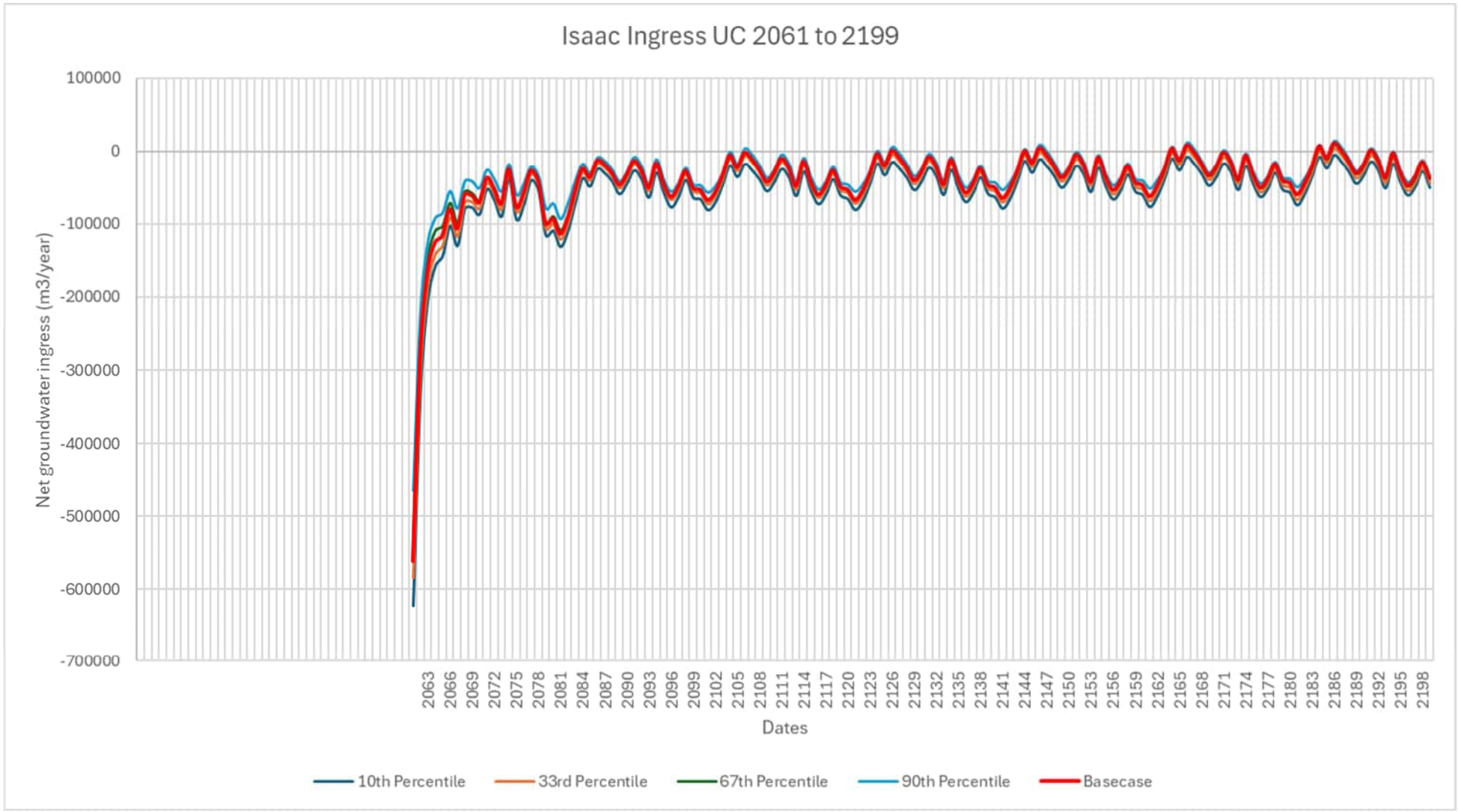
Similar to the Issac Pit , groundwater is predicted to flow out from Thiess Pit during mining, decommissioning, and post-closure, as included in Plate 49, as evident from the base case estimates using the parameters adopted in the predictive model.

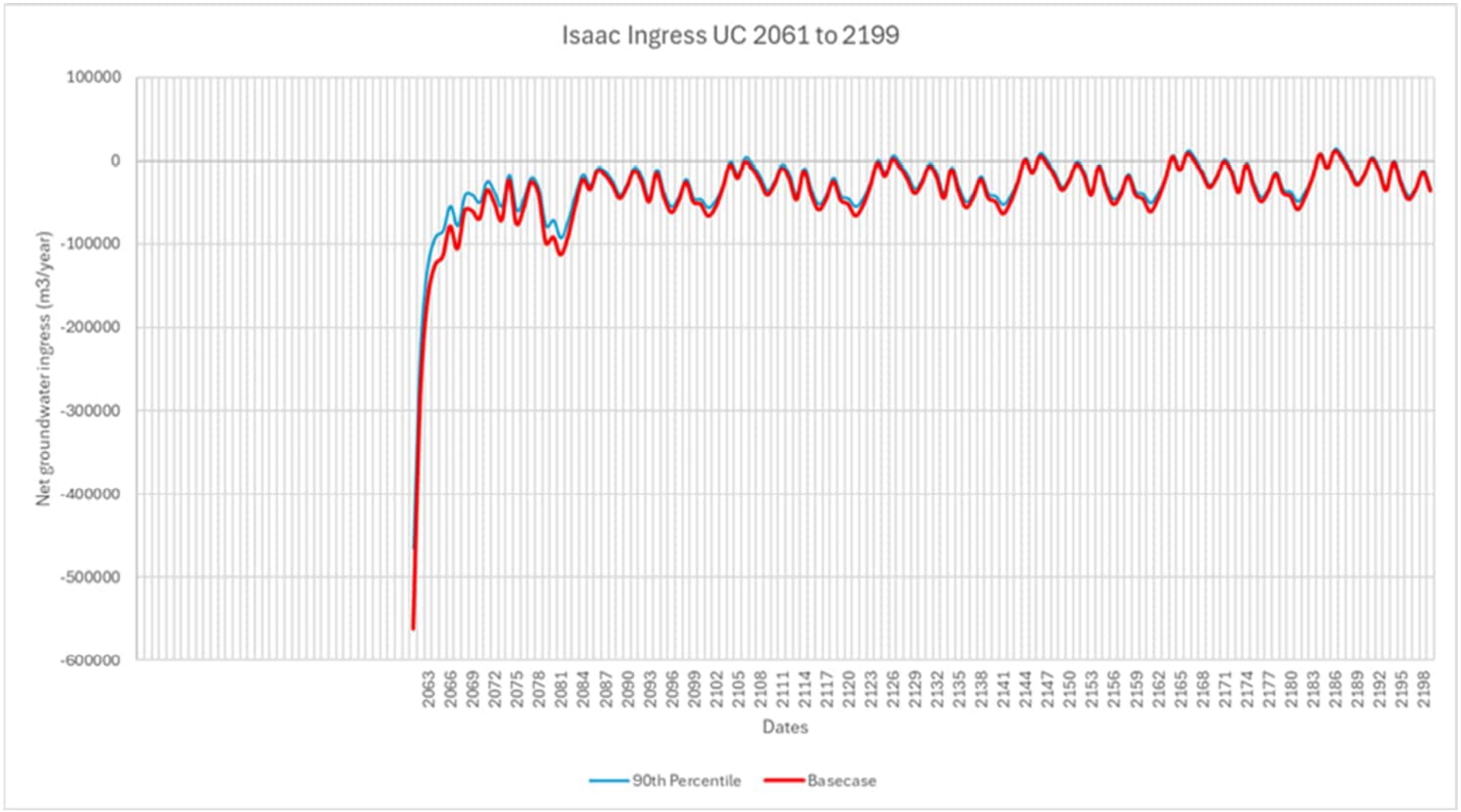
The multiple realizations of the model using different parameter combinations indicated the predictions allowed for the determination of a narrow band of estimates (all indicating groundwater loss post-closure

The base case (set of model parameters) ingress predictions is similar to the 33rd percentile results, which indicates the groundwater loss from the pit is likely to be less than these estimates (noting these are negative values).

Based on the statistics it is likely that the net ingress (loss) from Thiess Pit would be between the 33rd and 67th percentiles, which is not a marked difference.

Plate 49 Uncertainty graph for Isaac Pit




Isaac Ingress UC 2061 to 2199
Net groundwater ingress (m3/year)
100000
0
-100000
-200000
-300000
-400000
-500000
-600000
2063
2066
2069
2072
2075
2078
2081
2084
2087
2090
2093
2096
2099
2102
2105
2108
2111
2114
2117
2120
2123
2126
2129
2132
2135
2138
2141
2144
2147
2150
2153
2156
2159
2162
2165
2168
2171
2174
2177
2180
2183
2186
2189
2192
2195
2198
Dates
90th Percentile
Basecase

16.3.5 R32 East Pit

A range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations for Ramp 32 East. These percentiles of ingress estimates, across the stress periods for Ramp 32 East Pit, are included in Plate 51.

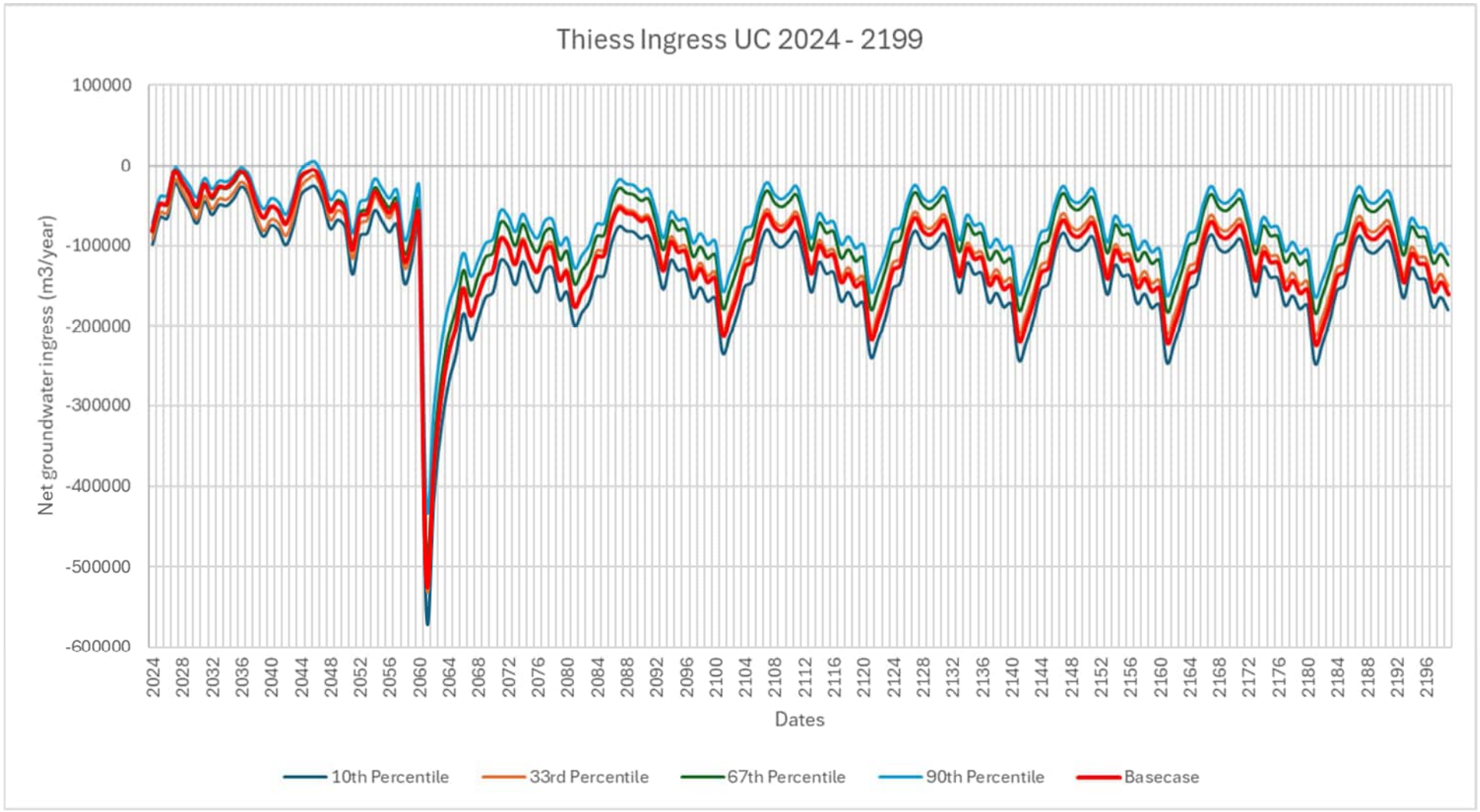
The base case (set of model parameters) ingress predictions fall between the 67th percentile and the 90th percentile (very unlikely the outcome is larger than this value). This indicates that the groundwater ingress to the pit is likely to be lower than included in the water balance model for the Ramp 32 East Pit water level predictions.

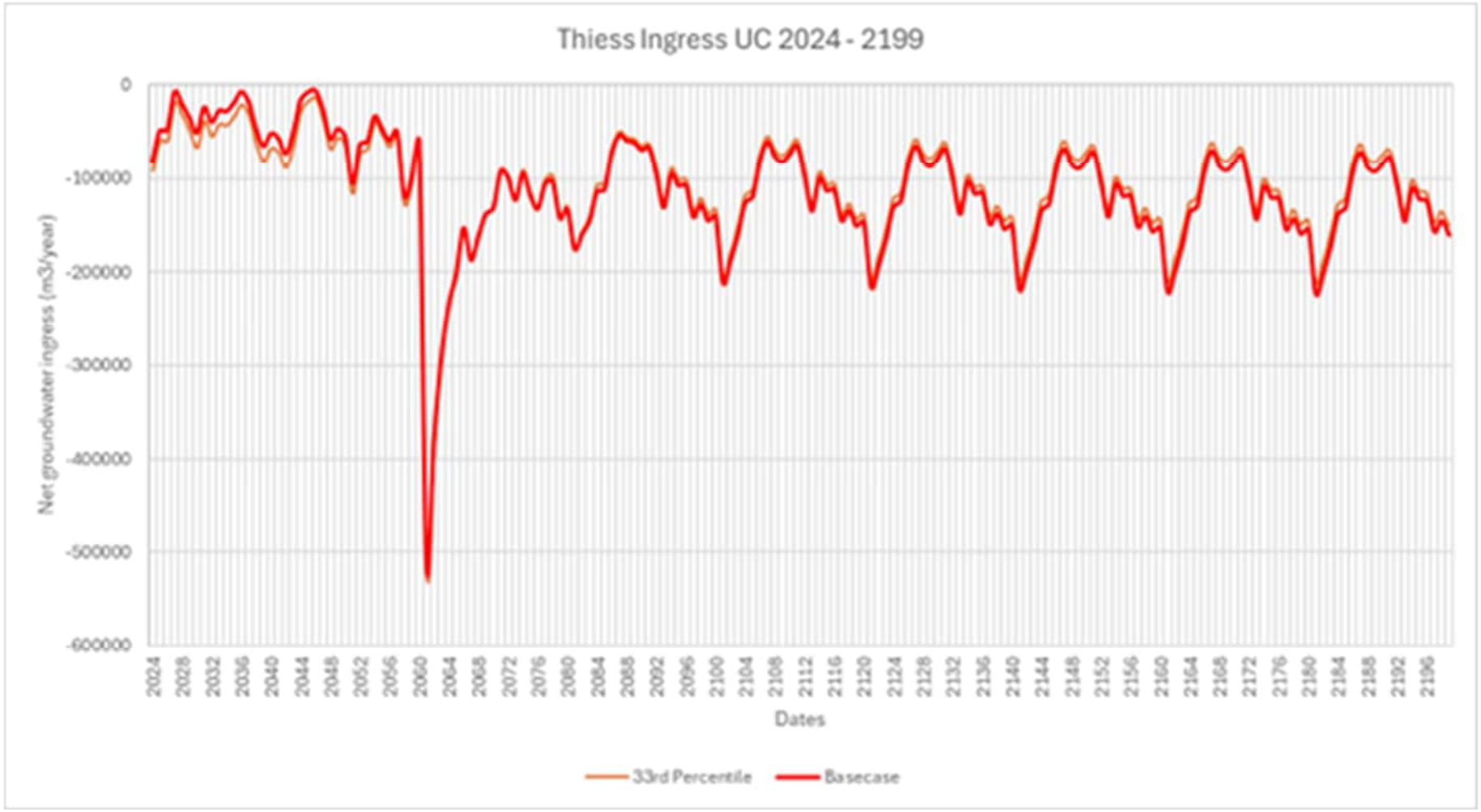
16.3.6 R32 South Pit

A range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations for Ramp 32 South. These percentiles of ingress estimates, across the stress periods for Ramp 32 South Pit, are included in Plate 52.

The base case ingress predictions match well with the 67th percentile results, which indicates that the estimates are likely not to be larger or smaller than these estimates.

Plate 50 Uncertainty graph for Thiess Pit




Thiess Ingress UC 2024 - 2199
Net groundwater ingress (m3/year)
0
-100000
-200000
-300000
-400000
-500000
-600000
2024
2028
2032
2036
2040
2044
2048
2052
2056
2060
2064
2068
2072
2076
2080
2084
2088
2092
2096
2100
2104
2108
2112
2116
2120
2124
2128
2132
2136
2140
2144
2148
2152
2156
2160
2164
2168
2172
2176
2180
2184
2188
2192
2196
Dates
33rd Percentile
Basecase

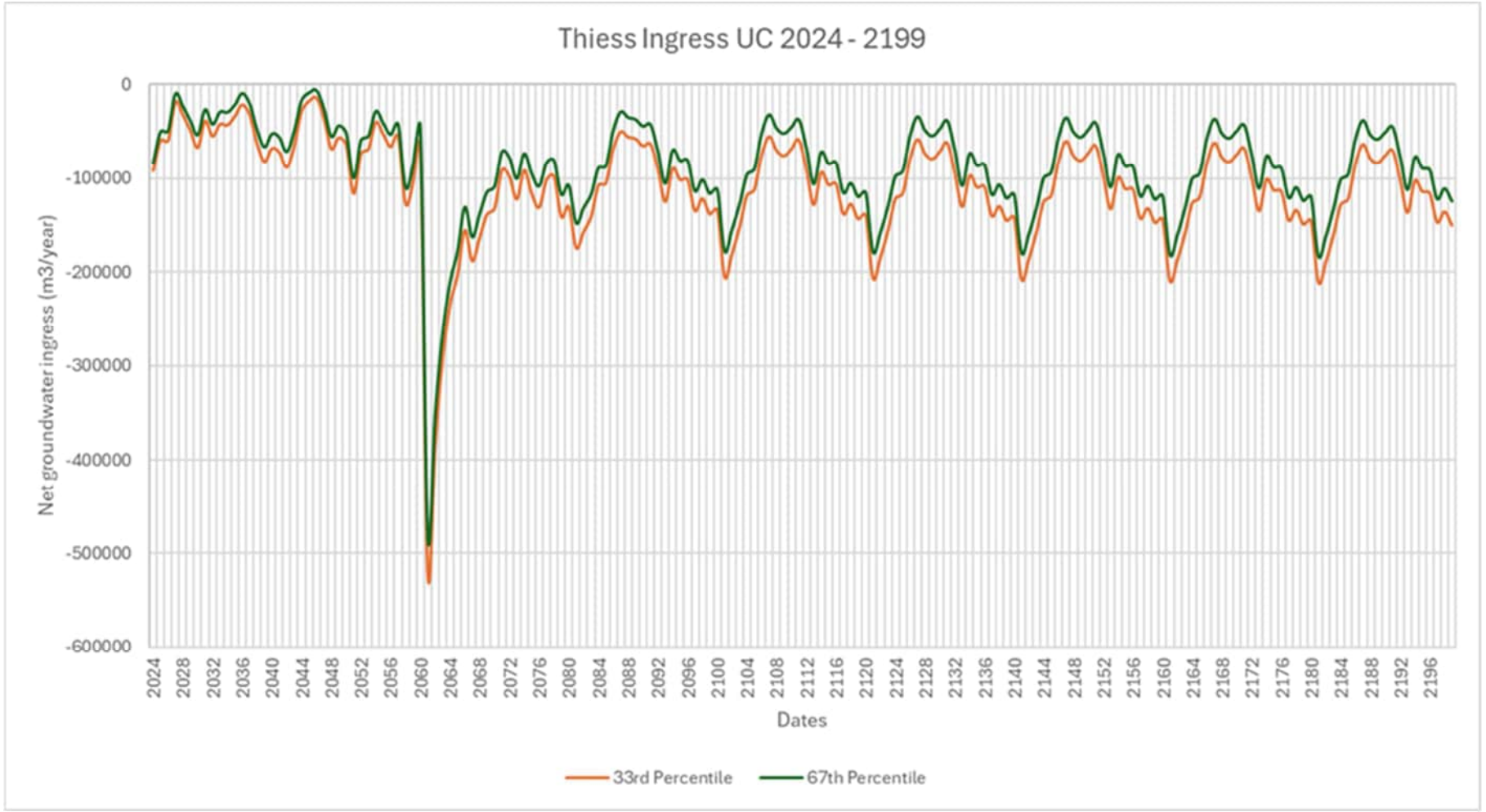
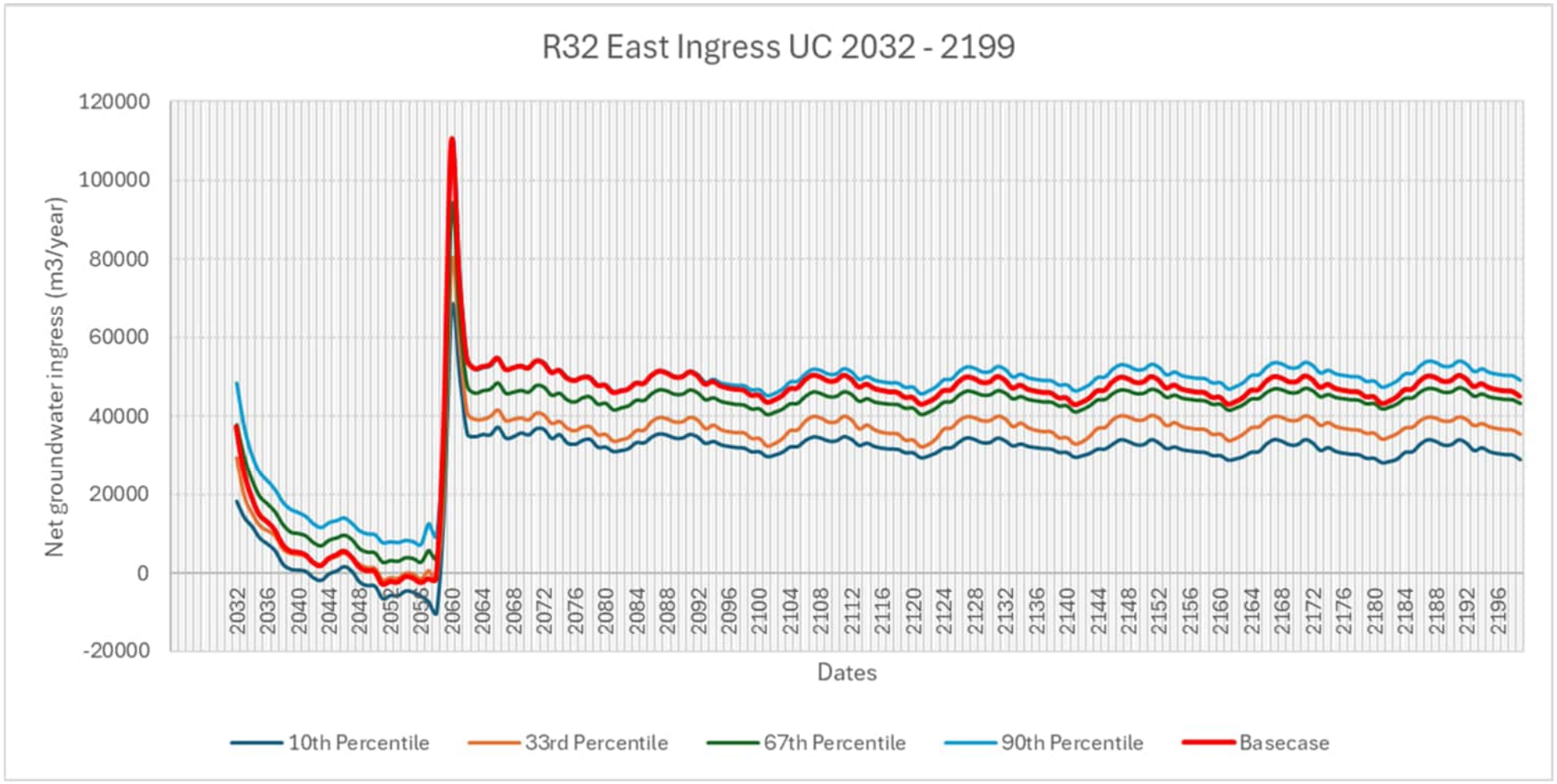

Thiess Ingress UC 2024 - 2199
Net groundwater ingress (m3/year)
0
-100000
-200000
-300000
-400000
-500000
-600000
2024
2028
2032
2036
2040
2044
2048
2052
2056
2060
2064
2068
2072
2076
2080
2084
2088
2092
2096
2100
2104
2108
2112
2116
2120
2124
2128
2132
2136
2140
2144
2148
2152
2156
2160
2164
2168
2172
2176
2180
2184
2188
2192
2196
Dates
33rd Percentile
67th Percentile

Plate 51 Uncertainty graph for R32 East Pit



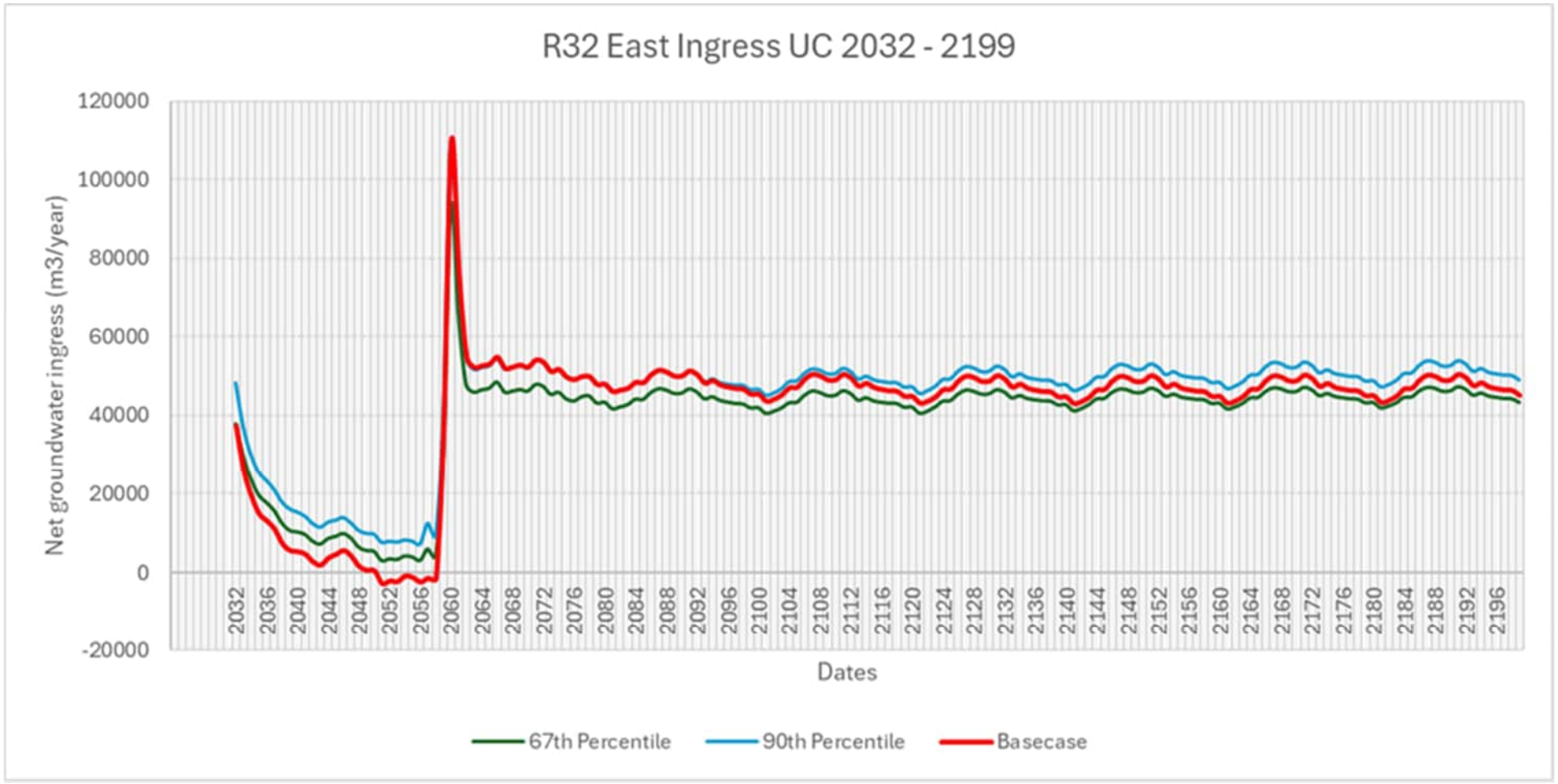
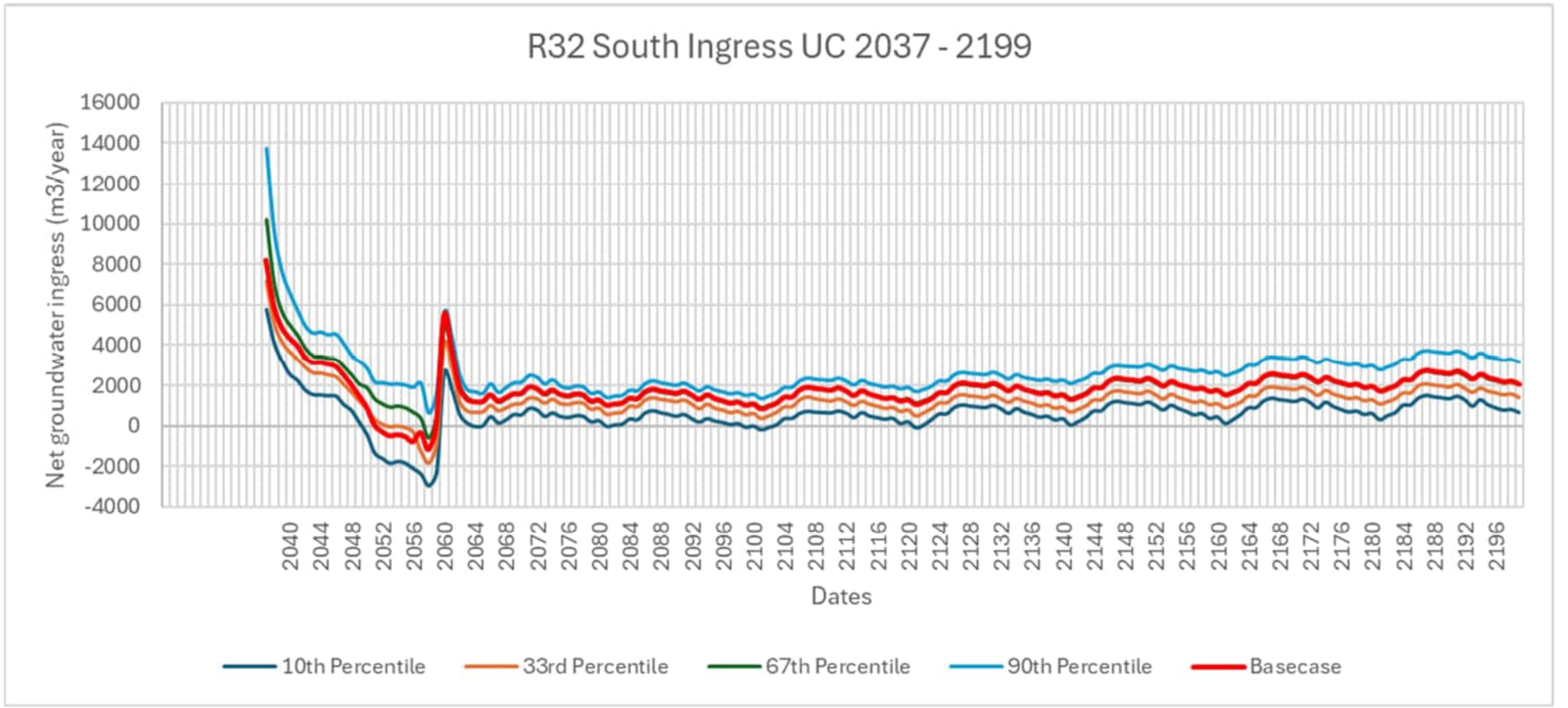

R32 East Ingress UC 2032 - 2199
Net groundwater ingress (m3/year)
120000
100000
80000
60000
40000
20000
0
-20000
2032
2036
2040
2044
2048
2052
2056
2060
2064
2068
2072
2076
2080
2084
2088
2092
2096
2100
2104
2108
2112
2116
2120
2124
2128
2132
2136
2140
2144
2148
2152
2156
2160
2164
2168
2172
2176
2180
2184
2188
2192
2196
Dates
67th Percentile
90th Percentile
Basecase

Plate 52 Uncertainty graph for R32 South Pit



16.3.7 Goonyella Pit

The uncertainty approach allowing for the quantifying of a range of possible parameter values and assessing the uncertainty of model predictions, was conducted for the Goonyella Pit. The range of groundwater ingress, in m^3/year, for the 50 realisations are presented as percentiles in Plate 53.

The base case parameter set included in the predictive modelling input into the Goonyella Pit water level modelling is recognised as conservative, where the base case is very similar to the 90th percentile of the uncertainty realisations after 2144 (see below). This indicates that the groundwater ingress volumes used in estimating the pit water level is unlikely to be larger than this value.

The base case model predictions, comprising the majority influx contribution to the residual void water balance (Section 16.3.1), is within the higher predictions from the uncertainty modelling. This implies that the pit water level may be lower than currently predicted. This indicates that the Goonyella Pit is not likely to NOT act as a groundwater sink and has negligible risk of overtopping or decant in the long term.

16.3.8 Ingress comments

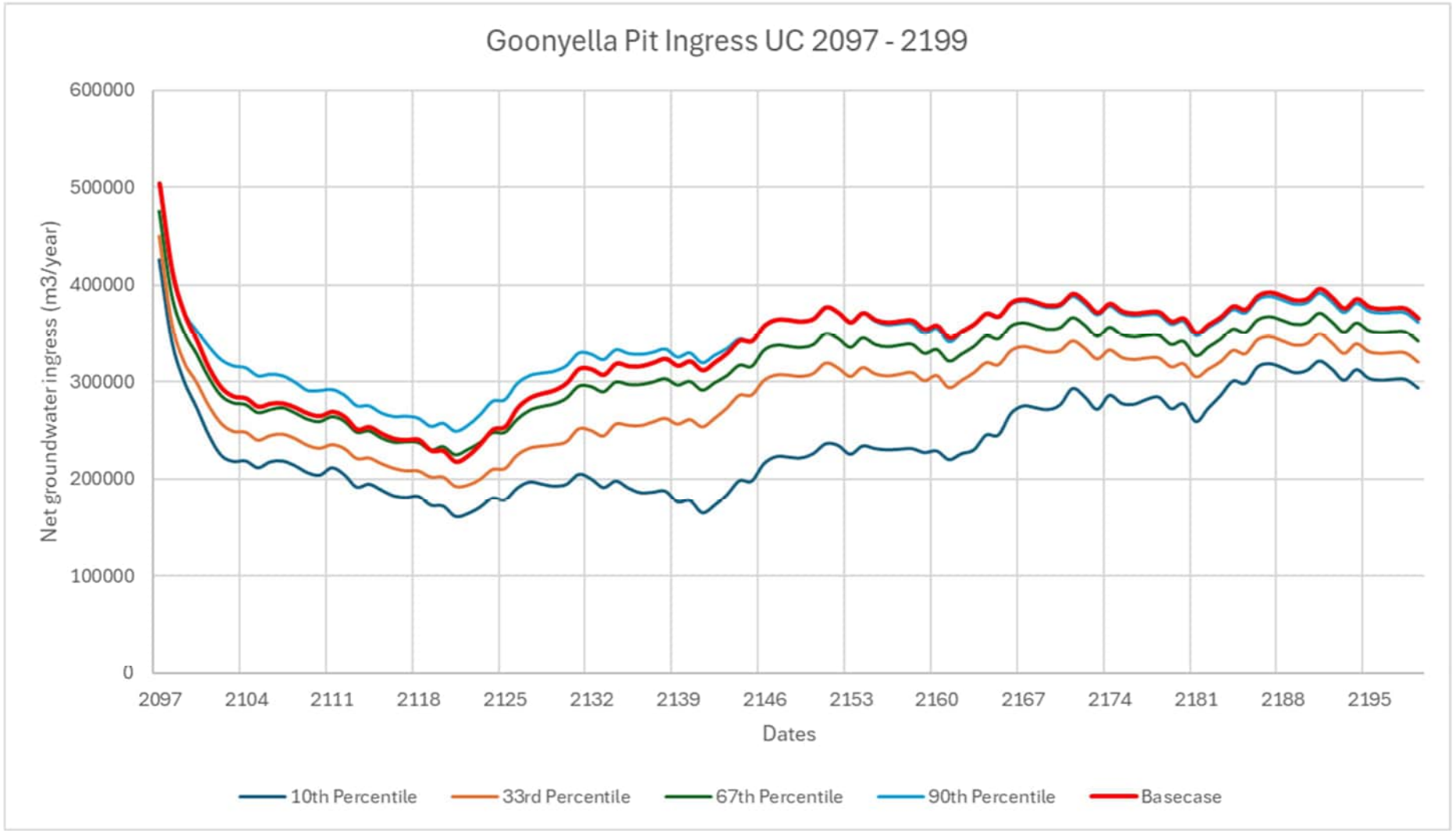
The base case parameters adopted in the groundwater model, allowing for groundwater ingress (or outflow) for the residual void water balance modelling, when considering the uncertainty analysis results allows for confidence in the predictions of pit water levels across the Project.

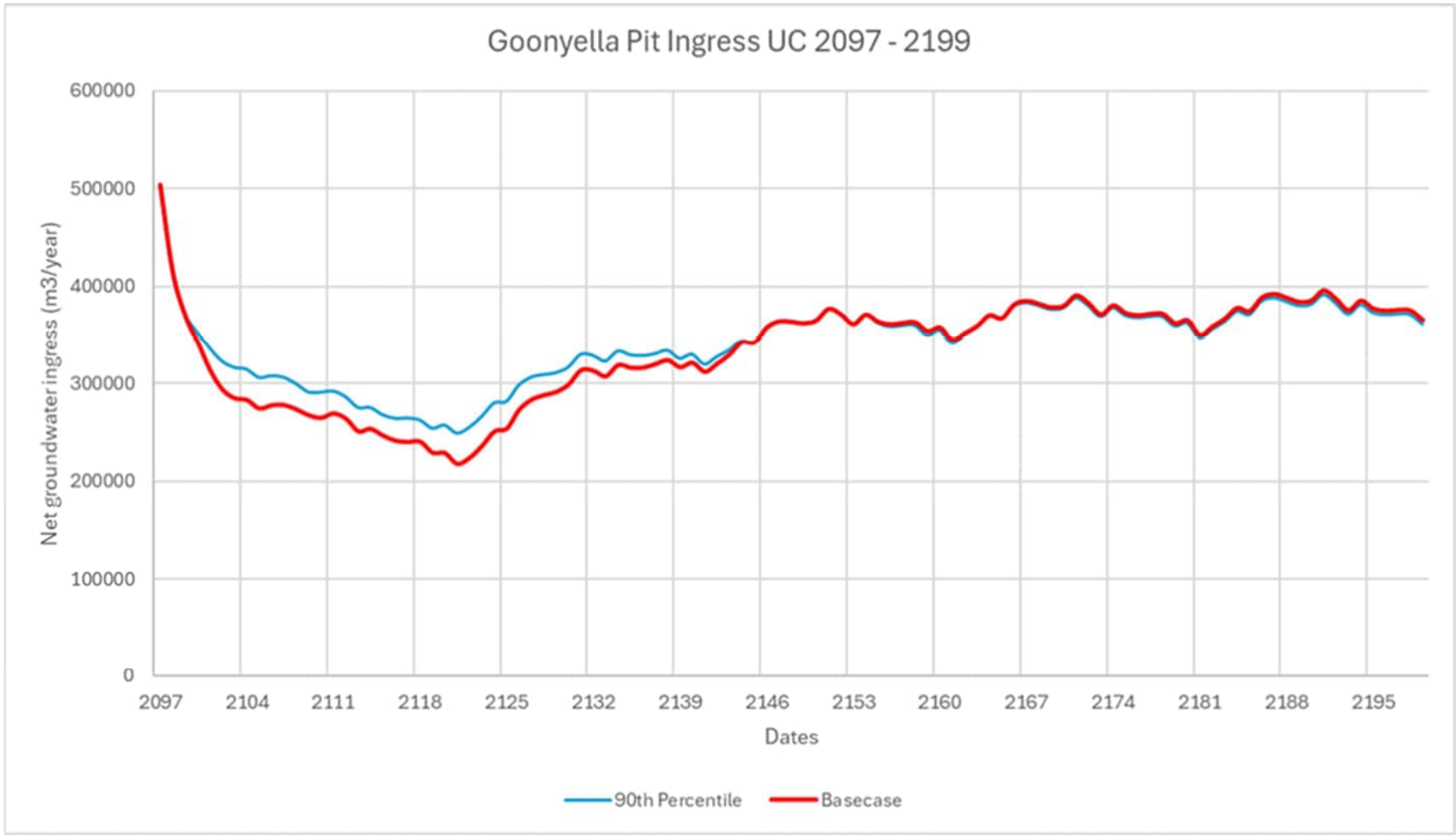
The dominant evaporation, orders of magnitude higher than the total influx estimates even when considering the upper groundwater (majority contribution) ingress estimates from the uncertainty analysis, indicate that the residual voids recognised to function as groundwater sinks will continue to do so.

The predictions of groundwater ingress into Goonyella residual void, within the higher predictions resulting from the uncertainty analysis parameter combinations, allows for confidence that the pit water level will be deep, some 20 mAHD (> 100 m deeper than other pit water levels) as detailed in Section 15.4.2.6. This deep groundwater sink influences long term groundwater flow patterns and prevents residual void and possible mine waste seepage water migration away from the Project.

The influence of the Goonyella residual void indicates there is no need for future (pit) water reduction requirements.

Plate 53 Uncertainty graph for Goonyella Pit




Goonyella Pit Ingress UC 2097 - 2199
Net groundwater ingress (m3/year)
600000
500000
400000
300000
200000
100000
0
2097
2104
2111
2118
2125
2132
2139
2146
2153
2160
2167
2174
2181
2188
2195
Dates
90th Percentile
Basecase

17.0 Conceptual Site Model – Post-Closure

17.1 Post-closure conceptual model

A conceptual model of the post-closure groundwater conditions, on completion of mining activities, rehabilitation, decommissioning, reinjection of water into the underground workings, and recovery of groundwater levels to pseudo-steady conditions is included in Figure 69, based on the end of mining CSM discussed in Section 11.0 (for open cut and underground workings) and the post-mining groundwater modelling presented in Section 13.0.

17.2 Assessment

There is no evidence from a groundwater perspective that the final landform #2.3 is unsuitable for the closure, based on an assessment of the groundwater regimes and predictive groundwater modelling.

The hydrogeological assessment identified the following key features:

- Residual void pit water level predictions, using the groundwater ingress, for the Goonyella Pit, stabilises markedly below the post-closure recovered groundwater elevations for all directly impacted hydrostratigraphic units, and below the other five residual void pit water levels. This groundwater sink effectively limits any potential poor quality water migrating away from the Project (Section 15.6 and 15.7).
- Residual groundwater drawdown within the MCM target coal seams as caused by the approved mining operations, with ongoing evaporative discharge from the residual voids, resulting in continued inwards hydraulic flow gradients in the coal measures to three of the six residual voids (Section 15.7).
    - Groundwater outflow from Thiess and Isaac pits is predicted to be captured within Goonyella Pit (Section 15.7).
    - Broadmeadow residual void is predicted to have outflow during the prediction periods, as detailed in Section 15.6. Long term stabilisation of groundwater levels and the residual void water level indicate groundwater outflow will reduce or cease in the long term (Section 16.3.1).
- The Goonyella residual void is predicted to capture any seepage from mine waste (TSF, MIA, rejects) and spoil / backfill areas, as evident in the particle tracking simulations (Section 15.7.2).
- The Goonyella residual void is predicted to influence groundwater levels within the Broadmeadow underground workings, were after water is introduced the (recovered) groundwater levels within the are predicted to decrease marginally.
    - Section 15.4.3.3 indicates that the GMS groundwater levels will increase by 200 m in 2092 (water introduced into the underground workings) from the initial 2024 groundwater elevations, this will decrease to 190 m difference in 2199 due to ingress into Goonyella residual void.
    - Section 15.4.3.4 indicates that the GLS groundwater levels will increase by 60 m in 2092 (water introduced into the underground workings) from the initial 2024 groundwater elevations, this will decrease to 50 m difference in 2199 due to ingress into Goonyella residual void.
- Little to no additional impact on surficial aquifers including the Isaac River alluvium caused by the PRCP Plan's final landform (15.5.1 and 15.8.2).
- Little to no impact on environmental (GDEs) receptors caused by the PRCP Plan's final landform (Section 15.8).
- The continuous removal of groundwater in perpetuity from the Goonyella residual void indicates that groundwater levels in proximity to the residual void will not recover.

- A single water supply bore, in proximity to the Goonyella Pit, will become dry as a result of approved mining. No anthropogenic receptors are identified to be impacted by the PRCP Plan's final landform (Section 15.8.1).

17.3 Source-Pathway-Receptor Analysis

A graphical representation of the CSM in source-pathway-receptor (SPR) format, with particular focus on the post-mining period, is presented as Figure 70.

The groundwater assessment for the PRC Plan does not identify a complete exposure pathways from the sources to water supply bores and ecological receptors. The Isaac River alluvium is not affected by drawdown and recharged from losing streams not the sources listed. The only water source bore identified to be affected is located in proximity to the Goonyella Pit highwall. This bore will be impacted by approved mining and is therefore not predicted to be impacted due to mine closure.

Figure 69 Post-closure conceptual model for the Goonyella Pit and underground workings

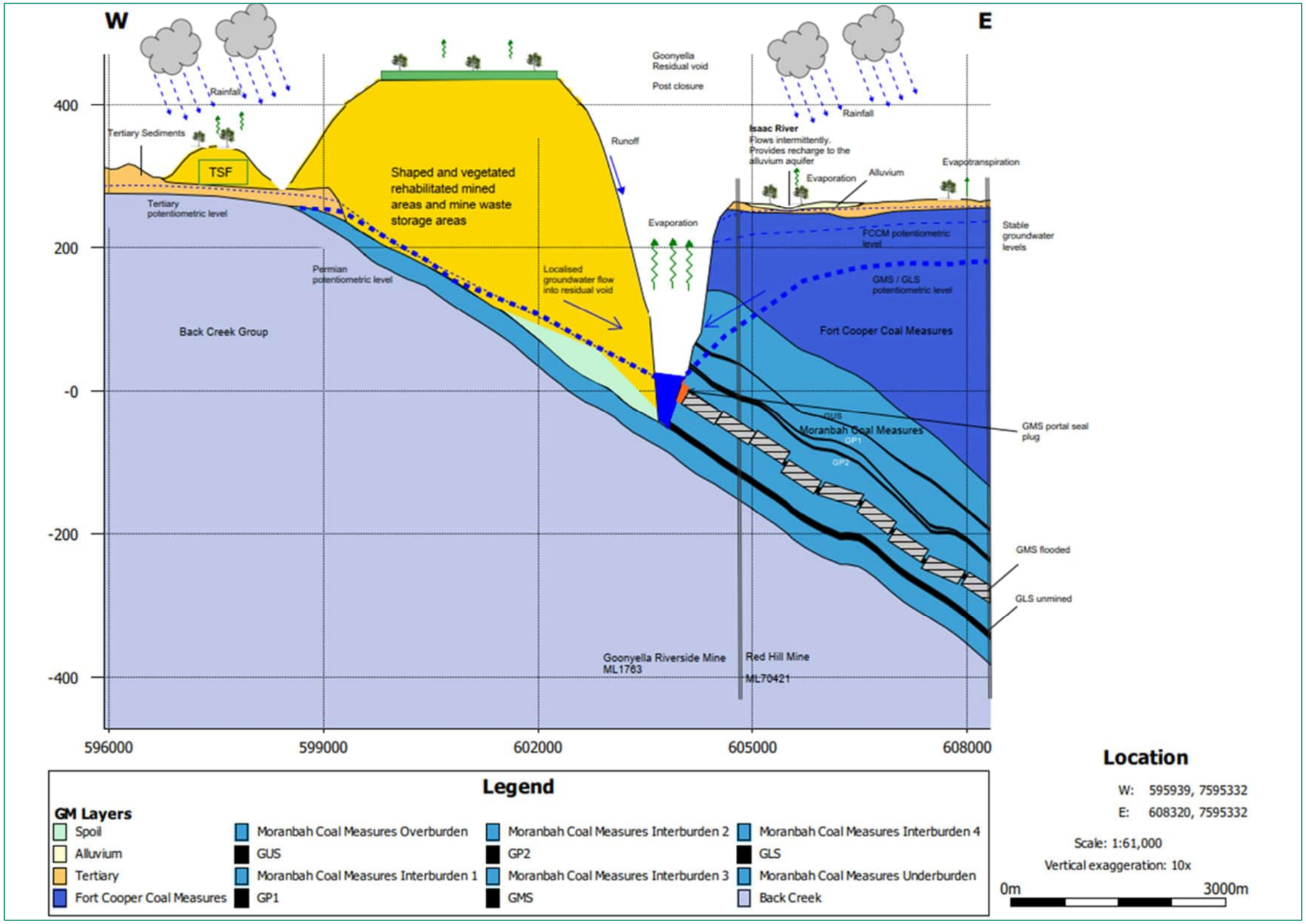


Figure 70 Source-Pathway-Receptor pathways post-closure

	Primary Sources		Secondary Sources		Transport Mechanisms		Exposure Pathways		Exposed Population
X	Residual Voids	X	Mine altered groundwater	X	Groundwater transport	X	Groundwater extraction		Water supply
X	Spoil / backfill areas					X	GDEs use		Industrial
X	MIA						Baseflow to surface water		Agricultural
X	TSF & Reject dumps								Ecological
X	Mine water storage		Surface water						
		X	Impacted soil, sediment	X	Leaching				

X - Potential

O - Not applicable

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Appendix A

Red Hill Mining Groundwater Modelling

Report

Red Hill Mining Lease EIS

Groundwater Impact Assessment

24 SEPTEMBER 2013

Prepared for
BM Alliance Coal Operations Pty Ltd

42627136

URS

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Status: Final

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Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
BBCGP	Bowen Basin Coal Growth Project
BMA	BHP Billiton Mitsubishi Alliance
BoM	Bureau of Meteorology
BRM	Broadmeadow underground mine
CHPP	coal handling and preparation plant
CSG	coal seam gas
DERM	Department of Environment and Resource Management
DSDIP	Department of State Development, Infrastructure and Planning
EIS	environmental impact statement
EPP (Water)	*Environmental Protection (Water) Policy 2009*
GDE	groundwater dependant ecosystems
GLS	Goonyella Lower Seam
GMA	groundwater management area
GMS	Goonyella Middle Seam
GPR	Ground Penetrating Radar
GRB	Goonyella Riverside and Broadmeadow
GRM	Goonyella Riverside Mine
GUS	Goonyella Upper Seam
IDAS	Integrated Development Assessment System
IMG	incidental mine gas
K	hydraulic conductivity
Kh	hydraulic conductivity – horizontal
Kv	hydraulic conductivity – vertical
LOM	life of mine
m	metre
MIA	mine industrial area
ML	mining lease
MLA	mining lease application
MR Act	*Mineral Resources Act 1989*
NRM	Department of Natural Resources and Mines
RHM	Red Hill Mine
RMSE	root-mean-square error
SP Act	*Sustainable Planning Act 2009*
STRM data	digital elevation data
TDS	total dissolved solids
ToR	Terms of Reference
URS	URS Australia Pty Ltd
VWP	Vibrating Wire Piezometers
Water Act	*Water Act 2000*
WQG	Water Quality Guidelines
WQO	Water Quality Objectives

Abbreviations

Unit	Description
^{o}C	degrees Celsius
%	per cent
GL	gigalitres
L/s	litres per second
m^3/t	cubic metres per tonne
m/day	metres per day
mbgl	metres below ground level
mg/L	milligrams per litre
µS/cm	microSiemens per centimetre

1

Introduction

The Red Hill Mining Lease is located adjacent to the existing Goonyella, Riverside and Broadmeadow (GRB) mine complex in the Bowen Basin, approximately 30 kilometres north of Moranbah and 220 kilometres south-west by road from Mackay, Queensland (refer **Figure 1–1**).

BHP Billiton Mitsubishi Alliance (BMA), through its joint venture manager, BM Alliance Coal Operations Pty Ltd, proposes to convert the existing Red Hill Mining Lease Application (MLA) 70421 to enable the continuation of existing mining operations associated with the GRB mine complex. Specifically, the mining lease conversion will allow for:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM).
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM).
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRM.

The three project elements described above are collectively referred to as 'the project'. Further detail on each project component is as follows:

- The extension of BRM longwall panels 14, 15, and 16 into MLA70421. Key aspects include:
  - No new mining infrastructure is proposed other than infrastructure required for drainage of incidental mine gas (IMG) to enable safe and efficient mining.
  - Management of waste and water produced from drainage of IMG will be integrated with the existing BRM waste and water management systems.
  - The mining of the BRM panel extensions is to sustain existing production rates of the BRM mine and will extend the life of mine by approximately one year.
  - The existing BRM workforce will complete all work associated with the extensions.
- The incremental expansion of the GRM. Key aspects include:
  - underground mining associated with the RHM underground expansion option to target the GMS on mine lease (ML) 1763;
  - a new mine industrial area (MIA);
  - a CHPP adjacent to the Riverside MIA on MLA1764 and ML1900 − the Red Hill CHPP will consist of up to three 1,200 tonne per hour modules;
  - construction of a drift for mine access;
  - a conveyor system linking RHM to the Red Hill CHPP;
  - associated coal handling infrastructure and stockpiles;
  - a new conveyor linking product coal stockpiles to a new rail load-out facility located on ML1900; and
  - means for providing flood protection to the mine access and MIA, potentially requiring a levee along the west bank of the Isaac River.
- A potential new Red Hill underground mine expansion option to the east of the GRB mine complex, to target the GMS on MLA 70421. Key aspects include:
  - the proposed mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south;
  - a network of bores and associated surface infrastructure over the underground mine footprint for mine gas pre-drainage (IMG) and management of goaf methane drainage to enable the safe extraction of coal;
  - a ventilation system for the underground workings;

— a bridge across the Isaac River for all-weather access. This will be located above the main headings, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply;
— a new accommodation village (Red Hill accommodation village) for the up to 100 per cent remote construction and operational workforces with capacity for up to 3,000 workers; and
— potential production capacity of 14 million tonnes per annum of high quality hard coking coal over a life of 20 to 25 years.

URS Australia Pty Ltd (URS) was commissioned by BMA to conduct a groundwater investigation and impact assessment as part of the project Environmental Impact Statement (EIS). For the purposes of this report, the area within the EIS study boundary is called the 'EIS study area'. The groundwater study, however, covered a larger area and this is defined as the 'survey area'. Refer to **Figure 1-1** which shows both boundaries.

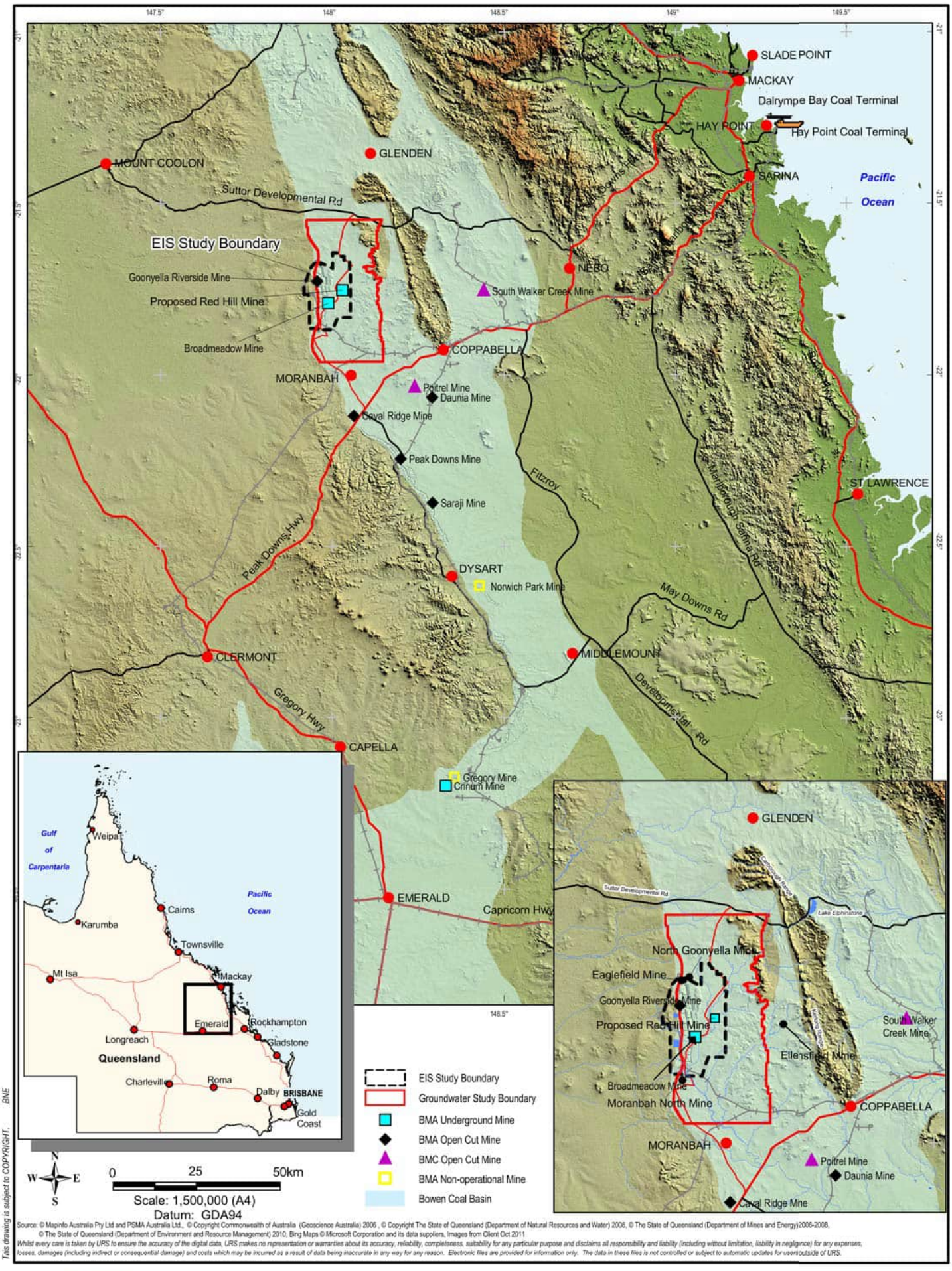
This standalone technical report provides details of an assessment of potential groundwater impacts associated with the proposed project, and includes recommended mitigation measures and monitoring protocols.

1.1 Scope of Work

The scope of work for the groundwater investigation was based on the terms of reference (ToR) for the project (Coordinator-General 2013).

The objective of this study was to assess the potential impacts of the proposed underground coal mining activities on the hydrogeological regime and, where necessary, identify measures for mitigation and/or monitoring of impacts as specified in the ToR. To achieve this objective, the scope of work included:

- A review of hydrogeological and geological data existing in the public domain, including reports and records held by the Department of Natural Resources and Mines (NRM) and maps published by the Geological Survey of Queensland.
- A review of exploration and monitoring bore data and groundwater reports provided by BMA.
- A review of hydrogeological data held on the NRM Groundwater Database for existing water bores in the area.
- Field investigations comprising groundwater sampling and aquifer parameter (variable head) tests.
- Survey of existing groundwater facilities (bores, wells) within the BMA properties and in neighbouring properties.
- An assessment and analysis of all available hydrogeological data though the development of a conceptual hydrogeological model and predictive hydrogeological modelling.
- Preparation of a report detailing the potential impacts of the proposed development on the groundwater regime.



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BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
GROUNDWATER IMPACT ASSESSMENT

SURVEY AREA LOCALITY

URS | GROUNDWATER | Figure: 1-1

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2

Legislative Framework and Requirements

A summary of the relevant policies, guidelines and legislation relevant to the project are outlined in **Table 2-1**.

Table 2-1 Summary of Relevant Policies, Guidelines and Legislation to the Project Area

Policy, Guidelines, or Legislation	Description	Relevance to the Project – Groundwater Impact Assessment
Environmental Protection Act 1994 (EP Act)	The objective of the EP Act is to protect the Queensland environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (Queensland Government 2012). Subordinate to this act is the Environmental Protection Regulation 2008, which provides for the effective administration and enforcement of the objectives and provisions of the EP Act.	All persons must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practical measures to prevent or minimise the harm (Section 319 of the Act). This general duty to the environment requires the implementation of proactive measures to prevent environmental degradation and act in accordance with the precautionary principle. This requirement is underpinned by the impact assessment and mitigation process in this study.
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The purpose of the Act is to provide for the protection of matters of national environmental significance (MNES), including groundwater dependant ecosystems (GDEs) and MNES species that rely on springs. Since June 2013, Queensland is a signatory to the Council of Australian Governments National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development (NPA). The NPA requires CSG or large coal mining development proposals undergoing environmental impact assessment that are likely to have a significant impact on water resources to be referred to an Independent Expert Scientific Committee (IESC).	The project is considered under the EPBC Act, as the EPBC Act is triggered for assessment of MNES. For groundwater this would be for assessment of impacts to mound springs or significant species habitat from drawdown. Regarding the EPBC Act, the depth of groundwater limits any potential use by listed or threatened species and migratory birds. Any potential changes in groundwater levels as a result of mine dewatering are therefore not considered to impact on listed or threatened species and migratory birds. After consultation between The Department of Environment and BMA this project is to include a summary report for the IESC as per the water resource trigger detailed in the NPA.
Water Act 2000 (Water Act)	The purpose of the Act is to provide for the sustainable management and efficient use of water and other resources, a regulatory framework for providing water services and the establishment and operation of water authorities. Water resource plans have been developed to define the availability and allocation of water and to ensure the sustainable management of water in Queensland. The objectives of the water resource plans are to balance the needs of humans and the environment in a sustainable manner.	Water use and the obligations, processes, and framework for coal mining in relation to groundwater monitoring, reporting, impact assessment and management of impacts on other water users including 'make good' agreements is regulated under the Act.

2 Legislative Framework and Requirements

Policy, Guidelines, or Legislation	Description	Relevance to the Project – Groundwater Impact Assessment
The Water Supply (Safety and Reliability) Act 2008	The purpose of the Act is to provide for the safety and reliability of water supply in Queensland. The Act sets out requirements for Environmental Management Plans and obligations in relation to the potential to impact on drinking water supplies.	The Project is automatically captured by this process for injection, direct supply or discharge of water, however; an exemption can be applied for.
Environmental Protection (Water) Policy 2009 (EPP (Water))	The purpose of the Policy is to achieve the objectives of the EP Act in relation to Queensland waters while allowing for ecologically sustainable development.	The environmental values are to be enhanced or protected (Section 6 of the Act). The relevant environmental values vary depending on the ecological value of the water, level of disturbance and intended use of the water. The management controls/ mitigation measures in this study were prepared to meet the requirements of this policy.
Sustainable Planning Act 2009	The purpose of the Act is to regulate the development of infrastructure outside petroleum tenures.	The Project is located within the Isaac Connors Groundwater Management Area (GMA) where any works for taking or interfering with water for purposes other than stock or domestic use (other than small diameter groundwater monitoring bores) are assessable activities and require a development permit.
Water Resource (Fitzroy Basin) Plan 2011	The Water Resource (Fitzroy Basin) Plan 2011 provides for the allocation and management of water in the Fitzroy Basin and the subordinate legislation under the Water Act.	Tenements in the northern portion of the Project area are located within the declared Isaac Connors GMA, as defined under Chapter 2, Section 7, Schedule 3, Schedule 4, and Schedule 7 of the Fitzroy Basin WRP 2011. Any long-term water take or interference from groundwater sources requires authorisation by way of a licence.

2.1 Water Act 2000

2.1.1 General

The *Water Act 2000* (Water Act) vests all rights to the use, flow and control of groundwater, overland flow water and water in watercourses, lakes, springs and dams in the State and provides a comprehensive planning and management regime for all vested water resources in Queensland.

Chapter 2 of the Water Act (allocation and sustainable management) seeks to advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water in accordance with the principles of ecologically sustainable development.

Part 6 of Chapter 2 deals with the process of the allocation of licences or permits for the taking of or interfering with water. This includes groundwater. Land owners and other approved entities, including an applicant for, or the holder of, a mineral development licence or mining lease under the *Mineral*

Resources Act 1989 (MR Act), may apply for a licence or permit to take or interfere with groundwater. This application process includes a public notification requirement, and requires that the chief executive consider information about the effects of interfering with the water on natural ecosystems and the physical integrity of the aquifers, among other considerations.

The Water Act also deals with the 'make good' obligations of an entity such as the holder of a mineral development licence or mining lease under the MR Act to the owner of a pre-existing Water Act bore.

2.1.2 Water Resource (Fitzroy Basin) Plan 2011

Water Resource Plans provide for the allocation and management of water in Queensland and are subordinate legislation under the Water Act. The Water Resource (Fitzroy Basin) Plan 2011 includes groundwater, in part due to the significant increase in the demand for groundwater resources in recent years, driven mainly by mining in the Isaac-Connors system. There is a risk that groundwater resources in this catchment may be over committed (DERM 2009).

The survey area is located within the declared Isaac Connors Groundwater Management Area (GMA), as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resource (Fitzroy Basin) Plan 2011. Within the declared management area, water licenses and/or development permits are not required for stock or domestic bores, and NRM also generally exclude groundwater monitoring bores from the requirement for development permits.

Other groundwater-related activities, such as drilling of test pumping bores, and undertaking pumping tests, requires authorisation (by way of permits) from NRM, as well as a development permit (operational works) to allow drilling and construction of water bores. Any long-term water take or interference (whether actively via bores or passively via drainage to and dewatering of mine workings) from groundwater sources requires authorisation by way of a licence. The project will require a water licence for groundwater interfered with as a result of IMG drainage and mine dewatering activities.

2.2 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SP Act) provides the mechanism (via the Integrated Development Assessment System (IDAS)) through which assessment of a proposed development is undertaken, and under which a development permit is granted.

Within the declared Isaac Connors GMA any works for taking or interfering with water for purposes other than stock or domestic use are assessable activities and will require a development permit. Works that are for stock and domestic purpose are self-assessable development and do not require a development permit but must conform to the relevant self-assessable development code. NRM currently allows small diameter groundwater monitoring bores to be constructed without a development permit.

2.3 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP (Water)) serves to protect Queensland's waters while allowing for ecologically sustainable development. This purpose is achieved within a framework that includes:

- Identifying environmental values for aquatic ecosystems and for human uses (e.g. water for drinking, farm supply, agriculture, industry and recreational use).

2 Legislative Framework and Requirements

- Determining water quality guidelines (WQGs) and water quality objectives (WQOs) to enhance or protect the environmental values.

The location of the proposed project is within the Isaac River sub-Basin of the Fitzroy Basin, as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries (irrigation, farm supply, stock water); and
- cultural and spiritual values.

As discussed further in **Section 6.4**, the beneficial use of groundwater for some of these human uses within the EIS study area is limited to cases where salinity is suitably low and metal/metalloid concentrations are below guideline levels. Groundwater suitability for these anthropogenic uses therefore need to be assessed on a case-by-case basis, and in some cases it is interpreted that groundwater would have no practical use.

3

Review of Available Information

This groundwater assessment is based on a desktop review of available information and additional data collected on-site between March and June 2011. Previous groundwater studies undertaken within the survey area (as defined in **Section 4**) and the additional data collected during the compilation of this EIS have been used to describe the existing groundwater resources and thus allow for the assessment of the project on the current groundwater status.

The description of existing hydrogeological conditions within the survey area is based on the following available information:

- historical reports and groundwater monitoring data held by BMA for the GRB mine complex;
- data collected by BMA from the exploration drilling conducted for the GRB mine complex and the RHM;
- regional and local aeromagnetic geophysical surveys;
- environmental impact studies conducted for other coal mines in the area (**Figure 1-1**), including:
  - Anglo Coal (Grosvenor) Pty Ltd – Grosvenor Project, located 3 kilometres north of Moranbah and south of Moranbah North Mine (JBT Consulting 2010);
  - Peabody (Bowen) Pty Ltd – Eaglefield Expansion Project, located 36 kilometres north of Moranbah and immediately north of Goonyella Riverside Mine (GRM) (METServe 2010); and
  - Ellensfield Coal Management Pty Ltd – Ellensfield Coal Mine Project, located 35 kilometres north-east of Moranbah (AGE 2008);
- Geological Survey of Queensland Mount Coolon 1:250,000 Geological Map (Sheet SF55-7) and Bowen Basin Digital Geology;
- a search of the NRM groundwater and licensing database for registered bores located within a 10 kilometre radius of the site (conducted on 13 September 2011);
- a survey of existing groundwater facilities (bores, wells) within the EIS study boundary and neighbouring properties;
- Underground Water Impact Report (Arrow Energy 2011); and
- additional groundwater data collected on-site by URS for baseline studies between March and June 2011.

Previous hydrogeological investigations undertaken at GRB mine complex have focussed on assessing potential inflows to pits and underground workings and the establishment of boxcut or pit dewatering bores for mine design and production purposes. In each case, monitoring and dewatering bores have been constructed in the coal seams targeted for mining rather than overlying or underlying lithological units. Thus the hydrogeological work conducted previously on the site has covered:

- an assessment of Tertiary (units) permeability for a proposed boxcut at GRM (Thatcher 1976);
- an assessment and design of dewatering requirements for the Cleanskin Pit boxcut extension in the Goonyella Lower Seam (GLS) and double bench mining (Coffey & Partners 1987a, 1987b);
- a geotechnical assessment of slope stability for mining of the GLS beneath the existing Goonyella Middle Seam (GMS) pit at Ramp 13 (BHP Engineering 1993);
- hydraulic testing of the Goonyella Upper Seam (GUS) and GMS accompanied by numerical modelling of the GMS for the then proposed Goonyella No2 Mine (Rust PPK 1996; IESA 1996);
- installation of monitoring bores, numerical modelling of inflows for feasibility and tender purposes for the BRM (AGE 1998a, 1998b, 2000, 2002; BMA 2003);

3 Review of Available Information

- construction of monitoring bores, numerical modelling and installation/operation of depressurisation bores for the initial Airstrip pit boxcut and subsequent southerly extension of the pit (IESA 2001a, 2001b; AGE 2004a); and
- installation of monitoring bores and numerical modelling for the proposed double bench mining at Ramp 8 (AGE 2004b).

4

Physical Setting

The EIS study area is located within the upper sub-catchment of the Isaac River, which lies within the northern part of the Fitzroy River Basin (**Figure 1-1**).

4.1 Topography and Drainage

The upper Isaac River sub-catchment containing the EIS study area is bordered by the Peak Range to the southwest, Denham Range to the northwest, and the Broadsound and Connors Ranges to the east and northeast, respectively (**Figure 1-1**). Drainage gradients in the Isaac River sub-catchment are generally low across the central part of the sub-catchment and high around the margins, with elevations varying from a maximum of over 700 metres in the Connors Range down to approximately 90 metres at the junction with the Mackenzie River (Pearce & Hansen 2006). The central part of the sub-catchment is essentially flat lying where change in relief is typically less than 60 metres (SKM 2009).

The EIS study area is located within a broad valley through which the Isaac River flows, generally in a southerly direction. The northern portion of the EIS study area is formed by a low broad ridge that defines the northern extent of the Isaac River catchment. The low hills located to the east of the Isaac River near the GRB mine complex are undulating with a well-developed system of drainage lines.

The topography of the Isaac River valley near the EIS study area varies from approximately 250 metres AHD elevation along the Isaac River in the east of the EIS study area to approximately 325 metres AHD elevation along portions of the Denham Range that define the western edge of the valley. The relatively steep slopes associated with the Denham Range contrast with the extensive flat areas across the base of the river corridor, where gradients are generally less than 1v:100h.

There are five main ephemeral creeks within the EIS study area: Goonyella Creek, Eureka Creek, Fisher Creek, Platypus Creek, and 12 Mile Gully. These are tributaries of the Isaac River.

4.2 Climate

The climate of the Isaac River sub-catchment is predominantly dry tropical with hot summers and mild winters. Average maximum daily temperatures range from approximately 24°C in June-July to 34°C in December-January, whilst average minimum daily temperatures vary from approximately 10°C in July to 22°C in January-February for the Moranbah area (Bureau of Meteorology (BoM) monitoring station 034038). Rainfall is highly variable, both spatially and temporally across the sub-catchment. In the Moranbah area, the mean annual rainfall is approximately 600 millimetres (**Chart 4-1**). Rainfall is summer dominant with approximately 70 per cent of annual rainfall falling during months of the wet season from November to March (**Chart 4-2**). Average monthly evaporation consistently exceeds average rainfall over all months. However episodic, high intensity rainfall events do occur related to monsoonal troughs and cyclones, resulting in excess rainfall above evaporation at a frequency of eight per cent, with a duration between events ranging from approximately one to six years (SKM 2009). It is considered that infiltration of rainfall and subsequent groundwater recharge may be most likely to occur during high intensity rainfall events.

4 Physical Setting

Chart 4-1 Total Yearly Rainfall at the Moranbah Monitoring Station (BoM station no: 034038)

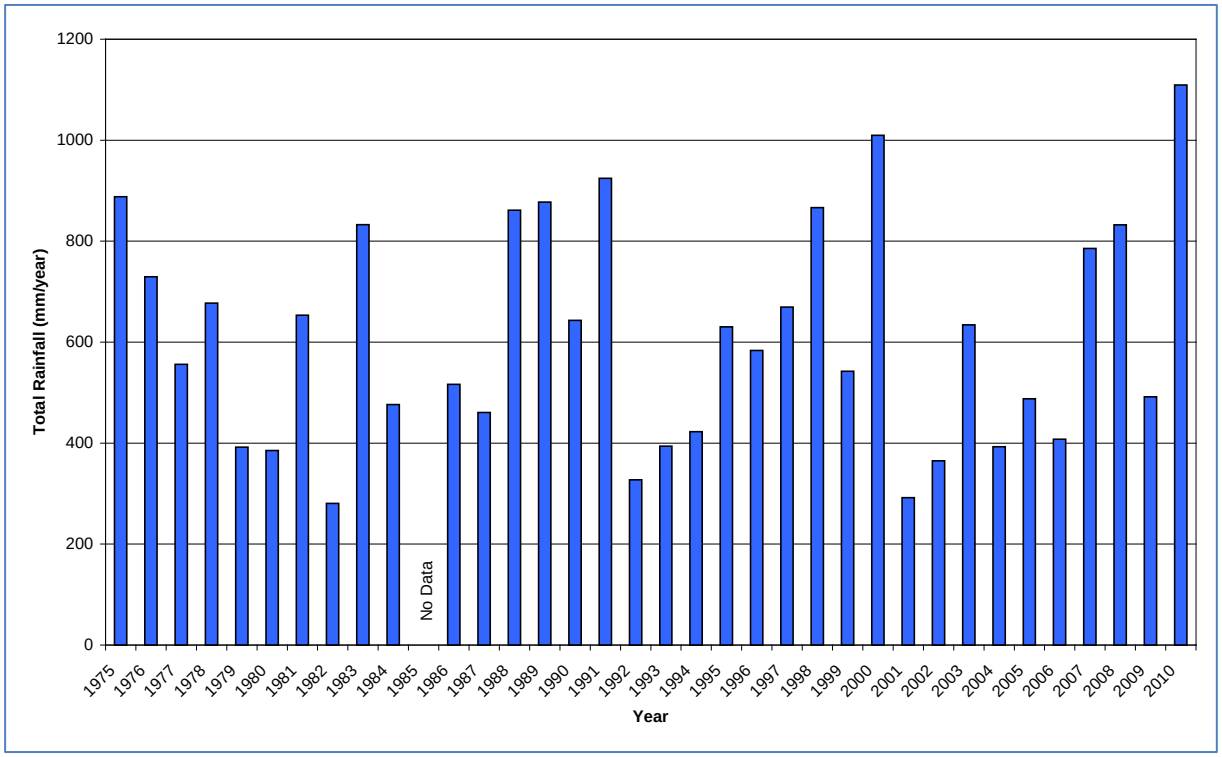
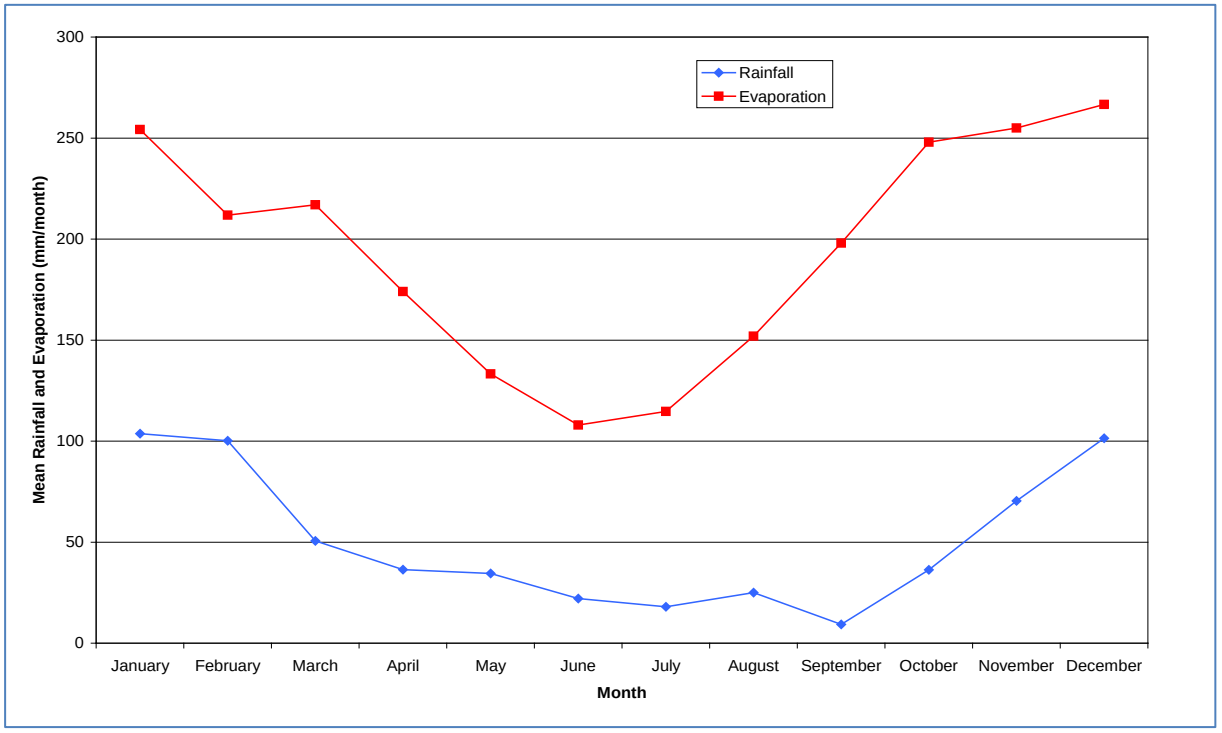


Chart 4-2 Mean Monthly Rainfall and Evaporation at the Moranbah Monitoring Station (BoM station no: 034038, 1986 to 2010)



4.3 Land Use

Since European settlement, the Isaac River sub-catchment has been extensively used for agriculture. SKM (2009) reported that approximately 90 per cent of land within the sub-catchment was dedicated to grazing (predominantly beef cattle) of relatively natural (limited clearing) environments. Dryland cropping and coal mining are the other significant land uses in the sub-catchment, the latter primarily focussed in the western part of the sub-catchment.

Coal mining is undertaken to the north and south of the EIS study area, with North Goonyella underground and open cut mine (Eaglefield Pit) operated by Peabody Energy to the north and the Moranbah North underground coal mine operated by Anglo American Coal to the south.

The existing GRM is an open cut operation producing hard coking coal while the BRM is an underground, punch longwall mine and has been developed in an existing highwall of the open cut operation.

The RHM footprint has previously been cleared for cattle grazing. However, small patches of remnant bushland and scrub remain, particularly along riparian corridors. The local agricultural industry is partially dependent on groundwater for stock watering; the remaining water requirements are met by surface water supplies. Groundwater is primarily extracted from the coal seam aquifers and sandstone units of the Bowen Basin or alluvium associated with the main rivers. Increasing demand on groundwater from both agriculture and mining has led to these groundwater systems being regulated in the Water Resource (Fitzroy Basin) Plan 2011.

5

Geological Setting

5.1 Regional Geology

The geological Bowen Basin is an elongated, north-south trending basin which extends from east-central Queensland to northern New South Wales. The basin covers an area of approximately 200,000 square kilometres, and is exposed over 600 kilometres from Collinsville in the north to Rolleston in the south. It contains a sedimentary sequence of Permo-Triassic clastics, which attain a maximum thickness of 9,000 metres in the depo-centre of the Taroom Trough.

The Bowen Basin is divided into a number of tectonic units comprising north/north-west – south/south-east trending platforms or shelves, separated by sedimentary troughs. The major structural unit surrounding the EIS study area is the Collinsville Shelf, underlain at shallow depths (one to two kilometres) by the Clermont Stable Block which bounds the northern Bowen Basin to the west. The Collinsville Shelf was a stable tectonic environment and is characterised by a monoclinal accumulation of sediments, which dip gently (two to eight degrees) and thicken to the east. Folding is gentle and mostly related to drag on thrust faults at the eastern margin of the basin limb. The boundary between the Collinsville Shelf and the adjoining major axis of deposition, the Nebo Synclinorium of the Taroom Trough, is marked by a major thrust fault termed the Burton Range Thrust Fault, which is located approximately 10 kilometres east of the EIS study area. This scarcity of regional significant structures or fault zones distinguishes the Collinsville Shelf sediments from the tightly folded and intruded sediments of the Nebo Synclinorium.

Regionally, the stratigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments of the Tertiary Suttor Formation and, in places, remnants of Tertiary basalt flows.

5.2 Local Geology and Stratigraphy

A summary of the stratigraphy from the survey area is presented in **Table 5-1** and the local geology is shown in **Figure 5-1**.

The marine influenced Early to Middle Permian Back Creek Group is the oldest Bowen Basin succession observed in the survey area. This is conformably overlain by the Late Permian Blackwater Group, which contains the coal seams of economic interest to BMA. Following deposition of the Blackwater Group, fluviolacustrine deposition led to the deposition of the Triassic Mimosa Group. Tertiary volcanic deposits composed mostly of basaltic lava flows overlie the Bowen Basin successions. These Tertiary volcanics occur as isolated exposures in the north of the survey area. Extensive Quaternary alluvial deposits are associated with the Isaac River system.

5 Geological Setting

Table 5-1 Stratigraphy of the Survey Area

Period		Stratigraphic Unit			Description	Max. Thickness (m)	Presence in Survey Area
Quaternary		Alluvium			Clay, silts, sand, gravel, floodplain alluvium	37 m in survey area	Confined to present day stream alignments and palaeochannels
Tertiary		Basalt			Olivine basalt flows	35 m in survey area	Isolated patches in north of survey area
		Suttor Formation			Clay, silts, sand, gravel, colluvial and residual deposits, fluvial and lacustrine deposits	80 m in survey area	Most extensive in the mine areas and to the east
Triassic	Early	Bowen Basin	Mimosa Group	Rewan Formation	Green lithic sandstone, pebble conglomerate, red and green mudstone	Unknown in survey area	Small area within the north east
Permian	Late	Bowen Basin	Blackwater Group	Rangal Coal Measures	Sandstone, siltstone, mudstone, coal, tuff, sandstone	100 m	Outcrops or subcrops in the majority of the survey area
				Fort Cooper Coal Measures – Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff	400 m	
				Fort Cooper Coal Measures – Fair Hill Formation	Labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal		
				Moranbah Coal Measures	Quartzose to sublabile, locally argillacoues sandstone, siltstone, mudstone, carbonaceous mudstone and coal	250 m	
	Early to Middle	Bowen Basin	Back Creek Group		Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Unknown in survey area	Outcrops west of mines and extends under mined areas to the east
Carboniferous	Early	Basement	Drummond Basin Succession	Mount Rankin Formation	White and grey siltstone and fine sandstone, minor medium to very coarse grained sandstone, chert, granule to pebble conglomerate, rare tuff, ignimbrite and dacite/andesite	Unknown in survey area	Outcrops west of the survey area and is inferred to form basement under the Bowen Basin in the mine areas
Devonian	Late	Basement	Silver Hills Volcanics		Rhyolite, dacite, rhyolitic ignimbrite, volcaniclastic sediments, sinter, minor sandstone and siltstone		
Proterozoic		Basement	Anakie Metamorphic Group		Siltstone, fine sandstone, phyllite, schist, commonly cleaved and multiply deformed		

5 Geological Setting

5.2.1 Basement Geology (Proterozoic-Carboniferous)

The nature and age of the crust beneath the Bowen Basin in the survey area is inferred from exposed rocks outside the basin and a deep seismic survey conducted by Geoscience Australia. Exploration drilling to date has not penetrated the basin succession away from its immediate margins.

Units that are exposed to the west of the Bowen Basin and that appear to continue underneath the survey area are the Proterozoic Anakie Metamorphic Group, Devonian Silver Hills Volcanics, and units of the Carboniferous Drummond Basin succession.

5.2.2 Back Creek Group

The Back Creek Group consists of Permian marine sediments, unconformable on the underlying basement. In the survey area, this unconformity is of low relief on a regional scale. The Back Creek Group is comprised of quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite. It is poorly exposed in and to the west of the EIS study area, and dips to the east below the Blackwater Group.

5.2.3 Blackwater Group

The Permian Blackwater Group contains, from oldest to youngest, the Moranbah Coal Measures, Fort Cooper Coal Measures, and Rangal Coal Measures.

The boundary between the Back Creek and Blackwater Groups is conformable and locally transitional. Due to the time involved in the gradual regression resulting in the deposition of the non-marine Blackwater Group, the boundary is diachronous, and the stratigraphy is complicated by facies changes and by changes in provenance of units.

Moranbah Coal Measures

The Moranbah Coal Measures outcrop or subcrop in the west and centre of the EIS study area, where they are mined in the GRM open cut pits.

The Moranbah Coal Measures were deposited in a predominantly fluvial flood plain environment. The lithology of the Moranbah Coal Measures is generally characterised by interbedded fine-grained lithic sandstone, siltstone, mudstone, claystone, and coal. The Moranbah Coal Measures show regular grading of lithological sequences from sandstone to siltstone and mudstone to coal, then tending back to sandstone, typical of depositional flood plain / river systems. The Moranbah Coal Measures are characterised by several laterally persistent thick coal seams interspersed with several thin minor seams, which split and coalesce. The three main seams are the GUS, GMS, and GLS. The GMS is the target seam for the proposed RHM.

Fort Cooper Coal Measures

The Late Permian Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures, and outcrop or subcrop in the centre to the east of the EIS study area. The Fort Cooper Coal Measures consist of lithic sandstone, siltstone, mudstone, coal, and tuffaceous sediments. A number of coal seams are contained within the Fort Cooper Coal Measures. These coal seams are typically highly banded with claystone, mudstone and siltstone and hence are non-commercial. The lower boundary of the Fort Cooper Coal Measures is taken as the base of a thick and widespread sequence of interbedded dull and stony coal, carbonaceous mudstone and tuff. This unit, referred to as the Fair

Hill Seam, ranges in thickness up to approximately 25 metres and lies approximately 60 to 70 metres above the GUS.

Rangal Coal Measures

The Rangal Coal Measures comprise light grey, cross-bedded, fine to medium grained sandstone, grey siltstone, mudstone, and coal seams. Cemented sections are common in the sandstone. The transition between the Fort Cooper Coal Measures and the Rangal Coal Measures is generally clearly marked by the Yarrabee Tuff, a basin-wide marker bed comprising weak, brown tuffaceous claystone.

5.2.4 Mimosa Group

The Permian sediments are unconformably overlain by the Triassic Rewan Formation. The Permian-Triassic boundary marks the change from the carbonaceous sediments of the coal measures to the non-carbonaceous mainly green, fine to medium grained, micaceous, lithic, labile, sandstone and red, brown, green and locally mottled mudstone.

5.2.5 Cainozoic Cover

The Permian and Triassic formations are mantled by an irregular cover of poorly consolidated Cainozoic sedimentary strata and both fresh and weathered basalt. The Cainozoic cover is up to 110 metres thick in parts towards the north of the survey area, where infilled deeply incised Tertiary palaeochannels.

Tertiary Formations

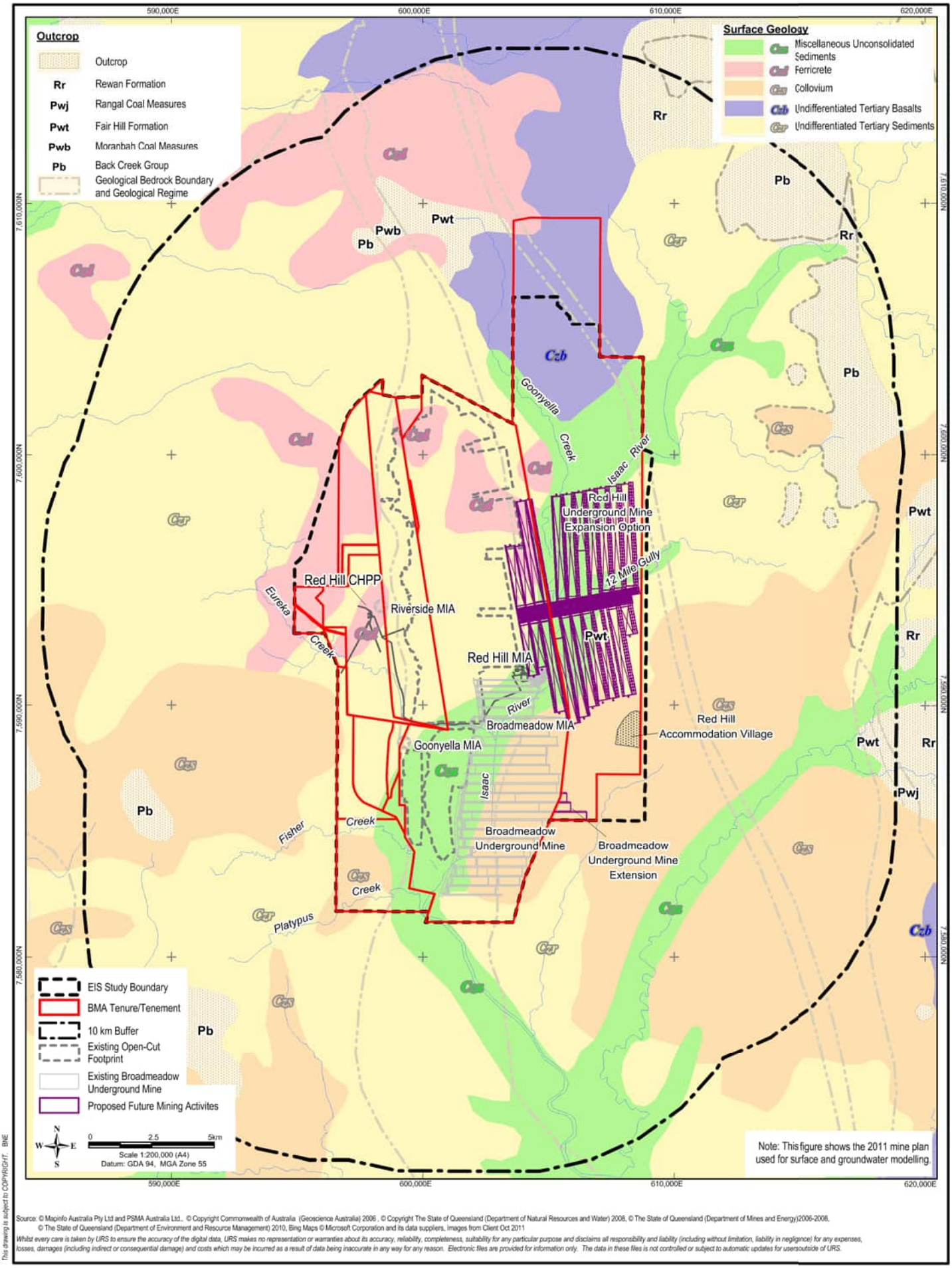
The mid-Tertiary Suttor Formation and its equivalents occur throughout the region, though outcrop is not continuous, and much of the Tertiary sequence is concealed by younger alluvium and colluvium. These strata consist of basalt, clay, silt, sand, weakly cemented sandstones, lignite and laterites. The Tertiary silts and clays are densely compacted and hard. Lag deposits of sand and gravel are found directly on the Tertiary/Permian unconformity.

The basalt appears to fill channels cut into the Tertiary sediments or into the Permian rocks. The basalts are deeply weathered and ferruginised in most places, but the thicker flows are fresher in their lower parts. Previous studies have reported basalt units range in thickness up to a maximum of 35 metres in palaeochannels in the GRM (Davies 1983).

A single major period of deep weathering has been identified for the region (Hutton *et al.* 1998). The weathering period was responsible for the strongly mottled and leached profiles on the Suttor Formation and its equivalents, and the basalts and older rocks. The associated duricrusts are generally cemented by clay minerals and silica.

Quaternary Formations

The Quaternary to Recent alluvial sediments consist of sand, gravel, clay and silt of varying content that have been unconformably deposited in an eroded, valley-fill environment associated with the creeks and drainage channels in the EIS study area. The alluvial deposits are thin, linear, irregular and lensoid in nature.



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RED HILL MINING LEASE
GROUNDWATER IMPACT ASSESSMENT

SURFACE GEOLOGY OF THE SURVEY AREA

URS | GROUNDWATER | Figure: 5-1

File No: 42627136-g-2096.wor | Drawn: VH | Approved: CT | Date: 24-06-2013 | Rev.A | A4

6

Hydrogeological Regime

6.1 Groundwater Occurrence

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. The groundwater regime in the survey area is considered to include:

- Quaternary alluvial aquifers associated with the creeks and Isaac River;
- Tertiary sediment aquifers;
- Tertiary basalt aquifers; and
- Permian-Triassic sedimentary fractured rock aquifers.

The EIS study area is located within the declared Isaac Connors GMA, as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resource (Fitzroy Basin) Plan 2011. Within the Isaac Connors GMA, aquifers in the Quaternary alluvium are known as the Isaac Connors Groundwater Unit 1, with all other aquifers grouped together as the Isaac Connors Groundwater Unit 2. The alluvium associated with the Isaac River in the survey area is defined as the Isaac Connors Alluvium groundwater sub-area of the Isaac Connors GMA. Groundwater supply is not considered to be a major water source in the groundwater survey area. Based on a review of available data, the beneficial use of groundwater in the survey area is considered to be low due to low sustainable yields and poor groundwater quality.

The occurrence and continuity of the above mentioned aquifers will be highly dependent on the spatial distribution of the corresponding geological units in the area. The conceptual model of the groundwater regime in the survey area is presented in **Figure 6–1**.

6.1.1 Quaternary Alluvial Aquifers

Distribution

Quaternary alluvial deposits in the survey area occur predominantly within the Isaac River floodplains as shown in **Figure 6-2**. Along the Isaac River these deposits consist of clay, sandy clay, and sands and gravels with varying proportions of clay, to a depth of up to 37 metres, as observed for monitoring wells GW01 and 43840. Investigations in the Isaac River at the Moranbah North mine (located immediately south of the EIS study area) indicated that the thickness of bed sands in the Isaac River was two to three metres (JBT Consulting 2010). The alluvium associated with Eureka Creek consists of approximately nine metres of silty sand and poorly sorted sand and gravel at monitoring well GW08, with no alluvium present at GW07.

The sand and gravel deposits are recognised within the creek beds with the overbank deposits being silty and clayey with minor sand. In the upper catchments of the smaller creeks rock bars are evident. Sand and gravel deposits tend to build up behind the rock bars.

Groundwater Occurrence, Recharge and Flow

Potential for usable groundwater resources exists within the more permeable sand and gravel dominant sections of the alluvium, and represents an unconfined to semi-confined aquifer. However, drilling in the survey area alluvium indicates variable saturated thickness and does not form a consistent interconnected aquifer. The alluvial aquifer is classed as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The volume of groundwater associated with the alluvium depends on the interconnection of permeable units, saturated thickness,

6 Hydrogeological Regime

and the ability to store groundwater, i.e. effective storage allowing for baseflow to creeks and rivers during the dry season.

The alluvial aquifers are considered to be strongly linked (recharged during flow events) to surface water (SKM 2009). The Isaac River and creeks within the EIS study area are ephemeral and recharge of the alluvium is by:

- recharge from surface water flow or flooding (losing stream); and
- surface infiltration of direct rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Available hydrologic data suggests that water infiltrates / drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. This saturation is sporadic, producing semi-permanent, localised, thin, aquifers.

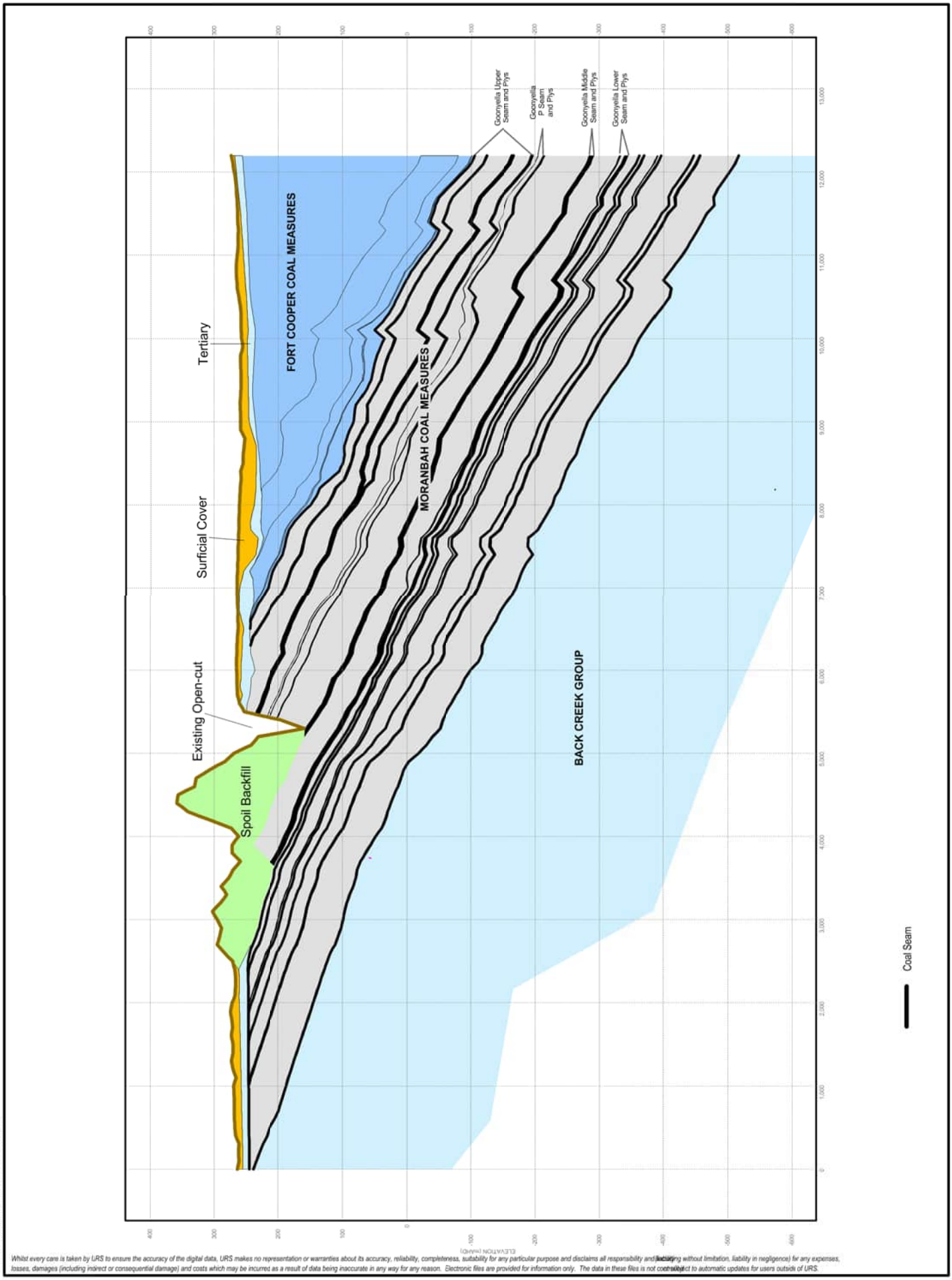
Groundwater discharge from the alluvium occurs through:

- evapotranspiration from vegetation growing in the creek beds and along the banks;
- short duration baseflow from the permeable sands and gravels within the alluvium material; and
- infiltration and recharge to the underlying older formations where the creeks cross more permeable zones within these units.

During a ground penetrating radar (GPR) survey of the Isaac River at Moranbah North mine, accessible during the dry season, it was noted that all test pits dug for the GPR survey within the bed sands were dry, or only damp in the base layer. This indicates that the Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round. Limited groundwater resources may, however, occur in the deeper and relatively narrow parts of the channel.

Due to the generally shallow saturated thickness and the lack of continuity of the more permeable gravel and sand sections, the Quaternary alluvium is not considered a significant aquifer as it has limited sustainable yield. However, during periods of creek or river flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams or other underlying aquifers. Drilling on site indicates that, where groundwater does occur, depth to groundwater in the Quaternary alluvium was approximately 11 to 13 metres below ground level (mbgl). The groundwater level in the alluvium, measured in a study by Thatcher (1976), was about 20 metres above the piezometeric (confined) water level in the coal at the same location. These groundwater levels indicate a marked separation between the perched alluvium groundwater level and the piezometeric levels associated with the deeper coal seam aquifer groundwater. It is, thus, unlikely that changes in groundwater levels in the coal would significantly impact on the perched water table associated with the alluvium.

Owing to the paucity of data for the Quaternary alluvium, limited information exists regarding groundwater flow, however regionally, groundwater flow within the aquifer is expected to follow topography and drainage patterns.



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RED HILL MINING LEASE
GROUNDWATER IMPACT STATEMENT

TYPICAL GEOLOGICAL CROSS SECTION

URS | **GROUNDWATER**

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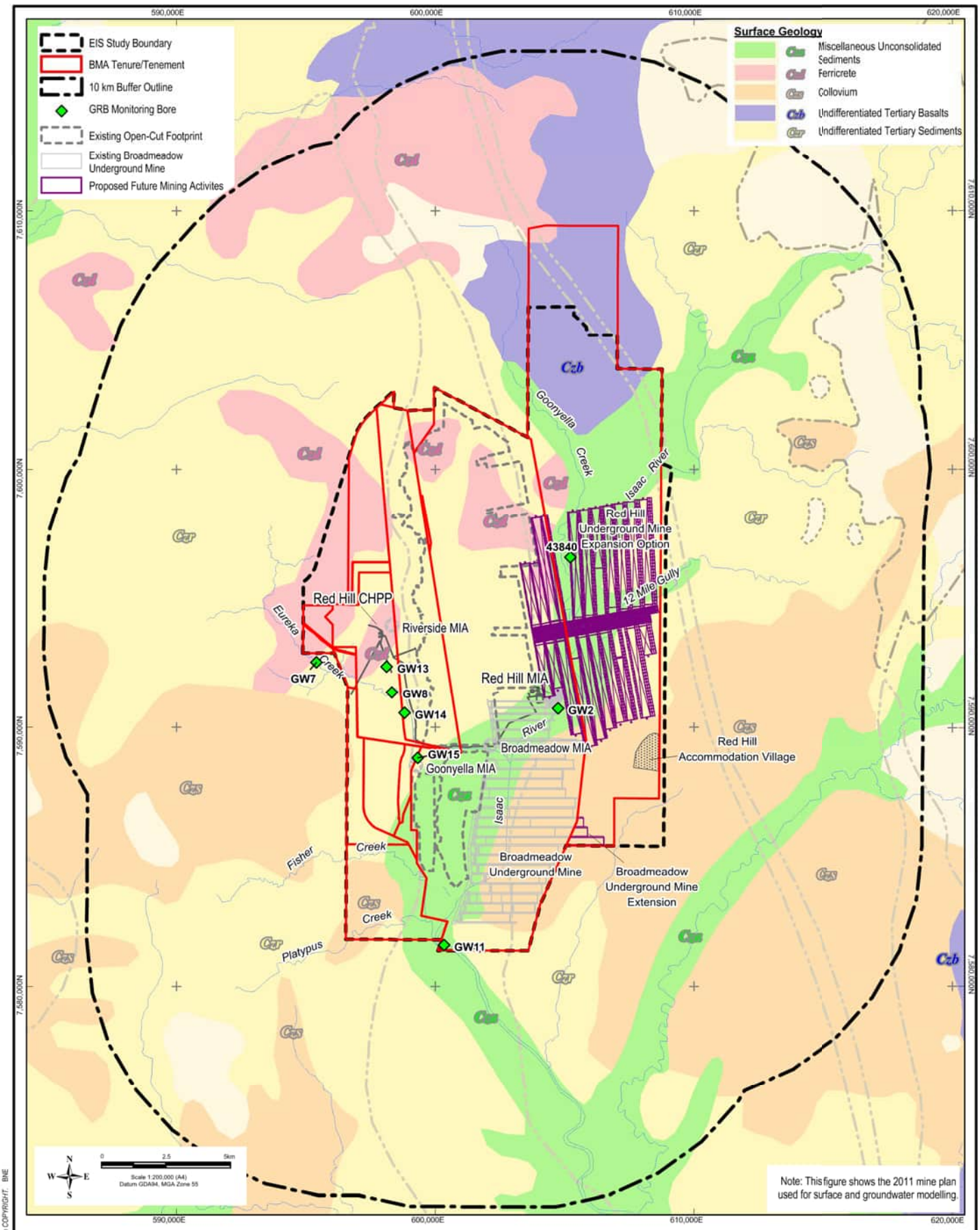
Figure: **6-1** Rev: **A** **A4**


EIS Study Boundary
BMA Tenure/Tenement
10 km Buffer Outline
GRB Monitoring Bore
Existing Open-Cut Footprint
Existing Broadmeadow Underground Mine
Proposed Future Mining Activites
Surface Geology
Miscellaneous Unconsolidated Sediments
Ferricrete
Colluvium
Undifferentiated Tertiary Basalts
Undifferentiated Tertiary Sediments
590,000E
600,000E
610,000E
620,000E
7,610,000N
7,600,000N
7,590,000N
7,580,000N
Red Hill Underground Mine Expansion Option
43840
12 Mile Gully
Red Hill CHPP
Riverside MIA
Red Hill MIA
Broadmeadow MIA
Goonyella MIA
Red Hill Accommodation Village
Broadmeadow Underground Mine
Broadmeadow Underground Mine Extension
GW7
GW13
GW8
GW14
GW2
GW15
GW11
Goonyella Creek
Isaac River
Eureka Creek
Isaac River
Fisher Creek
Creek
Platypus
Czb
Cer
Cez
Cal
Cez
Cez
Cez

6 Hydrogeological Regime

Hydraulic Parameters and Yield

Aquifer hydraulic properties of Quaternary alluvium material (Isaac River bed sands) and flood plain deposits were obtained from investigations undertaken at Moranbah North mine (JBT Consulting 2010). These hydrogeological investigations determined that permeability of the alluvium ranged from 8.9 to 45.4 metres per day (for some investigation sites water dissipated so rapidly that measurements could not be taken, indicating permeability higher than this range). These investigations also found that the Quaternary flood deposits (river bank sediments) were generally finer grained than the bed sands, and returned permeability values between 0.01 and 10 metres per day. This testing indicated that the river bank sediments were less permeable than the bed sands, and would be regarded as being of low to moderate permeability, compared to the higher permeability of the bed sands. Onsite, hydraulic testing of the Quaternary alluvium associated with the Eureka Creek at GW08 provided a hydraulic conductivity of 0.001 metres per day, typical for silty clay.

Even though the permeability of some areas of the Quaternary alluvial aquifers are high, the alluvium is not regionally extensive (continuous) and does not maintain a significant saturated thickness and hence is considered ephemeral in nature. Accordingly, groundwater extraction at high rates would not be sustainable in the long term (i.e. limited sustainable yields due to limited volumes held in storage).

6.1.2 Tertiary Sediment Aquifers

Distribution

The distribution of the Tertiary sediments is shown in **Figure 6–2**. The undifferentiated Tertiary sediments and Suttor Formation occurs extensively throughout the survey area, though outcrop is not always continuous, and much of the Tertiary sequence is concealed by younger alluvium and colluvium.

The Tertiary sediments generally consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. A review of the borehole logs within the RHM footprint showed the Tertiary sediments vary in thickness up to approximately 80 metres with a typical thickness of up to 15 metres. The thickness and extent of these Tertiary sediments are variable and for the most part, groundwater resources are limited and typically have poor quality. These Tertiary sediments have limited groundwater environmental values.

Groundwater Occurrence, Recharge and Flow

Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments, and represents an unconfined to confined aquifer depending on location, degree of weathering, the nature of the overlying alluvium, and clay content.

Variable permeability within the Tertiary sediment, resulting in different pore pressures, has resulted in occurrences of pit wall instability. However, due to the limited storage the Tertiary sediment aquifers dewater with time. Dry open cut mining (at the GRB mine complex) indicates that this is not an ongoing problem and that these units readily dewater.

Recharge processes in the Tertiary sediment aquifers are via:

- direct infiltration of rainfall and overland flow where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface; and
- overlying Quaternary alluvial aquifers.

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Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams); evapotranspiration; and
- groundwater extraction.

The depth to groundwater in monitoring wells on-site in the Tertiary sediment aquifer is typically less than 15 mbgl (IESA 2001a).

Hydraulic Parameters and Yield

Most of the clean sand and gravel lenses in the Tertiary sediments are permeable but are of limited lateral and vertical extent. Thus the volume of groundwater stored and the ability to transmit groundwater depends on the particle size of the material and the saturated thickness of the sediments. A review of bore logs within the RHM footprint showed that the Tertiary sediments are dominated by low permeability clays and sandy clays with isolated areas of loose more permeable sand. The interpreted hydraulic conductivity value of 6.6×10^{-4} metres per day obtained from the variable (falling) head test for monitoring well GYTD7 during investigations for the Airstrip Pit Boxcut (IESA 2001a) is very low, indicating predominantly clay intersected within this bore. No other site specific testing of hydraulic properties has been undertaken on the shallow Tertiary sediments. Installation of monitoring bores (GW1 to GW15) showed that the Tertiary sediments, where intersected, comprise predominantly of clays, containing only very minor sand lenses, and intersected little or no groundwater. Data from exploration drilling also indicates that these sediments are often dry, and occurrence of groundwater in these sediments is sparse. However, where the sediment is coarse in composition, the unit may have localised zones of enhanced hydraulic conductivity.

6.1.3 Tertiary Basalt Aquifers

Distribution

An aeromagnetic geophysical survey has been undertaken over the Bowen Basin (GSQ 2004). The resultant magnetic data indicates that Tertiary basalt exists as small discontinuous remnants to the south and in the west of the EIS study area, with a larger continuous unit to the north (**Figure 6-2**). No basalt is mapped within the footprint of the RHM.

Groundwater Occurrence, Recharge and Flow

For the majority of exploration boreholes that intersected basalt, the basalt is logged as highly to extremely weathered, clayey and dry. The distribution of less-weathered, fractured and vesicular water-bearing basalt is variable. The Tertiary basalt aquifers are classed as a secondary porosity aquifer and are expected to represent unconfined to confined aquifers depending on location. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass.

The depth of the basalt, and the generally clayey nature of the weathered upper basalt and the Tertiary sediments associated with the basalt, indicate that the recharge is low. Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall in rock outcrop areas where no substantial clay barriers exist in the shallow subsurface; and

- vertical seepage or though flow from overlying or adjacent alluvial or tertiary sediment aquifers.

Primary discharge mechanisms in the Tertiary basalt aquifers are likely to be:

- down gradient Tertiary basalt outcrop areas;
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams); evapotranspiration; and
- groundwater extraction.

Depth to groundwater in the Tertiary basalt aquifers have historically been measured at between 23 and 34 mbgl (AGE 2004b).

Hydraulic Parameters and Yield

The nature of the Tertiary basalt, and hence its permeability and porosity, is highly variable, depending on the degree of weathering and the intensity and interconnectedness of jointing and/or fracturing. Where the basalt is less weathered and more fractured or vesicular, the unit may have local zones of moderate to high hydraulic conductivity. Hydraulic testing at Moranbah North mine (JBT Consulting 2010) indicated the Tertiary basalt to be moderately permeable with hydraulic conductivity values ranging from one to four metres per day and storage coefficient between 1×10^{-2} and 1×10^{-4}. Onsite, interpreted hydraulic conductivity values of 1.21 and 0.48 metres per day were obtained from the variable head test for monitoring wells 45314 and 45319, respectively during investigations for the groundwater depressurisation assessment of the southern extension of the Airstrip Pit (AGE 2004a) located in the southwest of the EIS study area. The drilling program undertaken as part of this Airstrip Pit groundwater study showed that the Tertiary basalt appears to be highly heterogeneous and discontinuous locally. In the area of the Airstrip Pit, the basalt intersected during drilling was generally not water-bearing; however for the few holes that did intersect measurable groundwater flows, airlift yields were at most 1.25 litres per second (L/s).

6.1.4 Permian-Triassic Strata Aquifers

Distribution

The Permian-Triassic formations constitute the two dominant Permian formations, which are the Blackwater Group and the Back Creek Group as well as the Triassic Rewan Formation as shown in **Figure 6–3** and described in **Table 5-1**.

As with the rest of the Bowen Basin, the coal seams are the main aquifers within the Permian sequences, with the overburden and interburden rocks in most mines being described as essentially impervious to groundwater movement (AGE 2008). Within the EIS study area, the GLS, GMS and GUS coal seams constitute the most extensive aquifers. These seams have been removed in the majority of the western extent of the EIS study area through open cut mining. The Triassic Rewan Formation strata occur only in the very north-east of the EIS study area.

Groundwater Occurrence, Recharge and Flow

The coal seam aquifers are confined above and below by very low permeability geological formations and movement of water through the aquifer (transmissivity) is likely to be through the more permeable (cleats) coal rather than the confining units. The confining units also have very low vertical hydraulic conductivity (leakance), such that very slow, as is the rate at which water flows into the aquifer

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(recharge) is limited. Groundwater occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable (either due to high clay content or significant cementing) and form aquitards. The Permian and Triassic strata may, therefore, be categorised into the following hydrogeological units:

- hydrogeologically 'tight' and hence very low yielding to essentially dry claystone, mudstone, sandstone, siltstone and shale that comprise the majority of the strata;
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence; and
- localised fracture or fault systems which are open and have not been infilled by clay/carbonate deposition.

Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall and overland flow in outcrop and sub-crop areas;
- downward seepage or though flow from overlying or adjacent alluvial or tertiary aquifers where no significant clay barriers exist; and
- leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

Primary discharge mechanisms in the Permian-Triassic strata aquifers are likely to be:

- downgradient Permian-Triassic strata outcrop areas;
- through flow into adjacent (outcropping or sub-cropping coal seams) or seepage into underlying aquifers (via structural discontinuities); and
- groundwater extraction (IMG and other mine dewatering activities).

Groundwater levels in the Permian formations have been measured for hydrogeological investigations assessing potential inflows to pits and underground workings and the establishment of boxcut or pit dewatering bores for mine design and production purposes, as discussed in **Section 3**. There are 41 groundwater level measurements from 32 bores installed in the Permian formations over the period from 1995 to 2009, however many of these bores have been destroyed during mining. Consequently, there are no long term hydrographs of groundwater levels available, and the groundwater level information is not evenly spatially distributed.

Evidence from piezometeric observations for the coal seam aquifers during these previous investigations suggests the groundwater levels were slightly different for each seam, with the GUS seam being one to two metres higher than the GMS seam, and the GLS seam being up to 14 metres lower than the GMS seam at the same location. This variation in hydraulic heads between coal seams indicates the aquitard nature of the interburden and the limited potential for induced flow. The phreatic surface varied from 15 to 50 mbgl. Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers appears to have been from the north and west to the south and east across the site. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the west of the site and discharge occurring downgradient in the Isaac River subcatchment in the Bowen Basin. The current groundwater flow pattern has been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation. Groundwater modelling (AGE 2002) and groundwater level measurements indicate that groundwater levels are affected by mining induced drawdown up to 2.7 kilometres from the mine workings.

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The occurrence of groundwater in the interburden is limited. Aquifers in the interburden are discontinuous with heterogeneous hydraulic properties creating isolated, lens-like aquifers. Due to the heterogeneity and discontinuity of the interburden aquifers within the Permian strata, the groundwater flow direction cannot be determined on a regional scale for these aquifers.

No data exist on the seasonal fluctuations of groundwater level within the Permian-Triassic aquifers. However, due to the depth and confined nature of these aquifers, they are expected to show a subdued response to recharge or discharge.

Hydraulic Parameters and Yield

Interpreted hydraulic conductivity values determined for the Moranbah Coal Measures in the EIS study area are presented in **Table 6-1**. The aquifer testing results indicate that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability. WDS (2011) conducted an engineering study for coal seam degassing required prior to mining of the RHM, using data derived from packer testing in 31 seam/site combinations in the Moranbah and Fort Cooper Coal Measures. This study found that:

- with increasing depth, effective stress increases and permeability decreases;
- with increasing ash (mineral matter), rock stress and effective stress increases and permeability decreases; and
- with increasing gas content to the east, primary permeability decreases.

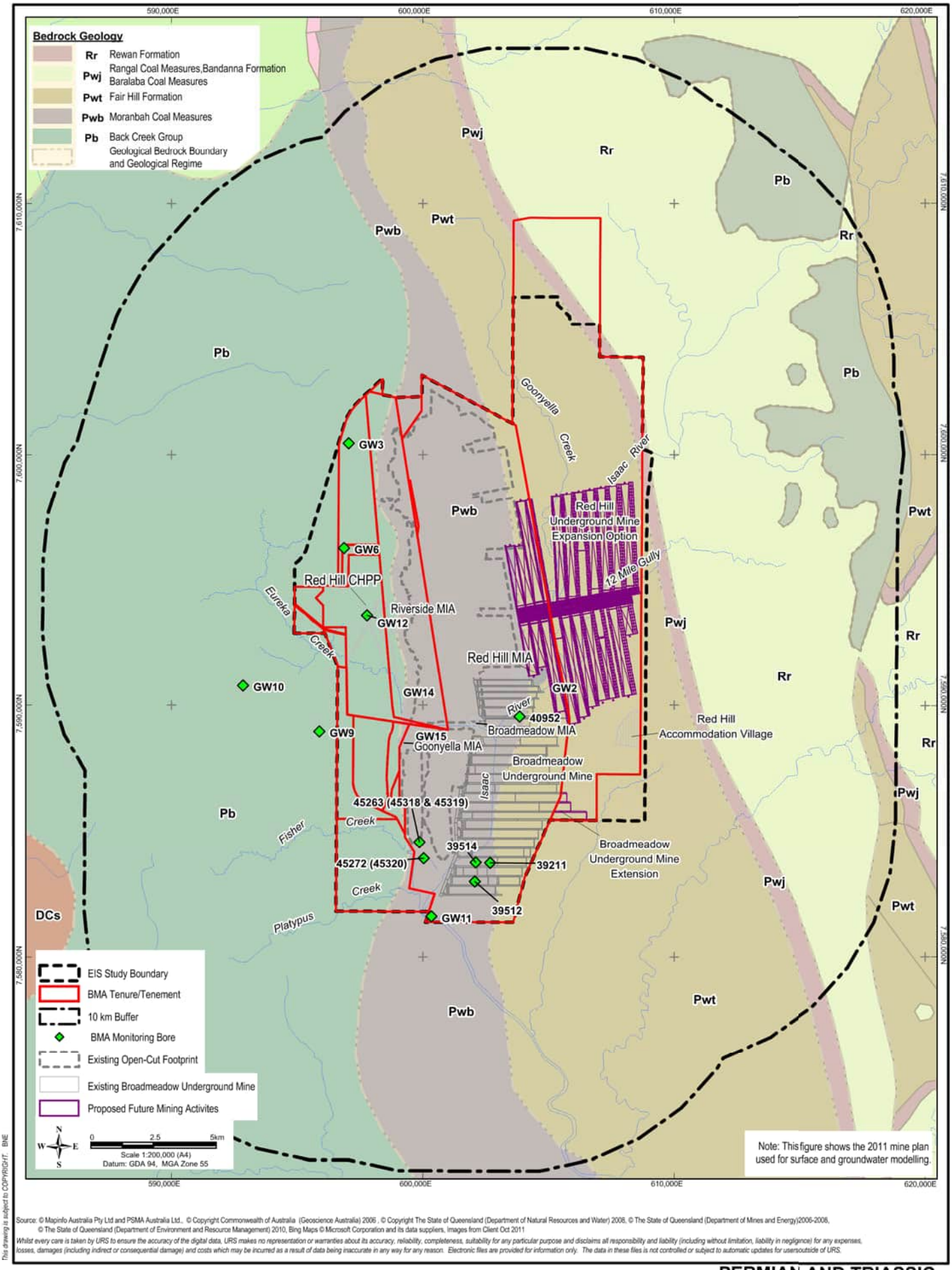
A relationship was determined for permeability variation with depth, ash, and gas content as part of this study. This relationship is:

- Permeability (mD[1]) = -0.00548 x Depth (metres) - 0.2549 x Gas Content at 15 per cent ash + 4.045688.
- It applies to the GUS, GMS and GLS seams for depths of 132 to 593 metres, Gas Content at 15 per cent ash of 0.2 to 13.7 cubic metres per tonne (m^3/t).

Interpreted hydraulic conductivity values determined for the Back Creek Group during investigations as part of the EIS were between 0.002 and 0.1 metres per day.

Hydraulic testing of the interburden units (AGE 2004b) and of drill core undertaken for this EIS revealed highly variable hydraulic conductivity from moderately pervious to highly impervious. This is evidence that the Permian formations are heterogeneous, having discrete zones of higher permeability over short distances and the very low hydraulic conductivity in the majority of the interburden and overburden isolate more conductive parts associated with the fracture/fault systems.

[1] milliDarcys an empirical unit of permeability



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GROUNDWATER IMPACT ASSESSMENT

PERMIAN AND TRIASSIC FORMATIONS WITHIN AND SURROUNDING THE EIS STUDY AREA

URS | GROUNDWATER | Figure: 6-3

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Table 6-1 Interpreted Hydraulic Conductivity of Permian Strata Aquifers

Area of Investigation	Permian Strata Investigated	Method of Determination	Hydraulic Conductivity (m/day)
Goonyella No2 (Rust PPK 1996)	GMS	Pumping test	0.003 to 0.034
	GMS	Packer test	0.009 to 0.085
Airstrip Boxcut (IESA 2001a)	GLS	Falling head slug test	0.06 to 0.47
Goonyella Longwall Development (AGE 2002)	GMS	Calibration of groundwater numerical model	0.0009 to 0.1
Airstrip South Boxcut (AGE 2004a)	GLS	Falling head slug test	0.06 to 0.80
		Calibration of groundwater numerical model	0.82
Ramp 8 (AGE 2004b)	GLS	Shut in pressure test	0.10
		Falling head slug test	0.01 to 0.03
	Interburden	Falling head slug test	2E-05 to 0.33
EIS study area	Interburden	Constant head core test	Horizontal 2E-06 to 3E-05 Vertical 9E-07 to 9E-05

A review of the BMA exploration bore database was undertaken to assess airlift yields recorded during drilling. An airlift yield is the rate at which groundwater is removed from a bore during drilling with an air flushed drilling method, and is an estimate of the potential yield of a bore. Of the 659 exploration bores in the RHM area identified with recorded yield data, 440 bores (67 per cent) were identified as no recordable yield (i.e. dry), and 174 (26 per cent) had airlift yields of less than 0.5 L/s. Airlift yields recorded during drilling of the exploration bores are summarised in **Chart 6-1**. Many of the exploration bores that did not have recorded airlift yields in the exploration database may have been dry, thus the above histogram may overestimate the yield from the Permian strata. The length of time for which the airlifting was conducted was not available, therefore the sustainability of these yields is not known. The airlift yields generally decrease with airlift depth as shown in **Chart 6-2** confirming permeability decreases with depth as a response to fractures being less open at depth.

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Chart 6-1 Histogram of Airlift Yields of Exploration Bores

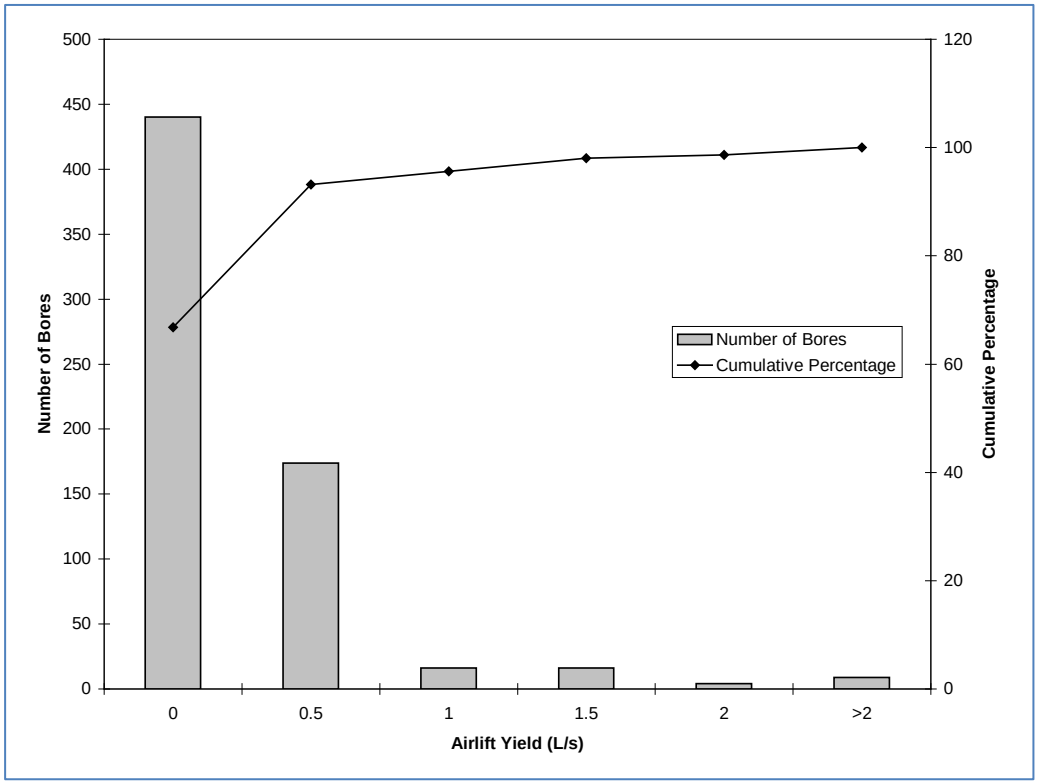
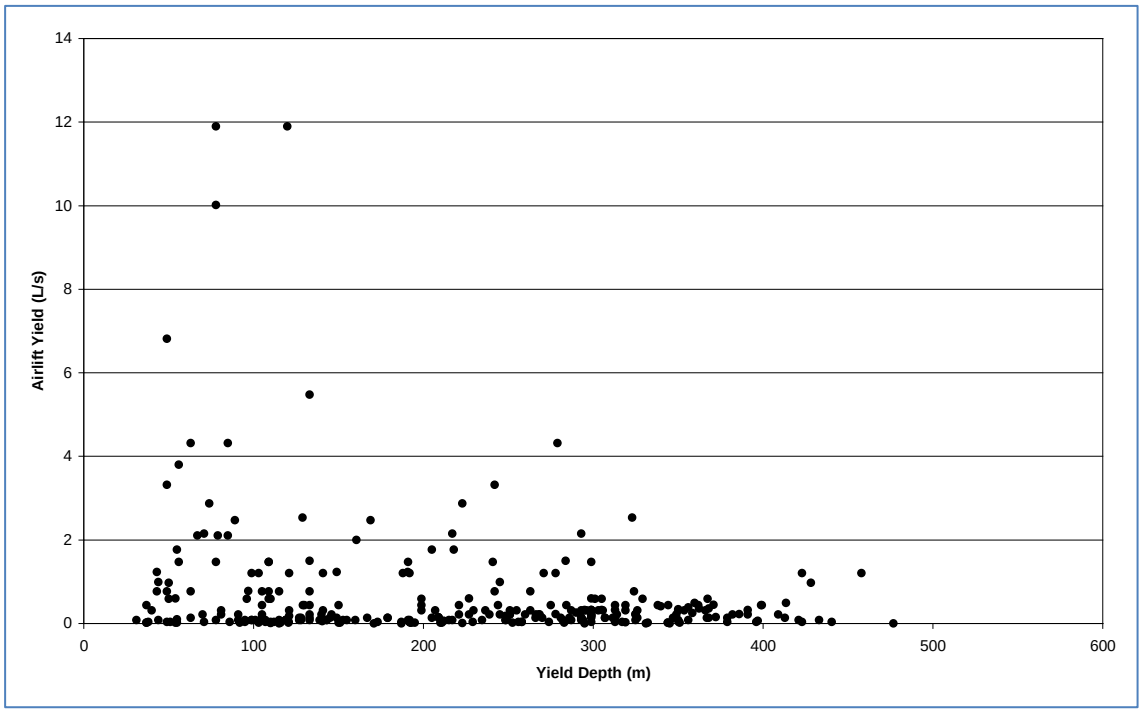


Chart 6-2 Airlift Yield and Airlift Depth for Exploration Bores



6.2 Groundwater Quality

Groundwater samples were collected for chemical analysis from piezometers installed around the site during previous site investigations and for this EIS study.

The physico-chemical results obtained during groundwater sampling within the EIS study area for the period 2001 to 2010, which have been summarised and presented in **Table 6–2**, indicate the groundwater chemistry is typically neutral to weakly alkaline (pH) for all formations. The Tertiary and Permian formations have variable salinity (measured as electrical conductivity), ranging from brackish to saline, while the groundwater quality within the alluvium is fresh.

It should be noted that the depth of the aquifer and its distance from the area of recharge are likely to influence the result at a given sample point, as salinity is highly variable, and appears to increase with depth and the distance from the area of recharge. Based on ANZECC/ARMCANZ (2000) guideline values, the groundwater may be suitable for livestock drinking water and irrigation of salt tolerant crops. However, the low yield typical of the aquifers would preclude use for large-scale irrigation.

Median groundwater salinity values were greater than the 50th percentile WQO nominated in the (Water) for groundwaters in the Isaac River Sub-basin (zone 34, which covers part of the survey area). The limited dataset does, however, indicate that groundwater results cover a wide range for each unit (due to depth, distance from recharge, and age of water). The lower end of the range results are within the WQO.

Results of the analyses of groundwater samples between 1998 and 2011 from monitoring bores installed on site are shown in **Table 6-3**. The Permian Moranbah Coal Measures and Back Creek Group has moderate to high salinity principally due to elevated levels of sodium and chloride ions. The Back Creek Group groundwater contains a relatively higher proportion of sulphate due to marine influence during deposition compared to the Moranbah Coal Measures. The groundwater from the Quaternary alluvium is dominated by sodium and bicarbonate ions, and has a lower salinity than the groundwater of the Permian formations.

Major ion concentrations for alluvial groundwater are less than the EPP (Water) 50th percentile water quality objectives for shallow (<30 metre depth) groundwater, while the maximum concentration of zinc recorded is above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

The median concentration of sodium for groundwater from the Moranbah Coal Measures is just less than the EPP (Water) 50th percentile water quality objective for deep (>30 metre depth) groundwater, while the median concentrations of chloride and bicarbonate are above the respective water quality objectives. The median concentration of manganese is also above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (chromium, copper and zinc) are also above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

The median concentration of all major ions for groundwater from the Back Creek Group are greater than the EPP (Water) 50th percentile water quality objective for deep (>30 metre depth) groundwater. The median concentration of manganese and iron are also above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (boron, cadmium, chromium, copper, nickel, selenium and zinc) are above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

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Table 6-2 Physico-Chemical Results for Aquifers in the EIS Study Area (2110-2010)

Aquifer	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Quaternary Alluvium	2	521-561		6.88-7.55	
Tertiary Basalt	3	2,670-15,384	13,100	8.19-8.67	8.38
Tertiary Sediment	1	5,060		9.30	
Permian Interburden	6	7,030-18,800	12,805	7.38-8.38	8.06
GMS	5	2,450-16,127	9,110	6.65-7.90	7.12
GLS	30	387-31,300	24,050	2.71-8.76	7.99
Back Creek Group	3	4,530-24,030	22,660	5.98-6.79	6.74
Undifferentiated from airlift sampling during exploration drilling	75	100-30,000	12,593	6.89-9.18	7.68
ANZECC/ARMCANZ (2000) upperlLimits[1] - irrigation - livestock – cattle		2,900-5,200 8,300-16,700[2]			
EPP (Water)[3] – 50th percentile - shallow groundwater (<30 m) - deep groundwater (>30 m)		2,150 6,100		7.75 7.80	

1 – ANZECC/ARMCANZ (2000) Water Quality Guidelines for livestock drinking water (cattle) and irrigation of salt tolerant crops

2 – Electrical Conductivity value based on TDS value for livestock (EC [µS/cm] = 1.67 × TDS [mg/L])

3 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34.

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Table 6-3 Summary of Water Chemistry for Representative Bores On-Site between 1998 and 2011

Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP(Water) – 50th Percentile, Deep (>30 m depth)[1]	ANZECC/ ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems [2]	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water[3]	NHMRC (2011) - Human Drinking Water[4]	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)
Major Ions																	
Sodium	747	1,100	ne	ne	30[6]	13	40	1096	3560	3	824	3470	4400	2	40	-	94
Calcium	84	145	ne	1,000	ne	13	<0.01	49	469	3	34	214	422	2	13	-	39
Magnesium	108	115	ne	ne	ne	13	<0.01	25	570	3	86	542	805	2	7	-	20
Potassium	ne	ne	ne	ne	ne	13	1.4	6	28	3	29	35	38	2	3	-	3
Chloride	1,309	1,900	ne	ne	ne	13	64	2024	7510	3	1390	7000	9750	2	10	-	71
Bicarbonate	536	330	ne	ne	ne	13	85	497	5656	3	10	417	774	2	180	-	293
Sulphate	140	138	ne	1,000	200[6]	13	0.2	4	626	3	223	692	763	2	6	-	26
Fluoride	0.28	0.155	ne	2	1.5	11	<0.1	0.2	1.2					2	0.2	-	0.4
Nutrients																	
Nitrite + Nitrate as N	0.95	2.15	0.015	ne	ne	13	0.02	0.2	0.9	3	0.05	0.09	0.33	2	0.125	-	0.315
Total Phosphorus as P	ne	ne	0.03	ne	ne	13	0.03	0.5	5.08	3	0.78	1.49	1.56	2	0.47	-	0.75
Metals (Dissolved)																	
Aluminium	ne	ne	0.055	5	ne	13	<0.01	<0.01	0.1	3	0.04	0.05	0.05	2	0.05	-	<0.1
Antimony	ne	ne	ne	ne	0.003	2	0.004	-	0.007	3	<0.001	0.004	0.004	-	-	-	-

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Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP(Water) – 50th Percentile, Deep (>30 m depth)[1]	ANZECC/ ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems [2]	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water[3]	NHMRC (2011) - Human Drinking Water[4]	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)
Arsenic	ne	ne	0.013	0.5	0.01	7	<0.001	0.002	0.024	3	0.001	0.008	0.013	2	<0.001	-	<0.01
Barium	ne	ne	ne	ne	2	2	0.168	-	0.313	3	0.046	0.095	0.107	-	-	-	-
Beryllium	ne	ne	ne	ne	0.06	2	<0.001	-	<0.001	3	<0.001	<0.001	0.001	-	-	-	-
Boron	ne	ne	0.37	5	4	7	<0.1	0.26	0.6	3	1.51	1.82	3.32	2	<0.1	-	0.1
Cadmium	ne	ne	0.0002	0.01	0.002	7	<0.0001	0.0002	0.005	3	0.0002	0.0005	0.0006	2	0.0002	-	<0.005
Chromium	ne	ne	0.001	1	0.05	7	<0.001	0.002	0.01	3	0.002	0.003	0.004	2	0.002	-	<0.01
Cobalt	ne	ne	ne	1	ne	7	<0.001	0.003	0.01	3	0.018	0.02	0.08	2	<0.001	-	<0.01
Copper	0.01	0.03	0.0014	1	2	7	<0.001	0.002	0.01	3	0.001	0.002	0.004	2	<0.001	-	<0.01
Gallium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Iron	0.03	0.05	ne	ne	ne	13	<0.01	<0.05	1.2	3	<0.05	0.12	1.94	2	<0.05	-	<0.05
Lead	ne	ne	0.0034	0.1	0.01	7	<0.001	0.001	0.01	3	<0.001	<0.001	<0.001	2	<0.001	-	<0.01
Lithium	ne	ne	ne	ne	ne	2	0.041	-	0.136	3	0.206	0.276	0.41	-	-	-	-
Manganese	0.01	0.05	1.9	ne	0.5	13	0.002	0.18	1.23	3	0.958	0.991	1.07	2	0.037	-	0.16
Mercury	ne	ne	0.00006	0.002	0.001	2	<0.0001	-	<0.0001	3	<0.0001	<0.0001	<0.0001	-	-	-	-
Molybdenum	ne	ne	ne	0.15	0.05	7	<0.001	0.01	0.021	3	<0.001	0.002	0.003	2	<0.00	-	<0.01

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Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP(Water) – 50th Percentile, Deep (>30 m depth)[1]	ANZECC/ ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems [2]	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water[3]	NHMRC (2011) - Human Drinking Water[4]	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Med (mg/L)	Max (mg/L)
															1		
Nickel	ne	ne	0.011	1	0.02	2	0.002	-	0.033	3	0.009	0.028	0.131	-	-	-	-
Selenium	ne	ne	0.005	0.02	0.01	7	<0.01	<0.01	0.05	3	<0.01	0.01	0.03	2	<0.01	-	<0.01
Strontium	ne	ne	ne	ne	ne	2	1.75	-	3.86	3	0.675	8.52	10.7	-	-	-	-
Thorium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Titanium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Uranium	ne	ne	ne	0.2	0.017	2	0.002	-	0.005	3	<0.001	0.002	0.003	-	-	-	-
Vanadium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Zinc	0.015	0.025	0.008	20	ne	7	<0.01	0.013	0.13	3	0.05	0.054	0.174	2	0.008	-	0.02

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater

2 – ANZECC/ARMCANZ (2000) and QWQG (2006) trigger values for moderately disturbed upland stream freshwater ecosystems

3 – ANZECC/ARMCANZ (2000) guidelines for livestock watering of beef cattle

4 – NHMRC (2011) health based guidelines for drinking water

5 – Number of samples

6 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for drinking water

ne – No guideline value established

6.3 Groundwater Use

The survey area is located within the declared Isaac Connors Groundwater Management Area, as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resources (Fitzroy Basin) Plan 2011. Within the declared management area, water licenses and/or development permits are not required for stock or domestic bores, and NRM also generally excludes groundwater monitoring bores from the requirement for development permits. In Queensland, all wells deeper than six metres, including monitoring wells, must be constructed by, or under the supervision of, a licensed water bore driller who has the correct endorsements on their licence for the type of activity being performed. It is a requirement of the Water Act that a licensed water bore driller submit the records of the drilling and installation of a water well to NRM within 30 days of completion of the well. These records are entered in the NRM database.

From a search of the NRM groundwater database, 31 bores are registered within 10 kilometres of the EIS study area boundary, as shown on **Figure 6-4**. Of the 31 bores, 27 have been installed for private use, and four have been installed by NRM for groundwater monitoring and assessment (three of which have been abandoned and destroyed). Of the 27 bores installed for private use, 16 were installed for coal seam gas (CSG) exploration in the Moranbah or Fort Cooper Coal Measures, with four of the seven other private bores in these formations being abandoned and destroyed. No stratigraphic or casing description information has been included in the NRM database for the three remaining non-CSG bores and accordingly it is not certain from which aquifer these bores extract groundwater. No information exists in the database on the normal pumping rates of these bores, or the drawdown that occurs during pumping. The current use of the bores is not specified in the NRM database, however typical groundwater use in the area is expected to be for stock watering owing to the variable salinity levels and generally low yields. No dewatering for CSG extraction is currently undertaken within the EIS study area, however CSG exploration has been undertaken in the area and producing CSG wells are located to the south east of the project.

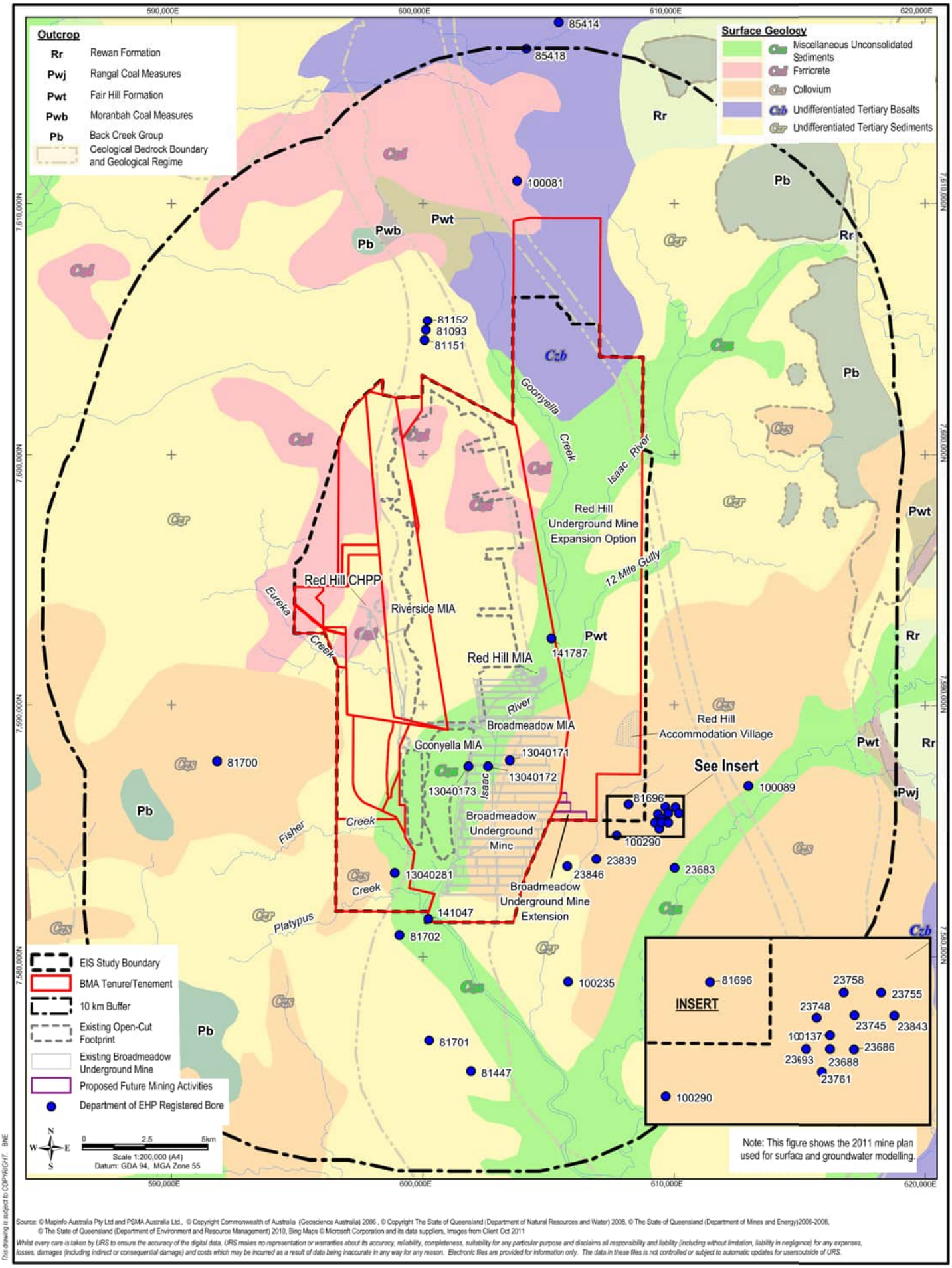
A groundwater bore census was conducted within and on properties surrounding the EIS study area boundary to collect information on groundwater bores installed before registration was a requirement, and additional information on bores registered in the NRM database. Four bores were recorded during the census, two on ‘Denham Park’ and two on ‘Broadmeadow’. The location of these bores is shown on **Figure 6–4** and summary of bore details are provided in **Table 6-4**. The bores on ‘Denham Park’ intersect the basalt aquifers to the northwest of the EIS study area, however, the basalt does not extend into the project’s infrastructure or mine areas and so these bores are unlikely to be impacted by it. The bores on ‘Broadmeadow’ are considered to be constructed into the base of Tertiary (basal sand/sandstone) or the top of the Permian formations. These bores are generally used for stock watering, with one (Tex’s bore on Denham Park) also used for house hold supply during drought.

6 Hydrogeological Regime

Table 6-4 Summary of Information Collected During Bore Census

Property	Bore Name	Drilled Depth (mbgl)	Depth to Water (mbgl)	Water Use	Pumping Rate (L/s)	Landholder Description of Water Quality
Denham Park	Tex's Bore	118.9	34.13	Domestic and stock watering in drought	4.5	
Denham Park	Old Mill Bore	117.1	90.66	Stock watering	1.9	
Broadmeadow	Skeleton Bore (NRM Registration 81696)	63.7	28.41	Stock watering when required	1.3	'Good'
Broadmeadow	Cleanskin Gully	25.34	14.02	Stock watering when required	2.6	'Good'

There have been groundwater dewatering bores on site at GRB in the past for the establishment of GRM boxcuts, however these were not replaced when they were mined out because groundwater inflow to the open cut pits is limited once mining is established. Due to the large surface area of the open cut pits and the significant excess of evaporation over rainfall in the area, groundwater which seeps from the coal seams in the open pits mostly evaporates, with limited amounts collected in sumps and pumped to the mine water system for reuse. Groundwater is not actively dewatered in advance of mining in the BRM, with seepage collected in sumps and pumped to the surface into the existing mine water system for reuse. Total groundwater contribution rates to the mine water system are not monitored as these are at low levels.



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LOCATION OF NRM REGISTERED BORES AND BORE CENSUS

URS | GROUNDWATER | Figure: 6-4

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6.4 Assessment of Groundwater Environmental Values

The location of the proposed project is within the Isaac River sub-basin of the Fitzroy Basin as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries (irrigation, farm supply, stock water); and
- cultural and spiritual values.

The existing groundwater environment, within the groundwater survey area, has been assessed against these environmental values.

Biological Integrity of a Pristine or Modified Aquatic Ecosystem

The local area within and around the RHM footprint has been cleared for agriculture, predominantly beef cattle grazing, as well as for coal mining purposes. These farming and mining practices modify the landscape, affecting the volume and rate of rainfall runoff, the flow characteristics of the creeks, and the recharge to groundwater. As such, the aquatic ecosystems of the area have been modified.

Groundwater dependant ecosystems (GDE) are ecosystems which have their species composition and natural ecological processes determined in part by groundwater. The groundwater parameters that sustain GDEs are flow rate, level, and quality, with dependence potentially being a function of one or all of these factors.

The water level measurements undertaken as part of the EIS indicate that the water table within all aquifers on site is generally greater than 10 mbgl, although the depth to water within the bed sands (ephemeral aquifer) in watercourses is less than this when saturated. These depths to groundwater, and the lack of permanent springs in the area, indicate that GDEs are not likely to exist in the vicinity of the site. This was confirmed in the Red Hill Mining Lease EIS Section 9. The vegetation species and regional soil/geology types suggest that the level of groundwater dependence is likely to be relatively low (riparian vegetation communities are considered as opportunistically groundwater dependent) and vegetation is likely to be able to satisfy plant water requirements using retained soil moisture. Water available to ecosystems may include a mix of groundwater with soil water (unsaturated zone) and surface water. Sampling for stygofauna was undertaken as part of the ecology study for the project (refer to Appendix K3 of the Red Hill Mining Lease EIS). No stygofauna were found in any of the accessible groundwater bores on site.

In addition the depth of groundwater limits any potential use by listed or threatened species and migratory birds. Any potential changes in groundwater levels as a result of mine dewatering are therefore not considered to impact on listed or threatened species and migratory birds.

Although groundwater investigations indicate very low potential for groundwater resources to be physically available to support GDEs, the groundwater analytical results, as presented in **Table 6-3**, have been assessed against the EPP (Water) (for Zone 34, which includes the Moranbah area), ANZECC/ARMCANZ (2000), and Queensland (DERM 2009) water quality guidelines (for the protection of moderately disturbed freshwater ecosystems, central region, upland streams). This allows consideration of whether the groundwater resources in the area are of a sufficient quality to provide environmental value to possible GDEs via flow into surface water bodies.

6 Hydrogeological Regime

The assessment of groundwater quality using these surface water guideline values has an inherent level of conservatism due to the assumptions made regarding the behaviour, fate and transport of the analytes detected in groundwater and the subsequent effects in the surface water ecosystem. The existing groundwater quality concentrations are above the water quality guidelines for freshwater ecosystems for some dissolved metals and nutrients, and the median concentrations of most of the major ions are above the 50th percentile WQO for the Isaac River sub-basin for the deeper groundwater (Back Creek Group and Moranbah Coal Measures). These existing exceedences indicate that even if the deeper groundwater was physically available to support GDEs, it has low environmental value for sustaining the biological integrity of aquatic ecosystems. Shallow groundwater in the alluvium may, however, sustain aquatic ecosystems as flow to GDEs or surface water bodies although shallow aquifers are ephemeral, only existing for short periods after recharge.

Suitability for recreational use (primary recreation)

This category of environmental value is considered not applicable to groundwater *in-situ*. There are also no registered groundwater springs in the area that could be considered for recreational use. Groundwater seepage from the alluvium into water courses can provided short duration baseflow into rivers and creeks immediately after heavy rains or flooding, however, after larger flood events suitability of these waters for recreation may be limited by other factors.

Suitability for Minimal Treatment before Supply as Drinking Water (raw water)

The groundwater analytical results, as presented in **Table 6-3**, have been assessed against the Australian drinking water guidelines (NHMRC 2011) to consider the potential health effects of drinking minimally treated groundwater. The EPP (Water) also give a drinking water guideline of 30 milligrams per litre (mg/L) for sodium and 200 mg/L for sulphate. The groundwater quality from the monitoring wells indicates that, in general, the groundwater is unsuitable for human consumption. This is due to elevated concentrations of sodium, sulphate and several dissolved metals (antimony, arsenic, manganese, nickel and selenium) in some of the groundwater samples collected from the Permian formations. Generally the groundwater samples contain elevated levels of salinity (>1,000 mg/L), which are above the guideline for aesthetics based on the groundwater having an unsatisfactory taste.

Groundwater resources within the survey area would require significant treatment before it could be utilised for drinking. The only local groundwater that may be suitable for human consumption is that which comes from the alluvium associated with the Isaac River. However, concentrations of sodium have been recorded at levels above the EPP (Water) limit of 30 mg/L. It is noted that the concentrations of sodium are less than the Australian drinking water guidelines (NHMRC 2011) limit of 180 mg/L.

The availability of reticulated mains water, rain water tank supplies, and the generally low yield and poor quality of the groundwater bores in the area, are also factors that preclude the usage and potential for usage of the groundwater as a drinking water source.

Suitability for Primary Industry Use

Groundwater quality results presented in **Table 6–2** and **Table 6-3** suggest that groundwater within the study area is generally suitable for stock watering for beef cattle. The higher salinities of the Back Creek Group and Blackwater Group aquifers would potentially result in loss of production and decline

in animal condition and health as salinity concentrations are > 5,000 mg/L. The groundwater in some of the Permian formations has levels of selenium that are slightly elevated above the guideline values.

Although groundwater quality is generally acceptable for stock watering, the generally low sustainable yield of the water bores in all aquifers in the area and the salinity of groundwater in the Back Creek Group and Blackwater Group precludes the usage and potential for usage of the groundwater as a source of irrigation water.

Maintenance of Cultural and Spiritual Values

There are no registered groundwater springs or seeps that supply surface water bodies in the survey area. No springs are known to have significant Aboriginal and/or non-indigenous cultural heritage associations.

Shallow groundwater (in the alluvium), however, may sustain baseflow in the Isaac River for short periods after heavy rains or flooding, although shallow aquifers are ephemeral, only existing for short periods after recharge. The Aboriginal cultural heritage values of that section of the Isaac River within the EIS study area are discussed in the Red Hill Mining Lease EIS Section 16.

7

Numerical Modelling

To assess the potential impacts of the proposed project and associated infrastructure on the regional groundwater regime, predictive groundwater modelling was undertaken. The objectives of the predictive modelling were to:

- estimate groundwater extraction (passive seepage and active dewatering for IMG control) over the mine life;
- predict the zone of influence of dewatering and the level and rate of drawdown at specific locations;
- identify areas of potential risk where groundwater impact mitigation/control measures may be necessary; and
- predict the impact of mine dewatering on groundwater discharges and other groundwater users.

7.1 Available data

To assist in constructing and calibrating the necessary numerical integrated model, the following information was considered:

- the EIS study area, comprises the proposed RHM, Broadmeadow extension, and includes GRB mine complex (approved mining operations);
- the Permian strata dips at between two and eight degrees to the east;
- the final underground mine depth will be approximately 500 metres;
- the geology within the area comprises Quaternary alluvial, Tertiary sediments, and Permian-Triassic formations with coal measures;
- mining of the GRB mine complex continues at currently approved rates with completion of BRM in 2030 and GRM in 2068;
- mining sequences for existing mines and RHM provided by BMA (mine plan dated October 2011);
- no major faults or intrusions are located within the RHM footprint;
- bore logs and hydrogeological data from monitoring bores and the BMA exploration database across the site;
- shape files for the topography, alluvium, tertiary, and coal seams; and
- climate data.

7.2 Model Approach

URS utilised the MODHMS (Hydrogeologic Inc., USA) groundwater modelling package to construct the required groundwater model. MODHMS is based on the standard MODFLOW groundwater modelling code. The MODFLOW code was developed by the United States Geological Survey (McDonald and Harbaugh 1984) for three-dimensional, finite-difference, modular, groundwater flow modelling. The MODFLOW code is the most widely used code for groundwater modelling and is currently considered an industry standard. MODHMS incorporates additional computational modules to enhance the simulation capabilities and robustness. MODHMS was selected as it allowed for:

- the modelling of variable saturation conditions, allowing for unsaturated and saturated conditions thus avoiding dry-cell problems;
- coupled flow and mass transport simulations (if required);
- the inclusion of discrete features, such as the backfill area of open cuts; and
- integrated groundwater and surface water modelling (if required).

A pseudo-steady state model was constructed based on the available data and represented current groundwater flow conditions due to the existing GRB mine complex dewatering. The outcome of this

modelling of the existing approved GRB mine complex impacts (drawdown extent) was used as initial conditions for the transient model, which undertook predictive scenarios for RHM. The modelling approach comprised the following:

- Simulations of dewatering cones and extent at the end of mining (both for the currently approved GRB mine complex, and the proposed RHM).
- Groundwater extraction volumes with time to simulate IMG depressurisation and mine dewatering.

7.3 Model Conceptualisation

Every numerical groundwater model has as its foundation a conceptual model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

The conceptual groundwater model of the groundwater survey area was developed based on geological and topographical maps, geological information from coal exploration bores drilled across the GRB mine complex and RHM footprint areas, geological modelling developed by BMA, results from previous hydrogeological investigations in the Bowen Basin, and relevant data from hydrogeological and gas drainage studies conducted by BMA.

The conceptual model area encompasses the upper units of the Back Creek Group, the Blackwater Group, and the overlying units of the Bowen Basin on the Collinsville Shelf and is bounded by:

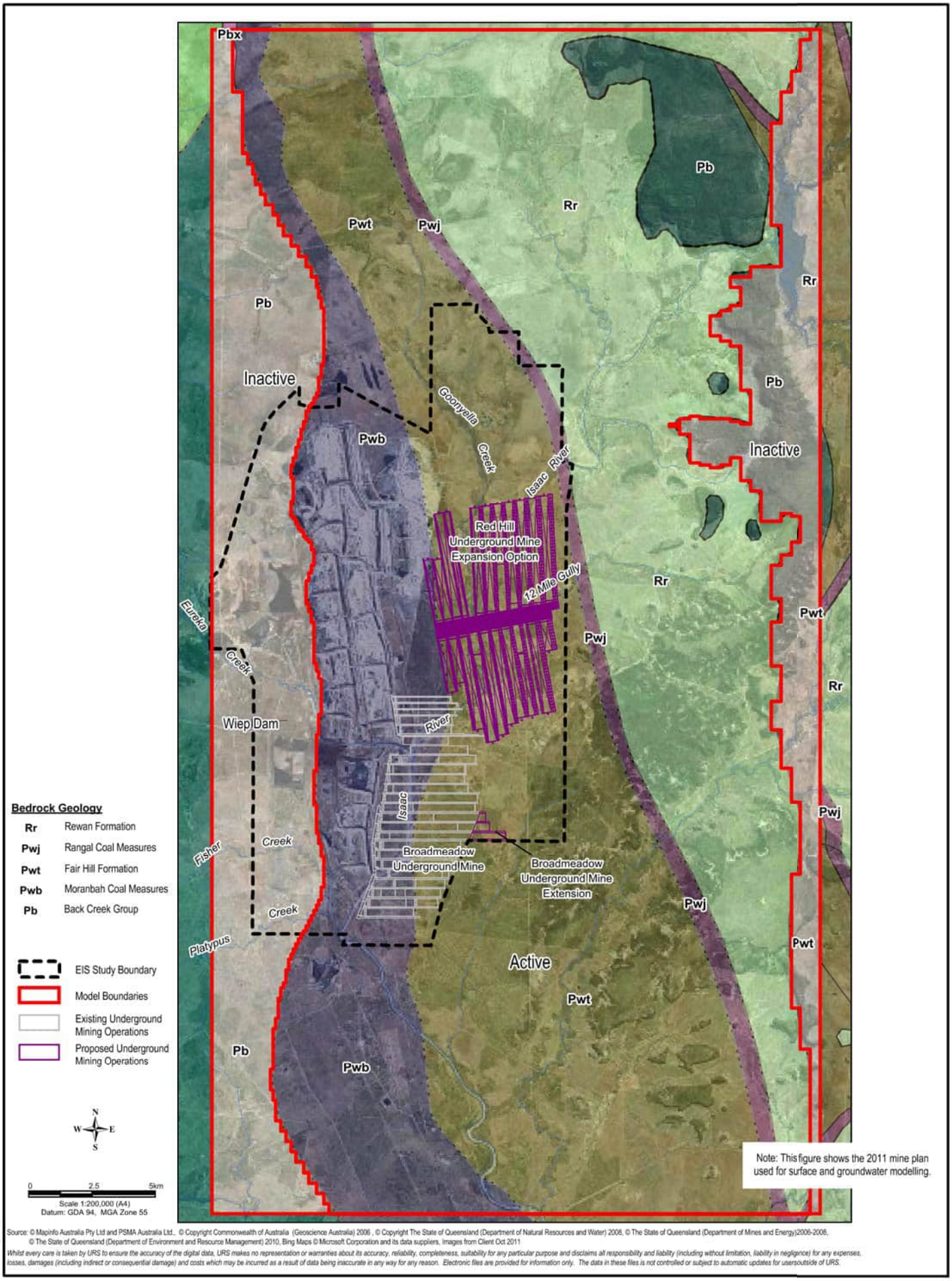
- the outcrop/subcrop of the Back Creek Group to the west of the mine;
- a system of thrust faults approximately 10 kilometres to the east of the proposed RHM that offset the Moranbah Coal Measures; and
- an arbitrary distance of approximately 25 kilometres to the north and south of the RHM that was judged to be beyond the influence of potential mine dewatering (**Figure 7-1**).

7.3.1 Model Extent and Grid

The regional groundwater model was constructed across an area of 24 by 46 kilometres as shown in **Figure 7-1**, with the EIS study area situated towards the western extent of the model based on boundary conditions.

The model was constructed with a refined grid of 100 by 100 metres for the mining area and with grid spacing of 400 by 400 metres outside the EIS study area, as shown in **Figure 7-2**. The finite difference model comprised:

- a model area of 1,104 square kilometres;
- 316 rows and 156 columns; and
- 667,522 active cells for a seventeen-layer model.



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NUMERICAL MODEL EXTENT

URS | GROUNDWATER | Figure: 7-1

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GROUNDWATER IMPACT ASSESSMENT

NUMERICAL MODEL GRID

URS

GROUNDWATER

Figure: **7-2**

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7 Numerical Modelling

7.3.2 Boundary Conditions

Model boundaries were based on available information and data limitations. The boundaries include:

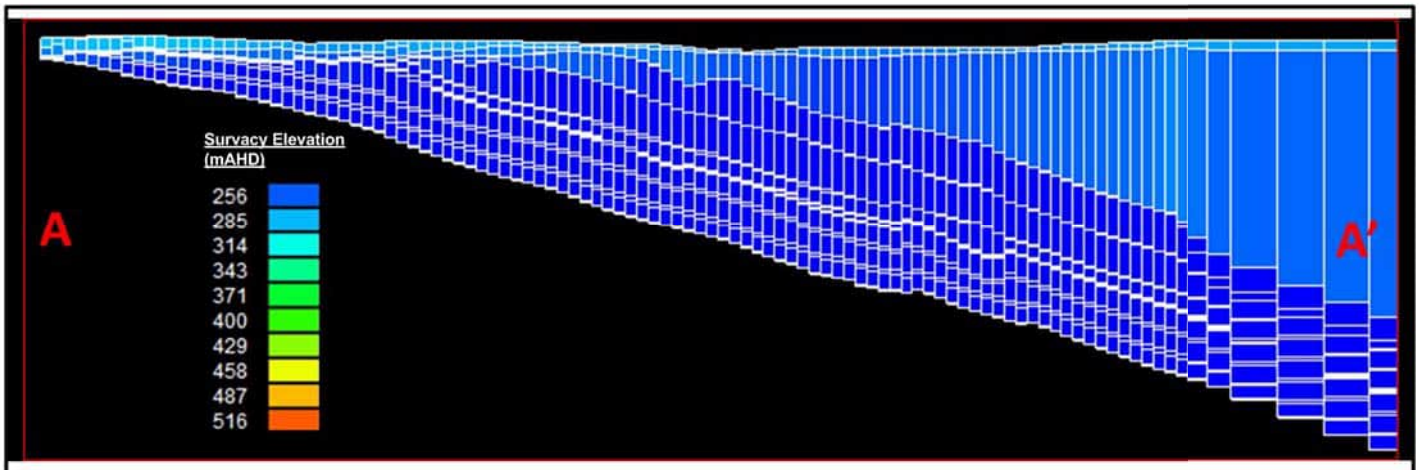
- **Top inflow boundary** comprising recharge and evaporation. Available precipitation and evaporation data was reviewed / verified;
- **Horizontal inflow boundary** based on groundwater level data, which is used to determine the model's east, west, north, and south boundary conditions. Geological log data and groundwater level information was used to set up representative prescribed head boundaries, sufficiently far from the RHM footprint for the southern and northern boundaries. Since few head observations were available near the boundaries, topographic elevations were used as reference elevations relative to groundwater levels. It was assumed that groundwater levels were 35 mbgl for the northern boundary and were 20 mbgl for the southern boundary based on average depth to groundwater from available observations across the survey area. No flow boundaries were ascribed to the western boundary at the outcrop/subcrop of the Back Creek Group, and to the eastern boundary defined as the Burton Fault, which has offset the Blackwater Group; and
- **Bottom inflow boundary** considered below the site. Model bottom elevations were determined from floor and roof elevation data in the geological model supplied by BMA. The no-flow boundary was assumed sufficiently far below the base of any mining (GMS and GLS) elevation based on available geological data.

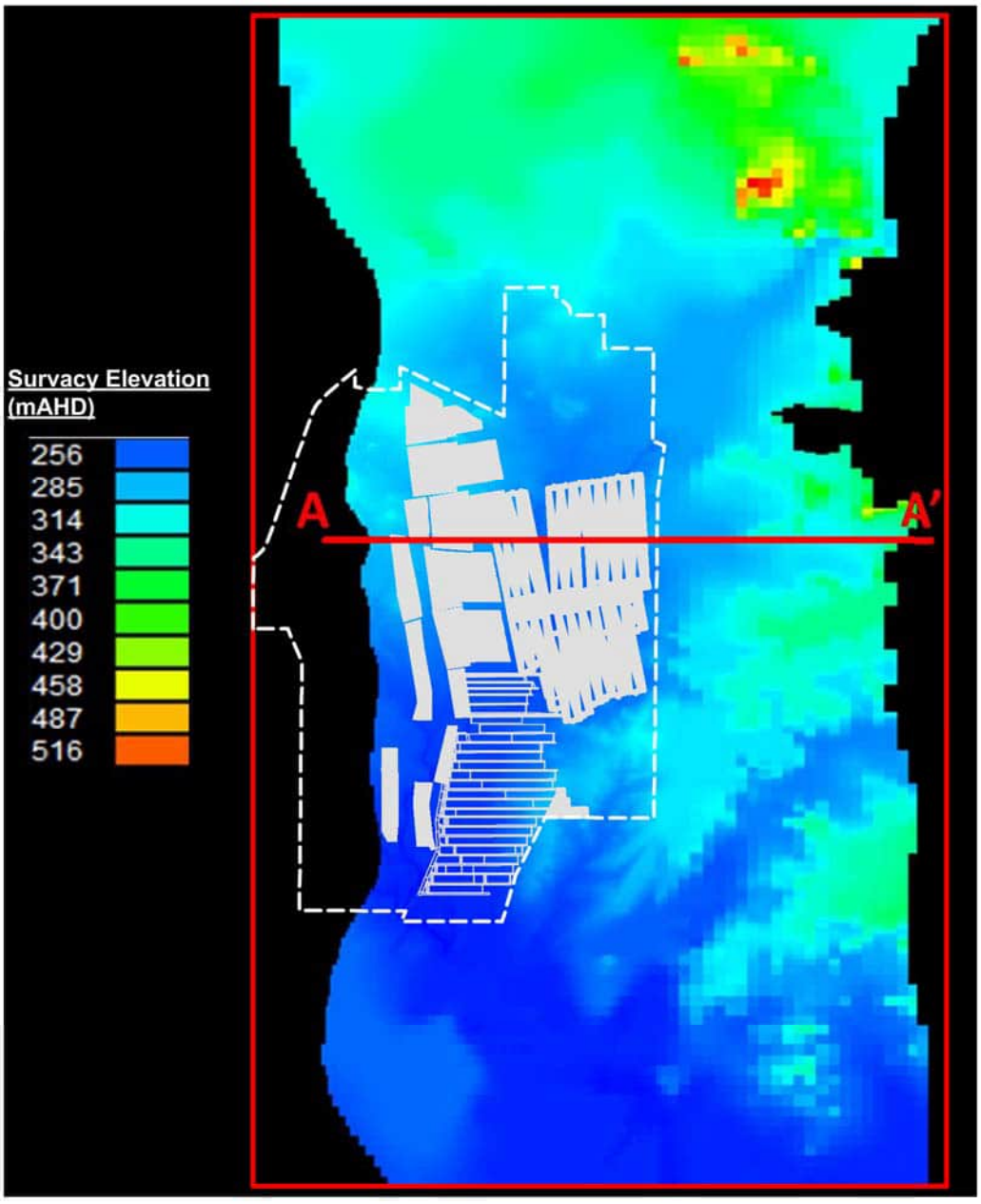
7.3.3 Model Layers

Publicly available digital elevation data (STRM data) with a 90 by 90 metre grid spacing was used to represent the ground surface in the model outside of the refined area (400 metre grid area in **Figure 7-2**), and BMA topographical data was used to represent the ground surface within the refined area (100 metre grid in **Figure 7-2**). The model layer elevations in the refined-grid area were generated based on the BMA geological model; while the layer elevations outside the refined area were extrapolated based on available data (Bowen Basin digital geology, Bowen Basin regional contouring of the top of the Moranbah Coal Measures on 50 metre intervals, and coal seam gas well logs) and assumptions. These data sets were used to create layer elevations throughout the model domain.

Seventeen layers, representing the different lithological units across the survey area, were included in the model (**Table 7-1**). **Figure 7-3** presents a west-east cross-section through the centre of the model, illustrating the model layers (pre-mining).

It is important to note that faults can act as both conduits for groundwater flow, or in the case of coal seams, barriers to flow. The eastern boundary of the model is along the Burton Fault, where the Moranbah Coal Measures are significantly offset, and is considered a no flow boundary. Within the groundwater survey area, the Moranbah Coal Measures have undergone some minor to moderate faulting that may interrupt the continuity of the aquifer and act as boundaries to groundwater flow. In the model domain, the coal seams are simplified to allow continuous groundwater flow and to tie in with the interpolated levels beyond the EIS study area where data is limited. The effect of this simplification was to remove barriers to groundwater flow, which effectively extends the predicted drawdowns and increases groundwater inflows to the workings. The model is therefore considered to be conservative and would likely to be a 'worst case scenario'.





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EIS Study Boundary

Open-Cut and Underground Mining Operations

Note: Ths figure shows the 2011 mine plan used for surface and groundwater modelling.

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SITE TOPOGRAPHY AND CROSS-SECTION THROUGH NUMERICAL MODEL SHOWING MODEL LAYERS

URS | GROUNDWATER | Figure: 7-3

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7 Numerical Modelling

Table 7-1 Numerical Model Layers

Model Layer	Unit
1 (top)	Tertiary, alluvium
2	Fort Cooper Coal Measures –
3	Fort Cooper Coal Measures FC1
4	Fort Cooper Coal Measures – Interburden
5	Fort Cooper Coal Measures FC2
6	Moranbah Coal Measures – Overburden
7	Moranbah Coal Measures - GUS
8	Moranbah Coal Measures – Interburden
9	Moranbah Coal Measures – Goonyella 'P' Seam GP1
10	Moranbah Coal Measures – Interburden
11	Moranbah Coal Measures – Goonyella 'P' Seam GP2
12	Moranbah Coal Measures – Interburden
13	Moranbah Coal Measures – GMS
14	Moranbah Coal Measures – Interburden
15	Moranbah Coal Measures –GLS
16	Moranbah Coal Measures – Underburden
17 (bottom)	Back Creek Group

7.3.4 Rainfall Recharge

Recorded site specific data, from the Moranbah weather station, is available for the period 1972 to 2011. However, for an extended period (120 years) of rainfall data, a statistical analysis of climate data from surrounding weather stations was compiled based on the Data Drill system. The rainfall and evaporation data for the period between 1889 and 2011 indicates an average 546.5 millimetre annual rainfall, and 2,093.8 millimetre annual evaporation rate.

Through a review of available data (AGE 2008; METServe 2010), recharge rates would be less than one per cent of mean annual average rainfall, and evapotranspiration was not considered due to the depth to groundwater observed for the deep aquifers.

7.3.5 Hydraulic Parameters

Probable ranges of hydraulic conductivity (K) and storativity values, as displayed in **Figure 7–2**, were derived from hydraulic test results (as described in **Section 6**) and literature values where onsite data was not available.

7 Numerical Modelling

Table 7-2 Ranges of Hydraulic Conductivity (K) and Storativity Values for Each Numerical Model Layer

	K(horizontal) (m/day)		K(vertical) (m/day)		Storage Coefficient		Specific Yield (/m)	
Layer	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	1.0E-02	1.0E+01	1.0E-03	5.0E-01	1.0E-06	1.0E-04	5.0E-02	2.0E-01
2	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	1.0E-02	1.0E-01
3	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
4	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
5	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
6	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
7	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
8	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
9	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
10	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
11	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
12	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
13	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
14	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
15	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
16	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
17	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01

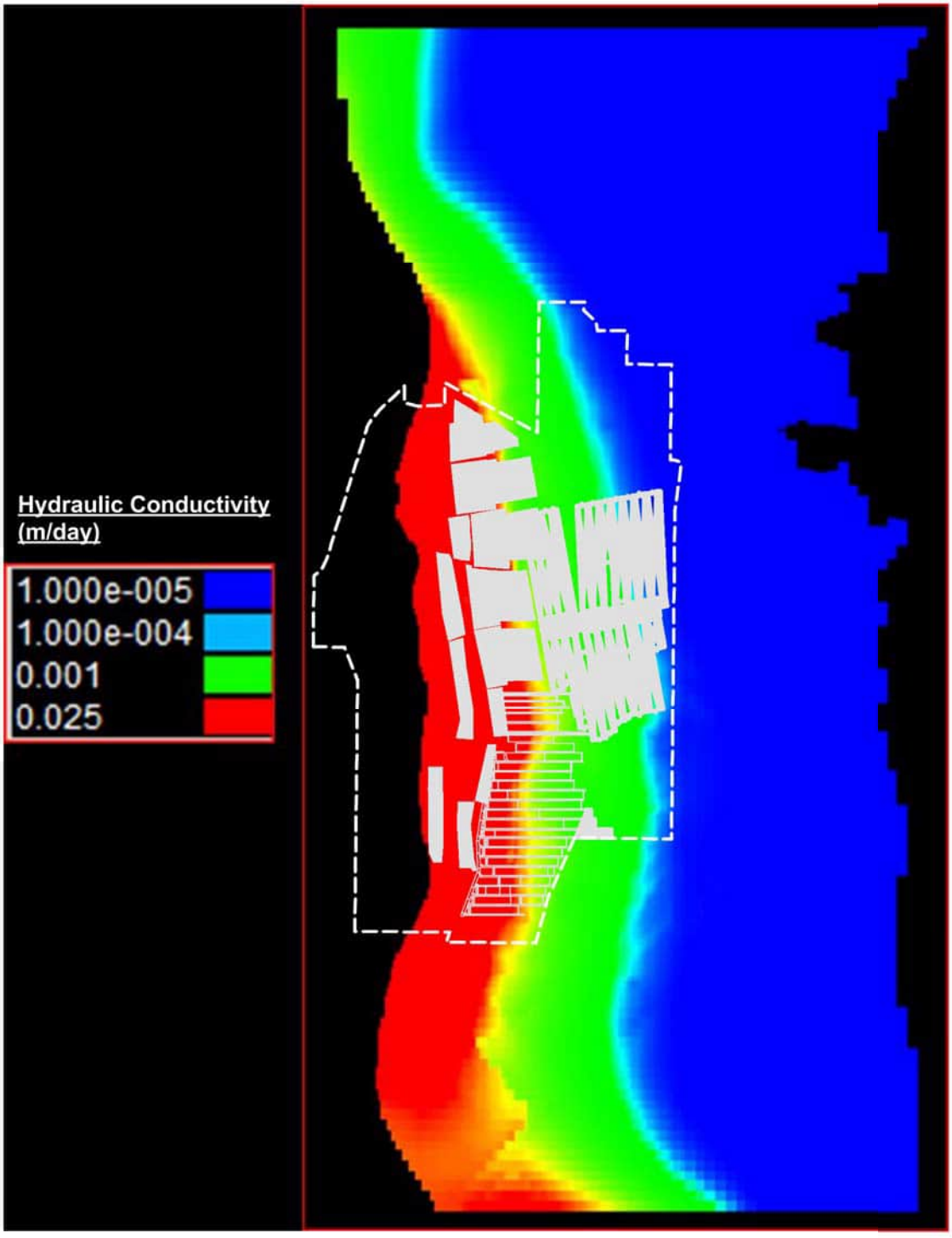
Parameterization

Following the principle of parsimony, model parameterization was kept as simple as possible while accounting for the system processes and characteristics that are evident in observations and important to predictions. For the numerical model, hydraulic conductivity (K) values were assigned as homogeneous values to the layers, except for the layers representing the Moranbah Coal Measure coal seams (layers 7, 9, 11, 13 and 15) to which a K distribution, allowing for the recognised permeability decrease with depth, was ascribed. This K distribution was based on the WDS (2011) study for coal seam gas depressurisation prior to mining. A regression formula from this study was derived as follows:

$$\text{Permeability (m/day)} = 233.52 \times e^{(-0.016 \times \text{depth})}$$

Where depth is below land surface (metres)

Based on the regression formula horizontal K distributions were derived for the coal seam layers, within constraints of the K values not being higher than 0.025 metres per day and not lower than 1×10^{-5} metres per day (derived from filed data and literature values). The horizontal K distribution for the GMS (layer 13 in the numerical model), the target coal seam for mining in the proposed RHM, is shown in **Figure 7–4**. The vertical K distributions within these layers follows the same distributions as the horizontal K distribution but with values one order of magnitude lower (typical modelling assumption where limited data available).



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Scale 1:250,000 (A4)

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

EIS Study Boundary

Open-Cut and Underground Mining Operations

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GROUNDWATER IMPACT ASSESSMENT

HORIZONTAL K DISTRIBUTION FOR GMS (LAYER 13) OF NUMERICAL MODEL

URS | GROUNDWATER | Figure: 7-4

File No: **42627136-g-2103.wor** | Drawn: **VH** | Approved: **CT** | Date: **24-06-2013** | Rev.**A** | A4

7 Numerical Modelling

As well as the K distribution for the five Moranbah Coal Measures coal seam layers, four horizontal and vertical K parameters were assigned to the remaining model layers as listed in **Table 7-3**, with the vertical parameters defined based on the ratio of Kh/Kv and tied to the horizontal parameters during the calibration.

Table 7-3 Relationship of Hydraulic Conductivity between Each Layer in the Numerical Model

Model Layer	Unit	K (horizontal) Parameter	K (vertical) Parameter
1	Tertiary, alluvium	K_1	K_{z1}
2	overburden	K_2	K_{z2}
3	FC1	K_3	K_{z3}
4	interburden	K_4	K_{z4}
5	FC2	K_3	K_{z3}
6	interburden	K_4	K_{z4}
7	GUS	K distribution	K distribution x 0.1
8	interburden	K_4	K_{z4}
9	GP1	K distribution	K distribution x 0.1
10	interburden	K_4	K_{z4}
11	GP2	K distribution	K distribution x 0.1
12	interburden	K_4	K_{z4}
13	GMS	K distribution	K distribution x 0.1
14	interburden	K_4	K_{z4}
15	GLS	K distribution	K distribution x 0.1
16	interburden	K_4	K_{z4}
17	Base	K_4	K_{z4}

7.3.6 Simulation of Mine Dewatering using Drains

In order to assess the potential zone of influence created around RHM due to mine dewatering, the MODHMS drain package was utilised. Using drains involved the setting of a reference (drain target) elevation (base of the target coal seam) and a conductance (leakage) term.

The bottom elevations of the drains were set at the base of the GMS coal seam to be mined. Groundwater levels in the model were compared to the elevation of the bottom of the drain in each model cell and when the groundwater level is above the bottom of the drain water was removed from the model domain at a rate determined by the head difference and the drain hydraulic conductance. The drains were activated according to the proposed mine plan (schedule and progression). Drain conductance was set at a high rate to ensure the groundwater level was lowered to the drain level (to simulate dry workings as required for mine safety).

This approach was adopted for the environmental impact assessment in order to estimate the total volume of groundwater to be removed during an estimated 25 year life of mine (LOM), and assess the resultant drawdown cone at the end of mine life.

7 Numerical Modelling

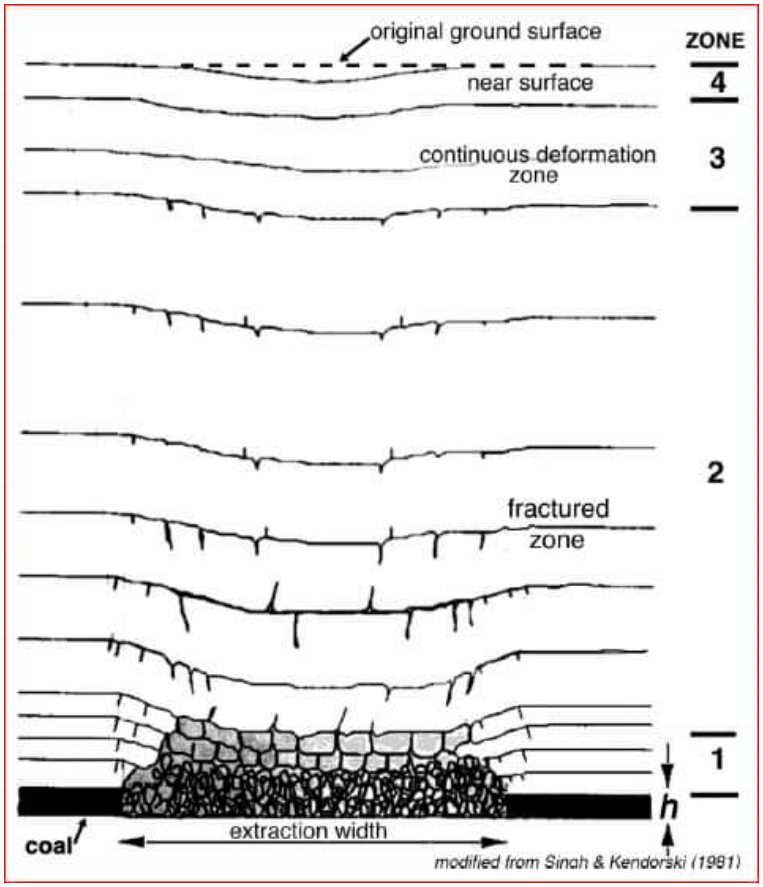
7.3.7 Simulation of Mine Dewatering considering Goaf Alteration

To further estimate mine impacts and estimates of groundwater ingress over the LOM, consideration and simulation of aquifer alteration (due to longwall mining (goaf)) was given.

As longwall mining progresses, goaf develops due to roof collapse in the mining retreat, resulting in a progressively upward collapse of the overburden and where propagation to surface, subsidence. The subsidence profile is divided into four distinct zones (Singh and Kendorski 1981) as shown in **Drawing 7-1**. In zone 1, the depth of strata directly affected by roof caving is 2 to 10 times the thickness of the mined out coal (up to six metres in the RHM area). In zone 2, the fractured zone, partial fracturing of strata occurs from 10 to 24 times the thickness of the mined out coal. In zone 3, the continuous deformation zone, buckling of strata occurs from 24 to 64 times the thickness of the mined out coal. The caved and fractured zones (zone 1 and 2) alter the natural groundwater flow system and can potentially introduce significant vertical leakage through fractures. The highest vertical leakage would occur in the caved zone (zone 1, 2 to 10 times the thickness of mined out coal), therefore it was envisaged that the range of zone 1 would be within the interburden between the GMS and GUS, which is layer 12 in the numerical model.

It was assumed (for groundwater modelling purposes) that goafing fully develops a year after the mine extraction.

Drawing 7-1 Typical Subsidence Profile (from Winters and Capo 2004)



7.3.7.1 Mine Dewatering Scenarios

Two approaches of estimating the additional groundwater inflow due to the development of goaf were adopted and compared.

The first approach was based on using the time-variant properties capabilities of MODHMS (2010) by assuming that vertical and horizontal K values were increased 10 times from the original values for the goaf area within layers 12 and 13, with this increase in K for these model layers remaining over the model run.

The second approach was based on using the drain package in MODFLOW to approximate additional inflows by adding drain cells to the goaf areas within model layers 12 and 13. Note that the drain conductance was determined through several trial runs and was estimated to be within the range of 0.1 to 1 rather than a large value used for freely drained cells.

7.4 Model Calibration

7.4.1 Calibration Data

Model calibration was to groundwater level data collected by BMA over time within the survey area and groundwater level information collected from the Eaglefield Expansion Project EIS (METServe 2010). Most of the observation locations had only one measurement record. Regional groundwater level data in this area were not available from the NRM registered bore database.

As mining commenced with the Goonyella mine in the 1970s and has been ongoing since that time, it is envisaged that significant groundwater level changes in the survey area would already have occurred due to mine dewatering. As mining pits progress and new mining areas were created over time, areas and impacts of dewatering would also vary with time. As time series groundwater level data were not available and historic records of dewatering rates and locations were not readily available, transient calibration of the model was not possible. Instead, a pseudo steady-state condition was calibrated, considering the length of mining in the area (40 years), in order to establish an initial condition for predictive simulations. This was done to assess the potential impacts of the project on groundwater already altered by approved mining.

7.4.2 Calibration Approach

Model calibration is a process of refining the model's depiction of the hydrogeological framework, aquifer hydraulic properties, and boundary conditions until a desired correspondence is achieved between the model simulated and measured field data. The end result of the model calibration process is a potential optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The major calibration target of the model was groundwater level data with constraints of reasonable ranges of hydraulic conductivity and other parameters (e.g. recharge). Transient calibration was not conducted due to limited available data.

The parameter estimation program PEST (Doherty 2008) along with detailed parameter output verification was used to calibrate the parameters of the regional groundwater flow model. PEST implements a nonlinear least-squares regression method to estimate model parameters by minimising the sum of squared weighted residuals of groundwater levels.

7 Numerical Modelling

The calibration process was assessed against the Murray-Darling Basin Commission Groundwater Flow Modelling Guideline (Aquaterra 2000).

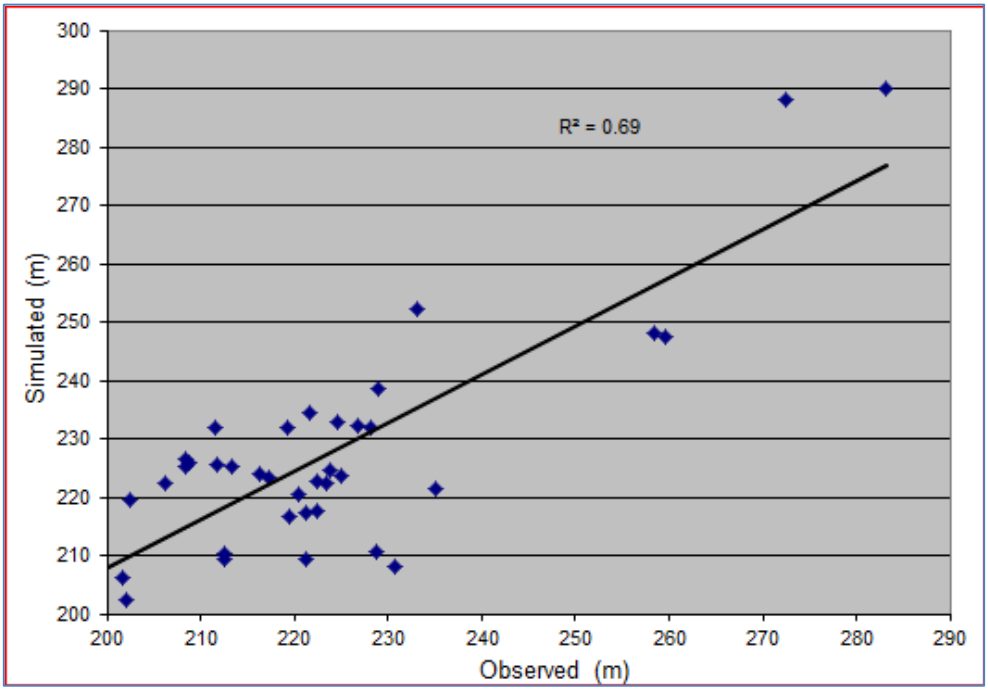
7.4.3 Calibration Assessment

The pseudo steady-state calibration aimed at representing an average state of groundwater levels. A total of 39 groundwater measurements from different monitoring points were used for the calibration process.

Parameter values of hydraulic conductivities, recharge, and drain conductance were estimated through PEST. Hydraulic conductivities were constrained by upper and lower limits and the spatial distribution as discussed in **Section 7.3.5**, while recharge rate was a single value for the model area.

The difference between the modelled and observed (measured) groundwater levels was the preferred indicator of model simulation error. A scatter plot of modelled versus observed groundwater levels is shown in **Chart 7-1** for steady-state calibration.

Chart 7-1 Modelled Versus Observed Head Values for Steady-State Calibration



Root-mean-square error (RMSE) was selected to evaluate the performance of the model calibration based on groundwater levels. Good agreements between modelled results and field measurements usually have RMSE less than 10 per cent of the difference between the observed maximum and minimum potentiometric heads within the model area. The RMSE for the steady-state calibration was 11.6 metres, which is 13.2 per cent of the approximate 87.7 metre range of groundwater levels.

Table 7-4 shows the calibration statistics for the steady-state calibration. These calibration statistics indicate that the model calibration is reasonable based on the parameter constraints (within site specific ranges) and data availability (impacted by mining).

7 Numerical Modelling

The 39 calibration head targets covered the period 1996 to 2009, with many of the measurements undertaken within discrete time intervals (e.g. eight groundwater bore levels were recorded on 12 October 1998). As discussed in **Section 7.4.1**, there are no pre-mining groundwater level data, and available groundwater level data would be largely impacted by mine dewatering. Since the pseudo steady-state model only reflects the existing mining conditions, close 'point-to-point' matching throughout the historic records was not possible, resulting in high residuals. Instead, the pseudo steady-state calibration was inclined to provide a regional flow pattern, which could be used as initial conditions for the predictive simulations.

Table 7-4 Calibration Statistics for Numerical Model Steady-State Calibration

Calibration Statistics	Steady-State Calibration (39 observations)
Mean Error (m)	-4.1
RMSE (m)	11.57
Standard Deviation (m)	10.97
Head Range (m)	87.73
Mean Error %	-4.6%
RMSE %	13.2%
Standard Deviation %	12.5%
R^2	0.69

The groundwater levels determined from the steady state simulation were contoured to provide an indication of groundwater level variations across the model domain. **Figure 7-5** presents the simulated pseudo steady state groundwater head distribution in the GMS. The calibrated parameters, which were then used for the predictive modelling, are presented in **Table 7–5**. Note that the K distribution for the Moranbah Coal Measure coal seams was adopted from the WDS regression formula (WDS 2011) without further calibration, as it is envisaged that these distributions include the best information available.

Table 7-5 Summary of Calibrated Parameters for Numerical Model

Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)
1	Tertiary, alluvium	0.49	0.049
2	overburden	1.00E-03	1.00E-04
3	FC1	1.00E-03	1.00E-04
4	interburden	1.08E-04	1.08E-05
5	FC2	1.00E-03	1.00E-04
6	interburden	1.08E-04	1.08E-05
7	GUS	Distribution*	Distribution* x 0.1
8	interburden	1.08E-04	1.08E-05
9	GP1	Distribution*	Distribution* x 0.1
10	interburden	1.08E-04	1.08E-05
11	GP2	Distribution*	Distribution* x 0.1
12	interburden	1.08E-04	1.08E-05

7 Numerical Modelling

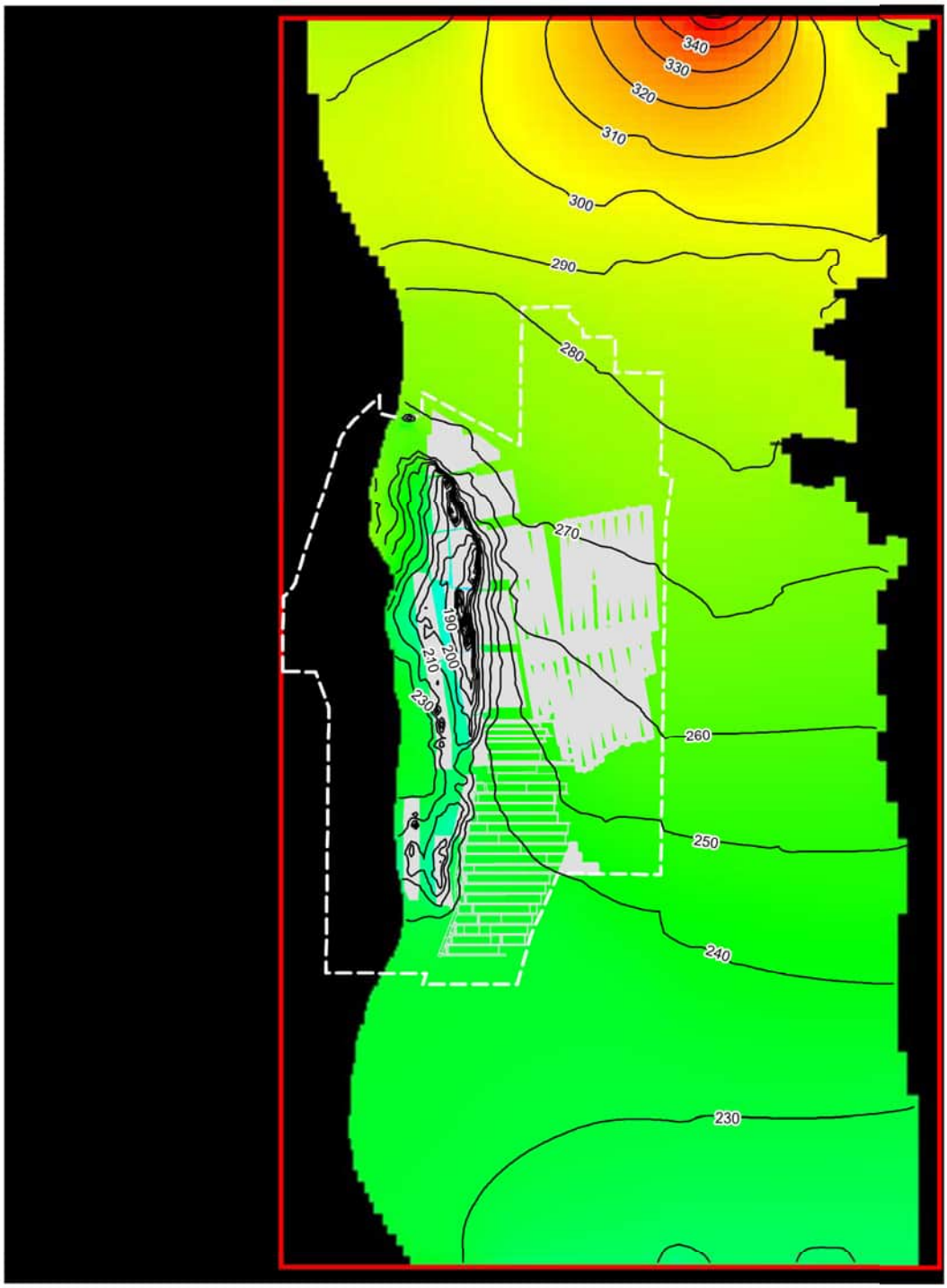
Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)
13	GMS	Distribution*	Distribution* x 0.1
14	interburden	1.08E-04	1.08E-05
15	GLS	Distribution*	Distribution* x 0.1
16	interburden	1.08E-04	1.08E-05
17	Base	1.08E-04	1.08E-05
Recharge		1.00E-07 m/day	

* K distribution derived from the WDS regression formula- 233.52*EXP(-0.016 X depth)

7.4.3.1 Comments on Model Calibration

The model calibration statistical results indicate a moderate agreement between the field measured groundwater levels or assumed steady-state water levels (as discussed in **Section 7.4.1**) and the model simulated levels. This is due to the following:

1. There are no pre-mining groundwater levels to calibrate against, and since the mining is an ongoing process, there was no steady-state condition that really existed. The available measurements in the historical records are impacted by historic mine dewatering. Higher residuals (field vs. model) at certain points were expected as dewatering can easily cause drawdown to be more than 50 metres.
2. Consideration of reducing residuals, to within a desirable range, was given, i.e. using a zonation or the pilot point approach to calibration. This approach was recognised, however, to result in an over-calibrated model, i.e. calibrated to noise or dewatering effects. As historic mine dewatering extraction rates were unavailable it was not possible to accurately incorporate this (mine dewatering) stress into the modelled system during pseudo steady-state calibration. Instead, the rule of parameter parsimony was adopted. The best data available was the approach of K values varying with depth using the regression formula. Thus the main purpose of calibration was to capture the regional groundwater flow trend rather than “point-to-point” matching.
3. The purpose of the calibration was to obtain an acceptable starting condition that represented the regional trend for the predictive simulation and reasonable parameter ranges.
4. Consideration of uncertainty was given as, trying to calibrate too closely to observed heads was likely to result in calibration to dewatering impacts and no actual aquifer conditions. This would have resulted in the model comprising a wide range of hydraulic conductivity, both spatial and with depth, which is not considered to match site conditions. The only way of verifying reliability of the model was to conduct uncertainty analysis for the predictive model, which is discussed in **Section 7.5.3**.



Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

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Scale

EIS Study Boundary

Open-Cut and Underground Mining Operations

230 Groundwater Elevation Contour (mAHD)

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GROUNDWATER IMPACT ASSESSMENT

MODELLED EXISTING GROUNDWATER HEAD DISTRIBUTION IN THE GMS

URS | GROUNDWATER | Figure: 7-5

File No: 42627136-g-2104.wor | Drawn: VH | Approved: CT | Date: 24-06-2013 | Rev.A | A4

7.4.4 Model Limitations

The groundwater flow model was a simplification of a real system, so it is subject to limitations. Limitations result from the simplification of the conceptual model upon which the numerical model is based, the grid scale, the inaccuracies of measurement data, and the incomplete knowledge of the spatial variability of input parameters.

There are no pre-mining groundwater levels available, and since mining has been ongoing since the 1970's, there was no steady-state condition to calibrate against. Thus the available groundwater level measurements in the historical records are impacted by historic mine dewatering; however, dewatering rates are also unavailable so the model could not be developed with a transient calibration. Therefore, the rule of parameter parsimony was adopted.

The best data available is the hydraulic conductivity values from aquifer tests, core tests, and the spatial distribution with depth identified by WDS (2011). The groundwater model was thus calibrated to capture the regional groundwater flow trend identified from groundwater levels with the objective of obtaining an acceptable starting condition that represented the regional trend for the predictive simulation and reasonable parameter ranges. Verification of reliability of the model was conducted by undertaking uncertainty analysis for the predictive model.

7.5 Predictive Simulations

After the steady state model was calibrated to the available data, the model was then converted to transient flow conditions to undertake the predictive scenarios for impact assessment. Predictive simulation was conducted for the ongoing GRM, BRM (including the extension into MLA70421), and proposed RHM for the active period of mining for the total complex (until 2068, the expected end of mining at GRM). Calibrated model parameters were used for the predictive simulation, and the modelling drain package was used for simulating open-cut and underground mining, approved and proposed.

The calibrated hydraulic conductivity values in **Table 7–5** were used for the predictive simulation; while the storativity values were adopted from literature and hydraulic tests as transient calibration was not possible with the available data. The model parameters used during the simulations are presented in **Table 7-6**.

7 Numerical Modelling

Table 7-6 Summary of Numerical Model Parameters Used in the Predictive Simulation

Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)	Storage Coefficient	Specific Yield
1	Tertiary, alluvium	0.49	0.049	1.00E-05	0.1
2	overburden	1.00E-03	1.00E-04	1.00E-05	3.00E-02
3	FC1	1.00E-03	1.00E-04	1.00E-05	1.00E-02
4	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
5	FC2	1.00E-03	1.00E-04	1.00E-05	1.00E-02
6	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
7	GUS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
8	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
9	GP1	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
10	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
11	GP2	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
12	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
13	GMS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
14	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
15	GLS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
16	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
17	Base	1.08E-04	1.08E-05	1.00E-05	3.00E-02
Recharge		**1.00E-07 m/day**			

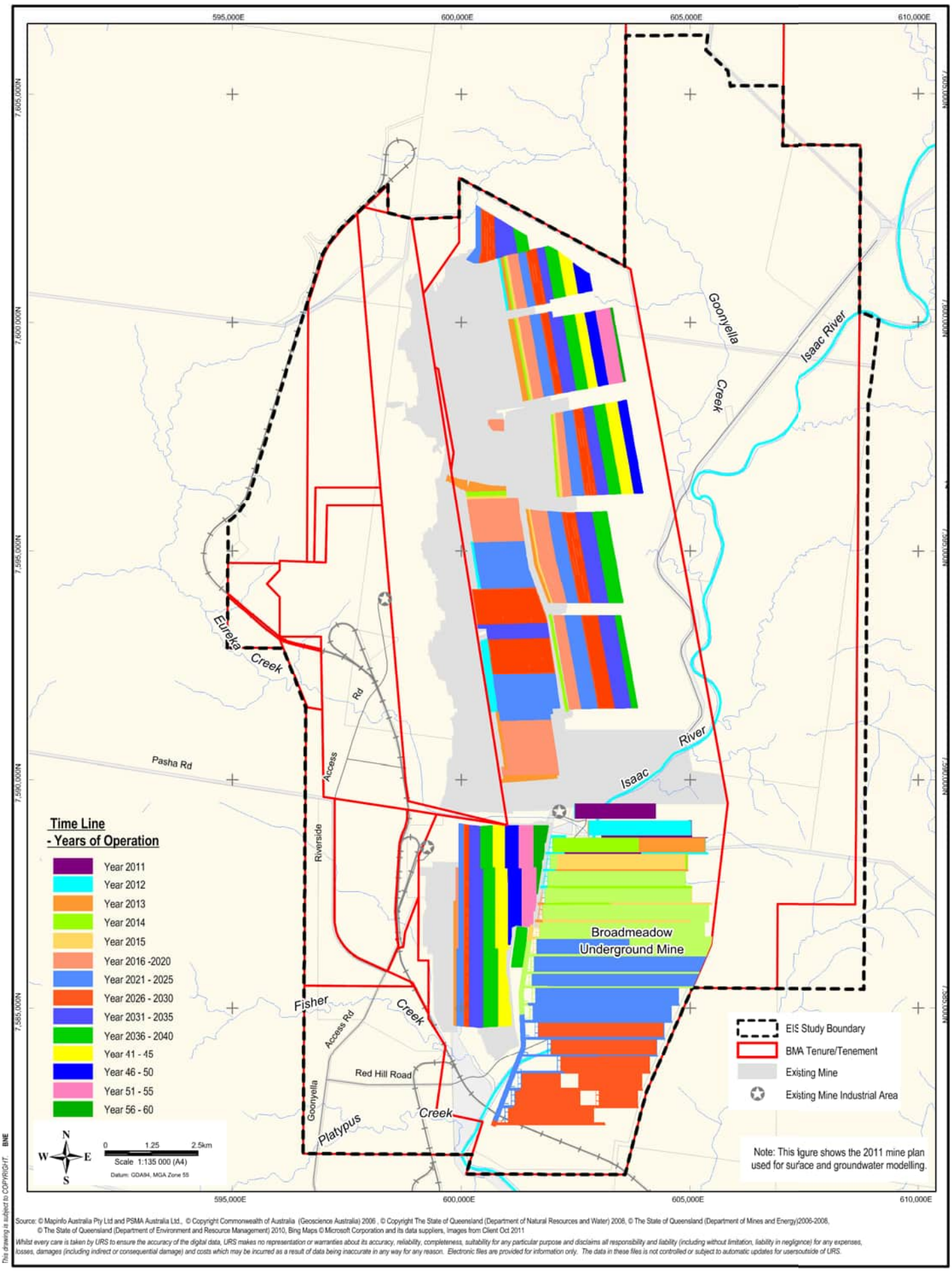
* K distribution derived from the WDS regression formula- 233.52*EXP(-0.016*depth)

7.5.1 Mine Progression Plans

Year-on-year mine plans for the existing GRM and BRM, as well as proposed mine plans for the RHM were simulated to assess the cumulative impacts of the proposed project. Several assumptions were made for the predictive simulation:

- Mining was assumed to progress on an annual time step as provided in the mine plans. Where the mine plans showed multi-year time steps, the mine plan was subdivided into equal (based on surface area) yearly time steps.
- Open-cut mining progress areas were assumed to be open for two years as backfilling occurs after mining.
- Underground mine areas will be maintained in a dewatered state for the life of each mine.
- Goafs were assumed to be formed in the year following mining (as discussed in **Section 7.3.7**).

GRM and BRM progression plans were provided with yearly progression to 2068 and 2030, the end of mining for each respectively. The mining progression plans for the proposed RHM were provided with yearly progression for the first four years and then five-yearly progression for the remainder on the LOM. The mine progression for the approved GRB mine complex is shown in **Figure 7-6**. The mine progression for the proposed RHM including the Broadmeadow extension is shown in **Figure 7-7**.



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GROUNDWATER IMPACT ASSESSMENT

MINE PROGRESSION FOR EXISTING APPROVED GOONYELLA RIVERSIDE AND BROADMEADOW MINES

URS | GROUNDWATER | Figure: 7-6

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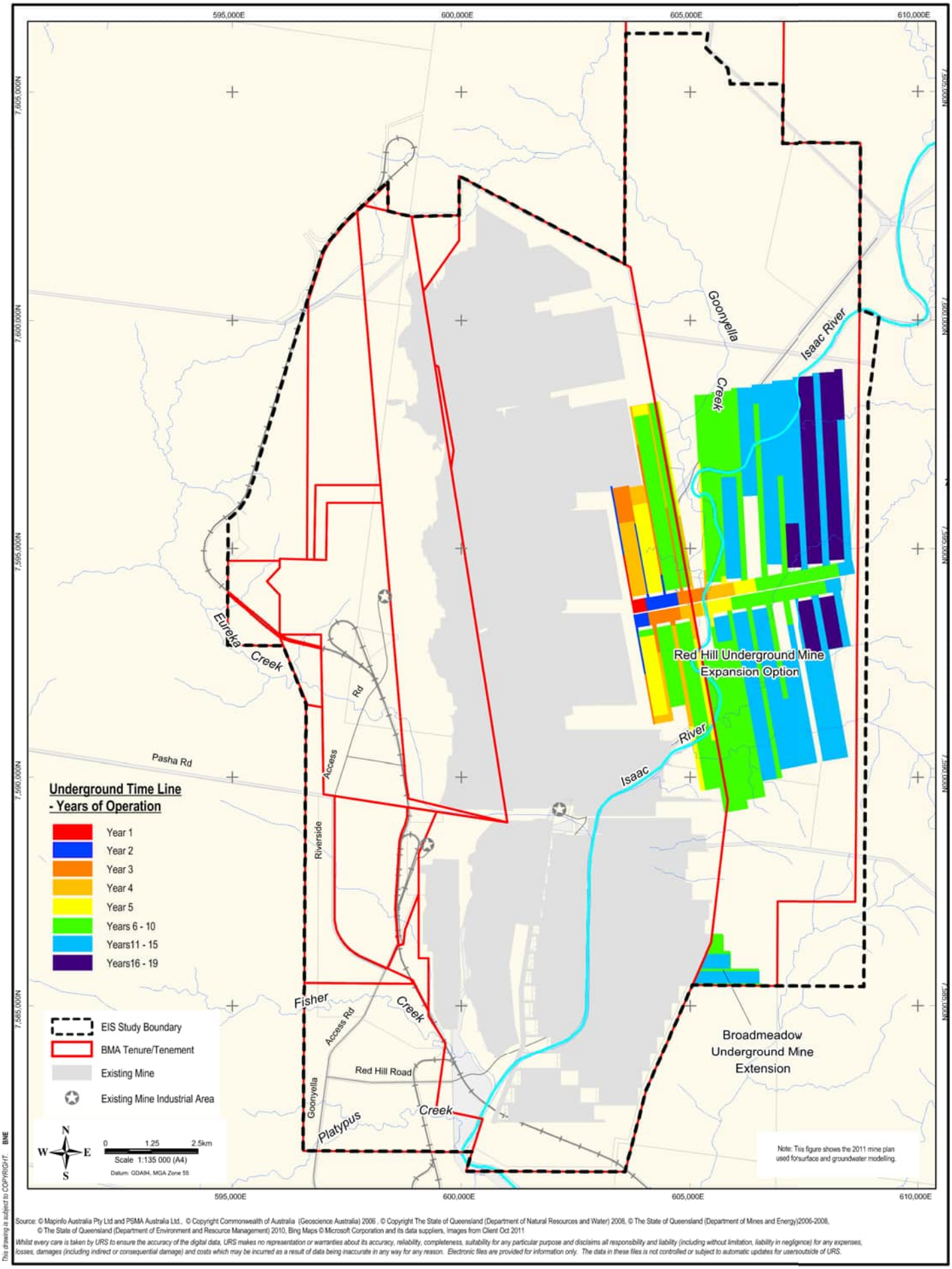

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GROUNDWATER IMPACT ASSESSMENT

MINE PROGRESSION FOR PROPOSED PROJECT

URS | GROUNDWATER | Figure: 7-7

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7 Numerical Modelling

7.5.2 Predicted Groundwater Drawdown and Inflow

Groundwater drawdown predictions were modelled on the October 2011 mine plan. A new mining sequence has since been developed for the RHM, Broadmeadow extension and the existing approved BRM. Further, both the BRM and the proposed Broadmeadow extension footprints have been revised. This has the potential to alter groundwater volumes and drawdown over the life of mine. However, the mine plan and revised schedule are indicative only and sequencing of production and annual production rates are dependent on a range of factors and likely to vary. Regardless of this, the changes are not anticipated to have a significant impact on modelling predictions.

In order to assess the potential impact of the project on groundwater, in addition (cumulative) to the impact of the existing approved GRB mine complex, predictive simulations were performed for two scenarios (with and without the project). Total drawdown contours for cumulative impact (approved GRB mine complex and the project) and for the impact caused by RHM beyond the approved baseline (additional drawdown due to the project calculated by the difference in predicted impact of the GRB mine complex by itself and with the project), for the Tertiary/Quaternary Formations (Layer 1) and for the GMS (the mined seam, Layer 13) are shown in **Figure 7–8** and **Figure 7–9** for 2040 (the modelled end of mining for the RHM) and **Figure 7–10** and **Figure 7-11** for 2068 (the end of mining at GRM) respectively.

Prediction of groundwater volumes to be removed, either through mine dewatering and / or active dewatering for IMG drainage, were estimated through the use of zone budgets in the MODHMS model simulation. Groundwater extraction with time for the two approaches to goaf simulation, use of time varying properties and use of drain cells, are shown in **Chart 7–2** and **Chart 7-3**. It is noted that the results of the two approaches are comparable.

Groundwater extraction is predicted to peak at approximately two gigalitres (GL) per year using the time varying properties approach, and 3.5 GL per year using the drain cell approach. Some of this predicted extraction will not be extracted by IMG drainage or seepage collection, but will be lost from the mine water balance as embodied water in extracted coal or evaporation through the mine ventilation system. Note that extraction from the underground mines stop at the completion of mining, but that groundwater would continue to flow into the mine void and goaf with a consequent lag in groundwater drawdown as this storage is filled.

7 Numerical Modelling

Chart 7-2 Estimated Total Groundwater Ingress Using Time Varying Properties

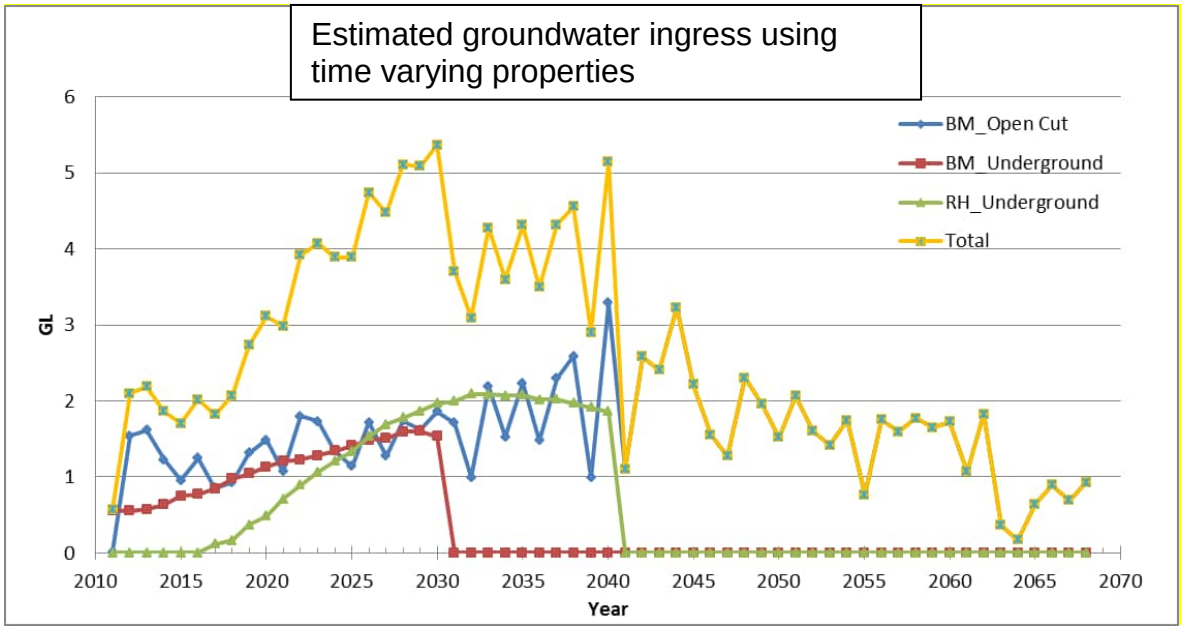
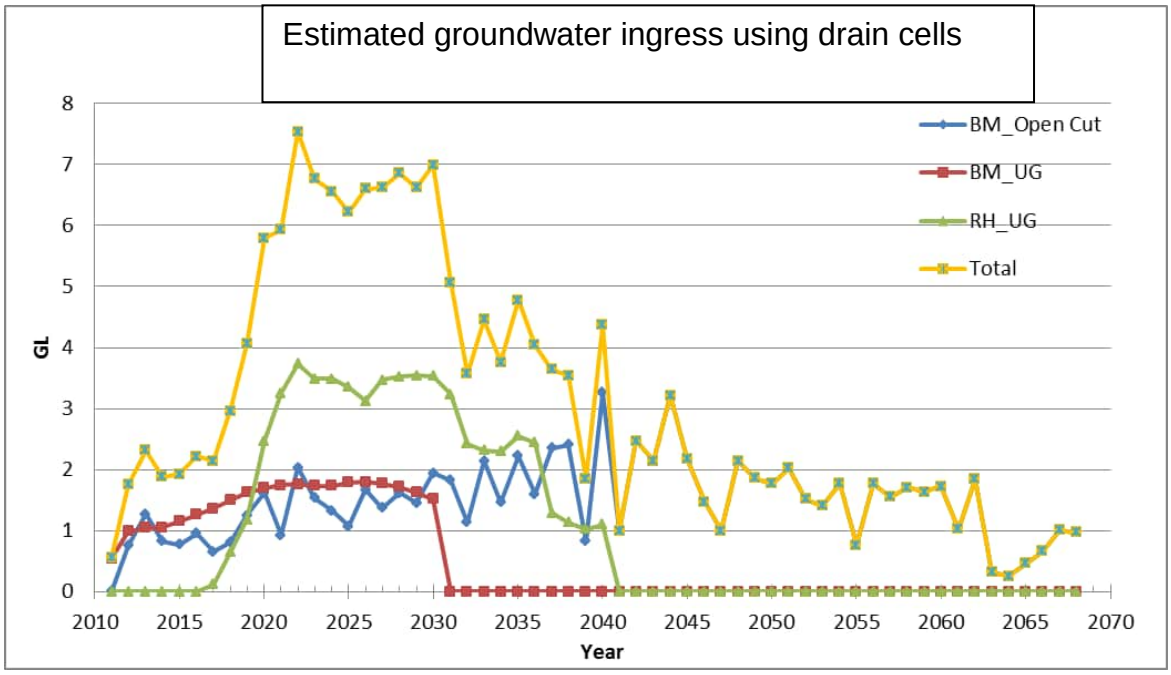
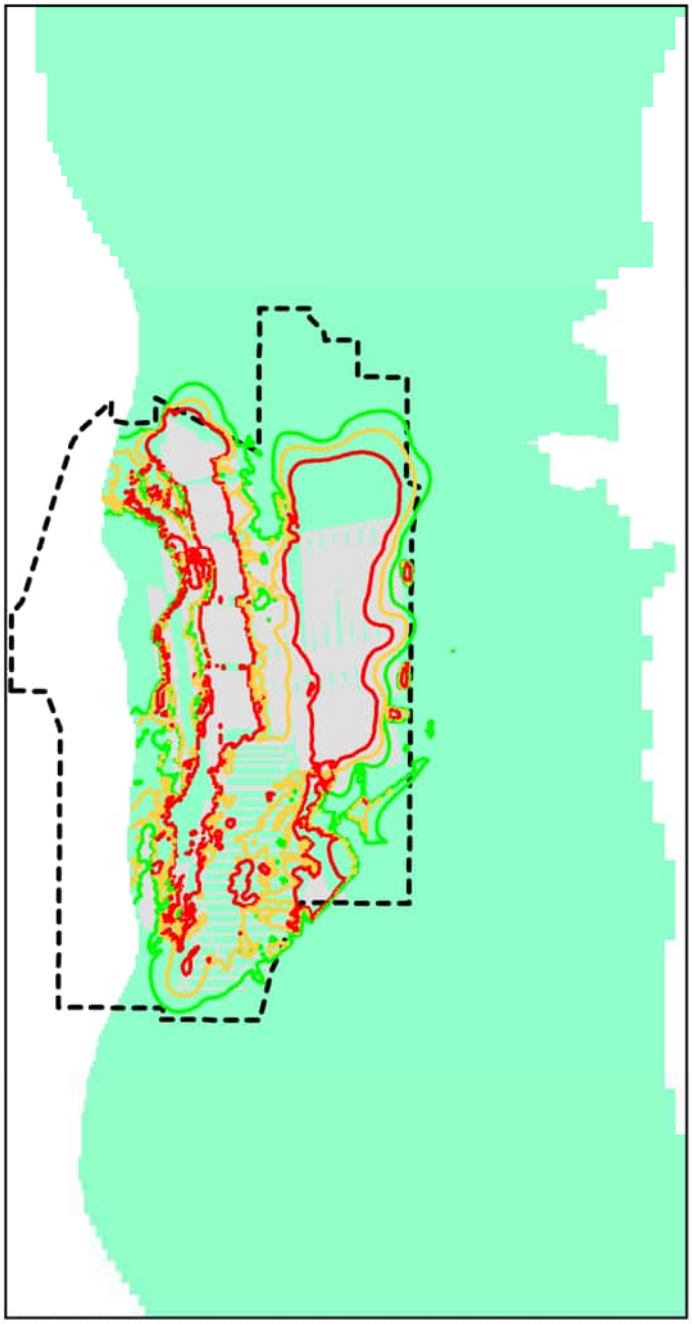
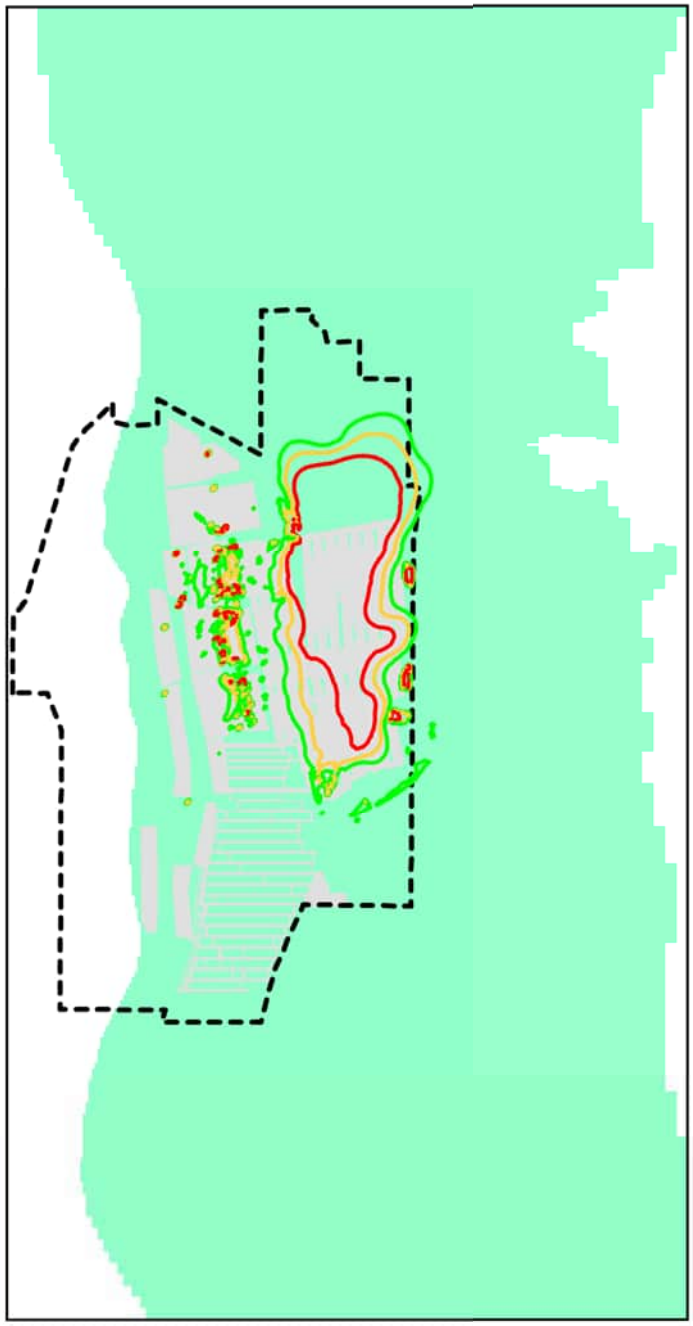


Chart 7-3 Estimated Total Groundwater Ingress Using Drain Cells





Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

N
W E
S

0 3.75 7.5km
Scale

Drawdown (m)
0.5
1
2

EIS Study Boundary
Open-Cut and Underground Mining Operations
Model Extent

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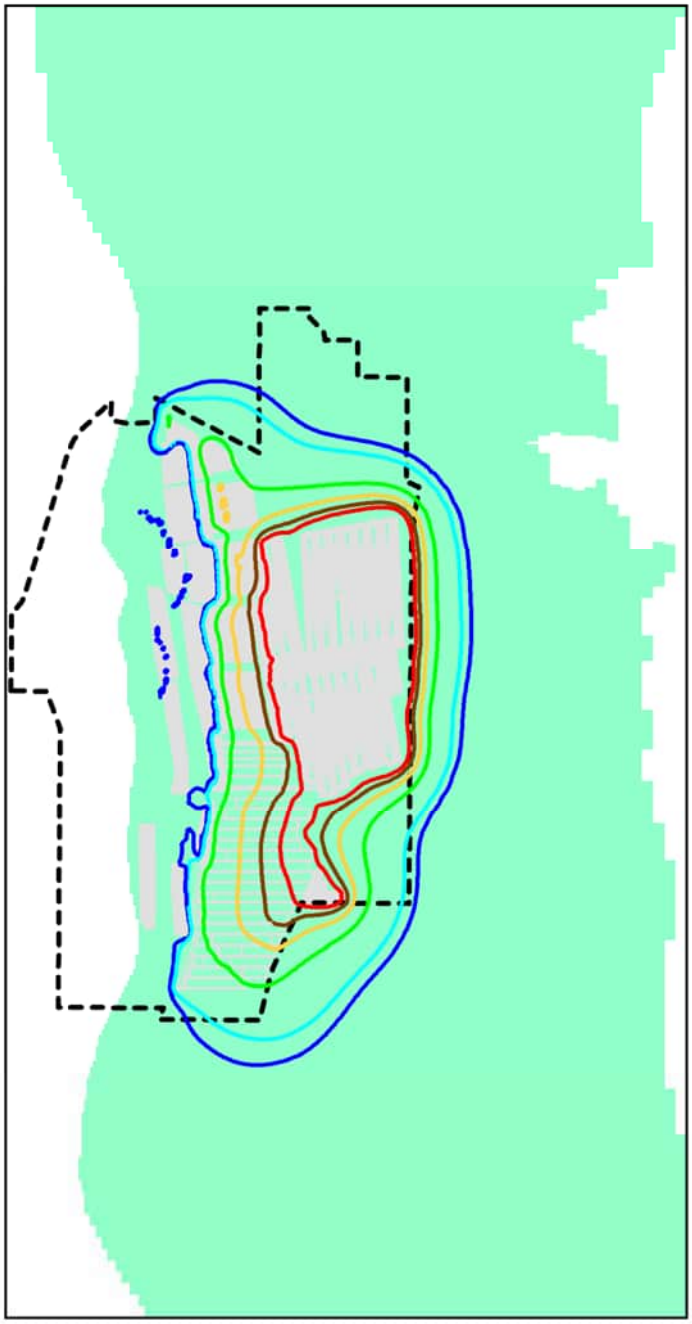
GROUNDWATER IMPACT ASSESSMENT

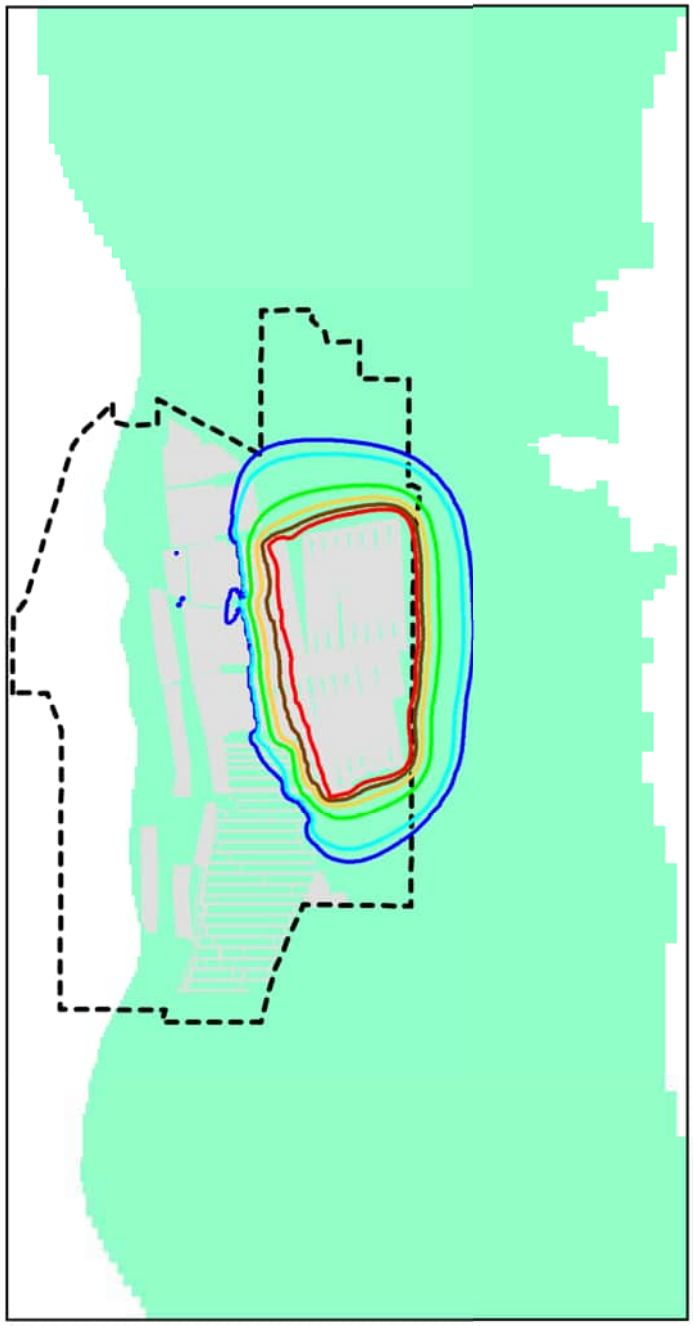
MODELLED DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2040

URS | GROUNDWATER | Figure: 7-8

File No: **42627136-g-2107.wor** | Drawn: **VH** | Approved: **CT** | Date: **24-06-2013** | Rev.**A** | A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Drawdown (m)
5
10
50
100
150
200

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

N
W E
S

0 3.75 7.5km
Scale

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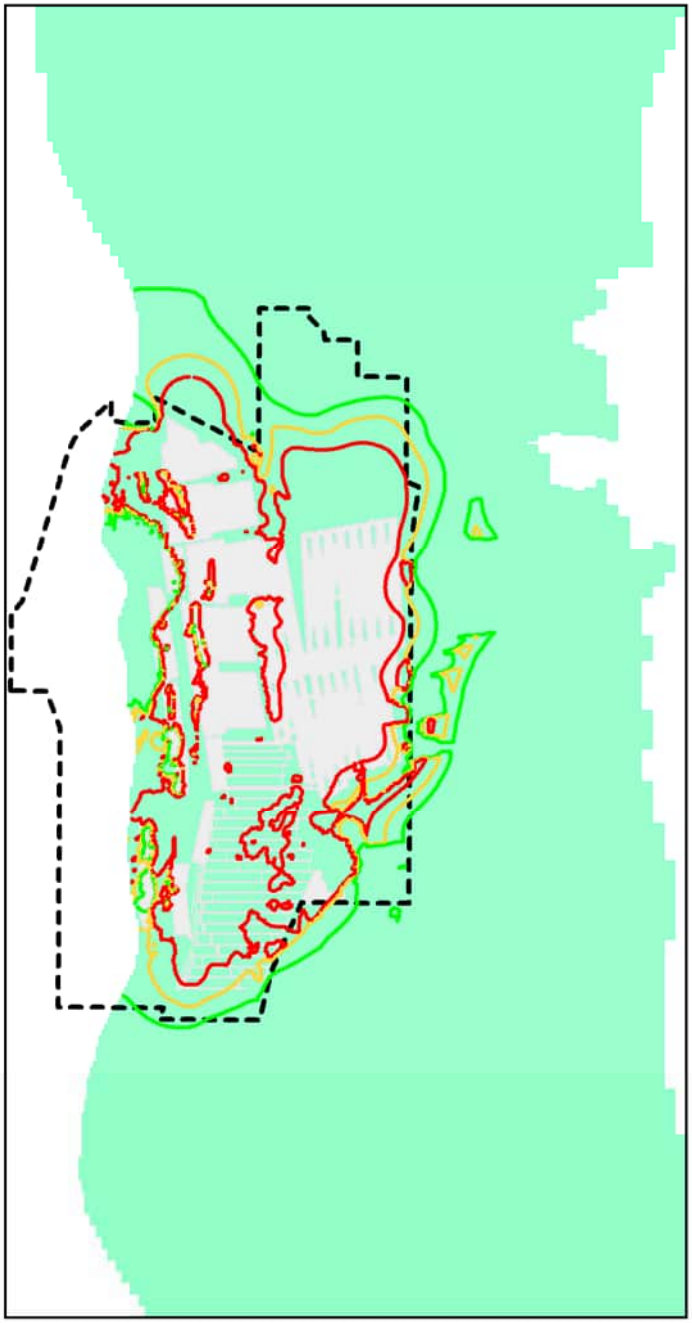
GROUNDWATER IMPACT ASSESSMENT

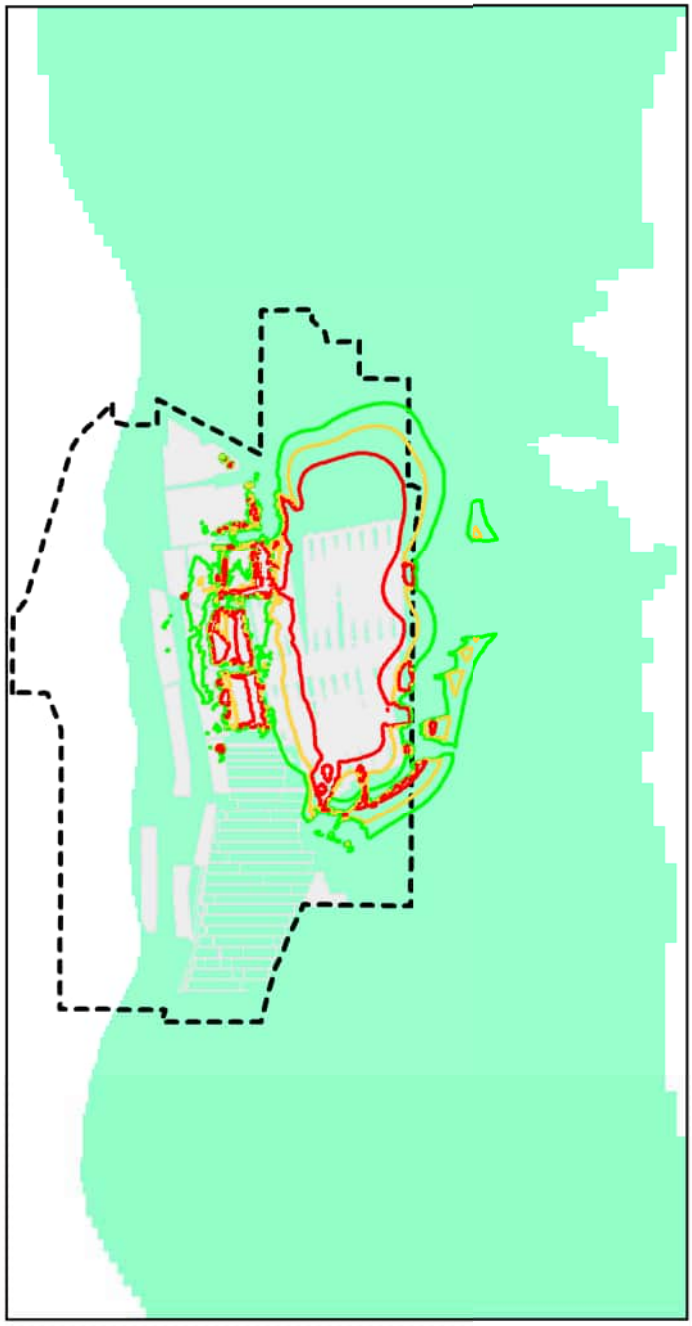
MODELLED DRAWDOWN IN GMS AT END OF 2040

URS | GROUNDWATER | Figure: 7-9

File No: **42627136-g-2108.wor** | Drawn: **VH** | Approved: **CT** | Date: **24-06-2013** | Rev.**A** | A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

N
W E
S

0 3.75 7.5km
Scale

Drawdown (m)
0.5
1
2

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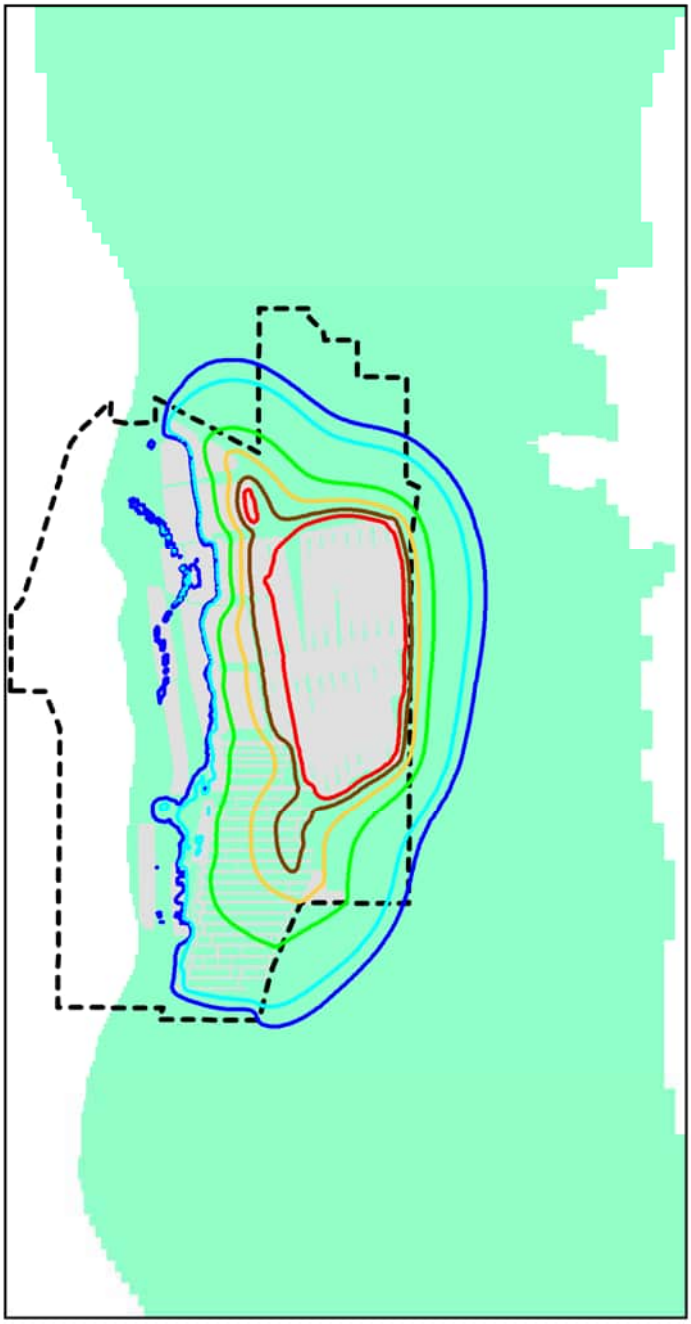
GROUNDWATER IMPACT ASSESSMENT

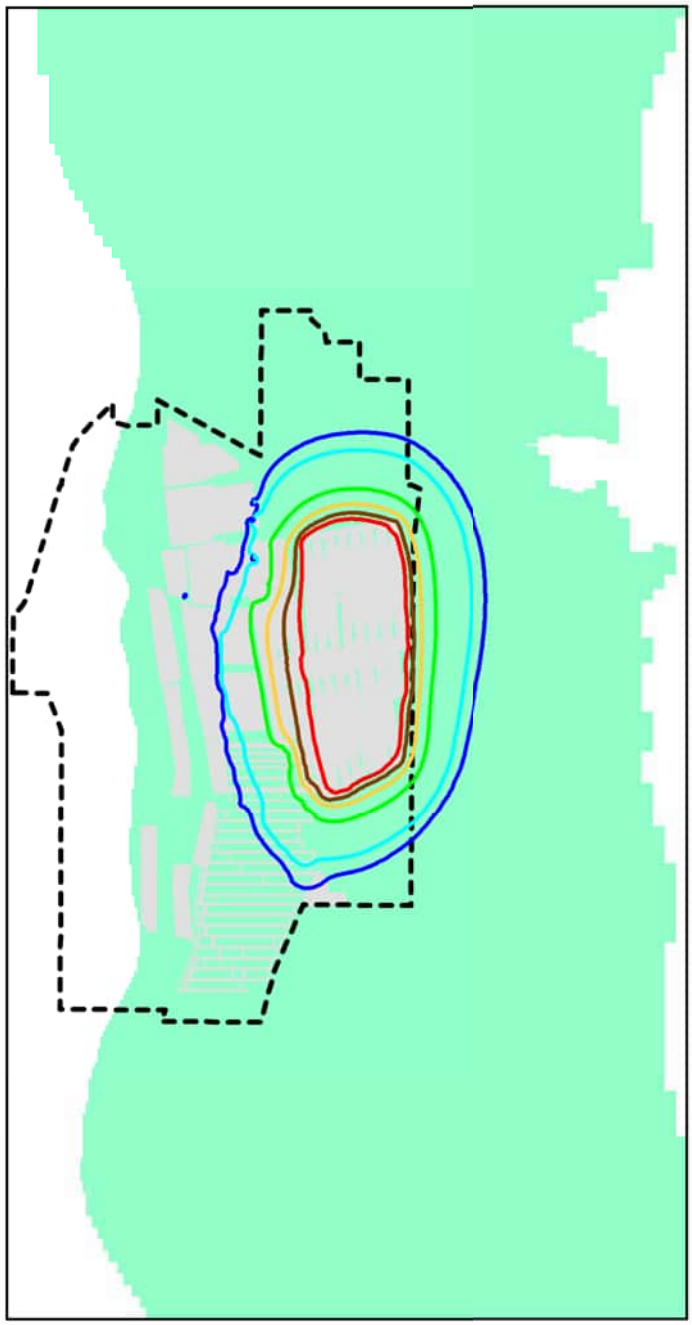
MODELLED DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2068

URS | GROUNDWATER | Figure: 7-10

File No: 42626730-g-2109b.wor | Drawn: VH | Approved: MS | Date: 24-06-2013 | Rev.B | A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Drawdown (m)
5
10
50
100
150
200

EIS Study Boundary
Open-Cut and Underground Mining Operations
Model Extent

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

N
W E
S

0 3.75 7.5km
Scale

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GROUNDWATER IMPACT ASSESSMENT

MODELLED DRAWDOWN IN GMS AT END OF 2068

URS | GROUNDWATER | Figure: **7-11**

File No: **42627136-g-2110.wor** | Drawn: **VH** | Approved: **CT** | Date: **24-06-2013** | Rev.**A** | A4

7 Numerical Modelling

7.5.3 Groundwater Ingress

Based on the model approach adopted to assess the potential impacts of mine dewatering, in terms of drawdown on the local and regional groundwater resources, conservative assumptions were included. This allowed for “worst-case” scenarios regarding potential impacts to be assessed.

The use of drains provided elevated groundwater ingress predictions, which were not suitable for inclusion in the mine water management assessment (Red Hill Mining Lease EIS Appendix I2), as this study requires a more realistic estimate of groundwater volumes for inclusion in the water balance.

The predictive model was revised to simulate year-on-year groundwater ingress volumes, considering impacts of longwall mining (goaf) resulting in the alteration of aquifers over time. The predictive model simulated cumulative dewatering of the GRM open cuts, the BRM, the Broadmeadow extension, and the RHM underground workings.

Table 7–7 presents the year-on-year volumes of groundwater associated with the proposed mine panels over the LOM for RHM and GRB mine complex mines. The estimates are predicted using the basecase set of aquifer parameters, determined during calibration. An estimated total groundwater volume of 35 GL will be removed during the RHM LOM (20 to 25 years).

The estimates for groundwater ingress into RHM range from 0.12 GL to 2,09 GL over the LOM. These data are shown in **Chart 7–2**.

Table 7-7 Groundwater Ingress Estimated for RHM (basecase) in cubic metres

Year	GRM	BRM	RHM	Total
2011	15,303	558,060	0	573,363
2012	1,542,580	554,985	0	2,097,565
2013	1,614,730	570,974	0	2,185,704
2014	1,227,470	633,868	0	1,861,338
2015	951,768	752,522	0	1,704,290
2016	1,244,380	771,574	0	2,015,954
2017	855,044	848,690	118,571	1,822,305
2018	930,070	977,918	165,444	2,073,432
2019	1,316,480	1,041,970	369,962	2,728,412
2020	1,488,760	1,134,290	487,836	3,110,886
2021	1,070,720	1,204,010	707,199	2,981,929
2022	1,796,650	1,226,570	891,687	3,914,907
2023	1,728,670	1,280,900	1,065,610	4,075,180
2024	1,342,020	1,342,580	1,205,810	3,890,410
2025	1,139,750	1,409,990	1,335,560	3,885,300
2026	1,716,190	1,488,220	1,533,330	4,737,740
2027	1,276,560	1,508,450	1,690,990	4,476,000
2028	1,740,780	1,591,900	1,777,100	5,109,780
2029	1,624,370	1,601,560	1,863,880	5,089,810
2030	1,859,850	1,533,980	1,969,540	5,363,370
2031	1,711,400	0	1,994,020	3,705,420

7 Numerical Modelling

Year	GRM	BRM	RHM	Total
2032	996,491	0	2,093,040	3,089,531
2033	2,187,430	0	2,087,220	4,274,650
2034	1,524,260	0	2,070,090	3,594,350
2035	2,234,130	0	2,079,210	4,313,340
2036	1,479,800	0	2,016,940	3,496,740
2037	2,294,810	0	2,022,040	4,316,850
2038	2,589,180	0	1,968,360	4,557,540
2039	986,844	0	1,911,950	2,898,794
2040	3,289,370	0	1,860,960	5,150,330
2041	1,107,730	0	0	1,107,730
2042	2,582,380	0	0	2,582,380
2043	2,404,440	0	0	2,404,440
2044	3,229,910	0	0	3,229,910
2045	2,216,570	0	0	2,216,570
2046	1,554,660	0	0	1,554,660
2047	1,274,060	0	0	1,274,060
2048	2,301,260	0	0	2,301,260
2049	1,963,800	0	0	1,963,800
2050	1,517,800	0	0	1,517,800
2051	2,064,960	0	0	2,064,960
2052	1,603,870	0	0	1,603,870
2053	1,418,090	0	0	1,418,090
2054	1,742,260	0	0	1,742,260
2055	763,412	0	0	763,412
2056	1,751,760	0	0	1,751,760
2057	1,597,000	0	0	1,597,000
2058	1,773,450	0	0	1,773,450
2059	1,647,270	0	0	1,647,270
2060	1,722,730	0	0	1,722,730
2061	1,067,610	0	0	1,067,610
2062	1,825,650	0	0	1,825,650
2063	363,198	0	0	363,198
2064	170,852	0	0	170,852
2065	640,507	0	0	640,507
2066	891,452	0	0	891,452
2067	686,828	0	0	686,828
2068	928,758	0	0	928,758

7 Numerical Modelling

For the purposes of establishing a mine water balance for RHM, it has been assumed that around 2,200 KL/day or 800 ML/year of water will be produced from gas extraction wells. Thus over 25 years of mining the volume of groundwater extracted from IMG will be ~ 20 GL and from mine dewatering ~ 15 GL.

Table 7–9 below provides an indication of the possible range of groundwater ingress estimates, based on model parameter sensitivity and uncertainty analysis. As noted above, this analysis is based on the 2011 indicative mine plan. However, the revised mine plan is not expected to result in significant changes to these conclusions.

7.5.4 Uncertainty Analysis

Prediction uncertainty arises mainly as a result of uncertainties in model conceptualisation and model parameters. The effects of alternative conceptualisations on the calibrated model were not explored in this study because the alternatives were considered very limited as the model has been built based on the best available information and understanding of the groundwater regime through site specific studies.

Parameter uncertainty was explored through varying selected parameters (one at a time) to examine the impacts on predicted groundwater drawdown or extraction. The base case model used was the calibrated predictive model using the time varying properties approach for goaf simulation. Uncertainty was assessed by conducting 12 additional model runs with varying parameters as shown in **Table 7–8**. The horizontal hydraulic conductivity (Kh) and vertical hydraulic conductivity (Kv) distributions were scaled up with factors of two and five and scaled down with factors of 0.5 and 0.2 for sensitivity runs one to four. The specific yield (Sy) for coal seams in the base case was 0.01 and was considered at the lower end, so only the effect of higher Sy was considered in sensitivity run five. The variation of Kh values for interburden was considered in sensitivity runs six and seven. Only scaling up of Kv for interburden was considered in sensitivity run eight as Kv of the base case was at the lower end. The variation of Kh and Kv values for overburden was considered in sensitivity runs nine to 12.

Table 7-8 Parameter Variations Used for Model Sensitivity Assessment as a Product of Calibrated Base Case Parameters Displayed in Table 7–5

Sensitivity Run	Unit	K (horizontal)	K (vertical)	Specific Yield
1	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 2	Base case	Base case
2	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 0.5	Base case × 1	Base case × 1
3	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 1	Base case × 5	Base case × 1
4	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 1	Base case × 0.2	Base case × 1
5	All coal seams (layers 3, 5, 7, 9, 11, 13, and 15)	Base case × 1	Base case × 1	Base case × 2
6	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 2	Base case × 1	Base case × 1
7	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 0.5	Base case × 1	Base case × 1

7 Numerical Modelling

Sensitivity Run	Unit	K (horizontal)	K (vertical)	Specific Yield
8	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 1	Base case × 5	Base case × 1
9	Overburden	Base case × 2	Base case × 1	Base case × 1
10	Overburden	Base case × 0.5	Base case × 1	Base case × 1
11	Overburden	Base case × 1	Base case × 5	Base case × 1
12	Overburden	Base case × 1	Base case × 0.2	Base case × 1

Mean drawdown of in the Alluvium/Tertiary layer and the GMS at the end of year 2068 is presented in **Table 7–9** for the base case model and sensitivity runs. For the base case, the mean drawdown was 8.26 and 64 metres respectively. The largest mean drawdown of 12.96 metres for the Alluvium/Tertiary occurred in sensitivity run eight, in which Kv of the interburden increased five times, allowing more drawdown to propagate upwards.

Table 7-9 Mean Drawdown from Sensitivity Runs for Alluvium/Tertiary and Goonyella Middle Seam, 2068

Sensitivity Run	Alluvium, Tertiary Mean Drawdown (m)	GMS Mean Drawdown (m)
Base Case	8.26	64.00
1	8.25	59.45
2	8.34	71.02
3	8.28	65.13
4	8.26	56.36
5	8.33	67.56
6	8.01	57.28
7	8.48	65.58
8	12.96	56.34
9	8.40	66.97
10	8.11	62.06
11	7.06	61.94
12	8.10	61.93

Total groundwater inflow for RHM and for RHM and the GRB mine complex are presented in **Table 7-10** for the sensitivity analysis. The highest groundwater inflow occurred in sensitivity run eight, where groundwater inflow was two times higher than the base case for RHM and was almost double the base case for RHM and GRB mine complex. Sensitivity run eight had a higher Kv value for the interburden, which allowed more leakage to the GMS.

Through the analysis of parameter uncertainty, it was identified that uncertainty of Kv of the interburden between coal seams could have marked impacts on predictive groundwater drawdown and inflow because the chosen sensitivity value of Kv value of 5×10^{-5} m/day (five times the base case value) was still within the reasonable parameter range.

7 Numerical Modelling

Table 7-10 Total Groundwater Inflows for each Sensitivity Run at the end of Mining

Sensitivity Run	Red Hill Mine Total Inflow (GL)	Red Hill Mine and GRB Mine Complex Total Inflow (GL)
Base Case	35.3	146
1	35.1	142
2	33.4	138
3	35.2	140
4	30.9	135
5	37.1	147
6	34.5	139
7	33.8	139
8	75.5	214
9	34.1	139
10	34.1	140
11	34.1	138
12	34.0	139

Of particular note, the greatest uncertainty identified surrounds the vertical permeability of interburden and goaf aquifer parameters and therefore corresponding groundwater inflows as there is no known published data for post goaf aquifer parameters. The uncertainty in the model results can be reduced through the collection of inflow data. If significant divergence is observed between the measured and model predicted inflows, revisiting the model and specifically re-calibration of the model parameters against the measured inflow data will reduce the model uncertainty and gain better predictions for the future. It is also recommended that model refinement and predictions be rerun (at intervals no longer than three years during the LOM based on monitoring data compiled.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

The impacts on groundwater from the development, operation, closure and post-closure of the project have been evaluated. Potential impact of the mine on the regional groundwater regime was assessed by predictive groundwater modelling. The groundwater model was developed to estimate groundwater extraction (passive seepage and active dewatering for gas control) over the mine life, project drawdown in aquifers, evaluate the zone of influence and direct and indirect impacts of dewatering, and evaluate the possible impact on other groundwater users. The groundwater model was constructed using the geological model, hydraulic parameters determined on site and from literature, and groundwater level information within the survey area.

Mining within the GRB mine complex area commenced after the granting of the original Goonyella mining lease (ML1763) in 1971 and the Riverside mining lease (ML1764) in 1978. While the main aquifers within the area are the coal seams, inflow from the exposed seams to the current GRM pit voids have not been significant. Dewatering in advance of mining is generally not required for the current open pit or underground workings.

The Goonyella North mine is located along the strike of the Moranbah Coal Measures immediately north of the EIS study area, with the Moranbah North mine located immediately south. Given the close proximity of these coal mines, this assessment considers the additional and, where possible, the cumulative impact of the project on the current (mine influenced) groundwater resources in the survey area.

8.1 Potential Impacts during Development and Operation

8.1.1 Potential Impacts on Regional Groundwater Levels

The project is within the declared Isaac Connors GMA; however, there are few groundwater users locally. From a search of the NRM groundwater database, seven bores are registered within 10 kilometres of the EIS study area boundary for water supply purposes. Other bores are present but these are either monitoring bores or coal seam gas exploration bores) as discussed in **Section 6.3**.

During the LOM, groundwater inflow from the aquifers to the underground mine workings or extraction as part of gas depressurisation can lead to increased drawdown of the potentiometric surface in the vicinity of the mine workings when compared to drawdown from the existing approved coal mines in the area.

8.1.1.1 Impacts on Permian Formation Aquifers

Dewatering resulting from IMG drainage and groundwater ingress into the mine workings will cause drawdown of groundwater levels as discussed in **Section 7.5.2** and presented in **Figure 7-9** and **Figure 7-11**. Resultant variations in the current groundwater levels, which have already been altered due to existing mine dewatering, were predicted.

Groundwater modelling was used to project drawdown caused by dewatering and IMG drainage of the proposed RHM. Predictive modelling indicates that drawdown of five metres (from pre-RHM mining levels) will occur to a distance of up to four kilometres from the proposed RHM footprint. The drawdown predictions were simulated for the target GMS, allowing for the prediction of the largest zone of influence at the end of mining.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

Groundwater drawdown will also occur in the units above the GMS due to induced flow towards the depressurised coal seam and the impact of the goaf resulting in increasing vertical permeability. The extent and degree of drawdown within the overlying units decreases with increasing distance above the dewatered seams.

The Goonyella North and Moranbah North mines are located along strike and also target the Moranbah Coal Measures to the north and south of RHM, respectively. The cumulative impact of these mines will be to superimpose the drawdown of each mine such that the Moranbah Coal Measures between the mines will be significantly dewatered. No groundwater users were identified between the mines.

Drawdown in bores of five metres or more is considered, in fractured rock aquifers, to have a material impact on bore yield. There are no identified groundwater supply bores within the predicted five metre drawdown zone. Thus no “at-risk” bores have been identified.

There are two production bores (Skeleton Bore (NRM Registration 81696), and Cleanskin Gully Bore) on the ‘Broadmeadow’ property are located outside the predicted five metre drawdown contours zone but still within the predicted cone of depression on the ‘Broadmeadow’ property (Skeleton Bore (NRM Registration 81696), and Cleanskin Gully Bore),as shown on **Figure 6–4** While it is expected that users of these two bores will still have access to groundwater and not realise a marked change in supply it is recommended that monitoring be conducted to validate predictions.

Additional bores that may potentially be affected by mine dewatering and IMG drainage are the CSG bores. These bores are, however, designed to remove groundwater to allow gas extraction, and hence, mine-induced drawdown should not cause any impacts on these bores.

8.1.1.2 Impacts on Tertiary and Quaternary Aquifers

All creeks and the Isaac River within the EIS study area are ephemeral and there are no perennial water holes or groundwater dependant environments present, as discussed in **Section 6.4**. Under dry season conditions, groundwater does not contribute or have any hydraulic connection with surface water resources within these drainages. In exceptionally wet years it is possible that the Quaternary alluvium and shallow Tertiary aquifers may contribute some groundwater to the surface water system along water courses for a short duration after rain events.

Where excavations required for the surface infrastructure and mine access portals encounter Quaternary alluvium near creeks or the Isaac River and / or Tertiary sediments, groundwater inflow may occur (i.e. direct drainage impacts). The aquifers in these units are typically ephemeral are not considered significant aquifers. Due to the expected low hydraulic gradients (one to two metres) and low conductivity, the drawdown zone of influence, as a result of the direct impacts, is considered to only extend some 10 to 100 metres around excavations. This area around the excavations will remain dewatered, as recognised in the GRB mine complex open cut pits, as evaporation exceeds recharge.

The Quaternary alluvium associated with the Isaac River is considered, based on permeability and water quality, to be the most significant aquifer within the survey area, but is unlikely to be significantly impacted by groundwater drawdown as there are no major excavations to take place in close proximity to the Isaac River and limited hydraulic connection between the perched water tables in the alluvium and the confined coal seam aquifers (which will be depressurised and dewatered).

Although the numerical model indicates the potential for drawdown of over two metres in the Tertiary/Quaternary (as shown in **Figure 7–8**), this is not considered to occur in reality due to the

ephemeral nature of the Cainozoic units. The model simulations assume fully saturated conditions in the Tertiary sediments and Quaternary alluvium and that these units are in hydraulic connection with the underlying confined aquifers. In reality due to the short periods over which the aquifers are actually, saturated, drawdown due to mining will be much less than predicted.

Subsidence is predicted to create cracking at surface (IMC 2011), the clay-rich nature of the Tertiary sediments, Quaternary alluvium, and weathered Permian will, however, self-heal. This will reduce the potential of leakage from surface to the mine workings. Observations at the adjacent BRM appear to confirm this.

All creeks and the Isaac River within the EIS study area are ephemeral and there are no perennial water holes or groundwater dependant ecosystems present, as discussed in **Section 6.4.** On this basis, impacts on groundwater dependent ecosystems are not expected.

Incidental mine gas drainage activities are not expected to impact on the Tertiary or Quaternary aquifers as the bores will be sealed where they intersect these aquifers.

8.1.2 Impacts on Groundwater Quality

The groundwater quality of the Permian strata is brackish to saline and not suitable for human consumption or irrigation, but has some use for stock water according to the limits set in ADWG (2004) and ANZECC/ARMCANZ (2000) water quality guidelines.

During mining operations, groundwater quality within aquifers surrounding the site is not expected to change from pre-mining conditions. This would be a result of all RHM water and waste storage facilities infrastructure being designed, constructed, and managed to ensure little or no potential of seepage. In the event that groundwater contamination did occur contaminant migration off site in the groundwater will not occur. This is expected as during degassing and mining operations, groundwater will be continually extracted from bores or sumps in the underground workings to ensure a safe working environment. This drainage of groundwater will create a depression in the potentiometric (groundwater) surface around the workings such that the net movement of groundwater is towards the workings during mine operation. This will prevent the movement of water that may have been impacted by mining from moving away from the mine operation area and into the surrounding aquifers. The resultant drawdown, changing groundwater flow patterns, effectively limits the potential for contaminant plumes to migrate off site via groundwater.

Groundwater quality away from the influence of the project will not deteriorate as these resources will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data (with respect to major anions and cations and dissolved metals) indicate that groundwater in the alluvial aquifers and basalt is of similar or better quality when compared to the coal seam aquifers of the Moranbah Coal Measures. Hence, any inadvertent mixing of groundwater (during and post mining) by induced downward movement from the upper to lower aquifers is unlikely to result in a deterioration of groundwater quality in the Permian aquifers.

Another potential source of contamination for groundwater is through contact with mine waste materials which may be acid forming or leach salt or metal contaminants to groundwater. A geochemical assessment of the coal and mine wastes (waste rock and tailings) was undertaken for the project (URS 2012a). The study indicates that the overburden (excavated for mine access) and rejects generated by the proposed mining and coal processing operation is predominantly

geochemically benign. Any possible seepage and /or surface run-off is expected to be slightly alkaline and have low-to-moderate salinity following surface exposure. Overburden and reject materials are unlikely to generate acid given the lack of oxidisable sulphur content, excess acid neutralising capacity and existing alkaline pH of these materials. As the direction of groundwater flow will be towards the mine workings, the buffering capacity of the groundwater is expected to neutralise any oxidation products of the coal seams due to mine dewatering, and any potential for the development of acid mine drainage is low.

The expected water quality of overburden and coal reject materials (runoff and seepage) and the water quality of the coal seam aquifers indicate that groundwater seeping into the underground mine will require dilution or treatment to reduce the salinity prior to reuse. The acid-base classification of coal samples found that most coal samples were potentially acid forming, although the potential for acidification of groundwater in contact with exposed coal seams is expected to be relatively low. This is due to the low sulphur concentration of coal and the significantly greater proportion of pH-neutral material and in the roof and floor of the underground mine compared to coal.

The waste rock dumps, waste placement areas, CHPP and coal stockpiles are located over the relatively saline aquifers of the Permian formations (Moranbah Coal Measures or Back Creek Group), not the fresh water aquifers of the Isaac River Quaternary alluvium or Tertiary sediments. Thus any potential seepage or runoff is unlikely to result in a marked alteration to groundwater quality of the underlying Permian formations.

The quality of the groundwater in the shallow Cainozoic groundwater resources that may exist within the project footprint (i.e. Quaternary alluvium and Tertiary sediments) have the potential to be impacted by spills and seepage from the MIA, and waste disposal and fuel storage areas where these are in sufficient quantities to leach through the soils to groundwater. Any spills from these areas are typically localised and not regionally significant in terms of groundwater impacts. The risks of groundwater contamination from chemical or fuel spills will be minimised by storage and handling of fuels, oils and other chemicals in accordance with Australian standards and requirements of Material Safety Data Sheets. The design of storage and handling facilities will provide full containment, and procedures for immediate clean-up of spills will be available. These measures are standard practice or a legislated requirement at mine sites. Areas of hydrocarbon and chemical storage will have spill control measures in place and a regular inspection regime will be required in order to monitor activities that could potentially lead to contamination of groundwater. Any accidental spills will be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil, in accordance with NRM requirements.

During mining, mobile and stationary machinery including excavators, cranes, trucks and other vehicles will be required. There is potential for hydrocarbon contamination of the soil associated with leaks or spills from this machinery (or fuel storage areas for the maintenance of machinery). Dissolved and free-phase hydrocarbon may impact on the shallow aquifers underlying and down-gradient of areas of fuel spillage.

During mine operation, groundwater quality within aquifers surrounding the mine areas will continue to be suitable for the same purposes applicable during the pre-mining period. The groundwater quality within the aquifers surrounding the EIS study area will be monitored to ensure no marked deterioration in groundwater is occurring as a result of the proposed mining activities.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

8.1.3 Additional Potential Impacts

8.1.3.1 Reduced recharge

Compression and/or sealing of the ground surface associated with the construction of roads and building foundations and IMG infrastructure is not expected to greatly alter the permeability of strata immediately beneath the site and, as such, will not markedly reduce rainfall recharge of the underlying aquifers. Works will be limited in the vicinity of the Isaac River, further limiting potential impacts on the Quaternary alluvial aquifer.

8.1.3.2 Subsidence

Underground mining using the thick seam mining method (longwall top coal caving) will result in subsidence of the overlying strata in the mined-out areas behind the longwall, with fracturing extending from the extraction horizon toward the surface. This caving and subsidence can cause fractures and joints in the overlying strata. AGE (2002) state that following the passage of longwall panels and stabilisation of subsidence, fracturing in the bulk of the strata will generally close up, allowing strata permeability to return to near to the pre-mining levels. Within the tensile zone above and adjacent to the longwall panels the vertical and horizontal strata permeability will be markedly and permanently altered due to sub-surface fracturing. The vertical extent of these fractures is dependent on numerous factors, such as mine design, geological conditions, surface topography, and the distance between the mine workings and the ground surface and in the RHM is predicted to extend up to 10 metres above the mine workings (IMC 2011).

8.1.3.3 Gas removal

To allow safe underground mining of the coal, degassing of the coal seams in advance of mining is required. Methods of degassing the coal are currently being developed for the project, and are likely to include installation of gas drainage wells (vertical or surface to in-seam). The drilling and installation of gas drainage wells has the potential to impact on groundwater (through water quality mixing, gas migration (pathways if not sealed correctly), and resulting in composite potentiometric heads) by creating potential pathways for leakage between formations.

Standard gas drainage well construction techniques, including fully cased and grouted wells and undertaking cement bond logs, will minimise the potential for inter-aquifer transfer through the bore. The IMG water production dam, where groundwater removed during the IMG drainage will be temporarily stored en-route to the mine water management system, will be fully lined with an impermeable lining, removing the potential for seepage to groundwater.

Permanent subsurface structures such as building foundations and road embankments can impede shallow groundwater flows and cause localised groundwater restrictions and waterlogging due to the build-up of pressure in the up-gradient area. The project does not require extensive subsurface structures in the vicinity of the Isaac River and associated alluvial aquifer. Detailed design will need to assess the need for engineering solutions such as pressure head relief.

8.2 Potential Impacts Post Mining

The main features of the final landform after mining ceases will comprise partially to totally filled mine voids in the underground workings, and subsidence troughs on the surface.

As with the impacts during mining, the increased permeability and storage for groundwater in the goaf will remain after mining.

8.2.1 Impacts on Regional Groundwater Levels

The remnants of the mine void will collect and accumulate water from groundwater ingress through the walls and goaf of the final workings. There is also the potential for groundwater ingress to occur from surface through leakage down the ventilation shafts, the mine access drift, old exploration holes or abandoned bores. These pathways facilitate groundwater rebound post mining

Typically, the mine workings will fill up and groundwater levels recover over time. The groundwater modelling, which does not take account of these leakage sources, indicates that a lag effect will persist after groundwater extraction is stopped, with residual drawdown in the GMS persisting until 2068. The groundwater system will re-adjust to the new (altered and enhanced) aquifer conditions surrounding and within the mined area. Groundwater levels and piezometeric pressures within the regional aquifers will, over time, attain a new equilibrium level. This new equilibrium for the groundwater system will have a different potentiometric surface from that which was present pre-mining owing to the presence of the mined workings and the different hydrogeological parameters of the goaf.

A detailed study of groundwater level recovery within RHM has not been conducted as part of the EIS because the closure requirements for the GRM will have a significant impact on recharge to groundwater and the rate of groundwater recovery. Groundwater levels are expected to recover within RHM after closure during the period of continued operation of GRM (2040 to 2068), and further work will need to be undertaken throughout the GRM mine life to determine the hydrological regimes, and the expected water quality of the mine voids. It is considered that the groundwater levels will recover in RHM, over time, to the base of the GRB mine complex open pits. The GRB mine complex final voids will, based on size and climate conditions (evaporation exceeding rainfall), permanently alter groundwater flow patterns towards the GRB mine complex final voids.

8.2.2 Impacts on Groundwater Quality

A rise in the groundwater salinity within the RHM void may occur as a result of atmospheric weathering of the exposure of wall, roof and floor rock during mining. However as discussed in **Section 8.1.2**, any increase in groundwater salinity is expected to be minor compared to the natural salinity of the groundwater in the Permian formations. Current and previous geochemical analysis in the Moranbah Coal Measures lithology show that there is low acid generation potential, with the roof and floor strata having excess buffering capacity, thus there is a low risk that metals will be mobilised into the groundwater.

Post-mining water quality within all aquifers surrounding the EIS study area is expected to remain similar to pre-mining water quality.

8.3 Mitigation Measures for Potential Impacts

8.3.1 General Groundwater Monitoring Program

A network of groundwater monitoring bores were previously installed around the EIS study area as shown in **Figure 6-3**. Additional groundwater monitoring bores and vibrating wire piezometers (VWPs) were also installed by BMA in early 2012. Further groundwater monitoring bores are to be installed down-gradient of mine water and waste storage facilities with locations to be determined after finalisation of the site layout. Further monitoring will be undertaken prior to the commencement of mining of the RHM underground expansion option to enable the long term monitoring of groundwater levels and groundwater quality, as well as to provide data for updates of the groundwater model.

Routine monitoring during the mining operation will provide early warning of any variation in response of the groundwater system to that predicted. This will enable BMA to undertake mitigation measures to minimise impact on surrounding groundwater users and the environment, such as the implementation of make good measures. In addition, the groundwater monitoring will enable the identification of any cumulative groundwater level drawdown impacts as a consequence of other mining operations in the area.

The monitoring bores are required to be completed in accordance with the Minimum Construction Requirements for Water Bores in Australia (Land and Water Biodiversity Committee 2003), the Water Act and undertaken by a licensed water bore driller. They must be surveyed for elevation levels of ground surface and monitoring measurement point to allow future groundwater levels to be measured to a consistent, known, datum and allow groundwater sampling as required.

Groundwater level and quality monitoring will be undertaken regularly to enable the detection of seasonal fluctuations and any groundwater level or quality trends or impacts. In turn, the monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate potential groundwater impacts.

A groundwater monitoring network and program will be developed and implemented for the RHM underground expansion option to detect any marked change to ground water quality due to activities. This will be consistent with the current suitability of the groundwater for agricultural use (stock watering), limited domestic use, and any discharge to surface waters that may occur after significant wet weather events.

Prior to commencement of mining for the RHM underground expansion option, at least 12 groundwater monitoring events will be undertaken, evenly spread across wet and dry seasons for at least two years. The monitoring events will record:

- groundwater levels; and
- groundwater quality with analysis of the parameters: - pH, electrical conductivity (EC), total dissolved solids (TDS), major cations and anions, nutrients (total nitrogen, nitrous oxides, ammonia, phosphorous), selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc), and total petroleum hydrocarbons (for bores monitoring potential fuel spill / seepage sources).

In addition, continuous groundwater level monitoring will be conducted across at least two wet and dry seasons using vibrating wire piezometers automatically recording water levels at regular intervals.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

The background groundwater monitoring program will consist of 12 sampling events evenly spread over a two year period to determine background groundwater quality as far as practicable in order to determine groundwater contaminant and trigger limits for comparison to the EPP (Water) groundwater quality objectives for the Isaac River sub-catchment (zone 34) (as shown in **Table 6-3**)

On completion of monitoring, groundwater trigger levels, based on the 85th percentile value of groundwater quality results and groundwater contaminant limits based on the 99th percentile of groundwater quality results will be determined.

During mining operations, groundwater monitoring will continue, including:

- Monitored of groundwater levels in standpipe monitoring bores and VWPs.
- Groundwater quality sampling undertaken at least once very wet season and once every dry season with analysis of the parameters: - pH, EC, TDS, major cations and anions, nutrients, selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium and zinc), and total petroleum hydrocarbons (for bores monitoring potential seepage sources).
- Additional monitoring in one or more bores may be undertaken in the event of a significant spill of fuels or other contaminants with potential to cause groundwater contamination.
- Measurement of daily precipitation, evaporation, and gas drainage and mine dewatering volumes will be undertaken through operations.

Groundwater monitoring and sampling will be conducted by a suitably qualified and experienced professional in accordance with the current edition of the DERM Monitoring and Sampling Manual, or subsequent updated versions; and the AS/NZS 5667.11:1998 Australian/New Zealand Standard for water quality – sampling Part 11; guidance on sampling groundwater.

Monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate groundwater trends.

If groundwater quality results exceed trigger levels set out in the environmental authority, monitoring will be repeated within 60 days. If concentrations exceed trigger levels in the second sampling event then an investigation into cause, optimum response, and the potential for environmental harm must be conducted and mitigation measures developed and implemented to address the outcome of the investigation.

An annual review of the monitoring program will be conducted by a suitably qualified and experienced hydrogeologist. This annual review of the monitoring program will be conducted to evaluate the effectiveness of each monitoring location, to assess where new locations and modifications to the monitoring program may be needed, and to evaluate impacts that may be occurring. These data will, on a regular basis (no longer than three years), be used to validate model predictions.

Post-mining groundwater monitoring will be subject to detailed closure/relinquishment conditions. It is expected that during the operational phase of the project, the groundwater data collected for the region will be comprehensive enough to accurately predict the long term recovery of the aquifers. This will assist in the development and implementation of the closure strategy and the refinement of post-mining groundwater monitoring programs.

8.3.2 Impacts on Nearby Groundwater Users

While groundwater model predictions do not indicate any significant impacts on adjacent groundwater users, should a detrimental impact on landholder groundwater supplies be detected, and shown to be related to the project operations, then BMA will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alternate water supplies. To this end, BMA will update its groundwater census of bores on properties within the predicted drawdown cone prior to commencement of mining, and enter into make-good agreements with landholders specifying trigger levels and appropriate responses.

Regular groundwater monitoring will enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores. In turn, alternative water supplies can be put in place before supplies from relevant existing landholder bores are adversely affected. Options for alternate supplies include:

- installations of new pumps capable of extracting groundwater from greater depth within existing bores;
- deepening of existing bores;
- installation of a new bore at another location on the property; and / or
- provision of piped water sourced from the mine (i.e. surplus water from the gas depressurisation program, depending on quality).

The specific arrangements for affected properties will be discussed with each relevant landholder with a view to reaching a mutually acceptable agreement.

8.3.3 Seepage from Stockpiles and Surface Water Control Structures

Good environmental practice requires that reasonable effort be made to minimise seepage from stockpiles and surface water control structures wherever this may affect the groundwater system. All mine water storages will be constructed in accordance with the NRM (2002) dam guidelines. These guidelines include requirements for management of seepage from mine water storages.

The surface water runoff collection system from the MIA and CHPP will be managed as a non-release system with water stormwater returned to the mine water management system. Raw and product coal stockpiles will be contained within hardstand or compacted areas and drainage will be directed to the mine water management system.

Early detection of significant seepage will enable management of any potential problems. Potential seepage from the project surface water management system (such as the IMG water production dam for gas drainage works) will be regularly assessed through the installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential seepage sources. Management of surface water will include monitoring of water at selected locations for potential contaminants.

Installation of monitoring bores down-gradient of potential seepage sources is proposed to enable early detection of any leachate entering the shallow Quaternary alluvial or Tertiary sediment aquifers. The key indicator parameters of seepage will be monitored including (but not restricted to) standing water level, salinity (as TDS), dissolved metals, and major ions initially on a quarterly basis.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

In the unlikely event of groundwater impact, mitigation strategies will include some or all of the following measures (depending on the specific requirements):

- investigation of water management system integrity;
- removal of contaminant source and repair / redesign of any water management structures as required;
- installation of and pumping from, groundwater interception wells; and / or
- installation of and pumping from groundwater interception trenches.

8.3.4 Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage and handling will be designed to contain spills and procedures will be in place to minimise likelihood of spills and provide a rapid response in the event that spills occur. Spill kits and spill clean-up training will be available on site.

Installation and monitoring of the monitoring bore network on site, including down-gradient of all potential spill areas, will enable early detection of any contaminated seepage.

Further information on the prevention and management of spills is provided in the Red Hill Mining Lease EIS Section 5.4.

8.3.5 Installation of Gas Drainage Bores

Any gas drainage wells will be designed and constructed in accordance with industry standards, with the goal of maintaining hydraulic isolation between discrete water-bearing formations, and will therefore inherently mitigate the risk of gas migration into overlying aquifers and/or releases at the surface. In addition, the integrity of the wellhead and casing will be monitored as part of normal operations.

8.3.6 Closure and Post Closure

There are no specific groundwater management requirements in relation to closure and post closure. If significant groundwater drawdown has occurred, groundwater levels may continue to be monitored to track recovery.

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Glossary

ALLUVIUM - Sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.

ALLUVIUM AQUIFER - A deposit of detrital material - mostly sediment - formed by river, stream and floodplain processes that store and transmit water in spaces between sediments grains. Stored water can be extracted and used.

ANISOTROPY - The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

AQUICLUDE - A low-permeability unit that forms either the upper or lower boundary of a groundwater flow system.

AQUITARD – These are geologic units that are of low permeability. Aquitards usually form a layer in a geologic sequence. They may contain water, but would not yield reasonable volumes of water to bores or wells. An example of an aquitard would be a saturated clay layer that is overlying a saturated sandy aquifer.

AQUIFER - A geological structure of formation or part thereof, permeated with water or capable of- (a) being permeated permanently or intermittently with water; and (b) transmitting water.

AQUIFER, CONFINED - An aquifer that is overlain and underlain by impervious layers. The water level in bores tapping confined aquifers rises within the bore to a level above the top of the aquifer, and may result in an artesian or sub artesian bore. Confined aquifers tend to occur in the central and deeper parts of the Basin.

AQUIFER, PERCHED - Perched Aquifers occur in the upper catchments. They sit over a thick layer of clayey weathered sediments and have no connection to the fractured rock aquifers beneath the clay. This lack of connection means that their ecosystems are highly dependent on rainfall runoff, lateral subflow, from unconsolidated sediments overlying the clay or upstream flow contributions. These systems are more sensitive to surface water changes. Development of surface water resources or disruptions to subsurface flow will have the greatest impact on flora and fauna in this setting.

AQUIFER, SEMICONFINED - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

AQUIFER TEST - A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

AQUIFER, UNCONFINED - An aquifer which has the water table as its upper surface which may be recharged directly by infiltration from the groundwater surface.

AUSTRALIAN HEIGHT DATUM (AHD) - The Australian height datum, adopted by the National Mapping Council of Australia, for referencing a level or height back to a standard base level.

BORE (WELL) - Any bore, well or excavation or any artificially constructed or improved underground cavity used or to be used for the purpose of—(a) the interception, collection, storage or extraction of groundwater; or (b) groundwater observation or the collection of data concerning groundwater; or (c) the drainage or desalination of any land; or (d) in the case of a bore that does not form part of a septic tank system, the disposal of any matter below the surface of the ground; or (e) the recharge of an

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aquifer— but does not include a bore that is used solely for purposes other than those specified in paragraphs (a), (b) and (d).

BOUNDARY CONDITIONS - Specified Head (or Fixed or Constant Head). Refer to Dirichlet Condition (also known as First Type Boundary). Specified Flow. Refer to Neumann Condition (also known as Second Type Boundary). Head-dependent Flow. Refer to Cauchy Condition (also known as Third Type Boundary).

CAUCHY CONDITION - Also known as Head-dependent Flow or Third Type Boundary Condition. A boundary condition for a groundwater model where the relationship between the head and the flow at a boundary is specified, and the model computes the groundwater flux for the head conditions applying.

CALIBRATION - Calibration of a model is the process where parameters in the model are fine tuned to get the best possible match between actual and modelled data over a defined period.

CALIBRATION, INITIAL CONDITIONS - The initial hydrologic conditions for a flow system that are represented by its aquifer head distribution at some particular time corresponding to the antecedent hydrologic conditions in that system. Initial conditions provide a starting point for transient simulations.

CALIBRATION, STEADY STATE - The calibration of a model to a set of hydrologic conditions that represent (approximately) an equilibrium condition, with no accounting for aquifer storage changes.

CALIBRATION, TRANSIENT - The calibration of a model to hydrologic conditions that vary dynamically with time, including consideration of aquifer storage changes in the mathematical model.

COMPEXITY - The degree to which a model application resembles, or is designed to resemble, the physical hydrogeological system. A hierarchical classification of three main complexities in order of increasing complexity: Basic, Impact Assessment and Aquifer Simulator. Higher complexity models have a capability to provide for more complex simulations of hydrogeological process and/or address resource management issues more comprehensively. In this guide, the term complexity is used in preference to fidelity.

COMPLEXITY – Basic Model - With limited data availability and status of hydrogeological understanding, and possibly limited budgets, a Basic model could be suitable for preliminary quantitative assessment (rough calculations), or to guide a field program.

COMPLEXITY – Impact Assessment Model - More detailed assessments are possible with an Impact Assessment approach, which usually requires more data, better understanding, and greater resources for the study.

COMPLEXITY – Aquifer Simulator - An Aquifer Simulator is a high complexity representation of the groundwater system, suitable for predicting the response of a system to arbitrary changes in hydrogeological conditions.

CONCEPTUAL MODEL - A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and our hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.

CONE OF DEPRESSION - The radial decline of potentiometric levels or underground water levels around a point of water extraction from an aquifer.

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DARCY'S LAW - An empirical equation developed to compute the quantity of water flowing through an aquifer. Usually expressed as Q=kiA, where Q=flow, k=hydraulic conductivity, I=hydraulic gradient, A=aquifer cross-sectional area.

DEWATERING - Removing underground water for construction or other activity. It is often used as a safety measure in mining below the water table or as a preliminary step to development in an area

DIRICHLET CONDITION - Also known as a Specified, Fixed or Constant Head Boundary, or Third Type Boundary Condition. A boundary condition for a groundwater model where the head is known and specified at the boundary of the flow field, and the model computes the associated groundwater flow.

DRAWDOWN - Refers to a lowering of the surface that represents the level to which water will rise in cased bores. Natural drawdown may occur due to seasonal climatic changes. Groundwater pumping may also result in seasonal and long-term drawdown.

EXTRACTION - In relation to any bore includes withdrawing, taking, using or permitting the withdrawing, taking or using of water from that bore.

EVAPOTRANSPIRATION - The sum of evaporation and transpiration.

FINITE-DIFFERENCE MODEL - A particular kind of numerical model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

Gigalitre (GL) - A volumetric measure equal to one million kilolitres or one billion litres.

GROUNDWATER - (a) Water occurring naturally below ground level (whether in an aquifer or otherwise); or (b) water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works.

GROUNDWATER FLOW MODEL - An application of a mathematical model to represent a site-specific groundwater flow system.

GROUNDWATER-DEPENDENT ECOSYSTEMS (GDE) - Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater.

HETEROGENEOUS - A medium which consists of different (non-uniform) characteristics in different locations.

HOMOGENEOUS - A medium with identical (uniform) characteristics regardless of location.

HYDRAULIC CONDUCTANCE - A term which incorporates model geometry and hydraulic conductivity into a single value for simplification purposes. Controls rate of flow to or from a given model cell, river reach, etc.

HYDRAULIC CONDUCTIVITY - A measure of the ease of flow through a pore space or fractures. Hydraulic conductivity has units with dimensions of length per time (e.g. m/s, m/min, or m/d).

HYDRAULIC GRADIENT - Spatial variation in the effective elevation of water table and/or potentiometric level, which drives lateral flow of underground water.

HYDRAULICALLY LINKED - In relation to sub artesian water, means there is a direct connection between the sub artesian water and surface water to the extent that— (a) if the aquifer is full and surface water is removed, sub artesian water begins, within approximately 1 day, to flow to the

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surface, replacing the surface water removed; and (b) if the aquifer is not full, surface water begins, within approximately 1 day, to seep into the aquifer causing the water level in the aquifer to rise.

HYDROLOGIC EQUATION - An expression of the law of mass conservation for purposes of water budgets. It may be stated as inflow equals outflow plus or minus changes in storage.

INFILTRATION - The flow of water downward from the land surface into and through the upper soil layers.

ISOTROPY - The condition in which hydraulic properties of the aquifer are equal in all directions.

LEAKANCE - Controls vertical flow in a model between cells in adjacent layers. Equivalent to effective vertical hydraulic conductivity divided by the vertical distance between layer midpoints.

MODEL CALIBRATION - The process by which the independent variables (parameters) of a numerical model are adjusted, within realistic limits, to produce the best match between simulated and observed data (usually water-level values). This process involves refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve the desired degree of correspondence between the model simulations and observations of the groundwater flow system.

NEUMANN CONDITION - Also called a constant flux boundary. The boundary condition for a groundwater flow model where a flux across the boundary of the flow region is known and specified, and the model computes the associated aquifer head.

NON-UNIQUENESS - The principle that many different possible sets of model inputs can produce nearly identical computed aquifer head distributions for any given model.

NUMERICAL MODEL - Refers to a mathematical representation of a physical system intended to mimic the behaviour of a real system, allowing description about empirical data and prediction about untested states of the system.

OBSERVATION WELL - A non-pumping well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer.

PARSIMONY – A principle that states that the simplest explanation that explains the greatest number of observations is preferred to more complex explanations.

PIEZOMETER - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

PIEZOMETERIC SURFACE - Is a surface that represents the level to which groundwater will rise in cased bores intersecting confined aquifers.

POROSITY - The ratio of the aggregate volume of the spaces between grains or fractures in a rock, sediment or soil to its total volume, generally expressed as a percentage.

RECHARGE - Is the addition of water, usually by infiltration, to an aquifer.

RECHARGE BOUNDARY - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

9 Glossary

RESIDUAL - The difference between the computed and observed value of a variable at a specific time and location.

SATURATED ZONE - The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer.

SEDIMENTARY AQUIFERS - These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest groundwater resources.

SENSITIVITY ANALYSIS - The measurement of the uncertainty in a calibrated model as a function of uncertainty in estimates of aquifer parameters and boundary conditions.

SIMULATION - One complete execution of a groundwater modelling program, including input and output.

SPECIFIC CAPACITY - The ratio of the rate of discharge of water from the well to the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

SPECIFIC STORAGE - The amount of water per unit volume of a saturated formation that is expelled from storage due to compression of the mineral skeleton and the pore water.

SPECIFIC YIELD - The ratio of the volume of water that a given mass of saturated soil or rock will yield by gravity to the volume of that mass.

SPRING - A spring of water naturally rising to and flowing over the surface of land, but does not include the discharge of underground water directly into a watercourse, wetland, reservoir or other body of water.

STOCHASTIC - A description of a parameter or a process with random qualities. A stochastic parameter has a range of possible values, each with a defined probability. The outcome of a stochastic process is not known with certainty.

STORAGE COEFFICIENT (STORATIVITY) - Is the volume of water released or taken into storage per unit plan area of aquifer per unit change of head. It is a dimensionless value. In an unconfined aquifer, it is equal to specific yield.

SUB-ARTESIAN - Groundwater that does not rise above the surface of the ground when accessed by a bore and must be pumped to the surface.

TOPOGRAPHIC DIVIDE - The boundary between adjacent surface water boundaries. It is represented by a topographically high area.

TRANSMISSIVITY - Aquifer hydraulic parameter used to indicate the ease of groundwater flow through a metre width of aquifer section.

UNCERTAINTY ANALYSIS - The quantification of uncertainty in model results due to incomplete knowledge of model aquifer parameters, boundary conditions or stresses.

VADOSE ZONE - Also known as the zone of aeration and the unsaturated zone. The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe.

9 Glossary

The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched groundwater, may exist in the unsaturated zone.

VERIFICATION - A test of the integrity of a model by checking if its predictions reasonably match the observations of a reserved data set, deliberately excluded from consideration during calibration.

WATER BUDGET - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

WATER TABLE - Is the upper surface of an unconfined aquifer.

YIELD, SAFE - The amount of naturally occurring groundwater that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the native groundwater quality or creating an undesirable effect such as environmental damage. It cannot exceed the increase in recharge or leakage from adjacent strata plus the reduction in discharge that is due to the decline in head caused by pumping.

YIELD, SUSTAINABLE - An accepted working definition of sustainable yield is (Kalaitzis et al, 1999): “Sustainable yield is that proportion of the long term average annual recharge which can be extracted each year without causing unacceptable impacts on groundwater users or the environment”.

10

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Appendix B

Geotechnical Report

BYRNES GEOTECHNICAL

ACN 633 507 623

BMA

Estimating changes in hydraulic conductivity induced by BMA longwall and pillar extraction mines.

BMA-11 Groundwater report

Date: 29/04/2024

R.W.Seedsman

RPEQ

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FOR INTERNAL BHP REVIEW

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EXECUTIVE SUMMARY

As the PRCP process has evolved, it has become apparent that there is a need to provide hydraulic conductivity and porosity estimates of the ground impacted by longwall extraction.

This is a somewhat controversial environmental issue in the NSW coalfields with different opinions held by mining companies, consultants, regulators, and environmental groups. The NSW experiences are not directly transferable to the Bowen Basin as the Queensland mines are much shallower.

This report reviews the evolution of hydrogeological models related to longwall extraction and introduces a geotechnical model for overburden fracturing that can be used to estimate hydraulic conductivity and porosity.

Recommendations are made on how the model could be implemented in groundwater studies.

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1 INTRODUCTION

Longwall mining involves wide extraction faces such that the overburden progressively collapses – in fact progressive collapse is essential. One factor in the design of longwall mines has been the prevention of unacceptable large inflows of water into the workings. The recognised hazards included consideration of whether flow rates in access roadways present a hazard during evacuation of the work force, whether there is adequate pumping capacity to remove the water, or whether there is adequate storage volume down-dip.

It is important to note that there are relatively few cases in which the prediction of mine water inflow is critical. The empirical models appear to work well, although they were severely tested in the case of Crinum North and subsequently revised.

As the technology developments allowed wider extraction panels, concern has arisen about the possible impact longwalls may have on the gradual lowering of water tables in near-surface aquifers. The mining depths associated with these environmental impacts are much greater than those involved in the inflow hazard and there is no evidence that the outflows from the aquifers result in hazardous inflows to mines. In NSW the environmental issue relates to longwall extraction under water catchments and it was also a component of EIS studies into longwall mining in the Galilee Basin relative to the Great Artesian Basin.

Compared to NSW, the depths of the BMA mines are much less such that caving extends to the overburden collapses extends to the surface. The mine geometry s referred to as “supercritical” compared to the NSW cases which are “subcritical”. There has been relatively little attention paid to the hydrogeological conditions of supercritical geometries.

This document presents a brief outline of the evolution of hydrogeological models and makes recommendations on how they can be applied to the preparation of PRCP management plans.

2 AVAILABLE DATA AND OBSERVATIONS

Longwall mining results in fracturing of the rock mass as the overburden sequence collapses/caves into the void left by the extraction of the coal. This is an intrinsic part of the mining system. Observations of the results of the collapse are limited to the sides of the collapse at seam level and also the ground conditions if there has been subsequent mining in overlying seams. There have been examples where longwall caving has been exposed during subsequent surface mining of lower seams but any studies of these have not been presented in the public domain. The collapse of the overburden can extend to the surface and result in mining-induced subsidence which has been extensively studied.

2.1 Seam level

At seam level at Mandalong Mine in NSW, which is considered to be typical of most longwall mines, the majority of visible blocks in the collapsed volume (Figure 1) were smaller than 0.8m, with only one between 0.8 and 0.9m in size, and another with a mean size of around 1m (Seedsman et al, 2023).

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Figure 1Typical nature of caved material at seam level

2.2 Overmining

Evidence from multiseam mining when conducted in an ascending order is that the bedding layers and orientation are maintained despite the vertical subsidence they have experienced. Mark et al (2007) produced a prediction equation for successful multiseam mining which suggests mining can be conducted at about 10 m above the lower seam if there is acceptance of additional ground support, and at about 35 m above the lower seam without any additional ground support. The author has direct experience with overmining in Australia that is consistent with this prediction.

Mining at Cumnock Colliery in the Lower Pikes Gully seam 35 m above 2.8 m thick lower seam (Li and Cairns, 2000) identified a consistent feature referred to as a D zone (Figure 2). Within the zone, the strata were delaminated with some open vertical fractures with apertures of several millimetres; ribs had open joints and small vertical steps. It was found to be very predictable by extending lines at angles of α = 15° (fracture angle) and β = 35° (full collapse angle) from the goaf edge. There was no noticeable fracturing/displacement above the majority of the mined-out underlying Liddel Seam. Chekan and Listak (1993) discuss the possible presence of a mining-induced shear zone present in a similar location.

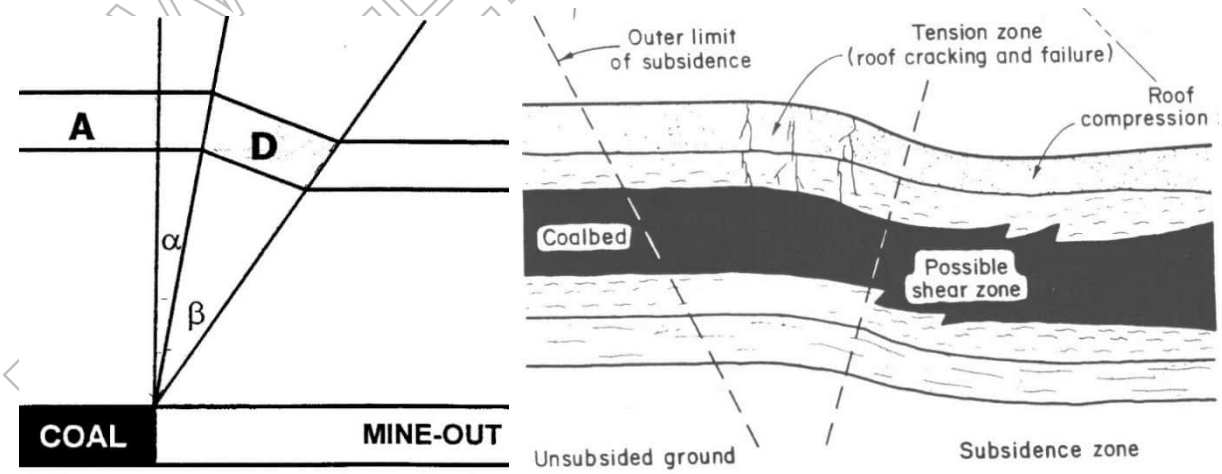

Figure 2 Mining conditions reported from overmining (left - Li and Cairns, 2000; right Chekan and Listak, 1993).

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2.3 Physical models

Physical models published by Whittaker and Reddish (1989) indicate there is negligible disruption to the layering during collapse (as experienced in overmining), negligible dilation along the centreline of the collapsed rock mass, there is a void at the top of the collapse that is about half the extraction thickness, and there is some dilation to the sides of the extraction consistent with D zone concept discussed).

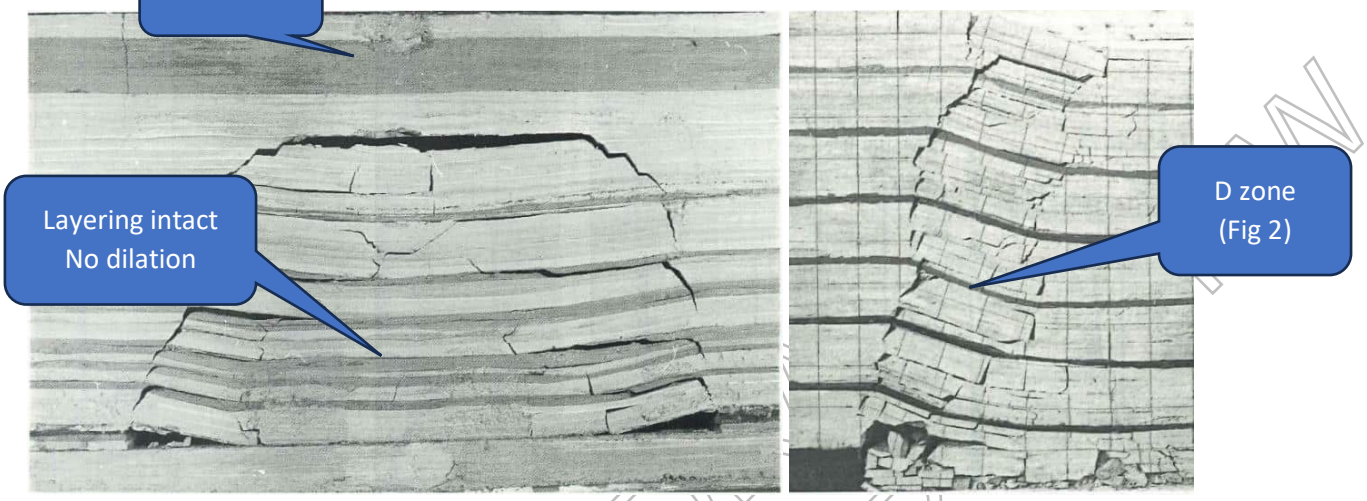

Figure 3 Physical models provide examples of collapse that are consistent with reported mining conditions.

Based on physical models such as Figure 3, identified continuous and discontinuous cracking with heights of A and B respectively , restricted to the sides of the cave. Discontinuous cracking reaches the surface when surface tensile strains are about 35 mm/m, and continuous cracking intersects the surface at 55 mm/m (Figure 4).

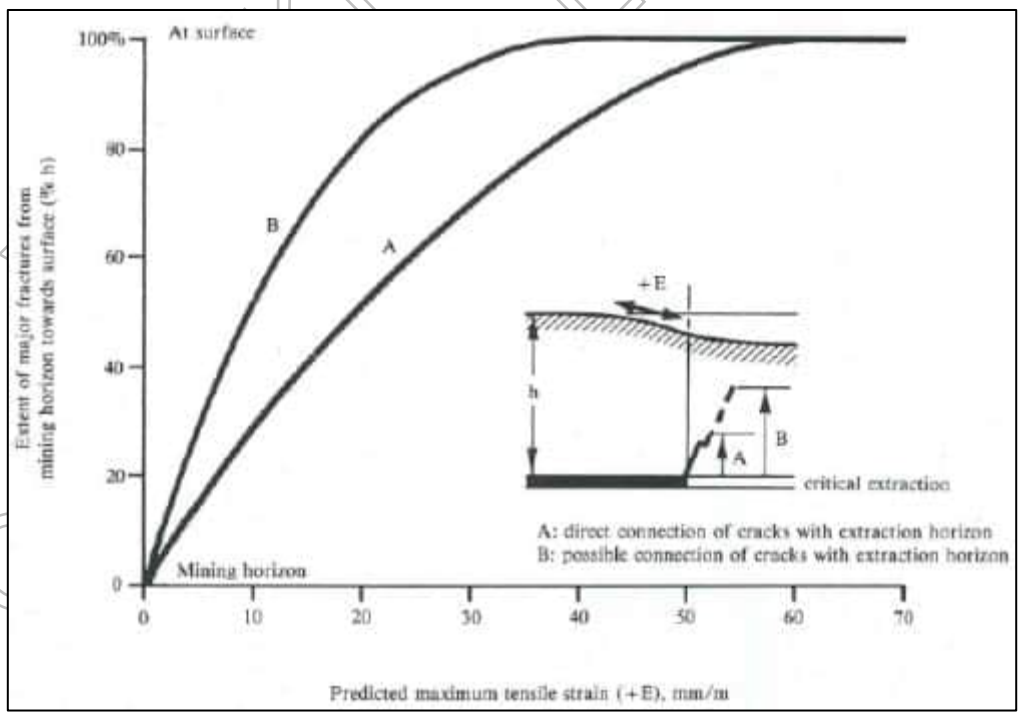

Figure 4 Zone A and Zone B fracturing in the Whittaker and Reddish model (note that the definition related to cracks at the edge of the extraction.

2.4 Surface subsidence

Surface subsidence data is typically presented in a normalised form with a smooth design line drawn to encompass most of the data (Figure 5). This can lead to the arguable interpretation that subsidence and hence overburden collapse is a smooth continuous process. An alternative interpretation of subsidence data invokes a step change between a subsidence/extraction thickness ratio of 0.2 to a Smax/T of 0.60 which also represents the change between subcritical to supercritical mine geometries. This step in the vertical movement would require that the underlying material has experienced little dilation between the layers as they collapsed – this is consistent with the overmining observations and also with physical models.

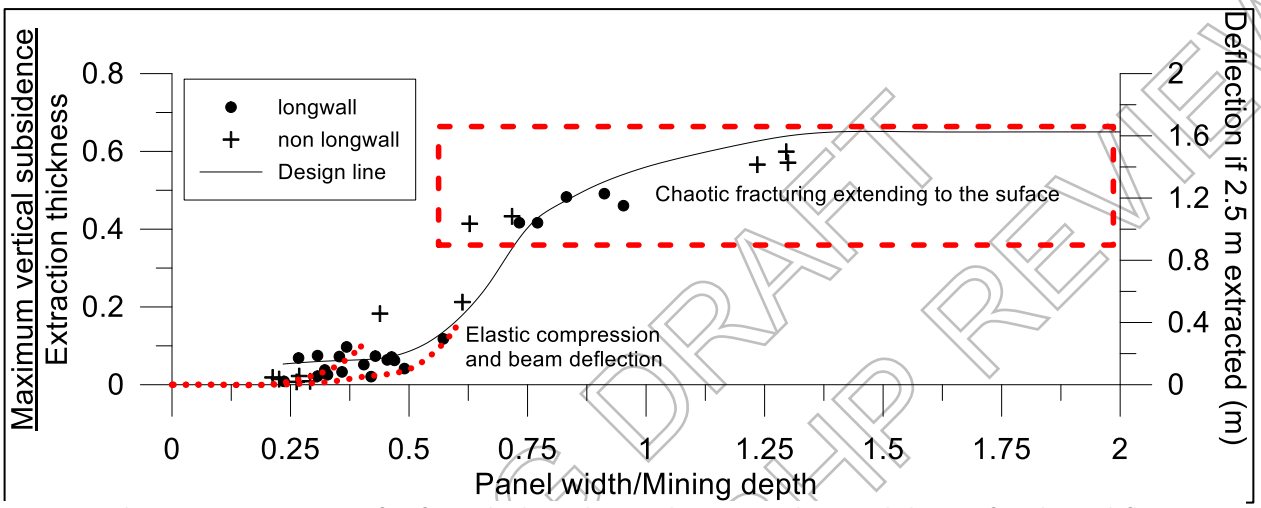

Figure 5 Alternative interpretation of surface subsidence data involving a step change in behaviour from beam deflection to chaotic fracturing.

3 MODELS FOR WATER INFLOWS

3.1 Kendorski models

Kendorski et al (1979) presented an assessment of the hazards of uncontrolled mine water inflows and this work was subsequently developed to produce one of the standard models for longwall collapse (Kendorski, 1993) which invokes four horizontal zones with their geometry defined as ratios of the extracted thickness (T). Other workers have used different terms for essentially the same zones. Progressing upwards from the mined coal seam, these zones are (Figure 6):

- Caved – the zone immediately above the mined coal, described as highly broken and chaotic with a thickness of between 2T to 10T.
- Fractured – described as having layering intact but some fracturing associated with the collapse of the rock mass, with a thickness of between 24T to 30T. Unacceptable flow into mine workings is possible through the fractured zone.
- Dilated – described as characterised by opening of the bedding but no collapse fracturing and with a thickness of up to 60 T. There is no increase in the vertical conductivity but there is an increase in horizontal conductivity.
- Constrained and Unaffected - where there is no bedding opening and no collapse fracturing.

Values for hydraulic conductivity were not provided.

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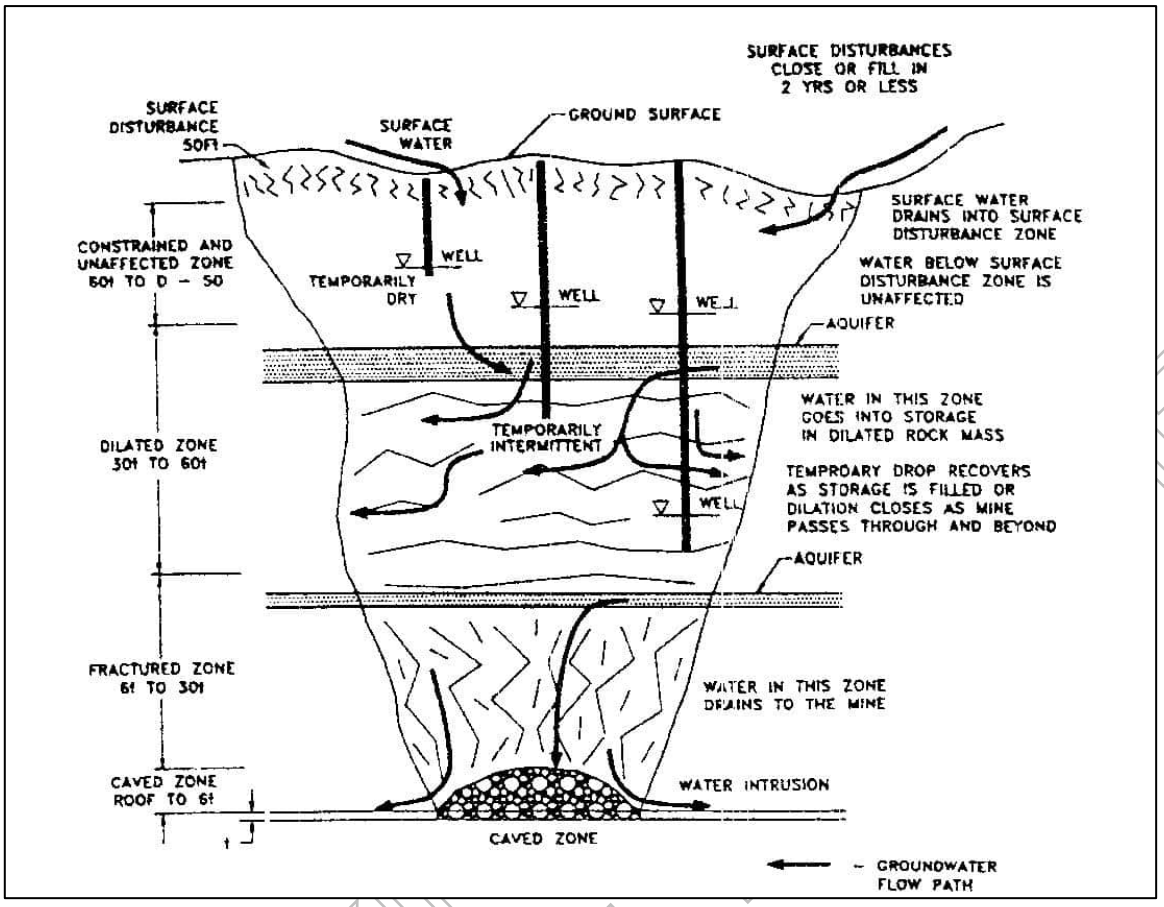

Figure 6 Kendorski 1993 inflow model

One difficulty with this model is that there is no reference to the width of the longwall extraction – recognising the rapid evolution of longwall mining in recent decades it is quite possible that the widths were in the order of 150 m. Another difficulty is the view that there is no increase in vertical conductivity in the dilated zone – perhaps this was in the context of hazardous mine water inflows and not meant to be an absolute statement.

3.2 Ditton and Merrick model

Ditton and Merrick (2014) developed equations to predict the heights based in panel width as well as extraction thickness specific to Australian mining conditions and geometries (Figure 7). They also extended the concept from rib-side cracking to zones across the full extraction to mirror the Kendorski model.

Zone A is referred to as the Continuous Fracture Zone, with continuous relating to connected fractures to the extraction level. The definition does not highlight the location of the continuous fractures being at the sides of the cave. For a 340 m wide face and 5 m extraction, the central prediction for Zone A only extends to the surface for depths less than 120 m (Figure 7).

Zone B is referred to as Discontinuous Fracture Zone. In a consulting report Ditton stated that: "*Overall the majority of the B Zone is considered to be a "constrained dilated" strata zone, with low connectivity potential to the mine workings. The B Zone therefore represents a sub-surface fracturing zone that causes only minor groundwater system disturbance*." For a 340 m wide face,

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Zone B is present at the surface for depths in excess of 120 m for the central prediction of Zone A or at depth in excess of 170 m for the upper bound prediction of Zone A.

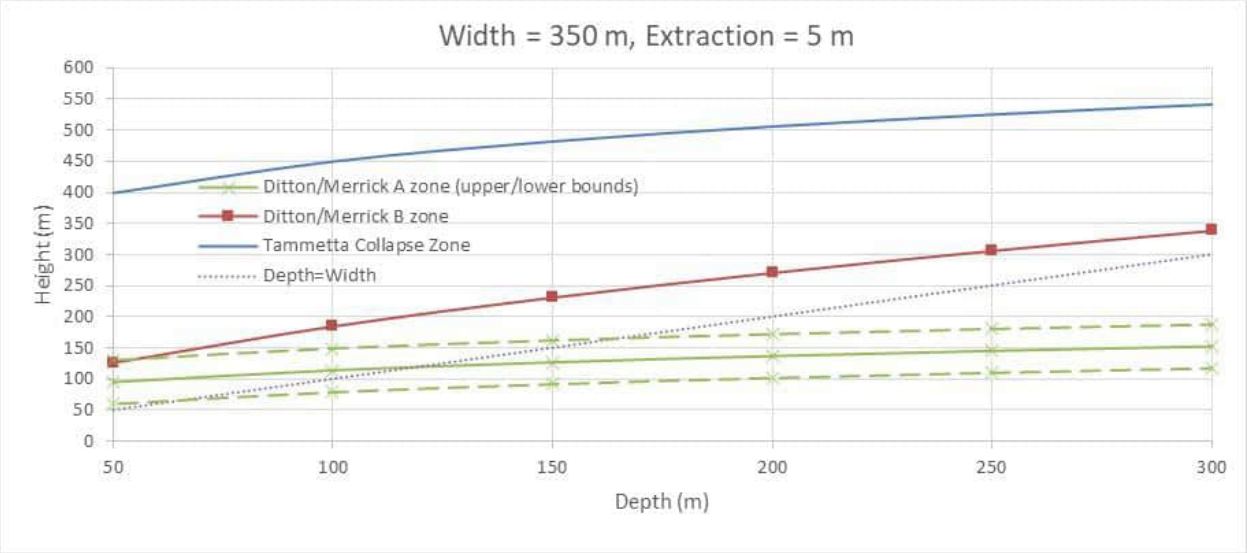

Figure 7 Ditton/Merrick and Tammetta zones

Specific hydraulic conductivity values are not given allocated to the A and B zones.

The application of the Ditton and Merrick method is assessed to be valid for the prediction of mine water inflows. Its application to environmental assessments has been questioned, probably in the context of what is "minor groundwater disturbance". For a 340 m wide face, the prediction of Zone B conditions at depth in excess of 120m/170m may be at odds with the likely surface subsidence of about 3.5 m indicating chaotic collapse extending to the surface.

3.3 Strata Control Technology model

The ACARP report (SCT 2008) used the FLAC numerical program along with in-house developed FISH codes to examine mine water inflows. FLAC is a continuum code which, by definition, does not consider dilation of fractures. The method is reported to simulate rock failure and hence fracturing and then provide a fracture aperture with a width equal to the non-elastic deformation assuming 1 fracture per element in the model: these widths are then used to calculate conductivity using standard fracture flow equations. Details of the method, including the size of each element, have not been published and hence are not subject to peer review.

The upper diagram in Figure 8 presents an example of the predicted hydraulic conductivity and it is noted that the patterns of conductivity, which are a function of the fracturing, have little resemblance to the physical models. The fracture models are not consistent with the reported ground conditions during overmining.

SCT (2008) also includes a cross plot of mining depth, vertical subsidence and average overburden conductivity. This average conductivity value relates to the average over a vertical profile, presumably at the centreline of the extraction – how it relates to the conductivity in a horizontal plane is not provided noting that the minimum conductivity in a horizontal plane would control inflows from the surface.

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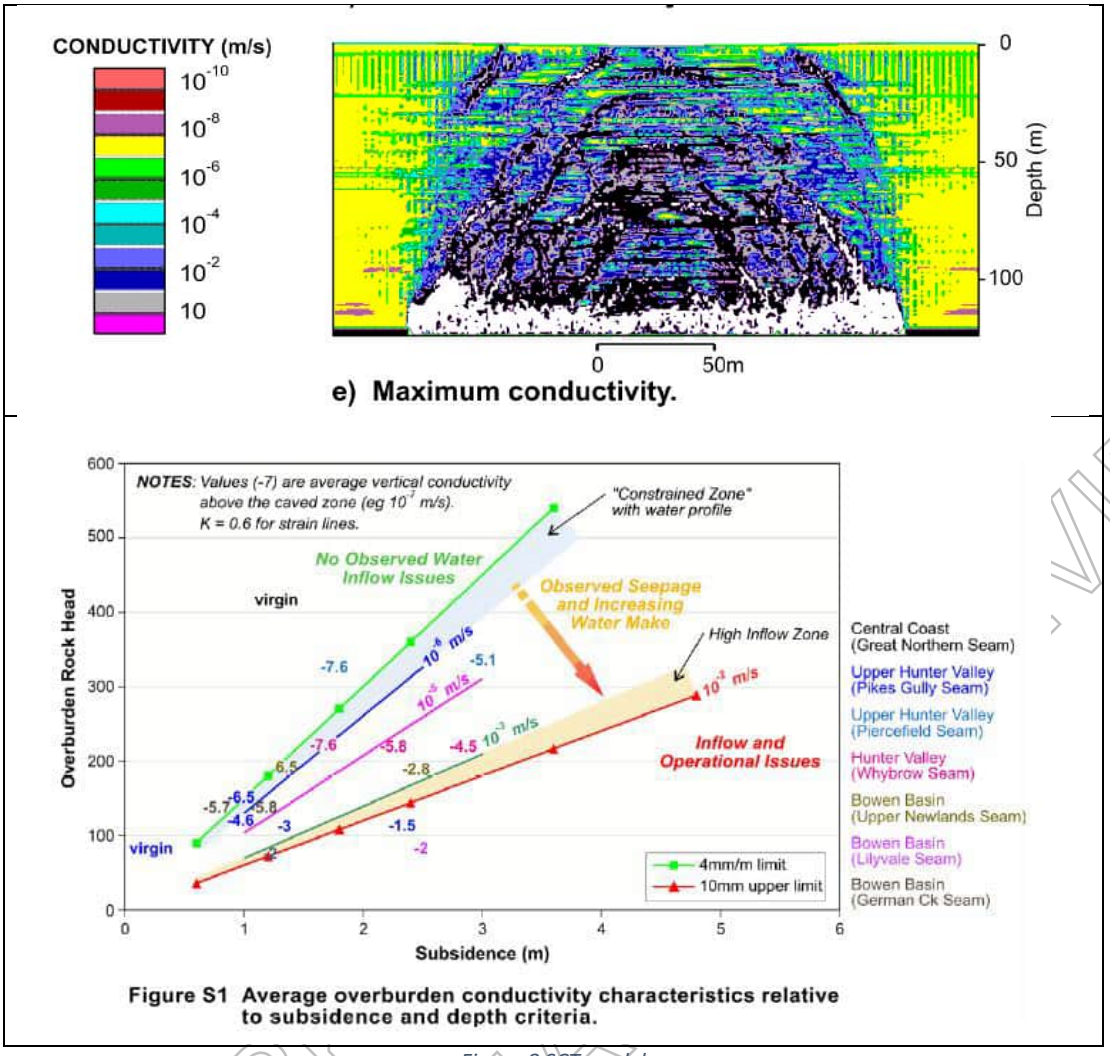

Figure 8 SCT model

4 MODELS FOR SHALLOW GROUNDWATER IMPACT

4.1 Tammetta model

Tammetta (2012) was primarily concerned with the impact of longwall on shallow ground water resources (Figure 9). His work was based on the interpretation of piezometer data to indicate the zone of complete groundwater drainage (unsaturated) which he refers to as the "Collapsed Zone". The maintenance of instrumentation, in particular cabling, is a challenge when differential movements in the caving overburden could be in the order of 1-2 m. The possibility of loss of signal due to cable breakage instead of a drop in the standing water level was not considered. We have concerns about the integrity of the data base that was utilised. The predictive equation for the height of a parabolic-shaped collapsed zone with complete drainage is independent of the overburden geology. The predicted height of his collapsed zone is significantly greater than that for Ditton/Merrick's Zone B (Figure 7) and in all cases implies connection to the surface for a 340 m wide longwall for all depths considered.

Tammetta (2013) provides empirical data on hydraulic conductivity from lugeon testing in boreholes. He presents data that indicate a 2 orders of magnitude increase down the panel centreline within the upper portion of the collapsed zone, and 1 order of magnitude above the collapse zone. There are no data for the lower portion of the collapsed zone but he extrapolates very high values.

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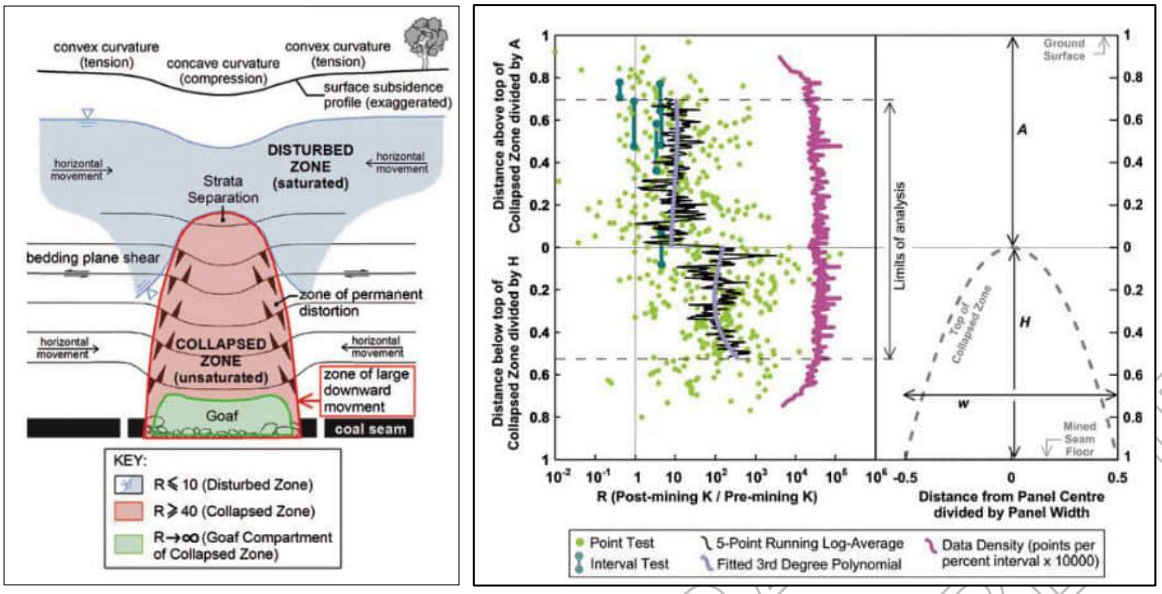

Figure 9 Tammetta's model for the extent and hydraulic conductivity in the Collapsed Zone.

The essential difference is that the Tammetta model allows the prediction of drainage path from the surface to the mine workings over a much greater range of depths compared to the Kendorski and Ditton/Merrick models. The hydraulic conductivity proposed by Tammetta is sufficient to impact shallow groundwater users but not present an inflow hazard to the underground mine.

The conceptual caving model presented in Galvin (2016) combines the Kendorski model with the zones limited by angles of draw with a derivative of the Tammetta collapsed zone within the fractured zone. Kendorski dilated zone is renamed as the constrained zone.

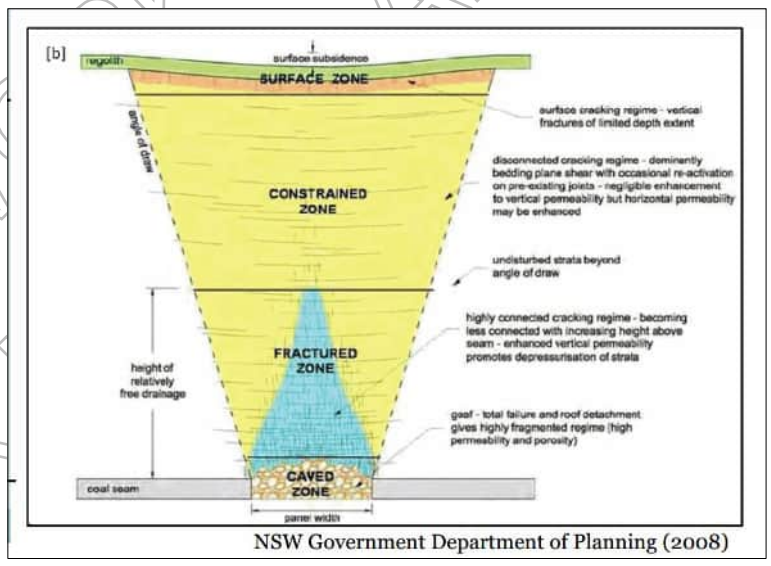

Figure 10 The Mackie conceptual model (Galvin, 2016)

4.2 CSIRO models

In a number of ACARP reports, CSIRO has developed a set of complex DEM (Discrete Element Method), PFC (Particle Flow Code) and finite element simulations to estimate hydraulic conductivity. DEM and PFC offer the possibility of specifically considering apertures which are then imported into

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a finite element code to assess hydraulic conductivity. The resulting fracture models are similar to the SCT models (Figure 11) and hence inconsistent with the observed mining conditions and the physical models. The results are presented in terms of changes in the permeability (which is the same as changes in hydraulic conductivity) and show extreme variation – up to 5 orders of magnitude at some depths.

The same limitations for application to mine closure studies are present – not readily accessible, possibly not representative of actual mine conditions, and lack of precision in terms of predicted hydraulic conductivity.

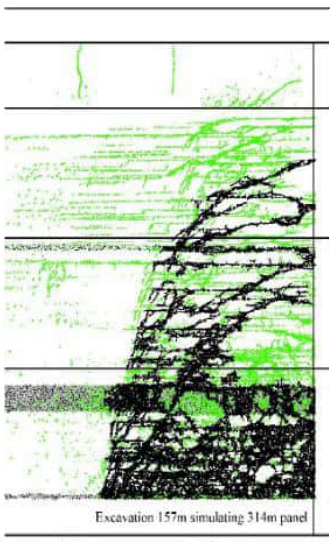

Figure 1 Fractures connected to mine workin
along the panel width with symmetry on the

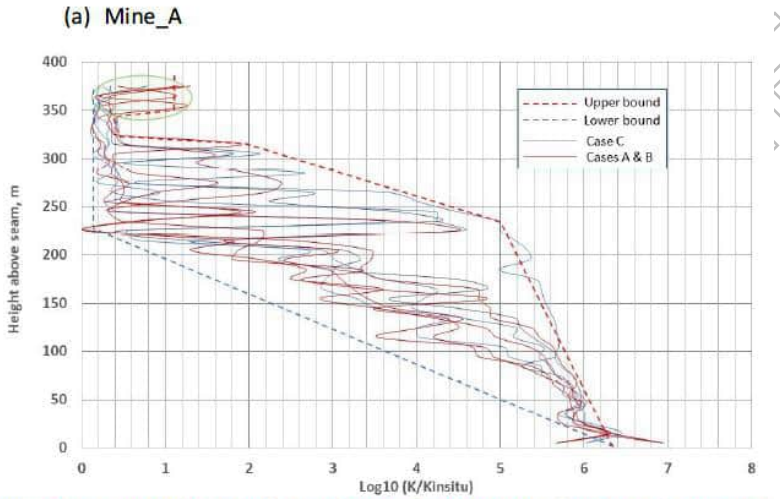

Figure S1 Estimated permeability changes for Mine_A; also plotted are propo
bound vertical permeability change curves.

Figure 11 CSIRO model

5 GEOTECHNICAL MODEL

5.1 Background

The previous 2 sections of this report outline some of the weaknesses of the available empirical models. In this context, the comment by Gavin (2017)[1]

> *The authors of the five reports relevant to this summary document are consistent in their advice that neither the Tammetta equation nor the Ditton equation for the height of free drainage is robust because neither properly and adequately accounts for geology, the mechanics of rock behaviour and time dependent hydrogeology processes. This has implications for the construction and calibration of some numerical models which have found application to Dendrobium Mine and, hence, to the reliability of predictions based on these models. Models may need to be updated and rerun.*

In the past 2 decades Crinum Mine conducted longwalling under a laterally extensive aquifer and as a result of intensive monitoring of ground levels and mine pump outs was able to supply key data to test the predictions of the available empirical models. An alternative model has been developed and reported in 3 peer-reviewed technical papers.

[1] Galvin and Associates Pty Ltd. 2017. Summary and explanation of height of fracturing issues at Dendrobium Mine. Report for NSW Department of Planning and Environment. Report No, 1716-11/1b.

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5.2 Inflows to Crinum Mine

Seedsman (2019) analysed several years of mine pump-out data for a shallow longwall mine in the Bowen Basin (Crinum North) that was located under a columnar-jointed basalt aquifer that was recharged three times by rainfall (Figure 12.

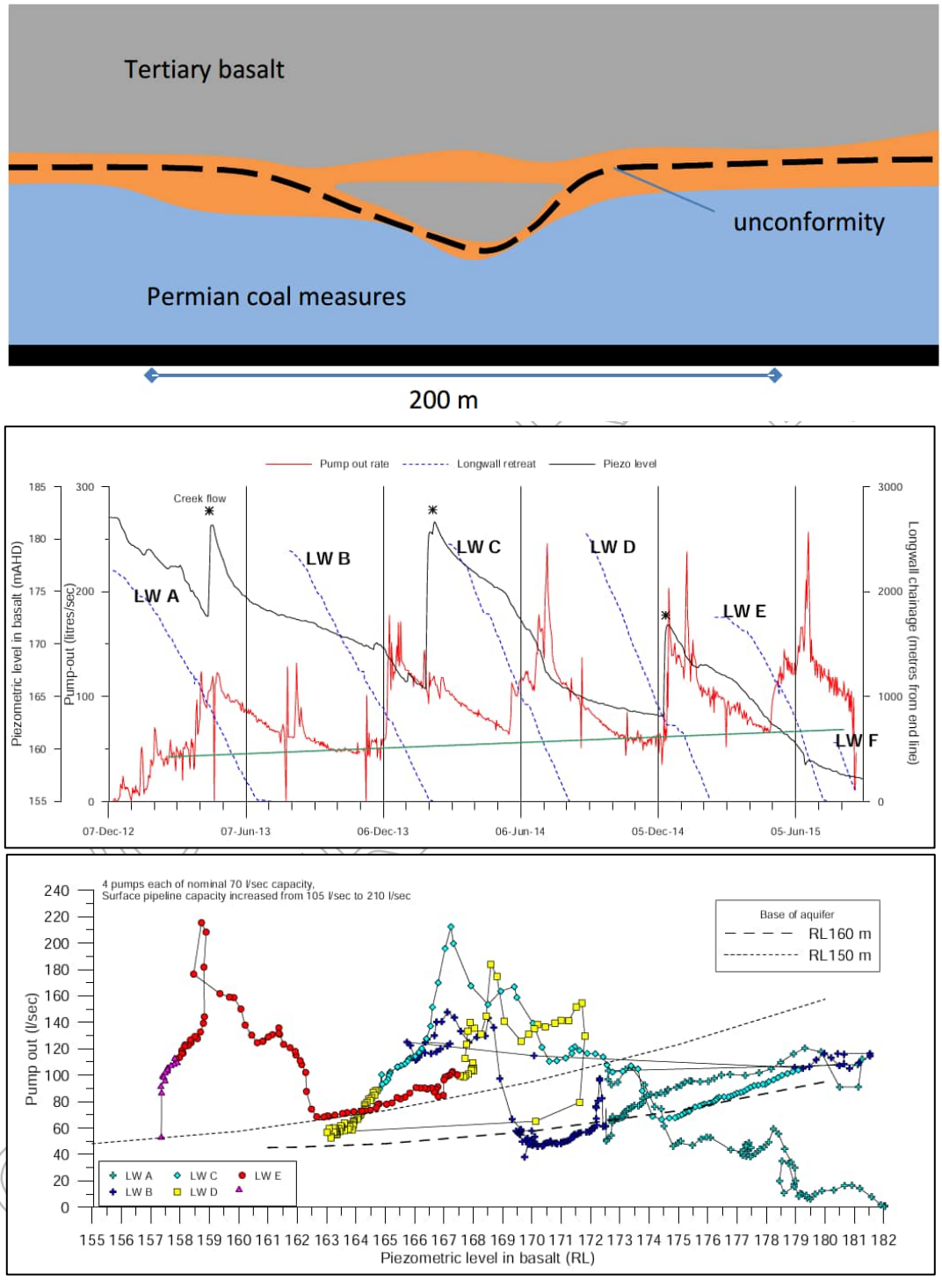

Figure 12 Crinum North: top is geological cross section at natural scale, middle are trends in pump out rates (black line), longwall retreat (dashed blue line), and groundwater level (black line), lower – cross plot of groundwater level and pumpout rate.

The pump-out rates did not increase with the progressive extraction of each longwall panel indicating that inflow was not related to cross-sectional area in a standard Darcian approach. Likewise, the peak pump-out rate did not correspond to the highest groundwater level. It was also noted that pump-outs were not required if the face was not moving, even when the basalt aquifer was recharged. Considering the data in the context of Dary flow, it was concluded that the inflow paths had different cross-sectional areas and hydraulic conductivity to those in the empirical models.

The proposed explanation was that inflow to the mine was related to a fracture connection to the aquifer that progressed with the retreating longwall face (Figure 13)– this was called the Enhanced Conductivity Zone (ECZ). The explanation also included the possibility of the material at the base of the collapse softening in the presence of water and then consolidating with a consequent major reduction in hydraulic conductivity – this was called the Potential Consolidation Zone (PCZ).

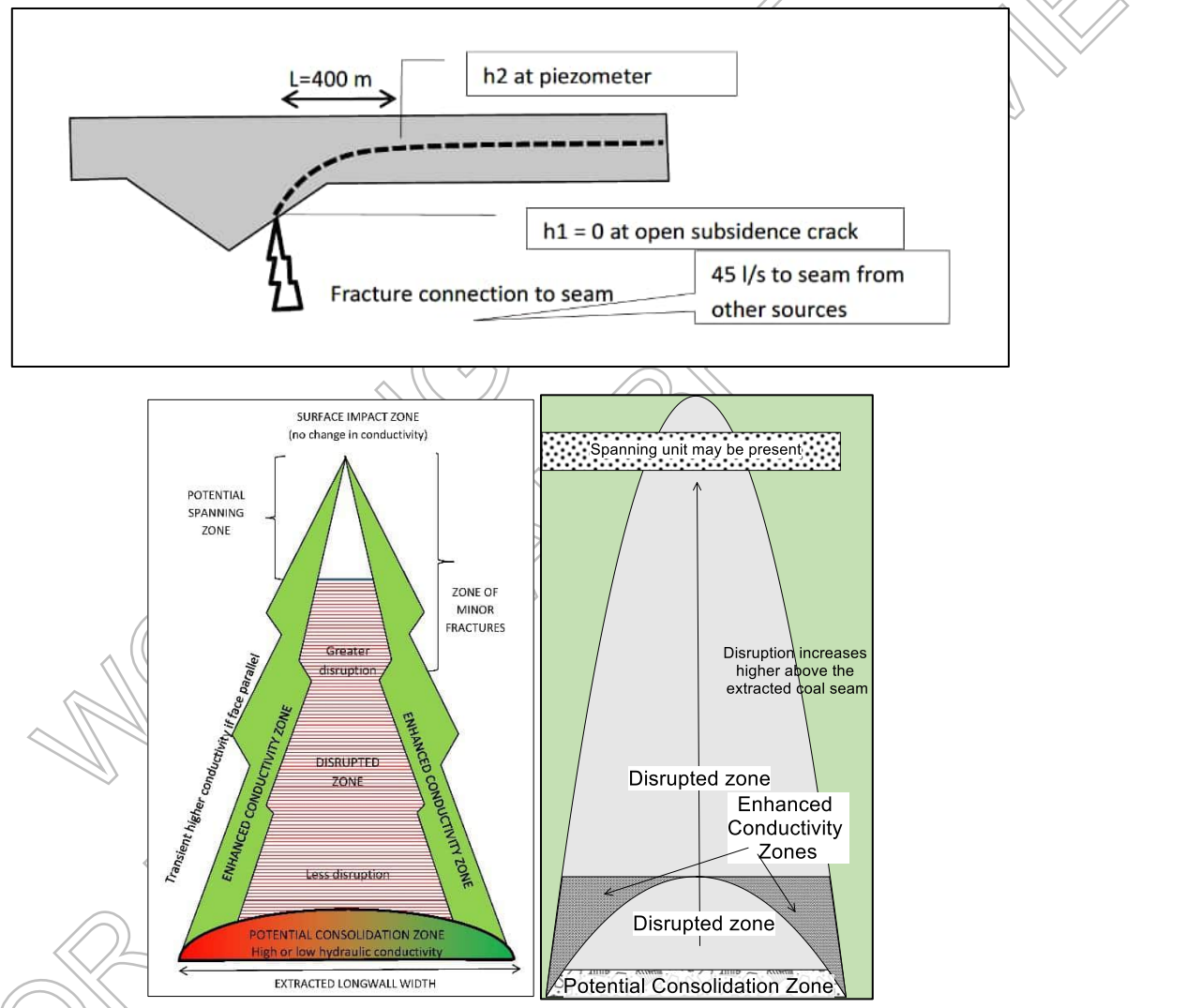

Figure 13 Evolution of the geotechnical model

5.3 Further development

These ideas were further developed in Seedsman (2021, 2023) with the following (Figure 13):

- The simple triangular-shape of the disrupted zone replaced by a parabolic shape following some numerical analysis of failure in bedding rock masses.

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- The height of the disrupted zone is a function of the average thickness of the bedded units in the overburden. The default height is two times the extraction width which is equivalent to the panel geometry that represents the step from subcritical to supercritical (Figure 5).
- The ECZ geometry is based on the D zone angles (Figure 2, with overall shape defined by two parabolas. The ECZ is the locus for high inflows so its height should be similar to heights of Kendorski fractured zone or Zone A.
- It was suggested that the limit of spanning deformation would be in the order of 400 mm. A corollary of this was that if the surface subsidence developed between adjacent chain pillars was in excess of this amount then there would be a fracture connection – albeit possibly tortuous – between the surface and the underground workings.

In research examining the possible use of abandoned longwall mines as lower reservoirs for pumped hydroelectric schemes, Seedsman et al (2023) focussed on the likely hydraulic properties of the various zones. Hydraulic conductivity within the ECZ and Disrupted zone was estimated using a simple geometric model (Figure 14) for the increase in length along a given horizontal line because of downward movement and assuming a given spacing of fractures (be they joints or mining induced). The model assumes no dilation at the centreline above the PCZ. The dilation is equally distributed between the fractures and conductivity is calculated based on laminar fracture flow with smooth interfaces. The predicted conductivity is isotropic. The parameters for the PCZ were derived from large scale permeameter tests. Figure 15 presents the data for conductivity and porosity.

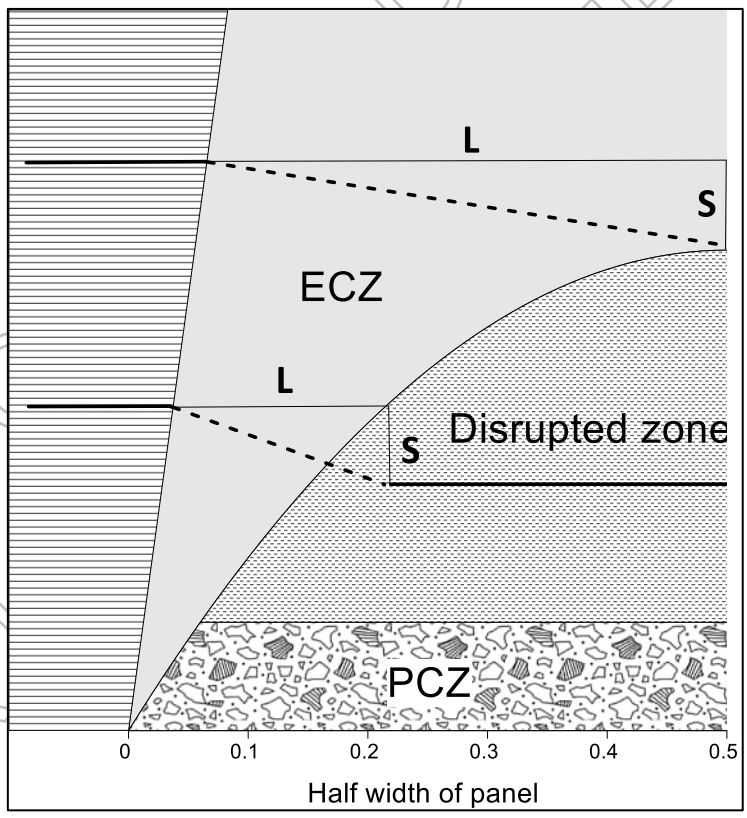

Figure 14 Basis of the geotechnical crack dilation model

The ECZ has conductivities in the order of 0.1-10 m/s with the higher values near the extraction. The values for the PCZ decrease progressively from the edge of the extraction in response to increasing consolidation associated by the progressive increase height of the goaf pile.

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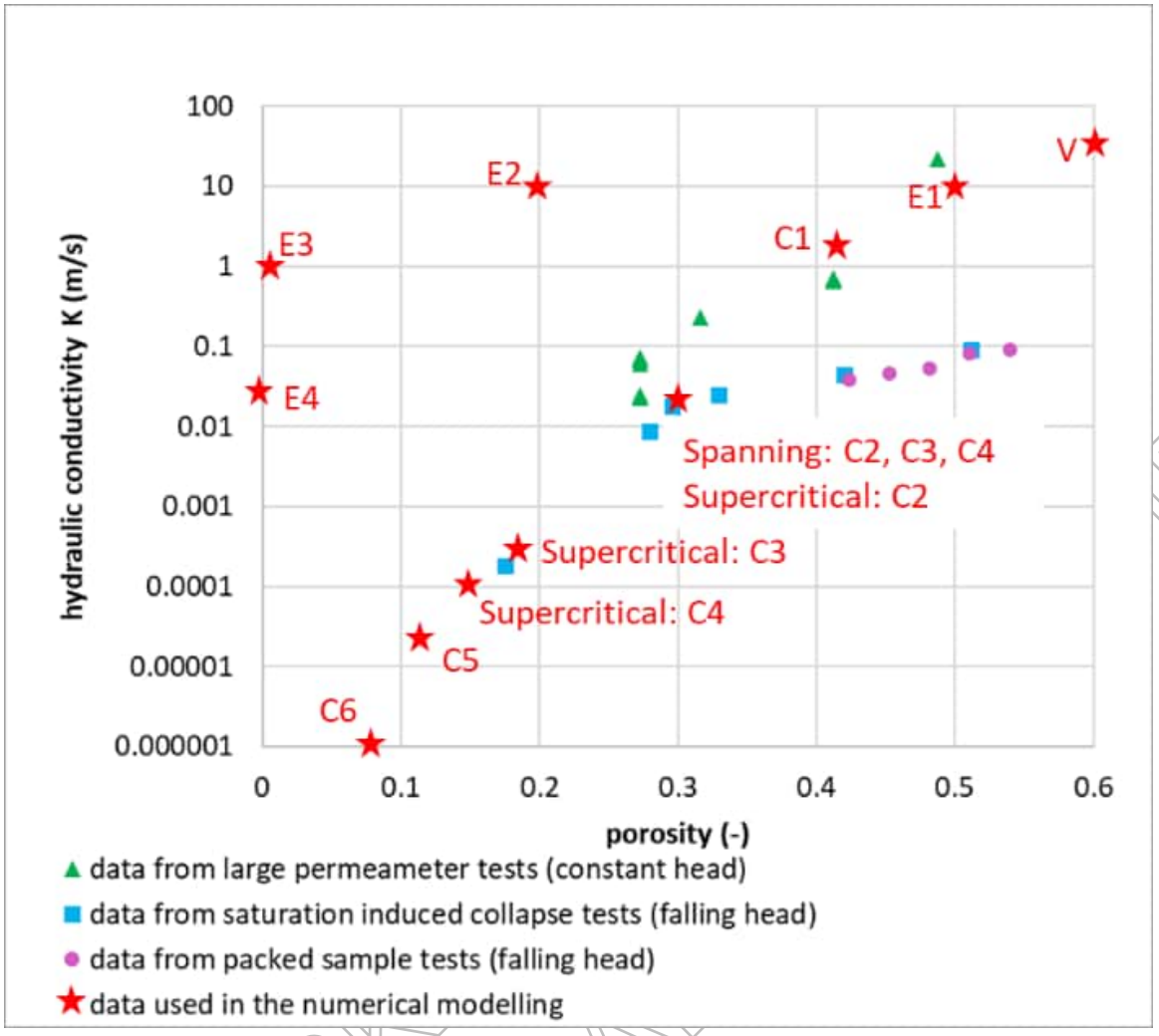

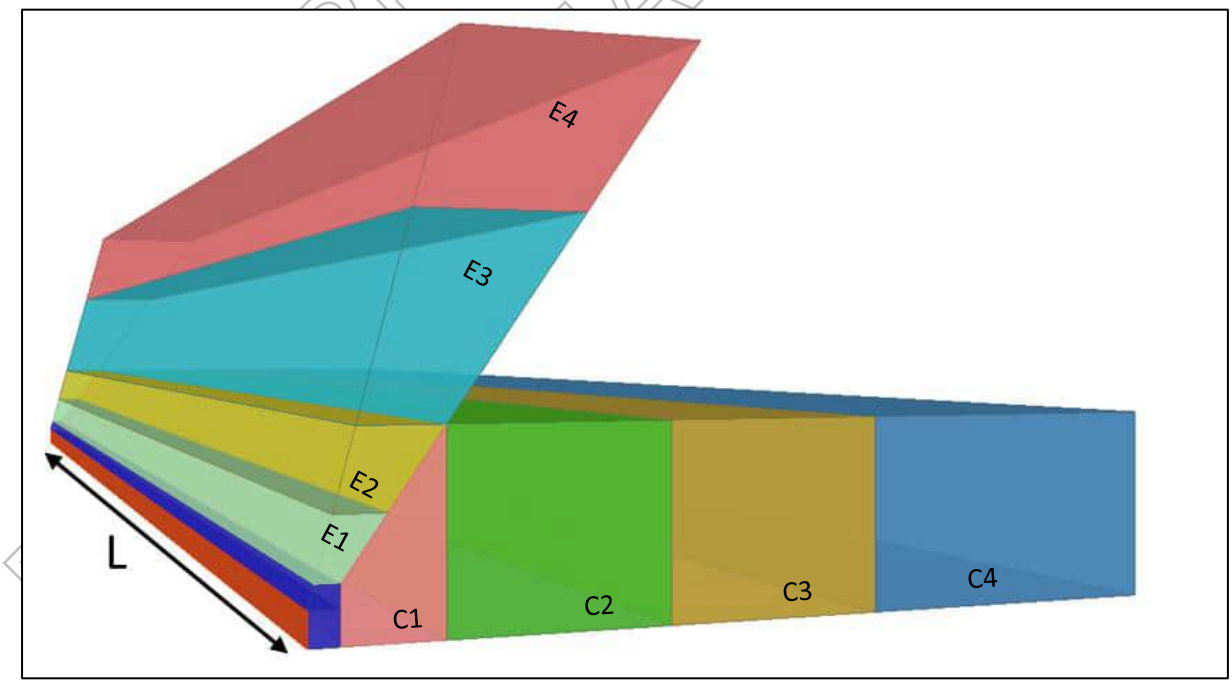

Figure 15 Estimates of the porosity and hydraulic conductivity of longwall goaf material (C1-C6 in the Potential Consolidation Zone, E1-E4 in the Enhanced Conductivity Zone, V is remnants of the initial access roadway).

6 PRCP PREDICTION

The Geotechnical model should be used as the basis for the prediction of hydraulic conductivity associated with the supercritical longwall geometry of BMA's longwall operations. It is important to note that there is no validation of the method available and it is difficult to imagine how it could be done as we are dealing with a large volume. Mine inflows are not useful in this context as they are most likely related to the ECZ and not the larger Disrupted zone and there is the problem of the low conductivity in the PCZ.

The only rock mass property used in the geotechnical model is the spacing of the joints – the rock mass is assumed to be a dilated fractured volume of rigid blocks. The geotechnical model is applicable to the Permian and Tertiary sequences but does not include the possible role of Quaternary and Recent alluvials at the surface.

The input variables to the geotechnical model are:

- Maximum vertical subsidence, or more precisely the difference in the maximum subsidence at /near the panel centreline relative to the subsidence above the chain pillars.
- The extraction width.
- The spacing of the cracks – these may be mining-induced or the natural geological joints. This is a highly uncertain parameter and its selection will require substantial judgement.

Output from the geotechnical Model includes the conductivity changes up to twice the excavation width – it can be sliced at any actual mining depth.

An example is presented in Figure 16 which also includes a sensitivity study on the choice of fracture spacing.

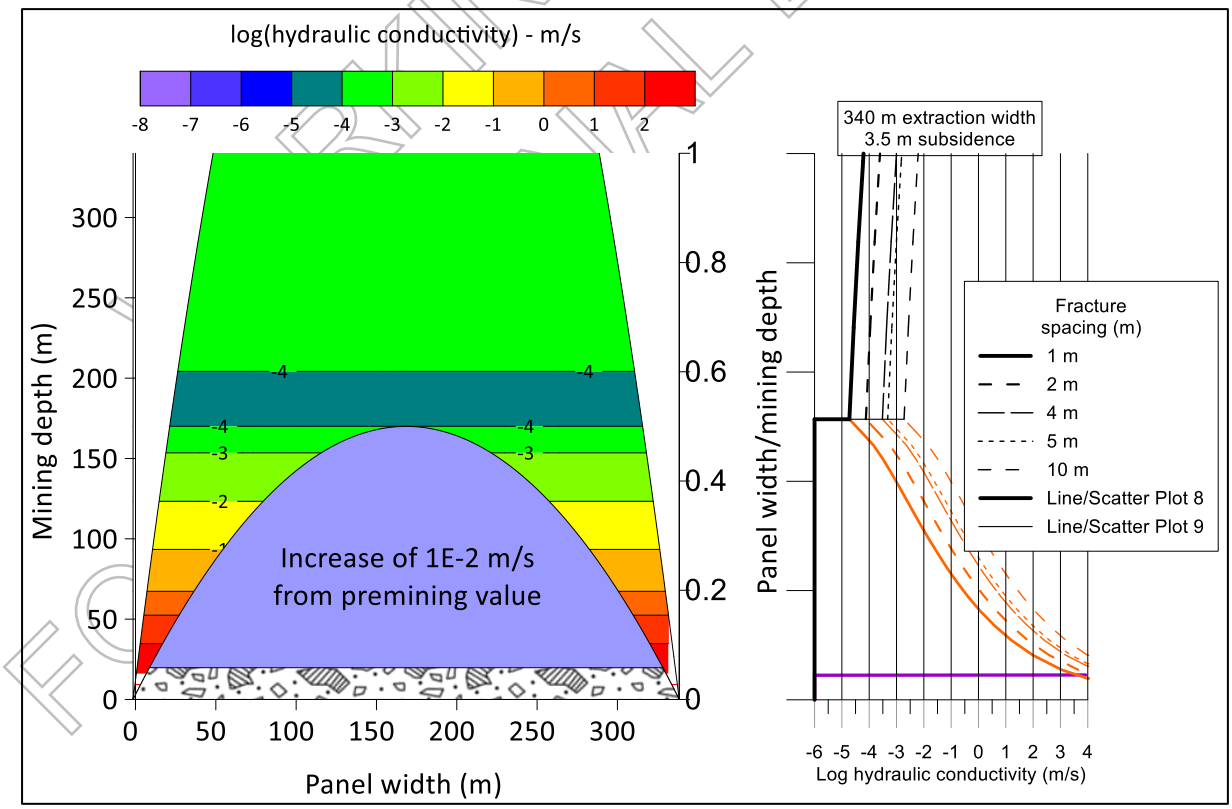

Figure 16 Example of hydraulic conductivity prediction for Broadmeadow with sensitivity to fracture spacing

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7 IMPLEMENTATION IN GROUNDWATER STUDIES

7.1 Overburden

It is noted that Byrnes Geotechnical have separately recommended intentional flooding of undergrounds to initiate any subsequent subsidence deformation as soon as possible in order to reduce geotechnical uncertainties.

The geotechnical model could be implemented in groundwater models as follows:

- The surface footprint of the mine should be the edge of the extraction – not the angle of draw that defines the extent of surface subsidence.
- The adopted hydraulic conductivities should be based on a crack spacing of 2 m. The horizontal and vertical conductivities should be equal.
- Porosity – Within in the Disrupted zone: at depths greater than half the panel width the porosity can be calculated as (seam thickness – maximum subsidence)/depth, At depth < half panel width – no mining-induced changes in porosity.
- Porosity – Within the ECZ

As mentioned in Section 6, there is no available validation of these suggestions.

7.2 Surface cracking

The technical literature consistently reports that there is no evidence that surface cracks are directly connected to the seam, but there will be an indirect connection via the disrupted zone. Site specific studies are recommended to provide data that can be used to confirm the currently available prediction tools.

Whether the cracks stay open will be a function of the surface lithology – sand, clay or rock. For soils the substrate will collapse over time, so the long term impact on the hydraulic conductivity is likely to be negligible.

There will be cracking at the surface where ever the induced tensile strains are in excess of about 5 mm/m. Figure 18 presents a typical subsidence cross line survey and shows how the tensile strains (positive values) develop near the edge of the extraction. The width of any rib side cracks is related to the induced tensile strains which themselves are related to the depth of mining and the extracted seam thickness. An upper bound estimate of the crack width can be derived from tensile strain and the peg spacing – all of the strain is accounted for by 1 crack. So for the example in Figure 18, the maximum tensile strain is 16.5 mm/m, indicating a crack width of 165 mm given that the survey pegs are at 10 m centres.

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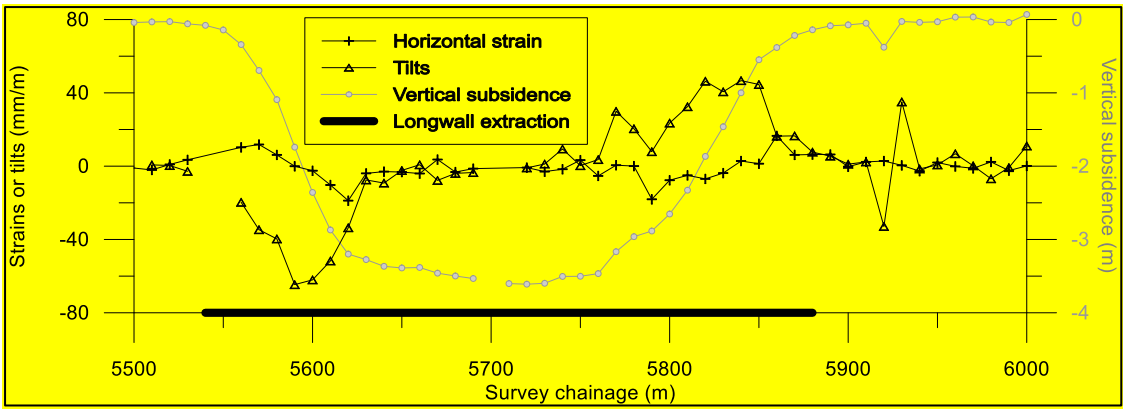

Figure 17 Typical subsidence survey cross line – survey pegs at 10 m centres.

The question of the depth of cracking has not been adequately studied or reported in the technical literature. For the USA mines studied, Kendowski suggested a surface zone that included temporary open fractures with a maximum thickness of 15 m (50 ft) but noted that the fractures did not extend through the full thickness of the zone and were only temporarily open; in 1993 he suggested the same depths and noted that the possibility of filling. It would appear that his case studies involved soils and friable materials at the surface – not rock.

Assuming rigid body movements, the survey data could be used to obtain an estimate of the depth of cracking – crack width/differential tilt either side of the crack. Referring to Figure 18, the maximum strain of 16.5 mm/m implies a crack width of 165 mm and this is associated with a differential tilt of 28 mm/m. The possible depth extent of the crack would be 5.9 m (0.165/0.028). Early application of this approach has given depths of up to 20 m for shallow longwall extraction.

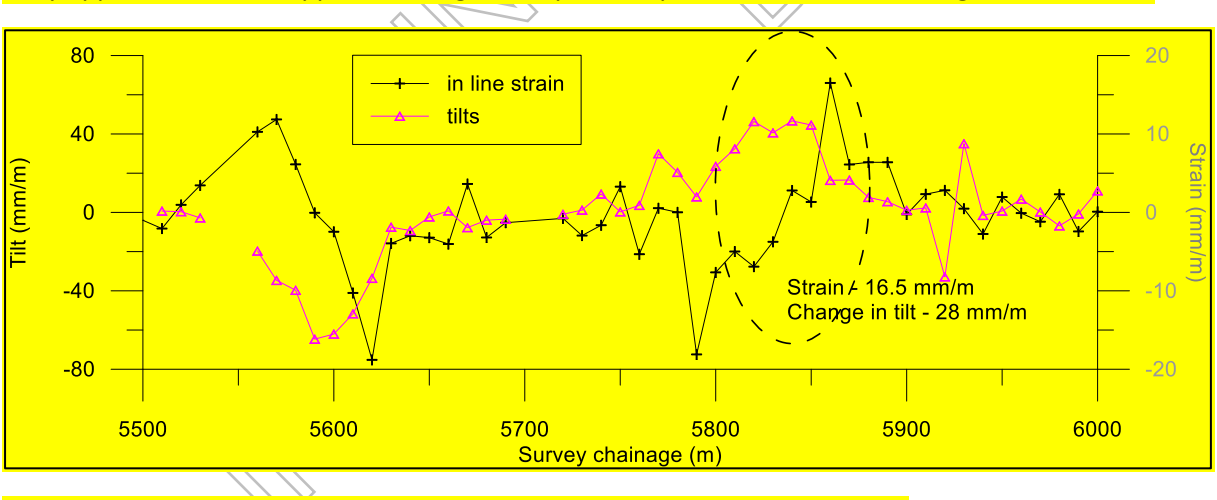

Figure 18 Detail of high strain and high tilt recorded on a subsidence cross line (180 m depth).

7.3 Risks and uncertainties

Any quantification will be challenged as nothing validated and not possible without case studies.

Can improve surface crack knowledge but unlikely to be material if there is a soil cover.

Inevitable that undergrounds will fill from the portal as bulkheads are not installed so surface infiltration may not be material.

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Appendix C

Calibration

Well	Easting	Northing	Obs (m)	Cal (m)	Obs_Cal	Res^2	Layer
DR-BH01	601292.419	7584122.067	226.6	2.22E+02	4.79	22.97285	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.14	26.40932	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.16	26.60496	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.18	26.87386	4
DR-BH01	601292.419	7584122.067	226.8	2.22E+02	5.11	26.07124	4
DR-BH01	601292.419	7584122.067	226.8	2.22E+02	5.13	26.35796	4
DR-BH01	601292.419	7584122.067	226.7	2.22E+02	5.05	25.5126	4
DR-BH01	601292.419	7584122.067	226.4	2.22E+02	4.81	23.14572	4
DR-BH01	601292.419	7584122.067	226.3	2.22E+02	4.74	22.44864	4
DR-BH01	601292.419	7584122.067	226.2	2.22E+02	4.66	21.68765	4
DR-BH01	601292.419	7584122.067	226.1	2.22E+02	4.60	21.1416	4
DR-BH02	601301.669	7584005.468	226.6	2.24E+02	2.92	8.503056	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.15	9.941409	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.17	10.0489	4
DR-BH02	601301.669	7584005.468	226.9	2.24E+02	3.29	10.83726	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.21	10.3041	4
DR-BH02	601301.669	7584005.468	226.7	2.24E+02	3.13	9.821956	4
DR-BH02	601301.669	7584005.468	226.6	2.24E+02	3.05	9.296401	4
DR-BH02	601301.669	7584005.468	226.4	2.23E+02	2.90	8.415801	4
DR-BH02	601301.669	7584005.468	226.2	2.23E+02	2.72	7.425625	4
DR-BH02	601301.669	7584005.468	226.1	2.23E+02	2.64	6.980164	4
DR-BH02	601301.669	7584005.468	225.9	2.23E+02	2.48	6.1504	4
DR-BH04	601335.479	7583739.129	174.6	1.85E+02	-10.12	102.3335	6
DR-BH04	601335.479	7583739.129	174.5	1.85E+02	-10.11	102.2728	6
DR-BH04	601335.479	7583739.129	174	1.84E+02	-10.19	103.8157	6
DR-BH04	601335.479	7583739.129	174.1	1.84E+02	-9.97	99.38096	6
DR-BH04	601335.479	7583739.129	174	1.84E+02	-10.00	99.90003	6
GN2480	603095.291	7607320.428	280.55	2.82E+02	-1.25	1.552516	1
GN2480	603095.291	7607320.428	280.54	2.82E+02	-1.21	1.466521	1
GN2481	603318.181	7607579.166	287.07	2.86E+02	1.24	1.545049	1
GN2481	603318.181	7607579.166	286.98	2.85E+02	1.61	2.601769	1
GN2482	603024.531	7608167.823	287.27	2.91E+02	-3.27	10.71253	1
GN2482	603024.531	7608167.823	287.09	2.89E+02	-1.85	3.433609	1
GRM_BH1	598515.474	7587336.538	249.5	2.48E+02	1.96	3.849444	1
GRM_BH1	598515.474	7587336.538	249	2.47E+02	1.81	3.286969	1
GRM_BH1	598515.474	7587336.538	248.9	2.47E+02	1.81	3.283344	1
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GRM_BH1	598515.474	7587336.538	248.9	2.47E+02	2.38	5.640625	1
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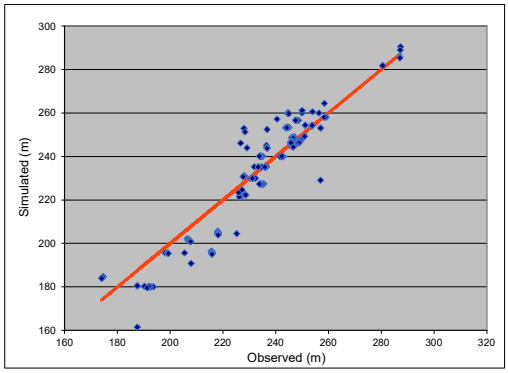
GRM_BH11	598003.996	7586750.999	240.5	2.57E+02	-16.71	279.3244	1
GRM_BH1A	598508.847	7587324.113	236.4	2.45E+02	-8.77	76.87782	4
GRM_BH1A	598508.847	7587324.113	236.6	2.44E+02	-7.59	57.62328	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.43	55.24949	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.26	52.63503	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.15	51.1368	4
GRM_BH2	598384.785	7587059.009	247.3	2.46E+02	1.27	1.610361	1
GRM_BH2	598384.785	7587059.009	246.9	2.46E+02	1.26	1.580049	1
GRM_BH2	598384.785	7587059.009	246.6	2.46E+02	1.06	1.1236	1
GRM_BH2	598384.785	7587059.009	246.5	2.45E+02	1.04	1.077444	1
GRM_BH2	598384.785	7587059.009	246.1	2.45E+02	0.89	0.793881	1
GRM_BH2	598384.785	7587059.009	246.1	2.45E+02	0.99	0.988036	1
GRM_BH2	598384.785	7587059.009	246	2.45E+02	0.95	0.908209	1
GRM_BH2	598384.785	7587059.009	246	2.45E+02	1.05	1.096209	1
GRM_BH2	598384.785	7587059.009	246.2	2.45E+02	1.32	1.750329	1
GRM_BH3	598539.067	7586975.078	247.7	2.46E+02	1.99	3.976036	1
GRM_BH3	598539.067	7586975.078	247.2	2.45E+02	1.90	3.625216	1
GRM_BH3	598539.067	7586975.078	246.9	2.45E+02	1.71	2.934369	1
GRM_BH3	598539.067	7586975.078	246.6	2.45E+02	1.50	2.238016	1
GRM_BH3	598539.067	7586975.078	246.4	2.45E+02	1.46	2.128681	1
GRM_BH3	598539.067	7586975.078	246.3	2.45E+02	1.47	2.146225	1
GRM_BH3	598539.067	7586975.078	246.2	2.45E+02	1.48	2.205225	1
GRM_BH3	598539.067	7586975.078	246.1	2.45E+02	1.44	2.079364	1
GRM_BH3	598539.067	7586975.078	246.2	2.45E+02	1.64	2.686321	1
GRM_BH3	598539.067	7586975.078	246.5	2.44E+02	2.02	4.0804	1
GRM_BH3	598539.067	7586975.078	246.6	2.44E+02	2.22	4.919524	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.25	39.0375	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.25	39.11252	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.26	39.21264	1
GRMMB1002	599903.255	7584138.951	205.4	1.96E+02	9.67	93.45089	14
GRMMB1002	599903.255	7584138.951	198	1.96E+02	2.28	5.193841	14
GRMMB1002	599903.255	7584138.951	198.9	1.96E+02	3.28	10.7584	14
GRMMB1002	599903.255	7584138.951	199.1	1.95E+02	3.60	12.9672	14
GRMMB1002	599903.255	7584138.951	199.2	1.95E+02	3.83	14.69956	14
GRM_MB_102_02	600178.596	7584579.081	187.5	1.81E+02	6.94	48.20525	12
GRM_MB_102_02	600178.596	7584579.081	187.5	1.81E+02	7.00	49	12
GRM_MB_103_02	600832.376	7584437.281	207.9	1.91E+02	17.06	291.0436	14
GRM_MB_104_01	596513.999	7592622	250	2.60E+02	-10.09	101.8888	1
GRM_MB_105_01	596871.731	7592581.368	250	2.61E+02	-11.20	125.5296	1
GRM_MB_119	597460	7587279.999	259	2.58E+02	0.90	0.813604	1
GRM_MB_119	597460	7587279.999	258.3	2.58E+02	0.21	0.045369	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.328329	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.327184	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.327184	1
GRM_MB_120_01	598018.995	7587281.999	253.5	2.54E+02	-0.77	0.599076	1
GRM_MB_120_01	598018.995	7587281.999	253.9	2.54E+02	-0.37	0.139876	1
GRM_MB_120_01	598018.995	7587281.999	253.8	2.54E+02	-0.47	0.224676	1

Mean Error	0.73
RMSE	8.66
SD	8.65
Head range	113.27
Scaled ME	0.64%
Scaled RMSE	7.6%
Scaled SD	7.6%
R^2	0.89

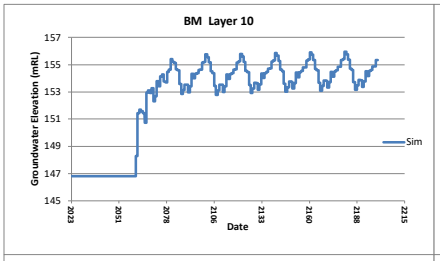


GRM_MB_120_01	598018.995	7587281.999	253.8	2.54E+02	-0.47	0.224676	1
GRM_MB_121	597466.001	7587106.999	244.5	2.60E+02	-15.46	239.0734	1
GRM_MB_121	597466.001	7587106.999	244.6	2.60E+02	-15.36	235.991	1
GRM_MB_121	597466.001	7587106.999	244.6	2.60E+02	-15.36	236.0525	1
GRM_MB_121	597466.001	7587106.999	244.7	2.60E+02	-15.26	232.9897	1
GRM_MB_121	597466.001	7587106.999	244.7	2.60E+02	-15.26	232.9897	1
GRM_MB_122_02	598212.995	7586970	245	2.53E+02	-8.44	71.30114	1
GRM_MB_122_02	598212.995	7586970	244.8	2.53E+02	-8.64	74.6496	1
GRM_MB_122_02	598212.995	7586970	244.5	2.53E+02	-8.93	79.79849	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.59509	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.59509	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.57702	1
GRM_MB_122_02	598212.995	7586970	244.5	2.53E+02	-8.93	79.78062	1
GRM_MB_123	598555.005	7586722.999	247.1	2.49E+02	-1.87	3.500641	1
GRM_MB_123	598555.005	7586722.999	246.8	2.49E+02	-2.12	4.477456	1
GRM_MB_123	598555.005	7586722.999	246.6	2.49E+02	-2.28	5.180176	1
GRM_MB_123	598555.005	7586722.999	246.2	2.49E+02	-2.55	6.477025	1
GRM_MB_123	598555.005	7586722.999	246.1	2.49E+02	-2.59	6.7081	1
GRM_MB_123	598555.005	7586722.999	246	2.49E+02	-2.66	7.091569	1
GRM_MB_123	598555.005	7586722.999	246.2	2.49E+02	-2.42	5.841889	1
GRM_MB_123	598555.005	7586722.999	246.4	2.49E+02	-2.18	4.743684	1
GRM_MB_123	598555.005	7586722.999	246.5	2.49E+02	-2.03	4.116841	1
GRM_MB_126	598346.468	7586716.581	246.2	2.47E+02	-0.91	0.824464	1
GRM_MB_126	598346.468	7586716.581	246	2.47E+02	-0.94	0.876096	1
GRM_MB_126	598346.468	7586716.581	245.8	2.47E+02	-0.89	0.793881	1
GRM_MB_126	598346.468	7586716.581	245.7	2.47E+02	-0.89	0.799236	1
GRM_MB_126	598346.468	7586716.581	245.7	2.47E+02	-0.84	0.703921	1
GRM_MB_126	598346.468	7586716.581	245.7	2.46E+02	-0.75	0.567009	1
GRM_MB_126	598346.468	7586716.581	245.7	2.46E+02	-0.68	0.4624	1
GRM_MB0202	598326.116	7591515.466	227.3	2.25E+02	2.53	6.416089	14
GRM_MB0303	603153.027	7582829.14	187.5	1.61E+02	26.02	676.9884	14
GRM_MB0402	606839.503	7599011.499	251.1	2.54E+02	-3.30	10.91642	1
GRM_MB0402	606839.503	7599011.499	251.1	2.54E+02	-3.30	10.91642	1
GRM_MB0403	606839.003	7599010.999	250.9	2.49E+02	1.59	2.515396	2
GRM_MB0403	606839.003	7599010.999	250.9	2.49E+02	1.59	2.515396	2
GRM_MB104	596513.999	7592622	256.3	2.60E+02	-3.80	14.46281	1
GW004A	604809	7590705	235	2.40E+02	-5.10	26.05082	1
GW004A	604809	7590705	234.5	2.40E+02	-5.62	31.55069	1
GW004A	604809	7590705	234.3	2.40E+02	-5.82	33.90733	1
GW004A	604809	7590705	234.2	2.40E+02	-5.93	35.21236	1
GW004A	604809	7590705	234.3	2.40E+02	-5.84	34.12896	1
GW004A	604809	7590705	234.2	2.40E+02	-5.95	35.3906	1
GW004A	604809	7590705	234	2.40E+02	-6.16	37.88403	1
GW004A	604809	7590705	233.8	2.40E+02	-6.36	40.43688	1
GW004B	604809	7590705	231.6	2.30E+02	1.60	2.56	2
GW004B	604809	7590705	230.5	2.30E+02	0.50	0.25	2
GW004B	604809	7590705	231.3	2.30E+02	1.30	1.69	2
GW004B	604809	7590705	231.3	2.30E+02	1.30	1.692601	2
GW004B	604809	7590705	232.3	2.30E+02	2.30	5.294601	2
GW004B	604809	7590705	231.2	2.30E+02	1.20	1.444804	2
GW004B	604809	7590705	231	2.30E+02	1.00	1.004004	2
GW004B	604809	7590705	231.1	2.30E+02	1.10	1.216609	2
GW007A	604966	7596895	257	2.53E+02	3.89	15.10877	1
GW007A	604966	7596895	256.9	2.53E+02	3.77	14.22044	1
GW007B	604966	7596895	242.6	2.40E+02	2.60	6.754801	2
GW007B	604966	7596895	242.6	2.40E+02	2.59	6.723649	2
GW007B	604966	7596895	242.6	2.40E+02	2.59	6.702921	2
GW007B	604966	7596895	242.7	2.40E+02	2.68	7.193124	2
GW007B	604966	7596895	242.6	2.40E+02	2.58	6.646084	2
GW007B	604966	7596895	242.6	2.40E+02	2.57	6.6049	2
GW007B	604966	7596895	241.6	2.40E+02	1.56	2.442969	2
GW007B	604966	7596895	242.6	2.40E+02	2.55	6.522916	2
GW007B	604966	7596895	242.3	2.40E+02	2.25	5.044516	2
MB20GRM05T	596804	7594820	258.4	2.64E+02	-6.05	36.56621	1
MB20GRM06A	599996.347	7582044.539	228	2.31E+02	-3.01	9.048064	1
MB20GRM06A	599996.347	7582044.539	228.1	2.31E+02	-2.89	8.3521	1
MB20GRM06A	599996.347	7582044.539	228.2	2.31E+02	-2.75	7.568001	1
MB20GRM06A	599996.347	7582044.539	228	2.31E+02	-2.91	8.444836	1
MB20GRM06A	599996.347	7582044.539	227.9	2.31E+02	-2.98	8.8804	1
MB20GRM06A	599996.347	7582044.539	227.9	2.31E+02	-2.96	8.785296	1
MB20GRM06A	599996.347	7582044.539	227.8	2.31E+02	-3.03	9.199089	1
MB20GRM06A	599996.347	7582044.539	227.7	2.31E+02	-3.11	9.665881	1
MB20GRM06A	599996.347	7582044.539	227.6	2.31E+02	-3.18	10.13786	1
MB20GRM07P	600004.181	7582053.168	218	2.06E+02	12.33	152.0536	4
MB20GRM07P	600004.181	7582053.168	218	2.06E+02	12.49	155.9252	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	12.90	166.4358	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	13.25	175.536	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	13.44	180.7411	4
MB20GRM07P	600004.181	7582053.168	225.2	2.05E+02	20.67	427.0836	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	13.89	192.9043	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	14.06	197.768	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	14.25	203.1195	4
MB20GRM08P	597829.347	7601264.539	253.9	2.61E+02	-6.67	44.4889	14
MB20GRM10T	598124.347	7593518.539	244.9	2.60E+02	-14.90	222.0994	14
MB20GRM11T	596740.566	7588713.433	227.9	2.53E+02	-25.08	629.0566	14
MB20GRM11T	596740.566	7588713.433	228.4	2.51E+02	-22.90	524.3184	14
MB20GRM12A	598157.658	7587227.806	244.7	2.53E+02	-8.70	75.75962	1
MB20GRM12A	598157.658	7587227.806	244.6	2.53E+02	-8.77	76.9129	1
MB20GRM12A	598157.658	7587227.806	244.3	2.53E+02	-9.06	82.06548	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.25	85.5625	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.23	85.22982	1
MB20GRM12A	598157.658	7587227.806	243.9	2.53E+02	-9.42	88.7364	1

MB20GRM12A	598157.658	7587227.806	243.8	2.53E+02	-9.51	90.4401	1
MB20GRM12A	598157.658	7587227.806	243.7	2.53E+02	-9.61	92.27524	1
MB20GRM12A	598157.658	7587227.806	243.9	2.53E+02	-9.40	88.30361	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.19	84.43772	1
MB20GRM12A	598157.658	7587227.806	244.2	2.53E+02	-9.08	82.42824	1
MB20GRM13T	598174.595	7587205.887	226.7	2.46E+02	-19.48	379.2756	4
MB20GRM13T	598174.595	7587205.887	229	2.44E+02	-15.00	224.88	4
MB20GRM15T	599509.748	7584101.525	236.4	2.35E+02	1.14	1.290496	1
MB20GRM15T	599509.748	7584101.525	236.4	2.35E+02	1.15	1.329409	1
MB20GRM15T	599509.748	7584101.525	231.9	2.35E+02	-3.34	11.14224	1
MB20GRM15T	599509.748	7584101.525	236	2.35E+02	0.77	0.594441	1
MB20GRM15T	599509.748	7584101.525	234.6	2.35E+02	-0.62	0.378225	1
MB20GRM15T	599509.748	7584101.525	233.4	2.35E+02	-1.80	3.250809	1
MB20GRM15T	599509.748	7584101.525	233.3	2.35E+02	-1.90	3.598609	1
MB20GRM15T	599509.748	7584101.525	235.9	2.35E+02	0.77	0.591361	1
MB20GRM15T	599509.748	7584101.525	235.9	2.35E+02	0.78	0.6084	1
MB20GRM16P	599508.681	7584096.733	206.4	2.02E+02	4.21	17.68203	14
MB20GRM16P	599508.681	7584096.733	206.7	2.02E+02	4.71	22.2218	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	4.91	24.09828	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	5.00	25.02	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	5.12	26.24513	14
MB20GRM16P	599508.681	7584096.733	207.1	2.02E+02	5.53	30.52563	14
MB20GRM16P	599508.681	7584096.733	207.2	2.02E+02	5.68	32.27376	14
MB20GRM16P	599508.681	7584096.733	207.1	2.01E+02	5.95	35.36681	14
MB20GRM16P	599508.681	7584096.733	207.5	2.01E+02	6.40	40.99841	14
MB20GRM16P	599508.681	7584096.733	207.6	2.01E+02	6.61	43.70532	14
MB20GRM16P	599508.681	7584096.733	207.7	2.01E+02	6.82	46.55333	14
MB20GRM18P	600039.475	7584114.619	215.5	1.96E+02	19.01	361.3801	14
MB20GRM18P	600039.475	7584114.619	215.6	1.96E+02	19.31	372.992	14
MB20GRM18P	600039.475	7584114.619	215.7	1.96E+02	19.60	383.964	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.82	392.7928	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.92	396.8462	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.98	399.0406	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	20.22	409.0102	14
MB20GRM18P	600039.475	7584114.619	215.7	1.95E+02	20.22	408.7675	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.37	415.0999	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.48	419.3485	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.60	424.2364	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.73	429.8573	14
MB21GRM03P	597032.115	7592090.401	236.7	2.52E+02	-15.76	248.2515	14
MB21GRM81P	598649.845	7588659.261	256.9	2.29E+02	27.82	773.7855	14
MB21GRM82T	597564.531	7587465.928	247.7	2.57E+02	-8.92	79.54856	1
MB21GRM82T	597564.531	7587465.928	248.6	2.57E+02	-8.01	64.17612	1
MB21GRM82T	597564.531	7587465.928	247.7	2.57E+02	-8.91	79.31684	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-9.00	81.036	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.85606	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.8201	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.78414	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.7482	1
MB21GRM82T	597564.531	7587465.928	247.5	2.57E+02	-9.08	82.50089	1
MB21GRM89C	600338.245	7587492.277	234.3	2.27E+02	6.89	47.45832	4
MB21GRM89C	600338.245	7587492.277	235.4	2.27E+02	8.00	64.06402	4
MB21GRM89C	600338.245	7587492.277	235.3	2.27E+02	7.91	62.58392	4
MB21GRM89C	600338.245	7587492.277	235	2.27E+02	7.62	58.03392	4
MB21GRM89C	600338.245	7587492.277	234.5	2.27E+02	7.13	50.80838	4
MB21GRM89C	600338.245	7587492.277	234	2.27E+02	6.64	44.04977	4
MB21GRM89C	600338.245	7587492.277	233.8	2.27E+02	6.44	41.49936	4
MB21GRM93C	600296.045	7585515.379	190.2	1.80E+02	9.92	98.42624	12
MB21GRM93C	600296.045	7585515.379	191.8	1.80E+02	11.61	134.7224	12
MB21GRM93C	600296.045	7585515.379	192.9	1.80E+02	12.78	163.4307	12
MB21GRM93C	600296.045	7585515.379	193.6	1.80E+02	13.53	183.1692	12
MB21GRM93C	600296.045	7585515.379	192.5	1.80E+02	12.47	155.5757	12
MB21GRM93C	600296.045	7585515.379	192	1.80E+02	12.00	143.904	12
MB21GRM93C	600296.045	7585515.379	191.2	1.80E+02	11.51	132.4571	12

Appendix D

Hydrographs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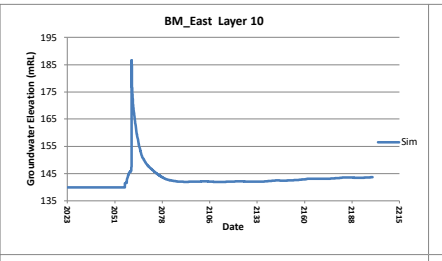
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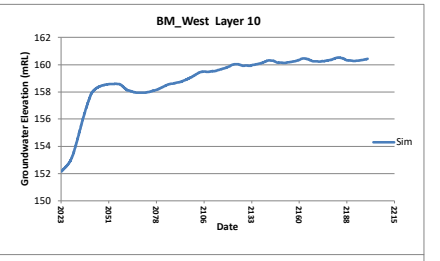
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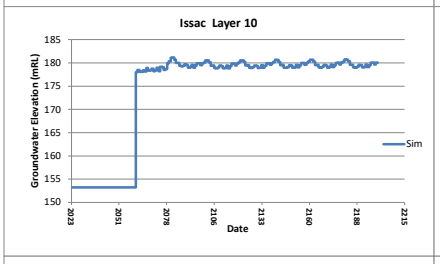
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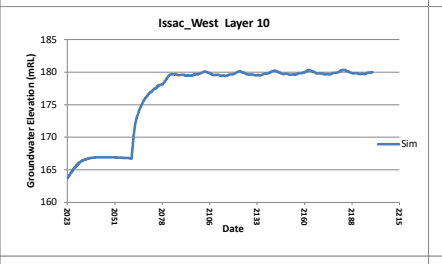
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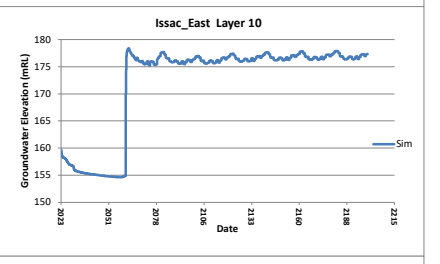
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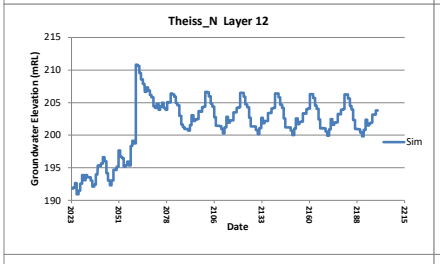
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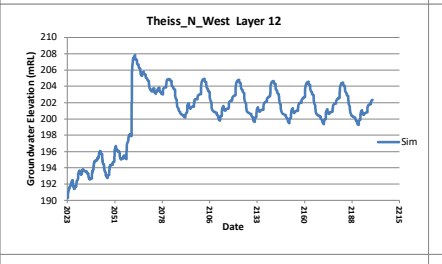
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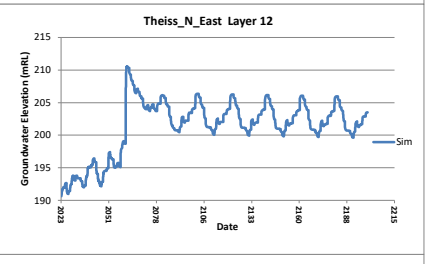
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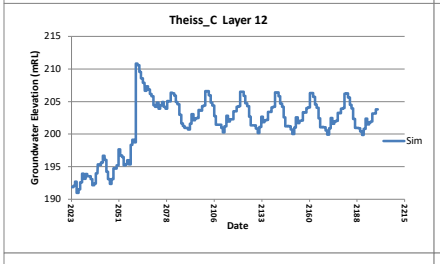
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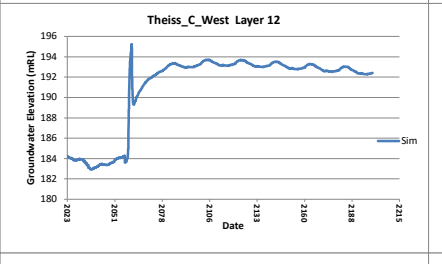
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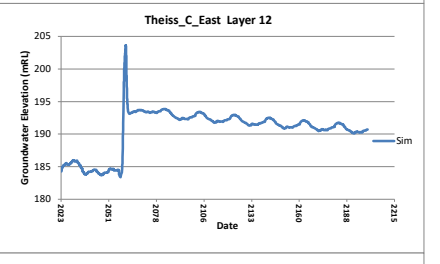
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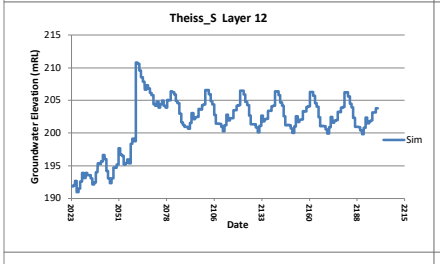
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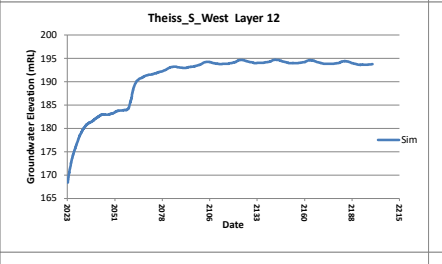
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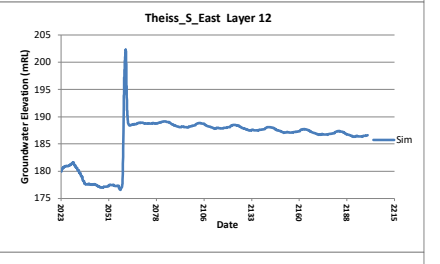
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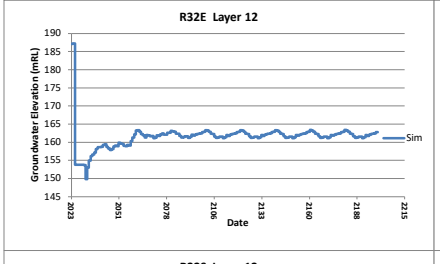
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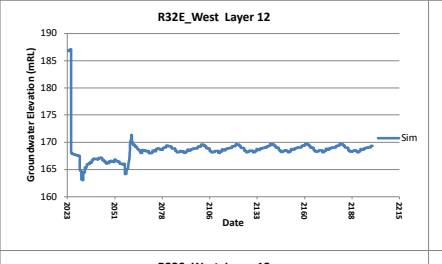
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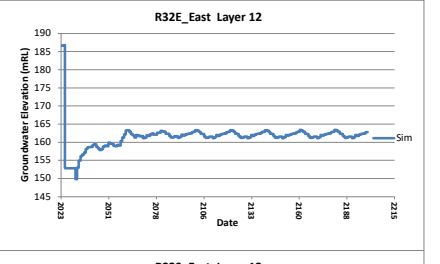
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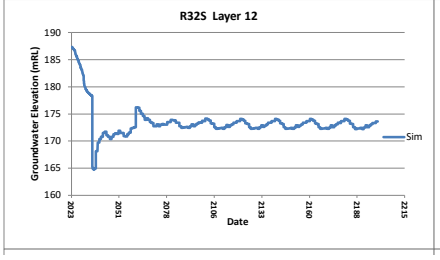
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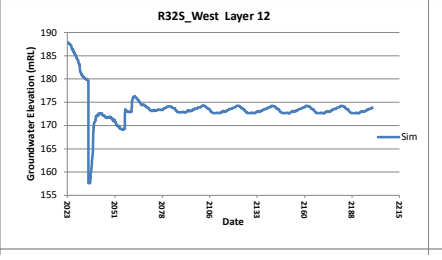
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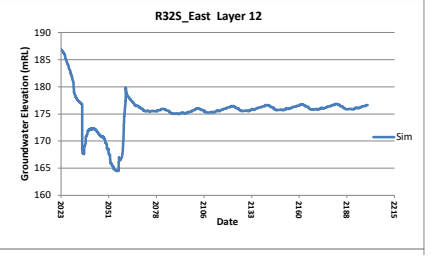
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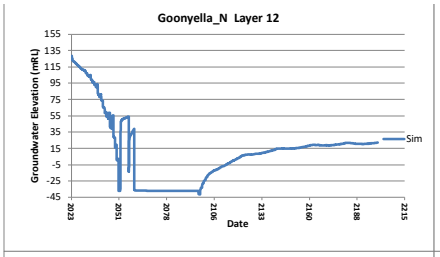
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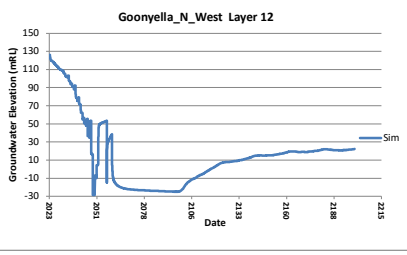
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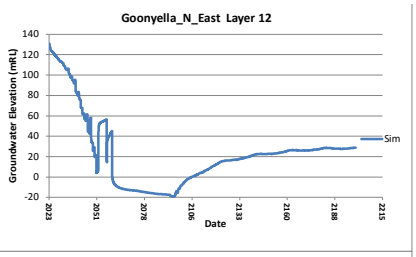
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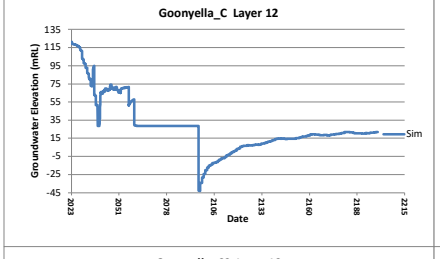
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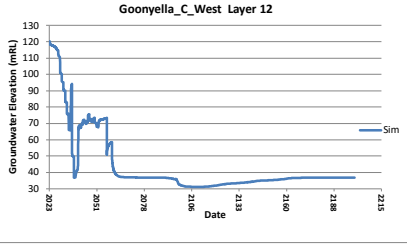
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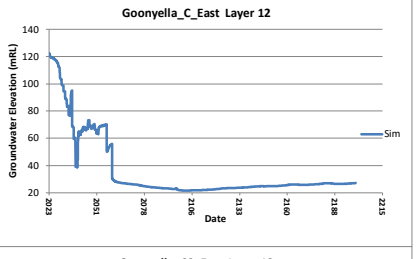
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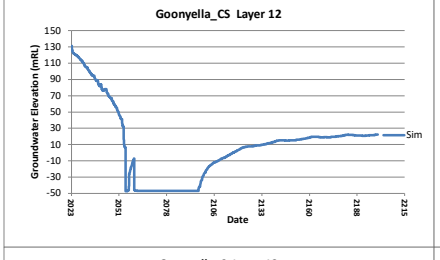
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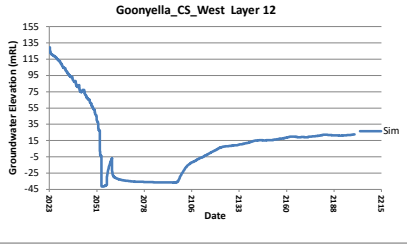
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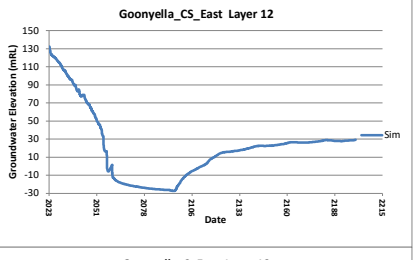
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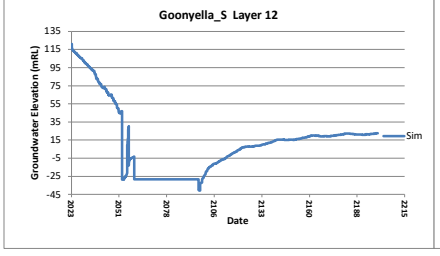
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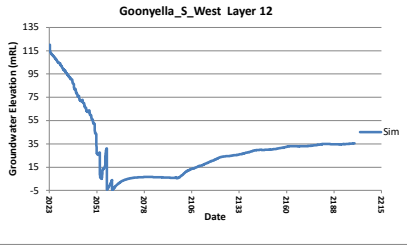
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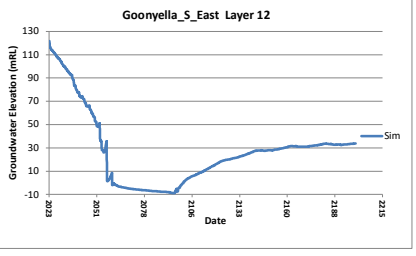
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Landloch

GOONYELLA RIVERSIDE MINE COMPLEX – MATERIAL CHARACTERISATION STUDY

October 2024

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Report Title: Goonyella Riverside Mine Complex – Material Characterisation Study

Client: BM Alliance Coal Operations Pty Ltd

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Rev 1	L. McGrath	BHP	03/10/2024

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1 INTRODUCTION

BHP Mitsubishi Alliance (BMA) engaged Landloch to provide a material characterisation study of potential growth media at the Goonyella Riverside Mine Complex (GRM). Specifically, the study is to evaluate the quality of materials for their use as growth media in rehabilitation.

To ensure rehabilitation success, the materials planned to be placed near the surface of the rehabilitated landforms need to be assessed for their suitability to support the vegetation required to meet the post-mining land use (PMLU).

1.1 Project description

GRM is a coal mine operated by BMA located approximately 30 km north of Moranbah in Queensland's Bowen Basin. It forms part of the Goonyella Riverside/Broadmeadow Mine Complex, that includes the Goonyella Riverside mine and the Broadmeadow underground mine (BRM). Both are operated by BMA. Mining activities commenced in 1971 and still operate today, consisting of an open cut mine using dragline and truck and shovel fleets, in conjunction with the underground operations at BRM. BMA also operates the Red Hill Mine, an approved underground mine located directly east of GRM.

1.2 Scope of work

The scope of work involved the following tasks:

1. Review previous soil, waste, and land assessments undertaken at GRM.
2. Review available published soils, geology, and land data within the region.
3. Conduct a data gap analysis to determine information required to:
    a. Develop an inventory of materials available for rehabilitation; and
    b. Assess the suitability of materials as a plant growth media.
4. Sample and analyse the topsoil stockpiles to gain data and fill the identified information gaps.
5. Collate existing and newly acquired soil and waste characterisation data.
6. Interpret data, characterise materials, and prepare a report.

2 DESKTOP REVIEW

2.1 Climate

The mine is situated in Queensland's sub-tropical climate zone, that is characterised by high summer temperatures, warm dry winters and a distinct wet and dry season.

The closest meteorological recording station is located at Moranbah Airport (Site No. 034035). Data from this station indicate mean seasonal temperature ranges from 20.5°C to 35.6°C in summer and 8.6°C to 26.1°C in winter, with a summer dominant rainfall pattern averaging a total of 562 mm annually (Bureau of Meteorology 2023). Rainfall events are often associated with short-duration, intense thunderstorms. These

high intensity rainfall events produce high runoff rates and can produce conditions conducive to erosion. The area is also susceptible to prolonged periods of drought.

2.2 Topography

The topography of the study area is flat to gently sloping landforms with low rolling hills. There are five creeks that exist within or are near GRM: Goonyella Creek, Eureka Creek, Fisher Creek, Platypus Creek, Holding Paddock Creek and 12 Mile Gully. These are all tributaries of the Isaac River which runs east of the current operations within the site boundary, forming part of the Isaac River Catchment.

2.3 Regional geology

Geoscience Australia mapping of the mine identifies four major geological units. Descriptions of each geological unit are provided in Table 1.

Table 1: Geological units and descriptions for GRM (Geoscience Australia 2024).

Geological unit	Description
Czs – Sand plain	Sand or gravel plains; may include some residual alluvium; quartz sand sheets commonly with ferruginous pisoliths or pebbles; local clay, calcrete, laterite, silcrete, silt and colluvium.
Qa - Alluvium	Channel and flood plain alluvium; gravel, sand, silt, clay; may be locally calcreted.
Czc – Suttor Formation	Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt.
Qrc – Colluvium	Residual deposits, sheetwash, talus, scree; boulder, gravel, sand; may include minor alluvial or sand plain deposits, local calcrete and reworked laterite.
Czb – Mafic Volcanic Rock	Volcanic rocks, predominantly mafic; basalt, trachyte, trachybasalt, trachyandesite, leucitite, basanite, nephelinite, limburgite, rhyolite, tuff and high level intrusives; rare volcaniclastic sediments

2.4 Waste materials

The waste materials at GRM consist of overburden/interburden materials (spoil), coal rejects, and tailings.

2.4.1 Spoils

Based on regional geology characteristics and spoil analysis data over the life of the mine, overburden/interburden geology at GRM can be broadly classified into:

- Tertiary/Weathered materials: Cainozoic tertiary colluvium (ferruginous) and Quaternary alluvial sediments consisting of clay, silt, sand, gravel, and soil. These weathered materials are typically sodic, highly erodible, and prone to clay

dispersion. They are also known to have varying levels of salinity, but their main constraint is their high erosion risk.

- Permian materials: Permian sediments from the Back Creek Group consist of quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite. Carbonaceous zones are present close to the coal seams. The physical and chemical properties of these materials are highly variable, but are generally sodic, alkaline and with varying salinity. Some carbonaceous strata are acidic or potentially acid forming. Erosion risk varies based on physical properties and sodicity, and generally the sandstones are more competent and resistant to weathering and erosion than the siltstones or carbonaceous material. The predominantly fresh, medium to coarse grained grey sandstone materials offer greater stability benefits to rehabilitation. However, their potential to weather increases after blasting.

2.4.2 Coal rejects

Coarse coal rejects are emplaced within the spoil materials. They are not currently used as a rehabilitation resource, but further investigation may identify some that are beneficial for rehabilitation use due to their high organic carbon and coarse physical structure. Alternatively, strategies may be developed in the future for mixing them with spoil of high ANC to produce a combined material that is more suitable for use as a growth medium. Characterisation of these materials is not included in this report.

2.4.3 Tailings

Tailings are not characterised in this report as they are not currently considered a rehabilitation resource.

2.5 Soils

2.5.1 Regional soils

Regional soils mapping of the mine identifies four broad soil groups (Department of Resources 2024). Relevant details of these soil groups are provided in Table 2.

Table 2: Summary details of regional soils.

Soil Landscape Code	Description	Associated Australian Soil Classification (ASC)
CC33	Uniform cracking and self-mulching, deep brown clays with >35% clay	Vertosol
My28	Gradational friable earths that are massive or only weakly structured.	Kandosol
Sl12	Strong texture contrast soils with sodic B horizons that are not strongly acidic.	Sodosol

Soil Landscape Code	Description	Associated Australian Soil Classification (ASC)
Va52	Texture-contrast soils with sodic subsoils	Sodosol

2.5.2 Recoverable soils

GSS Environmental (GSSE) undertook a detailed soil and land suitability assessment as part of the Red Hill Environmental Impact Statement, which covered areas of GRM. This report involved the compilation of data from two previous soil surveys undertaken on site (GJR Holding 2007; GSS Environmental 2009) with an additional fieldwork and assessment component undertaken by GSS Environmental in 2011 (GSS Environmental 2011).

The survey was undertaken at a scale of 1:50,000 for the entire project site and 1:25,000 for disturbance areas, in accordance with the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.* 2008). Soil samples were analysed for various physical and chemical soil attributes by a NATA accredited laboratory. Within the survey area, 11 soil types were identified and are detailed in Table 3. The table includes scores for land suitability focusing on grazing across each soil type. Land suitability scores were assessed using the land suitability classes defined for use in Queensland (Department of Natural Resources and Mines, 2015). Land suitability decreases progressively from Class 1 to Class 5.

A soil map displaying broad ASC soil types for the GRM and Red Hill area is provided in Figure A-13 (Appendix A). The data used to generate this map is a synthesis of soils data and mapping sourced from:

- existing soil assessments completed by the sources above;
- existing land systems information sourced from the QLD Globe online spatial data system (State of Queensland (Department of Resources), 2024); and
- a regional land resource assessment completed by (Burgess, 2003).

The map is Landloch's interpretation of the available soils information.

A grazing land suitability map for the GRM and Red Hill area is provided in Figure A-14 (Appendix A). The data used to generate this map is a synthesis of land suitability scores from the existing soils assessments that were used for the ASC mapping.

2.5.3 Stockpiled soils

Location and volume information on the current soil stockpiles was provided by BMA. The approximate volume of available stockpiled material is 6,619,361 m^3 (in April 2023). Locations of topsoil stockpiles on GRM are presented in Figure 1.

2.6 Post-mining land uses

BMA's rehabilitation objectives for GRM are to create a safe, stable, non-polluting, and sustainable landscape with PMLUs in accordance with the EA:

- Cattle grazing;
- Woodland habitat;

- Water storage; and
- Watercourse.

The predominant pre-mining land use was cattle grazing.

Table 3: Summary details of the soil types identified in the GSS Environmental (2011) soil survey.

Soil Type	Soil Description	Soil Landscape	Grazing Suitability Class	Area (ha)
Lithic Rudosol	Shallow rocky (skeletal) soils with a clay loam or clayey soil matrix associated with or underlain by shallow bedrock. Structurally stable with low potential for dispersion, and is generally of moderate salinity, strongly acidic.	Occur on the low hills and on lower escarpment slopes of sections throughout the eastern and western portion of the study area.	3	426
Tenosol	Poor structure and loose sandy texture comprising deep (>1 metre) sand or silty sand grading to loamy or light clayey sand subsoils. Generally nondispersive, and has low levels of salinity, with a neutral pH.	Flat lower area of the catchment, within drainage lines or on the immediate floodplain of the Isaac River.	4	269
Red Kandosol	Sandy loam to loamy surface and medium to heavy clay subsoils. The topsoil is non-dispersive to moderately dispersive, mainly non-saline to slightly saline and varies from slightly acidic to mildly alkaline.	Gently to moderately inclined slopes and undulating low rises, as well as some higher alluvial terraces, undulating plains and on mid to lower valley slopes.	2	2,051
Brown Kandosol	Sandy loam to light clayey surface soils grading to light to medium or heavy clay subsoils. Slightly to moderately dispersive, non-saline and mainly neutral to slightly acidic.	Occurs on gently inclined slopes to drainage lines, on flat to depressional plains, in depressional drainage ways and on low rises.	2	386
Brown Kurosol	Loamy surface duplex soil, acidic to strongly acidic dark brown heavy clay subsoil horizon. Moderately dispersive and slightly to moderately saline with a neutral pH.	This soil type occurs on gently to moderately inclined foot slopes in a small area to the northwest of the study area.	5	186
Brown Chromosol	Sandy and loamy surface duplex soils, non-sodic to marginally sodic, non-saline sandy clay or medium to heavy clay subsoils. The topsoil is structurally stable with a low potential for dispersion. Most topsoil is non-saline although can be slightly saline and is slightly acidic to moderately alkaline.	Occur on alluvial terraces and on broadly rounded rises and dissection slope interfluves, common throughout the eastern study area.	2	1,444
Brown Sodosol	Medium to deep hard-set thin loamy surface duplex soils, light medium to heavy clay deep subsoils. The topsoil is non-dispersive to moderately dispersive, is generally moderately saline, and the topsoil was generally neutral, or in some instances moderately acidic. The subsoils are generally highly sodic and dispersive.	Occur on alluvial flats, back-plains, and older alluvial plains, on gently inclined plains, gently undulating rises dissection and on slope interfluves and slopes to drainage.	3	1,757

Soil Type	Soil Description	Soil Landscape	Grazing Suitability Class	Area (ha)
Brown Dermosol	Hard-set or thin weak self-mulching clay loam to medium clay surface horizon. Non-dispersive to moderately dispersive, is non-saline and varied from slightly acidic to moderately alkaline, with occasionally high gravel content. The subsoils are generally moderately to highly dispersive.	Alluvial plains, depressional plains with prominent gilgai development and on older alluvial plains.	3	816
Shallow Vertosol	Cracking clay soils with a thin weak self-mulching surface soil over dark brown or brownish black sodic moderately saline heavy clay subsoils underlain by weathered rock. The topsoil is typically nondispersive, although occasionally has moderate dispersion ratings, is non-saline to slightly saline, and neutral to slightly alkaline.	Undulating plains and gently to moderately inclined slopes, but mainly on crestal areas and lower slopes in strongly undulating lands and on low rocky rises associated with the Tertiary Basalt geological regime.	3	692
Deep Vertosol	Cracking clay soils with a thin weak self-mulching surface soil over dark brown or brown strongly structured mostly sodic heavy clay subsoils. The topsoil is mainly non-dispersive, occasionally moderately dispersive, varying from non-saline to moderately saline and is slightly acidic to slightly alkaline. The subsoils are generally non-dispersive to moderately dispersive.	Occurs extensively mainly in the northern sector of the study area, comprising drainage-ways, drainage flats and alluvial plain, on near level older alluvial plains and gently undulating plain, and on gently inclined slopes, foot-slopes and low rises.	3	589
Deep Salic Vertosols	Cracking clay soils mostly with self-mulching surface soils, mainly non-dispersive, varies from non-saline to high saline and is moderately acidic to moderately alkaline. The subsoil is mainly non-dispersive.	Occurs extensively in the study area and is particularly common in the north-eastern areas, comprising drainage-ways, drainage flats and alluvial plain, on near level older alluvial plains and gently undulating plain, and on gently inclined slopes, foot-slopes and low rises.	3	2,674

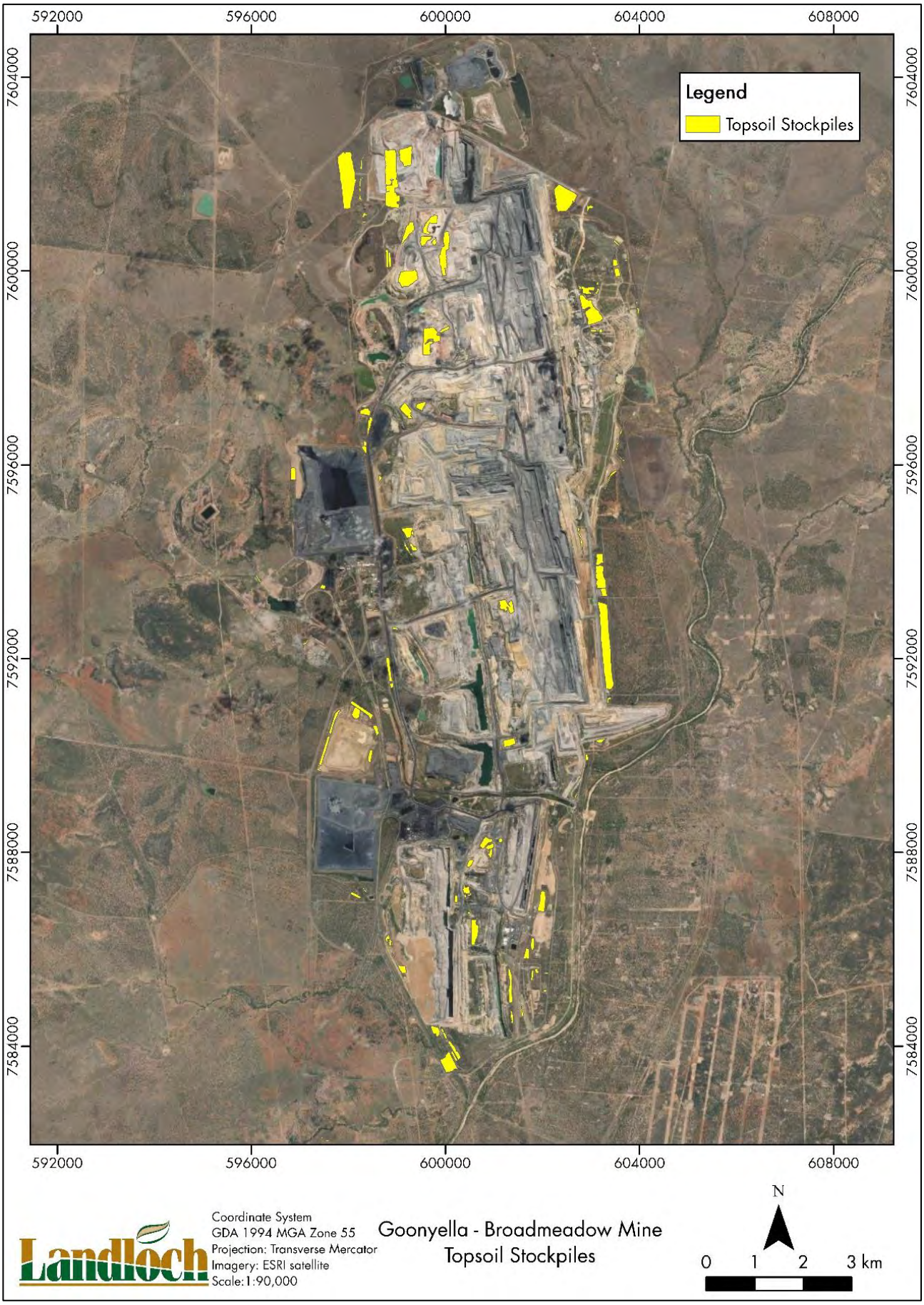

Figure 1: Stockpiled topsoil materials across GRM.

2.7 Revegetation methodology

The aim is to implement a planned progressive rehabilitation program across disturbed areas of GRM. Rehabilitation methods will vary between domains and PMLUs. Broadly, rehabilitation of disturbed areas will include:

- Respreading stockpiled or freshly stripped topsoil, or creating a growth media from spoil;
- Contour ripping;
- Seeding with an appropriate seed mix for the PMLU; and
- Applying appropriate fertiliser and ameliorants for plant establishment if required.

Where available, competent materials will be placed on steeper slopes to aid erosional stability. A suitable seed mix will be used to establish a sustainable vegetation cover.

The material characterisation and landform design studies aim to identify and improve where possible:

- Growth media placement depth and soil profile depths relevant to the PMLU;
- Growth media preparation details; and
- Expected growth media amelioration activities.

More details on revegetation methodology can be found in the relevant section of the PRC Plan.

3 MATERIAL CHARACTERISATION METHODOLOGY

3.1 Materials

Soils and spoils were targeted for consideration as potential growth media. When considering the growth media at GRM, the quality of the stockpiled soil rather than the *in situ* topsoils is more representative of the material available for rehabilitation. Therefore, stockpiled soils were sampled by Landloch in a field program completed as part of this study. Spoil data collected by Landloch, as part of erodibility assessments for the Landform Design section of the PRC Plan and data from previous studies were considered in the assessment of spoils as a potential growth media. All sampled materials were characterised in terms of their basic chemical and physical properties. Any materials with the potential to be used at the surface of a rehabilitated landform as a primary growth media were subjected to additional fertility assessments.

3.2 Stockpiled soils

3.2.1 Field program details

The field program was undertaken between 3 and 14 October 2023. Site conditions were dry across GRM at the time of the field program. For the month preceding the field program, the Bureau of Meteorology's Moranbah Airport weather station (34 km south-east of GRM) recorded less than 2 mm of rainfall.

3.2.2 Sampling plan and intensity

The soil sampling plan completed as part of this assessment is listed in Table 4 and the stockpile sampling locations are shown in Figures A1–A6 (Appendix A).

The sample density adopted is consistent with a 'high (detailed)' intensity 1:25,000 survey (McKenzie *et al.* 2008) and assumes soil will be placed at an average depth of 0.1–0.15 m at rehabilitation. Using these criteria, Table 5 shows the sample density for the stockpiles. Stockpile location details are provided in Table B1 (Appendix B).

Table 4: Soil stockpile sampling plan.

Stockpile ID	Area (ha)	Sampling Sites	Stockpile ID	Area (ha)	Sampling Sites
625	2.9	1	695	1.5	1
634	30.1	6	696	4.9	2
649	1.4	1	704	30.0	15
662	3.5	2	707	1.7	1
664	2.4	2	708	7.8	4
665	1.4	1	709	2.8	1
666	3.4	2	716	13.7	2
667	1.6	1	726	17.4	4
675	2.6	1	729	2.8	1
678	2.7	2	730	5.0	1
680	8.3	4	731	4.8	1
685	1.1	1	735	10.7	3
687	4.3	2	755	27.7	6
694	1.9	1			
				Total	69

Table 5: Sample density for soil stockpiles.

Soil Volume (m^3)	Reinstatement Coverage (ha)	Total Samples	Sampling Density	Sampling Density	Survey Scale
6,619,361	4,413*	276	1 sample/ 23,983 m^3	1 sample/ 16 ha	1:25,000

* Based on a replacement depth of 0.15m

3.2.3 Sample collection

Samples of materials were taken from test pits and the depth of excavation was to the base of the stockpile, or to the limit of excavation (~3–5 m). Samples were collected at depth intervals of 0.5–1.0 m (e.g. 0.5–1.0 m, 1.5–2.0 m, 2.5–3.0 m etc.). Brief details and descriptions of the collected materials were recorded in the field. Sampling included composite and discrete samples, where each composite sample was composed of materials from three discrete samples.

3.2.4 Laboratory analysis

Laboratory analysis was undertaken by East West EnviroAg, a laboratory with National Association of Testing Authorities (NATA) and Australian Soil and Plant Analysis Council (ASPAC) accreditations. Analysis of composite samples used a 'topsoil suite' to characterise the soil nutrients and physico-chemical parameters of the materials. Laboratory analysis of discrete samples used a 'basic suite' of pH and salinity to indicate the heterogeneity (variability) within the stockpile and expose potential extreme values that may be masked in the testing of the composite samples. Laboratory analyses are described in Table 6.

Table 6: Laboratory analytical suites.

Analyses	Analysis Suite	
	Topsoil	Basic
pH_w and Electrical Conductivity ($EC_{1:5}$).	✓	✓
Exchangeable cations (with calculations of effective cation exchange capacity and exchangeable sodium percentage) and chloride	✓	
Total nitrogen and phosphorous; available phosphorous, potassium, and sulphur; trace nutrients (Cu, Zn, Mn, Fe, B), chloride, organic carbon, phosphorus buffer index (PBI), field texture	✓	
Dispersion potential	✓	
Total number of samples	69	207

3.3 Spoil materials

Chemical and physical characterisation data for the spoils were collated from multiple assessments previously conducted for the project and from waste characterisation data collected as part of the PRC Plan preparation. Information sources included:

- *Spoil and Reject Characterisation – Goonyella/Riverside* (AGC Woodward-Clyde 1992);
- *Overburden and Interburden Characteristics of the Northern End of the Goonyella/Riverside Mine Area and Suitability of Specific Layers for Capping* (Land Reclamation Services 1993);
- *Environmental Geochemistry Characterisation of Out-of-pit Spoil at the BHP Goonyella/Riverside Mine* (Environmental Geochemistry International 1995);
- *Mineral Waste Geochemical Assessment – Goonyella-Riverside Expansion Project* (Terrenus Earth Sciences 2009);
- *Goonyella Riverside Mine Contaminants Sources Study, Mineral Waste Analysis for BM Alliance Coal Operations Pty Ltd* (Koskela Group 2013);
- Spoil data collected and analysed to inform Landloch's landform erodibility study as part of the PRC plan development (Landloch 2024); and
- Internal BMA spoil monitoring data.

4 FINDINGS

The two categories of materials available for rehabilitation were characterised as part of this assessment and include topsoil stockpiles and spoils.

This section of the report provides information about these materials. Site location details are provided in Figures A1–A6 (Appendix A) and in Table B1 (Appendix B). Stockpile description records are provided in Table B2–B3 and laboratory results are provided in Tables B4–B5 (Appendix B).

4.1 Topsoil stockpiles

A total of 278 samples were collected from 27 topsoil stockpiles. The 'topsoil suite' analysis was conducted on 69 samples and the 'basic suite' analysis was conducted on the remaining 207 samples. Stockpiled topsoil for use in rehabilitation was categorised into two management groups:

1. Clay topsoil; and
2. Loam topsoil.

A summary of key chemical and physical properties is presented in Table 7. Topsoil within each management group is detailed in the following sections. Land suitability scores have not been provided for stockpile topsoil materials. Land suitability measures are based on established profiles and cannot be until topsoil is reinstated at rehabilitation.

Table 7: Summary of key chemical and physical properties for topsoils at GRM.

Analysis	Clay Topsoil	Loam Topsoil
Chemical Properties		
pH_w (pH Units)	Slight to strongly alkaline (7.7 – 9.0)	Moderate to strongly alkaline (6.5 – 8.3)
$EC_{1:5}$ (dS/m)	Low to high (0.1 – 1.0)	Low (<0.2)
Chloride (mg/kg)	Low to high (42 – 1,317)	Low (<50)
Exchangeable sodium percentage (ESP) (%)	Non-sodic to strongly sodic (5.8 – 21.8)	Non-sodic to sodic (1.5 – 7.1)
Total N (mg/kg)	Low (323 – 775)	Low (171 – 724)
Available P (mg/kg)	Low (6 – 21)	Low (5 – 13)
Available K (mg/kg)	Low (63 – 123)	Low (130 – 191)
Total Organic Carbon (TOC) (%)	Low to moderate (0.4 – 1.3)	Low to moderate (0.4 – 1.0)
Effective Cation Exchange Capacity (ECEC) (meg/100g)	Low to moderate (5.6 – 20.1)	Low (1.9 – 7.9)
Ca/Mg (ratio)	Low to low Ca (0.8 – 2.4)	Low Ca to balanced (1.4 – 4.6)

Analysis	Clay Topsoil	Loam Topsoil
Physical Properties		
Clay content (%)	>35	>35
Rock content (%)	2 – 30	<20
Dispersion (EAT)	Dispersive to stable (1 – 7)	Slightly dispersive to slaking (3a – 5)
Permeability	Low to moderate	Moderate to high
Associated regional soil	CC33 (Vertosol)	Sl12 (Sodosol), Va52 (Sodosol) and My28 (Kandosol)
Associated SLU	Brown Dermosol, Shallow Vertosol, Deep Vertosol, Deep Salic Vertosol	Lithic Rudosol, Red Kandosol, Brown Kandosol, Brown Kurosol, Brown Chromosol, Brown Sodosol

Note: Chemical properties for topsoil are based on average 10th and 90th percentile values for all stockpile samples analysed.

4.1.1 Clay topsoils

Clay topsoils account for approximately 80% of samples assessed across GRM topsoil stockpiles and are concentrated in the northern, eastern, and southern areas of the mine. This ratio is likely to stay consistent through future stripping areas, particularly through the northern and eastern portions of the mine area. Generally, these soils have relatively similar physical properties, but occasional minor inclusions of loams were noted at varying stockpile depths. This is likely a result of topsoils from smaller texture-contrast or kandosol soil units being stripped simultaneously with the more dominant clays.

The soils are generally dark brown, brown, or reddish brown in colour with occasional mottling and have textures ranging from light to medium-heavy clay. Gravel content varies from 2% to 30% with gravel size being less than 60 mm in diameter. The soils often have vertic properties making them susceptible to slaking, thereby increasing the risk of erosion. Figures 2–5 illustrate representative clay topsoils and vegetation cover levels on clay stockpiles at GRM.

Stockpiled clay soils are commonly sodic and often have elevated salts, particularly chloride. Any soils with elevated salts should be prepared in a way that maximises infiltration to aid in the leaching of salts from the desired root zone. If sodic soils are placed on steeper-gradient outer batter slopes, management of erosion risk during the period of vegetation establishment would be critical for rehabilitation success, and establishment of appropriate levels of persistent vegetation groundcover will be essential. Incorporation of the clay soil with durable waste rock could be considered as a means of increasing the erosion resistance of this topsoil.

The main requirements for this soil are to ensure that its chemical limitations and erosion risks are managed. Any sodicity issues will need to be addressed by incorporating gypsum prior to rehabilitation. Fertility will need to be improved to ensure vigorous vegetation growth in the initial stage of rehabilitation and to maintain suitable levels of surface groundcover in the longer term. Incorporation of durable rock into this soil could be considered to improve erosion performance.

Figure 2: Soil material excavated at sampling site 685.

Figure 3: Soil profile at sampling site 685.

Figure 4: Soil material at sampling site 685.

Figure 5: Vegetation cover on sampling site 685.

4.1.2 Loam topsoils

Loam soils account for 20% of samples assessed across GRM topsoil stockpiles and are scattered around the south to south-west portion of the mine. This ratio is likely to stay consistent through future stripping areas, but loams will to be the dominant topsoil source in the southern portion of the mine. These materials have been recovered from a variety of soil types, but have similar physical soil properties once stockpiled, so have been grouped together to aid their management.

The soils are generally dark to pale brown in colour and have textures ranging from sandy loam to clay loam (sandy). Gravel content can be variable but is generally less than 20% with gravel size being less than 60 mm in diameter. The soils are susceptible to slaking, thereby increasing the risk of erosion. Figures 6–9 illustrate representative loam topsoils and stockpile vegetation cover levels at GRM.

The main requirement for this soil is to ensure that its chemical fertility is managed to support vigorous vegetation growth in the initial stage of rehabilitation and maintain suitable levels of surface groundcover in the longer term. A suitable rock armouring can also be applied to reduce the erosion risk while vegetation establishes. The use of loam topsoils as a capping layer on slopes should be assessed by an adequately qualified person to determine the rock and vegetation cover requirements.

Figure 6: Soil material excavated at sampling site 662a.

Figure 7: Soil profile at sampling site 662a.

Figure 8: Soil material at sampling site 664b.

Figure 9: Vegetation cover at sampling site 664b.

4.1.3 Topsoil limitations

Elevated salts were identified throughout stockpiled clay soils, particularly chloride-based salts. The measured salt concentrations are likely to affect seed germination rates, but once established, regional vegetation appears to be tolerant of salinity. If the stockpiled clay soils are required for use as a growth medium, it is recommended that vegetation establishment initially favours species that tolerate saline soil conditions such as Rhodes grass (*Chloris gayana*) until adequate leaching of the profile has occurred.

4.2 Spoils

From the previous assessments detailed in Section 3.3, spoil characteristics were found to be heterogeneous within each spoil type and across sampling areas. For this reason, spoils are categorised into three management groups that have broad similarities:

- Mudstone/Siltstone (dominant) spoils;
- Sandstone (dominant) spoils; and
- Tertiary materials.

A summary of key chemical and physical properties is presented in Table 8. Each spoil management group is described in further detail in the following sections.

Table 8: Summary of key chemical and physical properties for spoils at GRM.

Analysis	Mudstone/Siltstone Spoil	Sandstone Spoil	Tertiary
Chemical Properties			
pH_w	Moderately alkaline to strongly alkaline (8.2 – 9.7, can be neutral)	Moderately alkaline to strongly alkaline (8.3 – 9.9, can be acidic)	Strongly acidic to moderately alkaline (4.5 – 8.1)
$EC_{1:5}$ (dS/m)	Low to high (0.17 – 1.46)	Low to moderate (0.28 – 0.80)	Low to high (0.09 – 0.97)
Acid Neutralising Capacity (ANC) (H_2SO_4/t)	Low to high (5.7 – 203)	Low to high (24 – 365)	Low (7.1)
Potential for acid formation	Low	Low	Low
ECEC (meq/100g)	Low to adequate (12 – 27)	Low to adequate (8 – 24)	Low (8 – 12)
ESP (%)	Strongly sodic (25 – 41)	Sodic to strongly sodic (6 – 36)	Non-sodic to strongly sodic (5 – 35)
Ca/Mg (ratio)	Very low (0.4 – 0.8)	Very low to low Ca (0.4 – 1.2)	Very low (0.3 – 0.5)
Physical Properties			
Clay content (%)	20 – 50	10 – 35	>30
Rock content (%)	20 – 50%	Often >50%	10 – 20
Permeability	Low – Moderate	Moderate	Low
Dispersion potential	Moderate to high	Moderate to high	Moderate to high
Dispersion risk	High	Moderate to high	High

4.2.1 Mudstone/siltstone spoil

Mudstone and siltstone dominated spoils present at GRM are weathered Permian materials and tend to vary depending on the degree of weathered inclusions. Generally, materials have appreciable amounts of friable rock, consisting primarily of mudstone and siltstone with some sandstone inclusions. The clay content in the fine fraction ranges from 20–50%, and the coarse rock fraction similarly ranges from 20–50%. Water holding capacity and permeability are variable and depend on the clay content along with the volume and composition of rock present. It is generally grey or pale brown in colour but may vary to orange-brown after some weathering. The material ranges from moderately to highly dispersive but this can occasionally be masked by the presence of saline lenses. The material is considered to have reasonable ANC potential. Figure 10 is representative of mudstone and siltstone dominated spoil at GRM.

Weathered Permian is considered suitable as a secondary growth media but should be capped with a quality topsoil material to prevent its exposure at the final rehabilitated surface. If exposed, this material will be susceptible to erosion due to the tendency to rapidly weather and disperse. For material with elevated salinity, it is preferable to mix it with more permeable materials to promote infiltration and leaching of salts. If more permeable material isn't available, placement should be limited to slopes less than 10% gradient. Due to the heterogeneity, discrete characterisation testing should be conducted prior to rehabilitation that uses this material.

Figure 10: Mudstone/siltstone material present at the mine. A large portion of stockpiled material is weathered.

4.2.2 Sandstone spoil

Sandstone dominated spoils at GRM account for a large proportion of the unweathered Permian materials and tend to be reasonably consistent in their characteristics given the range of strata locations and proximity to carbonaceous layers. Generally, these materials have a high content of competent rock consisting of fine or coarse-grained sandstone with minor inclusions of other rock types. The clay content in the fine fraction ranges from 10–35% and the coarse rock fraction often exceeds 50% of the mass of the material. Similar to the mudstone/siltstone spoils, its water holding capacity and permeability are variable and depend on the clay content along with the volume and composition of rock present. It is generally grey in colour. The material ranges from slightly to highly dispersive. Salts are generally low. It is considered to have reasonable ANC potential. Figure 11 is representative of sandstone dominated spoil at GRM.

Of the spoil management groups, sandstone spoils are considered most suitable for placement close to the final rehabilitated surface for use as a secondary growth media. Due to the heterogeneity, discrete testing should be conducted prior to rehabilitation. Competent (durable), fresh Permian sandstone has potential to be used as a rock armour to greatly increase batter slope resistance to erosion and to stabilise steeper areas.

4.2.3 Tertiary materials

Tertiary materials are highly weathered and contain small portions of fragile (low durability) rock. Generally, it has a clay content above 35%, resulting in moderate to high water holding capacity. It is typically pale orange to pale brown in colour. The material tends to be strongly sodic and occasionally high in salinity. Compared to the sandstone spoil, the Tertiary material is more susceptible to slaking and dispersion but has similar dispersion characteristics of the weathered Permian spoil. Figure 12 is representative of Tertiary spoil at GRM.

Placement of this material close to the final rehabilitated surface is not recommended due to its susceptibility to erosion. However, testing did identify Tertiary materials that are slightly acidic to alkaline, non-sodic, and low in salts. If these materials can be identified and segregated consistently, they could form a valuable secondary growth medium for high productivity grazing areas for where required (i.e. possible alternative growth media).

Figure 11: Fresh Permian sandstone material present at the mine. Large-sized competent rock is present throughout the stockpile.

Figure 12: Tertiary material stockpiled at the mine.

5 GROWTH MEDIA SUITABILITY AND AMELIORATION

The materials encountered have been classified according to their ability to support plant growth, as either *primary* or *secondary* growth media.

5.1 Primary growth media

Primary growth media infers the ability of materials to be used as a topsoil or topsoil surrogate. It is the upper-most layer placed over the rehabilitated area. It can be applied at various thicknesses depending on the PMLU and consists of surface soil (topsoil) materials recovered prior to mining and applied over the area, or a growth medium developed from subsoils or spoil materials, ameliorated to a standard suitable to support sustainable plant growth. It is typically higher in organic matter and macro- and micro-nutrients and has low to negligible limitations to plant growth. Its primary purpose is to provide nutrients and a stable surface for vegetation establishment.

If sufficient suitable primary growth media is not available, an alternative growth media may be derived by amelioration of suitable subsoils or spoil materials. Amelioration products and application rates for the primary growth media should be assessed by an appropriately qualified person prior to rehabilitation, and to also ensure the desired PMLU and vegetation is considered. Amelioration must address both the physical and chemical suitability of the material.

5.2 Secondary growth media

Secondary growth media infers the ability of materials to be used as a subsoil or subsoil surrogate. Typically, secondary growth media layers are capped with primary growth media. In the absence of subsoil, it may be a spoil material, or an intermediate layer of ameliorated spoil situated above un-ameliorated spoil material.

The main purpose of the secondary growth medium is to increase the soil water storage capacity in the root zone, and/or meet the soil depth criterion for certain vegetative PMLUs and target vegetation communities.

In some circumstances, secondary growth media may be able to be sufficiently improved by the addition of ameliorants (e.g. gypsum, lime, organic matter) to convert them to a primary growth medium.

5.3 Suitability classification

A four-class suitability system is applied in the evaluation of materials as growth media. These classes are defined as follows:

Class A – Good Quality

- Negligible limitations to plant growth.
- Good quality material for intended purpose.
- Nil to low levels of ameliorants will be required.

Class B – Fair Quality

- Minor limitations to plant growth.
- Reasonable quality material for intended purpose.
- Low to moderate levels of ameliorants may will be required.

Class C – Marginal Quality

- Moderate limitations to plant growth.
- Moderate to high levels of ameliorants may be required to improve material quality to support plant growth.

Class D – Not Suitable

- Severe limitations to plant growth.
- It will generally be uneconomic or unviable to amend these materials to the degree needed to support plant growth.

The suitability of materials as primary or secondary growth media is presented with recommendations in Table 9.

5.4 Fertiliser and ameliorants

Fertiliser and amelioration rates for spoils are dependent on the intended PMLU for each rehabilitated area. For example, cattle grazing requires the generation of biomass and as such, nitrogen and phosphorus-based amendments would be recommended for these areas. As a guide to amelioration application for grazing, PMLU should aim to provide:

- Available phosphorus (Colwell) content of the growth media to within a target concentration of 25–40 mg/kg;
- An appreciable source of starter nitrogen;
- Adequate macro- and micronutrients; and
- Gypsum to reduce sodicity and potential for dispersion.

Amelioration recommendation for woodland areas should be assessed on a case-by-case basis and represent the specific requirements of the target vegetation community.

Table 9: Recommended fertiliser and ameliorant treatments for materials and growth media suitability classification.

Material	Limitations	Amendments	Suitability Class	
			Primary (1)	Secondary (2)
Clay topsoil	• Often strongly alkaline • Sometimes high salinity • Often sodic and sometimes dispersive • Susceptible to slaking • Often low ability to retain nutrients • Low N, P and K • Often low TOC and Ca	• Gypsum: due to heterogeneity between stockpiles, rates should be calculated for individual stockpile prior to use. • Fertiliser and/or compost rates are to be determined by an appropriately qualified person prior to individual stockpiles being used in rehabilitation. • Any soil with elevated salinity should be initially seeded with salt tolerant species. • Incorporation with rock to increase erosion resistance.	1B/C	2A
Loam topsoil	• Sometimes strongly alkaline • Occasionally sodic • Susceptible to slaking • Low ability to retain nutrients • Low N, P, K and Ca • Often low TOC	• Fertiliser and/or compost rates are to be determined by an appropriately qualified person prior to individual stockpiles being used in rehabilitation. • Incorporation with rock to increase erosion resistance.	1B	2A
Mudstone/siltstone spoil	• Strongly alkaline • Sometimes high salinity • Strongly sodic and dispersive • Often low ability to retain nutrients	• Gypsum: due to heterogeneity between spoil samples, rates should be calculated for broad spoil areas after placement. • Mix all saline material with a more benign and permeable material or bury to a depth greater than 2 m below the surface.	1D	2B/C
Sandstone spoil	• Strongly alkaline • Often strongly sodic and dispersive • Often low fertility and ability to retain nutrients • High variability in physical and chemical characteristics	• Gypsum: due to heterogeneity between spoil samples, rates should be calculated for broad spoil areas after placement. • If to be used as a primary growth media further assessment by an appropriately qualified person is required to determine amelioration required.	1B/C	2B
Tertiary spoil	• Often strongly acidic or strongly alkaline • Sometimes high salinity • Sodic or strongly sodic and dispersive • Low permeability • Low fertility	• Gypsum: due to heterogeneity between spoil samples, rates should be calculated for broad spoil areas after placement. • Mix all saline material with a more benign and permeable material or bury to a depth greater than 2 m below the surface. • Segregate the neutral pH, non-sodic and non-saline material for use as a secondary growth media where possible.	1C/D	2B/C

Note: Class A – Good Quality: Negligible limitations to plant growth; Class B – Fair Quality: Minor limitations to plant growth; Class C – Marginal Quality: Moderate limitations to plant growth; and Class D – Not Suitable: Severe limitations to plant growth.

5.4.1 Fertiliser

A balanced NPK fertiliser such as Crop King 55 (N: ~13.5 %, P: ~15 %, K: 12.5 %) and slow-release nitrogen source such as Coated Urea (N: ~46 %) or organic compost is recommended to provide a balanced source of nutrients to plants during rehabilitation. Any composted material should comply with the Australian Standard for Composting (AS4454-2012).

Accurate application rates and fertiliser types based on the required nutrients should be determined by an appropriately qualified person prior to use in rehabilitation.

Fertiliser and mulch/compost should be applied at seeding. It can be broadcast with a spreader or applied hydraulically or pneumatically. Spreaders are typically suitable for slopes with gradients <35%, and hydraulic or pneumatic applications will be required for steeper slopes.

5.4.2 Gypsum

Gypsum application is recommended for sodic/dispersive materials or where calcium is low. It should be applied in a manner that allows for as thorough mixing as is practicable of the surface materials. Gypsum should be applied during the soil preparation stages prior to seeding and fertilising.

Depth of sodicity amelioration depends on erosion risk/land gradient. Generally, for slopes with gradients less than ~35%, incorporate gypsum into the upper 0.3 m depth of sodic materials.

Considering the annual rainfall at GRM is approximately 560 mm, it is expected that (as a 'rule of thumb') gypsum will dissolve at a rate of 0.5–1.0 t/ha/y. Hence, there is benefit in applying gypsum at the time materials are recovered (i.e. stripped) or as soon as is practical in the rehabilitation program to allow the gypsum to be as effective as possible.

6 SUMMARY AND RECOMMENDATIONS

This material characterisation report describes and characterises the materials identified on-site for use in rehabilitation using the topsoil stockpile assessment, erodibility studies, previous soil and spoil assessments, and other GRM project-related documents.

6.1 Topsoil stockpiles

Generally, the stockpiled topsoil is considered to be of adequate quality for use as a primary growth media if chemical limitations are managed. Due to the high degree of heterogeneity, the summarised laboratory data should be considered representative of the soils as a whole, and not representative of individual stockpiles. The sampling program is considered adequate to describe these materials into broad soil management groups. Therefore, any stockpile not included in this assessment should be sampled and characterised prior to use in rehabilitation.

The main limitations of the stockpiled soils for use in rehabilitation are low fertility and for clay dominated topsoil, sodicity and salinity.

Chemical fertility of the stockpiled soils is often low. A balanced NPK fertiliser or compost should be applied during rehabilitation to provide a starter source of nutrients for initial vegetation growth. Subsequent applications of fertiliser, particularly nitrogen, may be required to maintain adequate fertility levels and ensure vegetation is established in the long-term.

Amelioration of sodicity requires the thorough incorporation of gypsum. Due to the high degree of heterogeneity of measured sodicity within stockpiles, gypsum rates should be calculated for individual stockpiles prior to use in rehabilitation.

Amelioration products and application rates should be assessed by an appropriately qualified person prior to use for rehabilitation and to complement the desired PMLU.

The elevated salinity identified in the clay topsoil, while high, should still allow the establishment of salt tolerant species. Species like Rhodes grass (*Chloris gayana*) should be favoured initially with the aim of establishing an adequate leaching profile to flush the salts from the rootzone before seeding species that are consistent with the desired PMLU.

Incorporation of durable rock into this soil could be considered to improve erosion performance.

6.2 Spoils

Generally, sandstone dominated spoils have the highest potential to be used as secondary growth media through varying degrees of amelioration. However, Tertiary materials with favourable chemistry also offer a possible value alternative as a secondary growth media on low gradient or flat areas, provided they can be identified and segregated consistently. Failure to do so would risk use of a Tertiary material that would not support the PMLU.

Where primary growth media availability is limited, a topsoil/unweathered sandstone spoil mix may be adopted to form a primary growth media with potential to support a

woodland PMLU, provided adequate amelioration is completed to negate any limiting properties of the spoil. If adopted, the chemical and physical properties and the overall viability of the proposed material should be assessed by a suitably qualified person before being applied to the broader rehabilitation.

All spoils with elevated salinity must be managed to adequately leach salts from the rootzone. Maximising infiltration by limiting slope gradient or mixing with a more permeable material are considered the most practical approaches.

Due to the high degree of heterogeneity in the spoils, the summarised laboratory data should only be considered a guide to their suitability. Targeted sampling of spoils planned for use in the upper cover layer profile (i.e. primary or secondary growth media) should be conducted prior to rehabilitation.

Chemical fertility of the spoils was no assessed as part of this study, but vegetation would benefit from an application of a balanced NPK fertiliser or compost to help alleviate some of the fertility issues identified with the stockpile topsoils.

6.3 Growth media for PMLU

Physical and chemical properties of the soil and spoils available on site will meet the requirements to establish the primary PMLUs for rehabilitated areas of cattle grazing and woodland habitat if appropriate amelioration is conducted. It is recommended that the growth media for each rehabilitation campaign be assessed by an appropriately qualified person prior to rehabilitation, to identify the required ameliorants and fertilisers.

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APPENDIX A: MAPS AND FIGURES

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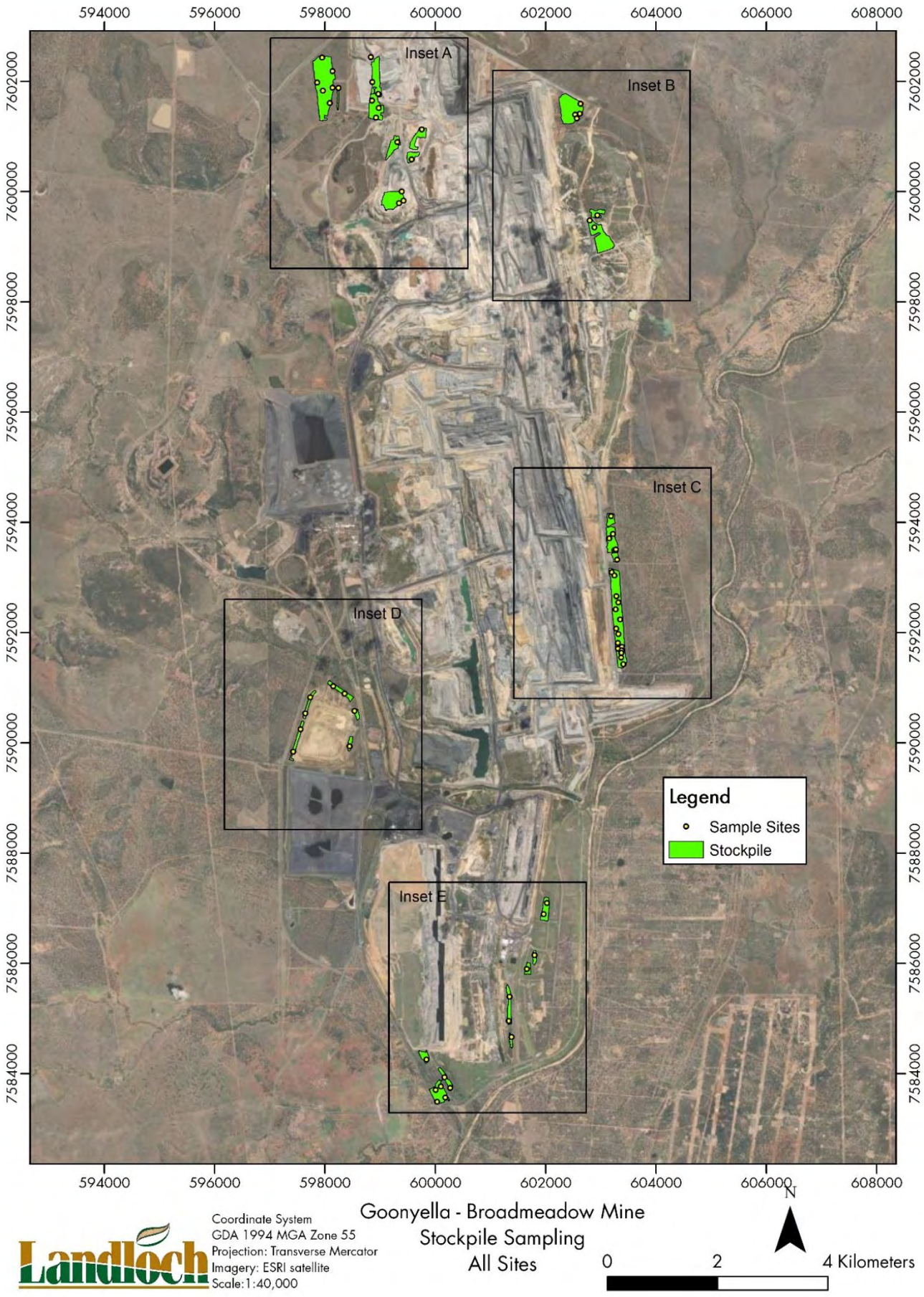

Figure A-1: GRM topsoil stockpile sampling locations.

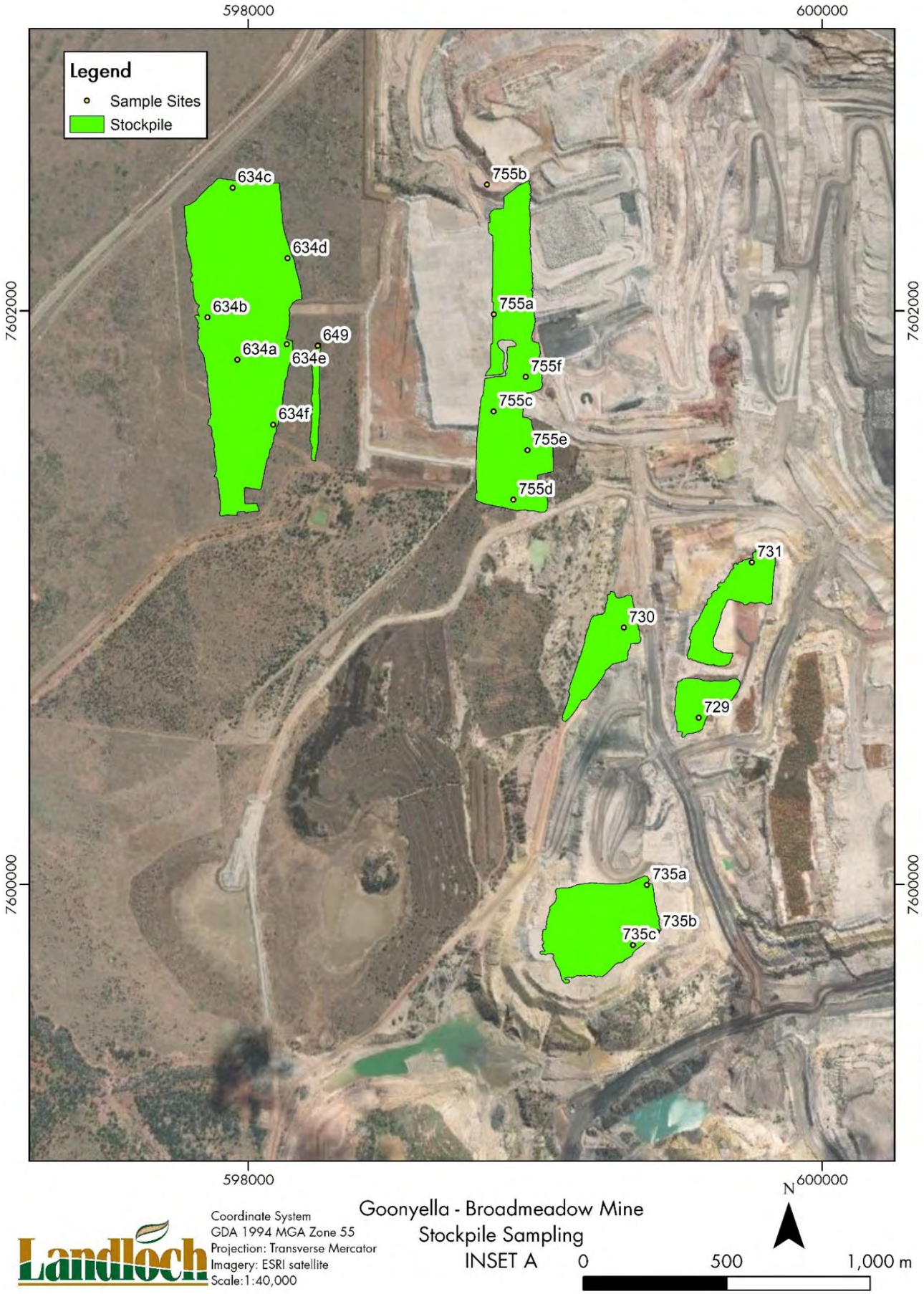

Figure A-2: GRM soil stockpile sampling locations in the mine area (Inset A).

Figure A-3: GRM soil stockpile sampling locations in the mine area (Insert B).

Figure A-4: GRM soil stockpile sampling locations in the mine area (Insert C).

Figure A-5: GRM soil stockpile sampling locations in the mine area (Insert D).

Figure A-6: GRM soil stockpile sampling locations in the mine area (Insert E).

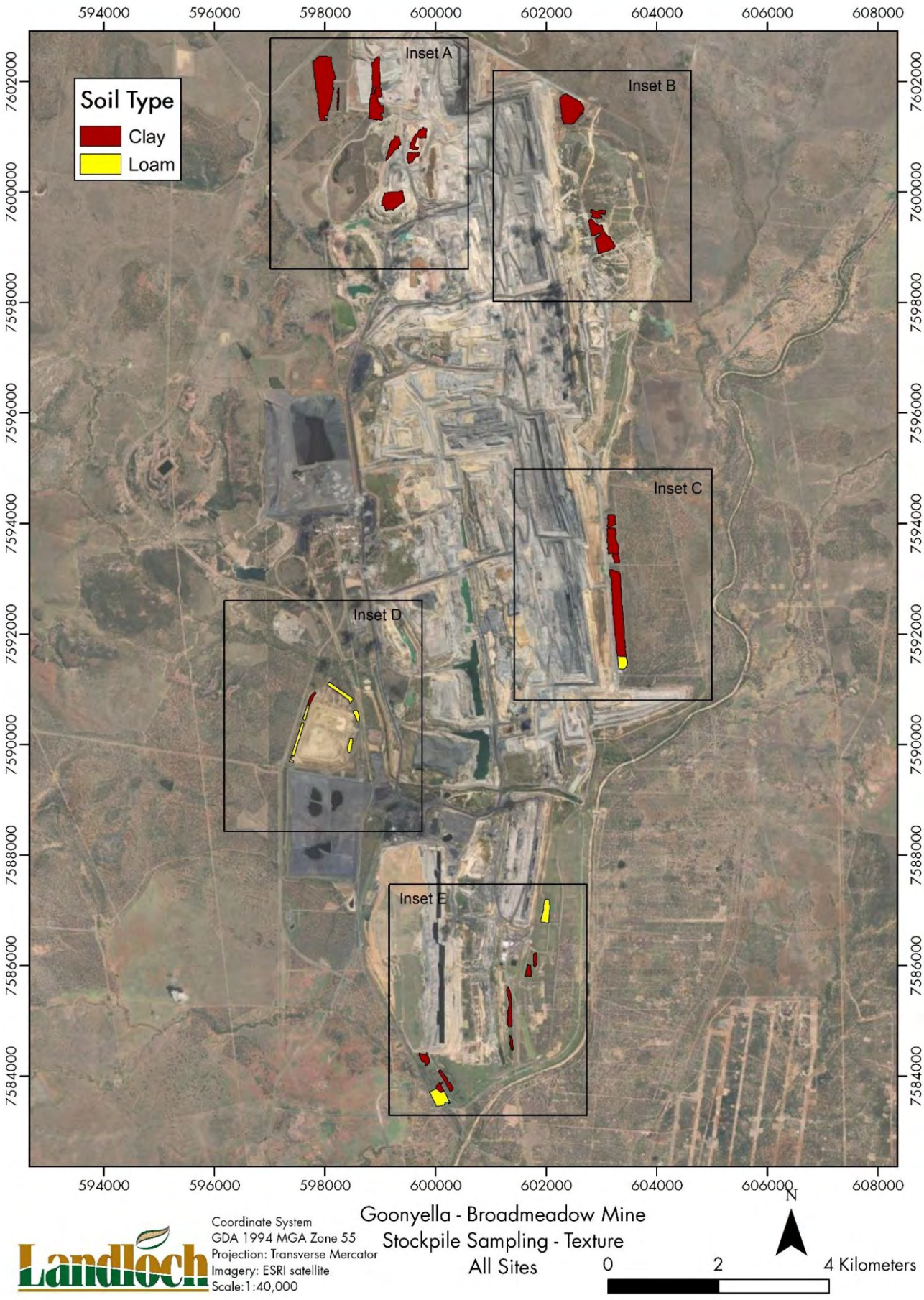

Figure A-7: Distribution of stockpiled topsoil materials at GRM.

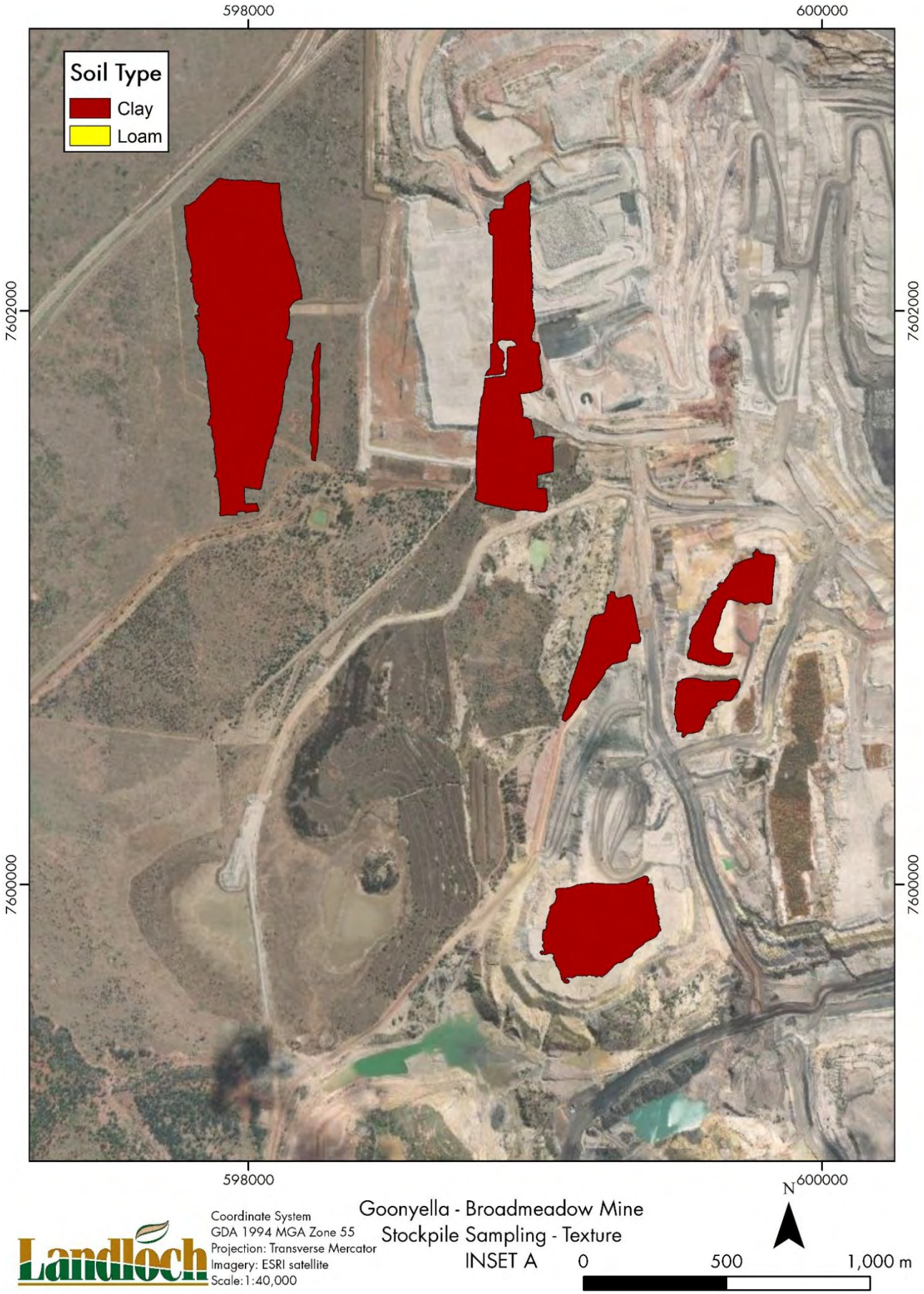

Figure A-8: Distribution of stockpiled soil materials at GRM (Insert A).

Figure A-9: Distribution of stockpiled soil materials at GRM (Insert B).

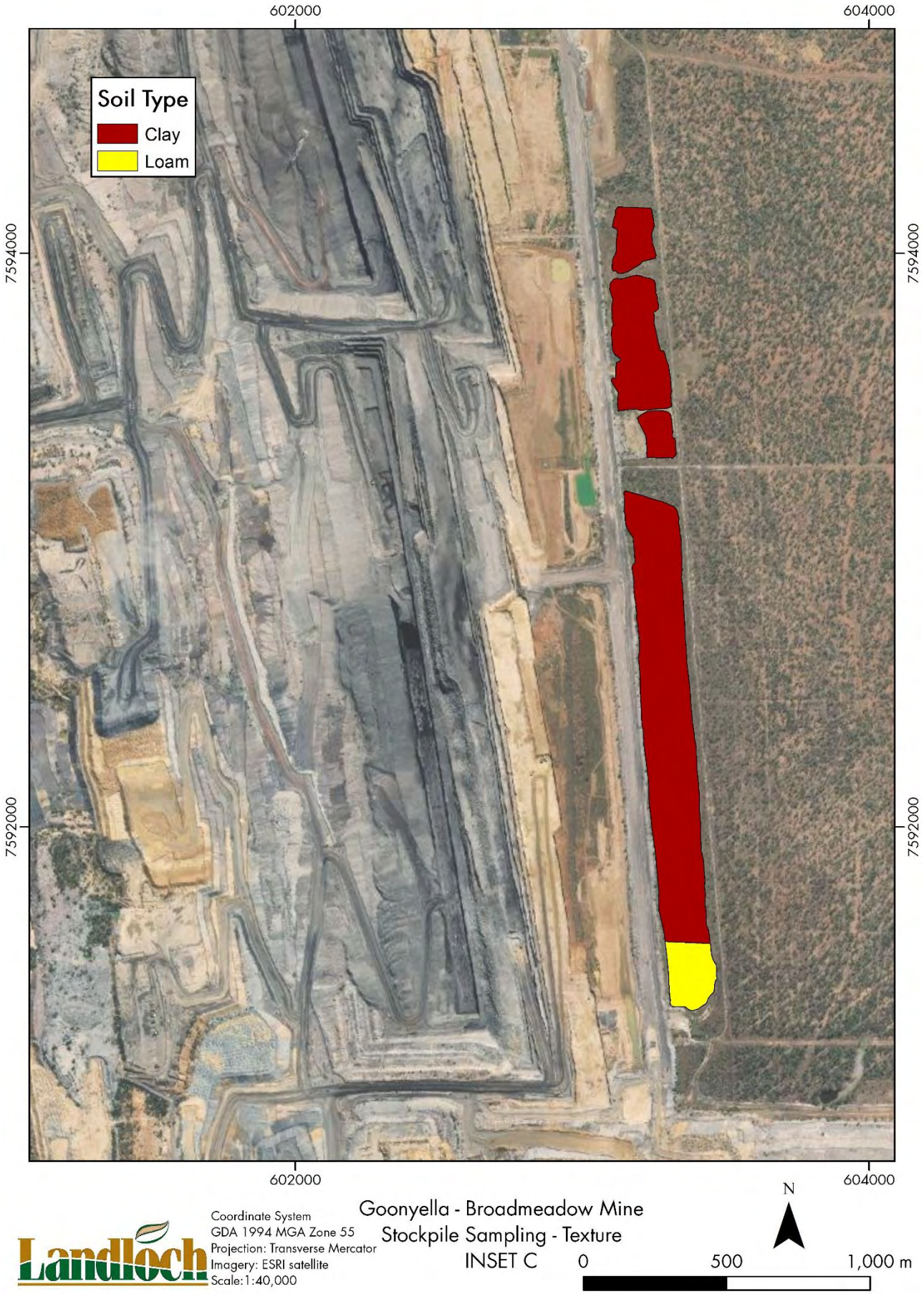

Figure A-10: Distribution of stockpiled soil materials at GRM (Insert C).

Figure A-11: Distribution of stockpiled soil materials at GRM (Insert D).

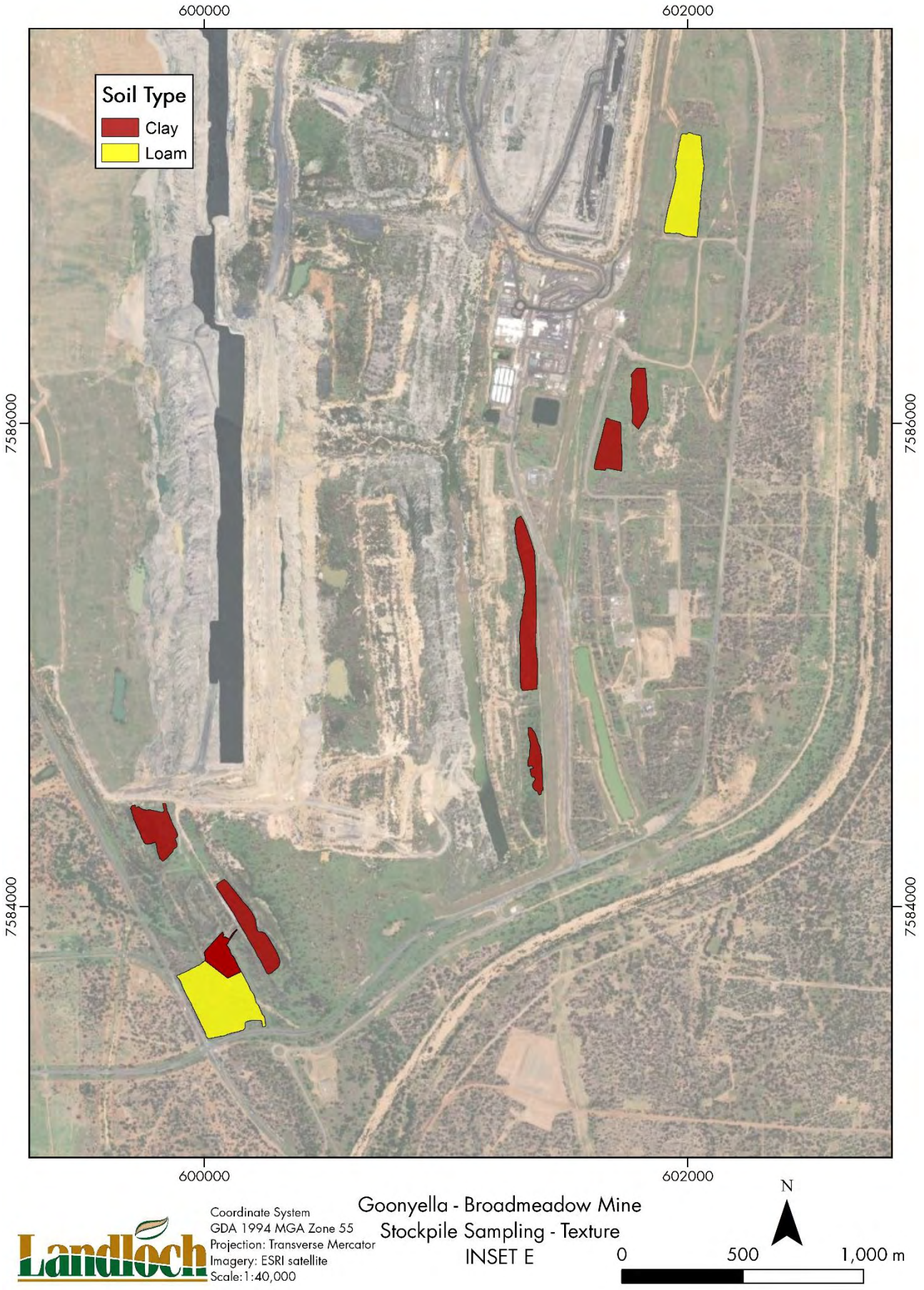

Figure A-12: Distribution of stockpiled soil materials at GRM (Insert E).

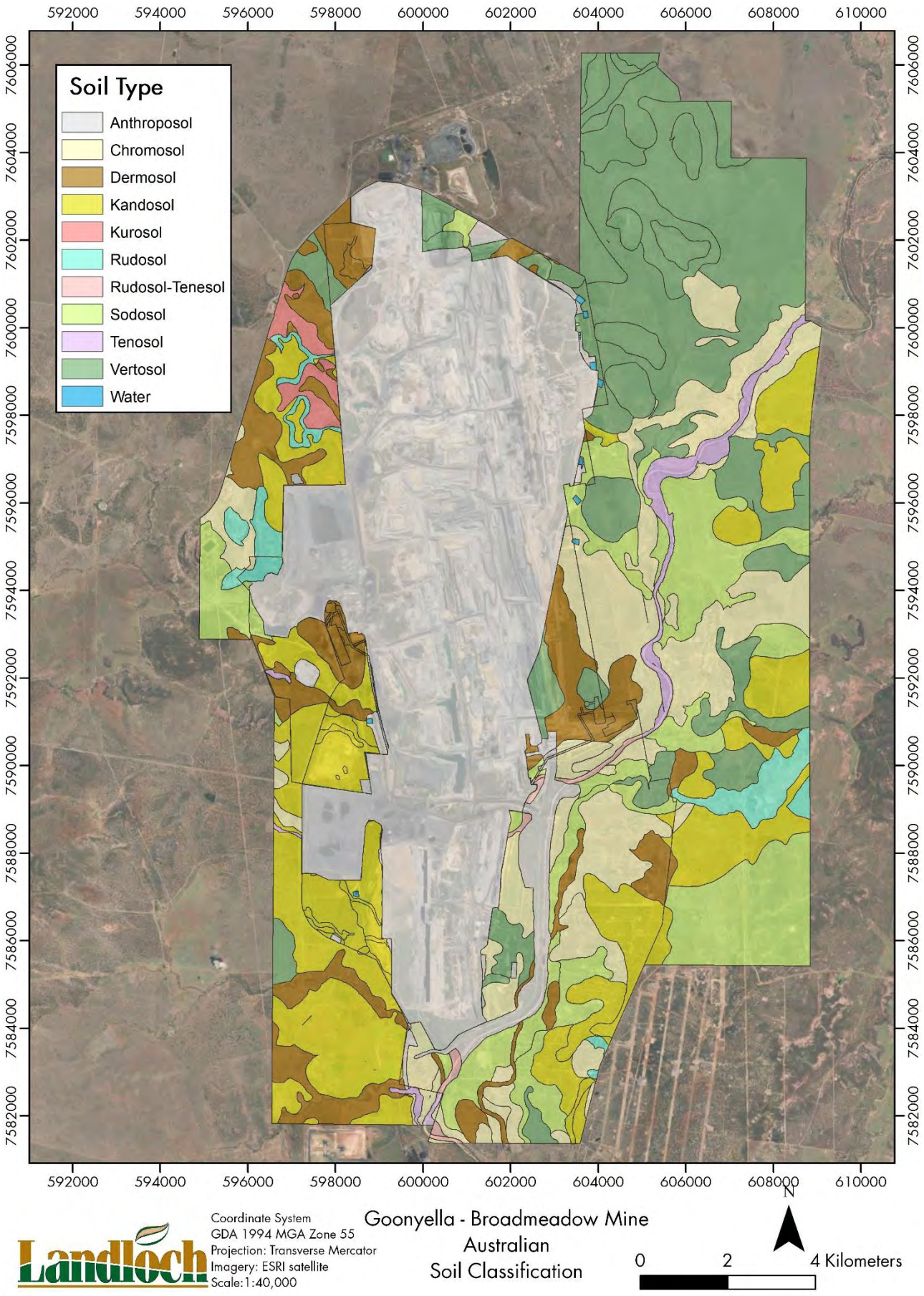

Figure A-13: ASC soil mapping synthesised from existing soil assessments.

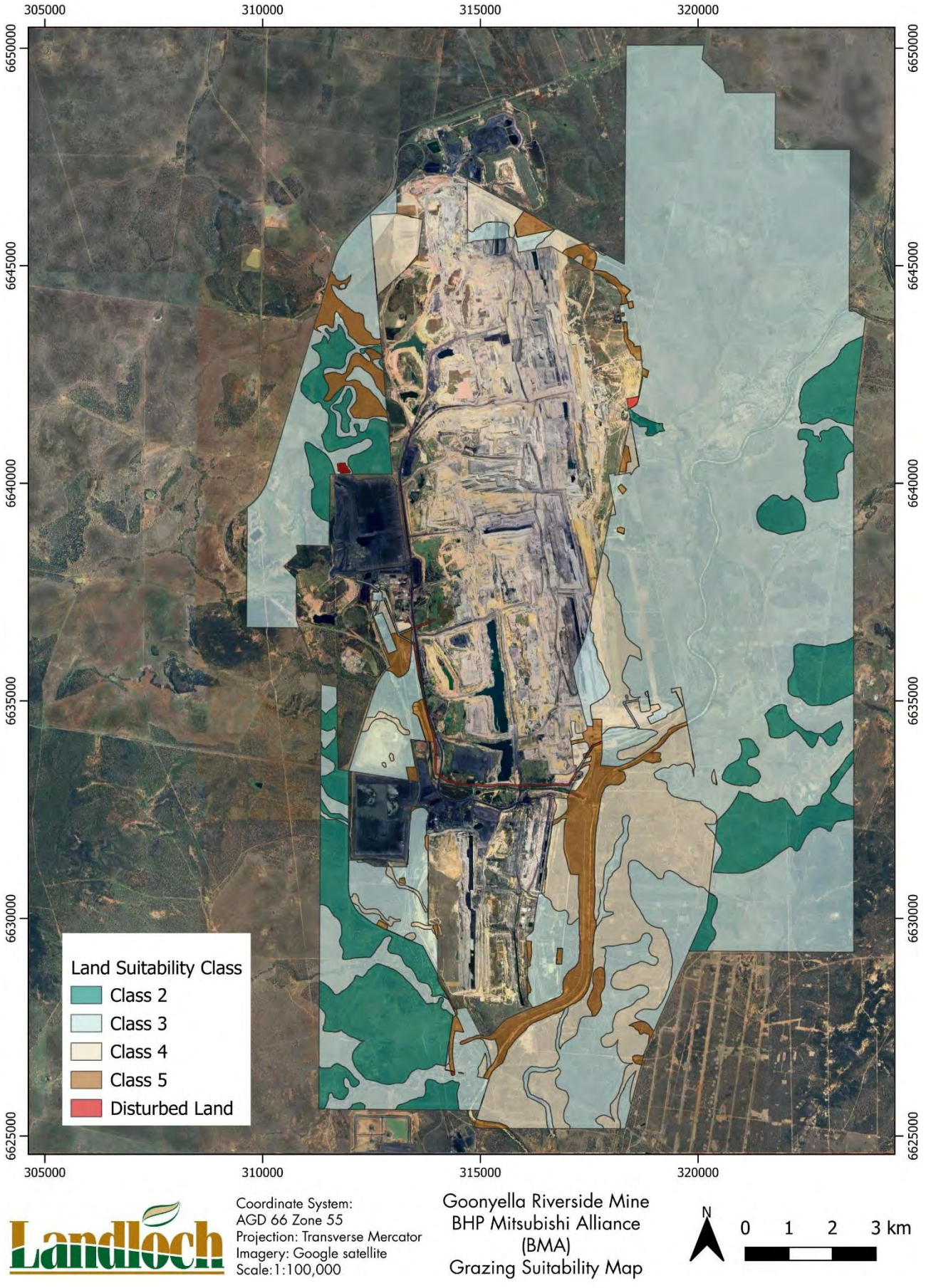

Figure A-14: Grazing land suitability class mapping synthesised from existing assessments.

APPENDIX B: DATA TABLES

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Table B-1: Sampling site locations.

Site ID	LATITUDE	LONGITUDE
625	-21.70432848	147.9951729
649	-21.68359622	147.9493759
665	-21.78577528	147.9531266
667	-21.79158645	147.9523015
675	-21.8428444	147.9661538
707	-21.76072472	147.9990511
709	-21.75359384	147.9978883
729	-21.69536833	147.9625542
730	-21.6925437	147.9600175
731	-21.69046203	147.9643118
634a	-21.68418225	147.9469384
634b	-21.6828513	147.9459266
634c	-21.67876491	147.946744
634d	-21.68097885	147.9486084
634f	-21.68622102	147.9481602
643e	-21.68368377	147.9486024
662a	-21.78176062	147.9493769
662b	-21.78294837	147.9513802
664a	-21.78622577	147.9445207
664b	-21.78360623	147.9453901
666a	-21.79253565	147.9424565
666b	-21.788835	147.9437345
678a	-21.84744675	147.9703407
678b	-21.84570871	147.9693235
680a	-21.84972811	147.9680712
680b	-21.8490352	147.969492
680b	-21.84903509	147.9694921
680c	-21.847223	147.9687005
680d	-21.84779716	147.9678087
704a	-21.77783334	148.0002574
704b	-21.776776	147.9998339

Site ID	LATITUDE	LONGITUDE
704c	-21.77599949	147.9998628
704d	-21.77559318	147.9998983
704e	-21.77531141	147.9992603
704f	-21.77502216	147.9999375
704g	-21.77436489	147.9992485
704h	-21.77293047	147.9993404
704i	-21.77204497	147.9989515
704j	-21.77051992	147.99962
704k	-21.76885661	147.9988301
704L	-21.76774284	147.9992958
704m	-21.76673899	147.9989609
704n	-21.76332133	147.9985948
704o	-21.76281223	147.9981089
708a	-21.7590476	147.9988043
708b	-21.75917464	147.9985599
708c	-21.75725212	147.9976429
708d	-21.75653654	147.9982578
716a	-21.7051901	147.9938422
716b	-21.70632616	147.9946898
726a	-21.68607085	147.9921159
726b	-21.68768247	147.9919724
726c	-21.68784167	147.991164
726c	-21.68846693	147.9914567
735a	-21.70064393	147.9608453
735b	-21.70211863	147.9611981
753c	-21.70253699	147.960388
755a	-21.68270393	147.9555755
755b	-21.67862097	147.955316
755c	-21.68575868	147.9555869
755d	-21.68853547	147.9562671
755e	-21.68697184	147.9567335
755f	-21.68466453	147.9566577

Table B-2: Ground observations and surface descriptions.

Site ID	Morphological Type	Stoniness (size)	Groundcover % (veg)	Veg/Litter	Stoniness (abundance)
625	Flat	<20mm	80-100%	80/20	2-10%
649	Bund	<20mm	80-100%	80/20	2-10%
665	Flat	<20mm	80-100%	80/20	2-10%
667	Flat	<20mm	0-20%	100/0	50-90%
675	Flat	<20mm	80-100%	80/20	2-10%
707	Flat	<20mm	80-100%	80/20	2-10%
709	Flat	<60mm	20-40%	80/20	20-50%
729	Flat	<60mm	80-100%	80/20	10-20%
730	Flat	<200mm	80-100%	80/20	10-20%
731	Flat	<200mm	60-80%	60/40	20-50%
634a	Flat		60-80%	80/20	2-10%
634b	Flat		60-80%	80/20	<2%
634c	Flat	<20mm	20-40%	80/20	10-20%
634d	Flat	<20mm	20-40%	80/20	10-20%
634f	Flat	<20mm	60-80%	80/20	2-10%
643e	Flat	<60mm	60-80%	80/20	2-10%
662a	Flat	<20mm	80-100%	80/20	2-10%
662b	Flat	<20mm	80-100%	80/20	2-10%
664a	Bund	<60mm	80-100%	80/20	10-20%
664b	Bund	<20mm	80-100%	80/20	2-10%
666a	Bund	<60mm	80-100%	80/20	10-20%
666b	Bund	<20mm	80-100%	80/20	2-10%
678a	Flat	<20mm	80-100%	80/20	2-10%
678b	Flat	<20mm	80-100%	80/20	2-10%
680a	Flat	<20mm	80-100%	80/20	2-10%
680b					
680b	Flat	<20mm	80-100%	80/20	2-10%
680c	Flat	<60mm	80-100%	80/20	2-10%
680d	Flat	<20mm	80-100%	80/20	2-10%
704a	Flat	<60mm	80-100%	80/20	2-10%
704b	Flat	<20mm	80-100%	80/20	

Site ID	Morphological Type	Stoniness (size)	Groundcover % (veg)	Veg/Litter	Stoniness (abundance)
704c	Flat	<20mm	80-100%	80/20	2-10%
704d	Flat	<60mm	80-100%	80/20	10-20%
704e	Flat	<200mm	80-100%	80/20	10-20%
704f	Flat	<60mm	80-100%	80/20	2-10%
704g	Flat	<20mm	80-100%	80/20	2-10%
704h	Flat	<20mm	80-100%	80/20	2-10%
704i	Flat	<60mm	80-100%	80/20	2-10%
704j	Flat	<20mm	80-100%	80/20	2-10%
704k	Flat	<20mm	80-100%	80/20	2-10%
704L	Flat	<20mm	80-100%	80/20	2-10%
704m	Flat	<60mm	80-100%	80/20	2-10%
704n	Flat	<20mm	80-100%	80/20	2-10%
704o	Flat	<20mm	80-100%	80/20	2-10%
708a	Flat	<20mm	80-100%	80/20	2-10%
708b	Flat	<200mm	80-100%	80/20	10-20%
708c	Flat	<200mm	80-100%	80/20	20-50%
708d	Flat	<20mm	80-100%	80/20	2-10%
716a	Flat	<20mm	60-80%	80/20	10-20%
716b	Flat	<60mm	80-100%	80/20	10-20%
726a	Flat	<20mm	20-40%	80/20	
726b	Flat	<20mm	20-40%	80/20	10-20%
726c	Flat	<20mm	20-40%	80/20	10-20%
726c	Flat	<20mm	20-40%	80/20	10-20%
735a	Flat	<20mm	60-80%	80/20	10-20%
735b	Flat	<20mm	60-80%	80/20	10-20%
753c	Flat	<20mm	60-80%	80/20	10-20%
755a	Batter Top	<60mm	0-20%		2-10%
755b	Batter Top	<60mm	0-20%		2-10%
755c	Flat	<60mm	0-20%		10-20%
755d	Flat	<60mm	0-20%		10-20%
755e	Flat	<60mm	0-20%		10-20%
755f	Flat	<60mm	0-20%		10-20%

Table B-3: Morphological description of stockpiled soil materials.

Site ID	Date	Total Depth (m)	Layer Depth (m)	Texture Group 1o	Texture Field	Colour (rapid)				Total Coarse Fragment %	Coarse Fragments 1°			Coarse Fragments 2°			Roots	Origin (i.e topsoil, subsoil, overburden); Parent Materials; and Proportions	Comments	Sample ID / Depth (m)	Sample Type
						Primary	Secondary	Mottles	Streaks		%	Size	Shape	%	Size (mm)	Shape					
649	5-Oct-23	1.5	0.5	CLAY	Light Clay	Dark Brown	Red	0		5-10	5-11	6-20	Sub-rounded				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Dark Brown	Red	10-20		10-20	5-10	6-20	Sub-rounded	5-10	2-6	Rounded	Common	topsoil	20% groups of coarse sand with small gravells, f	0.5-1	Grab
			1.5	CLAY	Medium Clay	Brown	Red	10-20		10-20	10-20	6-20	Sub-rounded				Few	subsoil	10-20% hard carbonates, MC with fine sand	1-1.5	Grab
																				composite	Composite
634a	5-Oct-23	2	0.5	CLAY	Medium Clay	Brown				5-10	5-10	6-20	Sub-rounded				Common	topsoil	mix of angular and subrounded ironstone and r	0-0.5	Grab
			1	CLAY	Medium Clay	Brown			2-5	10-20	5-10	6-20	Sub-rounded	5-10	6-20	Angular	Few	topsoil	mix of angular and subrounded ironstone and r	0.5-1	Grab
			2	CLAY	Medium Clay	Brown			2-5	10-20	5-10	6-20	Sub-rounded	5-10	6-20	Angular	Few	topsoil	mix of angular and subrounded ironstone and r	1.5-2	Grab
																				composite	Composite
634b	5-Oct-23	3	0.5	CLAY	Medium Clay	Brown				10-20	10-20	6-20	Sub-rounded				Common	topsoil	some soft carbonates, mudstone coarse frags, M	0-0.5	Grab
			1.5	CLAY	Medium Clay	Brown			2-5	10-20	10-20	6-20	Sub-rounded				Few	topsoil	some soft carbonates, mudstone coarse frags M	1-1.5	Grab
			3	CLAY	Medium Clay	Brown			2-5	5-10	5-10	6-20	Sub-rounded				Few	topsoil	MC fine sandy	2.5-3	Grab
																				composite	Composite
634c	5-Oct-23	3	0.5	CLAY	Medium Clay	Brown				20-30	10-20	6-20	Sub-rounded	5-10	20-60	Angular	Few	topsoil	angular weathered rock whitish and moderate s	0-0.5	Grab
			1.5	CLAY	Clay Loam Sandy	Brown				10-20	10-20	20-60	Angular				Nil	topsoil	angular weathered rock whitish and moderate s	1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Red	10-20	0	10-20	10-20	20-60	Angular				Nil	topsoil	grey medium clay fine sandy , angular weather	2.5-3	Grab
																				composite	Composite
634d	5-Oct-23	3	0.5	CLAY	Medium Clay	Brown	Red		10-20	5-10	10-20	6-20	Angular	5-10	6-20	Sub-rounde	Few	topsoil	grey and orange streaks. weathered rock mudst	0-0.5	Grab
			1.5	CLAY	Medium Clay	Brown	Red		10-20	10-20	10-20	6-20	Angular				Nil	topsoil	grey and orange streaks. weathered rock mudst	1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Red		5-10	5-10	5-10	20-60	Angular				Nil	topsoil	grey and orange streaks. weathered rock mudst	2.5-3	Grab
																				composite	Composite
634e	5-Oct-23	2	0.5	CLAY	Medium Clay	Brown	Red			5-10	5-10	20-60	Sub-rounded				Common	topsoil	mudstone and quartz fragments, MC fine sandy	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Red			5-10	5-10	20-60	Sub-rounded				Few	topsoil	mudstone and quartz fragments	0.5-1	Grab
			2	CLAY	Medium Clay	Brown	Red			5-10	5-10	20-60	Sub-rounded				Few	topsoil	mudstone and quartz fragments	1.5-2	Grab
																				composite	Composite
634f	6-Oct-23	3	0.5	CLAY	Medium Clay	Brown	Red			10-20	5-10	20-60	Sub-rounded	5-10	60-200	Sub-rounde	Few	topsoil	10% dark brown MHC material mixed	0-0.5	Grab
			1.5	CLAY	Medium Clay	Brown	Red			10-20	5-10	20-60	Sub-rounded	5-10	60-200		Few	topsoil	10% dark brown MHC material mixed	1-1.5	Grab
			3	CLAY	Light Clay	Red				20-30	20-30	6-20	Sub-angular				Nil	topsoil	clear boundary between material clear, gravelly	2.5-3	Grab
																				composite	Composite
755a	6-Oct-23	2	0.5	CLAY	Medium Clay	Brown	Pale Red			10-20	5-10	6-20	Sub-angular	5-10	20-60	Sub-rounde	Nil	topsoil	no clear boundaries	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Red			10-20	5-10	6-20	Sub-angular				Nil		no clear boundaries	0.5-1	Grab
			2	CLAY	Medium Clay	Brown	Pale Red			10-20	5-10	6-20	Sub-angular				Nil			1.5-2	Grab
			c																	composite	Composite
755b	6-Oct-23	3	0.5	CLAY	Light Medium Clay	Brown	Pale Red			2-5	2-5	6-20	Sub-angular				Nil	topsoil	ironstone coarse fragments present.	0.5-1	Grab
			1.5	CLAY	Light Medium Clay	Brown	Pale Red			2-5	2-5	6-20	Sub-angular				Nil		ironstone coarse fragments	1.5-2	Grab
			2.5	CLAY	Light Medium Clay	Brown	Pale Red			5-10	5-10	6-20	Sub-angular				Nil		ironstone fragments	2.5-3	Grab
			c																	composite	Composite
755c	6-Oct-23	2	0.5	CLAY	Medium Clay	Pale Brown	Brown			2-5	2-5	6-20	Sub-rounded				Nil	topsoil	ironstone fragments	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Red			2-5	2-5	20-60	Sub-angular				Nil		larger ironstone fragments	1-1.5	Grab
			2.5	CLAY	Medium Clay	Brown	Pale Red			2-5	2-5	6-20	Sub-angular				Nil			2-2.5	Grab
			c																	composite	Composite
755d	7-Oct-23	3	0.5	CLAY	Medium Clay	Pale Brown	Brown			5-10	5-10	20-60	Sub-angular				Common	topsoil	ironstone fragments	0-0.5	Grab
			1.5	CLAY	Medium Clay	Brown	Pale Brown			5-10	5-10	20-60	Sub-angular				Few			1-1.5	Grab
			2.5	CLAY	Medium Clay	Brown	Dark Brown			5-10	5-10	6-20	Sub-angular				Nil			2.5-3	Grab
			c																	composite	Composite
755e	7/10/2023	2	0.5	CLAY	Medium Clay	Brown	Pale Red			5-10	5-10	20-60	Sub-angular				Few	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Red			5-10	5-10	20-60	Sub-angular				Few			0.5-1	Grab
			1.5	CLAY	Medium Clay	Brown	Pale Red			5-10	5-10	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
755f	7/10/2023	2	0.5	CLAY	Medium Clay	Brown	Pale Brown			5-10	5-10	20-60	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Red			5-10	5-10	20-60	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Medium Clay	Dark Brown	Pale Red			5-10	5-10	20-60	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
730	7/10/2023	3	0.5	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Many	topsoil	all the same material . light clay with fine sand	0-0.5	Grab
			1.5	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Many			1-1.5	Grab
			3	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Common			2.5-3	Grab
			c																	composite	Composite
729	7/10/2023	2	0.5	CLAY	Medium Heavy Clay	Brown				5-10	5-10	6-20	Sub-angular				Common	topsoil	carbonates present. some fine sand in textures	0-0.5	Grab
			1	CLAY	Medium Heavy Clay	Brown				5-10	5-10	6-20	Sub-angular				Common		carbonates present. some fine sand in textures	0.5-1	Grab
			2	CLAY	Medium Heavy Clay	Brown				5-10	5-10	6-20	Sub-angular				Few		carbonates present. some fine sand in textures	1.5-2	Grab
			c																	composite	Composite

Site ID	Date	Total Depth (m)	Layer Depth (m)	Texture Group 1o	Texture Field	Colour (rapid)				Total Coarse Fragment %	Coarse Fragments 1°			Coarse Fragments 2°			Roots	Origin (i.e topsoil, subsoil, overburden); Parent Materials; and Proportions	Comments	Sample ID / Depth (m)	Sample Type
						Primary	Secondary	Mottles	Streaks		%	Size	Shape	%	Size (mm)	Shape					
731	7/10/2023	3	0.5	CLAY	Medium Clay	Brown	Pale Brown			10-20	10-20	20-60	Angular				Common	topsoil	3 separate face cuts made into stockpile edge	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Brown			5-10	5-10	20-60	Angular				Few			1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Pale Brown			5-10	5-10	20-60	Angular				Few			2.5-3	Grab
			c																	composite	Composite
735a	8/10/2023	3	0.5	CLAY	Medium Heavy Clay	Dark Brown		5-10	5-10	5-10	5-10	6-20	Angular				Few	topsoil	red and orange mottles/streaks,very tough for (	0-0.5	Grab
			1	CLAY	Medium Heavy Clay	Dark Brown		5-10	5-10	5-10	5-10	6-20	Angular				Few			1-1.5	Grab
			3	CLAY	Medium Heavy Clay	Dark Brown		5-10	5-10	5-10	5-10	6-20	Angular				Few			2.5-3	Grab
			c																	composite	Composite
735b	8/10/2023	3	0.5	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Nil	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Nil			1-1.5	Grab
			3	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Nil			2.5-3	Grab
			c																	composite	Composite
735c	8/10/2023	3	0.5	CLAY	Medium Clay	Brown		5-10		10-20	10-20	6-20	Angular	2-5	20-60	Sub-angular	Few	topsoil	some orange mottles	0-0.5	Grab
			1	CLAY	Medium Clay	Brown		5-10		10-20	10-20	6-20	Angular	2-5	20-60	Sub-angular	Few		as far as we could get access	1-1.5	Grab
			3	CLAY	Medium Clay	Brown		5-10		10-20	10-20	6-20	Angular	2-5	20-60	Sub-angular	Few		gravelly ironstone throughout	2.5-3	Grab
			c																	composite	Composite
726a	8/10/2023	3	0.5	CLAY	Medium Clay	Brown	Red			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Red			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few			1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Red			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few			2.5-3	Grab
			c																	composite	Composite
726b	8/10/2023	3	0.5	CLAY	Medium Clay	Brown	Red			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few	topsoil	some weak angular pale brown frags 50mm, gra	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Red			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few		gravelly ironstone	1-1.5	Grab
			3	CLAY	Medium Heavy Clay	Brown				5-10	5-10	6-20	Angular				Few		change to brown clay diffues at 2.5	2.5-3	Grab
			c																	composite	Composite
726c	8/10/2023	3	0.5	CLAY	Medium Clay	Brown	Red	10-20		10-20	10-20	6-20	Sub-angular				Few	topsoil	pale brown material 10-20%	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Red	10-20		10-20	10-20	6-20	Sub-angular				Few		pale brown material 10-20%	1-1.5	Grab
			3	CLAY	Medium Clay	Pale Brown				5-10	5-10	6-20	Angular				Few			2.5-3	Grab
			c																	composite	Composite
726d	8/10/2023	3	0.5	CLAY	Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few			1-1.5	Grab
			3	CLAY	Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few			2.5-3	Grab
			c																	composite	Composite
716a	8/10/2023	3	0.5	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Few	topsoil	gravellg ironstone throughout	0-0.5	Grab
			1	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Nil			1-1.5	Grab
			3	CLAY	Light Medium Clay	Red	Brown			10-20	10-20	6-20	Sub-angular	2-5	20-60	Sub-angular	Nil			2.5-3	Grab
			c																	composite	Composite
625	9/10/2023	3	0.5	CLAY	Medium Clay	Dark Brown	Brown			20-30	20-30	6-20	Sub-angular				Common	topsoil	small coarse fragments throughout	0-0.5	Grab
			1	CLAY	Medium Clay	Brown	Pale Brown			20-30	20-30	6-20	Sub-angular				Common		small coarse fragments throughout	1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Pale Brown			20-30	20-30	20-60	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
716b	9/10/2023	2	0.5	CLAY	Light Medium Clay	Pale Red	Pale Brown			5-10	5-10	20-60	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Pale Red				10-20	10-20	20-60	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Medium Clay	Pale Red	Pale Brown			10-20	10-20	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704a	10/10/2023	2	0.5	LOAM	Clay Loam Sandy	Pale Brown				5-10	5-10	20-60	Sub-angular				Common	topsoil	very compacted	0-0.5	Grab
			1	LOAM	Clay Loam Sandy	Pale Brown				5-10	5-10	20-60	Sub-angular				Few			0.5-1	Grab
			2	LOAM	Clay Loam Sandy	Pale Brown				5-10	5-10	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704b	10/10/2023	3	0.5	LOAM	Silty Clay Loam	Pale Brown				2-5	2-5	6-20	Sub-angular				Many	topsoil		0-0.5	Grab
			1	LOAM	Silty Clay Loam	Pale Brown				2-5	2-5	6-20	Sub-angular				Common			1-1.5	Grab
			3	LOAM	Silty Clay Loam	Pale Brown				2-5	2-5	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
704c	10/10/2023	2	0.5	CLAY	Light Clay	Pale Brown				20-30	20-30	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Pale Brown				20-30	20-30	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Clay	Pale Brown				20-30	20-30	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704d	10/10/2023	2	0.5	CLAY	Light Clay	Pale Brown	Pale Grey			10-20	10-20	6-20	Angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Pale Brown				5-10	5-10	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Clay	Pale Brown				5-10	5-10	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite

Site ID	Date	Total Depth (m)	Layer Depth (m)	Texture Group 1o	Texture Field	Colour (rapid)				Total Coarse Fragment %	Coarse Fragments 1°			Coarse Fragments 2°			Roots	Origin (i.e topsoil, subsoil, overburden); Parent Materials; and Proportions	Comments	Sample ID / Depth (m)	Sample Type
						Primary	Secondary	Mottles	Streaks		%	Size	Shape	%	Size (mm)	Shape					
704e	10/10/2023	2	0.5	CLAY	Light Medium Clay	Pale Brown	Pale Grey			20-30	20-30	20-60	Sub-angular				Common			0-0.5	Grab
			1	CLAY	Light Clay	Pale Brown	Pale Grey			20-30	20-30	20-60	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Clay	Pale Brown	Pale Grey			20-30	20-30	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704f	10/10/2023	2	0.5	CLAY	Light Medium Clay	Pale Brown	Pale Red			2-5	2-5	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Pale Brown	Pale Red			2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Medium Clay	Pale Brown				5-10	5-10	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704g	10/10/2023	2	0.5	CLAY	Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Many	topsoil	compacted	0-0.5	Grab
			1	CLAY	Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Many			0.5-1	Grab
			2	CLAY	Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
704h	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Many	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
704i	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704j	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Angular				Common		red/maroon and grey coarse fragments 20mm	0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Angular				Few		red/maroon and grey coarse fragments 20mm	1.5-2	Grab
			c																	composite	Composite
704k	11/10/2023	2	0.5	CLAY	Medium Clay	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704L	11/10/2023	2	0.5	CLAY	Light Clay	Dark Brown	Pale Red			2-5	2-5	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Brown	Pale Brown			2-5	2-5	20-60	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown	Pale Brown			2-5	2-5	20-60	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704m	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Medium Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Few		white material on pit face, possibly carbonates	1.5-2	Grab
			c																	composite	Composite
704n	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Many	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
704o	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Common	topsoil	very compacted	0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	2-6	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown	Pale Red			2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
707	11/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
708a	11/10/2023	2	0.5	CLAY	Medium Clay	Brown				5-10	5-10	6-20	Angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown				5-10	5-10	20-60	Angular				Few		grey rock	0.5-1	Grab
			2	CLAY	Medium Clay	Brown				2-5	2-5	6-20	Angular				Few			1.5-2	Grab
			c																	composite	Composite
708b	12/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown	Pale Brown			2-5	2-5	20-60	Sub-angular				Nil			1.5-2	Grab
			c																	composite	Composite
708c	12/10/2023	3	0.5	CLAY	Light Medium Clay	Pale Brown				10-20	10-20	20-60	Sub-angular				Few	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Pale Brown				10-20	10-20	20-60	Sub-angular				Few			1-1.5	Grab
			3	CLAY	Light Medium Clay	Pale Brown	Brown			10-20	10-20	20-60	Sub-angular				Nil			2.5-3	Grab
			c																	composite	Composite

Site ID	Date	Total Depth (m)	Layer Depth (m)	Texture Group 1o	Texture Field	Colour (rapid)				Total Coarse Fragment %	Coarse Fragments 1°			Coarse Fragments 2°			Roots	Origin (i.e topsoil, subsoil, overburden); Parent Materials; and Proportions	Comments	Sample ID / Depth (m)	Sample Type
						Primary	Secondary	Mottles	Streaks		%	Size	Shape	%	Size (mm)	Shape					
708d	12/10/2023	2	0.5	CLAY	Medium Clay	Brown	Dark Brown			2-5	2-5	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
709	12/10/2023	3	0.5	CLAY	Medium Clay	Brown	Dark Brown			5-10	5-10	6-20	Sub-angular				Few	topsoil		0-0.5	Grab
			1	CLAY	Medium Clay	Brown				10-20	10-20	6-20	Sub-angular				Few			1-1.5	Grab
			3	CLAY	Medium Clay	Brown	Dark Brown			20-30	20-30	6-20	Sub-angular				Nil			2.5-3	Grab
			c																	composite	Composite
666a	12/10/2023	3	0.5	LOAM	Sandy Clay Loam	Brown				2-5	2-5	6-20	Sub-angular				Many	topsoil	probably mixed pile	0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	6-20	Sub-angular				Common			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Brown	Dark Brown			2-5	2-5	6-20	Sub-angular				Common			2.5-3	Grab
			c																	composite	Composite
666b	12/10/2023	3	0.5	LOAM	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Many	topsoil	mixed pile. timber mixed in	0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Dark Brown	Brown			5-10	5-10	6-20	Sub-angular				Common			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Dark Brown	Brown			5-10	5-10	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
664a	12/10/2023	3	0.5	LOAM	Clay Loam Sandy	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	LOAM	Clay Loam Sandy	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Few			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Dark Brown	Brown			5-10	5-10	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
664b	12/10/2023	3	0.5	CLAY	Light Medium Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Many	topsoil		0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Common			1-1.5	Grab
			3	CLAY	Silty Clay Loam	Brown	Dark Brown			5-10	5-10	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
662a	12/10/2023	3	0.5	LOAM	Sandy Clay Loam	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Many	topsoil		0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Few			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
662b	12/10/2023	3	0.5	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	6-20	Sub-angular				Many	topsoil		0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	6-20	Sub-angular				Common			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
665	12/10/2023	3	0.5	LOAM	Sandy Clay Loam	Grey	Pale Brown			2-5	2-5	6-20	Sub-angular				Many	topsoil		0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Grey	Pale Brown			2-5	2-5	6-20	Sub-angular				Common			1-1.5	Grab
			3	LOAM	Sandy Clay Loam	Pale Brown	Pale Grey			2-5	2-5	6-20	Sub-angular				Few			2.5-3	Grab
			c																	composite	Composite
667	12/10/2023	2	0.5	LOAM	Sandy Clay Loam	Pale Brown				20-30	20-30	6-20	Sub-angular				Few	topsoil	stony surface	0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Pale Brown		2-5		20-30	20-30	6-20	Sub-angular				Few			0.5-1	Grab
			2	LOAM	Sandy Clay Loam	Pale Brown	Pale Red			10-20	10-20	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
678a	13/10/2023	2	0.5	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Many	topsoil	photo shows incorrect depth of 1-1.5. sample b	0-0.5	Grab
			1	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Common		very compacted	0.5-1	Grab
			2	CLAY	Light Medium Clay	Brown				2-5	2-5	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
680a	13/10/2023	2	0.5	LOAM	Clay Loam Sandy	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	LOAM	Clay Loam Sandy	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	LOAM	Sandy Clay Loam	Brown				2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
680b	13/10/2023	2	0.5	LOAM	Sandy Clay Loam	Brown				2-5	2-5	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Brown				2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	LOAM	Sandy Clay Loam	Brown				2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c		Sandy Clay Loam															composite	Composite
680c	13/10/2023	2	0.5	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Few			0.5-1	Grab
			2	CLAY	Light Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite
680d	13/10/2023	2	0.5	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Common			0.5-1	Grab
			2	LOAM	Sandy Clay Loam	Brown	Pale Brown			2-5	2-5	2-6	Sub-angular				Few			1.5-2	Grab
			c																	composite	Composite

Site ID	Date	Total Depth (m)	Layer Depth (m)	Texture Group 1o	Texture Field	Colour (rapid)				Total Coarse Fragment %	Coarse Fragments 1°			Coarse Fragments 2°			Roots	Origin (i.e topsoil, subsoil, overburden); Parent Materials; and Proportions	Comments	Sample ID / Depth (m)	Sample Type
						Primary	Secondary	Mottles	Streaks		%	Size	Shape	%	Size (mm)	Shape					
678b	13/10/2023	2	0.5	CLAY	Light Clay	Brown				5-10	5-10	2-6	Sub-angular				Common	topsoil		0-0.5	Grab
			1	CLAY	Light Clay	Brown				5-10	5-10	2-6	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Clay	Brown				5-10	5-10	6-20	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
675	13/10/2023	2	0.5	CLAY	Light Clay	Brown	Pale Brown			5-10	5-10	6-20	Sub-angular				Common	topsoil	compacted	0-0.5	Grab
			1	CLAY	Light Clay	Brown	Pale Brown			10-20	10-20	6-20	Sub-angular				Common			0.5-1	Grab
			2	CLAY	Light Clay	Brown	Dark Brown			5-10	5-10	6-20	Sub-angular				Common			1.5-2	Grab
			c																	composite	Composite
694	6/10/2023	4	1	LOAM	Sandy Clay Loam	Brown				0							Common	Topsoil		0-0.5	grab
			2	LOAM	Light Medium Clay	Brown		10-20	5-10	0							Few	Topsoil	mottles of g r ey MC and streaks of orange	1-1.5	grab
			3	LOAM	Clay Loam Sandy	Brown		10-20	5-10	0							Nil	Topsoil	mottles of g r ey MC and streaks of orange	2.5-3	grab
			4																	Composite	Composite
695	6/10/2023	6	1	CLAY	Light Clay	Brown				5-10	5-10	6-20	Angular				Common	subsoil	grey and orang mottled subsoily material, 20t e	0-0.5	grab
			2	CLAY	Light Clay	Brown				10-20	5-10	6-20	Angular	5-10	20-60	Sub-rounde	Few	subsoil	pale grey clay cgunks with small angular frags	1-1.5	grab
			3	CLAY	Light Clay	Brown				10-20	5-10	6-20	Angular	5-10	20-60	Sub-rounde	Nil	subsoil	dark grey MHC 5% In clumps	2.5-3	grab
			4																	Composite	Composite
696	6/10/2023	4	1	LOAM	Sandy Loam	Brown		5-10		5-10	5-10	6-20	Angular				Common	Topsoil	some slight 10% light brown mottles, some silt	0-0.5	grab
			2	LOAM	Sandy Loam	Brown		5-10		5-10	5-10	6-20	Angular				Few	Topsoil	some slight 10% light brown mottles, some silt	1-1.5	grab
			3	LOAM	Sandy Loam	Brown		5-10		5-10	5-10	6-20	Angular				Nil	Topsoil	some slight 10% light brown mottles,some silt	2.5-3	grab
			4																	Composite	Composite
696b	6/10/2023	3	1	LOAM	Sandy Loam	Brown		0									Common	Topsoil	5-10% of a orange grey mottled clay loamsandy	0-0.5	grab
			2	LOAM	Sandy Clay Loam	Brown		0									Few	Topsoil	10-20% of a orange grey mottled clay loamsand	1-1.5	grab
			3	LOAM	Sandy Clay Loam	Brown		0									Few	Topsoil	10-20% of a orange grey mottled clay loamsand	2.5-3	grab
			4																	Composite	Composite
687a	9/10/2023	4	1	CLAY	Medium Clay	Brown				5-10	5-10	6-20	Angular				Common	Topsoil	moderate strength angular mudstones, MC san	0-0.5	grab
			2	CLAY	Medium Clay	Brown				5-10	5-10	6-20	Angular				Few	Topsoil	moderate strength angular mudstones, MC san	1-1.5	grab
			3	CLAY	Medium Clay	Brown				5-10	5-10	6-20	Angular				Few	Topsoil	moderate strength angular mudstones, MC san	2.5-3	grab
			4																	Composite	Composite
687b	9/10/2023	5	1	CLAY	Clay Loam Sandy	Brown	Pale Brown			0							Common	Topsoil	pale brown sandy loam material intermixed, la	0-0.5	grab
			2	CLAY	Medium Clay	Brown				0							Nil	Topsoil	MC sandy	1-1.5	grab
			3	CLAY	Medium Clay	Dark Brown				0							Nil	Topsoil	very hard to excavate this material, couldnt tex	2.5-3	grab
			4																occasional bare patch sandy and gravelly	Composite	Composite
685	9/10/2023	2.5	1	CLAY	Clay Loam Sandy	Brown	Orange			0							Common	Topsoil	orange brown material, layer extends to appro	0-0.5	grab
			2	CLAY	Medium Clay	Brown	Orange			0							Few	Topsoil	MC sandy	0.5-1	grab
			3	CLAY	Medium Clay	Orange				0							Few	Topsoil	MC sandy with dark brown clay material 10-20%	2-2.5	grab
			4																	Composite	Composite

Table B-4: Laboratory analysis data for loam topsoils. Part 1 of 2.

Laboratory Results Loams														
	Lab No	232027-108	232027-112	232027-192	232027-196	232027-200	232027-208	232027-212	232027-216	232027-220	232027-228	232027-232	232027-240	232027-252
	Sample ID	704a	704b	666a	666b	664a	662a	662b	665	667	680a	680b	680d	694
	Sample Depth	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite
	Field Texture	CLS	CL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	CLS
Analyses	Unit	-	-	-	-	-	-	-	-	-	-	-	-	-
pH - Water	pH units	9.13	6.89	7.17	7.35	7.13	6.37	6.76	6.78	7.46	7.02	7.68	6.37	8.21
Electrical Conductivity	dS/m	0.23	0.11	0.06	0.06	0.07	0.05	0.04	0.04	0.1	0.02	0.05	0.03	0.07
Chloride	mg/kg	47.0	27.1	18.6	20.1	42.6	31.2	15.3	24.7	50.7	<5.00	10.3	9.6	29.8
Total Nitrogen - Kjeldahl	mg/kg	435.0	539.0	783.0	635.0	758.0	674.0	487.0	333.0	193.0	227.0	171.0	166.0	293.0
Phosphorus - Colwell extr	mg/kg	6.18	13.1	14.1	6.63	8.78	11.1	5.07	6.43	5.26	6.82	<5.00	<5.00	5.65
Potassium - Colwell ext	mg/kg	98.10	181.00	169.00	190.00	241.00	153.00	174.00	145.00	124.00	153.00	193.00	180.00	150.00
Sulphur - KCl	mg/kg	15.9	20.5	14.6	6.6	7.5	4.1	6.5	6.4	13.2	<3.00	7.3	8.5	7.5
Organic Carbon	%	0.76	0.74	1.51	0.79	1.03	1.03	0.54	0.51	<0.20	0.52	0.49	<0.20	0.39
Copper	mg/kg	0.6	0.92	1.02	1.12	1.28	0.98	0.7	0.56	0.22	0.35	0.2	0.22	0.7
Iron	mg/kg	10.10	12.40	63.20	43.20	32.40	53.20	30.50	19.60	6.62	6.67	6.04	5.96	8.48
Manganese	mg/kg	6.90	15.50	28.80	43.90	91.30	21.20	15.30	12.70	4.06	8.37	3.10	4.36	13.00
Zinc	mg/kg	0.28	0.20	0.40	0.48	0.56	0.54	0.34	0.30	0.28	0.26	0.24	0.24	0.28
Boron	mg/kg	1.42	0.74	0.72	0.70	0.66	0.62	0.48	0.58	1.42	0.78	0.98	0.48	0.56
Cation Extraction Method	Rayment& Lyons	15C1	15A1	15C1	15C1	15A1	15A1	15A1	15A1	15C1	15A1	15C1	15A1	15C1
Cation Exchange Capacity	meq/100g	11.6	9.3	2.7	2.9	5.9	5.3	4.0	4.0	2.2	4.5	1.7	2.8	4.8
Ex Calcium Percent	%	47.08	58.42	76.43	72.29	72.32	74.92	72.86	65.04	53.58	69.42	66.98	46.21	56.35
Ex Magnesium Percent	%	37.97	32.57	12.77	14.88	22.00	20.73	22.63	24.79	29.53	26.63	15.51	40.17	33.78
Ex Potassium Percent	%	1.55	4.87	8.39	9.33	3.91	1.59	1.98	7.24	8.49	2.43	12.74	11.24	4.23
Ex Sodium Percent	%	13.20	3.9	1.60	2.74	1.4	2.3	2.0	2.4	7.39	1.0	3.45	1.6	5.18
Ex Aluminium Percent	%	0.19	0.24	0.82	0.76	0.38	0.42	0.55	0.56	1.01	0.49	1.32	0.81	0.46
Exchangeable Calcium	mg/kg	1089	1082	416	425	849	801	585	516	235	630	226	255	545
Exchangeable Magnesium	mg/kg	527	362	41.7	52.5	155	133	109	118	77.7	145	31.4	133	196
Exchangeable Potassium	mg/kg	70.1	176	89	107	89.6	33.2	31	112	72.6	43	83.8	121	79.8
Exchangeable Sodium	mg/kg	351	83	10	18.5	18.7	28.8	18.3	21.7	37.3	10.8	13.4	10	57.6
Exchangeable Aluminium	mg/kg	2	2.00	2	2	2.00	2.00	2.00	2.00	2	2.00	2	2.00	2
Exchangeable Calcium	meq/100g	5.45	5.41	2.08	2.13	4.25	4.01	2.93	2.58	1.18	3.15	1.13	1.28	2.73
Exchangeable Magnesium	meq/100g	4.39	3.02	0.35	0.44	1.29	1.11	0.91	0.98	0.65	1.21	0.26	1.11	1.63
Exchangeable Potassium	meq/100g	0.18	0.45	0.23	0.27	0.23	0.09	0.08	0.29	0.19	0.11	0.21	0.31	0.20
Exchangeable Sodium	meq/100g	1.53	0.36	0.04	0.08	0.08	0.13	0.08	0.09	0.16	0.05	0.06	0.04	0.25
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	1.2	1.8	6.0	4.9	3.3	3.6	3.2	2.6	1.8	2.6	4.3	1.2	1.7
Emerson Aggregate	Class	2	3a	7	3b	3b	3b	3b	3b	5	3b	3a	5	3a
Phosphorus Buffer Index	mg/kg	65.7	56.3	41.1	49.2	41.3	50.2	29.8	28.1	58.9	31.4	34.1	45.5	29.9
Gypsum Amelioration	kg/m^3	1.45	0.30	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.06

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-4: Laboratory analysis data for loam topsoils. Part 2 of 2.

Laboratory Results Loams													
	Lab No	232027-260	232027-264	Mean	LCL 95%	UCL 95%	Std Dev	Count	CI 95% (+/-)	10%ile	90%ile	Min	Max
	Sample ID	696	696b										
	Sample Depth	Composite	Composite										
	Field Texture	SCL	SCL										
Analyses	Unit	-	-										
pH - Water	pH units	7.41	8.4	7.3	7.0	7.7	0.8	15	0.4	6.5	8.3	6.4	9.1
Electrical Conductivity	dS/m	0.04	0.05	0.1	0.0	0.1	0.1	15	0.0	0.0	0.1	0.0	0.2
Chloride	mg/kg	10.9	9.9	24.8	17.5	32.2	14.0	14	7.3	10.0	45.7	9.6	50.7
Total Nitrogen - Kjeldahl	mg/kg	172.0	206.0	404.8	290.2	519.4	226.5	15	114.6	171.4	724.4	166.0	783.0
Phosphorus - Colwell extr	mg/kg	<5.00	<5.00	8.1	6.2	10.0	3.2	11	1.9	5.3	13.1	5.1	14.1
Potassium - Colwell ext	mg/kg	139.00	143.00	162.2	145.2	179.2	33.7	15	17.0	130.0	191.8	98.1	241.0
Sulphur - KCl	mg/kg	7.1	4.4	9.3	6.8	11.8	4.8	14	2.5	5.0	15.5	4.1	20.5
Organic Carbon	%	<0.20	0.21	0.7	0.5	0.9	0.4	12	0.2	0.4	1.0	0.2	1.5
Copper	mg/kg	0.28	0.32	0.6	0.4	0.8	0.4	15	0.2	0.2	1.1	0.2	1.3
Iron	mg/kg	7.28	5.30	20.7	11.0	30.5	19.2	15	9.7	6.0	49.2	5.3	63.2
Manganese	mg/kg	12.90	6.64	19.2	7.7	30.7	22.7	15	11.5	4.2	37.9	3.1	91.3
Zinc	mg/kg	0.26	0.48	0.3	0.3	0.4	0.1	15	0.1	0.2	0.5	0.2	0.6
Boron	mg/kg	0.34	0.56	0.7	0.6	0.9	0.3	15	0.2	0.5	1.2	0.3	1.4
Cation Extraction Method	Rayment& Lyons	15C1	15C1	*	*	*	*	0	*	*	*	0.0	0.0
Cation Exchange Capacity	meq/100g	1.5	3.6	4.5	3.0	5.9	2.8	15	1.4	1.9	7.9	1.5	11.6
Ex Calcium Percent	%	63.84	58.16	63.6	58.6	68.6	9.9	15	5.0	49.7	74.1	46.2	76.4
Ex Magnesium Percent	%	21.28	29.68	25.7	21.5	29.9	8.3	15	4.2	15.1	36.3	12.8	40.2
Ex Potassium Percent	%	10.44	4.92	6.2	4.3	8.1	3.7	15	1.9	1.7	10.9	1.6	12.7
Ex Sodium Percent	%	2.94	6.63	3.8	2.2	5.5	3.2	15	1.6	1.5	7.1	1.0	13.2
Ex Aluminium Percent	%	1.50	0.62	0.7	0.5	0.9	0.4	15	0.2	0.3	1.2	0.2	1.5
Exchangeable Calcium	mg/kg	189	418	550.7	402.1	699.3	293.7	15	148.6	229.6	988.8	189.0	1089.0
Exchangeable Magnesium	mg/kg	37.8	128	149.8	82.7	216.9	132.6	15	67.1	39.4	295.6	31.4	527.0
Exchangeable Potassium	mg/kg	60.3	68.9	82.5	63.7	101.3	37.2	15	18.8	37.1	117.4	31.0	176.0
Exchangeable Sodium	mg/kg	10	54.8	49.6	6.0	93.2	86.1	15	43.6	10.0	72.8	10.0	351.0
Exchangeable Aluminium	mg/kg	2	2	2.0	2.0	2.0	0.0	15	0.0	2.0	2.0	2.0	2.0
Exchangeable Calcium	meq/100g	0.95	2.09	2.8	2.0	3.5	1.5	15	0.7	1.1	4.9	0.9	5.4
Exchangeable Magnesium	meq/100g	0.32	1.07	1.2	0.7	1.8	1.1	15	0.6	0.3	2.5	0.3	4.4
Exchangeable Potassium	meq/100g	0.15	0.18	0.2	0.2	0.3	0.1	15	0.0	0.1	0.3	0.1	0.5
Exchangeable Sodium	meq/100g	0.04	0.24	0.2	0.0	0.4	0.4	15	0.2	0.0	0.3	0.0	1.5
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.00	15.00	0.00	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	3.0	2.0	2.9	2.2	3.6	1.4	15	0.7	1.4	4.6	1.2	6.0
Emerson Aggregate	Class	5	3b	4.8	3.2	6.4	1.8	5	1.6	3.2	6.2	2.0	7.0
Phosphorus Buffer Index	mg/kg	19.7	31.4	40.8	34.2	47.5	13.2	15	6.7	28.8	57.9	19.7	65.7
Gypsum Amelioration	kg/m^3	0.00	0.00	0.03									

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-5: Laboratory analysis data for clay topsoils. Part 1 of 5.

Laboratory Results Clays																
	Lab No	232027-4	232027-8	232027-12	232027-16	232027-20	232027-24	232027-28	232027-32	232027-36	232027-40	232027-44	232027-48	232027-52	232027-56	232027-60
	Sample ID	649	634a	634b	634c	634d	634e	634f	755a	755b	755c	755d	755e	755f	730	729
	Sample Depth	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite
	Field Texture	LC	LMC	LMC	LMC	LMC	MC	LMC	LMC	LMC	LMC	MC	LMC	LMC	LC	MC
Analyses	Unit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH - Water	pH units	9.16	9.19	9.14	8.84	8.57	8.55	8.68	8.61	9.03	8.52	8.44	8.62	8.59	8.33	9.05
Electrical Conductivity	dS/m	0.36	0.91	1.05	0.45	0.76	0.68	0.63	0.76	0.48	1	1.27	1.02	1.07	0.3	0.91
Chloride	mg/kg	137.0	887.0	1150.0	247.0	885.0	569.0	491.0	881.0	297.0	1320.0	1910.0	1310.0	1520.0	138.0	932.0
Total Nitrogen - Kjeldahl	mg/kg	426.0	414.0	460.0	619.0	518.0	765.0	381.0	510.0	711.0	633.0	496.0	531.0	403.0	1052.0	540.0
Phosphorus - Colwell extr	mg/kg	<5.00	<5.00	11.0	22.2	16.9	5.1	<5.00	7.03	6.37	15.6	6.59	7.91	7.91	10.1	<5.00
Potassium - Colwell ext	mg/kg	62.70	56.20	72.10	213.00	63.70	72.50	60.70	73.60	83.70	98.30	68.50	65.90	49.90	109.00	87.80
Sulphur - KCl	mg/kg	24.3	58.6	78.5	29.6	7.4	36.8	29.5	48.8	40.5	25.7	41.5	51.9	47.8	35.6	59.1
Organic Carbon	%	0.85	0.46	0.69	0.83	1.20	1.17	0.38	0.65	0.74	0.78	0.49	0.61	0.48	1.36	0.61
Copper	mg/kg	0.47	0.62	0.86	0.60	0.64	0.86	0.28	0.54	0.84	0.66	1.3	0.68	0.68	1.2	0.82
Iron	mg/kg	11.00	12.10	11.80	11.30	12.40	16.10	9.66	9.72	12.70	13.30	21.60	12.80	13.70	14.20	21.80
Manganese	mg/kg	15.90	14.60	14.40	12.40	12.60	20.10	12.40	12.10	16.80	13.60	17.80	13.00	14.00	19.60	15.60
Zinc	mg/kg	0.48	0.46	0.52	0.62	0.58	0.54	0.44	0.58	0.58	0.66	0.82	0.54	0.52	0.82	0.54
Boron	mg/kg	1.72	2.50	2.76	1.84	2.04	1.64	2.24	1.84	2.12	2.35	2.18	2.00	1.90	0.84	2.22
Cation Extraction Method	Rayment& Lyons	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1
Cation Exchange Capacity	meq/100g	12.3	18.4	21.2	11.6	9.7	20.3	12.3	11.1	27.7	11.3	21.8	15.8	17.6	10.0	24.0
Ex Calcium Percent	%	40.97	32.95	31.29	38.66	37.80	42.66	43.56	40.58	42.34	33.97	46.11	36.23	36.16	58.17	34.31
Ex Magnesium Percent	%	44.87	42.93	44.21	44.51	43.31	42.07	40.50	44.08	44.34	44.20	35.54	46.28	47.22	34.32	45.61
Ex Potassium Percent	%	1.06	0.61	0.71	3.05	1.37	0.74	1.07	1.44	0.68	1.65	0.64	0.88	0.64	1.97	0.73
Ex Sodium Percent	%	12.92	23.39	23.68	13.58	17.28	14.43	14.70	13.70	12.57	19.98	17.61	16.46	15.86	5.32	19.26
Ex Aluminium Percent	%	0.18	0.12	0.10	0.19	0.23	0.11	0.18	0.20	0.08	0.20	0.10	0.14	0.13	0.22	0.09
Exchangeable Calcium	mg/kg	1009	1215	1326	896	736	1736	1072	899	2346	766	2013	1143	1275	1161	1650
Exchangeable Magnesium	mg/kg	663	950	1124	619	506	1027	598	586	1474	598	931	876	999	411	1316
Exchangeable Potassium	mg/kg	50.9	43.9	59	138	52.1	58.4	51.2	62.4	73	72.7	54.7	54.4	44.2	76.6	68.4
Exchangeable Sodium	mg/kg	366	992	1154	362	387	675	416	349	801	518	884	597	643	122	1065
Exchangeable Aluminium	mg/kg	2.0	2.0	2.0	2.0	2.0	2.0	2	2	2	2	2	2	2	2	2
Exchangeable Calcium	meq/100g	5.05	6.08	6.63	4.48	3.68	8.68	5.36	4.50	11.73	3.83	10.07	5.72	6.38	5.81	8.25
Exchangeable Magnesium	meq/100g	5.53	7.92	9.37	5.16	4.22	8.56	4.98	4.88	12.28	4.98	7.76	7.30	8.33	3.43	10.97
Exchangeable Potassium	meq/100g	0.13	0.11	0.15	0.35	0.13	0.15	0.13	0.16	0.19	0.19	0.14	0.14	0.11	0.20	0.18
Exchangeable Sodium	meq/100g	1.59	4.31	5.02	1.57	1.68	2.93	1.81	1.52	3.48	2.25	3.84	2.60	2.80	0.53	4.63
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	0.9	0.8	0.7	0.9	0.9	1.0	1.1	0.9	1.0	0.8	1.3	0.8	0.8	1.7	0.8
Emerson Aggregate	Class	7.0	4.0	2.0	4.0	2.0	7.0	4	4	4	5	6	4	4	5	4
Phosphorus Buffer Index	mg/kg	61.1	63.0	67.4	67.2	77.8	70.9	84.8	69	66.6	107	62.2	80.8	64.6	60.7	79.9
Gypsum Amelioration	kg/m^3	1.56	4.91	5.92	1.50	1.44	3.43	1.78	1.41	4.34	2.11	4.57	2.82	3.15	0.46	5.62

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-5: Laboratory analysis data for clay **top**soils. Part 2 of 5.

Laboratory Results Clays																
	Lab No	232027-64	232027-68	232027-72	232027-76	232027-80	232027-84	232027-88	232027-92	232027-96	232027-100	232027-104	232027-116	232027-120	232027-124	232027-128
	Sample ID	731	735a	735b	735c	726a	726b	726c	726d	716a	625	716b	704c	704d	704e	704f
	Sample Depth	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite
	Field Texture	LMC	LC	LMC	LC	LMC	LMC	LC	LC	LMC	LMC	LMC	LC	LC	LC	LC
Analyses	Unit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH - Water	pH units	8.51	8.5	8.29	8.87	8.61	8.69	8.38	7.71	7.42	8.58	7.26	8.63	8.65	8.58	8.32
Electrical Conductivity	dS/m	0.81	0.74	2.03	0.33	0.9	0.38	1.57	0.96	0.37	0.88	0.75	0.28	0.49	0.5	0.13
Chloride	mg/kg	984.0	994.0	2900.0	209.0	1060.0	216.0	2310.0	1380.0	262.0	1203.0	930.0	143.0	423.0	535.0	52.5
Total Nitrogen - Kjeldahl	mg/kg	458.0	428.0	575.0	598.0	612.0	778.0	492.0	440.0	851.0	1143.0	771.0	549.0	675.0	303.0	567.0
Phosphorus - Colwell extr	mg/kg	7.03	5.49	66.6	10.3	121	12.3	8.58	<5.00	13.2	42.3	22.5	9.08	11.8	9.66	10.2
Potassium - Colwell ext	mg/kg	82.00	69.80	70.80	57.50	67.80	103.00	68.20	59.70	176.00	155.00	167.00	126.00	126.00	151.00	154.00
Sulphur - KCl	mg/kg	51.2	25.0	114.0	27.4	51.4	29.9	62.3	41.8	34.0	44.4	42.3	33.8	39.5	56.1	19.5
Organic Carbon	%	0.51	0.5	0.6	0.64	1.32	1.65	0.86	0.47	1.04	1.24	1.33	0.74	1.34	0.64	0.61
Copper	mg/kg	0.74	0.7	0.64	0.88	0.82	1.08	0.82	0.48	0.68	2.96	0.68	1.14	0.98	0.56	1.14
Iron	mg/kg	10.40	17.10	11.40	13.50	12.80	17.60	10.50	11.80	10.90	14.20	14.30	11.50	9.17	9.02	12.40
Manganese	mg/kg	14.90	13.00	15.90	14.60	15.00	16.10	14.90	13.10	17.50	11.50	9.80	9.14	7.25	3.82	7.00
Zinc	mg/kg	0.52	0.54	0.52	0.56	0.56	0.60	0.58	0.54	0.60	0.64	0.32	0.22	0.30	0.28	0.24
Boron	mg/kg	2.02	2.28	2.76	1.78	2.65	1.76	2.24	2.40	1.08	2.18	1.32	1.16	1.30	1.62	1.10
Cation Extraction Method	Rayment& Lyons	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15A2	15C1	15C1	15C1	15C1
Cation Exchange Capacity	meq/100g	13.0	7.9	12.0	13.0	14.5	13.2	12.4	8.9	5.6	21.4	12.2	10.5	9.8	9.3	7.5
Ex Calcium Percent	%	49.49	24.81	36.00	41.13	38.80	50.59	39.22	41.32	75.81	37.90	44.69	52.81	48.61	37.45	56.42
Ex Magnesium Percent	%	36.99	45.47	44.98	46.00	44.83	35.16	38.85	42.79	16.09	43.58	45.29	32.13	35.12	37.61	29.39
Ex Potassium Percent	%	1.20	1.58	1.11	1.03	1.01	1.42	1.30	1.46	5.27	1.70	2.37	2.33	2.55	2.04	3.23
Ex Sodium Percent	%	12.15	27.86	17.74	11.67	15.20	12.66	20.45	14.19	2.43	16.72	7.47	12.52	13.50	22.66	10.67
Ex Aluminium Percent	%	0.17	0.28	0.19	0.17	0.15	0.17	0.18	0.25	0.40	0.10	0.18	0.21	0.23	0.24	0.29
Exchangeable Calcium	mg/kg	1289	391	863	1073	1125	1331	969	737	848	1622	1092	1104	955	697	851
Exchangeable Magnesium	mg/kg	578	430	647	720	780	555	576	458	108	1119	664	403	414	420	266
Exchangeable Potassium	mg/kg	60.8	48.5	51.7	52.6	57	73.1	62.6	50.7	115	142	113	95.1	97.8	74	94.9
Exchangeable Sodium	mg/kg	364	505	489	350	507	383	581	291	31.2	823	210	301	305	485	185
Exchangeable Aluminium	mg/kg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Exchangeable Calcium	meq/100g	6.45	1.96	4.32	5.37	5.63	6.66	4.85	3.69	4.24	8.11	5.46	5.52	4.78	3.49	4.26
Exchangeable Magnesium	meq/100g	4.82	3.58	5.39	6.00	6.50	4.63	4.80	3.82	0.90	9.33	5.53	3.36	3.45	3.50	2.22
Exchangeable Potassium	meq/100g	0.16	0.12	0.13	0.13	0.15	0.19	0.16	0.13	0.29	0.36	0.29	0.24	0.25	0.19	0.24
Exchangeable Sodium	meq/100g	1.58	2.20	2.13	1.52	2.20	1.67	2.53	1.27	0.14	3.58	0.91	1.31	1.33	2.11	0.80
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	1.3	0.5	0.8	0.9	0.9	1.4	1.0	1.0	4.7	0.9	1.0	1.6	1.4	1.0	1.9
Emerson Aggregate	Class	4	2	6	2	6	3a	4	6	7	7	5	3a	3b	2	3a
Phosphorus Buffer Index	mg/kg	88.4	73.3	97.3	94.3	110	94.7	142	117	86.8	81.1	53.9	64.8	60.3	40.4	67.1
Gypsum Amelioration	kg/m^3	1.60	1.57	2.06	1.54	2.32	1.69	2.49	1.02	0.06	4.23	0.89	1.18	1.14	1.75	0.55

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-5: Laboratory analysis data for clay topsoils. Part 3 of 5.

Laboratory Results Clays																
	Lab No	232027-132	232027-136	232027-140	232027-144	232027-148	232027-152	232027-156	232027-160	232027-164	232027-168	232027-172	232027-176	232027-180	232027-184	232027-188
	Sample ID	704g	704h	704i	704j	704k	704L	704m	704n	704o	707	708a	708b	708c	708d	709
	Sample Depth	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite
	Field Texture	LMC	LMC	LMC	LMC	LMC	LC	LMC	LC	LMC	LC	LC	LC	LMC	MC	MC
Analyses	Unit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH - Water	pH units	8.82	8.94	8.52	8.63	7.84	8.67	8.98	8.33	9.01	7.38	9.15	8.47	8.6	8.45	8.74
Electrical Conductivity	dS/m	0.56	0.42	0.77	0.31	0.13	0.15	0.26	0.15	0.36	0.09	0.31	0.52	0.48	0.42	0.87
Chloride	mg/kg	542.0	328.0	772.0	278.0	81.6	8.7	100.0	39.8	257.0	31.8	78.0	564.0	493.0	265.0	775.0
Total Nitrogen - Kjeldahl	mg/kg	561.0	472.0	695.0	253.0	453.0	480.0	539.0	623.0	438.0	497.0	479.0	579.0	478.0	837.0	577.0
Phosphorus - Colwell extr	mg/kg	5.02	<5.00	9.66	<5.00	15.5	7.92	7.54	7.73	6.38	10.8	8.5	7.54	6.18	16.9	6.96
Potassium - Colwell ext	mg/kg	119.00	122.00	168.00	90.00	87.20	89.50	104.00	240.00	121.00	216.00	109.00	114.00	131.00	117.00	108.00
Sulphur - KCl	mg/kg	63.7	34.3	49.3	33.6	31.5	19.1	21.7	17.5	26.3	21.1	26.2	38.9	39.6	40.9	78.0
Organic Carbon	%	0.77	0.6	1.28	0.27	0.72	0.46	0.82	0.49	0.44	0.82	0.8	0.38	0.71	1.1	0.59
Copper	mg/kg	1	1.08	1.22	0.58	0.86	0.82	0.8	0.54	0.72	0.68	1.12	0.76	0.54	0.98	1.3
Iron	mg/kg	15.10	14.80	16.80	9.26	13.00	11.10	10.10	7.56	8.22	10.20	9.82	7.00	5.44	12.50	10.60
Manganese	mg/kg	6.34	7.34	5.46	4.58	11.40	8.82	6.52	8.32	7.28	9.94	6.50	4.16	5.34	6.18	7.12
Zinc	mg/kg	0.22	0.20	0.32	0.22	0.28	0.32	0.22	0.27	0.22	0.98	0.24	0.20	0.34	0.26	0.22
Boron	mg/kg	3.76	2.86	2.74	1.74	0.84	0.92	1.68	0.66	2.24	0.74	1.82	1.86	1.60	1.76	3.66
Cation Extraction Method	Rayment& Lyons	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1
Cation Exchange Capacity	meq/100g	16.0	13.5	15.3	8.2	9.3	7.1	9.6	5.5	9.6	7.8	9.8	8.7	10.7	15.3	19.6
Ex Calcium Percent	%	43.82	41.76	46.00	57.78	54.06	43.42	44.24	78.41	44.32	70.55	39.47	41.63	37.76	55.04	37.48
Ex Magnesium Percent	%	35.19	39.25	37.98	29.61	33.13	38.48	36.95	11.17	33.89	20.65	35.41	36.36	43.46	35.38	42.67
Ex Potassium Percent	%	1.41	1.35	1.96	1.04	0.98	1.21	1.61	6.84	2.32	5.66	1.58	1.39	1.95	1.50	1.20
Ex Sodium Percent	%	19.45	17.48	13.92	11.30	11.60	16.58	16.98	3.17	19.23	2.85	23.31	20.37	16.62	7.93	18.53
Ex Aluminium Percent	%	0.14	0.16	0.14	0.27	0.24	0.31	0.23	0.41	0.23	0.29	0.23	0.26	0.21	0.15	0.11
Exchangeable Calcium	mg/kg	1399	1128	1411	943	1009	615	852	858	850	1099	773	725	808	1683	1467
Exchangeable Magnesium	mg/kg	674	636	699	290	371	327	427	73.3	390	193	416	380	558	649	1002
Exchangeable Potassium	mg/kg	87.5	70.9	117	33.1	35.6	33.5	60.4	146	86.9	172	60.4	47.1	81.3	89.3	91.7
Exchangeable Sodium	mg/kg	714	543	491	212	249	270	376	39.9	424	51	525	408	409	279	834
Exchangeable Aluminium	mg/kg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Exchangeable Calcium	meq/100g	7.00	5.64	7.06	4.72	5.05	3.08	4.26	4.29	4.25	5.50	3.87	3.63	4.04	8.42	7.34
Exchangeable Magnesium	meq/100g	5.62	5.30	5.83	2.42	3.09	2.73	3.56	0.61	3.25	1.61	3.47	3.17	4.65	5.41	8.35
Exchangeable Potassium	meq/100g	0.22	0.18	0.30	0.08	0.09	0.09	0.15	0.37	0.22	0.44	0.15	0.12	0.21	0.23	0.24
Exchangeable Sodium	meq/100g	3.10	2.36	2.13	0.92	1.08	1.17	1.63	0.17	1.84	0.22	2.28	1.77	1.78	1.21	3.63
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	1.2	1.1	1.2	2.0	1.6	1.1	1.2	7.0	1.3	3.4	1.1	1.1	0.9	1.6	0.9
Emerson Aggregate	Class	2	3b	4	3a	2	3a	2	5	2	3b	2	3a	3b	4	4
Phosphorus Buffer Index	mg/kg	81.9	76.5	99.1	51.4	64.9	58.8	69.5	64.6	63.7	50.8	74.6	61.5	44.2	72.6	65.8
Gypsum Amelioration	kg/m^3	3.39	2.42	2.30	0.68	0.90	0.74	1.39	0.07	1.56	0.16	1.96	1.40	1.62	1.30	4.20

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-5: Laboratory analysis data for clay topsoils. Part 4 of 5.

Laboratory Results Clays										
	Lab No	232027-204	232027-224	232027-236	232027-244	232027-248	232027-256	232027-268	232027-272	232027-276
	Sample ID	664b	678a	680c	678b	675	695	687a	687b	685
	Sample Depth	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite
	Field Texture	LC	LMC	LC	LMC	LC	LC	LC	LC	LC
Analyses	Unit	-	-	-	-	-	-	-	-	-
pH - Water	pH units	7.49	8.92	8.76	7.64	7.52	8.71	8.67	7.76	8.3
Electrical Conductivity	dS/m	0.11	0.17	0.12	0.05	0.06	0.24	0.29	0.3	0.16
Chloride	mg/kg	57.1	35.6	64.7	10.2	13.8	172.0	164.0	310.0	48.0
Total Nitrogen - Kjeldahl	mg/kg	833.0	263.0	179.0	371.0	281.0	259.0	469.0	450.0	584.0
Phosphorus - Colwell extr	mg/kg	9.16	9.16	5.65	<5.00	<5.00	<5.00	<5.00	7.6	13.5
Potassium - Colwell ext	mg/kg	235.00	122.00	135.00	104.00	97.10	142.00	200.00	157.00	134.00
Sulphur - KCl	mg/kg	14.9	7.4	7.2	10.0	9.3	23.6	22.6	17.9	11.8
Organic Carbon	%	1.03	0.22	<0.20	0.31	0.52	0.51	0.67	0.93	0.75
Copper	mg/kg	1.44	0.36	0.28	0.36	0.42	0.52	0.61	0.86	0.68
Iron	mg/kg	55.70	6.28	5.18	6.80	8.04	6.18	6.84	14.50	9.72
Manganese	mg/kg	60.50	5.12	3.76	7.80	11.80	11.30	5.75	10.30	8.00
Zinc	mg/kg	0.52	0.28	0.28	0.30	0.26	0.36	0.35	0.34	0.40
Boron	mg/kg	1.40	2.76	2.28	1.42	0.94	0.90	1.42	0.72	0.86
Cation Extraction Method	Rayment& Lyons	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1
Cation Exchange Capacity	meq/100g	4.2	6.6	5.7	4.3	3.9	4.2	7.5	8.1	7.8
Ex Calcium Percent	%	66.45	44.65	35.33	66.39	54.60	48.77	54.81	55.96	64.51
Ex Magnesium Percent	%	20.81	36.89	40.72	25.97	32.53	37.56	33.73	32.74	25.27
Ex Potassium Percent	%	7.01	2.35	1.24	2.89	3.75	4.41	2.71	2.73	2.93
Ex Sodium Percent	%	5.20	15.77	22.32	4.24	8.55	8.72	8.45	8.30	7.01
Ex Aluminium Percent	%	0.52	0.34	0.39	0.52	0.57	0.53	0.30	0.28	0.29
Exchangeable Calcium	mg/kg	564	591	402	571	428	409	818	903	1000
Exchangeable Magnesium	mg/kg	106	293	278	134	153	189	302	317	235
Exchangeable Potassium	mg/kg	116	60.7	27.4	48.4	57.4	72.1	79	86	88.5
Exchangeable Sodium	mg/kg	50.8	240	292	41.9	77.1	84.1	145	154	125
Exchangeable Aluminium	mg/kg	2	2	2	2	2	2	2	2	2
Exchangeable Calcium	meq/100g	2.82	2.96	2.01	2.86	2.14	2.05	4.09	4.52	5.00
Exchangeable Magnesium	meq/100g	0.88	2.44	2.32	1.12	1.28	1.58	2.52	2.64	1.96
Exchangeable Potassium	meq/100g	0.30	0.16	0.07	0.12	0.15	0.18	0.20	0.22	0.23
Exchangeable Sodium	meq/100g	0.22	1.04	1.27	0.18	0.34	0.37	0.63	0.67	0.54
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	3.2	1.2	0.9	2.6	1.7	1.3	1.6	1.7	2.6
Emerson Aggregate	Class	7	2	1	3a	3a	3b	3b	3b	3b
Phosphorus Buffer Index	mg/kg	68.4	62.4	49.9	62	56.6	30.6	54.4	39.3	39.4
Gypsum Amelioration	kg/m^3	0.02	0.60	0.55	0.02	0.00	0.02	0.43	0.49	0.38

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B-5: Laboratory analysis data for clay topsoils. Part 5 of 5.

Laboratory Results Clays											
		Mean	LCL 95%	UCL 95%	Std Dev	Count	CI 95% (+/-)	10%ile	90%ile	Min	Max
Analyses	Unit										
pH - Water	pH units	8.5	8.4	8.6	0.5	54	0.1	7.7	9.0	7.3	9.2
Electrical Conductivity	dS/m	0.6	0.4	0.7	0.4	54	0.1	0.1	1.0	0.1	2.0
Chloride	mg/kg	588.2	423.3	753.2	618.5	54	165.0	42.3	1317.0	8.7	2900.0
Total Nitrogen - Kjeldahl	mg/kg	543.5	493.7	593.3	186.8	54	49.8	323.4	775.9	179.0	1143.0
Phosphorus - Colwell extr	mg/kg	14.6	8.7	20.5	19.7	43	5.9	6.2	21.1	5.0	121.0
Potassium - Colwell ext	mg/kg	113.6	100.8	126.3	47.8	54	12.8	63.0	173.6	49.9	240.0
Sulphur - KCl	mg/kg	36.2	30.8	41.6	20.2	54	5.4	12.7	59.0	7.2	114.0
Organic Carbon	%	0.8	0.7	0.8	0.3	53	0.1	0.4	1.3	0.2	1.7
Copper	mg/kg	0.8	0.7	0.9	0.4	54	0.1	0.5	1.2	0.3	3.0
Iron	mg/kg	12.4	10.6	14.3	7.0	54	1.9	6.9	16.6	5.2	55.7
Manganese	mg/kg	11.8	9.7	14.0	8.0	54	2.1	5.4	16.6	3.8	60.5
Zinc	mg/kg	0.4	0.4	0.5	0.2	54	0.0	0.2	0.6	0.2	1.0
Boron	mg/kg	1.8	1.7	2.0	0.7	54	0.2	0.9	2.8	0.7	3.8
Cation Extraction Method	Rayment& Lyons	*	*	*	*	0	*	*	*	0.0	0.0
Cation Exchange Capacity	meq/100g	11.8	10.3	13.2	5.4	54	1.4	5.6	20.1	3.9	27.7
Ex Calcium Percent	%	46.3	43.2	49.3	11.4	54	3.0	35.5	62.6	24.8	78.4
Ex Magnesium Percent	%	37.3	35.2	39.4	8.0	54	2.1	27.0	45.2	11.2	47.2
Ex Potassium Percent	%	2.0	1.6	2.4	1.5	54	0.4	0.7	3.6	0.6	7.0
Ex Sodium Percent	%	14.2	12.6	15.8	5.9	54	1.6	5.8	21.8	2.4	27.9
Ex Aluminium Percent	%	0.2	0.2	0.3	0.1	54	0.0	0.1	0.4	0.1	0.6
Exchangeable Calcium	mg/kg	1027.7	921.3	1134.2	399.1	54	106.4	577.0	1575.5	391.0	2346.0
Exchangeable Magnesium	mg/kg	553.9	469.5	638.2	316.3	54	84.4	190.2	1001.1	73.3	1474.0
Exchangeable Potassium	mg/kg	74.0	65.8	82.2	30.6	54	8.2	45.1	115.7	27.4	172.0
Exchangeable Sodium	mg/kg	410.7	338.4	482.9	270.9	54	72.3	79.2	816.4	31.2	1154.0
Exchangeable Aluminium	mg/kg	2.0	#NUM!	#NUM!	0.0	54	#NUM!	2.0	2.0	2.0	2.0
Exchangeable Calcium	meq/100g	5.1	4.6	5.7	2.0	54	0.5	2.9	7.9	2.0	11.7
Exchangeable Magnesium	meq/100g	4.6	3.9	5.3	2.6	54	0.7	1.6	8.3	0.6	12.3
Exchangeable Potassium	meq/100g	0.2	0.2	0.2	0.1	54	0.0	0.1	0.3	0.1	0.4
Exchangeable Sodium	meq/100g	1.8	1.5	2.1	1.2	54	0.3	0.3	3.5	0.1	5.0
Exchangeable Aluminium	meq/100g	0.02	0.02	0.02	0.00	54.00	0.00	0.02	0.02	0.02	0.02
Calcium/Magnesium Ratio	-	1.4	1.2	1.7	1.1	54	0.3	0.8	2.4	0.5	7.0
Emerson Aggregate	Class	4.1	3.5	4.6	1.8	38	0.6	2.0	7.0	1.0	7.0
Phosphorus Buffer Index	mg/kg	70.7	65.2	76.2	20.5	54	5.5	50.2	96.5	30.6	142.0
Gypsum Amelioration	kg/m^3	1.60									

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Goonyella Riverside and Broadmeadow Mine (GRM and BRM) Progressive Rehabilitation and Closure Plan (PRCP) - Community Consultation Register

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	**Stakeholder Title**	**Organisation/ Property**	**Previous engagement**	**Consultation type**	**Consultation date**	**Information provided**	**Issues raised/discussed**	**How issues were considered**	**Decisions/outcomes of engagement**	**Commitments**
Traditional Owners	Chair	Barada Barna Aboriginal Corporation (BBAC)	BMA has regular engagement with Barada Barna People on a range of issues including cultural heritage and community and economic development. BMA holds a Native Title Project Agreement with BBAC on behalf of Barada Barna peoples. The Agreement was signed on 31 July 2024. Engagement includes meetings and correspondence through the BBAC-BMA Relationship Committee and regular Barada Barna and BMA Closure Planning Working Group meetings. Businesses owned by BBAC and/ or their members are currently involved in rehabilitation works at BMA sites.	Letter, via email to BBAC Chair Meeting and correspondence Monthly meeting Several meetings and emailed correspondence	4/07/2024 Frequent FY 24 monthly September and October 2024	Queensland Government requirements for mine rehabilitation and closure planning PRCP inclusions Asset location Environmental Authority held for RHM PRCP submission date Mining leases within the EA area and approved activities Life of asset BMA's commitment to progressive rehabilitation Rehabilitation objective and methods EP Act requirements for rehabilitation PRCP requirements Progressive rehabilitation timeframes (in general terms) Approved post-mining land use (PMLU) options Commitment to future engagement on PRCPs Invitation to seek information or discussion about PRCP Contacts for further information Seeding requriments and recommendations (Barada Barna only) Spatial data in relation to Area 4 (Barada Barna only)	No issues raised in response to the letter, but issues discussed in other engagements between BMA and BBAC include opportunities to be involved in rehabilitation execution via Barada Barna-owned businesses, cultural heritage management and access to land that is no longer required for mining.	Ongoing opportunities for the involvement of Barada Barna People and businesses in rehabilitation works and land management are planned across BMA assets, as rehabilitation is a core contracting commitment in the BMA and BBAC Native Title Project Agreement.	Traditional Owners will have access to land within the EA area in accordance within the terms of the registered Indigenous Land Use Agreement. Ongoing opportunities for the involvement of Barada Barna People and businesses in rehabilitation works and land management are planned across BMA, as rehabilitation is a core contracting commitment in the Native Title Project Agreement. Barada Barna People's interest in environmental management and mine rehabilitation will be progressed as part of ongoing engagement with them. Exclusion zone boundaries in relation to Area 4 and specific locations where rehabiliation activities should be carried out in relation to historical disturbance.	BMA will continue to consult with the Barada Barna People, and seek their inputs on rehabilitation and PMLUs. BMA will engage with Traditional Owners and Indigenous businesses to understand business capabilities and the pipeline of opportunities that relate to rehabilitation work and land management, and to involve Traditional Owners' businesses in supplying progressive rehabilitation works. Treatment of Area 4 in relation to exclusion zone and rehabiliatoin activies as described in the PRCP
	Secretary	Widi People of the Nebo Estate #2	BMA has a constructive relationship with Widi People, meeting as needed.	Letter, via email to Secretary	4/11/2024	As detailed in the first row.	No feedback received and no issues raised.	No feedback received and no issues raised.	Opportunities for the involvement of Widi People and businesses in rehabilitation works and land management are anticipated.	BMA will continue to consult with Widi People, and seek their inputs on rehabilitation and PMLUs. BMA will engage with Traditional Owners and Indigenous businesses to understand business capabilities and the pipeline of opportunities that relate to rehabilitation work and land management, and to involve Traditional Owners' businesses in supplying progressive rehabilitation works.
Local Government	Mayor, Councillors and CEO	Isaac Regional Council (IRC)	BMA has regular bi-annual meetings with IRC, and meets with Councillors and officers as needed on specific issues. BMA provides regular briefings and updates to Council on BMA's PRCPs. IRC owns land within the EA area for a road reserve (Red Hill Road). BMA and IRC engage in commercial discussions regarding use of IRC land within the EA area, as required.	Bi-annual meetings with Council Additional meetings with Council with a focus on roads on 19/1/24 and 16/4/24 and 30/5/24	06/11/2023 30/05/2024 19/01/24 16/04/24 30/05/2024	As detailed in the first row.	Council receives regular updates and opportunities for discussion on PRCPs for BMA assets via IRC-BMA meetings. The future use, management and maintenance of roads within the EA area is of significant interest to Council.	Council's interest in PRC planning and PRCP outcomes is addressed in the PRCP consultation plan. Engagement processes for PRCPs will include a strategic approach to consultation with Council, to minimise demands on Council's time in responding to PRCP consultation for BMA's assets.	The CEO of the IRC sent an acknowledgement email of the letter that was sent to IRC in relation to the GRM and BRM PRCP. No issues were raised with respect to the GRM and BRM PRCP in general. BMA will continue to engage with IRC regarding PRCPs for GRM and BRM. PRCP updates will be provided at each meeting between BMA and IRC or as agreed with IRC. BMA will also consult IRC on management plans if rehabilitation and/or closure activities would impact on IRC assets including road management and recycling facilities. Future engagement with Council will include discussion of rehabilitation methods and milestones.	BMA will engage with IRC to understand Council's strategic analysis and planning for the Isaac LGA and the GRM and BRM project area as relevant. BMA will work with Council and other stakeholders in future PRCP consultations to identify and implement social value opportunities. BMA will engage with IRC regarding any impacts on Council roads or road reserves as part of the progressive rehabilitation and closure process, and will update IRC on PRCPs regularly. The PRCP landform proposes a realignment of Red Hill Road. To effect realignment, BMA acknowledge it would need to apply for and obtain, a Works On Road Corridor Permit from IRC. Engineering studies will need to be completed before the permit is applied for. Concerns raised by IRC in relation to any realignment proposal for Red Hill Road will be considered during the permitting process. If changes are made to the proposed realignment as a result of future planning or permitting processes that impact the PRCP schedule, a PRCP amendment will be required.
	Executive Manager of Advocacy and External Affairs and Manager Galilee and Bowen Basin Operations	IRC	BMA meets with Council officers from time to time on issues of shared interest.	Letter to stakeholders and community members provided to Council managers, via email	21/06/2024	As detailed in the first row.	No feedback received and no issues raised.	As above.	As above.	As above.
Underlying landowners	Owner	Private agricultural business	BHP has a long and constructive working relationship with the landowner, including with respect to underlying land and a license agreement for use of BMA-owned land within the EA area. The landowner also owns land which is adjacent to the EA area. BMA engages with the landowner regarding matters relating to land use management and commercial arrangements from time to time.	Letter, via email and post	14/06/2024	As detailed in the first row.	No feedback or enquiries were received. BMA's regular engagements with the landowner indicate that they are interested in long-term grazing options.	BMA's regular engagements with the landowner indicate that their issues of interest include environmental management, land access under current land access and lease agreements, and access to BMA land for grazing use whilst is not required for mining. Landowners' interest in use of the land for grazing was considered in framing PMLUs.	Land within the MLs will continue to be available for grazing under existing agreements with landholders. Landholders and cattle will be excluded from affected areas while land disturbance is occurring. As disturbed land becomes available, it will be rehabilitated to a state suitable for the approved PML) e.g. grazing, woodland, water courses, or managed as a NUMA.	BMA will continue to consult with the landholder and seek their inputs on the GRM and BRM rehabilitation schedule and approved PMLUs. BMA will continue to consult with licensees and lessees regarding licence and lease agreements as and when affected by rehabilitation and/or closure.

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	**Stakeholder Title**	**Organisation/ Property**	**Previous engagement**	**Consultation type**	**Consultation date**	**Information provided**	**Issues raised/discussed**	**How issues were considered**	**Decisions/outcomes of engagement**	**Commitments**
	Executor	Private estate/agricultural business	BHP had a long and constructive working relationship with the landowner, including with respect to underlying land and a license agreement for use of BMA-owned land within the EA area. The Estate also owns land which is adjacent to the EA area. BMA engages with the Estate executor regarding matters relating to land use management and commercial arrangements from time to time.	Letter, via post	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	BMA's regular engagements with the landowner indicated that their issues of interest include environmental management, land access under current land access and lease agreements, and access to BMA land for grazing use whilst is not required for mining. Landowners' interest in use of the land for grazing was considered in framing PMLUs.	Land within the MLs will continue to be available for grazing under existing agreements with landholders. Landholders and cattle will be excluded from affected areas while land disturbance is occurring. As disturbed land becomes available, it will be rehabilitated to a state suitable for the approved PMLU e.g. grazing, woodland, water courses, or managed as a NUMA.	BMA will continue to consult with the Estate executor or the new landowner as relevant, and seek their inputs on the GRM and BRM rehabilitation schedule and approved PMLUs. BMA will continue to consult with licensees and lessees regarding licence and lease agreements as and when affected by rehabilitation and/or closure.
	CEO	IRC	IRC owns land within the EA area including road reserves and land adjacent to the Goonyella Branch Railway. BMA and IRC have engaged in discussions regarding use of IRC land within the EA area during 2023 and 2024.	Three meetings during 2023-2024 to date discussing roads with the EA area	19/1/2024, 16/4/2024 and 30/5/2024	Information specific to BMA and IRC's interests in roads and road reserves within the EA area	The future use, management and maintenance of roads within the EA area is of significant interest to Council.	IRC interests in planning for roads i.e. Red Hill Road (to be established), and Goonyella Road (a private BMA road used by the public) are addressed in the PRCP.	IRC road reserves are located within the EA area, which has been considered in the PRCP. Prior information and consultation will be required with IRC regarding the future use of roads and road reserves within the EA area.	Consultation with IRC on future PRCP amendments will include consideration of the future use of roads and road reserves within the EA area.
	Site and Third Party Interface Manager	Moranbah North Coal Pty Ltd & Others (Anglo American Australia)	Anglo American Australia owns land which overlaps the EA area. BMA and Anglo American Australia engage in commercial discussions regarding use of land within the EA area, as required.	Letter, via post	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No issues were raised.	BMA will engage with Anglo American Australia regarding any effects of rehabilitation or closure works on land within the MLs that is owned by Anglo American Australia.	BMA will maintain engagement with Anglo American Australia regarding its progressive rehabilitation activities land within the MLs that is owned by Anglo American Australia.
	Manager Tenements Portfolio Australia	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.)	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.) owns a parcel of land in the top north of the EA area, adjacent to the North Goonyella Industrial Area. BMA and Peabody (Bowen) Pty. Ltd. (Centurion Coal Mining Pty Ltd going forward) engage in commercial discussions regarding use of land within the EA area, as required.	Letter, via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will engage with Centurion Coal Mining Pty Ltd regarding any effects of rehabilitation or closure works on land within the MLs that is owned by Centurion Coal Mining Pty Ltd	BMA will maintain engagement with Centurion Coal Mining Pty Ltd regarding its progressive rehabilitation activities land within the MLs that is owned by Centurion Coal Mining Pty Ltd
	Senior Business Analyst, Network Asset Management	Aurizon Network	Aurizon Network Pty. Ltd owns land within the EA area. DTMR owns the land on which the Goonyella Railway is located (refer to Row 39).	Letter, via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	Prior information and consultation will be required with Aurizon Network regarding the decommissioning of rail infrastructure within the EA area. BMA will advise Aurizon Network of any substantive changes to closure planning or the rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will maintain engagement with Aurizon Network regarding its progressive rehabilitation activities as they affect rail assets, and undertake engagement regarding the decommissioning of load out facility/rail infrastructure prior to its closure, in accordance with agreements between BMA and QR/Aurizon at the time.
	A/Deputy Director-General	Lands Division, Department of Resources	Unallocated state land is located within the EA area.	Letter, via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep Lands Division, Department of Resources informed of any planning or implementation of closure or rehabilitation activities that affect unallocated state land within the EA area.	BMA will keep Lands Division, Department of Resources informed of any planning or implementation of closure or rehabilitation activities that affect unallocated state land within the EA area.
Utility owners	Customer Account Manager	Aurizon Network	Goonyella Hay Point Railway, North Goonyella Railway, Goonyella Mine Loop and Riverside Mine Loop are owned by Aurizon Network on land owned by Department of Transport and Main Roads (DTMR) (see also Row 39). Engagement with Aurizon Network is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise Aurizon Network of any substantive changes to closure planning or the rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will maintain engagement with Aurizon Network regarding its progressive rehabilitation activities as they affect rail assets, and undertake engagement regarding the decommissioning of load out facility/rail infrastructure prior to its closure, in accordance with agreements between BMA and QR/Aurizon at the time.
	Commercial Customers Manager	Eungella Water Pipeline Pty Ltd (Sunwater Pty. Ltd.) and the Burdekin Water Pipeline (Sunwater)	Eungella Pipeline and Burdekin Pipeline (and various Sunwater easements) are located within the EA area. Engagement with Sunwater is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will maintain correspondence with Sunwater regarding progressive rehabilitation activities as they affect Sunwater assets, and undertake consultation regarding crossing/interface agreements, if required. Prior information and consultation will be required with Sunwater regarding how closure and rehabilitation activities may impact on the Eungella Water Pipeline.	BMA will advise and consult Sunwater regarding any impacts of closure/rehabilitation activity that may affect Sunwater's asset.
	Tenement Manager	Whitehaven Coal	Whitehaven Coal owns the Braeside West Water Pipeline which is located in close proximity to GRM and BRM. Engagement with Whitehaven Coal is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will maintain correspondence with Whitehaven regarding progressive rehabilitation activities as and if they affect Whitehaven Coal assets.	BMA will advise and consult Whitehaven Coal regarding any impacts of closure/rehabilitation activity that may affect Whitehaven Coal's asset.
	Property Services and Management Team Leader	Powerlink	Powerlines and powerline easements are owned/held by Powerlink / QEC Pty Ltd). Engagement with Powerlink is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will maintain correspondence with Powerlink regarding progressive rehabilitation activities as and if they affect Powerlink assets.	BMA will advise and consult Powerlink regarding any impacts of closure/rehabilitation activity that may affect Powerlink's assets.

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	**Stakeholder Title**	**Organisation/ Property**	**Previous engagement**	**Consultation type**	**Consultation date**	**Information provided**	**Issues raised/discussed**	**How issues were considered**	**Decisions/outcomes of engagement**	**Commitments**
	Sales Operations Manager	Telstra	Telstra holds easements within the EA area. Engagement with Telstra is via routine correspondence on commercial and statutory issues.	Letter, via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	Prior information and consultation will be required with Telstra regarding the decommissioning/future use of telecommunications infrastructure within the EA area. BMA will maintain correspondence with Telstra regarding progressive rehabilitation activities as they affect Telstra assets, and undertake consultation about telecommunications infrastructure agreements, if required.	BMA will advise and consult Telstra Amplitel regarding any impacts of the closure/rehabilitation activity that may affect their assets.
BMA personnel and suppliers	Personnel	BMA workforce and contractors	BMA communicates with its personnel on a continual basis through toolbox talks, emails, and safety meetings, and through Community Connect and Coal Connect, which are regular newsletters.	Information provided for distribution through Coal Connect	19/06/2024	Progressive rehabilitation as a key focus for BMA PRCP requirements and purpose Timing for PRCP development Commitment to ongoing engagement Contact details for further information or queries.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep the workforce updated as the PRCP is implemented and revised.	BMA will keep the workforce updated if there are changes to the PRCP. BMA will provide a communication channel for personnel to ask questions or contribute to discussions about PRCPs and rehabilitation.
	Local and regional business owners	GRM and BRM Suppliers	BMA's procurement team have relationships with an extensive network of small business suppliers. BMA communicates with its suppliers on a continual basis through the C-Res portal, emails, and Community Connect, a regular newsletter.	Information provided through Community Connect	10/06/24 - 16/06/24	Progressive rehabilitation as a key focus for BMA PRCP requirements and purpose Timing for PRCP development Commitment to ongoing engagement Contact details for further information or queries	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep suppliers updated as the PRCP is implemented and revised.	BMA will keep suppliers updated if there are changes to the PRCP. BMA will provide a communication channel for suppliers to ask questions or contribute to discussions about PRCPs and rehabilitation.
Moranbah Community	Community Members	Moranbah residents, businesses and community groups	BMA communicates with Moranbah residents, businesses and community groups through stakeholder meetings, community events and forums, media and social media, and Community Connect, a regular newsletter.	Letter box drop to Moranbah postcode (POA 4744) Information provided through Community Connect	15/07/2024 - 19/07/24 10/6/24 - 16/6/24	Information provided via the letterbox drop as per Row 4. Information provided in Community Connect included: Progressive rehabilitation as a key focus for BMA PRCP requirements and purpose Timing for PRCP development Commitment to ongoing engagement Contact details for further information or queries.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep community members updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to Moranbah community members, and consider their feedback in future PRCP development.
	STAC Members	Moranbah STAC	The Smart Transformation Project including the Moranbah and Dysart Smart Transformation Advisory Councils (STACs) was established by BMA in 2019. Moranbah STAC members meet every two months to consider a range of issues and priorities related to the future and sustainability of Moranbah's community and economy.	Letter, via email	12/07/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep STAC members updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to Moranbah STAC members, and consider their feedback in future PRCP development. BMA will participate in initiatives led by the Council, industry or local communities which aim to harness social value from mine closure and rehabilitation planning, and/or work towards economic transformation.
	Chair	Isaac Business Chamber	The Isaac Business Chamber has recently formed to represent businesses within the Isaac LGA. BMA has financially supported the Isaac Business Chamber and attended its launch event.	Letter, via email	15/07/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep the Isaac Business Chamber updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to the Isaac Business Chamber, and consider their feedback in future PRCP development.
Adjacent and nearby mining interests	Manager Tenements Portfolio Australia	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.)	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.) owns an open-cut mine known as Eaglefield and an underground mine previously known as North Goonyella and now called Centurion Coal Mine, adjacent to GRM and BRM's north. Centurion Coal Mining Pty Ltd, a Peabody-owned company, has a petroleum lease adjacent to the EA area. Engagement to date, with Peabody (Bowen) Pty. Ltd., is via routine correspondence on commercial and statutory issues.	Letter via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will engage with Centurion Coal Mining Pty Ltd regarding any effects of rehabilitation or closure works on adjacent mining operations.	BMA will keep Centurion Coal Mining Pty Ltd updated if there are substantive future changes to the PRCP.
	Tenure and Compliance Manager, and Site and Third Party Interface Manager	Anglo American Australia	Anglo American Australia owns the Moranbah North Coal Mine to the south, including land within the GRM and BRM EA area. Anglo also holds nearby PPLs for gas pipelines. Engagement with Anglo American is via routine correspondence on commercial and statutory issues.	Letter via email	14/06/2024	As detailed in the first row.	Acknowledgement received	No feedback received and no issues raised.	BMA will engage with Anglo American Australia regarding any effects of rehabilitation or closure works on adjacent mining operations.	BMA will keep Anglo American Australia updated if there are substantive future changes to the PRCP.
	Authorised Holder Representative	Wealth Mining Pty Ltd	Wealth Mining hold adjacent MDL and EPC tenements. BMA and Wealth Energy have not previously engaged.	Letter via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep Wealth Mining Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Wealth Mining Pty Ltd updated if there are substantive future changes to the PRCP.
	Authorised Holder Representative	Mayfair Energy Pty Ltd	Mayfair Energy hold nearby EPC (but not adjacent). BMA and Mayfair Energy have not previously engaged.	Letter via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep Mayfair Energy Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Mayfair Energy updated if there are substantive future changes to the PRCP.
	Manager Tenure & Senior Geologist	Stanmore SMC Pty Ltd	Stanmore SMC Pty Ltd owns the Wards Well underground development project, which is located immediately north of the Peabody's Centurion (North Goonyella) Mine. BMA and Stanmore have previously engaged with respect to the transfer of ownership of the Wards Well project from BMA to Stanmore.	Letter via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will keep Stanmore SMC Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Stanmore SMC Pty Ltd updated if there are substantive future changes to the PRCP.

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	**Stakeholder Title**	**Organisation/ Property**	**Previous engagement**	**Consultation type**	**Consultation date**	**Information provided**	**Issues raised/discussed**	**How issues were considered**	**Decisions/outcomes of engagement**	**Commitments**
Petroleum tenement holders	Principal Commercial Adviser	CH4 Pty Ltd (Arrow Energy Pty. Ltd.)	CH4 Pty Ltd (Arrow Energy Pty. Ltd.) holds an Authority to Prospect within the EA area and also an Authority to Prospect (ATP1103) which overlaps ML70421. There is a Co-Development Agreement in place between Arrow Energy and BMA, which governs and coordinates activities on Red Hill ML 70421 and Arrow Energy's overlapping PL 486. BMA communicates with Authorised Resource Holders regarding tenure issues on an as-needed basis.	Letter via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise CH4 Pty Ltd (Arrow Energy Pty. Ltd.) of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will advise CH4 Pty Ltd (Arrow Energy Pty. Ltd.) of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.
	Principal Commercial Adviser	Arrow CSG (Apt 364) Pty Ltd (Arrow Energy Pty. Ltd.)	Arrow CSG (Apt 364) Pty Ltd has a petroleum licence adjacent to the EA area, with a Co-Development Agreement in place. BMA communicates with Authorised Resource Holders regarding tenure issues on an as-needed basis.	Letter via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise Arrow CSG (ATP 364) Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will advise Arrow CSG (ATP 364) Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.
	General Manager Power and Pipelines	North Queensland Pipeline No 1 Pty Ltd	PPL 89 for the Moranbah to Townsville (North Qld Gas Pipeline) is in close proximity to GRM and BRM. The pipeline is owned by North Queensland Pipeline No 1 Pty Ltd and is located within easements held by Enertrade Pty Ltd.	Letter via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise North Queensland Pipeline No 1 Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will advise North Queensland Pipeline No 1 Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.
	Authorised Holder Representative	Enertrade Pty. Ltd.	Enertrade holds the easements under the North Qld Gas Pipeline which is near the EA area.	Letter via email	14/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise Enertrade Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.	BMA will advise Enertrade Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for GRM and BRM.
State Government	PRCP Team	Department of Environment Science and Innovation (DESI)	BMA and DESI have engaged through meetings and correspondence regarding the preparation and delivery of the PRCP.	Pre-notification meeting	29/11/2021	PRCP Notification memo	Provision of draft PRCP and discussion of requirements	DESI feedback was considered in the development of the PRCP.	The PRCP will be completed in accordance with BMA's agreements with DESI.	BMA will comply with the legislative and regulatory requirements for PRCPs.
				Pre-submission meeting	4/11/2024	Draft PRCP main points	Site specific issues	DESI feedback was considered in the development of the PRCP.	The PRCP will be completed in accordance with BMA's agreements with DESI.	BMA will comply with the legislative and regulatory requirements for PRCPs.
	Deputy Director-General Georesources	Department of Resources	BMA provides briefings to the Deputy Director-General Georesources on an as needed basis, and meets and corresponds with Department of Resources regarding resource development commitments.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the Deputy Director-General Georesources on any future changes to the PRCP.	BMA will provide updates on PRCPs to the Deputy Director General Georesources as requested
	Acting Director Native Title Services and Coal Hub, Rockhampton	Department of Resources	BMA provides briefings to the Acting Director Native Title Services and Coal Hub on an as needed basis, and meets and corresponds with Department of Resources regarding resource development commitments.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the Director Native Title Services and Coal Hub, Rockhampton on any substantive future changes to the PRCP.	BMA will provide updates on PRCPs to the Director Native Title Services and Coal Hub, Rockhampton as requested.
	A/Deputy Director-General Lands Division	Department of Resources	Unallocated state land is located within the EA area. Recent consultation with the Lands Division has not been required.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the DDG Lands Division, Department of Resources on any substantive future changes to the PRCP.	BMA will provide updates on PRCPs to the DDG Lands Division, Department of Resources, as requested.
	A/Regional Planning Manager (Central Queensland) and Principal Town Planner	DTMR	DTMR owns land within the EA area on which rail infrastructure is located.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the A/Regional Planning Manager (Central Queensland) and Principal Town Planner on any substantive future changes to the PRCP.	BMA will provide updates on PRCPs to the Regional Planning Manager (Central Queensland) and Principal Town Planner as requested.
	Chief of Staff/Secretary	Office of the Minister for Resources and Critical Minerals	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Agriculture Industry Development and Fisheries and Minister Rural Communities	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister Energy, and Clean Economy Jobs	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Environment, Science and Innovation and Minister for the Great Barrier Reef	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Regional Development and Manufacturing and Minister for Water	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Queensland Parliament - Member for Burdekin	BMA provides briefings to the Member for Burdekin's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Member's office as requested.	BMA will update the Member's office on any substantive future changes to the PRCP.

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
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	Chief of Staff/Secretary	Queensland Parliament - Shadow Minister for Natural Resources and Mines	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Environment and the Great Barrier Reef and Shadow Minister for Science and Innovation	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Energy and Cost of Living	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Water and the Construction of Dams	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Regional Development and Manufacturing	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
Federal Government	Chief of Staff/Secretary	Office of the Minister and Dep. Sec. Environment Protection, Department of Climate Change, Energy, the Environment and Water	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.

Goonyella Riverside Mine Progressive Rehabilitation and Closure Plan

Voids in Floodplain Report

BHP Mitsubishi Alliance

409 Adelaide St,
Brisbane City
QLD
4000

Prepared by:

SLR Consulting Australia Pty Ltd

Level 16, 175 Eagle Street, Brisbane, QLD, Australia,
4000

SLR Project No.: 620.31051.00000

20 November 2024

Revision: R01-v3.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
R01-v2.0	20 November 2024	HM	MD	HM
R01-v2.0	27 September 2024	HM	MD	HM
R01-v1.0	27 March 2024	HM	MD	MD

Basis of Report

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with BHP Mitsubishi Alliance (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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Appendices

Appendix A – TUFLOW Model Results

Acronyms and Abbreviations

1D	One dimensional
2D	Two dimensional
AEP	Annual Exceedances Probability
ARF	Aerial Reduction Factor
ARR	Australian Rainfall and Runoff
BMA	BHP Mitsubishi Alliance
BoM	Bureau of Meteorology
DR	Department of Resources
DEM	Digital Elevation Model
EA	Environmental Authority
EP	Environmental Protection
GRM	Goonyella Riverside Mine
GSDM	Generalised Short Duration Method
GTSMR	Revised Generalised Tropical Storm Method
IFD	Intensity-Frequency-Duration
NUMA	Non-use Management Areas
PRCP	Progressive Rehabilitation and Closure Plan
PMLU	Post Mining Land Use
QRT	Quantile Regression Technique
RFFE	Regional Flood Frequency Estimate
SA	Source Area
WBNM	Watershed Bounded Network Model

1.0 Introduction

SLR was engaged by BHP to undertake floodplain modelling at Goonyella Riverside Mine (GRM). The modelling was undertaken to inform the Transitional Progressive Rehabilitation and Closure Plan (PRCP) for GRM.

GRM is located in Central Queensland, approximately 170 kilometres west of Rockhampton and 20 kilometres north of Moranbah. **Figure 1** illustrates the location of GRM and key surrounding features including the Isaac River which drains through the Mine. The GRM complex includes the Mining Leases shown in Table 1

Table 1 Goonyella Complex Mining Leases

Goonyella Mine Complex Mining Leases	
• ML1763 – Goonyella	• ML70288 – Goonyella Industrial
• ML1764 – Riverside	• ML70289 – West Airstrip Pit
• MLML1802 – Riverside Extended	• ML70421 – Red Hill
• ML1900 – Riverside West	• ML70468 – Riverside West Extension 1
• ML700003 – Mabbin	• ML70469 – Riverside West Extension 2
• ML70121 – Riverside Tailings Extension	• ML70478 – Goonyella West 1
• ML70193 – Riverside West Extension North	• ML70478 – Goonyella West 2
• ML70194 – Riverside West Extension South	• ML70493 – Riverside North West
• ML70287 – Goonyella Tailings	• ML70494 – Riverside North

The assessment detailed in this document was undertaken specifically to address the voids in floodplain modelling as part of the PRCP requirements for GRM.

1.1 Aims and Objectives

To meet the requirements of the Environmental Protection Act 1994 (EP Act) and Environmental Protection Regulation 2019 (EP Regulation), floodplain modelling is required for all relevant watercourses in the vicinity of voids, to assess the flood immunity and extents for the final landform conditions.

The scope of this project is to undertake floodplain modelling of the relevant watercourses as defined by the EP Regulation in relation to the proposed voids, including the following key tasks:

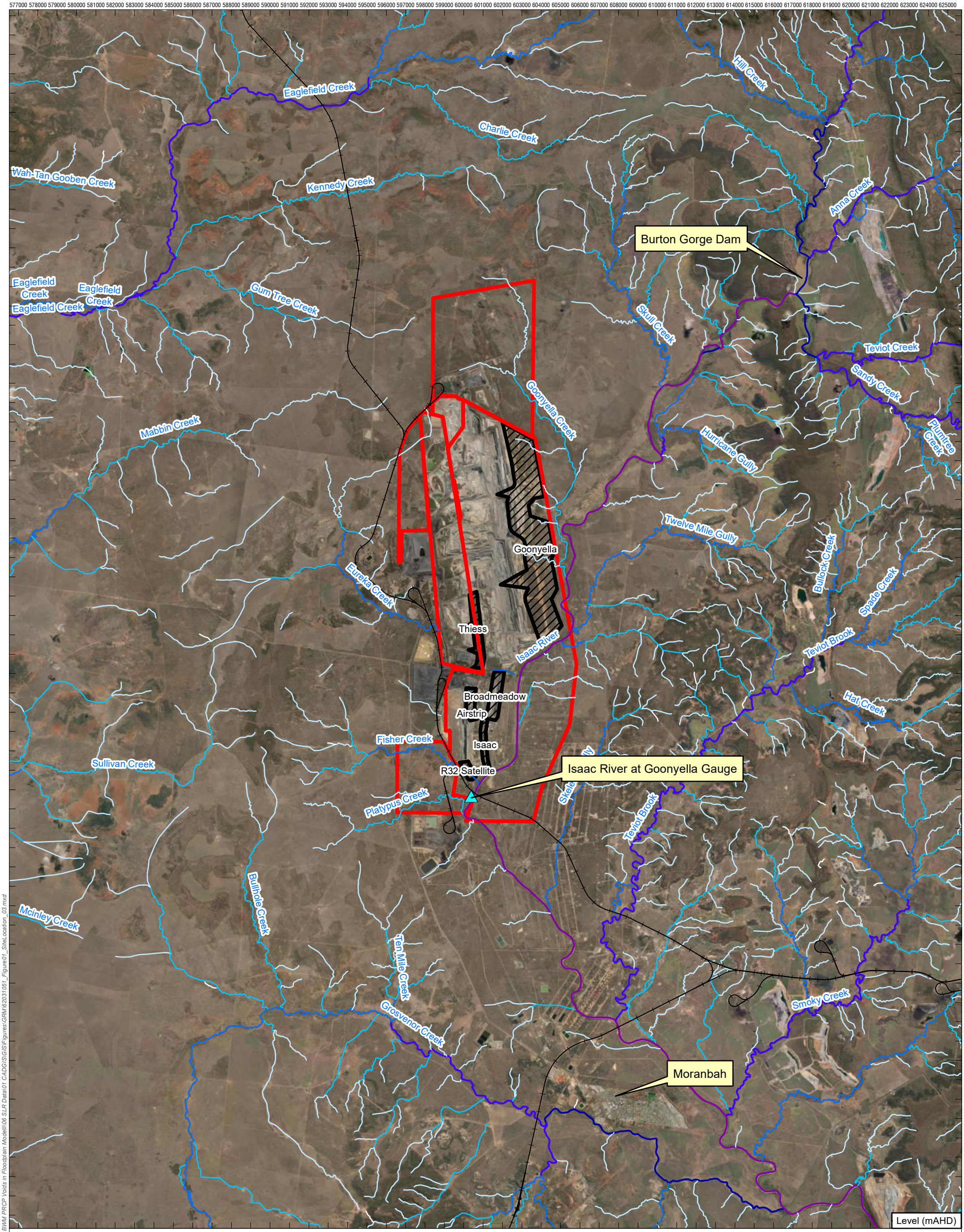
- Undertake a catchment study for each proposed void in the floodplain, including determining the pre-mining landform and developing or updating hydrologic modelling to be consistent with the requirements of Australian Rainfall and Runoff (AR&R 2019).
- Update and/or develop hydraulic models for the purpose of identifying flood risks posed to the proposed voids. The purpose of this is to define the baseline flood risks caused by the major creeks, which will be used to assess the inundation risk in the 0.1% Annual Exceedance Probability (AEP) flood event for each void, informed by the re-constructed pre-mining topography.
- Produce a Voids in Floodplain Model Report detailing the methodology and findings of the above assessments, including all relevant mapping of flood extents, levels and depths. GIS data and models will also be provided as an output of this assessment.

The assessments detailed in this report were undertaken and reviewed by appropriately qualified persons.

1.2 Input Data

Data for the assessment, including locations and extents of final voids, was provided by BHP.

Further data was obtained for use in the assessment from public sources, including topographic data, rainfall data, catchment specific hydrologic data, watercourse data and hydraulic structure data. Further detail on the data utilised in the assessment is provided in **Section 3.0**.



0 1.25 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:175,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	GN/HM

LEGEND

- Mining Leases
- Residual Voids
- Stream Gauge
- Rail Network

Watercourses **Stream Order**

0
1
2
3
4
5
6

SLR

Service Layer Credits: Source: Esri, Maxar, Earthstar

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

Site Location

Figure 1

H:\Projects-SLR\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelling\06 SLR Data\01 CADG\SIG\SIFigures\GRM\620.31051_Figure01_SiteLocation_03.mxd

2.0 Legislation and Guidelines

This assessment has been undertaken in accordance with the following legislation and guidelines:

- *Environmental Protection Act 1994;*
- *Environmental Protection Regulation 2019;*
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, March 2020; and
- *'Guideline – Progressive Rehabilitation and Closure Plans*', Department of Environment and Science, March 2021 (PRCP Guideline).

The Environmental Protection Act 1994 states:

'In accordance with section 126D(3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.'

The Environmental Protection Regulation 2019 section 41C(3) also states:

"The administering authority must treat the land as a flood plain to the extent the results of the flood plain modelling show that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the ARR."

Further guidance is provided in the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Sections 3.4 and 3.6.1 of the PRCP Guideline both require a floodplain assessment to be carried out. Specifically, Section 3.4 requires a Void in Floodplain assessment for all unapproved NUMA voids (i.e. floodplain assessment of the pre-mining landform), whilst Section 3.6.1 requires a post-mining landform assessment irrespective whether a post-mining land use (PMLU) or NUMA is proposed.

2.1 Applicability to the Project

Based on the review of the EP Act, EP Regulation, PRCP Guideline and the Voids in Floodplains information sheets, it is considered that the legislative requirements set out in **Table 2** are applicable to the project.

Table 2 Applicable Legislative Requirements

Requirement	Application to the Project	Source
For transitional sites, a floodplain assessment is required where: A void has been identified as a NUMA in a land outcome document but the location has not been specified; or Where there are no land outcomes in the land outcome document.	The PRCP for GRM includes six final voids which are proposed to be developed as NUMAs. Therefore, floodplain assessment is required.	PRCP Guideline Section 3.4
Floodplains associated with a stream order 4 or greater are required to be modelled.	Using the Strahler classification system, the Isaac River is a stream order 5 watercourse that may affect the proposed voids. Therefore, floodplain modelling of the Isaac River was undertaken. No other watercourses in the vicinity of GRM are of a stream order 4 or greater.	Voids in Flood Plains Information Sheet Section 5.
The modelling must not include any artificial features on the site. However, the modelling must include all existing and approved artificial features that, at the	A Digital Elevation Model (DEM) of the area was created to be used as the model landform for the assessment.	Voids in Flood Plains Information

Requirement	Application to the Project	Source
time of modelling, are located outside of the mining tenure boundary.	The model landform DEM was developed to represent the pre-mining topography within the Mining Lease (ML), and existing and future topography outside of the ML, including on adjacent MLs where applicable. The topography outside of the ML included existing and future artificial features, including Burton Gorge Dam, based on available data.	Sheet Section 4.
The requirement for a flood assessment under section 3.6.1 of the Guideline applies to the post mining landform across the whole site irrespective of whether a PMLU or a NUMA are proposed. Furthermore, section 3.6.1 is not only required to indicate flood risk but also to demonstrate the final landform (including waste rock dumps and diversions) will remain in a stable condition in a range of flood flow conditions.	Not included in the scope of this assessment.	PRCP Guideline Section 3.6.1.

2.2 Definitions and Terminology

Table 3 provides the definitions and terminology that are utilised in this assessment, in accordance with the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Table 3 Definitions and Terminology

Term	Definition	Source
Voids	An area of land to be excavated in carrying out a mining activity. Therefore, all voids (PMLU or NUMA) are subject to the requirements of the EP Act.	Section 126D of the EP Act.
Flood plain	A void is considered to be located in a flood plain if the flood plain modelling shows that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level in a 0.1% AEP for a relevant watercourse under the guideline Australian Rainfall and Runoff (2019) (ARR).	Section 41C of the EP Regulation; and PRCP Guideline Section 3.4.
Stable condition	The land is safe and structurally stable; There is no environmental harm being caused by anything on or in the land; and The land can sustain a PMLU.	Section 126D(3) of the EP Act; and PRCP Guideline Section 3.6.3.
Relevant watercourse	a) A watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or b) If a watercourse mentioned in paragraph (a) is permanently diverted under – (i) A condition, or proposed condition, of an environmental authority mentioned in the Water Act 2000, section 98; or (ii) A water license or proposed water license under the Water Act 2000; the watercourse as permanently diverted.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 5.
Flood plain modelling	For land the subject of a PRCP schedule, means modelling of the landform of the land –	PRCP Guideline Section 8; and

Term	Definition	Source
	a) Carried out under the ARR; (and) b) Excluding any artificial features for the land	Voids in Flood Plains information Sheet Section 4.
Artificial feature	For land the subject of a PRCP schedule, means – a) A structure or feature that is temporary and, under the PRCP schedule or otherwise, is to be removed from the land; or b) A structure or feature that, under the PRCP schedule, will require a level of maintenance after the land is surrendered that is greater than the level of maintenance that would be required for the land if the relevant activities the subject of the PRCP schedule had not been carried out; or c) A feature forming part of the landform of the land, other than the natural landform, if the feature interferes with or affects – i) A relevant watercourse; or ii) The natural flow of water on the land.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 6.

3.0 Data

3.1 Available Data

A data package was provided to SLR by BHP for use in the assessment. The package included:

- PRCP Residual Void Locations and Extents;
- Pre-mining topographic data (dated 1968) within the GRM Mine Lease extents as a DEM with 2m grid cell spacing;
- LiDAR topographic data (dated 2023) within Goonyella Mine extents as a DEM with 1m grid cell spacing.
- LiDAR topographic data (dated 2023) within Red Hill Mine extents as a DEM with 1m grid cell spacing.

Additional data was obtained from publicly available sources including:

- Fitzroy River catchment 25m DEM (Department of Resources (DR), 2023);
- Watercourse Lines – Queensland GIS dataset (DR, 2023);
- Lake Elphinstone 1m DEM (Department of Natural Resources and Mines, 2023);
- 1 second SRTM 30 metre DEM terrain data (Geoscience Australia);
- Historic gauged stream flow data for the Goonyella (130414A) and Deverill (130410A) Stream Gauges (DNRM); and
- Burton Gorge Dam Emergency Action Plan, 2018, (Peabody).

The provided data was analysed for suitability for the purposes of this assessment. The outcomes of the review are detailed below.

3.2 Watercourses

A review of the existing watercourses in the vicinity of GRM was undertaken using hydrologic streamline data sourced from DR.

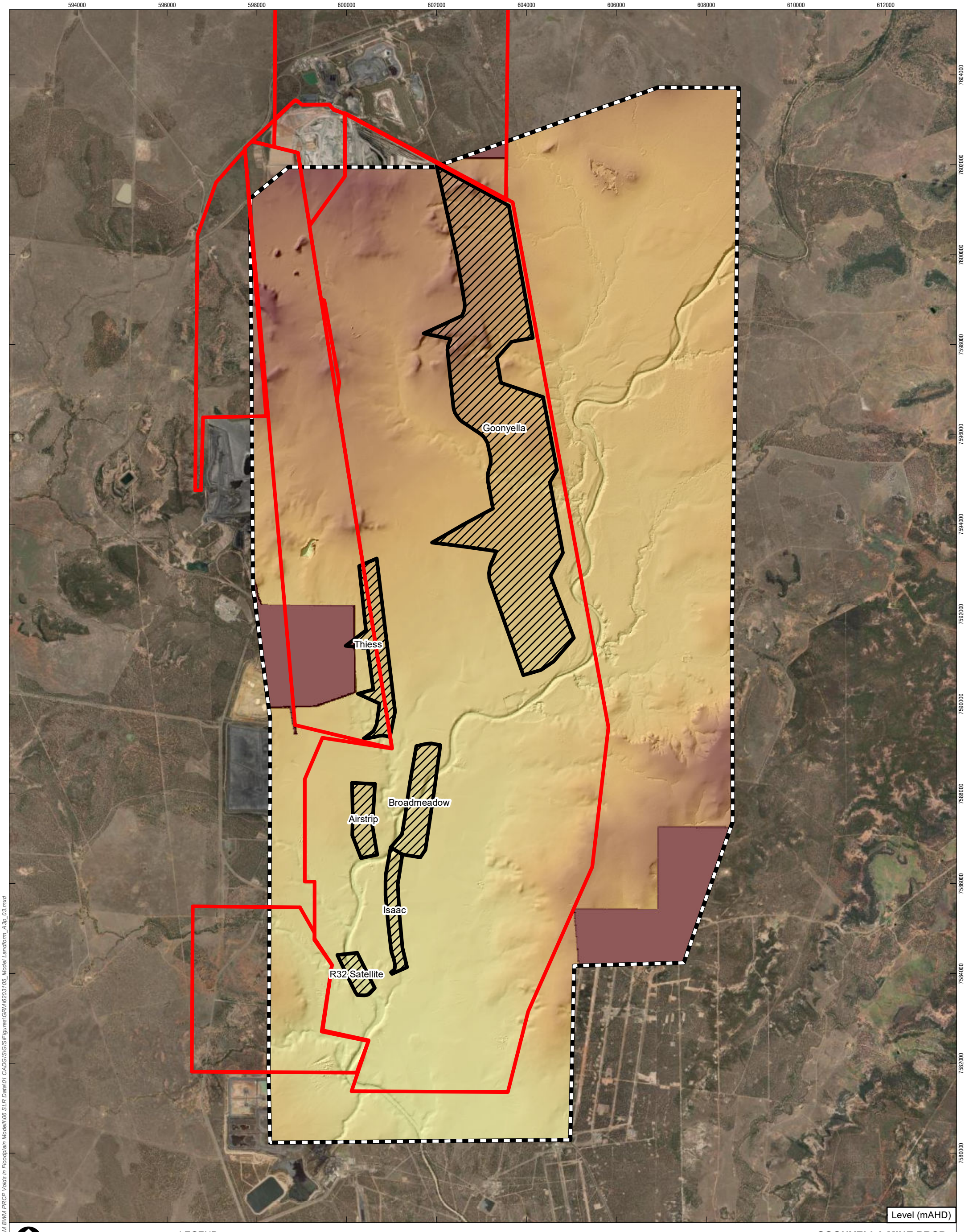
The dataset contained Strahler Stream Order classifications for each watercourse, which ranged from order 1 to order 9 within the extent of the data. The dataset was reviewed and interrogated to identify watercourses of Strahler stream order 4 or greater and may affect the proposed final voids.

As outlined in **Table 2** and illustrated in **Figure 1**, the Isaac River was the only watercourse of stream order 4 or greater in the vicinity of GRM. Therefore, flood modelling of the Isaac River in the vicinity of GRM was undertaken.

3.3 Topography and Landforms

A Model Landform was developed for use in the floodplain modelling of the Isaac River. The landform consisted of a combination of the 2023 Red Hill LiDAR DEM, which was applied outside of the GRM extents and the 1968 GRM Pre-mining topography DEM which was applied within the GRM extents.

The model landform is illustrated in **Figure 2**.



0 0.5 1 2 km

LEGEND

- Mining Leases
- Residual Voids
- Model Extent

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:75,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	GN/HM

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

Model Landform

SLR

Service Layer Credits: Source: Esri, Maxar, Earthstar

Figure 2

H:\Projects-SLR\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelli\06 SLR Data\01 CADG\SIG\SIGFigures\GRM\620310S_Model Landform_A3p_03.mxd

3.4 Artificial Features

A review of the existing landscape in the vicinity of GRM was undertaken. The following noteworthy artificial features were identified:

- Burton Mine
- Burton Gorge Dam
- Moranbah North Mine
- Goonyella System Rail Line

Of the identified artificial features, the Burton Gorge Dam has the potential to influence flooding conditions within GRM, and was therefore included in the hydrologic model, as detailed in the following sections.

4.0 Hydrologic Modelling

4.1 Model Setup

4.1.1 Software

Hydrologic modelling was undertaken to estimate runoff hydrographs at various locations throughout the catchments of the relevant watercourses. The model was developed using the Watershed Bounded Network Model Version 2019 (WBNM). WBNM is an industry standard rainfall-runoff routing software package.

4.1.2 Catchment Characterisation

The Isaac River model covers a catchment area of approximately 1,250 km^2, spanning from the catchment headwaters upstream of Burton Gorge Dam to approximately 6km downstream of GRM. The model extent covers the Goonyella gauge, which is located within the GRM ML1763 at the Isaac River crossing of the Goonyella System Rail Line.

Two model scenarios were developed:

- **Existing Catchment Scenario**. Representing the current catchment conditions. The model sub-catchments were delineated based on available topographic data that best represented the existing conditions including the 2023 LiDAR DEM datasets for Goonyella and Red Hill Mines and the SRTM DEM. As part of the sub-catchment delineation, areas within the model extent that drained to existing mining pits, which act as sinks, were excluded from the model area. The model was utilised to verify the model results in comparison to the Flood Frequency Analysis undertaken for the Isaac River stream gauge at Goonyella. The model layout is illustrated in **Figure 3**.
- **Model Landform Scenario**. Representing the model landform catchment conditions. That is, pre-mining topography within the GRM extents excluding all artificial features. Model sub-catchments were delineated based on the model landform, otherwise this scenario adopted all model parameters as per the Existing Catchment Scenario. The model layout is illustrated in **Figure 4**.

4.1.3 Storm Events

The 0.1% AEP event was the primary design storm event for this assessment. In accordance with ARR, Probably Maximum Flood (PMF) temporal patterns were adopted for the 0.1% AEP event. ARR recommends the Generalised Short Duration Method (GSDM) for events with a duration up to 6 hours, and the Revised Generalised Tropical Storm Method (GTSMR) for durations of 24 hours or more. There is no set guidance for which method to adopt for storms with durations between 6 and 12 hours, therefore the GSDM temporal pattern was adopted for all durations up to and including the 12 hour duration, and the GTSMR temporal patterns for durations of between 12 hours and 72 hours.

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000 7570000

IR02
IR03
IR01
IR08c
IR04
IR08b
IR08d
IR04
IR09b
IR08f
IR08e
IR08a
IR07
IR09c
IR05
IR09a
IR08h
IR09d
IR08g
IR06
IR10d
IR09e
IR10b
IR09g
IR10e
IR09f
IR10a
IR10c
IR11b
IR11a
IR10f
IR12a
IR12b
IR15a
IR13
IR12c
IR15b

0 1.5 3 6 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A3
Project Number:	620.31051
Date:	25-Mar-2024
Drawn by:	GN

LEGEND

- Mining Leases
- WBNM Catchment Boundaries

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

WBNM Model Layout
Existing Catchment Scenario

SLR

Figure 3

H:\Projects-SLR\620-BNE\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelli\06 SLR Data\01 CADG\SIG\S\Figures\GRM\620.3105_WBNMLayout_Existing_02.mxd

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000 7570000

IR02
IR03
IR01
IR08c
IR04
IR08b
IR08d
IR04
IR09b
IR08f
IR08e
IR08a
IR07
IR09c
IR05
IR09a
IR08h
IR09d
IR08g
IR06
IR10d
IR09e
IR10b
IR09g
IR09h
IR09f
IR10e
IR10a
IR10c
IR10f
IR11b
IR11a
IR12a
IR12b
IR15a
IR13
IR12c
IR15b

0 1.5 3 6 km

LEGEND

Mining Leases

WBNM Catchment Boundaries

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A3
Project Number:	620.31051
Date:	25-Mar-2024
Drawn by:	GN

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

WBNM Model Layout
PRCP Model Landform Catchment Scenario

SLR

Service Layer Credits: Source: Esri, Maxar, Earthstar

Figure 4

H:\Projects-SLR\620-BNE\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelli\06 SLR Data\01 CADG\SIG\S\Figures\GRM\620310 5_WBNMLayout_ModelLandform_02.mxd

4.1.4 Intensity-Frequency-Duration Rainfall Data

Rainfall Intensity-Frequency-Duration (IFD) data for the catchment was sourced from the Bureau of Meteorology (BoM) online IFD data portal for a range of Annual Exceedance Probabilities (AEP). The adopted design rainfall intensity for the 0.1% AEP event is provided below.

Table 4 Design Rainfall Intensity Frequency Duration Data – 0.1% AEP

Storm Duration (h)	Design AEP Event Rainfall Depth (mm)
1	132
1.5	151
2	165
3	188
4.5	216
6	239
9	277
12	309
18	362
24	404
30	438
36	466
48	512

4.1.5 Losses

An initial loss of 0 mm was applied given the expected antecedent catchment conditions in the 0.1% AEP event. A continual loss value of 2.70 mm/h was applied based on the data provided by the ARR Data Hub for the area.

4.1.6 Lag Parameter

A catchment lag parameter of 1.60 was adopted in the WBNM model. The WBNM documentation recommends a lag parameter value between 1.40 and 1.80 where possible, therefore the adopted lag parameter was within the recommended range.

4.1.7 Aerial Reduction Factor

An Aerial Reduction Factor (ARF) was applied in the model. The ARF was based on a catchment area of 1,100 km^2, which is the area to the point at which the Isaac River discharges from the GRM site.

4.1.8 Storages

The Burton Gorge Dam is located on the Isaac River some 23 km upstream of GRM. The catchment area draining to the Dam is 540 km^2, approximately 50% of the catchment area of the Isaac River that drains through GRM. The Dam was incorporated into the hydrologic model as a reservoir storage node. Outflows from the Dam were modelled using a stage-storage-discharge relationship based on the storage and discharge curves provided in the Burton Gorge Dam Emergency Action Plan.

An initial water level of 298 mAHD (Full Supply Level + 500mm) was adopted in the model.

Table 5 WBNM Model – Burton Gorge Dam Stage-Storage-Discharge Relationship

Stage (m AHD)	Storage Volume (ML)	Discharge (m^3/s)
297	12,750	0
297.5	14,830	34
298	16,910	95
298.5	18,990	267
299	21,070	489
299.5	23,150	753
300	25,230	1,054
300.5	27,310	1,386
301	29,390	1,748
301.5	31,470	2,136
302	33,550	2,700
302.5	35,630	3,250
303	37,710	3,850

4.2 Validation

4.2.1 Stream Gauge

Flood frequency analysis was undertaken for Isaac River. Stream gauge data upstream of the site was obtained from the Qld Government Water Monitoring Information Portal.

There are two stream gauges upstream of the site; Isaac River at Goonyella (13414A) and Isaac River at Burton Gorge (130402A). Although there is 38 years of data available, due to the construction of the Burton Gorge Dam, the Isaac River at Goonyella gauge is considered to be lacking in homogeneity, and hence it is not suitable for flood frequency analysis.

Flood frequency analysis was therefore undertaken for the gauge at Isaac River at Burton Gorge (130402A). Data for this gauge is available between 1964 and 1988 (24 years). Burton Gorge Dam was constructed in 1992, so the dataset is not influenced by the dam.

4.2.2 Flood Frequency Analysis

RMC-BestFit v1.0, a Bayseian estimation and fitting software developed by the US Army Corps of Engineers (USACE) Risk Management Center (RMC), was used for flood frequency analysis.

A Log-Pearson Type III distribution was fitted to the data. The peak flow prediction beyond 1% AEP goes outside the 90% credible intervals, and therefore should not be used for comparison with hydrological model results. Note that the peak flow of $0m^3/s$ from 1969 was treated as low outlier data and not included in the analysis.

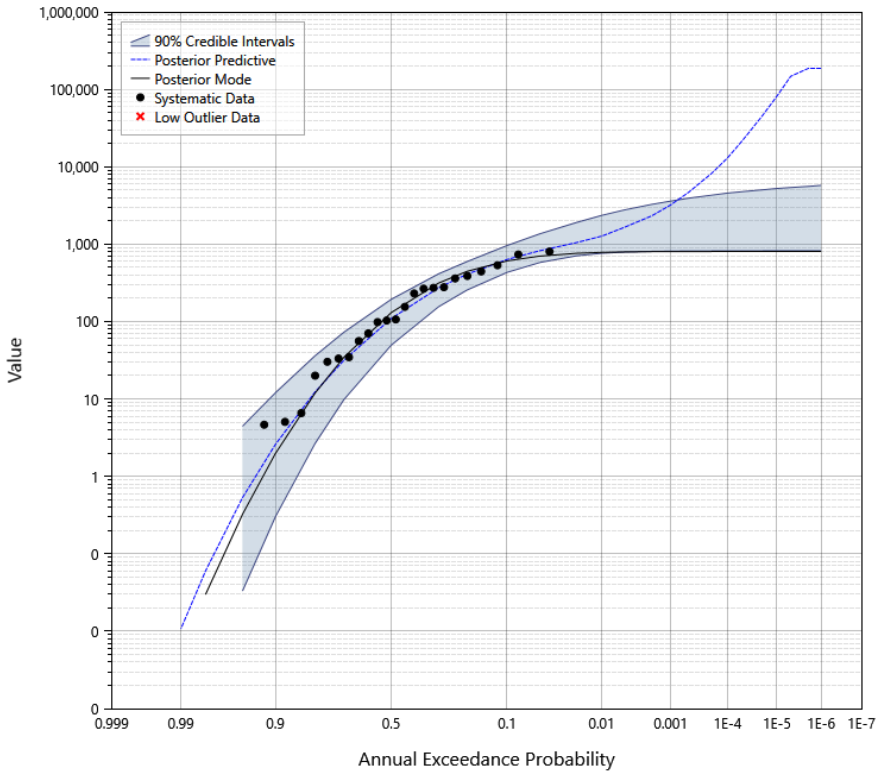
The results of the FFA are shown in **Table 6** and **Figure 5** below.

Table 6 FFA Results for Issac River at Burton Gorge gauge

AEP	Peak Flow (m^3/s)	Lower 90% confidence limit (m^3/s)	Upper 90% confidence limit (m^3/s)
39%	165	83	273

AEP	Peak Flow (m^3/s)	Lower 90% confidence limit (m^3/s)	Upper 90% confidence limit (m^3/s)
20%	412	257	597
10%	635	433	961
5%	824	581	1,362
2%	1,052	710	1,914
1%	1,269	763	2,354

Figure 5 FFA Results for Issac River at Burton Gorge gauge



4.2.3 Comparison to 2019 FFA

A flood frequency analysis was undertaken for the Goonyella and Broadmeadow mines in the Goonyella and Broadmeadow Hydraulic Assessment (WRM 2019).

Analysis was undertaken for the Isaac River at Goonyella gauge. An "all-data" scenario using all 35 years of data and a "post-dam" scenario which uses only the data after Burton Gorge Dam construction (27 years). Although the Isaac River at Goonyella gauge was deemed not suitable for an FFA (refer to **Section 4.4.1**), the peak flows from the WRM FFA and subsequent XP-RAFTS model results are of similar magnitude to the WBNM model output. Comparison to these results are shown in **Table 8**.

4.3 Results

The peak flows from the WBNM model at Burton Gorge gauge were compared to the peak flow from the FFA in **Table 7**.

The WBNM peak flows were generally consistent with the 2% and 1% AEP FFA results. The WBNM model peak flow was lower than the FFA results in the 39% AEP. However, the 39% AEP results were utilised to assess the peak flood bed shear stress, stream power and velocity and subsequently the associated scour and erosion risk, and these parameters are not significantly affected by relatively small changes in peak flow.

Table 7 Peak flow at Burton Gorge gauge

AEP (%)	WBNM Peak Flow (m^3/s)	FFA Peak Flow (m^3/s)	% difference from FFA	RFFE Discharge (m^3/s)	RFFE Lower confidence Limit 5% (m^3/s)	RFFE Upper confidence Limit 95% (m^3/s)
39	112	165.6	-32%	-	-	-
10	463	635	-27%	707	334	1,560
5	682	825	-17%	874	397	2,010
2	1,025	1,052	-2%	1,110	476	2,700
1	1,307	1,270	3%	1,300	532	3,310
0.1	2,502	-	-	-	-	-

The peak flows from the WBNM model at Isaac River at Goonyella gauge were compared to the peak flow from the FFA from WRM as shown in **Table 8**.

Table 8 Peak flow at Isaac River at Goonyella

AEP (%)	WBNM Peak Flow (m^3/s)	WRM (2019) Peak Flow (m^3/s)	% difference from WRM
10	718	830	-13%
5	1,080	1,167	-7%
2	1,689	1,707	-1%
1	2,187	2,079	5%
0.1	4,365	3,808	15%

The flows produced by the WBNM model are comparable to the peak flows from the FFA and the RFFE at Burton Gorge. The results are also comparable to the flows from the WRM (2019) FFA at Goonyella. Although the outcome suggests that the 0.1% AEP results may be conservative on the high side, there is insufficient gauge information to confirm this.

Therefore the WBNM model was deemed suitable for use for this assessment.

Flow hydrographs generated by the WBNM model for the 0.1% AEP event were extracted from the WBNM model at the outlet of each sub-catchment. The hydrographs were utilised as inflow boundaries for the TUFLOW hydraulic model, details of which are provided in the following section.

5.0 Hydraulic Modelling

5.1 Software

Hydraulic modelling was undertaken for the Isaac River in the vicinity of GRM, including the proposed final voids.

The industry standard hydrodynamic modelling software TUFLOW (build 2023-03-AD) was utilised for the hydraulic modelling.

Details of the modelling approach, setup and results are provided below.

5.2 Topography

The following topographic data were utilised in the TUFLOW model:

- Red Hill Mine 2023 LiDAR 1m DEM.
- GRM pre-mining (1968) 1m DEM.

The GRM pre-mining DEM was applied within the GRM mine lease extents and downstream of GRM, and the Red Hill Mine LiDAR DEM was applied within the Red Hill Mine extent upstream of GRM.

The model extent was dictated by the extent of the available topographic data, as illustrated in **Figure 6**.

5.3 Model Grid Cell Size

A grid cell size of 20m was adopted. The native sub-grid sampling functionality was applied in the model, with a sampling distance of 2m.

This approach provided adequate resolution of the Isaac River watercourse cross-section, which is generally 20-50m in width within the model extent.

5.4 Hydraulic Roughness

The hydraulic roughness for the model was determined based on available aerial imagery. The Manning's n values adopted in the model are detailed in **Table 9**.

Table 9 TUFLOW Model Manning's n Values

Land use	Manning's n
Light Vegetation	0.06
Overbanks	0.08
Channel bed	0.04

5.5 Boundaries

Flow hydrographs extracted from the WBNM model were applied as inflows to the TUFLOW models. They were applied as local or total hydrographs where appropriate.

Stage-discharge relationships were applied as the downstream boundary conditions in each model. The relationships were derived based on the flood surface gradient at each boundary location using the built-in functionality provided in TUFLOW.

In the Isaac River model, the downstream boundary is located approximately 2.8km downstream of the nearest final void, and the peak flood levels at the boundary were approximately 6 metres lower than in the vicinity of the nearest final void. Therefore, the model boundary did not influence peak flood levels in in the vicinity of the final void extents.

591000 592000 593000 594000 595000 596000 597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000 609000 610000 611000 612000 613000 614000 615000 616000 617000 618000 619000 620000 621000

7613000 7612000 7611000 7610000 7609000 7608000 7607000 7606000 7605000 7604000 7603000 7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000 7580000 7579000 7578000 7577000 7576000 7575000

Elevation (mAHD)
High : 1000
Low : 71.141

0 0.75 1.5 3 km

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:110,008 at A3
Project Number: 620.31051
Date: 25-Mar-2024
Drawn by: GN

LEGEND
- Model Extent
- Mining Leases
- SA Inflows
- Downstream Boundary

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

TUFLOW Model Layout

SLR

Figure 6

H:\Projects-SLR\620-BNE\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelli\06 SLR Data\01 CADG\SIG\SIFigures\GRM\620310 5_TuflowLayout.mxd

5.6 Results

The TUFLOW models were simulated for the 0.1% AEP event for a range of storm durations, including as detailed in **Section 4.1.3.** The critical storm durations across the model extent were extracted from the model results, as illustrated in **Figure 7**.

Peak flood levels, depths and velocities were extracted from the model results and are presented in **Appendix A.**

The peak 0.1% AEP flood inundation extent generated by the TUFLOW model is illustrated in **Figure 8**. The model results show that each of the proposed final voids are located within the 0.1% AEP floodplain extent.

For the Thiess and Goonyella final voids, the floodplain extends in limited areas in the south of the void extents and a small area along the eastern extremities of the Goonyella void.

For the Broadmeadow, R32 Satellite and Isaac voids, the majority of the void extents are located within the 0.1% AEP floodplain extent. The Airstrip void is only partially within the 0.1% AEP Floodplain extent. It is noted that the existing Isaac River Diversion is situated approximately 1 km west of the Broadmeadow final void. The TUFLOW model topography was based on the 1968 DEM which represents the pre-mining topography prior to the development of the Isaac River Diversion.

593000 594000 595000 596000 597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000 609000

7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Goonyella

Thiess

Broadmeadow

Airstrip

Isaac

R32 Satellite

Duration (h)
- 9 h
- 12 h
- 24 h
- 36 h

0 0.5 1 2 km

LEGEND
- Mining Leases
- Residual Voids
- Model Extent

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:60,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	GN/HM

SLR

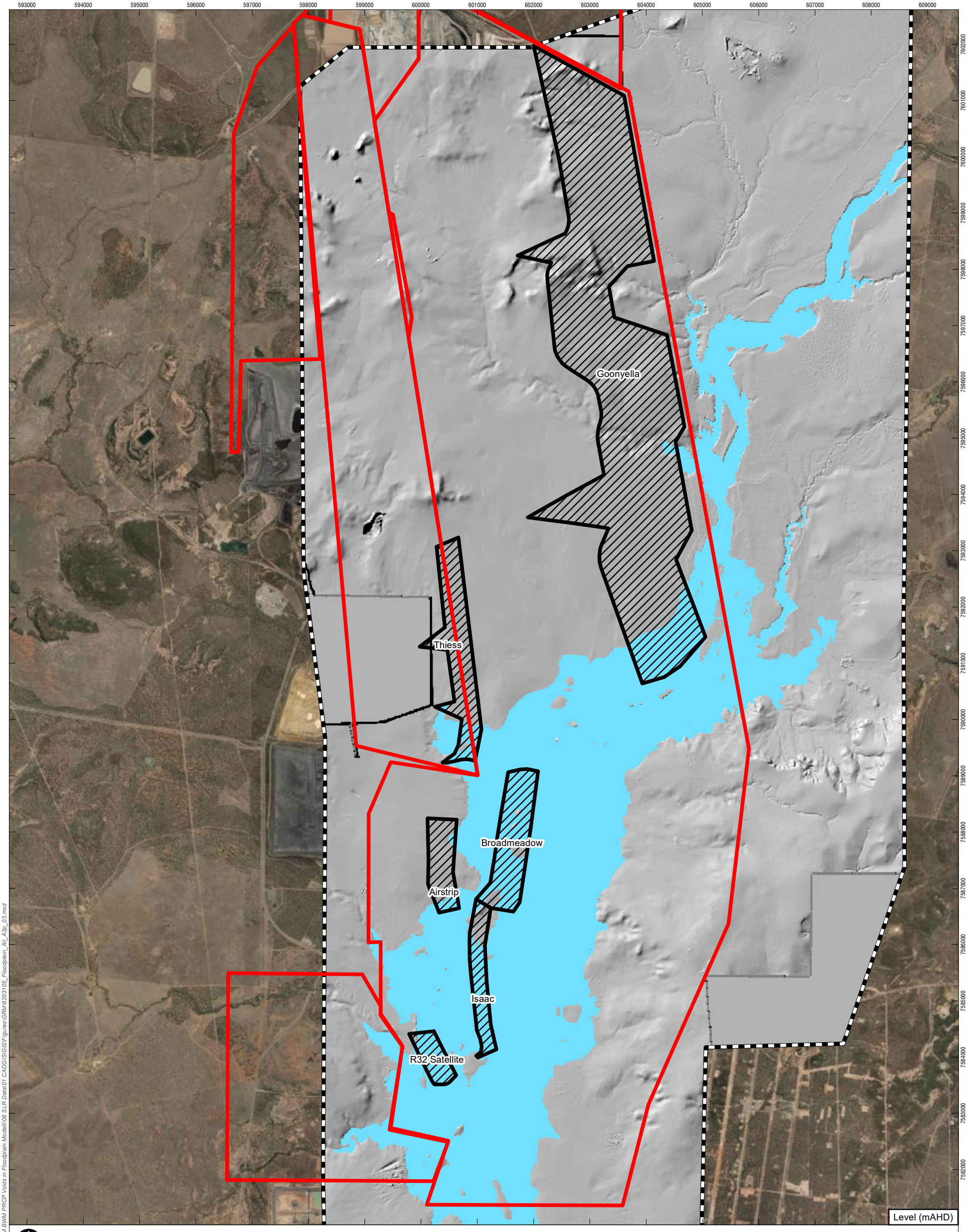
Service Layer Credits: Source: Esri, Maxar, Earthstar

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

TUFLOW Model Results
Critical Storm Durations
0.1% AEP Event

Figure 6

H:\Projects-SLR\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelling\06 SLR Data\01 CAD\GIS\GIS\Figures\GRM\620.31051_CritDur_TUFLOW_02.mxd



0 0.5 1 2 km

LEGEND

- Mining Leases
- Residual Voids
- Model Extent
- 0.1% AEP Inundation Event

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:60,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	GN/HM

GOONYELLA MINE PRCP
VOIDS IN FLOODPLAIN MODELLING

TUFLOW Model Results
Modelled Flood Inundation Extent
0.1% AEP Event

SLR

Service Layer Credits: Source: Esri, Maxar, Earthstar

Figure 7

H:\Projects-SLR\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Model\06 SLR Data\01 CADGIS\GIS\Figures\GRM\620310S_Floodplain_All_A3p_03.mxd

6.0 Groundwater Impact on Floodplain Extents

Consideration was made to the potential effects of groundwater on the floodplain extents. The floodplain extents were based on the peak 0.1% AEP event flood levels. During a flood event of this magnitude, any groundwater interaction with surface water would have a negligible impact on the resulting floodplain extents.

7.0 Conclusion

As part of the PRCP for Goonyella Mine, it is proposed to incorporate six final voids as NUMAs. Therefore, in accordance with the EP Act and EP Regulation and specifically Section 3.4 of the PRCP Guideline, floodplain modelling has been undertaken for all relevant watercourses that may affect the voids.

Data for the assessment was provided by BHP, and sourced from various public providers. The data was reviewed and modified for use where appropriate. Model landforms were developed to account for relevant artificial features outside of the GRM mine extents, and pre-mining topography within the mine extents based on the information available at the time of the study.

A hydrologic model was developed for the catchment of the Isaac River in the vicinity of GRM. The model results were verified against peak flows generated by flood frequency estimates and the results of an at-site Flood Frequency Analysis based on gauged stream flow data.

A hydraulic model of the Isaac River floodplain was developed using available topographic data. The model landform was developed to represent the pre-mining topography within the GRM mine lease extents in accordance with the PRCP Voids in Floodplain Modelling Guidelines. Hydrographs from extracted from the hydrologic model at relevant locations were applied as inflows to the hydraulic model.

The results of the hydraulic model provided the predicted 0.1% AEP flood event inundation extent based on the model landform. Predicted peak flood levels and depths were also produced by the hydraulic model. The model results showed that the proposed final voids were situated within the modelled pre-mining 0.1% AEP flood inundation extents.

8.0 Limitations

This report, including the hydrologic and hydraulic modelling, is not necessarily suitable for application for purposes other than as detailed above.

This Voids in Floodplain Assessment has relied upon, and assumed accurate, information which was received from BHP and other sources. Except where noted, no verification of accuracy of the information has been carried out. In the event that some of the information which was relied upon for this assessment is found to be inaccurate, then some or all of the findings may change.

Although the analyses undertaken as detailed in this report were done so with the appropriate care and professionalism, this report shall only be used for the purposes intended. The analyses detailed in the sections above were undertaken solely for the purpose of addressing the requirements for voids in floodplain modelling for Goonyella Riverside Mine in accordance with:

- *Environmental Protection Act 1994;*
- *Environmental Protection Regulation 2019;*
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, March 2020; and
- *'Guideline – Progressive Rehabilitation and Closure Plans'*, Department of Environment and Science, March 2021 (PRCP Guideline).

This report should be read in full and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of BHP Metcoal Holdings Pty Ltd and SLR accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Appendix A TUFLOW Model Results

Goonyella Riverside Mine Progressive Rehabilitation and Closure Plan

Voids in Floodplain Report

BHP Mitsubishi Alliance

SLR Project No.: 620.31051.00000

20 November 2024

595000 596000 597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000 609000 610000 611000

7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Goonyella

Thiess

Broadmeadow

Airstrip

Isaac

R32 Satellite

Level (m AHD)
- 199 - 225
- 226 - 230
- 231 - 235
- 236 - 240
- 241 - 245
- 246 - 250
- 251 - 255
- 256 - 260
- 261 - 265
- 266 - 270
- 271 - 275
- 276 - 280
- 281 - 285
- 286 - 290
- 291 - 295
- 296 - 300

0 0.5 1 2 km

LEGEND
- TUFLOW Model Extent
- Mining Leases
- Final Void Extents

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:60,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	HM

GOONYELLA RIVERSIDE MINE PRCP VOIDS IN FLOODPLAIN MODELLING

Isaac River
Peak Flood Levels - 0.1% AEP

SLR

APPENDIX A1

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7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Goonyella

Thiess

Broadmeadow

Airstrip

Isaac

R32 Satellite

Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- Above 3.5

0 0.5 1 2 km

LEGEND
- TUFLOW Model Extent
- Mining Leases
- Final Void Extents

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:60,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	HM

SLR

GOONYELLA RIVERSIDE MINE PRCP VOIDS IN FLOODPLAIN MODELLING

Isaac River
Peak Flood Depths - 0.1% AEP

APPENDIX A2

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7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Goonyella

Thiess

Broadmeadow

Airstrip

Isaac

R32 Satellite

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.5 1 2 km

LEGEND
- TUFLOW Model Extent
- Mining Leases
- Final Void Extents

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:60,000 at A3
Project Number:	620.31051
Date:	27-Sep-2024
Drawn by:	HM

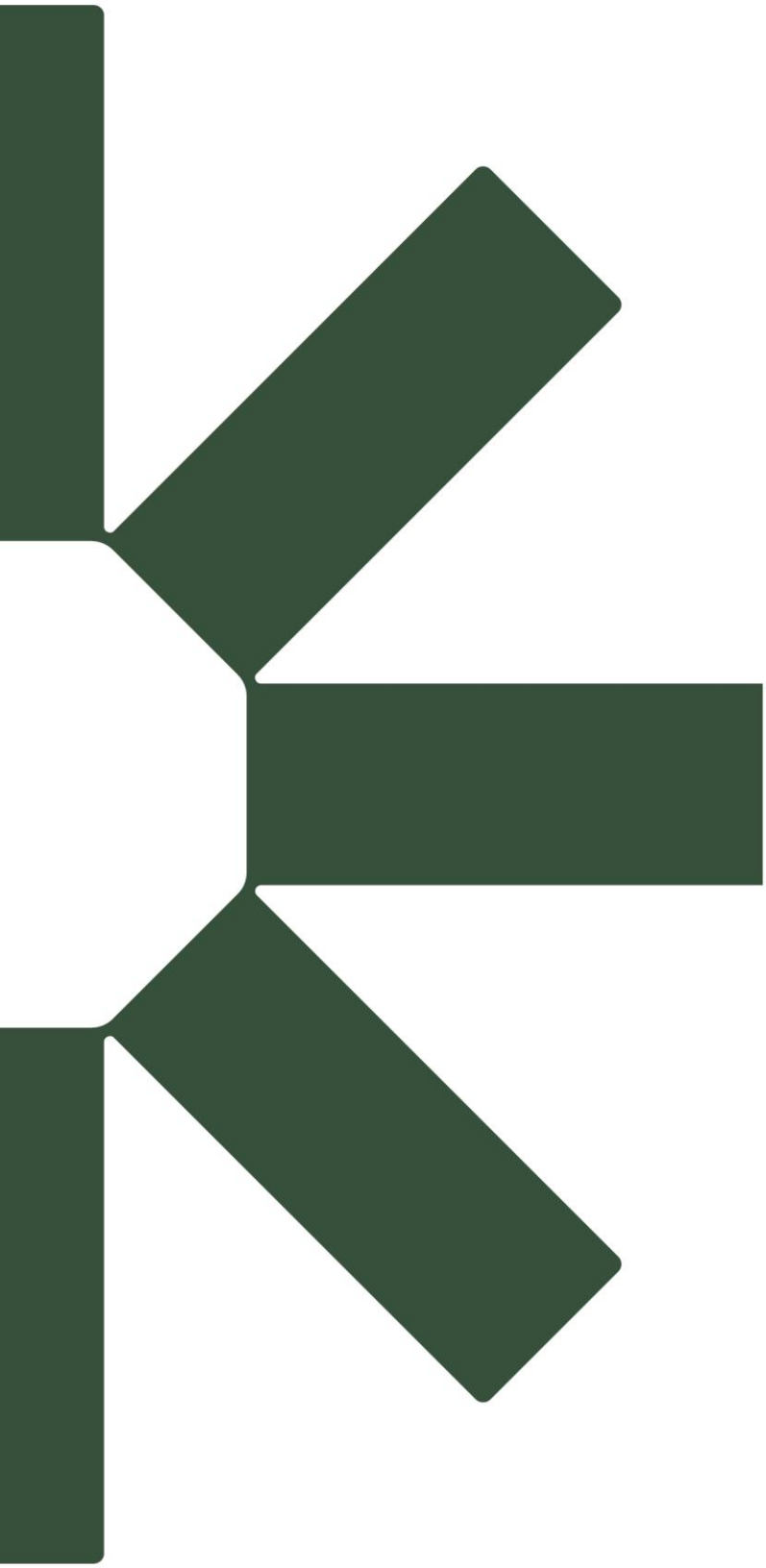
GOONYELLA RIVERSIDE MINE PRCP VOIDS IN FLOODPLAIN MODELLING

Isaac River
Peak Flood Velocities - 0.1% AEP

SLR

APPENDIX A3

H:\Projects-SLR\620-BNE\620.31051.00000 GRM BWM PRCP Voids in Floodplain Modelling\06 SLR Data\01 CADD\GIS\SIFigures\GRM\Automapping\Output\MXDs\620.31051.00000_APPENDIX A3_E17_1in1000_V.mxd



Making Sustainability Happen

Goonyella Complex

Progressive Rehabilitation and Closure Plan
Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

409 Adelaide Street
Brisbane City
QLD 4000

Prepared by:

SLR Consulting Australia

SLR Project No.: 620.040713.0000

18 November 2024

Revision: 3

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
1.0	27 September 2024	TS	HM	HM
2.0	30 October 2024	TS	HM (RPEQ 27137)	HM
3.0	18 November 2024	TS	HM (RPEQ 27137)	HM

Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with BHP Mitsubishi Alliance (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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Appendix A Flood Risk Profile Assessment

Appendix B Fluvial Model Results

Appendix C Pluvial Model Results

Acronyms and Abbreviations

ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ASC	Australian Soil Classification
BoM	Bureau of Meteorology
CSM	Conceptual Site Model
DEM	Digital Elevation Model
DESI	Department of Environment, Science and Innovation
DNRM	Department of Natural Resources and Mines
EP	Environmental Protection
FFA	Flood Frequency Analysis
Fi	Fraction Impervious
FRP	Flooding Risk Profile
GRM	Goonyella Riverside Mine
GSDM	Generalised Short Duration Method
GTSMR	Revised Generalised Tropical Storm Method
IFD	Intensity Frequency Duration
LiDAR	Light Detection and Ranging
MFL	Maximum Foreseeable Loss
ML	Mining Lease
NUMA	Non-Use Management Area
PMF	Probable Maximum Flood
PMLU	Post-mining land use
PMP	Probable Maximum Precipitation
PRCP	Progressive Rehabilitation and Closure Plan
RFFE	Regional Flood Frequency Estimation
RMC	Risk Management Center
RMG	Risk Management Guidelines
RRR	Residual Risk Rating
SGS	Sub-grid sampling
SRTM	Shuttle Radar Topography Mission
TEC	Threatened Ecological Communities
TP	Temporal pattern
TUFLOW	Two-Dimensional Unsteady Flow

USACE	US Army Corps of Engineers
USDA	United States Department of Agriculture
WBNM	Watershed Bounded Network Model

1.0 Introduction

1.1 Scope of Work

SLR was contracted by BHP Mitsubishi Alliance (BMA) to support the preparation of the Goonyella, Riverside and Broadmeadow mines (collectively known as Goonyella Complex) Progressive Rehabilitation and Closure Plan (PRCP). Specifically, the scope of work involved undertaking flood modelling of the Goonyella Complex in accordance with Section 3.6.1 and Section 3.6.4 of 'Guideline – Progressive Rehabilitation and Closure Plans', Department of Environment, Science and Innovation (DESI) (The Guideline) (Department of Environment, Science and Innovation 2024). Section 3.6.1 and Section 3.6.4 of The Guideline provides the following direction on general rehabilitation practices in relation to flooding:

Section 3.6.1 General Rehabilitation Practices (Flooding):

- Consider the location of domains in relation to potential flood levels;
- Consider alteration of flow upstream and downstream;
- Model flood levels (including probable maximum flood levels) for a range of design storm events; and
- Develop a flooding risk profile.

Section 3.6.4 Underground Mining:

- Changes to hydrological regime;
- Changes in surface topography and local drainage characteristics - this may result in some areas becoming more free-draining while runoff may be reduced in other areas, resulting in the ponding of water in areas where previously no ponding occurred; and
- Changes in surface drainage, leading to changes in the composition of vegetation communities and distribution of flora and fauna species.

This report details the assessments undertaken including hydrologic and hydraulic modelling of relevant watercourses and conceptual site modelling at the Goonyella Complex to address the above points.

1.2 Site Details

The Goonyella Complex is located in Central Queensland, approximately 170 kilometres west of Rockhampton and 20 kilometres north of Moranbah. **Figure 1-1** illustrates the location of Goonyella Complex and key surrounding features including the Isaac River which drains through the Mine. The Goonyella Complex includes the Mining Leases shown in **Table 1-1**.

Table 1-1 Goonyella Complex Mining Leases

Goonyella Mine Complex Mining Leases	
• ML1763 – Goonyella • ML1764 – Riverside • MLML1802 – Riverside Extended • ML1900 – Riverside West • ML700003 – Mabbin • ML70121 – Riverside Tailings Extension • ML70193 – Riverside West Extension North • ML70194 – Riverside West Extension South • ML70287 – Goonyella Tailings	• ML70288 – Goonyella Industrial • ML70289 – West Airstrip Pit • ML70421 – Red Hill • ML70468 – Riverside West Extension 1 • ML70469 – Riverside West Extension 2 • ML70478 – Goonyella West 1 • ML70478 – Goonyella West 2 • ML70493 – Riverside North West • ML70494 – Riverside North

1.3 Relevant Documentation

This assessment was undertaken in accordance with the following guidelines and documentation:

- *Environmental Protection Act 1994*;
- *Environmental Protection Regulation 2019*.
- *'Guideline – Progressive Rehabilitation and Closure Plans'*, Version 3.01, Department of Environment and Science, September 2024 (PRCP Guideline);
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, February 2024 (Voids in Flood Plains Information Sheet);
- *'Australian Rainfall and Runoff: A guide to Flood estimation'*, Geoscience Australia, v4.2 (Ball, et al. 2019); and
- *'Bowen Basin River Diversions – Design and Rehabilitation Criteria'*, Australian Coal Association Research Program, July 2002 (ACARP 2002).

585000 590000 595000 600000 605000 610000 615000 620000

7615000 7610000 7605000 7600000 7595000 7590000 7585000 7580000 7575000 7570000 7565000

Hill Creek
Charlie Creek
Eaglefield Creek
Kennedy Creek
Anna Creek
Eaglefield Creek
Gum Tree Creek
Skull Creek
Isaac River
Teviot Creek
Sandy Creek
Goonyella Creek
Mabbin Creek
Hurricane Gully
Goonyella
Twelve Mile Gully
Bullock Creek
Eureka Creek
Spade Creek
Thiess
Teviot Brook
Broadmeadow
R32 East
Hat Creek
Fisher Creek
Isaac
Sullivan Creek
R32 South
Skeleton Gully
Platypus Creek
Teviot Brook
Bullhole Creek
Isaac River
Ten Mile Creek
Grosvenor Creek
Smoky Creek
Moranbah

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

0 1 2 4 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:150,000 at A3
Project Number:	620.040713
Date:	26-Sep-2024
Drawn by:	TS

LEGEND

- Mining Leases
- Residual Voids
- Rail Network
- Isaac River at Burton Gorge Gauge
- Isaac River at Goonyella Gauge

Watercourses

Stream Order

- 0
- 1
- 2
- 3
- 4
- 5
- 6

Goonyella Complex PRCP Rehabilitation Flood Assessment

Site Location

Figure 1-1

H:\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CAD\GIS\GIS\Arc\Figures\GRM\620040713_Project_Location_Fig1-1_001.mxd

1.4 Assumptions and Limitations

This assessment was undertaken specifically for the purposes for undertaking floodplain modelling of relevant watercourses in accordance with the requirements of the EP Act and EP Regulation. The following assumptions and limitations apply to this assessment.

- The accuracy of the assessment is reliant on the accuracy of the utilised data, as detailed in **Section 3.0**. SLR has assumed all source data to be fit for purpose and sufficiently accurate for the purpose of this assessment. Except where noted, no verification of accuracy of the information has been carried out. In the event that some of the information which was relied upon for this assessment is found to be inaccurate, then some or all of the findings may change.
- Generation of the model landform for the assessment was undertaken in accordance with the PRCP Guidelines. Hydraulic modelling was undertaken only for the post-mining landform conditions.
- Although the analyses undertaken as detailed in this report were done so with the appropriate care and professionalism, this report shall only be used for the purposes intended. The analyses detailed in this report were undertaken solely for the purpose of addressing the requirements for general rehabilitation practices for Goonyella Complex in accordance with the relevant documentation as detailed in **Section 2.0**.
- This report should be read in full, and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of BMA and SLR accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.
- The Flood Risk Profile outlined in this report was undertaken specifically in accordance with the BHP Risk Framework (refer **Appendix A**), and therefore may not be applicable with other risk assessment methodologies.
- The TUFLOW model results for velocity bed shear stress and stream power are calculated using a depth-averaged approach for each model grid cell. Results of the TUFLOW hydraulic model were therefore utilised for general indication (only) of watercourse stability. TUFLOW does not account for geomorphological processes including watercourse re-alignment, therefore the assessment was based on the assumption of static topographic conditions.
- Groundwater levels in the area will have no significant effect on the outcomes of the flood modelling.

1.5 Document Structure

The structure of this report is set out as follows:

- **Section 1** – Introduction;
- **Section 2** - Relevant legislation and guidelines;
- **Section 3** - Data Review and Gap Analysis, including details of the model landform;
- **Section 4** - Hydrologic Modelling;
- **Section 5** - Hydraulic Modelling;
- **Section 6** – Flood Risk profile;

- **Section 7** – Outcomes;
- **Section 8** – Conclusions; and
- **Section 9** – References.

Details of each component of the assessment are provided in the following sections.

2.0 Legislation and Guidelines

2.1 Relevant Legislation and Guidelines

The relevant documentation for this assessment is detailed in **Section 1.3**. Key details in the context of the assessment are provided below.

The Environmental Protection Act 1994 states:

'*In accordance with Section 126D(3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition*.'

The Environmental Protection Regulation 2019 Section 41C(3) also states:

'*The administering authority must treat the land as a flood plain to the extent the results of the flood plain modelling show that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the ARR*'

Further guidance is provided in the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Sections 3.4 and 3.6.1 of the PRCP Guideline both require a floodplain assessment to be carried out. Specifically, Section 3.4 requires a Void in Floodplain assessment for all unapproved Non-Use Management Area (NUMA) voids (i.e. floodplain assessment of the pre-mining landform), whilst Section 3.6.1 requires a post-mining landform assessment irrespective whether a post-mining land use (PMLU) or NUMA is proposed. A Voids in Floodplain assessment was undertaken by SLR as detailed in 'Goonyella Riverside Mine - Progressive Rehabilitation and Closure Plan – Voids in Floodplain Report' (ref 620.31051.00000-R03-v2.0). This current assessment was undertaken only to address the requirements of Section 3.6.1.

The hydrologic and hydraulic analyses were undertaken in accordance with ARR.

2.2 Applicability to the Project

Based on the review of the EP Act, EP Regulation, PRCP Guideline and the Voids in Floodplains information sheets, it is considered that the legislative requirements set out in **Table 2-1** are applicable to the project.

Table 2-1 Applicable Legislative Requirements

Requirement	Application to the Project	Source
For transitional sites, a floodplain assessment is required where: • A void has been identified as a NUMA in a land outcome document, but the location has not been specified; or • Where there are no land outcomes in the land outcome document.	The PRCP for Goonyella Complex includes six final voids which are proposed to be developed as NUMAs. Therefore, floodplain assessment is required. A Voids in Floodplain assessment was undertaken by SLR as detailed in 'Goonyella Riverside Mine - Progressive Rehabilitation and Closure Plan – Voids in Floodplain Report' (ref 620.31051.00000-R03-v2.0).	PRCP Guideline Section 3.4

Requirement	Application to the Project	Source
The requirement for a flood assessment under section 3.6.1 of the Guideline applies to the post mining landform across the whole site irrespective of whether a PMLU or a NUMA are proposed. Furthermore, section 3.6.1 is not only required to indicate flood risk but also to demonstrate the final landform (including waste rock dumps and diversions) will remain in a stable condition in a range of flood flow conditions.	The PRCP for Goonyella Complex includes six final voids which are considered to be pre-approved NUMAs and therefore will be retained in the post-mining landform where it can be shown the voids are in a stable condition. Therefore, a flood assessment is required to show that the proposed voids will remain in a stable condition following the closure of Goonyella Complex. The voids are: • R32 East • Broadmeadow • Goonyella • Isaac • R32 South • Thiess The void locations are shown in **Figure 1-1**.	PRCP Guideline Section 3.6.1.
Section 3.6.4 Underground Mining	The PRCP for Goonyella Complex includes rehabilitation of underground mining domains including subsidence. Therefore assessment of the relevant flooding aspects in relation to the planned subsidence is required.	PRCP Guideline Section 3.6.4.

2.3 Definitions and Terminology

Table 2-2 provides the definitions and terminology that are utilised in this assessment, in accordance with the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Table 2-2 Definitions and Terminology

Term	Definition	Source
Voids	An area of land to be excavated in carrying out a mining activity. Therefore, all voids (PMLU or NUMA) are subject to the requirements of the EP Act.	Section 126D of the EP Act.
Flood plain	A void is considered to be located in a flood plain if the flood plain modelling shows that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level in a 0.1% AEP for a relevant watercourse under the guideline Australian Rainfall and Runoff (2019) (ARR).	Section 41C of the EP Regulation; and PRCP Guideline Section 3.4.
Stable condition	• The land is safe and structurally stable; • There is no environmental harm being caused by anything on or in the land; and • The land can sustain a PMLU.	Section 126D(3) of the EP Act; and PRCP Guideline Section 3.6.3.

Term	Definition	Source
Relevant watercourse	• A watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or • If a watercourse mentioned in paragraph (a) is permanently diverted under – ○ A condition, or proposed condition, of an environmental authority mentioned in the Water Act 2000, section 98; or ○ A water license or proposed water license under the Water Act 2000; • the watercourse as permanently diverted.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 5.
Flood plain modelling	For land the subject of a PRCP schedule, means modelling of the landform of the land – a) Carried out under the ARR; (and) b) Excluding any artificial features for the land	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 4.
Artificial feature	For land the subject of a PRCP schedule, means – a) A structure or feature that is temporary and, under the PRCP schedule or otherwise, is to be removed from the land; or b) A structure or feature that, under the PRCP schedule, will require a level of maintenance after the land is surrendered that is greater than the level of maintenance that would be required for the land if the relevant activities the subject of the PRCP schedule had not been carried out; or c) A feature forming part of the landform of the land, other than the natural landform, if the feature interferes with or affects – • A relevant watercourse; or • The natural flow of water on the land.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 6.

3.0 Data Review and Gap Analysis

3.1 Available Data

The following data was provided to SLR by BMA for use in the assessment:

- Goonyella Riverside Mine Complex – Characterisation Study (Landloch 2024);
- PRCP Final Landform DEM;
- Additional LiDAR topographic data (dated 2024) within Goonyella Mine extents as a DEM with 1m grid cell spacing;
- Aerial imagery dated 2024;
- Goonyella and Broadmeadow Hydraulic Assessment (WRM 2019); and
- GRM Operational TUFLOW hydraulic model.

Additional data was obtained from publicly available sources including:

- Watercourse Lines – Queensland GIS dataset (Department of Resources, 2023);
- 1 second SRTM 30 metre DEM terrain data (Geoscience Australia);
- Rainfall intensity-frequency-duration (IFD) data for the area (Bureau of Meteorology (BoM));
- Catchment specific hydrologic data (ARR Data Hub);
- Historic gauged stream flow data for the Isaac River at Goonyella (130414A) and Isaac River at Burton Gorge (130402A) Stream Gauges (DNRM); and
- Burton Gorge Dam Emergency Action Plan (Peabody 2023).

The provided data was analysed for suitability for the purposes of this assessment. The outcomes of the review are detailed below.

3.2 Watercourses

A review of the existing watercourses in the vicinity of Goonyella Complex was undertaken using hydrologic streamline data sourced from Department of Resources. The following watercourses were included in the assessment:

- Isaac River: Isaac River runs north to south with a span of over 450 km and along the eastern side of Goonyella Mine, which is located in the upper part of the river. Much of the river is permanently diverted to the eastern side of the voids. It has a catchment area of approximately 1100km^2.
- 12 Mile Gully: 12 Mile Gully spans east to west for over 15 km. It is located east of Goonyella Mine, where it drains into the Isaac River at the southern end of Goonyella Void. It has a catchment area of approximately 67km^2.
- Goonyella Creek: Goonyella Creek spans approximately 20 km from north of Goonyella Mine and along the eastern side of Goonyella Void. It flows south before draining into the Isaac River. It has a catchment area of approximately 87km^2.
- Eureka Creek: Located within Riverside Mine, Eureka Creek runs for 10 km west to southeast and becomes a permanent diversion channel which then joins the Isaac River permanent diversion. It has a catchment area of approximately 118km^2.

- Fisher Creek: Fisher creek runs 11.5 km west to east along the south west of the Goonyella Complex and drains into the Isaac River. It has a catchment area of approximately 39km^2.
- Platypus Creek: Platypus Creek runs south of Fisher Creek for 10 km west to east before draining into the Isaac River. It has a catchment area of approximately 35km^2.

3.3 Landform

3.3.1 Landform Data

For the purposes of the hydrologic modelling, a landform DEM was developed which utilised the following topographic datasets, layered in order from bottom to top:

- SRTM DEM (outside Goonyella Complex extents only);
- Existing topography (1m resolution) for Goonyella Complex (2024); and
- Goonyella Complex PRCP Landform DEM (1m resolution).

The landform DEM is illustrated in **Figure 3-1**.

3.3.2 Conceptual Site Model

As part of this assessment, a Conceptual Site Model (CSM) was developed for the extent of the landform that included subsidence. Preliminary results of the pluvial hydraulic modelling (refer **Section 5.4**) were utilised to inform the development of the CSM. Where significant subsidence ponding was identified, conceptual modifications to the landform were incorporated to limit the depth of ponding to less than 1m depth in the 2% AEP event, and provide free drainage to the Isaac River, including:

- Backfilling within subsidence depressions; and
- Drainage paths (generally 10m-30m width) between subsidence depressions.

The depth of ponding limit was chosen by the teams managing the rehabilitation and ecosystems on site, based on the proposed vegetation.

Mapped threatened ecological communities (TECs) were obtained from BMA, and these areas were avoided where possible. There are some locations where drains were proposed where there were already existing flow paths. It is likely that the existing drains have not been well captured in the LiDAR in these locations, so disruption to the TECs may be minimal in these drains.

The CSM is illustrated in **Figure 3-1.**

595000 596000 597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000

7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

0 0.4 0.8 1.6 km

LEGEND

- Mining Leases
- Proposed Backfill Areas
- TECs
- Proposed Drains

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:50,000 at A3
Project Number:	620.040713
Date:	27-Sep-2024
Drawn by:	GN

Goonyella Complex PRCP Rehabilitation Flood Assessment

Final Landform and CSM

SLR

Figure 3-1

H:\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\Figures\GRM\620040713_Final_landform_Fig3-1_001.mxd

4.0 Hydrologic Modelling

4.1 Software

A hydrologic model was developed for the Goonyella Complex catchments using Watershed Bounded Network Model (WBNM) Version 2017. The WBNM software is an industry standard rainfall-runoff routing program. Storm Injector Version 1.3.9.0 was utilised to assist in setup and analysis of ARR design storm ensembles and to review model results.

4.2 Model Setup

4.2.1 Catchment

The hydrologic model covers a total area of 1,240 km^2. Sub-catchments for the WBNM model were delineated based on the landform DEM detailed in **Section 3.3**. The WBNM model layout is illustrated in **Figure 4-1**.

The total catchment for each watercourse is detailed in **Table 4-1**.

Table 4-1 Catchment areas

Catchment	Total Area (km^2)
Isaac River	1,096
Eureka Creek	118
Platypus Creek	35
Fisher Creek	39

Catchment land use was adopted based on the final landform and aerial imagery. The predominant land use within the catchment is rural. Therefore, the majority of the catchment was modelled as fully pervious, with areas of imperviousness incorporated where appropriate, including water surfaces. The fraction impervious (Fi) values adopted for the various land use categories are shown in **Table 4-2**.

Table 4-2 Land Use Fraction Pervious

Category	Fraction Impervious
Water Bodies	1
Natural / Undisturbed	0
Rehabilitated	0

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000

IR02
IR03
IR01
IR08c
IR04
IR08b
IR08d
IR04
IR09b
IR08e
IR08f
IR07
IR08a
IR05
IR09c
IR09a
IR08h
IR09d
IR08g
IR10d
IR06
IR09e
IR10b
IR09g
IR10e
IR09f
IR10a
IR10c
IR11b
IR12a1
IR10f
IR11a
IR12a2
IR15a
IR12b1
IR12a3
IR12b2
IR13
IR12c
IR15b

0 1.25 2.5 5 km

LEGEND

Mining Leases

WBNM Catchment Boundaries

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:180,000 at A3
Project Number:	620.040713
Date:	27-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

WBNM Layout

Figure 4-1

H:\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\Arc\Figures\GRM\620040713_WBNMSetup_Fig4-1_002.mxd

4.3 Design Storm Analysis

4.3.1 Design Storm Events

The WBNM model was simulated for the 39%, 2%, 1%, 0.1% AEP and PMP events with a range of storm durations between 1 hour to 48 hours and ten temporal patterns for each duration accordance with ARR.

For each AEP-duration combination, the design storm temporal pattern which produced a peak flow nearest to the mean peak flow of the suite of 10 temporal patterns was adopted as the design storm. Preference was given to flows greater than the mean, with a bias factor of 2 applied. The adopted temporal pattern event for each creek was selected based on the focal point in the creek as given in **Table 4-3**.

Table 4-3 WBNM model adopted focal points for temporal pattern selection

River / Creek	Sub-catchment
Isaac River	IR15a
Eureka Creek	IR10f
Platypus Creek and Fisher Creek	IR12b2

For the 0.1% AEP event, in accordance with the procedures outlined in ARR, the Generalised Short Duration Method (GSDM) temporal pattern was applied. The GSDM temporal pattern, which is applicable for short durations (up to and including 6 hours only), was extended to the 12 hour event with time steps adjusted accordingly. This approach ensures that the critical duration was accurately captured. For storms from 12 hours to 48 hours, the GTSMR temporal pattern was applied. For the 0.1% AEP event, the model was simulated for durations ranging from 60 minutes to 48 hours.

For the PMP event, the GSDM temporal pattern was applied for events between 60 minutes and 6 hours, and the Revised Generalised Tropical Storm Method (GTSMR) 1000km^2 temporal pattern was applied for events between 24 hours and 48 hours.

A critical duration assessment was undertaken using the hydraulic model. The results of the assessment are provided in **Section 5.3**.

4.3.2 Intensity-Frequency-Duration Data

Rainfall Intensity-Frequency-Duration (IFD) data for the catchment was sourced from the Bureau of Meteorology (BoM) online IFD data portal. The IFD data adopted in the model is provided in **Table 4-4**.

Table 4-4 Rainfall Intensity-Frequency Duration Data

Storm Duration (min)	Design AEP Event Rainfall Intensity (mm/h)			
	39%	2%	1%	0.1%
60	41.8	75.5	82.2	132
90	46.8	86.3	94.1	151
120	50.2	94.2	103	165

Storm Duration (min)	Design AEP Event Rainfall Intensity (mm/h)			
	39%	2%	1%	0.1%
180	54.9	106	117	188
270	59.9	120	134	216
360	63.8	132	148	239
540	70.2	151	171	277
720	75.7	167	191	309
1080	85.2	195	224	362
1440	93.2	217	251	404
1800	100	237	275	438
2160	107	253	295	466
2880	117	281	328	512

4.3.3 Losses

Rainfall initial and continuing losses for the catchment were sourced from the ARR Online DataHub. The initial loss for each design storm event was calculated by subtracting the median pre-burst rainfall depth from the global catchment initial loss, in accordance with the methodology outlined in ARR. The adopted global loss values are shown in **Table 4-5**.

Table 4-5 Design Rainfall Losses – ARR Data Hub

Global Storm Loss	Loss Value
Initial Loss	36 mm
Continuing loss	2.7mm/h

For the 0.1% AEP and PMP events, an initial loss of 0 mm was adopted, given an event of such magnitude would typically occur following a period of significant antecedent rainfall.

4.3.4 Lag Parameter

A catchment lag parameter of 1.6 was applied for the design storm events, which is within the range recommended in the WBNM documentation (typically 1.3 to 1.8).

4.3.5 Areal Reduction Factor

Areal reduction factors (ARFs) are required under ARR, as design rainfall IFDs are based on specific points in a catchment rather than the whole catchment, and these point rainfall intensities are not representative of the areal average rainfall intensity across the catchment. The ARFs represent the ratio between the areal average rainfall and point rainfall for the same AEP and storm duration. ARFs are calculated based on the catchment area, AEP, and storm duration.

For the Isaac River catchment, the Areal Reduction Factor (ARF) was based on the catchment area of 1,100km^2.

For Fisher and Platypus creeks, ARFs were based on an area of 35km^2 and for Eureka Creek, ARFs were based on an area of 118km^2.

An ARF of 1.0 was used for the PMP event.

4.3.6 Probable Maximum Precipitation Event

A Probable Maximum Precipitation (PMP) analysis was undertaken in accordance with ARR. PMP rainfall depths were calculated using the Generalised Tropical Storm Method Revised (GTSMR) for the Isaac River catchment for durations between 24 and 120 hours. Generalised Short Duration Method (GSDM) was used for durations between 15 minutes and 6 hours.

PMP rainfall depths were calculated using GSDM for Eureka Creek, Fisher Creek and Platypus Creek for durations ranging from 15 minutes to 6 hours. These catchments were limited to GSDM due to their catchment size being less than 1000km^2, as per the GSTMR guidebook (Bureau of Meteorology 2005).

4.4 Validation

4.4.1 Stream Gauge

Flood frequency analysis was undertaken for Isaac River. Stream gauge data upstream of the site was obtained from the Qld Government Water Monitoring Information Portal.

There are two stream gauges upstream of the site; Isaac River at Goonyella (13414A) and Isaac River at Burton Gorge (130402A). Although there is 38 years (1983-2021) of data available, due to the construction of the Burton Gorge Dam, the Isaac River at Goonyella gauge is considered to be lacking in homogeneity, and hence it is not suitable for flood frequency analysis.

Flood frequency analysis was therefore undertaken for the gauge at Isaac River at Burton Gorge (130402A). Data for this gauge is available between 1964 and 1988 (24 years). Burton Gorge Dam was constructed in 1992, so the dataset is not influenced by the dam.

4.4.2 Flood Frequency Analysis

RMC-BestFit v1.0, a Bayesian estimation and fitting software developed by the US Army Corps of Engineers (USACE) Risk Management Center (RMC), was used for flood frequency analysis.

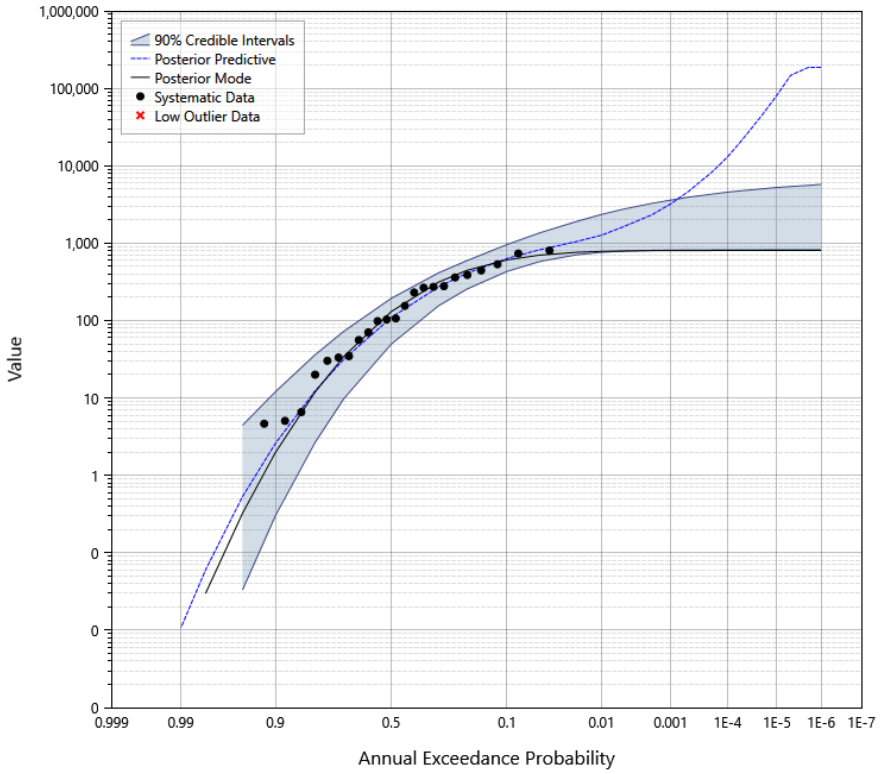
A Log-Pearson Type III distribution was fitted to the data. The peak flow prediction beyond 1% AEP goes outside the 90% credible intervals, and therefore should not be used for comparison with hydrological model results. Note that the peak flow of 0m^3/s from 1969 was treated as low outlier data and not included in the analysis.

The results of the FFA are shown in **Table 4-6** and **Figure 4-2** below.

Table 4-6 FFA Results for Issac River at Burton Gorge gauge

AEP	Peak Flow (m^3/s)	Lower 90% confidence limit (m^3/s)	Upper 90% confidence limit (m^3/s)
39%	165	83	273
20%	412	257	597
10%	635	433	961
5%	824	581	1,362
2%	1,052	710	1,914
1%	1,269	763	2,354

Figure 4-2 FFA Results for Issac River at Burton Gorge gauge



4.4.3 Comparison to 2019 FFA

A flood frequency analysis was undertaken for the Goonyella and Broadmeadow mines in the Goonyella and Broadmeadow Hydraulic Assessment (WRM 2019).

Analysis was undertaken for the Isaac River at Goonyella gauge. An “all-data” scenario using all 35 years of data and a “post-dam” scenario which uses only the data after Burton Gorge Dam construction (27 years) were undertaken. Although the Isaac River at Goonyella gauge was deemed not suitable for an FFA (refer to **Section 4.4.1**), the peak flows from the WRM FFA using the “post-dam” scenario and subsequent XP-RAFTS model results are of

similar magnitude to the WBNM model output. Comparison to these results are shown in **Table 4-8**.

4.5 Results

4.5.1 Isaac River

The peak flows from the WBNM model at Burton Gorge gauge were compared to the peak flow from the FFA in **Table 4-7**.

The WBNM peak flows were generally consistent with the 2% and 1% AEP FFA results. The WBNM model peak flow was lower than the FFA results in the 39% AEP. However, the 39% AEP results were utilised to assess the peak flood bed shear stress, stream power and velocity and subsequently the associated scour and erosion risk, and these parameters are not significantly affected by relatively small changes in peak flow.

Table 4-7 Peak flow at Burton Gorge gauge

AEP (%)	WBNM Peak Flow (m^3/s)	FFA Peak Flow (m^3/s)	% difference from FFA	RFFE Discharge (m^3/s)	RFFE Lower confidence Limit 5% (m^3/s)	RFFE Upper confidence Limit 95% (m^3/s)
39	112	165.6	-32%	-	-	-
10	463	635	-27%	707	334	1,560
5	682	825	-17%	874	397	2,010
2	1,025	1,052	-2%	1,110	476	2,700
1	1,307	1,270	3%	1,300	532	3,310
0.1	2,502	-	-	-	-	-

The peak flows from the WBNM model at Isaac River at Goonyella gauge were compared to the peak flow from the XP-RAFTS model results from WRM as shown in **Table 4-8**.

Table 4-8 Peak flow at Isaac River at Goonyella

AEP (%)	WBNM Peak Flow (m^3/s)	WRM (2019) "Post-Dam" FFA Peak Flow (m^3/s)	WRM (2019) XP-RAFTS Peak Flow (m^3/s)	% difference from WRM XP-RAFTS Peak Flow
10	718	896	830	-13%
5	1,080	1,308	1,167	-7%
2	1,689	1,786	1,707	-1%
1	2,187	2,078	2,079	5%
0.1	4,365	-	3,808	15%

The flows produced by the WBNM model are comparable to the peak flows from the FFA and the RFFE at Burton Gorge. The results are also comparable to the flows from the WRM (2019) FFA at Goonyella. Although the outcome suggests that the 0.1% AEP results may be conservative on the high side, there is insufficient gauge information to confirm this.

Therefore the WBNM model was deemed suitable for use for this assessment.

4.6 Climate Change Assessment

The effects of climate change were considered as part of the hydrologic analysis. Sensitivity analyses were carried out with respect to the modelled design rainfall Intensity-Frequency-Duration data. The three scenarios were modelled in accordance with the *CTD-WTR-GLD-001_Guideline for Climate Change Adaptation in Mine Water Planning and Hydrologic Assessments*:

- 6% increase in rainfall intensity;
- 11% increase in rainfall intensity; and
- 20% increase in rainfall intensity.

Hydrographs for each scenario for the 0.1% AEP events were extracted and utilised as inflows in the hydraulic model.

4.7 Consideration of Alteration of Flows

In accordance with Section 3.6.1 of the PRCP Guidelines, alteration of flows upstream and downstream should be considered. Catchment areas were compared between pre-mining and post-mining scenarios. The pre-mining scenario incorporated the pit areas excluded in the PRCP model landform scenario.

The catchment areas of the pre-mining scenario were compared to those of the PRCP model landform scenario to quantify potential alteration of flows downstream of the site. The results are summarised in **Table 4-9**. The WBNM model peak flows of the pre-mining scenario were compared to the results of the PRCP model landform scenario in **Table 4-10**.

Upstream of the site, the pre-mining scenario and rehabilitation scenario are identical. Hence there will be no alteration to upstream flows.

Table 4-9 Catchment area comparison – Pre-mining scenario vs PRCP model landform scenario

Location	Rehabilitation Scenario Area (km^2)	Pre-mining Scenario Area (km^2)	Change (km^2) Rehab – Pre-mining	Change in catchment area (%)
Isaac River	1,096	1,161	-65	-6.0

Table 4-10 WBNM Model Results – Pre-mining scenario vs PRCP model landform scenario

AEP	Rehabilitation Scenario Flow (m^3/s)	Pre-mining Scenario Flow (m^3/s)	Change (m^3/s) Rehab – Pre-mining	Change in Peak Flow (%)
1%	2187.2	2353.6	-166.5	-7%
2%	1688.8	1825.0	-136.2	-7%
5%	1080.2	1169.7	-89.5	-8%
10%	718.39	783.59	-65.2	-8%
20%	429.69	469.67	-40.0	-9%
39%	198.2	213.3	-15.1	-7%

The comparison of catchment areas show that there is an approximately 6% decrease in catchment area in the rehabilitation scenario. The difference can be attributed to the reduction in catchment area due to the pit final voids. The change in peak flows correlate with the change in catchment area and show a reduction in peak flow of approximately 7% to 9% for downstream flows.

5.0 Hydraulic Modelling

5.1 Modelling Approach

2-dimensional hydraulic modelling was undertaken as part of the assessment. The following modelling approaches and the respective purposes were applied:

- The **Fluvial Model** was developed to quantify flooding conditions within the Isaac River, Eureka Creek, Platypus Creek and Fisher Creek for a range of design storm events. A traditional source inflow approach was applied for the model whereby discharge hydrographs generated by the WBNM model were applied as inflow conditions at appropriate discrete locations. The results of the model were utilised to assess the risk of inundation of the residual voids and stability of the final landform.
- The **Pluvial Model** was developed to simulate local catchment rainfall runoff behaviour over the areas of the final landform where subsidence will occur. A direct rainfall (Rain-on-Grid) approach was applied. The model results were utilised to investigate potential ponding in subsidence areas.

5.2 Software

The hydrodynamic modelling software TUFLOW (Build 2023-03-AE) was used for the hydraulic modelling. The sub-grid sampling (SGS) feature of TUFLOW provides increased definition of model terrain, which improves estimate of flow conveyance. This enables model resolution to be improved without significant increases in model run times.

5.3 Fluvial Model Setup

5.3.1 Topography

The final landform DEM received from BMA was adopted as the topography for the model. A model grid cell size of 10m was adopted.

A sub-grid sampling distance of 1m was applied, which was considered to provide adequate model resolution for the purposes of this assessment, which has creeks with channel widths of approximately 8 to 10m. The model DEM is shown in **Figure 5-1**.

Break lines were used to represent key discrete topographic features including creek beds and bunds around pits in order to capture the low and high points of the terrain in the model topography. The topography was increased by approximately 500mm at the northern side of R32 South Void to prevent pit ingress.

5.3.2 Hydraulic Roughness

The hydraulic roughness for the model was determined based on aerial imagery and the model landform. The model hydraulic roughness is shown in **Figure 5-2**. The Manning's n values adopted in the model are listed in **Table 5-1**.

Table 5-1 TUFLOW Model Manning's n Values

Land use	Manning's n
Sparse Trees	0.06
Dense Trees	0.08
Water Surfaces	0.02

5.3.3 Inflows

Flow hydrographs for the TUFLOW model were extracted from the WBNM model. The hydrographs were applied as inflow boundaries via source area polygons or polylines as total or local inflows at appropriate locations, as shown in **Figure 5-1**.

5.3.4 Downstream boundaries

Downstream model boundaries were applied as stage-discharge relationships based on the water surface gradient in the vicinity of the boundaries. The stage-discharge relationships are automatically calculated using the TUFLOW in-built functionality. The downstream boundaries are shown in **Figure 5-1**.

5.3.5 Hydraulic structures

Existing culverts were included in the model at two crossings. The structural data adopted for the modelled culverts was extracted from the hydraulic model used in the GRM operations model, received from BMA. There are two culverts in the model crossing Goonyella Road and the Coppabella to North Goonyella section of the Goonyella System, which are shown in **Figure 5-1**.

5.3.6 Critical Duration Assessment

A range of design storm events was simulated in the fluvial models for a range of AEPs which include 39%, 2%, 1%, 0.1% AEP and PMF (Probable Maximum Flood). Three climate change events were run for the 0.1% AEP. As there are multiple areas of interest, a range of durations were used to create a maximum grid for each AEP.

Critical durations are listed in **Table 5-2**.

Table 5-2 Critical Durations for Fluvial Model

AEP / Location	Isaac River	Eureka Creek	Fisher Creek / Platypus Creek
39%	720, 1080, 1440 min	1080 min	1440 min
2%	720, 1080 min	1440 min	360, 720 min
1%	1080, 1440 min	1440 min	360, 720 min
0.1%	720, 1440 min	540 min	270, 360 min

AEP / Location	Isaac River	Eureka Creek	Fisher Creek / Platypus Creek
0.1% + 6% rainfall intensity CC	720, 1440 min	540 min	270, 360 min
0.1% + 11% rainfall intensity CC	720, 1440 min	540 min	270, 360 min
0.1% + 20% rainfall intensity CC	720, 1440 min	540 min	270, 360 min
PMF	1440 min	360 min	180, 240, 300 min

5.4 Pluvial Model Setup

5.4.1 Topography

The final landform DEM received from BMA was adopted as the topography for the model. A model grid of 10m was adopted. A sub-grid sampling distance of 1m was applied.

The model DEM is shown in **Figure 5-3**.

5.4.2 Evaporation

Evaporation data was obtained from the SILO database on the state government Long Paddock website. The closest point (Latitude -21.8, Longitude 148) was chosen for evaporation data. The average evaporation rate applied in the model was 5.52 mm/day, or 0.23 mm/h.

5.4.3 Soil Type

The soil type within the pluvial model area was determined from the Australian Soil Classification (ASC) map from the *Goonyella Riverside Mine Complex- Material Characterisation Study* (Landloch 2024). The Australian soil types were matched to corresponding USDA soil types, which is used in the TUFLOW soils file to calculate infiltration rates. The choice of USDA soil types were confirmed with BMA's soils specialist on site. The ASC map as well as the USDA types corresponding to the ASC types are included in **Figure 5-4** and **Table 5-3** respectively.

Table 5-3 ASC Soil Types and corresponding USDA soil types

ASC Soil Type	USDA Soil Type
Anthroposol	Sandy Clay Loam*
Chromosol	Sandy Loam
Dermosol	Clay loam
Kandosol	Loam
Kurosol	Loam
Rudosol	Clay Loam

ASC Soil Type	USDA Soil Type
Sodosol	Loam
Vertosol	Clay
Rudosol-Tenosol	Sandy Clay Loam
Tenosol	Sand

* Note that Anthroposol does not have a corresponding USDA soil type but was nominally assumed to be sandy clay loam. There are no subsidence areas within the anthroposol classed areas.

5.4.4 Hydraulic Roughness

The hydraulic roughness for the fluvial model was also used in the pluvial model, shown in **Figure 5-2**.

5.4.5 Inflows

Inflows were applied using the direct rainfall method in TUFLOW, where rainfall is directly applied to 2D cells over the entire model area, as shown in **Figure 5-3**.

All ten temporal patterns were simulated for each design storm duration, and the median temporal pattern based on peak flood levels was adopted for each duration across the model domain using the TUFLOW post-processing utility. A maximum grid for all the envelope of durations for each AEP was then calculated.

Rainfall depths were determined using the ARR to TUFLOW tool for the 2% AEP Event. ARF was applied to all events. Initial loss and continuing loss were not applied for the pluvial model as infiltration was accounted for in the TUFLOW soils file.

5.4.6 Downstream boundaries

Downstream model boundaries were applied as stage-discharge relationships based on the water surface gradient in the vicinity of the boundaries. The stage-discharge relationships are automatically calculated using the TUFLOW in-built functionality. The downstream boundaries are shown in **Figure 5-3**.

5.4.7 Pond Backfill and Drainage Channels

The components of the CSM as described in **Section 3.3.2** were incorporated into the model terrain using the z-shape functionality within TUFLOW.

5.4.8 Critical Duration Assessment

A range of durations were simulated in the pluvial hydraulic model for the 2% AEP for all temporal patterns from the 45 min to the 1440 min storm event. The 2% AEP event was run to determine the worst ponding possible out of all the events specified in the proposal. More frequent events will result in lower ponding depths.

The median temporal pattern was chosen for each duration and a maximum of these grids was analysed to determine the critical durations. The median temporal pattern was chosen to have a representative temporal pattern for each storm duration, as per ARR. The critical durations for the pluvial model are listed in **Table 5-4**. Note that the 1440min is only critical for one pond, which is being maintained as a pond (refer to **Section 5.5.3** for further discussion).

Table 5-4 Pluvial model critical durations for 2% AEP event

Duration	Temporal Pattern
90min	TP09
120min	TP05
360min	TP09
540min	TP10
1440min	TP01

593000 594000 595000 596000 597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000 609000 610000 611000 612000 613000

7605000 7604000 7603000 7602000 7601000 7600000 7599000 7598000 7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000 7580000 7579000

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

0 0.5 1 2 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:75,000 at A3
Project Number:	620.040713
Date:	23-Sep-2024
Drawn by:	GN

LEGEND

- Mining Leases
- TUFLOW Model Extent
- SA Inflows
- Downstream Boundary
- Upstream Inflow
- Gully Breaklines
- Culverts

Topography (mAHD)

High : 400

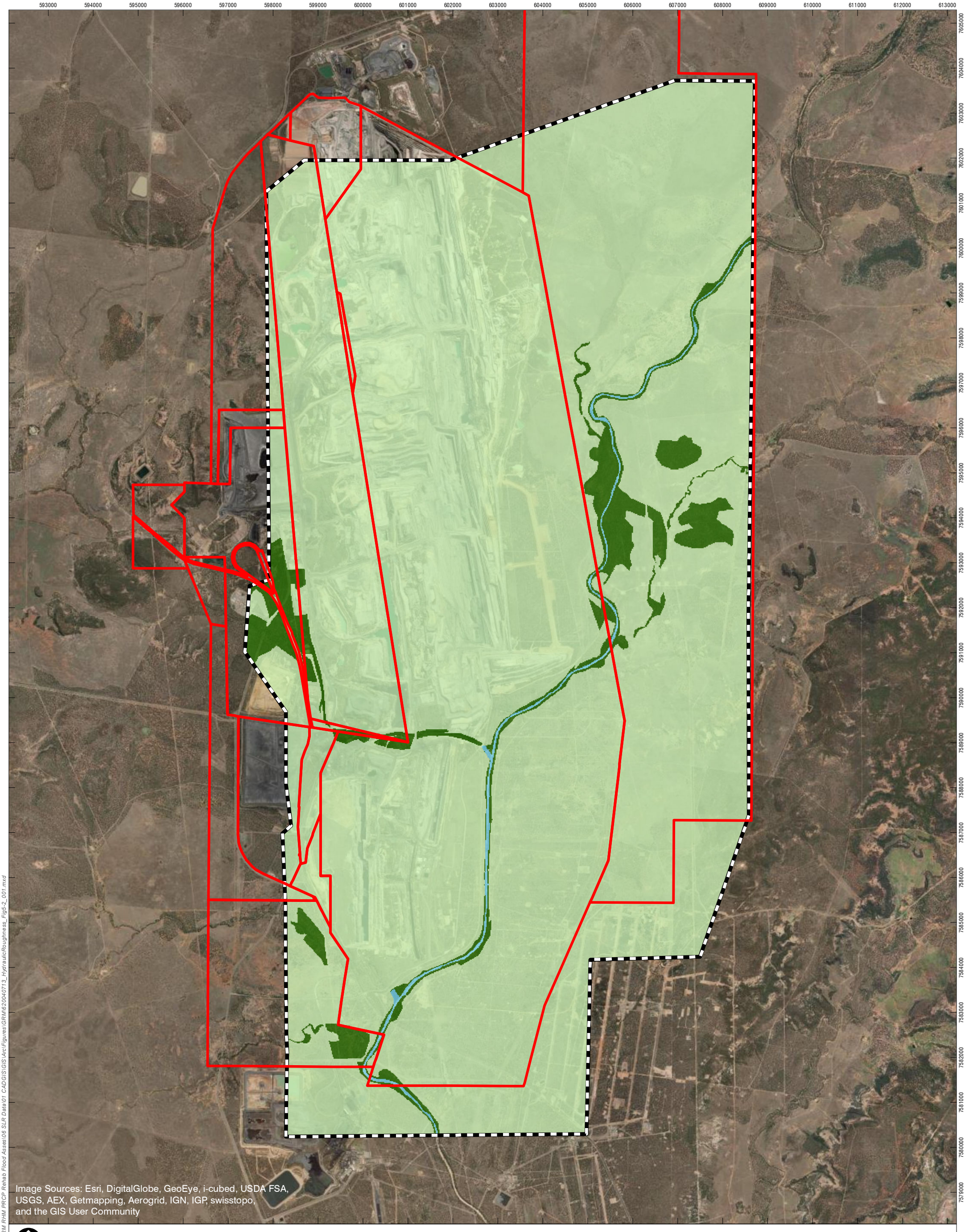
Low : -70

Goonyella Complex PRCP Rehabilitation Flood Assessment

TUFLOW Fluvial Model Layout

Figure 5-1

H:\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\Figures\GRM\620040713_Fluvial_TUFLOW_Layout_Fig5-1_001.mxd



H:\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\Arc\Figures\GRM\620040713_HydraulicRoughness_Fig5-2_001.mxd

0 0.5 1 2 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:75,000 at A3
Project Number:	620.040713
Date:	23-Sep-2024
Drawn by:	GN

LEGEND

- Mining Leases
- TUFLOW Model Extent

Manning's n Value

- 0.06
- 0.08
- 0.02

Goonyella Complex PRCP
Rehabilitation Flood Assessment

TUFLOW Model Hydraulic Roughness

Figure 5-2

599000 600000 601000 602000 603000 604000 605000 606000

7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

0 0.225 0.45 0.9 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:30,000 at A3
Project Number:	620.040713
Date:	20-Sep-2024
Drawn by:	GN

LEGEND

- Mining Leases
- TUFLOW Model Extent
- Proposed Backfill Areas
- Downstream Boundary
- Proposed Drains

Topography (mAHD)

High : 340.803

Low : 227.034

Goonyella Complex PRCP Rehabilitation Flood Assessment

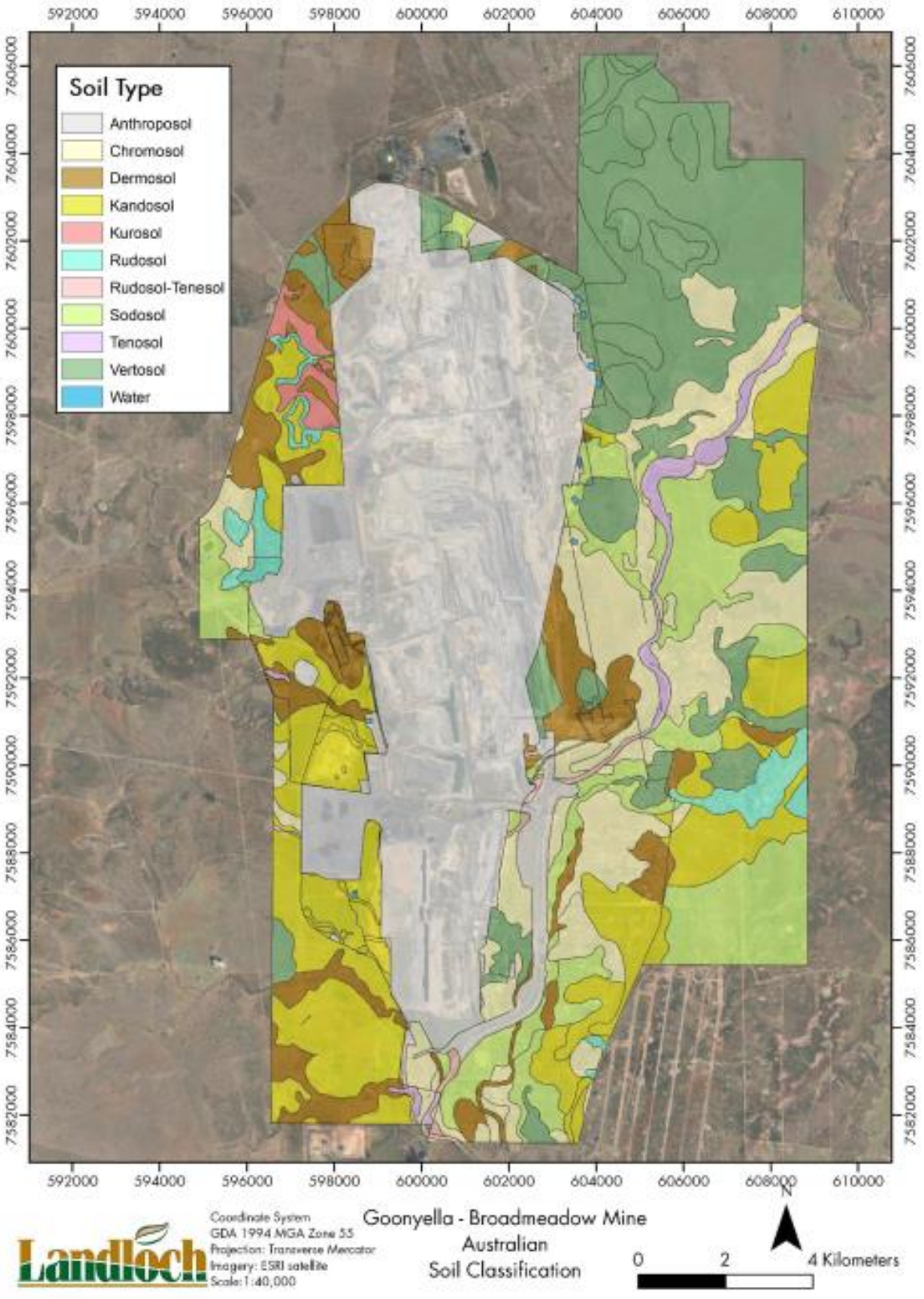
TUFLOW Pluvial Model Layout

SLR

Figure 5-3

H:\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\Arc\Figures\GRM\620040713_Pluvial_TUFLOW_Layout_Fig5-3_001.mxd

Figure 5-4 Goonyella – Broadmeadow Mine Australian Soil Classification (Landloch 2024)



5.5 Results

5.5.1 Flood Ingress to Voids

The TUFLOW model results (refer **Figure 5-5**) show that all final voids are free from inundation from Isaac River, Eureka Creek, Platypus Creek and Fisher Creek in all modelled events up to and including the 0.1% AEP climate change event with 20% increase in rainfall intensity.

The results show that Goonyella Void and Isaac Void are subject to inundation from Isaac River in the PMF event, as shown in **Figure 5-6**.

Thiess Void is subject to inundation from Eureka Creek and Broadmeadow Void is subject to inundation from Eureka Creek and Isaac River in the PMF event (refer to **Appendix B2-1-4**).

R32 South residual void is subject to inundation from the R32/Airstrip tailing storage facility rehabilitated surface to the north and Isaac River from the south in the PMF event (refer to **Appendix B3-1-4**).

5.5.2 Scour and Erosion Potential

Table 1 from DNRM's '*Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000*' (State of Queensland 2019) provides indicative parameter thresholds for scour potential vegetated diversions in the Bowen Basin from ACARP. The criteria (refer to **Table 5-5**) is directed towards diversion design, which is not the purpose of this assessment. However it also provides general indication of scour and erosion potential in all waterways in the Bowen Basin and was therefore utilised in the analysis of the hydraulic model results.

Table 5-5 DNRM Design Criteria for Vegetated Bowen Basin Diversions

Scenario	Parameter	ACARP Criteria
39% AEP event	Stream Power (W/m^2)	<60
	Velocity (m/s)	<1.5
	Shear Stress (N/m^2)	<40
2% AEP event	Stream Power (W/m^2)	<150
	Velocity (m/s)	<2.5
	Shear Stress (N/m^2)	<80*

*Table 1 of the DNRM Guideline contains a known error for the 2% AEP Shear Stress value, which is listed as 50 N/m^2, but should be 80 N/m^2 in accordance with the ACARP documentation from which it is derived.

Depth-averaged bed shear stress, stream power and velocities were extracted from the fluvial model results for the 2% and 39% AEP events. It is noted that the model results for velocity, bed shear stress and stream power are calculated using a depth-averaged approach and were therefore used as indicative information only and likely provide a conservative estimate of erosion / scour potential.

The model results for the 39% AEP event showed that there are localised areas where the velocity, bed shear stress, and stream power exceeds the ACARP guideline values in Isaac River, Eureka Creek, Fisher Creek and Platypus Creek (refer **Appendices B1-3-1**, **B1-4-1**, **B1-5-1** for Isaac Creek, Appendices **B2-3-1**, **B2-4-1**, **B2-5-1** for Eureka Creek, and

Appendices **B3-3-1**, **B3-4-1**, **B3-5-1** for Fisher and Platypus Creek). Generally, these localised areas are within the waterways and unlikely to destabilise any landforms.

A similar pattern is seen for the 2% AEP event (refer Appendices **B1-3-2**, **B1-4-2**, **B1-5-2** for Isaac River, Appendices **B2-3-2**, **B2-4-2**, **B2-5-2** for Eureka Creek, and Appendices **B3-3-2**, **B3-4-2**, **B3-5-2** for Fisher and Platypus Creek).

Within the Eureka Creek diversion, the model results show the ACARP guideline values are exceeded for extended reaches, including in locations adjacent to landform features including the Thiess void and Goonyella void waste rock dumps and Broadmeadow void (refer to **Figure 5-7**). It is understood that diversion design is being undertaken by others which will include detailed analysis and mitigation of scour in the Eureka Creek diversion.

From the Isaac River results, some areas within the subsidence ponds show high bed shear stress and stream power values exceeding the ACARP guideline values, in addition to high values in the Isaac River. Localised scour in these locations are also unlikely to destabilise any landforms.

Additionally, the values of shear stress, stream power and velocity are consistent with the undisturbed reaches upstream and downstream of the site boundaries. Therefore, the characteristics are reflective of the natural conditions of the waterway and are not a product of the final landform configuration.

5.5.3 Subsidence ponding

Consultation with the Queensland Herbarium and the BMA ecology team was undertaken to determine what would constitute an acceptable ponding in the Broadmeadow final landform. The following was used as a guideline for criteria of acceptable subsidence ponding:

- Maximum 1m depth of ponding (2% AEP event);
- No specific duration of ponding;
- Mitigation approaches to include drains and backfilling of deeper points in the landform;
- For relatively minor ponded areas that would require extensive cutting of drains or off-site work, recommend keeping as ponds in support of PMLU.
- No limit of water take within the subsidence ponding.

Pond backfill and drainage channels as described in **Section 5.4.7** were included in the CSM and applied to the pluvial model. The pluvial model results are shown in **Appendix C**. The model results show the peak water levels, depths and velocity for a 2% AEP event. The model results show that the peak ponding depths in subsidence areas are less than 1m in the 2% AEP event, except for areas where there are existing channels in the topography (e.g. refer to points 28, 29 in **Figure 5-8**). The pond at point 30 in **Figure 5-8** cannot be drained to the Isaac River without works outside of the EA/BMA mining lease boundaries or significant disturbance to existing vegetation within the tenement. It is therefore recommended to be maintained as a pond. In areas excluding existing watercourses, drainage lines, existing ponds, dams, and the pond at point 30, the subsidence areas will be predominantly free-draining.

Additional analysis of long-term ponding was undertaken for ponds at point 28, 29, and 30. The pluvial model was run with the following conditions:

- 3 month model run time;

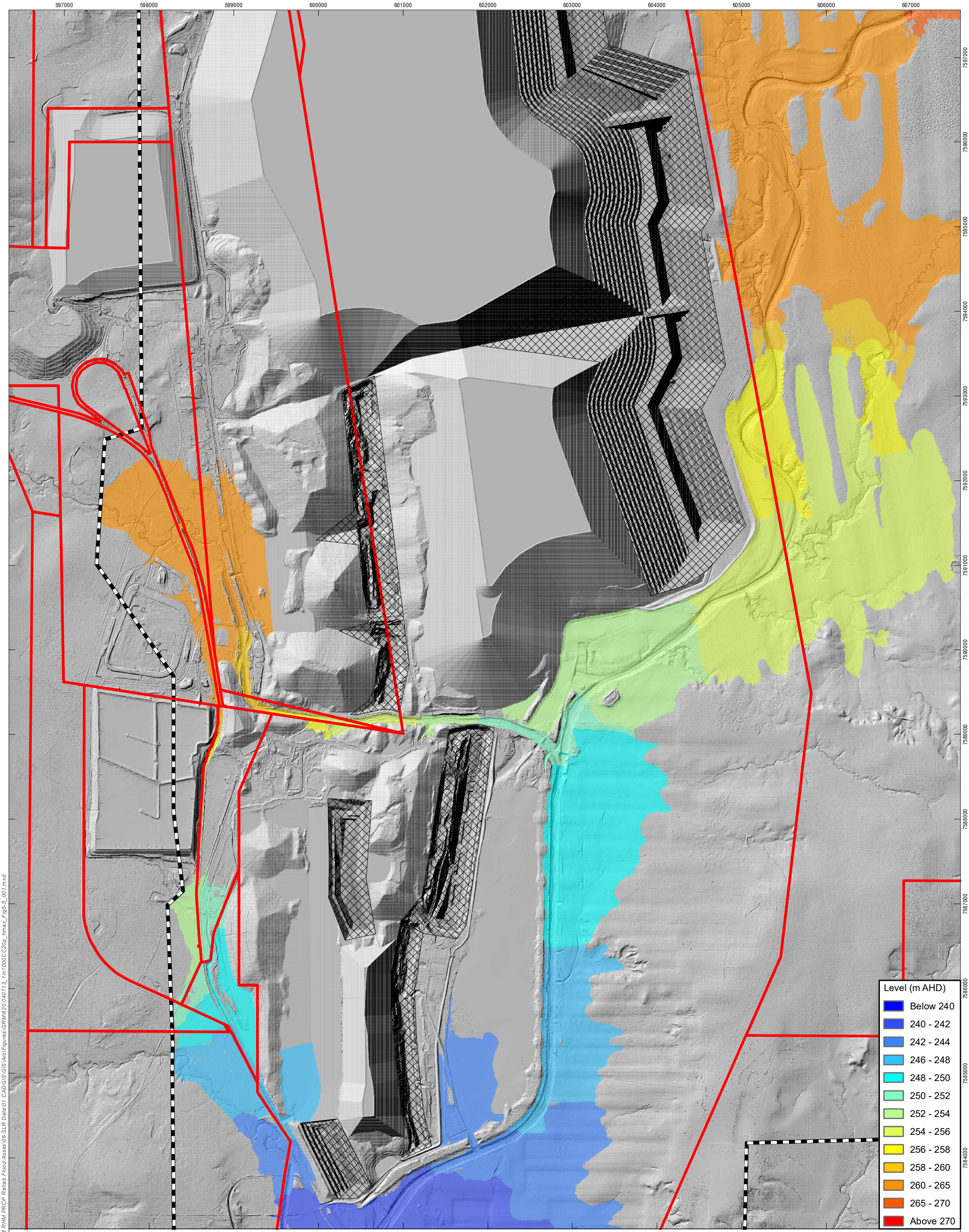
- Initial water level of ponds as full (236.6 mAHD for ponds 28 and 29 and 237.2mAHD for pond 30);
- No additional rainfall; and
- Infiltration and evaporation applied.

The modelling results showed that:

- Pond 28 was emptied within 1700 hours (70 days);
- Pond 29 was emptied within 1030 hours (43 days); and
- Pond 30 was emptied within 880 hours (37 days).

Therefore, the model results indicate there will be no residual ponding that would last more than 3 months at these points.

Drain sizes have been specified as proof of concept only and were not optimised as part of this assessment. Further refinement of the CSM components including drain sizing should be considered in future design phases.



0 0.325 0.65 1.3 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity

SLR

Figure 5-5

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597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	27-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - PMF

Figure 5-6

H:\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\Figures\GRM\620.040713_PMP_hmax_Fig5-6-001.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Bed Shear Stress - 2% AEP

SLR

Figure 5-7

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-4-2_F08_02p_bss.mxd

599000 600000 601000 602000 603000 604000 605000 606000

7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

14 13 15 12 16 11 17 9 10 8 18 19 20 7 22 21 6 23 5 4 3 2 1 24 25 26 27 28 29 30

Depth (m)
- Below 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- > 2

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

0 0.225 0.45 0.9 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:30,000 at A3
Project Number:	620.040713
Date:	26-Sep-2024
Drawn by:	TS

LEGEND
- Mining Leases
- TUFLOW Model Extent
- Proposed Backfill Areas
- Proposed Drains
- Reporting Points

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

TUFLOW Pluvial Model Results

Figure 5-8

H:\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\Arc\Figures\GRM\620040713_Pluvial_Model_Results_Fig5-8_001.mxd

6.0 Flooding Risk Profile

A Flooding Risk Profile (FRP) was developed for the Goonyella Complex post-closure conditions. The FRP was based on the results of the hydraulic model (as detailed in **Section 5.3**), as applied to the BHP Risk Framework. The BHP Risk Management Guidelines (RMG) and results of the FRP assessment are provided in **Appendix A**.

The risk assessment was undertaken using the methodology outlined in the RMG as follows:

1. Identify Risk
2. Assess Risk (including determining Maximum Foreseeable Loss (MFL) level and identifying material risks).
3. Identify possible risk prevention/mitigation measures.
4. Calculate Residual Risk Rating (RRR) for material risks.
5. Determine appetite for Risk based on RRR factored by likelihood and severity, where RRR < 90 is within appetite, otherwise exceeding appetite.

A summary of the identified flood risks, MFL, possible mitigation measures and residual risk ratings (RRR) are detailed in **Table 6-1**.

Table 6-1 Flood Risk Profile Summary

Identified Risk	MFL	Mitigation / Prevention Measures	RRR	Residual Risk Appetite Category
Goonyella Pit Final Void floodwater ingress (Isaac River) (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Isaac Pit Final Void floodwater ingress (Isaac River) (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Broadmeadow Pit Final Void floodwater ingress (Isaac River and Eureka Creek) (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Thiess Pit Final Void floodwater ingress (Eureka Creek) (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)

Identified Risk	MFL	Mitigation / Prevention Measures	RRR	Residual Risk Appetite Category
R32 South Pit Final Void floodwater ingress (Isaac River and R32/Airstrip tailings storage facility rehabilitated surface) (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Alteration of flows downstream of site	Measurable but limited impact to the environment, where recovery of ecosystem function takes less than 1 year	Not required due to MFL < 4	0 / NA	Within appetite (RRR<90)

As shown in Table 6-1, the RRR for each identified flood risk is <90 and therefore within the appetite in accordance with the RMG.

7.0 Outcomes

The results of the assessment detailed in this report provided the following outcomes in relation to the scope of work outlined **Section 1.1**.

Section 3.6.1 General Rehabilitation Practices (Flooding)

- *Consider the location of domains in relation to potential flood levels.*

The results of the fluvial hydraulic model illustrate that the residual voids are immune to inundation from riverine and creek floodwaters for all modelled design storm events up to and including the 0.1% AEP + 20% rainfall intensity increase climate change event.

- *Consider alteration of flow upstream and downstream.*

Analysis of the final landform showed that a reduction in peak flow at the site discharge location of approximately 7-9% will occur due to the residual voids, in comparison to pre-mining conditions at the site downstream discharge location. No alteration of flows upstream of the site will occur.

- *Model flood levels (including probable maximum flood levels) for a range of design storm events.*

A range of design flood events were simulated using the fluvial hydraulic model including the 39%, 2%, 1%, 0.1% AEP and PMF. The effects of climate change were also assessed and the model was simulated for a range of future climate scenarios, as outlined in **Section 4.6**.

- *Develop a flooding risk profile.*

A risk profile was developed based on the results of the assessment using the BHP Risk Management Guidelines. Refer to **Section 6.0**.

Section 3.6.4 Underground Mining

- *Changes to hydrological regime.*

In areas where subsidence will occur, the final landform and CSM were developed based on the criteria for ponding as outlined in **Section 3.3.2** and **Section 5.5.3**.

- *Changes in surface topography and local drainage characteristics - this may result in some areas becoming more free-draining while runoff may be reduced in other areas, resulting in the ponding of water in areas where previously no ponding occurred.*

The final landform and CSM were developed such that ponding in subsidence areas will generally free-drain to discharge to the Isaac River in keeping with the pre-mining hydrologic regime.

- *Changes in surface drainage, leading to changes in the composition of vegetation communities and distribution of flora and fauna species.*

The criteria for allowable ponding within subsidence areas was informed by Queensland Herbarium and BMA ecology specialists as outlined in **Section 3.3.2** and **Section 5.5.3**. The results of the pluvial modelling illustrated that the criteria were generally achieved throughout the subsidence areas of the final landform.

8.0 Conclusions

SLR was contracted by BMA to support the preparation of the Goonyella Complex Progressive Rehabilitation and Closure Plan (PRCP). The assessment detailed in this report was undertaken specifically to address Section 3.6.1 and 3.6.4 of the PRCP Guideline, which relates to the analysis of flooding as part of the PRCP.

A model landform was developed for the project, which was based on the post-mining surface provided by BMA and included the proposed final voids for Goonyella, Thiess, R32 East, Isaac, R32 South and Broadmeadow Pits as well as rehabilitated dump areas.

Using the model landform, hydrologic models were developed for the Isaac River, Eureka Creek and Fisher and Platypus Creek catchments. The model was calibrated using recorded stream flow data for Isaac River. The results of the models were also verified against results of empirical flow estimation methods and previous studies. The hydrologic models were simulated for a suite of design storm events including a range of temporal patterns, storm durations and AEP events including the 0.1% AEP and PMF.

Hydraulic models covering Isaac River, Eureka Creek and Fisher and Platypus Creek catchments were developed. The model topography was based on the model landform for the purpose of assessing the post-mining flooding conditions in accordance with Section 3.6.1 and 3.6.4 of the PRCP Guideline. Flow hydrographs produced by the hydrologic models were utilised as inflows for the hydraulic model.

The results of the hydraulic model showed the proposed final voids are not subject to inundation for the modelled flood events up to and including the 0.1% AEP event with 20% increase in intensity increase scenario.

The results showed that the Goonyella, Issac, Broadmeadow, Thiess and R32 South Pit final voids are subject to inundation for the PMF event.

A pluvial hydraulic model was developed which was utilised to investigate potential ponding during local catchment rainfall events within the areas of the final landform where subsidence will occur. A Conceptual Site Model was developed including conceptual drainage connections and backfilling within subsidence depressions, which was driven by the defined criteria for ponding in subsidence areas.

The results of the model illustrated that the criteria for ponding can be achieved by the final landform including the CSM components.

A Flood Risk Profile was developed based on the hydrologic and hydraulic model results. The FRP was developed using the framework provided in BHP's Risk Management Guideline. The outcome of the FRP was that the residual risk ratings of the identified flood risks are acceptable.

9.0 References

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Appendix A Flood Risk Profile Assessment

Goonyella Complex

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

18 November 2024

Previously GLD | 017
(printed copies are uncontrolled)
Version 7.4 (01 July 2021)
Internal

Risk Management
Our Requirements

Why is this important?

Through the delivery of best in class risk management, we protect what BHP has today and grow value for tomorrow.

The identification and management of risks is central to achieving our strategic objectives. It protects us against downside risk; enables us to take risk for strategic reward; and improves our resilience against emerging risks.

An essential element of effective risk management is to have an enterprise view so that the full risk exposure can be prioritised, and the aggregate impact from cumulative risks can be understood. As such, BHP operates to one Risk Framework for all risks.

In addition to Our Requirements for Risk Management, other Our Requirements set minimum controls for managing specific areas of risk (e.g. Safety, Aviation, Environment and Climate Change, Water and Tailings Storage Facilities, Capital Projects, Closure and Finance).

Who does this apply to?

- Anyone involved in identifying, assessing, controlling, monitoring or reporting risks or using this information to make decisions.

See Our Code of Conduct for the standard of behaviour expected of you at BHP.

See Our Requirements for Organisation Design for functional accountabilities.

What approvals are required?

- Alternative risk governance model
- Operate while remediation plan is implemented to bring performance within defined key risk indicator limits
- Operate outside of defined key risk indicator limits
- Risk register completeness and continued management of risks within appetite
- Operate while remediation plan is implemented to bring risk within appetite
- Operate while risk is within tolerance

Please note that hyperlinks to documents in the Our Requirements suite will redirect you to a landing or search page where you can navigate to the latest controlled version.

Risk Strategy

Risk Framework

- Apply BHP's Risk Framework for the identification and management of all risks.
- Strengthen our risk culture.

Strengthen our risk culture by demonstrating the following behaviours that support great risk management:

- everyone can speak up without fear;
- leaders own and prioritise threats and opportunities;
- we learn from mistakes and successes;
- everyone takes responsibility for risk;
- we encourage the right behaviour.

A strong risk culture enables us to make decisions that balance risk and reward and actively seek to take risk within appetite.

BHP operates to a global risk framework aligned to ISO31000. The level of effort applied should be prioritised commensurate with the level of risk. Notify the Global Risk team of any opportunities to improve BHP's Risk Framework.

Strategic business decisions

- When making a strategic business decision for BHP:
  - use BHP's Risk Appetite Statement and Group Risk Architecture to make sure the decision is within BHP's appetite for risk;
  - use recommended techniques from the Risk Framework when additional analysis is required to be certain that a decision is within appetite; and
  - apply the risk process to the selected decision.

BHP's Risk Appetite Statement and Group Risk Architecture are central to understanding the type and extent of risk BHP chooses to accept in pursuit of achieving strategic and operational objectives.

Risk Governance

- Implement the Three Lines model for all Group Risks or get approval for an alternative risk governance model.
- When any of the defined key risk indicator limits (elevated or avoidant) specified in the Group Risk Architecture are exceeded:
  - review the appropriateness of the Risk Appetite Statement and defined key risk indicator limits and determine if an update is required; and
  - develop a remediation plan to bring performance within defined key risk indicator limits, and get approval to continue to operate while implementing the remediation plan; or
  - get approval to continue to operate outside of defined key risk indicator limits where there are no reasonable remediation actions to bring the Group Risk within appetite and have the approval reviewed annually.

Refer to the Risk Framework for a description of the roles and responsibilities for risk management under the Three Lines model.

Risk Process

Identify risk

- Identify threats and opportunities by considering:
  - what can go wrong and what must go right;
  - five year plans, Life of Asset planning and other deliverables from Our Requirements for Corporate Alignment Planning;
  - purpose statements from Our Requirements for Organisation Design;
  - the Group Risk Architecture;
  - internal and external sources of risk;
  - intended and unintended consequences when introducing change;
  - current risks and emerging risks.
- Prioritise for assessment and treatment any risks that can impact the achievement of strategic and operational business objectives.

Assess risk

- For each identified risk:
  - classify the risk as a current risk or an emerging risk;
  - use one or more recommended techniques in the Risk Framework to perform a risk assessment;
  - use Appendix 1 to determine the maximum foreseeable loss (MFL) and for each risk or risk scenario with an MFL ≥ level 4 impact determine the residual risk rating (RRR);
  - determine maximum foreseeable gain (MFG) for an opportunity;
  - tell the Group Risk Representative immediately of any newly identified risk with MFL level 5 impact;
  - review, and when applicable, update your risk assessment following any risk relevant change; and
  - make sure people with relevant expertise and experience are involved in all risk assessments.
- For each current risk, classify it as a current material risk if it has an MFL ≥ level 4 impact.
- For each current material risk, identify critical controls, and for each critical control determine:
  - the critical aspects of the design and operating performance criteria required to achieve the control's primary objective;
  - the verification activities required to check that the critical control is operating effectively according to its design; and
  - a manual test plan to test that the critical control is achieving its primary objective and effectively managing the risk.

Critical controls are not mandated for opportunities, emerging risks, non-material risks or one-off short-term material risks.

Some risk events may have multiple scenarios, in which case risk owners should consider whether these scenarios have a higher RRR than the MFL scenario and whether they have additional causes or impacts and require additional controls.

Treat Risk

- For each current risk (either material risk or non-material risk) and each one-off short-term material risk:
  - implement preventative controls to prevent the causes of a threat, and mitigating controls to reduce its impacts;
  - implement controls to enable and/or enhance an opportunity; and
  - if the RRR ≥ 90, stop the activity or get approval to continue the activity by completing a risk evaluation under Appendix 2.
- For each emerging risk, make sure contingency controls are in place when the RRR ≥ 90.

Monitor and Review

- For each current material risk follow Appendix 2 to perform a critical control effectiveness test (CET) and risk evaluation at least annually.
- For each emerging risk, review the risk at least annually to confirm:
  - the risk remains an emerging risk and has not become a current risk;
  - the RRR remains accurate; and
  - any required contingency controls remain in place.
- Review the risk register for completeness and continued management of risks within appetite and get approval annually.

Communicate

- For each risk with an MFL ≥ level 4 impact, record the risk in 1SAP Governance Risk and Compliance (GRC).

This requirement will be expanded to include each risk with an MFL level 3 impact once material risks are adequately represented and managed.

Remember to consult with the Global Risk team when providing risk information to the Board or Executive, functional or asset leadership teams.

Appendix 1
Severity and likelihood tables

Severity table[1]: Use this table to select the MFL severity level and the RRR severity factor. The RRR severity factor measures the worst case expected outcome for the risk event, assuming the mitigating controls that are in place are operating in accordance with their design.

Severity Level	Descriptor	Severity Factor
5	6 or more fatalities or 6 or more chronic life threatening illnesses; or Severe impact to the environment and where recovery of ecosystem function takes 10 years or more; or Severe impact on community lasting more than 12 months or a substantiated human rights violation impacting 6 or more people; or Severe impact on company reputation, investment attractiveness, legal rights or compliance, social value proposition or ability to access opportunities at a global level; or US$2 billion or more[2].	1000
4	1-5 fatalities or 1-5 chronic life threatening illnesses; or Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years; or Serious impact on community lasting 6-12 months or a substantiated human rights violation impacting 1-5 persons; or Serious impact on company reputation, investment attractiveness, legal rights or compliance, social value proposition or ability to access opportunities at a national level; or Between US$250 million and up to US$2 billion[2].	300
3	Life altering or long term/permanent disabling injury or illness to one or more persons; or Substantial impact to the environment, where recovery of ecosystem function takes between 1 and up to 3 years; or Substantial impact on community lasting 2-6 months; or Substantial impact on company reputation, legal rights or compliance, social value proposition, or ability to access opportunities at a sub national level (state, territory, province); or Between US$50 million and up to US$250 million[2].	100
2	Non-life altering or short-term disabling injury or illness to one or more persons; or Measureable but limited impact to the environment, where recovery of ecosystem function takes less than 1 year; or Measureable but limited community impact lasting less than one month; or Measureable but limited impact on company reputation, legal rights or compliance, or social value proposition at a local level (region, city, town); or Between US$2 million and up to US$50 million[2].	30
1	Low level impact resulting in first aid only; or Minor, temporary impact to the environment, where the ecosystem recovers with little intervention; or Minor, temporary community impact that recovers with little intervention; or Minor, temporary impact on company reputation, legal rights or compliance, or social value proposition; or Less than US$2 million[2].	10

(1) Guidance on using the severity table is available here.

(2) Assess the cash impact on revenue, operating cost and capital cost or cash equivalent impact (net present value). The impact should be assessed for the full life cycle of a single immediate occurrence of the event and calculated in US$ (BHP share). If the sum of the initial impact assessed is greater than US$250 million (BHP share) a valuation aligned to Our Requirements for Decision Evaluation should support the analysis.

Current risk likelihood table[3]**:** Use this table when calculating RRR to select the current risk likelihood factor. The likelihood factor measures the likelihood of the risk event occurring, assuming the preventative controls that are in place are operating in accordance with their design.

Calculate the RRR using the formula: **RRR = severity factor x current risk likelihood factor.**

Uncertainty	Frequency	Likelihood factor
Highly Likely	Likely to occur within a 1 year period.	**3**
Likely	Likely to occur within a 1 - 5 year period.	**1**
Possible	Likely to occur within a 5 - 20 year period.	**0.3**
Unlikely	Likely to occur within a 20 - 50 year period.	**0.1**
Highly Unlikely	Not likely to occur within a 50 year period.	**0.03**

Emerging risk likelihood table: Use this table to measure the timeframe and velocity in the calculation of the RRR.

Calculate the RRR using the formula: **RRR = severity factor x emerging risk likelihood factor.**

Timeframe & Velocity	Description	Likelihood factor
Near Term & Fast	Risk event is possible within the next 2 years. Impact would occur within six months of the initial onset of the risk event.	**3**
Near Term & Slow	Risk event is possible within the next 2 years. Impact would occur slowly over a period of greater than six months from the initial onset of the risk event.	**1**
Medium Term & Fast	Risk event is possible within 2 - 5 years. Impact would occur immediately or within six months of the initial onset of the risk event.	**0.3**
Medium Term & Slow	Risk event is possible within 2 - 5 years. Impact would occur slowly over a period of greater than six months from the initial onset of the risk event.	**0.1**
Long Term (no velocity required)	Risk event is possible within 5 - 10 years, but not sooner.	**0.03**

(3) Guidance on using the likelihood table is available here.

RRR heat map: Use this table to help determine whether a risk is exceeding appetite based on RRR.

Likelihood	Severity Level				
	1	2	3	4	5
Highly Likely	30	90	300	900	3000
Likely	10	30	100	300	1000
Possible	3	9	30	90	300
Unlikely	1	3	10	30	100
Highly Unlikely	0.3	0.9	3	9	30

The levels in the severity table are aligned to the Risk Appetite Statement to allow for screening that RRR is within appetite. When the RRR is ≥ 90 the risk is exceeding appetite.

Appendix 2
Critical control and risk evaluation

Critical control effectiveness test

A critical control effectiveness test (1SAP GRC control effectiveness manual test) must evaluate whether the control remains effective at managing the risk event. At a minimum, it must consider results from: verification activities and any trends, actual or similar control failures, internal and external audits and management reviews.

Critical control effectiveness test	Explanation
Adequate	The design, operation and verification of the critical control are appropriate, effective and achieve the control objective.
Deficient	The design, operation or verification of the critical control is not appropriate, not effective or does not achieve the control objective.

Issues identified from a critical control effectiveness test must be rated using the categories below and remediated.

Issue rating	Explanation
Low	The deficiency is unlikely to compromise the achievement of the control objective.
High	The deficiency is likely to compromise the achievement of the control objective.

Risk evaluation

Each current material risk and each non-material risk with an RRR ≥ 90 and one-off short-term material risk with an RRR ≥ 90 must be evaluated by the Risk Owner using the categories below. The risk evaluation must consider the overall effectiveness of the control environment, critical control effectiveness test(s), internal or external control failures related to the risk, audit findings, management reviews, and internal or external risk relevant changes.

Rating	Explanation
Within appetite	1. The RRR < 90; and 2. There are no deficient CETs with a high issue rating where the deficiency is specifically related to the risk being assessed.
Exceeding appetite with remediation	1. The RRR ≥ 90; and/or 2. One or more CET(s) are rated as deficient with a high issue rating and the deficiency is specifically related to the risk being assessed; and 3. Approval has been granted to continue to operate while a remediation plan is implemented to bring the risk back within appetite.
Within tolerance	1. The RRR ≥ 90; and/or 2. One or more CETs are rated as deficient with a high issue rating and the deficiency is specifically related to the risk being assessed; and 3. There are no reasonable remediation actions to bring the risk within appetite; and 4. The activity has been stopped or approval has been granted to operate while the risk is within tolerance.

Risk Title:	MFL Impacts					MFL	Control	Control Description	Control Owner	Control Purpose	Likelihood	Residual Severity					Residual Severity Factor	RRR	Actions	Accountability	Timeline
	IM1	IM2	IM3	IM4	IM5							IM1	IM2	IM3	IM4	IM5					
	Planning & Technical	Legal, Compliance & Stakeholder Relations	Financial Management	Environment, Climate Change & Community	Health & Safety							Planning & Technical	Legal, Compliance & Stakeholder Relations	Financial Management	Environment, Climate Change & Community	Health & Safety					
Goonyella Pit Final Void floodwater ingress (Isaac River)	1	4	2	4	1	4	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	Engineering Controls		Preventative	*Highly Unlikely (0.03)*	1	1	1	1	1	*10*	0.3			
Isaac Pit Final Void floodwater ingress (Isaac River)	1	4	2	4	1	4	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	Engineering Controls		Preventative	*Highly Unlikely (0.03)*	1	1	1	1	1	*10*	0.3			
Broadmeadow Pit Final Void floodwater ingress (Isaac River and Eureka Creek)	1	4	2	4	1	4	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	Engineering Controls		Preventative	*Highly Unlikely (0.03)*	1	1	1	1	1	*10*	0.3			
Thiess Pit Final Void floodwater ingress (Eureka Creek)	1	4	2	4	1	4	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	Engineering Controls		Preventative	*Highly Unlikely (0.03)*	1	1	1	1	1	*10*	0.3			
R32 South Pit Final Void floodwater ingress (Isaac River and R32/ Airstrip tailings storage facility rehabilitated surface)	1	4	2	4	1	4	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	Engineering Controls		Preventative	*Highly Unlikely (0.03)*	1	1	1	1	1	*10*	0.3			
Alteration of flows downstream of site	1	2	2	2	2	2	Not required due to MFL < 4														

Appendix B Fluvial Model Results

Goonyella Complex

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

18 November 2024

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 39% AEP

SLR

APPENDIX B1-1-1

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 2% AEP

SLR

APPENDIX B1-1-2

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Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP

APPENDIX B1-1-3

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Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - PMF

APPENDIX B1-1-4

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Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 39% AEP

SLR

APPENDIX B1-2-1

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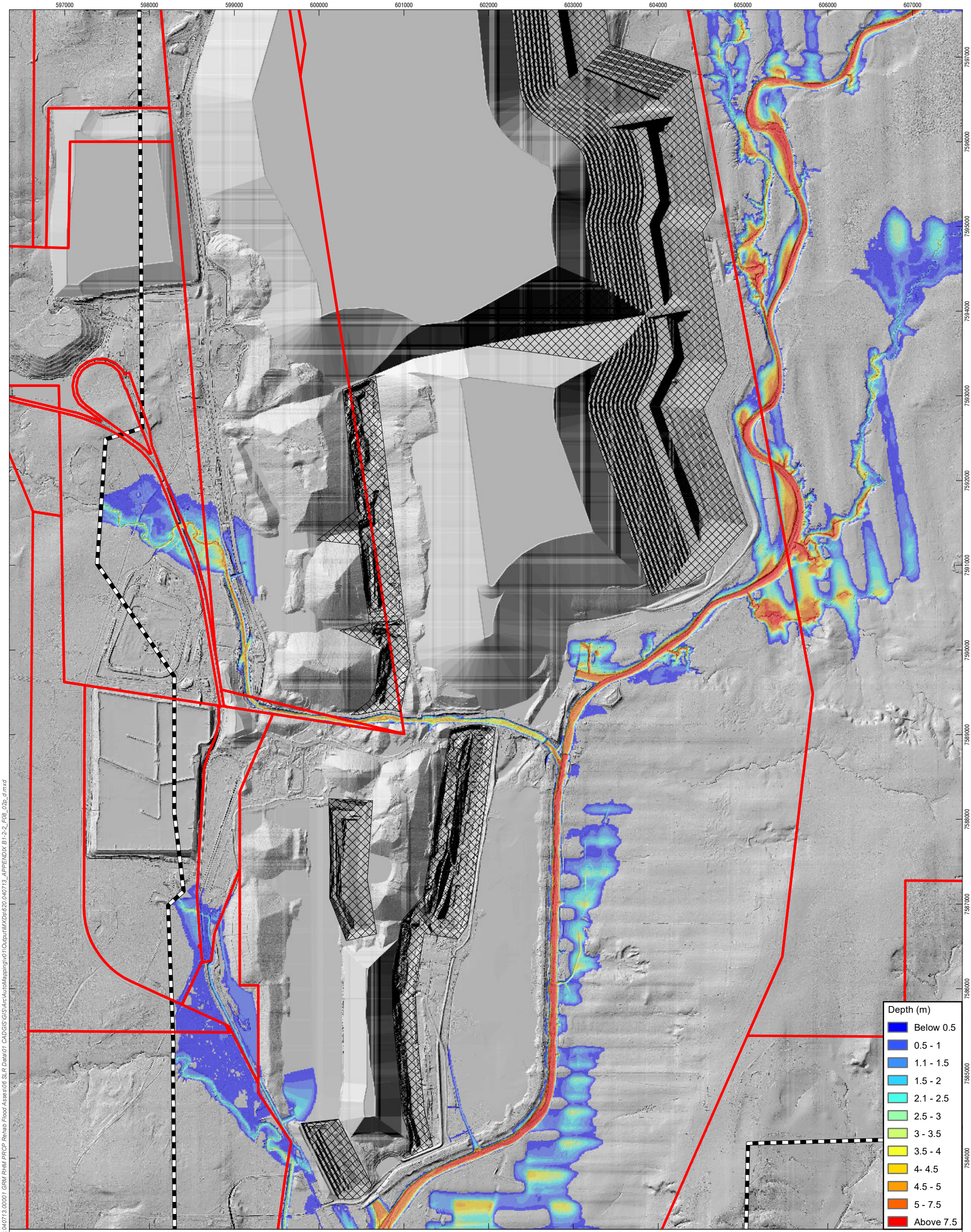

0 0.325 0.65 1.3 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 2% AEP

SLR

APPENDIX B1-2-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-2-2_F08_02p_d.mxd

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions Peak Depths - 0.1% AEP

APPENDIX B1-2-3

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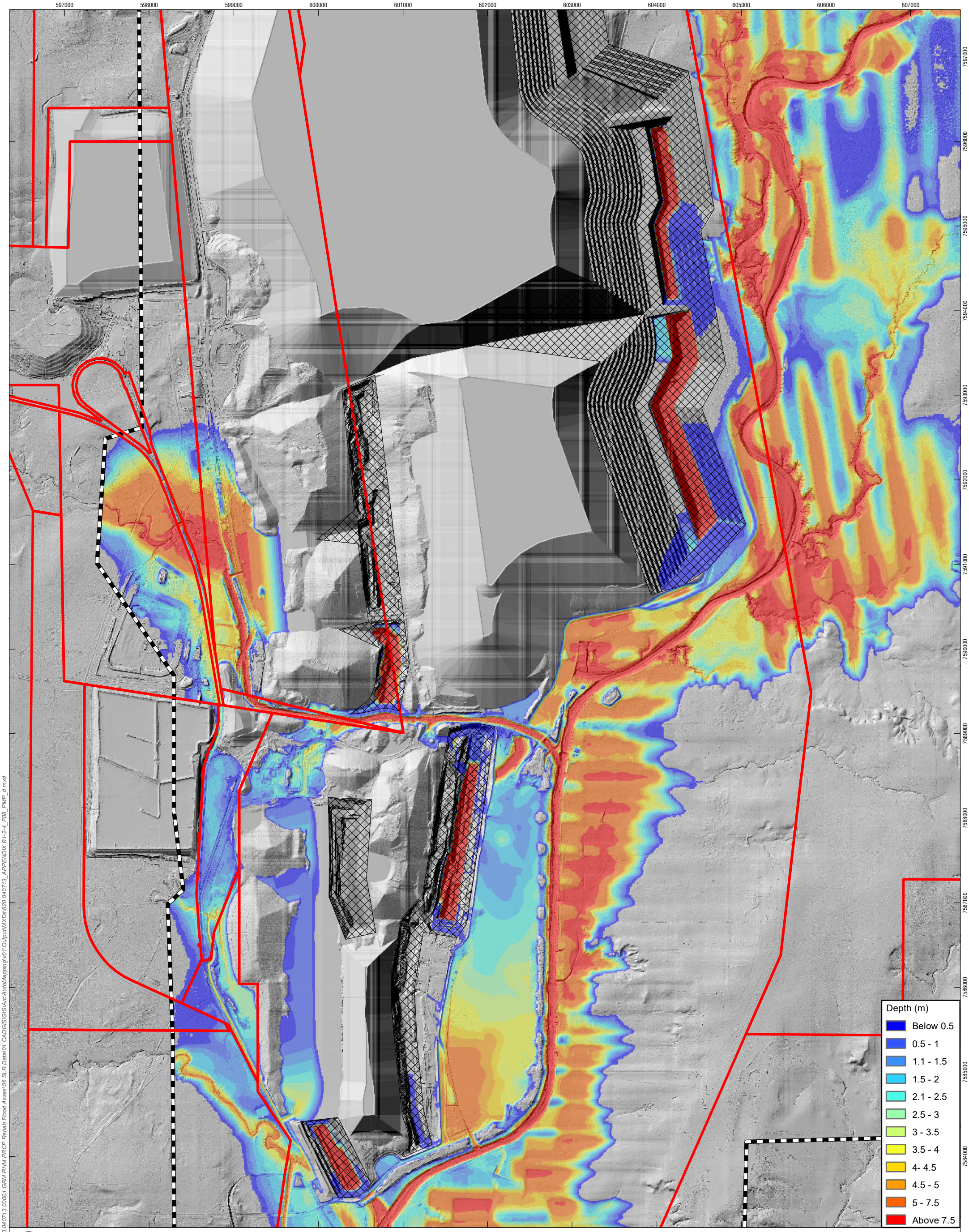

0 0.325 0.65 1.3 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - PMF

SLR

APPENDIX B1-2-4

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions Peak Velocities - 39% AEP

SLR

APPENDIX B1-3-1

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 2% AEP

SLR

APPENDIX B1-3-2

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions Peak Velocities - 0.1% AEP

APPENDIX B1-3-3

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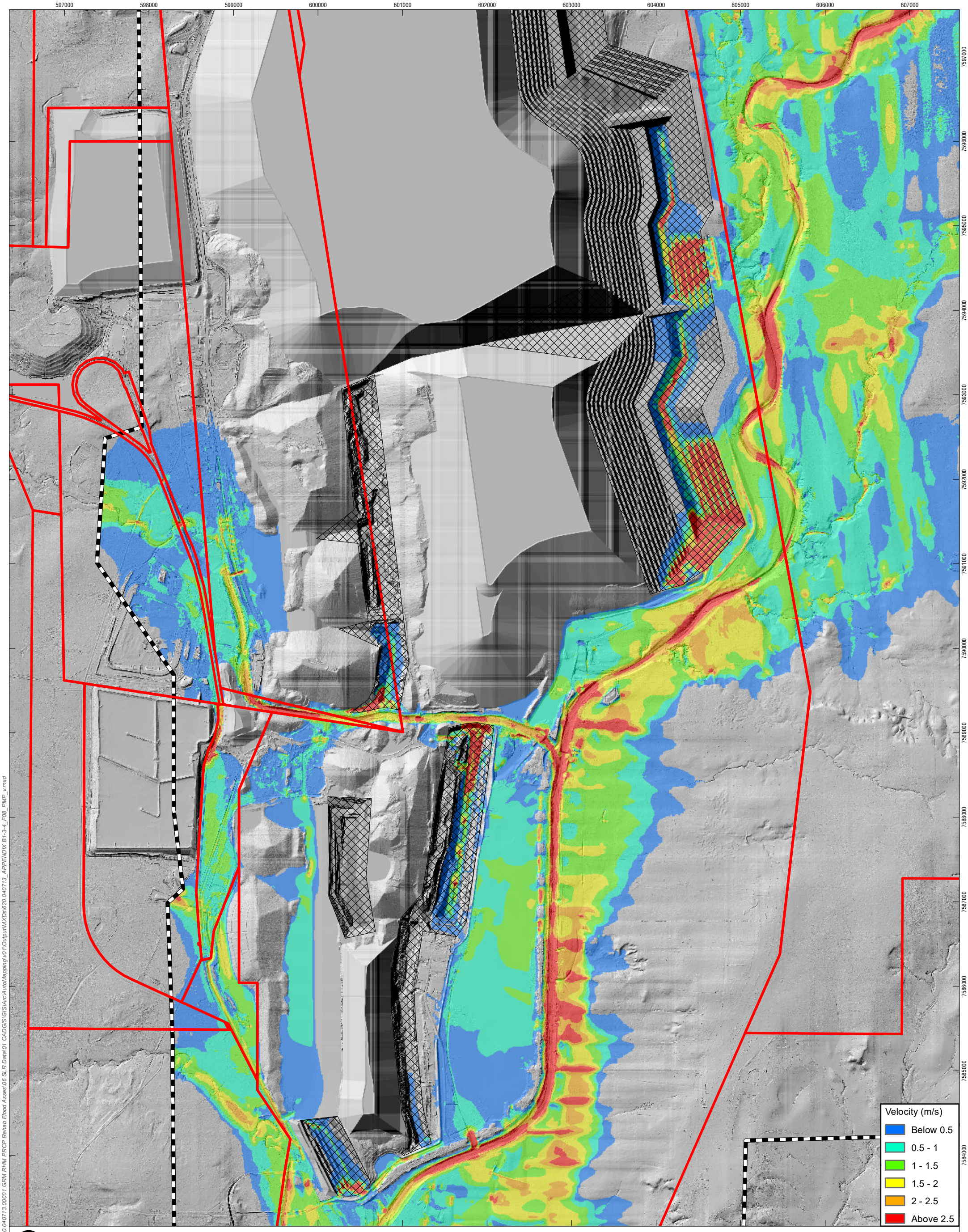

0 0.325 0.65 1.3 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - PMF

APPENDIX B1-3-4

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Bed Shear Stress - 39% AEP

SLR

APPENDIX B1-4-1

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions Peak Bed Shear Stress - 2% AEP

SLR

APPENDIX B1-4-2

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7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Stream Power - 39% AEP

SLR

APPENDIX B1-5-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-5-1_F08_39p_sp.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Stream Power - 2% AEP

APPENDIX B1-5-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-5-2_F08_02p_sp.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B1-6-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-6-1_F08_1in1000CC06p_h.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 11% rainfall intensity

APPENDIX B1-6-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-6-2_F08_1in1000CC11p_h.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 246 - 248
- 248 - 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- 265 - 270
- Above 270

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity

APPENDIX B1-6-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-6-3_F08_1in1000CC20p_h.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B1-7-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-7-1_F08_1in1000CC06p_d.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B1-7-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-7-2_F08_1in1000CC11p_d.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B1-7-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CAD\GIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-7-3_F08_1in1000CC20p_d.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B1-8-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-8-1_F08_1in1000CC06p_v.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B1-8-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-8-2_F08_1in1000CC11p_v.mxd

597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000

7597000 7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.325 0.65 1.3 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:40,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B1-8-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B1-8-3_F08_1in1000CC20p_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Levels - 39% AEP

SLR

APPENDIX B2-1-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-1-1_F08_39p_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Levels - 2% AEP

SLR

APPENDIX B2-1-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-1-2_F08_02p_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Levels - 0.1% AEP

SLR

APPENDIX B2-1-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-1-3_F08_1in1000_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Levels - PMF

APPENDIX B2-1-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-1-4_F08_PMP_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Depths - 39% AEP

SLR

APPENDIX B2-2-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADG\SIG\S\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-2-1_F08_39p_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Depths - 2% AEP

SLR

APPENDIX B2-2-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-2-2_F08_02p_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Depths - 0.1% AEP

SLR

APPENDIX B2-2-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-2-3_F08_1in1000_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Depths - PMF

SLR

APPENDIX B2-2-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-2-4_F08_PMP_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Velocities - 39% AEP

SLR

APPENDIX B2-3-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-3-1_F08_39p_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Velocities - 2% AEP

SLR

APPENDIX B2-3-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-3-2_F08_02p_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Velocities - 0.1% AEP

SLR

APPENDIX B2-3-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-3-3_F08_1in1000_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Velocities - PMF

APPENDIX B2-3-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcMAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-3-4_F08_PMP_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Bed Shear Stress - 39% AEP

SLR

APPENDIX B2-4-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-4-1_F08_39p_bss.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Bed Shear Stress - 2% AEP

SLR

APPENDIX B2-4-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-4-2_F08_02p_bss.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Stream Power - 39% AEP

SLR

APPENDIX B2-5-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-5-1_F08_39p_sp.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions Peak Stream Power - 2% AEP

SLR

APPENDIX B2-5-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-5-2_F08_02p_sp.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Levels - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B2-6-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-6-1_F08_1in1000CC06p_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Levels - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B2-6-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-6-2_F08_1in1000CC11p_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Level (m AHD)
- Below 250
- 250 - 252
- 252 - 254
- 254 - 256
- 256 - 258
- 258 - 260
- 260 - 265
- Above 265

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B2-6-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-6-3_F08_1in1000CC20p_h.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Depths - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B2-7-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-7-1_F08_1in1000CC06p_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Depths - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B2-7-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-7-2_F08_1in1000CC11p_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Depths - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B2-7-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-7-3_F08_1in1000CC20p_d.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 6% rainfall intensity

APPENDIX B2-8-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-8-1_F08_1in1000CC06p_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B2-8-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-8-2_F08_1in1000CC11p_v.mxd

598000 599000 600000 601000 602000

7593000 7592000 7591000 7590000 7589000 7588000 7587000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Eureka Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B2-8-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B2-8-3_F08_1in1000CC20p_v.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - 39% AEP

SLR

APPENDIX B3-1-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\OutputMXDs\620.040713_APPENDIX B3-1-1_F08_39p_h.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - 2% AEP

APPENDIX B3-1-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-1-2_F08_02p_h.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Levels - 0.1% AEP

APPENDIX B3-1-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CAD\GIS\GIS\ArcMAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-1-3_F08_1in1000_h.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - PMF

APPENDIX B3-1-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-1-4_F08_PMP_h.mxd

598000
599000
600000
601000
602000
7587000
7586000
7585000
7584000
7583000
7582000
7581000

Depth (m)
Below 0.5
0.5 - 1
1.1 - 1.5
1.5 - 2
2.1 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4- 4.5
4.5 - 5
5 - 7.5
Above 7.5

0 0.15 0.3 0.6 km

LEGEND
Mining Leases
Voids
TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Depths - 39% AEP

SLR

APPENDIX B3-2-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-2-1_F08_39p_d.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - 2% AEP

APPENDIX B3-2-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\OutputMXDs\620.040713_APPENDIX B3-2-2_F08_02p_d.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - 0.1% AEP

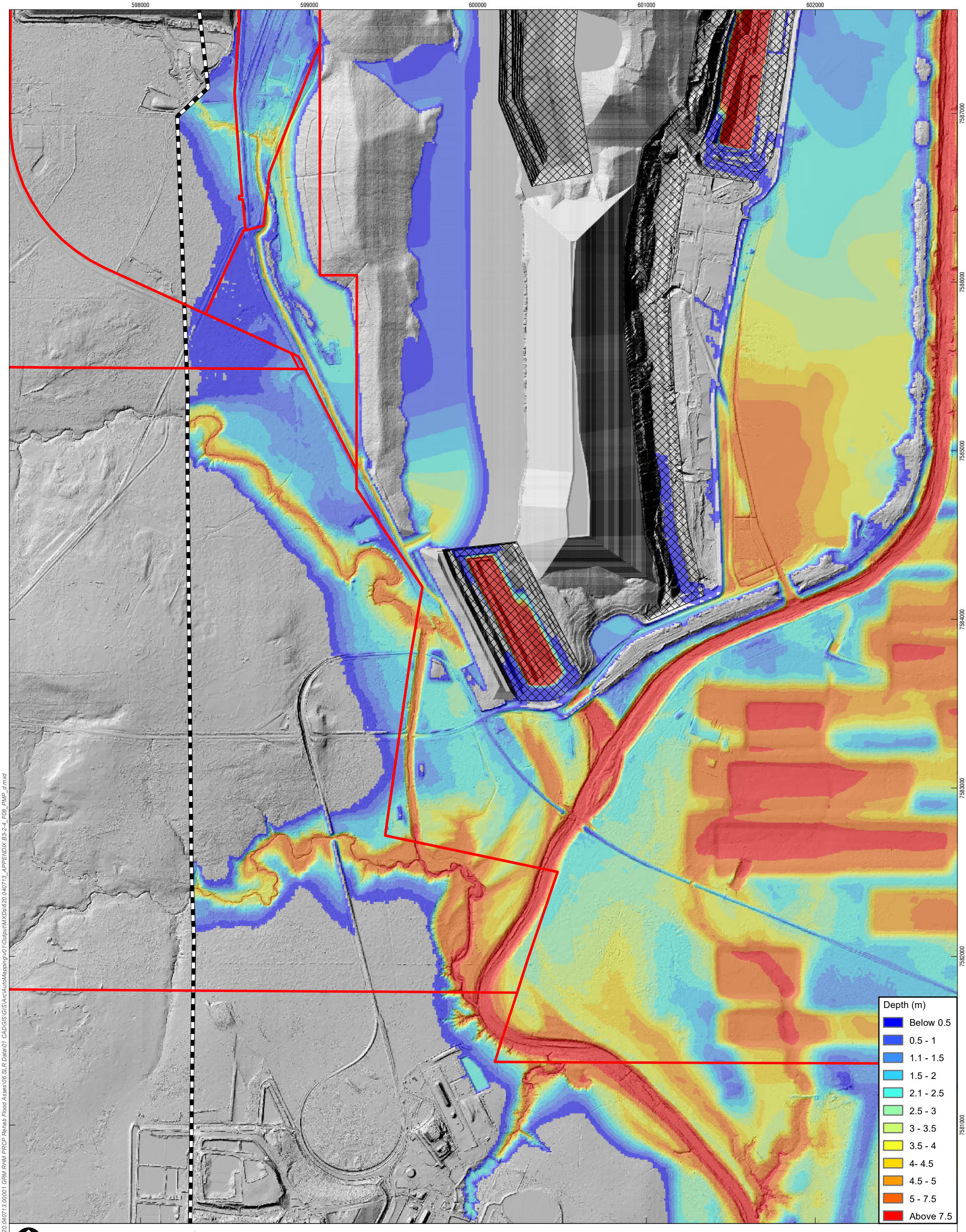
SLR

APPENDIX B3-2-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-2-3_F08_1in1000_d.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000



0 0.15 0.3 0.6 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - PMF

APPENDIX B3-2-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-2-4_F08_PMP_d.mxd

598000
599000
600000
601000
602000
7587000
7586000
7585000
7584000
7583000
7582000
7581000

Velocity (m/s)
Below 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
Above 2.5

0 0.15 0.3 0.6 km

LEGEND
Mining Leases
Voids
TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Velocities - 39% AEP

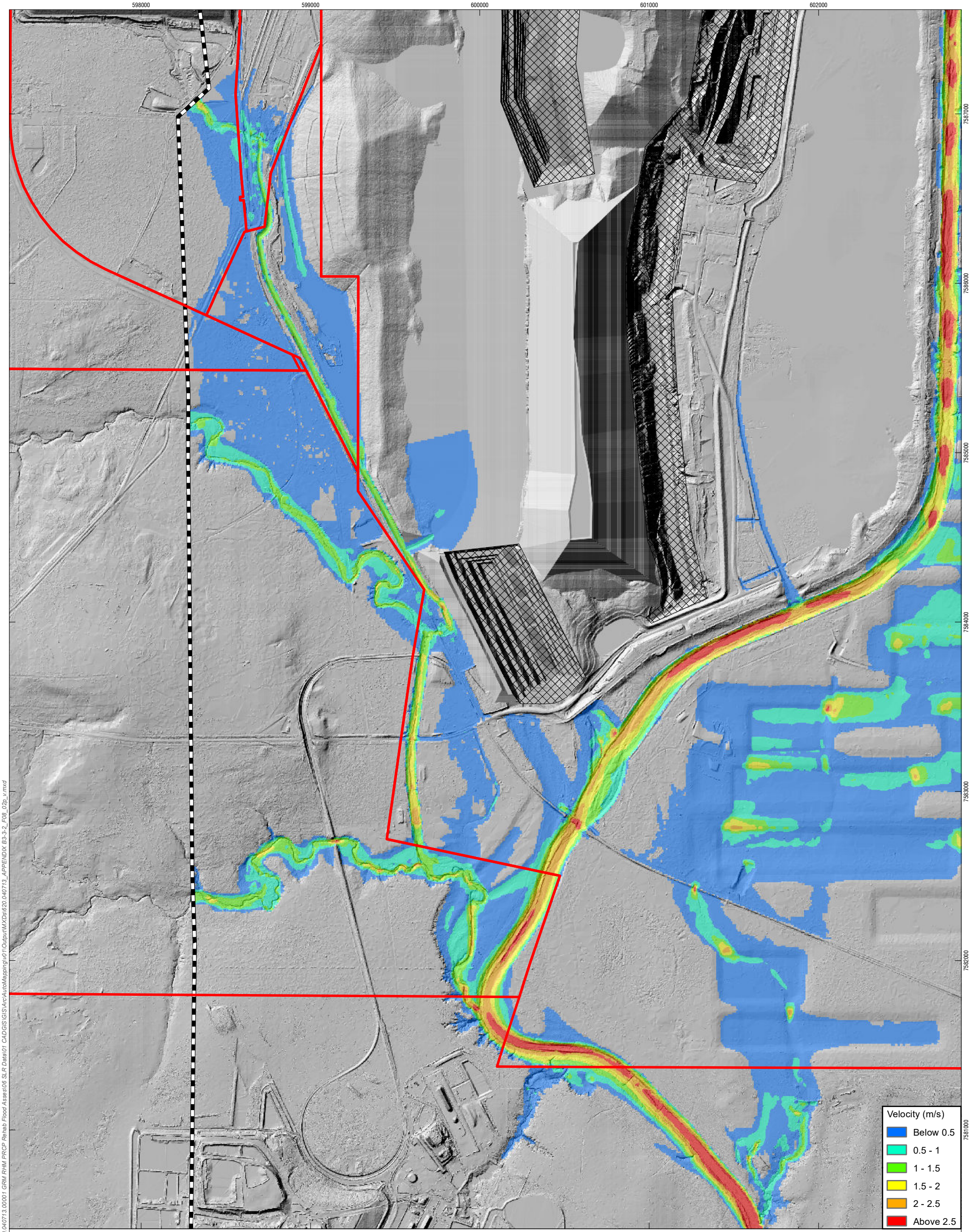
SLR

APPENDIX B3-3-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-3-1_F08_39p_v.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000



0 0.15 0.3 0.6 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Velocities - 2% AEP

SLR

APPENDIX B3-3-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-3-2_F08_02p_v.mxd

598000
599000
600000
601000
602000
7587000
7586000
7585000
7584000
7583000
7582000
7581000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Velocities - 0.1% AEP

APPENDIX B3-3-3

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assesi\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\OutputMXDs\620.040713_APPENDIX_B3-3-3_F08_1in1000_v.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Velocities - PMF

SLR

APPENDIX B3-3-4

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcAutoMapping\v01\OutputMXDs\620.040713_APPENDIX_B3-3-4_F08_PMP_v.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Bed Shear Stress - 39% AEP

SLR

APPENDIX B3-4-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-4-1_F08_39p_bss.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Bed Shear Stress - 2% AEP

APPENDIX B3-4-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\Arc\AutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-4-2_F08_02p_bss.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions Peak Stream Power - 39% AEP

SLR

APPENDIX B3-5-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-5-1_F08_39p_sp.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Stream Power (W/m²)
- Below 25
- 25 - 35
- 35 - 45
- 45 - 50
- 50 - 100
- 100 - 150
- Above150

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Stream Power - 2% AEP

SLR

APPENDIX B3-5-2

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598000
599000
600000
601000
602000
7587000
7586000
7585000
7584000
7583000
7582000
7581000

Level (m AHD)
Below 240
240 - 242
242 - 244
244 - 246
246 - 248
248 - 250
Above 250

0 0.15 0.3 0.6 km

LEGEND
Mining Leases
Voids
TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B3-6-1

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Assess\06 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v01\Output\MXDs\620.040713_APPENDIX B3-6-1_F08_1in1000CC06p_h.mxd

598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B3-6-2

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598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 240
- 240 - 242
- 242 - 244
- 244 - 246
- 246 - 248
- 248 - 250
- Above 250

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B3-6-3

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598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - 0.1% AEP + 6% rainfall intensity

SLR

APPENDIX B3-7-1

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598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - 0.1% AEP + 11% rainfall intensity

SLR

APPENDIX B3-7-2

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598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Depth (m)
- Below 0.5
- 0.5 - 1
- 1.1 - 1.5
- 1.5 - 2
- 2.1 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4- 4.5
- 4.5 - 5
- 5 - 7.5
- Above 7.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

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Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Depths - 0.1% AEP + 20% rainfall intensity

APPENDIX B3-7-3

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598000 599000 600000 601000 602000

7587000 7586000 7585000 7584000 7583000 7582000 7581000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

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Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 6% rainfall intensity

APPENDIX B3-8-1

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598000
599000
600000
601000
602000
7587000
7586000
7585000
7584000
7583000
7582000
7581000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.15 0.3 0.6 km

LEGEND
- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
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Date:	25-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 11% rainfall intensity

APPENDIX B3-8-2

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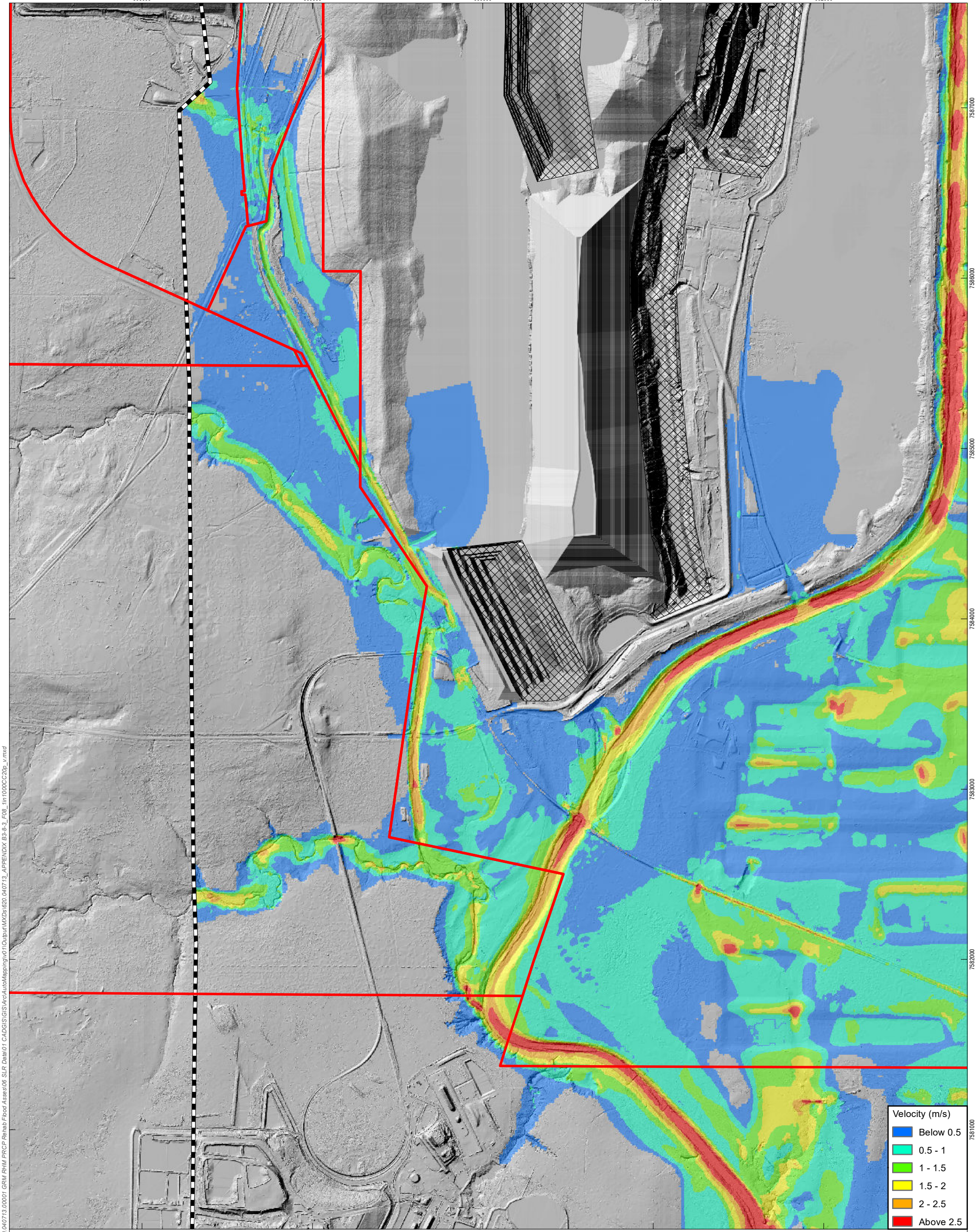
7587000 7586000 7585000 7584000 7583000 7582000 7581000



0 0.15 0.3 0.6 km

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:20,000 at A3
Project Number:	620.040713
Date:	25-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

Platypus and Fisher Creek PRCP Conditions
Peak Velocities - 0.1% AEP + 20% rainfall intensity

SLR

APPENDIX B3-8-3

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Appendix C Pluvial Model Results

Goonyella Complex

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

18 November 2024

599000 600000 601000 602000 603000 604000 605000 606000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Level (m AHD)
- Below 235
- 235 - 240
- 240 - 245
- 245 - 250
- 250 - 255
- 255 - 260
- 260 - 265
- 265 - 270
- 270 - 275
- 275 - 280
- 280 - 290
- Above 290

0 0.225 0.45 0.9 km

LEGEND
- Mining Leases
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:30,000 at A3
Project Number:	620.040713
Date:	26-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP
Rehabilitation Flood Assessment

PRCP Conditions Pluvial Modelling
Peak Levels - 2% AEP

APPENDIX C1-1-1

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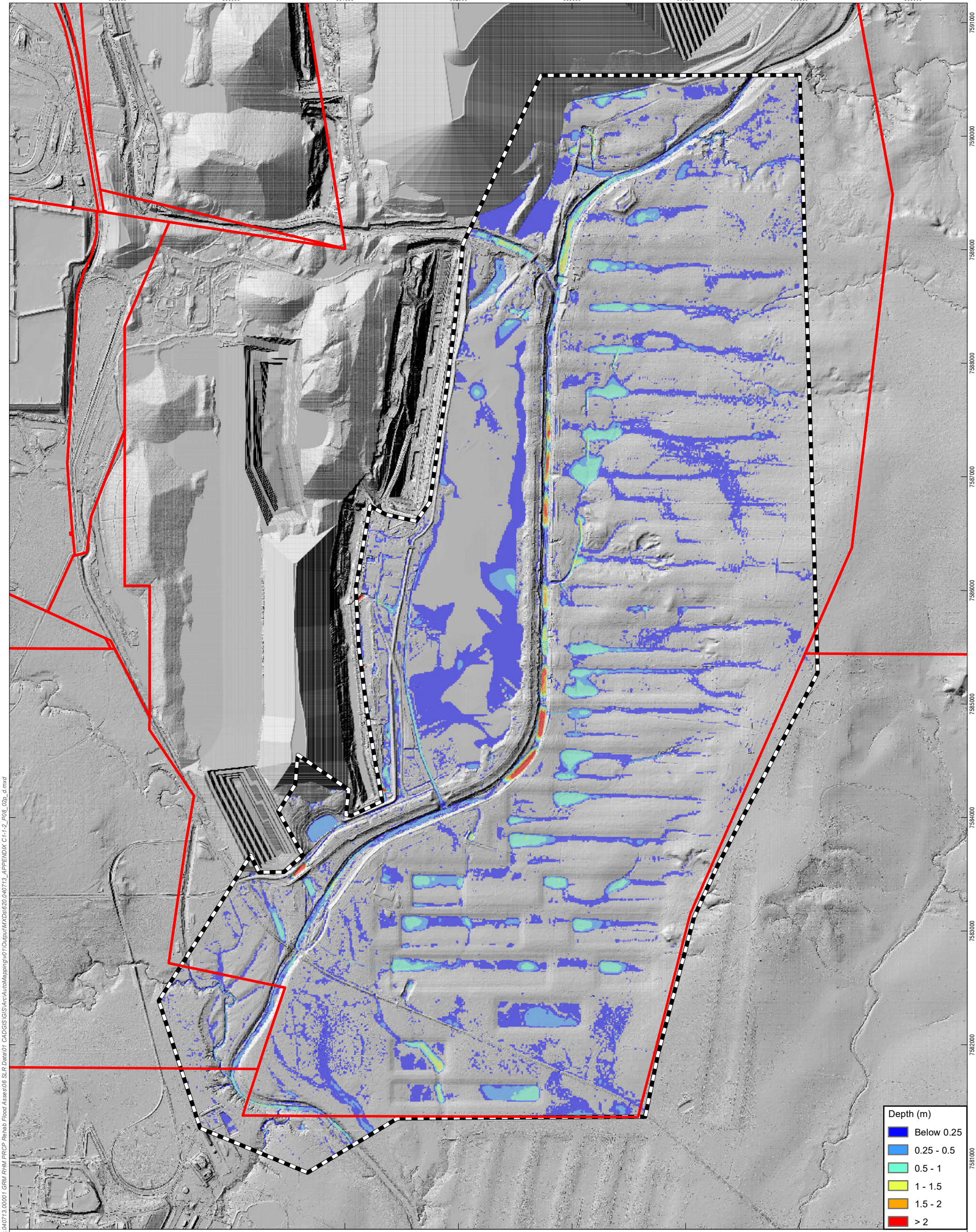
7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000



0 0.225 0.45 0.9 km

LEGEND

Mining Leases

TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:30,000 at A3
Project Number:	620.040713
Date:	26-Sep-2024
Drawn by:	TS

SLR

Goonyella Complex PRCP Rehabilitation Flood Assessment

PRCP Conditions Pluvial Modelling Peak Depths - 2% AEP

APPENDIX C1-1-2

\\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.040713.00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v01\Output\MXDs\620.040713_APPENDIX C1-1-2_P08_02p_ d.mxd

599000 600000 601000 602000 603000 604000 605000 606000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Velocity (m/s)
- Below 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- Above 2.5

0 0.225 0.45 0.9 km

LEGEND
- Mining Leases
- TUFLOW Model Extent

Coordinate System:	GDA2020 MGA Zone 55
Scale:	1:30,000 at A3
Project Number:	620.040713
Date:	26-Sep-2024
Drawn by:	TS

Goonyella Complex PRCP
Rehabilitation Flood Assessment

PRCP Conditions Pluvial Modelling
Peak Velocities - 2% AEP

SLR

APPENDIX C1-1-3

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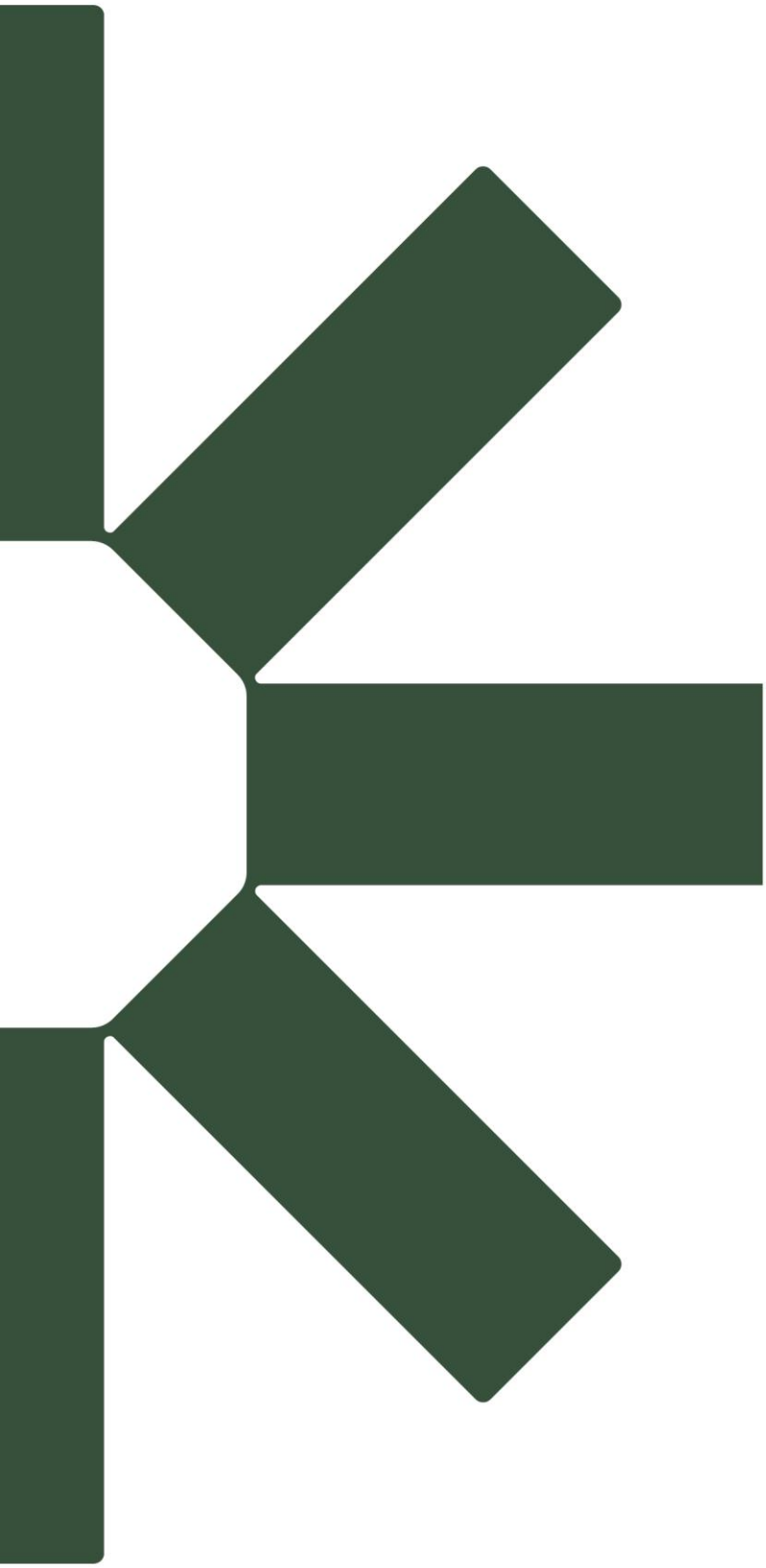

Making Sustainability Happen

BHP

Goonyella Riverside and Broadmeadow Mine

Progressive Rehabilitation and Closure Plan

Environmental Geochemical Characterisation and Risk Assessment of Mineral Waste

4 November 2024

Final Rev 0.

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EXECUTIVE SUMMARY

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials located on Goonyella Riverside and Broadmeadow Mine (GRBM), as supporting information for the progressive rehabilitation and closure plan (PRCP) for GRBM. GRBM comprises two operations: an open-cut mining operation called Goonyella Riverside Mine (GRM) and an underground mining operation called Broadmeadow Mine (BRM). Collectively, they are referred to here as GRBM.

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at GRBM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

GRBM is located approximately 25 kilometres (km) north of Moranbah township, in central Queensland, and is operated by BHP Mitsubishi Alliance Pty Ltd (BMA).

GRM commenced operations in 1971 and comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facilities (TSFs), rejects dumps, coal stockpiles, coal processing facilities, rail loadout facilities, process water and raw water dams, surface water drains and administration areas. BRM commenced operations in 2005 and comprises longwall underground mining infrastructure to extract coal and surface infrastructure to transfer run-of-mine (ROM) coal via overland conveyor to the coal handling and preparation plants (CHPPs) located at GRM. In this report BRM is considered only the underground operations, therefore no mineral waste is located at BRM and BRM does not contain any pits that, at closure, may remain as residual voids. As such, this environmental geochemical assessment is focused on GRM – where all mineral waste is generated and/or disposed.

The BMA Red Hill Mine (RHM) is an approved longwall underground mine neighbouring GRBM. Coal from RHM is approved to be processed at GRBM and the tailings and rejects will be disposed at GRBM. As such – and consistent with BRM – no mineral waste will be located at RHM and RHM will not contain any pits that, at closure, may remain as residual voids.

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Run-of-mine (ROM) coal processing at two coal handling and preparation plants (CHPPs): Goonyella (GY) CHPP and Riverside (RV) CHPP, which both produce two mineral waste types:
    - Tailings. Clay, silt and very fine to medium-grain sized sand material; disposed as a slurry into TSFs;
    - Rejects. Coarse sand to cobble-sized material; primarily disposed (buried) within spoil dumps. Historic rejects from Riverside CHPP were disposed at the Riverside rejects dump. Rejects have also been used in construction of TSF embankments and infrastructure pads; and capping of tailings at TSFs.
- Disposal of tailings from the CHPPs to the in-pit Ramp 32 TSF (Airstrip pit) [active since approximately 2019];
- Disposal of rejects from the CHPPs to in-spoil disposal areas;
- Short-term storage of ROM coal on the ROM Pads;
- Short-term storage of product coal on the product coal stockpiles, awaiting off-site transport by rail;

Historic activities of relevance to this waste characterisation report comprise:

- Disposal of tailings from GY CHPP to the above-ground GS1 TSF [inactive since late 2020];
- Disposal of tailings from RV CHPP to the above-ground RS1 TSF [inactive since early 2021];
- Disposal of tailings from the CHPPs to the in-pit DRE5 TSF [inactive since 2022].

Material types and quantities

GRBM has three main types of mineral waste, and the geochemical characteristics and potential hazards associated with mineral waste materials on site are discussed by type:

- Spoil (overburden and interburden) comprises approximately 98% of all mineral waste at GRBM and includes weathered waste (Tertiary and Permian-age) and fresh (unweathered) waste (all Permian-age).
- Tailings are generated at the CHPPs from processing ROM coal and typically represent the clay, silt and fine sand fractions of ROM waste. Throughout operations at GRBM, tailings have been disposed as a slurry into several TSFs – the current (active) TSF being Ramp 32 in-pit TSF. Tailings comprise approximately 0.5% of all mineral waste at GRBM – with this approximated proportion expected for the remaining life of asset mine plan.
- Rejects are generated at the CHPPs from processing ROM coal and typically represent coarser and rockier seam roof, partings and floor material. Rejects are trucked to spoil dumps and disposed (buried) within spoil. Historic rejects from RV CHPP were disposed at Riverside rejects dump. Some rejects have been used in construction of TSF embankments and infrastructure pads (e.g. ROM and coal stockpile pads) and for capping RS1 TSF. Rejects comprise approximately 1.5% of all mineral waste at GRBM – with this approximated proportion expected for the remaining life of asset mine plan.

Coal is also included in the assessment; however, coal is generally not considered mineral waste, with the exception of small quantities of sub-economic seams that may report to the spoil dumps, and remnant coal exposed on pit highwalls (such as in residual voids).

AMD Potential of Mineral Waste and Coal Material Types

Mineral waste samples have undergone environmental geochemical characterisation and assessment with regard to their potential to generate acid and metalliferous drainage (AMD), which comprises acid drainage (AD), neutral and metalliferous drainage (NMD) and/or saline drainage (SD) [salinity due to sulphate derived from sulphide oxidation]. Additionally, samples have been assessed with regard to their potential to generate salinity (non-oxidative) and, for spoil materials, their sodicity and dispersion potential.

AMD potential of spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 93% of spoil, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for mine spoil in the Bowen Basin.

Based on the results, non-carbonaceous spoil has a low potential to generate AMD as either AD and/or NMD and/or SD, but for a small proportion that is assessed to have a higher potential to generate AMD (as AD, NMD and/or SD). However, in consideration of the mixing and dispersion of a small volume of waste at higher potential for AMD within the broader spoil material, the overall potential for non-carbonaceous spoil (and bulk spoil, generally) to generate AMD is assessed to be low.

The total sulphur (S) concentration of non-carbonaceous spoil is very low, with a 90th percentile total S concentration of 0.08%. As such, and combined with moderate to high acid neutralising capacity (ANC) values (median 40 kg H_2SO_4/t), approximately 96% of 1169 non-carbonaceous spoil samples tested were classified as non-acid forming (NAF), with a further 3% (approximately) of samples classified as UC(NAF) [uncertain, but expected to be NAF]. Only 1.5% (approximately) of non-carbonaceous spoil samples were classified as potentially acid forming (PAF), PAF-LC [PAF, low capacity] or UC(PAF) [uncertain, but expected to be PAF]. No samples were classified as NAF-S [NAF, but with total S greater than 1%].

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-75% available under field conditions, with iron-dolomite and dolomite expected to be the main carbonate minerals contributing to the acid buffering potential of the spoil. Overall, non-carbonaceous spoil has excess acid neutralising capacity and is expected to be bulk acid consuming.

Total metal and metalloid concentrations from 114 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. About 30% of samples were significantly enriched with regard to selenium (Se); and a further 12 samples (11% of samples) were significantly enriched with regard to one or more of arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), S and/or antimony (Sb). There was no clear correlation found between these 'enriched' samples and their AMD classifications, however the enrichment in these elements in a small number of samples is not cause for concern. In summary, non-carbonaceous spoil (as a bulk material) has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 139 non-carbonaceous samples) indicate that leachate from this material is expected to contain low concentrations of soluble metals and metalloids under pH-neutral to alkaline conditions.

About 20% of samples produced moderate soluble metal concentrations in one or more of aluminium (Al), As, cobalt (Co), iron (Fe), manganese (Mn), nickel (Ni) and/or zinc (Zn) – under pH-neutral to alkaline leaching conditions (excluding two samples that produced weakly acidic pH leachate). Peroxide leaching undertaken on three non-carbonaceous spoil samples with PAF classification showed that some PAF material, when oxidised, has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

AMD potential of spoil – carbonaceous

Carbonaceous spoil represents approximately 7% of spoil material at GRBM and – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil. Most carbonaceous spoil is fresh (unweathered).

Based on the results from 143 samples, most carbonaceous spoil has a generally low to moderate potential to generate AD and/or NMD and/or SD. Some carbonaceous spoil – generally associated with coal seams – has a greater potential to generate low-level AD and/or NMD and/or SD.

The total S concentration of carbonaceous spoil is low, with a 90th percentile total S concentration of 0.38% (from 202 samples).

Approximately 90% (128 out of 143) of carbonaceous spoil samples were classified as NAF. The remaining 10% of carbonaceous spoil samples were classified as PAF, PAF-LC or UC(PAF) and had a low-moderate 75th percentile total S value of 0.62%. No samples were classified as NAF-S.

The test-work undertaken on a small sub-set of six samples has demonstrated that the ANC in these samples is expected to be about 20-50% available under field conditions, with iron-dolomite expected to be the main carbonate mineral contributing to the acid buffering potential of the carbonaceous spoil. Overall, carbonaceous spoil has modest acid neutralising capacity.

Total metal and metalloid concentrations from 22 carbonaceous spoil samples tested are generally very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. Similar to non-carbonaceous spoil, 10 carbonaceous spoil samples out of 22 were significantly enriched with regard to one or more of As and/or Se. The enrichment in these elements in a small number of samples is not cause for concern. There was no clear correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment. In summary, carbonaceous spoil (as a bulk material) has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 22 samples) indicate that leachate from carbonaceous spoil is expected to contain generally low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. Of the 22 samples, 16 had low soluble metal and metalloid concentrations under pH-neutral to alkaline conditions, and one sample had low soluble metal and metalloid concentrations under weakly acidic conditions. The remaining five samples had moderate soluble metal and metalloid concentrations – predominantly under pH-neutral to alkaline conditions. Peroxide leaching was undertaken on two fresh carbonaceous spoil samples classified as PAF and UC(PAF), which showed that PAF samples, when oxidised, have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

AMD potential of tailings

The geochemical characteristics differed between fresh tailings from the CHPPs verses aged tailings from the TSFs – particularly total S, ANC, net acid generation (NAG) pH and $pH_{1:5}$. However, the overall geochemical (AMD) hazard posed by tailings from the two sources (fresh vs aged) was generally similar. There was also no significant difference in the geochemical characteristics between the fresh tailings from each CHPP (i.e. GY CHPP versus RV CHPP) or between aged tailings from each of the main TSFs (i.e. GS1 TSF versus RS1 TSF). As such, the discussion that follows only differentiates between the two tailings sources (fresh versus aged) where the differences between the two sources was significant for some parameters and worthy of discussion. Else, the AMD potential of tailings is discussed as a bulk material – regardless of source.

Based on the results, approximately 51% of tailings has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, and remaining 49% (approximately) has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

The total S concentration of tailings is low-moderate, with a 75th percentile total S concentration of 0.7%. Fresh CHPP tailings had higher total S concentrations (median = 0.61%) compared to aged tailings samples (median = 0.39%) from TSFs. Scr accounts for approximately 49% (median value) of total S in fresh CHPP tailings and 45% (median value) of total S in aged tailings – the slightly lower proportion of Scr in aged tailings (compared to fresh tailings) is likely due to some sulphide in aged tailings being oxidised to sulphate (SO_4).

As a bulk material, tailings have generally moderate ANC (median 17 kg H_2SO_4/t), however the CHPP tailings had about twice the ANC of aged tailings – suggesting that a significant proportion of the neutralising material in tailings in the TSFs had been consumed since deposition. Combined with tailings (all) having generally low-moderate maximum potential acidity (MPA; median 17 kg H_2SO_4/t) values, resulted in approximately 49% of the tailings samples being classified as NAF [including 53 samples classified as UC(NAF)] and 48% of samples classified as PAF, PAF-LC or UC(PAF). Twelve samples were classified as NAF-S. That is, approximately half of all tailings were classified as 'PAF' (of some type) or NAF-S.

Test-work indicated that about 30-60% of the ANC is likely available under field conditions, however the 'field availability' of ANC ranged from 9% to 100%. The acid buffering characterisation curve (ABCC) data suggested iron-dolomite, dolomite, and lesser siderite, were the likely dominant carbonate minerals, which is broadly consistent with the mineralogy data. Carbonate concentrations were generally higher in fresh CHPP tailings (and rejects) samples compared to aged samples – the reason for this may be due to carbonate being consumed in the aged samples due to buffering reactions associated with sulphide oxidation. Consumption of carbonate is also consistent with the lower ANC values in aged tailings compared to fresh tailings.

Total metal and metalloid concentrations from 95 tailings samples tested are very low compared to average element abundance in soil in the earth's crust. However, all tailings samples were significantly enriched with regard with Se. Furthermore, 18 tailings samples were significantly enriched with regard to one or more of As and/or S. There was no clear correlation found between AMD classifications of the tailings samples compared to elemental enrichment.

Solubility data indicate that most tailings samples under freshwater (deionised water) leaching conditions are expected to have low soluble metals concentrations and have near-neutral to alkaline pH. About 5% of the tailings samples – mostly 'PAF' – had moderate soluble metals concentrations under weakly acidic to pH-neutral conditions; and one sample (classified as PAF) was elevated in soluble metals concentrations and was moderately acidic, confirming its' PAF classification. This suggests that overtime, 'PAF' tailings can generate AD as field ANC is consumed. Under saline leaching conditions tailings produced low concentrations of soluble metals and metalloids.

Peroxide leaching undertaken on 33 tailings samples (about two-thirds classified as 'PAF' of some type) showed that when exposed to highly oxidising conditions a significant proportion of tailings can produce weakly to highly acidic leachate with moderate to elevated soluble metals and metalloid concentrations. It must be noted that samples with potentially high organic carbon concentrations, such as some tailings samples, may be influenced by organic acids producing acidity and correspondingly elevated soluble metals concentrations unrelated to AMD. As such, the results for such coaly/carbonaceous samples should be interpreted with this in mind. Nevertheless, PAF tailings [including tailings classified as UC(PAF)] have typically produced moderate to elevated soluble metals and metalloid concentrations from the freshwater and peroxide leaching tests. These results indicate that PAF tailings have the potential to generate low pH leachate (AD), however the salinity (sulphate) loads are not expected to be high – due to generally low total S concentrations (with minor exceptions).

AMD potential of rejects

The geochemical characteristics of fresh rejects from the CHPP, aged rejects from TSFs and aged rejects from Riverside rejects dump were generally similar – except for NAGpH results. Excluding NAGpH, there was also no significant difference in the geochemical characteristics between the fresh rejects from each CHPP (i.e. GY CHPP versus RV CHPP) or between aged rejects from each of the main TSFs (i.e. GS1 TSF versus RS1 TSF) and/or between the TSFs and Riverside rejects dump. As such, the discussion that follows only differentiates between the three rejects sources (fresh versus aged TSF versus aged rejects dump) where the differences between the three sources was significant for some parameters and worthy of discussion. Else, the AMD potential of rejects is discussed as a bulk material – regardless of source.

Based on the results, 22% of the rejects (aged and fresh) has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas the remaining 78% (aged and fresh) has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

The total S concentration of rejects (fresh and aged) is generally low, with a median value of 0.31%. Scr accounts for approximately 72% (median value) of total S in aged rejects from Riverside rejects dump; 56% (median value) of total S in fresh CHPP rejects; and 49% (median value) of total S in aged rejects from TSFs. The slightly lower proportion of Scr in aged rejects from the TSFs compared to fresh rejects, and also compared to aged rejects from Riverside rejects dump is likely due to some sulphide in aged rejects in the TSFs being oxidised to sulphate.

Similar to tailings, rejects have generally moderate ANC (median 18 kg H_2SO_4/t) and generally low MPA (median 9 kg H_2SO_4/t) values, resulting in approximately 78% of the rejects samples being classified as NAF or UC(NAF). One sample was classified as NAF-S. The remaining 22% (approximately) of samples were classified as PAF, PAF-LC or UC(PAF). Test-work indicated that about 25-50% of the ANC in fresh rejects is expected to be available under field conditions; and about 35-65% available for the aged rejects. The ABCC data suggested iron-dolomite, dolomite and siderite were expected to be the dominant carbonate minerals, which is broadly consistent with the mineralogy data.

Total metal and metalloid concentrations from 52 rejects samples tested are very low compared to average element abundance in soil in the earth's crust. However, similar to tailings samples, all rejects samples were significantly enriched with regard to Se. Nine rejects samples were also significantly enriched with As. There was no clear correlation found between AMD classifications of the rejects samples compared to elemental enrichment.

Solubility data indicate that most rejects samples (54 out of 61 samples) under freshwater (deionised water) leaching conditions are expected to have low soluble metals concentrations and have near-neutral to alkaline pH. Four (of 61) rejects samples have moderate metals concentration associated with near-neutral to alkaline pH; and three rejects samples have moderate metals concentration associated with moderately to weakly acidic pH.

Peroxide leaching undertaken on 11 rejects samples (of mixed NAF/PAF classifications) showed that when exposed to highly oxidising conditions PAF rejects can produce moderately to highly acidic leachate with moderate to elevated soluble metals and metalloid concentrations – consistent with PAF tailings. The results suggest that under acid/acidic conditions, some rejects are capable of generating elevated metal and metalloid loads, however the sulphate (and salinity) loads are not expected to be high – due to the generally low total S concentration (with some exceptions).

AMD potential of coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time. However, some minor coal seams/plys will report directly as waste, and remnant coal (seams) will be exposed on the highwalls of residual voids at closure.

Coal represents about 8% (on average) of all lithological material at GRBM (about 5% to 10% of the highwall meterage) and, assuming the large majority all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste (i.e. nominally 1-2% at the most).

Based on the results, and as a bulk material, ROM coal is assessed as having a low-moderate to moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal (all seams) would have a moderate to moderate-high potential to generate AMD. ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

Coal samples had low total S values resulting in low MPA values (median 11 kg H_2SO_4/t), however due to the generally very low to low ANC values (median 6 kg H_2SO_4/t) resulted in 77% of coal samples being classified as PAF, PAF-LC or UC(PAF). The proportion of PAF (of any kind) is comparable across all coal seam groups being mined at GRBM. The low total S concentrations suggests that 'PAF' coal is unlikely to generate significant acid(ity).

Approximately 23% of coal samples tested (6 out of 26 samples) were classified as NAF, and coal seam material represented by these NAF samples has very low sulphur values, excess ANC (relative to the MPA) and clearly has negligible capacity to generate acidity or release significant sulphate from sulphide oxidation.

These results suggest that coal stored on the ROM pad, coal located within pit walls and un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would likely be bulk PAF – albeit, low capacity. From an acid

generating perspective, coal poses a potential source hazard with respect to AD and/or NMD/SD; and overall, is expected to generate low acidity loads.

Solubility data from three composite coal samples (classified as PAF and PAF-LC) tested under freshwater (deionised water) leaching conditions indicates low soluble metals concentrations at near-neutral to alkaline pH. An additional composite coal sample (classified as PAF) had moderate soluble metals concentration associated with near-neutral to alkaline pH.

Salinity, Sodicity and Dispersion Potential of Mineral Waste and Coal Material Types

Salinity, sodicity and dispersion potential of spoil – non-carbonaceous

Non-carbonaceous spoil has low median and moderate 90th percentile electrical conductivity (EC)$_{1:5}$ values of 414 and 910 microSiemens per centimetre (µS/cm), respectively, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally non-saline to slightly saline, as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity). Weathered non-carbonaceous spoil generally has higher EC$_{1:5}$ values compared to fresh non-carbonaceous spoil.

Non-carbonaceous spoil has modest cation exchange capacity (CEC) values and generally high exchangeable sodium percentage (ESP) values, resulting in most samples being classified as ‘sodic’ to ‘strongly sodic’ and, therefore, with potential for dispersion. Based on Emerson aggregate class testing to directly measure dispersion, about 31% of the samples displayed some degree of dispersion. Although not entirely consistent with the ESP results, the Emerson Class test results suggest a significant proportion of spoil is expected to be dispersive to some degree.

Salinity, sodicity and dispersion potential of spoil – carbonaceous

Carbonaceous spoil has median and 90th percentile EC$_{1:5}$ values of 272 and 655 µS/cm, respectively, and has low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be similar to non-carbonaceous spoil. That is, generally non-saline to slightly saline, primarily as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples had similar CEC values compared to non-carbonaceous spoil, and comparable ESP values – with the exception of weathered carbonaceous samples, which had lower ESP values compared to fresh samples. This resulted in the fresh samples being classified as ‘strongly sodic’ and the weathered samples classified as ‘sodic’ to ‘strongly sodic’. As such, and based solely on the moderate to high sodicity values, carbonaceous spoil is expected to be sodic (to some degree) with potential for dispersion. Sixteen carbonaceous spoil samples underwent Emerson aggregate class testing to directly measure dispersion, which found three (out of 16) samples were dispersive.

Salinity potential of tailings

Tailings samples have EC$_{1:5}$ values ranging from 118 to 5320 µS/cm, with median and 90th percentile EC$_{1:5}$ values of 717 and 1556 µS/cm, respectively. The EC$_{1:5}$ values were generally similar between fresh and aged tailings, resulting in tailings generally being slightly to moderately saline. The generally low total S for aged tailings and low-moderate total S for fresh tailings conservatively suggests a low-moderate potential for SD (from sulphide oxidation).

Salinity potential of rejects

Rejects samples have EC$_{1:5}$ values ranging from 389 to 3260 µS/cm, with median and 90th percentile EC$_{1:5}$ values of 389 and 774 µS/cm, respectively. The fresh CHPP rejects were generally non-saline with a 90th percentile EC$_{1:5}$ value of 550 µS/cm. Aged rejects had higher EC$_{1:5}$ values compared to fresh rejects with 90th percentile values of 792 µS/cm (for the TSF samples) and 1090 µS/cm (for Riverside rejects dump samples). Most rejects had low total S concentrations (median = 0.31%), suggesting the potential for SD (from sulphide oxidation) from rejects is low.

Salinity potential of coal

Coal has low median and 90th percentile EC$_{1:5}$ values of 90 and 524 µS/cm, respectively; and has generally low to low-moderate total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk

material, is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity).

Geochemical Source Hazard Assessment of Material Types

A geochemical source hazard assessment was applied to the source material types comprising carbonaceous and non-carbonaceous spoil, tailings, rejects and coal (where relevant). The source hazard score is a formula devised by the authors that takes into account the propensity to generate AMD, the AMD capacity (severity) and the quantity (volume/tonnage) of material that could produce AMD. The AMD source hazard scores are as follows:

- Spoil – non-carbonaceous: AMD source hazard score = **Low-Moderate**
- Spoil – carbonaceous: AMD source hazard score = **Moderate**
- Tailings: AMD source hazard score = **Moderate-High** (score ranged from Moderate to High depending upon the TSF facility, but was generally Moderate-High).
- Rejects: AMD source hazard score = **Moderate** (score ranged from Low-Moderate to Moderate depending upon the rejects facility, but was generally Moderate)
- Coal: AMD source hazard score = **Low-Moderate**

When combined, and taking into account the proportion of material that could generate AMD relative to the total proportion of all materials in a final landform (spoil or TSF or rejects landform and residual voids), the AMD hazard score for the landforms, void highwalls and void floors at closure has been determined. The AMD source hazard of likely future mineral wastes generated from GRM, BRM and RHM is expected to be consistent with the AMD source hazard based on current data and existing mineral wastes.

Spoil landforms

There are four spoil landforms at GRBM that will remain at closure:

- Goonyella
- Thiess
- Airstrip
- Broadmeadow-Isaac

The GRBM PRCP considers Thiess spoil dump as part of Goonyella spoil landform. However, due to its' proximity to Thiess pit, it has been assessed herein as a separate spoil landform. Each landform will have a similar construction, comprising mined overburden and interburden disposed behind the active mining face to form a low-wall spoil dump, which will be reshaped to form a final spoil landform.

Goonyella, Airstrip and Broadmeadow-Isaac spoil landforms contain a small proportion of existing or planned future rejects (between 0.1% and 3%, depending on the landform). Thiess spoil landform comprises approximately 16% existing rejects located predominantly at R22 rejects dump. Due to the location of R22 rejects dump at the periphery of Thiess spoil landforms where rejects are concentrated, R22 rejects dump has been conservatively assessed as a 'stand-alone' rejects dump.

DRE5 in-pit TSF will be located within the north-western area of Thiess spoil dump at closure and will comprise less than 1% of the landform, and Ramp 32 in-pit TSF will be located within the Airstrip spoil dump and will comprise approximately 7% of the landform. Due to the location of these two TSFs at the base of their respective spoil landforms where tailings are concentrated, these two TSFs have been conservatively assessed as 'stand-alone' TSFs. There are no current tailings/TSFs within Goonyella or Broadmeadow-Isaac spoil landforms.

Taking into account material quantities (proportions) and expected proportion of PAF and NAF-S materials reporting to each individual landform:

- Each of the four spoil landforms poses a **Low** AMD hazard, with AMD generation rated as **Highly Unlikely**.

The 'Low' AMD hazard is largely a result of less than 2% of non-carbonaceous spoil samples being classified as PAF of some type (or NAF-S) – and non-carbonaceous spoil comprises the overwhelming majority of mineral waste within each spoil landform.

GS1 TSF landform

GS1 TSF is a large 'turkey's nest' style TSF. The embankments are comprised of earthen-filled 'starter' embankments then raised (expanded) with rejects. The core of the TSF contains tailings. The TSF operated from approximately 1971 to 2021, receiving tailings from GY CHPP.

The source materials within GS1 TSF includes tailings, which are estimated to comprise approximately 95% of the landform; and rejects, which are estimated to comprise about 5% of the landform and form the basis of the embankments. The assessment assumes the TSF landform also includes a small proportion (approximately 0.5%) of spoil/fill material, predominantly within embankments.

Investigative drilling coupled with near-surface sampling has demonstrated that some tailings in the field at GS1 TSF are generating AMD (as AD and SD). Oxidation fronts are present in the TSF as demonstrated by decreasing sulphide concentrations from surface down, consumption of ANC, presence of secondary minerals generated through sulphide oxidation, and acid contact pH water. AMD has also been observed in seepage from the toe of the TSF and in nearby Holding Paddock Creek.

The source hazard assessment for the mineral wastes within the TSF landform has utilised the same general methodology as applied to the spoil landforms. The source hazard assessment has found the tailings within GS1 TSF landform poses a **Moderate-High** AMD source hazard; and rejects poses a **Moderate** AMD source hazard. Fill material poses a **Low-Moderate** AMD source hazard. On this basis, and taking into account material quantities (proportions):

- GS1 TSF landform (currently, without a rehabilitation cover) poses a **Moderate-High** AMD hazard, with AMD generation rated as **Highly Likely** – the highest landform AMD likelihood category – noting that AMD processes and/or AMD impacted contact water have already been observed at/from this TSF. The AMD hazard is considered to predominantly lie with the tailings, and lesser so the rejects.

The AMD hazard scores for the tailings and rejects materials are considered to be conservative and the landform domain AMD hazard score for GS1 TSF is also considered to be conservative.

RS1 TSF

RS1 TSF is a large 'turkey's nest' style TSF. The TSF has been constructed as two compartments: a western compartment comprised of rejects and an eastern compartment comprised of tailings. The tailings (from RV CHPP) are contained within earth- and rejects-filled eastern and southern embankments and a northern embankment constructed from rejects. The western compartment contains (holds back) the tailings on the western side. The TSF commenced operations in approximately 1983 and ceased receiving tailings in 2021. Rejects from RV CHPP are currently disposed into the TSF (primarily the western compartment). Future rejects from RV CHPP are planned to be disposed onto the eastern compartment and will cover the tailings.

Separate AMD source hazard assessments have been completed for each compartment of RS1 TSF. The western compartment comprises rejects only. The eastern compartment is estimated to comprise approximately 85% tailings and 15% rejects. The assessment assumes the eastern compartment also includes a small proportion (approximately 0.5%) of spoil/fill material, predominantly within embankments.

Investigative drilling coupled with near-surface sampling has demonstrated that some tailings in the field at RS1 TSF are generating AMD (as AD and SD). Oxidation fronts are present in the TSF as demonstrated by decreasing sulphide concentrations from surface down, consumption of ANC, presence of secondary minerals generated through sulphide oxidation, and acid contact pH water.

- RS1 TSF western compartment [rejects only] (currently, without a rehabilitation cover) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.
- RS1 TSF eastern compartment [tailings and rejects] (currently, without a rehabilitation cover) poses a **Moderate-High** AMD hazard, with AMD generation rated as **Highly Likely** – noting that AMD processes and/or AMD impacted contact water have already been observed from RS1 TSF. The AMD hazard is considered to predominantly lie with the tailings, and lesser so the rejects.

The AMD hazard scores for the tailings and rejects materials are considered to be conservative and the AMD hazard scores for each compartment of RS1 TSF are also considered to be conservative.

DRE5 in-pit TSF

DRE5 in-pit TSF is located within the pit shell of Thiess pit (Thiess void) and within the Thiess spoil landform footprint. As such, it is not a true 'stand-alone' TSF landform, however, is conservatively assessed as such given the concentrated nature of tailings at the base of the spoil landform.

The source materials within the TSF includes tailings only. No investigative drilling has been undertaken in the vicinity of this TSF. No evidence of AMD has been observed in the field. The AMD source hazard assessment is based on data from fresh (CHPP) tailings.

The source hazard assessment for the tailings within the TSF has utilised the same general methodology as applied to other TSF landforms. The source hazard assessment has found the tailings within the TSF landform pose a **Moderate** AMD source hazard.

On this basis, and taking into account material quantities (all tailings):

- DRE5 in-pit TSF (prior to rehabilitation and when fully unsaturated) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.

The AMD hazard score for the tailings is considered to be conservative and the landform domain AMD hazard score for the TSF is also considered to be conservative.

Ramp 32 in-pit TSF

Ramp 32 in-pit TSF is located within Airstrip pit and within the Airfield spoil landform footprint. As such, it is not a true 'stand-alone' TSF landform, however, is conservatively assessed as such given the concentrated nature of tailings at the base of the spoil landform.

The source materials within the TSF includes tailings only. No investigative drilling has been undertaken in the vicinity of this TSF. No evidence of AMD has been observed in the field. The AMD source hazard assessment is based on data from fresh (CHPP) tailings.

The source hazard assessment for the tailings within the TSF has utilised the same general methodology as applied to other TSF landforms. The source hazard assessment has found the tailings within the TSF landform pose a **Moderate** AMD source hazard.

On this basis, and taking into account material quantities (all tailings):

- Ramp 32 in-pit TSF (prior to rehabilitation and when fully unsaturated) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.

The AMD hazard score for the tailings is considered to be conservative and the landform domain AMD hazard score for the TSF is also considered to be conservative.

Riverside rejects landform

Riverside rejects dump received rejects from RV CHPP until approximately 1998. The dump underwent some rehabilitation activities in the early 2000s, but due to the substantial corrective action required to achieve the required post-mining land use (PMLU) it has not been included as existing rehabilitation in the PRCP schedule. The dump will remain as a 'stand-alone' rejects landform at closure. The dump is located to the southwest of RS1 TSF.

Excluding the spoil cover currently in place, the dump essentially comprises only rejects (over 99% by volume). It is assumed a small amount of 'fill' (assume spoil) may lie within the dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of the landform.

The source hazard assessment for the mineral wastes within the rejects dump has utilised the same general methodology as applied to the spoil and TSF landforms. The assessment excludes the existing spoil cover. The source hazard assessment has found the rejects within the dump poses a **Moderate** AMD source hazard. Fill

material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- Riverside rejects dump (excluding the cover) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**. The AMD hazard lies with the rejects, which comprise essentially all of the dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dump is also considered to be conservative.

GS2, GS11 and R22 rejects landforms

GS2, GS11 and R22 rejects dumps receive rejects from GY CHPP. GS2 dump is located to the northeast of (and adjacent to) GS1 TSF. GS11 dump is located east of GS1 TSF between Ramp 32 TSF and Eureka Creek. GS2 and GS11 rejects dumps are located outside of a spoil landform and will remain as 'stand-alone' rejects landforms at closure.

R22 rejects dump is located within the southwestern periphery of the Thiess spoil landform. As such, it is not a true 'stand-alone' rejects landform, however, is conservatively assessed as such given the concentrated nature of rejects near the edge of the spoil landform and where they are unlikely to be deeply buried by spoil within the core of the spoil landform. The rejects dump is situated on top of the Thiess spoil dump (i.e. it is underlain by spoil).

All three dumps essentially comprise only rejects (over 99% by volume). It is assumed a small amount of 'fill' (assume spoil) may lie within each dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of each landform.

The source hazard assessment for the mineral wastes within the rejects dumps has utilised the same general methodology as applied to the spoil and TSF landforms. The source hazard assessment has found the rejects within the dumps poses a **Low-Moderate** AMD source hazard. Fill material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- GS2, GS11 and R22 rejects dumps pose a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. The AMD hazard lies with the rejects, which comprise essentially all of each dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dumps is also considered to be conservative.

Residual voids

There are five pit groups at GRBM that will remain at closure as residual voids:

- Goonyella void; approximately 11 km long with an average depth of 304 m (at closure);
- Thiess void; approximately 3.9 km long with an average depth of 78 m (at closure);
- Broadmeadow-Isaac void; approximately 5.1 km long with an average depth of 83 m (at closure);
- Ramp 32 East void; approximately 1.6 km long with an average depth of 94 m (at closure); and
- Ramp 32 South void; approximately 1.0 km long with an average depth of 69 m (at closure).

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD hazard associated with residual void highwalls and floors.

The highwall AMD hazard assessment has found that approximately 7% to 10% of the void highwall in all voids is estimated to be PAF, which includes material classified as UC(PAF), PAF-LC and NAF-S – and most of this is expected to be associated with coal seams. As such, the assessment has found that the overall likelihood of AMD generation from the void highwalls is **Unlikely**. The expression of AMD from coal seams in the highwalls of residual voids, if any, will most likely be localised.

Excluding Broadmeadow-Isaac void, the floor of all residual voids at closure will be the GLS seam. The floor of Broadmeadow-Isaac void is the GMS seam. Assuming the floor of each void is all coal – which is a highly conservative assumption – the void floor AMD hazard assessment has found that essentially all of the floor of each

void is estimated to be 'PAF', which includes material classified as PAF, UC(PAF), PAF-LC and NAF-S. As such, the conservative assessment has found that the likelihood of AMD generation from the floor of these voids is **Probable/Likely** until such time that the floor becomes submerged by groundwater (post-closure). In practice, mining takes all coal to the bottom of the seam, therefore very little coal would be expected to remain on the floor of the voids.

Geochemical Source-Pathway-Receptor (SPR) Assessment

The source-pathway-receptor (SPR) assessment includes the likelihood of the event occurring (e.g. the likelihood of AMD impacting a local creek), the severity of the event (should it occur) and the calculated risk rating (likelihood times severity). A risk rating was calculated for each spoil landform, each TSF landform, each rejects landform and each residual void with respect to plausible surface water and groundwater receptors.

Conceptual site model and conceptual facility models

A post-mining conceptual site model (CSM), which applies generically to the spoil landforms and their respective residual voids at GRBM, and the relationship that spoil landforms and residual voids have with surface water and groundwater in the district, has been produced by AECOM (2024).

The CSM assists with the SPR assessment with regard to potential environmental geochemical impacts from mineral waste facilities. A key element of the CSM based on the AECOM (2024) hydrogeological assessment (which included groundwater modelling) was that all residual voids at GRBM will be groundwater 'sinks' (i.e. groundwater at GRBM will flow into/towards the residual voids, and the voids will be the receptors of seepage from all facilities at GRBM).

A conceptual facility model (CFM) has been developed for each TSF and for Riverside rejects dump to illustrate potential run-off and seepage pathways and surface water and groundwater receptors associated with these key mineral waste facilities.

Plausible pathways and receptors

Note: the assessment of shallow groundwater at GRBM – particularly where shallow permeable strata may be not present in some areas, discontinuous and/or not interconnected – is limited by/to the distribution of the shallow bore network, which is sporadic. Therefore, despite the apparent low likelihood of substantial connection between shallow permeable strata and surface water features, the SPR assessment has adopted a highly conservative approach and assumed a plausible pathway *may* exist between shallow permeable strata and surface water features. All creeks at GRBM are ephemeral. The surface water features (creeks) at GRBM are:

- Isaac River flows into the site from the northeast, then flows east of the Goonyella void and east of Broadmeadow-Isaac void, exiting the site south of Ramp 32 South void. The river channel is a diversion channel (i.e. not the original/natural watercourse) from approximately the southern end of Goonyella void through until the river exits the site;
- Goonyella Creek is located in the north-eastern area of the site and flows southwards into Isaac River east of Goonyella void;
- Eureka Creek traverses the site in an approximately northwest to southeast direction between Thiess pit/void and Broadmeadow-Isaac pit/void; and joins the Isaac River east of Broadmeadow-Isaac void and south of Goonyella void;
- Holding Paddock Creek is a small creek that flows from (and around) the southwestern and southern side of GS1 TSF southwards around Airstrip pit spoil dump and joins into Fisher Creek west of Ramp 32 South void;
- Fisher Creek flows into the southwestern corner of the site from the west, joining into Platypus Creek near the southern boundary of the site (ML boundary);
- Platypus Creek flows into the southwestern corner of the site from the west, joining into Isaac River at approximately the southern boundary of the site.

Minor tributaries flow into the above watercourses outside of GRBM.

With regard to the spoil landforms, the plausible mechanisms for AMD affected water and/or non-oxidative salinity, if any, to report to receptors are:

- Surface water run-off from spoil landforms into nearby creeks;
- Seepage from spoil landforms via shallow permeable strata into nearby creeks;
- Seepage from spoil landforms into the residual voids; and
- Surface water run-off and seepage from void highwalls into residual voids.

With regard to the TSF and rejects landforms, the plausible mechanisms for AMD affected water and/or non-oxidative salinity, if any, to report to receptors are:

- Surface water run-off from TSF or rejects landforms into nearby creeks;
- Seepage from TSF or rejects landforms via shallow permeable strata into nearby creeks; and
- Seepage from TSF or rejects landforms via groundwater into residual voids.

The SPR has conservatively assumed that shallow permeable strata are a plausible pathway linking a potential AMD source to deeper groundwater via downwards migration and linking a potential AMD source to nearby creeks via lateral migration. However, shallow permeable strata are assumed to be an *implausible final receptor* of run-off and seepage from final landforms and final voids. That is, the assumption based on information available is that AMD (source) entering shallow permeable strata (however (un)likely) will ultimately find its' way into deeper groundwater [residual voids] and/or local surface water features.

SPR risk rating of rehabilitated spoil landforms

There are plausible surface water and residual void receptors associated with final spoil landforms; and the run-off and seepage pathways linking the sources (final spoil landforms) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from final spoil landforms is **Low**. With respect to non-oxidative salinity the overall SPR risk from final spoil landforms is also rated as **Low**.

DRE5 in-pit TSF and Ramp 32 in-pit TSF are located within Thiess and Airstrip spoil landforms, respectively, and contain a concentration of tailings. As such, these two TSFs are addressed as stand-alone facilities and are not included as part of their respective spoil landforms. Similarly, R22 in-pit rejects landform is located within Thiess spoil landform (at the southern edge of the landform) and contains a concentration of rejects. As such, this rejects dump is addressed as a stand-alone facility and is not included as part of the Thiess spoil landform.

SPR risk rating of rehabilitated GS1 TSF landform

There are plausible surface water receptors located very close to GS1 TSF; and the run-off and seepage pathways linking the source (GS1 TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low** to **Medium**. The 'Low-Medium' risk rating applies to AMD associated with seepage via shallow permeable strata into Holding Paddock Creek, located less than 100 m from the TSF. The likelihood of AMD reaching Holding Paddock Creek is unlikely, however the severity of the event, should it occur, has been rated as moderate (S3). With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is rated as **Low**.

Groundwater modelling (AECOM, 2024) indicates there are no plausible groundwater receptors from GS1 TSF post-closure landform due to the significant depth to the water table below the TSF (>50 m) and the significant thickness of low-permeability sediments forming an aquitard.

SPR risk rating of rehabilitated RS1 TSF landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (RS1 TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**. The likelihood of AMD reaching any of the receptors was rated as 'Highly Unlikely' (due to the significant distance from the TSF to the nearest receptor [Eureka Creek]) however

the severity of AMD potentially impacting the water quality of Eureka Creek via a shallow permeable pathway, should it occur, has been rated as moderate (S3).

Groundwater modelling (AECOM, 2024) suggests that seepage from RS1 TSF would likely report to Goonyella residual void. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of Goonyella residual void has been rated 'Unlikely'.

SPR risk rating of rehabilitated Ramp 32 in-pit TSF landform

There are plausible residual void receptors, and the seepage pathways linking the source (Ramp 32 in-pit TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) suggests that seepage from Ramp 32 in-pit TSF would likely report to Ramp 32 East and Ramp 32 South residual voids. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of these two residual voids has been rated 'Unlikely'.

SPR risk rating of rehabilitated DRE5 in-pit TSF landform

There are plausible residual void receptors, and the seepage pathways linking the source (DRE5 in-pit TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) suggests that seepage from DRE5 in-pit TSF landform into groundwater will ultimately report to Goonyella residual void, likely via Thiess residual void. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of these two residual voids has been rated 'Unlikely'.

SPR risk rating of rehabilitated Riverside rejects landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (Riverside rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) suggests that seepage from Riverside rejects landform would likely report to Goonyella residual void. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Goonyella residual void has been rated 'Unlikely'.

SPR risk rating of rehabilitated GS2 rejects landforms

Eureka Creek is located very close to the facility; and the run-off and seepage pathways linking the source (GS2 rejects landform) to Eureka Creek have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. The likelihood of seepage reaching nearby Eureka Creek is considered probable, however the severity of the event, should it occur, is low. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) indicates there are no plausible groundwater receptors from GS2 rejects post-closure landform due to the significant depth to the water table below the facility (>50 m) and the significant thickness of low-permeability sediments forming an aquitard.

SPR risk rating of rehabilitated GS11 rejects landforms

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (GS11 rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) indicates that seepage from GS11 rejects landform into groundwater is expected to report to Ramp 32 East residual void. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Ramp 32 East residual void has been rated 'Unlikely'.

SPR risk rating of rehabilitated R22 rejects landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (R22 rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**.

Groundwater modelling (AECOM, 2024) suggests that seepage from R22 rejects landform into groundwater is expected to report to Thiess residual void and then continue on towards Goonyella residual void. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Thiess and Goonyella residual voids has been rated 'Unlikely'.

SPR risk rating of residual voids

Modelling undertaken by AECOM (2024) shows Goonyella void to be a strong groundwater sink – drawing in groundwater from most of the site. Thiess and Broadmeadow-Isaac voids will be local 'sinks' – receiving surface water run-off and seepage from their respective spoil landforms and surface water run-off from their void highwalls. Ultimately, seepage from Thiess and Broadmeadow-Isaac residual voids will migrate to Goonyella residual void. Ramp 32 East and South residual voids are expected to function as week groundwater sinks from their local area. Each residual void is expected to receive inflow from the Permian groundwater aquifer.

The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure residual void floor would impact on residual void water quality to any significant degree, as other processes such as evapoconcentration (WSP, 2024) are the key drivers of void lake water quality. Therefore, the AMD SPR risk rating on the overall water quality of the residual voids is **Low to Low-Medium**. A "Low to Medium" risk rating has been conservatively applied to the risk of AD or SD due to the AMD risk associated with exposed coal seams in the highwalls (coal seams comprise between 5% to 10% of the exposed highwalls). However, not all exposed coal is expected to be PAF (and/or have high total and sulphide concentrations).

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by AECOM (2024) shows that seepage from Thiess and Broadmeadow-Isaac void lakes into groundwater would report to (be captured by) Goonyella void, and that seepage from Goonyella void outwards into the regional groundwater aquifer is implausible due to Goonyella void being a strong groundwater sink. Modelling also shows that Ramp 32 East and South voids are expected to be weak groundwater sinks, therefore seepage from Ramp 32 East and South void lakes into groundwater is not expected and, if it were to occur, would be limited and would ultimately be captured by Goonyella void.

Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by spoil landforms likely to be present at closure are generally low. As such, no specific AMD management measures (e.g. alkaline amendment or engineered capping systems) are expected to be required to manage spoil landforms during rehabilitation and closure – outside of operational mixing/burial of PAF waste amongst NAF waste, spoil placement and landform reshaping activities already proposed (refer below and to the main volume of the PRCP).

The environmental risk associated with the current (rehabilitated) Riverside rejects dump is generally low and there is no field evidence of AMD coming from the facility. The rejects buried within the landform have been assessed as posing a moderate AMD source hazard and the facility will continue to be monitored during operations. The facility will undergo further rehabilitation to meet the required PMLU.

Currently (i.e. prior to rehabilitation), the AMD source hazard associated with GS1 TSF is moderate-high and, as such, the TSF landform will require specific AMD management measures to manage this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this stand-alone TSF landform is expected to decrease.

Currently (i.e. prior to rehabilitation), the AMD source hazard associated with RS1 TSF is moderate to moderate-high. The western compartment comprising rejects only has a moderate source hazard (i.e. this compartment is essentially a rejects dump). The eastern compartment comprising predominantly tailings, with less rejects, has a moderate-high AMD source hazard (this compartment is the TSF). This stand-alone landform will require specific AMD management measures to manage this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this stand-alone landform is expected to decrease.

The AMD source hazard associated with Ramp 32 in-pit TSF (currently; prior to rehabilitation) is moderate. This in-pit TSF will be backfilled with spoil, which is an appropriate strategy to manage the AMD hazard posed by this facility post-closure. Once rehabilitated (backfilled), the post-closure environmental risk posed by this TSF is expected to decrease.

The AMD source hazard associated with DRE5 in-pit TSF (currently; prior to rehabilitation) is moderate. This small in-pit TSF will be partially backfilled with spoil to encourage free-drainage from the southern end of the facility onto the Thiess spoil landform. This is an appropriate strategy to manage the AMD hazard posed by this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this TSF is expected to decrease.

The AMD source hazard associated with GS2, GS11 and R22 rejects dumps (currently; prior to rehabilitation) is low-moderate. After re-shaping and installation of a spoil cover (i.e. once rehabilitated) the post-closure environmental risk posed by these spoil dumps is expected to decrease.

Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

Proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report comprise the following actions. Refer to the main volume of the PRCP for detailed information.

- Pits: will remain as residual voids under five groups:
    - Goonyella void;
    - Thiess void;
    - Broadmeadow-Isaac void;
    - Ramp 32 East void; and
    - Ramp 32 South void.
- Spoil dumps: Lenton pit is currently being backfilled and becoming part of the Goonyella spoil landform. Airstrip spoil dump (associated with Ramp 32 East and Ramp 32 South voids) will be reshaped and rehabilitated. All other spoil dumps will be reshaped into three final spoil landforms (as related to their respective voids listed above) and seeded.
- GS1 TSF (out-of-pit; above ground; stand-alone) will be covered by an engineered spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of the out-of-pit TSF will be determined following further assessment prior to covering.
- RS1 TSF (out-of-pit; above ground; stand-alone) will be covered by an engineered spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of the out-of-pit TSF will be determined following further assessment prior to covering.
- DRE5 in-pit TSF will be covered by spoil (partially backfilled) within the Thiess spoil landform – noting that Thiess spoil landform is a sub-zone within Goonyella spoil landform. The optimal design and thickness of spoil cover to manage the AMD hazard of the in-pit TSF will be determined following further assessment prior to covering.
- Ramp 32 in-pit TSF (Airstrip pit) will be backfilled by spoil within the Airstrip spoil landform.
- Riverside rejects dump (above ground; stand-alone) is already covered with spoil, but further rehabilitation activities are scheduled to achieve the PMLU.
- GS2 and GS11 rejects dumps (out-of-pit; above ground; stand-alone) will be covered by a spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of these two rejects dumps will be determined following further assessment prior to covering.

- R22 in-pit rejects dump will be covered by a spoil cover within the Thiess spoil landform. The optimal design and thickness of spoil cover to manage the AMD hazard of this rejects dump will be determined following further assessment prior to covering.
- All other rejects (in-spoil co-disposal): Managed during operations (disposed within spoil) and progressively covered by spoil. No additional remediation for the rejects (at closure) is required. The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment prior to covering.
- ROM pads: Remove remnant coal from ROM pads and dispose within spoil. All former ROM pads will be reshaped, covered with soil, ripped and seeded.
- Coal stockpiles: Remove remnant coal from coal stockpile pads and dispose within spoil. Cover with suitable soil material, rip and seed.

GLOSSARY OF TERMS

Key terms and definitions as used in this report are listed below:

Acid	A measure of hydrogen ion (H^+) concentration in water; generally expressed as pH.
Acidity	A measure of hydrogen concentration and latent acidity generated by metal hydroxylation, expressed as mg/L.
Acid-Base Account (ABA)	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determined by the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below. See also ANC and MPA.
AD	Acid drainage. A component of AMD, AD occurs where drainage is acidic as a result of sulphide oxidation reactions, and contains elevated trace metals and metalloids in solution.
AMD	Acid and metalliferous drainage. AMD has three components: acid drainage (AD), pH-neutral and metalliferous drainage (NMD) and/or sulphide-derived saline drainage (SD) – and/or any combination of these, all generated by sulphide oxidation processes +/- neutralisation reactions.
ANC	Acid neutralising capacity, expressed as kg H_2SO_4 per tonne of rock/material. A measure of a sample's maximum potential ability to neutralise acid.
ANC/MPA ratio	Ratio of the acid neutralising capacity (ANC) to the maximum potential acidity (MPA) of a sample. Used to assess the risk of a sample generating acid conditions. See also ANC and MPA.
BRM	Broadmeadow Mine. The name of the underground mining operation at GRBM.
CFM	Conceptual facility model.
CHPP	Coal handling and preparation plant. GRBM has two CHPPs: Goonyella (GY) CHPP and Riverside (RV) CHPP.
Co-Disposal	The practice of disposing different waste types together. For example, disposing coarse reject amongst spoil.
CFM	Conceptual facility model.
CSM	Conceptual site model.
EC	Electrical conductivity, expressed as µS/cm.
GLS	Goonyella Lower Seam group.
GMS	Goonyella Middle Seam group.
GUS	Goonyella Upper Seam group.
GRBM	Goonyella Riverside and Broadmeadow Mine. The name of the site subject to this PRCP.
GRM	Goonyella Riverside Mine. The name of the open-pit mining operation at GRBM.
Interburden	Potential spoil material located between mined coal seams. See also Overburden, Mineral waste and Spoil.
Kinetic test	Procedure used to measure the geochemical/weathering behaviour of a sample of mine material over time.
Mineral waste	Material comprising mine spoil, ± coarse/fine reject, ± waste coal. Sometimes called 'mine waste' or 'mining waste'.

MPA	Maximum potential acidity. Calculated by multiplying the total sulphur (S) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne of rock/material (kg H_2SO_4/t). Assumes all sulphur is present as sulphide and will oxidise to generate acid.
NAF	Non-acid forming. Geochemical classification criterion for a sample that would not generate acid conditions. A sample classified as NAF may, or may not, have a significant sulphur content but the availability of neutralising material within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acid(ic) drainage, however NAF material may still develop NMD and/or SD, depending on sulphur concentration.
NAG	Net acid generating test. A pulp sample is reacted with hydrogen peroxide to encourage rapid oxidation. Any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity (after neutralising material is consumed) is measured and expressed as kg H_2SO_4/t. At the conclusion of the NAG test the resulting liquor is called peroxide (NAG) leachate, and can be analysed for various parameters, such as soluble metals.
NAPP	Net acid producing potential, expressed as kg H_2SO_4 per tonne of rock/material (kg H_2SO_4/t). Calculated by subtracting the ANC from the MPA.
NMD	Neutral and metalliferous drainage. A component of AMD, NMD occurs where drainage is pH-neutral or higher yet contains elevated trace metals and metalloids in solution.
Org S	Organic sulphur.
Overburden	Mineral (mining) waste located above (overburden proper) or between (interburden) coal seams and reports to spoil dumps. Typically comprises non-coaly and non-carbonaceous material, such as sandstone, siltstone and claystone/mudstone, but also includes a small percentage of carbonaceous material (e.g. carbonaceous siltstone) and sub-economic waste coal.
PAF	Potentially acid forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions. A sample classified as PAF has an acid generating potential (MPA) that exceeds the inherent acid neutralising capacity (ANC) of the material. This means that such a material is likely to generate acidic drainage (AD) if exposed to atmospheric conditions. See also PAF-LC.
PAF-LC	Potentially acid forming (low capacity). Geochemical classification criterion for a sample that has the potential to generate relatively low-level AD.
PRCP	Progressive rehabilitation and closure plan.
Product coal	Coal produced from the CHPP after being washed/processed. Coal that is ready for sale.
Rejects	Coarse sand to cobble-sized rock material produced during coal processing. Rejects are typically associated with the roof, floor and partings of coal seams and are separated from ROM coal in the CHPP. Rejects comprises about 1.5% of mineral waste at GRBM.
Rejects dump	In-pit or out-of-pit reject disposal location.
ROM	Run-of-Mine. The term given to mined coal before being processed at the CHPP.
ROM pad	Location where ROM coal is temporarily stored pending processing at the CHPP.
S	Sulphur.
Scr	Chromium reducible sulphur. Analytical procedure to determine the sulphide-sulphur concentration in a sample. This typically represents the proportion of sulphur associated with sulphide (reactive) minerals.

SD	Saline drainage. A component of AMD, SD occurs where drainage is saline due to elevated sulphate as a result of sulphide oxidation and neutralisation reactions.
SO_4	Sulphate.
Spoil	Rock material overlying and between 'target' coal seams, which will report as waste. Waste rock overlying a coal seam is called overburden. Waste rock between mined coal seams is called interburden. See also Overburden and Interburden. Spoil comprises about 98% of mineral waste at GRBM.
Spoil dump	In-pit or out-of-pit spoil disposal location.
SPR	Source-pathway-receptor.
Static test	Procedure for characterising the geochemical nature of a sample at one point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid-Base Account.
Tailings	Very fine to medium grained sand, silt and clay-sized material, which is commonly coaly and carbonaceous, produced during coal washing. Tailings are associated with coal seams and are separated from ROM coal in the CHPP. Tailings produced at GRBM are disposed within Tailings Storage Facilities (TSFs). Tailings comprises about 0.5% of mineral waste at GRBM.
TSF	Tailings storage facility. A dam or pit used to dispose tailings, which are delivered to the TSF as a slurry. The tailings solid forms a 'beach' and the water drains to one end of the TSF in an area referred to as the decant pond. The decant water is recycled back into the mine water management system. At GRBM, tailings have been disposed into several above-ground and in-pit TSFs – the current (operational) TSF being Ramp 32 in-pit TSF.
Uncertain	In the context of classifying a material (sample) as NAF or PAF. An 'Uncertain' (UC) classification applies when there is an apparent conflict in results such that neither NAF nor PAF classification can be given, or there is insufficient information to unequivocally classify as NAF or PAF. UC samples are sometimes given a tentative sub-classification, such as UC(NAF) or UC(PAF) where preliminary data suggests the sample may be NAF or PAF, respectively.
Waste coal	Sub-economical coal that reports directly to the spoil dumps as waste (i.e. not ROM coal). Waste coal can be fresh or weathered (oxidised). All weathered/oxidised and coked (cindered) coal is waste. At GRBM, all P seam coal reports as waste.
Water extract	A method to determine the water-soluble parameters in soil. Solid samples undergo a bottle leach method where 10 g of pulped solid (85% passing 75 µm) is combined with 20 grams or 50 grams of water (leaching fluid) into a glass bottle. Depending on the type of leaching undertaken the leaching fluid may be deionised water (DI water extract) or saline water (saline water extract). The 1:2 or 1:5 solution (1 part solid to 2 or 5 parts water) is tumbled end-over-end for one hour. Solutes are leached from the soil by the continuous suspension and agitation. The water extract solution is measured for pH and electrical conductivity (EC) prior to filtering for solute analysis (e.g. metals/metalloids and major ions).

1 Introduction and Context

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials located at Goonyella Riverside and Broadmeadow Mine (GRBM), as supporting information for the progressive rehabilitation and closure plan (PRCP) for GRBM. GRBM comprises two operations: an open-cut mining operation called Goonyella Riverside Mine (GRM) and an underground mining operation called Broadmeadow Mine (BRM). Collectively, they are referred to here as GRBM.

The management of mineral wastes at GRBM are defined under the current Environmental Authority (EA) EPML00853413, held by BHP Mitsubishi Alliance (BMA). In this report the term 'mineral waste' refers to all geologic material (mine spoil, tailings and rejects) located at GRBM.

It is a requirement of a PRCP that mineral waste is adequately characterised such that appropriate rehabilitation strategies can be selected and implemented. The PRCP guidance document: "*Guideline – Progressive Rehabilitation and Closure Plans*" (DES, 2023) outlines the requirements and considerations for producing a PRCP, including documenting the relevant aspects of mineral waste characterisation for the purposes of PRCPs.

1.1 Approach

The general approach to mineral waste characterisation and assessment includes the following key steps:

- Briefly describe the current/existing background information for GRBM of relevance to the generation and ultimate storage/disposal of mineral waste materials;
- Document the methodology used to characterise mineral waste materials (samples);
- Present and discuss the geochemical results;
- Describe the potential environmental geochemical hazards with respect to mineral waste materials;
- Present the conceptual site model (CSM), which illustrates the relationship between AMD and salinity sources, potential environmental and human health receptors and plausible pathways between the AMD and salinity sources and the receptors (Source-Pathway-Receptor [SPR]) at closure;
- Present the acid and metalliferous drainage (AMD) and salinity SPR risk assessment undertaken on the mineral waste materials;
- Outline the AMD specific management and rehabilitation measures proposed for mineral waste materials; and
- Outline a forward work plan to address any gaps identified from the assessment.

1.2 Objective

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at GRBM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

2 Background

2.1 Site Overview

GRBM is located approximately 25 kilometres (km) north of Moranbah township, in central Queensland, and is operated by BHP Mitsubishi Alliance Pty Ltd (BMA). The site is located between North Goonyella underground mine to the north (operated by Peabody), Moranbah North mine to the south (operated by Anglo American) and is flanked on the east and west by pastoral leases. Open-cut mining commenced at GRM in 1971 and underground mining commenced at BRM in 2005.

GRM commenced operations in 1971 and comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facilities (TSFs), rejects dumps, coal stockpiles, coal processing facilities, rail loadout facilities, process water and raw water dams, surface water drains and administration areas.

BRM commenced operations in 2005 and comprises longwall underground mining infrastructure to extract coal and surface infrastructure to transfer run-of-mine (ROM) coal via overland conveyor to the coal handling and preparation plants (CHPPs) located at GRM. That is, all coal produced from BRM is processed at GRM, no mineral waste is located at BRM and BRM does not contain any pits that, at closure, may remain as residual voids.

The BMA Red Hill Mine (RHM) is an approved longwall underground mine neighbouring GRBM. ROM coal from RHM is approved to be processed at the GRBM CHPPs and the tailings and rejects will be disposed at GRBM. As such – and consistent with BRM – no mineral waste will be located at RHM, nor will RHM contain any pits that, at closure, may remain as residual voids.

As such, this environmental geochemical assessment is focused on GRM – where all mineral waste is generated and/or disposed.

The key facilities and natural features at GRBM of relevance to this waste characterisation report are shown on **Figure 1**. [Also shown on **Figure 1** are geochemical sampling locations and the locations of geological sections along and across each pit group].

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- ROM coal processing at two CHPPs: Goonyella (GY) CHPP and Riverside (RV) CHPP, which both produce two mineral waste types:
    - Tailings. Clay, silt and very fine to medium-grain sized sand material; disposed as a slurry into TSFs;
    - Rejects. Coarse sand to cobble-sized material; disposed at a number of locations (refer below). Rejects have also been used in construction of TSF embankments and infrastructure pads; and capping of tailings at TSFs.
- Disposal of tailings from the CHPPs to the in-pit Ramp 32 TSF (Airstrip pit) [active since approximately 2019];
- Disposal of rejects from RV CHPP to RS1 TSF western compartment, with some rejects also disposed into spoil areas;
- Disposal of rejects from GY CHPP to GS2, GS11 and R22 rejects areas;
- Short-term storage of ROM coal on the ROM Pads;
- Short-term storage of product coal on the product coal stockpile, awaiting off-site transport by rail;

Historic activities of relevance to this waste characterisation report comprise:

- Disposal of tailings from GY CHPP to the above-ground GS1 TSF [inactive since late 2020];
- Disposal of tailings from RV CHPP to the above-ground RS1 TSF [inactive since early 2021];
- Disposal of tailings from the CHPPs to the in-pit DRE5 TSF [inactive since 2022];
- Disposal of rejects from RV CHPP to Riverside rejects dump [inactive since approximately 2000].

RHM has approval to construct a new (additional) CHPP at GRBM. As such, future ROM coal from GRM, BRM and/or RHM could be processed at all three CHPPs, with tailings and rejects disposed and managed at GRBM as approved.

An overview of the proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report are outlined in **Section 8**. Refer to the main volume of the PRCP for detailed information:

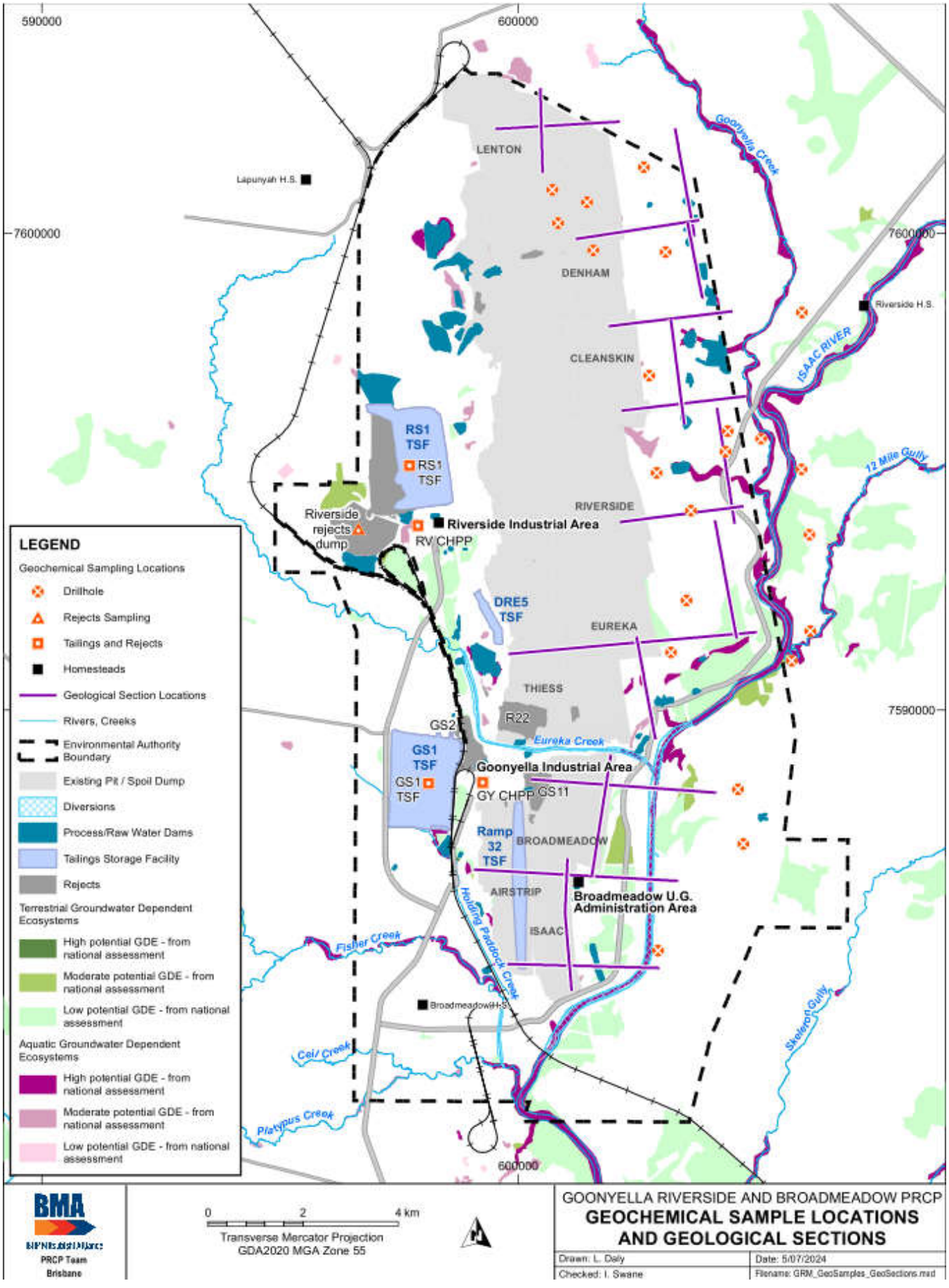

Figure 1. Current mine layout, geochemical sample locations and locations of geological sections

2.2 Mine Domains

The mine domains of direct relevance to mineral waste characterisation and management at GRBM are:

- Residual voids (pits remaining at end of mine life):
    - Goonyella residual void
    - Thiess residual void
    - Broadmeadow-Isaac residual void
    - Ramp 32 East residual void
    - Ramp 32 South residual void

  A number of pits will be backfilled during operations, including historic Lenton, Mitsui and Dampier pits, which have already been backfilled and currently form part of (what will ultimately be) Goonyella spoil landform.

  DRE5 in-pit TSF will be partially backfilled during operations and will form part of Thiess spoil landform. Airstrip pit (Ramp 32 in-pit TSF) will be backfilled during operations and will form part of Airstrip spoil landform.

- Spoil landforms:
    - Goonyella spoil landform [including several backfilled pits as outlined above].
    - Thiess spoil landform [including partially backfilled DRE5 in-pit TSF and R22 in-pit rejects dump].

      From a rehabilitation and post-closure perspective the low-wall west of the Thiess pit/void will form part of the Goonyella spoil landform. However, for the purposes of this AMD assessment, the low-wall spoil dump associated with Thiess pit is assessed as a separate spoil landform, herein called Thiess spoil landform.
    - Broadmeadow-Isaac spoil landform.
    - Airstrip spoil landform [including backfilled Ramp 32 in-pit TSF].

  Note: these spoil landforms are not ‘discrete’ (completely stand-alone) features. Instead, they should be thought of as zones within a single landform with a hummocky, rolling topography – higher spoil areas behind (west of) each residual void, where mining occurred – and lower between voids, where pit ramps were located.

  DRE5 TSF (inactive) is an in-pit TSF located at the periphery of the Thiess spoil landform. Due to the concentration of tailings at this TSF situated near the edge of the spoil landform where the tailings will not be deeply buried within the core of the spoil landform, and also at the base of the spoil landform, this TSF has been conservatively assessed as a TSF landform (adjoining spoil landforms), rather than the tailings being assessed as a relatively minor component of its’ much larger spoil landform. See TSF landforms below.

  R22 in-pit rejects dump (active) is located at the southwestern periphery of the Thiess spoil landform. Due to the concentration of rejects and situated near the edge of the spoil landform where the rejects will not be deeply buried within the core of the spoil landform, this rejects dump has been conservatively assessed as a ‘stand-alone’ rejects landform, rather than the rejects being assessed as a relatively minor component of its’ much larger spoil landform. See rejects landforms below.

  Ramp 32 TSF (the current/active TSF) is an in-pit TSF within Airstrip pit, which will be backfilled during or prior to closure. Due to the concentration of tailings at this TSF situated at the base of the Airstrip spoil landform, this TSF has been conservatively assessed as a TSF landform (within a spoil landform), rather than the tailings being assessed as a relatively minor component of its’ much larger spoil landform. See TSF landforms below.

- TSF landforms:
    - RS1 TSF is an out-of-pit above-ground facility [i.e. not located within a pit shell or spoil landform ‘footprint’]. The TSF has a western compartment comprising rejects only (the current/active rejects disposal location for rejects from RV CHPP) and an inactive eastern compartment predominantly comprising tailings, with minor rejects.

  - GS1 TSF (inactive/decommissioned) is an out-of-pit above-ground facility [i.e. not located within a pit shell or spoil landform 'footprint'].
  - DRE5 TSF (active) is an in-pit facility located at the western periphery of the Thiess pit shell, within the Thiess spoil landform 'footprint'. The TSF is maintained as a 'commissioned' TSF to allow for temporary use (in the event that tailings cannot be discharged into the active TSF).
  - Ramp 32 TSF (active) is an in-pit facility within Airstrip pit, which will be backfilled with spoil. The pit will be within the Airstrip spoil landform 'footprint', which ultimately is part of the Ramp 32 East, Ramp 32 South and Broadmeadow-Isaac void shell.

- Rejects landforms: excluding rejects broadly co-disposed within a spoil landform.
  - Riverside rejects dump (inactive/decommissioned) is an out-of-pit above-ground facility [i.e. not located within a pit shell or spoil landform 'footprint']. The dump was rehabilitated in the early 2000s, but due to the substantial corrective action required to achieve the PMLU it has been scheduled for further rehabilitation in the PRCP schedule.
  - GS2 rejects dump (active) is an out-of-pit above-ground facility [i.e. not located within a pit shell or spoil landform 'footprint']. The dump is located northeast of and adjacent to GS1 TSF.
  - GS11 rejects dump (active) is an out-of-pit above-ground facility [i.e. not located within a pit shell or spoil landform 'footprint']. The dump is located north of Ramp 32 TSF, between the TSF and Eureka Creek.
  - R22 rejects dump (active) is an in-pit facility within the southwestern periphery of the Thiess pit shell, within the Thiess spoil landform 'footprint'.
- Coal stockpiles: ROM coal pads and stockpiles; and Product coal pads and stockpiles.

2.2.1 Material Types and Quantities

GRBM has three main types of mineral waste, and the geochemical characteristics and potential hazards associated with mineral waste materials on site are discussed by type:

- Spoil (overburden and interburden) currently comprises approximately 98% of all mineral waste at GRBM and includes weathered waste (Tertiary and Permian-age) and fresh (unweathered) waste (all Permian-age).
- Tailings are generated at the CHPPs from processing ROM coal and typically represent the clay, silt and fine sand fractions of ROM waste. Throughout operations at GRBM, tailings have been disposed as a slurry into several TSFs – the current (active) TSF being Ramp 32 in-pit TSF (Airstrip pit). Tailings comprise approximately 0.5% of all mineral waste at GRBM – with this approximated proportion expected for the remaining life of asset mine plan.
- Rejects are generated at the CHPPs from processing ROM coal and typically represents coarser and rockier seam roof, partings and floor material. Rejects are disposed into several current and historic rejects dumps and into spoil dumps. Rejects have also been used in construction of TSF embankments and infrastructure pads (e.g. ROM and coal stockpile pads). Rejects comprise approximately 1.5% of all mineral waste at GRBM – with this approximated proportion expected for the remaining life of asset mine plan.

Coal is also included in the assessment; however, coal is generally not considered mineral waste, with the exception of small quantities of sub-economic seams that may report to the spoil dumps, and remnant coal exposed on pit highwalls (such as in residual voids).

2.3 Baseline Information

2.3.1 Topography

The topography at GRBM is relatively flat. The mine is located within a broad valley through which the Isaac River flows. The valley is defined to the west by the Denham Range and to the east by the Carborough Range. The southern end of the valley broadens out on to a wide flood plain. A low broad ridge to the north defines the northern

part of the Isaac River catchment. The low hills located to the east of the Isaac River near the existing mine are strongly undulating with a well-developed system of drainage lines.

The topography of the Isaac River valley near the GRBM area varies from approximately 250m Australian Height Datum (AHD) along the Isaac River to the east to approximately 325m AHD elevation along portions of the Denham Range that define the western edge of the valley. The relatively steep slopes associated with the Denham Range contrast with the extensive flat areas across the base of the river corridor, where gradients are generally less than 1:100.

2.3.2 Climate

The following information about climate is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about climate at GRBM.

GRBM is located within Queensland's semi-arid climatic zone, which is characterised by high summer temperatures, warm dry winters and generally distinct wet and dry seasons; with higher rainfall and higher evaporation occurring over the summer months (December to February). Climate data (rainfall, evaporation and temperature) is available from Moranbah Water Treatment Plant and Moranbah Airport, located approximately 25 km and 33 km, respectively, south of GRBM.

Median maximum temperatures range from approximately 24°C in June/July to 35°C in December/January, with minimum temperatures ranging from approximately 9°C in July to 21°C in January. The average annual rainfall and evaporation are approximately 600 and 2000 mm per year, respectively, with evaporation greatly exceeding rainfall. The evaporation rate is highest in the summer months - mean daily rate of approximately 8 mm in December, and lowest in the cooler months - mean daily rate of approximately 3 mm in June. Rainfall events are often associated with thunderstorms, which are typically short-lived, intense and have variable coverage. Sustained rainfall over a large landscape area is experienced when tropical lows with cyclonic activity occur in coastal area. However, periods of prolonged drought do occur within the region.

2.3.3 Geology

GRBM is located on the north-western margin of the Bowen Basin on the Collinsville Shelf. The Bowen Basin in the area is characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation. The lithology at GRBM is characterised by typical basin-fill sediments, comprising mudstone, claystone, siltstone, sandstone (typically fine- to medium-grained), carbonaceous sediments and coal seams. Basalt is encountered within Tertiary-age material. The depth to base of weathering averages about 30 m below natural surface but ranges from about 20 m to 50 m below natural surface, depending on the local topography.

In coal environments (i.e. at coal mines) fresh carbonaceous materials typically have higher sulphide concentrations compared with fresh non-carbonaceous materials and, as such, typically pose a greater environmental geochemical hazard compared with fresh non-carbonaceous material. Comparatively, non-carbonaceous lithologies are essentially void of (or have negligible) carbonaceous material and thus have low or nil sulphide mineral concentration. The key exception is that non-carbonaceous materials located within coal seams or immediately above and below (within, say, 0.5m of) coal seams tend to have a higher sulphide concentration compared to bulk overburden/interburden located away from seams.

The coal bearing sequences at GRBM are primarily from the Permian-age Moranbah Coal Measures (MCM), with minor coal from the Permian-age Fort Cooper Coal Measures (FCCM). These coal measures comprising the following seam groups in stratigraphic order, from youngest to oldest:

- Goonyella F (GF) seam group; the base seam group of the FCCM comprising several plys. The GF is a minor seam group, which is not present in the western pit areas of GRBM (i.e. post-closure, will only be exposed in Goonyella residual void). The GF seam group has not been mined for ROM coal to date, however some plys of the GF seam may be mined for ROM coal from the Goonyella pit group in later years;
- Goonyella Upper Seam (GUS) group; the uppermost seam group of the MCM and a significant seam group at GRBM that comprises several plys – not all of which are mined as ROM coal;
- P seam; a 'waste' seam group at GRBM (i.e. P seam is not mined as ROM coal);

- Goonyella Middle Seam (GMS) group; a significant seam group at GRBM that comprises several plys, most of which are mined as ROM coal; and
- Goonyella Lower Seam (GLS) group; a significant seam group at GRBM that comprises several plys, most of which are mined as ROM coal.

Below the GLS group lies the GLL seam group, which is not mined at GRBM.

The GUS is associated with a marine transgression (a brackish environment), whilst the GMS and GLS groups are interpreted to have formed in fresh(er) water basins.

Seam splitting and coalescing occurs along the length (north-south) of the site.

Mining at GRBM to date has been from the MCM and overlying Tertiary-age material. The FCCM sub-crop east of the current mining activities at GRBM. Based on the current mine plan, the FCCM will begin to be encountered (during mining) from approximately now (at the northern Goonyella pits) through until the end of mine life from all Goonyella pits. The FCCM is not encountered in Thiess, Airstrip, Ramp 32 East, Ramp 32 South or Broadmeadow-Isaac pits.

Overlying the FCCM/MCM is a thin veneer of Quaternary- and Tertiary-age sediments. Throughout the region, the Quaternary and Tertiary sediments are highly weathered, semi-consolidated and typically comprise sand, clay and gravel.

To date, all ROM coal mined from GRM (i.e. open-pit mining) has been from the GMS and GLS seam groups. P seam is mined as spoil. GF seam has not been encountered to any significant extent and, where encountered in northern pit areas, the GF seam has been mined as spoil. As mining progresses eastwards (down-dip) the GUS seam group will become more prevalent. In the latter stages of mining in Goonyella pits, some coal from GF seam may be mined as ROM.

All current ROM coal mined from BRM (i.e. underground) has been from the GMS seam group. Future mining will extract coal from the GMS and GLS seams. RHM (i.e. underground) is located adjacent to GRBM (east and northeast of GRBM) and will mine the GMS seam group – therefore ROM coal from RHM is expected to have similar geochemical characteristics to ROM coal from BRM.

An indicative stratigraphic column showing the seam groups is provided in **Figure 2**, which also includes the number of geochemical samples collected from each overburden and interburden zone, and also from within each seam group (refer to **Section 4.2** for information regarding sample collection).

Geological long-sections (indicatively north-south) approximately along the future highwall of the voids are provided in **Attachment A – Figures A1 to A3**. Geological cross-sections (indicatively west-east) through the pits are provided at **Attachment A – Figures A4 to A9**. Refer to **Figure 1** for section locations. The seam groups are shown in the geological sections. Note: some of the pits within the Goonyella void/pit area have already been backfilled or will be backfilled during operations and, as such, will not remain at closure.

Due to the generally eastward dip of the seams and the nature of the seams splitting and coalescing, the location of the weathered zone shown in the stratigraphic column (**Figure 2**) varies from pit to pit (north to south) and also from west (start of mining) to east (current and future mining). Refer to the geological sections in **Attachment A**.

Underlying the MCM is the Permian-age Back Creek Group, which has geological similarities with the host rock of the MCM (i.e. quartzose to lithic sandstone, siltstone, carbonaceous shale and minor coal).

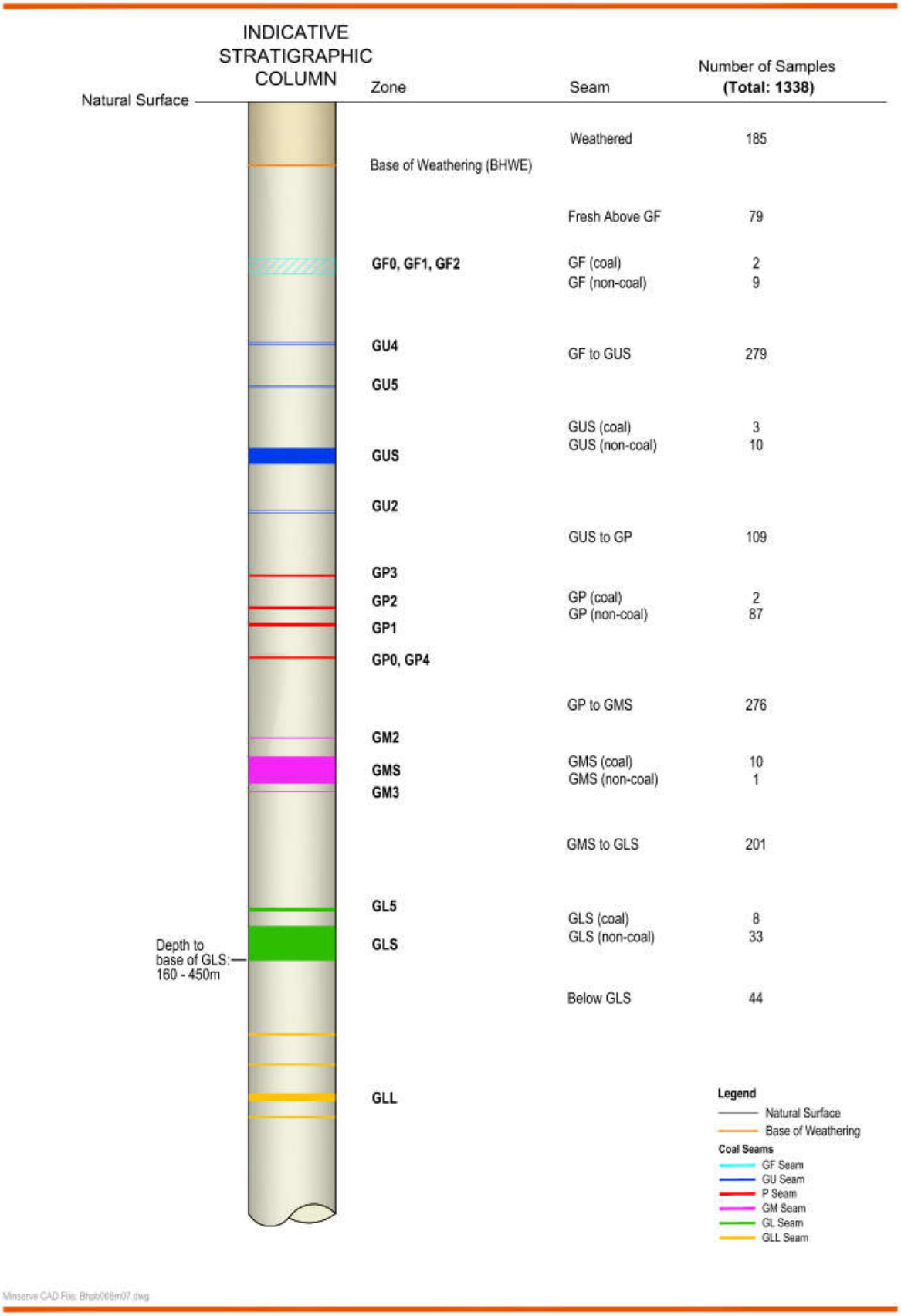

Figure 2. Indicative stratigraphic column

2.3.4 Surface Water / Hydrology

The following information about surface water / hydrology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about surface water quality at GRBM.

GRBM is located within the Isaac Connors surface water catchment – a sub-catchment of the upper Fitzroy Basin. The surface water catchment for the GRBM begins west of the site and flows downstream to meet the Isaac River, which flows approximately north to south through the site (east of the highwalls/voids). The Isaac River is the dominant watercourse in the region.

All watercourses within and surrounding GRBM – including the Isaac River – are highly ephemeral and only flow briefly after significant rainfall, enough to generate sufficient overland flow. The creeks at GRBM are shown on **Figure 1** and include:

- Isaac River, which flows into the site from the northeast, then flows east of the Goonyella void and east of Broadmeadow-Isaac void, exiting the site south of Ramp 32 South void. The river channel is a diversion channel (i.e. not the original/natural watercourse) from approximately the southern end of Goonyella void through until the river exits the site;
- Goonyella Creek, located in the north-eastern area of the site and flows southwards into Isaac River east of Goonyella void;
- Eureka Creek, which traverses the site in an approximately northwest to southeast direction between the southern end of Thiess pit/void and the northern end of Broadmeadow-Isaac pit/void and joins the Isaac River east of Broadmeadow-Isaac void and south of Goonyella void;
- Holding Paddock Creek is a small creek that flows from (and around) the southwestern and southern side of GS1 TSF southwards around the western edge of Airstrip pit spoil dump and joins into Fisher Creek west of Ramp 32 South void;
- Fisher Creek, which flows into the southwestern corner of the site from the west, joining into Platypus Creek near the southern boundary of the site (ML boundary);
- Platypus Creek, which flows into the southwestern corner of the site from the west, joining into Isaac River at approximately the southern boundary of the site.

Minor tributaries flow into these creeks and Isaac River outside of GRBM.

2.3.5 Groundwater / Hydrogeology

The following information about groundwater / hydrogeology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about groundwater quality at GRBM.

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in usable quantities. The Quaternary alluvial formations, Tertiary sediment and the Permian coal measures generally yield low sustainable volumes of poor-quality water. As such, these formations are not recognised as ‘true’ aquifers in the area. However, for the purpose of the discussion, groundwater-bearing zones at GRBM are referred to as aquifers.

The main factors influencing natural groundwater levels are groundwater recharge, evapo-transpiration and regional flow patterns. Due to the heterogeneity and discontinuity of the Quaternary alluvium aquifers and Tertiary sediment aquifers, the groundwater flow direction in these aquifers cannot be determined on a regional scale – and is likely to be topographically controlled, flowing from higher elevations to lower elevations. The ‘pre-mining’ groundwater flow direction within the Permian coal seams is generally west to east across the site, and consistent with recharge into sub-cropping seams west of GRBM.

The coal seams within the MCM are the primary aquifer at GRBM. The coal seams can be characterised as confined aquifers, with the GUS, GMS and GLS seam groups forming the main hydrostratigraphic units locally. The overburden and interburden within the MCM and FCCM act as aquitards and are typically dry or very low yielding.

The hydrogeological units at GRBM comprise:

- Quaternary alluvium – unconfined aquifer (sporadically discontinuous water-bearing strata of permeable unconsolidated sand or gravel) localised at or near to GRBM along the Isaac River, Eureka Creek and Goonyella Creek, and more regionally along the Isaac River where it is particularly well developed.
- Permian-age coal measures interburden and overburden units – low permeability sedimentary rock with aquitard properties; and
- Permian-age coal seams – exhibiting water bearing properties associated with secondary porosity through cracks and fissures.

2.3.6 Potential Environmental and Human Health Receptors

A conceptual environmental geochemical model (source-pathway-receptor (SPR) model) for GRBM identified the potential environmental and human health receptors and is discussed within this report. Of relevance to this assessment (i.e. hazards and risks posed by AMD), the following potential receptors are noted:

Potential surface water receptors

The primary surface water feature in the district is the Isaac River, located within and adjacent to GRBM.

- The northern area of the site, comprising almost all of Goonyella spoil dumps/landform, Thiess spoil dumps/landform, RS1 TSF landform and Riverside rejects landform drains west / southwest /south to Eureka Creek and its tributaries.
    - The highwall area east of Goonyella void drains eastwards to Goonyella Creek (+/- via tributaries) and Isaac River.
- The central area – comprising the Thiess spoil dumps/landform, RS1 TSF landform and Riverside rejects landform drains west / southwest to Eureka Creek. The current Eureka spoil dump (future southern section of Goonyella spoil landform) drains south to Eureka Creek and Isaac River. The northern part of Broadmeadow spoil landform drains north to Eureka Creek.
- The southern area of the site comprising GS1 TSF landform and Airstrip spoil landform drains west and south to Holding Paddock creek.

All of these creeks eventually drain into the Isaac River. GRBM shares the Isaac River Catchment with several other coal mines upstream and downstream of GRBM.

Potential groundwater receptors

Aquatic and terrestrial groundwater dependent ecosystems (from national assessment) are shown in **Figure 1**.

Potential domestic (human) receptors

The nearest homesteads to GRBM – both located within the PRCP area – are *Broadmeadow* homestead, located approximately 1.9 km southwest of Ramp 32 residual void, and *Riverside* homestead, located approximately 3.1 km east of Goonyella residual void highwall. These homesteads are located in surface water sub-catchments that do not receive drainage from GRBM and are located upgradient (via groundwater) from GRBM. *Riverside* homestead is situated above the future Red Hill underground mining area.

The next closest homesteads are *Lapunyah* homestead, located on the north-western side of GRBM about 1.2 km northwest of the ML boundary; and Red Hill homestead, located about 1 km east of the PRCP area and almost 6 km east of the Goonyella residual void. These homesteads are both located upstream (via surface water) and upgradient (via groundwater) from GRBM.

The two remaining homesteads in the district – both located well outside GRBM – are *Burton Downs* homestead, located over 4 km northeast of GRBM and *Denham* homestead, located approximately 5.8 km northwest of GRBM.

2.3.7 Acid and Metalliferous Drainage

Environmental geochemical information with regard to AMD from mineral waste materials at GRBM has been sourced from the BHP Coal Geochemical Database (hereafter called 'the geochemical database') and is presented and discussed within this report.

2.3.8 Salinity, Sodicity and Dispersion

Environmental geochemical information with regard to salinity, sodicity and dispersion of mineral waste materials at GRBM has been sourced from the geochemical database and is presented and discussed within this report. Refer to the main volume of the PRCP for detailed information about soils and rehabilitation of spoil dumps at GRBM.

3 Potential Environmental Geochemical Hazards

3.1 Acid and Metalliferous Drainage

The term 'AMD' is used to describe low-quality seepage or drainage (from soil and rock) that has been affected by the oxidation of sulphide minerals (primarily pyrite and marcasite) and/or by the dissolution of acid generating sulphate minerals (primarily alunite and jarosite) and associated neutralisation reactions, if any. The term AMD is used to describe any drainage type affected by this process.

AMD may be produced when sulphide minerals (such as pyrite) are exposed to oxygen and water. Oxidation of sulphide minerals may result in the production of acid(ity), sulphate (SO_4) and, depending on mineralogy, the release of metals and salinity. AMD comprises three key components, which are defined below as per recognised Australian and international guidelines (INAP, 2009[1]; DIIS, 2016[2]). BHP (2021) has adopted these recognised definitions:

- Acid drainage (AD): where contact water is acidic and, in most cases, also contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid generating capacity exceeds the acid neutralisation capacity of a sample.
- Neutral and metalliferous drainage (NMD): where contact water is pH-neutral/alkaline and contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid neutralising capacity exceeds the acid generating capacity of a sample.
- Saline drainage (SD): where contact water contains elevated sulphate concentration due to oxidation of sulphide minerals, and very low metal/metalloid concentration. This drainage type is generated when the acid neutralising capacity vastly exceeds the acid generating capacity of a sample with high sulphide concentration.

Whether contact water is impacted by AD, NMD and/or SD largely depends on the relative proportion of acid generating minerals (sulphides / sulphates) and acid neutralising minerals (carbonates) in the source materials.

3.2 Salinity, Sodicity and Dispersion

An assessment of salinity characteristics of mineral waste materials has been undertaken on materials using available EC data from the geochemical database. An assessment of sodicity and dispersion characteristics of potential final landform materials has also been undertaken using exchangeable cation and Emerson Class data from overburden/interburden samples (data obtained from the geochemical database). Salinity released from the dissolution of geogenic salts (non-oxidative) is a separate and distinct process from SD associated with sulphide oxidation.

1 INAP, 2009. Global Acid Rock Drainage Guide.

2 DIIS, 2016. Preventing Acid and Metalliferous Drainage. Handbook from Australian Federal Government's Leading Practice Sustainable Development Program for the Mining Industry. https://www.industry.gov.au/data-and-publications/leading-practice-handbook-preventing-acid-and-metalliferous-drainage.

4 Assessment Methodology

This section provides the methodology used for the geochemical characterisation and assessment of spoil, tailings and rejects (mineral wastes) and coal at GRBM.

4.1 Information Review

Sampling and laboratory test-work has been undertaken by BHP and consultants throughout the development and operation of GRBM. The geochemical database contains all available geochemical data for mineral waste samples. All data has been compiled and reviewed by BHP specifically to support the PRCP, to provide a unified and consistent interpretation of all available data. Past characterisation reports are superseded by this review and assessment undertaken to support the PRCP.

4.2 Sample Collection

Drill-hole Samples – representing spoil, ROM coal, pit walls and pit floor

All data used to assess spoil and ROM coal (and pit walls and floor) has been derived from drill-hole sampling. Drill-hole samples for geochemical analysis have been collected from 22 drill-holes located throughout GRBM (shown in **Figure 1**), dating from 1996 through to 2024.

Most of the drill-holes are distributed along strike (approximately north-south) in the vicinity of the current pit highwalls of the pits that will comprise the Goonyella void. Some drillholes are located outside the open-pit mining area and were targeting sample collection for the current and planned underground mining areas. The drill-holes intersect all current mined geological units, with sampling undertaken from surface to full drill-hole depth (approximately to below the lowest mined seam). As such, the drill-hole samples that have undergone test-work are representative of the geology/stratigraphy at GRBM from existing mining (disturbance) areas. No drill-hole sampling has bene undertaken from the areas closely associated with Thiess pit, Airstrip pit, Broadmeadow pit or Isaac pit, however the geology and lithology of these old pit areas is consistent with the geology and lithology elsewhere on site.

With regard to future mining areas, the FCCM (overlying the MCM) are currently not mined at GRBM and won't be mined in significant quantities at GRBM for several years. The FCCM are only mined from the pits comprising the Goonyella void. As such, most of the drill-hole samples are from the MCM. The FCCM will essentially comprise overburden only – with the low possibility of some ROM coal being mined from the F seam group. The assessment has not differentiated between the MCM and FCCM (i.e. all samples are assessed the same regardless of whether from MCM or FCCM). Further geochemical characterisation and assessment of FCCM samples will be undertaken during operations to support and inform rehabilitation and closure planning. Drillhole samples from GMS and GLS seam groups from GRBM are representative of the geology/stratigraphy from future mining areas at GRM, BRM and RHM.

Geochemical data is available for 1338 drill-hole samples collected from 22 drill-holes. Geochemical samples collected and tested were sourced from the following key mineral waste domains:

- Weathered, non-carbonaceous spoil. 154 samples.
- Weathered, carbonaceous spoil, including weathered coal. 31 samples.
- Fresh, non-carbonaceous spoil. 1015 samples.
- Fresh, carbonaceous spoil. 112 samples. These samples typically include carbonaceous siltstone, carbonaceous sandstone, carbonaceous mudstone and coaly shale, but also includes similar coaly and carbonaceous materials other than coal.
- Fresh, coal. 26 samples.

All samples were collected from drill-core. The samples were collected as discrete samples – typically a 15-25 cm interval of core within targeted sampling zones. Most drill-core samples were collected semi-continuously across the entire stratigraphic sequence, with greater emphasis placed on those stratigraphy's posing a greater AMD

hazard, such as carbonaceous spoil plus material located within and very close to coal seams, which includes roof/parting/floor (carbonaceous and non-carbonaceous), and coal.

A significant proportion of the spoil samples were sampled close to seams – typically interburden or parting between plys of the same seam group. As such, seam and near-seam zones were proportionally oversampled (relative to sampling of thick overburden/interburden areas well away from seams) to target seam zones that were interpreted as posing a higher AMD hazard compared to general spoil well away from seams. Therefore, this sampling technique is potentially biased towards higher AMD hazard materials.

It is understood that most fresh coal will report to ROM coal and be processed. A small fraction of coal will be mined as spoil (waste) due to coal quality and mining considerations, and a small proportion of coal will remain exposed in seams on pit walls and floor at closure. The coal samples discussed herein represent 'pure' coal and do not include associated roof, parting and floor samples that would ordinarily be mined with the seam as ROM coal. Carbonaceous roof, parting or floor samples are included in the 'fresh, carbonaceous' sample group.

The geochemical sampling locations are shown on **Figure 1** (site layout) and the number of drill-hole samples from each stratigraphic zone is shown on **Figure 2** (indicative stratigraphic column).

Tailings Samples – representing very fine to fine-grained coal process waste

Geochemical data is available (within the geochemical database) for 467 tailings samples, comprising:

- 244 'fresh' tailings samples collected from the two CHPPs;
- 139 'aged' tailings samples collected from geotechnical investigation drill-holes within GS1 TSF;
- 84 'aged' tailings samples collected from geotechnical investigation drill-holes within RS1 TSF.

Tailings data are presented and discussed as two groups being representative of:

- Fresh (CHPP) tailings samples [n=244]; and
- Aged (TSF) tailings samples [n=223].

Tailings samples collected from the CHPPs are deemed to be representative of 'fresh' tailings currently and recently produced at GRBM. Tailings samples collected from TSFs are deemed to be representative of 'aged' tailings within GS1 and RS1 TSFs at GRBM.

Rejects Samples – representing mid- to very coarse coal process waste

Geochemical data is available (within the geochemical database) for 338 rejects samples, comprising:

- 118 'fresh' rejects samples collected from the CHPPs;
- 20 'aged' rejects samples collected from geotechnical investigation drill-holes within GS1 TSF;
- 126 'aged' rejects samples collected from geotechnical investigation drill-holes within RS1 TSF;
- 74 'aged' rejects samples collected from drill-holes and test pits at Riverside rejects dump.

Rejects data are presented and discussed as three groups being representative of:

- Fresh CHPP rejects samples [n=118];
- Aged TSF rejects samples [n=146] – collected from GS1 TSF and RS1 TSF;
- Aged dump rejects samples [n=74] – collected from Riverside rejects dump.

Rejects samples collected from the CHPPs are deemed to be representative of 'fresh' rejects currently and recently produced at GRBM. Rejects samples collected from Riverside rejects dump and from TSFs are deemed to be representative of 'aged' rejects that may be found in at rejects disposal areas or within TSFs awaiting burial/rehabilitation.

Other Samples

Geochemical data is available (within the geochemical database) for three 'fill' samples and 18 'natural ground' samples collected from geotechnical investigation drillholes within RS1 TSF. These samples were collected and analysed as part of the geotechnical investigations. Fill (spoil) material is often used as part of TSF embankment construction. At the base of the investigation drillholes (base of the TSFs, below the base tailings or rejects) natural ground was encountered and was also sampled as part of the investigations.

4.3 Sample Characterisation

The aim of the environmental geochemical test-work is to understand the geochemical characteristics of the mineral waste materials with respect to AMD, geogenic salinity, erosion and dispersion potential; and to inform management and closure options for these materials.

A phased approach was implemented to define the geochemical behaviour of the key material types generated at GRBM, as discussed below.

Solid Samples – Static Tests

Samples have generally undergone similar test-work methods. Test-work was generally undertaken in stages, with most samples being subjected to 'screening' tests followed by more detailed test-work undertaken on selected samples.

Almost all samples have undergone 'screening' tests (stage 1 tests) for:

- pH and electrical conductivity (EC) on 1:5 w:v water extracts (on pulps [100% passing 212 microns]);
- Net acid producing potential (NAPP) test, which comprises total sulphur (total S) and acid neutralising capacity (ANC) determination. The NAPP test provides the fundamental information about the theoretical maximum amount of acid-producing and acid-neutralising material that a sample could produce;

Based on the results of the screening tests, selected samples were subjected to some or all of the following tests:

- Total carbon (total C), and organic carbon (C-org);
- Total sulphate (SO_4);
- Sulphide (chromium reducible sulphur – Scr) – a test to determine the proportion of total S present as sulphide;
- Acid buffering characterisation curve (ABCC) - a test to determine the proportion of ANC that's in a readily-available form and to provide an indication of the carbonate mineralogy of the neutralising material;
- Net Acid Generation (NAG) [single addition] - a test that encourages the oxidation of a sample to determine if acid can be produced, and how much acid could be produced;
- Sequential net acid generation test (S-NAG) – a refinement of the single addition NAG test to resolve potential issues associated with incomplete oxidation of samples with high sulphide concentrations;
- Extended boil net acid generation test (NAG Extended) – a refinement of the NAG test to resolve uncertainty due to potential organic acid interference (where non-acid generating organic acids can provide false positive results in the NAG test);
- Total metals and metalloids by 4-acid (mixed) or 2-acid (aqua regia) digest with analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and/or Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Flow Injection Mercury System (FIMS);
- Quantitative x-ray diffraction (QXRD) – to determine the mineralogical composition;
- Short-term leaching tests, including:
    - Deionised water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using de-ionised water, with filtered leachate analysed for:
        - Major and minor ions [calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), SO_4, chloride (Cl) and fluoride (F)];

  - Alkalinity [total alkalinity, bicarbonate (HCO_3) and carbonate (CO_3)] and Acidity (pH dependent);
  - Soluble metals and metalloids [approximately 28 elements by ICP-MS, ICP-AES and FIMS].
- Saline water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using saline water (2 g/L NaCl), with filtered leachate analysed for the soluble analytes listed above.
- Peroxide (NAG) leach – analysis of the solution on completion of the NAG or NAG Extended test, with filtered leachate analysed for the same (or similar) suite of soluble analytes as listed above.

- Exchangeable cations (Calcium [Ca], Magnesium [Mg], Sodium [Na], Potassium [K]) (with pre-treatment for salinity, if required). Results were used to calculate the cation exchange capacity (CEC);
- Emerson Aggregate Class testing.

For most samples, laboratory test work was undertaken by ALS Environmental (ALS) Brisbane, using National Association of Testing Authorities (NATA) accredited methods (where such accreditation exists). Mineralogical analysis (QXRD) was undertaken by a university (research) mineralogical laboratory in Melbourne (via Earth Systems Consulting).

Tailings Liquor Samples

Tailings samples collected from the CHPPs are collected as a slurry – representative of the tailings slurry that reports to TSFs for disposal. At the TSF the water drains to one end of the TSF – called a decant pond/area – and is collected for re-use in the CHPPs. Geochemical data is available (in the geochemical database) for tailings liquor from 85 sampling events undertaken at the CHPPs (40 samples from GY CHPP and 45 samples from RV CHPP) between January 2022 and July 2023. The liquor samples were analysed for a typical suite of water quality parameters, such as pH and EC, major cations and anions and soluble metals and metalloids.

4.4 Geochemical Source Hazard Assessment

Geochemical data was assessed with regard to the samples potential to generate AMD. Only after making such an assessment to understand the potential AMD hazard can appropriate AMD specific management measures be formulated to adequately mitigate the risks, as required.

AMD Classification

The Acid-Base Account (ABA) method was used to assess the acid-neutralising and acid-generating characteristics of the samples to determine an acid (AD) classification for the mineral waste materials.

The maximum potential acidity (MPA) and acid neutralising capacity (ANC) represent each side of the acid-base account. MPA is calculated from total S and is the theoretical maximum potential acidity that can be generated if all of the S, assumed to be associated entirely with pyritic sulphide, is able to oxidise and generate acid (H_2SO_4). ANC represents the theoretical maximum amount of acid-neutralising capacity of a sample assuming all neutralising material is in a readily available form. The net acid producing potential (NAPP) is the difference between the MPA and the ANC. In simple terms, a negative NAPP indicates an excess of ANC and the sample is likely to be non-acid forming (NAF) and a positive NAPP indicates an excess of MPA and the sample is likely to be potentially acid forming (PAF) – though there can be exceptions to this simplified interpretation. Note that NAF samples have the potential to generate NMD and SD, depending on the sulphur concentration.

Sample classification of mineral waste material follows some general rules. Samples were initially classified using Total S, NAPP and ANC/MPA ratio (and NAG data, where available), into three broad categories:

NAF	Non-acid Forming;
PAF	Potentially Acid Forming;
Uncertain	Those samples with inconclusive results, leading to a degree of uncertainty about their ability to generate acid

Where available, additional geochemical information such as pH, Scr, ABCC, NAG extended and NAG sequential results were used to resolve acid classification uncertainties. The general approach was to build in a level of conservatism in the preliminary classification, as shown in **Table 1**.

Table 1. Preliminary AMD classification criteria

Preliminary classification	Sulphur %	NAPP kg H_2SO_4/t	ANC/MPA ratio	NAGpH (if data available)
NAF	≤ 0.01	-	-	-
	≤ 1	< 0	≥ 2	-
	≤ 1	< 0	-	≥ 4.5
NAF-Sulphur (NAF-S)	> 1	< 0	≥ 2	-
	> 1	< 0	-	≥ 4.5
PAF – Low Capacity (PAF-LC)	≤ 1	≥ 0 and < 10	< 2	-
	-	≥ 0 and < 10	-	< 4.5
PAF	-	≥ 10	< 2	-
	-	≥ 10	-	< 4.5
Uncertain	Any result outside of the above criteria, or results that appear to significantly conflict with the expected result based on lithology or mineralogy			

Sulphur Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific total S cut-off values were used to discuss sulphur data, as shown in **Table 2**.

Table 2. Sulphur category and associated cut-off

Sulphur category	Total S wt. %
Very low	< 0.1
Low	0.1 – 0.5
Low-moderate	0.5 – 1.0
Moderate	1.0 – 1.5
High	> 1.5

ANC Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific ANC cut-off values were used to discuss ANC data as shown in **Table 3**.

Table 3. ANC category and associated cut-off

ANC category	ANC kg H_2SO_4/t
Very low	< 5
Low	5 - 15
Moderate	15 - 30
High	30 - 50
Very high	> 50

Soil Salinity

The term 'soil' salinity (and 'soil' pH – refer below) is an industry-adopted term to refer to the salinity and pH measured on any solid geologic matrix, such as soil, spoil, rock, sediment, tailings, reject, etc. That is, in this context, the term 'soil' applies to all solid samples, not just shallow surface (root zone) material.

Classifying whether a sample/material is non-saline, highly saline, or somewhere in between will depend upon the methods used to measure soil salinity. Soil salinity data is obtained from a 1:5 (w:v) [and 1:2 w:v] water extract procedure typically on pulp samples (pulping the sample minimises the potential to underestimate salinity on sandy samples/materials). The soil salinity classes shown in **Table 4** are expressed in units of microSiemens per centimetre (µS/cm) and are based on a 1:5 w:v method. These soil salinity classes are used as an indicative guide. The classes are broadly based on soil salinity classes reported by DME (1995).

Table 4. Soil salinity classification

Soil salinity classification	EC1:5 µS/cm
Non-saline	< 450
Slightly saline	450 - 900
Moderately saline	900 - 2000
Saline	2000 - 4000
Strongly saline	> 4000

Soil pH type

Classifying whether a sample/material is acid, pH-neutral or alkaline or somewhere in between will depend upon the methods used to measure soil pH. Soil pH data is obtained from a 1:5 (w:v) [and in a small number of cases 1:2 w:v] water extract procedure typically on pulp samples. The soil pH types shown in **Table 5** are based on a 1:5 w:v method. These soil pH types are used as an indicative guide.

Table 5. Soil pH type and associated cut-off

Soil pH type	pH1:5
Highly acid	< 3.0
Moderately acid	3.0 – 4.5
Weakly acid	4.5 – 6.0
Near neutral	6.0 – 7.5
Alkaline	7.5 – 9.0
Highly alkaline	> 9.0

Mineralogy

Mineralogical data (QXRD) provides supporting information for the geochemical data, particularly with regard to sulphide and carbonate mineralogy of a sample, showing results for mineralogical forms (e.g. what sulphide or carbonate minerals are present) and their concentrations (reported in weight %). These data are also used to validate the results from ABCC test-work and assist with interpretation of the ABA data.

Element Enrichment

The total concentration for each element were compared to average element abundance in soil in the earth's crust (Bowen, 1979) to measure how the total elemental concentrations in the samples compare against average elemental concentrations in unmineralised soil (worldwide). Such a comparison is undertaken to identify samples

that contain what may be regarded as 'elevated' concentrations of metals and metalloids to identify potential element of concern. However, enrichment in any metals/metalloids in the solids, does not translate to enhanced leachability or mobilization and/or bioavailability of that specific element.

From the comparison with average crustal abundance in rocks a geochemical abundance index (GAI) was calculated. The GAI quantifies an assay result for a particular element in terms of the average abundance for that element (in sedimentary rocks). The index, based on a log 2 scale, is expressed in seven integer increments (0 to 6), which correspond to enrichment factors from 0 to over 96 times average crustal abundance, as shown in **Table 6**.

Table 6. Geochemical abundance index (GAI)

GAI	Enrichment factor	GAI	Enrichment factor
0	Less than 3-fold enrichment	**4**	24 to 48-fold enrichment
1	3 to 6-fold enrichment	**5**	48 to 96-fold enrichment
2	6 to 12-fold enrichment	**6**	Greater than 96-fold enrichment
3	12 to 24-fold enrichment		

As a general rule, a GAI greater than or equal to three indicates enrichment compared to unmineralised soil that may warrant further investigation to assess their mobility under laboratory conditions.

Elements identified as enriched may not necessarily be a concern for revegetation and rehabilitation, human and animal health or drainage water quality. Similarly, if an element is not enriched it does not mean it would not be mobilised, because under some conditions (e.g. low pH, reducing conditions) the geochemical behaviour of metals/metalloids such as Al, As, Cu, Cd and Zn can change (i.e. become less or more mobile).

Solubility

Metal/metalloid mobility from samples has been assessed using deionised water, 'saline' water and peroxide (NAG) leaching methods. The deionised and saline water leaches assess the initial solubility under fresh water and saline water conditions, whereas the peroxide leach assesses the solubility after the samples have been oxidised. The objective of the saline leaching procedure is to better mimic the brackish to moderately saline water commonly used in the CHPPs to process ROM coal.

The solubility data from bottle leaching provides an indication of likely solubility/release of salt and metals/ metalloids under field pH and redox (oxidation) conditions (and/or saline or low-pH conditions, where applicable). Peroxide (NAG) leachate data provides an indication of potential acidity and concentrations of metals and metalloids that could be released from samples that are fully and rapidly oxidised. This test provides an assumed 'worst case' scenario in term of metal/metalloid mobility. Solubility data from OxCon testing provides an indication of likely solubility/release of salt and metals/metalloids when the samples are oxidised and can be used to estimate release rates.

To ensure a consistent approach to describe the samples geochemical characteristics, specific concentration cut-off values were used to discuss leachate composition as shown in **Table 7**. These same concentration cut-off values were also applied to tailings liquor data.

Table 7. Soluble trace element concentration category and associated cut-off

Classification	Trace element soluble concentration mg/L
Close to detection	≤ 0.001
Very low	> 0.001 – 0.05
Low	> 0.05 – 0.1
Moderate	> 0.1 – 1.0
High	> 1.0 – 10
Very high	> 10

A classification scheme initially developed by Ficklin *et al*. (1992) has been adapted to summarise major attributes of the solubility data by plotting pH against soluble metal and metalloid concentrations for groups of elements, with the classification scheme shown in **Figure 3**. The soluble metal and metalloid concentrations are shown as the sum of soluble metal concentrations for base metals (Cd + Co + Cu + Ni + Pb + Zn) and/or the sum of soluble As + Mn + Mo + Se. These two groups of elements are chosen because they remain in solution across a wide range of pH and are not only associated with AD conditions, but also with NMD/SD conditions.

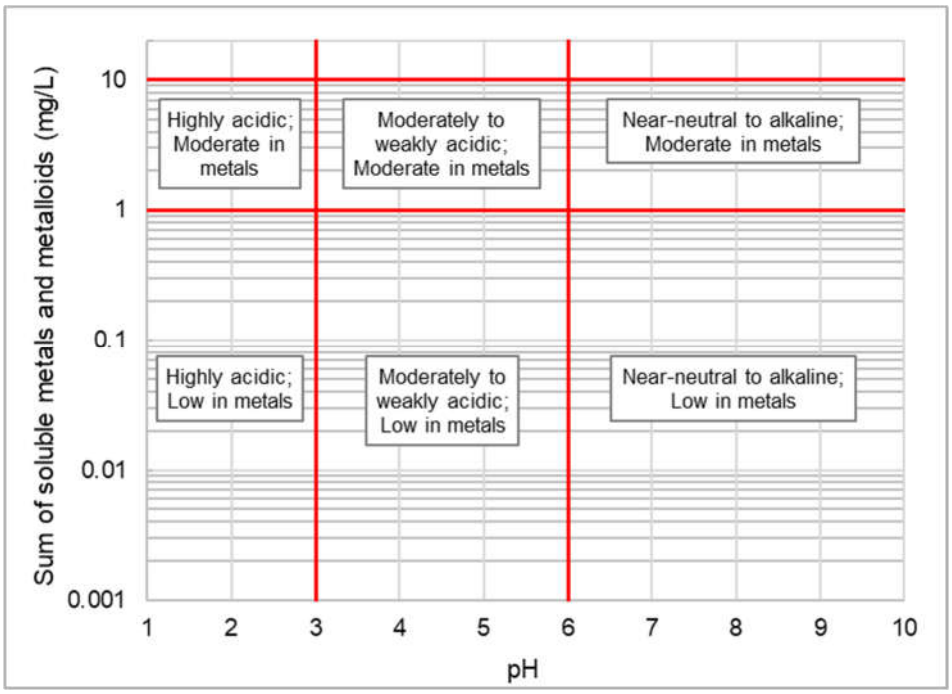

Figure 3. Classification of soluble metals and metalloids as a function of pH

No comparison is made between leachate results and water quality guideline values, such as ANZG (2018), as such a comparison is inappropriate. The guideline values provided in ANZG (2018) are for receiving water environments (e.g. creeks), whereas the soluble element data in this assessment is 'point source' obtained from a finely pulped sample subjected to rigorous and artificial extraction to obtain a concentration approaching 'near maximum'. Furthermore, contact water will undergo a number of geochemical reactions along a pathway from source to receptor, including retardation, adsorption and precipitation – and also likely dilution, which will attenuate the concentration as seepage/contact water migrates from the source. These processes are not accounted for in a laboratory setting.

Sodicity and Dispersion

Potential spoil samples (representing material that is likely to report to final landform surface) are broadly classified with respect to sodicity on the basis of the exchangeable sodium percentage (ESP) value, as shown in **Table 8** (after Northcote and Skene, 1972; Isbell, 2002):

Table 8. Sodicity classification

Sodicity classification	ESP %
Non-sodic	≤ 6
Sodic	6 – 14
Strongly sodic	> 14

The sodicity will depend upon a range of factors, such as clay mineralogy, soil sodium concentration, soil salinity and irrigation water (rainwater) chemistry, which may enhance or limit that potential for soil to be sodic or become sodic over time. Therefore, values of 6% ESP and 14% ESP to represent soils as being sodic or strongly sodic are used as a general guide only and should not be taken as definitive. Sodicity assessments only apply to materials likely to report to final landform surfaces, such as overburden/interburden (i.e. not coal reject or waste coal).

Sodicity information is broadly used to understand potential revegetation and dispersion aspects, and is supported by Emerson Aggregate Class test information, which provides a direct measure of soil slaking and dispersion based on the Standards Australia (2017) classification. Soils are divided into classes on the basis of their coherence in water and presence (or absence) of calcium-rich minerals (**Table 9**). Slaking occurs when dry soil crumbs, after being immersed in deionised water, break up and run along the bottom of the beaker into a flat pile. Most dry soil crumbs slake when immersed in deionised water. Dispersion describes the tendency for the clay fraction of a soil to go into colloidal suspension in deionised water. Materials are generally regarded as being dispersive (or prone to dispersion) if they have an Emerson Class number of three or less.

Table 9. Emerson classifications

Class	Description	Class	Description
1	Slaking and complete dispersion	5	No calcite or gypsum present; dispersion
2	Slaking and some dispersion	6	No calcite or gypsum present; flocculation
3	Dispersion [remoulded]	7	Non-slaking and swelling
4	Calcite or gypsum present; dispersion	8	Non-slaking and non-swelling

4.4.1 Using Coal Quality Data for AMD Classification

Coal quality data has been used to aid with the assessment of AMD hazard associated with coal seams. In particular, the BHP coal quality database was used to supplement the geochemical database and provide additional understanding of the AMD potential of likely ROM coal, remnant coal, waste coal and rejects. Coal plys were grouped into their respective seam groups on a per-pit basis, such as GUS seam, GMS seam etc. for each pit group.

Total S concentrations can be used conservatively to assess the AMD hazard for any given sample; thus, statistical analyses were conducted on total S as a function of seam group and for all seams combined to define the AMD hazard of coal. The data were used to understand the sulphur grade range for each seam group to gain an understanding of the potential AMD hazard posed by each coal seam group. The results were then compared with detailed geochemical data available for coal to 'calibrate' the coal quality total sulphur data.

Coal samples from less than 20m depth were assumed to be completely or predominantly oxidised and were interpreted as 'weathered carbonaceous spoil' and, therefore, excluded from the assessment of potential ROM

coal. Acid producing sulphate minerals, such as jarosite, may be present within weathered coal and carbonaceous material, however, mineralogical data available from BMA mines in the district mining the MCM suggests that jarosite is an insignificant mineral within the MCM.

4.4.2 Residual Void Highwall Assessment

An assessment of the AMD hazard associated with exposures of all lithological materials, such as remnant coal, weathered materials, fresh non-carbonaceous and carbonaceous overburden was undertaken – being representative of the highwall of the residual void associated with a given pit group.

The frequency of occurrence of relevant material types within each pit was determined from the stratigraphic distribution within selected drill holes under the assumption that the frequency of distribution of each material type is broadly indicative of their respective surface exposures on current highwalls. For example, if GUS seam group had a frequency of occurrence (by meters) of 5% in the drill-hole data set, then the assumption is that the same coal seam group would represent approximately 5% of the surface exposure on the void highwall. This method – whilst being relatively simple – provides an acceptable approximation with regard to which seam groups or mineral waste types are most likely to be significantly present in pit walls versus those material types most likely present in relatively minor proportions.

To estimate the proportion of key material domains on the highwalls in each void, exploration drill-holes in proximity to the future void highwall/s were selected by for each pit. Most holes extended to depths approximating future pit floor depths.

Stratigraphy, age, weathering, location with respect to the water table, and major stratigraphic horizons (as recorded in the BHP coal geology database) were used to assign individual (discrete) lithological units to a material domain as follows:

- Weathered, non-carbonaceous;
- Weathered, carbonaceous [includes weathered coal];
- Fresh, non-carbonaceous;
- Fresh, carbonaceous;
- Fresh, coal.

Coal plys were grouped into their respective seam groups, such as GUS, GMS, etc.

For each void highwall, a statistical assessment was conducted on each drill-hole sub-set (as applicable to each void) to summarise the frequency of occurrence of drill core intervals as a function of each of the material groups listed above.

The inherent AMD hazard of each material group listed above was inferred from the geochemical database and coal quality database for similar material types. The combined AMD hazard for the material groups likely to be exposed on the highwall was then used to estimate the AMD hazard of the highwall at each pit.

4.4.3 Residual Void Floor Assessment

An assessment of the AMD hazard associated with exposures of remnant coal on the floor of each pit group was undertaken – being representative of the floor of the residual void associated with a given pit group.

As explained in **Section 4.4.1** coal quality data was assessed to understand the potential AMD hazard associated with coal. For the task of assessing the AMD hazard specific to pit floors (on a pit-group basis), only the coal quality data from the seam group likely to form the pit floors at a given pit group was assessed. At GRBM, the GMS seam group forms the floor of the Broadmeadow-Isaac void and the GLS seam group forms the floor of all other voids.

It is acknowledged that there are generally minor geochemical differences between the various plys of any given seam group. Also, the AMD hazard of the floor of a pit may change depending on whether a significant proportion of the pit floor resides on coal(ly) or non-carbonaceous material. Furthermore, the AMD hazard of any pit floor is not just associated with its surface exposure, but more so with the composition of the sub-drill zone, which

represents an extensively fractured coal / interburden comprising the upper sections of a pit floor. For this assessment, the AMD hazard was estimated only for assumed surface exposures of coal / plys.

In practice, mining takes all coal to the bottom of the seam (at the bottom of a pit), therefore very little coal would be expected to remain on the floor of the voids. As such, the assessment has adopted a highly conservative position assuming the floor of each void is all coal, and the coal floor is completely exposed.

4.4.4 TSF Assessment

At closure, GS1 TSF and RS1 TSF will both remain as discrete facilities (TSF landforms). These TSFs are non-operational and will undergo rehabilitation prior to or during mine closure. Geochemical data from samples collected from GS1 and RS1 TSFs were used to assess the geochemical AMD source hazard of these facilities.

RS1 TSF is constructed as two compartments: a western compartment, comprised of rejects only; and an eastern compartment predominantly comprised of tailings, with rejects embankments (i.e. a 'typical' TSF). The entire RS1 TSF landform will be rehabilitated as single landform, however the landform more closely resembles a rejects dump abutting (adjoining) a TSF. The AMD source hazard of each compartment has been determined.

The primary current/operational TSF is Ramp 32 TSF (Airstrip pit) – an in-pit TSF that will be backfilled during rehabilitation and will form part of the Airstrip spoil landform. However, due to the location of this TSF at the base of the Airstrip spoil landform, this TSF has been conservatively assessed as a discrete facility (TSF landform) within the spoil landform. The AMD source hazard of Ramp 32 TSF landform was assessed using tailings geochemical data from the CHPPs representing 'fresh' tailings samples. No rejects are located within this in-pit TSF.

DRE5 TSF is a small in-pit TSF that will be partially backfilled during rehabilitation and will form part of the Thiess spoil landform. However – and similar to Ramp 32 TSF – due to the location of this small TSF at the base of the Thiess spoil landform, this TSF has been conservatively assessed as a discrete facility (TSF landform) within the spoil landform. The AMD source hazard of DRE5 TSF landform was assessed using tailings geochemical data from the CHPPs representing 'fresh' tailings samples. No rejects are located within this in-pit TSF.

4.4.5 Reject Dump Assessment

At closure, Riverside rejects dump (located immediately southwest of RS1 TSF) will remain as a discrete facility (rejects landform). This inactive facility underwent rehabilitation in the early 2000s and has a spoil cover, however further rehabilitation is scheduled to ensure the PMLU is achieved. Geochemical data from samples collected from within this rejects dump were used to assess the geochemical AMD source hazard of this facility. The samples were collected from the facility in 2004, during rehabilitation (prior to the existing spoil cover placement).

GS2 rejects dump – located northeast of GS1 TSF – is located outside of a spoil landform area. As such, this facility has been assessed as a 'stand-alone' rejects landform. No geochemical data is specifically available from this rejects dump. The assessment has used data from all 'aged' rejects generated from GY CHPP – being the source of rejects disposed at this dump.

GS11 rejects dump – located north of Ramp 32 TSF (airstrip pit) between the TSF and Eureka Creek – is located outside of a spoil landform area. As such, this facility has been assessed as a 'stand-alone' rejects landform. No geochemical data is specifically available from this rejects dump. The assessment has used data from all 'aged' rejects generated from GY CHPP – being the source of rejects disposed at this dump.

R22 rejects dump – located within the southwestern periphery of Thiess spoil landform – is assessed as a 'stand-alone' facility due to the concentration of rejects close to the edge of the spoil landform. No geochemical data is specifically available from this rejects dump. The assessment has used data from all 'aged' rejects generated from GY CHPP – being the source of rejects disposed at this dump.

4.4.6 AMD Hazard Scoring

Estimating the AMD hazard is the first step in estimating the geochemical risk associated with potential sulphide oxidation of mineral wastes. The authors have developed an internal procedure to standardise the AMD hazard assessment to maintain consistency across all BHP coal sites and material domains, with the process described below.

AMD hazard scoring and the AMD geochemical likelihood describe the Geochemical Hazard. The former describes the hazard for AMD generation and the latter describes the likelihood of an AMD event to occur.

A source material is a distinct material type (e.g. non-carbonaceous spoil or rejects or tailings), whereas a landform is a domain comprising one or more source material types (e.g. rejects disposed within non-carbonaceous spoil). AMD hazard scorings are assigned for individual source materials reporting to a landform as well as to landforms as a whole (i.e. landform AMD hazard score).

The likelihood of a landform developing AMD was determined based on the landform AMD hazard score. AMD hazard scores (**Table 10**) are estimated by analysing three key components, which are used to describe the geochemical hazard of a source material/landform:

1. Geochemical propensity to generate AMD;
2. AMD capacity; and
3. AMD quantity.

In undertaking the AMD hazard assessment, the assumption is that the source materials (within the landforms) will predominantly be dry or moist, but not wet or saturated. That is, the landforms will be unsaturated. This assumption is realistic, since most spoil landforms, rejects landforms and aged/inactive TSF landforms are generally unsaturated. This assumption is also conservative, since the potential for oxidation (to some degree) is assumed.

Table 10. AMD hazard scoring matrix

Component	Rating		Definition
Propensity for AMD generation Per material types/domain: - Non-carb. - Coaly & carb. - Reject - Tailings Per landform	1	Implausible	Geochemical properties suggest that the vast majority of the material has a negligible potential for AMD generation (less than 5% of the samples identified at potential for AMD in the samples set)
	5	Plausible	Geochemical properties suggest that significant proportion of the material may have potential for AMD generation (5-40% of the samples identified at potential for AMD in the samples set)
	7	Expected	Geochemical properties strongly suggest that the material has a high potential for AMD generation but has not yet been observed in the field (due to lag time) - (>40% of the samples identified at potential for AMD in the samples set)
	15	Certain	Evidence of AMD processes have been observed in the field
AMD **Capacity** Per material types/domain: - Non-carb. - Coaly & carb. - Reject - Tailings Per landform	1	Low	Source has a negligible potential for AMD generation. PAF samples have 75th percentile total S concentration less than 0.1%.
	3	Low-Moderate (NMD)	Assumed to be bulk NAF but sulphide bearing, with NAF samples having 75th percentile total S greater than 1% (i.e. the material is predominantly NAF-S). Dominant AMD sources contain material that will likely generate NMD and/or SD (related to sulphide oxidation).
	5	Moderate	PAF and NAF-S samples have 75th percentile total S concentration ranging 0.1-1.0% and with potential to generate AD.
	7	Moderate-High	PAF and NAF-S samples have 75th percentile total S concentration ranging 1.0-1.5% and with potential to generate AD.
	10	High	PAF and NAF-S samples have 75th percentile total S concentration greater than 1.5% and with potential to generate AD.
AMD **Quantity** Per material types/domain: - Non-carb. - Coaly & carb. - Reject - Tailings Per landform	1	Low	Material rated LOW for AMD capacity; or less than 5% of material reporting to a landform is rated LOW-MODERATE for AMD Capacity
	3	Low-Moderate	Less than 5% of material reporting to a landform rated as MODERATE for AMD capacity
	5	Moderate	Greater than 5% of material reporting to a landform rated as LOW-MODERATE or MODERATE for AMD capacity
	7	Moderate-High	Less than 5% of material reporting to a landform rated as MODERATE-HIGH or HIGH for AMD capacity
	10	High	Greater than 5% of material reporting to a landform rated as MODERATE-HIGH or HIGH for AMD capacity
AMD **Quantity** Residual void (pit) highwall & floor Per residual void	1	Low	Less than 10% of drill-hole meters (or less than 10% of pit floor exposure) are classified as PAF or NAF-S
	3	Low-Moderate	Between 10% and 30% of drill-hole meters (or 10-30% of pit floor exposure) are classified as PAF or NAF-S
	7	Moderate-High	Greater than 30% of drill-hole meters (or greater than 30% of pit floor exposure) are classified as PAF or NAF-S
	10	High	Observed AMD on highwall or floor of pit or AMD affected water in pit

AMD Propensity is the geochemical propensity of a given material type to generate AMD. The propensity to generate AMD is determined based on the proportion of samples that have potential for AMD as determined from laboratory test-work and the subsequent assessment – the higher the percentage of materials that can generate AMD within a sample set, the greater the AMD propensity. This approach is conservative, since sampling is slightly skewed towards material types considered to pose a potentially higher AMD hazard, such as carbonaceous materials.

AMD Capacity represents the 'severity' of AMD generation, with total S concentrations used as a proxy for scoring this component, which represents a conservative approach as some sulphur is associated with non-acid generating minerals. For example, the higher the total S concentration in materials with potential for AMD, the higher the hazard, the higher the score. Furthermore, the AMD capacity also takes into account the type of drainage a source material can produce, i.e. AD, NMD and/or SD, where discrimination or prediction is possible. The various drainage types should be differentiated (where the data allows) to reflect the difference in impact severity and difficulty to manage or treat. For example, on an equal quantity basis, AD is likely going to cause more severe impacts than NMD or SD and therefore is assigned a higher score.

As a first approximation the AMD Capacity of each material type is estimated based on 75th percentile value of the total S concentration for the samples classified as PAF and NAF-S. This is a conservative assumption, as not all total S is associated with reactive minerals and choosing the 75th percentile total S value of PAF and NAF-S samples to assess the AMD capacity will attract a higher AMD Capacity scoring. For example, if two material types had the same proportion of samples with the same propensity for AMD, but one has a higher total S concentration associated with PAF and NAF-S materials, then this sample would receive a higher AMD Capacity score.

Generally, amongst Bowen Basin Permian- and Tertiary-age materials, a very small number of samples are classified as NAF-S – almost all samples with high total S (>1%) are typically classified as 'PAF' of some type. Therefore, AMD Capacity does take into consideration potential NMD/SD by including NAF-S samples with PAF samples, however the very few NAF-S samples (compared to PAF samples) means that NAF-S samples typically have a negligent bearing on the AMD Capacity of a material. For example, of the 2164 samples at GRBM that underwent geochemical characterisation, only 13 samples – all of which were tailings – were classified as NAF-S.

AMD Quantity is the amount of material (tonnages) that has the potential to generate AMD. The greater the tonnage of AMD generating material the greater the hazard scoring. The AMD Quantity scores are assigned to material types for each landform.

4.4.7 Landform AMD Likelihood Scoring

The likelihood of a landform generating AMD is estimated by analysing two key components:

1. Source material AMD hazard score; and
2. Landform AMD hazard score.

Source material AMD hazard score: Describes the potential for AMD generation by the respective material types within each landform. It is estimated from the weighted combined scores of each component used to describe the AMD source hazard:

- Propensity to generate AMD. Assigned a 50% weighting (weighting = 1);
- AMD capacity. Assigned a 25% weighting (weighting = 0.5); and
- AMD quantity. Assigned a 25% weighting (weighting = 0.5).

Landform AMD hazard score: Describes the likelihood for AMD generation by each final landform and each residual void. It is estimated from the source material AMD hazard scores for each material type assumed to be present within that specific landform.

At closure, GRBM has four spoil landforms, five residual voids, four TSF landforms [GS1 and RS1 above-ground TSFs; and Ramp 32 and DRE5 in-pit TSFs] and four rejects landforms [Riverside, GS2, GS11 and R22], as listed in **Section 2.2**.

- **Landforms**: The landform AMD hazard score is estimated from the weighted average of the source material AMD hazard and the proportion of PAF and NAF-S waste expected to report to the landform from each material type.
- **Residual voids**: the landform AMD hazard score is estimated from the average of the source material AMD hazard scores for each material type likely to be exposed on the highwall or floor of each residual void.

To support the assessment of the AMD closure risks, the landform AMD hazard score is assigned a likelihood score (**Table 11**) as consistent as possible with BHP risk management methodology, which is aligned with ISO 31000. ISO 31000 is a family of standards relating to risk management codified by the International Organization for Standardization. For landforms and residual voids with AMD hazard scores between 10 and 20 a preliminary likelihood of 'Probable / Likely' is assigned unless/until kinetic data are available to provide a time frame for AMD generation. This likelihood can be revised as more data, such as kinetic or field data, becomes available.

Table 11. Landform AMD hazard score and landform AMD likelihood

Landform AMD hazard score	Landform AMD likelihood
0 - 5	Highly Unlikely: Highly unusual; may occur in extreme circumstances
5 - 10	Unlikely: Known to occur, but only rarely
10 - 15	Probable: May occur
15 - 20	Likely: Could easily occur
>20	Highly Likely: Expected to occur

5 Results

Environmental geochemical data is available for 1312 overburden/interburden (spoil) samples and 26 coal samples [sampled from drill-core] and 244 fresh tailings samples, 223 aged tailings samples, 118 fresh rejects samples and 220 'aged' rejects samples – all of which have undergone a range of environmental geochemical tests. The samples are representative of the following mineral waste and coal groups:

Spoil

- Weathered Non-carbonaceous: Weathered non-carbonaceous overburden. 154 drill-hole samples
- Weathered Carbonaceous: Weathered carb. overburden [includes weathered coal]. 31 drill-hole samples
- Fresh, Non-carbonaceous: Fresh non-carbonaceous overburden/interburden. 1015 drill-hole samples;
- Fresh, Carbonaceous: Fresh carbonaceous overburden/interburden. 112 drill-hole samples

Coal

- Fresh Coal: Fresh coal, representative of ROM coal. 26 drill-hole samples

Tailings

- Fresh: Fresh tailings from the CHPPs. 244 samples
- Aged: Aged tailings from GS1 and RS1 TSFs. 223 drill-hole samples

Rejects

- Fresh: Fresh rejects from the CHPPs. 118 samples
- Aged: Aged rejects from GS1 and RS1 TSFs. 146 drill-hole samples
- Aged: Aged rejects from Riverside rejects dump (74 samples) from test pits and boreholes

Additional to the above waste material types, geochemical data is also available for three 'fill' samples and 18 natural ground samples collected from geotechnical investigation drill-holes within RS1 TSF. The fill samples are likely part of embankment construction. The natural ground samples usually represent the base of TSF (immediately below tailings) encountered during geotechnical investigations. This data is presented in the figures/graphs herein for context, however, is not discussed in detail.

5.1 Mineralogy

Data is available for 20 tailings samples and 6 rejects samples that underwent mineralogical analysis by Quantitative X-Ray Diffraction (QXRD). The samples were selected to cover a broad range of mineral waste types. The results are summarised in **Figure 4**. QXRD test-work for spoil samples is underway (results unavailable for this assessment).

Across both tailings and rejects, the key acid generating mineral is pyrite (+/- marcasite), and the key acid neutralising minerals are calcite and iron-dolomite / dolomite. Although siderite is a carbonate, it provides no net acid neutralising capacity. In particular:

- Most samples are dominated by clay and quartz minerals (silicate group minerals) and non-crystalline (amorphous) material, variable contributions of carbonate and other silicate minerals. Amorphous (non-crystalline) material was detected in all samples, but generally present in greater proportions in the aged tailings and rejects (combined) samples (median = 40%) compared to the fresh CHPP samples (median = 13%). The nature of the non-crystalline material is largely unknown, although for tailings and rejects it's likely associated with organic carbon.
- The tailings reported high concentrations of sulphide minerals, with 13 out of 20 samples having greater than 1.5% sulphide (as pyrite). Furthermore, fresh CHPP tailings reported higher sulphide mineral concentration (median = 2.55%) compared to aged tailings (median = 0.75%).

- The rejects generally reported low-moderate concentrations of sulphide minerals, with only 1 of the 6 samples having greater than 1.5% sulphide (as pyrite).
- Most fresh tailings and rejects samples have low sulphate concentrations (<1.5%), which is present as jarosite, gypsum and basanite.
    - Sulphate concentrations are slightly higher in the aged tailings samples compared to the fresh tailings samples. Comparatively, there is little difference in sulphate concentrations between fresh and aged rejects.
- Carbonate group minerals predominantly comprise calcite, ankerite and siderite in variable proportions and broadly aligned with the expected carbonate minerals based on the ABCC data.

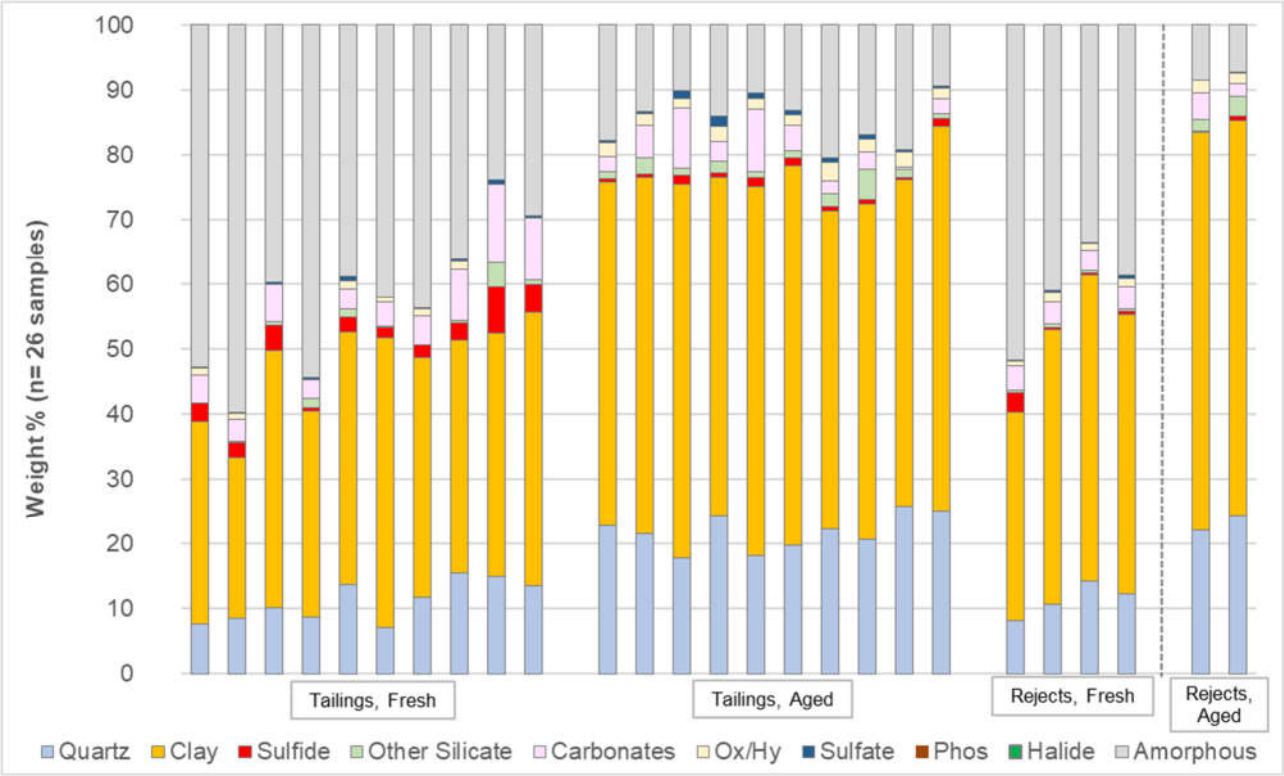

Figure 4. Mineral distribution within tailings and rejects samples

5.2 Acid-Base Accounting (Potential for AMD)

Acid-base accounting (ABA) is a theoretical balance between the potential for a sample to generate acid and neutralise acid, and is expressed in units of kilograms of sulphuric acid per tonne of sample (kg H_2SO_4/t). The ABA results for the samples that underwent geochemical characterisation are statistically summarised in **Table 12** (spoil samples), **Table 13** (rejects and coal samples) and **Table 14** (tailings and TSF fill/natural ground samples) and discussed in the following sections.

Table 12. ABA results statistics for spoil samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Spoil Weath[5]., non-carb[6].	Count (*n*)	*154*	*19 (19)*	*141*	*154*	*141*	*141*	*22*
	Maximum	0.64	0.44 (0.58)	298	20	17	715	8.3
	95th percentile	0.17	0.32 (0.32)	97	5.3	0.6	92	8.1
	75th percentile	0.05	0.14 (0.18)	15	1.5	-4.0	36	7.8
	Median	**0.02**	**0.06 (0.16)**	**7.3**	**0.6**	**-6.1**	**18**	**7.4**
	25th percentile	0.01	0.04 (0.13)	5.8	0.3	-11	6	4.9
	5th percentile	0.01	0.01 (0.1)	3.1	0.2	-85	1.4	3.1
	Minimum	<0.01	0.01 (0.08)	1.3	0.2	-297	<0.1	3.1
Spoil Weath., carb.	Count (*n*)	*31*	*18 (18)*	*31*	*31*	*31*	*31*	*9*
	Maximum	0.76	0.61 (0.76)	48	23	17	74	7.8
	95th percentile	0.67	0.53 (0.69)	36	21	11	23	7.5
	75th percentile	0.23	0.15 (0.42)	11	7.0	1.3	4.1	6.9
	Median	**0.14**	**0.08 (0.23)**	**6.0**	**4.3**	**-1.5**	**1.5**	**5.5**
	25th percentile	0.04	0.06 (0.16)	3.0	1.2	-6.4	0.9	4.2
	5th percentile	0.02	0.01 (0.11)	1.7	0.5	-24	0.3	3.6
	Minimum	<0.01	<0.01 (0.11)	0.8	0.2	-38	<0.1	3.2
Spoil Fresh, non-carb.	Count (*n*)	*1015*	*154 (154)*	*997*	*1015*	*997*	*997*	*90*
	Maximum	2.78	2.57 (2.78)	546	85	78	3311	11.4
	95th percentile	0.11	0.25 (0.33)	227	3.5	-5.5	443	10.8
	75th percentile	0.05	0.07 (0.1)	91	1.5	-21	108	9.3
	Median	**0.03**	**0.03 (0.05)**	**47**	**0.9**	**-45**	**46**	**8.9**
	25th percentile	0.02	0.02 (0.03)	23	0.6	-89	19	7.6
	5th percentile	0.01	0.01 (0.01)	8.8	0.3	-224	4.7	3.6
	Minimum	<0.01	<0.01 (0.01)	2.4	0.2	-544	<0.1	2.1
Spoil Fresh, Carb.	Count (*n*)	*112*	*27 (27)*	*112*	*112*	*112*	*112*	*19*
	Maximum	1.29	0.48 (0.72)	203	39	21	1326	9.4
	95th percentile	0.45	0.37 (0.51)	64	14	-1.2	54	9.0
	75th percentile	0.13	0.08 (0.24)	30	4.0	-8.7	19	8.7
	Median	**0.06**	**0.09 (0.19)**	**19**	**1.8**	**-16**	**8.7**	**7.3**
	25th percentile	0.03	0.02 (0.06)	13	0.9	-25	4.5	6.3
	5th percentile	0.02	0.01 (0.03)	5.9	0.6	-56	1.1	4.4
	Minimum	<0.01	<0.01 (0.02)	5.4	0.2	-203	0.4	3.0
Spoil ALL	Count (*n*)	*1312*	*218 (218)*	*1281*	*1312*	*1281*	*1281*	*140*
	Maximum	2.78	2.57 (2.78)	546	85	78	3311	11.4
	95th percentile	0.26	0.41 (0.47)	200	8.0	0.6	367	11
	75th percentile	0.06	0.11 (0.18)	80	1.8	-12	84	9.1
	Median	**0.03**	**0.04 (0.07)**	**35**	**0.9**	**-32**	**33**	**8.3**
	25th percentile	0.02	0.02 (0.03)	15	0.6	-77	13	6.5
	5th percentile	0.01	0.01 (0.01)	5.4	0.2	-196	1.4	3.5
	Minimum	0.01	0.01 (0.01)	0.8	0.2	-544	<0.1	2.1

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr was generally measured on potential spoil samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S. [4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.
[5] Weath.: weathered; [6] Carb.: carbonaceous.

Table 13. ABA results statistics for rejects and coal samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Coal	Count (*n*)	*26*	*1*	*26*	*26*	*26*	*26*	*1*
	Maximum	0.50	0.05 (0.06)	75	15	13	27	9.0
	95th percentile	0.47	-	48	14	13	18	-
	75th percentile	0.40	-	12	12	9.0	1.1	-
	Median	**0.35**	**-**	**6.0**	**11**	**4.3**	**0.5**	**-**
	25th percentile	0.31	-	4.3	9.5	-1.1	0.3	-
	5th percentile	0.15	-	1.4	4.5	-44	0.1	-
	Minimum	0.06	0.05 (0.06)	1.4	1.8	-71	<0.1	9.0
Rejects Fresh CHPPs	Count (*n*)	*118*	*118 (118)*	*118*	*118*	*118*	*118*	*118*
	Maximum	1.64	1.22 (1.64)	44	50	26	8.3	8.8
	95th percentile	1.23	0.84 (1.23)	32	38	14	5.1	8.5
	75th percentile	0.38	0.25 (0.38)	24	12	-6.7	3.7	8.2
	Median	**0.27**	**0.15 (0.27)**	**21**	**8.3**	**-12**	**2.5**	**7.9**
	25th percentile	0.20	0.11 (0.2)	18	6.1	-16	1.5	6.7
	5th percentile	0.14	0.07 (0.14)	13	4.3	-22	0.7	3.4
	Minimum	0.09	0.05 (0.09)	11	2.8	-30	0.3	2.7
Rejects Aged GS1 & RS1 TSFs	Count (*n*)	*146*	*42 (42)*	*146*	*146*	*146*	*146*	*38*
	Maximum	2.12	0.52 (0.66)	30	65	45	8.9	8.5
	95th percentile	0.57	0.39 (0.55)	25	18	2.9	3.6	8.1
	75th percentile	0.35	0.20 (0.34)	18	11	-2.4	2.1	5.0
	Median	**0.30**	**0.15 (0.31)**	**14**	**9.2**	**-5.4**	**1.6**	**4.1**
	25th percentile	0.25	0.11 (0.26)	12	7.7	-8.4	1.3	3.6
	5th percentile	0.17	0.07 (0.15)	9.4	5.3	-17	0.8	3.2
	Minimum	0.09	0.04 (0.09)	6.3	2.8	-26	0.3	3.2
Rejects Aged Riverside Dump	Count (*n*)	*74*	*74 (74)*	*74*	*74*	*74*	*74*	*0*
	Maximum	1.24	0.79 (1.24)	49	38	34	5.0	-
	95th percentile	0.74	0.48 (0.73)	38	23	6.4	3.3	-
	75th percentile	0.49	0.39 (0.49)	28	15	0.9	2.1	-
	Median	**0.43**	**0.32 (0.43)**	**17**	**13**	**-4.4**	**1.3**	**-**
	25th percentile	0.39	0.21 (0.39)	12	12	-14	0.9	-
	5th percentile	0.31	0.07 (0.30)	9.2	9.4	-27	0.5	-
	Minimum	0.25	0.01 (0.25)	3.7	7.7	-34	0.1	-

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S. [4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.

Table 14. ABA results statistics for tailings and TSF fill/natural ground samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Tailings Fresh CHPPs	Count (*n*)	*244*	*244 (244)*	*244*	*244*	*244*	*244*	*182*
	Maximum	2.58	1.94 (2.58)	70	79	47	3.6	9.5
	95th percentile	1.25	0.94 (1.25)	35	38	17	2.2	9.0
	75th percentile	0.81	0.49 (0.81)	29	25	3.1	1.7	8.3
	Median	**0.61**	**0.30 (0.61)**	**24**	**19**	**-6.0**	**1.3**	**7.7**
	25th percentile	0.50	0.22 (0.5)	19	15	-11	0.9	4.0
	5th percentile	0.37	0.13 (0.37)	11	11	-16	0.5	3.2
	Minimum	0.22	0.05 (0.22)	1.1	6.7	-31	<0.1	2.8
Tailings Aged GS1 & RS1 TSFs	Count (*n*)	*223*	*90 (90)*	*223*	*223*	*223*	*223*	*74*
	Maximum	2.68	2.47 (2.68)	26	82	63	2.3	7.4
	95th percentile	1.44	1.02 (1.58)	20	44	36	1.6	6.6
	75th percentile	0.58	0.34 (0.63)	15	18	6.4	1.2	4.4
	Median	**0.39**	**0.20 (0.44)**	**12**	**12**	**0.2**	**1.0**	**3.3**
	25th percentile	0.33	0.10 (0.34)	9.1	10	-2.1	0.6	2.8
	5th percentile	0.26	0.04 (0.28)	3.7	8.0	-5.3	0.2	2.6
	Minimum	0.14	0.02 (0.21)	<0.5	4.2	-13	0.0	2.2
TSF Other (fill / Natural ground samples)	Count (*n*)	*21*	*4 (4)*	*21*	*21*	*21*	*21*	*4*
	Maximum	0.76	0.45 (0.76)	23	23	5.7	30	6.2
	95th percentile	0.40	0.41	18	12	1.7	15	6.2
	75th percentile	0.23	0.27	10	7.0	-1.7	5.8	6.2
	Median	**0.06**	**0.13**	**5.0**	**1.8**	**-3.1**	**2.8**	**4.9**
	25th percentile	0.03	0.04	4.0	0.9	-4.4	1.5	3.4
	5th percentile	0.01	0.02	2.6	0.3	-10	0.9	3.0
	Minimum	<0.01	0.02 (0.06)	2.6	0.2	-11	0.3	2.9

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S. [4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.

Sulphur and Sulphide

The total sulphur (total S) distribution for all samples is presented in **Figure 5**. The total S concentration of spoil samples was generally very low to low with:

- A very low median value of 0.03%; and
- A low 95th percentile value of 0.26%.

Carbonaceous spoil samples had higher total S values compared to non-carbonaceous spoil. Of the 1312 spoil samples, only one sample had a high total S value (greater than 1.5%).

Total S concentration of most rejects, tailings and TSF fill samples were generally higher than most spoil samples, but generally comparable to coal samples. However, as evident in **Figure 5**, CHPP tailings had slightly higher total S concentrations compared to tailings samples from the TSFs.

Comparatively, the total S concentrations of fresh (CHPP) rejects and aged rejects from TSFs were similar. The total S concentrations from aged rejects from Riverside rejects dump was higher compared to fresh (CHPP) rejects and aged rejects from TSFs.

Natural ground samples from beneath the TSFs all have generally very low total S concentrations, as expected.

Coal samples from drill core had generally low total S values, with median and 75th percentile values of 0.35% and 0.40%, respectively. The 26 coal samples have a total S distribution lower than the larger BHP coal quality database. In particular, the 7011 'coal' samples from the GRBM coal quality database have median and 75th percentile total S values of 0.54% and 0.58%, respectively – noting that some of the samples in the coal quality database are not coal but are instead 'carbonaceous spoil' material within seams.

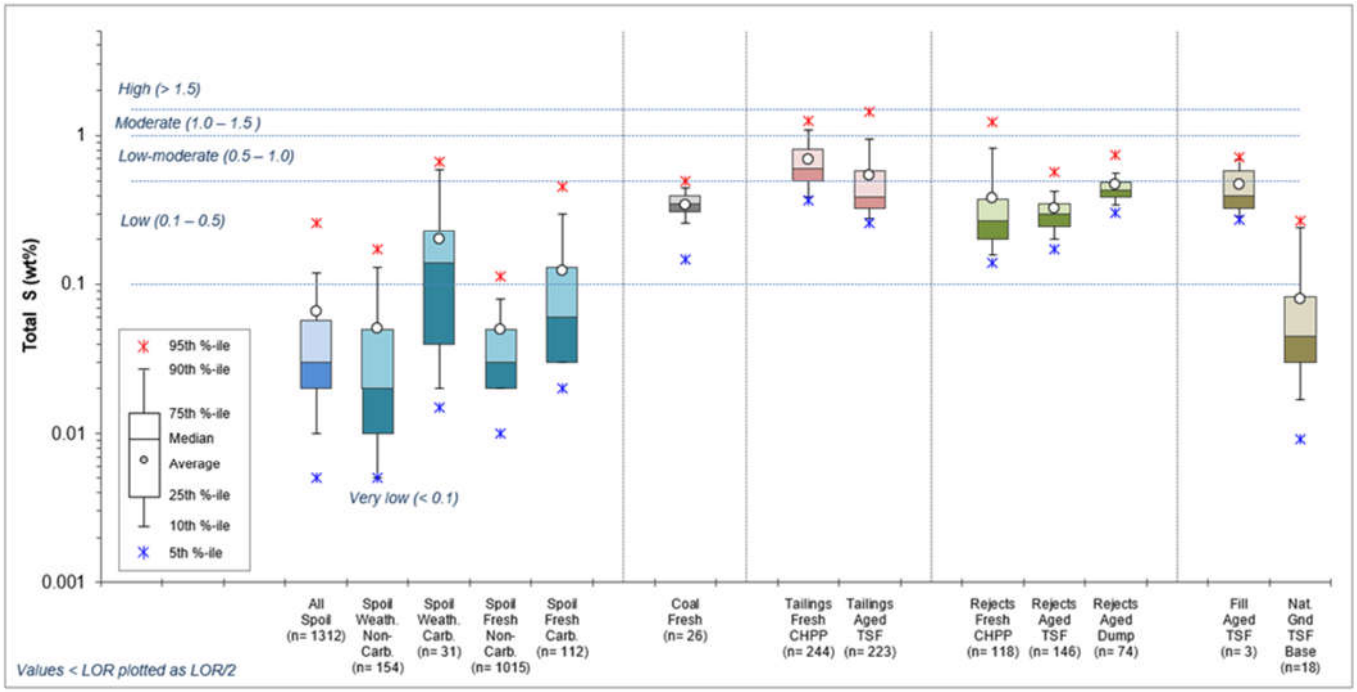

Figure 5. Sulphur (S) distribution

Chromium reducible sulphur (Scr) data is available for 218 spoil samples, 334 tailings samples, 234 rejects samples and one coal sample (**Tables 12, 13 and 14**). Scr was measured on most tailings and fresh rejects samples; and generally measured on all spoil samples with total S values greater than 0.1%. Where sulphide was measured in weathered spoil samples, this was generally only in those samples described as being 'slightly' weathered. The total S and Scr distribution for spoil samples is shown at **Figure 6**; and for tailings and rejects samples at **Figure 7**. Total S values are shown only for the samples that underwent Scr tests.

As evident in **Figure 6** all spoil samples had lower Scr distributions compared to the total S distributions from the same group of spoil samples. The differences were more pronounced in weathered spoil samples compared to fresh spoil samples.

As evident in **Figure 7**, all tailings and rejects samples have Scr values slightly lower than the total S values from the same samples, suggesting that a proportion of sulphur may be associated with organic S or sulphate; and also that oxidation of sulphide to sulphate is likely occurring in the aged samples, specifically.

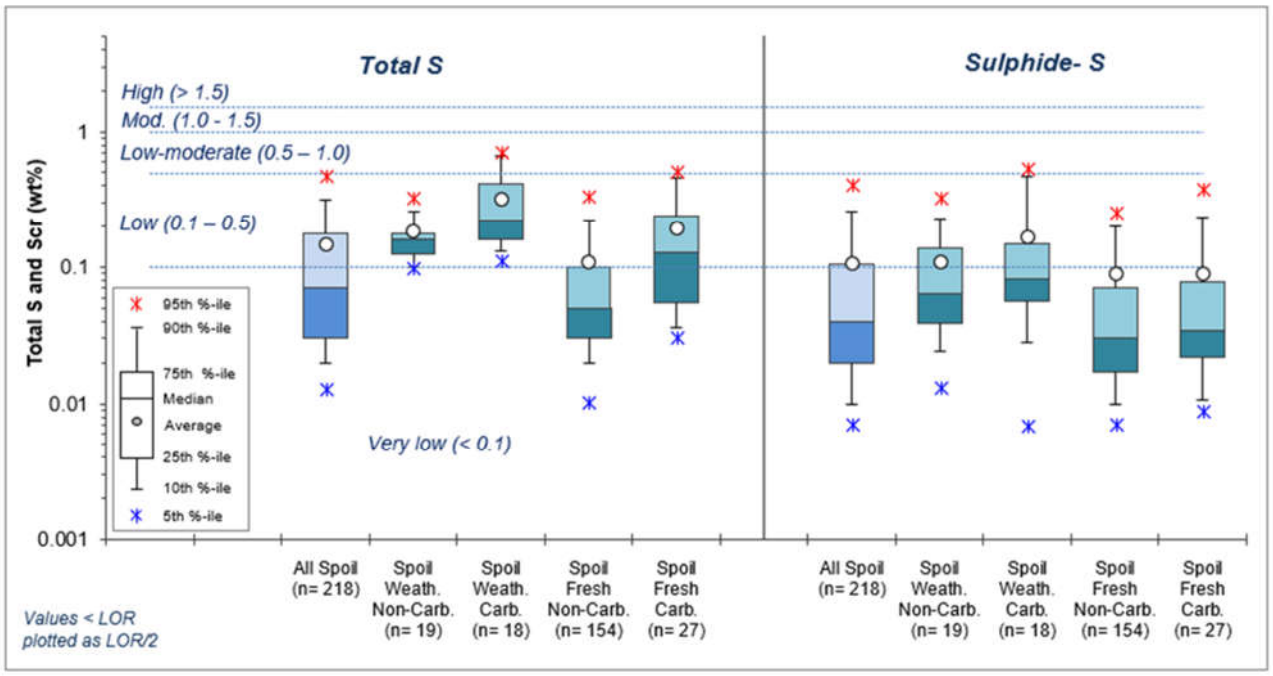

Figure 6. Sulphur (S) and sulphide (Scr) distribution of spoil samples

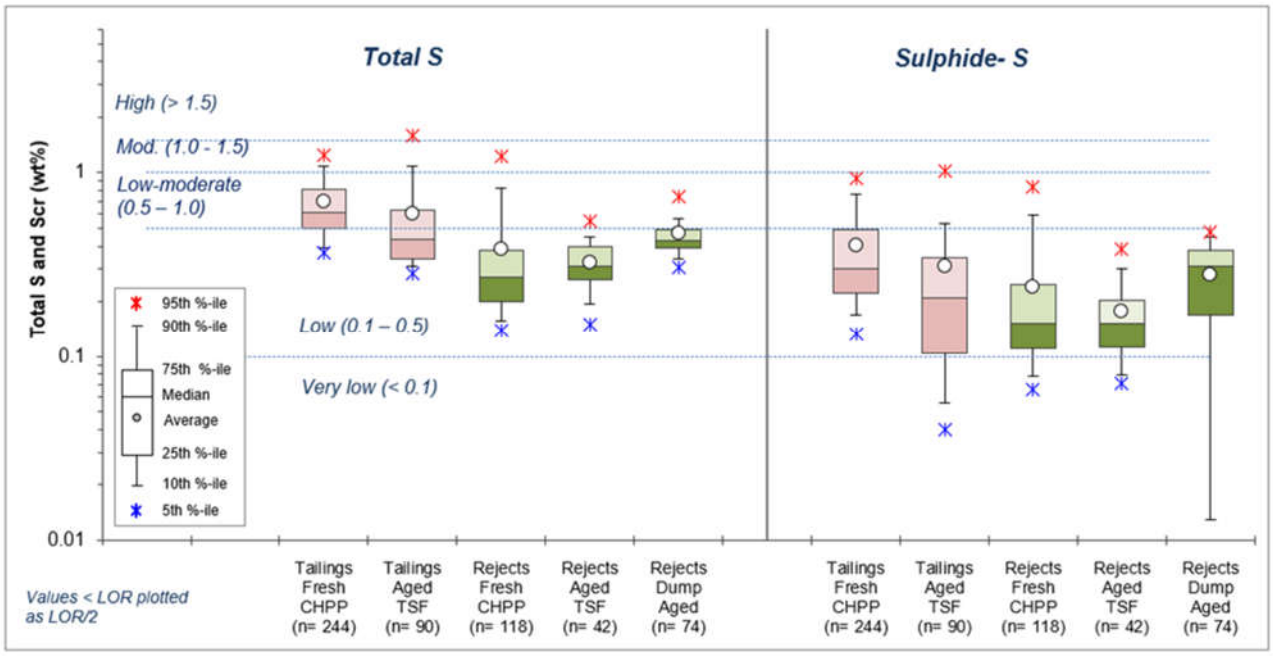

Figure 7. Sulphur (S) and sulphide (Scr) distribution of tailings and rejects samples

Where Scr data is available, the relationship between Scr versus total S is shown in **Figure 8** for spoil samples; and in **Figure 9** for tailings and rejects samples.

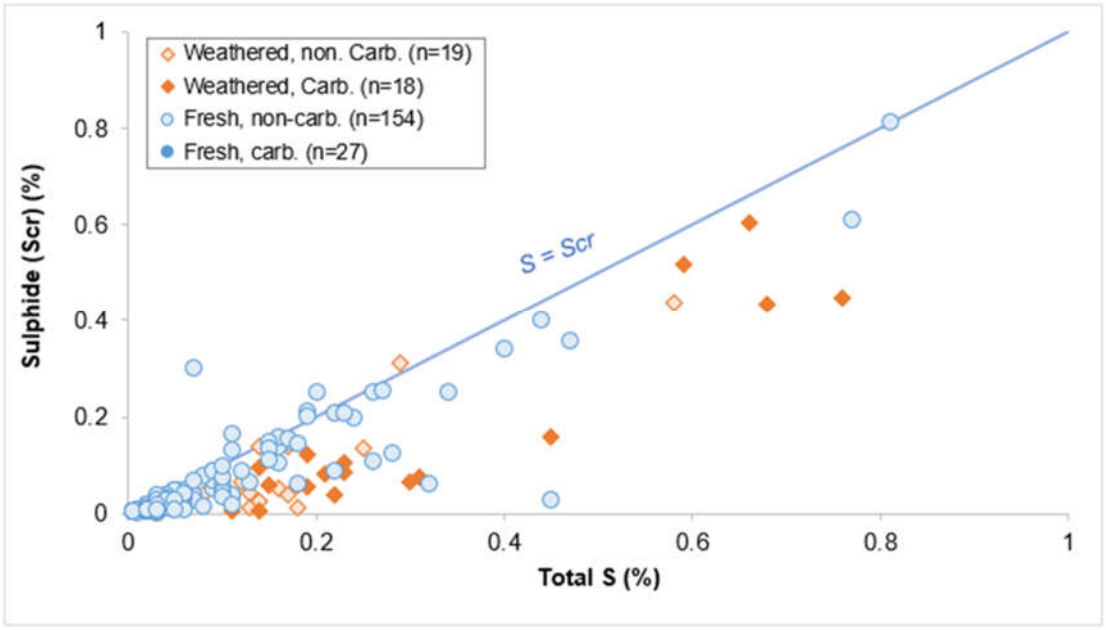

Figure 8. Sulphide (Scr) versus sulphur (S) for spoil samples
One non-carbonaceous fresh spoil sample had a total S value of 2.78% and Scr value of 2.57% and is not shown in the plot.

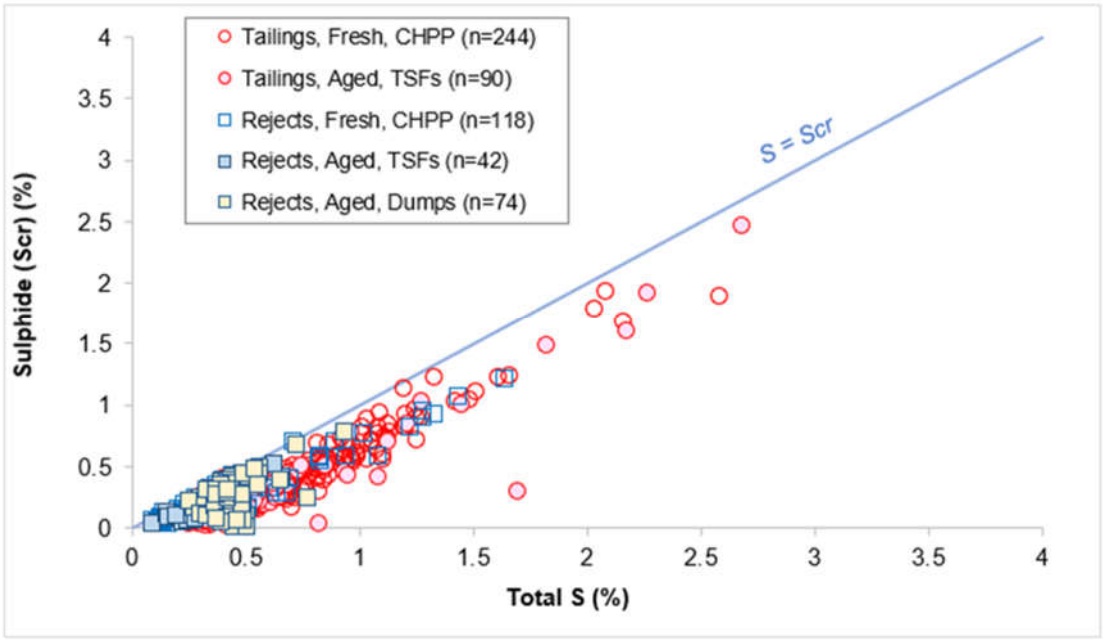

Figure 9. Sulphide (Scr) versus sulphur (S) for tailings and rejects samples

As a proportion of total S, Scr accounts for:

- Spoil samples: 57% (median value) of total S. Scr accounts for approximately 70% (median value) of total S in non-carbonaceous spoil and 32% (median value) of total S in carbonaceous spoil. The lower proportion of Scr in carbonaceous spoil (compared to non-carbonaceous spoil) is likely due to a larger proportion of total S being present as organic sulphur in the carbonaceous sample.

- Tailings samples: Scr accounts for approximately 50% (median value) of total S in fresh CHPP tailings and 48% (median value) of total S in aged tailings.

- Rejects samples: Scr accounts for approximately 56% (median value) of total S in fresh CHPP rejects; 49% (median value) of total S in aged rejects from TSFs; and 72% (median value) of total S in aged rejects from Riverside rejects dump. The slightly lower proportion of Scr in aged rejects from the TSFs compared to fresh rejects, and also compared to aged rejects from Riverside rejects dump is likely due to some sulphide in aged rejects in the TSFs being oxidised to sulphate. No sulphate data is available.

- Coal samples: Scr data is only available for one coal sample, of which almost all total S was present as Scr (Scr = 0.05%; total S = 0.06%). Sulphate data is available for seven coal samples and the sulphate concentrations were all less than 0.01% (as S). It is reasonable to assume that all fresh (unweathered) coal samples would have negligible sulfate concentrations and that a significant proportion of total S in all coal samples is likely present as organic sulphur.

These results indicate that the maximum potential acidity (MPA) that could be generated by most samples from these material domains is generally low and that using total S as an indication of AMD hazard will result in a conservative outcome.

Maximum Potential Acidity

MPA is calculated from total S, therefore the MPA distribution for each material type mimics the total S distribution for the same samples (refer to **Figure 5**). Due to the generally very low to low total S values for spoil samples the MPA was correspondingly low, with a 75th and 95th percentile MPA values of 1.8 and 8 kg H_2SO_4/t, respectively (n=1312 samples). As such, spoil represented by these samples is expected to have negligible potential to generate acid/acidity and negligible potential to release sulphate-derived salinity from sulphide oxidation. The small proportion of spoil with 'high' MPA (as a result of the high total S) would be well mixed throughout the bulk spoil and, as such, would not lead to spoil generating acid/acidity or sulphate-derived salinity.

Coal samples (n=26) produced MPA values generally higher than spoil – as expected by the higher overall total S values of coal samples. Coal samples had 75th and 95th percentile MPA values of 12 and 14 kg H_2SO_4/t, respectively.

Tailings and rejects produced total S values generally ranging from low to low-moderate, which resulted in a correspondingly similar low range of MPA values. Each tailings and rejects sub-type have a 75th percentile MPA value less than 25 kg H_2SO_4/t.

Acid Neutralising Capacity

The ANC distribution for all samples is presented in **Figure 10**. ANC values of spoil samples are typically in excess of the MPA values and span a very large range, from less than 0.5 to 546 kg H_2SO_4/t, with a moderate median ANC value of 35 kg H_2SO_4/t.

Over 84% of spoil samples have an ANC greater than 10 kg H_2SO_4/t which, if all ANC was readily available, would neutralise the acidity generated by material containing 0.33 wt% S. Approximately 2% of spoil samples had total S values greater than 0.33% – approximately equal proportions of carbonaceous and non-carbonaceous spoil samples.

The ANC for tailings and rejects samples was generally moderate, with median ANC values of approximately 20 kg H_2SO_4/t for each sub-type.

Coal samples had a wide range of ANC values from very low to high, but the overall ANC was low, with median and 10th percentile ANC values of 6 and 2 kg H_2SO_4/t, respectively. Fill samples from the TSFs had moderate ANC values and natural ground samples from the TSFs had very low to low ANC values.

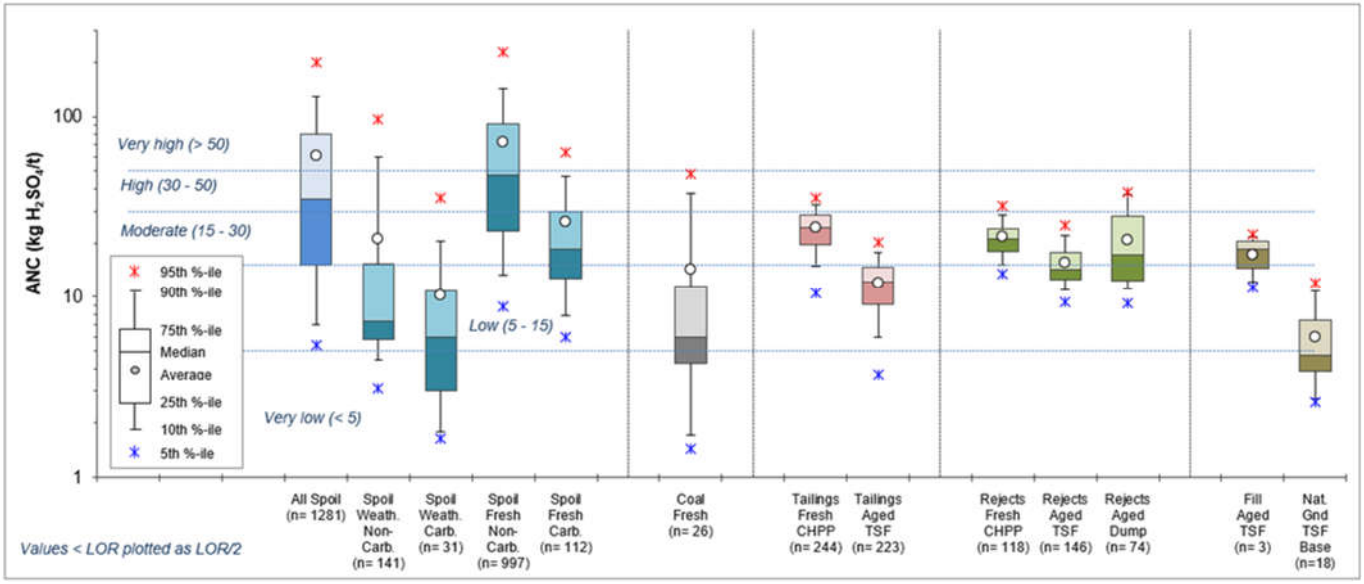

Figure 10. Acid neutralising capacity (ANC) distribution

Of the 997 fresh non-carbonaceous spoil samples, approximately 8% (84 samples) are located within 1.5 m above or below coal seams (i.e. 'near seam'). These near-seam samples have a median ANC of 18 kg H_2SO_4/t. Comparatively, the remaining 92% of fresh, non-carbonaceous samples have a median ANC of 53 kg H_2SO_4/t (i.e. approximately three times the 'near seam' ANC) – highlighting that fresh, non-carbonaceous spoil near seams has much lower ANC (generally), compared to fresh, non-carbonaceous spoil away from the seams. For the same two sample groups (i.e. near-seam versus distal to seams) the median total S was similar: 0.04% S for the 'near seam' samples and 0.03% S for samples away from seams.

Comparatively, of the 112 fresh carbonaceous spoil samples, approximately 23% (26 out of 112 samples) were located 'near seams'. These samples had a median ANC of 17 kg H_2SO_4/t and the samples away from seams had a similar median ANC of 20 kg H_2SO_4/t. Both groups had very similar median total S values: 0.060% S for the 'near seam' samples and 0.055% S for samples away from seams.

Available Acid Neutralising Capacity

Acid buffering characterisation curve (ABCC) tests were undertaken on samples to assess the proportion of ANC that may be 'readily available' (i.e. short-acting) in these materials under field conditions and provide some indication of what carbonate minerals are providing the ANC. 'Ready availability' is regarded as the proportion of ANC that is available for buffering reaction at pH 4.5. The results are summarised in **Figure 11**.

- Spoil samples (n=62). The proportion of ANC likely available under field conditions ranged from 10% to nominally 100% of the ANC, with a median of approximately 51%[3];
- Tailings, fresh (n=31). The proportion of ANC likely available under field conditions ranged from 11% to nominally 100% of the ANC, with a median of approximately 49%[3];
- Tailings, aged (n=13). The proportion of ANC likely available under field conditions ranged from 9% to 66% of the ANC, with a median of approximately 35%;
- Rejects, fresh (n=16). The proportion of ANC likely available under field conditions ranged from 12% to 69% of the ANC, with a median of approximately 35%;
- Rejects, aged (n=5) [all from GS1 TSF]. The proportion of ANC likely available under field conditions ranged from 31% to nominally 100% of the ANC, with a median of approximately 43%[3].

3 Because the ABCC test is a separate test to the ANC test – performed on different sample splits – it is possible to achieve results with greater than 100% ANC being readily available for the same sample. Such a result effectively means that all of the ANC for that sample is in a readily available form (i.e. a practical maximum of 100% availability). Similarly, at the lower end, the lowest 'readily available' amount may actually be slightly greater.

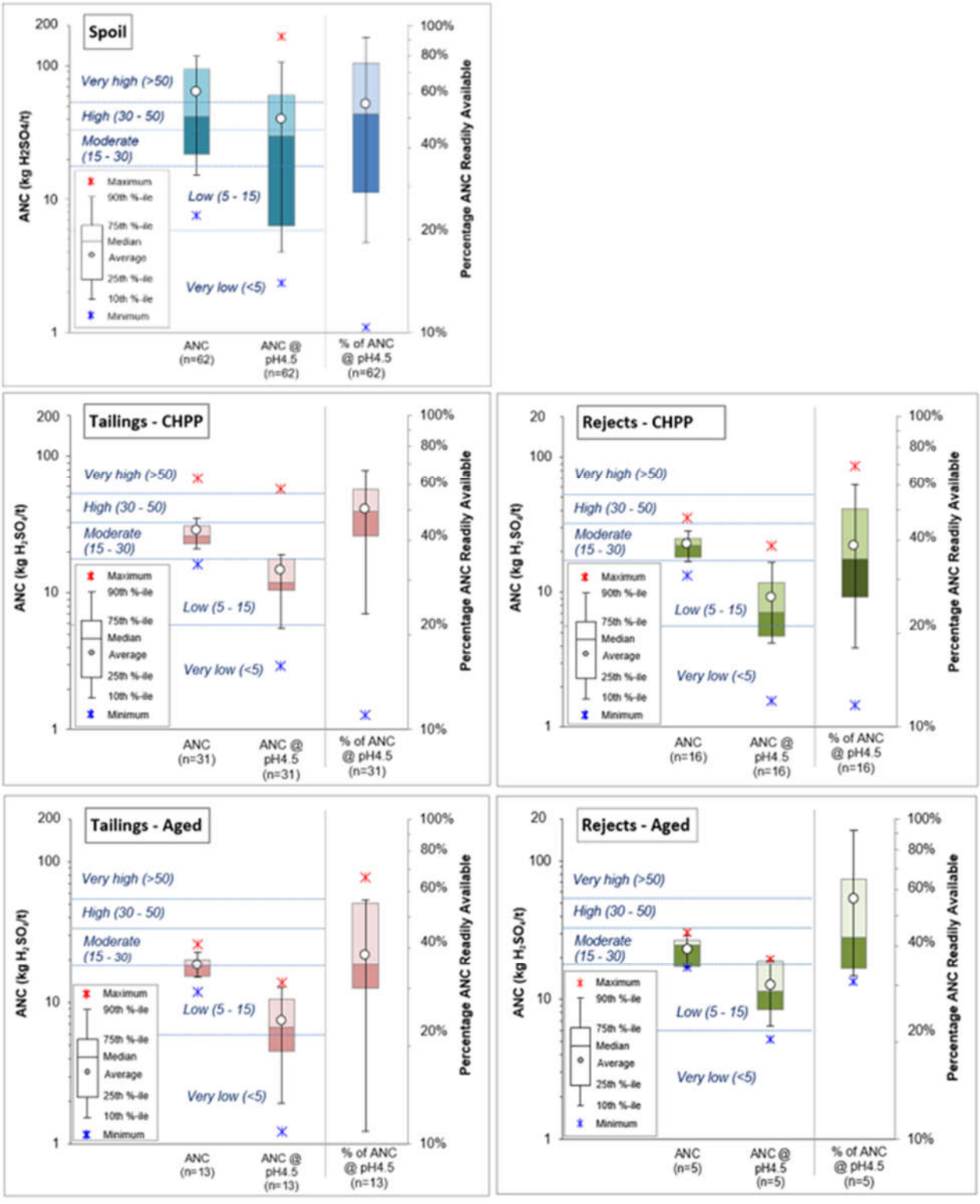

Figure 11. Distribution of acid neutralising capacity (ANC) [total], ANC at pH4.5 and proportion (%) of ANC expected to be readily available for spoil, tailings and rejects

The relationship between ANC @ pH 4.5 [i.e. ABCC ANC] and ANC [total] (for samples where ABCC data is available) is shown in **Figure 12**.

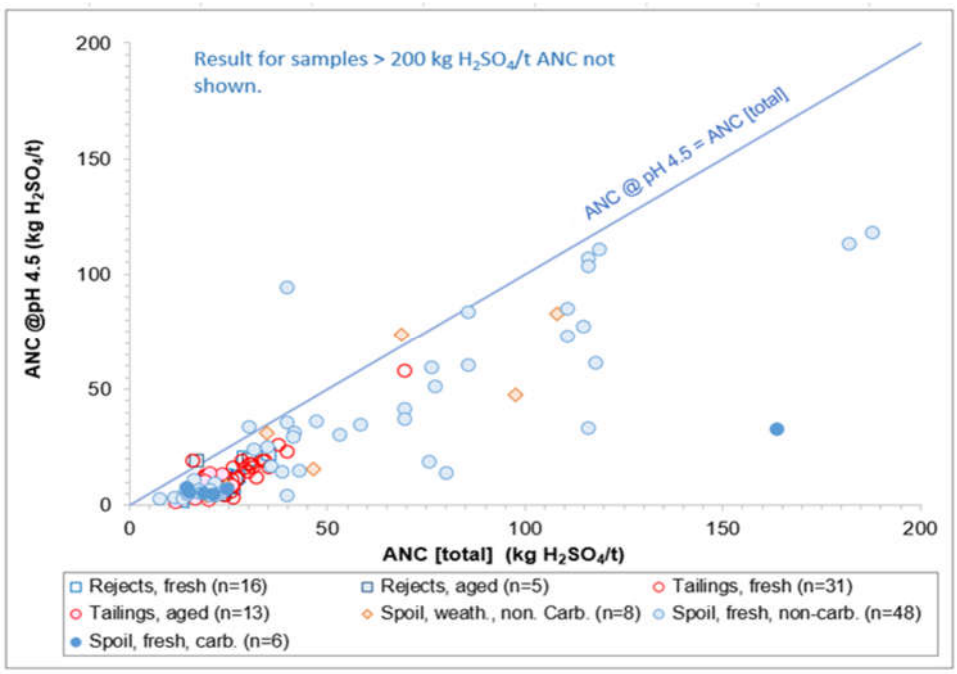

Figure 12. ABCC ANC [ANC @ pH 4.5] versus ANC

The shape of the ABCC curves (the reaction rate) can also be used to infer likely carbonate mineralogy based on standard curves/data for different carbonate minerals at varying ANC values. For the spoil samples, iron dolomite (Fe-dolomite / ankerite) and dolomite appear to be the dominant carbonate minerals based on the ABCC curves, with minor siderite. Siderite is fairly common throughout the Permian sediments of the Bowen Basin, albeit in generally relatively small amounts. For the tailings and rejects samples, Fe-dolomite is the dominant carbonate mineral based on the ABCC curves, with minor siderite. Several samples appear to have trace amounts of dolomite.

Based on the above and supported by the mineralogy data (**Section 5.1**), the carbonate mineral in bulk spoil, tailings and rejects is likely to be Fe-dolomite +/- siderite with varying influence from dolomite.

ANC / MPA Ratio

Generally, those samples with an ANC/MPA ratio greater than two are considered to have a negligible/low risk of acid generation (DIIS, 2016; INAP, 2009[4]), especially where sulphide concentrations are very low and reactive ANC is moderate to high – as is the case with the potential spoil samples.

The results, illustrated in **Figure 13**, show that:

- Ninety-five per cent (95%) of 1281 spoil samples have an ANC/MPA ratio greater than two – noting that 79% of all spoil samples are fresh, non-carbonaceous. Approximately 91 of fresh carbonaceous spoil samples (102 out of 112 samples) have an ANC/MPA ratio greater than two.
- Most tailings samples (fresh and aged) had ANC/MPA ratios less than two.
- Most aged rejects have ANC/MPA ratios less than or equal to two, whereas fresh rejects have a range of ANC/MPA values – with 58% of the fresh rejects having ANC/MPA ratios greater than two.
- Coal samples mostly had ANC/MPA ratios less than or equal to two.
- Natural ground samples from the base of the TSFs (below the embankments and outer tailings) had ANC/MPA ratios greater than two.
- Fill samples (from the TSFs) had a similar range of ANC/MPA ratios to aged tailings and aged rejects samples – mostly with ANC/MPA ratios less than two.

4 INAP (2009) considers that mine materials with an ANC/MPA ratio greater than two are likely to be NAF unless significant preferential exposure of sulphide minerals occurs along fracture planes, in combination with insufficiently reactive ANC.

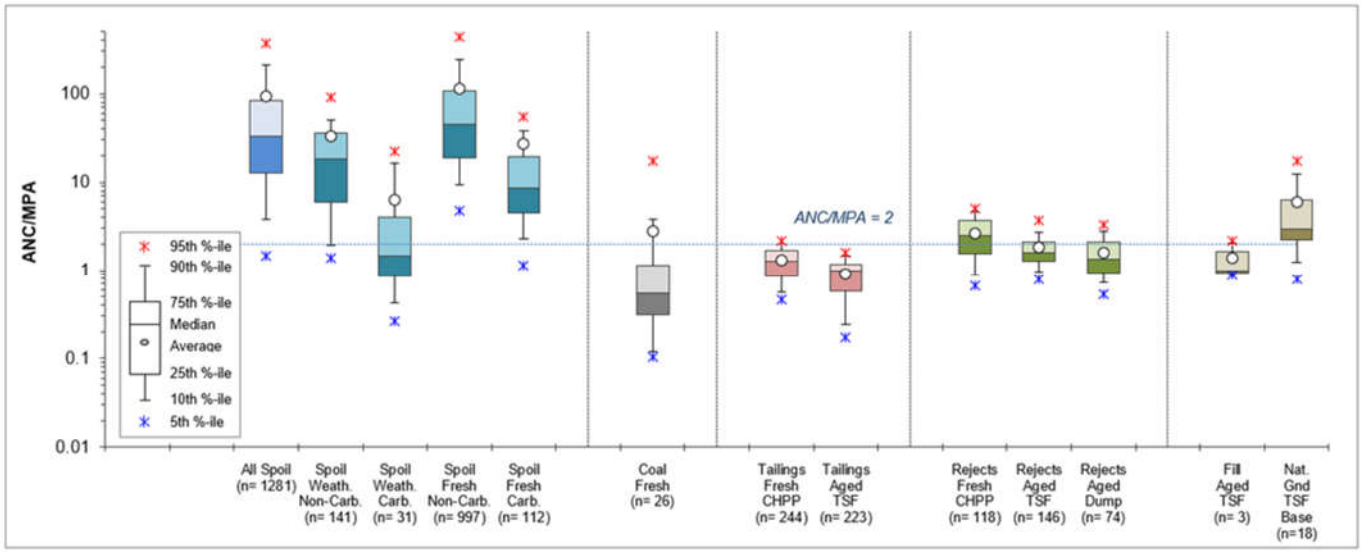

Figure 13. Distribution of the ratio of acid neutralising capacity (ANC) to maximum potential acidity (MPA) [ANC/MPA ratio]

Net Acid Producing Potential

The NAPP distribution for all samples is presented in **Figure 14**.

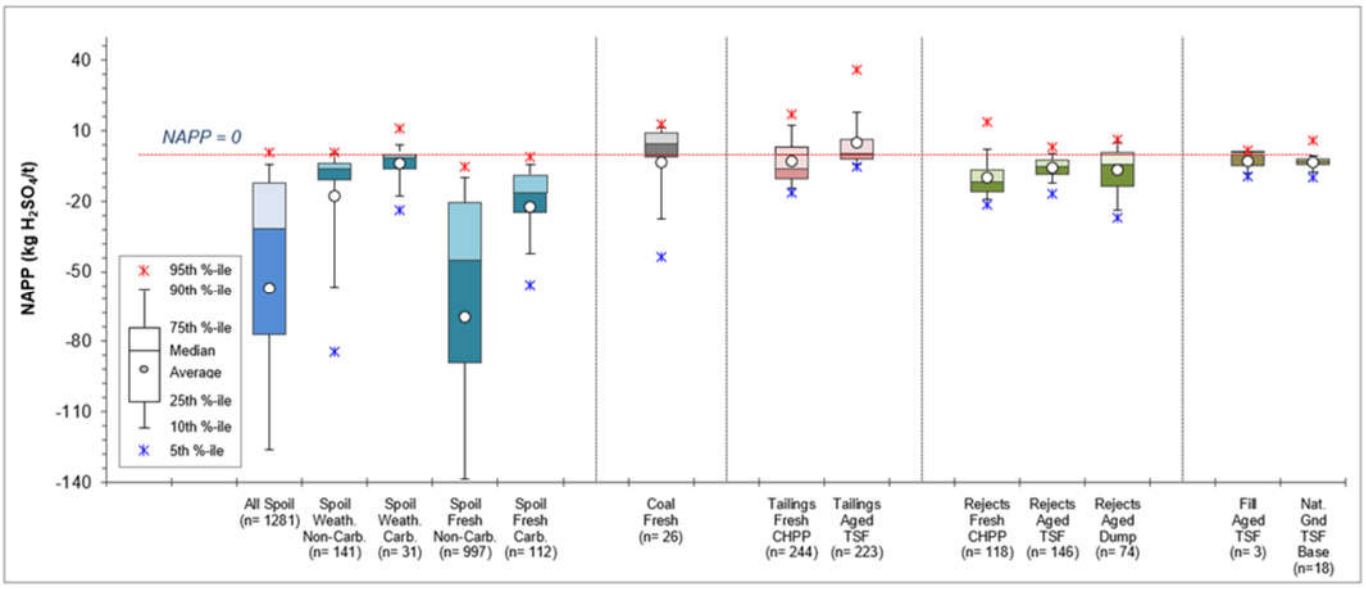

Figure 14. Distribution of net acid producing potential (NAPP)
Non-carbonaceous fresh spoil had a 5th percentile value of -224 kg H_2SO_4/t and is not shown in the plot. The 5th percentile for all spoil is -196 kg H_2SO_4/t.

Based on the generally low MPA and higher ANC values (relative to the MPA), the calculated NAPP values are negative for most of the spoil samples. Some carbonaceous spoil samples (those samples more closely associated with seams) have low positive NAPP values. The results indicate that, overall, there is significantly excess neutralising capacity (ANC) compared to potential acidity (MPA) for spoil samples. Most TSF fill and natural ground samples have negative NAPP values.

Coal, tailings and rejects have a mix of low negative and low positive NAPP values. About 15% of rejects samples, 40% of tailings samples and 73% of coal samples had positive NAPP values.

Net Acid Generation Capacity

NAG test results are used in conjunction with NAPP values in determining the acid classification of samples. The calculated NAPP value assumes that all sulphur (present as sulphide) will oxidise to generate acid (MPA) and that all neutralising material in a sample is in a readily available form to neutralise any acid that could be generated (ANC). Unlike the theoretical basis of the NAPP test, in a NAG test a sample is encouraged to oxidise by reaction with hydrogen peroxide and any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity is measured and expressed as kg H_2SO_4/t.

Samples with NAGpH values greater than pH 4.5 are considered to be NAF. Samples with NAGpH values less than or equal to pH 4.5 (i.e. acid-generating) would also be expected to have measurable NAG capacity (i.e. NAG capacity greater than 0.1 kg H_2SO_4/t). As a guide, NAG capacity values between 0.1 and 5 kg H_2SO_4/t are considered 'low capacity' (AMIRA, 2002).

NAG test data (a combination of single addition and extended boil NAG) is available for 140 spoil samples, 1 coal sample, 256 tailings samples, 156 rejects samples, 1 TSF fill sample and three TSF natural ground samples (**Tables 12, 13 and 14**) – with the NAGpH distribution for these samples shown in **Figure 15**. The majority of tailings samples (68% of samples) and fresh CHPP rejects (85% of samples) had NAGpH values greater than pH4.5. Fourteen out of 38 (37% of) aged rejects samples and 13 out of 74 (18% of) aged tailings samples tested had NAGpH values greater than pH4.5. One coal sample and two natural ground sample from TSF had NAGpH value greater than pH4.5. One TSF fill sample tested had NAGpH value less than pH4.5.

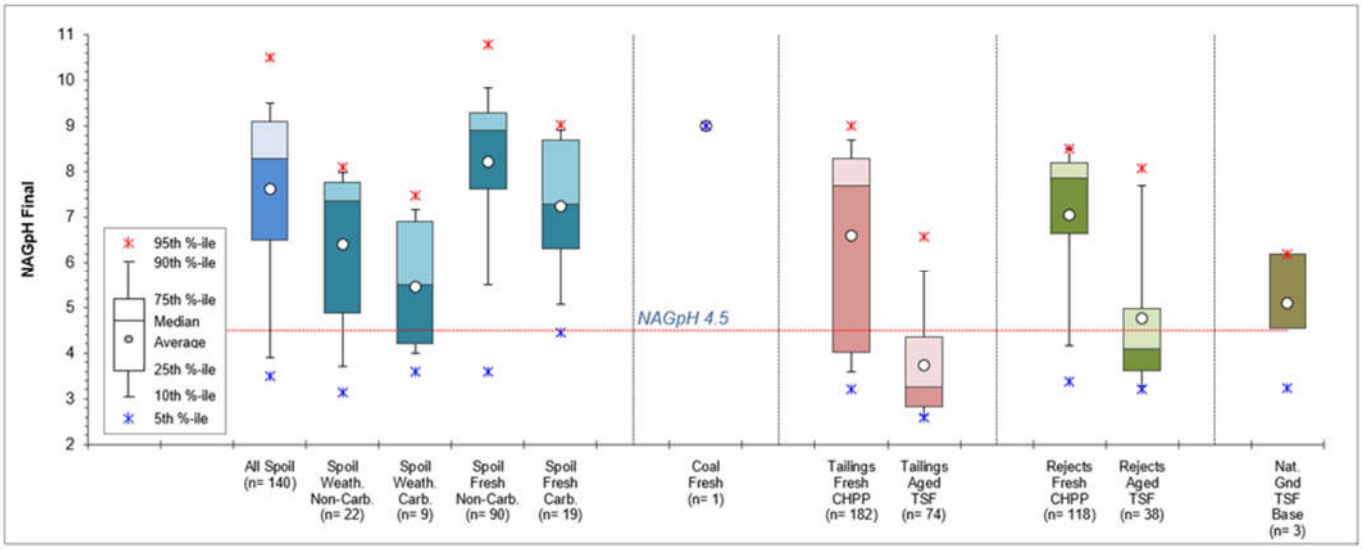

Figure 15. Distribution of net acid generation pH (NAG single or NAG Extended or Stage 1 NAG Sequential)

The NAG test can be influenced by organic acid (i.e. organic acid can produce NAGpH between approximately pH 4 to 4.5, thus providing a 'false positive' for sulphuric acid). Organic acid is typically produced by samples with high organic carbon content – such as coal and highly carbonaceous samples. To attempt to resolve some of the uncertainty with the 'single addition' NAG test for coaly and highly carbonaceous samples, 40 samples comprising 6 rejects and 34 tailings samples underwent an Extended Boil NAG method (NAG Extended).

Sixteen (16) of these 40 samples (or 40% of samples) returned Extended NAGpH values greater than pH4.5, suggesting that for 40% of the samples tested, the acidity generated in the 'single addition' NAG test was likely associated with the oxidation of organic carbon and not with sulphide oxidation.

AMD Classification

The ABA results presented in this section have been used to classify the acid forming nature of the samples following the classification criteria outlined in **Section 4.4**. Additional relevant data, such as ABCC and Extended NAG test results were used to aid in the classification of samples where there was uncertainty following the preliminary AMD classification. The acid forming nature of these samples is summarised in **Table 15**.

Table 15. Geochemical classification of samples

Material Type	NAF	UC(NAF)	NAF-S	UC(PAF)	PAF-LC	PAF
	Number and (%) of samples					
Spoil, weath, non-carb. (n=154)	135 (88%)	14 (9%)	-	-	2 (1%)	3 (2%)
Spoil, weathered carbonaceous (n=31)	24 (77%)	-	-	3 (10%)	2 (6.5%)	2 (6.5%)
Spoil, fresh non-carbonaceous (n=1015)	983 (97%)	19 (~2%)	-	9 (~1%)	1 (<0.5%)	3 (<0.5%)
Spoil, fresh carbonaceous (n=112)	104 (93%)	-	-	2 (~2%)	5 (~5%)	1 (<1%)
Spoil [all] (n=1312)	1246 (95%)	33 (~2%)	-	14 (~1%)	10 (~1%)	9 (~1%)
	1279 (97%)		***-***	***33 (~3%)***		
Coal (n=26)	6 (23%)	-	-	1 (4%)	15 (58%)	4 (15%)
	6 (23%)		***-***	***20 (77%)***		
Tailings, fresh, CHPPs (n=244)	150 (61%)	12 (5%)	12 (5%)	46 (19%)	14 (6%)	10 (4%)
Tailings, aged, GS1 & RS1 TSFs (n=223)	26 (12%)	41 (18%)	-	67 (30%)	61 (27%)	28 (13%)
Tailings [all] (n=467)	176 (38%)	53 (11%)	12 (3%)	113 (24%)	75 (16%)	38 (8%)
	229 (49%)		***12 (3%)***	***226 (48%)***		
Rejects, fresh, CHPPs (n=118)	99 (84%)	7 (6%)	1 (<1%)	3 (3%)	6 (5%)	2 (2%)
Rejects, aged, GS1 & RS1 TSFs (n=146)	51 (35%)	70 (48%)	-	9 (6%)	15 (10%)	1 (~1%)
Rejects, aged, Riverside dump (n=74)	23 (31%)	12 (16%)	-	12 (16%)	25 (34%)	2 (3%)
Rejects [all] (n=338)	173 (51%)	89 (26%)	1 (<1%)	24 (7%)	46 (14%)	5 (~1%)
	262 (78%)		***1 (<1%)***	***75 (22%)***		
Fill, aged, TSF (n=3)	1 (~33%)	-	-	1 (~33%)	1 (~33%)	-
Natural ground beneath TSFs (n=18)	16 (89%)	-	-	1 (~6%)	1 (~6%)	-

Spoil

The classifications in **Table 15** show that approximately 97% of spoil samples were classified as NAF or were expected to be NAF [and have been classified as UC(NAF)]. These spoil samples (and spoil material represented by these samples) have very low sulphur concentration, significant excess ANC (relative to the MPA) and clearly have negligible capacity to generate AMD. The remaining 3% (approximately) of spoil samples (33 out of 1312 samples) were classified as PAF, PAF-LC or UC(PAF). No spoil samples were classified as NAF-S.

Data show that potential spoil, as a bulk material, would be overwhelmingly NAF – and essentially all spoil away from seams (which is the overwhelming bulk of spoil) is expected to be NAF. Furthermore, the very low sulphur concentrations in spoil indicates that the sulphate concentration that could be generated in spoil from sulphide oxidation (in addition to any salinity unrelated to sulphide oxidation) would also be very low.

Tailings

Forty-eight per cent (48%) of tailings samples were classified as PAF, PAF-LC or UC(PAF) – including moist to wet aged tailings samples from the TSFs and fresh (CHPP) tailings samples; and a further 3% (approximately) of

tailings samples were classified as NAF-S. Of the 'PAF' tailings samples, approximately 8% were classified as PAF (specifically), while 40% were classified as UC(PAF) or PAF-LC.

Approximately half of the tailings samples are classified as 'PAF' (of some type) or NAF-S. As such, from an acid generating perspective, tailings pose a source hazard with respect to AD and/or NMD and/or SD; and overall, are expected to generate low to moderate acidity loads.

Rejects

The results show that approximately 78% of the rejects samples (262 of 338 samples) were classified as NAF or UC(NAF) and the remaining 22% were classified as 'PAF' of some type, which included one NAF-S sample.

From an acid generating perspective rejects pose a potential source hazard with respect to AD and/or NMD/SD and are expected to generate low acidity loads.

Coal

Coal samples had higher total S values and marginally lower ANC values compared to spoil, which resulted in 77% of coal samples being classified as PAF, PAF-LC or UC(PAF). The proportion of PAF (of any kind) is comparable across all coal seam groups being mined at GRBM (and likely future mining at GRBM and RHM). It is worth noting that 16 out of 20 coal samples classified as some form of 'PAF' had generally low total S concentrations coupled with generally low ANC and, as such showed limited or uncertain capacity to generate acidity, suggesting that 'PAF' coal is unlikely to generate significant acid(ity).

Approximately 23% of coal samples tested (6 out of 26 samples) were classified as NAF, and coal seam material represented by these samples has very low sulphur values, excess ANC (relative to the MPA) and clearly has no capacity to generate acidity or release significant sulphate from sulphide oxidation.

These results suggest that coal represented by these samples and stored on a ROM pad, located within pit walls and un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would potentially be bulk PAF – albeit likely low-capacity. From an acid generating perspective, coal poses a potential source hazard with respect to AD and/or NMD/SD; and overall, is expected to generate low acidity loads.

Fill and Natural Ground

Most (2 out of 3) fill samples within the TSFs were classified as PAF-LC or UC(PAF).

Sixteen out of 18 natural ground samples beneath the TSFs were classified as NAF, as expected. The remaining two samples were classified as PAF-LC or UC(PAF).

5.3 Total Metals and Metalloids

Multi-element (metal and metalloid) data is available for 283 samples, comprising 136 spoil samples, 57 fresh tailings samples, 38 aged tailings samples from TSFs, 37 fresh rejects samples and 15 aged rejects samples from TSFs. The degree of enrichment with respect to elements potentially of environmental interest for the spoil, tailings and rejects materials is shown in **Figure 16**.

The GAI values show that 44 (out of 136) spoil samples were significantly enriched [GAI ≥3] with regard to one or more of arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), sulphur (S) and/or antimony (Sb) – and all 44 of these spoil samples were significantly enriched in Selenium (Se). Only three spoil samples were significantly enriched in S. The level of S enrichment in spoil samples is consistent with the ABA data for these same samples. Limited multi-element data (i.e. total concentration for a smaller suite of elements) is available for an additional 24 spoil samples, which showed that for the elements where data was available the degree of enrichment was comparable to the main spoil dataset.

All tailings and rejects samples were significantly enriched in Se; and 18 tailings and rejects samples were significantly enriched with one or more of As and/or S.

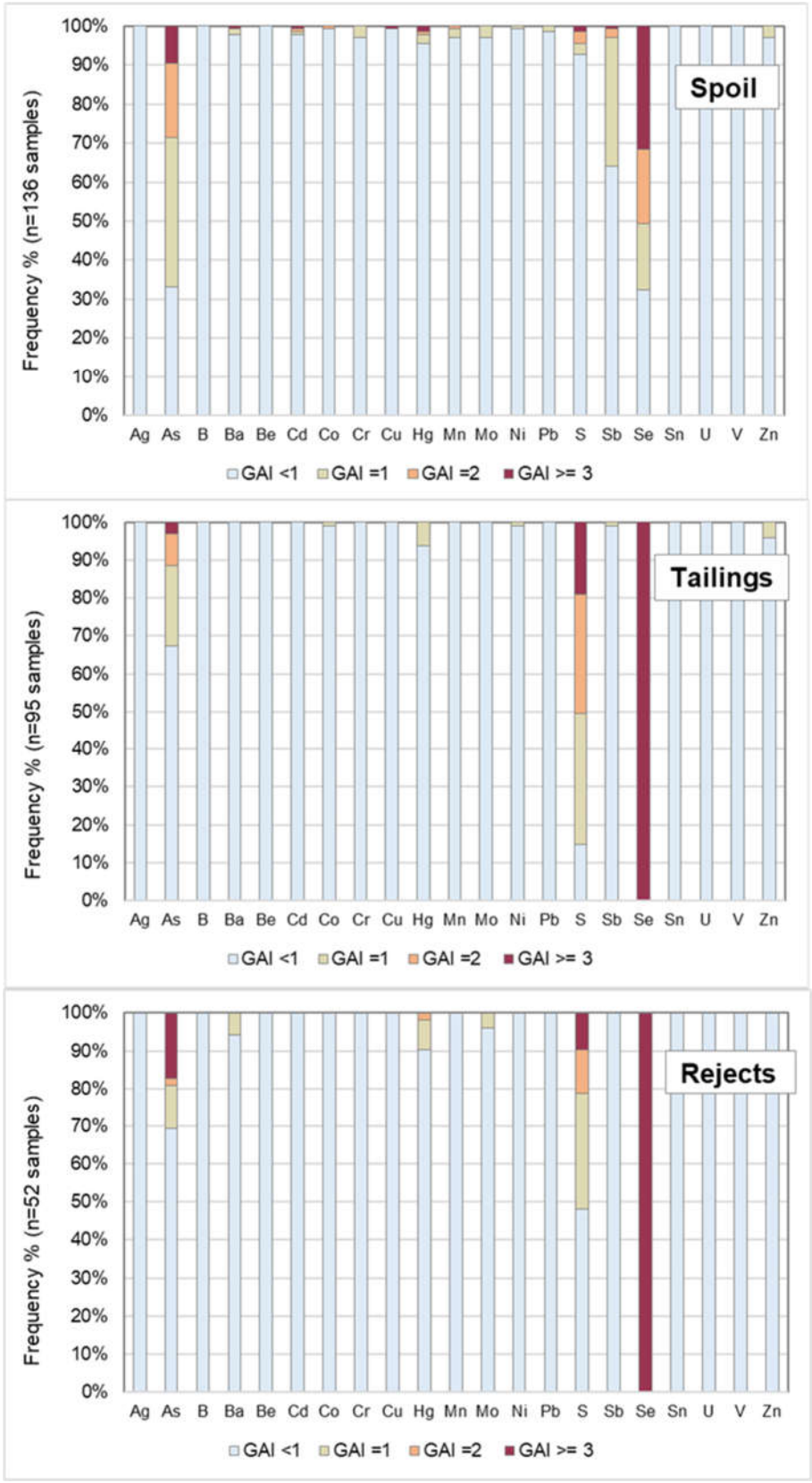

Figure 16. Frequency distribution of geochemical abundance indices (GAI) of selected elements in spoil, tailings and rejects

The GAI values also show that a considerable number of samples tested (of all material types) had minor enrichment (GAI = 1 or 2) with regard to As, Hg, S, Sb and Se. A much smaller number of samples had minor

enrichment with regard to one or more of barium (Ba), Cd, chromium (Cr), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb) and/or zinc (Zn).

Overall, the results suggest that bulk mineral waste materials have generally low levels of metal and metalloid enrichment, which is consistent with Permian-age coal measures throughout eastern Australia. A small proportion of samples (of all material types) have a higher degree of enrichment in some metals – notably As, Cd, Cu, Se, Sb, Hg and S – however enrichment in these materials is not cause for concern.

5.4 Initial Solubility in Deionised Water

Water extract test results are available for a wide range of samples (**Table 16**). EC and pH results are available for 2406 samples, and test results for major ions and soluble metals/metalloids are available for 322 samples.

Therefore, a large dataset is available to assess the potential for leaching of salt and environmentally important elements from mineral wastes (spoil and rejects) and coal at GRBM. Water extract tests provide a preliminary indication of the elements that may be readily mobilised from any given material type.

Table 16. Samples subjected to deionised water solubility tests

Material type	pH and EC	Soluble metals and metalloids
	Number of samples	
Spoil	1541	161
Tailings	467	96
Rejects	347	61
Fill within TSF	3	-
Natural ground beneath TSF	18	-
Coal	30	4

The samples underwent a 1:5 w:v (solid:water) deionised water bottle leach procedure on fine pulps. Note that the use of fine pulped materials in water extract tests will enable a high level of reaction and dissolution. The results from these tests are summarised and discussed below.

The test-work has found that the mineral wastes are pH-alkaline, generally non-saline to slightly saline and have very low concentrations of soluble metals and metalloid concentrations – within the range typical for Permian sedimentary materials in the Bowen Basin. For most samples, the soluble metals and metalloids are at concentrations below or marginally above the laboratory limit of reporting (LOR).

Electrical Conductivity (EC) and pH

EC and pH data is available for 2406 samples at 1:5 w:v on pulp (**Figure 17** and **Table 16**).

The $EC_{1:5}$ of 1541 spoil samples spanned a large range from 16 to 3680 µS/cm, with generally low median and 75th percentile $EC_{1:5}$ values of 401 and 545 µS/cm, respectively. The fresh (unweathered samples), which comprise the greatest proportion of spoil, have generally lower $EC_{1:5}$ values compared to the weathered samples, however spoil – as a bulk material – is generally non-saline to slightly saline. These $EC_{1:5}$ results are common (if not typical) for Bowen Basin Permian-age and Tertiary-age material in the region.

Coal samples are generally non-saline. Tailings samples are generally slightly to moderately saline with a 75th percentile $EC_{1:5}$ of 1100 µS/cm. All rejects samples are generally non-saline to slightly saline with a 75th percentile $EC_{1:5}$ of 538 µS/cm.

The pH distribution by material type shows most spoil, coal, fresh tailings and fresh rejects samples to be generally alkaline to highly alkaline. These pH results for spoil materials and fresh tailings/rejects are common (if not typical) for Bowen Basin Permian-age and Tertiary-age material in the region. Aged TSF rejects and TSF fill samples were also generally pH-alkaline.

The pH distribution of aged rejects from Riverside rejects dump ranged from moderately acidic to alkaline with a median value of pH 5.9. The natural ground samples from beneath the TSFs are generally weakly acidic to alkaline.

Of the 2406 samples, 112 samples (5% of samples) had $pH_{1:5}$ values less than pH 6.0. These comprised 32 spoil samples, 30 tailings samples, 44 rejects samples and 6 natural ground samples.

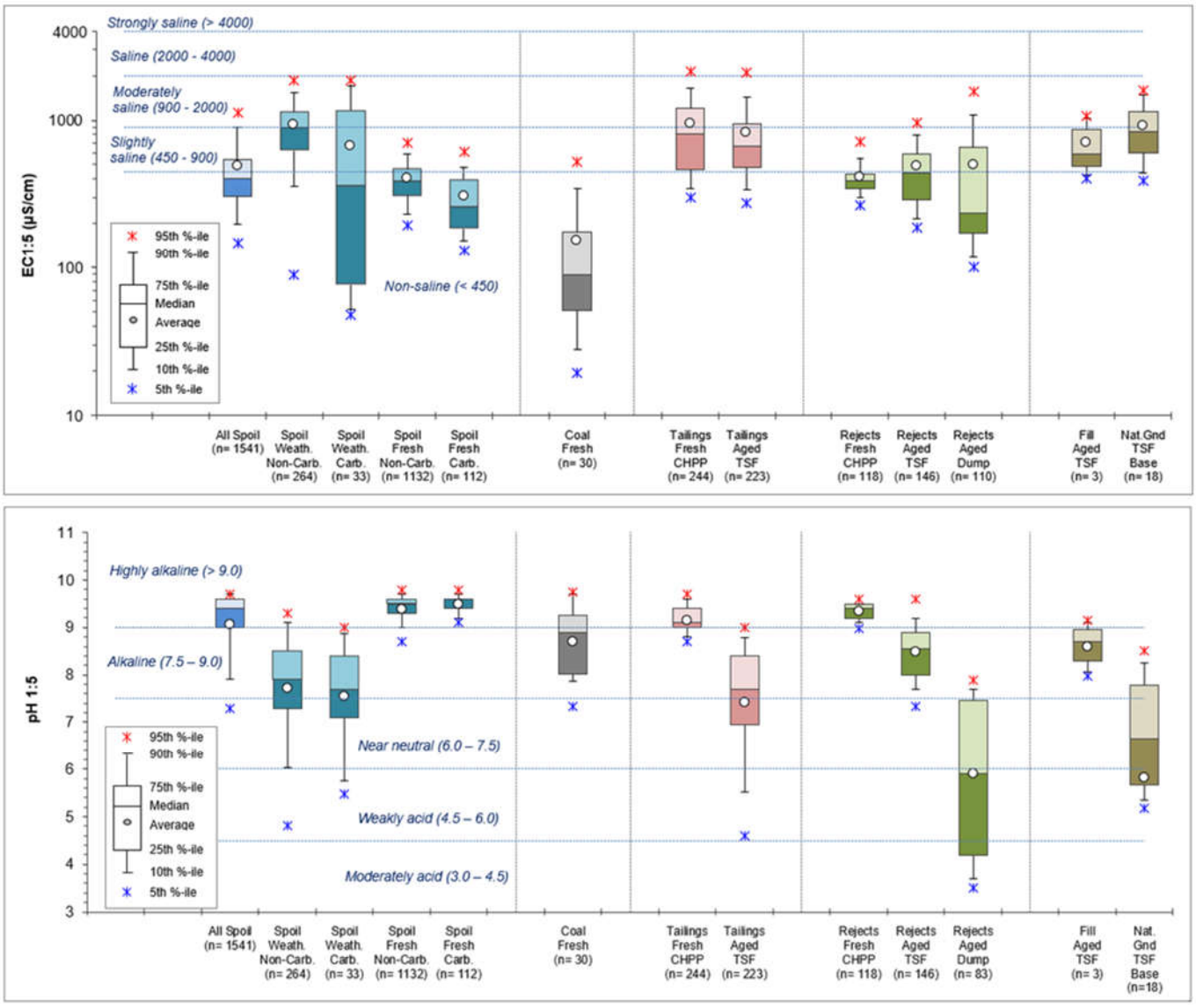

Figure 17. Electrical conductivity (EC) and pH distribution

Soluble Metals and Metalloids

Deionised water extract (leaching) data for major ions and a broad suite of metals/metalloids are available for 322 samples (**Table 16**). All samples underwent a 1:5 w:v (solid:water) water extract procedure on pulps, and were analysed under ICP-MS method. The sum of 16 environmentally important elements are plotted as a function of pH in **Figure 18**, in a modified version of what is referred to as a Ficklin plot (after Ficklin *et al*., 1992). The 16 selected

metals/metalloids comprise: aluminium (Al), Sb, As, Cd, cobalt (Co), Cr, Cu, Pb, Hg, Mn, Mo, Ni, Se, uranium (U), vanadium (V) and Zn.

Of the 322 samples, 270 samples (84% of samples tested) have low soluble metals concentrations and have near-neutral to alkaline pH – indicating that under freshwater leaching conditions soluble metals concentrations are low for most mineral waste and coal materials.

Thirty-two (of 161) spoil samples, four (of 61) rejects samples, one (of 96) tailings samples, and one (of 4) coal samples have moderate metals concentrations associated with near-neutral to alkaline pH.

Three (of 161) spoil samples and four (of 96) tailings samples have moderate metals concentrations associated with moderately to weakly acidic pH (pH 3 to 6). All seven samples were classified as PAF. Four composite rejects samples were also found to have moderate metals concentrations associated with moderately to weakly acidic pH (pH 3 to 6).

One tailings sample (classified as PAF) had elevated metals concentration associated with moderately to weakly acidic pH. One composite rejects sample (classified as PAF-LC) had low soluble metals concentrations associated with moderately to weakly acidic pH (pH 3 to 6).

In pH-neutral to alkaline waters, many metals/metalloids cannot remain in solution and, thus, trace metal/metalloid concentrations are generally low. Comparatively, in acid(ic) waters, many metals/metalloids are highly soluble and remain in solution and, thus, trace metal/metalloid concentrations are generally high. Notable exceptions to these general rules include elements such as As, Mn, Sb and Se, which remain soluble through a wide pH range. Other trace metals that are somewhat soluble under pH-neutral to alkaline conditions include Cd, Cr, Mo and Zn. As such, under the pH-alkaline conditions of the leach, the mobility of these elements would not be inhibited.

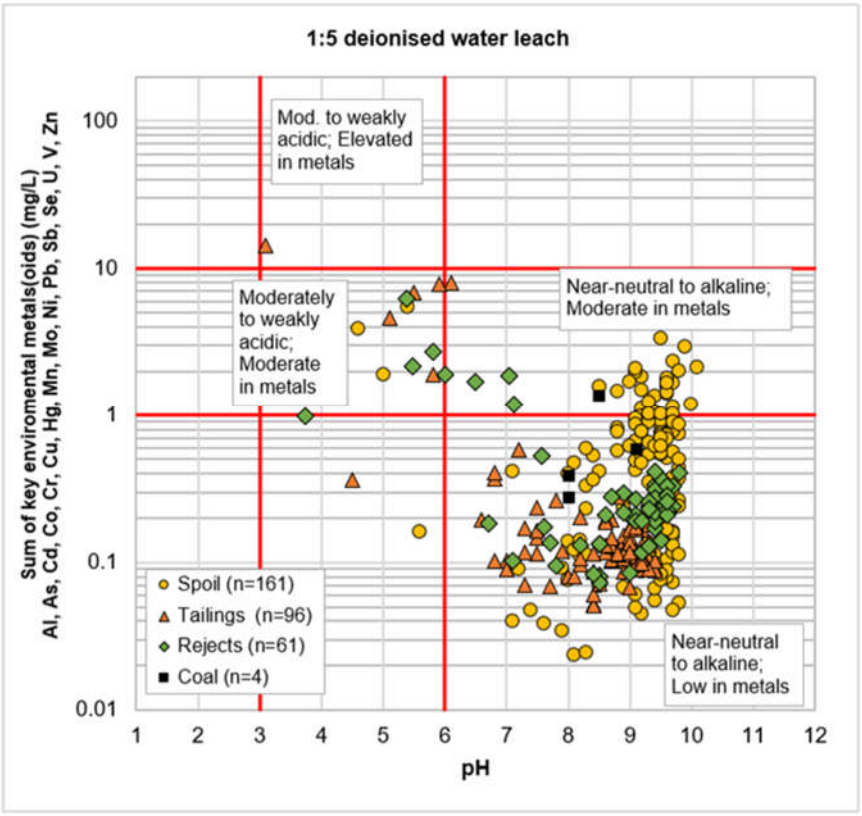

Figure 18. Sum of key environmental metals versus pH in deionised water extracts

The median concentrations of major ions and environmentally important metals/metalloids in deionised water extracts are shown in **Table 17** for spoil, coal, tailings and rejects.

Table 17. Median concentrations of major ions and selected elements in deionised water extracts for spoil, tailings and rejects

Median concentration mg/L	Spoil (n=161)	Tailings (n=96)	Reject (n=61)
≤ 0.0001	Cd, Hg	Cd, Hg	Cd, Hg,
≤ 0.001	Ag, Be, Bi, Co, Cr, Cu, Mn, Ni, Pb, Sn, U	Ag, Be, Bi, Co, Cr, Cu, Pb, Sb, Sn, U	Ag, Be, Bi, Co, Cr, Cu, Mn, Ni, Pb, Sb, Sn, U
≤ 0.01	Sb, Se, Ti, V, Zn	As, Mn, Ni, Se, Ti, V, Zn	As, Ti, V, Zn
≤ 0.1	Al, As, B, Ba, Fe, Mo	Al, B, Ba, Fe, Mo	Al, B, Ba, Fe, Mo, Se
≤ 1.0	F, Ca, Mg, P	F, P	F, Mg, P
≤ 10	K	Ca, Mg, K	Ca, K
≤ 100	Na, Cl, SO_4	SO_4, Cl, Na	SO_4, Cl, Na
≤ 1000	-	-	-

Limited deionised water extract (leaching) data is available for an additional four coal samples – all of which were collected from an older sampling program (mid-2000s). The water extract data for these additional four samples does not have solubility information for several of the key 16 elements identified in **Figure 18** and, as such, these samples have been excluded from the dataset shown in **Figure 18** (and **Table 17**). Where data is available for these coal samples it shows that all four samples were pH-neural to alkaline, three of the samples had low soluble metals concentrations, and the remaining sample had moderate soluble metals concentration.

5.5 'Saline' Water Solubility of Tailings and Rejects

Sixty-two (62) tailings and 38 rejects samples underwent a 1:5 w:v (solid:water) mildly saline (brackish) water extract procedure on pulps using a 2 g/L sodium chloride (NaCl) leaching solution. This leach was undertaken to determine the solubility of metals and metalloids under 'brackish' conditions – which better simulate the normal (brackish) water quality of the CHPP process water. Note that the salinity of CHPP process water varies from fresh to brackish on a day-to-day basis depending upon the source of the water from within the mine water management system. The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the saline leach solution for tailings and rejects in **Figure 19** (along with the data for the tailings liquor solutions – see Section 5.6 below). The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach.

The results have shown that the solubility of tailings and rejects is low under 'brackish' leaching conditions. Two tailings samples had moderately to weakly acidic pH – one of the samples had moderate soluble metals concentration and the other sample had low soluble metals concentration.

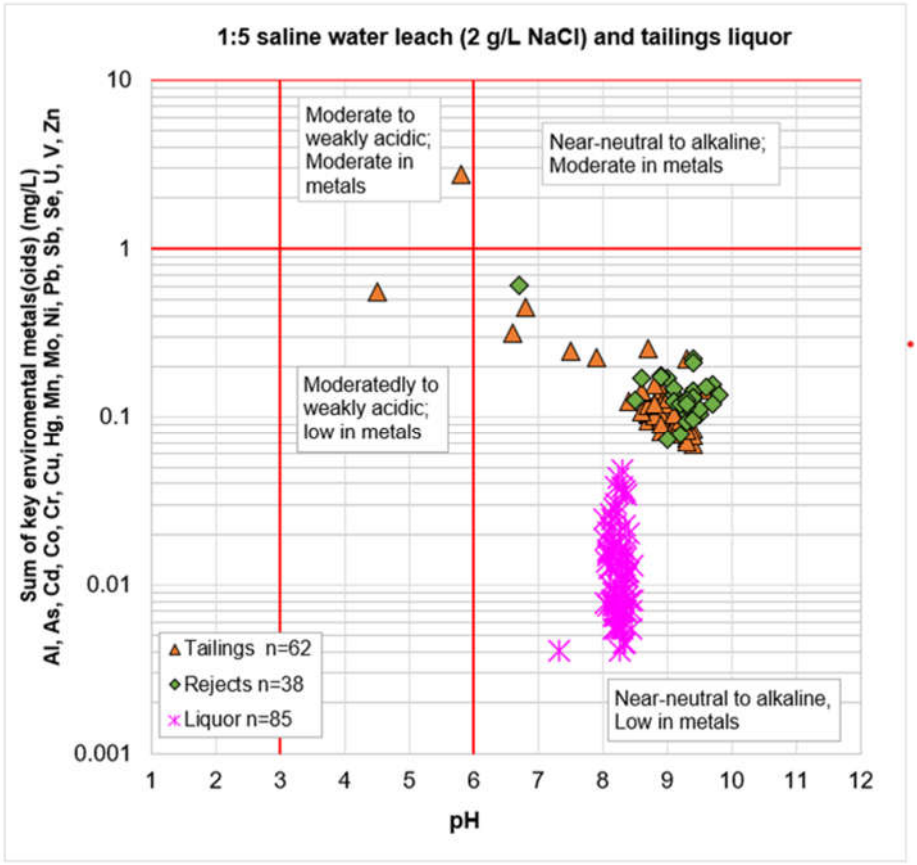

Figure 19. Sum of key environmental metals versus pH in saline water extracts and tailings liquor

5.6 Characteristics of Tailings Liquor (Water)

Water quality data for tailings liquor is available for 85 tailings slurry samples collected from the CHPP (at the thickener underflow). The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the tailings liquor solution in **Figure 19** (along with the data for the saline leach solutions). The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach, saline water leach and peroxide leach.

All liquor samples have near neutral to alkaline pH and low soluble metals concentrations. The liquor is highly saline, with EC values ranging from 3160 to 6930 µS/cm (median = 5,830 µS/cm) and a median total dissolved solids (TDS) concentration of 3423 mg/L. The dominant cation is Na and the dominant anions are Cl and SO_4 (equally dominant). Tailings liquor has generally low to moderate alkalinity, median 198 mg/L as $CaCO_3$, and essentially all present as bicarbonate alkalinity.

Comparatively, the 2 g/L NaCl saline leach solution was much less saline, with a median TDS for tailings 'saline' leach samples of 685 mg/L, respectively; i.e. roughly one fifth the salinity of the tailings liquor. The dominant cations and anions in the saline leach were Na and Cl, respectively, as expected due to the NaCl used to create the saline solution.

5.7 Peroxide Leachate Solutions

Peroxide leachate (NAG leach) data is available for 61 samples, namely:

- 5 spoil samples (non-carbonaceous and carbonaceous) classified as PAF or UC(PAF);
- 33 tailings samples of mixed classifications (approximately two-thirds 'PAF', and remaining one-third NAF or UC(NAF));
- 11 rejects samples of mixed classifications (NAF and PAF, including UC(NAF), UC(PAF)).

Peroxide leachate is the solution resulting from a single addition (standard) NAG test after the sample has been oxidised with peroxide to encourage oxidation and associated neutralising reactions, if ANC is available. The test encourages complete and rapid oxidation and associated neutralisation, with the resulting leach representing an assumed 'worse case' scenario in term of metal/metalloid mobility. The purpose of this test is to understand what metals/metalloids can be mobilised following full oxidation. The samples submitted for this test were selected to assess the hazard of similar waste type or to assist clarifying borderline geochemical properties.

It must be noted that samples with potentially high organic carbon concentrations, such as coal, some tailings and some reject samples, may be influenced by organic acids producing acidity and correspondingly elevated soluble metals concentrations unrelated to AMD. As such, the results for coaly and highly carbonaceous samples should be interpreted with this in mind.

The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the peroxide leachate solution in **Figure 20**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach and the saline leach.

After undergoing a peroxide (NAG) leach a significant number of samples have acidic pH (ranging from weakly to highly acidic) and moderate to elevated soluble metals concentrations – primarily due to the low pH enhancing solubility.

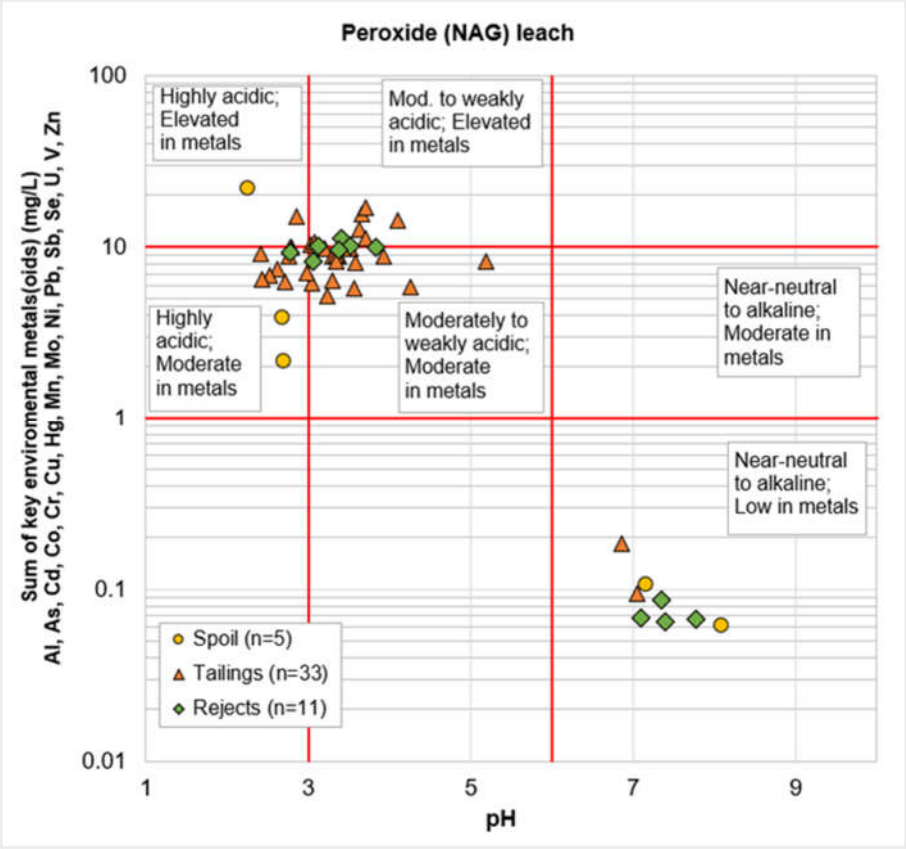

Figure 20. Sum of key environmental metals versus pH in peroxide (NAG) leachate solution

Three (out of 5) spoil samples, all classified as PAF, have moderate or elevated soluble metals concentrations and all were highly acidic (pH <3). The remaining two (out of 5) spoil samples have low soluble metals concentrations and near-neutral to alkaline pH.

Of the 11 rejects samples, six were moderately to weakly acidic with moderate to elevated metals concentrations – and most were classified as PAF of some type. One rejects sample that was classified as PAF has highly acidic pH and moderate metals concentration. The remaining four rejects samples – and were classified as NAF – have low soluble metals concentrations and near-neutral to alkaline pH.

Almost all (31 out of 33) tailings samples have moderate to elevated soluble metals concentrations associated with highly to weakly acidic pH. The remaining two tailings samples (and classified as NAF) have low soluble metals concentration associated with near-neutral to alkaline pH.

The median concentrations of major ions and environmentally important metals/metalloids in peroxide leachate solution from spoil, tailings and reject samples are shown in **Table 18**. Compared to the 1:5 deionised water extract solutions, the median concentration of several metals and metalloids in the peroxide leach solutions is higher, as expected, notably B, Ba, Cr, Co, Cu, Fe, Mg, Mn, Ni, SO_4 and Zn. However, overall, the concentrations of most elements and major ions in the peroxide leach solution are comparable to the deionised water solubility concentrations.

The results suggest that under acid/acidic conditions, materials represented by these samples are capable of generating elevated metal and metalloid loads for several metals/metalloids, however the SO_4 (and salinity) loads are not expected to be elevated – due to the generally low total S concentrations. These data suggest that if PAF/PAF-LC material is allowed to oxidise without ANC available in the bulk media to buffer acidity, material similar to that tested might mobilise metals and metalloids at elevated concentrations, over time.

Table 18. Median concentrations of major ions and selected elements in peroxide (NAG) leachate solution

Median concentration mg/L	**Spoil** (n=5)	**Tailings** (n=33)	**Reject** (n=11)
≤ 0.0001	Hg	Hg	Hg,
≤ 0.001	Sb, As, Be, Bi, Cd, Mo, Ag, Sn, U	Sb, As, Bi, Cd, Mo, Ag, Sn	Sb, As, Bi, Cd, Ag, Sn, U
≤ 0.01	Pb, Ni, Se, V	Be, Se, Ti, U, V	Be, Cr, Mo, Se, Ti, V
≤ 0.1	F, Cr, Co, Cu, Zn	Ba, B, Cr, Co, Pb, Ni	F, Ba, B, Co, Pb, Ni
≤ 1.0	Ba, B, Fe, Mn, P	F, Cu, P, Zn	Cu, P, Zn
≤ 10	Cl, Mg, K, Al	Mg, K, Al, Mn	Cl, Mg, K, Al, Mn
≤ 100	Ca, Na	Cl, Ca, Na, Fe	Ca, Na, Fe
≤ 1000	SO_4	SO_4	SO_4

5.8 Cation Exchange Capacity, Sodicity and Dispersion of Spoil

Exchangeable cation concentrations are used to evaluate the potential 'soil quality' of materials. Exchangeable cation data [as cation exchange capacity (CEC)] and exchangeable sodium percentage (ESP) data are available for 170 spoil samples. The results are summarised in **Figure 21**.

The CEC spans a moderate range from less than 1 milliequivalents per 100 grams (meq/100g) to 34 meq/100g, with a relatively low median CEC value of 11 meq/100g. The CEC for non-carbonaceous spoil was higher than carbonaceous spoil.

The ESP results generally ranged from less than 1% to 63%, with a median ESP of 32%. Approximately 94% of samples had ESP values greater than 14% and a further 4% of samples had ESP values between 6% and 14%. Therefore, based on the ESP values alone, approximately 98% of the spoil samples are regarded as being 'sodic' to 'strongly sodic' and, as such, essentially all mine spoil at GRBM can be expected to have potential for dispersion.

A subset of 91 spoil samples also underwent Emerson aggregate class tests to determine whether these samples were dispersive. Emerson aggregate class tests are a direct measure of soil dispersion, whereas ESP values are used as an indirect measure of the *potential* for a sample to have structural stability problems and hence *may be* dispersive.

The results show that about 25% of samples (23 out of 91 samples) had some dispersion [slaking] (Class 2), one sample had complete dispersion (Class 1), and two samples had an Emerson Class of 3 [calcite or gypsum present; dispersion] – meaning about 29% of samples were dispersive to some degree. The remaining 71% of samples (65 samples out of 91) had Emerson Class greater than 3, which indicates no dispersion.

In summary, the Emerson Class testing suggests about 30% of the samples may be prone to dispersion. Refer to **Section 4.4** for class descriptions. Although not entirely consistent with the ESP results, the Emerson Class test results suggest a significant proportion of spoil would be dispersive.

Based on the CEC, ESP and Emerson aggregate class test results, a significant proportion of spoil at GRBM is expected to be sodic to strongly sodic and dispersive.

These exchangeable cation (and Emerson aggregate class) results are common for Bowen Basin Permian and Tertiary material in the region.

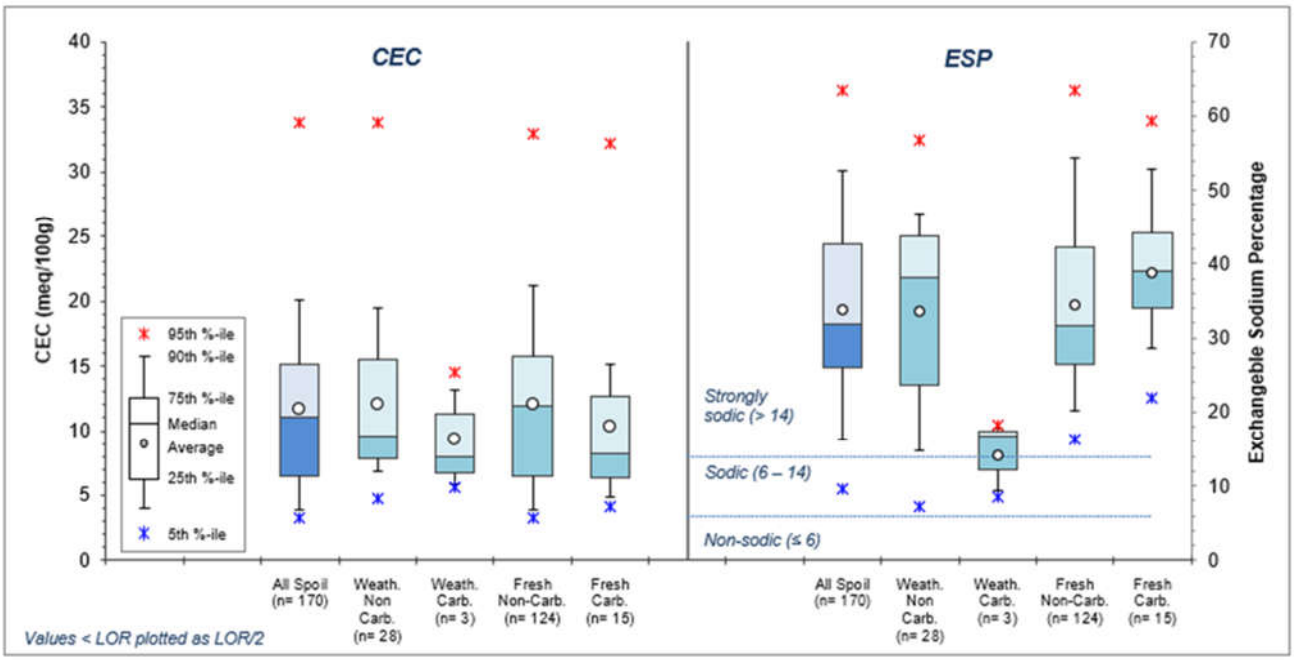

Figure 21. Cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) of spoil

6 Summary of Geochemical Characteristics

The geochemical characteristics of mineral wastes (overburden/interburden [spoil], tailings and reject) from GRBM have been assessed – as have the characteristics of coal samples that may report as ROM coal or as waste to the spoil dumps. The assessment was undertaken to understand the environmental geochemical characteristics of these samples, as being representative of their respective mineral waste types.

Within the context of this PRCP, spoil comprises essentially all of (approximately 98% of) the mineral waste at GRBM. Rejects and tailings comprise approximately 1.5% and 0.5%, respectively, of mineral waste at GRBM. Spoil is overwhelmingly comprised of non-carbonaceous material. Carbonaceous spoil (of which almost all is fresh/unweathered) comprises a small proportion of the spoil.

6.1 AMD Potential of Mineral Wastes and Coal

AMD Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 93% of spoil, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for mine spoil in the Bowen Basin.

Based on the results, non-carbonaceous spoil has a low potential to generate AMD as either AD and/or NMD and/or SD, but for a small proportion that is assessed to have a higher potential to generate AMD (as AD, NMD and/or SD). However, in consideration of the mixing and dispersion of a small volume of waste at higher potential for AMD within the broader spoil material, the overall potential for non-carbonaceous spoil (and bulk spoil, generally) to generate AMD is assessed to be low.

The total S concentration of non-carbonaceous spoil is very low, with a 90th percentile total S concentration of 0.08%. As such, and combined with moderate to high ANC values (median 40 kg H_2SO_4/t), approximately 96% of 1169 non-carbonaceous spoil samples tested were classified as NAF, with a further 3% (approximately) of samples classified as UC(NAF). Only 1.5% (approximately) of non-carbonaceous spoil samples were classified as PAF, PAF-LC or UC(PAF). No samples were classified as NAF-S.

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-75% available under field conditions, with iron-dolomite and dolomite expected to be the main carbonate minerals contributing to the acid buffering potential of the spoil. Overall, non-carbonaceous spoil has excess acid neutralising capacity and is expected to be bulk acid consuming.

Total metal and metalloid concentrations from 114 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. About 30% of samples were significantly enriched with regard to Se; and a further 12 samples (11% of samples) were significantly enriched with regard to one or more of As, Cd, Cu, Hg, S and/or Sb. There was no clear correlation found between these 'enriched' samples and their AMD classifications, however the enrichment in these elements in a small number of samples is not cause for concern. In summary, non-carbonaceous spoil (as a bulk material) has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 139 non-carbonaceous samples) indicate that leachate from this material is expected to contain low concentrations of soluble metals and metalloids under pH-neutral to alkaline conditions. About 20% of samples produced moderate soluble metal concentrations in one or more of Al, As, Co, Fe, Mn, Ni and/or Zn – under pH-neutral to alkaline leaching conditions (excluding two samples that produced weakly acidic pH leachate). Peroxide [NAG] leaching undertaken on three non-carbonaceous spoil samples with PAF classification showed that some PAF material, when oxidised, has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

AMD Potential of Spoil – carbonaceous

Carbonaceous spoil represents approximately 7% of spoil material at GRBM and – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil. Most carbonaceous spoil is fresh (unweathered).

Based on the results from 143 samples, most carbonaceous spoil has a generally low to moderate potential to generate AD and/or NMD and/or SD. Some carbonaceous spoil – generally associated with coal seams – has a greater potential to generate low-level AD and/or NMD and/or SD.

The total S concentration of carbonaceous spoil is low, with a 90th percentile total S concentration of 0.38% (from 202 samples).

Approximately 90% (128 out of 143) of carbonaceous spoil samples were classified as NAF. The remaining 10% of carbonaceous spoil samples were classified as PAF, PAF-LC or UC(PAF) and had a low-moderate 75th percentile total S value of 0.62%. No samples were classified as NAF-S.

The test-work undertaken on a small sub-set of six samples has demonstrated that the ANC in these samples is expected to be about 20-50% available under field conditions, with iron-dolomite expected to be the main carbonate mineral contributing to the acid buffering potential of the carbonaceous spoil. Overall, carbonaceous spoil has modest acid neutralising capacity.

Total metal and metalloid concentrations from 22 carbonaceous spoil samples tested are generally very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. Similar to non-carbonaceous spoil, 10 carbonaceous spoil samples out of 22 were significantly enriched with regard to one or more of As and/or Se. The enrichment in these elements in a small number of samples is not cause for concern. There was no clear correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment. In summary, carbonaceous spoil (as a bulk material) has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 22 samples) indicate that leachate from carbonaceous spoil is expected to contain generally low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. Of the 22 samples, 16 had low soluble metal and metalloid concentrations under pH-neutral to alkaline conditions, and one sample had low soluble metal and metalloid concentrations under weakly acidic conditions. The remaining five samples had moderate soluble metal and metalloid concentrations – predominantly under pH-neutral to alkaline conditions. Peroxide leaching was undertaken on two fresh carbonaceous spoil samples classified as PAF and UC(PAF), which showed that PAF samples, when oxidised, have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

AMD Potential of Tailings

The geochemical characteristics differed between fresh tailings from the CHPPs verses aged tailings from the TSFs – particularly total S, ANC, NAGpH and $pH_{1:5}$. However, the overall geochemical (AMD) hazard posed by tailings from the two sources (fresh vs aged) was generally similar. There was also no significant difference in the geochemical characteristics between the fresh tailings from each CHPP (i.e. GY CHPP versus RV CHPP) or between aged tailings from each of the main TSFs (i.e. GS1 TSF versus RS1 TSF). As such, the discussion that follows only differentiates between the two tailings sources (fresh versus aged) where the differences between the two sources was significant for some parameters and worthy of discussion. Else, the AMD potential of tailings is discussed as a bulk material – regardless of source.

Based on the results, approximately 51% of tailings has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, and remaining 49% (approximately) has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

The total S concentration of tailings is low-moderate, with a 75th percentile total S concentration of 0.7%. Fresh CHPP tailings had higher total S concentrations (median = 0.61%) compared to aged tailings samples (median = 0.39%) from TSFs. Scr accounts for approximately 49% (median value) of total S in fresh CHPP tailings and 45% (median value) of total S in aged tailings – the slightly lower proportion of Scr in aged tailings (compared to fresh tailings) is likely due to some sulphide in aged tailings being oxidised to sulphate.

As a bulk material, tailings have generally moderate ANC (median 17 kg H_2SO_4/t), however the CHPP tailings had about twice the ANC of aged tailings – suggesting that a significant proportion of the neutralising material in tailings in the TSFs had been consumed since deposition. Combined with tailings (all) having generally low-moderate MPA (median 17 kg H_2SO_4/t) values, resulted in approximately 49% of the tailings samples being classified as NAF [including 53 samples classified as UC(NAF)] and 48% of samples classified as PAF, PAF-LC or UC(PAF). Twelve

samples were classified as NAF-S. That is, approximately half of all tailings were classified as 'PAF' (of some type) or NAF-S.

Test-work indicated that about 30-60% of the ANC is likely available under field conditions, however the 'field availability' of ANC ranged from 9% to 100%. The ABCC data suggested iron-dolomite, dolomite, and lesser siderite, were the likely dominant carbonate minerals, which is broadly consistent with the mineralogy data. Carbonate concentrations were generally higher in fresh CHPP tailings (and rejects) samples compared to aged samples – the reason for this may be due to carbonate being consumed in the aged samples due to buffering reactions associated with sulphide oxidation. Consumption of carbonate is also consistent with the lower ANC values in aged tailings compared to fresh tailings.

Total metal and metalloid concentrations from 95 tailings samples tested are very low compared to average element abundance in soil in the earth's crust. However, all tailings samples were significantly enriched with regard with Se. Furthermore, 18 tailings samples were significantly enriched with regard to one or more of As and/or S. There was no clear correlation found between AMD classifications of the tailings samples compared to elemental enrichment.

Solubility data indicate that most tailings samples under freshwater (deionised water) leaching conditions are expected to have low soluble metals concentrations and have near-neutral to alkaline pH. About 5% of the tailings samples – mostly 'PAF' – had moderate soluble metals concentrations under weakly acidic to pH-neutral conditions; and one sample (classified as PAF) was elevated in soluble metals concentrations and was moderately acidic, confirming its' PAF classification. This suggests that overtime, 'PAF' tailings can generate AD as field ANC is consumed. Under saline leaching conditions tailings produced low concentrations of soluble metals and metalloids.

Peroxide leaching undertaken on 33 tailings samples (about two-thirds classified as 'PAF' of some type) showed that when exposed to highly oxidising conditions a significant proportion of tailings can produce weakly to highly acidic leachate with moderate to elevated soluble metals and metalloid concentrations. It must be noted that samples with potentially high organic carbon concentrations, such as some tailings samples, may be influenced by organic acids producing acidity and correspondingly elevated soluble metals concentrations unrelated to AMD. As such, the results for such coaly/carbonaceous samples should be interpreted with this in mind. Nevertheless, PAF tailings [including tailings classified as UC(PAF)] have typically produced moderate to elevated soluble metals and metalloid concentrations from the freshwater and peroxide leaching tests. These results indicate that PAF tailings have the potential to generate low pH leachate (AD), however the salinity (sulphate) loads are not expected to be high – due to generally low total S concentrations (with minor exceptions).

AMD Potential of Rejects

The geochemical characteristics of fresh rejects from the CHPP, aged rejects from TSFs and aged rejects from Riverside rejects dump were generally similar – except for NAGpH results. Excluding NAGpH, there was also no significant difference in the geochemical characteristics between the fresh rejects from each CHPP (i.e. GY CHPP versus RV CHPP) or between aged rejects from each of the main TSFs (i.e. GS1 TSF versus RS1 TSF) and/or between the TSFs and Riverside rejects dump. As such, the discussion that follows only differentiates between the three rejects sources (fresh versus aged TSF versus aged rejects dump) where the differences between the three sources was significant for some parameters and worthy of discussion. Else, the AMD potential of rejects is discussed as a bulk material – regardless of source.

Based on the results, 22% of the rejects (aged and fresh) has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas the remaining 78% (aged and fresh) has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

The total S concentration of rejects (fresh and aged) is generally low, with a median value of 0.31%. Scr accounts for approximately 72% (median value) of total S in aged rejects from Riverside rejects dump; 56% (median value) of total S in fresh CHPP rejects; and 49% (median value) of total S in aged rejects from TSFs. The slightly lower proportion of Scr in aged rejects from the TSFs compared to fresh rejects, and also compared to aged rejects from Riverside rejects dump is likely due to some sulphide in aged rejects in the TSFs being oxidised to sulphate.

Similar to tailings, rejects have generally moderate ANC (median 18 kg H_2SO_4/t) and generally low MPA (median 9 kg H_2SO_4/t) values, resulting in approximately 78% of the rejects samples being classified as NAF or UC(NAF). One sample was classified as NAF-S. The remaining 22% (approximately) of samples were classified as PAF,

PAF-LC or UC(PAF). Test-work indicated that about 25-50% of the ANC in fresh rejects is expected to be available under field conditions; and about 35-65% available for the aged rejects. The ABCC data suggested iron-dolomite, dolomite and siderite were expected to be the dominant carbonate minerals, which is broadly consistent with the mineralogy data.

Total metal and metalloid concentrations from 52 rejects samples tested are very low compared to average element abundance in soil in the earth's crust. However, similar to tailings samples, all rejects samples were significantly enriched with regard to Se. Nine rejects samples were also significantly enriched with As. There was no clear correlation found between AMD classifications of the rejects samples compared to elemental enrichment.

Solubility data indicate that most rejects samples (54 out of 61 samples) under freshwater (deionised water) leaching conditions are expected to have low soluble metals concentrations and have near-neutral to alkaline pH. Four (of 61) rejects samples have moderate metals concentration associated with near-neutral to alkaline pH; and three rejects samples have moderate metals concentration associated with moderately to weakly acidic pH.

Peroxide leaching undertaken on 11 rejects samples (of mixed NAF/PAF classifications) showed that when exposed to highly oxidising conditions PAF rejects can produce moderately to highly acidic leachate with moderate to elevated soluble metals and metalloid concentrations – consistent with PAF tailings. The results suggest that under acid/acidic conditions, some rejects are capable of generating elevated metal and metalloid loads, however the sulphate (and salinity) loads are not expected to be high – due to the generally low total S concentration (with some exceptions).

AMD Potential of Coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time. However, some minor coal seams/plys will report directly as waste, and remnant coal (seams) will be exposed on the highwalls of residual voids at closure.

Coal represents about 8% (on average) of all lithological material at GRBM (about 5% to 10% of the highwall meterage; refer to **Table 20**) and, assuming the large majority all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste (i.e. nominally 1-2% at the most).

Based on the results, and as a bulk material, ROM coal is assessed as having a low-moderate to moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal (all seams) would have a moderate to moderate-high potential to generate AMD. ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

Coal samples had low total S values resulting in low MPA values (median 11 kg H_2SO_4/t), however due to the generally very low to low ANC values (median 6 kg H_2SO_4/t) resulted in 77% of coal samples being classified as PAF, PAF-LC or UC(PAF). The proportion of PAF (of any kind) is comparable across all coal seam groups being mined at GRBM. The low total S concentrations suggests that 'PAF' coal is unlikely to generate significant acid(ity).

Approximately 23% of coal samples tested (6 out of 26 samples) were classified as NAF, and coal seam material represented by these NAF samples has very low sulphur values, excess ANC (relative to the MPA) and clearly has negligible capacity to generate acidity or release significant sulphate from sulphide oxidation.

These results suggest that coal stored on the ROM pad, coal located within pit walls and un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would likely be bulk PAF – albeit, low capacity. From an acid generating perspective, coal poses a potential source hazard with respect to AD and/or NMD/SD; and overall, is expected to generate low acidity loads.

Solubility data from three composite coal samples (classified as PAF and PAF-LC) tested under freshwater (deionised water) leaching conditions indicates low soluble metals concentrations at near-neutral to alkaline pH. An additional composite coal sample (classified as PAF) had moderate soluble metals concentration associated with near-neutral to alkaline pH.

6.2 Salinity, Sodicity and Dispersion Potential of Mineral Wastes and Coal

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has low median and moderate 90th percentile $EC_{1:5}$ values of 414 and 910 µS/cm, respectively, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally non-saline to slightly saline, as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity). Weathered non-carbonaceous spoil generally has higher $EC_{1:5}$ values compared to fresh non-carbonaceous spoil.

Non-carbonaceous spoil has modest CEC values and generally high ESP values, resulting in most samples being classified as 'sodic' to 'strongly sodic' and, therefore, with potential for dispersion. Based on Emerson aggregate class testing to directly measure dispersion, about 31% of the samples displayed some degree of dispersion. Although not entirely consistent with the ESP results, the Emerson Class test results suggest a significant proportion of spoil is expected to be dispersive to some degree.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has median and 90th percentile $EC_{1:5}$ values of 272 and 655 µS/cm, respectively, and has low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be similar to non-carbonaceous spoil. That is, generally non-saline to slightly saline, primarily as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples had similar CEC values compared to non-carbonaceous spoil, and comparable ESP values – with the exception of weathered carbonaceous samples, which had lower ESP values compared to fresh samples. This resulted in the fresh samples being classified as 'strongly sodic' and the weathered samples classified as 'sodic' to 'strongly sodic'. As such, and based solely on the moderate to high sodicity values, carbonaceous spoil is expected to be sodic (to some degree) with potential for dispersion. Sixteen carbonaceous spoil samples underwent Emerson aggregate class testing to directly measure dispersion, which found three (out of 16) samples were dispersive.

Salinity Potential of Tailings

Tailings samples have $EC_{1:5}$ values ranging from 118 to 5320 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 717 and 1556 µS/cm, respectively. The $EC_{1:5}$ values were generally similar between fresh and aged tailings, resulting in tailings generally being slightly to moderately saline. The generally low total S for aged tailings and low-moderate total S for fresh tailings conservatively suggests a low-moderate potential for SD (from sulphide oxidation).

Salinity Potential of Rejects

Rejects samples have $EC_{1:5}$ values ranging from 389 to 3260 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 389 and 774 µS/cm, respectively. The fresh CHPP rejects were generally non-saline with a 90th percentile $EC_{1:5}$ value of 550 µS/cm. Aged rejects had higher $EC_{1:5}$ values compared to fresh rejects with 90th percentile values of 792 µS/cm (for the TSF samples) and 1090 µS/cm (for Riverside rejects dump samples). Most rejects had low total S concentrations (median = 0.31%), suggesting the potential for SD (from sulphide oxidation) from rejects is low.

Salinity Potential of Coal

Coal has low median and 90th percentile $EC_{1:5}$ values of 90 and 524 µS/cm, respectively; and has generally low to low-moderate total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk material, is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity).

7 Risk Assessment

7.1 Geochemical Source Hazard Assessment of Material Types

7.1.1 Spoil Landforms

There are four spoil landforms at GRBM – all associated with existing spoil dumps – that will remain at closure:

- Goonyella
- Thiess
- Airstrip
- Broadmeadow-Isaac

The GRBM PRCP considers Thiess spoil dump as part of Goonyella spoil landform. However, due to its' proximity to Thiess pit, it has been assessed herein as a separate spoil landform. Each landform will have a similar construction, comprising mined overburden and interburden disposed behind the active mining face to form a low-wall spoil dump, which will be reshaped to form a final spoil landform. The spoil dumps located close to the CHPPs contain rejects.

Rejects have been disposed into several locations at GRBM. Rejects from RV CHPP have primarily been disposed into Riverside rejects dump (now inactive) and into the western compartment of RS1 TSF. Minor rejects have also been disposed within the Goonyella spoil dump (Dampier spoil) and Thiess spoil dumps. Future rejects from RV CHPP are planned to be disposed into RS1 TSF area (western compartment and onto tailings in the eastern compartment), and potentially also co-disposed throughout general spoil within Goonyella spoil dump.

Rejects from GY CHPP have been disposed into the Thiess, Airstrip and Broadmeadow spoil dump areas, and into GS2, GS11 and R22 rejects dumps. Future rejects from GY CHPP are expected to be disposed at GS11 and R22 rejects dump and co-disposed throughout general spoil within Broadmeadow spoil dump.

R22 rejects dump is located at the southern periphery of Thiess spoil dump and will comprise about 16% of the Thiess spoil landform. Due to the location of the rejects dump close to the edge of the Thiess spoil landform, the AMD hazard has been assessed based on the rejects dump being a stand-alone facility (i.e. a rejects landform), rather than the component material (rejects) being assessed as part of the Thiess spoil landform. This provides a conservative assessment of this facilities risk and takes into account the rejects within this dump being concentrated in an area at the edge of the spoil landform.

DRE5 in-pit TSF will be located within the north-western area of Thiess spoil dump at closure and will comprise less than 1% of the landform. Ramp 32 in-pit TSF will be located within the Airstrip spoil dump and will comprise approximately 7% of the landform. These two in-pit TSFs are comprised only of tailings. Due to the location of both of these TSFs at the base of their respective spoil landforms, the AMD hazard has been assessed based on these TSFs being stand-alone facilities (i.e. TSF landforms), rather than their component materials (tailings) being assessed as part of the spoil landform. This provides a conservative assessment of these facilities risk and takes into account the tailings within these TSFs being concentrated in an area at the base of the spoil landform.

The locations of all TSFs and rejects landforms are shown in **Figure 22**. There are no current tailings/TSFs within Goonyella or Broadmeadow-Isaac spoil landforms. The general layout of the conceptual spoil landforms (and residual voids) at closure is shown in **Figure 22**, which shows that Goonyella spoil landform is considerably larger than all other spoil landforms – comprising approximately 91% of all spoil at GRBM. At closure, the current spoil dumps will be reshaped and rehabilitated (refer to the PRC Plan for spoil dump rehabilitation details).

The source materials within the spoil dumps comprise weathered and fresh spoil. The geochemical assessment has found that, from an environmental geochemical perspective, the geochemical differences between weathered and fresh spoil are relatively minor. As such, the geochemical source hazard assessment has combined weathered and fresh non-carbonaceous spoil, and weathered and fresh carbonaceous spoil, as appropriate. Furthermore, assuming all spoil is 'fresh' – particularly carbonaceous spoil – adds a degree of conservatism to the assessment, since fresh carbonaceous material poses a greater AMD hazard compared to weathered carbonaceous material.

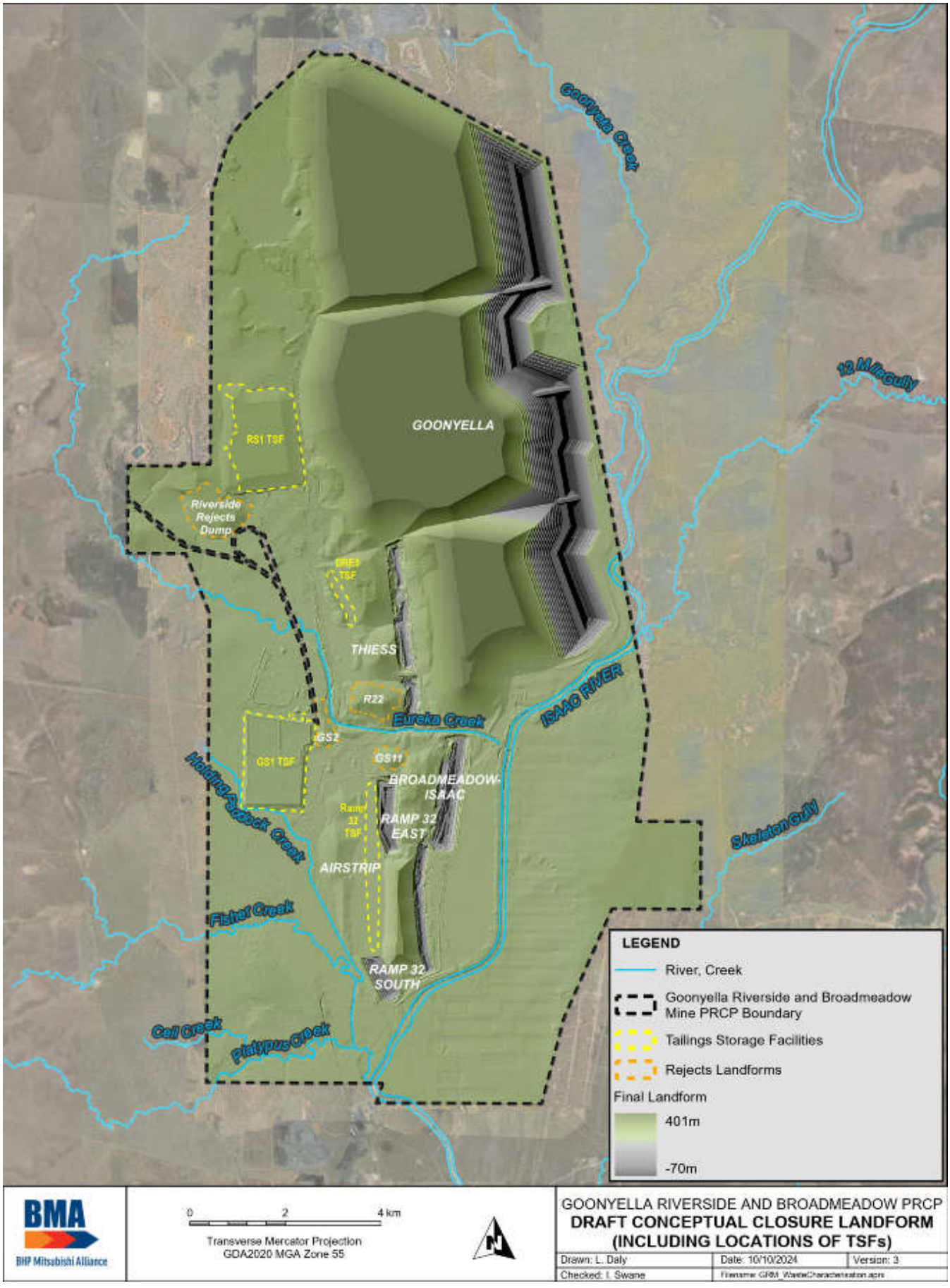

Figure 22. Conceptual closure landform

The source hazard assessment methodology outlined in **Section 4.4.6** (AMD hazard scoring) and **Section 4.4.7** (landform AMD likelihood scoring) has been applied to the spoil and rejects within each spoil landform (i.e. excluding DRE5 and Ramp 32 in-pit TSFs). Stratigraphic information from the coal geology database for GRBM was used to assess the proportion of carbonaceous lithologies relative to non-carbonaceous lithologies (and excluding coal) for each landform and void area – and from this, assign the same proportions to each spoil landform. The assessment found that carbonaceous spoil (overburden/interburden) is estimated to comprise approximately 5% to 9% (average 7%) of spoil within each landform, with non-carbonaceous spoil estimated to comprise the remaining 93% (approximately, on average) of all spoil. Assuming some fresh coal material currently assigned as 'coal' is not mined as ROM coal but remains as waste coal, the proportion of coaly and carbonaceous overburden in each landform is likely to be slightly higher. However, coal comprises approximately 8% of the stratigraphy at GRBM, therefore if a small amount of coal was to report as 'waste' the increase to the proportion of carbonaceous spoil would be minimal.

The source materials, and their approximate proportions within each spoil landform, based on geological, mining and coal processing information, are summarised in **Table 19**.

Table 19. Source material approximate proportions (%) within each spoil landform

Spoil landform	Spoil non-carbonaceous %	Spoil Carbonaceous and/or coaly[a] %	Rejects %	Tailings %
Goonyella	91	9	~0.1	none
Thiess[b,c]	91	9	~0.2[b]	none[c]
Airstrip[d]	92	5	3	none[d]
Broadmeadow-Isaac	91	8	1	none

a Coaly material refers to obvious waste coal lithologies (i.e. excludes potential ROM coal).

b R22 in-pit rejects dump is located within Thiess spoil dump and the assessment has not included this in-pit rejects dump as part of the Thiess spoil landform – instead assessed as a rejects landform.

c DRE5 in-pit TSF is located within Thiess spoil dump and the assessment has not included this in-pit TSF as part of the Thiess spoil landform – instead assessed as a TSF landform.

d Ramp 32 in-pit TSF is located within Airstrip spoil dump and the assessment has not included this TSF as part of the Airstrip spoil landform – instead assessed as a TSF landform.

The source hazard assessment, which describes the AMD hazard of individual material domains within each landform (i.e. also considers material quantity), has found that non-carbonaceous spoil – which comprises the significant majority of the mineral waste – poses a **Low-Moderate** AMD source hazard, and carbonaceous spoil has been assessed to pose a **Moderate** AMD source hazard. Rejects within each spoil landform have also been assessed to pose a **Low-Moderate** AMD source hazard. The AMD hazard scoring tables for spoil landforms are provided in **Attachment B – Tables B1 to B4**.

Approximately 3% of spoil samples have been classified as PAF of some type (no samples were classified as NAF-S) (**Table 15**) – and approximately half of this is from carbonaceous material, which comprises a minor proportion of spoil. Approximately one-third of the 'PAF' samples in overburden/interburden from drill-hole sampling were associated with seams as either roof, parting, floor or otherwise near-seam material (<1.5m above or below coal). As such, it is likely that some PAF spoil samples would be mined as part of ROM coal and would therefore end up as rejects instead of general spoil. Therefore, the AMD hazard score for spoil materials is considered to be conservative and consequently the final landform AMD hazard score also conservative.

On this basis and taking into account material quantities (proportions) and expected proportion of PAF and NAF-S materials reporting to each individual landform, each of the four spoil landforms poses a **Low** AMD hazard, with AMD generation rated as **Highly Unlikely**. The 'Low' AMD hazard is largely a result of non-carbonaceous NAF spoil comprising the overwhelming majority of mineral waste within each spoil landform, combined with the very small proportion of each landform expected to be 'PAF' – ranging from 2.4% to 5.5% (average 3%).

7.1.2 TSF Landforms

GS1 TSF and RS1 TSF will remain as stand-alone TSF landforms at closure and will not reside within a spoil landform. DRE5 in-pit TSF and Ramp 32 in-pit TSF will reside within their respective spoil landforms; however, as mentioned earlier, they have been assessed as stand-alone TSF landforms. Refer to **Figure 1** and **Figure 22** for the location of these TSFs.

GS1 TSF

GS1 TSF is a large 'turkey's nest' style TSF. The embankments are comprised of earthen-filled 'starter' embankments then raised (expanded) with rejects. The core of the TSF contains tailings. The TSF operated from approximately 1971 to 2021, receiving tailings from GY CHPP.

The source materials within GS1 TSF includes tailings, which are estimated to comprise approximately 95% of the landform; and rejects, which are estimated to comprise about 5% of the landform and form the basis of the embankments. The assessment assumes the TSF landform also includes a small proportion (approximately 0.5%) of spoil/fill material, predominantly within embankments.

Investigative drilling coupled with near-surface sampling has demonstrated that some tailings in the field at GS1 TSF are generating AMD (as AD and SD). Oxidation fronts are present in the TSF as demonstrated by decreasing sulphide concentrations from surface down, consumption of ANC, presence of secondary minerals generated through sulphide oxidation, and acid contact pH water. AMD has also been observed in seepage from the toe of the TSF and in nearby Holding Paddock Creek. Approximately 64% of the tailings samples collected from GS1 TSF are 'PAF' (of some type), whereas approximately 20% of the rejects samples from GS1 TSF are 'PAF'. As such, it is assumed that the AMD observed in/from GS1 TSF is primarily generated from tailings, more so than rejects.

The source hazard assessment for the mineral wastes within the TSF landform has utilised the same general methodology as applied to the spoil landforms. The source hazard assessment has found the tailings within GS1 TSF landform poses a **Moderate-High** AMD source hazard; and rejects poses a **Moderate** AMD source hazard. Fill material poses a **Low-Moderate** AMD source hazard. On this basis, and taking into account material quantities (proportions):

- GS1 TSF landform (currently, without a rehabilitation cover) poses a **Moderate-High** AMD hazard, with AMD generation rated as **Highly Likely** – noting that AMD processes and/or AMD impacted contact water have already been observed from GS1 TSF. The AMD hazard is considered to predominantly lie with the tailings, and lesser so the rejects.

The AMD hazard scores for the tailings and rejects materials are considered to be conservative and the landform domain AMD hazard score for GS1 TSF is also considered to be conservative. The AMD hazard scoring table for GS1 TSF landform is provided in **Attachment B – Table B5**.

RS1 TSF

RS1 TSF is a large 'turkey's nest' style TSF. The TSF has been constructed as two compartments: a western compartment comprised of rejects and an eastern compartment comprised of tailings. The tailings (from RV CHPP) are contained within earth- and rejects-filled eastern and southern embankments and a northern embankment constructed from rejects. The western compartment contains (holds back) the tailings on the western side. The TSF commenced operations in approximately 1983 and ceased receiving tailings in 2021. Rejects from RV CHPP are currently disposed into the TSF (primarily the western compartment). Future rejects from RV CHPP are planned to be disposed onto the eastern compartment and will cover the tailings.

Separate AMD source hazard assessments have been completed for each compartment of RS1 TSF. The western compartment comprises rejects only. The eastern compartment is estimated to comprise approximately 85% tailings and 15% rejects. The assessment assumes the eastern compartment also includes a small proportion (approximately 0.5%) of spoil/fill material, predominantly within embankments.

Investigative drilling coupled with near-surface sampling has demonstrated that some tailings in the field at RS1 TSF are generating AMD (as AD and SD). Oxidation fronts are present in the TSF as demonstrated by decreasing sulphide concentrations from surface down, consumption of ANC, presence of secondary minerals generated through sulphide oxidation, and acid contact pH water. Approximately 80% of the tailings samples collected from

RS1 TSF are 'PAF' (of some type), whereas approximately 17% of the rejects samples from RS1 TSF are 'PAF' (and approximately 30% of all aged rejects generated from RV CHPP are 'PAF'). As such, it is assumed that the AMD observed in/from RS1 TSF is primarily generated from tailings, more so than rejects.

- RS1 TSF western compartment [rejects only] (currently, without a rehabilitation cover) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.
- RS1 TSF eastern compartment [tailings and rejects] (currently, without a rehabilitation cover) poses a **Moderate-High** AMD hazard, with AMD generation rated as **Highly Likely** – noting that AMD processes and/or AMD impacted contact water have already been observed from RS1 TSF. The AMD hazard is considered to predominantly lie with the tailings, and lesser so the rejects.

The AMD hazard scores for the tailings and rejects materials are considered to be conservative and the AMD hazard scores for each compartment of RS1 TSF are also considered to be conservative. The AMD hazard scoring tables for RS1 TSF are provided in **Attachment B – Tables B6 and B7**.

DRE5 in-pit TSF

DRE5 in-pit TSF is located within the pit shell of Thiess pit (Thiess void) and within the Thiess spoil landform footprint. As such, it is not a true 'stand-alone' TSF landform, however, is conservatively assessed as such given the concentrated nature of tailings at the base of the spoil landform.

The source materials within the TSF includes tailings only. No investigative drilling has been undertaken in the vicinity of this TSF. No evidence of AMD has been observed in the field. The AMD source hazard assessment is based on data from fresh (CHPP) tailings.

The source hazard assessment for the tailings within the TSF has utilised the same general methodology as applied to other TSF landforms. The source hazard assessment has found the tailings within the TSF landform pose a **Moderate** AMD source hazard.

On this basis, and taking into account material quantities (all tailings):

- DRE5 in-pit TSF (prior to rehabilitation and when fully unsaturated) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.

The AMD hazard score for the tailings is considered to be conservative and the landform domain AMD hazard score for the TSF is also considered to be conservative. The AMD hazard scoring table for DRE5 in-pit TSF landform is provided in **Attachment B – Table B8**.

Ramp 32 in-pit TSF

Ramp 32 in-pit TSF is located within Airstrip pit and within the Airfield spoil landform footprint. As such, it is not a true 'stand-alone' TSF landform, however, is conservatively assessed as such given the concentrated nature of tailings at the base of the spoil landform.

The source materials within the TSF includes tailings only. No investigative drilling has been undertaken in the vicinity of this TSF. No evidence of AMD has been observed in the field. The AMD source hazard assessment is based on data from fresh (CHPP) tailings.

The source hazard assessment for the tailings within the TSF has utilised the same general methodology as applied to other TSF landforms. The source hazard assessment has found the tailings within the TSF landform pose a **Moderate** AMD source hazard.

On this basis, and taking into account material quantities (all tailings):

- Ramp 32 in-pit TSF (prior to rehabilitation and when fully unsaturated) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**.

The AMD hazard score for the tailings is considered to be conservative and the landform domain AMD hazard score for the TSF is also considered to be conservative. The AMD hazard scoring table for Ramp 32 in-pit TSF landform is provided in **Attachment B – Table B9**.

7.1.3 Rejects Landforms

Riverside rejects dump

Riverside rejects dump received rejects from RV CHPP until approximately 1998. The dump underwent some rehabilitation activities in the early 2000s, but due to the substantial corrective action required to achieve the required post-mining land use (PMLU) it has not been included as existing rehabilitation in the PRCP schedule. The dump will remain as a 'stand-alone' rejects landform at closure. The dump is located to the southwest of RS1 TSF (**Figure 1** and **Figure 22**).

Excluding the spoil cover currently in place, the dump essentially comprises only rejects (over 99% by volume). It is assumed a small amount of 'fill' (assume spoil) may lie within the dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of the landform.

The source hazard assessment for the mineral wastes within the rejects dump has utilised the same general methodology as applied to the spoil and TSF landforms. The assessment excludes the existing spoil cover. The source hazard assessment has found the rejects within the dump (based on rejects sampled from the dump) poses a **Moderate** AMD source hazard. Fill material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- Riverside rejects dump (excluding the cover) poses a **Moderate** AMD hazard, with AMD generation rated as **Probable / Likely**. The AMD hazard lies with the rejects, which comprise essentially all of the dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dump is also considered to be conservative. The AMD hazard scoring table for Riverside rejects dump is provided in **Attachment B – Table B10**.

GS2 rejects dump

GS2 rejects dump receives rejects from GY CHPP and is located to the northeast of GS1 TSF (**Figure 1** and **Figure 22**). The dump will remain as a 'stand-alone' rejects landform at closure.

The dump essentially comprises only rejects (over 99% by volume). It is assumed a small amount of 'fill' (assume spoil) may lie within the dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of the landform.

The source hazard assessment for the mineral wastes within the rejects dump has utilised the same general methodology as applied to the spoil and TSF landforms. The source hazard assessment has found the rejects within the dump (based on rejects from GY CHPP) poses a **Low-Moderate** AMD source hazard. Fill material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- GS2 rejects dump poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. The AMD hazard lies with the rejects, which comprise essentially all of the dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dump is also considered to be conservative. The AMD hazard scoring table for Riverside rejects dump is provided in **Attachment B – Table B11**.

GS11 rejects dump

GS11 rejects dump receives rejects from GY CHPP and is located east of GS1 TSF between Ramp 32 TSF and Eureka Creek (**Figure 1** and **Figure 22**). The dump is located at the periphery of Broadmeadow spoil dump and is not planned to be covered within the Broadmeadow-Isaac spoil landform. As such, it is expected to remain as a 'stand-alone' rejects landform at closure.

The dump essentially comprises only rejects (over 99% by volume). It is assumed a small amount of 'fill' (assume spoil) may lie within the dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of the landform.

The source hazard assessment for the mineral wastes within the rejects dump has utilised the same general methodology as applied to the spoil and TSF landforms. The source hazard assessment has found the rejects within the dump (based on rejects from GY CHPP) poses a **Low-Moderate** AMD source hazard. Fill material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- GS11 rejects dump poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. The AMD hazard lies with the rejects, which comprise essentially all of the dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dump is also considered to be conservative. The AMD hazard scoring table for Riverside rejects dump is provided in **Attachment B – Table B12**.

R22 in-pit rejects dump

R22 in-pit rejects dump receives rejects from GY CHPP and is located at the southern periphery of, and within, the Thiess spoil landform footprint (**Figure 1** and **Figure 22**). As such, it is not a 'stand-alone' rejects landform, however, is conservatively assessed as such given the concentrated nature of rejects at the periphery of the spoil landform where they will not be buried deeply within the core of the spoil landform.

The dump comprises only rejects. It is assumed a small amount of 'fill' (assume spoil) may lie within the dump, and the 'fill' is conservatively estimated to comprise approximately 0.5% of the landform.

The source hazard assessment for the mineral wastes within the rejects dump has utilised the same general methodology as applied to the spoil and TSF landforms. The source hazard assessment has found the rejects within the dump (based on rejects from GY CHPP) poses a **Low-Moderate** AMD source hazard. Fill material has been assessed as posing a **Low** AMD source hazard based on the geochemical characteristics of all GRBM spoil. Taking into account material quantities (proportions):

- R22 rejects dump poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. The AMD hazard lies with the rejects, which comprise essentially all of the dump.

The AMD hazard score for the rejects materials is considered to be conservative and the landform domain AMD hazard score for the rejects dump is also considered to be conservative. The AMD hazard scoring table for Riverside rejects dump is provided in **Attachment B – Table B13**.

7.1.4 Residual Voids – Exposed Walls and Floor

There are five pit groups at GRBM that will remain at closure as residual voids:

- Goonyella void; approximately 11 km long with an average depth of 304 m (at closure);
- Thiess void; approximately 3.9 km long with an average depth of 78 m (at closure);
- Broadmeadow-Isaac void; approximately 5.1 km long with an average depth of 83 m (at closure);
- Ramp 32 East void; approximately 1.6 km long with an average depth of 94 m (at closure); and
- Ramp 32 South void; approximately 1.0 km long with an average depth of 69 m (at closure).

Excluding Broadmeadow-Isaac void, the floor of all residual voids at closure will be the GLS seam. The floor of Broadmeadow-Isaac void will be the GMS seam.

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD hazard associated with residual void highwalls and floors, as explained in **Sections 4.4.1** to **4.4.3**.

The statistical distribution of residual void highwall materials and the proportion of exposed coal seam (groups) is summarised in **Table 20**. Also shown is the composition (proportion) of each seam group exposed on the highwall in each void (based on drill-hole data). As each void depth varies – especially Goonyella void compared to all other voids – not all seams are exposed in each void. For example, GF seam is only exposed in Goonyella void. Overall, remnant coal (seam) is expected to comprise between 5% to 10% (average 7.5%) of the highwalls in the residual voids.

Note that the source hazard assessment methodology outlined in **Section 4.4** has been applied to the materials expected to be exposed on the void highwalls and floor at closure.

The highwall AMD hazard assessment has found that approximately 7% to 10% of the void highwall in all voids is estimated to be PAF, which includes material classified as UC(PAF), PAF-LC and NAF-S – and most of this is expected to be associated with coal seams. As such, the assessment has found that the overall likelihood of AMD generation from the void highwalls is **Unlikely**. The expression of AMD from coal seams in the highwalls of residual voids, if any, will most likely be localised.

On the highly conservative (if not overly conservative) assumption that the floor of each void is all coal, the void floor AMD hazard assessment has found that essentially all of the floor of each void is estimated to be 'PAF', which includes material classified as PAF, UC(PAF), PAF-LC and NAF-S. As such, the conservative assessment has found that the likelihood of AMD generation from the floor of these voids is **Probable/Likely** until such time that the floor becomes submerged by groundwater (post-closure). In practice, mining takes all coal to the bottom of the seam, therefore very little coal would be expected to remain on the floor of the voids. The AMD hazard scoring tables for the residual voids are provided in **Attachment B – Tables B14 to B18**.

Table 20. Estimated wall rock exposure as a function of material type for each residual void

Component		Goonyella	Thiess	Broadmeadow -Isaac	Ramp 32 East	Ramp 32 South
Weathered, non-carbonaceous	%	10	44	26	34	23
Weathered, carbonaceous	%	1.3	3.2	0.8	3	2
Fresh, non-carbonaceous	%	71	38	61	53	63
Fresh, carbonaceous	%	5.5	3.7	1.5	5	6
Unknown OB/IB	%	2.1	1.9	4.0	-	-
Coal (fresh)	%	10	9.4	6.7	5	6
Coal seam groups *Proportion of seam group (% of highwall exposure)*		*GF: 5.9% GUS: 0.9% P: 0.7% GMS: 1.5% GLS: 1.1%*	*GF: n/a GUS: n/a P: n/a GMS: 5.2% GLS: 4.2%*	*GF: n/a GUS: 0.5% P: 2.2% GMS: 4.0% GLS: n/a*	*GF: n/a GUS: n/a P: n/a GMS: 2.5% GLS: 2.5%*	*GF: n/a GUS: n/a P: n/a GMS: 3% GLS: 3%*

7.2 Geochemical Source-Pathway-Risk Assessment

7.2.1 Conceptual Site Model and Conceptual Facility Models

Conceptual site model

A post-closure conceptual site model (CSM), which applies to the spoil landforms and their respective residual voids and the relationship these facilities have with surface water and groundwater in the district, has been produced by AECOM (2024) (**Figure 23)**. The CSM assists with the source-pathway-receptor (SPR) assessment with regard to potential environmental geochemical impacts from mineral waste facilities. The CSM, which focuses on the relationship with surface water and groundwater (these being the most relevant pathways and receptors for AMD and salinity), is used to illustrate the relationship between potential sources of run-off and seepage (e.g. spoil, tailings), plausible receptors (e.g. creeks, groundwater) and the pathways between the two (e.g. seepage, drainage).

Permian groundwater flow at GRBM is towards the east and largely follows the coal seams down-dip. Shallower groundwater that is likely associated with shallow permeable strata is likely to flow in a direction that broadly mimics surface topography. Groundwater modelling undertaken by AECOM (2024) shows that residual voids will be receptors of run-off and seepage from the spoil landforms and run-off from void highwalls, as illustrated in the CSM (**Figure 23**). However, the modelling also shows that ultimately all groundwater will report to Goonyella residual void. Thiess and Broadmeadow-Isaac residual void lakes have potential to be 'sources' for groundwater on its' path towards Goonyella residual void. Ramp 32 East and Ramp 32 South residual voids are expected to be weak groundwater sinks – largely drawing in groundwater from their immediate vicinity. Groundwater associated with the underground mining areas (including future mining at RHM) will report to Goonyella residual void. The residual voids are classified as non-use management areas (NUMAs).

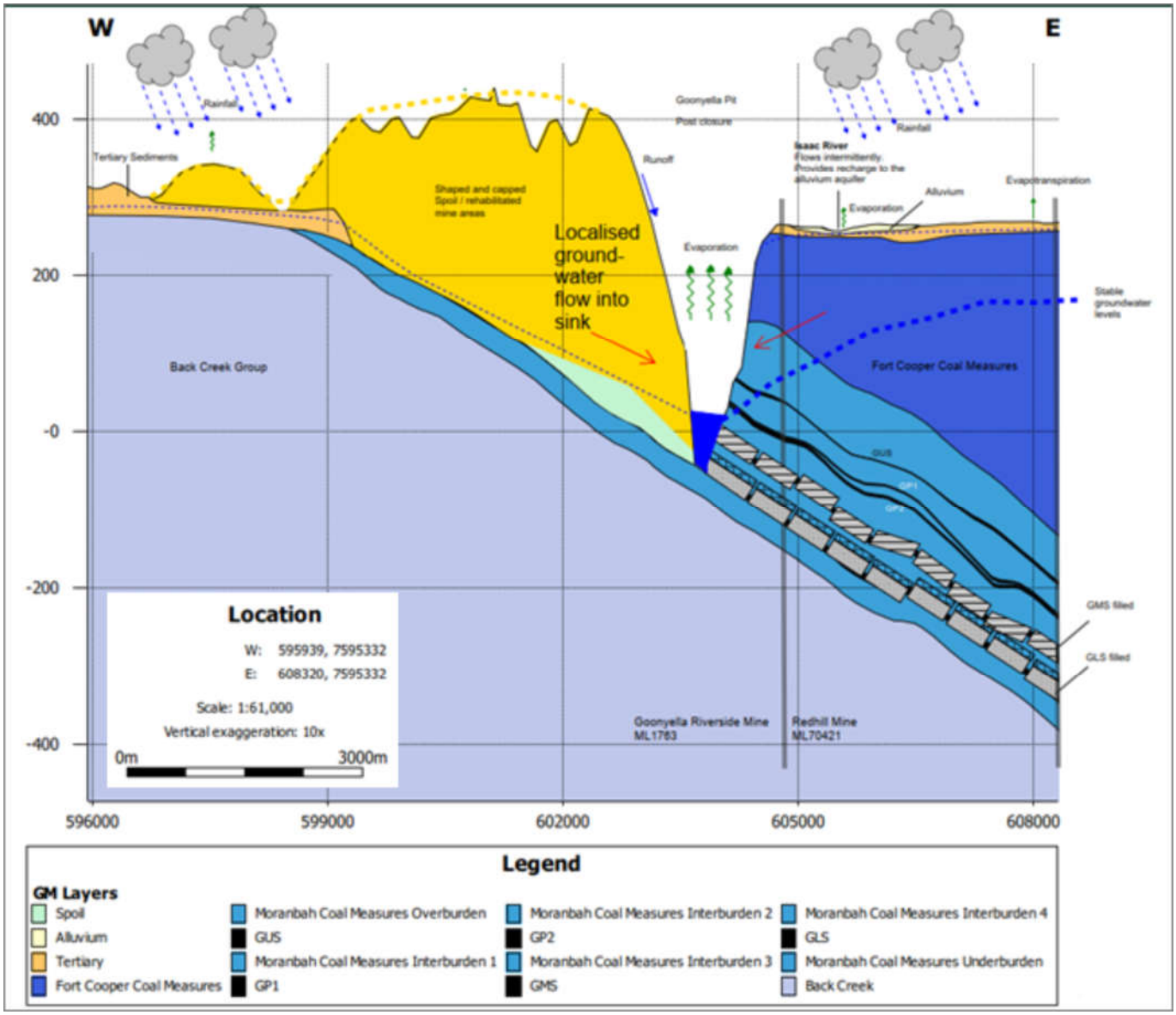

Figure 23. Source-Pathway-Receptor (SPR) conceptual site model post-closure
(AECOM, 2024)

The assessment indicates there may be shallow permeable strata present sporadically along (and/or near to) several creeks at GRBM and – where present – shallow groundwater is expected to be well below the base of all creeks in the area; suggesting that connectivity between shallow permeable strata and surface water features at GRBM is unlikely. Furthermore, modelling (including particle tracking) undertaken by AECOM (2024) found no evidence of connectivity between groundwater and surface water features. The model suggests that shallow

groundwater (and by extension shallow seepage) migrating through the site from the western side of the pit voids will be eventually report to the mine pits/voids [and, for most of the site, eventually reporting to Goonyella residual void]. The general downward migration of shallow groundwater (and seepage) into deeper groundwater and towards the residual voids is logical, given the very large drawdown (sink) of the voids – particularly Goonyella residual void.

The assessment of shallow groundwater at GRBM – particularly where shallow permeable strata may not be present in some areas, may be discontinuous and/or not interconnected – is limited by/to the distribution of the shallow bore network, which is sporadic. Therefore, despite the apparent low likelihood of substantial connection between shallow permeable strata and surface water features, the SPR assessment has adopted a *highly conservative approach* and assumed a plausible pathway *may* exist between shallow permeable strata and surface water features.

The Isaac River and adjacent wetlands are not plausible receptors of undiluted run-off and seepage from mineral waste landforms and seepage from residual voids due to lack of a connecting pathway.

Conceptual facility models

A conceptual facility model (CFM) has been developed for each TSF and rejects landform to illustrate potential run-off and seepage pathways and surface water and groundwater receptors associated with these key mineral waste facilities post-closure.

- GS1 TSF – prior to rehabilitation – has a Moderate-High AMD source hazard with the likelihood of AMD generation from the landform rated as Highly Likely – noting that AMD has already been observed from GS1 TSF. CFM shown at **Figure 24**;
- RS1 TSF – prior to rehabilitation. The western compartment has a Moderate AMD source hazard with the likelihood of AMD generation rated as Probable/Likely. The eastern compartment has a Moderate-High AMD source hazard with the likelihood of AMD generation rated as Highly Likely. CFM shown at **Figure 25** with Riverside rejects dump;
- DRE5 in-pit TSF within Thiess spoil landform – prior to rehabilitation – has a Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Probable/Likely. CFM shown at **Figure 26**;
- R22 in-pit rejects dump within Thiess spoil landform – prior to rehabilitation – has a Low-Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Unlikely. CFM shown at **Figure 27**.
- Ramp 32 in-pit TSF within Airstrip spoil landform – prior to rehabilitation – has a Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Probable/Likely. CFM shown at **Figure 28**;
- Riverside rejects dump – excluding the spoil cover – has a Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Probable/Likely. CFM shown at **Figure 25** with RS1 TSF;
- GS2 rejects dump – prior to rehabilitation – has a Low-Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Unlikely. CFM shown at **Figure 29**; and
- GS11 rejects dump – prior to rehabilitation – has a Low-Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Unlikely. CFM shown at **Figure 30**.

*Note: the intent of the simplified CFM illustrations shown as **Figures 24 to 30** is to conceptualise potential surface water run-off and seepage pathways between key landform domains and potential receptors. The CFM figures are not to scale and may not be a true representation of the system at each location.*

CFMs have not been developed for general rejects co-disposed (broadly distributed) throughout spoil dumps/ landforms, such as the small quantity of rejects currently disposed at Ramp 23 within Thiess spoil dump.

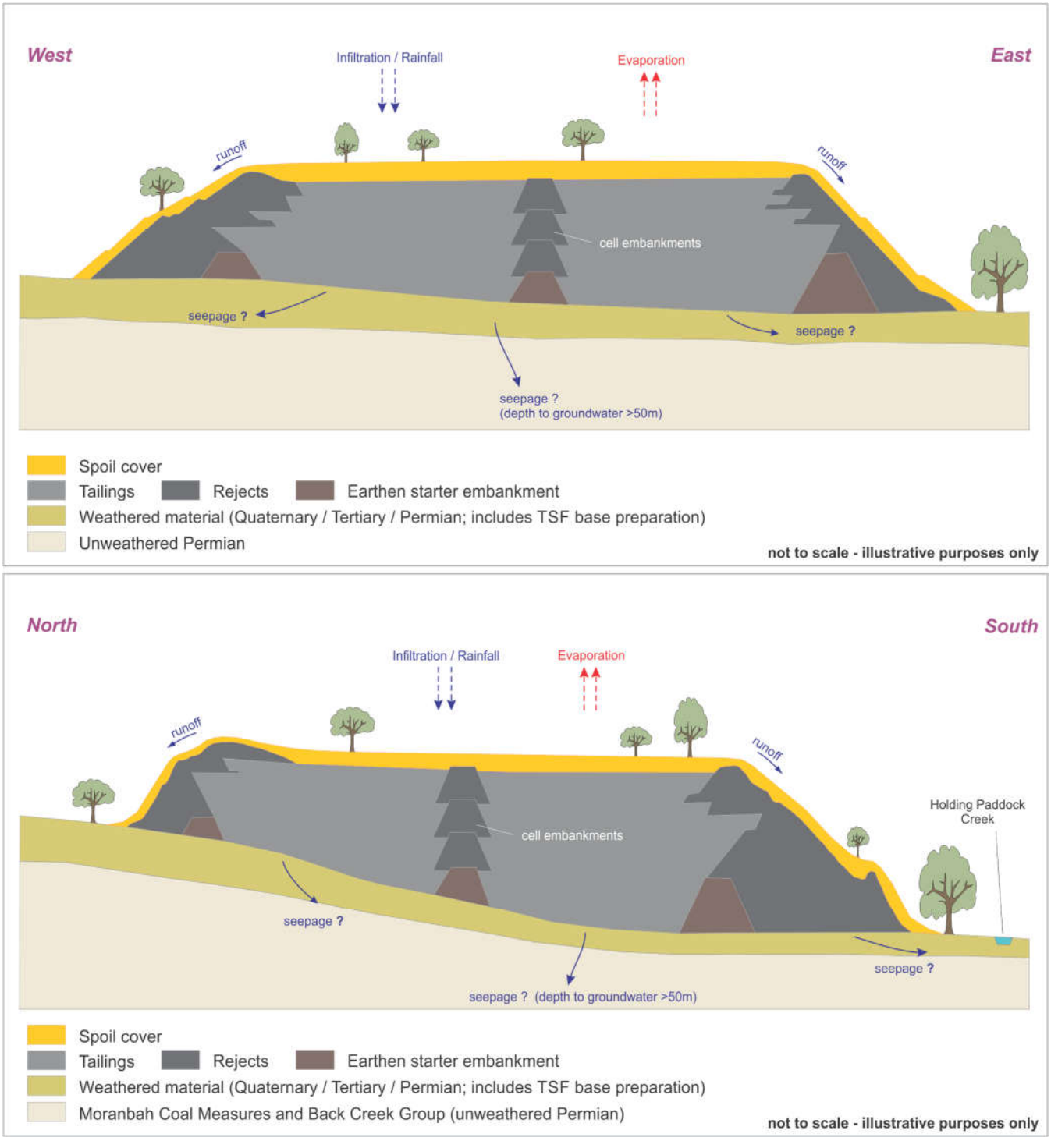

Figure 24. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for GS1 TSF landform

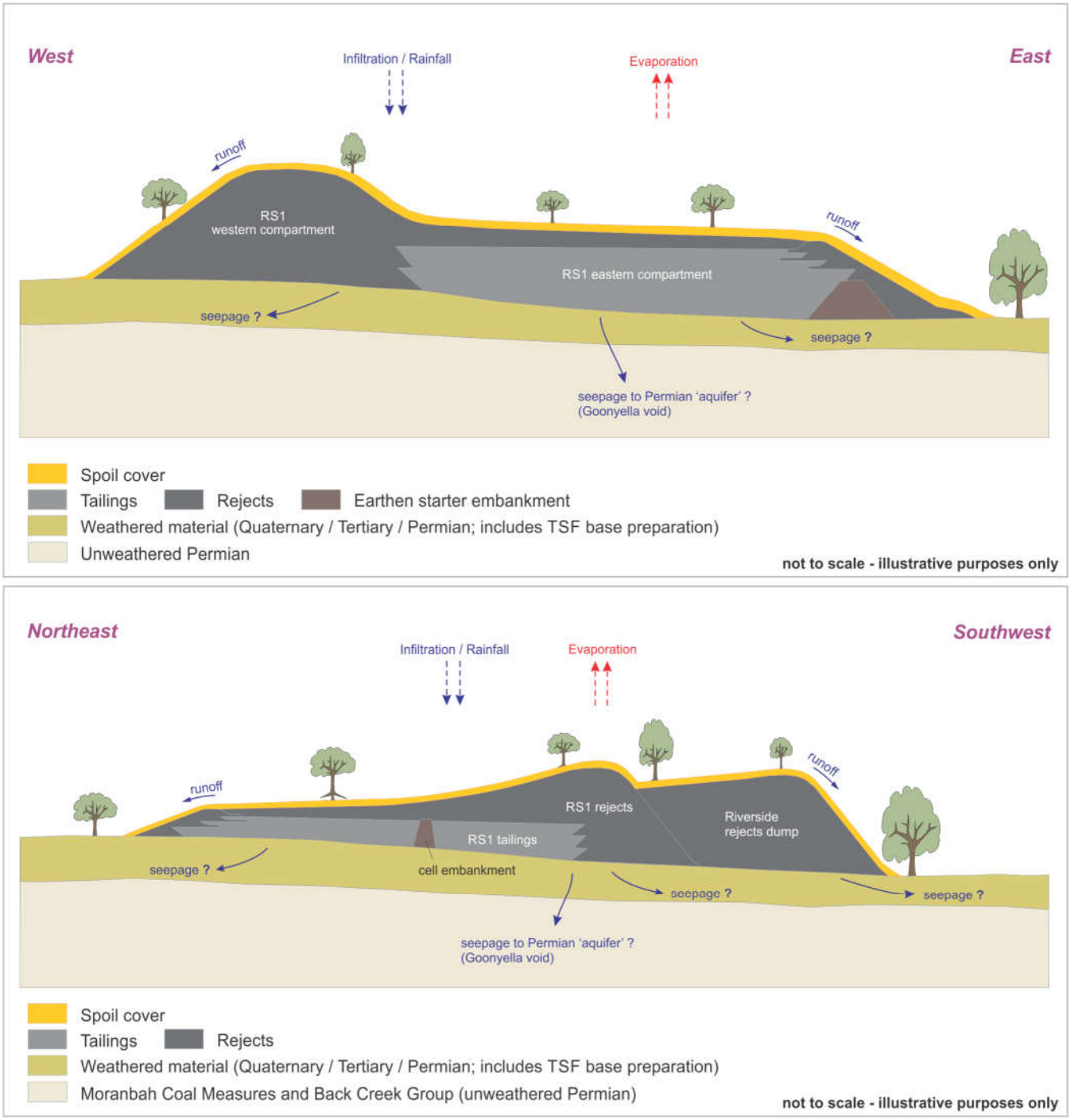

Figure 25. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for RS1 TSF landform and Riverside rejects landform

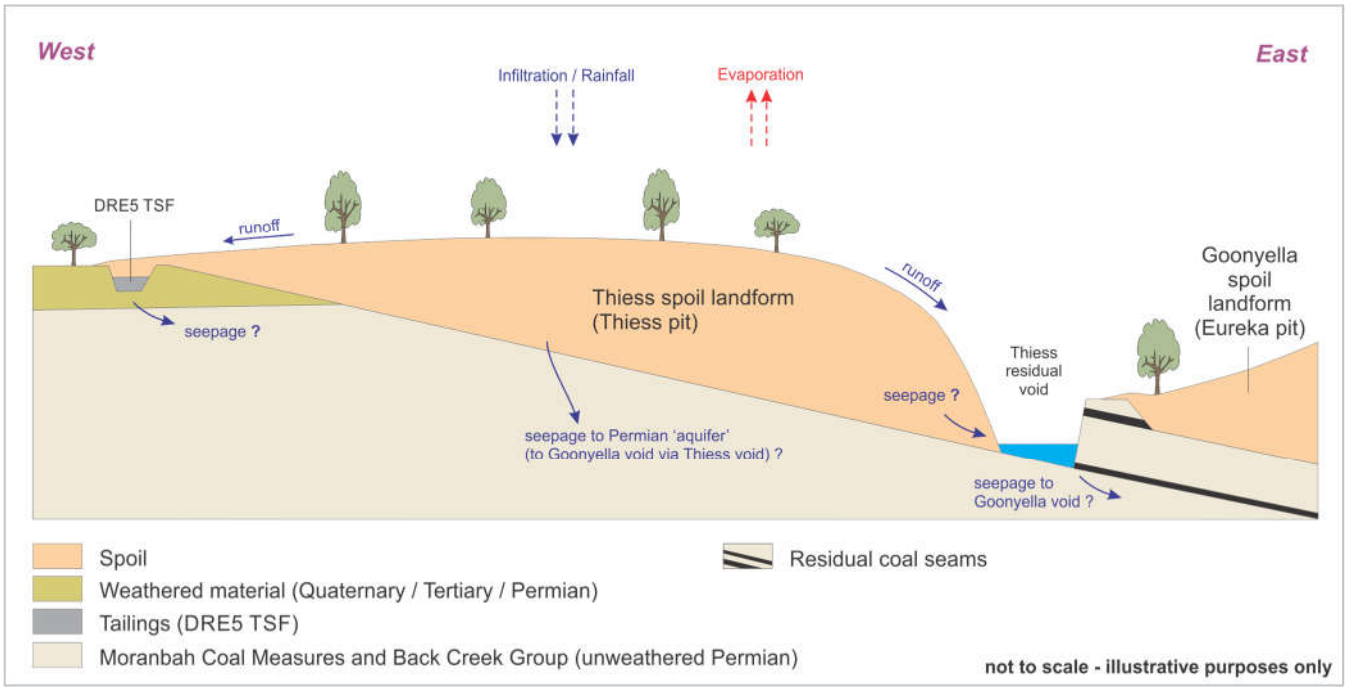

Figure 26. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for DRE5 in-pit TSF landform [within the Thiess spoil landform]

DRE5 in-pit TSF is a below-ground TSF within the footprint and pit shell of Thiess spoil landform and, as such, there are no plausible surface water receptors via run-off or via shallow permeable strata.

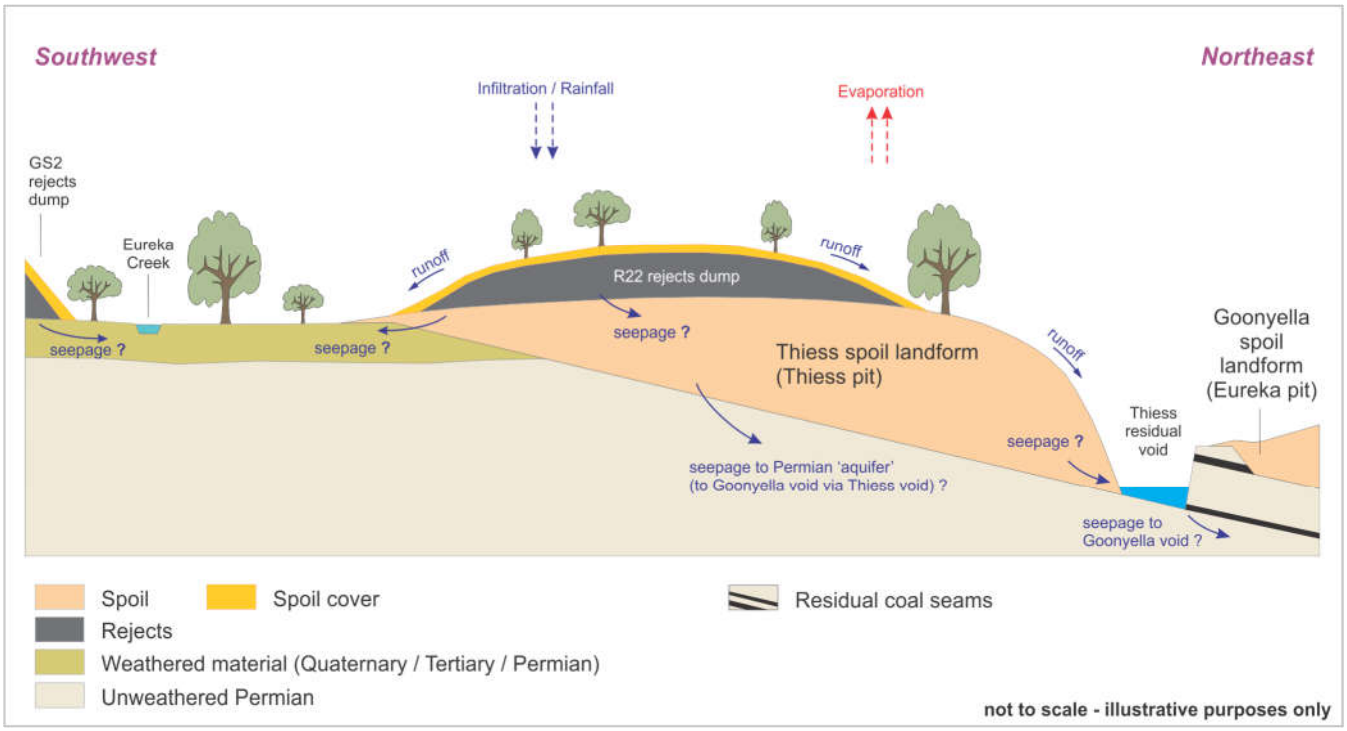

Figure 27. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for R22 in-pit rejects landform [within the southern end of Thiess spoil landform]

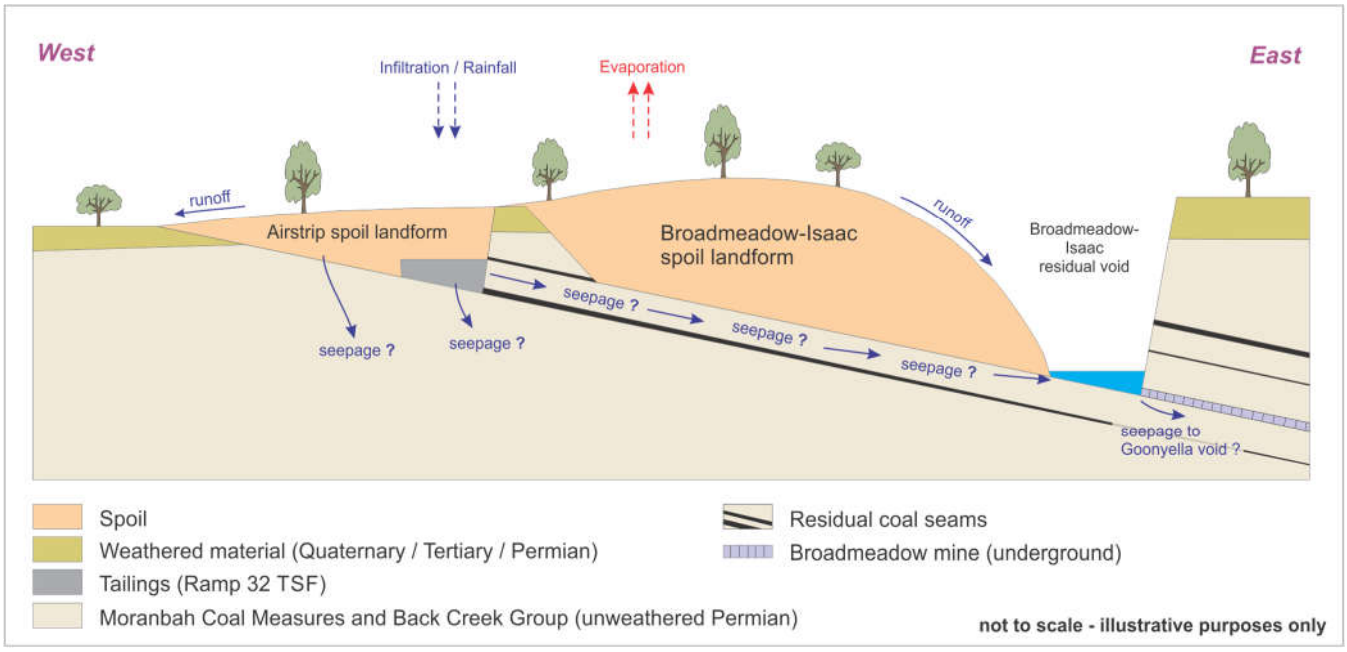

Figure 28. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for Ramp 32 in-pit TSF landform [within the Airstrip spoil landform]

Ramp 32 in-pit TSF is a below-ground TSF within the footprint and pit shell of Airstrip spoil landform and, as such, there are no plausible surface water receptors via run-off or via shallow permeable strata.

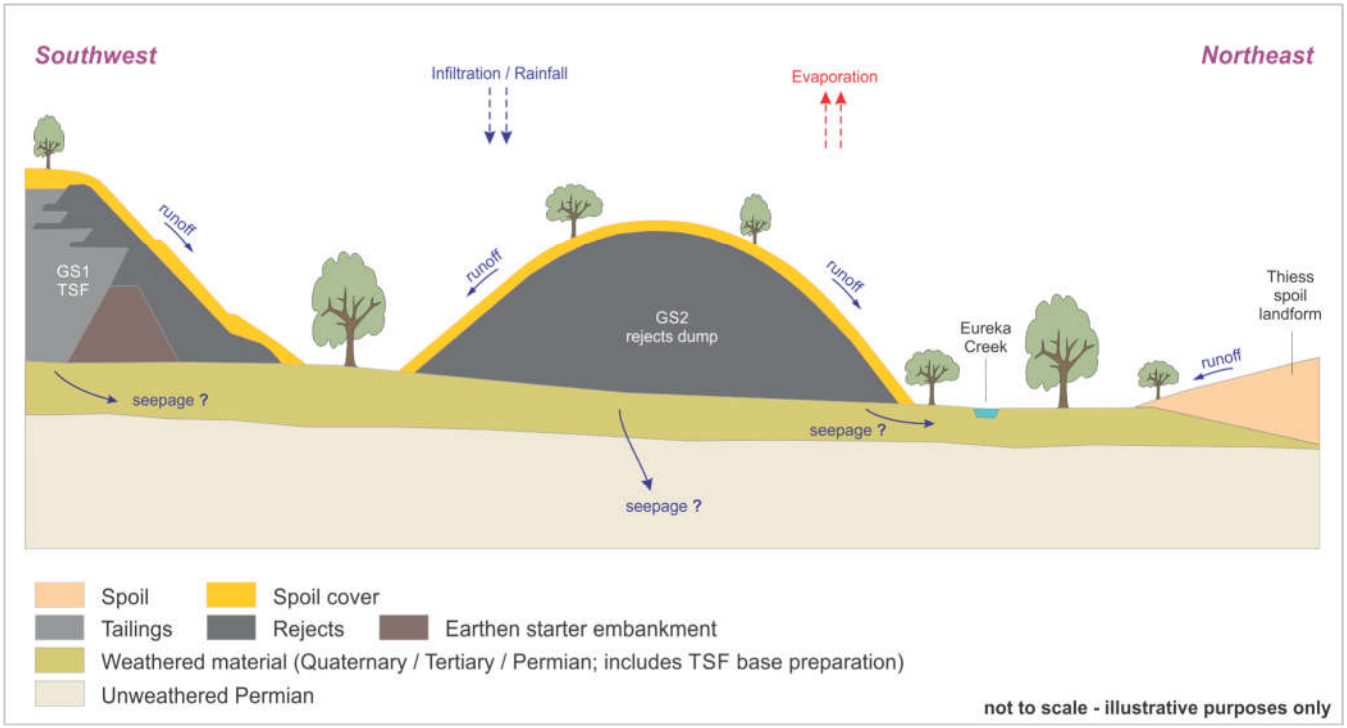

Figure 29. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for GS2 rejects landform

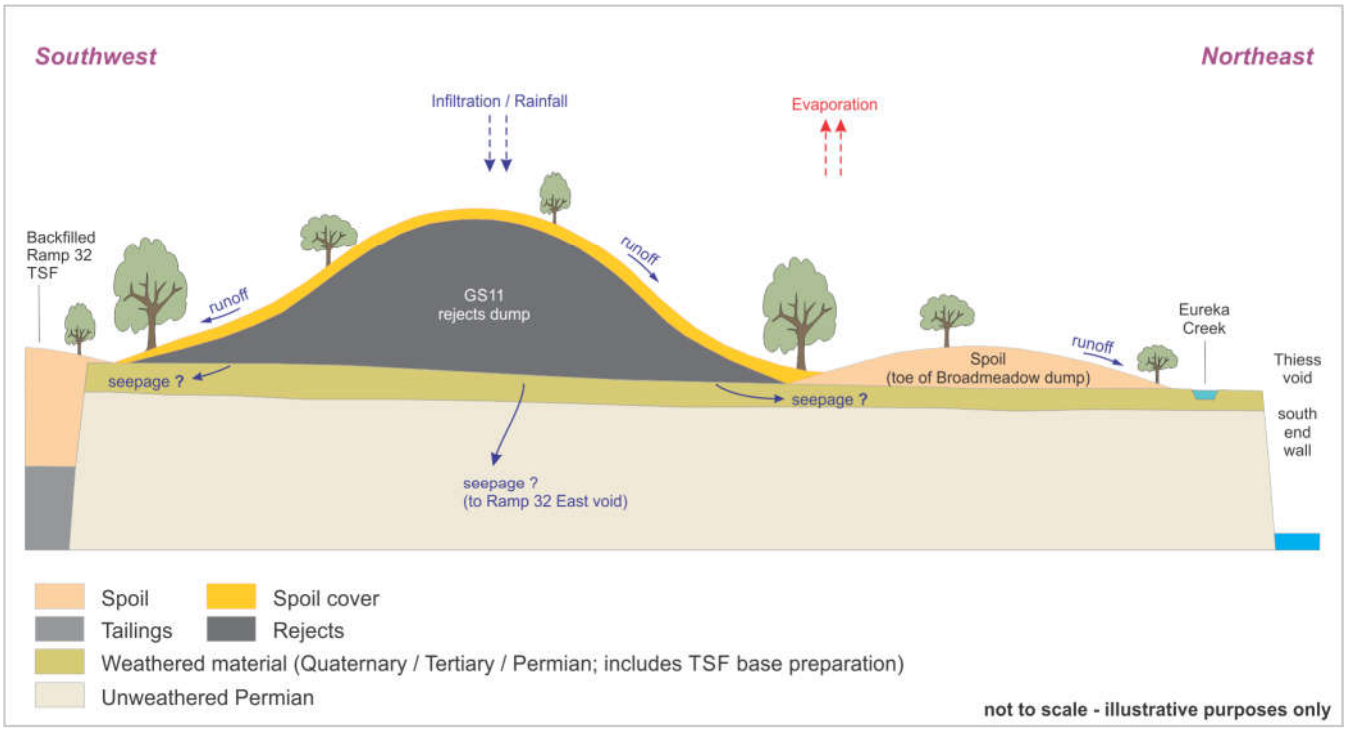

Figure 30. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for GS11 rejects landform

With regard to the mineral waste facilities the plausible mechanisms for AMD affected water and/or non-oxidative salinity to report to receptors are identified in **Table 21** (spoil landforms), **Table 22** (TSF landforms) and **Table 23** (rejects landforms). With regard to void highwalls (as a potential source of AMD affected water and/or non-oxidative salinity), the only plausible receptor is the void, via surface water [run-off] from the highwall.

Table 21. Sources, potential receptors and potential pathways between the source and receptor (post-closure) for spoil landforms

Sources	Potential Pathways from Source	Potential Receptors from Source
Spoil landforms		
Goonyella	Surface water [run-off]	Goonyella Creek [+/- tributaries] (north) / Isaac River (south) / Eureka Creek (south) / Goonyella residual void
	Seepage [shallow permeable strata]	Goonyella Creek [+/- tributaries] (north) / Isaac River (south) / Eureka Creek (south)
	Seepage [groundwater 'aquifer']	Goonyella residual void
Thiess	Surface water [run-off]	Eureka Creek (west and south) / Thiess residual void
	Seepage [shallow permeable strata]	Eureka Creek (west and south)
	Seepage [groundwater 'aquifer']	Goonyella residual void via Thiess residual void
Airstrip	Surface water [run-off]	Holding Paddock Creek (west and southwest) / Ramp 32 East and South residual voids
	Seepage [shallow permeable strata]	Holding Paddock Creek (west and southwest)
	Seepage [groundwater 'aquifer']	Ramp 32 East and Ramp 32 South residual voids [+/-Broadmeadow-Isaac residual void]
Broadmeadow-Isaac	Surface water [run-off]	Eureka Creek (north) / Isaac River (south) / Ramp 32 East, Ramp 32 South and Broadmeadow-Isaac residual voids
	Seepage [shallow permeable strata]	Eureka Creek (north) / Isaac River (south)
	Seepage [groundwater 'aquifer']	Goonyella residual void via Broadmeadow-Isaac residual void

Table 22. Sources, potential receptors and potential pathways between the source and receptor (post-closure) for TSF landforms

Sources	Potential Pathways from Source	Potential Receptors from Source
TSF landforms		
GS1 TSF	Surface water [run-off]	Holding Paddock Creek (west and south) / Eureka Creek (north)
	Seepage [shallow permeable strata]	Holding Paddock Creek / Eureka Creek
	Seepage [groundwater 'aquifer']	*No plausible groundwater receptors (low-permeability aquitard; >50 m to groundwater)*
RS1 TSF	Surface water [run-off]	Eureka Creek [+/- tributaries] (west and south)
	Seepage [shallow permeable strata]	Eureka Creek [+/- tributaries] (west and south)
	Seepage [groundwater 'aquifer']	Goonyella residual void
DRE5 in-pit TSF	Surface water [run-off]	*No plausible receptors via surface water run-off (in-pit TSF below ground level within the pit shell)*
	Seepage [shallow permeable strata]	*No plausible receptors via shallow permeable strata (in-pit TSF below ground level within the pit shell)*
	Seepage [groundwater 'aquifer']	Goonyella residual void [+/- Thiess residual void]
Ramp 32 in-pit TSF	Surface water [run-off]	*No plausible receptors via surface water run-off (in-pit TSF below ground level within the pit shell)*
	Seepage [shallow permeable strata]	*No plausible receptors via shallow permeable strata (in-pit TSF below ground level within the pit shell)*
	Seepage [groundwater 'aquifer']	Ramp 32 East residual void

Table 23. Sources, potential receptors and potential pathways between the source and receptor (post-closure) for rejects landforms

Sources	Potential Pathways from Source	Potential Receptors from Source
Rejects landforms		
Riverside rejects dump	Surface water [run-off]	Eureka Creek [+/- tributaries]
	Seepage [shallow permeable strata]	Eureka Creek [+/- tributaries]
	Seepage [groundwater 'aquifer']	Goonyella residual void
GS2 rejects dump	Surface water [run-off]	Eureka Creek (east)
	Seepage [shallow permeable strata]	Eureka Creek (east)
	Seepage [groundwater 'aquifer']	*No plausible groundwater receptors (low-permeability aquitard; >50 m to groundwater)*
GS11 rejects dump	Surface water [run-off]	Eureka Creek (north) / Ramp 32 East residual void
	Seepage [shallow permeable strata]	Eureka Creek (north) / Ramp 32 East residual void / backfilled Airstrip pit (Ramp 32 TSF)
	Seepage [groundwater 'aquifer']	Ramp 32 East residual void
R22 in-pit rejects dump	Surface water [run-off]	Eureka Creek (west and south) / Thiess residual void
	Seepage [shallow permeable strata]	Eureka Creek (west and south)
	Seepage [groundwater 'aquifer']	Goonyella residual void via Thiess residual void

The BHP residual risk rating heat map (**Table 24**) has been adopted to assess the risks associated with SPR from the spoil, TSF and rejects landforms. In reference to the Risk Matrix, the SPR assessment includes the likelihood of the event occurring, the severity of the event (should it occur) and the calculated risk rating (likelihood X severity).

Table 24. Risk matrix for SPR assessment

Risk Rating = Likelihood x Severity		Severity				
		S1	S2	S3	S4	S5
Likelihood	Highly Likely	Medium	Medium to High	High	High	High
	Likely	Low to Medium	Medium	Medium to High	High	High
	Probable	Low	Low to Medium	Medium	Medium to High	High
	Unlikely	Low	Low	Low to Medium	Medium	Medium to High
	Highly Unlikely	Low	Low	Low	Low to Medium	Medium

The risk ratings for the mineral waste landforms with respect to plausible surface water and void receptors is shown in **Attachment C** and report sections as follows:

Surface water receptors of landform sources

- Spoil landforms with respect to plausible surface water receptors: **Attachment C Tables C1 to C4** and discussed in **Section 7.2.2**;
- TSF and rejects landforms with respect to plausible surface water receptors: **Attachment C Tables C5 to C10** and discussed in **Sections 7.2.3** to **7.2.10**.

Residual void receptors of landform sources

Groundwater modelling (AECOM, 2024) has shown that Goonyella void – being very large and deep – will draw in seepage/groundwater from all pit/void areas at GRBM. That is, collectively, all residual voids at GRBM will be groundwater 'sinks'. As such, seepage into the Permian groundwater system from any/all facilities at GRBM will ultimately report into Goonyella residual void.

- Spoil landforms with respect to residual void receptors: **Attachment C Tables C11 and C12** and discussed in **Section 7.2.2**;
- TSF landforms with respect to residual void receptors: **Attachment C Table C13** and discussed in **Sections 7.2.3 to 7.2.6**;
- Rejects landforms with respect to residual void receptors: **Attachment C Table C14** and discussed in **Sections 0 to 7.2.10**.

Residual void receptors of highwalls and void floor sources

The risk ratings for the residual void highwall and floor (for each void) with respect to final void receptors is shown in **Attachment C Table C14** and discussed in **Section 7.2.11**. The potential impact of seepage from the residual voids into the Permian groundwater aquifer is discussed in the void closure plan (WSP, 2024).

7.2.2 Final spoil landforms

DRE5 in-pit TSF and Ramp 32 in-pit TSF are located within the 'footprint' of Thiess and Airstrip spoil landforms, respectively, and contain a concentration of tailings at the base of the spoil landforms. Similarly, R22 in-pit rejects dump is located within the 'footprint' of Thiess spoil landform, and contains a concentration of rejects at the

periphery of the spoil landform. As such, a conservative approach has been adopted and these two TSFs and R22 rejects dump are addressed as stand-alone facilities (as discussed in **Section 7.1.1**) and are not included as part of their respective spoil landforms for the purposes of the assessment.

Source materials hazard

Spoil landforms are predominantly comprised of non-carbonaceous overburden/interburden with coaly and carbonaceous material (predominantly in the form of carbonaceous spoil and reject) comprising a minor proportion – typically about 9% for most spoil landforms [and excluding rejects within R22 rejects dump at Thiess landform]. Non-carbonaceous overburden/interburden from Permian-age material in the Bowen Basin is widely recognised as posing a low to low-moderate AMD risk. Rejects generally pose a low-moderate to moderate AMD source hazard and comprise a very small proportion of each spoil landform (typically less than 1%).

Source materials generally have low to low-moderate EC values and are expected to produce slightly saline (potentially slightly to moderately saline) run-off and seepage, with release of (non-oxidative) salinity rated as a low to low-moderate hazard. Source materials generally have low to low-moderate total S values and generally excess ANC. The hazard for AMD generation for all spoil landforms is considered to be 'Low', with the likelihood for AMD generation from spoil landforms rated as 'Highly Unlikely'.

Pathways

Surface water

Surface water receptors (ephemeral creeks) are located adjacent to each spoil landform – typically less than 300m from some areas of each landform. It is plausible (highly likely) for surface water run-off from rehabilitated landforms to reach these creeks. Refer to **Figure 22** and **Table 21** for surface water receptors associated with each spoil landform.

Seepage / Groundwater

The water table is expected to intersect the deeper zones of each in-pit spoil landform within the Permian coal measures (AECOM, 2024). However – with the exception of Ramp 32 East and South residual voids – all groundwater on site is ultimately captured by the Goonyella residual void (as a large groundwater sink). Therefore, although a direct connection is expected to exist between deeper parts of the final landforms and groundwater (the water table), this groundwater will ultimately report to the Goonyella residual void – not to the broader aquifer beyond the site. Ramp 32 East and South residual voids are weak groundwater sinks for groundwater in their immediate vicinity only.

As discussed in **Section 7.2.1** it is plausible for seepage from the near-surface and unsaturated zone of the in-pit spoil landforms to migrate downwards into the water table. It is also plausible that seepage may occur into discontinuous shallow permeable strata locally associated with existing creeks or palaeodrainage channels. Due to the highly discontinuous and/or not interconnected nature of shallow permeable strata at GRBM, the understanding surrounding any potential link between shallow groundwater and surface water is limited. As such, whether seepage into shallow permeable strata would continue further downwards into deeper groundwater (primary aquifer) or, instead, report to nearby surface water features, is also somewhat unclear. Despite this potential limitation, the overall groundwater gradient at GRBM is downwards and towards (into) Goonyella residual void (potentially via the nearest residual void associated with each spoil landform). Therefore, it is reasonably assumed that the likelihood of seepage from spoil landforms reaching a surface water receptor via shallow groundwater is 'Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between a spoil landform via shallow permeable strata into a nearby surface water receptor (ephemeral creek).

Refer to **Attachment C Tables C1 to C4** for conceptual shallow seepage pathways and nearby surface water receptors associated with the spoil landforms and **Attachment C Tables C11 and C12** for groundwater pathways from spoil landforms to the residual voids.

Receptors

Plausible receptors identified in this qualitative assessment include ephemeral creeks and residual voids. Refer to **Attachment C – Tables C1 to C4** for surface water receptors associated with each spoil landform and **Attachment C – Tables C11 and C12** for residual void receptors associated with the spoil landforms.

Due to the geochemical nature of the spoil landforms, the likelihood of AMD from spoil landforms to impact on the water quality of surface water receptors and on the water quality of residual voids has been rated unlikely. The likelihood of non-oxidative salinity from spoil landforms to impact on the water quality of surface water receptors (via surface water run-off) has been rated unlikely, and the severity should it occur is low, hence the risk rating is low.

Consideration was also made to people living in the homesteads near the project area. Homesteads within 2 km of GRBM are located in surface water sub-catchments that do not receive drainage from GRBM and/or are upstream (via surface water) from GRBM and/or upgradient (via groundwater) from GRBM. As such, all of these homesteads are implausible receptors of AMD or saline drainage from the final spoil landforms.

SPR risk rating of final spoil landforms

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the sources (final spoil landforms) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from final spoil landforms is **Low**. With respect to non-oxidative salinity the overall SPR risk from final spoil landforms is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) spoil landforms to impact on the water quality of the residual voids has been rated ‘Unlikely’.

7.2.3 GS1 TSF landform

Source materials hazard

Excluding the final cover/cap to be installed over GS1 TSF, the TSF landform is currently comprised of approximately 95% tailings, with the remainder being rejects (about 5%, as embankment material). It is assumed the TSF may contain up to 0.5% fill material (predominantly within or close to embankments). Tailings within the unrehabilitated TSF pose a moderate-high AMD hazard and rejects (embankments) pose a moderate AMD hazard.

Source materials generally have low-moderate EC values and are expected to produce slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard. Overall, the hazard for AMD generation from the current GS1 TSF landform is ‘Moderate-High’ and the likelihood for AMD generation from the current landform is rated as ‘Highly Likely’ (the highest ‘likelihood’ rating available under the applied AMD hazard scoring methodology) – noting that field evidence of AMD (as AD) exists at the facility.

Pathways

Pathways from GS1 TSF landform to plausible receptors are shown in **Figure 22** (post-closure landform), **Figure 24** (CFM for GS1 TSF landform), **Table 22** and **Attachment C Table C5**. There are no plausible groundwater receptors (e.g. residual voids) from GS1 TSF.

Surface water

All surface water receptors are ephemeral. Holding Paddock Creek is located less than 100 m south of the TSF landform and Eureka Creek is located approximately 500 m northeast of the TSF landform. It is likely that surface water run-off from the TSF landform will reach these creek tributaries – particularly Holding Paddock Creek. The TSF will be covered by a spoil cover to manage the AMD source hazard, therefore all post-closure run-off from the TSF landform will be from general spoil (overburden/interburden) material and no tailings or rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or,

instead, report through the shallow permeable strata into nearby surface water features (in this case, Holding Paddock Creek and Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is downwards and towards the residual voids – including from areas outside of a pit shell, such as GS1 TSF.

Groundwater modelling (AECOM, 2024) shows the water table to be greater than 50 m below ground level at GS1 TSF (at closure), with low-permeability sediments forming an aquitard between the TSF and the nearest aquifer. However, due to the close proximity of Holding Paddock Creek to the above-ground TSF landform, it is reasonably assumed that the likelihood of seepage from GS1 TSF landform (post-closure) reaching a surface water receptor (particularly, Holding Paddock Creek) via shallow groundwater is 'Probable'.

In summary, the SPR has assumed a plausible (probable) local seepage pathway *may* exist between GS1 TSF landform via shallow permeable strata into nearby Holding Paddock Creek and a plausible (unlikely) local seepage pathway *may* exist between GS1 TSF landform via shallow permeable strata into Eureka Creek.

Receptors

Plausible receptors of surface water run-off and seepage from GS1 TSF landform are shown in **Figure 22** (Post-closure landform), **Figure 24** (CFM for GS1 TSF landform), **Table 22** and **Attachment C Table C5**. There are no plausible groundwater receptors from GS1 TSF.

Surface water

The only plausible surface water receptors identified in this qualitative assessment of GS1 TSF landform are two ephemeral creeks: Holding Paddock Creek located less than 100 m south of the TSF and Eureka Creek located approximately 500 m northeast of the TSF. This applies to potential surface water run-off and potential seepage through shallow permeable strata into the surface water receptor(s).

The rehabilitated TSF landform will have a spoil cover designed to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) TSF landform to impact on the water quality of the surface water receptor(s) (via run-off or shallow seepage) has been rated unlikely. The likelihood of non-oxidative salinity from the TSF landform to impact on the water quality of the surface water receptor(s) has also been rated unlikely.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) indicates there are no plausible groundwater receptors from GS1 TSF post-closure landform due to the significant depth to the water table below the TSF (>50 m) and the significant thickness of low-permeability sediments forming an aquitard.

SPR risk rating of GS1 TSF landform

There are plausible surface water receptors located very close to GS1 TSF; and the run-off and seepage pathways linking the source (GS1 TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low** to **Medium**. The 'Low-Medium' risk rating applies to AMD associated with seepage via shallow permeable strata into Holding Paddock Creek, located less than 100 m from the TSF. The likelihood of AMD reaching Holding Paddock Creek is unlikely, however the severity of the event, should it occur, has been rated as moderate (S3). With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is rated as **Low**.

7.2.4 RS1 TSF landform

Source materials hazard

Excluding the final cover/cap to be installed over RS1 TSF, the TSF landform is currently comprised of approximately 85% tailings (located in the eastern compartment) and 15% rejects (predominantly located in the western compartment). It is assumed the eastern compartment may contain up to 0.5% fill material (predominantly within or close to embankments). Tailings within the unrehabilitated TSF pose a moderate-high AMD hazard and rejects pose a moderate AMD hazard.

Source materials generally have low-moderate EC values and are expected to produce slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard. Overall, the hazard for AMD generation from the current RS1 TSF landform is 'Moderate-High' and the likelihood for AMD generation from the current landform is rated as 'Highly Likely' (the highest 'likelihood' rating available under the applied AMD hazard scoring methodology) – noting that field evidence of AMD (as AD) exists at the facility.

Pathways

Pathways from RS1 TSF landform to plausible surface water and groundwater receptors are shown in **Figure 22** (Post-closure landform), **Figure 25** (CFM for RS1 TSF landform), **Table 22** and **Attachment C Tables C6 and C13**.

Surface water

Eureka Creek, an ephemeral creek, is located over 1 km south of the TSF landform with the closest tributary located approximately 800 m west-southwest of RS1 TSF. The TSF will be covered by a spoil cover to manage the AMD source hazard, therefore all post-closure run-off from the TSF landform will be from general spoil (overburden/interburden) material and no tailings will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, tributaries of Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is downwards and towards Goonyella residual void – including from areas outside of a pit shell, such as RS1 TSF.

Groundwater modelling (AECOM, 2024) shows that seepage from RS1 TSF landform would report to Goonyella residual void. Therefore, it is reasonably assumed that the likelihood of seepage from RS1 TSF landform reaching a surface water receptor (approximately 800 m from the TSF) via shallow seepage is 'Highly Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between RS1 TSF landform via shallow permeable strata into nearby surface water receptors (tributaries of Eureka Creek).

Receptors

Plausible receptors of surface water run-off and seepage from RS1 TSF landform are shown in **Figure 22** (Post-closure landform), **Figure 25** (CFM for RS1 TSF landform), **Table 22** and **Attachment C Tables C6 and C13**.

Surface water

The only plausible surface water receptor identified in this qualitative assessment of RS1 TSF landform is the ephemeral Eureka Creek, with the closest tributarily located approximately 800 m west-southwest of the TSF landform. This applies to potential surface water run-off and potential seepage through shallow permeable strata into the surface water receptor(s).

The rehabilitated TSF landform will have a spoil cover designed to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) TSF landform to impact on the water quality of Eureka Creek (via run-off or shallow seepage) has been rated 'Highly Unlikely'. The likelihood of non-oxidative salinity from the TSF landform to impact on the water quality of Eureka Creek has been rated 'Highly Unlikely'.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) shows that seepage from RS1 TSF landform into groundwater will ultimately report to Goonyella residual void.

SPR risk rating of RS1 TSF landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (RS1 TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**. The likelihood of AMD reaching any of the receptors was rated as 'Highly Unlikely' (due to the significant distance from the TSF to the nearest receptor [Eureka Creek]) however the severity of AMD impacting the water quality of Eureka Creek via a shallow permeable pathway, should it occur, has been rated as moderate (S3). The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of Goonyella residual void has been rated 'Unlikely'.

7.2.5 Ramp 32 in-pit TSF landform

Source materials hazard

Excluding the spoil cover to be installed over Ramp 32 in-pit TSF, the TSF landform is currently comprised entirely of tailings, which pose a moderate AMD hazard.

The tailings generally have moderate EC values and are expected to produce moderately saline run-off and seepage, with release of (non-oxidative) salinity rated as a moderate hazard. Overall, the hazard for AMD generation from the current Ramp 32 in-pit TSF landform is 'Moderate' and the likelihood for AMD generation from the current landform is rated as 'Probable / Likely'.

Pathways

Ramp 32 in-pit TSF (i.e. below ground level) will be backfilled with spoil and will reside within the Airstrip spoil landform. As such, there are no plausible surface water receptors from the TSF via surface water run-off or via shallow permeable strata. All post-closure run-off from the backfilled pit (TSF) will be from general spoil (overburden/interburden) material and no tailings will be exposed to (or at risk of) surface water run-off.

Groundwater modelling (AECOM, 2024) suggests that seepage from Ramp 32 in-pit TSF would likely report to Ramp 32 East and Ramp 32 South residual voids. Pathways from Ramp 32 in-pit TSF landform to plausible groundwater (residual void) receptors are shown in **Figure 28** (CFM for Ramp 32 in-pit TSF landform), **Table 22** and **Attachment C Table C13**.

Receptors

Groundwater modelling (AECOM, 2024) suggests that seepage from Ramp 32 in-pit TSF landform into groundwater will ultimately report to Ramp 32 East and Ramp 32 South residual voids.

SPR risk rating of Ramp 32 in-pit TSF landform

There are plausible residual void receptors, and the seepage pathways linking the source (Ramp 32 in-pit TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of these two residual voids has been rated 'Unlikely'.

7.2.6 DRE5 in-pit TSF landform

Source materials hazard

Excluding the spoil cover to be installed over DRE5 in-pit TSF, the TSF landform is currently comprised entirely of tailings, which pose a moderate AMD hazard.

The tailings generally have moderate EC values and are expected to produce moderately saline run-off and seepage, with release of (non-oxidative) salinity rated as a moderate hazard. Overall, the hazard for AMD generation from the current DRE5 in-pit TSF landform is 'Moderate' and the likelihood for AMD generation from the current landform is rated as 'Probable / Likely'.

Pathways

DRE5 in-pit TSF (i.e. below ground level) will be backfilled/covered with spoil and will reside within the Thiess spoil landform. As such, there are no plausible surface water receptors from the TSF via surface water run-off or via shallow permeable strata. All post-closure run-off from the backfilled pit (TSF) will be from general spoil (overburden/interburden) material and no tailings will be exposed to (or at risk of) surface water run-off.

Groundwater modelling (AECOM, 2024) suggests that seepage from DRE5 in-pit TSF would likely report to Goonyella residual void, potentially via Thiess residual void. Pathways from DRE5 in-pit TSF landform to plausible groundwater (residual void) receptors are shown in **Figure 26** (CFM for DRE5 in-pit TSF landform), **Table 22** and **Attachment C Table C13**.

Receptors

Groundwater modelling (AECOM, 2024) suggests that seepage from DRE5 in-pit TSF landform into groundwater will ultimately report to Goonyella residual void, likely via Thiess residual void.

SPR risk rating of DRE5 in-pit TSF landform

There are plausible residual void receptors, and the seepage pathways linking the source (DRE5 in-pit TSF landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure TSF landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure TSF landform is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) TSF landform to impact on the water quality of these two residual voids has been rated ‘Unlikely’.

7.2.7 Riverside rejects landform

Source materials hazard

Riverside rejects landform underwent some rehabilitation in the early 2000s and further rehabilitation activities are scheduled to achieve the PMLU. Excluding the spoil cover, the rejects landform is comprised almost entirely of rejects, which pose a moderate AMD hazard.

The rejects generally have low to low-moderate EC values and are expected to produce slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low to low-moderate hazard. Overall, the hazard for AMD generation from the current Riverside rejects dump is ‘Moderate’ and the likelihood for AMD generation from the current landform is rated as ‘Probable / Likely’.

Pathways

Pathways from Riverside rejects landform to plausible surface water and groundwater receptors are shown in **Figure 22** (Post-closure landform), **Figure 25** (CFM for Riverside rejects and RS1 TSF landforms), **Table 23** and **Attachment C Tables C7 and C14**.

Surface water

Eureka Creek, an ephemeral creek, is located over 1 km south of the rejects landform with the closest tributary located approximately 350 m south of the landform. The rejects landform is already rehabilitated and covered by a spoil cover, which will be augmented if/as required to manage the AMD source hazard. Therefore, all post-closure run-off from the rejects landform will be from general spoil (overburden/interburden) material and no rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, tributaries of Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is

downwards and towards Goonyella residual void – including from areas outside of a pit shell, such as Riverside rejects dump.

Groundwater modelling (AECOM, 2024) shows that seepage from Riverside rejects landform would report to Goonyella residual void. Therefore, it is reasonably assumed that the likelihood of seepage from the rejects landform reaching a surface water receptor (approximately 350 m from the landform) via shallow seepage is 'Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between Riverside rejects landform via shallow permeable strata into nearby surface water receptors (tributary of Eureka Creek).

Receptors

Plausible receptors of surface water run-off and seepage from Riverside rejects landform are shown in **Figure 22** (Post-closure landform), **Figure 25** (CFM for Riverside rejects and RS1 TSF landforms), **Table 23** and **Attachment C Tables C7 and C14**.

Surface water

The only plausible surface water receptor identified in this qualitative assessment of Riverside rejects landform is the ephemeral Eureka Creek, with the closest tributarily located approximately 350 m south of the rejects landform. This applies to potential surface water run-off and potential seepage through shallow permeable strata into the surface water receptor(s).

The rejects landform is already rehabilitated and covered by a spoil cover, which may be subject to additional rehabilitation to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) rejects landform to impact on the water quality of Eureka Creek (via run-off or shallow seepage) has been rated 'Unlikely'. The likelihood of non-oxidative salinity from the rejects landform to impact on the water quality of Eureka Creek has been rated 'Unlikely'.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) shows that seepage from Riverside rejects landform into groundwater will ultimately report to Goonyella residual void.

SPR risk rating of Riverside rejects landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (Riverside rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Goonyella residual void has been rated 'Unlikely'.

7.2.8 GS2 rejects landform

Source materials hazard

Excluding the spoil cover to be installed over GS2 rejects dump, the rejects landform is comprised almost entirely of rejects, which pose a low-moderate AMD hazard.

The rejects generally have low EC values and are expected to produce low- to slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard. Overall, the hazard for AMD generation from the current GS2 rejects landform is 'low-Moderate' and the likelihood for AMD generation from the current landform is rated as 'Unlikely'.

Pathways

Pathways from GS2 rejects landform to plausible receptors are shown in **Figure 22** (Post-closure landform), **Figure 29** (CFM for GS2 rejects landform), **Table 23** and **Attachment C Table C8**. There are no plausible groundwater receptors (e.g. residual voids) from GS2 rejects dump.

Surface water

Eureka Creek, an ephemeral creek, is located less than 150 m east of the rejects landform. It is likely that surface water run-off from the rejects landform will reach this creek. The rejects dump will be covered by a spoil cover to manage the AMD source hazard, therefore all post-closure run-off from the rejects landform will be from general spoil (overburden/interburden) material and no rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is downwards and towards the residual voids – including from areas outside of a pit shell, such as GS2 rejects dump.

Groundwater modelling (AECOM, 2024) shows the water table to be greater than 50 m below ground level at GS2 rejects dump (at closure), with low-permeability sediments forming an aquitard between the rejects dump and the nearest aquifer. However, due to the close proximity of Eureka Creek to the above-ground rejects landform, it is reasonably assumed that the likelihood of seepage from GS2 rejects landform (post-closure) reaching Eureka Creek via shallow groundwater is ‘Probable’.

In summary, the SPR has assumed a plausible (probable) local seepage pathway *may* exist between GS2 rejects landform via shallow permeable strata into nearby Eureka Creek.

Receptors

Plausible receptors of surface water run-off and seepage from GS2 rejects landform are shown in **Figure 22** (Post-closure landform), **Figure 29** (CFM for GS2 rejects landform), **Table 23** and **Attachment C Table C8**. There are no plausible groundwater receptors from GS2 rejects landform (post-closure).

Surface water

The only plausible surface water receptor identified in this qualitative assessment of GS2 rejects landform is Eureka Creek located less than 150 m east of the facility. This applies to potential surface water run-off and potential seepage through shallow permeable strata into Eureka Creek.

The rehabilitated rejects landform will have a spoil cover designed to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) rejects landform to impact on the water quality of Eureka Creek (via run-off or shallow seepage) has been rated unlikely. The likelihood of non-oxidative salinity from the rejects landform to impact on the water quality of Eureka Creek has also been rated unlikely.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) indicates there are no plausible groundwater receptors from GS2 rejects post-closure landform due to the significant depth to the water table below the facility (>50 m) and the significant thickness of low-permeability sediments forming an aquitard.

SPR risk rating of GS2 rejects landform

Eureka Creek is located very close to the facility; and the run-off and seepage pathways linking the source (GS2 rejects landform) to Eureka Creek have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. The likelihood of seepage reaching nearby Eureka Creek is considered

probable, however the severity of the event, should it occur, is low. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**.

7.2.9 GS11 rejects landform

Source materials hazard

Excluding the spoil cover to be installed over GS11 rejects dump, the rejects landform is comprised almost entirely of rejects, which pose a low-moderate AMD hazard.

The rejects generally have low EC values and are expected to produce low- to slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard. Overall, the hazard for AMD generation from the current GS11 rejects landform is 'low-Moderate' and the likelihood for AMD generation from the current landform is rated as 'Unlikely'.

Pathways

Pathways from GS11 rejects landform to plausible receptors are shown in **Figure 22** (Post-closure landform), **Figure 30** (CFM for GS11 rejects landform), **Table 23** and **Attachment C Tables C9 and C14**.

Surface water

Eureka Creek, an ephemeral creek, is located approximately 400 m north of the rejects landform. It is plausible (although unlikely) that surface water run-off from the rejects landform could reach this creek. The rejects dump will be covered by a spoil cover to manage the AMD source hazard, therefore all post-closure run-off from the rejects landform will be from general spoil (overburden/interburden) material and no rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is downwards and towards the residual voids.

Groundwater modelling (AECOM, 2024) shows that seepage from GS11 rejects landform is expected to report to Ramp 32 East residual void. Therefore, it is reasonably assumed that the likelihood of seepage from the rejects landform reaching a surface water receptor (approximately 400 m from the landform) via shallow seepage is 'Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between GS11 rejects landform via shallow permeable strata into Eureka Creek.

Receptors

Plausible receptors of surface water run-off and seepage from GS11 rejects landform are shown in **Figure 22** (Post-closure landform), **Figure 30** (CFM for GS11 rejects landform), **Table 23** and **Attachment C Tables C9 and C14**.

Surface water

The only plausible surface water receptor identified in this qualitative assessment of GS11 rejects landform is Eureka Creek located approximately 400 m north of the facility. This applies to potential surface water run-off and potential seepage through shallow permeable strata into Eureka Creek.

The rehabilitated rejects landform will have a spoil cover designed to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) rejects landform to

impact on the water quality of Eureka Creek (via run-off or shallow seepage) has been rated unlikely. The likelihood of non-oxidative salinity from the rejects landform to impact on the water quality of Eureka Creek has also been rated unlikely.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) indicates that seepage from GS11 rejects landform into groundwater is expected to report to Ramp 32 East residual void.

SPR risk rating of GS11 rejects landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (GS11 rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Ramp 32 East residual void has been rated 'Unlikely'.

7.2.10 R22 rejects landform

Source materials hazard

Excluding the spoil cover to be installed over R22 rejects dump, the rejects landform is comprised almost entirely of rejects, which pose a low-moderate AMD hazard.

The rejects generally have low EC values and are expected to produce low- to slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard. Overall, the hazard for AMD generation from the current R22 rejects landform is 'low-Moderate' and the likelihood for AMD generation from the current landform is rated as 'Unlikely'.

Pathways

Pathways from R22 rejects landform to plausible receptors are shown in **Figure 22** (Post-closure landform), **Figure 27** (CFM for R22 rejects landform), **Table 23** and **Attachment C Tables C10 and C14**. R22 rejects dump is located on top of spoil within the southern end of Thiess pit shell.

Surface water

Eureka Creek, an ephemeral creek, is located approximately 250 m from the rejects landform. It is plausible that surface water run-off from the rejects landform could reach this creek. The rejects dump will be covered by a spoil cover to manage the AMD source hazard, therefore all post-closure run-off from the rejects landform will be from general spoil (overburden/interburden) material and no rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has conservatively assumed it is plausible that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, Eureka Creek), is somewhat unclear. Despite this potential limitation, the overall seepage gradient at GRBM is downwards and towards the residual voids.

Groundwater modelling (AECOM, 2024) shows that seepage from R22 rejects landform is expected to report to Thiess residual void and then continue on towards Goonyella residual void. Therefore, it is reasonably assumed that the likelihood of seepage from the rejects landform reaching Eureka Creek (approximately 250 m from the landform) via shallow seepage is 'Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between R22 rejects landform via shallow permeable strata into Eureka Creek.

Receptors

Plausible receptors of surface water run-off and seepage from R22 rejects landform are shown in **Figure 22** (Post-closure landform), **Figure 27** (CFM for R22 rejects landform), **Table 23** and **Attachment C Tables C10 and C14**.

Surface water

The only plausible surface water receptor identified in this qualitative assessment of R22 rejects landform is Eureka Creek located approximately 250 m west and south of the facility. This applies to potential surface water run-off and potential seepage through shallow permeable strata into Eureka Creek.

The rehabilitated rejects landform will have a spoil cover designed to manage the AMD hazard of the landform. The spoil cover has been assumed to pose a low AMD source hazard, based on the conservative AMD source hazard applied to general spoil. As such, the likelihood of AMD from the rehabilitated (post-closure) rejects landform to impact on the water quality of Eureka Creek (via run-off or shallow seepage) has been rated unlikely. The likelihood of non-oxidative salinity from the rejects landform to impact on the water quality of Eureka Creek has also been rated unlikely.

Seepage / Groundwater

Groundwater modelling (AECOM, 2024) suggests that seepage from R22 rejects landform into groundwater is expected to report to Thiess residual void and then continue on towards Goonyella residual void.

SPR risk rating of R22 rejects landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (R22 rejects landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the post-closure rejects landform is **Low**. With respect to non-oxidative salinity the overall SPR risk from the post-closure rejects landform is also rated as **Low**. The likelihood of AMD and non-oxidative salinity from the rehabilitated (post-closure) rejects landform to impact on the water quality of Thiess and Goonyella residual voids has been rated ‘Unlikely’.

7.2.11 Residual voids

Source materials hazard

The surfaces of residual void highwalls are comprised of approximately 83% to 90% non-carbonaceous overburden/ interburden, 2% to 8% carbonaceous overburden/interburden (incl. sub-economic seams reporting to waste) and about 5% to 10% coal (seams). The proportion of weathered material in the residual void highwalls ranges from approximately 11% in Goonyella void, 37% in Ramp 32 East void and 47% in Thiess void. Weathered material comprises about 25% of the highwall in Broadmeadow-Isaac and Ramp 32 South voids. Fresh and weathered non-carbonaceous overburden/interburden material in the Bowen Basin is widely recognised as posing a low AMD risk.

Therefore, due to the geochemical nature of the materials exposed in the highwall of each void and taking into account their proportions in the highwall, the overall hazard for AMD generation from residual void highwalls is low-moderate and the likelihood for AMD generation from residual void highwalls is ‘Unlikely’. Any expression of AMD from the highwalls of residual voids is likely to be localised and minimal.

Generally, highwall materials have low EC values, with release of (non-oxidative) salinity rated as a low hazard.

Excluding the Broadmeadow-Isaac void, which has GMS seam as the floor, the floor of all other voids is comprised of GLS seam. Based on available geochemical data and applying a total S ‘cut-off value’ to data from the coal quality database based on the total S of ‘PAF’ coal samples, both the GMS and GLS seams are conservatively estimated to be predominantly comprised of PAF coal. Therefore, assuming at closure the pit floors comprise all coal (100% of the floor is coal) it is conservatively predicted that the pit-floors will expose materials at potential for AMD (i.e. PAF). However, this is a highly unlikely scenario as essentially all of the basal seam will have been mined out prior to closure (as is normal operational practice to remove all/most coal from pit floors), and the coal remining on the floor, if any, will not all be PAF. In the event that some coal will remain exposed on a pit floor, this will be eventually flooded, thus suppressing any AMD reaction.

Pathways

Surface water

There are no plausible pathways between the residual voids and surface water. Surface water run-off from the void highwall (of each void) will report to the void lake (of each void).

Seepage / Groundwater

The residual voids will act as local groundwater sinks and the water table will intersect the deeper zones of the residual voids, resulting in the formation of a relatively small void lake in each void (AECOM, 2024; and **Figure 23**) that will submerge the void floor and lower section of the void highwall. For each void, seepage from the spoil landform and run-off from the highwall will report to the residual void. Ultimately, seepage from Thiess and Broadmeadow-Isaac residual voids will migrate to Goonyella residual void.

Receptors

Modelling undertaken by AECOM (2024) shows Goonyella void to be a strong groundwater sink – drawing in groundwater from most of the site. Thiess and Broadmeadow-Isaac voids will be local 'sinks' – receiving surface water run-off and seepage from their respective spoil landforms and surface water run-off from their void highwalls. Ultimately, seepage from Thiess and Broadmeadow-Isaac residual voids will migrate to Goonyella residual void. Ramp 32 East and South residual voids are expected to function as week groundwater sinks from their local area.

Each residual void is expected to receive inflow from the Permian groundwater aquifer. The water quality of the void and potential impact of water seeping, if any, from the residual voids into the Permian groundwater aquifer is discussed in the void closure plan (WSP, 2024).

The floor of each residual void will be covered post-closure by water as rainfall and groundwater reporting to the void will form a void lake. As such, PAF coal will no longer be exposed to atmospheric conditions and the risk of AMD being generated is greatly reduced. The likelihood of undiluted salinity or AMD from a flooded post-closure residual void floor to impact on residual void water quality to any significant degree has been rated unlikely.

SPR risk rating of residual voids

The receptor for seepage from the spoil landform (for each spoil landform) and run-off from the highwall (of each void) is the void lake / residual void. The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure residual void floor would impact on residual void water quality to any significant degree, as other processes such as evapoconcentration (WSP, 2024) are the key drivers of void lake water quality. Therefore, the AMD SPR risk rating on the overall water quality of the residual voids is **Low to Low-Medium**. [**Attachment C Table C15**]. A "Low to Medium" risk rating has been conservatively applied to the risk of AD or SD due to the AMD risk associated with exposed coal seams in the highwalls (coal seams comprise between 5% to 10% of the exposed highwalls). However, not all exposed coal is expected to be PAF (and/or have high total and sulphide concentrations).

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by AECOM (2024) shows that seepage from Thiess and Broadmeadow-Isaac void lakes into groundwater would report to (be captured by) Goonyella void, and that seepage from Goonyella void outwards into the regional groundwater aquifer is implausible due to Goonyella void being a strong groundwater sink. Modelling also shows that Ramp 32 East and South voids are expected to be weak groundwater sinks, therefore seepage from Ramp 32 East and South void lakes into groundwater is not expected and, if it were to occur, would be limited and would ultimately be captured by Goonyella void.

8 Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by spoil landforms likely to be present at closure are generally low. As such, no specific AMD management measures (e.g. alkaline amendment or engineered capping systems) are expected to be required to manage spoil landforms during rehabilitation and closure – outside of operational mixing/burial of PAF waste amongst NAF waste, spoil placement and landform reshaping activities already proposed (refer below and to the main volume of the PRCP).

The environmental risk associated with the current (rehabilitated) Riverside rejects dump is generally low and there is no field evidence of AMD coming from the facility. The rejects buried within the landform have been assessed as posing a moderate AMD source hazard and the facility will continue to be monitored during operations. The facility will undergo corrective rehabilitation to meet the required PMLU.

Currently (i.e. prior to rehabilitation), the AMD source hazard associated with GS1 TSF is moderate-high. This stand-alone TSF landform will require specific AMD management measures to manage this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this stand-alone TSF landform is expected to decrease.

Currently (i.e. prior to rehabilitation), the AMD source hazard associated with RS1 TSF is moderate to moderate-high. The western compartment comprising rejects only has a moderate source hazard (i.e. this compartment is essentially a rejects dump). The eastern compartment comprising predominantly tailings, with less rejects, has a moderate-high AMD source hazard (this compartment is the TSF). This stand-alone landform will require specific AMD management measures to manage this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this stand-alone landform is expected to decrease.

The AMD source hazard associated with Ramp 32 in-pit TSF (currently; prior to rehabilitation) is moderate. This in-pit TSF will be backfilled with spoil, which is an appropriate strategy to manage the AMD hazard posed by this facility post-closure. Once rehabilitated (backfilled), the post-closure environmental risk posed by this TSF is expected to decrease.

The AMD source hazard associated with DRE5 in-pit TSF (currently; prior to rehabilitation) is moderate. This small in-pit TSF will be partially backfilled with spoil to encourage free-drainage from the southern end of the facility onto the Thiess spoil landform. This is an appropriate strategy to manage the AMD hazard posed by this facility post-closure. Once rehabilitated, the post-closure environmental risk posed by this TSF is expected to decrease.

The AMD source hazard associated with GS2, GS11 and R22 rejects dumps (currently; prior to rehabilitation) is low-moderate. After re-shaping and installation of a spoil cover (i.e. once rehabilitated) the post-closure environmental risk posed by these spoil dumps is expected to decrease.

Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

Proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report comprise the following actions. Refer to the main volume of the PRCP for detailed information.

- Pits: will remain as residual voids under five groups:
    - Goonyella void;
    - Thiess void;
    - Broadmeadow-Isaac void;
    - Ramp 32 East void; and
    - Ramp 32 South void.
- Spoil dumps: Lenton pit is currently being backfilled and becoming part of the Goonyella spoil landform. Airstrip spoil dump (associated with Ramp 32 East and Ramp 32 South voids) will be reshaped and rehabilitated. All other spoil dumps will be reshaped into three final spoil landforms (as related to their respective voids listed above) and seeded.

- GS1 TSF (out-of-pit; above ground; stand-alone) will be covered by an engineered spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of the out-of-pit TSF will be determined following further assessment.
- RS1 TSF (out-of-pit; above ground; stand-alone) will be covered by an engineered spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of the out-of-pit TSF will be determined following further assessment.
- DRE5 in-pit TSF will be covered by spoil (partially backfilled) within the Thiess spoil landform – noting that Thiess spoil landform is a sub-zone within Goonyella spoil landform. The optimal design and thickness of spoil cover to manage the AMD hazard of the in-pit TSF will be determined following further assessment.
- Ramp 32 in-pit TSF (Airstrip pit) will be backfilled by spoil within the Airstrip spoil landform.
- Riverside rejects dump (above ground; stand-alone) is already covered with spoil and partially rehabilitated, but further rehabilitation activities are scheduled to achieve the PMLU.
- GS2 and GS11 rejects dumps (out-of-pit; above ground; stand-alone) will be covered by a spoil cover. The optimal design and thickness of spoil cover to manage the AMD hazard of these two rejects dumps will be determined following further assessment.
- R22 in-pit rejects dump will be covered by a spoil cover within the Thiess spoil landform. The optimal design and thickness of spoil cover to manage the AMD hazard of this rejects dump will be determined following further assessment.
- All other rejects (in-spoil co-disposal): Managed during operations (disposed within spoil) and progressively covered by spoil. No additional remediation for the rejects (at closure) is required. The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment.
- ROM pads: Remove remnant coal from ROM pads and dispose within spoil. All former ROM pads will be reshaped, covered with soil, ripped and seeded.
- Coal stockpiles: Remove remnant coal from coal stockpile pads and dispose within spoil. Cover with suitable soil material, rip and seed.

9 Forward Work Program

The environmental geochemical characterisation and assessment of mineral waste samples outlined in this report is representative of the mineral waste materials likely to require rehabilitation at closure. However, BHP will continue to undertake sampling of likely mineral waste materials (and subsequent characterisation and assessment of those samples) from GRBM (and RHM) during operations and into decommissioning – to validate the findings of the current assessment, ensure the risks continue to be understood and the management measures proposed are commensurate with the risks. Where required, management measures will be revised and implemented.

Further work may also be required prior to closure to better understand the relationship between shallow and deeper groundwater at GRBM and between shallow groundwater and surface water systems at GRBM – particularly in the vicinity of TSF and rejects landforms.

10 References

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Attachment A – Geological Sections

Pit and void highwall long-sections

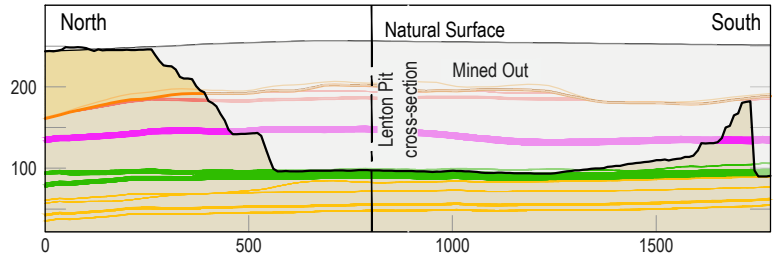
- Figure A1 Lenton pit; and Goonyella void at Red Hill and Denham pits
- Figure A2 Goonyella void at Cleanskin, Riverside and Eureka pits
- Figure A3 Eureka pit (south); and Broadmeadow-Isaac void at Broadmeadow and Isaac pits

Pit and void highwall cross-sections

- Figure A4 Ramp 14 North (Lenton pit); Ramp 14 (Denham pit and Goonyella void); Ramp 10 North (Cleanskin pit and Goonyella void)
- Figure A5 Ramp 10 South (Cleanskin pit and Goonyella void); Ramp 6 North (Riverside pit and Goonyella void)
- Figure A6 Ramp 6 South (Thiess and Eureka pits and Goonyella void); Ramp 4 South (Broadmeadow pit and Broadmeadow-Isaac void)
- Figure A7 Ramp 2 and Ramp 2 South (Airstrip and Isaac pits; and Broadmeadow-Isaac void)

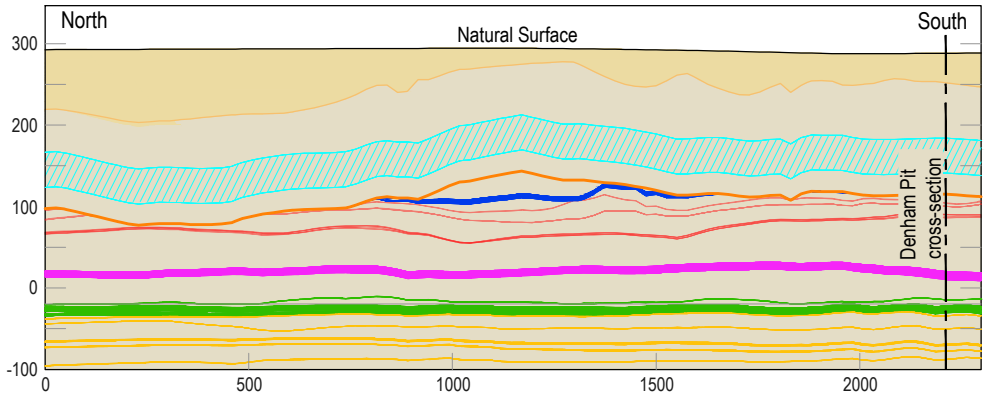
LONG SECTION | Lenton Pit

Viewed Looking North (Vertical Exaggeration x2.0)



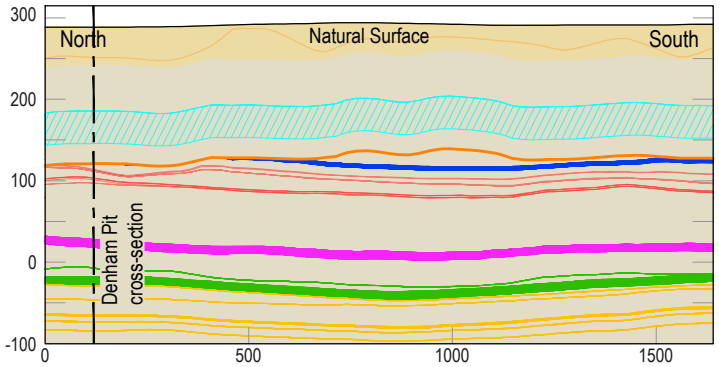
LONG SECTION | Red Hill Pit (Goonyella void)

Viewed Looking North (Vertical Exaggeration x2.0)



LONG SECTION | Denham Pit (Goonyella void)

Viewed Looking North (Vertical Exaggeration x2.0)



Legend

- Natural Surface
- Base of Weathering
- Current Pit Shell

Coal Seams

- GF Seam
- GU Seam
- P Seam
- GM Seam
- GL Seam
- GLL Seam

Vertical Scale

0 — 250m

Horizontal Scale

0 — 500m

(V/H = 2:1)

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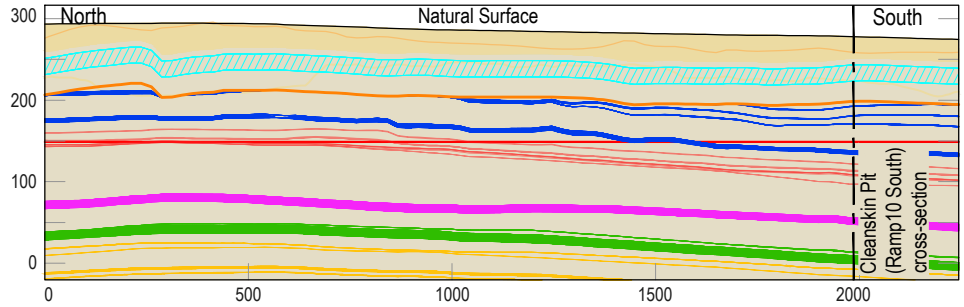
Pit highwall long-sections

Figure **A1**

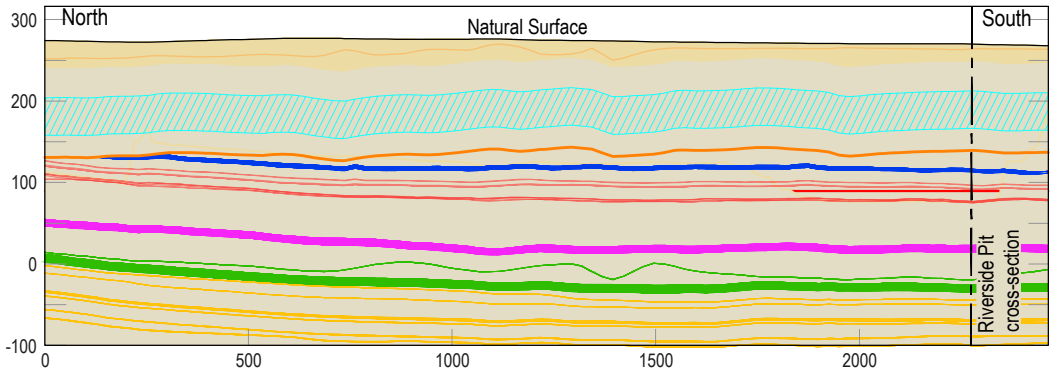
LONG SECTION | Cleanskin Pit (Goonyella void)

Viewed Looking North (Vertical Exaggeration x2.0)



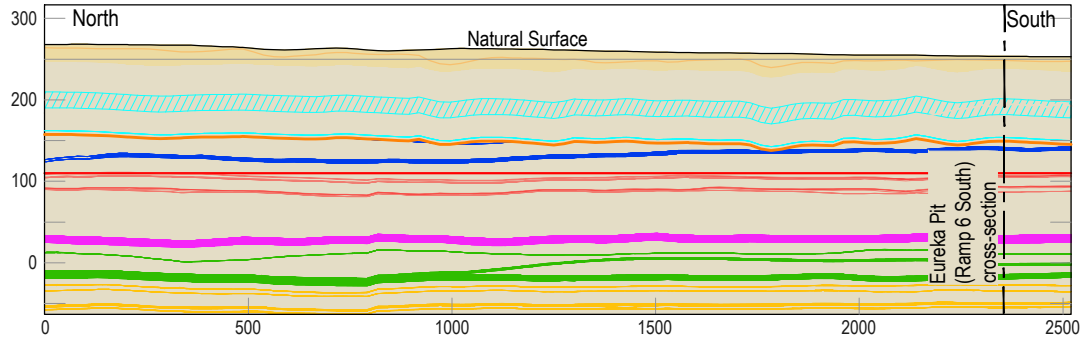
LONG SECTION | Riverside Pit (Goonyella void)

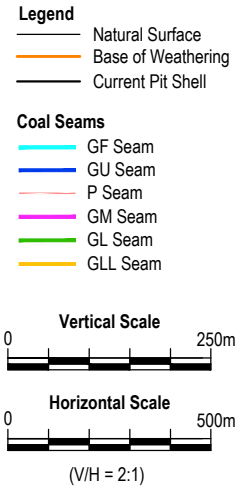
Viewed Looking North (Vertical Exaggeration x2.0)



LONG SECTION | Eureka Pit (Goonyella void)

Viewed Looking North (Vertical Exaggeration x2.0)



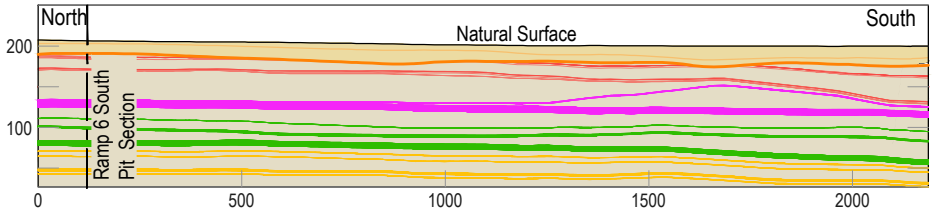


Pit highwall long-sections

Figure **A2**

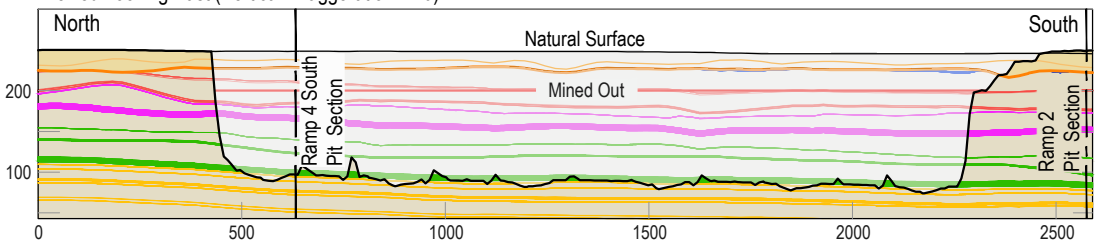
LONG SECTION | Eureka Pit South

Viewed Looking East (Vertical Exaggeration x2.0)



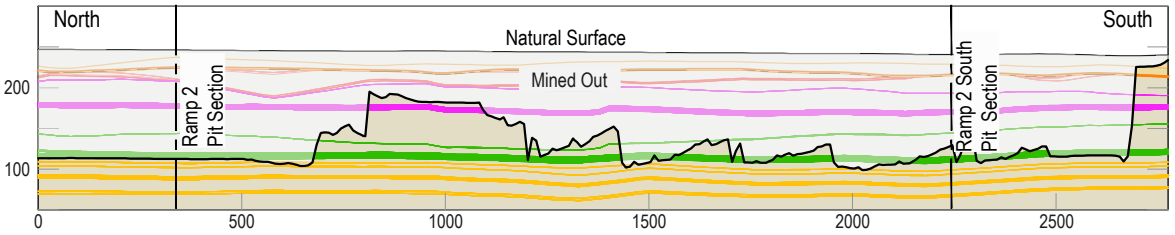
LONG SECTION | Broadmeadow Pit (Broadmeadow-Isaac void)

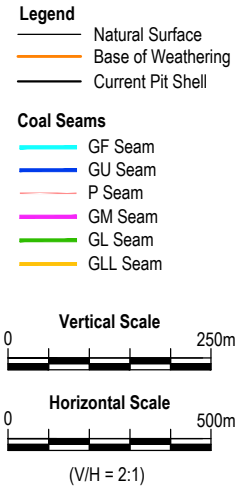
Viewed Looking East (Vertical Exaggeration x2.0)



LONG SECTION | Isaac Pit (Broadmeadow-Isaac void)

Viewed Looking East (Vertical Exaggeration x2.0)

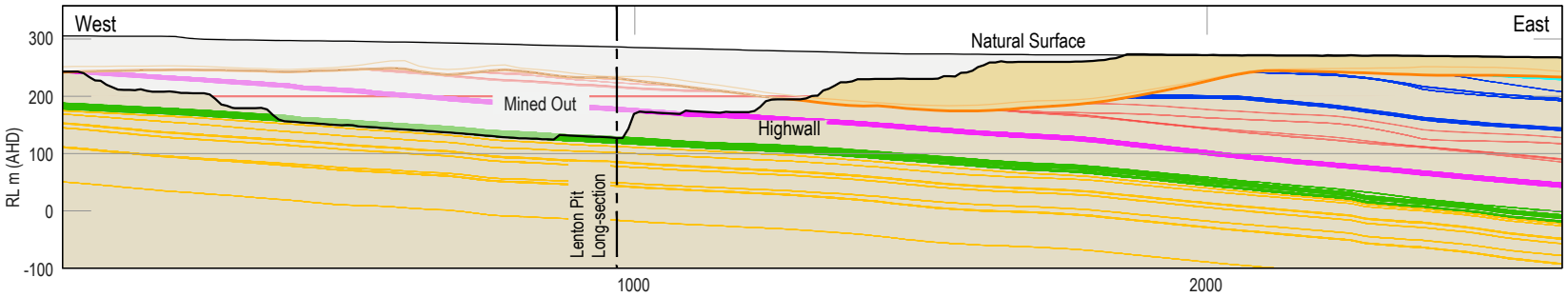




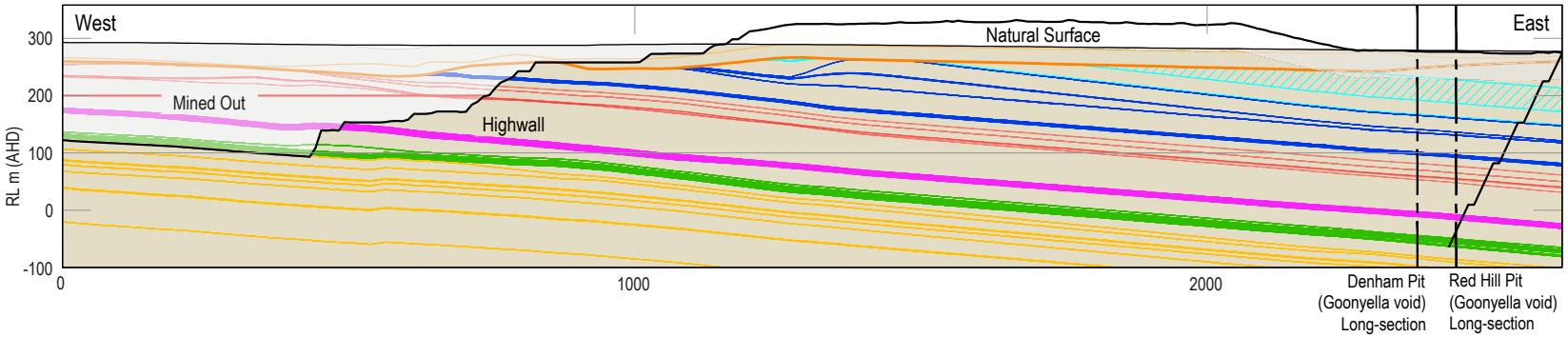
Pit highwall long-sections

Figure **A3**

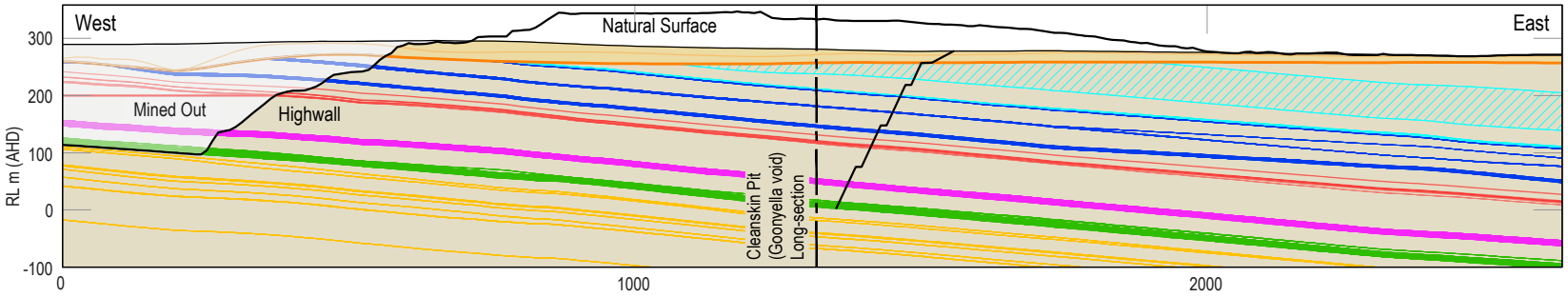
CROSS SECTION | Ramp14 North (Lenton Pit)
Viewed Looking North



CROSS SECTION | Ramp 14 (Denham Pit)
Viewed Looking North



CROSS SECTION | Ramp 10 North (Cleanskin Pit)
Viewed Looking North



Legend
- Natural Surface
- Base of Weathering
- Current Pit Shell

Coal Seams
- GF Seam
- GU Seam
- P Seam
- GM Seam
- GL Seam
- GLL Seam

Scale
(V/H = 1)
0 200 400m

Pit cross-sections

Figure **A4**

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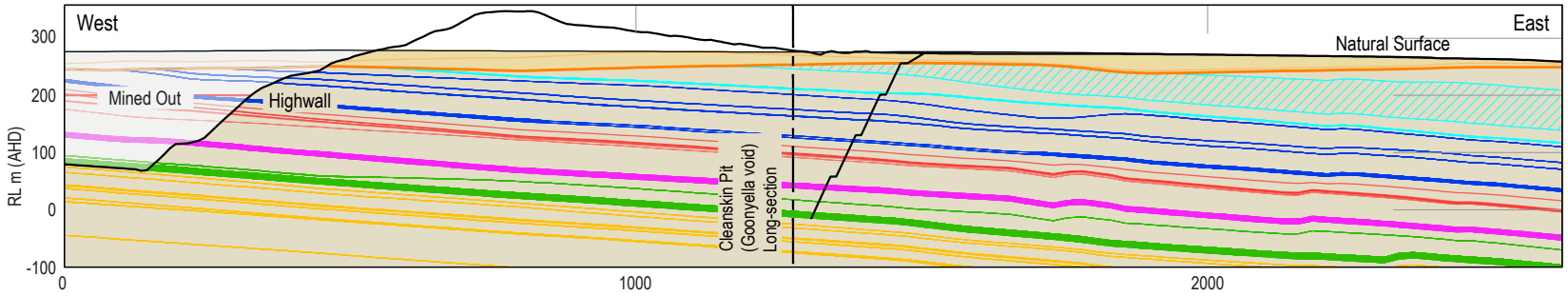
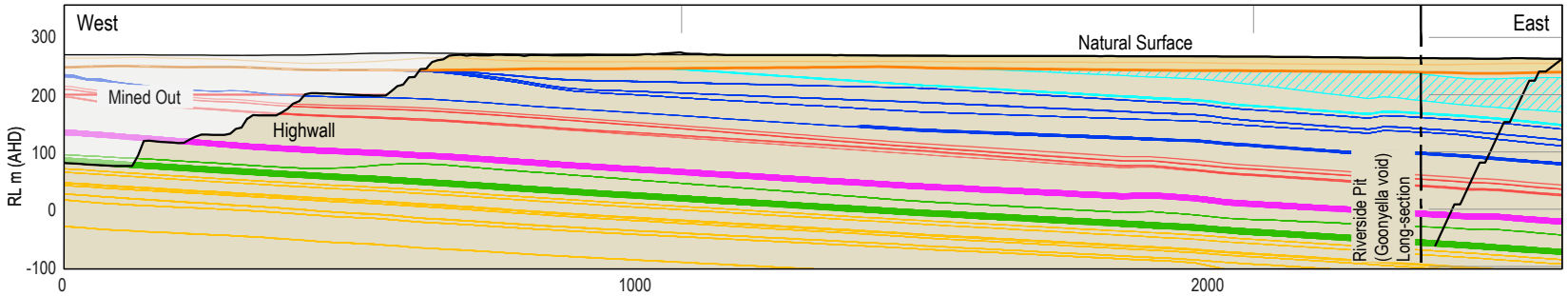
CROSS SECTION | Ramp 10 South (Cleanskin Pit)

Viewed Looking North



CROSS SECTION | Ramp 6 North (Riverside Pit)

Viewed Looking North



Legend

- Natural Surface
- Base of Weathering
- Current Pit Shell

Coal Seams

- GF Seam
- GU Seam
- P Seam
- GM Seam
- GL Seam
- GLL Seam

Scale

(V/H = 1)

0 200 400m

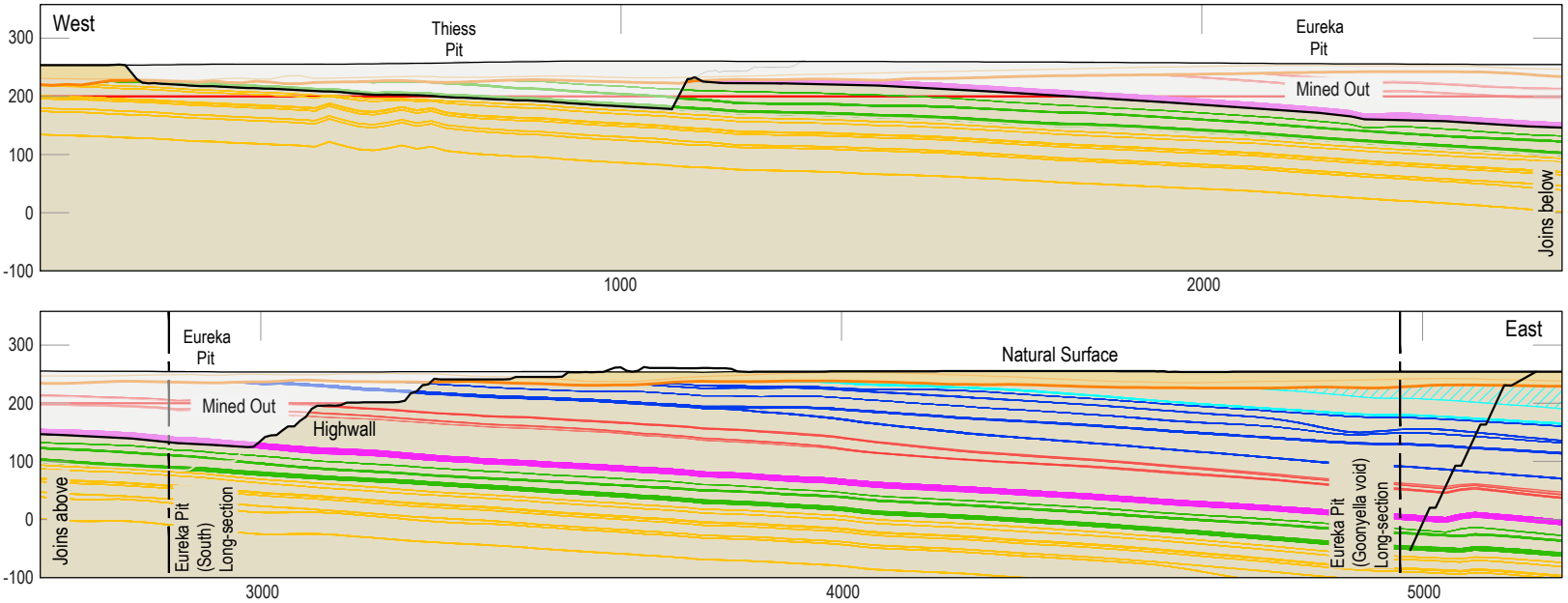
Pit cross-sections

Figure **A5**

Minserve CAD File: Bhpb008m07.dwg

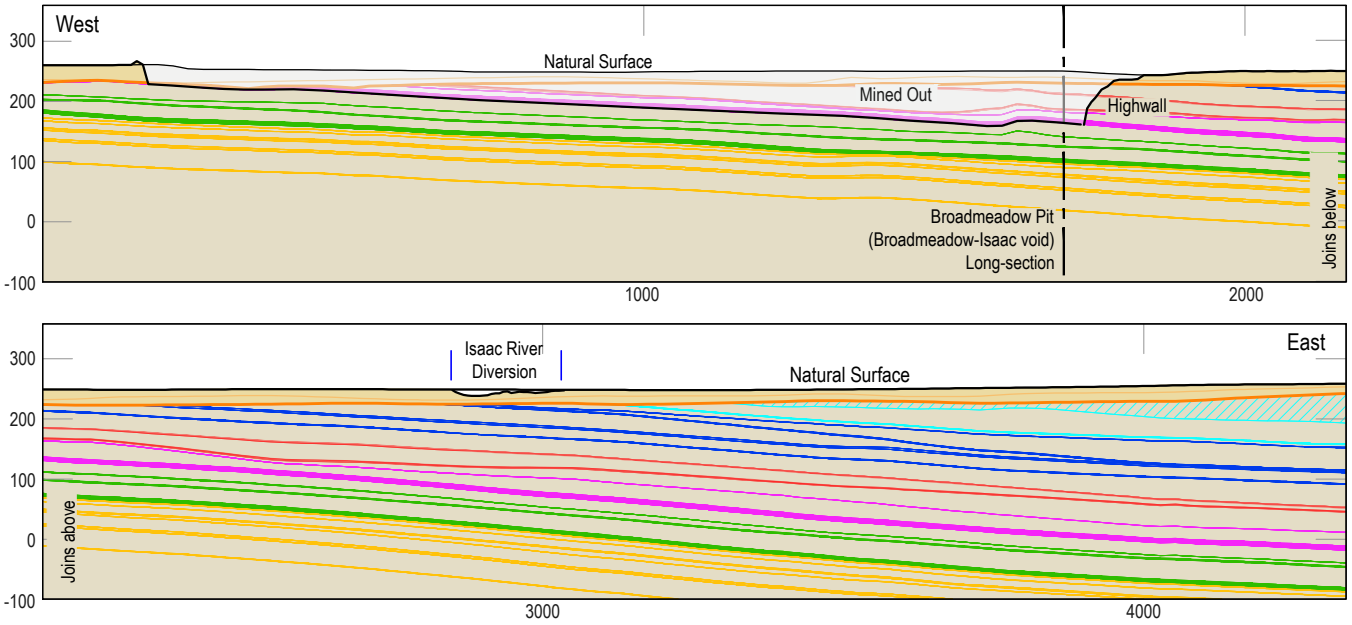
CROSS SECTION | Ramp 6 South (Thiess Pit, Eureka Pit and Goonyella void)

Viewed Looking North



CROSS SECTION | Ramp 4 South (Broadmeadow Pit)

Viewed Looking North



Legend

- Natural Surface
- Base of Weathering
- Current Pit Shell

Coal Seams

- GF Seam
- GU Seam
- P Seam
- GM Seam
- GL Seam
- GLL Seam

Scale

(V/H = 1)

0 200 400m

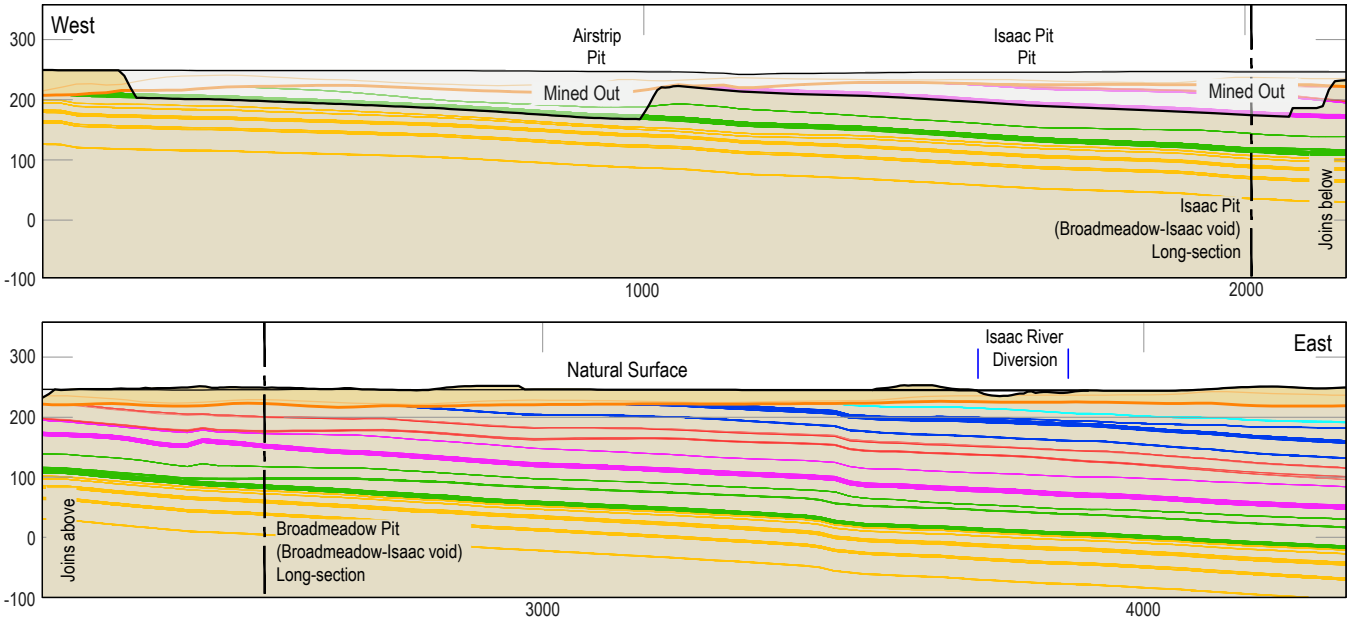
Minserve CAD File: Bhpb008m07.dwg

Pit cross-sections

Figure **A6**

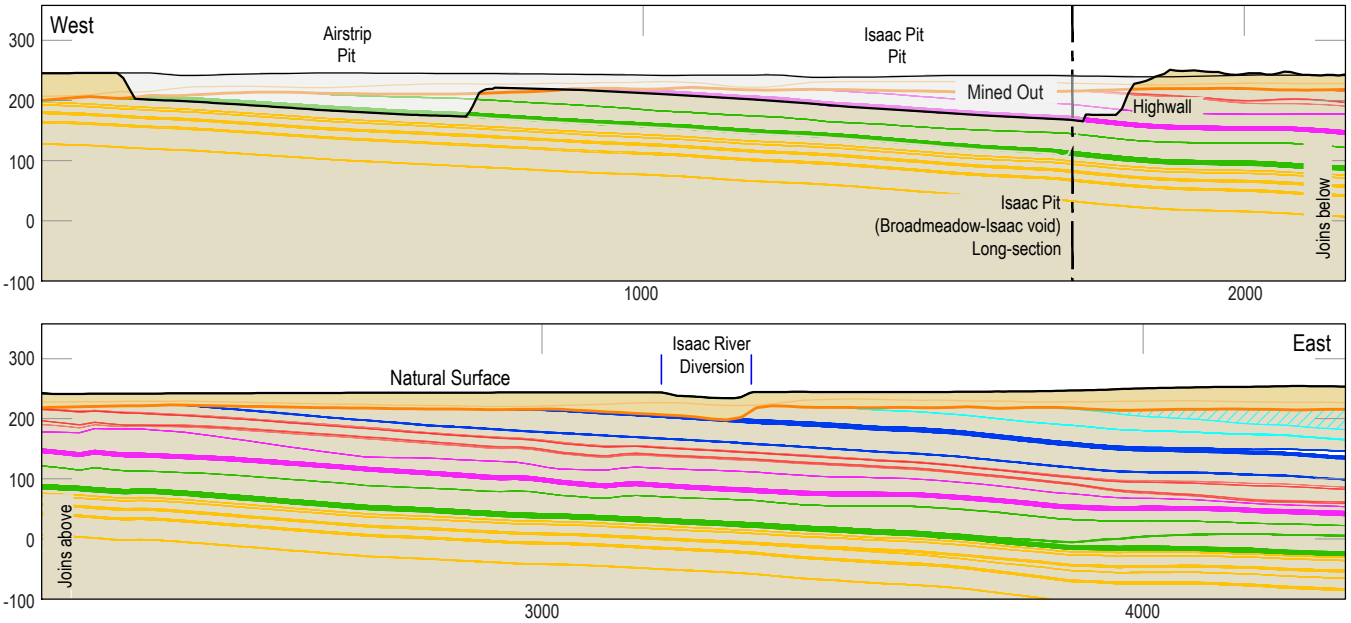
CROSS SECTION | Ramp 2 (Airstrip Pit and Isaac Pit - Broadmeadow-Isaac void)

Viewed Looking North



CROSS SECTION | Ramp 2 South

Viewed Looking North



Legend

- Natural Surface
- Base of Weathering
- Current Pit Shell

Coal Seams

- GF Seam
- GU Seam
- P Seam
- GM Seam
- GL Seam
- GLL Seam

Scale

(V/H = 1)

0 200 400m

Minserve CAD File: Bhpb008m08.dwg

Pit cross-sections

Figure **A7**

Attachment B – AMD Hazard Scoring Tables

AMD hazard and likelihood of AMD generation from spoil landforms

- Table B1 Goonyella final landform
- Table B2 Thiess final landform
- Table B3 Airstrip final landform
- Table B4 Broadmeadow-Isaac final landform

AMD hazard and likelihood of AMD generation from TSF landforms

- Table B5 GS1 TSF landform
- Table B6 RS1 TSF landform – western compartment
- Table B7 RS1 TSF landform – eastern compartment
- Table B8 DRE5 in-pit TSF landform
- Table B9 Ramp 32 in-pit TSF landform

AMD hazard and likelihood of AMD generation from rejects landform

- Table B10 Riverside rejects landform
- Table B11 GS2 rejects landform
- Table B12 GS11 rejects landform
- Table B13 R22 in-pit rejects landform

AMD hazard and likelihood of AMD generation from residual voids

- Table B14 Goonyella residual void walls and floor
- Table B15 Thiess residual void walls and floor
- Table B16 Ramp 32 East residual void walls and floor
- Table B17 Ramp 32 South residual void walls and floor
- Table B18 Broadmeadow-Isaac residual void walls and floor

Table B1. AMD hazard scoring for source materials and likelihood for AMD generation from Goonyella final landform

Goonyella: Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score	Likelihood for AMD generation from Goonyella spoil landform
Non-carbonaceous spoil Distributed throughout	91%	1.5%	1.4%	Total S is very low (75th percentile = 0.05%). NAF samples have a very low 75th percentile total S value of 0.05%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.62% (and AMD capacity is based on this number). Based on sample numbers (n=1169), approximately 1.5% of non-carbonaceous spoil - mostly fresh/unweathered - is conservatively classified as 'PAF' of some type. 75th percentile EC of non-carbonaceous spoil = 470 µS/cm. About half of the 'PAF' samples are associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 91% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**1** Low	**10** High	**1** Low	**7** Low-Moderate	**3.9** Low	Goonyella spoil landform - the largest of all spoil landforms at GRBM and accouting for approximately 90% of all mineral waste on site - is essentially comprised of spoil only. Rejects comprise approximately 0.1% of the landform. General spoil is overwhelmingly NAF with very low sulphur, excess neutralising capacity and low soluble metals concentration. About one-third of 'PAF' materials are associated with seams - as parting or within 1.5m (typically) above and below seams. As such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. Approximately 22% of the rejects are 'PAF', however rejects comprise a negligible proportion of the landform (approximately 0.1%) and are disposed (buried) within spoil. Overall, about 2.4% of the landform is conservatively estimated to be either PAF, PAF-LC, UC(PAF) or NAF-S material, and about one-third of this is associated with near-seam spoil. Carbonaceous spoil is regarded as posing a moderate AMD source hazard and is expected to comprise about 9% of the landform. Rejects are regarded as posing a low-moderate AMD source hazard and are present in negligible quantities. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 464 µS/cm. The hazard for AMD generation from Goonyella spoil landform at GRBM is considered to be **LOW**. The likelihood for AMD generation from Goonyella spoil landform at GRBM is rated **HIGHLY UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	9.0%	10%	0.9%	Total S is low (75th percentile = 0.12%). NAF samples have a low 75th percentile total S value of 0.12%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.67% (and AMD capacity is based on this number). Based on sample numbers, approximately 10% of carbonaceous spoil is conservatively classified as 'PAF' of some type. 75th percentile EC of carbonaceous spoil = 400 µS/cm. 'PAF' samples were broadly distributed throughout the stratigraphy (ie. not just associated with seams). Non-carbonaceous spoil is estimated to comprise approximately 9% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**10** High	**1** Low	**11** Moderate		
Rejects Small quantity of historic rejects disposed at northern area of landform (Lenton pit area)	0.1%	22%	0.0%	Approximately 22% of rejects at GRBM have been conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. Of these 'PAF' samples, most were classified as PAF-LC or UC(PAF). Total S is generally low (75th percentile = 0.12%). NAF samples have a 75th percentile S value of 0.37%, whereas 'PAF' samples have a 75th percentile S value of 0.65% (and AMD capacity is based on this number). 75th percentile EC of rejects = 538 µS/cm. Rejects will comprise a very small proportion of mineral waste in the landform - approximately 0.1%. That is, the final spoil landform will essentially be comprised of spoil. AMD quantity conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects that is PAF.	**5** Plausible	**5** Moderate	**1** Low	**8** Low-Moderate		
Tailings No current or future tailings disposed into landform	0%	51%	0%	No tailings located within Goonyella landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B2. AMD hazard scoring for source materials and likelihood for AMD generation from Thiess final landform

Thiess: Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score	Likelihood for AMD generation from Thiess spoil landform
Non-carbonaceous spoil Distributed throughout	91%	1.5%	1.4%	Total S is very low (75th percentile = 0.05%). NAF samples have a very low 75th percentile total S value of 0.05%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.62% (and AMD capacity is based on this number). Based on sample numbers, approximately 1.5% of non-carbonaceous spoil - mostly fresh/unweathered - is conservatively classified as 'PAF' of some type. 75th percentile EC of non-carbonaceous spoil = 470 µS/cm. About half of the 'PAF' samples are associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 77% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**1** Low	**10** High	**1** Low	**7** Low-Moderate	**3.8** Low	Excluding R22 rejects dump (which is assessed seperately), Thiess spoil landform is essentially comprised of spoil only. Rejects at Ramp 23 are estimated to comprise less than 0.5% of the landform. General spoil is overwhelmingly NAF with very low sulphur, excess neutralising capacity and low soluble metals concentration. About one-third of 'PAF' materials are associated with seams - as parting or within 1.5m (typically) above and below seams. As such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. Excluding R22 rejects dump located at the periphery of the spoil landform, less than 0.5% of the landform is rejects located at Ramp 23. [DRE5 in-pit TSF - located within the western area of the spoil landform - is assessed as a 'stand-alone' TSF landform]. Overall, about 2.5% of the landform is conservatively estimated to be either PAF, PAF-LC, UC(PAF) or NAF-S material. Carbonaceous spoil is regarded as posing a moderate AMD source hazard and is expected to comprise about 9% of the landform. Rejects are regarded as posing a low-moderate AMD source hazard and are expected to comprise less than 0.5% of the landform. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 464 µS/cm. The hazard for AMD generation from Thiess spoil landform at GRBM is considered to be **LOW**. The likelihood for AMD generation from Thiess spoil landform at GRBM is rated **HIGHLY UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	9.0%	10%	0.9%	Total S is low (75th percentile = 0.12%). NAF samples have a low 75th percentile total S value of 0.12%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.67% (and AMD capacity is based on this number). Based on sample numbers, approximately 10% of carbonaceous spoil is conservatively classified as 'PAF' of some type. 75th percentile EC of carbonaceous spoil = 400 µS/cm. 'PAF' samples were broadly distributed throughout the stratigraphy (ie. not just associated with seams). Non-carbonaceous spoil is estimated to comprise approximately 8% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**10** High	**1** Low	**11** Moderate		
Rejects Minor rejects located at Ramp 23. Almost all rejects are located at R22 rejects dump, which is assessed sperately (refer to Table B13).	0.2%	22%	0.1%	Approximately 22% of rejects at GRBM have been conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. Of these 'PAF' samples, most were classified as PAF-LC or UC(PAF). Total S is generally low (75th percentile = 0.12%). NAF samples have a 75th percentile S value of 0.37%, whereas 'PAF' samples have a 75th percentile S value of 0.65% (and AMD capacity is based on this number). 75th percentile EC of rejects = 538 µS/cm. Rejects at Ramp 23 are estimated to comprise less than 0.5% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects that is PAF.	**5** Plausible	**5** Moderate	**1** Low	**8** Low-Moderate		
Tailings DRE5 TSF at base of landform	0.0%	51%	0.0%	DRE5 TSF is located within the landform footprint. The TSF (pit) will be partially backfilled and become part of the spoil landform. Due to the concentrated nature of tailings at the base of the landform the TSF has been conservatively assessed as a 'stand alone' TSF landform. Refer to the AMD hazard assessment of DRE5 TSF landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B3. AMD hazard scoring for source materials and likelihood for AMD generation from Airstrip final landform

Airstrip: Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score	Likelihood for AMD generation from Airstrip spoil landform
Non-carbonaceous spoil Distributed throughout	91%	1.5%	1.4%	Total S is very low (75th percentile = 0.05%). NAF samples have a very low 75th percentile total S value of 0.05%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.62% (and AMD capacity is based on this number). Based on sample numbers, approximately 1.5% of non-carbonaceous spoil - mostly fresh/unweathered - is conservatively classified as 'PAF' of some type. 75th percentile EC of non-carbonaceous spoil = 470 µS/cm. About half of the 'PAF' samples are associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 91% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**1** Low	**10** High	**1** Low	**7** Low-Moderate	**3.7** Low	Airstrip spoil landform is essentially comprised of spoil only. Rejects are estimated to comprise approximately 1% of the landform. General spoil is overwhelmingly NAF with very low sulphur, excess neutralising capacity and low soluble metals concentration. About one-third of 'PAF' materials are associated with seams - as parting or within 1.5m (typically) above and below seams. As such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. Approximately 1% of the landform is rejects (based on an assumed proportion of historic rejects potentially disposed in this landform), and approximately 22% of GRBM rejects are 'PAF'. Rejects (if any) within this landform are disposed (buried) broadly within spoil. [Ramp 32 in-pit TSF - located within the 'footprint' of the spoil landform - is assessed as a 'stand-alone' TSF landform]. Overall, about 2.5% of the landform (excluding Ramp 32 TSF) is conservatively estimated to be either PAF, PAF-LC, UC(PAF) or NAF-S material, and most of this is associated with spoil. Carbonaceous spoil is regarded as posing a moderate AMD source hazard and is expected to comprise about 8% of the landform. Rejects are regarded as posing a low-moderate AMD source hazard and are expected to comprise about 1% of the landform. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 465 µS/cm. The hazard for AMD generation from Airstrip spoil landform at GRBM is considered to be **LOW**. The likelihood for AMD generation from Airstrip spoil landform at GRBM is rated **HIGHLY UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	7.9%	10%	0.8%	Total S is low (75th percentile = 0.12%). NAF samples have a low 75th percentile total S value of 0.12%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.67% (and AMD capacity is based on this number). Based on sample numbers, approximately 10% of carbonaceous spoil is conservatively classified as 'PAF' of some type. 75th percentile EC of carbonaceous spoil = 400 µS/cm. 'PAF' samples were broadly distributed throughout the stratigraphy (ie. not just associated with seams). Non-carbonaceous spoil is estimated to comprise approximately 8% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**10** High	**1** Low	**11** Moderate		
Rejects No known rejects. Assume some historic rejects disposed.	1.0%	22%	0.2%	Approximately 22% of rejects at GRBM have been conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. Of these 'PAF' samples, most were classified as PAF-LC or UC(PAF). Total S is generally low (75th percentile = 0.12%). NAF samples have a 75th percentile S value of 0.37%, whereas 'PAF' samples have a 75th percentile S value of 0.65% (and AMD capacity is based on this number). 75th percentile EC of rejects = 538 µS/cm. Rejects are estimated to comprise approximately 1% of mineral waste in the landform, based on assumed historic rejects disposal into this landform. AMD quantity conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects that is PAF.	**5** Plausible	**5** Moderate	**1** Low	**8** Low-Moderate		
Tailings Ramp 32 TSF at base of landform	0.0%	51%	0.0%	Ramp 32 TSF (Airstrip pit) is located within the landform footprint. The TSF (pit) will be backfilled and become part of the spoil landform. Due to the concentrated nature of tailings at the base of the landform the TSF has been conservatively assessed as a 'stand alone' TSF landform. Refer to the AMD hazard assessment of Ramp 32 TSF landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B4. AMD hazard scoring for source materials and likelihood for AMD generation from Broadmeadow-Isaac final landform

Broadmeadow-Isaac: Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score	Likelihood for AMD generation from Broadmeadow-Isaac spoil landform
Non-carbonaceous spoil Distributed throughout	92%	1.5%	1.4%	Total S is very low (75th percentile = 0.05%). NAF samples have a very low 75th percentile total S value of 0.05%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.62% (and AMD capacity is based on this number). Based on sample numbers, approximately 1.5% of non-carbonaceous spoil - mostly fresh/unweathered - is conservatively classified as 'PAF' of some type. 75th percentile EC of non-carbonaceous spoil = 470 µS/cm. About half of the 'PAF' samples are associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 92% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**1** Low	**10** High	**1** Low	**7** Low-Moderate	**3.4** Low	Broadmeadow-Isaac spoil landform is comprised of about 97% spoil. Rejects (based on estimated future rejects quantities potentially disposed in this landform) are estimated to comprise approximately 3% of the landform. General spoil is overwhelmingly NAF with very low sulphur, excess neutralising capacity and low soluble metals concentration. About one-third of 'PAF' materials are associated with seams - as parting or within 1.5m (typically) above and below seams. As such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. Approximately 22% of the rejects are 'PAF', however rejects comprise a small proportion of the landform (approximately 3%) and will be disposed (buried) within spoil. Overall, about 2.6% of the landform is conservatively estimated to be either PAF, PAF-LC, UC(PAF) or NAF-S material, and about one-third of this is associated with near-seam spoil. Carbonaceous spoil is regarded as posing a moderate AMD source hazard and are expected to comprise about 5% of the landform. Rejects are regarded as posing a low-moderate AMD source hazard and expected to comprise about 3% of the landform. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 469 µS/cm. The hazard for AMD generation from Broadmeadow-Isaac spoil landform at GRBM is considered to be **LOW**. The likelihood for AMD generation from Broadmeadow-Isaac spoil landform at GRBM is rated **HIGHLY UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	4.9%	10%	0.5%	Total S is low (75th percentile = 0.12%). NAF samples have a low 75th percentile total S value of 0.12%. 'PAF' samples, which includes samples classified as PAF, PAF-LC, UC(PAF) or NAF-S, have a high 75th percentile total S value of 1.67% (and AMD capacity is based on this number). Based on sample numbers, approximately 10% of carbonaceous spoil is conservatively classified as 'PAF' of some type. 75th percentile EC of carbonaceous spoil = 400 µS/cm. 'PAF' samples were broadly distributed throughout the stratigraphy (ie. not just associated with seams). Non-carbonaceous spoil is estimated to comprise approximately 5% of mineral waste in the landform. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**10** High	**1** Low	**11** Moderate		
Rejects Negligible existing rejects. Future rejects likely located at the northern end of the landform.	3.0%	22%	0.7%	Approximately 22% of rejects at GRBM have been conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. Of these 'PAF' samples, most were classified as PAF-LC or UC(PAF). Total S is generally low (75th percentile = 0.12%). NAF samples have a 75th percentile S value of 0.37%, whereas 'PAF' samples have a 75th percentile S value of 0.65% (and AMD capacity is based on this number). 75th percentile EC of rejects = 538 µS/cm. Rejects are estimated to comprise approximately 3% of mineral waste in the landform, based on potential future rejects disposal into this landform. AMD quantity conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects that is PAF.	**5** Plausible	**5** Moderate	**1** Low	**8** Low-Moderate		
Tailings No tailings disposed into landform	0.0%	51%	0.0%	No tailings located within Broadmeadow-Isaac landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B5. AMD hazard scoring for source materials and likelihood for AMD generation from GS1 TSF landform (without cover)

GS1 TSF: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from GS1 TSF (before rehabilitation)
Tailings	95%	64%	61%	AMD (as AD and NMD/SD) has been observed in surface water and groundwater in the vicinity of GS1 TSF. Based on geochemical information it is assumed the AMD observed to date is primarily from tailings moreso than rejects. Based on data from 139 tailings samples from GS1 TSF, up to 64% of tailings are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a relatively low-moderate 75th percentile S value of 0.66% (PAF samples). NAF samples have a relatively low 75th percentile S value of 0.48%. Conservatively assumes proportion of PAF tailings samples approximates the proportion of tailings in the TSF that are PAF. Assumes equal distribution of PAF/NAF tailings throughout the TSF.	**15** Certain	**5** Moderate	**5** Moderate	**20** Moderate-High	**19** Moderate-High	The hazard for AMD generation is based on the bulk of the TSF being tailings (estimated at approximately 95%), of which 64% is conservatively estimated to be 'PAF' (which includes PAF, PAF-LC, UC(PAF) and NAF-S). Rejects - present in embankments - are conservatievly estimated to comprise about 5% of the TSF. Approximately 20% of rejects samples have been classified as 'PAF' of some type. Overall, about 62% of GS1 TSF is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material - most of which is tailings, which are assessed as posing a Moderate-High AMD source hazard. Rejects are estimated to comprise about 5% of the TSF (as embankment material) and are assessed as posing a Moderate AMD source hazard. Natural ground beneath the TSF is considered to pose a low-moderate AMD source hazard (likely due to AMD from the overlying tailings). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 821 µS/cm. The hazard for AMD generation from GS1 TSF is conservatively considered to be **MODERATE-HIGH**. The likelihood for AMD generation from GS1 TSF is conservatively rated as **HIGHLY LIKELY** - noting that AMD has already been observed from GS1 TSF.
Rejects Located within embankments	5%	20%	1%	Based on data from 20 aged rejects samples from GS1 TSF, approximately 20% of the rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a low 75th percentile S value of 0.30% (PAF samples). NAF samples also have a low 75th percentile S value of 0.30%. Conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects in the TSF that are PAF. Assumes equal distribution of PAF/NAF rejects throughout the areas of the TSF where rejects are located.	**5** Plausible	**5** Moderate	**3** Low-Moderate	**11** Moderate		
Fill & Natural Ground Spoil fill within the embankments and natural ground material at the base of the TSF	0.5%	19.0%	0.1%	No geochemical data is available for fill or foundation material specifically from GS1 TSF. Have applied RS1 TSF fill and foundation data, on the assumption it would expected to be similar to GS1 TSF. AMD capacity is based on a 75th percentile S value of 0.49% (PAF samples). NAF samples have a 75th percentile S value of 0.06%.	**5** Plausible	**5** Moderate	**3** Low-Moderate	**9** Low-Moderate		

Table B6. AMD hazard scoring for source materials and likelihood for AMD generation from RS1 TSF landform (without cover) – western compartment

RS1 TSF western compartment: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from RS1 TSF western compartment (before rehabilitation)
Tailings No tailings disposed into western compartment	0%	80%	0%	No tailings located within western compartment of RS1 TSF landform.	**n/a**	**n/a**	**n/a**	**n/a**	**12** Moderate	RS1 TSF is constructed and managed as two compartments: western and eastern. The western compartment (this table) comprises rejects only. Approximately 30% of rejects samples were is conservatively estimated to be 'PAF' (which includes PAF, PAF-LC, UC(PAF) and NAF-S) and, as such, about 30% of the western compartment of RS1 TSF is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material. Rejects are assessed as posing a Moderate AMD source hazard. The 75th percentile EC of the western compartment (based on the EC of the rejects) is estimated at 615 µS/cm. The hazard for AMD generation from the western compartment of RS1 TSF is conservatively considered to be **MODERATE**. The likelihood for AMD generation from the western compartment of RS1 TSF is conservatively rated as **PROBABLE / LIKELY**.
Rejects The western compartment is comprised almost entirely of rejects	100%	30%	30%	AMD (as AD and NMD/SD) has been observed in surface water and groundwater in the vicinity of RS1 TSF, however it is considered that the main source of this AMD is probably from the eastern compartment (the tailings), and lesser so the western compartment (rejects). Based on data from 200 aged rejects samples from RS1 TSF and Riverside rejects dump (ie. aged rejects originally derived from RV CHPP), approximately 30% of the rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a relatively low-moderate 75th percentile S value of 0.56% (PAF samples). NAF samples have a low 75th percentile S value of 0.39%. Conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects in the western compartment that are PAF. Assumes equal distribution of PAF/NAF rejects throughout the western compartment of RS1 TSF.	**7** Expected	**5** Moderate	**5** Moderate	**12** Moderate		
Fill & Natural Ground Spoil fill within the western (rejects) compartment	0%	n/a	n/a	No fill samples have been identified or collected from the western compartment. If fill material was present, presumably would be spoil. Therefore, assume all (or predominantly) NAF with low total S.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B7. AMD hazard scoring for source materials and likelihood for AMD generation from RS1 TSF landform (without cover) – eastern compartment

RS1 TSF eastern compartment: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from RS1 TSF eastern compartment (before rehabilitation)
Tailings	85%	80%	68%	AMD (as AD and NMD/SD) has been observed in surface water and groundwater in the vicinity of RS1 TSF. Based on geochemical information it is assumed the AMD observed to date is primarily from tailings (eastern compartment) moreso than rejects. Based on data from 84 tailings samples from RS1 TSF, up to 80% of tailings are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a relatively low-moderate 75th percentile S value of 0.68% (PAF samples). NAF samples have a low 75th percentile S value of 0.34%. Conservatively assumes proportion of PAF tailings samples approximates the proportion of tailings in the TSF that are PAF. Assumes equal distribution of PAF/NAF tailings throughout the TSF.	**15** Certain	**5** Moderate	**5** Moderate	**20** Moderate-High	**16** Moderate-High	RS1 TSF is constructed and managed as two compartments: western and eastern. The eastern compartment (this table) comprises tailings as the major material, with rejects located in the eastern and southern embankments and as cover on the tailings. The hazard for AMD generation is based on the bulk of the TSF being tailings (estimated at approximately 85%), of which 80% is conservatively estimated to be 'PAF' (which includes PAF, PAF-LC, UC(PAF) and NAF-S). Rejects - present in embankments and capping tailings - are conservatievly estimated to comprise about 15% of the eastern compartment. Approximately 30% of rejects samples have been classified as 'PAF' of some type. Overall, about 72% of RS1 TSF eastern compartment is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material - most of which is tailings, which are assessed as posing a Moderate-High AMD source hazard. Rejects are estimated to comprise about 15% of the eastern compartment and are assessed as posing a Moderate AMD source hazard. Natural ground beneath the TSF is considered to pose a low-moderate AMD source hazard (lilkely due to AMD from the overlying tailings). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 799 µS/cm. The hazard for AMD generation from the eastern compartment of RS1 TSF is conservatively considered to be **MODERATE-HIGH**. The likelihood for AMD generation from the eastern compartment of RS1 TSF is conservatively rated as **HIGHLY LIKELY** - noting that AMD has already been observed from RS1 TSF (likely from the eastern compartment where tailings are located).
Rejects Located within the southern and eastern TSF embankments and covering some or all of the tailings	15%	30%	4.4%	AMD (as AD and NMD/SD) has been observed in surface water and groundwater in the vicinity of RS1 TSF. Based on geochemical information it is assumed the AMD observed to date is primarily from tailings moreso than rejects. Based on data from 200 aged rejects samples from RS1 TSF and Riverside rejects dump (ie. aged rejects originally derived from RV CHPP), approximately 30% of the rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a relatively low-moderate 75th percentile S value of 0.56% (PAF samples). NAF samples have a low 75th percentile S value of 0.39%. Conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects in the eastern compartment that are PAF. Assumes equal distribution of PAF/NAF rejects throughout the eastern compartment of RS1 TSF.	**7** Expected	**5** Moderate	**3** Low-Moderate	**11** Moderate		
Fill & Natural Ground Spoil fill within the eastern compartment (part of embankments) and natural ground material at the base of the TSF	0.5%	19.0%	0.1%	Based on data from 18 natural ground samples from the base of RS1 TSF eastern compartment and three fill samples from within the TSF embankments of the eastern compartment, 17 (out of 21) samples were classified as NAF or UC(NAF). The remaining four samples were classified as PAF-LC or UC(PAF). The 75th percentile S value for all 21 samples = 0.23%. The 75th percentile S value for PAF samples is 0.49%. The 75th percentile S value for NAF samples is 0.06%.	**5** Plausible	**5** Moderate	**3** Low-Moderate	**9** Low-Moderate		

Table B8. AMD hazard scoring for source materials and likelihood for AMD generation from DRE5 in-pit TSF landform (without cover; prior to partial backfilling)

DRE5 TSF: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from DRE5 TSF (before rehabilitation)
Tailings	100%	34%	34%	No tailings samples have been collected from DRE5 in-pit TSF. This TSF is relatively new (commenced receiving tailings in approximately 2019). AMD source hazard is based on fresh CHPP tailings samples. Approximately 34% of tailings are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 1.07% (PAF samples). NAF samples have a low 75th percentile S value of 0.62%. Conservatively assumes proportion of PAF tailings samples approximates the proportion of tailings in the TSF that are PAF. Assumes equal distribution of PAF/NAF tailings throughout the TSF.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate	**14** Moderate	The landform is comprised of tailings only, of which 34% of the tailings samples (based on data from fresh (CHPP) tailings samples) were conservatively estimated to be 'PAF' (which includes PAF, PAF-LC, UC(PAF) and NAF-S). The tailings are assessed as posing a Moderate AMD source hazard. The 75th percentile EC of the tailings is 1205 µS/cm. The hazard for AMD generation from DRE5 in-pit TSF is conservatively considered to be **MODERATE**. The likelihood for AMD generation from DRE5 in-pit TSF is conservatively rated as **PROBABLE / LIKELY**.
Rejects No rejects disposed into TSF	0%	n/a	n/a	No rejects located within DRE5 in-pit TSF.	**n/a**	**n/a**	**n/a**	**n/a**		
Fill No fill disposed into TSF	0%	n/a	n/a	No fill located within DRE5 in-pit TSF.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B9. AMD hazard scoring for source materials and likelihood for AMD generation from Ramp 32 in-pit TSF landform (without cover; prior to backfilling)

Ramp 32 TSF: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from Ramp 32 TSF (before rehabilitation)
Tailings	100%	34%	34%	No tailings samples have been collected from Ramp 32 in-pit TSF. This TSF is relatively new (commenced receiving tailings in approximately 2021). AMD source hazard is based on fresh CHPP tailings samples. Approximately 34% of tailings are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 1.07% (PAF samples). NAF samples have a low 75th percentile S value of 0.62%. Conservatively assumes proportion of PAF tailings samples approximates the proportion of tailings in the TSF that are PAF. Assumes equal distribution of PAF/NAF tailings throughout the TSF.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate	**14** Moderate	The landform is comprised of tailings only, of which 34% of the tailings samples (based on data from fresh (CHPP) tailings samples) were conservatively estimated to be 'PAF' (which includes PAF, PAF-LC, UC(PAF) and NAF-S). The tailings are assessed as posing a Moderate AMD source hazard. The 75th percentile EC of the tailings is 1205 µS/cm. The hazard for AMD generation from Ramp 32 in-pit TSF is conservatively considered to be **MODERATE**. The likelihood for AMD generation from Ramp 32 in-pit TSF is conservatively rated as **PROBABLE / LIKELY**.
Rejects No rejects disposed into TSF	0%	n/a	n/a	No rejects located within Ramp 32 in-pit TSF.	**n/a**	**n/a**	**n/a**	**n/a**		
Fill No fill disposed into TSF	0%	n/a	n/a	No fill located within Ramp 32 in-pit TSF.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B10. AMD hazard scoring for source materials and likelihood for AMD generation from Riverside rejects landform (currently with a spoil cover and rehabilitated)

Riverside rejects dump: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from Riverside rejects dump (before rehabilitation)
Tailings No tailings disposed into Riverside rejects landform.	0%	0%	0%	No tailings located within Riverside rejects dump	n/a	n/a	n/a	n/a	**12** Moderate	Riverside rejects dump contains rejects generated from RV CHPP. The dump underwent rehabiliation (in the early 2000s) and has a spoil cover. This AMD source hazard assessment excludes the existing spoil cover and focusses on the rejects only. The hazard for AMD generation in Riverside rejects dump is based on the facility being comprised essentially of rejects only, of which 30% are conservatively estimated to be PAF, PAF-LC, UC(PAF) or NAF-S. Fill material within the rejects dump (ie. excluding any spoil cover) is assumed to comprise a negligible proportion. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 615 µS/cm. The hazard for AMD generation from Riverside rejects landform is conservatively considered to be **MODERATE**. The likelihood for AMD generation from Riverside rejects landform is conservatively rated as **PROBABLE / LIKELY**.
Rejects All of the landform is comprised of rejects	99.5%	30%	30%	The rejects dump is essentially comprised of rejects only with an assumed very minor (negligible) proportion of fill material. Based on data from 200 aged rejects samples from Riverside rejects dump and RS1 TSF (ie. aged rejects originally derived from RV CHPP), approximately 30% of the rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a relatively low-moderate 75th percentile S value of 0.56% (PAF samples). NAF samples have a low 75th percentile S value of 0.39%. Conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects in the eastern compartment that are PAF. Assumes equal distribution of PAF/NAF rejects throughout the eastern compartment of RS1 TSF.	**7** Expected	**5** Moderate	**5** Moderate	**12** Moderate		
Fill & natural ground Assume very minor proportion of fill disposed within Riverside rejects landform. Excludes spoil cover.	0.5%	2.5%	0.0%	No geochemical data is available for fill material specifically from Riverside rejects dump. Based on data from all spoil samples at GRBM, up to 2.5% of 'fill' is conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 0.58% (PAF samples). NAF samples have a 75th percentile S value of 0.05%. Conservatively assumes proportion of PAF fill samples approximates the proportion of fill in the rejects dump that are PAF. Assumes equal distribution of PAF/NAF fill throughout the areas of the rejects dump where fill may be encountered.	**1** Low	**5** Moderate	**3** Low-Moderate	**5** Low		

Table B11. AMD hazard scoring for source materials and likelihood for AMD generation from GS2 rejects landform (without cover)

GS2 rejects dump: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from GS2 rejects dump (before rehabilitation)
Tailings No tailings disposed into GS2 rejects dump	0%	0%	0%	No tailings located within GS2 rejects dump	**n/a**	**n/a**	**n/a**	**n/a**	**10** Low-Moderate	GS2 rejects dump receives rejects from GY CHPP and is located east of GS1 TSF - between GS1 TSF and Thiess spoil landform. The hazard for AMD generation in GS2 rejects dump is based on the facility being comprised esentially of rejects only, of which 7% are conservatively estimated to be PAF, PAF-LC, UC(PAF) or NAF-S. Fill material within the rejects dump (ie. excluding any spoil cover) is assumed to comprise a negligible proportion. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 412 µS/cm. The hazard for AMD generation from GS2 rejects landform is conservatively considered to be **LOW-MODERATE**. The likelihood for AMD generation from GS2 rejects landform is conservatively rated as **UNLIKELY**.
Rejects Essentially all of the landform is comprised of rejects	99.5%	7.1%	7.1%	The rejects dump is essentially comprised of rejects only with an assumed negligible proportion of fill material. GS2 rejects are generated from GY CHPP. Based on data from 70 rejects samples from GY CHPP and GS1 TSF (ie. GY rejects only) approximately 7% of rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. PAF samples have a low 75th percentile S value of 0.31%. NAF samples have a 75th percentile S value of 0.27%. Conservatively assumes proportion of PAF and NAF-S rejects samples approximates the proportion of rejects in the rejects dump that are PAF and NAF-S. Assumes equal distribution of PAF/NAF rejects throughout the rejects dump.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Fill Negligible fill within the rejects dump	0.5%	2.5%	0.01%	No geochemical data is available for fill material specifically from GS2 rejects dump. Based on data from all spoil samples at GRBM, up to 2.5% of 'fill' is conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 0.58% (PAF samples). NAF samples have a 75th percentile S value of 0.05%. Conservatively assumes proportion of PAF fill samples approximates the proportion of fill in the rejects dump that are PAF. Assumes equal distribution of PAF/NAF fill throughout the areas of the rejects dump where fill may be encountered.	**1** Low	**5** Moderate	**3** Low-Moderate	**5** Low		

Table B12. AMD hazard scoring for source materials and likelihood for AMD generation from GS11 rejects landform (without cover)

GS11 rejects dump: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from GS11 rejects dump (before rehabilitation)
Tailings No tailings disposed into GS11 rejects dump	0%	0%	0%	No tailings located within GS11 rejects dump	**n/a**	**n/a**	**n/a**	**n/a**	**10** Low-Moderate	GS11 rejects dump receives rejects from GY CHPP and is located at the northwestern periphery of Broadmeadow-Isaac spoil landform, however is unlikely to be rehabilitated as part of the Broadmeadow-Isaac spoil landform. Hence, it has been assessed as a 'stand-alone' rejects landform. The hazard for AMD generation in GS11 rejects dump is based on the facility being comprised essentially of rejects only, of which 7% are conservatively estimated to be PAF, PAF-LC, UC(PAF) or NAF-S. Fill material within the rejects dump (ie. excluding any spoil cover) is assumed to comprise a negligible proportion. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 412 µS/cm. The hazard for AMD generation from GS11 rejects landform is conservatively considered to be **LOW-MODERATE**. The likelihood for AMD generation from GS11 rejects landform is conservatively rated as **UNLIKELY**.
Rejects Essentially all of the landform is comprised of rejects	99.5%	7.1%	7.1%	The rejects dump is essentially comprised of rejects only with an assumed negligible proportion of fill material. GS11 rejects are generated from GY CHPP. Based on data from 70 rejects samples from GY CHPP and GS1 TSF (ie. GY rejects only) approximately 7% of rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. PAF samples have a low 75th percentile S value of 0.31%. NAF samples have a 75th percentile S value of 0.27%. Conservatively assumes proportion of PAF and NAF-S rejects samples approximates the proportion of rejects in the rejects dump that are PAF and NAF-S. Assumes equal distribution of PAF/NAF rejects throughout the rejects dump.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Fill Negligible fill within the rejects dump	0.5%	2.5%	0.01%	No geochemical data is available for fill material specifically from GS11 rejects dump. Based on data from all spoil samples at GRBM, up to 2.5% of 'fill' is conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 0.58% (PAF samples). NAF samples have a 75th percentile S value of 0.05%. Conservatively assumes proportion of PAF fill samples approximates the proportion of fill in the rejects dump that are PAF. Assumes equal distribution of PAF/NAF fill throughout the areas of the rejects dump where fill may be encountered.	**1** Low	**5** Moderate	**3** Low-Moderate	**5** Low		

Table B13. AMD hazard scoring for source materials and likelihood for AMD generation from R22 in-pit rejects landform (without cover)

R22 rejects dump: Components (without cover)	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity rating	AMD capacity rating	AMD quantity rating	AMD hazard score	Landform AMD hazard score (pre-rehabilitation)	Likelihood for AMD generation from R22 rejects dump (before rehabilitation)
Tailings No tailings disposed into R22 rejects dump	0%	0%	0%	No tailings located within R22 rejects dump	n/a	n/a	n/a	n/a	**10** Low-Moderate	R22 rejects dump receives rejects from GY CHPP and is located at the south-western periphery of Thiess spoil landform. The hazard for AMD generation in R22 rejects dump is based on the facility being comprised essentially of rejects only, of which 7% are conservatively estimated to be PAF, PAF-LC, UC(PAF) or NAF-S. Fill material within the rejects dump (ie. excluding any spoil cover) is assumed to comprise a negligible proportion. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 412 µS/cm. The hazard for AMD generation from R22 rejects landform is conservatively considered to be **LOW-MODERATE**. The likelihood for AMD generation from R22 rejects landform is conservatively rated as **UNLIKELY**.
Rejects Essentially all of the landform is comprised of rejects	99.5%	7%	7%	The rejects dump is essentially comprised of rejects only with an assumed negligible proportion of fill material. R22 rejects are generated from GY CHPP. Based on data from 70 rejects samples from GY CHPP and GS1 TSF (ie. GY rejects only) approximately 7% of rejects are conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. PAF samples have a low 75th percentile S value of 0.31%. NAF samples have a 75th percentile S value of 0.27%. Conservatively assumes proportion of PAF and NAF-S rejects samples approximates the proportion of rejects in the rejects dump that are PAF and NAF-S. Assumes equal distribution of PAF/NAF rejects throughout the rejects dump.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Fill Negligible fill within the rejects dump	0.5%	2.5%	0.0%	No geochemical data is available for fill material specifically from R22 rejects dump. Based on data from all spoil samples at GRBM, up to 2.5% of 'fill' is conservatively classified as PAF, PAF-LC, UC(PAF) or NAF-S. AMD capacity is based on a 75th percentile S value of 0.58% (PAF samples). NAF samples have a 75th percentile S value of 0.05%. Conservatively assumes proportion of PAF fill samples approximates the proportion of fill in the rejects dump that are PAF. Assumes equal distribution of PAF/NAF fill throughout the areas of the rejects dump where fill may be encountered.	**1** Low	**5** Moderate	**3** Low-Moderate	**5** Low		

Table B14. AMD hazard scoring for source materials and likelihood for AMD generation from Goonyella residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table (where known)	Below current water table (where known)	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Goonyella void highwall
Goonyella Void Highwall	Weathered, non-carbonaceous	10.3%	74%	26%	0%	3.2%	Five out of 154 weathered non-carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Most of this material lies above the water table.	0.3%	Expected to comprise approximately 10% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Very low proportion of PAF material. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.05%. AMD capacity is based on PAF samples 75th %ile total S of 0.58%.	1	5	1	4	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall. The potential exposure of PAF materials on the highwall is estimated to represent approximately 10% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embedded in a matrix of NAF and ANC-rich materials. Overall, void wall run-off reporting to the residual void is unlikely to produce significant acidity. The hazard for AMD generation from void highwall = **LOW-MODERATE**. The likelihood for AMD generation from void highwall (generally) = **UNLIKELY**
	Weathered, carbonaceous & coaly	1.3%	53%	47%	0%	23%	Seven out of 31 weathered carbonaceous samples were classified as 'PAF' (data from geochemical database). It is expected that weathered material is predominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. About half of this material lies above the water table.	0.3%	Expected to comprise approximately 1.3% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Significant proportion of PAF material, however all predominantly oxidised and generally low S. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.23%. AMD capacity is based on PAF samples 75th %ile total S of 0.63%.	5	5	1	8	
	Fresh, non-carbonaceous	71%	43%	57%	71%	1.3%	Approximately 1.3% of the 1015 fresh, non-carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 43% of this material lies above the water table and would be potentially subject to oxidation.	0.9%	Estimated to comprise approximately 71% of the void wall material by meterage. Overall, fresh, non-carb. spoil is overwhelmingly NAF with excess ANC. Likely to be an important source of ANC. Approximately 1.3% of samples were PAF (of some type). This material is overwhelmingly NAF. The 75th %ile total S value is 0.05%. AMD capacity based on PAF samples 75th %ile total S of 0.47%.	1	5	1	4	
	Fresh, carbonaceous	5.5%	43%	57%	5.5%	7.1%	Approximately 7% of the 112 fresh, carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 43% of this material lies above the water table and would be potentially subject to oxidation.	0.4%	Generation of AMD from fresh carbonaceous units cannot be excluded as approximately 7% of the samples tested were classed as PAF (of some type), however most were closely associated with seams. Estimated to comprise approximately 5.5% of the void wall material. The 75th %ile total S value is 0.13%. AMD capacity based on PAF samples 75th %ile total S of 0.51%.	5	5	1	8	
	Coal (fresh)	10.2%	56%	44%	10.2%	77%	Approximately 77% of the 26 fresh, coal samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 56% of this material lies above the water table and would be potentially subject to oxidation.	7.9%	Expected to comprise about 10% of the void wall material by meterage and about 8% of the highwall is expected to be 'PAF' coal. The 75th %ile S value for all coal samples is 0.40%. AMD capacity based on PAF samples 75th %ile total S of 0.44%. With regard to the coal quality database (n=7011 samples), the 75th %ile total S value is 0.58% - higher, but generally consistent with the smaller geochemical database.	7	5	1	10	
	Unknown	2.1%	64%	36%	1.2%	7.1%	Lithology unknown. Majority of material is below base of weathering and above water table. Conservatively assume PAF samples based on fresh carb spoil.	0.1%	Very low proportion and majority is 'fresh'. Conservatively assume 'Moderate' AMD capacity rating - consistent with fresh carbonaceous material.	5	5	1	8	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							9.9%						

Material domain	Material type on void floor	Proportion of exposure on void floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on void floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Goonyella void floor	
Goonyella Void Floor	Coal: GLS (Goonyella Lower Seam)	100%	0%	100%	100%	98%	PAF proportion estimated by applying a total S 'cut-off' of 0.42% to the coal quality data for GLS seam samples (3372 samples). 3303 out of 3372 GLS samples (ie. 98% of samples) had total S ≥0.42%. The S cut-off was based on the median total S value for 'PAF' coal and rejects samples (combined) from the geochemical database. 'PAF' comprises samples classified as PAF, PAF-LC, UC(PAF) and NAF-S. Based on the geochemical database, 77% of 26 coal samples (from all seams) were conservatively classified as 'PAF' of some type. Whereas, based on the much larger coal quality database (3372 samples), almost all of the void floor is estimated to be PAF. The assessment assumes the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining.	98%	The floor of Goonyella void is expected to be GLS seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.57% (based on 3372 GLS samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 0.44% for PAF coal samples from the geochemical database. Almost all of GLS seam coal samples from GRBM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from essentially all of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Almost alll of the void floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire void floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. The likelihood for AMD generation from exposed Goonyella void floor = **PROBABLE/LIKELY**

Table B15. AMD hazard scoring for source materials and likelihood for AMD generation from Thiess residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table (where known)	Below current water table (where known)	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Thiess void highwall
Thiess Void Highwall	Weathered, non-carbonaceous	44%	100%	0%	0%	3.2%	Five out of 154 weathered non-carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. All of this material lies above the water table.	1.4%	Expected to comprise approximately 44% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Very low proportion of PAF material. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.05%. AMD capacity is based on PAF samples 75th %ile total S of 0.58%.	1	5	1	4	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall. The potential exposure of PAF materials on the highwall is estimated to represent approximately 10% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embedded in a matrix of NAF and ANC-rich materials. Overall, void wall run-off reporting to the residual void is unlikely to produce significant acidity. The hazard for AMD generation from void highwall = **LOW-MODERATE**. The likelihood for AMD generation from void highwall (generally) = **UNLIKELY**
	Weathered, carbonaceous & coaly	3.2%	100%	0%	0%	23%	Seven out of 31 weathered carbonaceous samples were classified as 'PAF' (data from geochemical database). It is expected that weathered material is predominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. All of this material lies above the water table.	0.7%	Expected to comprise approximately 3% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Significant proportion of PAF material, however all predominantly oxidised and generally low S. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.23%. AMD capacity is based on PAF samples 75th %ile total S of 0.63%.	5	5	1	8	
	Fresh, non-carbonaceous	38%	100%	0%	38%	1.3%	Approximately 1.3% of the 1015 fresh, non-carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that all of this material lies above the water table and would be potentially subject to oxidation.	0.5%	Estimated to comprise approximately 38% of the void wall material by meterage. Overall, fresh, non-carb. spoil is overwhelmingly NAF with excess ANC. Likely to be an important source of ANC. Approximately 1.3% of samples were PAF (of some type). This material is overwhelmingly NAF. The 75th %ile total S value is 0.05%. AMD capacity based on PAF samples 75th %ile total S of 0.47%.	1	5	1	4	
	Fresh, carbonaceous	3.7%	100%	0%	3.7%	7.1%	Approximately 7% of the 112 fresh, carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that all of this material lies above the water table and would be potentially subject to oxidation.	0.3%	Generation of AMD from fresh carbonaceous units cannot be excluded as approximately 7% of the samples tested were classed as PAF (of some type), however most were closely associated with seams. Estimated to comprise approximately 3.7% of the void wall material. The 75th %ile total S value is 0.13%. AMD capacity based on PAF samples 75th %ile total S of 0.51%.	5	5	1	8	
	Coal (fresh)	9.4%	100%	0%	9.4%	77%	Approximately 77% of the 26 fresh, coal samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that all of this material lies above the water table and would be potentially subject to oxidation.	7.2%	Expected to comprise about 9% of the void wall material by meterage and about 7% of the highwall is expected to be 'PAF' coal. The 75th %ile S value for all coal samples is 0.40%. AMD capacity based on PAF samples 75th %ile total S of 0.44%. With regard to the coal quality database (n=7011 samples), the 75th %ile total S value is 0.58% - higher, but generally consistent with the smaller geochemical database.	7	5	1	10	
	Unknown	1.9%	100%	0%	0.9%	7.1%	Lithology unknown. Half of material is below base of weathering and all above water table. Conservatively assume PAF samples based on fresh carb spoil.	0.1%	Very low proportion and about half is 'fresh'. Conservatively assume 'Moderate' AMD capacity rating - consistent with fresh carbonaceous material.	5	5	1	8	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							10%						

Material domain	Material type on void floor	Proportion of exposure on void floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on void floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Thiess void floor	
Thiess Void Floor	Coal: GLS (Goonyella Lower Seam)	100%	0%	100%	100%	98%	PAF proportion estimated by applying a total S 'cut-off' of 0.42% to the coal quality data for GLS seam samples (3372 samples). 3303 out of 3372 GLS samples (ie. 98% of samples) had total S ≥0.42%. The S cut-off was based on the median total S value for 'PAF' coal and rejects samples (combined) from the geochemical database. 'PAF' comprises samples classified as PAF, PAF-LC, UC(PAF) and NAF-S. Based on the geochemical database, 77% of 26 coal samples (from all seams) were conservatively classified as 'PAF' of some type. Whereas, based on the much larger coal quality database (3372 samples), almost all of the void floor is estimated to be PAF. The assessment assumes the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining.	98%	The floor of Thiess void is expected to be GLS seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.57% (based on 3372 GLS samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 0.44% for PAF coal samples from the geochemical database. Almost all of GLS seam coal samples from GRBM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from essentially all of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Almost alll of the void floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire void floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. The likelihood for AMD generation from exposed Thiess void floor = **PROBABLE/LIKELY**

Table B16. AMD hazard scoring for source materials and likelihood for AMD generation from Ramp 32 East residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table (where known)	Below current water table (where known)	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Ramp 32 East void highwall
Ramp 32 East Void Highwall	Weathered, non-carbonaceous	34%	unkn.	unkn.	0%	3.2%	Five out of 154 weathered non-carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Water table information unknown - assume all above the water table.	1.1%	Expected to comprise approximately 34% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Very low proportion of PAF material. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.05%. AMD capacity is based on PAF samples 75th %ile total S of 0.58%.	1	5	1	4	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall. The potential exposure of PAF materials on the highwall is estimated to represent approximately 7% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embedded in a matrix of NAF and ANC-rich materials. Overall, void wall run-off reporting to the residual void is unlikely to produce significant acidity. The hazard for AMD generation from void highwall = **LOW-MODERATE**. The likelihood for AMD generation from void highwall (generally) = **UNLIKELY**
	Weathered, carbonaceous & coaly	2.6%	unkn.	unkn.	0%	23%	Seven out of 31 weathered carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Water table information unknown - assume all above the water table.	0.6%	Expected to comprise approximately 2.6% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Significant proportion of PAF material, however all predominantly oxidised and generally low S. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.23%. AMD capacity is based on PAF samples 75th %ile total S of 0.63%.	5	5	1	8	
	Fresh, non-carbonaceous	53%	unkn.	unkn.	53%	1.3%	Approximately 1.3% of the 1015 fresh, non-carbonaceous samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	0.7%	Estimated to comprise approximately 53% of the void wall material by meterage. Overall, fresh, non-carb. spoil is overwhelmingly NAF with excess ANC. Likely to be an important source of ANC. Approximately 1.3% of samples were PAF (of some type). This material is overwhelmingly NAF. The 75th %ile total S value is 0.05%. AMD capacity based on PAF samples 75th %ile total S of 0.47%.	1	5	1	4	
	Fresh, carbonaceous	5.0%	unkn.	unkn.	5.0%	7.1%	Approximately 7% of the 112 fresh, carbonaceous samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	0.4%	Generation of AMD from fresh carbonaceous units cannot be excluded as approximately 7% of the samples tested were classed as PAF (of some type), however most were closely associated with seams. Estimated to comprise approximately 5% of the void wall material. The 75th %ile total S value is 0.13%. AMD capacity based on PAF samples 75th %ile total S of 0.51%.	5	5	1	8	
	Coal (fresh)	5.0%	unkn.	unkn.	5.0%	77%	Approximately 77% of the 26 fresh, coal samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	3.9%	Expected to comprise about 5% of the void wall material by meterage and about 4% of the highwall is expected to be 'PAF' coal. The 75th %ile S value for all coal samples is 0.40%. AMD capacity based on PAF samples 75th %ile total S of 0.44%. With regard to the coal quality database (n=7011 samples), the 75th %ile total S value is 0.58% - higher, but generally consistent with the smaller geochemical database.	7	5	1	10	
	Unknown	0.0%	n/a	n/a	0.0%	0%	No material of unknown type.	0%	No material of unknown type.	n/a	n/a	n/a	n/a	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							6.6%						

Material domain	Material type on void floor	Proportion of exposure on void floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on void floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Ramp 32 East void floor	
Ramp 32 East Void Floor	Coal: GLS (Goonyella Lower Seam)	100%	0%	100%	100%	98%	PAF proportion estimated by applying a total S 'cut-off' of 0.42% to the coal quality data for GLS seam samples (3372 samples). 3303 out of 3372 GLS samples (ie. 98% of samples) had total S ≥0.42%. The S cut-off was based on the median total S value for 'PAF' coal and rejects samples (combined) from the geochemical database. 'PAF' comprises samples classified as PAF, PAF-LC, UC(PAF) and NAF-S. Based on the geochemical database, 77% of 26 coal samples (from all seams) were conservatively classified as 'PAF' of some type. Whereas, based on the much larger coal quality database (3372 samples), almost all of the void floor is estimated to be PAF. The assessment assumes the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining.	98%	The floor of Ramp 32 East void is expected to be GLS seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.57% (based on 3372 GLS samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 0.44% for PAF coal samples from the geochemical database. Almost all of GLS seam coal samples from GRBM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from essentially all of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Almost alll of the void floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire void floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. The likelihood for AMD generation from exposed Ramp 32 East void floor = **PROBABLE/LIKELY**

Table B17. AMD hazard scoring for source materials and likelihood for AMD generation from Ramp 32 South residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table (where known)	Below current water table (where known)	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Ramp 32 South void highwall
Ramp 32 South Void Highwall	Weathered, non-carbonaceous	23%	unkn.	unkn.	0%	3.2%	Five out of 154 weathered non-carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Water table information unknown - assume all above the water table.	0.7%	Expected to comprise approximately 34% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Very low proportion of PAF material. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.05%. AMD capacity is based on PAF samples 75th %ile total S of 0.58%.	1	5	1	4	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall. The potential exposure of PAF materials on the highwall is estimated to represent approximately 7% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embedded in a matrix of NAF and ANC-rich materials. Overall, void wall run-off reporting to the residual void is unlikely to produce significant acidity. The hazard for AMD generation from void highwall = **LOW-MODERATE**. The likelihood for AMD generation from void highwall (generally) = **UNLIKELY**
	Weathered, carbonaceous & coaly	2.0%	unkn.	unkn.	0%	23%	Seven out of 31 weathered carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Water table information unknown - assume all above the water table.	0.5%	Expected to comprise approximately 2.6% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Significant proportion of PAF material, however all predominantly oxidised and generally low S. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.23%. AMD capacity is based on PAF samples 75th %ile total S of 0.63%.	5	5	1	8	
	Fresh, non-carbonaceous	63%	unkn.	unkn.	63%	1.3%	Approximately 1.3% of the 1015 fresh, non-carbonaceous samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	0.8%	Estimated to comprise approximately 53% of the void wall material by meterage. Overall, fresh, non-carb. spoil is overwhelmingly NAF with excess ANC. Likely to be an important source of ANC. Approximately 1.3% of samples were PAF (of some type). This material is overwhelmingly NAF. The 75th %ile total S value is 0.05%. AMD capacity based on PAF samples 75th %ile total S of 0.47%.	1	5	1	4	
	Fresh, carbonaceous	6.0%	unkn.	unkn.	6.0%	7.1%	Approximately 7% of the 112 fresh, carbonaceous samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	0.4%	Generation of AMD from fresh carbonaceous units cannot be excluded as approximately 7% of the samples tested were classed as PAF (of some type), however most were closely associated with seams. Estimated to comprise approximately 5% of the void wall material. The 75th %ile total S value is 0.13%. AMD capacity based on PAF samples 75th %ile total S of 0.51%.	5	5	1	8	
	Coal (fresh)	6.0%	unkn.	unkn.	6.0%	77%	Approximately 77% of the 26 fresh, coal samples were classified as 'PAF' (data from geochemical database). Water table information unknown. Assume 50% of this material lies above the water table and would be potentially subject to oxidation.	4.6%	Expected to comprise about 5% of the void wall material by meterage and about 4% of the highwall is expected to be 'PAF' coal. The 75th %ile S value for all coal samples is 0.40%. AMD capacity based on PAF samples 75th %ile total S of 0.44%. With regard to the coal quality database (n=7011 samples), the 75th %ile total S value is 0.58% - higher, but generally consistent with the smaller geochemical database.	7	5	1	10	
	Unknown	0.0%	n/a	n/a	0.0%	0%	No material of unknown type.	0%	No material of unknown type.	n/a	n/a	n/a	n/a	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							7.1%						

Material domain	Material type on void floor	Proportion of exposure on void floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on void floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Ramp 32 South void floor	
Ramp 32 South Void Floor	Coal: GLS (Goonyella Lower Seam)	100%	0%	100%	100%	98%	PAF proportion estimated by applying a total S 'cut-off' of 0.42% to the coal quality data for GLS seam samples (3372 samples). 3303 out of 3372 GLS samples (ie. 98% of samples) had total S ≥0.42%. The S cut-off was based on the median total S value for 'PAF' coal and rejects samples (combined) from the geochemical database. 'PAF' comprises samples classified as PAF, PAF-LC, UC(PAF) and NAF-S. Based on the geochemical database, 77% of 26 coal samples (from all seams) were conservatively classified as 'PAF' of some type. Whereas, based on the much larger coal quality database (3372 samples), almost all of the void floor is estimated to be PAF. The assessment assumes the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining.	98%	The floor of Ramp 32 South void is expected to be GLS seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.57% (based on 3372 GLS samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 0.44% for PAF coal samples from the geochemical database. Almost all of GLS seam coal samples from GRBM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from essentially all of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Almost alll of the void floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire void floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. The likelihood for AMD generation from exposed Ramp 32 South void floor = **PROBABLE/LIKELY**

Table B18. AMD hazard scoring for source materials and likelihood for AMD generation from Broadmeadow-Isaac residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table (where known)	Below current water table (where known)	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Broadmeadow-Isaac void highwall
Broadmeadow-Isaac Void Highwall	Weathered, non-carbonaceous	26%	99%	1%	0%	3.2%	Five out of 154 weathered non-carbonaceous samples were 'PAF' (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF. Almost all of this material lies above the water table.	0.8%	Expected to comprise approximately 26% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Very low proportion of PAF material. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.05%. AMD capacity is based on PAF samples 75th %ile total S of 0.58%.	1	5	1	4	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall. The potential exposure of PAF materials on the highwall is estimated to represent approximately 7% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embedded in a matrix of NAF and ANC-rich materials. Overall, void wall run-off reporting to the residual void is unlikely to produce significant acidity. The hazard for AMD generation from void highwall = **LOW-MODERATE**. The likelihood for AMD generation from void highwall (generally) = **UNLIKELY**
	Weathered, carbonaceous & coaly	0.8%	100%	0%	0%	23%	Seven out of 31 weathered carbonaceous samples were classified as 'PAF' (data from geochemical database). It is expected that weathered material is prodominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. All of this material lies above the water table.	0.2%	Expected to comprise less than 1% of the void wall material by meterage. Assumed to be non-mineralised, with very low sulphide concentration. Significant proportion of PAF material, however all predominantly oxidised and generally low S. The potential for AMD from acid sulphate minerals is very low. Likely source of ANC. The 75th %ile total S value is 0.23%. AMD capacity is based on PAF samples 75th %ile total S of 0.63%.	5	5	1	8	
	Fresh, non-carbonaceous	61%	46%	54%	61%	1.3%	Approximately 1.3% of the 1015 fresh, non-carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 46% of this material lies above the water table and would be potentially subject to oxidation.	0.8%	Estimated to comprise approximately 61% of the void wall material by meterage. Overall, fresh, non-carb. spoil is overwhelmingly NAF with excess ANC. Likely to be an important source of ANC. Approximately 1.3% of samples were PAF (of some type). This material is overwhelmingly NAF. The 75th %ile total S value is 0.05%. AMD capacity based on PAF samples 75th %ile total S of 0.47%.	1	5	1	4	
	Fresh, carbonaceous	1.5%	43%	57%	1.5%	7.1%	Approximately 7% of the 112 fresh, carbonaceous samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 43% of this material lies above the water table and would be potentially subject to oxidation.	0.1%	Generation of AMD from fresh carbonaceous units cannot be excluded as approximately 7% of the samples tested were classed as PAF (of some type), however most were closely associated with seams. Estimated to comprise approximately 1.5% of the void wall material. The 75th %ile total S value is 0.13%. AMD capacity based on PAF samples 75th %ile total S of 0.51%.	5	5	1	8	
	Coal (fresh)	6.7%	35%	65%	6.7%	77%	Approximately 77% of the 26 fresh, coal samples were classified as 'PAF' (data from geochemical database). Available drill-hole data indicates that approximately 35% of this material lies above the water table and would be potentially subject to oxidation.	5.2%	Expected to comprise about 7% of the void wall material by meterage and about 5% of the highwall is expected to be 'PAF' coal. The 75th %ile S value for all coal samples is 0.40%. AMD capacity based on PAF samples 75th %ile total S of 0.44%. With regard to the coal quality database (n=7011 samples), the 75th %ile total S value is 0.58% - higher, but generally consistent with the smaller geochemical database.	7	5	1	10	
	Unknown	4.0%	96%	4%	2.8%	7.1%	Lithology unknown. Majority of material is below base of weathering and above water table. Conservatively assume PAF samples based on fresh carb spoil.	0.3%	Very low proportion and over two-thirds is 'fresh'. Conservatively assume 'Moderate' AMD capacity rating - consistent with fresh carbonaceous material.	5	5	1	8	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							7.4%						

Material domain	Material type on void floor	Proportion of exposure on void floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on void floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Broadmeadow-Isaac void floor	
Broadmeadow-Isaac Void Floor	Coal: GMS (Goonyella Middle Seam)	100%	0%	100%	100%	98%	PAF proportion estimated by applying a total S 'cut-off' of 0.42% to the coal quality data for GMS seam samples (2227 samples). 2175 out of 2227 GMS samples (ie. 98% of samples) had total S ≥0.42%. The S cut-off was based on the median total S value for 'PAF' coal and rejects samples (combined) from the geochemical database. 'PAF' comprises samples classified as PAF, PAF-LC, UC(PAF) and NAF-S. Based on the geochemical database, 77% of 26 coal samples (from all seams) were conservatively classified as 'PAF' of some type. Whereas, based on the much larger coal quality database (2227 samples), almost all of the void floor is estimated to be PAF. The assessment assumes the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining.	98%	The floor of Broadmeadow-Isaac void is expected to be GMS seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.53% (based on 2227 GMS samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 0.44% for PAF coal samples from the geochemical database. Almost all of GMS seam coal samples from GRBM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from essentially all of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material - which is highly unlikely, given that the entire seam (coal) is taken during mining. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Almost alll of the void floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire void floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. The likelihood for AMD generation from exposed Broadmeadow-Isaac void floor = **PROBABLE/LIKELY**

Attachment C – SPR Assessment Tables

SPR assessment of post-closure spoil landform (source) to surface water (receptor)

- Table C1 Goonyella spoil landform
- Table C2 Thiess spoil landform
- Table C3 Airstrip spoil landform
- Table C4 Broadmeadow-Isaac spoil landform

SPR assessment of post-closure TSF and rejects landform (source) to surface water (receptor)

- Table C5 GS1 TSF landform
- Table C6 RS1 TSF landform
- Table C7 Riverside rejects landform
- Table C8 GS2 rejects landform
- Table C9 GS11 rejects landform
- Table C10 R22 in-pit rejects landform

SPR assessment of post-closure spoil landform (source) to residual void (receptor)

- Table C11 Airstrip spoil landform
- Table C12 Goonyella, Thiess and Broadmeadow-Isaac spoil landforms

SPR assessment of post-closure TSF and rejects landform (source) to residual void (receptor)

- Table C13 TSF landforms
- Table C14 Rejects landforms

SPR assessment of residual void highwall and floor (source) to residual void (receptor)

- Table C15 All voids

Table C1. Source-Pathway-Receptor (SPR) assessment of Goonyella post-closure spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Goonyella spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 9% carbonaceous spoil; and approximately 0.1% rejects (historic rejects disposed in the Lenton pit area). No tailings *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	From Goonyella spoil landform via surface water run-off into ephemeral creeks: • Goonyella Ck tributary. Distance <300m northeast. • Eureka Ck. Distance ~150m south. • Isaac River. Distance ~250m southeast. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creeks (via surface water run-off): • Goonyella Ck tributary @ northeast. • Eureka Ck @ south. • Isaac River @ southeast. *Potential for AMD to reach either of these creeks: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach either of these creeks: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella Ck, Eureka Ck and/or Isaac River [via run-off]	Highly Unlikely	S1	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella Ck, Eureka Ck and/or Isaac River [via run-off]	Unlikely	S1	Low
			Saline drainage (sulphide oxidation): Salt (sulphate) impacting Goonyella Ck, Eureka Ck and/or Isaac River [via run-off]	Highly Unlikely	S1	Low
			Saline drainage (non-oxidative): Salt impacting Goonyella Ck, Eureka Ck and/or Isaac River [via run-off]	Unlikely	S1	Low
	From Goonyella spoil landform via seepage into shallow permeable strata then into ephemeral creeks: • Goonyella Ck tributary. Distance <300m northeast. • Eureka Ck. Distance ~150m south. • Isaac River. Distance ~250m southeast. *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow permeable strata: **Unlikely***	Ephemeral creeks (via shallow permeable strata): • Goonyella Ck tributary. Distance <300m northeast. • Eureka Ck. Distance ~150m south. • Isaac River. Distance ~250m southeast. *Potential for AMD to reach either of these creeks: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach either of these creeks: **Highly Unlikely***	**Acid/acidic drainage:** Low pH & metalliferous water impacting Goonyella Ck, Eureka Ck and/or Isaac River [via seepage]	Highly Unlikely	S1	Low
			Neutral metalliferous drainage: Metals/metalloids impacting Goonyella Ck, Eureka Ck and/or Isaac River [via seepage]	Unlikely	S1	Low
			Saline drainage (sulphide oxidn.): Salt (sulphate) impacting Goonyella Ck, Eureka Ck and/or Isaac River [via seepage]	Highly Unlikely	S1	Low
			Saline drainage (non-oxidative): Salt impacting Goonyella Ck, Eureka Ck and/or Isaac River [via seepage]	Unlikely	S1	Low

Table C2. Source-Pathway-Receptor (SPR) assessment of Thiess post-closure spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Thiess spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 9% carbonaceous spoil; and less than 0.5% rejects (R23 rejects). [R22 rejects dump assessed separately] No tailings [DRE5 TSF addressed separately] *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	From Thiess spoil landform via surface water run-off into ephemeral Eureka Creek. Distance ~150m to receptor @ west; and <100m to receptor @ south. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek @ western and southern sides of Thiess spoil landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water and metalliferous impacting Eureka Creek [via run-off]	Highly Unlikely	S1	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Creek [via run-off]	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Creek [via run-off]	Highly Unlikely	S1	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Creek [via run-off]	Unlikely	S1	Low
	From Thiess spoil landform via seepage into shallow permeable strata then into ephemeral Eureka Creek. Distance ~150m to receptor @ west; and <100m to receptor @ south. *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek @ western and southern sides of Thiess spoil landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Creek [via seepage]	Highly Unlikely	S1	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Creek [via seepage]	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Creek [via seepage]	Highly Unlikely	S1	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Creek [via seepage]	Unlikely	S1	Low

DRE5 in-pit TSF and R22 in-pit rejects dump are both within the footprint and pit shell of Thiess spoil landform, but are conservatively assessed as stand-alone TSF and rejects landforms due to the concentrated nature of tailings and rejects within the landform (i.e. the SPR assessments for DRE5 TSF and R22 rejects dump have been undertaken separate to Thiess spoil landform). DRE5 in-pit TSF is below ground and will be mostly backfilled with spoil such that the backfilled facility will free drain into the Thiess landform. R22 rejects dump will be covered by spoil to manage the AMD hazard. Refer to **Figure 26** for the CFM for DRE5 TSF and **Figure 27** for the CFM for R22 rejects dump. Refer to **Table C10** for the SPR for surface water receptors associated with R22 rejects dump. There are no plausible surface water receptors associated with DRE5 TSF.

Table C3. Source-Pathway-Receptor (SPR) assessment of Airstrip post-closure spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Airstrip spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 8% carbonaceous spoil; and approximately 1% rejects [broadly distributed]. No tailings *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	From Airstrip spoil landform via surface water run-off into ephemeral Holding Paddock Creek. Distance <100m to receptor @ west and southwest. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Holding Paddock Creek @ western and southwestern sides of Airstrip spoil landform. *Potential for AMD to reach Holding Paddock Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Holding Paddock Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Holding Paddock Creek [via run-off]	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Holding Paddock Creek [via run-off]	Unlikely	S1	**Low**
			Saline drainage (sulphide oxidation): Salt (sulphate) impacting Holding Paddock Creek [via run-off]	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Holding Paddock Creek [via run-off]	Unlikely	S1	**Low**
	From Airstrip spoil landform via seepage into shallow permeable strata then into ephemeral Holding Paddock Creek. Distance <100m to receptor @ west and southwest. *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Holding Paddock Creek @ western and southwestern sides of Airstrip spoil landform. *Potential for AMD to reach Holding Paddock Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Holding Paddock Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Holding Paddock Creek [via seepage]	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Holding Paddock Creek [via seepage]	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Holding Paddock Creek [via seepage]	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Holding Paddock Creek [via seepage]	Unlikely	S1	**Low**

Ramp 32 in-pit TSF (Airstrip pit) is within the footprint and pit shell of Airstrip spoil landform, but is conservatively assessed as a stand-alone TSF landform due to the concentrated nature of tailings in one area of the landform (i.e. the SPR assessment of Ramp 32 in-pit TSF has been undertaken separate to Airstrip spoil landform). Ramp 32 in-pit TSF is below ground and will be backfilled with spoil, therefore there are no plausible surface water receptors. Refer **Figure 28** for the CFM.

Table C4. Source-Pathway-Receptor (SPR) assessment of Broadmeadow-Isaac post-closure spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Broadmeadow-Isaac spoil landform (post-closure) Comprised of approximately 92% non-carbonaceous spoil; approximately 5% carbonaceous spoil; and approximately 3% rejects (rejects mostly disposed at northern end of the landform). No tailings *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	From Broadmeadow-Isaac spoil landform via surface water run-off into ephemeral creeks: • Eureka Creek. Distance <100m north. • Isaac River. Distance ~250m southeast. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creeks (via surface water run-off): • Eureka Creek @ northern side of landform. • Isaac River @ southeast *Potential for AMD to reach either of these creeks: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach either of these creeks: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Creek and/or Isaac River [via run-off]	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Creek and/or Isaac River [via run-off]	Unlikely	S1	**Low**
			Saline drainage (sulphide oxidation): Salt (sulphate) impacting Eureka Creek and/or Isaac River [via run-off]	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Creek and/or Isaac River [via run-off]	Unlikely	S1	**Low**
	From Broadmeadow-Isaac spoil landform via seepage into shallow permeable strata then into ephemeral creeks: • Eureka Creek. Distance <100m north. • Isaac River. Distance ~250m southeast. *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow permeable strata: **Unlikely***	Ephemeral creeks (via shallow permeable strata): • Eureka Creek. Distance <100m north. • Isaac River. Distance ~250m southeast *Potential for AMD to reach either of these creeks: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach either of these creeks: **Highly Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Creek and/or Isaac River [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Creek and/or Isaac River [via seepage] Risk lies with the rejects disposed at northern end of the spoil landform, approximately 500m from the edge of the rejects to Eureka Creek]	Highly Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidn.): Salt (sulphate) impacting Eureka Creek and/or Isaac River [via seepage] Risk lies with the rejects disposed at northern end of the spoil landform, approximately 500m from the edge of the rejects to Eureka Creek]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Creek and/or Isaac River [via seepage]	Unlikely	S1	**Low**

Table C5. Source-Pathway-Receptor (SPR) assessment of GS1 TSF post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
GS1 TSF landform (post-closure) Excluding cover, the TSF is comprised of approximately 95% tailings and approximately 5% rejects. It is assumed that the TSF may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Moderate-High*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Moderate*** TSF will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the likely spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated GS1 TSF landform via surface water run-off into ephemeral creeks: • Holding Paddock Ck. Distance <100m south and west. • Eureka Ck. Distance ~500m northeast. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creeks (via surface water run-off): • Holding Paddock Ck. Distance <100m south and west. • Eureka Ck. Distance ~500m northeast *Potential for AMD to reach these creeks: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach these creeks: **Unlikely***	**Acid drainage:** Low pH and metalliferous water impacting Holding Paddock Ck and/or Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Neutral metal. drainage: Metals and metalloids impacting Holding Paddock Ck and/or Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage. (sulphide oxdn.): Salt (sulphate) impacting Holding Paddock Ck and/or Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Holding Paddock Ck and/or Eureka Ck [via run-off]	Unlikely	S2	**Low**
	From rehabilitated GS1 TSF landform via seepage into shallow permeable strata then into ephemeral creeks: • Holding Paddock Ck. Distance <100m south and west. • Eureka Ck. Distance ~500m northeast. *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow permeable strata: **Unlikely***	Ephemeral creeks (via shallow permeable strata): • Holding Paddock Ck. Distance <100m south and west. • Eureka Ck. Distance ~500m northeast *Potential for AMD to reach these creeks: **Probable** (for Holding Paddock Ck) **Unlikely** (for Eureka Creek)* *Potential for salt (non-oxidative) >900 µS/cm to reach these creeks: **Unlikely***	**Acid drainage:** Low pH and metalliferous water impacting Holding Paddock Ck and/or Eureka Ck [via seepage] Risk primarily lies with seepage to Holding Paddock Creek, located very close to the TSF.	Unlikely	S3	**Low to Medium**
			Neutral metal. drainage: Metals and metalloids impacting Holding Paddock Ck and/or Eureka Ck [via seepage] Risk primarily lies with seepage to Holding Paddock Creek, located very close to the TSF.	Unlikely	S3	**Low to Medium**
			Saline drainage (sulphide oxdn.): Salt (sulphate) impacting Holding Paddock Ck and/or Eureka Ck [via seepage]. Risk primarily lies with seepage to Holding Paddock Creek, located very close to the TSF.	Unlikely	S3	**Low to Medium**
			Saline drainage (non-oxidative): Salt impacting Holding Paddock Ck and/or Eureka Ck [via seepage]	Unlikely	S2	**Low**

Table C6. Source-Pathway-Receptor (SPR) assessment of RS1 TSF post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
RS1 TSF landform (post-closure) Excluding cover, the western compartment comprises rejects only. The eastern compartment comprises approximately 85% tailings and 15% rejects. The eastern compartment may contain up to 0.5% fill. *Overall, the unrehabilitated TSF landform has a **Moderate-High** AMD source hazard. The hazard primarily lies with the tailings.* *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Moderate*** The TSF will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the likely spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated RS1 TSF landform via surface water run-off into ephemeral tributary of Eureka Creek. Distance ~800m to receptor @ west and southwest. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek tributary @ western and southwestern sides of RS1 TSF landform. *Potential for AMD to reach Eureka Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via run-off]	Highly Unlikely	S2	**Low**
	From rehabilitated RS1 TSF landform via seepage into shallow permeable strata then into ephemeral tributary of Eureka Creek. Distance ~800m to receptor @ west and southwest. *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow permeable strata: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek tributary @ western and southwestern sides of RS1 TSF landform. *Potential for AMD to reach Eureka Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via seepage] Eureka Creek tributary is located a significant distance (~800m) from the TSF.	Highly Unlikely	S3	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via seepage] Eureka Creek tributary is located a significant distance (~800m) from the TSF.	Highly Unlikely	S3	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via seepage] Eureka Creek tributary is located a significant distance (~800m) from the TSF.	Highly Unlikely	S3	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via seepage]	Highly Unlikely	S2	**Low**

Table C7. Source-Pathway-Receptor (SPR) assessment of Riverside rejects post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Riverside rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low***	From rehabilitated Riverside rejects landform via surface water run-off into ephemeral Eureka Creek (+/- via tributaries). Distance ~350m to receptor (south). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek tributary @ southern side of Riverside rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via run-off]	Unlikely	S2	Low
The rejects landform already has a spoil cover. The facility may be subject to additional rehabilitation to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated Riverside rejects landform via seepage into shallow permeable strata then into ephemeral Eureka Creek (+/- via tributaries). Distance ~350m to receptor (south). *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek tributary @ southern side of Riverside rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via seepage]	Unlikely	S2	Low

Table C8. Source-Pathway-Receptor (SPR) assessment of GS2 rejects post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
GS2 rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low***	From rehabilitated GS2 rejects landform via surface water run-off into ephemeral Eureka Creek. Distance <150m to receptor (east). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek @ eastern side of GS2 rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via run-off]	Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via run-off]	Unlikely	S2	Low
The rejects landform will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated GS2 rejects landform via seepage into shallow permeable strata then into ephemeral Eureka Creek. Distance <150m to receptor (east). *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek @ eastern side of GS2 rejects landform. *Potential for AMD to reach Eureka Creek: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via seepage]	Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via seepage]	Unlikely	S2	Low

Table C9. Source-Pathway-Receptor (SPR) assessment of GS11 rejects post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
GS11 rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low***	From rehabilitated GS11 rejects landform via surface water run-off into ephemeral Eureka Creek. Distance ~400m to receptor (north). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek @ northern side of GS11 rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
The rejects landform will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated GS11 rejects landform via seepage into shallow permeable strata then into ephemeral Eureka Creek. Distance ~400m to receptor (north). *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek @ northern side of GS11 rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**

Table C10. Source-Pathway-Receptor (SPR) assessment of R22 rejects post-closure landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
R22 rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low***	From rehabilitated R22 rejects landform via surface water run-off into ephemeral Eureka Creek. Distance ~250m to receptor (south and west). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Unlikely***	Ephemeral creek (via surface water run-off): Eureka Creek @ southern and western side of R22 rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via run-off]	Unlikely	S2	**Low**
The rejects landform will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	From rehabilitated R22 rejects landform via seepage into shallow permeable strata then into ephemeral Eureka Creek. Distance ~250m to receptor (south and west). *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Unlikely***	Ephemeral creek (via shallow permeable strata): Eureka Creek @ southern and western side of R22 rejects landform. *Potential for AMD to reach Eureka Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Eureka Creek: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Eureka Ck [via seepage]	Unlikely	S2	**Low**

Table C11. Source-Pathway-Receptor (SPR) assessment of Airstrip post-closure spoil landform: Ramp 32 East and Ramp 32 South residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Airstrip spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 8% carbonaceous spoil; and approximately 1% rejects [broadly distributed]. No tailings *AMD source hazard of the spoil landform is* ***Low*** *Salinity (non-oxidative) source hazard of the spoil landform is* ***Low***	Seepage / percolation from Airstrip spoil landform into groundwater, which flows into Ramp 32 East and/or Ramp 32 South residual voids. Residual voids are expected to intersect the water table. Residual voids are groundwater 'sinks', drawing all groundwater within the groundwater catchment of these two voids towards the residual voids. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	Ramp 32 East and Ramp 32 South residual voids (both NUMAs). *Potential for AMD to reach residual voids:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual voids:* ***Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S1	**Low**

Ramp 32 in-pit TSF (Airstrip pit) is within the footprint and pit shell of Airstrip spoil landform, but is conservatively assessed as a stand-alone in-pit TSF landform due to the concentrated nature of tailings in one area of the landform (i.e. the SPR assessment of Ramp 32 in-pit TSF has been undertaken separate to Airstrip spoil landform). Refer **Table C13** for Ramp 32 in-pit TSF landform residual void receptor.

Table C12. Source-Pathway-Receptor (SPR) assessment of Goonyella, Thiess and Broadmeadow-Isaac post-closure spoil landforms: Goonyella residual void receptor

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Goonyella spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 9% carbonaceous spoil; and approximately 0.1% rejects (historic rejects disposed in the Lenton pit area). No tailings *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	Seepage / percolation from Goonyella spoil landform into groundwater, which flows into Goonyella residual void. Residual void will intersect the water table. Goonyella residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Goonyella residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella residual void water quality	Unlikely	S1	**Low**
Thiess spoil landform (post-closure) Comprised of approximately 91% non-carbonaceous spoil; approximately 9% carbonaceous spoil; and less than 0.5% rejects (disposed @ Ramp 23). [Essentially all rejects within Thiess landform are disposed at R22 rejects dump, which is assessed as a separate facility.] No tailings (excluding DRE5 in-pit TSF) *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	Seepage / percolation from Thiess spoil landform into groundwater, which flows into Goonyella residual void [via Thiess residual void]. Both voids are expected to intersect the water table. Goonyella residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Goonyella residual void (NUMA) via Thiess residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella [and Thiess] residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella [and Thiess] residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**
Broadmeadow-Isaac spoil landform (post-closure) Comprised of approximately 92% non-carbonaceous spoil; approximately 5% carbonaceous spoil; and approximately 3% rejects (rejects mostly disposed at northern end of the landform). No tailings *AMD source hazard of the spoil landform is **Low*** *Salinity (non-oxidative) source hazard of the spoil landform is **Low***	Seepage / percolation from Goonyella spoil landform into groundwater, which flows into Goonyella residual void [via Broadmeadow-Isaac residual void]. Both voids are expected to intersect the water table. Goonyella residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Goonyella residual void (NUMA) via Broadmeadow-Isaac residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella [and Broadmeadow-Isaac] residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella [and Broadmeadow-Isaac] residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella [and Broadmeadow-Isaac] residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella [and Broadmeadow-Isaac] residual void water quality	Unlikely	S1	**Low**

DRE5 in-pit TSF and R22 in-pit rejects dump are both within the footprint and pit shell of Thiess spoil landform, but are conservatively assessed as stand-alone TSF and rejects landforms due to the concentrated nature of tailings and rejects within the landform (i.e. the SPR assessments for DRE5 TSF and R22 rejects dump have been undertaken separate to Thiess spoil landform). Refer to **Table C13** for the SPR for DRE5 in-pit TSF landform residual void receptor and **Table C14** for the SPR for R22 in-pit rejects landform residual void receptor.

Table C13. Source-Pathway-Receptor (SPR) assessment of post-closure TSF landforms: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
RS1 TSF landform (post-closure) Excluding cover, the western compartment comprises rejects only and the eastern compartment comprises approximately 85% tailings and 15% rejects. The eastern compartment may contain up to 0.5% fill. *Overall, the unrehabilitated TSF landform has a **Moderate-High** AMD source hazard. The hazard primarily lies with the tailings.* *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Moderate**.* The TSF will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the likely spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from RS1 TSF landform into groundwater, which flows into Goonyella residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Probable***	Goonyella residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella residual void water quality	Unlikely	S2	**Low**
DRE5 in-pit TSF landform (post-closure). Located at the base of Thiess spoil landform. Excluding cover, the TSF is comprised of tailings only. *AMD source hazard of the unrehabilitated landform is **Moderate**.* *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Moderate**.* TSF will be partially (mostly) backfilled with spoil to allow free-drainage onto the Thiess spoil landform. The backfill cover will be installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the likely spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from DRE5 in-pit TSF landform into groundwater, which flows into Goonyella residual void [via Thiess residual void]. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Probable***	Goonyella residual void (NUMA) via Thiess residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella [and Thiess] residual void water quality	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella [and Thiess] residual void water quality	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella [and Thiess] residual void water quality	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella [and Thiess] residual void water quality	Unlikely	S2	**Low**
Ramp 32 in-pit TSF landform (post-closure). Located at the base of Airstrip spoil landform. Excluding cover, the TSF is comprised of tailings only. *AMD source hazard of the unrehabilitated landform is **Moderate**.* *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Moderate**.* TSF will be backfilled with spoil. The backfill cover will be installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the likely spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from Ramp 32 in-pit TSF landform into groundwater, which flows into Ramp 32 East and/or Ramp 32 South residual voids. Residual voids are expected to intersect the water table. Residual voids are a groundwater 'sink', drawing groundwater within the void groundwater catchment towards the residual voids. *Potential for AMD to enter groundwater: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Probable***	Ramp 32 East and Ramp 32 South residual voids (both NUMAs). *Potential for AMD to reach residual voids: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual voids: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Ramp 32 East and/or Ramp 32 South residual void water quality	Unlikely	S2	**Low**

GS1 TSF landform (post-closure)

Groundwater modelling indicates there are no groundwater (or residual void) receptors associated with GS1 TSF landform. Seepage from GS1 TSF landform would remain within the low-permeability Tertiary sediments beneath the landform. Migration to groundwater (>50 m depth) is implausible.

Table C14. Source-Pathway-Receptor (SPR) assessment of post-closure rejects landforms: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Riverside rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low*** The rejects landform already has a spoil cover. The facility may be subject to additional rehabilitation to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from Riverside rejects landform into groundwater, which flows into Goonyella residual void. Residual void will intersect the water table. Goonyella residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Goonyella residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella residual void water quality	Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella residual void water quality	Unlikely	S1	**Low**
GS11 rejects landform (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low*** The rejects landform will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from GS11 rejects landform into groundwater, which flows into Ramp 32 East residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Ramp 32 East residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Ramp 32 East residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Ramp 32 East residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Ramp 32 East residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Ramp 32 East residual void water quality	Unlikely	S1	**Low**
R22 in-pit rejects landform. Located within Thiess spoil landform. (post-closure) Excluding cover, the facility is essentially comprised of rejects only. It is assumed that the facility may contain up to 0.5% fill. *AMD source hazard of the unrehabilitated landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of the unrehabilitated landform is **Low*** The rejects landform will have a spoil cover installed at an appropriate thickness to manage the AMD hazard of the landform. *AMD source hazard of the spoil cover is **Low**. Salinity (non-oxidative) source hazard of the likely spoil cover is **Low***	Seepage / percolation from R22 in-pit rejects landform into groundwater, which flows into Goonyella residual void [via Thiess residual void]. Both voids are expected to intersect the water table. Goonyella residual void is a groundwater 'sink', drawing all groundwater within the void groundwater catchment towards the residual void. *Potential for AMD to enter groundwater: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater: **Unlikely***	Goonyella residual void (NUMA) via Thiess residual void (NUMA). *Potential for AMD to reach residual void: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void: **Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Goonyella [and Thiess] residual void water quality	Unlikely	S1	**Low**

<u>GS2 rejects landform (post-closure)</u>

Groundwater modelling indicates there are no groundwater (or residual void) receptors associated with GS2 rejects landform. Seepage from GS2 rejects landform would remain within the low-permeability Tertiary sediments beneath the landform. Migration to groundwater (>50 m depth) is implausible.

Table C15. Source-Pathway-Receptor (SPR) assessment of residual void highwall and floor: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Highwall and floor of residual voids (post-closure) Highwalls of the residual voids are comprised of approximately: • 83% to 90% non-carbonaceous overburden/interburden; • 2% to 8% carbonaceous overburden/interburden; • 5% to 10% coal (residual coal seams). 'PAF' and NAF-S exposure on highwalls conservatively estimated at approximately 8% (vertical meterage). A proportion of this will be in lower seams, which will be submerged. 'PAF' and NAF-S exposure on pit floors conservatively estimated at approximately 98% (ie. essentially all of the pit floor), however all pit floors will be submerged by water. *AMD source hazard from exposed highwalls and submerged pit floors is* ***Moderate*** *Salinity (non-oxidative) source hazard of the exposed highwalls and submerged pit floors is* ***Low***	Surface water run-off from highwall into residual voids. *Potential for AMD to enter surface water run-off from highwall:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off from highwall:* ***Unlikely***	Residual voids (NUMA). *Potential for AMD to reach residual voids:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual voids:* ***Unlikely***	**Acid/acidic drainage:** Low pH and metalliferous water impacting residual void water quality. Risk primarily lies with coal seams exposed in the highwall, of which PAF coal is broadly distributed throughout all likely exposed seams. Coal seams comprise between 5 to 10% of the vertical meterage of the highwall. Most 'PAF' coal is low S and is classified as PAF-LC.	Probable	S2	**Low to Medium**
			Neutral metalliferous drainage: Metals and metalloids impacting residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting residual void water quality. Risk primarily lies with coal seams exposed in the highwall, of which PAF coal is broadly distributed throughout all likely exposed seams. Coal seams comprise between 5 to 10% of the vertical meterage of the highwall. Most 'PAF' coal is low S and is classified as PAF-LC.	Probable	S2	**Low to Medium**
			Saline drainage (non-oxidative): Salt impacting residual void water quality	Unlikely	S1	**Low**

BHP

EROSION AND LANDFORM EVOLUTION SIMULATIONS TO SUPPORT WASTE LANDFORM DESIGN: GOONYELLA RIVERSIDE MINE COMPLEX

September 2024

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Client: BM Alliance Coal Operations Pty Ltd (BMA)

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1 SUMMARY

For waste landforms at Goonyella Riverside Mine Complex (GRM), Landloch Pty Ltd has completed:

a) Initial WEPP runoff/erosion model simulations;
b) Derivation of parameters for the SIBERIA landform evolution model; and
c) Landform evolution simulations for 3-D waste landforms provided by BMA.

Erodibility data for materials considered in WEPP simulations were sourced from previous erodibility studies that assessed GRM materials and from direct measurement of materials from GRM, and included:

- Clay topsoil;
- Clay topsoil mixed with fresh Permian waste; and
- Fresh Permian waste.

WEPP simulations were carried out for the following batter slope geometries:

- 500m long, at 30% gradient;
- 600m long at 25% gradient;
- 750m long at 20% gradient;
- 1,000m long, at 15% gradient; and
- 1,000m long, at 10% gradient.

Each of these batter slope geometries were sheeted with:

- Clay soil with vegetation groundcover levels of 0–90%;
- Clay soil mixed with fresh Permian waste with vegetation groundcover levels of 0–70%; and
- Fresh Permian waste with vegetation groundcover levels of 0–50%.

In deriving and applying SIBERIA parameters, it was assumed that the:

- Clay topsoil mixed with fresh Permian waste with vegetation groundcover levels of 50% will be used for outward-facing batters with 15% gradient on:
  - Goonyella;
  - Airstrip; and
  - Broadmeadow/Isaac.
- Fresh Permian waste with vegetation groundcover levels of 30% will be used for inward-facing (low wall) batters with 30% gradient on:
  - Goonyella;
  - Airstrip; and
  - Broadmeadow/Isaac.

It is considered that these simulations address all options being considered for GRM.

SIBERIA model output showed batter slopes erode at rates below target levels in all cases. Some gully erosion is predicted to occur after 300 years for the clay topsoil mixed with fresh Permian waste and the fresh Permian waste covered slopes, when used on the Goonyella and Broadmeadow/Isaac landforms.

In these circumstances, given the material underlying these surfaces is likely to be the more erosion-resistant fresh Permian waste, the risk of exposing problematic (more erodible) materials over the long-term via gully erosion and not achieving the post-mining land use is considered low. However, gully erosion should be monitored and assessed by an appropriately qualified person as part of the rehabilitation monitoring and maintenance process. Gully erosion was not predicted to occur for the Airstrip landform after 300 years.

2 INTRODUCTION

2.1 Overview

Landloch has been engaged by BMA to carry out specific specialist studies for soils and capping, and landform design, to provide information for the subsequent compilation of transitional Progressive Rehabilitation and Closure Plans (PRC Plans) for its existing operational coal assets located within the Bowen Basin.

This report considers the design of stable waste landforms on the Goonyella Riverside Mine Complex (GRM). GRM includes the Goonyella Riverside mine and the Broadmeadow underground mine.

2.2 Objectives of landform design

A key requirement of landform design is to demonstrate that the rehabilitated landform shapes can confidently be expected to be erosionally stable over the long term, while also supporting the target Post Mining Land Use (PMLU). As part of that requirement, this landform study reports:

- Materials to be used in landform rehabilitation and their erodibility;
- Erosion assessments for a range of material and slope profile options, considering interactions between soil erodibility, rainfall erosivity, and landform height, gradient and vegetation groundcover. These assessments aim to identify options that will achieve acceptable erosion rates over a 100-year period; and
- Landform evolution simulations using the SIBERIA landform evolution model (LEM) to assess stability of 3-dimensional (3-D) rehabilitation landform designs over a period of 300 years.

3 LANDFORM STUDY METHODS

The landform study consisted of four stages:

a) Sourcing and review of erosion model and LEM input data and information;
b) Simulations of runoff and erosion for a range of landform batter options using the WEPP (Water Erosion Prediction Project) model (Flanagan and Livingston 1995);
c) Derivation of input parameters for the SIBERIA LEM (Willgoose *et al.* 1989); and
d) LEM simulations using SIBERIA for 3-D landform shapes provided by BMA.

3.1 Data sources

Information on the soil and waste types present at GRM were sourced from:

- Data collected as part of the development of this report;
- Landloch's GRM material characterisation study report (Landloch 2024);
- Landloch's assessment of GRM's rocky Permian wastes (unpublished data); and
- Historical erodibility testing of GRM's soils (Sheridan 2001).

3.2 Topsoils

The GRM material characterisation study report (Landloch 2024) assessed the properties of 27 topsoil stockpiles. This material represents the soil available for use in rehabilitation at GRM.

Clay topsoils account for 80% of samples assessed across the GRM topsoil stockpiles. They are concentrated in the northern, eastern, and southern areas of the mine. Generally, the clay soil samples have similar properties, but occasional minor inclusions of loams were noted at some stockpiles. This is likely a result of topsoils from minor texture contrast or Kandosol soil units being stripped with the more dominant clays.

Loam topsoils account for 20% of samples assessed across the GRM topsoil stockpiles They are scattered around the south and south-west portion of the mine. These materials have been recovered from a variety of soil types, but have similar physical soil properties once stockpiled, so have been grouped together to aid their management.

Given the dominance of the clay topsoil at GRM, only the clay topsoil was considered further for erodibility testing of the soils.

A summary of the properties of the available soil types is given in Table 1. The table includes data from the assessment of stockpiled soils (Landloch 2024) and data from the assessment of a clay topsoil subjected to erodibility testing as part of this project. The data shows that the clay soils for which WEPP erodibility parameters are available are consistent with the properties of the stockpiled clay soils and hence can be used to model long-term erosion potential for GRM. Figure 1 shows the clay topsoil tested immediately after exposure to high intensity simulated rain. Erodibility data for a clay soil was also available from Sheridan (2001). These data sources were incorporated to produce an aggregated erodibility parameter dataset for the clay topsoils.

Table 1: Properties of soils at GRM as reported in Landloch (2024) and measured as part of this study.

Analysis	Clay Topsoil (Landloch 2024)	Clay Topsoil (GRM_TS_004)	Loam Topsoil (Landloch 2024)
pH_w (pH Units)	7.7–9.0	8.8	6.5–8.3
$EC_{1:5}$ (dS/m)	<1.0	0.8	<0.2
ECEC (meg/100g)	5.6–20	11	1.9–7.9
Exchangeable sodium percentage (ESP) (%)	5.8–22	19	1.5–7.1
Clay content (%)	>35	53	>35
Rock content (%)	<30	8	<20

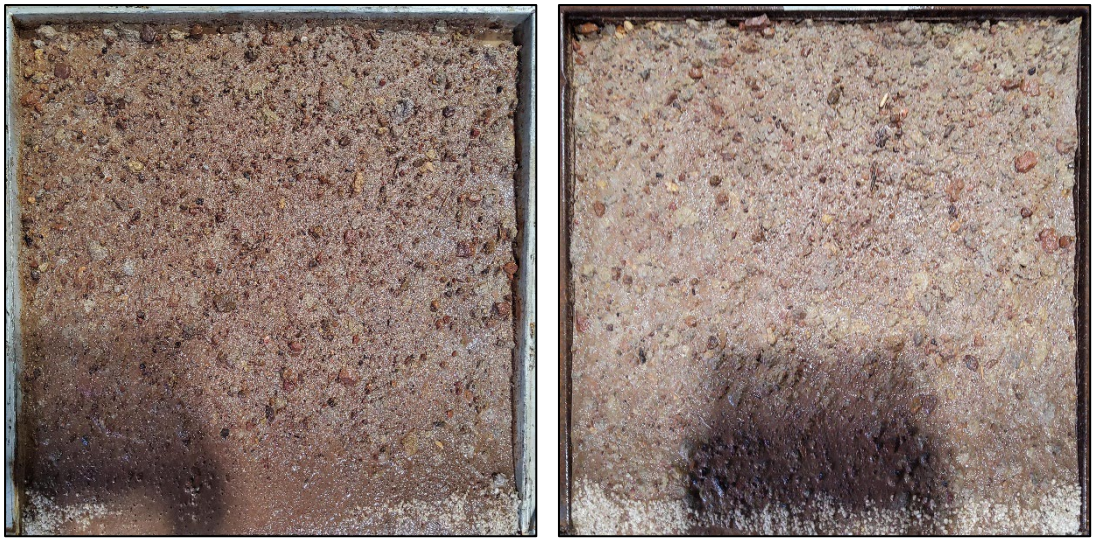

Figure 1: Test plots immediately following application of simulated rain to a clay topsoil. GRM_TS_004 Plot 1 (left) and Plot 2 (right).

3.3 Wastes

Waste materials at GRM include sandstone, mudstone/siltstone, and tertiary materials.

Sandstone wastes account for a large proportion of the fresh Permian wastes and tend to be reasonably consistent in their characteristics given the range of strata locations and proximity to carbonaceous layers. Fresh Permian wastes are considered most suitable for placement close to the final rehabilitated surface for use as a secondary growth media. They also have the potential to be used as a rock armour to increase batter slope resistance to erosion and to stabilise steeper areas.

Weathered Permian wastes tend to vary in properties depending on the degree of weathered inclusions. They are considered suitable as a secondary growth media but should be capped with a suitable quality topsoil to prevent its exposure at the final rehabilitated surface. If exposed, this material will be susceptible to erosion due to its tendency to rapidly weather and disperse. Tertiary wastes are a highly weathered and contain small portions of fragile (low durability) rock. As a result, their placement close to the final rehabilitated surface is not recommended. Assessment of erodibility of the wastes only considered fresh Permian wastes because the weathered Permian and Tertiary wastes are not recommended to be placed close to the final rehabilitation surface.

A summary of the properties of the fresh Permian wastes are given in Table 2. Data from the GRM material characterisation study (Landloch 2024) and an assessment of the rocky Permian wastes done as part of this study are provided. The data shows that fresh Permian waste for which erodibility parameters are available are consistent with the properties reported more broadly for the same material (Landloch 2024). Hence, they can be used to model long-term erosion potential for GRM. This data was aggregated to produce a single erodibility parameter dataset for the fresh Permian waste. Figure 2 shows the Permian wastes tested immediately after exposure to high intensity simulated rain.

Table 2: Properties of Permian wastes at GRM as reported in Landloch (2024) and measured as part of this study.

Analysis	Sandstone Permian Spoil (Landloch 2024)	Fresh Permian Waste (This Study)
pH_w (pH Units)	8.3–9.9	9.4–9.6
$EC_{1:5}$ (dS/m)	<0.8	<1.0
ECEC (meg/100g)	8–24	7.4–11
ESP (%)	6–36	25–26
Clay content (%)	10–35	23–28
Rock content (%)	>50	66–73

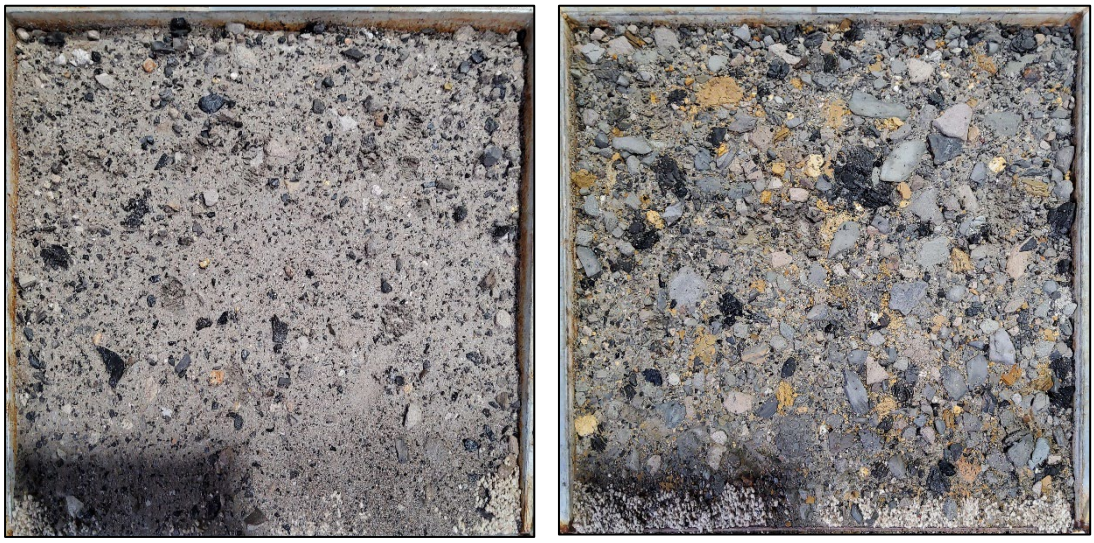

Figure 2: Test plots immediately following application of simulated rain to a Permian waste. R14_002 (left) and AH003_02 (right).

3.4 Summary

Clay soil and fresh Permian wastes are available for use at the surface of rehabilitated waste landforms. Erosion modelling of the landforms at GRM assumed different surface materials as follows:

- Clay topsoil mixed with fresh Permian waste will be used for outward-facing batters on:
  - Goonyella;
  - Airstrip; and
  - Broadmeadow/Isaac.
- Fresh Permian waste will be used for inward facing (low wall) batters on:
  - Goonyella;
  - Airstrip; and
  - Broadmeadow/Isaac.

A mixture of fresh Permian waste with the clay soil was found to be more suitable than topsoil alone, given the high erodibility measured for the clay topsoils at GRM.

3.5 WEPP simulations

3.5.1 Parameters used

Erodibility parameters for WEPP runoff/erosion simulations have been determined experimentally for clay topsoil and fresh Permian waste. These parameters include:

- Effective hydraulic conductivity;
- Interrill erodibility;
- Rill erodibility; and
- Critical flow shear stress for initiation of rilling.

3.5.2 Slope, materials, and vegetation groundcover options

Initial WEPP simulations were carried out for:

- Batter slopes 500m long, at 30% gradient, surfaced with:
  - Clay soil with vegetation groundcover levels of 0–90%;
  - Fresh Permian waste with vegetation groundcover levels of 0–30%; and
  - Clay soil mixed with Fresh Permian wastes with vegetation cover levels of 0–70%.
- Batter slopes 600m long, at 25% gradient, surfaced with:
  - Clay soil with vegetation groundcover levels of 0–90%;
  - Fresh Permian waste with vegetation groundcover levels of 0–30%; and
  - Clay soil mixed with Fresh Permian wastes with vegetation cover levels of 0–70%.
- Batter slopes 750m long, at 20% gradient, surfaced with:
  - Clay soil with vegetation groundcover levels of 0–90%;
  - Fresh Permian waste with vegetation groundcover levels of 0–30%; and
  - Clay soil mixed with Fresh Permian wastes with vegetation cover levels of 0–70%.
- Batter slopes 1,000m long, at 15% gradient, surfaced with:
  - Clay soil with vegetation groundcover levels of 0–90%;
  - Fresh Permian waste with vegetation groundcover levels of 0–30%; and
  - Clay soil mixed with Fresh Permian wastes with vegetation cover levels of 0–70%.
- Batter slopes 1,000m long, at 10% gradient, surfaced with:
  - Clay soil with vegetation groundcover levels of 0–90%;
  - Fresh Permian waste with vegetation groundcover levels of 0–30%; and
  - Clay soil mixed with Fresh Permian wastes with vegetation cover levels of 0–70%.

In considering clay topsoil mixed with fresh Permian waste, input parameters used the hydraulic conductivity of the soil and the critical flow shear stress of the fresh Permian waste (consistent with Landloch's unpublished data for such mixtures).

3.5.3 Vegetation groundcover impacts

Impacts of vegetation groundcover on infiltration rates were estimated using the relationship reported by Kato *et al.* (2009), and direct impacts of vegetation groundcover on erosion rates were estimated using Cover (C) factors for the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.* 1993) listed in Rosewell (1993).

Vegetation groundcover levels of 30% for relatively low fertility fresh Permian waste, and 50% for soil/fresh waste mixtures, and 70% for the more fertile clay soils were adopted in erosion simulations.

This report details materials and the associated vegetation groundcover levels for the representative materials available at the time of sampling. The modelled vegetation groundcover levels are conservative. This study was designed to support the total groundcover levels in the EA acceptance criteria and is not intended to prescribe exact vegetation groundcover levels.

3.5.4 Assumptions with respect to effects of cover on erosion

Points to be noted:

a) In considering "vegetation groundcover" this report specifically considers contact cover of vegetation on the soil surface. Practically, this means a combination of grass cover and anchored (not readily moved) surface litter.
b) The vegetation groundcover levels can be varied in the modelling. Rock groundcover for the material tested is accounted for within the parameters used in the WEPP simulations.
c) Different materials with higher rock groundcover, require lower levels of vegetation groundcover.
d) Total groundcover (vegetation groundcover plus rock groundcover combined) limits erosion.

3.5.5 Climate

All simulations used a synthetic 100-year climate file prepared to match all relevant characteristics of Moranbah climate.

3.5.6 Key assumptions – landforms and vegetation

The simulations are based on two key assumptions:

a) There will be no uncontrolled discharge of runoff from landform tops onto outer batter slopes; and
b) The assumed vegetation groundcover levels will be achieved sustainably, with those levels being set as triggers for investigation and remedial action should monitoring indicate that they are not being achieved.

It should be recognised there are also underlying assumptions of good rehabilitation practice such that:

- There will not be discharges of concentrated flows onto any batter slopes at any point of their rehabilitation;
- Batter slopes will not be formed with significant flow-concentrating profiles (e.g. variations in surface elevation such that there is cross-slope concentration of flow into consistent depressions running downslope);
- Any cross-slope ripping will be carried out strictly on the contour; and
- Soil management (including stripping, stockpiling, replacement, amendment, and fertilisation) will be carried out effectively to maximise early and continuing plant growth.

3.5.7 Soil loss targets

This study used runoff, and erosion modelling to identify landform options that would erode at rates low enough to provide long-term erosional stability. Effectively, the landforms are planned to be consistent with tolerable rates of soil loss. Wischmeier and Smith (1978) defined tolerable soil loss for cropland as, "the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely."

A value of 11.2t/ha/y averaged over an area of interest is often cited as a tolerable soil loss rate, but that value was derived by US soil conservation agencies for deep, fertile cultivated soils, and has little relevance to most rehabilitated minesites. Using similar criteria to those applied for crop land, a lower soil loss tolerance value of 4.5t/ha/y was developed by US agencies for erosion of rangeland soils and shallow cultivated soils (Wight and Siddoway 1979).

Lower tolerance values are relevant to rangeland and minesite situations, as not only are the soils shallower and more susceptible to fertility decline, but the lack of regular tillage or disturbance means that any rills or points of scour that form are more likely to extend and develop into gullies over time. These are typically of concern for minesite landforms where there is no bedrock layer at depth to limit long-term depths of incision.

For that reason, a key priority in setting a tolerable erosion target is the prevention of significant rill or gully development. On that basis, for slopes where long-term erosion risk (for a range of reasons) is considered high, a maximum rate of erosion of 5t/ha/y at any point on the batter slopes being modelled has commonly been applied by Landloch on the basis that; at this rate rilling is largely if not completely absent.

Typically, the high risk category includes slopes where the overall landform height is >50m, and situations where – due to rainfall limitations and/or soil fertility concerns – vegetation growth is unlikely to rapidly colonise and stabilise any rills that form.

As the landforms at GRM are planned to be considerably higher than 50m, the adopted target erosion value for this assessment is a maximum at any point of the outer batter slopes of 5t/ha/y. However, for low wall slopes that drain to pits, there are no potential off-site impacts of erosion, and planned PMLU is typically native vegetation. For those situations, a slightly higher erosion target (a maximum of 10t/ha/y) has been adopted.

The elimination of rilling reduces the potential for channelised flow to form gullies, and experience to date with a large number of waste landforms designed by Landloch has shown that the target soil loss values adopted have achieved acceptable levels of stability to erosion.

3.6 Derivation of SIBERIA parameters

To run SIBERIA, the parameters β_1, m_1, n_1, β_3, and m_3 are usually needed. However, if the batter area to be modelled is identical to the batter for which erosion data are available for calibration, m_3 and β_3 can be taken as 1.0 and a value for n_1 of 1.5 can be adopted for situations where slope gradient does not affect slope erodibility (Willgoose, pers. comm.). Therefore, the two key parameters that require derivation are β_1 and m_1.

The β_1 parameter can be considered a "rate parameter", as it primarily controls the rate of sediment movement. The m_1 parameter can be considered as primarily controlling slope length responses. However, in practice, there is interaction between all the parameters with the result that a large number of parameter sets will all show the same rate of erosion though some aspects of the pattern of erosion that is predicted will vary. It is for this reason that, where possible, fixed values of n_1 and m_3 are adopted – thereby reducing the difficulty of deriving parameter values.

Input parameters for SIBERIA are typically derived by fitting the various model equations to time series data of runoff and erosion. To generate the necessary data, Landloch has developed method that involves:

a) Run the WEPP model to generate data sets of runoff and erosion for slopes consistent with the proposed landforms and for materials of interest using site specific climate data.
b) Analyse the WEPP output to derive the required SIBERIA input parameters.

This approach ensures that SIBERIA parameters are effectively benchmarked to the WEPP output, and thereby, effectively based on measured erodibility parameters for site materials and on site climate.

4 RESULTS OF WEPP SIMULATIONS

Simulations considered slope lengths of 500m and 1,000m. The target erosion rate for modelling outward-facing batters (clay topsoil) is an average annual rate of 5t/ha/y. The target erosion rate for modelling inward-facing batters (low walls, fresh Permian waste) is an average annual rate of 10t/ha/y.

4.1 Slopes surfaced with vegetated clay topsoil

For the clay topsoil modelled, long-term WEPP erosion simulations indicate that gradients of >15% would require very high vegetation groundcover levels (>90%) (Figures 3–6). Slopes using clay topsoils are predicted to be erosionally stable only when gradients of

10% or less are adopted for slope lengths up to 1,000m, and when vegetation groundcover levels of 90% are achieved (Figure 7), for slope lengths less than 1,000m.

These results indicate that the clay topsoil are GRM is highly erodible. Erosion of a clay soil mixed with rock was considered as a means of maintaining soil as the primary growth media while also increasing the erosion resistance of the rehabilitation surface.

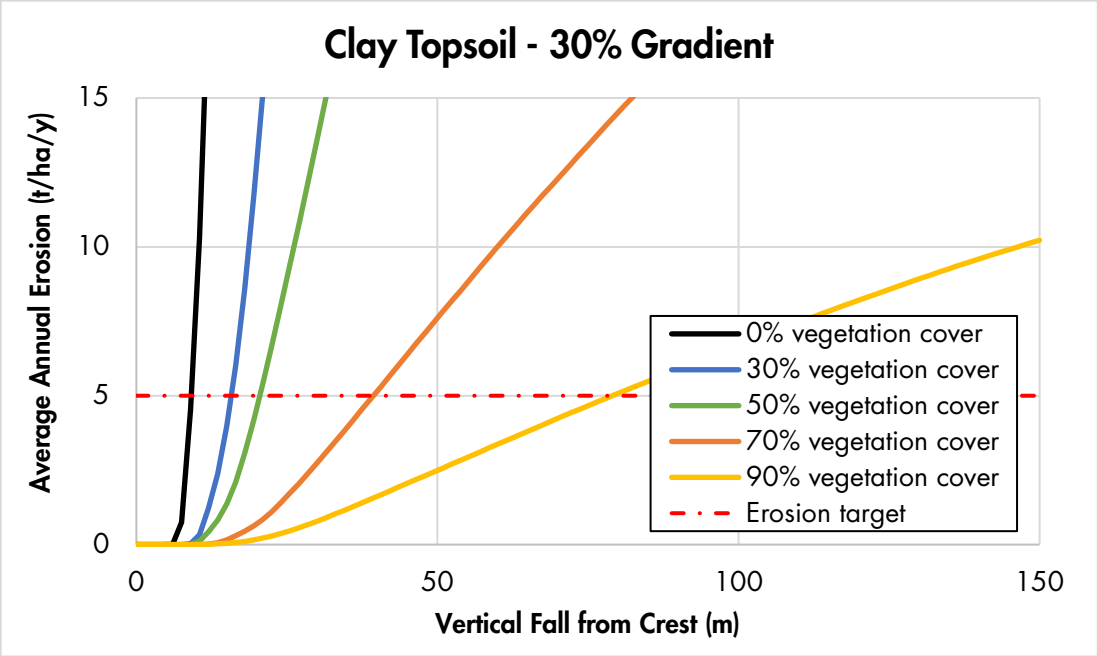

Figure 3: Predicted erosion rates on 30% gradient outward-facing slope sheeted with clay topsoil.

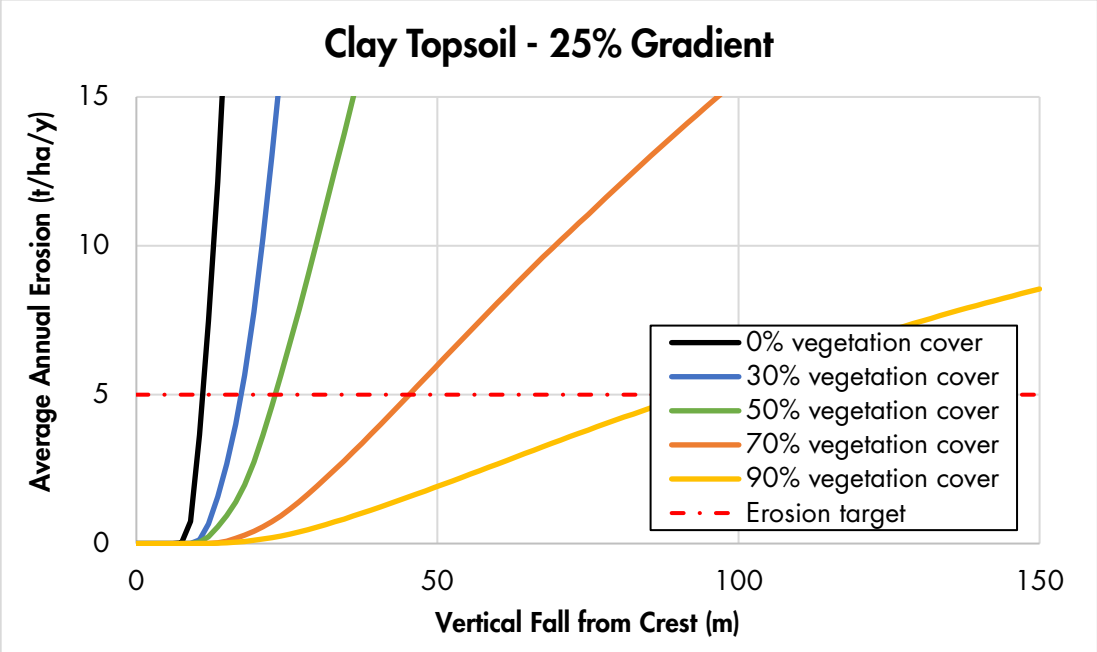

Figure 4: Predicted erosion rates on a 25% gradient outward-facing slope sheeted with clay topsoil.

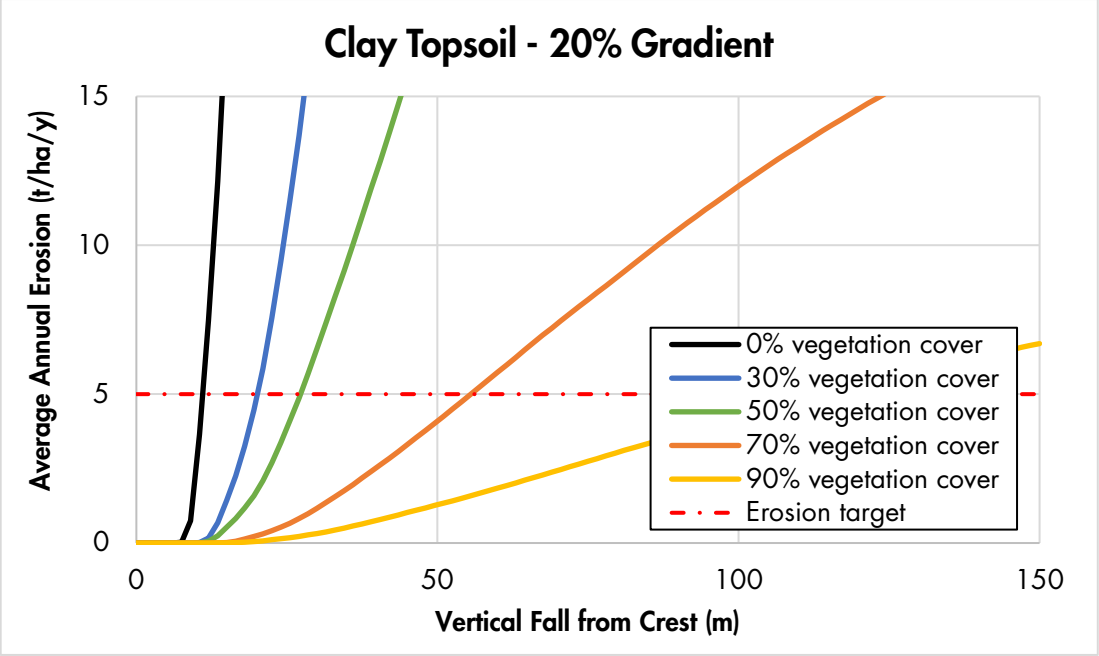

Figure 5: Predicted erosion rates on a 20% gradient outward-facing slope sheeted with clay topsoil.

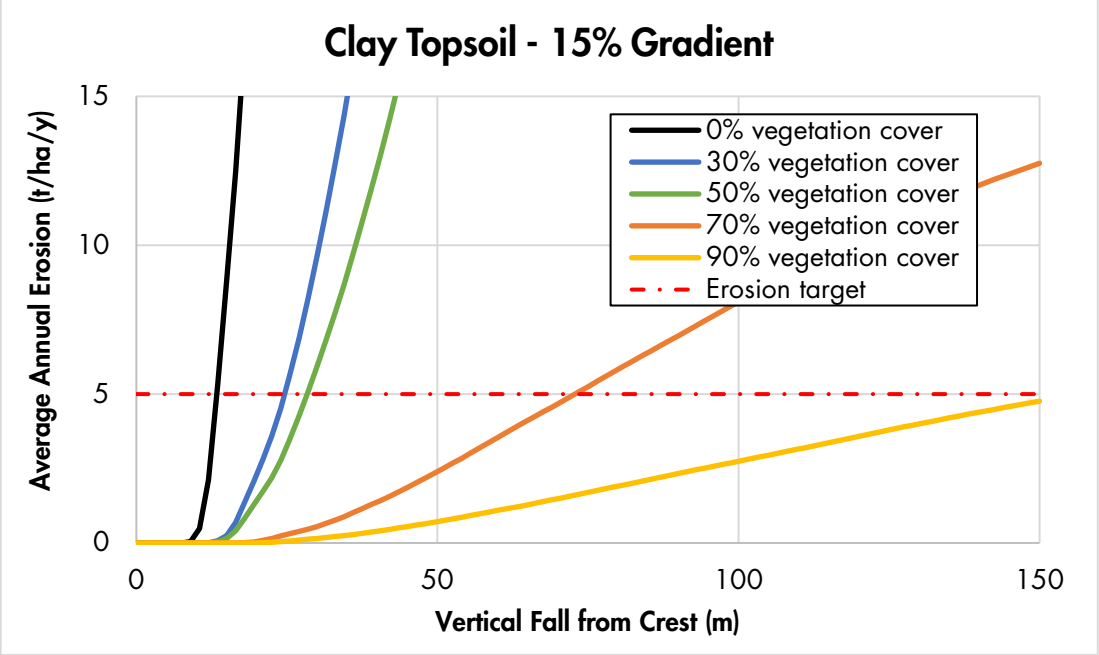

Figure 6: Predicted erosion rates on 15% gradient outward-facing slope sheeted with clay topsoil.

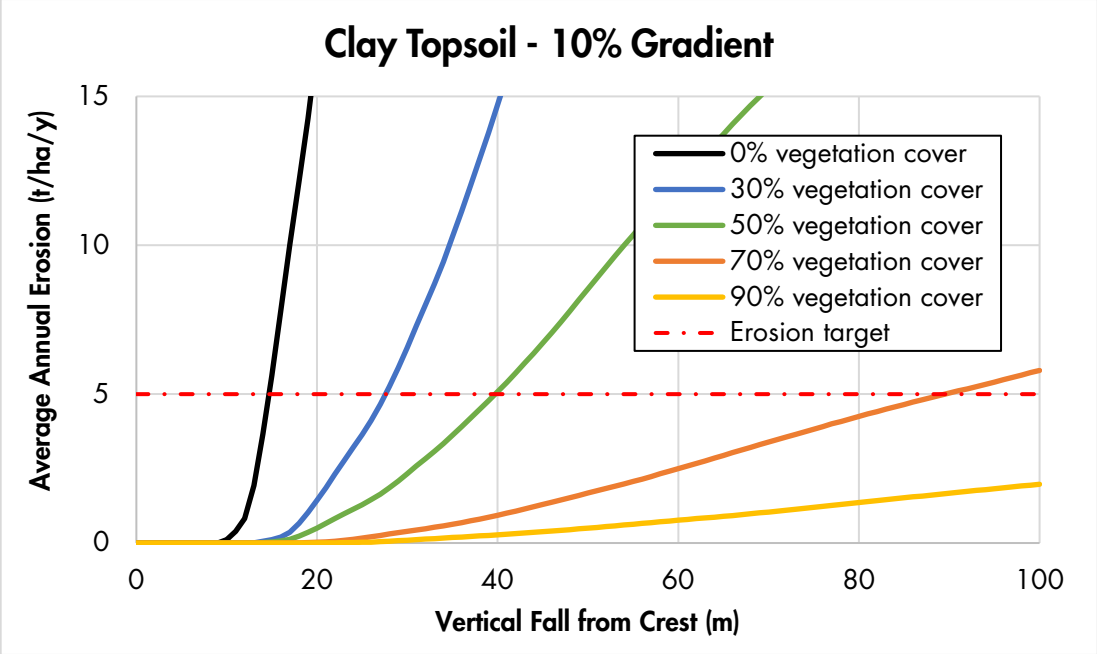

Figure 7: Predicted erosion rates on a 10% gradient outward-facing slope sheeted with clay topsoil.

4.2 Slopes surfaced with vegetated clay topsoil/fresh waste mixture

For the modelled clay topsoil mixed with fresh Permian waste, long-term WEPP erosion simulations indicate that gradients of 30% would require very high vegetation groundcover levels (>70%) (Figure 8). Slopes with gradients of 20–30% would also require high vegetation groundcover levels (>70%) (Figures 9–10), for slope lengths less than 1,000m. Slopes using clay topsoils mixed with fresh Permian waste are predicted to be erosionally stable only when gradients of 15% or less are adopted for slope lengths up to 1,000m, and when vegetation groundcover levels of 50% or greater are achieved (Figures 11–12).

The results indicate that incorporating Permian waste into the surface of the outward-facing slopes reduces the required vegetation groundcover compared to soils alone.

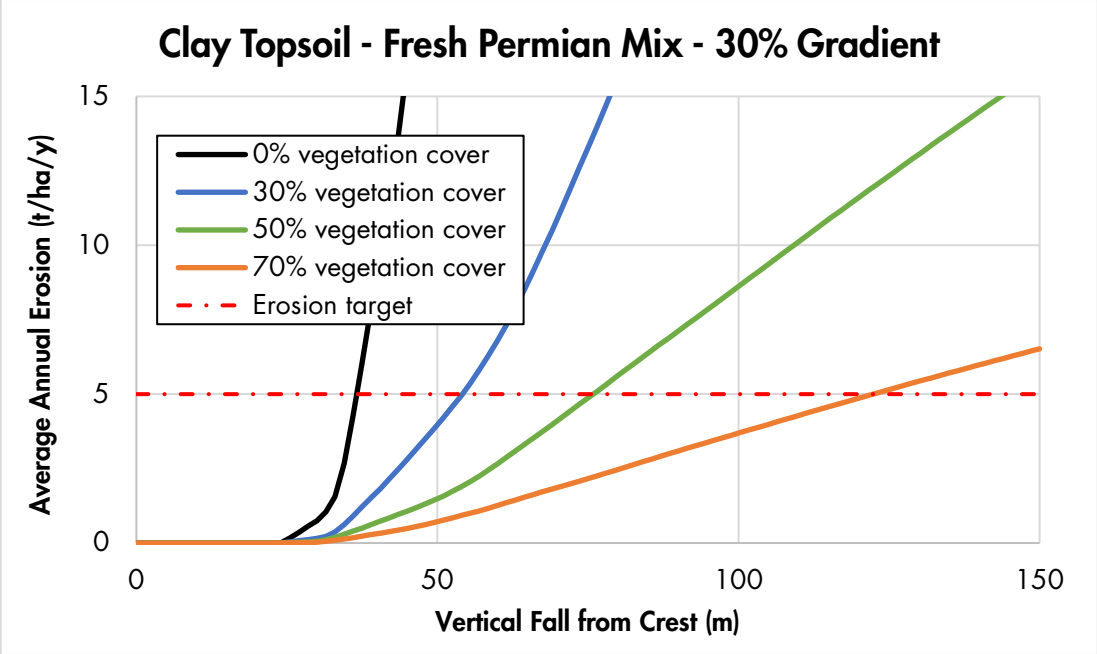

Figure 8: Predicted erosion rates on 30% gradient outward-facing slope sheeted with clay topsoil mixed with fresh Permian waste.

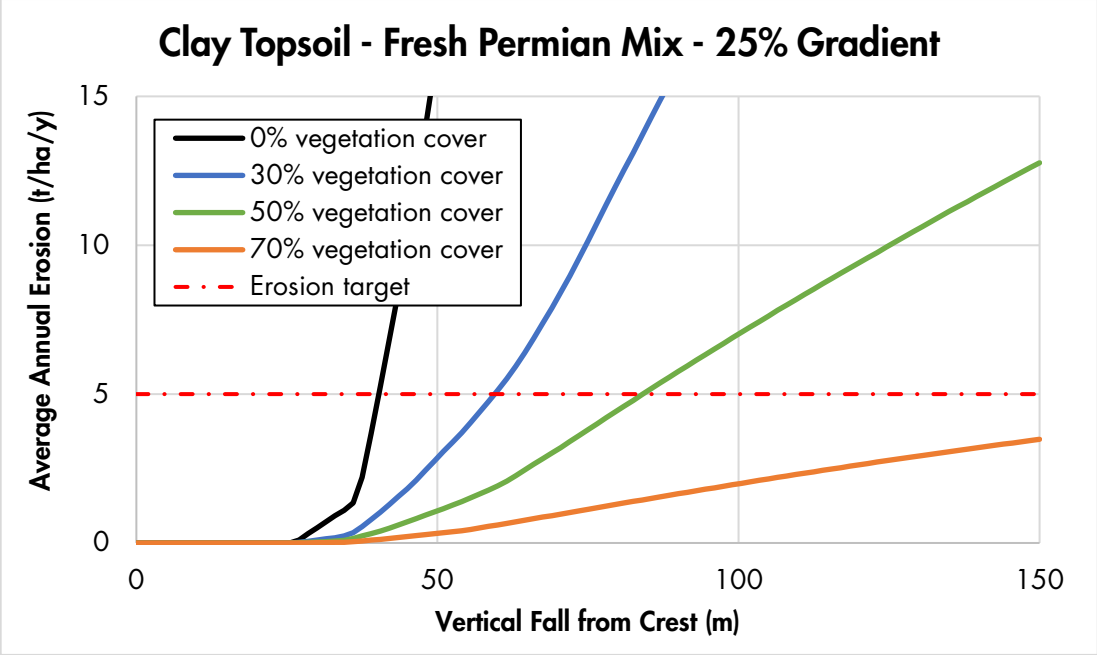

Figure 9: Predicted erosion rates on 25% gradient outward-facing slope sheeted with clay topsoil mixed with fresh Permian waste.

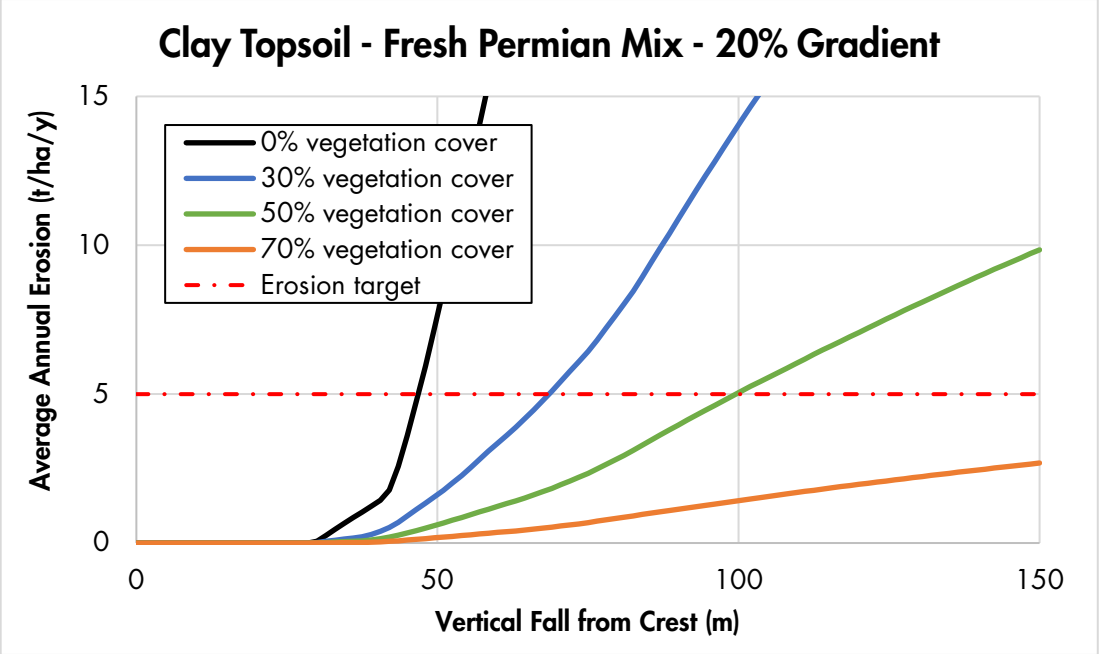

Figure 10: Predicted erosion rates on 20% gradient outward-facing slope sheeted with clay topsoil mixed with fresh Permian waste.

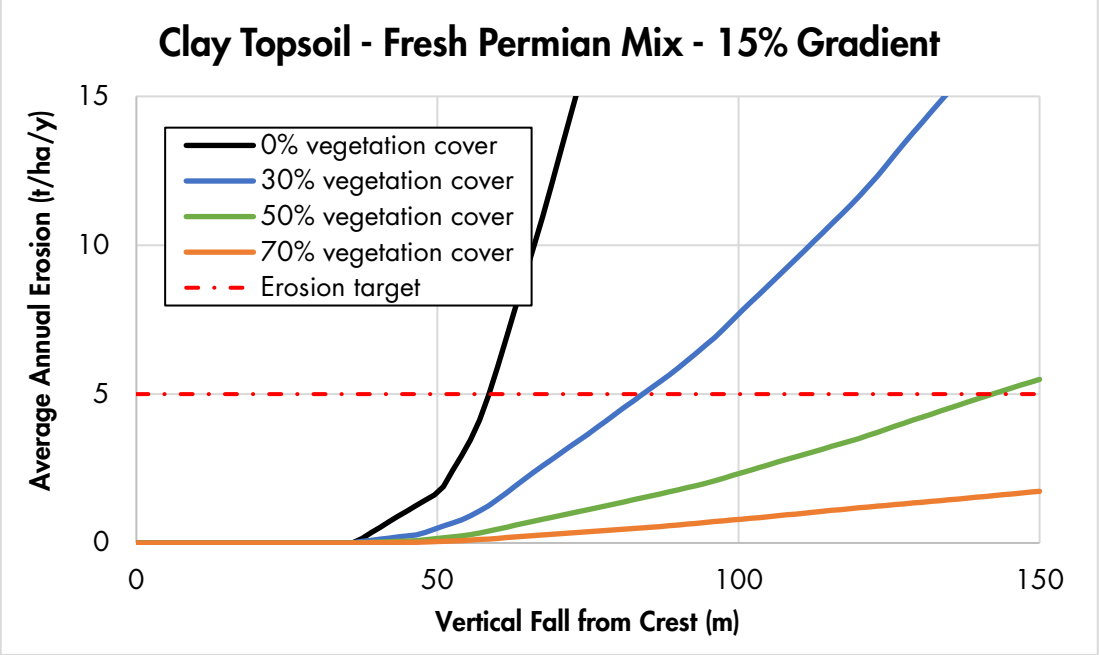

Figure 11: Predicted erosion rates on 15% gradient outward-facing slope sheeted with clay topsoil mixed with fresh Permian waste.

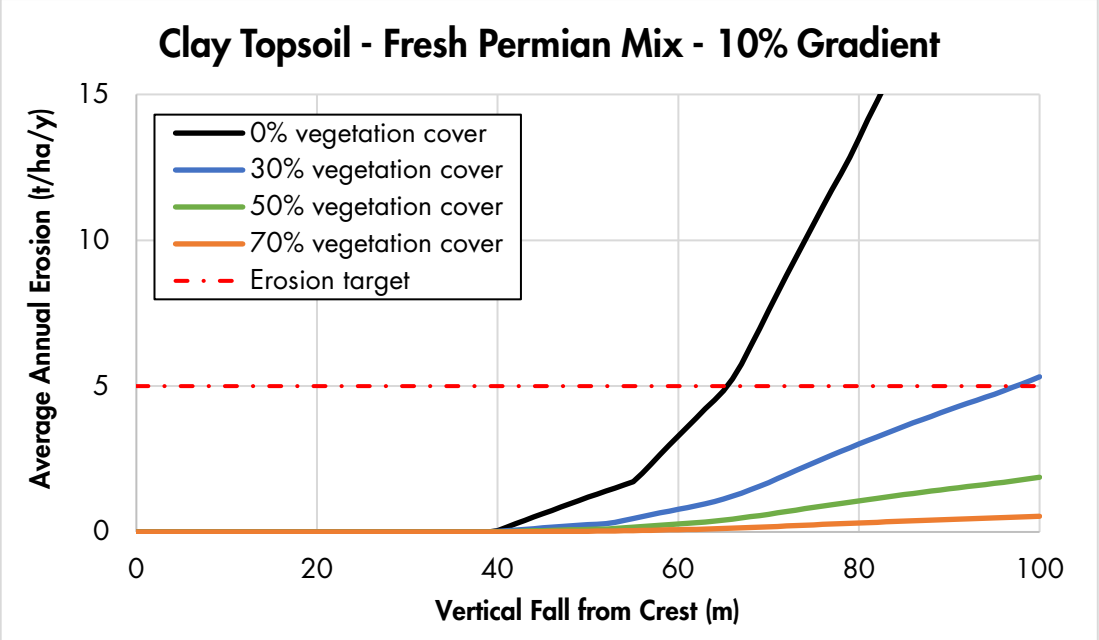

Figure 12: Predicted erosion rates on 10% gradient outward-facing slope sheeted with clay topsoil mixed with fresh Permian waste.

4.3 Slope surfaced with vegetated Permian waste

For the fresh Permian waste modelled, simulations indicate that slopes with gradients of 15–30% are predicted to be stable for a vegetation groundcover level of >50% (Figures 13–16) and slopes with gradients of 10% are predicted to be stable for a vegetation groundcover level of >30% (Figure 17). The results also indicate that using Permian waste on the outward-facing slopes would reduce the vegetation groundcover requirements compared to soils alone.

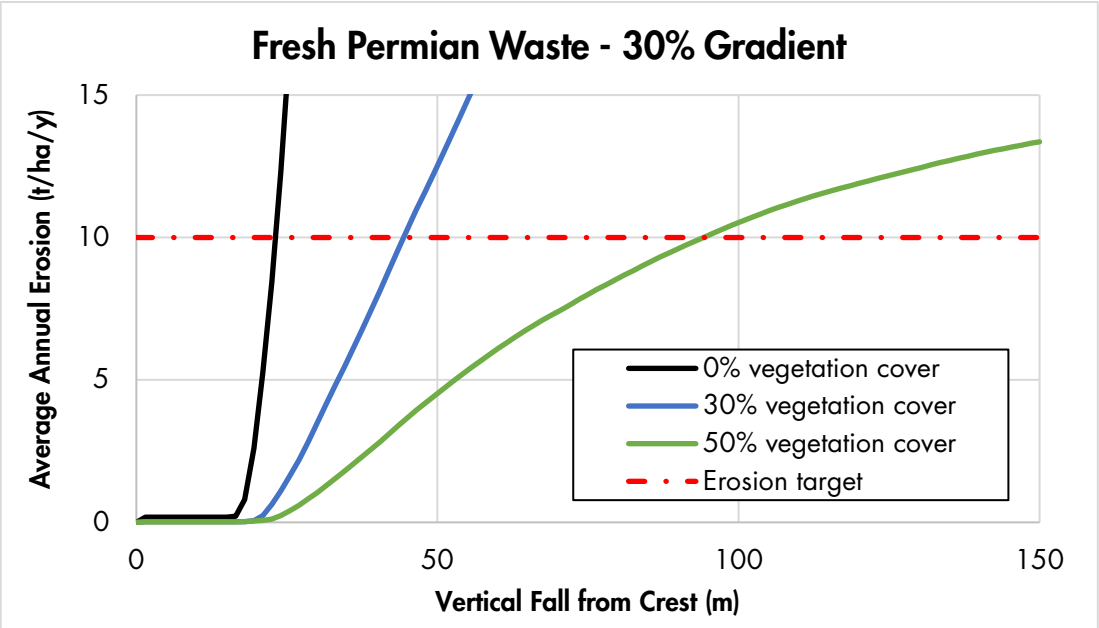

Figure 13: Predicted erosion rates on a 30% gradient inward-facing slope sheeted with fresh Permian waste.

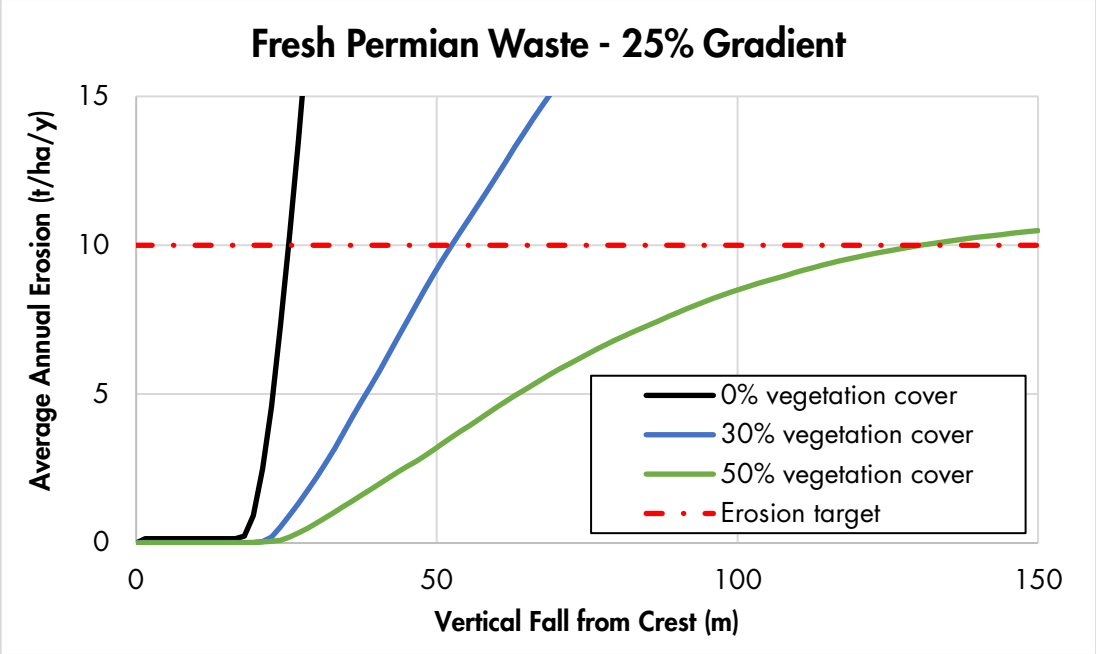

Figure 14: Predicted erosion rates on a 25% gradient inward-facing slope sheeted with fresh Permian waste.

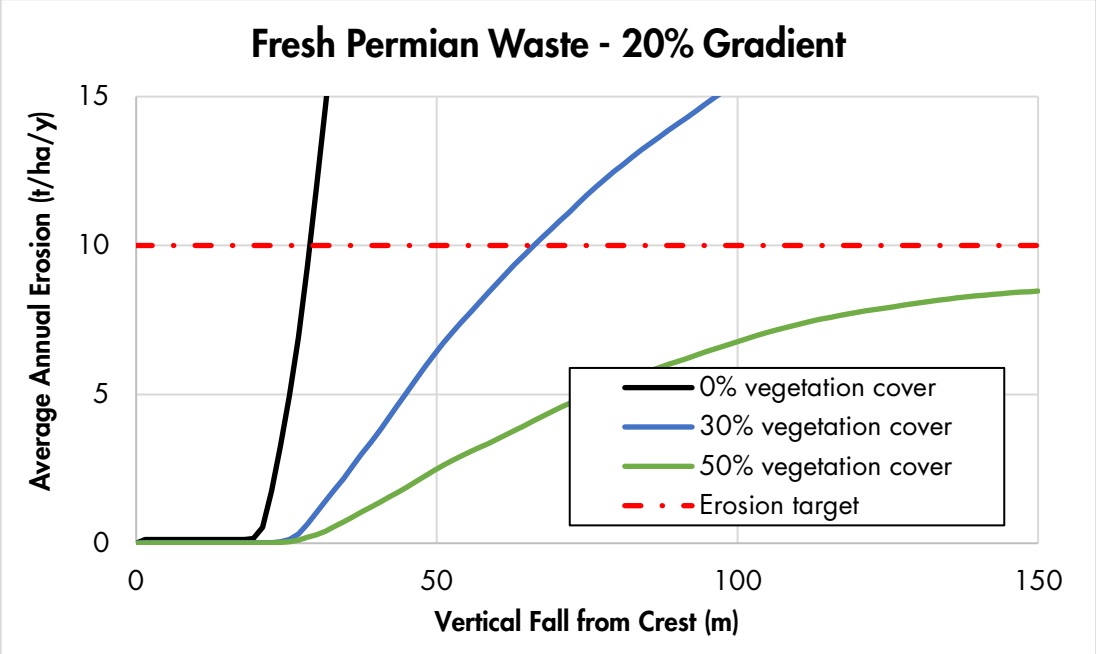

Figure 15: Predicted erosion rates on a 20% gradient inward-facing slope sheeted with fresh Permian waste.

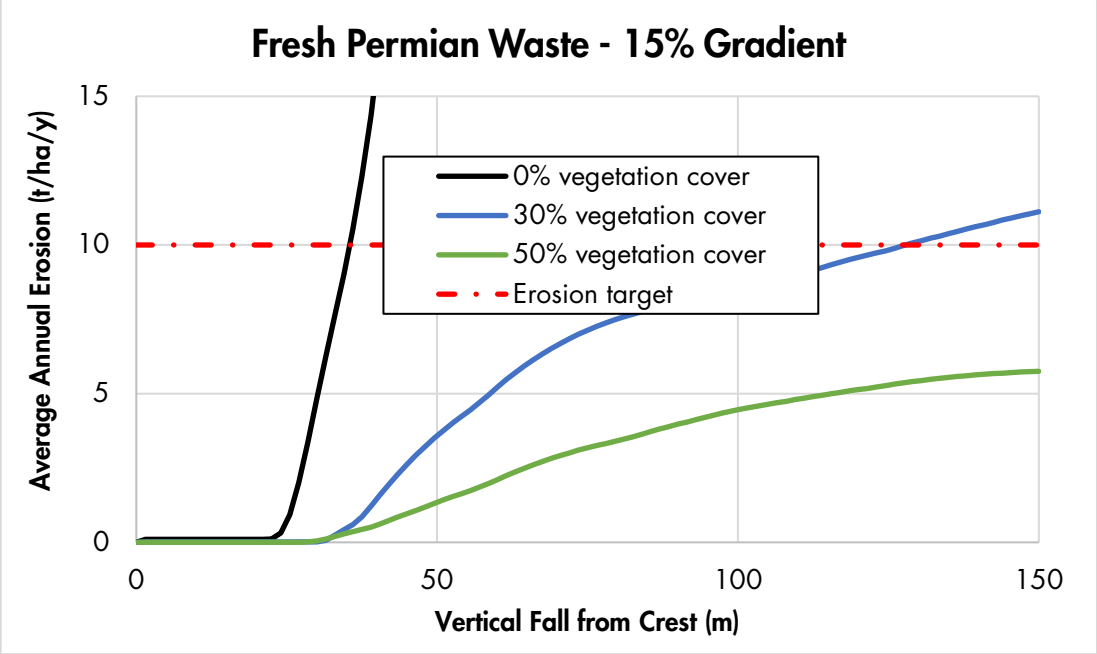

Figure 16: Predicted erosion rates on a 15% gradient inward-facing slope sheeted with fresh Permian waste.

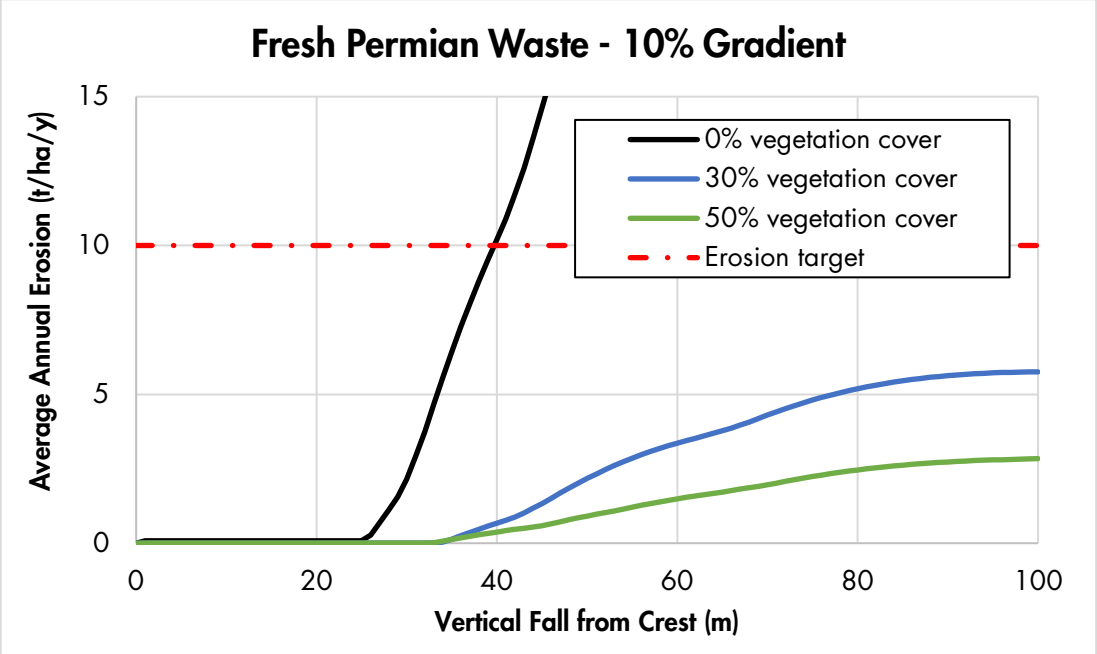

Figure 17: Predicted erosion rates on a 10% gradient inward-facing slope sheeted with fresh Permian waste.

4.4 Summary

Based on the erosion modelling results, it was concluded that use of vegetated clay soil mixed with fresh Permian waste and fresh Permian waste surfaces can be erosionally stable. Given this finding, SIBERIA landform evolution modelling used the following for the Goonyella, Airstrip, and Broadmeadow/Isaac landforms:

- Clay topsoil mixed with fresh Permian waste with vegetation groundcover levels of 50% for outward-facing batters with 15% gradient, and
- Fresh Permian waste with vegetation groundcover levels of 30% for inward-facing (low wall) batters with 30% gradient.

5 SIBERIA MODEL SETUP

5.1 Parameters

SIBERIA model parameters derived from WEPP simulations are shown in Table 3. As noted previously (Section 3.5.3), the vegetation groundcover levels assumed are conservative, with some variation to account for lower fertility of the wastes.

It should be noted that the method of deriving parameters attempts to ensure that the m_1 parameter is optimised so that SIBERIA simulations show a similar impact of slope length to that predicted by WEPP. However, because the two models use different methods to consider impacts of slope length, it is not reasonable to expect complete agreement between the two models over the full range of slope lengths considered.

Table 3: Estimated SIBERIA parameters.

Material	Vegetation Groundcover (%)	m_1	β_1	n_1
Clay topsoil – fresh Permian waste mix	50	1.3285	0.00103	1.5
Fresh Permian waste	30	1.1952	0.00105	1.5

5.2 Elevation models

Proposed 3-D final landform design files for GRM were provided by BMA. The landforms modelled included:

- Goonyella;
- Airstrip; and
- Broadmeadow/Isaac.

These landforms were designed on the basis of WEPP model runoff/erosion results for potential surface materials to be applied (Figures 18–20). These figures also show the regions in which different surface materials and vegetation groundcover levels were applied.

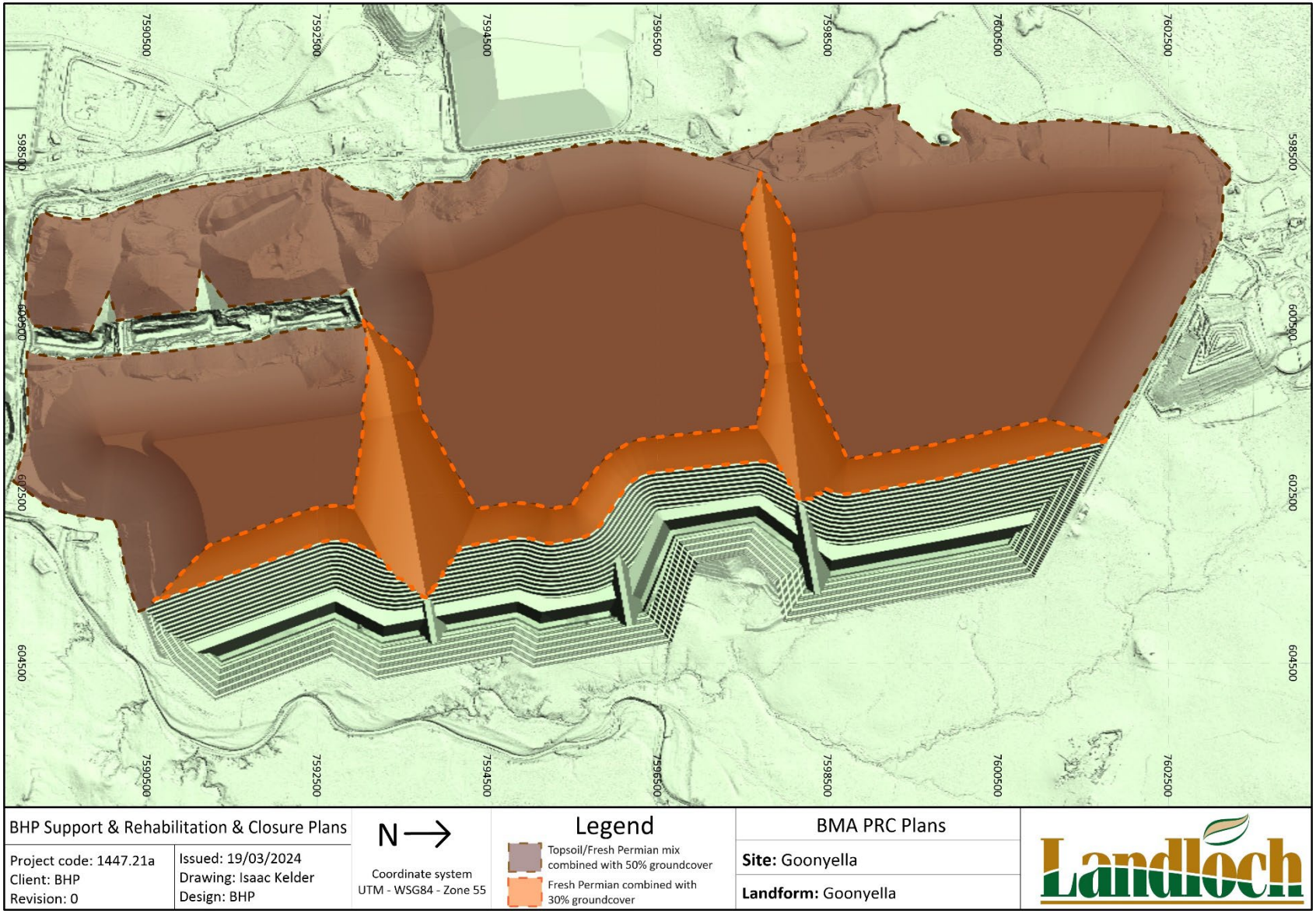

Figure 18: Goonyella rehabilitation landform.

Figure 19: Airstrip rehabilitation landform.

Figure 20: Broadmeadow/Isaac rehabilitation landform.

6 LANDFORM EVOLUTION MODEL OUPUTS

Using input parameters derived for the materials to be used on the landforms, the SIBERIA model was run for 300 years, with outputs provided between 50 years and 300 years. At each output year, visualisations of the rate of erosion and gully development are provided, along with a table that includes rates for each material on the landform. Rates of gullying depth that exceeds 0.3m are highlighted in the visualisations. Visualisations for 300 years are shown below. However, all visualisations (50, 100, 200, and 300 years) are provided in Appendix A.

6.1 Goonyella landform

Rehabilitation of the Goonyella landform is planned to use vegetated clay topsoil combined with fresh waste rock on the outward-facing slopes and vegetated fresh Permian waste on the inward-facing (low wall) slopes (Figure 18). SIBERIA modelling has assumed a vegetation groundcover of 50% for the outward-facing heavy clay topsoil surfaces and 30% for the inward-facing Permian waste surfaces.

Predicted erosion rates shown in Table 4 indicate that at a vegetation groundcover level of 50%, predicted erosion rates of the outward-facing batter slopes are below the target level of 5t/ha/y for the entire simulation period. If vegetation groundcover of the inward-facing batters is 30% (or greater), then erosion rates of these batters are also predicted to be below the target rate (10t/ha/y). This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that using Permian waste on the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to the soil mix.

Table 4: Predicted erosion rates and gully depths for the Goonyella landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay topsoil - Fresh Permian waste mix, with 50% vegetation groundcover			
50	-	3.1	12
100	-	2.6	22
200	-	2.6	32
300	0.3	2.6	42
Fresh Permian waste with 30% vegetation groundcover			
50	-	4.2	16
100	-	4.2	32
200	-	4.1	48
300	0.3	3.9	63

Figure 21 shows SIBERIA output after 300 years of simulation. The SIBERIA output indicates that the Goonyella landform is not prone to significant levels of gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

Some gully erosion is predicted to occur after 300 years for both the vegetated clay topsoil combined with fresh waste rock surfaces and the vegetated fresh Permian waste covered surfaces. However, given the underlying secondary growth media material is likely to be erosion-resistant fresh Permian waste, the risk of exposing problematic (more erodible) materials and for erosion to accelerate over the long-term is considered low. Gully erosion should be monitored as part of the rehabilitation monitoring process and remediated if assessed as required by an appropriately qualified person to achieve the post-mining land use.

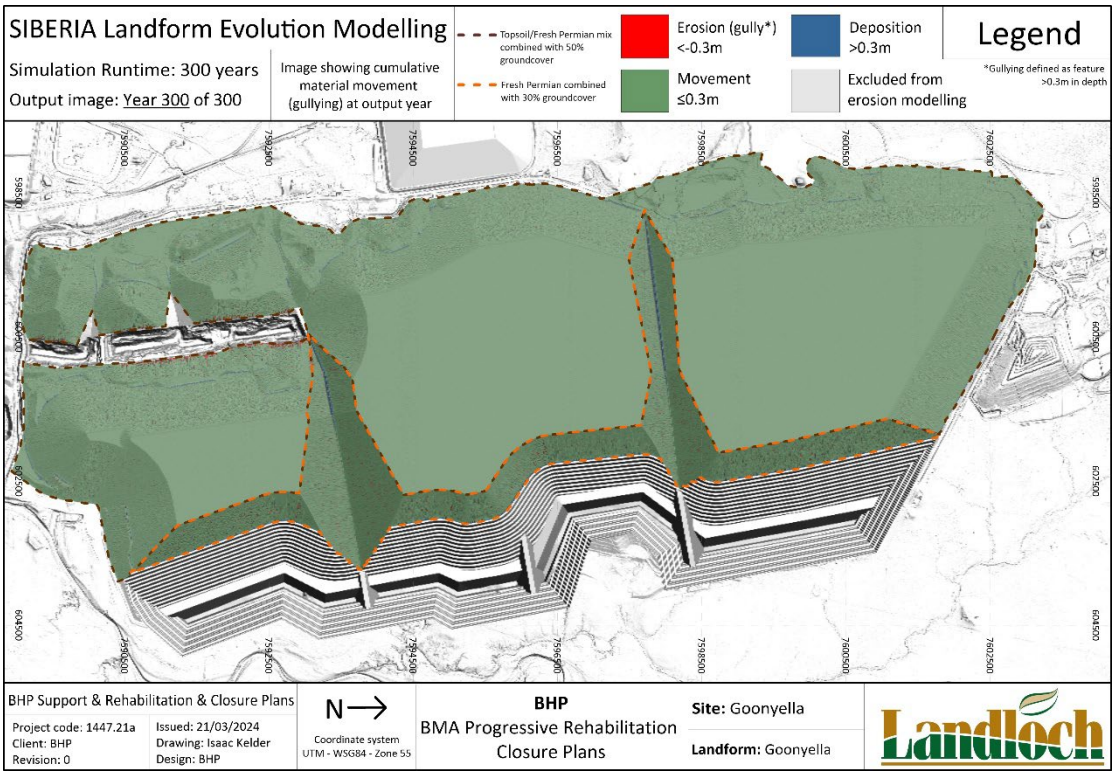

Figure 21: Predicted erosion and deposition depths of the Goonyella rehabilitation landform after 300 years.

6.2 Airstrip landform

Rehabilitation of the Airstrip landform has used vegetated clay topsoil combined with fresh waste rock on all slopes (Figure 19). SIBERIA modelling has assumed a vegetation groundcover of 50% for these surfaces.

Predicted erosion rates shown in Table 5 indicate that at a vegetation groundcover level of 50%, predicted erosion rates of the batter slopes will be below the target level of 5t/ha/y. This indicates lower vegetation groundcover levels can meet the target erosion rate.

Table 5: Predicted erosion rates and gully depths for the Airstrip landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay topsoil - Fresh Permian waste mix, with 50% vegetation groundcover			
50	-	2.1	8
100	-	1.6	14
200	-	1.4	20
300	-	1.3	25

Figure 22 shows SIBERIA output after 300 years of simulation. The SIBERIA output indicates that the Airstrip landform is not prone to significant levels of gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved. Some rill erosion is predicted to occur in areas where the slope interacts with the final void.

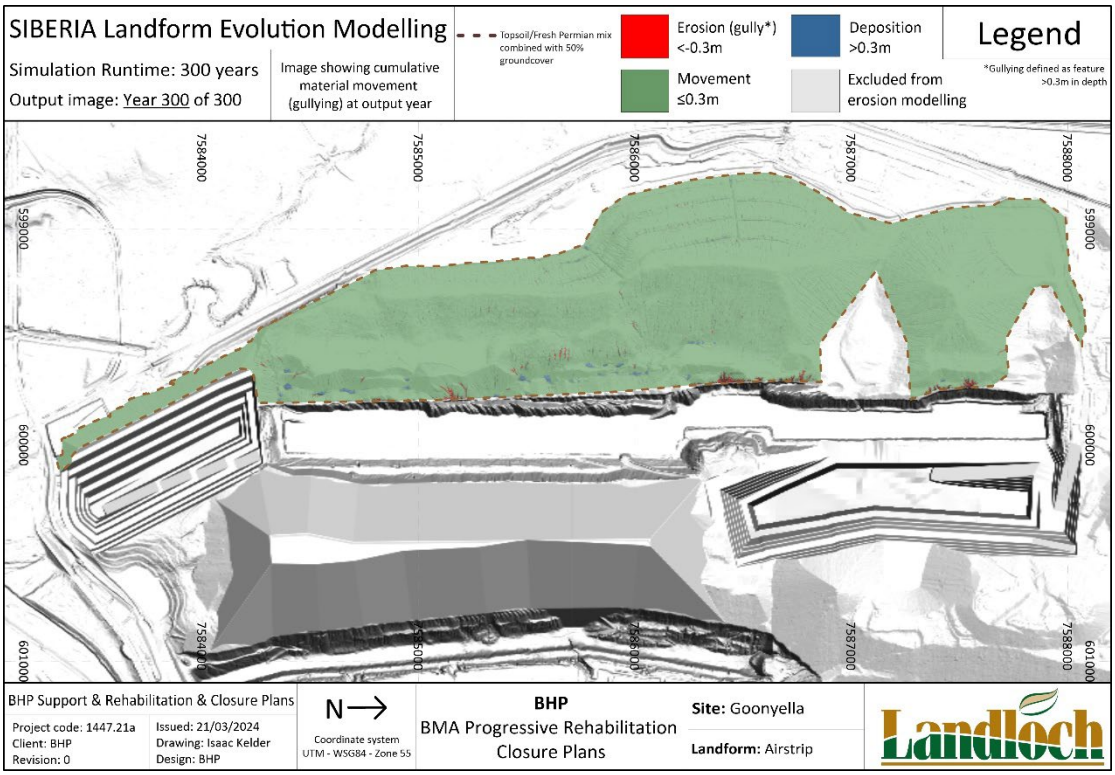

Figure 22: Predicted erosion and deposition depths of the Airstrip rehabilitation landform after 300 years.

6.3 Broadmeadow/Isaac landform

Rehabilitation of the Broadmeadow/Isaac landform is planned to use vegetated clay topsoil combined with fresh waste rock on the outward-facing slopes and vegetated fresh Permian waste on the inward-facing (low wall) slopes (Figure 20). SIBERIA modelling has assumed a vegetation groundcover of 50% for the outward-facing surfaces and 30% for the inward-facing surfaces.

Predicted erosion rates shown in Table 6 indicate that at a vegetation groundcover level of 50%, predicted erosion rates of the outward-facing batter slopes are below the target

level (5t/ha/y). If vegetation groundcover of the inward-facing batters is 30% or greater, batter slope erosion rates are also predicted to be below the target rate (10t/ha/y). This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that using Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to the soil mix.

Figure 23 shows SIBERIA output after 300 years of simulation. The SIBERIA output indicates that the Broadmeadow/Isaac landform is not prone to significant levels of gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved. Some gully erosion is predicted to occur after 300 years for both the vegetated clay topsoil combined with fresh waste rock surfaces and the vegetated fresh Permian waste covered surfaces. This occurs at the interface between a new dump area and existing surface. The result is an artefact of the elevations within 3-D design file supplied; in reality this transition area will be smoother than modelled and this area is not likely to erode at rates that would increase the risk of rill or gully erosion. However, given the underlying secondary growth media material is likely to be erosion-resistant fresh Permian waste, the risk of exposing problematic (more erodible) materials and for erosion to accelerate over the long-term is considered low. Gully erosion should be monitored as part of the rehabilitation monitoring process and remediated if assessed as required by an appropriately qualified person to achieve the post-mining land use.

Table 6: Predicted erosion rates and gully depths for the Broadmeadow/Isaac landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay topsoil - Fresh Permian waste mix, with 50% vegetation groundcover			
50	-	4.0	16
100	-	2.8	26
200	-	2.3	35
300	0.3	2.1	43
Fresh Permian waste with 30% vegetation groundcover			
50	-	6.4	24
100	-	5.4	45
200	-	5.3	65
300	0.3	5.3	86

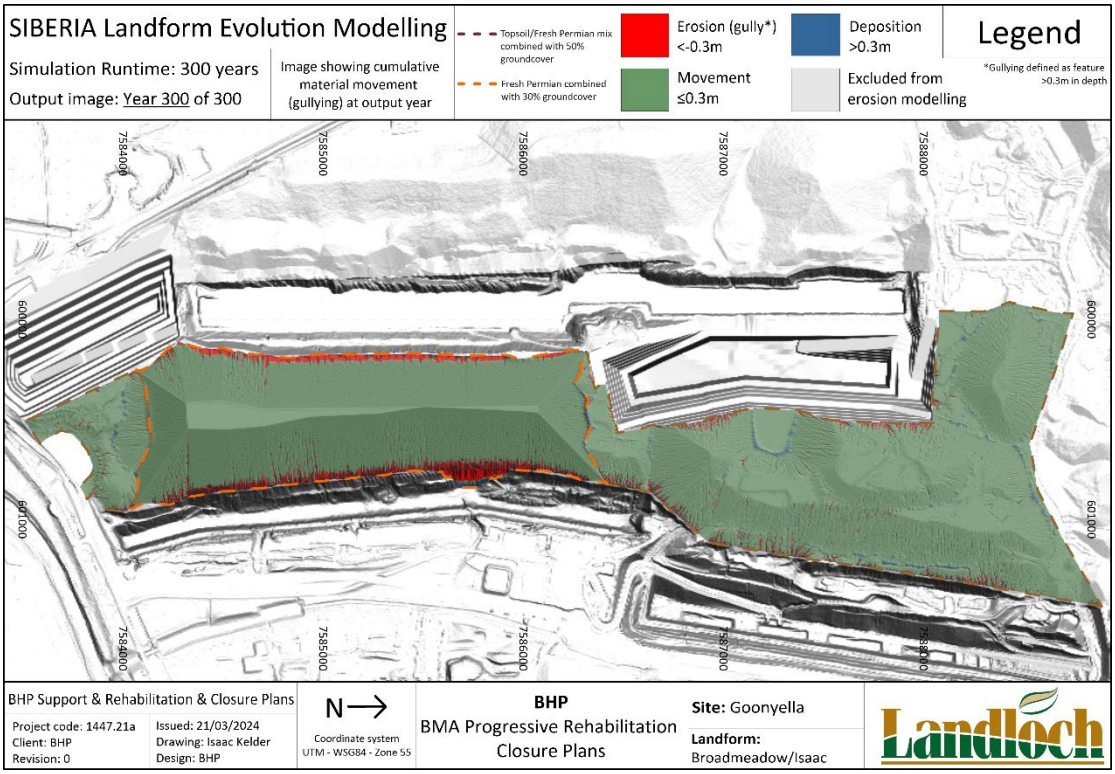

Figure 23: Predicted erosion and deposition depths of the Broadmeadow/Isaac rehabilitation landform after 300 years.

7 WATER MANAGEMENT

Water management recommendations for waste landforms at GRM are summarised as:

- No construction of permanent berms or graded banks and rock chutes on batter slopes. Temporary berms are to be used only where considered absolutely essential.
- Prevention of discharge from the relatively small areas of level dump tops onto the dump slopes is critical.

Simulations of runoff and erosion indicate that – once vegetation is established – there is no requirement for installation of berms or graded banks to reduce slope length and erosion risk. It is anticipated that batter slope rehabilitation will be carried out progressively, working gradually up from the bottom of the slope, so that there will be increasing vegetation groundcover on lower sections of a slope as the works gradually (over a number of years) move towards the top of the landform.

It should be noted that – on well-vegetated surfaces – annual rainfall excess on average will be 2–5% of annual rainfall, so preventing water discharge onto the slopes results in only a very small increase in the amount of water retained on the land surface and made available for vegetation growth. It is also noted that the quite small increase in drainage to depth that will be caused by retention of runoff on the tops of the landforms will be insignificant.

8 CONCLUSIONS

Both runoff/erosion simulations using the WEPP model and landform evolution simulations using the SIBERIA model indicate that the proposed waste landforms at GRM can be expected to be stable over the long term (up to 300 years) provided the correct surface materials and the required levels of vegetation groundcover for those materials are achieved.

This report details materials and associated vegetation groundcover levels for the representative materials available at the time of sampling. The modelled vegetation groundcover levels are conservative. The modelling detailed in this report is intended to support the total groundcover levels in the EA acceptance criteria and is not intended to prescribe exact vegetation groundcover levels.

Water management recommendations for the site include the prevention of discharge from the small areas of level dump tops onto the slopes and avoidance of any permanent bunds or rock chutes on batter slopes.

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APPENDIX A: SIBERIA VISUALISATIONS

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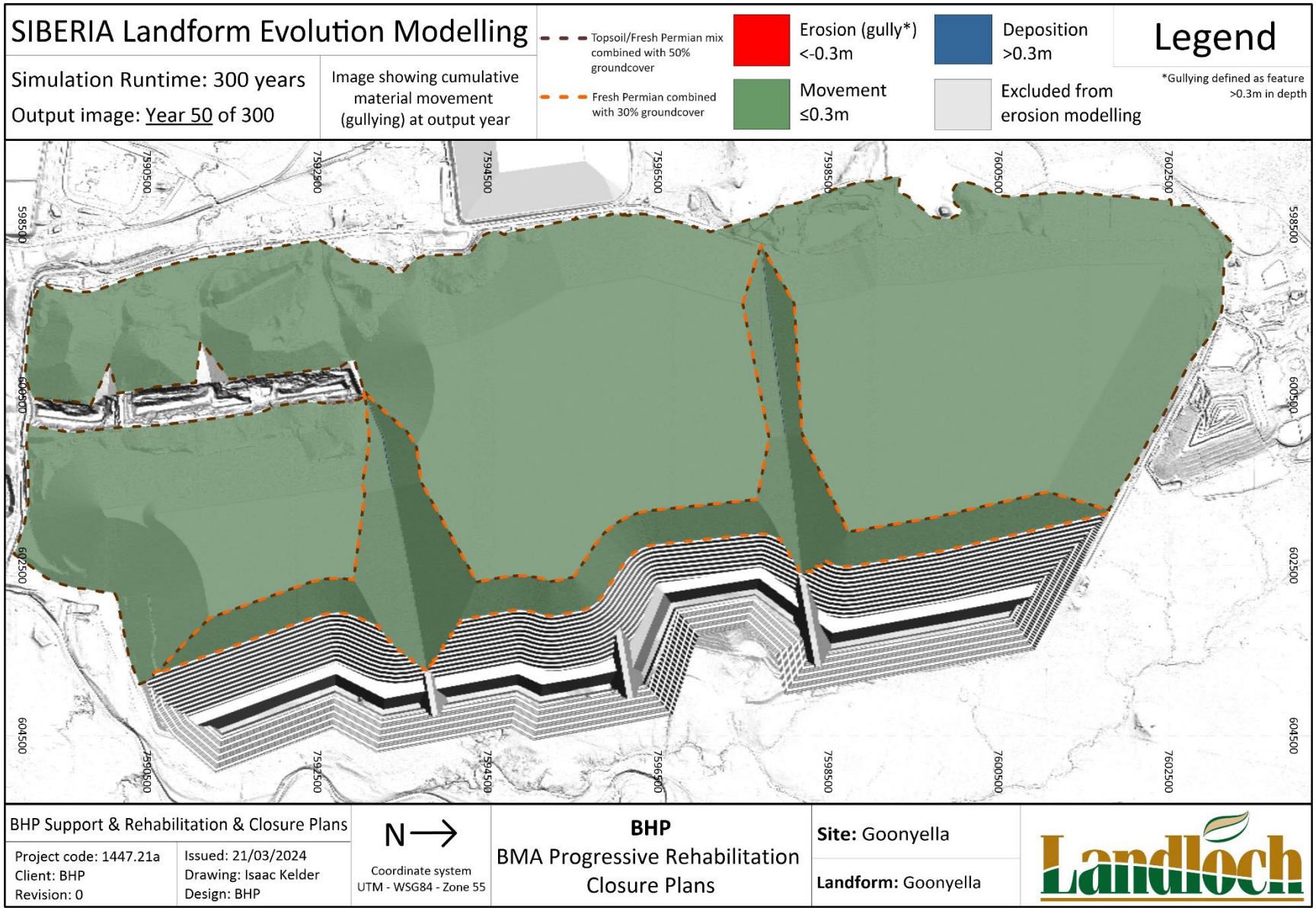

Figure A-1: Predicted erosion and deposition depths of the Goonyella rehabilitation landform after 50 years.

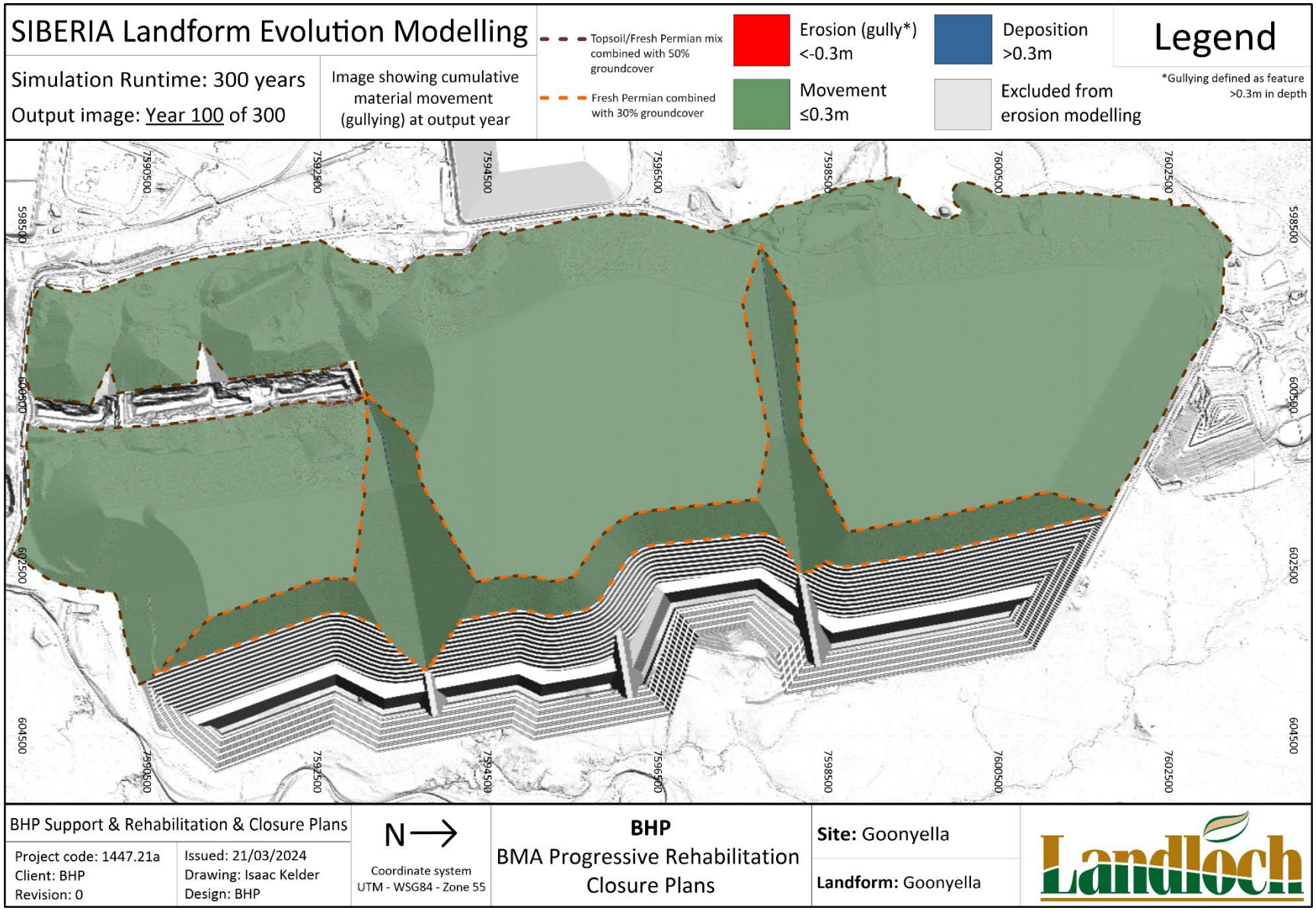

Figure A-2: Predicted erosion and deposition depths of the Goonyella rehabilitation landform after 100 years.

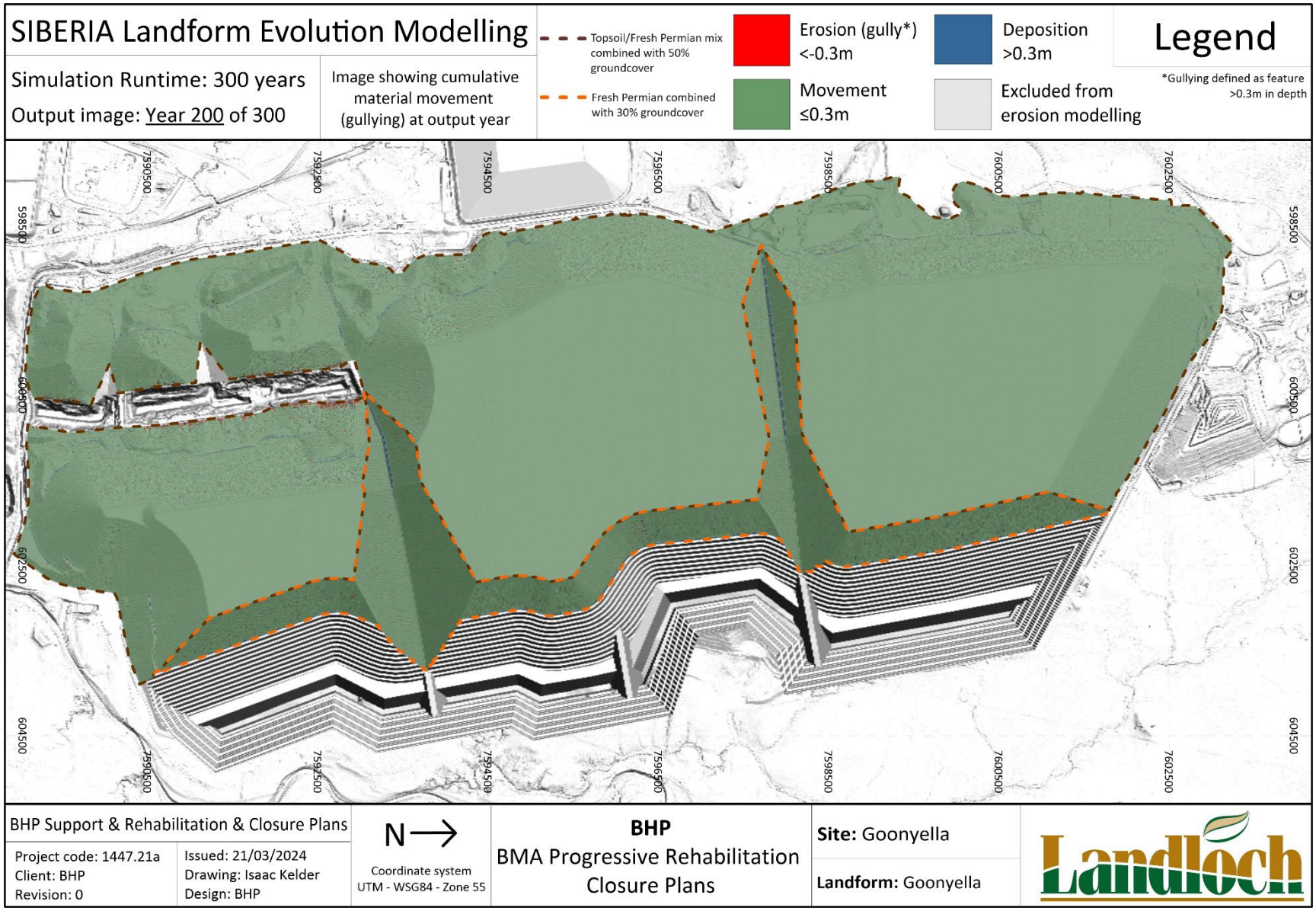

Figure A-3: Predicted erosion and deposition depths of the Goonyella rehabilitation landform after 200 years.

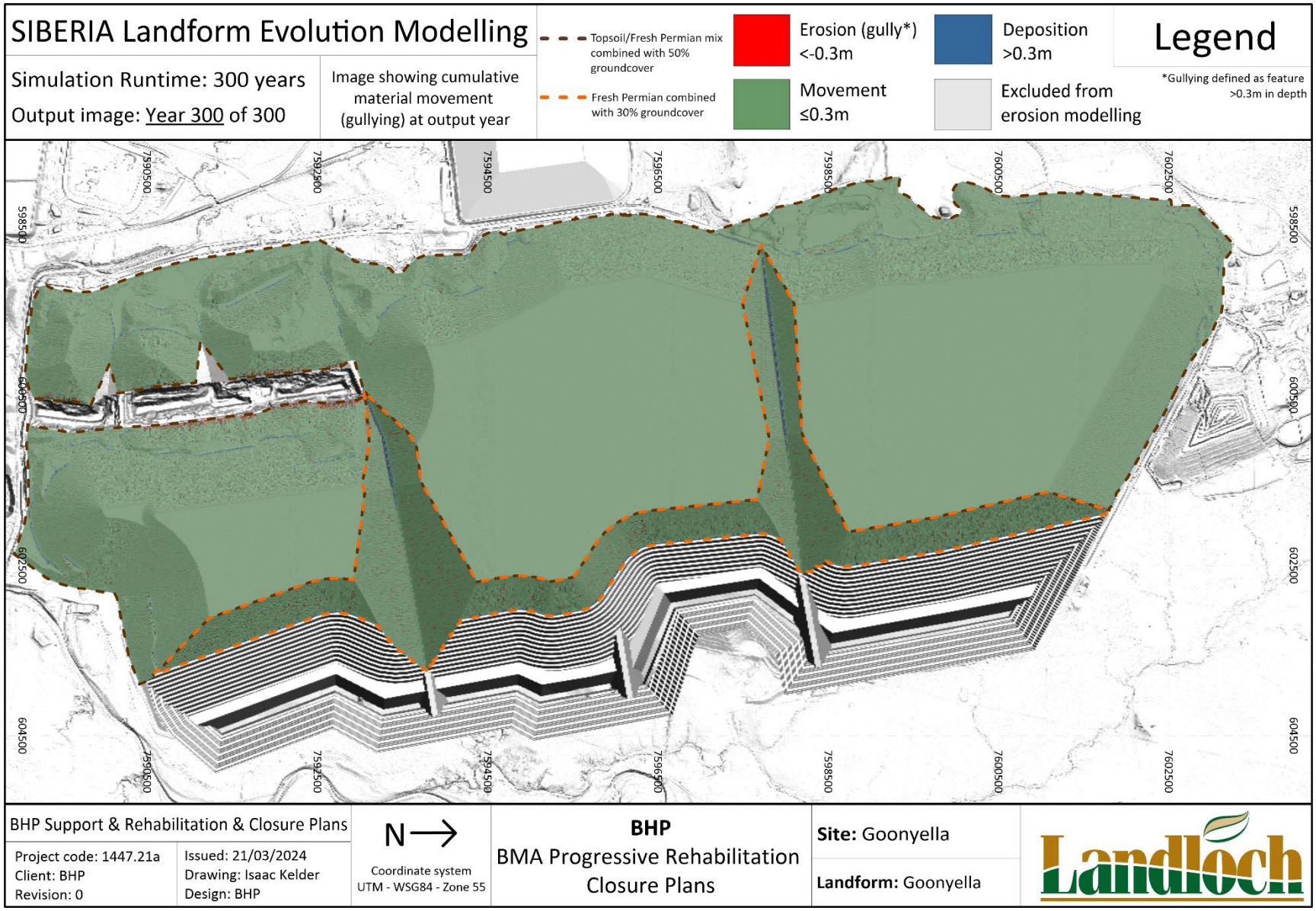

Figure A-4: Predicted erosion and deposition depths of the Goonyella rehabilitation landform after 300 years.

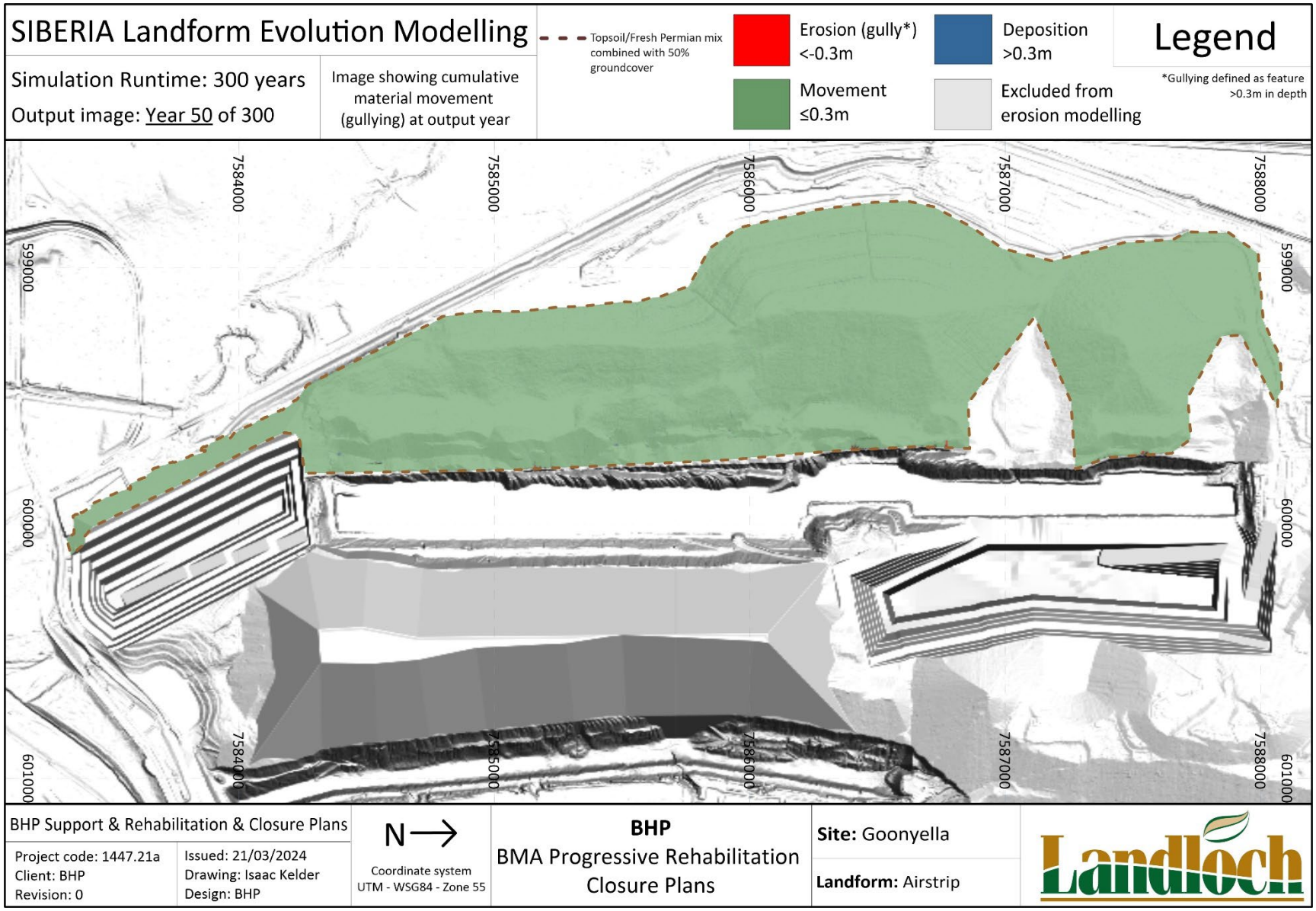

Figure A-5: Predicted erosion and deposition depths of the Airstrip rehabilitation landform after 50 years.

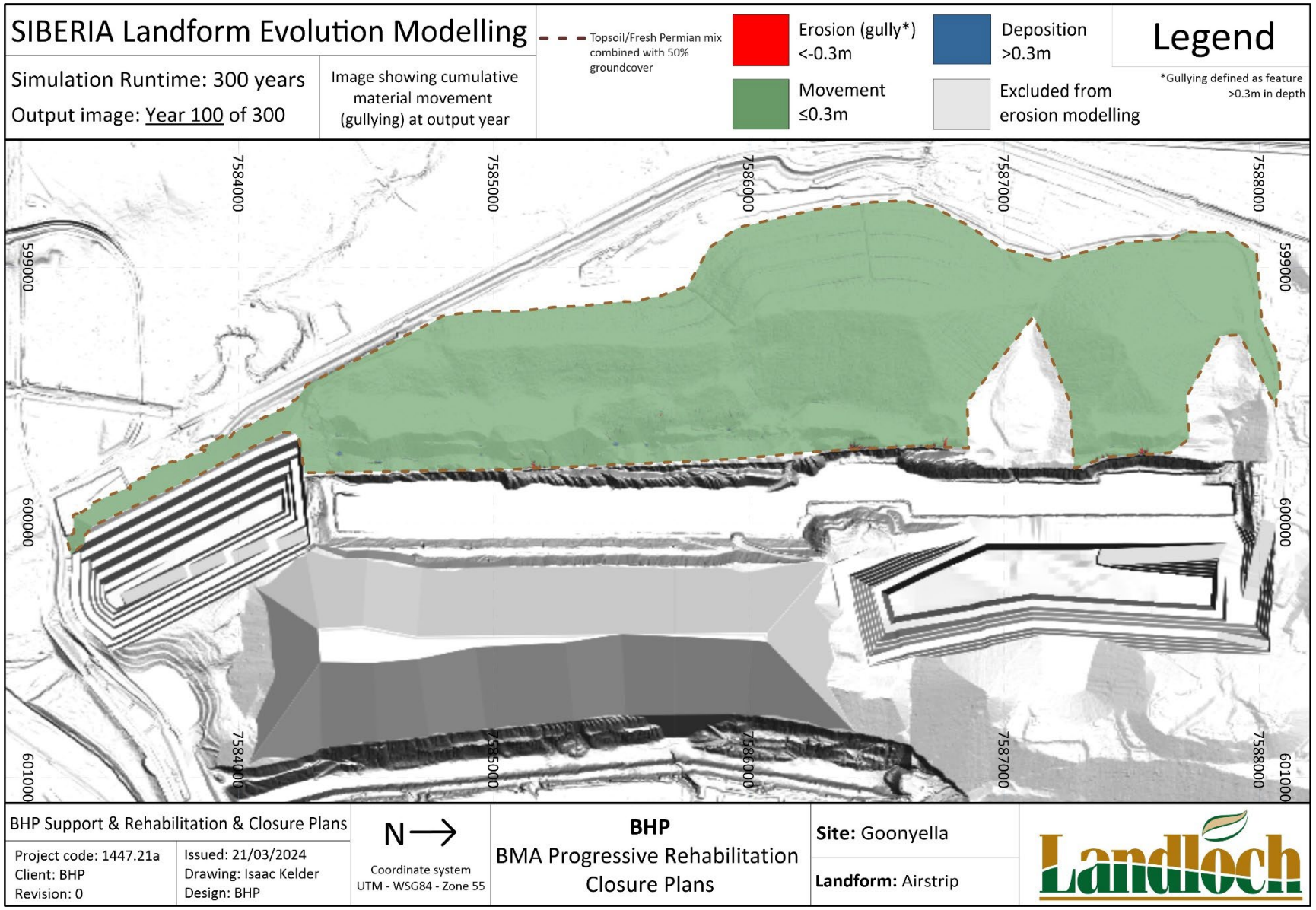

Figure A-6: Predicted erosion and deposition depths of the Airstrip rehabilitation landform after 100 years.

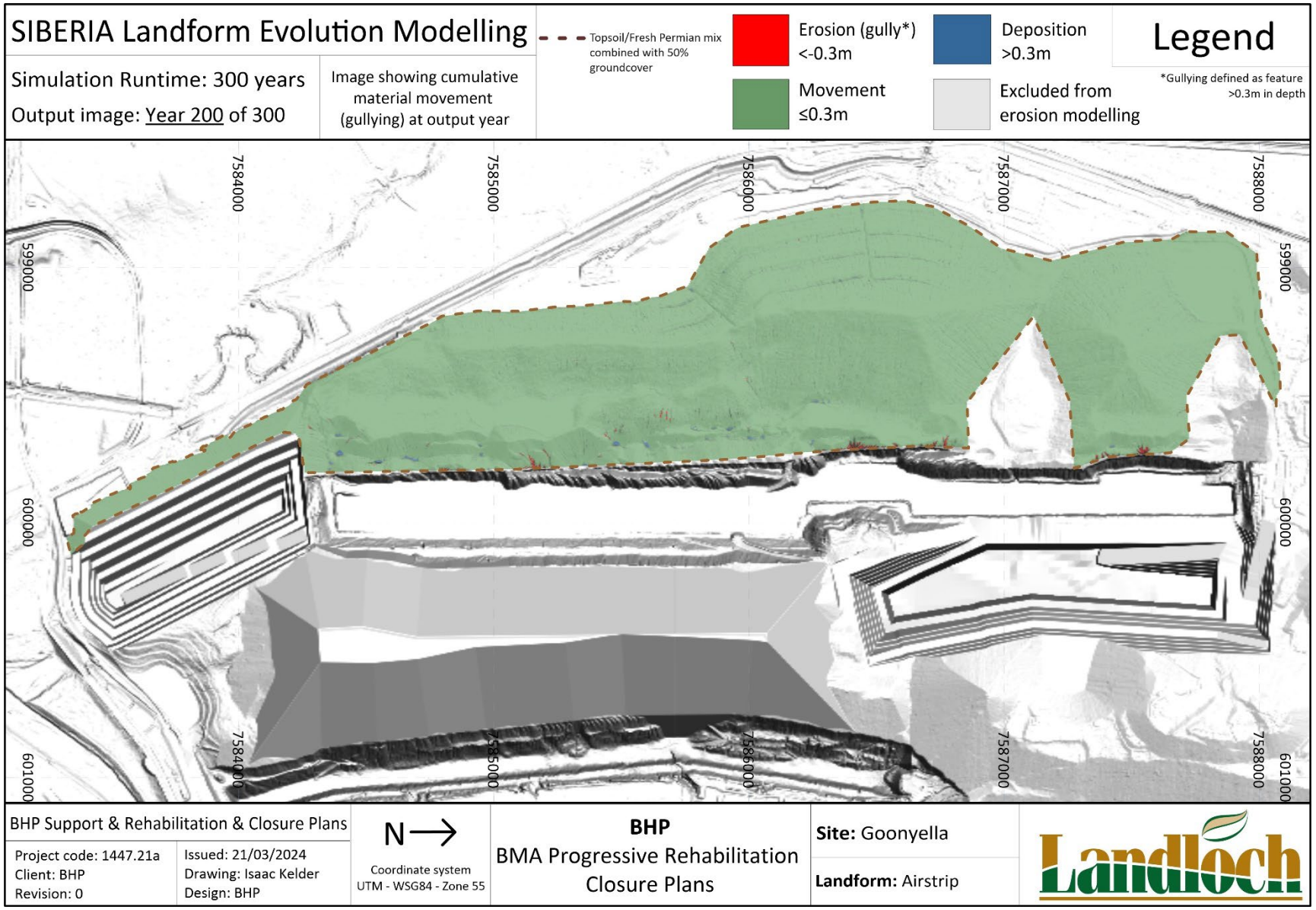

Figure A-7: Predicted erosion and deposition depths of the Airstrip rehabilitation landform after 200 years.

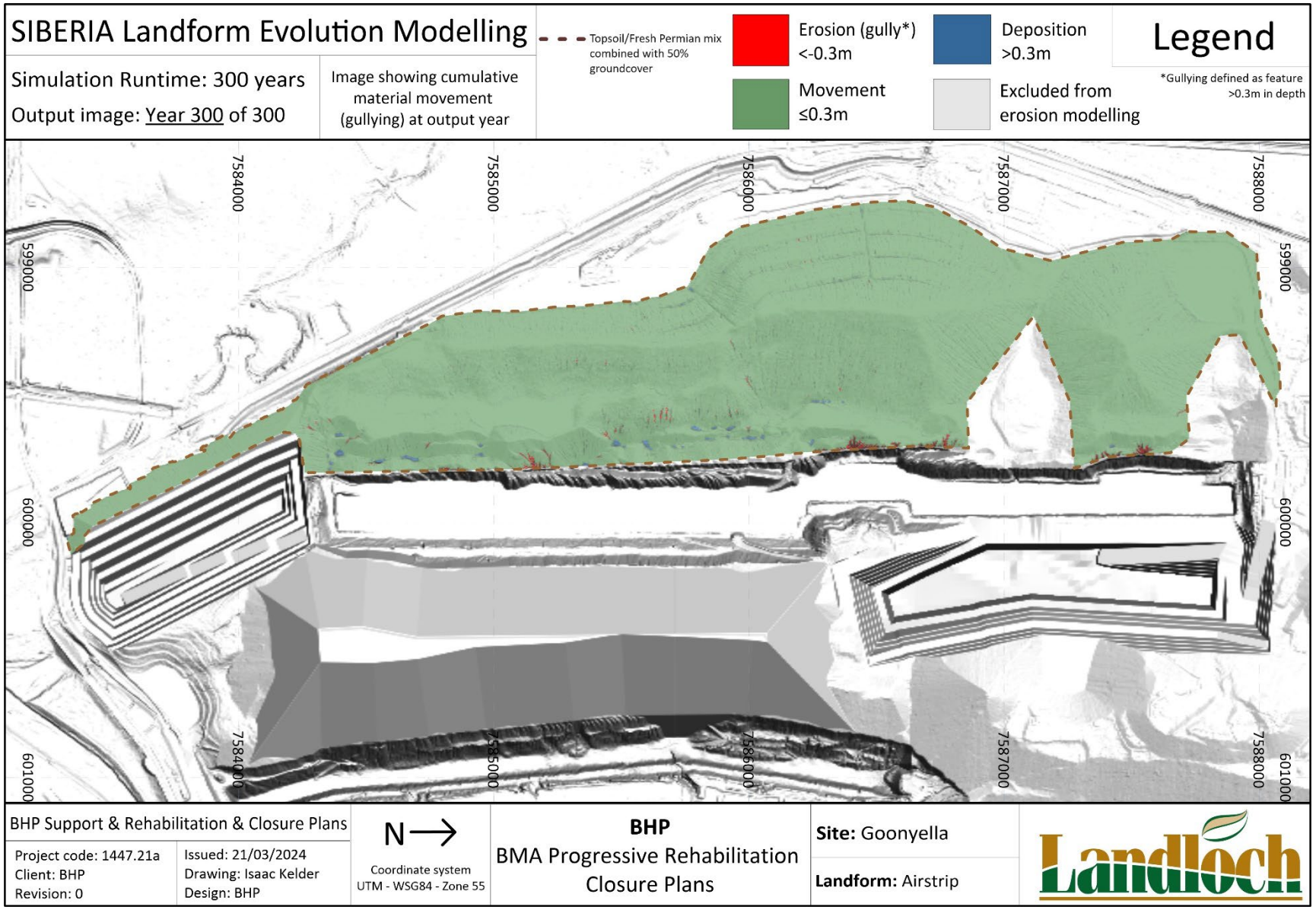

Figure A-8: Predicted erosion and deposition depths of the Airstrip rehabilitation landform after 300 years.

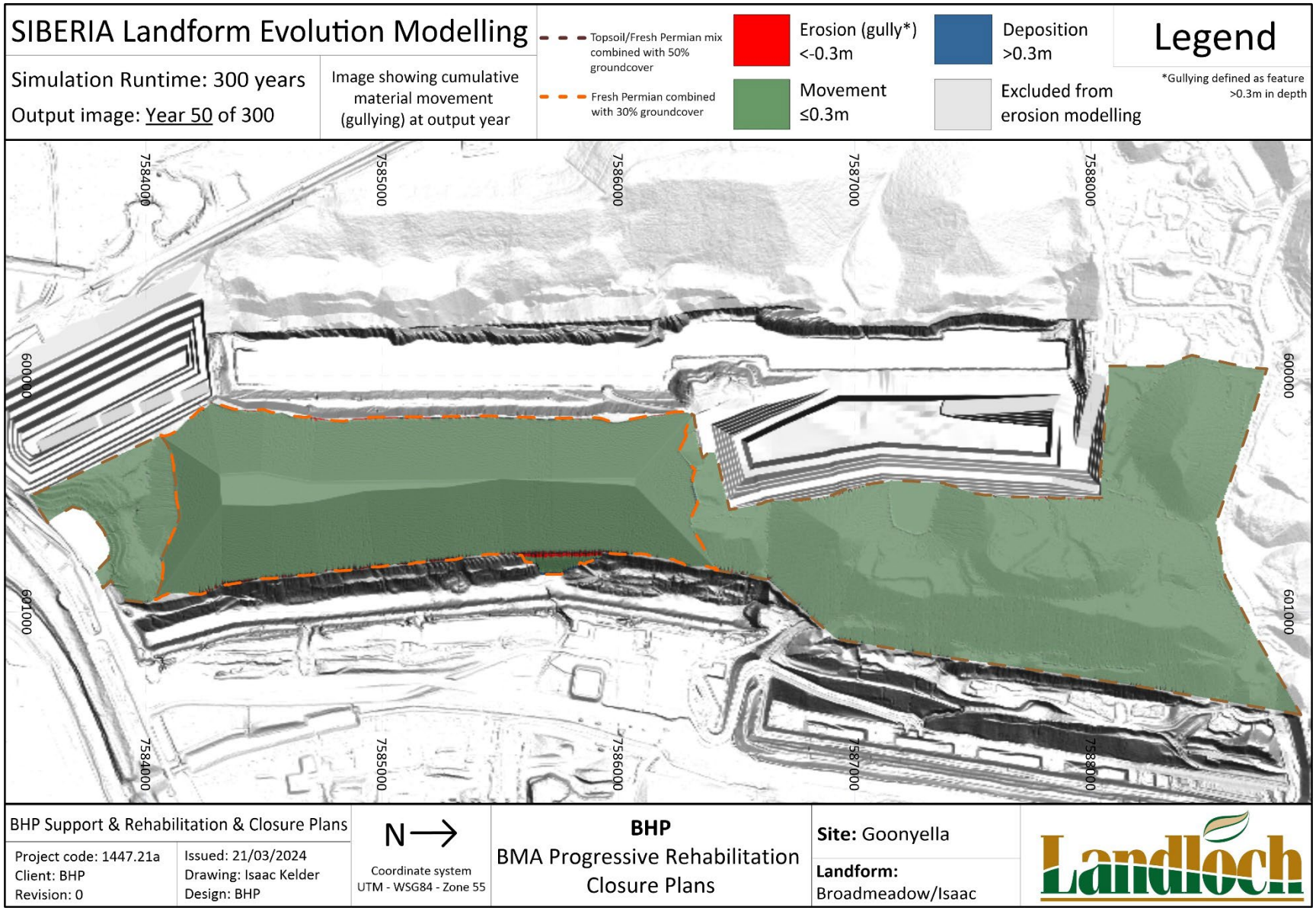

Figure A-9: Predicted erosion and deposition depths of the Broadmeadow/Isaac rehabilitation landform after 50 years.

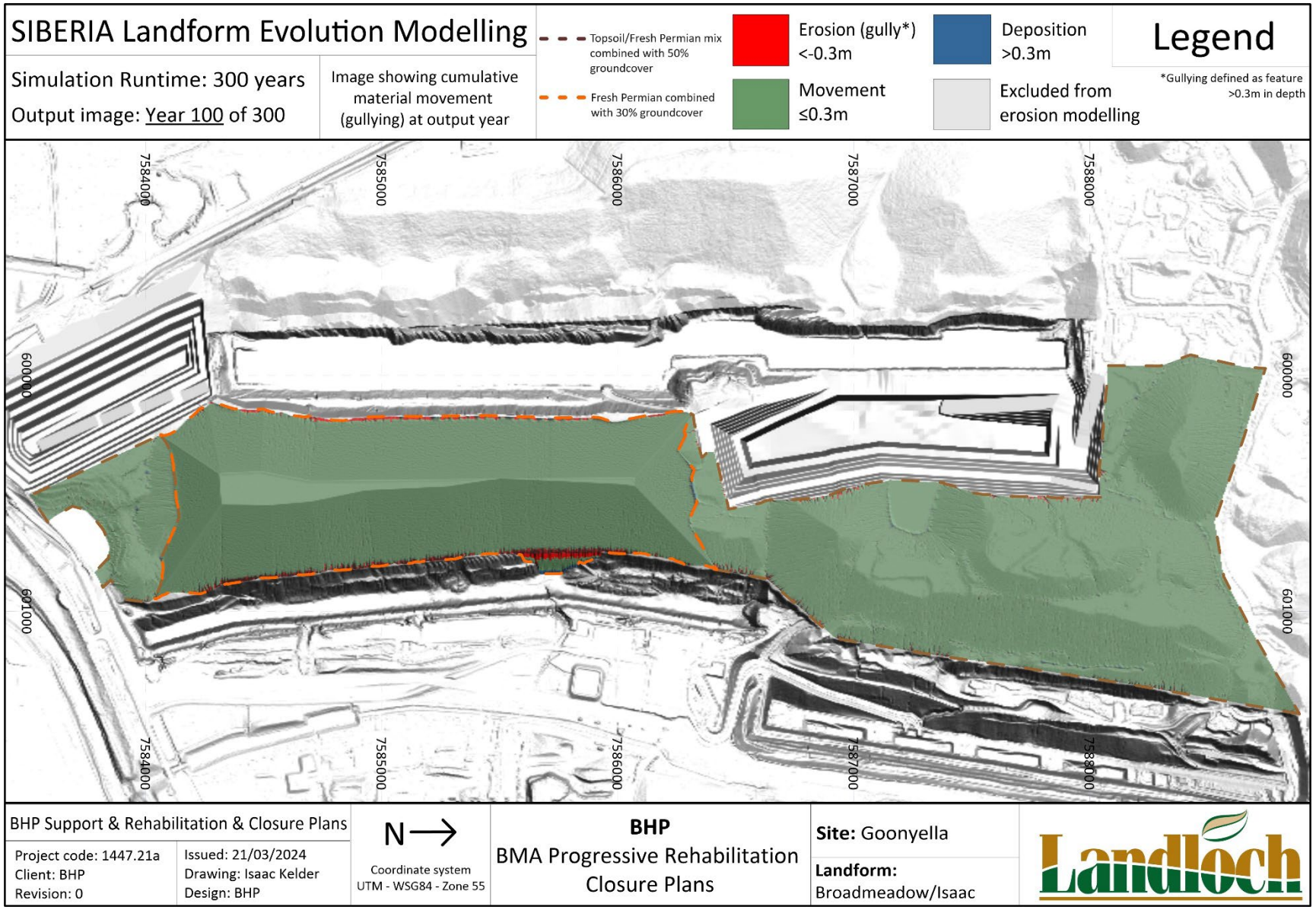

Figure A-10: Predicted erosion and deposition depths of the Broadmeadow/Isaac rehabilitation landform after 100 years.

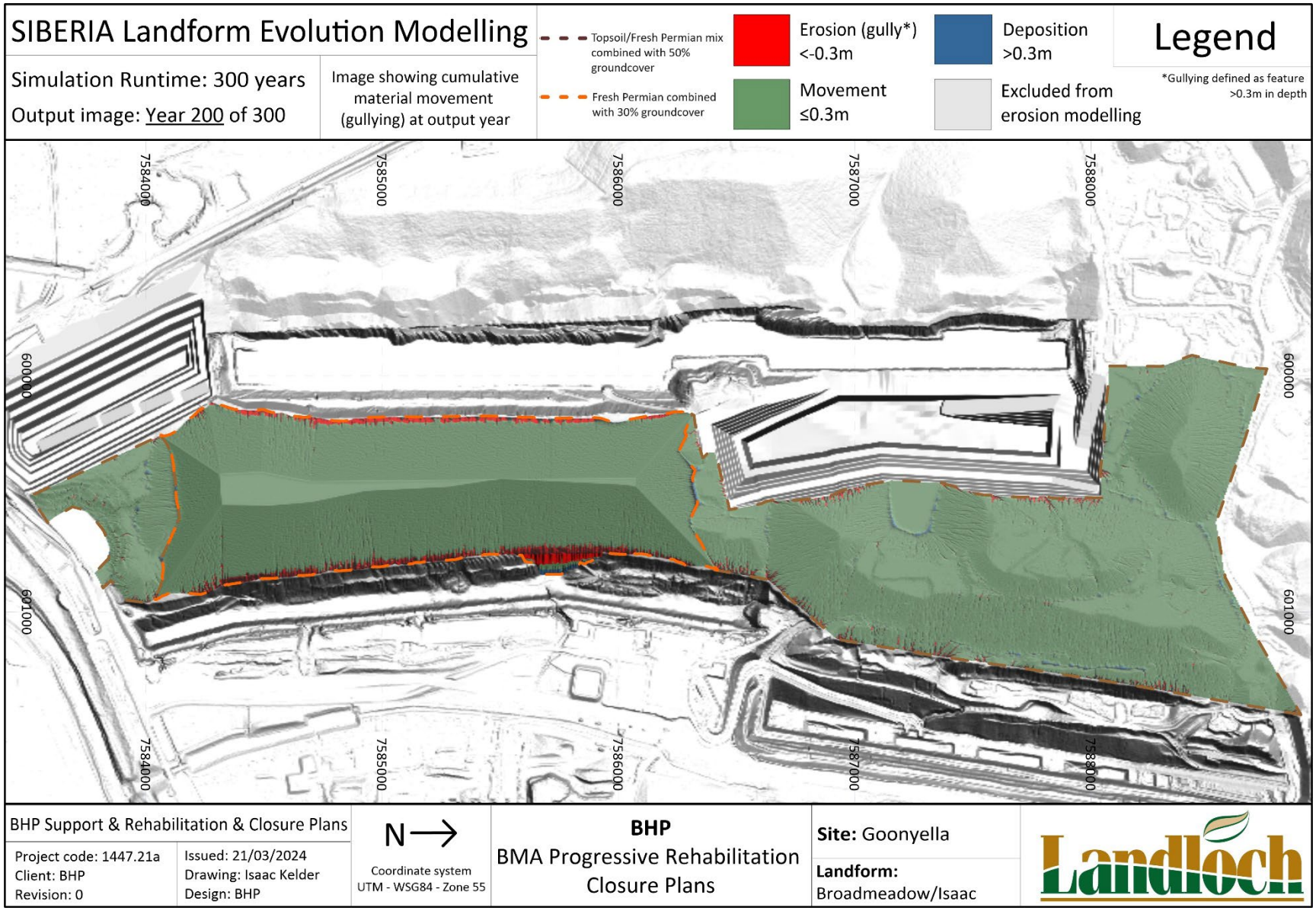

Figure A-11: Predicted erosion and deposition depths of the Broadmeadow/Isaac rehabilitation landform after 200 years.

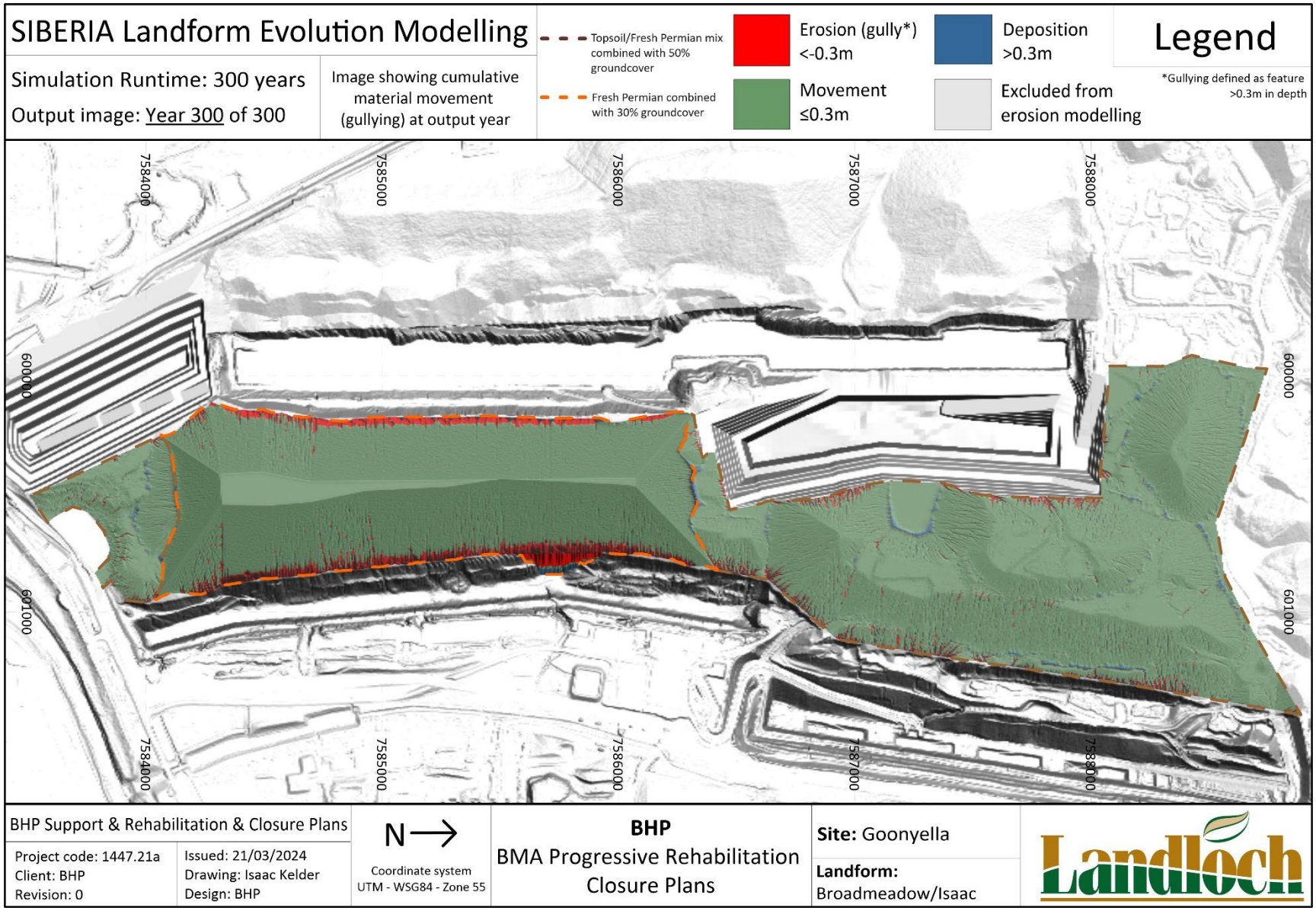

Figure A-12: Predicted erosion and deposition depths of the Broadmeadow/Isaac rehabilitation landform after 300 years.

ENGENY

BMA

PRCP Concept Design Report

Isaac River Diversion

QC1000_051-REP-004-4

25 AUGUST 2025

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0	1/08/2024	Issue for Review	Christian Hansen & Sumaiya Sifa	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
1	21/08/2024	Client Issue	Christian Hansen & Sumaiya Sifa	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
2	03/10/2024	Client Issue	Christian Hansen & Sumaiya Sifa	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
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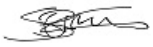
4	18/08/2025	Client Issue	Louis North	Ben Kiernan	Samantha Breslin	Ben Kiernan
5	25/08/2025	Client Issue	Louis North	Ben Kiernan	Samantha Breslin	Ben Kiernan
Signatures:						

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Isaac River Diversion which satisfies the conditions under Environmental Authority (EA) EPML00853413. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Goonyella Riverside Mine (GRM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for GRM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options identification, assessment and selection.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium resulting in a relinquishable state for the diversion. The following methodology was utilised:

- A desktop geomorphic assessment of the Isaac River was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

The Isaac River flows south along the eastern boundary of GRM, approximately 25 km north of Moranbah within the Bowen Basin. The river has a large catchment area that includes multiple tributaries amounting to a drainage sub-basin covering 22,324 km^2. It eventually discharges into the Mackenzie River and ultimately the Fitzroy River.

The Isaac River was diverted between 1985 and 1987 on the GRM and Broadmeadow Mine (BRM) mining operations leases to allow access to coal deposits by open cut mining. The diversion begins over the top of where longwall LW 105 of BRM was mined in 2011. The diversion replaced approximately 9 km of river channel with 7.7 km of diversion channel including two drop structures, each around 2 m in height. The drop structures were designed to control bed grade due to the decreased length. Both structures have failed since construction with the upstream drop structure replaced in 2020 and the downstream drop structure now redundant (Nelly Group Engineering, 2021). The diversion has 8 longwalls subsiding much of the upstream half of the diversion.

2.2 Pre-Mining Condition

Prior to mining, the predominant land use was agriculture. The upstream catchment area is shared with two other coal mines (North Goonyella and Burton), while several other coal mines are located downstream, along significant tracts of the Isaac River watercourse. This channel bed width is comparable with the pre-development bed width as well as the bed widths upstream and downstream, however the diversion design had steeper banks, did not include benches, and lacked geomorphic variability seen in the natural/pre-development river reach which resulted in a reduced overall waterway area. The pre-mining natural upstream, downstream and diversion reaches have been described as follows:

- **Upstream reach –** The Isaac River flowed southwest passing through cattle grazing vegetation and continues to have multiple tributaries flowing into it.
- **Downstream reach –** The downstream reach banks have been described as comprising highly erodible tertiary sediments, however the channel banks were noted as generally stable, with attached benches and thick obliquely deposited mud drapes which have contributed to stability (Alluvium, 2009).
- **Diversion reach (pre-mining)** – The length of Isaac River that was diverted between 1985 and 1987 consisted of an irregularly meandering, moderately sinuous, low gradient channel. Channel dimensions were largely consistent with the upstream and downstream reaches, with benches present throughout. Inset floodplains were prevalent throughout the reach, allowing flows to break out of the main channel more frequently. Further, bank full height was lower than the current diversion and the floodplain adjoining the channel was generally >500 m on both sides of the channel, allowing flows to spread across a very large area. This would have reduced flow hydraulic values within the channel (in comparison with the current diversion) in larger events. An Ortho-DEM was developed using aerial imagery from 1975 to confirm the length of the original section of Isaac River that was diverted (Advisian, 2020). This data calculated a length of approximately 8.97 km, which is 1.3 km longer than the current diversion. Therefore, the diversion channel was constructed with a bed gradient that is steeper than the original section of river diverted.

2.3 Current Conditions

A monitoring program for the Isaac River diversion was initiated in 2007 with the last major monitoring was completed in 2021 by Alluvium. As part of the major monitoring report, the latest condition of the Isaac River diversion has been described at the time of writing as follows (Alluvium, 2022):

- Upstream of the diversion, there have been significant changes to the in-channel vegetation since baseline monitoring. There were larger layers of shrub woody vegetation in the mobile bed sediments that have since been removed by large flow events in early 2008 to 2013. The bed width of the upstream reach is comparable to pre-development widths. The main detractor from condition is the aggradation of the stream bed with high sediment inputs from reaches further upstream. Banks are generally stable across these reaches, there are local instances of bank erosion, one notable site between U7 and U8. The channel bed is bedrock controlled in this area and the low flow

channel has migrated across the rock bar into the bank. Other instances of bank erosion are where the channel impinges on the terrace creating a near vertical scarp, however these are often eroding at low rates due to the more consolidated nature of the Tertiary sediments.

- The downstream reach continued to be in moderate to good condition. The main detractors in the IDC score were primarily due to excess sediment inputs aggrading the stream bed resulting in a reduction of morphologic diversity and suppressed native riparian vegetation. Subsidence influences on bedload sediment transport, both upstream and downstream of this reach were not yet apparent.

The results of the IDC assessment for the GRM and BRM Isaac River diversion monitoring reaches for 2021 showed the diversion reach to be in moderate condition overall with lower IDC and geomorphic and riparian indices than the upstream and downstream reaches. Since baseline monitoring in 2007, the diversion reach IDC has shown a slow and steady improving condition trajectory. This will largely be attributable to maturing vegetation on the bank attached benches in-channel and the morphologic diversity such as pools created by subsidence. The diversion bank did not include benches and lacked geomorphic variability seen in the pre-development river reach which resulted in a reduced overall waterway area.

The current location of the upstream, downstream and diversion reaches of Isaac River are shown in Figure 2.1.

598000 599000 600000 601000 602000 603000 604000 605000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Legend

- Current Diversion Reach
- Pre-mining Reach
- Isaac Upstream Reach
- Isaac Downstream Reach
- Watercourses
- ML Boundary
- GS4A Dam
- Existing Railway
- Existing Roads

Ramp 22
Ramp 6
ML 1764
Isaac River
Ramp 21
Eureka Creek
GS1 Tailings Dam
ML 70288
ML 70287
Ramp 2
Ramp 32
ML 1763
Red Hill Road
ML 70478
ML 70289
ML 70421
Isaac River
Holding Paddock Creek
Ramp 0
ML 70479
Fisher Creek
ML 701
Glenden
Moranbah

BMA PRCP GRM Isaac River Diversion

Figure 2.1
Location of Isaac River Diversion

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: | DATE: 30/07/2024

GENERAL NOTES:

0 250 500 750 1,000 m

Scale @ A3: 1:30,000

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3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

3.1 DNRME Guidelines

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for the Isaac River diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Isaac River diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.

- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential; however, stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - no vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.1 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the construction.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.2.

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass *(Cenchrus ciliaris)*	40
Structurally diverse suite of established native vegetation	120

4. OPTIONS IDENTIFICATION

Engeny identified three potential options for the diversion as part of stage 1 (summarised below in Table 4.1). The following constraints were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the mining lease (ML) boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2	Option 3
Description	Retain existing diversion alignment (7.7 km). Diversion grade is approximately 0.12%.	Western Route passing through Holding Paddock Creek diversion. Diversion channel significantly longer (10 km). Approximately half of the diversion route is located in an area already disturbed. The intent of this option is to divert Fisher Creek, HPC and Eureka Creek altogether along with Isaac River.	Combination of mid and lower meander. Retain the existing diversion alignment and add meander west and east of the existing diversion to add further geomorphic diversity to the Isaac River and return the pre-mining reach length. Diversion length 8.7 km (similar to the pre-mining length).
Likelihood that diversion will achieve state of dynamic equilibrium	Low – has an alignment with a length (7.7 km) shorter than the pre-mining alignment. Isaac River is currently performing below license conditions due to the drop structures which could not be retained in closure. Further remediation works are to be completed to return the Isaac River to a state of dynamic equilibrium.	Lowest – has an alignment with a length (10 km) longer than the pre-mining alignment. Substantial difference in grade (0.08%). Option 2 will include two catchments and crosses the planned R32 South void.	High – has an alignment with a length (8.7km) and grade (0.10%) similar to the pre-mining alignment.
Order of magnitude cost estimate*	$5 M	$152 M	$98 M
Ability to isolate diversion from flows during establishment period	No – Will be constructed on the existing diversion alignment.	Yes – The entirety of the diversion can be constructed offline from the existing diversion.	Partially – Option 3 cuts across the existing alignment. It is possible but there is some engineering risk.

* Option 1 estimates are based solely on direct diversion cut requirement costs. Option 2 & 3 are adopted from the 'Isaac River Diversion Pre-IPS report' by Advisian in May 2020, and the material volume and costs associated with the option have been adopted from the report.

598000 599000 600000 601000 602000 603000 604000

7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Legend

- Watercourses
- Existing Roads
- Existing Railway
- ML Boundary

Isaac River Options

- Option 1
- Option 2
- Option 3
- GS4A Dam

Eureka Creek
ML 1764
Ramp 21
Isaac River
GS1 Tailings Dam
ML 70288
ML 70287
Ramp 2
Red Hill Road
Ramp 32
ML 70478
ML 70289
ML 1763
Isaac River
Holding Paddock Creek
Fisher Creek
Ramp 0
ML 70479
Fisher Creek
ML 70108

BMA PRCP GRM Isaac River Diversion

Figure 4.1
Isaac River Diversion Realignment Options

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 30/07/2024

GENERAL NOTES:

0 250 500 750 1,000 m
Scale @ A3: 1:25,000

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5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BMA and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	50%
Order of magnitude cost estimate	30%
Ability to isolate diversion from flows during establishment period	20%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 3 to be carried forward into concept design as a preferred option, since it scored highest out of the two options and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2	Option 3
Overall Weighted Score	-0.4	-1.7	1.2
Relative Risk	Neutral Risk	Highest Risk	Lowest Risk
Fatal Flaw	No	Yes	No

6. CONCEPT DESIGN

6.1 Design Parameters and Plan

Table 6.1 details the parameters for each outcome in Section 3, forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND ACARP PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function, and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis. b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed).	☒ ☐	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	Outcome 5 – Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Concept Design Diversion Alignment

Option 3 was identified to be the preferred option alignment using the MCA. The option was further refined to optimise the earthworks. The current length of the diversion is approximately 7.7 km, whereas the pre-mining length for the same reach was approximately 8.97 km. The proposed diversion is designed to be approximately 8.7 km in length. The full concept drawing package for the permanent Isaac River diversion is included in Appendix E and the interaction of the design with the PRCP landform is in Appendix F.

6.3 Channel Geometry and Grade

Table 6.2 summarises the selected typical channel cross-section for the concept design. These dimensions are adopted based on the geomorphology assessment done by Hydrobiology in 2019, which identified the average geomorphic characteristics of the upstream, diversion, and downstream reaches of the Isaac River (Hydrobiology, 2019).

Figure 6.1 shows the adopted cross-section for the for the proposed alignment. The concept design drawings in Appendix E show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY FOR CONCEPT DESIGN

Channel Geometry	Suggested Quantity	Adopted Quantity	Comments
Channel Bed Width	50 – 60 m	50 m	
Bench Width	10 – 20 m	10 m	
Channel Depth	8 – 10 m	3 m	Consistent depth of low flow channel at 3 m.
Batter Slope	1:3 – 1:5	1V:4H	For both the low flow channel and high flow channel batters. The batters will be covered with topsoil, hydromulch and hydroseed (Appendix E) to ensure stability and prompt revegetation of the channel batters.

The concept design does not seek to change the vertical grade. The current diversion closely approximates the pre-mining conditions for the Isaac River. The grade of the proposed diversion is 0.1%, which is the same as the existing grade of the current diversion. The proposed diversion is approximately 8.7 km in length, which is a 3% reduction from the pre-mining length. The reduced length in the channel is not expected to adversely impact sediment transport/deposition within the channel. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix E.

Figure 6.1: Design Channel Cross Section of Isaac River

6.4 Hydrology

A hydrologic model of Isaac River (concept design) was developed using WBNM software. The model was used to estimate flows for the 1 in 1000-year flood event. Peak flows for frequent events (39% AEP and 2% AEP) for the Isaac River proposed diversion was estimated using the ACARP (2002) method. The details of the hydrologic model development are presented in Appendix B. The Isaac River catchment is presented in Figure 6.2.

590000 595000 600000 605000 610000 615000 620000 625000 630000

7635000 7630000 7625000 7620000 7615000 7610000 7605000 7600000 7595000 7590000 7585000 7580000 7575000

Legend

- Existing Railway
- ML for Goonyella

WBNM Model Sub-catchment

- Issac River

Watercourse Stream Order

- 1
- 2
- 3
- 4
- 5
- 6

BMA PRCP GRM Isaac River Diversion

Figure 6.2
Catchment Map

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 24/07/2024

GENERAL NOTES:

0 2 4 km

Scale @ A3: 1:170,000

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6.4.1 Frequent Events

Peak flows for frequent events (39% AEP and 2% AEP) for the Isaac River diversion (concept design) and significant tributaries were estimated using the ACARP (2002) methods. The flow estimation details using the ACARP (2002) methods are included in Appendix B2. Table 6.3 summarises the total Isaac River diversion design flow downstream of the channel design.

The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Isaac River diversion concept design and has been compared to the ACARP (2002) diversion channel design parameters.

TABLE 6.3: ISAAC RIVER DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
2% AEP (50-year ARI)	2736.46
39% AEP (2-year ARI)	390.16

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform was assessed to inform the interaction between the diversion and final voids landform. Peak flows for 0.1 % for the Isaac River diversion (concept design) and significant tributaries were estimated using the WBNM software (refer to Appendix B1). The 0.1% peak flow rate at the end of the diversion is 5291 m^3/s.

6.5 Hydraulics

6.5.1 Frequent Events

A two-dimensional TUFLOW flood model was developed to assess the compliance with the DNRME and ACARP hydraulic performance criteria for the 39% and 2% AEP events. The model simulated both the diversion design channel and the upstream reach, extending approximately 9.5 km upstream of the design. The extents and depths of the 39% and 2% AEP flooding are depicted in Figure 6.3 and Figure 6.4.

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in the 39% and 2% AEP events (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP (2-year ARI)		2% AEP (50-year ARI)	
Design Criteria	Diversion	DNRME Design Parameter (2019)	Diversion	DNRME Design Parameter (2019)
Stream Power (W/m^2)	38.7	<60	131.7	<150
Stream Velocity (m/s)	1.77	<1.5	2.46	<2.5
Shear Stress (N/m^2)	21.8	<40	54.3	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

It can be seen from Table 6.4 that all the average diversion hydraulic results are below design parameters for both the 39% AEP and 2% AEP storm events except for the 39% AEP velocity.

The modelled velocity is generally consistent with the velocities observed in the upstream and downstream reaches with the velocity exceeding the threshold values due to the large capacity of the channel with no floodplain engagement which would be typically for smaller capacity watercourses throughout the Bowen Basin from which the threshold values where derived.

6.5.2 Rare Events

The TUFLOW flood model was also developed to assess the interaction between the diversion and final voids landform for the 0.1% AEP event. The extents and depths of the 0.1% AEP flooding are depicted in Figure 6.5.

The results indicate that the concept diversion design does not interact with any final voids. However, there is a high possibility of interaction from the upstream reaches of the diversion design. Additionally, the 0.1% AEP flood event shows flows to the Ramp 0 and Ramp 2, located west of the diversion. It's important to note that these results are based on landform version 2. However, the latest landform version 2.3 includes flood protection measures that mitigate this risk.

6.5.3 Subsidence management

Water ponding in areas of subsidence will drain to the Isaac River diversion, as it will be a natural low point in the topography. Based on the expected subsided zones, ponding in subsided areas may discharge into the Isaac River laterally over the diversion banks. Excess flow from subsided areas discharging into the diversion banks increases the risk of local bank erosion and gully erosion. Rock armoured inlet points have been designed to limit bank or head cut erosion formed as a part of lateral drainage. In addition to these inlet points, a drain will be required to convey water away from the old diversion, as it will be backfilled. Locations of concept drainage and subsidence inlets can be seen in Figure 6.6. Design details for these structures are displayed in Appendix E.

590000 595000 600000 605000 610000 615000 620000 625000 630000

7635000 7630000 7625000 7620000 7615000 7610000 7605000 7600000 7595000 7590000 7585000 7580000 7575000

Legend

- Existing Railway
- ML for Goonyella

WBNM Model Sub-catchment

- Issac River

Watercourse Stream Order

- 1
- 2
- 3
- 4
- 5
- 6

BMA PRCP GRM Isaac River Diversion

Figure 6.2
Catchment Map

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 24/07/2024

GENERAL NOTES:

0 2 4 km

Scale @ A3: 1:170,000

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CRS: AGD66 / AMG zone 55 (EPSG:20255)

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597000 598000 599000 600000 601000 602000 603000 604000 605000 606000 607000 608000

7596000 7595000 7594000 7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

ML 70493
ML 70121
ML 1900
ML 70193
ML 1764
ML 70194
Ramp 22
Ramp 6
Ramp 21
Eureka Creek
ML 1763
Isaac River
Upstream Reach
ML 70421
GS1 Tailings Dam
ML 70288
ML 70287
Ramp 2
ML 70478
Ramp 32
Design Channel
ML 70289
Holding Paddock Creek
Ramp 0
ML 70479
ML 70108
Skeleton Gully
Downstream Reach
Isaac River

Legend

- ML Boundary
- Existing Railway
- Watercourses

Flood Depth (m)

- <= 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 7
- 7 - 18
- > 18

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Isaac River Diversion

Figure 6.3
39% AEP Flood Event with PRCP Landform 2

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 24/07/2024

GENERAL NOTES:

0 250 500 750 1,000 m
Scale @ A3: 1:41,000

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BMA PRCP GRM Isaac River Diversion

Figure 6.4
2% AEP Flood Event with PRCP Landform 2

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 24/07/2024

GENERAL NOTES:

0 250 500 750 1,000 m
Scale @ A3: 1:41,000

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598000 599000 600000 601000 602000 603000 604000 605000

7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

ML 1900
ML 1764
Eureka Creek
Isaac River
Isaac River
ML 70288
ML 70287
ML 1763
ML 70289
ML 70478
Holding Paddock Creek
Fisher Creek
ML 70479
Isaac River

Legend

- ML Boundary
- Existing Railway
- Existing Roads
- Watercourses

Flood Depth (m)

- <= 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 7
- 7 - 18
- > 18

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Isaac River Diversion

Figure 6.5
0.1% AEP Flood Event with PRCP Landform 2

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 24/07/2024

GENERAL NOTES:

0 250 500 750 1,000 m
Scale @ A3: 1:25,000

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600000 601000 602000 603000 604000 605000

7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Eureka Creek

Isaac River

Isaac River

Legend

- Current Diversion Infill
- Concept Drainage Paths
- Concept Inlet Locations
- Existing Railways
- Watercourses
- Preferred Diversion Alignment

PRPC Landform v2.3 (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Isaac River Diversion

Figure 6.6
Conceptual Subsidence Drainage - PRCP Landform 2.3

REV.	DETAILS	DATE
0		

DRAWN: LN | CHECKED: BK

APPROVED: BK | DATE: 25/08/2025

GENERAL NOTES:

0 200 400 600 800 m

Scale @ A3: 1:20,000

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6.6 Risks and Mitigation Measures

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised for this risk assessment align with BHP Global Standard – Risk Management.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to frequent (up to 20% AEP / 5 year ARI) flood events. Diversion alignment unable to be taken offline.	Likely	2	30	Diversion channel constructed during dry season. Detailed revegetation plan to be implemented to promote rapid establishment. Seed mix to include fast establishing species to rapidly stabilise diversion.	Likely	1	10
Damage to the new diversion channel due to extreme/rare (0.1% AEP / 1000 year ARI) flood event (mainly overland flow and bank erosion).	Unlikely	2	3	Revegetation plan to include large species capable of withstanding shear stresses associated with rare events.	Highly Unlikely	2	0.9
Construction program impacted by frequent flow event (up to 20% AEP / 5 year ARI). Diversion unable to be taken offline.	Probable	1	3	Diversion construction to be timed to minimise risk of large flows while still maintaining enough watering to promote vegetation establishment and growth. Potential to construct upstream detention to minimise the peak flows if allowed by existing water licence.	Likely	1	10
Constructability of diversion channel – encountering bedrock, material availability and access.	Unlikely	2	3	Geotechnical and soil investigations as part of functional design.	Highly Unlikely	1	0.3
Flood ingress into final voids.	Likely	2	30	Final landform design to provide flood protection to ensure no flooding ingress in 0.1% AEP flood with 1.0 m freeboard.	Highly Unlikely	2	0.9
Upstream rehabilitation of mining areas unsatisfactory leading to increase sediment loads to the final diversion channel.	Highly Unlikely	2	0.9	Additional upstream controls could be considered during functional design. Offline flow through sediment basins during vegetation establishment phase of rehabilitated catchments reporting to the Eureka Diversion.	Likely	2	30

6.7 Additional Design and Construction Considerations

6.7.1 Surface Water Infrastructure

The final landform will be designed to ensure flood protection to final voids to mitigate this risk. Final voids are to be offset from the Isaac River by a sufficient distance to limit seepage into the voids. The PRCP landform (Version 2) shows flows to the Ramp 0 and Ramp 2, located west of the diversion. However, the latest iteration of the landform (Version 2.3) effectively addresses this risk, providing sufficient distance from the Isaac River to prevent seepage into the voids. The PRCP landform (Version 2.3) will be implemented to ensure that the 0.1% AEP flood event does not contribute to external inflows into the void. Additionally, the design will guarantee the flood protection of final voids located north-west upstream of the concept design, incorporating a sufficient buffer between the upstream reach and the final voids (refer to the PRCP for flood mitigation details). The overall intent for the flood protection landform will not require ongoing maintenance to maintain function.

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Hydraulic modelling has demonstrated that the 39% AEP average velocity (1.77 m/s) is slightly above the DNRME guideline value of 1.5 m/s for a stable channel with vegetation and 1 m/s for a stable channel without vegetation (refer Table 3.2). Additionally, the 39% AEP average shear stress of 38.7 N/m2 is slightly above the DNRME guideline value of 35 N/m^2 for a stable channel with no vegetation (refer Table 3.2). Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Isaac River as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the GRM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with BMAs watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable),and following periods of high flow in the diversion.

6.7.5 Subsidence Management

Subsidence troughs along the riverbed could result in a loss in stream power. This ultimately results in a disruption to the sediment transport regime, causing sediment to deposit and leading to potential downstream channel widening. As described in Table 4-1 of the Goonyella Riverside and Broadmeadow Mine Subsidence Management Plan (Lucas, et al., 2015), this channel deepening and widening has both negative (bank erosion) and positive (habitat creation) impacts. Negative impacts can be mitigated through channel bed and bank protective measures installed during monitoring periods. Adaptive methodologies to be utilised during monitoring are described in the Broadmeadow Subsidence Management Plan (BMA, 2023).

Disruptions to sediment transport as a result of subsidence, will only be temporary, relative to a closure scale. Boarder sediment transport impacts are discussed the Isaac River Cumulative Subsidence Impacts Assessment (IRCIA), which investigated the impacts subsidence will have on sediment transport throughout the Isaac River. This study was later updated to include updated mining plans downstream and upstream of GRM and BRM (Lucas & Crerar, 2013). This estimated that subsidence infilling will occur between 10 – 100 years following the completion of mining. These studies demonstrate that disruptions to sediment transport, as a result of subsidence, will not result in long-term instability of the Isaac River post closure as the riverbed will infill to a natural state.

7. CONCLUSION

The existing diversion is experiencing increasing bank erosion, lack of geomorphic and vegetation features like those in the local landscape, sediment aggradation and sediment deposition downstream.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of GRM.

Three options for rehabilitation of the diversion were identified and assessed using the BMA MCA outlined in Section 5. The selected option to proceed with the concept design was Option 3. This option retains the existing diversion alignment but meanders west and east of the existing diversion to add further geomorphic diversity to the Isaac River and return the pre-mining reach length. Maintenance and rehabilitation of the existing diversion is to be conducted along the channel. The final concept design, typical cross sections and longitudinal section are presented in Appendix E.

The highest risk to successful performance of the diversion is vegetation failure and subsequent erosion of the banks and bed of the diversion. It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated. Given that the alignment is unable to be taken offline during construction, it will be critical that vegetation of the channel be established following construction to minimise erosion risk during frequent events. The concept design could be optimised in detailed design to further reduce the stream power and velocities in conjunction with a planned diversion revegetation strategy.

The latest PRCP landform (Version 2.3) has been designed to effectively provide flood protection for Ramp 0 and Ramp 2, ensuring that the 0.1% AEP flood event does not contribute to additional external inflows into the void. Additionally, the latest iteration of the landform ensures flood protection for the final voids located northwest and upstream of the concept design, maintaining a sufficient buffer between the upstream reach and the final voids.

8. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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  (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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(f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

(g) This Report does not provide legal advice.

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APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Isaac River Diversion

Project: PRCP GRM Diversions
Workshop Date:

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	50%	-2	-2	2	Option 1: Has an alignment with a length (7.7 km) shorter than the pre-mining alignment. Isaac river is currently performing below license conditions due to the drop structures which could not be retained in closure. Further remediation works are to be completed to return the river to a state of dynamic equilibrium. Option 2: Has an alignment with a length (10 km) longer than the pre-mining alignment. Substantial difference in grade (0.08%). Option 2 will include two catchments. Option 3: Has an alignment with a length (8.7km) and grade (0.10%) similar to the pre-mining alignment.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	30%	2	-2	0	Option 1 estimates are based solely on direct diversion cut requirement costs. Option 2 & 3 are adopted from the 'Isaac River Diversion Pre-IPS report' by Advisian in May 2020, and the material volume and costs associated with the option have been adopted from the report.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	20%	0	2	1	Option 1: Will be constructed on the existing diversion alignment. Option 2: The entirety of the diversion can be constructed offline from the existing diversion. Option 3: Option 3 cuts across the existing alignment. It is possible but there is some engineering risk.
	Overall Weighted Score		-0.4	-1.2	1.2	

Is there a Fatal Flaw?	**No**	**No**	**No**
Relative Risk	**Neutral Risk**	**High Risk**	**Lowest Risk**

APPENDIX B: HYDROLOGIC MODEL DEVELOPMENT

B.1 Hydrologic Model Setup - WBNM

The WBNM (Watershed Bound Network Model) runoff routing software (2021 version) was used to develop the hydrology model. WBNM automatically calculates catchment routing based on the sub-catchment area, pervious/impervious areas and parameters, and the sub-catchment flow paths.

B.1.1 Catchment Inputs

The hydrological model includes the total catchment for the Isaac River (inclusive of Eureka, HPC, and Fisher creeks) extending downstream past the Goonyella mine, covering a total area of approximately 1180 km^2. Sub-catchment delineation for GRM was developed using the PRCP landform (Version 2) topography displayed in Figure F.1. The final landform topography data did not extend over a portion of the hydraulic model assessment area. Additional Shuttle Radar Topographic Mission (SRTM) topography data was used to complete the model topography required

Three open water bodies are located in the upper catchment: Lake Elphinstone, Teviot Dam and Burton Gorge Dam. Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

The design life of the Teviot Creek Dam and Burton Gorge Dam, as part of mining closure operations, could impact design flow estimates. For this study, the WBNM model did not include the Burton Gorge Dam, Teviot Dam, and Lake Elphinstone located upstream of the study area, considering a worst-case scenario.

Figure B.1 provides the sub-catchment extents used for the WBNM.

B.1.2 Model Parameters

The final landform is proposed to be rehabilitated; therefore, the hydrology model has assumed no impervious surfaces remain and a 0% impervious fraction (Fi) for all catchments including the remaining spoil areas and voids.

The default routing parameter of 1, pervious lag parameter of 1.8 and impervious lag parameter of 0.1 have been adopted for the WBNM.

B.1.3 Design Rainfall

The 0.1% AEP (1000yr) was sourced using the Australian Rainfall and Runoff 2019 IFD generation tool available on the Bureau of Meteorology (BoM) website (www.bom.gov.au), at Latitude 21.6652 (S), Longitude 148.0792 (E). Aerial Reduction Factors (ARFs) have been used for all design events to convert point rainfall estimates to areal rainfall estimates.

B.1.4 Temporal Patterns

Design events (1% - 0.1% AEP) have utilised the 'East Coast North' areal temporal patterns, as the total catchment area for the model exceeds 75 km^2. All ten temporal patterns were simulated for storm durations ranging from the 3 hours to 168 hours.

B.1.5 Design Rainfall Losses

The initial and continuing losses obtained from the ARR Datahub for Isaac River catchment to Goonyella gauge are 36 mm and 2.7 mm/h, respectively.

The adopted design rainfall losses were selected to achieve the best match between the XP-RAFTS design discharges with the design discharges estimated by the FFA at the Isaac River Goonyella gauge. The following is of note:

- For the 50%, 20%, 10%, 5%, 2% and 1% AEP events, the default ARR initial losses of 36 mm and continuing losses of 2.7 mm/h were adopted, respectively. The initial loss will decrease for larger events as the catchment is likely to be more saturated prior to the design rainfall burst.
- For the 0.1% AEP design event, a conservative 0 mm initial loss was adopted. A continuing loss of 2.5 mm/h was adopted as per the flood assessment done by WRM in 2019 (WRM, 2019).

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000

Legend

Stream Gauge

WBNM Model Sub Catchments

- Eureka Creek
- Fisher Creek
- Holding Paddock Creek
- Isaac River

Lake Elphinstone

Burton Gorge Dam

Teviot Dam

Eureka Creek at the railway

Eureka Creek at the GS4A Weir

Isaac River at Goonyella

BMA PRCP GRM Isaac River Diversion

Figure B.1
WBNM Hydrologic Model Layout

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 01/08/2024

GENERAL NOTES:

0 2 4 km

Scale @ A3: 1:180,000

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B.1.6 Model Validation

The 50%, 20%, 10%, 5%, 2% and 1% AEP peak flows estimated from the hydrology model were validated using the following methods:

- **Regional Flood Frequency Estimation Model (RFFE)** - is a recommended peak flow validation method from the ARR 2019 guidelines (Ball, et al., 2019). The RFFE provides peak flow estimations based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).
- **Flood Frequency Analysis (FFA)** - provides peak flow estimates for different AEPs by developing a fitted distribution from recorded peak flows from historical flood events.

  A flood frequency analysis (FFA) of recorded flows at the Isaac River Goonyella Gauge was conducted by Engeny in 2021. The FFA results were used for validation in the Isaac River Flood Model, completed by Engeny in March 2021. The analysis focused on peak annual discharges (from October to September) recorded at the Isaac River at Goonyella (130414A) streamflow gauge by Queensland's Department of Natural Resources Mines and Energy (DNRME) between 1982 and 2020. A Log Pearson Type 3 (LPIII) distribution was applied to the annual maximum series of peak flows from the gauge (Engeny, 2021).
- **Peak flow estimates from previous flood studies** –
  - A hydrologic modelling of the Isaac River catchment including the Grosvenor Mine (GRV) and Moranbah North Mine (MNM) using the XPRAFTS runoff-routing model was developed to estimate the 39%, 10%, 5%, 2%, 1%, 0.2% and 0.1% annual exceedance probability (AEP) and probable maximum flood (PMF) design discharges for the Isaac River and its tributaries (Engeny, 2021). The estimated peak flows at the Isaac River at Goonyella Streamflow Gauge were compared to the WBNM and RFFE peak flows (refer to Figure B.2). It is to be noted that the Burton Gorge Dam, Teviot Dam and Lake Elphinstone upstream of the study area were modelled as detention basins in the XPRAFTS model.
  - Design peak discharges in the Isaac River at Goonyella, Eureka Creek upstream of the railway and Eureka Creek at the GS4A for the 10%, 5%, 2%, 1%, 0.1% were estimated using the XP-RAFTS model by WRM in 2019. These flows were compared to the WBNM model design peak discharges at these three gauge locations.

B.1.7 Model Validation Results

Table B.1 shows the WBNM estimated design discharges at the Isaac River at Goonyella, Eureka Ck at the Railway and Eureka Ck at the GS4A for design events between 10% to 0.1% AEP, and the comparison to the WRM design discharges. A visual comparison of the WBNM design peak discharges at the Isaac River streamflow gauge (130414A) against the flood frequency distribution curve, XP-RAFTS estimated peak flows by Engeny in 2021 and RFFE is provided in Figure B.2.

Validation of the design hydrology peak flow estimates indicates the following.

- **Isaac River Gauge**
  - Modelled peak flows for all design events are higher (3%-26%) than the LPIII expected quantile from the FFA. This is expected considering the exclusion of Burton Gorge Dam, Teviot Dam and Lake Elphinstone (Figure B.2).
  - Modelled peak flows compared to the RFFE method were higher for events rarer than the 10% AEP and lower for events more frequent than the 10% AEP. This irregularity is not concerning as the RFFE can provide irregular results if catchment characteristics are mostly different from the nearby gauged waterways used to derive the RFFE. Additionally, the Issac gauge catchment (1071.21 km^2) is outside the RFFE recommended catchment size of 0.5-1000 km^2, hence results have lower accuracy (Figure B.2).
  - WBNM estimated peak flows for all design events are higher (11%-28%) than the WRM 2019 flood modelling report (Table B.1).
- **Eureka Ck Gauge**
  - WBNM estimated peak flows for all design events are higher (10%-37%) than the WRM 2019 flood modelling report. This is expected considering the 37% increase of the Eureka catchment (Table B.1).

TABLE B.1: COMPARISON OF WBNM DESIGN DISCHARGES TO THE WRM 2019 FLOWS

		WRM (2019) Peak Discharge (m3/s)	WRM (2019) Critical duration (hours)	WBNM Peak Discharge (m3/s)	WBNM Critical duration (hours)	Difference (%)
Isaac River at Goonyella	Catchment Area (km^2)	-		1071.12 km^2		-
	Design event (AEP%)					
	10	830	18 hr	932	18 hr	11%
	5	1167	18 hr	1363	18 hr	14%
	2	1707	18 hr	2061	18 hr	17%
	1	2079	24 hr	2616	18 hr	21%
	0.1	3808	24 hr	5291	18 hr	28%
Eureka Creek at the railway	Catchment Area (km^2)	76.4 km^2		113.78 km^2		33%
	Design event (AEP%)					
	10	140	6 hr	159	18 hr	12%
	5	180	6 hr	217	18 hr	17%
	2	256	6 hr	299	18 hr	14%
	1	299	6 hr	374	18 hr	20%
	0.1	499	6 hr	692	12 hr	28%
Eureka Creek at the GS4A	Catchment Area (km^2)	80.7 km^2		129.05 km^2		37%
	Design event (AEP%)					
	10	147	6 hr	163	18 hr	10%
	5	189	6 hr	225	18 hr	16%
	2	267	6 hr	320	18 hr	17%
	1	311	6 hr	400	18 hr	22%
	0.1	521	6 hr	728	18 hr	28%

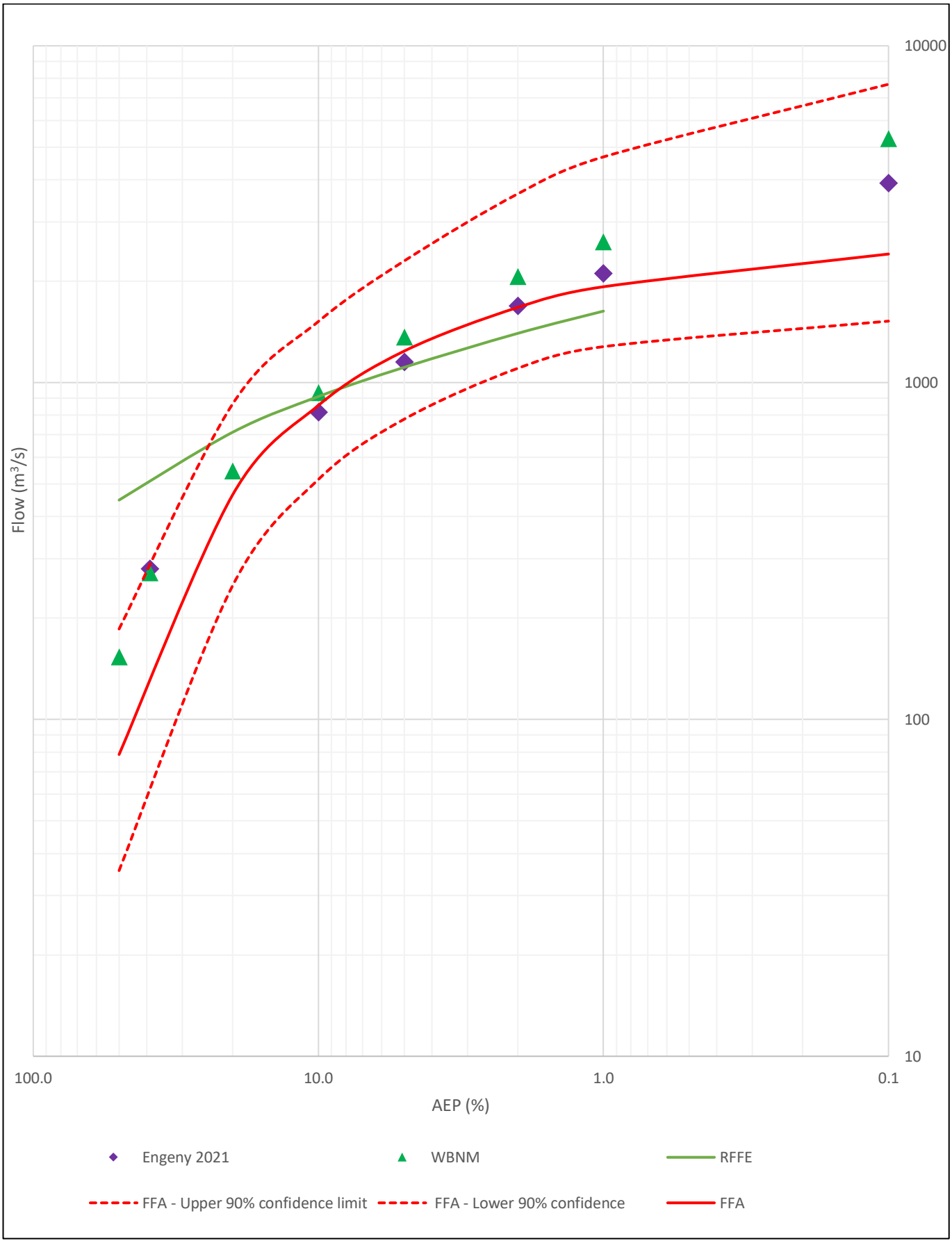

FIGURE B.2: COMPARISON OF WBNM DESIGN DISCHARGES TO THE FFA AND RFFE DESIGN DISCHARGES TO THE ISAAC RIVER GAUGE

B.2 Hydrologic Model Setup - ACARP

Peak flows for frequent events (39% AEP and 2% AEP) for the Isaac River diversion (concept design) and significant tributaries were estimated using the ACARP (2002) methods. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity.

Table B.2 summarises the estimated design flows of Isaac River and it's tributaries using the ACARP (2002) method. These design flows were subsequently applied as steady state inflow boundaries in the Tuflow model to determine diversion design limits for shear stress, stream power and velocity. Figure C.2 shows the location of the applied design flows in the Tuflow model.

TABLE B.2: DESIGN FLOWS OF ISAAC RIVER AND IT'S TRIBUTARIES USING THE (ACARP, 2002) METHOD

Isaac River & Tributaries	2% AEP (50-year ARI) Design Flow (m^3/s)	39% AEP (2-year ARI) Design Flow (m^3/s)
Isaac River	165.54	1542.25
Eureka Creek	275.4	53.8
Goonyella Creek	48.68	291.65
Twelve Mile Creek	36.22	195.06
Unnamed Gully	23.82	110.28
Platypus Creek	22.74	103.55
HPC & Fisher Creek	39.34	218.26
Total	**390.16**	**2736.46**

APPENDIX C: HYDRAULIC MODEL DEVELOPMENT

C.1 Model Extent and Topography

The hydraulic model utilised the TUFLOW HPC solver. The Digital Elevation Model (DEM) used in the hydraulic model was based on the most recent PRCP landform (Version 2) provided by BHP.

A grid cell size of 4 m was selected for the TUFLOW model, which is suitable for representing the width of the diversion across multiple modelling cells. To enhance the resolution of sub-grid scale features, an SGS (Sub-Grid Scale) sample distance of 2 m was implemented.

The selected extent for the model is from upstream of where Isaac design starts to downstream of Isaac River in the extent of the ML Goonyella Riverside. The modelling layout is shown in Figure C.1 and Figure C.2.

The proposed diversion design option was included in the model using design tins produced by 12D and merging it to the PRCP landform (Version 2).

C.2 Hydraulic Roughness

The hydraulic roughness has been selected based on the inspection of aerial imagery and expected treatments within the diversion. As per the MCA workshop, roads will be removed as part of the closure, including the GS4A dam. The GS1 tailings dam will be rehabilitated. The rail, which is not owned by BMA and goes to Moranbah North, was considered in the base land use mapping of the site. The adopted Manning's 'n' roughness values are summarized in Table C.1 below.

TABLE C.1: ADOPTED MANNING'S N ROUGHNESS

Land Use	Manning's' 'n'
Railway	0.015
Dense Vegetation	0.080
Eureka Creek Design Channel	0.050
Isaac Constructed Channel (Bed)	0.027
Isaac Constructed Channel (Right and left Bank)	0.050
Existing Watercourses (Isaac River Tributaries)	0.030
Existing Isaac River Bed (Upstream & Downstream Reach)	0.027

C.3 Model Inflows and Boundary Conditions

Boundary conditions are required in the model to define hydrology inflows, flow leaving the model domain and interfaces between the one dimensional and two-dimensional model domains. The following boundary conditions used in the models are:

- Upstream: The upstream boundary condition used a combination of 'SA' and 'BC' type boundaries, allocating flow to the defined model grid cells based on the design hydrograph from the hydrologic model (flow per unit of time) input. Total inflow hydrographs were applied to Isaac River at the upstream boundary.
- Downstream: Three normal depth outflow boundaries were adopted with a hydraulic grade based on the Isaac River channel grade at the downstream extent of the model. The boundary was located a sufficient distance downstream to not influence the flood behaviour near the areas of interest.

Peak flows as estimated by the WBNM hydrologic model (only for 0.1% AEP event) have been applied at various locations dependent on the diversion being assessed. The location of the model inflows (0.1% AEP) can also be seen in Figure C.1**.** As mentioned in section 6.4.1, for the 39% and 2% AEP event, constant ACARP flows were applied throughout the diversion as shown in Figure C.2**.**

596000 597000 598000 599000 600000 601000 602000 603000 604000 605000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000 7580000

Legend

Hydraulic Roughness Areas

- Railway
- Isaac River Tributaries
- Isaac Exisitng Channel
- Eureka Design Channel
- Isaac Design Channel - Bed
- Isaac Design Channel - Right & Left Bank
- Dense Vegetation

- Inflow Boundary
- Outflow Boundary
- Tuflow Model Boundary
- Local Catchment Inflow

BMA PRCP GRM Isaac River Diversion

Figure C.1
Hydraulic Model Layout - 0.1% AEP

REV.	DETAILS	DATE
0		23/07/2024
1		20/08/2024

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 20/08/2024

GENERAL NOTES:

0 250 500 750 1,000 m

Scale @ A3: 1:35,000

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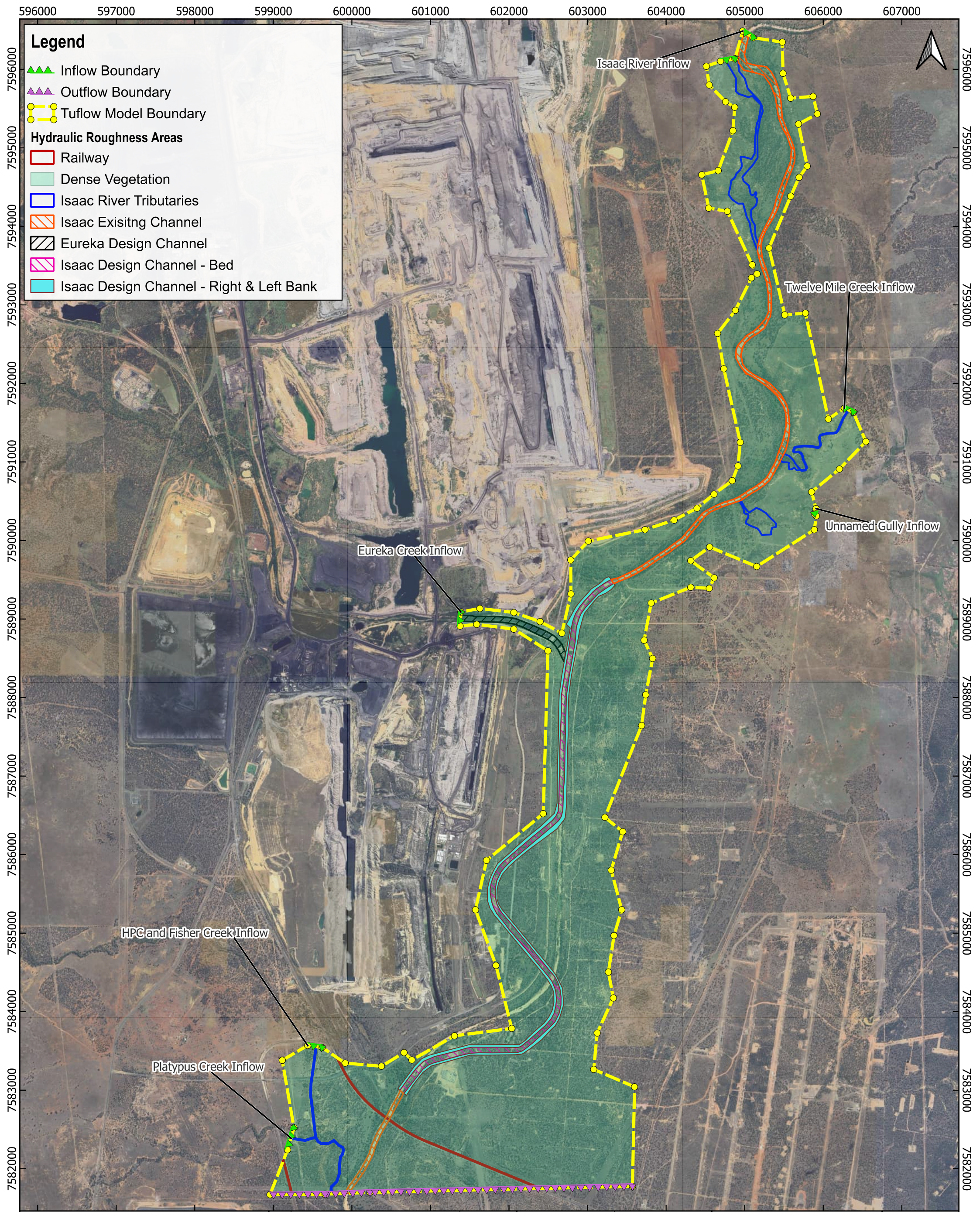

BMA PRCP GRM Isaac River Diversion

Figure C.2
Hydraulic Model Layout - 39 and 2% AEP

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1		20/8/2024

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 20/08/2024

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APPENDIX D: HYDRAULIC PARAMETER MODELLING RESULT

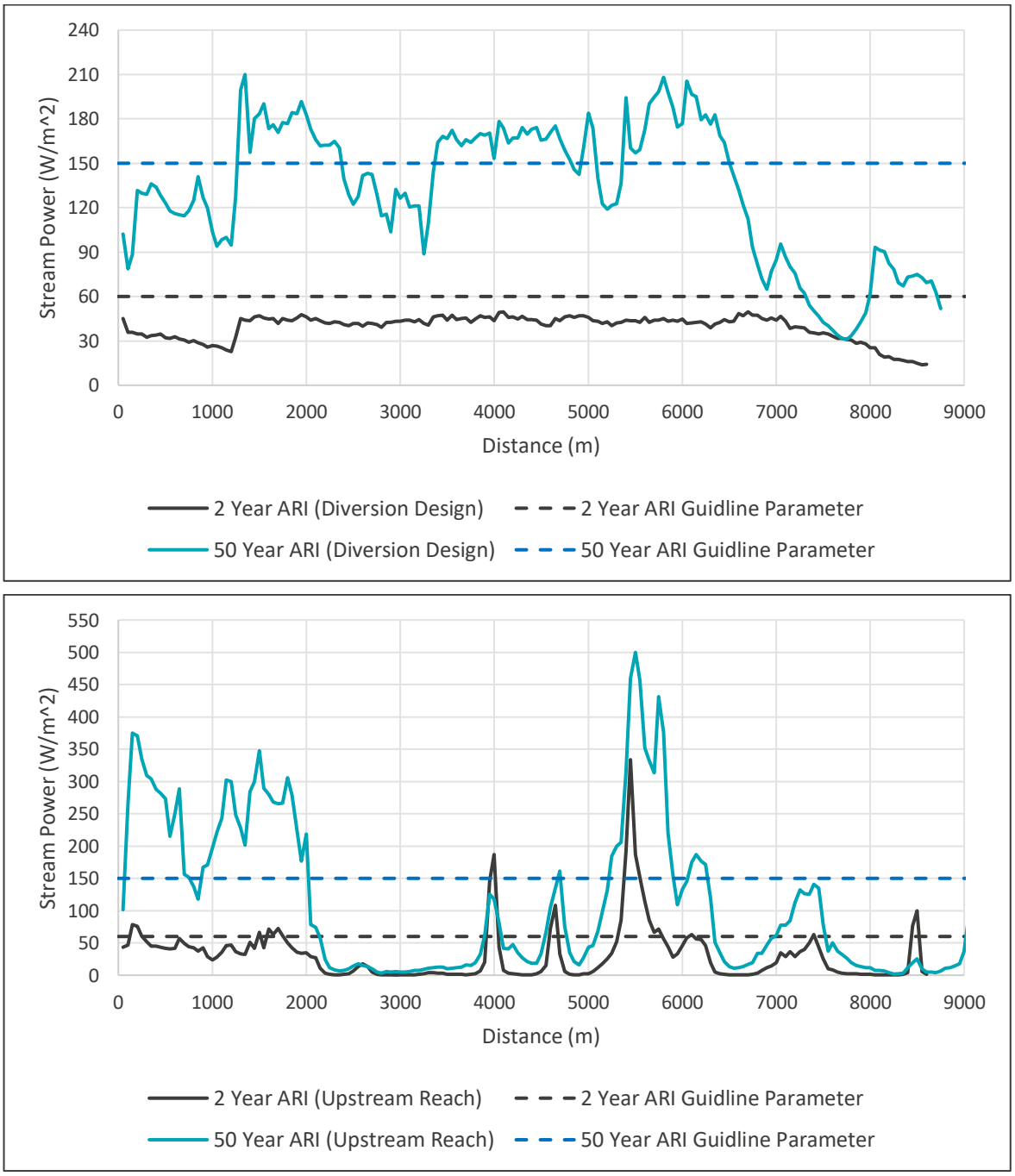
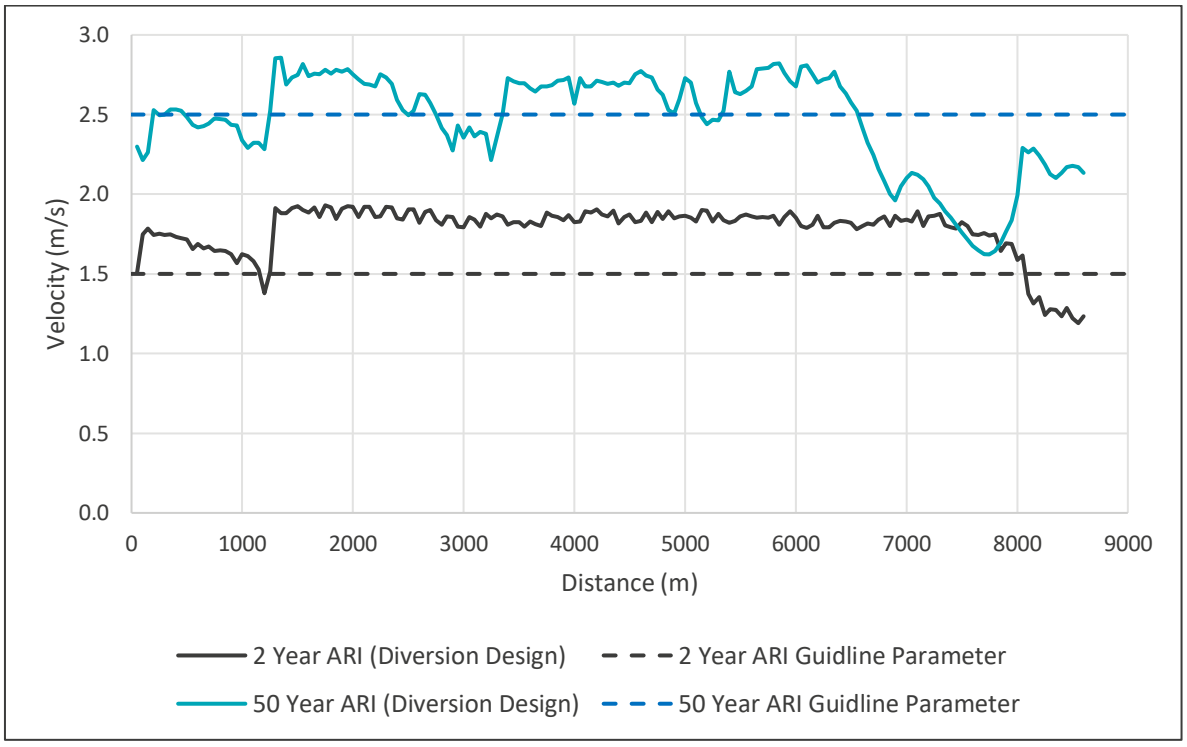


FIGURE D.1: STREAM POWER TUFLOW MODEL RESULTS (DIVERSION DESIGN AND UPSTREAM REACH)



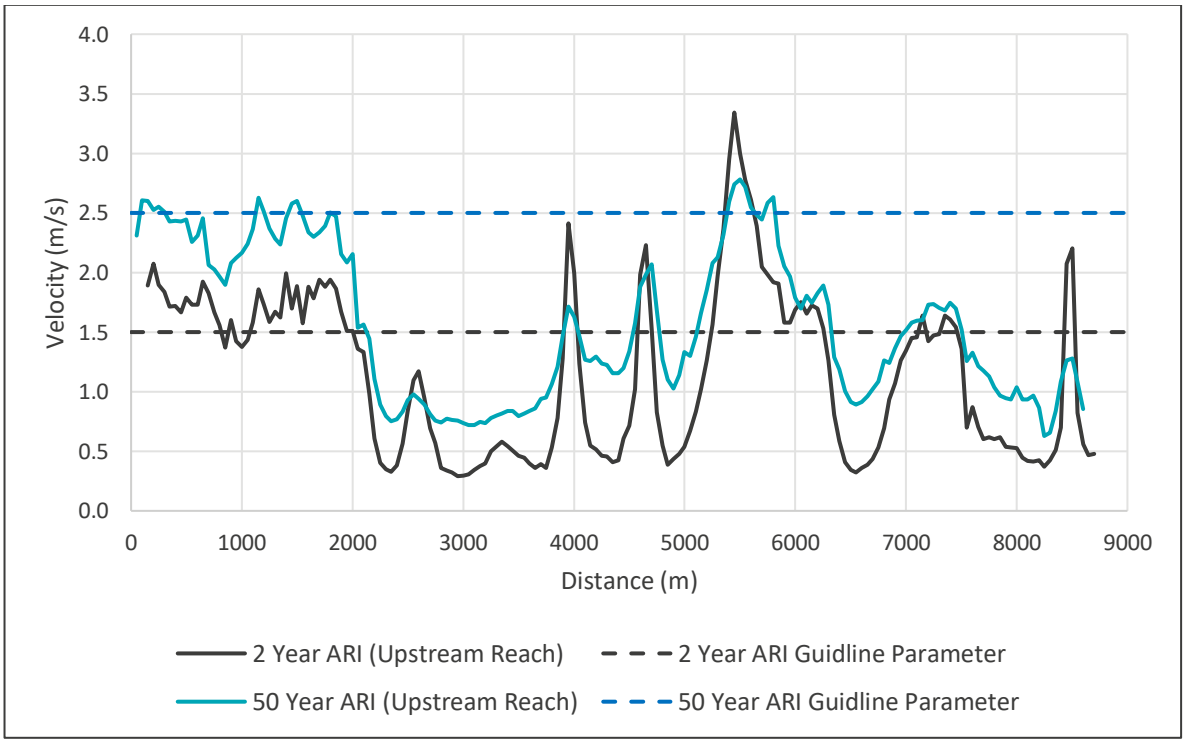


FIGURE D.2: VELOCITY TUFLOW MODEL RESULTS (DIVERSION DESIGN AND UPSTREAM REACH)

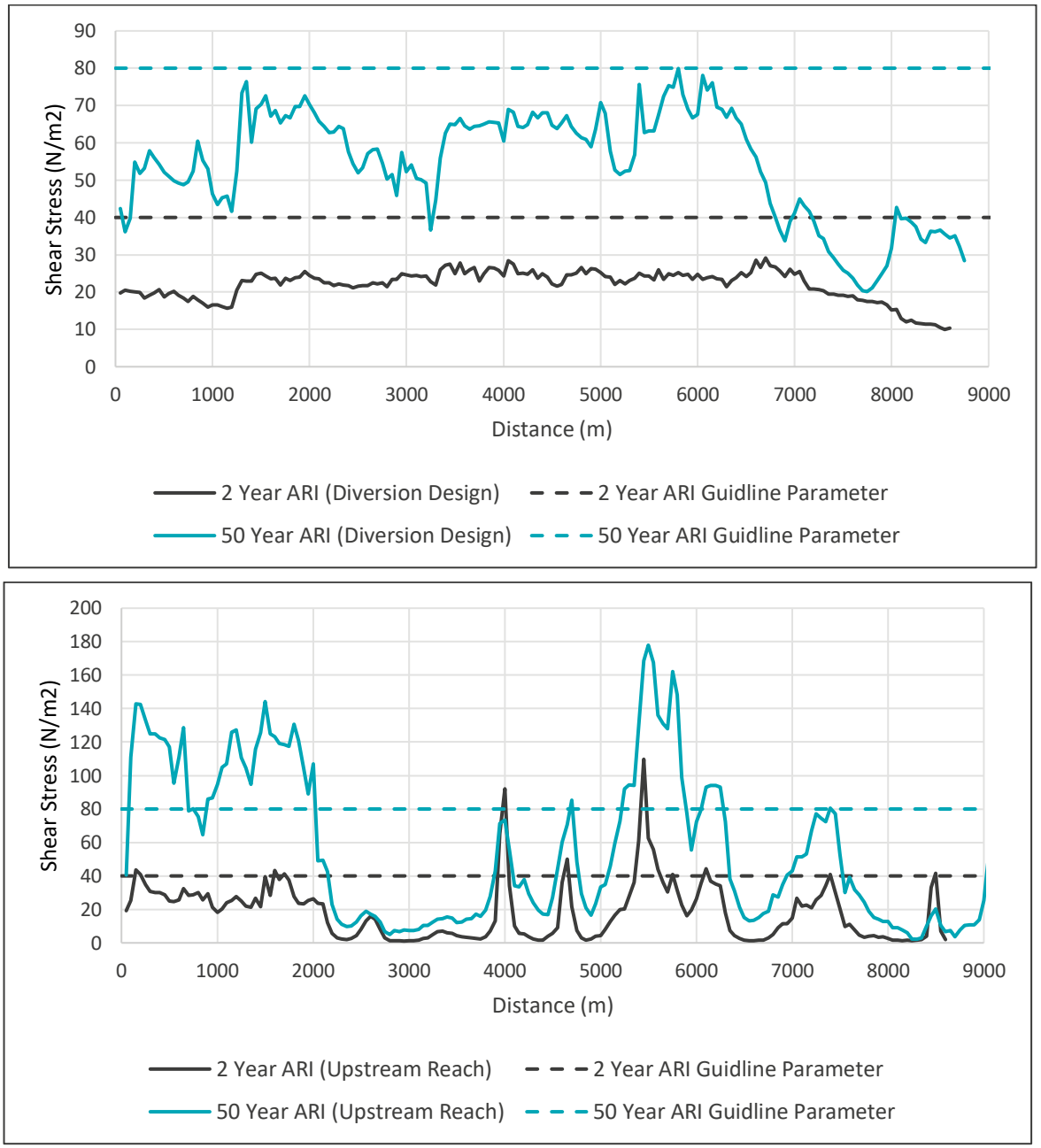


FIGURE D.3: SHEAR STRESS TUFLOW MODEL RESULTS (DIVERSION DESIGN AND UPSTREAM REACH)

APPENDIX E: PREFERRED OPTION CONCEPT DESIGN DRAWINGS

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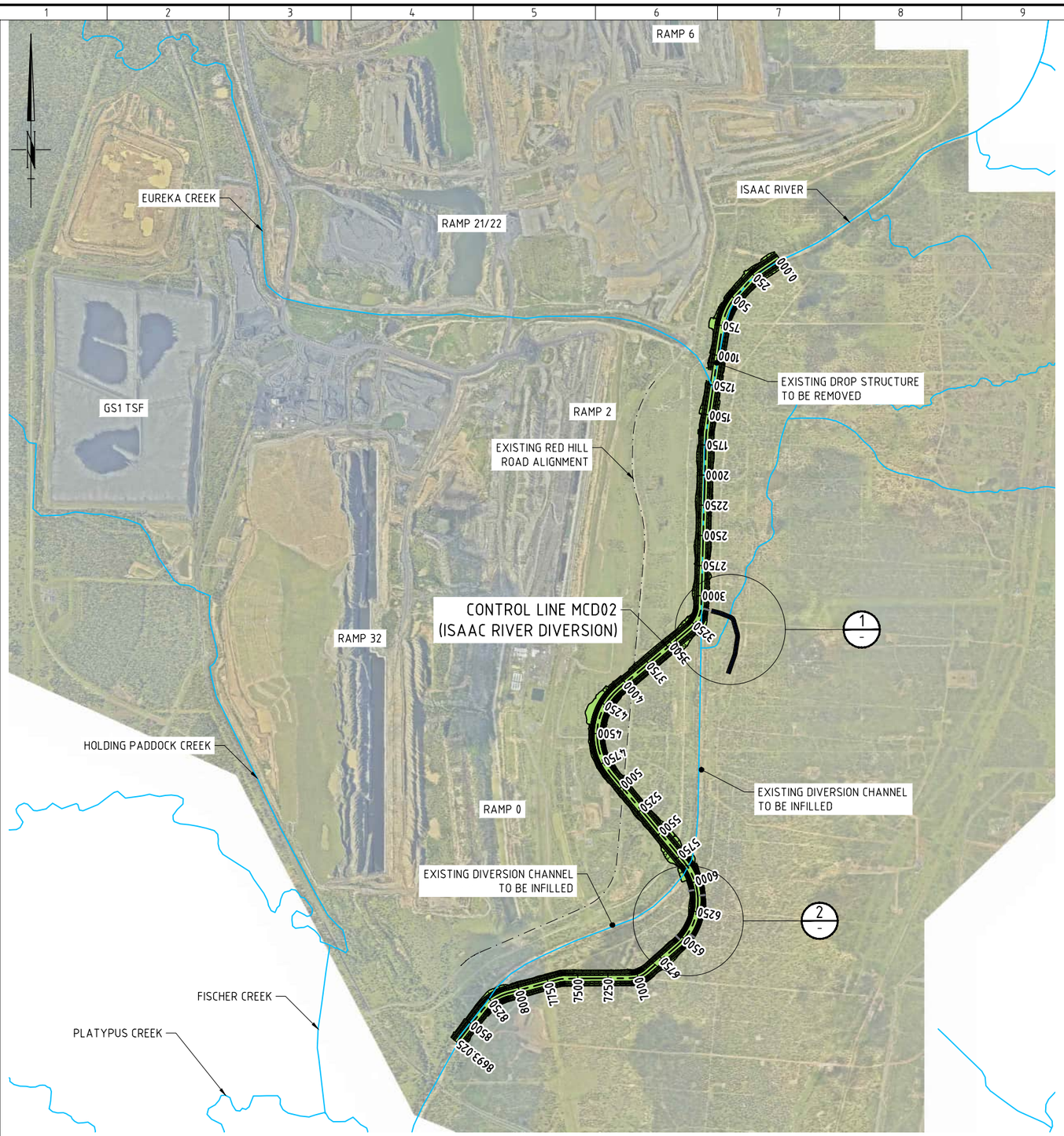

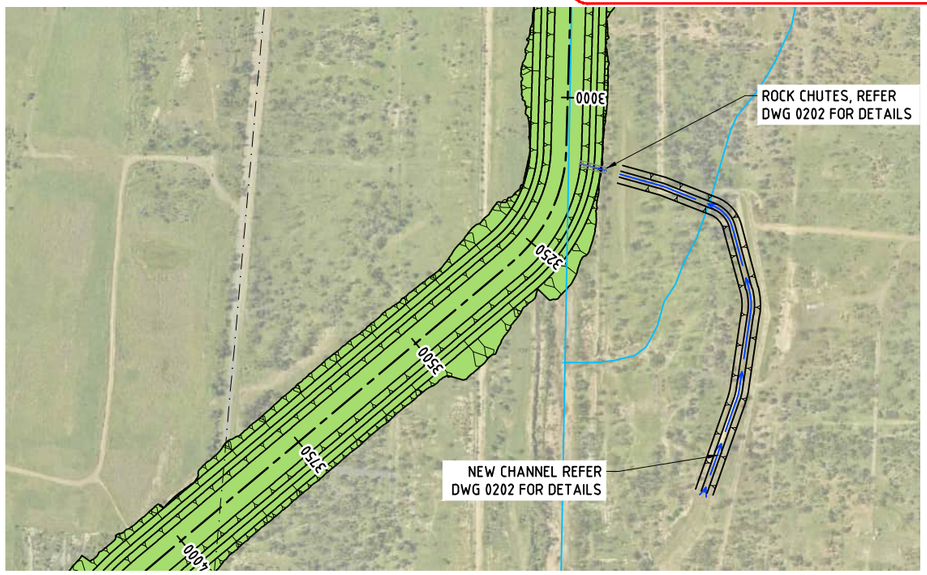

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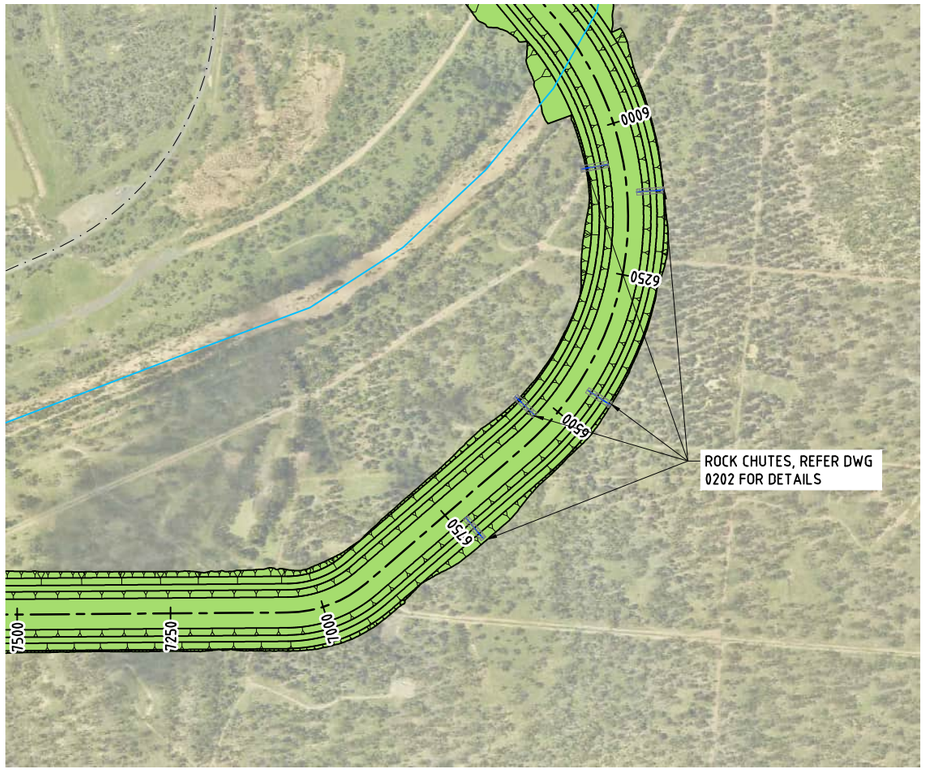

DETAIL 2
SCALE 1:5000

LEGEND

- EXISTING WATERCOURSE
- ISAAC RIVER DIVERSION EXTENTS
- EXISTING RED HILL ROAD ALIGNMENT

GENERAL ARRANGEMENT PLAN
SCALE: 1:20,000

0 50 100 150 200 250m
SCALE 1:5000 (A1)
SCALE BEFORE REDUCTION

0 200 400 600 800 1000m
SCALE 1:20,000 (A1)
SCALE BEFORE REDUCTION

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	A	14.08.25	FOR INFORMATION	NWN				
	REV	DATE	DESCRIPTION	DRN	ENG	APP	DRAWING No.	TITLE
	REVISION						REFERENCE DRAWINGS	

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DRN. CHK		
ENGINEER		
ENG. CHK (QA)		
APPROVED		

RPEQ APPROVAL
RPEQ ENGINEER
RPEQ No. DATE
PROJECT No.
EQUIPMENT TAG

BMA REVIEW
SIGNATURE
DATE

GOONYELLA MINE
PRCP ISAAC RIVER DIVERSION
GENERAL ARRANGEMENT PLAN

DRG. No.
LEGACY DRG No.
STATUS: NOT FOR CONSTRUCTION – FOR REVIEW

Sht
Sht Size A1
Scale –
Rev. No. B

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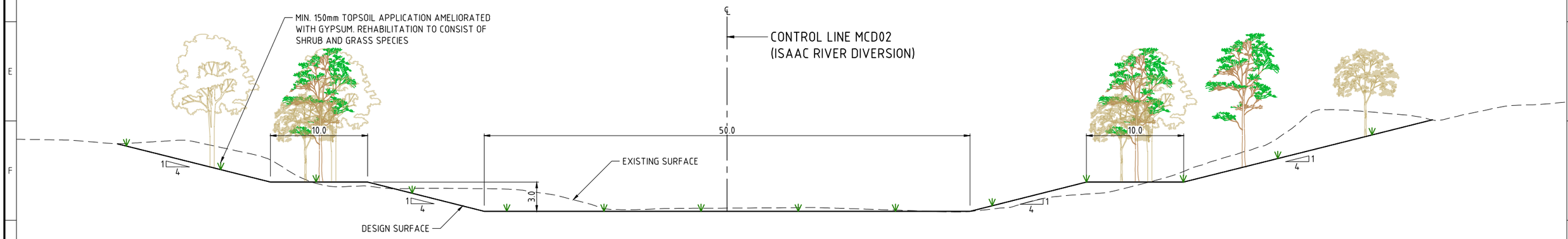

ISAAC RIVER DIVERSION TYPICAL SECTION

SCALE 1:200

LEGEND

EXISTING SURFACE

DESIGN SURFACE

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SCALE 1:200 (A1)
SCALE BEFORE REDUCTION

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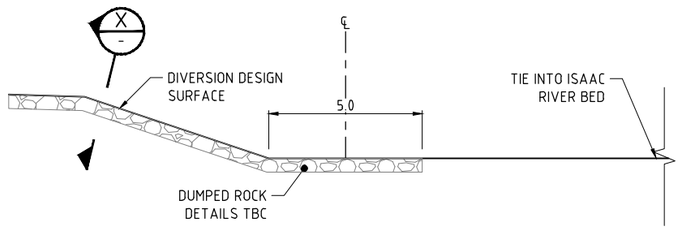

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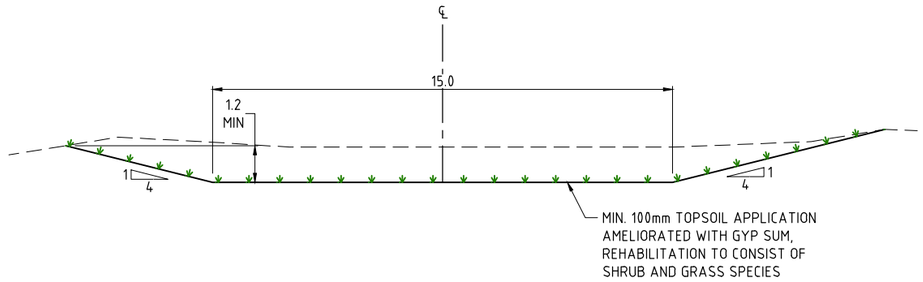

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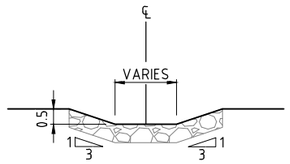

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LEGEND

EXISTING SURFACE

DESIGN SURFACE

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SCALE BEFORE REDUCTION

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A	14.08.25	FOR INFORMATION	NWN		

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EQUIPMENT TAG

BMA REVIEW
SIGNATURE
DATE

GOONYELLA MINE
PRCP ISAAC RIVER DIVERSION
CONCEPTUAL TYPICAL SECTIONS AND DETAILS
SHEET 2 OF 2

DRG. No.
LEGACY DRG No.
STATUS: NOT FOR CONSTRUCTION - FOR REVIEW
DO NOT SCALE

Sht
Sht Size: A1
Scale: -
Rev. No.: B

CAD FILE: QC1000-051-DWG-0202.dwg

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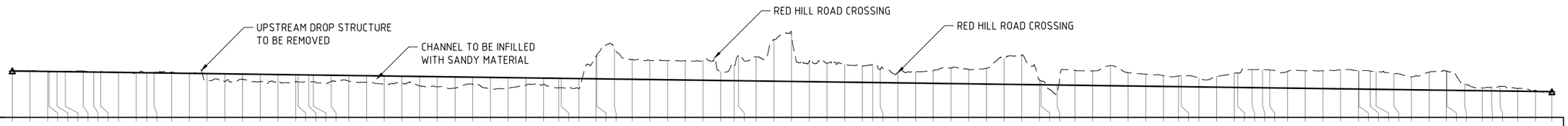

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200.000	75893.63.526	603140.286	-0.169	240.710	240.542
208.040	75893.58.989	603133.650	-0.269	240.702	240.432
252.887	75893.29.756	603099.763	-0.041	240.653	240.612
300.000	75892.95.184	603067.757	0.148	240.602	240.750
400.000	75892.21.802	602999.822	0.419	240.494	240.913
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500.000	75891.47.373	602933.081	0.284	240.386	240.670
600.000	75890.63.170	602879.446	-0.031	240.278	240.247
700.000	75889.69.991	602843.609	-0.433	240.171	239.738
759.084	75889.12.215	602831.410	0.028	240.107	240.135
800.000	75888.71.752	602825.336	0.159	240.063	240.222
900.000	75887.72.860	602810.492	0.532	239.955	240.486
1000.000	75886.73.968	602795.647	0.214	239.847	240.061
1100.000	75885.75.076	602780.803	-3.193	239.739	236.546
1200.000	75884.76.184	602765.958	-3.447	239.631	236.184
1300.000	75883.77.292	602751.114	-2.271	239.523	237.252
1400.000	75882.78.400	602736.269	-3.254	239.415	236.161
1500.000	75881.79.508	602721.425	-3.084	239.307	236.223
1600.000	75880.80.616	602706.580	-3.019	239.199	236.180
1614.181	75880.66.593	602704.475	-3.291	239.184	235.892
1674.184	75880.06.863	602699.145	-3.132	239.119	235.987
1700.000	75879.81.057	602698.397	-3.043	239.091	236.048
1800.000	75878.81.099	602695.498	-2.867	238.983	236.117
1900.000	75877.81.141	602692.600	-2.512	238.875	236.363
2000.000	75876.81.183	602689.701	-2.866	238.767	235.902
2100.000	75875.81.225	602686.803	-3.633	238.660	235.026
2200.000	75874.81.267	602683.904	-3.521	238.552	235.030
2300.000	75873.81.309	602681.006	-4.248	238.444	234.196
2400.000	75872.81.351	602678.107	-4.560	238.336	233.776
2500.000	75871.81.393	602675.208	-5.039	238.228	233.189
2600.000	75870.81.435	602672.310	-3.212	238.120	234.908
2700.000	75869.81.477	602669.411	-5.131	238.012	232.881
2800.000	75868.81.519	602666.513	-4.683	237.904	233.221
2900.000	75867.81.561	602663.614	-3.261	237.796	234.535
3000.000	75866.81.603	602660.716	-2.758	237.688	234.930
3085.035	75865.96.604	602658.251	-4.208	237.596	233.389
3100.000	75865.81.667	602657.370	-4.211	237.580	233.370
3200.000	75864.86.448	602629.074	-4.458	237.472	233.014
3295.602	75864.12.566	602669.322	10.085	237.369	247.454
3300.000	75864.09.734	602565.957	10.715	237.364	248.080
3400.000	75863.45.347	602489.443	13.665	237.256	250.921
3500.000	75862.80.961	602412.929	8.798	237.149	245.947
3600.000	75862.16.574	602336.415	8.582	237.041	245.622
3700.000	75861.52.188	602259.901	8.587	236.933	245.519
3800.000	75860.87.801	602183.388	8.692	236.825	245.517
3900.000	75860.23.415	602106.874	9.050	236.717	245.767
4000.000	75859.59.028	602030.360	4.071	236.609	240.680
4076.233	75859.09.944	601972.031	7.158	236.527	243.685
4100.000	75858.94.215	601954.216	11.491	236.501	247.992
4200.000	75858.19.405	601888.109	10.844	236.393	247.237
4300.000	75857.32.953	601838.181	18.718	236.285	255.003
4400.000	75856.38.306	601806.425	21.275	236.177	257.452
4500.000	75855.39.235	601794.104	9.378	236.069	245.447
4600.000	75854.39.692	601801.712	8.455	235.961	244.416
4700.000	75853.43.645	601828.944	8.048	235.853	243.902
4800.000	75852.54.922	601874.715	7.310	235.746	243.056
4858.003	75852.08.227	601909.068	8.112	235.683	243.794
4900.000	75851.75.898	601935.875	5.963	235.638	241.601
5000.000	75850.98.919	601999.704	4.912	235.530	240.442
5100.000	75850.21.939	602063.534	5.125	235.422	240.547
5200.000	75849.44.960	602127.363	5.799	235.314	241.113
5300.000	75848.67.981	602191.193	7.114	235.206	242.320
5400.000	75847.91.002	602255.022	6.477	235.098	241.575
5500.000	75847.14.023	602318.852	7.129	234.990	242.119
5600.000	75846.37.044	602382.682	11.642	234.882	246.524
5700.000	75845.60.065	602446.511	13.376	234.774	248.151
5800.000	75844.83.085	602510.341	2.118	234.666	236.784
5808.859	75844.76.266	602515.996	1.818	234.657	236.475
5900.000	75844.01.207	602567.472	-3.883	234.558	230.675
6000.000	75843.09.648	602607.266	6.767	234.450	241.217
6100.000	75842.12.007	602628.078	6.560	234.342	240.903
6200.000	75841.12.179	602629.076	9.084	234.235	243.319
6300.000	75840.14.142	602610.222	6.043	234.127	240.169
6400.000	75839.21.805	602572.266	5.447	234.019	239.465
6500.000	75838.38.850	602516.723	4.830	233.911	238.741
6584.665	75837.78.415	602457.573	4.799	233.819	238.619
6600.000	75837.68.403	602445.958	4.934	233.803	238.737
6700.000	75837.03.108	602370.217	4.001	233.695	237.696
6800.000	75836.37.813	602294.477	4.827	233.587	238.414
6900.000	75835.72.519	602218.736	6.393	233.479	239.872
6918.251	75835.60.602	602204.913	6.620	233.459	240.079
7000.000	75835.21.177	602133.948	8.129	233.371	241.500
7059.025	75835.12.088	602075.843	8.193	233.307	241.500
7100.000	75835.11.777	602034.869	8.010	233.263	241.273
7200.000	75835.11.018	601934.872	7.504	233.155	240.659
7300.000	75835.10.258	601834.875	7.954	233.047	241.002
7400.000	75835.09.498	601734.878	8.062	232.939	241.002
7500.000	75835.08.738	601634.881	8.614	232.831	241.446
7600.000	75835.07.979	601534.884	8.333	232.724	241.057
7602.988	75835.07.956	601531.897	8.329	232.720	241.049
7667.182	75834.99.277	601468.469	8.190	232.651	240.841
7700.000	75834.90.702	601436.791	7.947	232.616	240.563
7800.000	75834.64.571	601340.266	7.092	232.508	239.599
7900.000	75834.38.441	601243.740	5.784	232.400	238.184
8000.000	75834.12.310	601147.215	8.102	232.292	240.394
8096.573	75833.87.075	601053.997	8.783	232.188	240.970
8100.000	75833.86.166	601050.693	8.687	232.184	240.871
8200.000	75833.47.514	600958.747	3.159	232.076	235.235
8300.000	75833.08.863	600879.221	1.300	231.968	233.268
8352.762	75832.87.095	600843.987	1.628	231.911	233.539
8400.000	75832.68.317	600814.803	2.126	231.860	233.986
8500.000	75832.31.318	600753.022	1.084	231.752	232.837
8600.000	75832.13.685	600691.242	0.516	231.644	232.160
8693.025	75832.98.536	600633.770	0.008	231.544	231.551

CONTROL LINE MCD02 (ISAAC RIVER DIVERSION)

SCALE 1:12500 HORZ.
SCALE 1:1000 VERT.

LEGEND

EXISTING SURFACE

DESIGN SURFACE

0 12.5 25 37.5 50 62.5m
SCALE 1:1250 (A1)
SCALE BEFORE REDUCTION

0 125 250 375 500 625m
SCALE 1:12,500 (A1)
SCALE BEFORE REDUCTION

VENDOR DRG NUMBER
QC1000-051-DWG-0301

VENDOR LOGO
ENGENY

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A	14.08.25	FOR INFORMATION	NWN		

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DRAWING No.	TITLE

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DRN. CHK		
ENGINEER		
ENG. CHK (QA)		
APPROVED		

RPEQ APPROVAL
RPEQ ENGINEER
RPEQ No. DATE
PROJECT No.
EQUIPMENT TAG

BMA REVIEW
SIGNATURE
DATE

GOONYELLA MINE
PRCP ISAAC RIVER DIVERSION
LONGITUDINAL SECTIONS

DRG. No.
LEGACY DRG No.
STATUS: NOT FOR CONSTRUCTION - FOR REVIEW
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Sht
Sht Size A1
Scale -
Rev. No. A

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APPENDIX F: CONCEPT DESIGN WITH PRCP LANDFORM (VERSION 2.3) INTERACTION

598000 599000 600000 601000 602000 603000 604000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000

ML 1900
ML 1764
Eureka Creek
Isaac River
Isaac River
ML 70288
ML 70287
ML 1763
ML 70289
Holding Paddock Creek
ML 70478
Fisher Creek
ML 70479
Isaac River

Legend

- Preferred Diversion Alignment
- Watercourses
- ML Boundary

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Isaac River Diversion

Figure F.1
Isaac River Concept Design with PRCP Landform 2.3

REV.	DETAILS	DATE
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DRAWN: LN | CHECKED: BK
APPROVED: BK | DATE: 25/08/2025

GENERAL NOTES:

0 250 500 750 1,000 m
Scale @ A3: 1:25,000

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ENGENY

BHP MITSUBISH ALLIANCE

PRCP Concept Design Report

Eureka Creek Diversion

QC1000_051-REP-001-3

26 SEPTEMBER 2024

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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Signatures:						

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Eureka Creek Diversion which is an authorised watercourse diversion under the *Water Act 2000* located at Goonyella Riverside Mine (GRM). The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the GRM. In addition, the GRM Environmental Authority (EA) (EPML00853413) requires all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified rehabilitation requirements.

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per Environmental Authority requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives, and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for GRM as described in the Queensland Department of Environment, Science, and Innovation (DESI) Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options identification, assessment and selection.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium resulting in a relinquishable state for the diversion. The following methodology was utilised:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Eureka Creek is a tributary of the Isaac River, located in the Fitzroy River Basin. It is located 25 km north of Moranbah and 200 km southwest of Mackay QLD. The location within the Queensland region is shown in Figure 2.1. The catchment upstream covers an area of approximately 92 km^2 and flows through open woodlands across gently sloping plains for 19 km west of the GRM site. The watercourse was diverted in the late 1980's to facilitate mining activities with a redirection initially south on the western side of GRM then east towards the Isaac River. The GS4A dam at the downstream end of the diversion collects the mine affected water (MAW) from the channel and impounds it for storage and recirculation of MAW.

596000 597000 598000 599000 600000 601000 602000 603000 604000

7593000 7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000

ML 70468
ML 70193
ML 70469
ML 70194
ML 1764
Ramp 22
Ramp 6
ML 1900
Ramp 21
Isaac River
Eureka Creek
GS1 Tailings Dam
ML 70288
ML 70287
ML 70478
ML 1763
Ramp 2
Ramp 32 TSF Pit
ML 70289
Isaac River
Holding Paddock Creek
Ramp 0
ML 70479
Fisher Creek

Legend

- Watercourses
- ML Boundary
- Township
- Eureka Pre-mining Reach
- Eureka Current Alignment
- Eureka Upstream Reach
- Isaac Pre-mining Reach
- GS4A Dam

Mount Coolon
Glenden
Moranbah

0 500 1,000 1,500 2,000 m

JOB NUMBER: QC1000_051	CRS: AGD66 / AMG zone 55 (EPSG:20255)
REVISION: 0	Figure 1.1
AUTHOR: CH	Scale @ A3: 1:30,000
CHECKED: BK	GENERAL NOTES:
DATE: 11/07/2024	1. Aerial imagery courtesy of ESRI.
ENGENY / BMA BHP Mitsubishi Alliance	2. All unit measurements are provided in metres unless otherwise specified.
	3. Figure has been designed and exported to A3 page size.

BMA PRCP GRM Eureka Creek Diversion

Location of Eureka Creek Diversion

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2.2 Pre-Mining Conditions

Rehabilitation monitoring of the GRM and Eureka Creek diversion has been conducted since 1995 (Grigg, A. et al., 2001) and since 2015 under the new Department of Natural Resources and Mines (DNRM) model licence conditions (Engeny, 2016). Therefore, any pre-mining information of the area prior to this is limited. The pre-mining natural upstream, downstream and diversion reaches have been described as follows:

- **Upstream reach –** Based on the most recent monitoring report (Alluvium, 2022), Eureka Creek has four stream order one tributaries flowing into the Creek which flow southeast towards the GRM and Isaac River. Much of the catchment was cleared for grazing and is still grazed today. Upstream of the mine, Eureka Creek is a low capacity, moderately sinuous channel with a broad floodplain.
- **Downstream reach –** As the Eureka creek flows into the Isaac River, there is no specific downstream reach. Prior to the diversion, the reach entered the Isaac River further downstream where mining infrastructure is currently located. The pre-mining condition of the Isaac River diversion is reported separately.
- **Diversion reach (pre-mining) –** Utilising historical imagery from 1975 and sourced from the Queensland Open Data Portal, the pre-mining reach was approximately 6.5 km long and joined the Isaac River approximately 2 km downstream of the current confluence. The catchment area was approximately 93 km^2 prior to the construction of the diversion and is estimated to have been reduced by 10-15% post mining activity.

2.3 Current Conditions

Rehabilitation monitoring of the Eureka Creek diversion has been undertaken since 1995 and the last major monitoring was completed in 2021 by Alluvium. As part of the major monitoring, the latest condition of the Eureka Creek diversion has been described at the time of writing as follows (Alluvium, 2022):

- The upstream reach is in overall moderate to good condition with the occasional isolated bank erosion which is then offset by sediment build up. The riparian vegetation continuity is also generally good. Species diversity is conforming with biocondition benchmarks and provides a seed source for the diversion.
- The diversion reach remains in poor condition and requires significant management intervention to reduce the export of fine sediment from its batters. This is partly because of the GSA dam which was constructed immediately before Eureka Creek merges into the Isaac River and involves a weir and culvert structure. It forms part of the mine affected water (MAW) system and uses the GS4A dam impoundment and pumping however, it is not on a trajectory to achieve relinquishment. The riparian vegetation is typically limited to a narrow strip beside the channel and the lack of woody vegetation leads to reduced leaf litter, fallen logs, and hollow-bearing trees, resulting in poorer habitat value. Ground cover is often dense through the diversion and dominated by *Cenchrus ciliaris*, in particular upstream of the haul road.

Due to this current condition, it is considered unlikely that the existing diversion with the dam structure will achieve a state of dynamic equilibrium and be suitable for relinquishment following closure of the GRM. The upstream and current diversion reach of the Eureka diversion at the GRM are shown in Figure 2.1.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

3.1 DNRME Guidelines

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Eureka Creek diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Eureka Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.

- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential; however, stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - no vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.1 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the construction.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.2.

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass *(Cenchrus ciliaris)*	40
Structurally diverse suite of established native vegetation	120

4. OPTIONS IDENTIFICATION

Engeny identified two potential options for the Diversion as part of stage 1 (summarised below in Table 4.1). The following constraints were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the ML boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the Diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2
Description	Retain existing diversion alignment, GS4A to be desilted and weir removed. Total length is 5.7 km.	Divert to the east of GS1 tailings dam and connect to the Fisher Creek diversion. Alignment sits close to existing railway loop and will link up with the existing Holding Paddock Creek diversion. Total length is 8.8 km
Likelihood that diversion will achieve state of dynamic equilibrium	High – Similar grade to the pre-mining alignment (0.21%). There is no significant difference in geometry or appearance to the existing creek. The existing channel will be regraded and rehabilitated.	Low – Large difference in grade (0.15%) with potential risk with sediment transport regime. Large difference in length (8.8 km). Significant difference in geometry and could have impacts to Platypus Creek.
Order of magnitude cost estimate*	$12.4 M	$24 M
Ability to isolate diversion from flows during establishment period	No – it will be constructed on the existing diversion alignment so there is risk of inflows during construction	Yes – the majority of the diversion can be constructed offline from the existing diversion.

* Costs estimated based on average $10/m^3.

597000 598000 599000 600000 601000 602000 603000 604000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

ML 70194
ML 1900
Eureka Creek
ML 1764
Ramp 6
Ramp 22
Ramp 21
Isaac River
GS1 Tailings Dam
ML 70288
ML 70287
ML 70478
Ramp 2
Ramp 32
ML 1763
ML 70289
Ramp 0
Holding Paddock Creek
Fisher Creek
ML 70479
ML 70108
Isaac River

Legend

- Option 1
- Option 2
- Watercourses
- Existing Railway
- Existing Roads
- ML Boundary

0 500 1,000 1,500 m

JOB NUMBER: QC1000_051	CRS: AGD66 / AMG zone 55 (EPSG:20255)
REVISION: 1	Figure 4.1
AUTHOR: CH	Scale @A3 1:27,500
CHECKED: BK	GENERAL NOTES:
DATE: 11/07/2024	1. Aerial imagery courtesy of ESRI.
ENGENY / BMA BHP Mitsubishi Alliance	2. All unit measurements are provided in metres unless otherwise specified.
	3. Figure has been designed and exported to A3 page size.

BMA PRCP GRM Eureka Creek Diversion

Eureka Creek Diversion Realignment Options

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5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BMA and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	50%
Order of magnitude cost estimate	30%
Ability to isolate diversion from flows during establishment period	20%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 1 to be carried forward into concept design as a preferred option, since it scored highest out of the two options and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2
Overall Weighted Score	0.8	-0.2
Relative Risk	Lowest Risk	Neutral Risk
Fatal Flaw	No	No

6. CONCEPT DESIGN

6.1 Design Parameters and Plan

Table 6.1 details the parameters for each outcome in Section 3, forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND ACARP PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function, and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis. b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed).	☒ ☐	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	Outcome 5 – Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME (2019). Stream power benchmark values were adopted from ACARP (2014) due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Concept Design Diversion Alignment

The alignment of Option 1 was determined to be the preferred option using the MCA. The option was further refined to optimise the earthworks. The full concept drawing package for the permanent Eureka Creek diversion is included in Appendix E and the interaction of the design with the PRCP landform in Appendix F.

Typically, the works associated with the channel predominately involve flattening over-steep batters, cleaning out accumulated sediment and formalising the low flow channel. In addition, the GS4A weir and culvert structure will need to be removed to facilitate the works with future road crossing requirements for Eureka Creek to be determined during future phases of study.

6.3 Channel Geometry and Grade

The reference cross-sections are shown in

Figure 6.1. The typical upstream channel cross-sections are presented in Figure 6.2. These dimensions were based on the average upstream channel geometry and grade.

Table 6.2 summarises the typical channel cross-section selected for the concept design. The concept design drawings in Appendix E show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY FOR CONCEPT DESIGN

Channel Geometry	Quantity	Comments
Channel Bed Width	5 m	
Bench Width	6 m	
Channel Depth	2.5 m	Consistent depth of low flow channel at 2.5 m
Batter Slope	1V:3H	For both the low flow channel and high flow channel batters. As per Section 6.2, the diversion works only involve excavation of in-situ material through the following activities: - Flattening over-steep batters - Removing out accumulated sediment and formalising the low flow channel. The batters will be covered with topsoil, hydromulch and hydroseed (Appendix E) to ensure stability and prompt revegetation of the channel batters.

596000 597000 598000 599000 600000 601000 602000 603000

7592000 7591000 7590000 7589000 7588000

ML 70194
ML 1900
ML 1764
Ramp 22
Ramp 21
ML 1763
ML 70478
ML 70287
ML 70288
Isaac River

Legend

- Reference Cross-section Locations
- Eureka Preferred Option
- Eureka Upstream Reach
- Watercourses
- ML Boundary
- Existing Railways
- Existing Roads

0 250 500 750 1,000 m

JOB NUMBER: QC1000_051	
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DATE: 25/09/2024	

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Location of Reference Cross-Sectional Areas

CRS: AGD66 / AMG zone 55 (EPSG:20255)

Figure 6.1
Scale @ A3: 1:19,000

GENERAL NOTES:
1. Aerial imagery courtesy of Google.
2. All unit measurements are provided in metres unless otherwise specified.
3. Figure has been designed and exported to A3 page size.

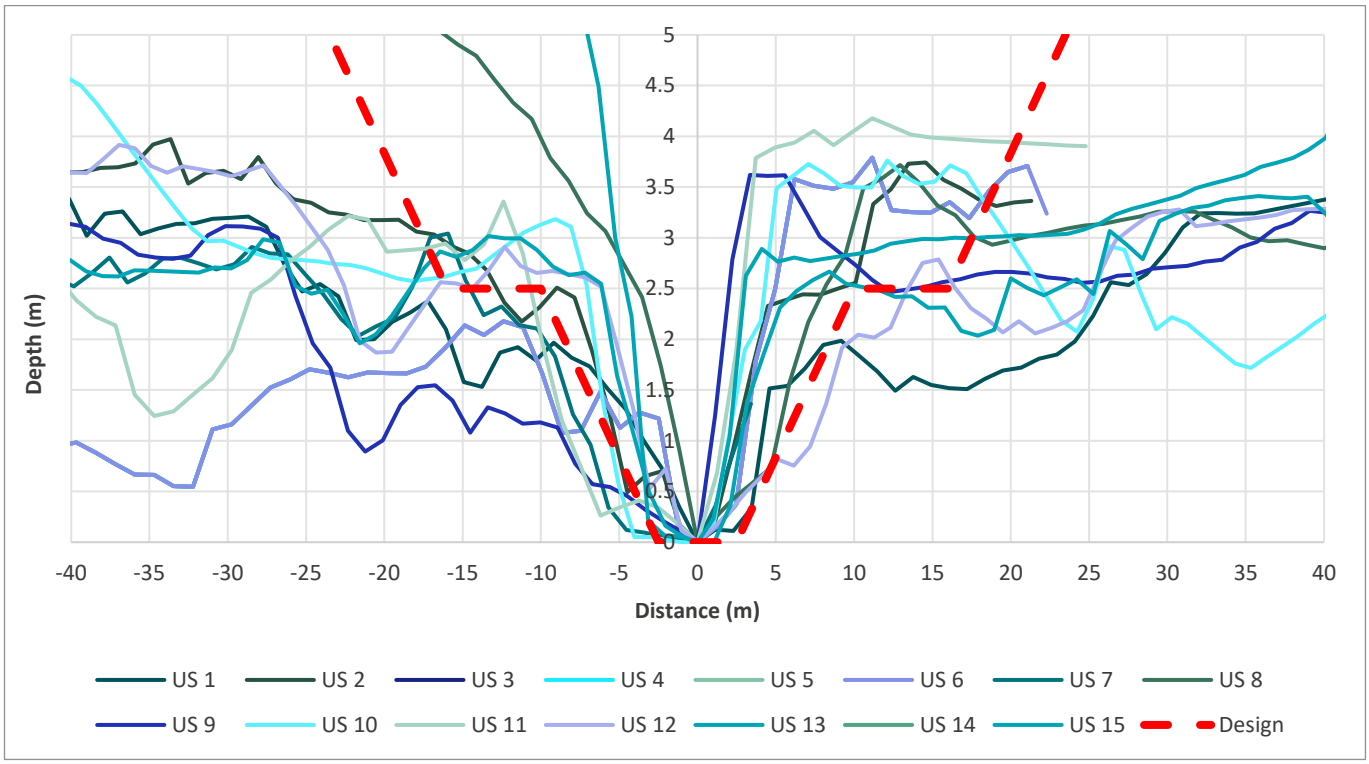

Figure 6.2: Typical Upstream Channel Cross Section of Eureka Creek

The concept design does not seek to add sinuosity to the channel. This is due to the spatial limitations and constraints of the surrounding environment. The current diversion closely approximates the pre-mining conditions for the creek. The current length of the diversion is approximately 5.7 km, the pre-mining length for the same reach was approximately 6.5 km. The existing grade of the diversion is 0.27%, while the design grade is 0.21%. The reduction in grade was implemented to ensure that it aligns with the future planned slope of the Isaac River bed. The reduced length (approximately 12%) in the channel is not expected to adversely impact sediment transport/deposition within the channel. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix E.

6.4 Hydrology

A hydrologic model of Eureka Creek (concept design) was developed using WBNM software. The model was used to estimate flows for the 1 in 1000-year flood event. The details of the hydrologic model development are presented in Appendix B. Peak flows for frequent events (39% AEP and 2% AEP) for the Eureka Creek diversion were estimated using the ACARP (2002) methods and are presented in Table 6.3. The Eureka Creek catchment is presented in Figure 6.3.

585000 590000 595000 600000

7605000 7600000 7595000 7590000 7585000

Legend

- ML Boundary
- Existing Railway

WBNM Model Sub-catchments

- Eureka Creek

Watercourse Stream Order

- 1
- 2
- 3
- 4
- 5
- 6

ML 6949
ML 70494
ML 700003
ML 70421
ML 70493
ML 1802
ML 70121
ML 1764
ML 70468
ML 1900
ML 70469
ML 70193
ML 70194
ML 1763
ML 70288
ML 70478
ML 70287
ML 70289
ML 70479

0 1 2 3 4 km

JOB NUMBER: QC1000_051	
REVISION: 0	
AUTHOR: CH	
CHECKED: BK	
DATE: 25/06/2024	

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Catchment Map

CRS: AGD66 / AMG zone 55 (EPSG:20255)

Figure 6.3
Scale @ A3: 1:70,000

GENERAL NOTES:
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2. All unit measurements are provided in metres unless otherwise specified.
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6.4.1 Frequent Events

Peak flows for frequent events (39% AEP and 2% AEP) for the Eureka Creek diversion (concept design) were estimated using the ACARP (2002) methods and are presented in Table 6.3. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Eureka Creek diversion concept design and has been compared to the ACARP (2002) diversion channel design parameters.

TABLE 6.3: EUREKA CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m3/s
2% AEP (50-year ARI)	172
39% AEP (2-year ARI)	65

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform was assessed to inform the interaction between the diversion and final voids landform. The 0.1% peak flow rate at the end of the diversion is 727.17 m3/s.

6.5 Hydraulics

A two-dimensional TUFLOW flood model was developed to assess the compliance with the DNRME and ACARP hydraulic performance criteria for the 39% and 2% AEP events.

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in the 39% and 2% AEP events (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP (2-year ARI)		2% AEP (50-year ARI)	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	39.09	<60	76.59	<150
Stream Velocity (m/s)	1.04	<1.5	1.44	<2.5
Shear Stress (N/m^2)	34.39	<40	51.56	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

It can be seen from Table 6.4 that all the average diversion hydraulic results are below the design parameters for both the 39% AEP and 2% AEP storm events.

It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated. Given that the alignment is unable to be taken offline during construction, it will be critical that vegetation of the channel be established following construction to minimise erosion risk during frequent events. The concept design could be optimised in detailed design to further reduce the stream power and shear stress in conjunction with a planned diversion revegetation strategy.

The extents and depths of the 0.1% flooding are depicted in Figure 6.4. The result shows that there is no risk of flood ingress to any final voids.

598000 599000 600000 601000 602000 603000

7591000

7590000

7589000

7588000

ML 1900

ML 1764

ML 1763

ML 70288

Isaac River

Isaac River

Legend

- Existing Roads
- Existing Railways
- ML Boundary

Flood Depth (m)

- <= 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 7
- 7 - 18
- > 18

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

0 250 500 750 1,000 m

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AUTHOR: CH	
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DATE: 26/07/2024	

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0.1% AEP Flood Event with PRCP Landform 2

CRS: AGD66 / AMG zone 55 (EPSG:20255)

Figure 6.4
Scale @ A3: 1:15,000

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6.6 Risks and Mitigation Measures

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised for this risk assessment align with BHP Global Standard – Risk Management.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to frequent (up to 20% AEP / 5 year ARI) flood events. Diversion alignment unable to be taken offline.	Likely	2	30	Diversion channel constructed during dry season. Detailed revegetation plan to be implemented to promote rapid establishment. Seed mix to include fast establishing species to rapidly stabilise diversion.	Probable	1	3
Damage to the new diversion channel due to extreme/rare (0.1% AEP / 1000 year ARI) flood event (mainly overland flow and bank erosion)	Highly Unlikely	2	0.9	Revegetation plan to include large species capable of withstanding shear stresses associated with rare events.	Highly Unlikely	2	0.9
Construction program impacted by frequent flow event (up to 20% AEP / 5 year ARI). Diversion unable to be taken offline	Unlikely	1	1	Diversion construction to be timed to minimise risk of large flows while still maintaining enough watering to promote vegetation establishment and growth. Potential to construct upstream detention to minimise the peak flows if allowed by existing water licence.	Probable	1	3
Constructability of diversion channel – encountering bedrock, material availability and access	Highly Unlikely	2	0.9	Geotechnical and soil investigations as part of functional design.	Highly Unlikely	1	0.3
Flood ingress into final voids	Highly Unlikely	2	0.9	Final landform design to provide flood protection to ensure no flooding ingress in 0.1% AEP flood with 1.0 m freeboard	Highly Unlikely	2	0.9
Upstream rehabilitation of mining areas unsatisfactory leading to increase sediment loads to the final diversion channel	Likely	2	30	Additional upstream controls could be considered during functional design. Offline flow through sediment basins during vegetation establishment phase of rehabilitated catchments reporting to the Eureka Diversion	Unlikely	2	9

6.7 Additional Design and Construction Considerations

6.7.1 Surface Water Infrastructure

The GS4A weir and culvert structure will need to be removed to facilitate the works.

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Hydraulic modelling has demonstrated that the 39% AEP average shear stress of 39.09 N/m2 is slightly above the DNRME guideline value of 35 N/m^2 for a stable channel with no vegetation (refer Table 3.2). Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Eureka Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the Goonyella Riverside Mine Progressive Rehabilitation and Closure Plan.

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include Geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with BMAs watercourse diversion monitoring program and during the closure phases of the mine is required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7. CONCLUSION

The existing diversion is experiencing increasing bank erosion, lack of geomorphic and vegetation features like those in the local landscape, sediment aggradation and sediment deposition downstream.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of GRM.

Two options for rehabilitation of the Diversion were identified and assessed using the BMA Multi-Criteria Analysis outlined in Section 5. Option 1 was selected to proceed as the preferred concept design as it retains the existing diversion alignment with maintenance efforts to regrade and rehabilitate along the channel and removes mining infrastructure such as the GS4A dam to achieve the closure objectives. The final concept design, typical cross sections and longitudinal section are presented in Appendix E.

The highest risk to successful performance of the diversion is vegetation failure and subsequent erosion of the banks and bed of the diversion. It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated. Given that the alignment is unable to be taken offline during construction, it will be critical that vegetation of the channel be established following construction to minimise erosion risk during frequent events. The concept design could be optimised in detailed design to further reduce the stream power and velocities in conjunction with a planned diversion revegetation strategy.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

(c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

  (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

  (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

(d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

(e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

(f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

(g) This Report does not provide legal advice.

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APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Eureka Creek Diversion

Project: PRCP GRM Diversions
Workshop Date:

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	50%	1	0	Option 1: Has an alignment with a length (5.7km) and grade (0.21%) similar to the pre-mining alignment. Works will include removing the GS4A dam and regrading and rehabilitating the current diversion. Option 2: Substantial difference in length (8.8 km) and grade (0.15%). Potential impacts to Platypus Creek.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	30%	1	-2	Option 1: Utilises existing diversion corridor. Approximately 1.2MBCM of cut. Option 2: Crosses Existing Rail Loop and there might be interaction with Tailings Dam for the closure.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	20%	0	2	Option 1: Will be constructed on the existing diversion alignment. Option 2: The majority of the diversion can be constructed offline from the existing diversion.
	Overall Weighted Score		0.8	-0.2	

Is there a Fatal Flaw?	**No**	**No**
Relative Risk	**Lowest Risk**	**Neutral Risk**

APPENDIX B: HYDROLOGIC MODEL DEVELOPMENT

HYDROLOGIC MODEL SETUP

The WBNM (Watershed Bound Network Model) runoff routing software (2021 version) was used to develop the hydrology model. WBNM automatically calculates catchment routing based on the sub-catchment area, pervious/impervious areas and parameters, and the sub-catchment flow paths.

Catchment Inputs

Sub-catchment delineation for GRM was developed using the PRCP landform (Version 2) topography displayed in **FIGURE F.1**. The hydrological model includes the total catchment for the Isaac River (inclusive of Eureka, HPC, and Fisher creeks) extending downstream past the Goonyella mine, covering a total area of approximately 1180 km^2.

Three open water bodies are located in the upper catchment: Lake Elphinstone, Teviot Dam and Burton Gorge Dam. Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

The design life of the Teviot Creek Dam and Burton Gorge Dam, as part of mining closure operations, could impact design flow estimates. For this study, the WBNM model did not include the Burton Gorge Dam, Teviot Dam, and Lake Elphinstone located upstream of the study area, considering a worst-case scenario.

FIGURE B.1 provides the sub-catchment extents used for the WBNM.

Model Parameters

The final landform is proposed to be rehabilitated; therefore, the hydrology model has assumed no impervious surfaces remain and a 0% impervious fraction (Fi) for all catchments including the remaining spoil areas and voids.

The default routing parameter of 1, pervious lag parameter of 1.8 and impervious lag parameter of 0.1 have been adopted for the WBNM.

Design Rainfall

The 0.1% AEP (1000yr) was sourced using the Australian Rainfall and Runoff 2019 IFD generation tool available on the Bureau of Meteorology (BoM) website (www.bom.gov.au), at Latitude 21.6652 (S), Longitude 148.0792 (E). Aerial Reduction Factors (ARFs) have been used for all design events to convert point rainfall estimates to areal rainfall estimates.

Temporal Patterns

Design events (1% - 0.1% AEP) have utilised the 'East Coast North' areal temporal patterns, as the total catchment area for the model exceeds 75 km^2. All ten temporal patterns were simulated for storm durations ranging from the 3 hours to 168 hours.

Design Rainfall Losses

The initial and continuing losses obtained from the ARR Datahub for Isaac River catchment to Goonyella gauge are 36 mm and 2.7 mm/h, respectively.

The adopted design rainfall losses were selected to achieve the best match between the XP-RAFTS design discharges with the design discharges estimated by the FFA at the Isaac River Goonyella gauge. The following is of note:

- For the 50%, 20%, 10%, 5%, 2% and 1% AEP events, the default ARR initial losses of 36 mm and continuing losses of 2.7 mm/h were adopted, respectively. The initial loss will decrease for larger events as the catchment is likely to be more saturated prior to the design rainfall burst.
- For the 0.1% AEP design event, a conservative 0 mm initial loss was adopted. A continuing loss of 2.5 mm/h was adopted as per the flood assessment done by WRM in 2019 (WRM, 2019).

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000

Legend

Stream Gauge

WBNM Model Sub catchments

- Eureka Creek
- Fisher Creek
- Holding Paddock Creek
- Isaac River

Lake Elphinstone

Burton Gorge Dam

Teviot Dam

Eureka Creek at the railway

Eureka Creek at the GS4A Weir

Isaac River at Goonyella

0 5 10 km

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WBNM Hydrologic Model Layout

CRS: AGD66 / AMG zone 55 (EPSG:20255)

Figure B1
Scale @ A3: 1:180,000

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MODEL VALIDATION

The 50%, 20%, 10%, 5%, 2% and 1% AEP peak flows estimated from the hydrology model were validated using the following methods:

- **Regional Flood Frequency Estimation Model (RFFE)** - is a recommended peak flow validation method from the ARR 2019 guidelines (Ball, et al., 2019). The RFFE provides peak flow estimations based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).

- **Flood Frequency Analysis (FFA)** - provides peak flow estimates for different AEPs by developing a fitted distribution from recorded peak flows from historical flood events.

  The Eureka Creek gauges (Eureka Creek at the railway and GS4A) had an insufficient monitoring duration to conduct a reliable Flood Frequency Analysis (FFA). As a result, the FFA for the nearby Isaac River at the Goonyella gauge, located 7 km downstream of Eureka, was used for validation purposes. This analysis was completed as part of the Isaac River Flood Model by Engeny in March 2021.

  Isaac River FFA was undertaken on the peak annual (water year from October to September) discharges recorded at Isaac River at Goonyella (130414A) streamflow gauge by Queensland Department of Natural Resources Mines and Energy (DNRME) between 1982 and 2020. A Log Pearson Type 3 (LPIII) distribution was fitted to an annual maximum series of peak flows from the gauge (Engeny, 2021). To adapt the Isaac River FFA to Eureka Creek, peak flows were scaled based on the catchment area using the QRT method. The formula used for this adjustment is:

$$Q_u = \left(\frac{A_u}{A_g}\right)^n Q_g$$

  Where,

  Q_u is the estimated peak flow for the ungauged catchment.

  A_u is the area for the ungauged catchment.

  A_g is the catchment area for the stream gauging station.

  Q_g is the peak flow for the gauging station determined from the flood frequency analysis.

  The exponent n has been determined from the regional flood frequency regression analysis (RFFE) undertaken by the Queensland Department of Transport and Main Roads (Palmen & Weeks, 2008).

- **Peak flow estimates from previous flood studies** –

  - A hydrologic modelling of the Isaac River catchment including the Grosvenor Mine (GRV) and Moranbah North Mine (MNM) using the XPRAFTS runoff-routing model was developed to estimate the 39%, 10%, 5%, 2%, 1%, 0.2% and 0.1% annual exceedance probability (AEP) and probable maximum flood (PMF) design discharges for the Isaac River and its tributaries (Engeny, 2021). The estimated peak flows at the Isaac River at Goonyella Streamflow Gauge were compared to the WBNM and RFFE peak flows (refer toFigure B.2). It is to be noted that The Burton Gorge Dam, Teviot Dam and Lake Elphinstone upstream of the study area were modelled as detention basins in the XPRAFTS model.

  - Design peak discharges in the Isaac River at Goonyella, Eureka Creek upstream of the railway and Eureka Creek at the GS4A for the 10%, 5%, 2%, 1%, 0.1% were estimated using the XP-RAFTS model by WRM in 2019. These flows were compared to the WBNM model design peak discharges at these three gauge locations.

Model Validation Results

Table B.1 shows the WBNM estimated design discharges at the Isaac River at Goonyella, Eureka Ck at the Railway and Eureka Ck at the GS4A for design events between 10% to 0.1% AEP, and the comparison to the WRM design discharges. A visual comparison of the WBNM design peak discharges at the Isaac River streamflow gauge (130414A) against the flood frequency distribution curve, XP-RAFTS estimated peak flows by Engeny in 2021 and RFFE is provided in Figure B.2.

Validation of the design hydrology peak flow estimates indicates the following.

- **Isaac River Gauge**
  - Modelled peak flows for all design events are higher (3%-26%) than the LPIII expected quantile from the FFA. This is expected considering the exclusion of Burton Gorge Dam, Teviot Dam and Lake Elphinstone (Figure B.2).
  - Modelled peak flows compared to the RFFE method were higher for events rarer than the 10% AEP and lower for events more frequent than the 10% AEP. This irregularity is not concerning as the RFFE can provide irregular results if catchment characteristics are mostly different from the nearby gauged waterways used to derive the RFFE. Additionally, the Issac gauge catchment (1071.21 km^2) is outside the RFFE recommended catchment size of 0.5-1000 km^2, hence results have lower accuracy (Figure B.2).
  - WBNM estimated peak flows for all design events are higher (11%-28%) than the WRM 2019 flood modelling report (Table B.1).
- **Eureka Ck Gauge**
  - WBNM estimated peak flows for all design events are higher (10%-37%) than the WRM 2019 flood modelling report. This is expected considering the 37% increase of the Eureka catchment (Table B.1).

TABLE B.1: COMPARISON OF WBNM DESIGN DISCHARGES TO THE WRM 2019 FLOWS

		WRM (2019) Peak Discharge (m3/s)	WRM (2019) Critical duration (hours)	WBNM Peak Discharge (m3/s)	WBNM Critical duration (hours)	Difference (%)
Isaac River at Goonyella	Catchment Area (km^2)	-		1071.12 km^2		-
	Design event (AEP%)					
	10	830	18 hr	932	18 hr	11%
	5	1167	18 hr	1363	18 hr	14%
	2	1707	18 hr	2061	18 hr	17%
	1	2079	24 hr	2616	18 hr	21%
	0.1	3808	24 hr	5291	18 hr	28%
Eureka Creek at the railway	Catchment Area (km^2)	76.4 km^2		113.78 km^2		33%
	Design event (AEP%)					
	10	140	6 hr	159	18 hr	12%
	5	180	6 hr	217	18 hr	17%
	2	256	6 hr	299	18 hr	14%
	1	299	6 hr	374	18 hr	20%
	0.1	499	6 hr	692	12 hr	28%
Eureka Creek at the GS4A	Catchment Area (km^2)	80.7 km^2		129.05 km^2		37%
	Design event (AEP%)					
	10	147	6 hr	163	18 hr	10%
	5	189	6 hr	225	18 hr	16%
	2	267	6 hr	320	18 hr	17%
	1	311	6 hr	400	18 hr	22%
	0.1	521	6 hr	728	18 hr	28%

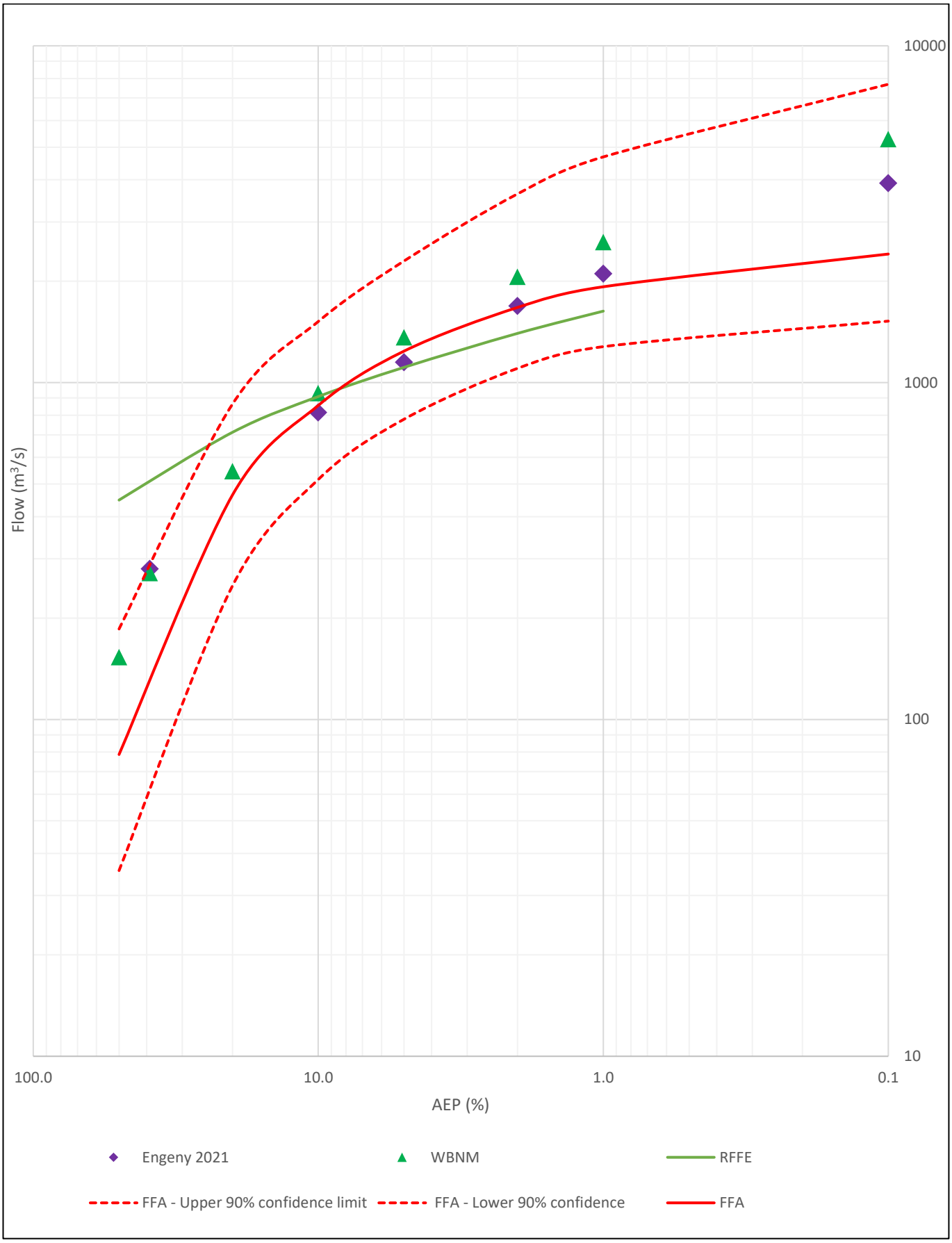

FIGURE B.2: COMPARISON OF WBNM DESIGN DISCHARGES TO THE FFA AND RFFE DESIGN DISCHARGES TO THE ISAAC RIVER GAUGE

APPENDIX C: HYDRAULIC MODEL DEVELOPMENT

MODEL EXTENT AND TOPOGRAPHY

The hydraulic model utilised the TUFLOW HPC solver. The Digital Elevation Model (DEM) used in the hydraulic model was based on the most recent PRCP landform (Version 2) provided by BHP.

A grid cell size of 4 m was selected for the TUFLOW model, which is suitable for representing the width of the diversion across multiple modelling cells. To enhance the resolution of sub-grid scale features, an SGS (Sub-Grid Scale) sample distance of 2 m was implemented.

The selected extent for the model is from upstream of where Eureka design starts to downstream of Isaac River in the extent of the ML Goonyella Riverside. The modelling layout is shown in FIGURE C.1 and FIGURE C.2.

The proposed diversion design option was included in the model using design tins produced by 12D and merging it to the PRCP landform (Version 2).

HYDRAULIC ROUGHNESS

The hydraulic roughness has been selected based on the inspection of aerial imagery and expected treatments within the diversion. As per the MCA workshop, roads and the GS4A dam will be removed as part of the closure and the GS1 tailings dam will be rehabilitated. The rail, which is not owned by BMA and goes to Moranbah North, was considered in the base land use mapping of the site. The adopted Manning's 'n' roughness values are summarized in TABLE C.1 below.

TABLE C.1: ADOPTED MANNING'S N ROUGHNESS

Land Use	Manning's' 'n'
Railway	0.015
Constructed Channel	0.050
Dense Vegetation	0.080

MODEL INFLOWS AND BOUNDARY CONDITIONS

Boundary conditions are required in the model to define hydrology inflows, flow leaving the model domain and interfaces between the one dimensional and two-dimensional model domains. The following boundary conditions used in the models are:

- Upstream: The upstream boundary condition used a combination of 'SA' and 'BC' type boundaries, allocating flow to the defined model grid cells based on the design hydrograph from the hydrologic model (flow per unit of time) input. Total inflow hydrographs were applied to Eureka Ck at the upstream boundary.
- Downstream: A normal depth outflow boundary was adopted with a hydraulic grade based on the Isaac River channel grade at the downstream extent of the model. The boundary was located a sufficient distance downstream to not influence the flood behaviour near the areas of interest.

Peak flows as estimated by the WBNM hydrologic model (only for 0.1% AEP event) have been applied at various locations dependent on the diversion being assessed. The location of the model inflows (0.1% AEP) can also be seen in Figure C.1**.** As mentioned in section 6.4.1, for the 39% and 2% AEP event, constant ACARP flows were applied throughout the diversion as shown in Figure C.2**.**

597000 598000 599000 600000 601000 602000 603000 604000 605000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Holding Paddock Creek
Isaac River
Fisher Creek
Platypus Creek

Legend

- Inflow
- Outflow
- Tuflow Model Boundary
- Local Catchment Inflow
- Watercourses

Hydraulic Roughness Areas

- Eureka Design Channel
- Dense Vegetation
- Railway

0 500 1,000 1,500 m

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DATE: 26/07/2024	

BMA PRCP GRM Eureka Creek Diversion

Hydraulic Model Layout - 0.1% AEP

Figure C.1
Scale @ A3: 1:32,000

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597000 598000 599000 600000 601000 602000 603000 604000

7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000

Isaac River
Holding Paddock Creek
Holding Paddock Creek
Fisher Creek
Fisher Creek
Platypus Creek
Isaac River

Legend

- Inflow
- Outflow
- Tuflow Model Boundary
- Watercourses

Hyfrauloc Roughness Areas

- Eureka Design Channel
- Dense Vegetation
- Railway

0 500 1,000 1,500 2,000 m

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Hydraulic Model Layout - 39% and 2% AEP

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Figure C2
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APPENDIX D: HYDRAULIC PARAMETER MODELLING RESULT

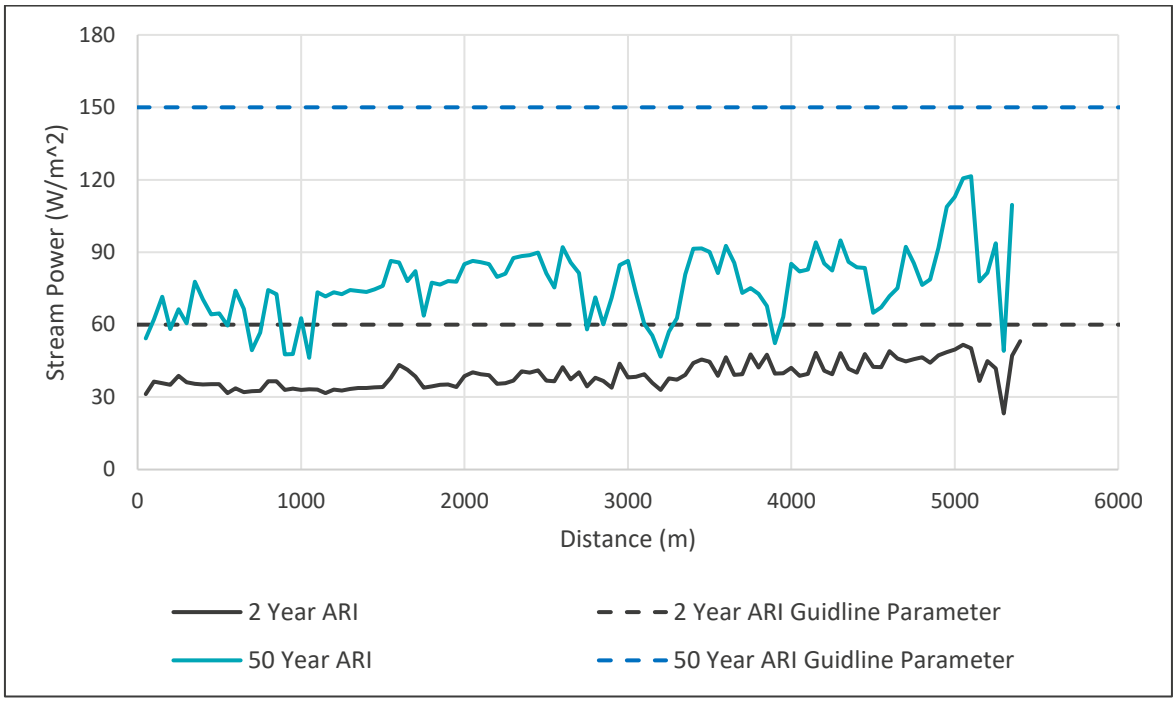


FIGURE D.1: STREAM POWER TUFLOW MODEL RESULTS

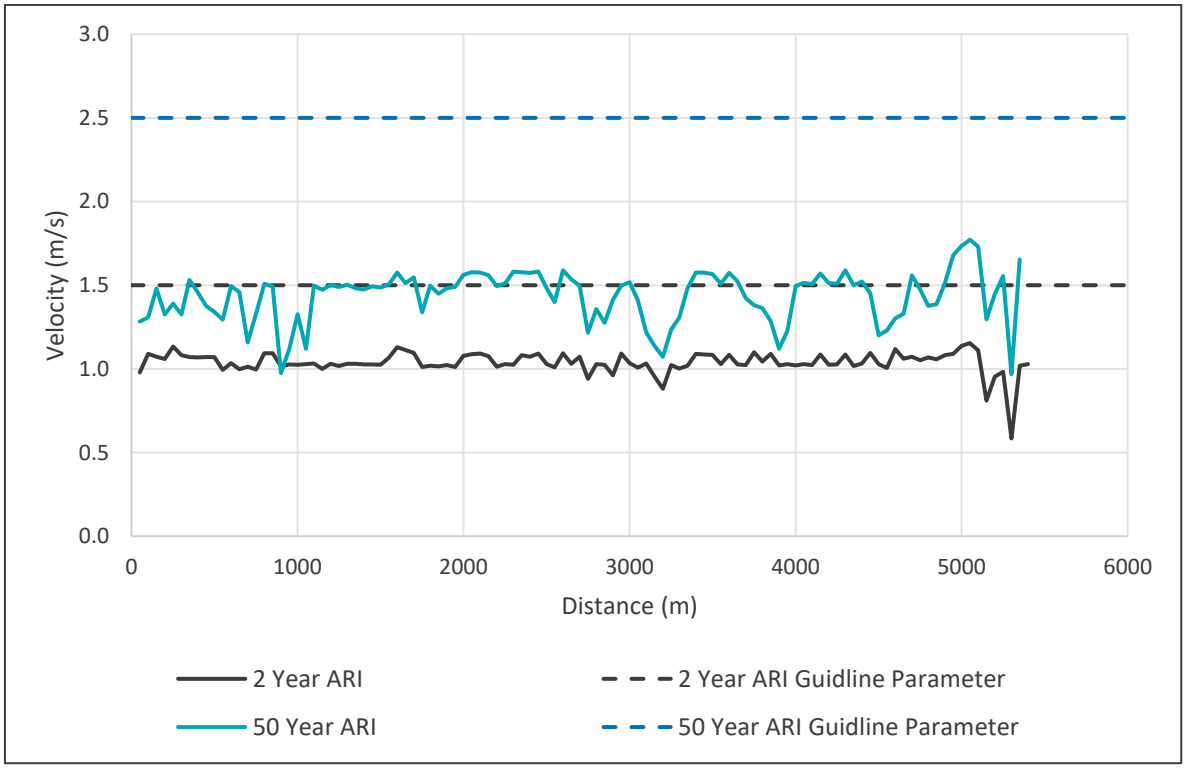


FIGURE D.2: VELOCITY TUFLOW MODEL RESULTS

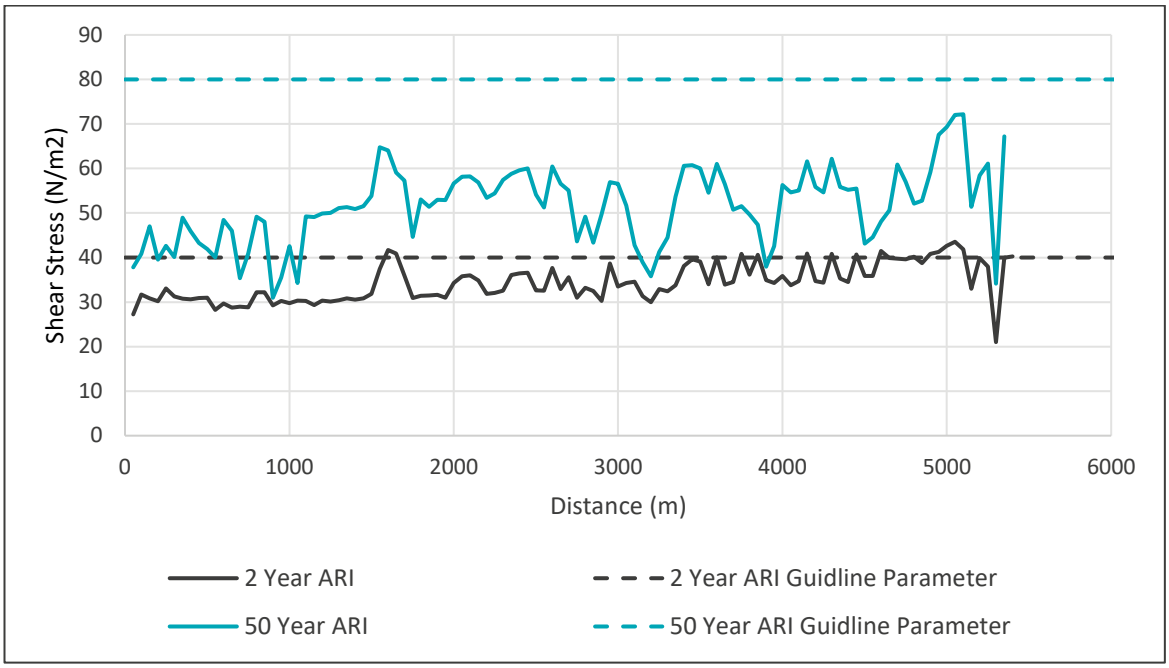
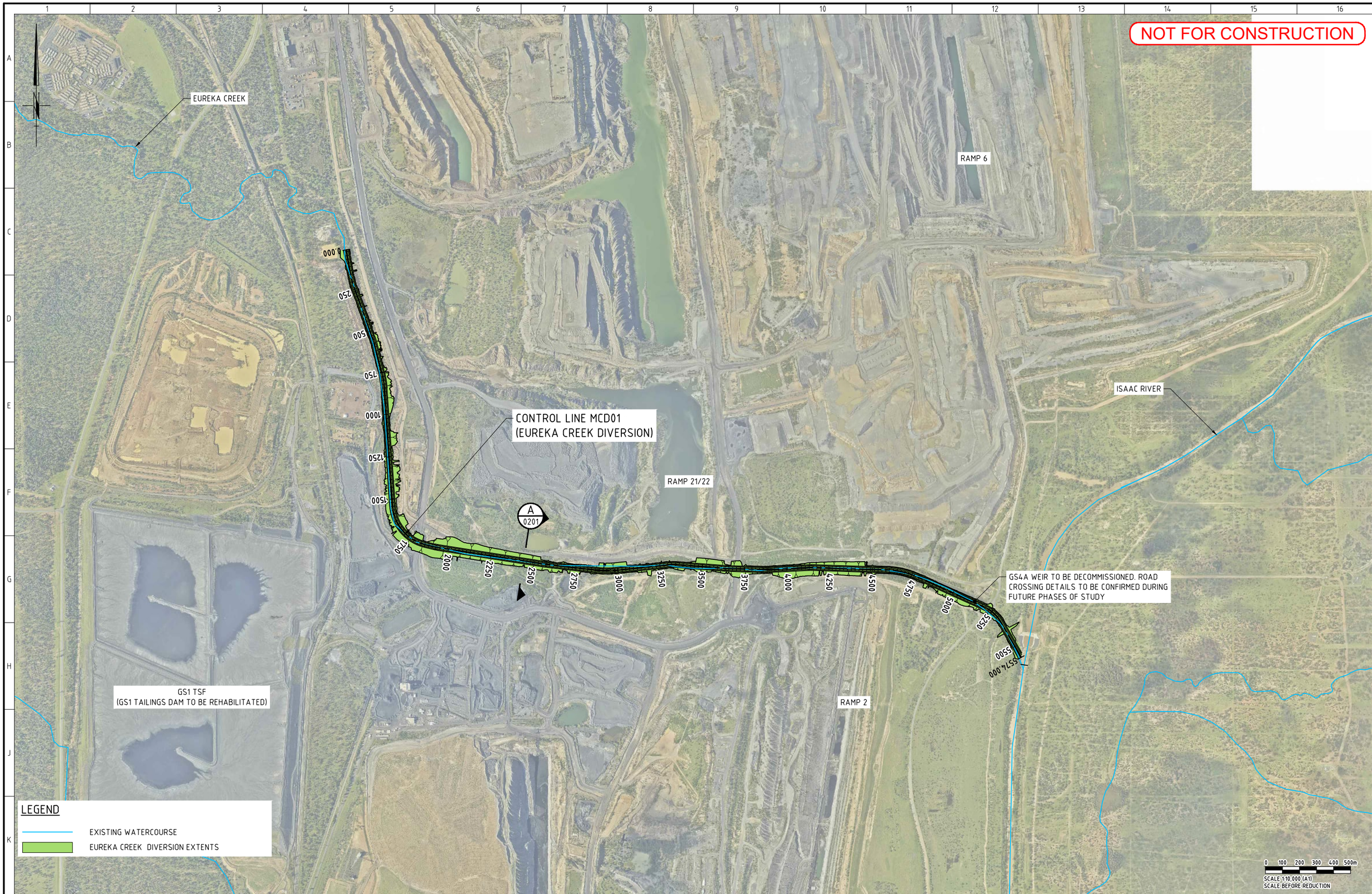


FIGURE D.3: SHEAR STRESS TUFLOW MODEL RESULTS

APPENDIX E: PREFERRED OPTION CONCEPT DESIGN DRAWINGS



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GOONYELLA MINE
PRCP EUREKA CREEK DIVERSION
GENERAL ARRANGEMENT PLAN

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LEGACY DRG No.
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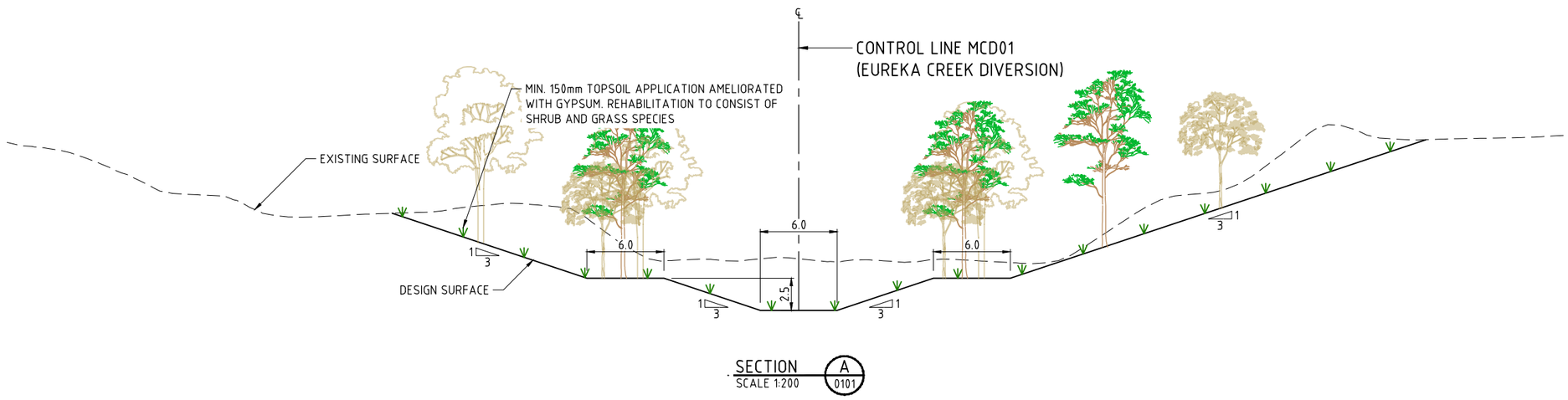

SECTION A
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LEGEND

EXISTING SURFACE

DESIGN SURFACE

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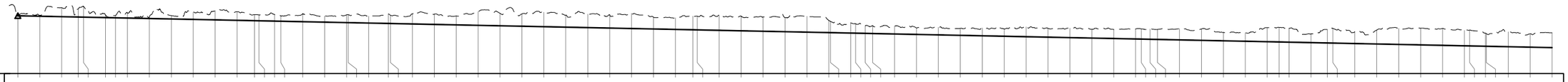

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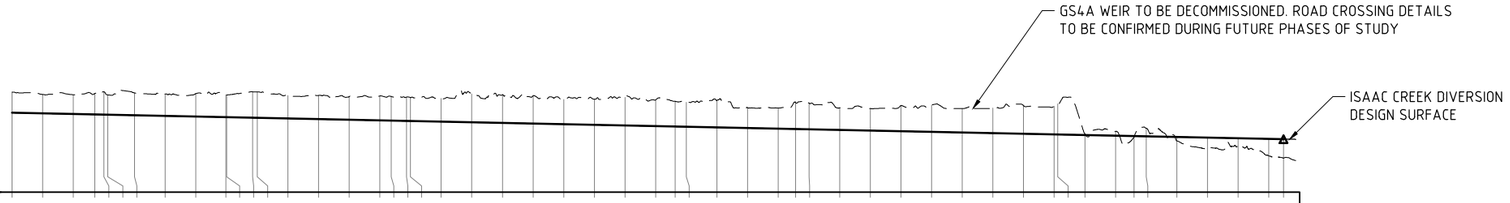

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APPENDIX F: CONCEPT DESIGN WITH PRCP LANDFORM INTERACTION

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Eureka Creek Concept Design with PRCP Landform 2

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Figure F.1
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PRCP Concept Design Report

Holding Paddock Creek Diversion

QC1000_051-REP-003-2

1 OCTOBER 2024

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	30/08/2024	Issue for Review	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
1	11/09/2024	Client Issue	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
2	1/10/2024	Client Issue	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
Signatures:						

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Holding Paddock Creek (HPC) Diversion which must satisfy the conditions within EA EPML00853413 located at Goonyella Riverside Mine (GRM). The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the GRM.

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per Environmental Authority requirements).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for GRM as described in the Queensland Department of Environment, Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options identification, assessment, and selection.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium resulting in a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.
- Groundwater studies.

2. OVERVIEW

2.1 Location

GRM is located approximately 150 km southwest of Mackay and 25 km north of Moranbah within the Bowen Basin. The HPC diversion begins at the western boundary of the GS1 Tailings Storage Facility (TSF) located on ML 70287 and flows southeast towards the southern end of the GRM. It was constructed parallel to but further south of the pre-mining alignment and joins with Fisher Creek to continue the diversion downstream. The diversion is approximately 6.1 km in length compared to the pre-mining length of 4.7 km. The location of the HPC diversion is shown in Figure 2.1.

2.2 Pre-Mining Condition

HPC is an ephemeral tributary within the Isaac River sub catchment which is part of the wider Fitzroy River catchment. It has a catchment area of approximately 32 km^2 and watercourse flowing directly into the Isaac River.

- **Upstream reach** – The upstream reach is located west of the mine and is situated amongst open woodland. As the vegetation was mostly cleared in 2011 due to some erosion prevention works, the pre-mining condition had significantly more vegetation as can be also seen in historical imagery.
- **Downstream reach** – Fisher Creek acts as the downstream reach of the HPC diversion and is described in the Fisher Creek Diversion report (Engeny, 2024).
- **Diversion reach (pre-mining)** – The pre-mining reach flowed north of the current alignment and was shorter at 4.7 km. There is little historical imagery before diversion was constructed however, consistent to the surrounding vegetation, dense and open woodland and native plants would have surrounded the waterways and HPC. The reach originally flowed through the middle of the GS1 TSF.

2.3 Current Conditions

The last major monitoring effort and report at the time of writing was completed in 2022 by Alluvium. As part of the major monitoring, the latest condition of the HPC diversion has been described as follows (Alluvium, 2022):

- The upstream reach of the HPC channel is not well defined and is assumed to have been that way prior to mining activity. Over the length of the natural upstream reach, the natural geomorphic conditions are assumed to have been similar to the diversion reach (alluvial, low flow channel).
- Limited information is available on the natural geomorphic conditions of the diversion reach. Over the length of the natural diversion reach, the natural geomorphic conditions are assumed to have been similar to the upstream reach (alluvial, low flow channel).

It is important to note the current diversion arrangement has no defined downstream reach as it directly discharges into Fisher Creek. Due to this current condition, it is considered unlikely that the existing diversion will achieve a state of dynamic equilibrium and be suitable for relinquishment following closure of the GRM.

596000 597000 598000 599000 600000

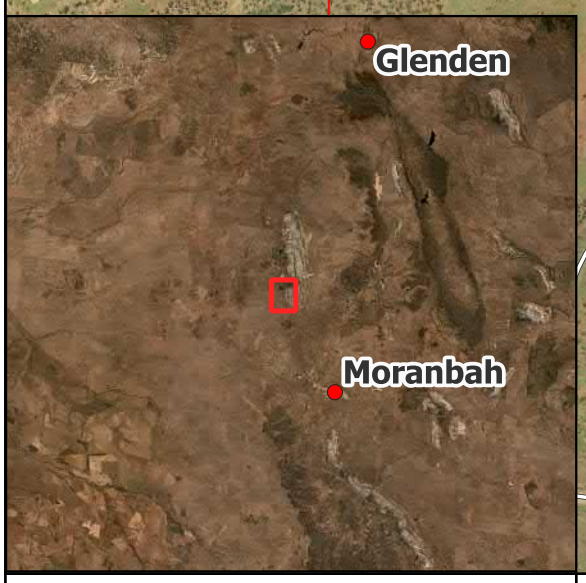
7589000 7588000 7587000 7586000 7585000 7584000

Legend

- Upstream Reach
- Current Diversion Reach
- Intermediate Reach
- Downstream Reach
- Pre Mining Reach
- Existing Railway
- Existing Roads
- Watercourses
- ML Boundary

ML 70478
ML 70287
ML 70288
ML 70289
ML 70479
ML 1763

Holding Paddock Creek
Fisher Creek



BMA PRCP GRM Holding Paddock Creek Diversion

Figure 2.1
Location of Holding Paddock Creek diversion

REV.	DETAILS	DATE
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DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 08/08/2024

GENERAL NOTES:

0 250 500 m
Scale @ A3: 1:17500

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3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

The DNRME and ACARP Guidelines have both been used to inform the basis of design for the diversion, as summarised in Table 3.1.

TABLE 3.1: DNRME AND ACARP GUIDELINES USED FOR DESIGN BASIS

Guideline	Design Parameter
DNRME	Diversion Design Outcomes and Design Recommendations.
	Velocity, shear stress, stream power (39% AEP) guidelines.
ACARP	General Design Process.
	Stream power (2% AEP event Guideline).

3.1 DNRME Guidelines

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for the HPC diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the HPC diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.2 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential; however, stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.2: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - no vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.2 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the construction.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and,
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m²)	Stream Power 2% AEP (W/m²)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock Controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.4.

TABLE 3.4: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m²)
Buffel Grass *(Cenchrus ciliaris)*	40
Structurally Diverse Suite of Established Native Vegetation	120

4. OPTIONS IDENTIFICATION

Engeny identified four potential options for the diversion as part of stage 1 (summarised below in Table 4.1). The following criteria were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the mining lease (ML) boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the Diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The four options assessed are shown in Figure 4.1 and summarised in Table 4.1.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2	Option 3	Option 4
Description	Retain existing diversion alignment (6.1 km)	The diversion would cross Riverside Mine Road between GS1 and the sub-station, then travels east to a downstream tie in location in the existing HPC, on the western extent of GS15. The total length of the diversion is approximately 6.5 km with the new diversion extent being the initial 2.9 km prior to the downstream tie in on the western extent of GS15 with a grade of 0.38%.	Option 3 runs north-south on the west of Riverside Mine Road. The intent of Option 3 is to assess the benefit of removing road/service crossings. The downstream tie in location is to the existing Fisher Creek, approximately 2.5km south of GS1. The total length of the diversion is approximately 3.8 km.	Option 4 crosses Riverside Mine Road at a similar location to Option 2, however, continues south to Fisher Creek, without crossing the rail line. The total length of the diversion is approximately 5.6 km.
Likelihood that diversion will achieve state of dynamic equilibrium	Low – Retain existing alignment - length 6.1 km and grade 0.34%. Potential seepage from the GS1 TSF could impact diversion performance. Reshaping of GS1 embankment at closure will likely toe out into the current diversion alignment.	High – Total diversion length is 6.5 km with the new diversion extent being the initial 2.9 km prior to the downstream tie in on the western extent of GS15 with a grade of 0.38%.	Moderate - Diversion length is 3.8 km with a grade of 0.31%. Option 3 will result in increasing the catchment area of HPC.	High - Diversion length is 5.6 km with a grade of 0.39%.
Order of magnitude cost estimate*	$1.38 M	$25.4 M	$38.7 M	$47.7 M

Statistic	Option 1	Option 2	Option 3	Option 4
Ability to isolate diversion from flows during establishment period	No – Will be constructed on the existing diversion alignment.	Partially – Option 2 cuts across the existing alignment. It is possible but there is some engineering risk.	Yes – The entire of the diversion can be constructed offline from the existing diversion	Yes – The entire of the diversion can be constructed offline from the existing diversion

* Costs estimated based on average $10/m^3.

597000 598000 599000 600000

7588000 7587000 7586000 7585000 7584000

GS1 Tailings Dam

ML 70288

Holding Paddock Creek

ML 70287

ML 70478

Ramp 32

ML 1763

ML 70289

Holding Paddock Creek

Fisher Creek

ML 70479

Fisher Creek

Legend

- Existing Railway
- Existing Roads
- Watercourses
- ML Boundary

Holding Paddock Creek Diversion Options

- Option 1
- Option 2
- Option 3
- Option 4

BMA PRCP GRM Holding Paddock Creek Diversion

Figure 4.1
Holding Paddock Creek Diversion Realignment Options

REV.	DETAILS	DATE
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APPROVED: BK | DATE: 08/08/2024

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0 100 200 300 400 m

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5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BMA and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	50%
Order of magnitude cost estimate	30%
Ability to isolate diversion from flows during establishment period	20%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 2 to be carried forward into concept design as a preferred option, since it scored highest out of the four options and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2	Option 3	Option 4
Overall Weighted Score	-0.9	1.2	0.6	0.8
Relative Risk	Highest Risk	Lowest Risk	Low Risk	Low Risk
Fatal Flaw	Yes	No	No	No

6. CONCEPT DESIGN

6.1 Design Parameters and Plan

Table 6.1 details the parameters for each outcome in Section 3, forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND THE AUSTRALIAN COAL ASSOCIATION RESEARCH PROGRAM (ACARP) PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function, and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] A hydrologic model for the southern extent of GRM inclusive of HPC was originally developed as part of the Eureka Flood Study (Engeny, 2024).	☒ ☐	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	Outcome 5 – Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME (2019). Stream power benchmark values were adopted from ACARP (2014) due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Concept Design Diversion Alignment

The alignment of Option 2 was determined to be the preferred option using the MCA. Option 2 was chosen due to a high likelihood of achieving a state of dynamic equilibrium. The full concept drawing package for the permanent HPC diversion is included in Appendix E and the interaction of the design with the concept PRCP landform 2 in Appendix F.

6.3 Channel Geometry and Grade

The location of the reference cross sections is shown in Figure 6.1. The typical intermediate reach channel cross sections are presented in Figure 6.2. This reach represents the original pre-mining alignment which joins the upstream and downstream diversion reaches for HPC. These dimensions were based on the average natural downstream channel geometry and grade as assessed in the options identification phase.

Table 6.2 summarises the typical channel cross section selected for the concept design. The concept design drawings in Appendix E show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY FOR CONCEPT DESIGN

Channel Geometry	Quantity	Comments
Channel Bed Width	4 m	Based on the current upstream HPC representative cross sections
Channel Depth	1.5 m	Consistent depth of low flow channel at 1.5 m
Batter Slope	1V:4H (Low Flow Channel) 1V:8H (High Flow Channel)	Based on the existing upstream HPC representative cross sections. The batters will be covered with topsoil, hydromulch, and hydroseed (Appendix E) to ensure stability and prompt revegetation of the channel batters.

597000 597500 598000 598500

7588000 7587500 7587000 7586500 7586000

GS1 Tailings Dam

Holding Paddock Creek

US1 US2 US3 US4 US5 US6 US7 US8 US9 US10

ML 70287

ML 70288

ML 70478

ML 70289

Legend

- HPC Reference Cross-section Locations
- HPC Preferred Option
- Current Diversion Reach
- Watercourses
- Existing Railway
- Existing Roads
- ML Boundary

BMA PRCP GRM Holding Paddock Creek Diversion

Figure 6.1
Location of Reference Cross-Sectional Areas

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 08/08/2024

GENERAL NOTES:

0 100 200 m

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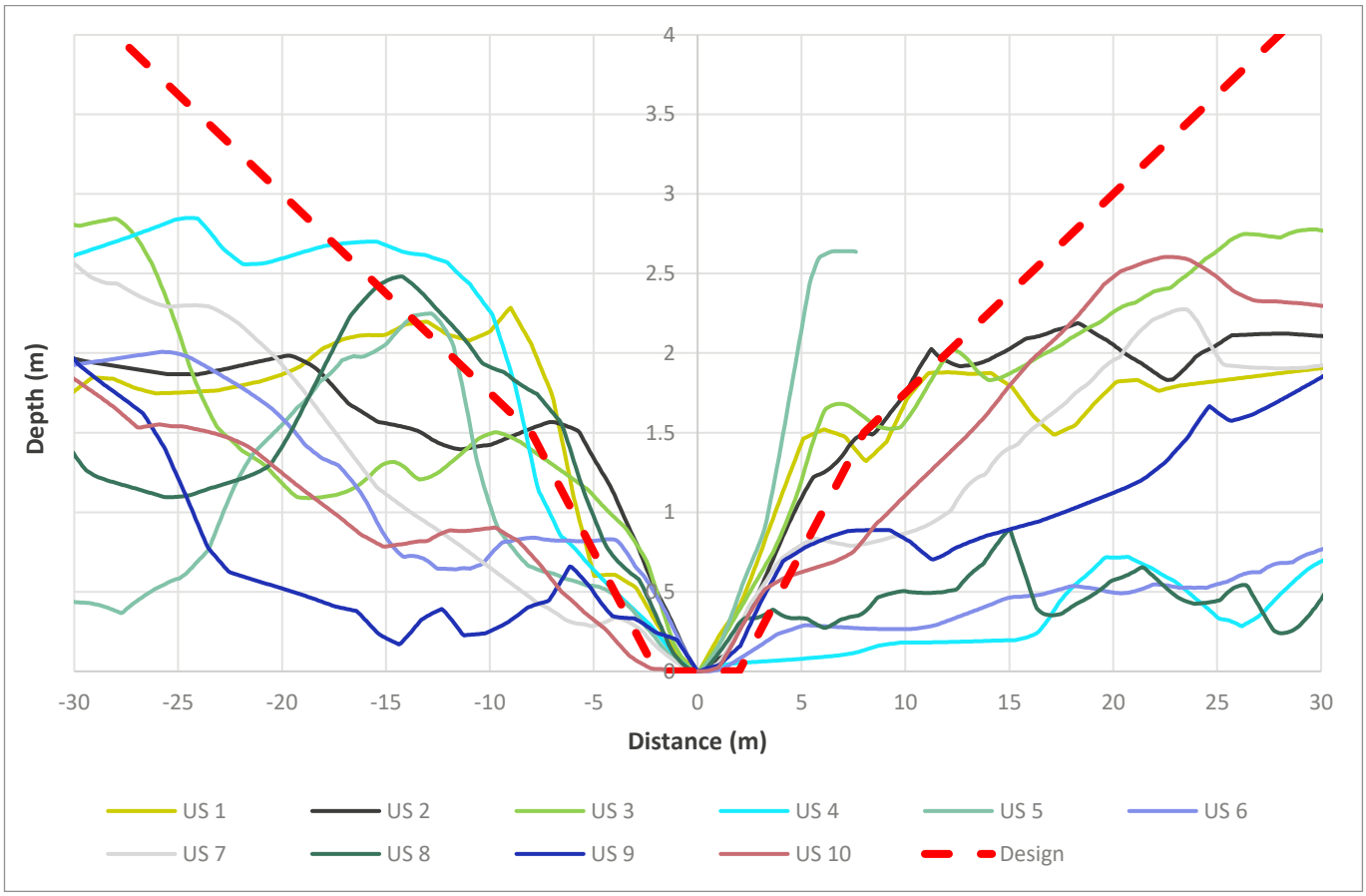

Figure 6.2: Typical Downstream Channel Cross Section of Holding Paddock Creek

The grade of the proposed diversion is 0.38% while the grade of the current diversion is 0.34%. The total proposed diversion is approximately 6.5 km in length, which is a 7% increase from the current alignment which is approximately 6.1 km in length. This change in alignment allows the diversion to be further away from the GS1 but is not expected to adversely impact sediment transport/deposition within the channel. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix E.

6.4 Hydrology

A hydrologic model for the southern extent of GRM inclusive of HPC was developed for the Eureka Creek Diversion using WBNM software and was validated against the Isaac River Gauge. The model was also used for the HPC (concept design) to estimate flows for the 0.1% AEP (1 in 1000 year) flood event. The details of the hydrologic model development are presented in Appendix B. Peak flows for frequent events (39% AEP and 2% AEP) for the HPC diversion were estimated using the ACARP (2002) methods and are presented in Table 6.3. The HPC catchment is presented in Figure 6.3.

588000 589000 590000 591000 592000 593000 594000 595000 596000 597000 598000 599000 600000 601000

7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000

Legend

- ML Boundary
- Existing Railway
- Watercourses

WBNM Model Sub-Catchment

- Holding Paddock Creek

ML 70194
ML 1900
ML 1764
ML 70288
ML 70287
ML 70478
ML 1763
ML 70289
ML 70479

Fisher Creek
Fisher Creek
Fisher Creek
Holding Paddock Creek
Fisher Creek
Isaac River

BMA PRCP GRM Holding Paddock Creek Diversion

Figure 6.3
Catchment Map

REV.	DETAILS	DATE
0	Client Issue	

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Scale @ A3: 1:35000

0 500 1,000 m

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6.4.1 Frequent Events

Peak flows for frequent events (39% AEP and 2% AEP) for the HPC diversion were estimated using the ACARP (2002) methods and are presented in Table 6.3. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity to provide a conservative estimate. This approach has been adopted to determine the flows within the proposed HPC diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters.

TABLE 6.3: ACARP DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m3/s
2% AEP (50-year ARI)	52.6
39% AEP (2-year ARI)	27.3

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the concept PRCP landform 2 has been assessed as part of the rehabilitation flood modelling completed for the PRCP. This informs the interaction between the diversion and final voids landform. The 0.1% AEP peak flow rate at the end of the diversion is estimated at 172 m^3/s.

6.5 Hydraulics

A two-dimensional TUFLOW flood model was developed to assess the compliance with the DNRME and ACARP hydraulic performance criteria for the 39% and 2% AEP events.

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in the 39% and 2% AEP event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP (2-year ARI)		2% AEP (50-year ARI)	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	28	<60	36	<150
Stream Velocity (m/s)	0.77	<1.5	0.84	<2.5
Shear Stress (N/m^2)	24	<40	28	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

It can be seen from Table 6.4 that all the average diversion hydraulic results are below the design parameters for both the 39% and 2% AEP events. Moreover, 39% AEP (2yr ARI) stream power and velocities meet the DNRME design criteria for stability if the channel remains unvegetated. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

The extents and depths of the 0.1% AEP design flood event with the concept PRCP landform 2 and the concept diversion design are depicted in Figure 6.4. The result shows that there is no risk of flood ingress to any final voids.

597000
598000
599000
7588000
7587000
7586000
Holding Paddock Creek
ML 70287
ML 70288
ML 1763
ML 70289
L 70478

Legend

- ML Boundary
- Existing Roads
- Existing Railway
- Watercourses

Flood Depth (m)

- <= 0
- 0.1 - 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- 1.2 - 1.6
- 1.6 - 2.0
- 2.0 - 2.4
- 2.4 - 2.8
- > 2.8

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Holding Paddock Creek Diversion

Figure 6.4
0.1% AEP Flood Event with Concept PRCP Landform 2

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 08/08/2024

GENERAL NOTES:

0 100 200 300 400 m
Scale @ A3: 1:9000

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6.6 Risks and Mitigation Measures

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised for this risk assessment align with the BMA risk tables.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to frequent (up to 20% AEP / 5 year ARI) flood events.	Probable	2	9	Diversion channel constructed during dry season. Entire diversion able to be constructed while offline. Detailed revegetation plan to be implemented to promote rapid establishment. Seed mix to include fast establishing species to rapidly stabilise diversion.	Unlikely	1	1
Damage to the new diversion channel due to extreme/rare (0.1% AEP / 1000 year ARI) flood event (mainly overland flow and bank erosion)	Unlikely	2	3	Revegetation plan to include large species capable of withstanding shear stresses associated with rare events.	Highly Unlikely	2	0.9
Construction program impacted by frequent flow event (up to 20% AEP / 5 year ARI).	Unlikely	1	1	Diversion construction to be timed to minimise risk of large flows while still maintaining enough watering to promote vegetation establishment and growth. Entire diversion able to be constructed while offline.	Highly Unlikely	1	0.3
Constructability of diversion channel – encountering bedrock, material availability and access	Unlikely	2	3	Geotechnical and soil investigations as part of functional design.	Highly Unlikely	1	0.3
Flood ingress into final voids	Highly Unlikely	2	0.9	Final landform design to provide flood protection to ensure no flooding ingress in 0.1% AEP flood with 1.0 m freeboard.	Highly Unlikely	2	0.9
Upstream rehabilitation of mining areas unsatisfactory leading to increase in sediments loads to the final diversion channel	Unlikely	2	3	Additional upstream controls could be considered during functional design. Diversion able to be constructed offline so no offline flows through diversion.	Unlikely	2	3

6.7 Additional Design and Construction Considerations

6.7.1 Infrastructure

A landform to direct flow into the concept diversion design may be required along the western side of Riverside Mine Road heading south which the upstream section of the existing diversion crosses, dependent on the closure scenario of the Riverside Mine Road. This landform will require review as part of the detailed design work for the HPC diversion and will need to be tied in with the final landform for GS1 to the east. Appendix E shows the concept design drawings with the current alignment of Riverside Mine Road and a landform design based on this current road alignment and its interaction with the proposed concept design of HPC.

6.7.2 Roads and Culverts

Riverside Mine Road runs parallel to the western side of the diversion heading south. The current alignment of Riverside Mine Road may be impacted by the HPC diversion and if it were to remain would have the requirement for a culvert as part of the closure design. This will require review as part of the detailed design work for the HPC diversion. Appendix E shows the concept design drawings with the current alignment of Riverside Mine Road and its interaction with the proposed concept design of HPC.

6.7.3 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, potentially dominated by dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers, and surface treatments.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.4 Revegetation

Hydraulic modelling has demonstrated that the design criteria values for stream power, stream velocity and shear stress for both 39% AEP and 2% AEP storm events, are within the ACARP (2002) diversion channel design parameters (refer Table 3.2). Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the functional design for HPC as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understorey, and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the Goonyella Riverside Mine Progressive Rehabilitation and Closure Plan.

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower banks (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.

- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.5 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with BMAs watercourse diversion monitoring program, and following construction and rehabilitation of the new diversion alignment is required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7. CONCLUSION

The existing diversion is experiencing increasing bank erosion, lack of geomorphic and vegetation features like those in the local landscape, sediment aggradation and sediment deposition downstream.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of GRM.

Four options for rehabilitation of the diversion were identified and assessed using the BMA MCA outlined in Section 5. Option 2 was selected to proceed as the preferred concept design as it had a high likelihood of achieving a state of dynamic equilibrium due to the length and grade of the diversion and maintaining the current catchment area for HPC. The chosen concept design, typical cross sections and longitudinal section are presented in Appendix E.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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  (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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(g) This Report does not provide legal advice.

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APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Holding Paddock Creek Diversion

Project: PRCP GRM Diversions
Workshop Date:

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Option 4	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	50%	-3	2	1	2	Option 1: Retain existing alignment - length 6.1 km and grade 0.34%. Potential seepage from GS1 tailings storage facility could impact diversion performance. Reshaping of GS1 embankment at closure will likely toe out into the current diversion alignment. Option 2: Total diversion length is 6.5 km with a grade of 0.32%. Option 3: Diversion length is 3.8 km with a grade of 0.31%. Option 3 will result in increasing the catchment area of HPC. Option 4: Diversion length is 5.6 km with a grade of 0.39%.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	30%	2	0	-1	-2	Option 1: Compared based on direct diversion cut requirement costs only. Option 2, Option 3 & Option 4: Compared based on the 'HPC Diversion Alignment Trade-Off' project completed by Engeny (Engeny, 2023).
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	20%	0	1	2	2	Option 1: Will be constructed on the existing diversion alignment. Option 2: Cuts across the existing alignment. It is possible but there is some engineering risk. Option 3 & Option 4: The entire of the diversion can be constructed offline from the existing diversion
		Overall Weighted Score	-0.9	1.2	0.6	0.8	
		Is there a Fatal Flaw?	**Fatal Flaw**	**No**	**No**	**No**	
		Relative Risk	**Highest Risk**	**Lowest Risk**	**Low Risk**	**Low Risk**	

APPENDIX B: HYDROLOGIC MODEL DEVELOPMENT

HYDROLOGIC MODEL SETUP

The WBNM (Watershed Bound Network Model) runoff routing software (2021 version) was used to develop the hydrology model. WBNM automatically calculates catchment routing based on the sub-catchment area, pervious/impervious areas and parameters, and the sub-catchment flow paths.

Catchment Inputs

Sub-catchment delineation for GRM was developed using the PRCP landform (Version 2) topography displayed in Figure B.1. The hydrological model includes the total catchment for the Isaac River (inclusive of Eureka, HPC, and Fisher creeks) extending downstream past the Goonyella mine, covering a total area of approximately 1180 km^2.

Three open water bodies are located in the upper catchment: Lake Elphinstone, Teviot Dam and Burton Gorge Dam. Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

The design life of the Teviot Creek Dam and Burton Gorge Dam, as part of mining closure operations, could impact design flow estimates. For this study, the WBNM model did not include the Burton Gorge Dam, Teviot Dam, and Lake Elphinstone located upstream of the study area, considering a worst-case scenario.

Figure B.1 provides the sub-catchment extents used for the WBNM.

Model Parameters

The final landform is proposed to be rehabilitated; therefore, the hydrology model has assumed no impervious surfaces remain and a 0% impervious fraction (Fi) for all catchments including the remaining spoil areas and voids.

The default routing parameter of 1, pervious lag parameter of 1.8 and impervious lag parameter of 0.1 have been adopted for the WBNM.

Design Rainfall

The 0.1% AEP (1000yr) was sourced using the Australian Rainfall and Runoff 2019 IFD generation tool available on the Bureau of Meteorology (BoM) website (www.bom.gov.au), at Latitude 21.6652 (S), Longitude 148.0792 (E). Aerial Reduction Factors (ARFs) have been used for all design events to convert point rainfall estimates to areal rainfall estimates.

Temporal Patterns

Design events (1% - 0.1% AEP) have utilised the 'East Coast North' areal temporal patterns, as the total catchment area for the model exceeds 75 km^2. All ten temporal patterns were simulated for storm durations ranging from the 3 hours to 168 hours.

Design Rainfall Losses

The initial and continuing losses obtained from the ARR Datahub for Isaac River catchment to Goonyella gauge are 36 mm and 2.7 mm/h, respectively.

The adopted design rainfall losses were selected to achieve the best match between the XP-RAFTS design discharges with the design discharges estimated by the FFA at the Isaac River Goonyella gauge. The following is of note:

- For the 50%, 20%, 10%, 5%, 2% and 1% AEP events, the default ARR initial losses of 36 mm and continuing losses of 2.7 mm/h were adopted, respectively. The initial loss will decrease for larger events as the catchment is likely to be more saturated prior to the design rainfall burst.
- For the 0.1% AEP design event, a conservative 0 mm initial loss was adopted. A continuing loss of 2.5 mm/h was adopted as per the flood assessment done by WRM in 2019 (WRM, 2019).

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000

Legend

Stream Gauge

WBNM Model Sub Catchments

- Eureka Creek
- Fisher Creek
- Holding Paddock Creek
- Isaac River

Lake Elphinstone

Burton Gorge Dam

Teviot Dam

Eureka Creek at the railway

Eureka Creek at the GS4A Weir

Isaac River at Goonyella

BMA PRCP GRM Holding Paddock Creek Diversion

Figure B.1
WBNM Hydrologic Model Layout

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 08/08/2024

GENERAL NOTES:

0 2 4 km

Scale @ A3: 1:180,000

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MODEL VALIDATION

The 50%, 20%, 10%, 5%, 2% and 1% AEP peak flows estimated from the hydrology model were validated using the following methods:

- **Regional Flood Frequency Estimation Model (RFFE)** - is a recommended peak flow validation method from the ARR 2019 guidelines (Ball, et al., 2019). The RFFE provides peak flow estimations based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).

- **Flood Frequency Analysis (FFA)** - provides peak flow estimates for different AEPs by developing a fitted distribution from recorded peak flows from historical flood events.

  There is no gauge station for HPC, while the Eureka Creek gauges (Eureka Creek at the railway and GS4A) had an insufficient monitoring duration to conduct a reliable Flood Frequency Analysis (FFA). As a result, the FFA for the nearby Isaac River at the Goonyella gauge, located 7 km downstream of Eureka, was used for validation purposes. This analysis was completed as part of the Isaac River Flood Model by Engeny in March 2021.

  Isaac River FFA was undertaken on the peak annual (water year from October to September) discharges recorded at Isaac River at Goonyella (130414A) streamflow gauge by Queensland Department of Natural Resources Mines and Energy (DNRME) between 1982 and 2020. A Log Pearson Type 3 (LPIII) distribution was fitted to an annual maximum series of peak flows from the gauge (Engeny, 2021). To adapt the Isaac River FFA to Eureka Creek (as there was no gauge station data for HPC nor was it covered as part of the WRM 2019 flood modelling report), peak flows were scaled based on the catchment area using the QRT method. The formula used for this adjustment is:

$$Q_u = \left(\frac{A_u}{A_g}\right)^n Q_g$$

  Where,

  Q_u is the estimated peak flow for the ungauged catchment.

  A_u is the area for the ungauged catchment.

  A_g is the catchment area for the stream gauging station.

  Q_g is the peak flow for the gauging station determined from the flood frequency analysis.

  The exponent n has been determined from the regional flood frequency regression analysis (RFFE) undertaken by the Queensland Department of Transport and Main Roads (Palmen & Weeks, 2008).

- **Peak Flow Estimates from Previous Flood Studies** –

  - A hydrologic modelling of the Isaac River catchment including the Grosvenor Mine (GRV) and Moranbah North Mine (MNM) using the XPRAFTS runoff-routing model was developed to estimate the 39%, 10%, 5%, 2%, 1%, 0.2% and 0.1% annual exceedance probability (AEP) and probable maximum flood (PMF) design discharges for the Isaac River and its tributaries (Engeny, 2021). The estimated peak flows at the Isaac River at Goonyella Streamflow Gauge were compared to the WBNM and RFFE peak flows (refer to Figure B.2). It is to be noted that The Burton Gorge Dam, Teviot Dam and Lake Elphinstone upstream of the study area were modelled as detention basins in the XPRAFTS model.

  - Design peak discharges in the Isaac River at Goonyella, Eureka Creek upstream of the railway and Eureka Creek at the GS4A for the 10%, 5%, 2%, 1%, 0.1% were estimated using the XP-RAFTS model by WRM in 2019. These flows were compared to the WBNM model design peak discharges at these three gauge locations.

Model Validation Results

Table B.1 shows the WBNM estimated design discharges at the Isaac River at Goonyella, Eureka Ck at the Railway and Eureka Ck at the GS4A for design events between 10% to 0.1% AEP, and the comparison to the WRM design discharges. This was due to there being no WRM design discharges for HPC. A visual comparison of the WBNM design peak discharges at the Isaac River streamflow gauge (130414A) against the flood frequency distribution curve, XP-RAFTS estimated peak flows by Engeny in 2021 and RFFE is provided in Figure B.2.

Validation of the design hydrology peak flow estimates indicates the following.

- **Isaac River Gauge**
  - Modelled peak flows for all design events are higher (3%-26%) than the LPIII expected quantile from the FFA. This is expected considering the exclusion of Burton Gorge Dam, Teviot Dam and Lake Elphinstone (Figure B.2).
  - Modelled peak flows compared to the RFFE method were higher for events rarer than the 10% AEP and lower for events more frequent than the 10% AEP. This irregularity is not concerning as the RFFE can provide irregular results if catchment characteristics are mostly different from the nearby gauged waterways used to derive the RFFE. Additionally, the Isaac gauge catchment (1071.21 km^2) is outside the RFFE recommended catchment size of 0.5-1000 km^2, hence results have lower accuracy (Figure B.2).
  - WBNM estimated peak flows for all design events are higher (11%-28%) than the WRM 2019 flood modelling report (Table B.1).
- **Eureka Ck Gauge**
  - WBNM estimated peak flows for all design events are higher (10%-37%) than the WRM 2019 flood modelling report. This is expected considering the 37% increase of the Eureka catchment (Table B.1).

TABLE B.1: COMPARISON OF WBNM DESIGN DISCHARGES TO THE WRM 2019 FLOWS

		WRM (2019) Peak Discharge (m3/s)	WRM (2019) Critical duration (hours)	WBNM Peak Discharge (m3/s)	WBNM Critical duration (hours)	Difference (%)
Isaac River at Goonyella	Catchment Area (km^2)	-		1071.12 km^2		-
	Design event (AEP%)					
	10	830	18 hr	932	18 hr	11%
	5	1167	18 hr	1363	18 hr	14%
	2	1707	18 hr	2061	18 hr	17%
	1	2079	24 hr	2616	18 hr	21%
	0.1	3808	24 hr	5291	18 hr	28%
Eureka Creek at the railway	Catchment Area (km^2)	76.4 km^2		113.78 km^2		33%
	Design event (AEP%)					
	10	140	6 hr	159	18 hr	12%
	5	180	6 hr	217	18 hr	17%
	2	256	6 hr	299	18 hr	14%
	1	299	6 hr	374	18 hr	20%
	0.1	499	6 hr	692	12 hr	28%
Eureka Creek at the GS4A	Catchment Area (km^2)	80.7 km^2		129.05 km^2		37%
	Design event (AEP%)					
	10	147	6 hr	163	18 hr	10%
	5	189	6 hr	225	18 hr	16%
	2	267	6 hr	320	18 hr	17%
	1	311	6 hr	400	18 hr	22%
	0.1	521	6 hr	728	18 hr	28%

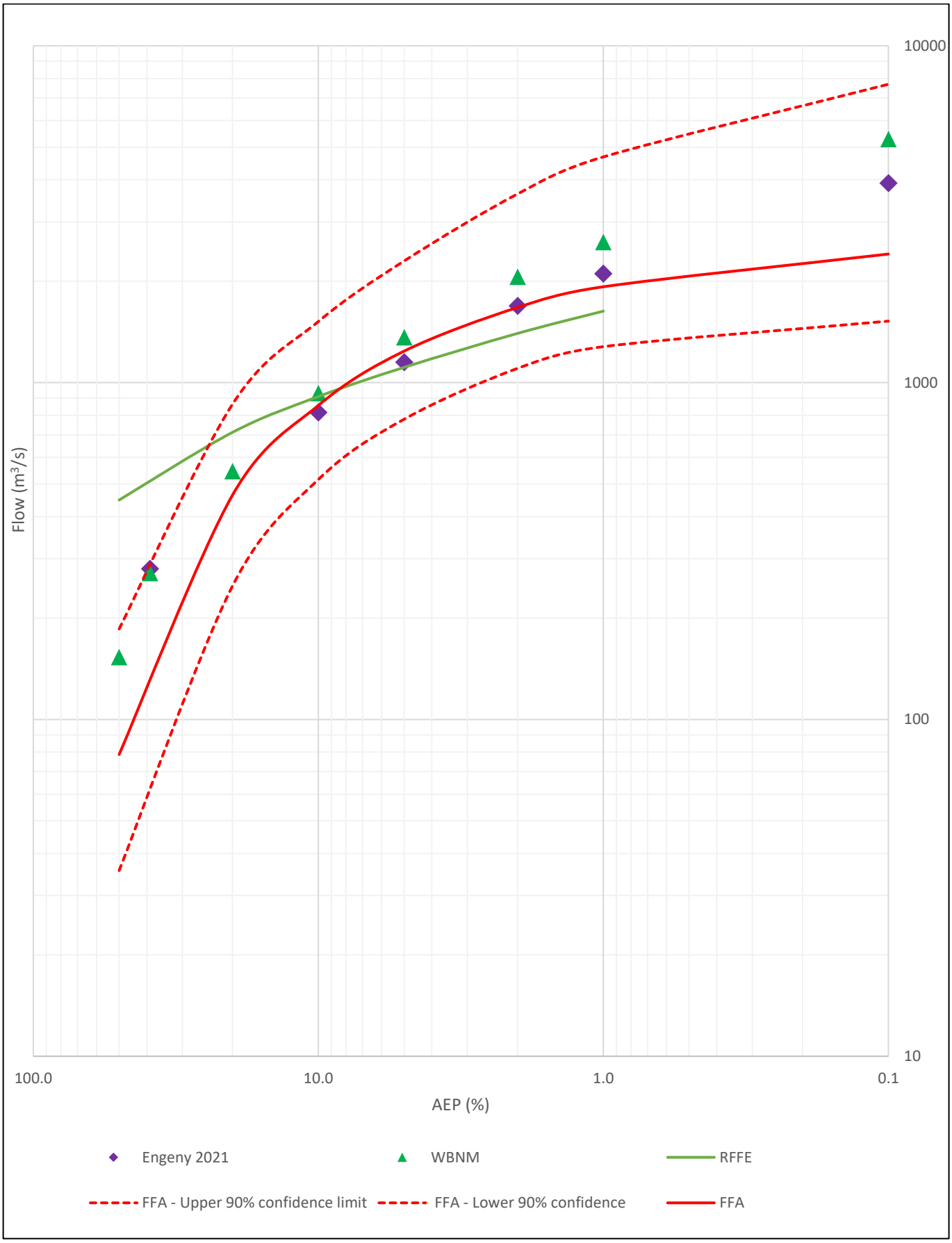


FIGURE B.2: COMPARISON OF WBNM DESIGN DISCHARGES TO THE FFA AND RFFE DESIGN DISCHARGES TO THE ISAAC RIVER GAUGE

APPENDIX C: HYDRAULIC MODEL DEVELOPMENT

MODEL EXTENT AND TOPOGRAPHY

The hydraulic model utilised the TUFLOW HPC solver. The Digital Elevation Model (DEM) used in the hydraulic model was based on the most recent PRCP landform (Version 2) provided by BMA.

A grid cell size of 4 m was selected for the TUFLOW model, which is suitable for representing the width of the diversion across multiple modelling cells.

The selected extent for the HPC TUFLOW model covers upstream of where both HPC and Eureka Creek starts to the Isaac River, downstream of where HPC, Fisher Creek, and Platypus Creek join into the Isaac River from the west which are all in the extent of the ML Goonyella Riverside. This was chosen to maintain a consistent modelling extent for the 0.1% AEP runs for all the GRM diversions across each of the hydraulic models. The modelling layout is shown in Figure C.1 and Figure C.2.

The proposed diversion design option was included in the model using design tins produced by 12D and merging it to the PRCP landform (Version 2) as well as the addition of the proposed landform to provide flood protection and battering of the GS1 Tailings Dam dump top outer extents.

HYDRAULIC ROUGHNESS

The hydraulic roughness has been selected based on the inspection of aerial imagery and expected treatments within the diversion as well as historical investigations into hydraulic roughness values for existing watercourse channels at GRM. The rail, which is not owned by BMA and goes to Moranbah North, was considered in the base land use mapping of the site. The adopted Manning's 'n' roughness values are summarized in TABLE C.1 below.

TABLE C.1: ADOPTED MANNING'S N ROUGHNESS

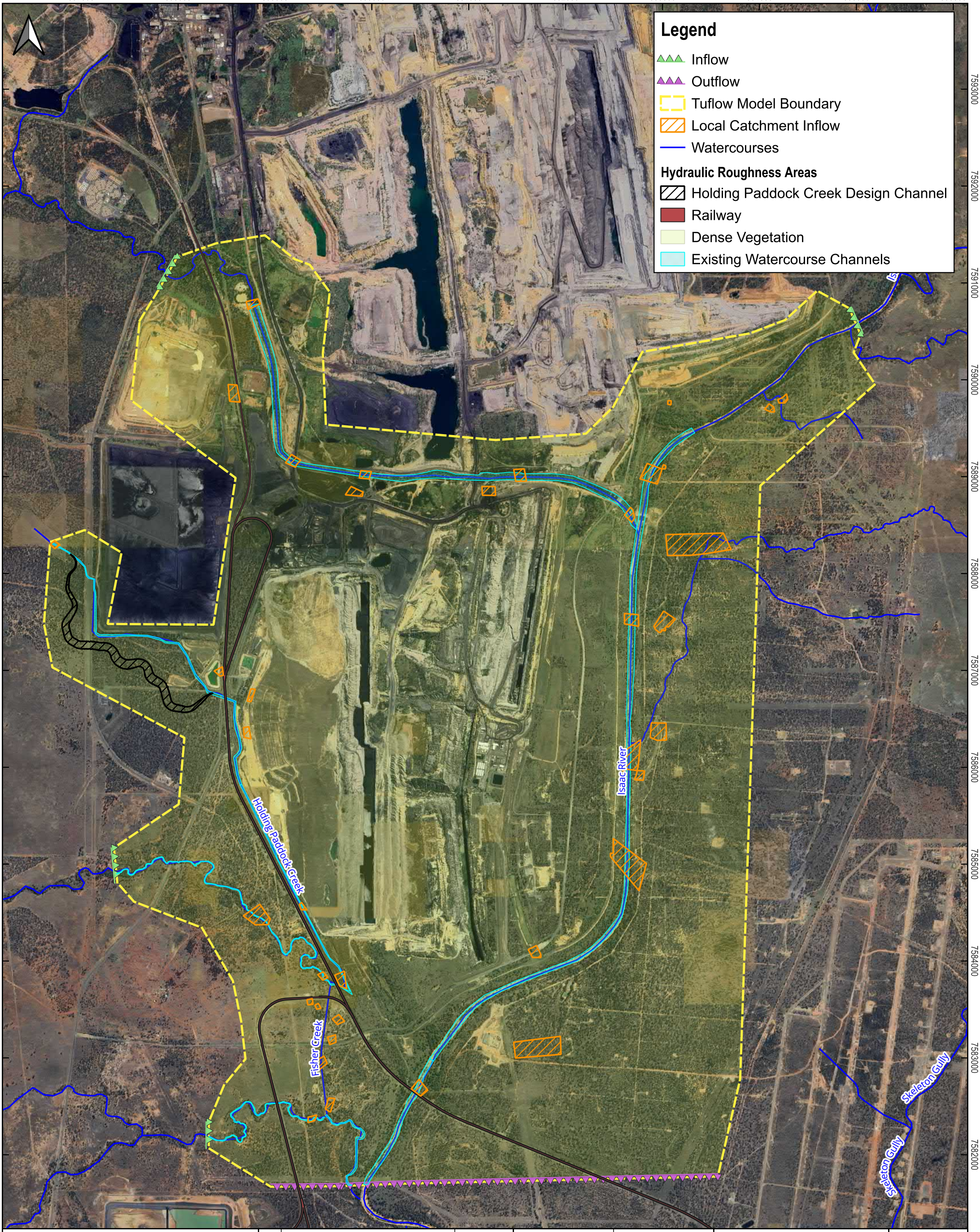
Land Use	Manning's' 'n'
Railway	0.015
Constructed Channel	0.050
Dense Vegetation	0.080
Isaac River Existing Channel	0.020
Platypus Creek Existing Channel	0.030
Holding Paddock Creek and Fisher Creek Existing Channel	0.050

MODEL INFLOWS AND BOUNDARY CONDITIONS

Boundary conditions are required in the model to define hydrology inflows, flow leaving the model domain and interfaces between the one dimensional and two-dimensional model domains. The following boundary conditions used in the models are:

- Upstream: The upstream boundary condition used a combination of 'SA' and 'BC' type boundaries, allocating flow to the defined model grid cells based on the design hydrograph from the hydrologic model (flow per unit of time) input. Total inflow hydrographs were applied to HPC, Fisher Creek, Isaac River, and Platypus Creek at the upstream boundaries.
- Downstream: A normal depth outflow boundary was adopted with a hydraulic grade based on the Isaac River channel grade at the downstream extent of the model. The boundary was located a sufficient distance downstream to not influence the flood behaviour near the areas of interest.

Peak flows as estimated by the WBNM hydrologic model (only for 0.1% AEP event) have been applied at various locations dependent on the diversion being assessed. The location of the model inflows (0.1% AEP) can also be seen in Figure C.1**.** As mentioned in section 6.4.1, for the 39% and 2% AEP event, constant ACARP flows were applied throughout the diversion as shown in Figure C.2**.**



BMA PRCP GRM Holding Paddock Creek Diversion

Figure C.1
Hydraulic Model Layout - 0.1% AEP

REV.	DETAILS	DATE
0		

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APPROVED: BK | DATE: 28/08/2024

GENERAL NOTES:

0 250 500 750 1,000 m
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596000 597000 598000 599000 600000 601000

7588000 7587000 7586000 7585000 7584000 7583000 7582000

Legend

- Inflow
- Outflow
- Tuflow Boundary Model
- Watercourses

Hydraulic Roughness Areas

- Railway
- Holding Paddock Creek Design Channel
- Dense Vegetation
- Existing Watercourse Channels

Holding Paddock Creek
Fisher Creek
Holding Paddock Creek
Fisher Creek
Isaac River
Platypus Creek
Platypus Creek

BMA PRCP GRM Holding Paddock Creek Diversion

Figure C.2
Hydraulic Model Layout - 39% and 2% AEP

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APPENDIX D: HYDRAULIC PARAMETER MODELLING RESULT

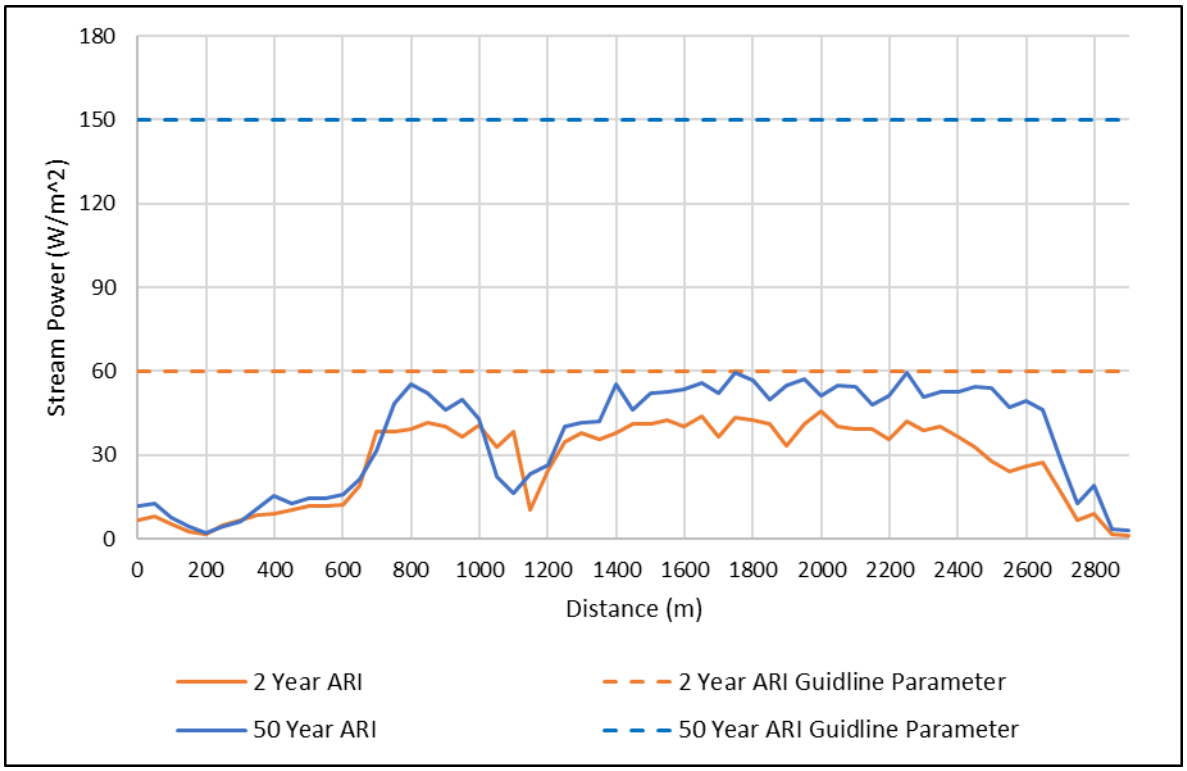

FIGURE D.1: STREAM POWER TUFLOW MODEL RESULTS

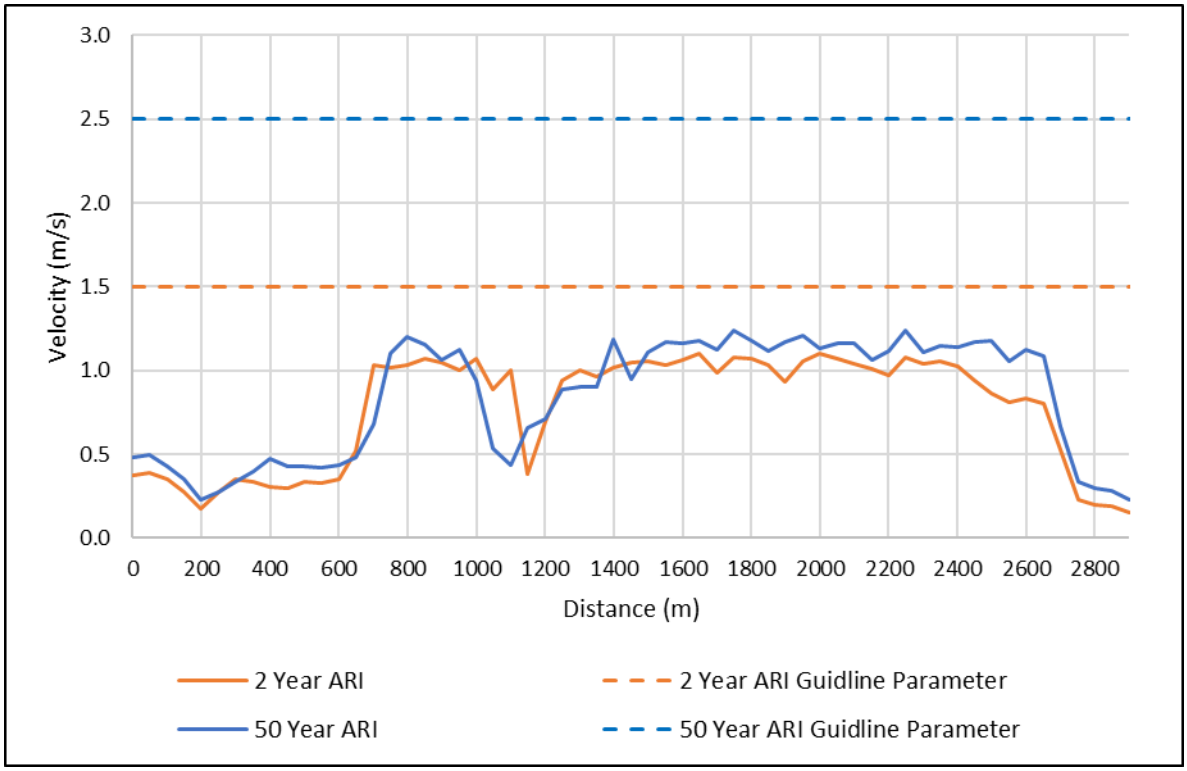

FIGURE D.2: VELOCITY TUFLOW MODEL RESULTS

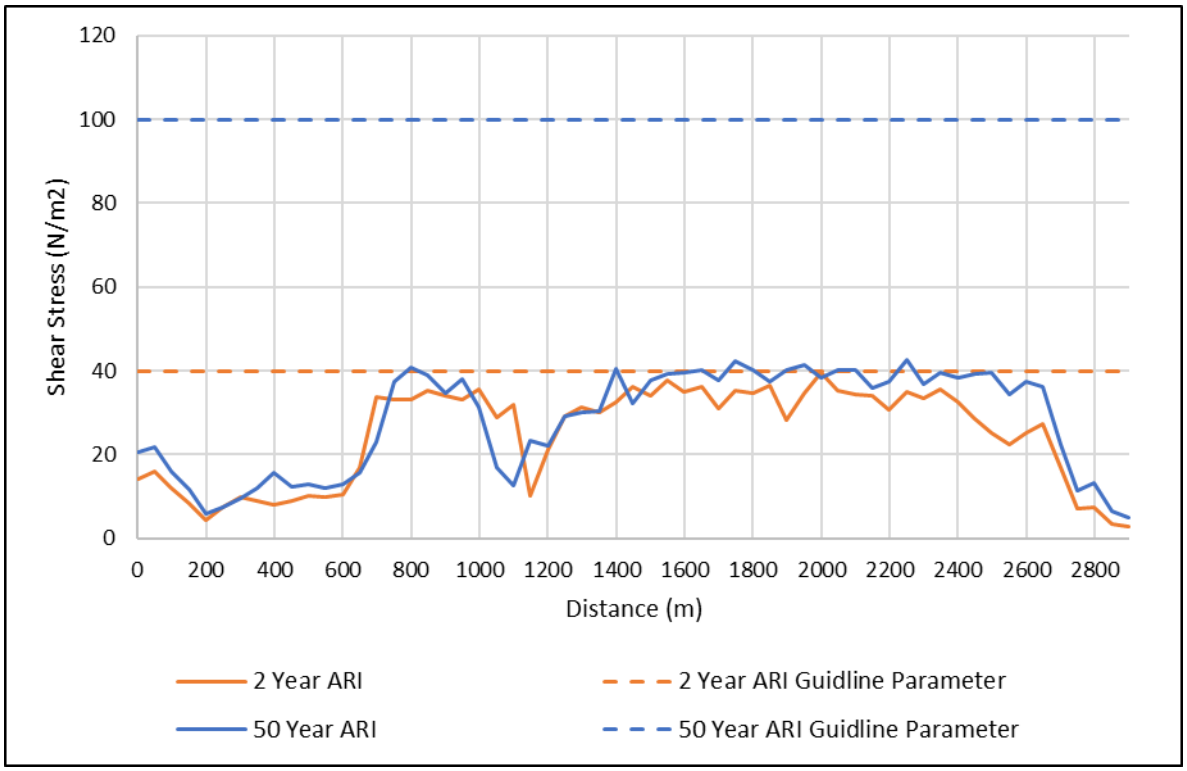

FIGURE D.3: SHEAR STRESS TUFLOW MODEL RESULTS

APPENDIX E: PREFERRED OPTION CONCEPT DESIGN DRAWINGS

NOT FOR CONSTRUCTION

CONTROL MCE01
(LANDFORM)

CONTROL MCD01
(HOLDING PADDOCK
CREEK DIVERSION)

1093.745
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0.000

GS1 TSF

HOLDING PADDOCK CREEK

RIVERSIDE MINE ROAD

ROAD CROSSING DETAILS TO BE CONFIRMED
DURING FUTURE PHASES OF STUDY

0.000
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
2822.21

0 50 100 150 200 250m
SCALE 1:5000 (A1)
SCALE BEFORE REDUCTION

LEGEND - EXISTING

- BURIED WATER LINE
- POWER LINE
- PROPERTY BOUNDARY
- WATERCOURSE
- PIT DEWATERING LINE
- UNKNOWN BURIED SERVICE
- RAILWAY TRACK

LEGEND - DESIGN

- DIVERSION EXTENTS
- BATTER TICK
- CONTROL LINE
- DIRECTION OF FLOW

VENDOR DRG NUMBER
QC1000-098-DWG-0101

VENDOR LOGO
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REV	DATE	DESCRIPTION	DRN	ENG	APP
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DRN. CHK		
ENGINEER		
ENG. CHK (QA)		
APPROVED		

RPEQ APPROVAL
RPEQ ENGINEER
RPEQ No. DATE
PROJECT No.
EQUIPMENT TAG

BMA REVIEW
SIGNATURE
DATE

GOONYELLA MINE
HOLDING PADDOCK CREEK DIVERSION
GENERAL ARRANGEMENT PLAN

DRG. No.
LEGACY DRG No.
STATUS: NOT FOR CONSTRUCTION - FOR REVIEW
DISCIPLINE:

Sht
Sht Size A1
Scale –
Rev. No. A

CAD FILE: QC1000-098-DWG-0101.dwg

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HOLDING PADDOCK CREEK DIVERSION TYPICAL SECTION

SCALE 1:125

LEGEND

EXISTING SURFACE

DESIGN SURFACE

SCALE 1:125 (A1)
SCALE BEFORE REDUCTION

VENDOR DRG NUMBER: QC1000-098-DWG-0201

VENDOR LOGO: ENGENY

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RPEQ ENGINEER
RPEQ No. DATE
PROJECT No.
EQUIPMENT TAG

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GOONYELLA MINE
HOLDING PADDOCK CREEK DIVERSION
TYPICAL SECTIONS AND DETAILS

DRG. No.
LEGACY DRG No.
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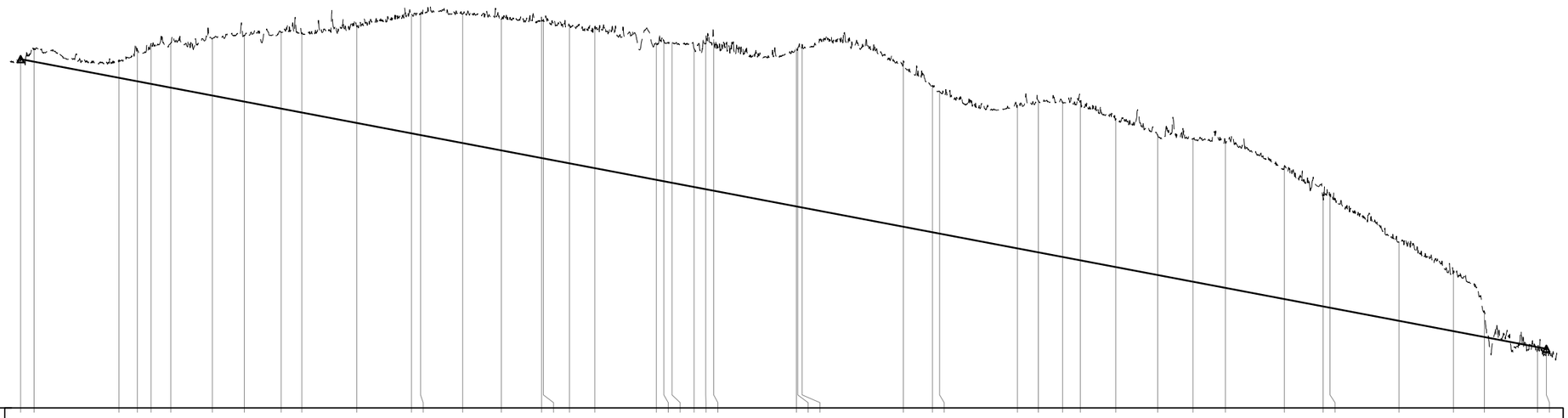

DATUM 247.0

| | | |

APPENDIX F: CONCEPT DESIGN WITH CONCEPT PRCP LANDFORM 2 INTERACTION

597000
598000
599000
7588000
7587000
7586000
Holding Paddock Creek
ML 70288
ML 70287
ML 1763
ML 70478
ML 70289
ML 70479
Holding Paddock Creek

Legend

- Preferred Diversion Alignment
- Watercourses
- ML Boundary

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Holding Paddock Creek Diversion

Figure F.1
Holding Paddock Creek Concept Design with Concept PRCP Landform 2

REV.	DETAILS	DATE
0	Client Issue	

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PRCP Concept Design Report

Fisher Creek Diversion

QC1000_051-REP-002-2

30 SEPTEMBER 2024

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	24/07/2024	Issue for Review	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
1	14/08/2024	Issue for Review	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
2	30/09/2024	Client Issue	Christian Hansen & Sean Willmett	Ben Kiernan	Ryan Kinnealy	Ben Kiernan
Signatures:						

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Fisher Creek Diversion to comply with the conditions under EA EPML00853413. The diversion was authorised through the *Central Queensland Coal Associates Agreement Act 1968* (CQCAA Act). Therefore, the diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Goonyella Riverside Mine (GRM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per Environmental Authority requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for GRM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options identification, assessment and selection.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium resulting in a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Fisher Creek is a tributary of the Isaac River hydrologically connected to Holding Paddock (upstream) and Platypus Creek (downstream). The creek is located approximately 25 km north of Moranbah and is part of the Fitzroy River Basin within the Bowen Basin geological formation. The location within the Queensland region is shown in Figure 2.1. The upstream catchment covers an area of approximately 64 km^2 and flows through open woodlands across gently sloping plains with cattle grazing vegetation. The upstream reach flows along the southwestern border of the Goonyella Riverside Mine (GRM) Mining Lease (ML 1763) towards the diversion reach which crosses a road and railway south of the mine.

2.2 Pre-Mining Condition

Fisher Creek was previously a direct tributary of the Isaac River and was independent of Platypus Creek, flowing eastward, upstream of the Goonyella rail bridge with the pre-mining reach shown in Figure 2.1. After the Holding Paddock Creek was diverted into Fisher Creek during the 1980's as part of the mining development, Fisher Creek was then diverted into Platypus Creek just downstream of the two creeks.

- **Upstream reach** – Based on historical imagery and the latest diversion monitoring report (Alluvium, 2021), Fisher Creek had three tributaries prior to the Holding Paddock Creek diversion. The reach has been subject to heavy cattle grazing which has limited vegetation regrowth; however, remnant vegetation was continuous and more dense pre-mining activity.
- **Diversion reach** – The diversion reach originally flowed directly into the Isaac River passing through grazing vegetation. Vegetation has been cleared and thinned since mining activities have begun adjacent to the reach.
- **Downstream reach** – As the diversion flows directly into Platypus Creek and originally the Isaac River, there is no defined Fisher Creek downstream reach.

2.3 Current Conditions

Monitoring of the Fisher Creek diversion has been undertaken since baseline monitoring in 2009. The last major monitoring effort at the time of writing was conducted in 2020 (Alluvium, 2021) and the Fisher Creek diversion has been described in the report as follows:

- The upstream reach has continued to remain mostly static in geomorphic conditions. The riparian condition has deteriorated due to drought stress and cattle grazing which resulted in reduced ground cover. Where the bank remains stable, there is good vegetation cover however, excess sediment inputs from further upstream are smothering the bed where some morphologic diversity remains. As the catchment has effectively doubled by the Holding Paddock Creek (HPC) diversion, the reach has undergone erosional adjustments but has since recovered partly due to the high sediment inputs.
- The diversion reach discharges directly into Platypus Creek which has been considered the downstream reach of the diversion. The geomorphic condition of Platypus Creek has deteriorated significantly over time with extreme bank erosion and mass failures due to cattle grazing, vegetation clearing in the sodic soils, and increased flow rates and durations as a result of the increased catchment area from the diversion works. Severe bank erosion has occurred where vegetation has been cleared along the entire reach. The extent of groundcover has not improved since baseline monitoring and while trees and shrubs have increased in density, they are still sparce and the overall riparian condition has shown only minor improvement. A large rock chute approximately 100m upstream of the confluence between Fisher and Platypus Creeks has also been constructed in 2012 to stabilise a large erosion head originating from a failed drop structure at the Platypus Creek confluence.

The upstream and diversion reaches of the Fisher Creek diversion at the GRM are shown in Figure 2.1.

598250 598500 598750 599000 599250 599500 599750 600000 600250 600500 600750

7585250 7585000 7584750 7584500 7584250 7584000 7583750 7583500 7583250 7583000 7582750 7582500 7582250 7582000 7581750

ML 70478
ML 70289
ML 70479
ML 1763
Holding Paddock Creek
Fisher Creek
Fisher Creek
Platypus Creek
Isaac River
Ramp 32
Ramp 0
Moranbah

Legend

- Upstream Reach
- Current Diversion Reach
- Pre mining Reach
- ML Boundary
- Existing Railway
- Existing Roads
- Watercourses

BMA PRCP GRM Fisher Creek Diversion

Figure 2.1
Location of Fisher Creek Diversion

REV.	DETAILS	DATE
0		

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APPROVED: BK | DATE: 10/07/2024

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3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

The DNRME and ACARP Guidelines have both been used to inform the basis of design for the diversion, as summarised in Table 3.1.

TABLE 3.1: DNRME AND ACARP GUIDELINES USED FOR DESIGN BASIS

Guideline	Design Parameter
DNRME	Diversion Design Outcomes and Design Recommendations
	Velocity, shear stress, stream power (39% AEP) guidelines
ACARP	General Design Process
	Stream power (2% AEP event Guideline)

3.1 DNRME Guidelines

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Fisher Creek diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Fisher Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.2 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential; however, stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.2: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - No Vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - Vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.2 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the construction.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and,
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m²)	Stream Power 2% AEP (W/m²)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock Controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.4.

TABLE 3.4: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m²)
Buffel grass *(Cenchrus ciliaris)*	40
Structurally diverse suite of established native vegetation	120

4. OPTIONS IDENTIFICATION

Engeny identified two potential options for the diversion as part of stage 1 (summarised below in Table 4.1). The following criteria were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the ML boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2
Description	Retain existing diversion alignment, the total length of the diversion is approximately 1500m	Meanders to the east of the existing diversion. The diversion crosses Red Hill Road and Goonyella Hay Point Railway between Holding Paddock and Platypus creek. Total length of the diversion is approximately 1800m.
Likelihood that diversion will achieve state of dynamic equilibrium	Low – has an alignment with a length (1.4 km) and grade (0.39%) similar to the pre-mining alignment. However, Option 1 has drop structure; Creek deteriorating. Further remediation works to be completed to return creek to state of dynamic equilibrium.	High – has an alignment with a length (1.8 km) and grade (0.28%) similar to the pre-mining alignment.
Order of magnitude cost estimate*	$1.0 M	$6.9 M
Ability to isolate diversion from flows during establishment period	No – will be constructed on the existing diversion alignment	Yes – option 2 cuts across the existing alignment at two separate locations. It is possible but there is some engineering risk.

* Costs estimated based on average $10/m^3.

599000 599250 599500 599750 600000

7584000 7583750 7583500 7583250 7583000 7582750 7582500 7582250

Legend

- ML Boundary
- Existing Railway
- Existing Roads
- Watercourses

Fisher Creek Diversion Options

- Option 1
- Option 2

Fisher Creek

Holding Paddock Creek

ML 1763

ML 70479

Fisher Creek

Platypus Creek

BMA PRCP GRM Fisher Creek Diversion

Figure 4.1
Fisher Creek Diversion Realignment Options

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 16/07/2024

GENERAL NOTES:

0 100 200 m

Scale @ A3: 1:5,000

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5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BMA and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	50%
Order of magnitude cost estimate	30%
Ability to isolate diversion from flows during establishment period	20%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 2 to be carried forward into concept design as a preferred option, since it scored highest out of the two options and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2
Overall Weighted Score	-0.4	1.2
Relative Risk	Neutral Risk	Lowest Risk
Fatal Flaw	No	No

6. CONCEPT DESIGN

6.1 Design Parameters and Plan

Table 6.1 details the parameters for each outcome in Section 3, forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND THE AUSTRALIAN COAL ASSOCIATION RESEARCH PROGRAM (ACARP) PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function, and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] A hydrologic model for the southern extent of GRM inclusive of Fisher Creek was originally developed as part of the Eureka Flood Study (Engeny, 2024).	☒ ☐	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	Outcome 5 – Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME (2019). Stream power benchmark values were adopted from ACARP (2014) due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Concept Design Diversion Alignment

The alignment of Option 2 was determined to be the preferred option using the MCA. Option 1 was not chosen due to the high grade of the existing diversion (0.39%) predicted to not be able to perform within the hydraulic design criteria even with remediation works. Option 2 was further refined to closely match the pre-mining grade and compliance with the hydraulic design criteria. The full concept drawing package for the permanent Fisher Creek diversion is included in Appendix E and the interaction of the design with the PRCP landform 2 in Appendix F.

6.3 Channel Geometry and Grade

The location of the reference cross sections is shown in Figure 6.1. The typical upstream channel cross sections are presented in Figure 6.2. These dimensions were based on the average natural downstream channel geometry and grade as assessed in the options identification phase.

Table 6.2 summarises the typical channel cross section selected for the concept design. The concept design drawings in Appendix E show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY FOR CONCEPT DESIGN

Channel Geometry	Quantity	Comments
Channel Bed Width	9.5 m	Based on current upstream Fisher Creek representative cross sections and additional catchment area inflows from Holding Paddock Creek factored into the downstream diversion cross section
Bench Width	4 m	
Channel Depth	2 m	Consistent depth of low flow channel at 2 m
Batter Slope	1V:5H (Low Flow Channel) 1V:6H (High Flow Channel)	Based on the existing upstream Fisher Creek representative cross sections. The batters will be covered with topsoil, hydromulch and hydroseed (Appendix E) to ensure stability and prompt revegetation of the channel batters.

598250 598500 598750 599000 599250 599500 599750 600000 600250

7585000 7584750 7584500 7584250 7584000 7583750 7583500 7583250 7583000 7582750 7582500

ML 70289

US1 US2 US3 US4 US5 US6 US7 US8

Fisher Creek

Holding Paddock Creek

Ramp 32

ML 1763

ML 70479

Moranbah North Mine Loop

Fisher Creek

Isaac River

Legend

- Reference Cross-sections
- Fisher Creek Preferred Option
- Upstream Reach
- Current Diversion Reach
- Watercourses
- ML Boundary
- Existing Railway
- Existing Roads

BMA PRCP GRM Fisher Creek Diversion

Figure 6.1
Location of Reference Cross-Sectional Areas

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK

APPROVED: BK | DATE: 17/07/2024

GENERAL NOTES:

0 100 200 m

Scale @ A3: 1:8,000

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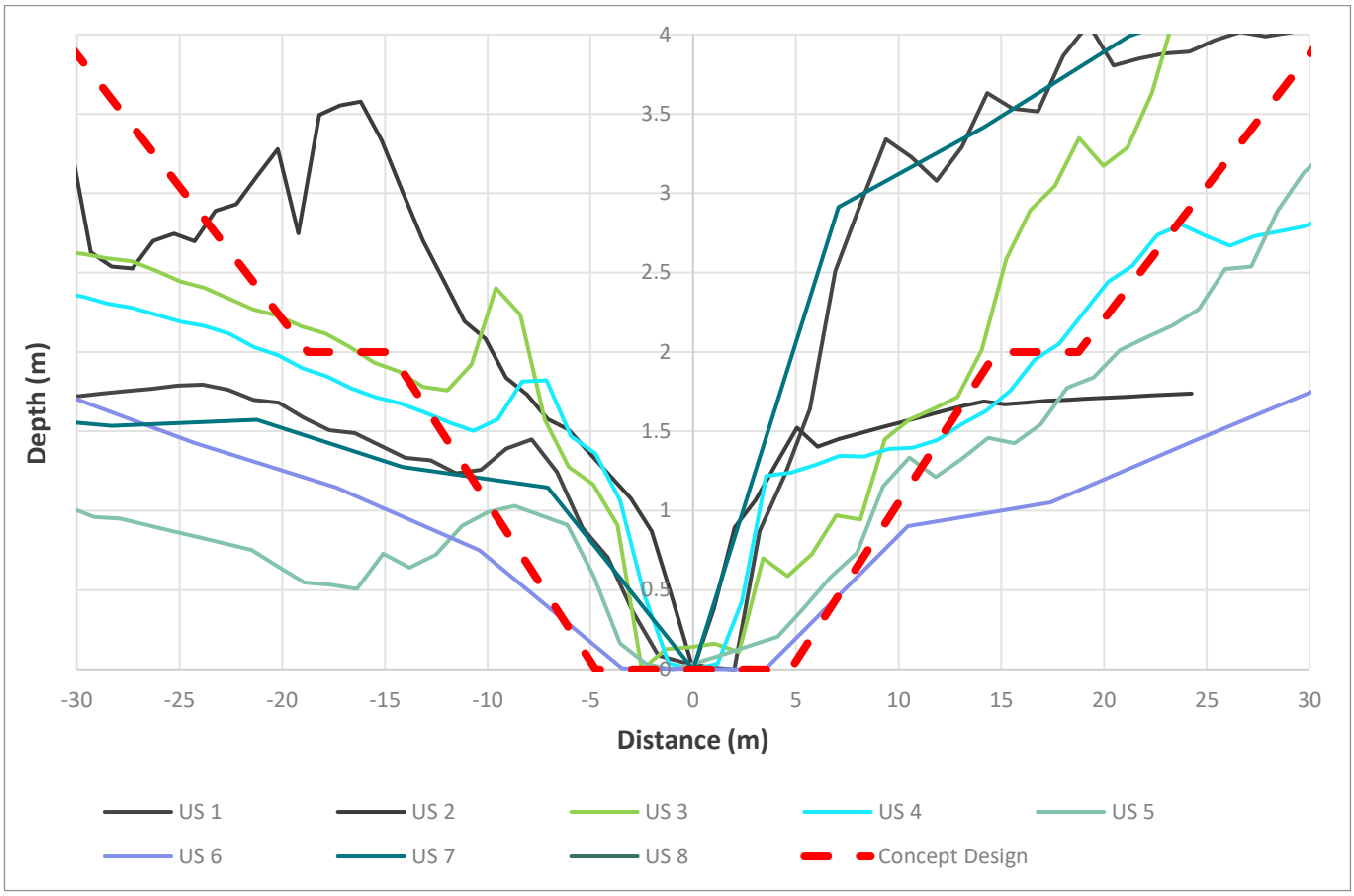
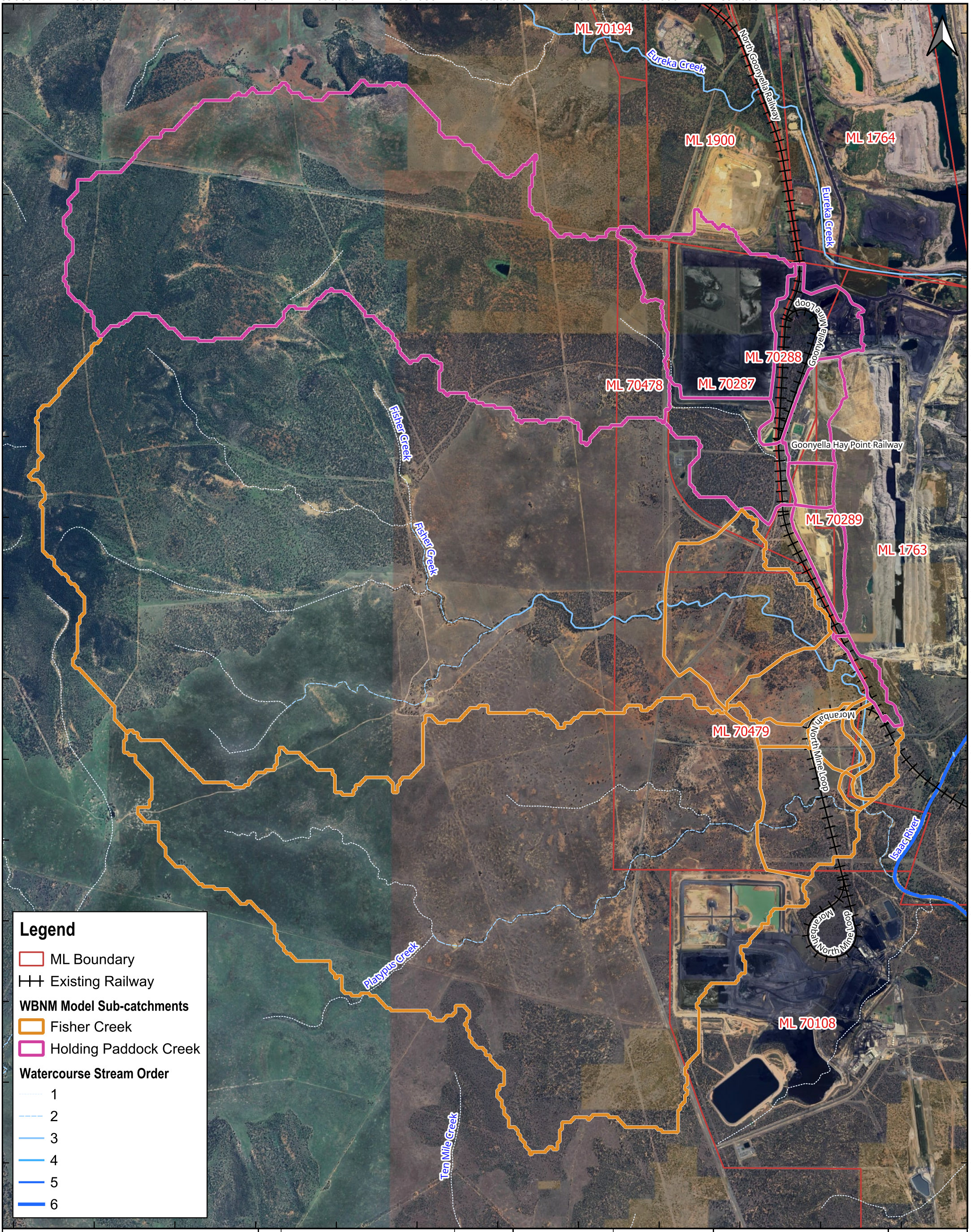


Figure 6.2: Typical Upstream Channel Cross Section of Fisher Creek

The concept design seeks to change the vertical grade, which is reduced from 0.39% in the existing diversion to a grade of 0.28%, with the new diversion design attributed to the more natural sinuosity adopted which is closer to the original pre-mining length. The current length of the diversion is approximately 1400m, the pre-mining length for the same reach was approximately 1500m. The new diversion design has a length of approximately 1800m and joins into Platypus Creek as opposed to the Isaac River which is depicted in the original pre-mining alignment. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix E.

6.4 Hydrology

A hydrologic model for the southern extent of GRM inclusive of Fisher Creek was developed for the Eureka Creek Diversion using WBNM software and was validated against the Isaac River Gauge. This model was also used for the Fisher Creek (concept design) to estimate flows for the 0.1% AEP (1 in 1000 year) flood event. The details of the hydrologic model development are presented in Appendix B. Peak flows for frequent events (39%AEP and 2%AEP) for the Fisher Creek diversion were estimated using the ACARP (2002) method and are presented in Table 6.3. The Fisher Creek catchment is presented in Figure 6.3.



BMA PRCP GRM Fisher Creek Diversion

Figure 6.3
Catchment Map

REV.	DETAILS	DATE
1	Catchment Map of Fisher Creek Diversion	

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APPROVED: BK | DATE: 12/08/2024

GENERAL NOTES:

0 250 500 750 1,000 m
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6.4.1 Frequent Events

Peak flows for frequent events (39% AEP and 2% AEP) for the Fisher Creek diversion (concept design) were estimated using the ACARP (2002) methods and are presented in Table 6.3. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity to provide a conservative estimate. This approach has been adopted to determine the flows within the proposed Fisher Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters. The diversion channel design flows were calculated based on the catchment area and rainfall intensities of both the Fisher Creek and Holding Paddock Creek catchments due to both watercourses entering the upstream section of the Fisher Creek Diversion. Alongside this the ACARP flows for both Platypus Creek and the Isaac River were also calculated and used in the hydraulic model due to their tailwater effects influencing the Fisher Creek diversion.

TABLE 6.3: ACARP DESIGN FLOWS

Rainfall Event	Peak Catchment Design Flows (ACARP, 2002) m^3/s			
-	**Fisher Creek**	**Holding Paddock Creek**	**Platypus Creek**	**Isaac River**
2% AEP (50-year ARI)	73	53	55	1174
39% AEP (2-year ARI)	35	27	28	267

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP landform 2 has been assessed as part of the rehabilitation flood modelling completed for the PRCP. This informs the interaction between the diversion and final voids landform. The 0.1% AEP peak flow rate at the end of the diversion is estimated at 438m^3/s.

6.5 Hydraulics

A two-dimensional TUFLOW flood model was developed to assess the compliance with the DNRME and ACARP hydraulic performance criteria for the 39% and 2% AEP events.

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in the 39% and 2% AEP event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP (2-year ARI)		2% AEP (50-year ARI)	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	28.46	<60	36.60	<150
Stream Velocity (m/s)	0.84	<1.5	0.99	<2.5
Shear Stress (N/m^2)	24.20	<40	28.67	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

It can be seen from Table 6.4 that all the average diversion hydraulic results are below the design parameters for both the 39% AEP and 2% AEP events. Moreover, 39% AEP (2yr ARI) stream power and velocities meet the DNRME design criteria for stability if the channel remains unvegetated. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix D.

The extents and depths of the 0.1% AEP design flood event with the PRCP landform 2 and concept diversion design are depicted in Figure 6.4. The result shows that there is no risk of flood ingress to any final voids.

598000 598500 599000 599500 600000 600500

7585000 7584500 7584000 7583500 7583000 7582500 7582000

ML 70478
ML 70289
ML 1763
ML 70479
Holding Paddock Creek
Fisher Creek
Moranbah North Mine Loop
Platypus Creek
Isaac River

Legend

- Existing Roads
- Existing Railway
- ML Boundary

Flood Depth (m)

- <= 0
- 0 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- > 8

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

BMA PRCP GRM Fisher Creek Diversion

Figure 6.4
0.1% AEP Flood Event with PRCP Landform 2

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 17/07/2024

GENERAL NOTES:

0 100 200 300 400 m
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6.6 Risks and Mitigation Measures

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised for this risk assessment align with the BHP Global Standard- Risk Management.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to frequent (up to 20% AEP / 5 year ARI) flood events.	Probable	2	9	Diversion channel constructed during dry season. Majority of diversion able to be constructed while offline. Detailed revegetation plan to be implemented to promote rapid establishment. Seed mix to include fast establishing species to rapidly stabilise diversion.	Unlikely	1	1
Damage to the new diversion channel due to extreme/rare (0.1% AEP / 1000 year ARI) flood event (mainly overland flow and bank erosion)	Highly Unlikely	2	0.9	Revegetation plan to include large species capable of withstanding shear stresses associated with rare events.	Highly Unlikely	2	0.9
Construction program impacted by frequent flow event (up to 20% AEP / 5 year ARI).	Unlikely	1	1	Diversion construction to be timed to minimise risk of large flows while still maintaining enough watering to promote vegetation establishment and growth. Majority of diversion able to be constructed while offline.	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Unlikely	2	3	Geotechnical and soil investigations as part of functional design.	Highly Unlikely	1	0.3
Flood ingress into final voids	Highly Unlikely	2	0.9	Final landform design to provide flood protection to ensure no flooding ingress in 0.1% AEP flood with 1.0 m freeboard	Highly Unlikely	2	0.9
Upstream rehabilitation of mining areas unsatisfactory leading to increase sediment loads to the final diversion channel	Unlikely	2	3	Additional upstream controls could be considered during functional design. Offline flow through diversion from upstream watercourses (Fisher Creek and Holding Paddock Creek) could report to the Fisher Diversion	Unlikely	2	3

6.7 Additional Design and Construction Considerations

6.7.1 Infrastructure

The section of Red Hill Road impacted by the concept diversion design will be removed and given a post-mining land use (PMLU) at closure and as such will not affect the concept diversion design.

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Hydraulic modelling has demonstrated that the design criteria values for stream power, stream velocity and shear stress for both 39% AEP and 2% AEP storm events, are within the ACARP (2002) diversion channel design parameters (refer Table 3.2). Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the functional design for Fisher Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understorey and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the Goonyella Riverside Mine Progressive Rehabilitation and Closure Plan.

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include Geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with BMAs watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment is required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7. CONCLUSION

The existing diversion is experiencing increasing bank erosion, lack of geomorphic and vegetation features like those in the local landscape, sediment aggradation and sediment deposition downstream.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of GRM.

Two options for rehabilitation of the diversion were identified and assessed using the BMA Multi-Criteria Analysis outlined in Section 5. Option 2 was selected to proceed as the preferred concept design as it has a grade similar to the pre-mining alignment which is required for hydraulic performance criteria compliance. The final concept design, typical cross sections and longitudinal section are presented in Appendix E.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

(c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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  (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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(g) This Report does not provide legal advice.

9. REFERENCES

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APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Fisher Creek Diversion

Project: PRCP GRM Diversions
Workshop Date:

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	50%	-2	2	Option 1: Has an alignment with a length (1.4 km) and grade (0.39%) similar to the pre-mining alignment. However, Option 1 has drop structure; Creek deteriorating. Further remediation works to be completed to return creek to state of dynamic equilibrium. Option 2: Has an alignment with a length (1.8 km) and grade (0.3%) similar to the pre-mining alignment
Order of magnitude cost estimate	Assumes $10/m3 of cut.	30%	2	0	Compared based on direct diversion cut requirement costs only.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	20%	0	1	Option 1: Will be constructed on the existing diversion alignment Option 2: Cuts across the existing alignment at two separate locations. It is possible but there is some engineering risk.
	Overall Weighted Score		-0.4	1.2	

Is there a Fatal Flaw?	**No**	**No**
Relative Risk	**Neutral Risk**	**Lowest Risk**

APPENDIX B: HYDROLOGIC MODEL DEVELOPMENT

HYDROLOGIC MODEL SETUP

The WBNM (Watershed Bound Network Model) runoff routing software (2021 version) was used to develop the hydrology model. WBNM automatically calculates catchment routing based on the sub-catchment area, pervious/impervious areas and parameters, and the sub-catchment flow paths.

Catchment Inputs

Sub-catchment delineation for GRM was developed using the PRCP landform (Version 2) topography displayed in Figure B.1. The hydrological model includes the total catchment for the Isaac River (inclusive of Eureka, HPC, and Fisher creeks) extending downstream past the Goonyella mine, covering a total area of approximately 1180 km2.

Three open water bodies are located in the upper catchment: Lake Elphinstone, Teviot Dam and Burton Gorge Dam. Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

The design life of the Teviot Creek Dam and Burton Gorge Dam, as part of mining closure operations, could impact design flow estimates. For this study, the WBNM model did not include the Burton Gorge Dam, Teviot Dam, and Lake Elphinstone located upstream of the study area, considering a worst-case scenario.

Figure B.1 provides the sub-catchment extents used for the WBNM.

Model Parameters

The final landform is proposed to be rehabilitated; therefore, the hydrology model has assumed no impervious surfaces remain and a 0% impervious fraction (Fi) for all catchments including the remaining spoil areas and voids.

The default routing parameter of 1, pervious lag parameter of 1.8 and impervious lag parameter of 0.1 have been adopted for the WBNM.

Design Rainfall

The 0.1% AEP (1000yr) was sourced using the Australian Rainfall and Runoff 2019 IFD generation tool available on the Bureau of Meteorology (BoM) website (www.bom.gov.au), at Latitude 21.6652 (S), Longitude 148.0792 (E). Aerial Reduction Factors (ARFs) have been used for all design events to convert point rainfall estimates to areal rainfall estimates.

Temporal Patterns

Design events (1% - 0.1% AEP) have utilised the 'East Coast North' areal temporal patterns, as the total catchment area for the model exceeds 75 km^2. All ten temporal patterns were simulated for storm durations ranging from the 3 hours to 168 hours.

Design Rainfall Losses

The initial and continuing losses obtained from the ARR Datahub for Isaac River catchment to Goonyella gauge are 36 mm and 2.7 mm/h, respectively.

The adopted design rainfall losses were selected to achieve the best match between the XP-RAFTS design discharges with the design discharges estimated by the FFA at the Isaac River Goonyella gauge. The following is of note:

- For the 50%, 20%, 10%, 5%, 2% and 1% AEP events, the default ARR initial losses of 36 mm and continuing losses of 2.7 mm/h were adopted, respectively. The initial loss will decrease for larger events as the catchment is likely to be more saturated prior to the design rainfall burst.
- For the 0.1% AEP design event, a conservative 0 mm initial loss was adopted. A continuing loss of 2.5 mm/h was adopted as per the flood assessment done by WRM in 2019 (WRM, 2019).

590000 600000 610000 620000 630000

7630000 7620000 7610000 7600000 7590000 7580000

Legend

Stream Gauge

WBNM Model Sub Catchments

- Eureka Creek
- Fisher Creek
- Holding Paddock Creek
- Isaac River

Lake Elphinstone

Burton Gorge Dam

Teviot Dam

Eureka Creek at the railway

Eureka Creek at the GS4A Weir

Isaac River at Goonyella

BMA PRCP GRM Fisher Creek Diversion

Figure B.1
WBNM Hydrologic Model Layout

REV.	DETAILS	DATE
0		

DRAWN: CH | CHECKED: BK
APPROVED: BK | DATE: 08/08/2024

GENERAL NOTES:

0 2 4 km

Scale @ A3: 1:180,000

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MODEL VALIDATION

The 50%, 20%, 10%, 5%, 2% and 1% AEP peak flows estimated from the hydrology model were validated using the following methods:

- **Regional Flood Frequency Estimation Model (RFFE)** - is a recommended peak flow validation method from the ARR 2019 guidelines (Ball, et al., 2019). The RFFE provides peak flow estimations based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).

- **Flood Frequency Analysis (FFA)** - provides peak flow estimates for different AEPs by developing a fitted distribution from recorded peak flows from historical flood events.

  There is no gauge station for Fisher Creek, while the Eureka Creek gauges (Eureka Creek at the railway and GS4A) had an insufficient monitoring duration to conduct a reliable Flood Frequency Analysis (FFA). As a result, the FFA for the nearby Isaac River at the Goonyella gauge, located 7 km downstream of Eureka, was used for validation purposes. This analysis was completed as part of the Isaac River Flood Model by Engeny in March 2021.

  Isaac River FFA was undertaken on the peak annual (water year from October to September) discharges recorded at Isaac River at Goonyella (130414A) streamflow gauge by Queensland Department of Natural Resources Mines and Energy (DNRME) between 1982 and 2020. A Log Pearson Type 3 (LPIII) distribution was fitted to an annual maximum series of peak flows from the gauge (Engeny, 2021). To adapt the Isaac River FFA to Eureka Creek (as there was no gauge station data for Fisher Creek nor was it covered as part of the WRM 2019 flood modelling report), peak flows were scaled based on the catchment area using the QRT method. The formula used for this adjustment is:

$$Q_u = \left(\frac{A_u}{A_g}\right)^n Q_g$$

  Where,

  Q_u is the estimated peak flow for the ungauged catchment.

  A_u is the area for the ungauged catchment.

  A_g is the catchment area for the stream gauging station.

  Q_g is the peak flow for the gauging station determined from the flood frequency analysis.

  The exponent n has been determined from the regional flood frequency regression analysis (RFFE) undertaken by the Queensland Department of Transport and Main Roads (Palmen & Weeks, 2008).

- **Peak flow estimates from previous flood studies** –

  - A hydrologic modelling of the Isaac River catchment including the Grosvenor Mine (GRV) and Moranbah North Mine (MNM) using the XPRAFTS runoff-routing model was developed to estimate the 39%, 10%, 5%, 2%, 1%, 0.2% and 0.1% annual exceedance probability (AEP) and probable maximum flood (PMF) design discharges for the Isaac River and its tributaries (Engeny, 2021). The estimated peak flows at the Isaac River at Goonyella Streamflow Gauge were compared to the WBNM and RFFE peak flows (refer to Figure B.2). It is to be noted that The Burton Gorge Dam, Teviot Dam and Lake Elphinstone upstream of the study area were modelled as detention basins in the XPRAFTS model.

  - Design peak discharges in the Isaac River at Goonyella, Eureka Creek upstream of the railway and Eureka Creek at the GS4A for the 10%, 5%, 2%, 1%, 0.1% were estimated using the XP-RAFTS model by WRM in 2019. These flows were compared to the WBNM model design peak discharges at these three gauge locations.

Model Validation Results

Table B.1 shows the WBNM estimated design discharges at the Isaac River at Goonyella, Eureka Ck at the Railway and Eureka Ck at the GS4A for design events between 10% to 0.1% AEP, and the comparison to the WRM design discharges. This was due to there being no WRM design discharges for Fisher Creek. A visual comparison of the WBNM design peak discharges at the Isaac River streamflow gauge (130414A) against the flood frequency distribution curve, XP-RAFTS estimated peak flows by Engeny in 2021 and RFFE is provided in Figure B.2.

Validation of the design hydrology peak flow estimates indicates the following.

- **Isaac River Gauge**
  - Modelled peak flows for all design events are higher (3%-26%) than the LPIII expected quantile from the FFA. This is expected considering the exclusion of Burton Gorge Dam, Teviot Dam and Lake Elphinstone (Figure B.2).
  - Modelled peak flows compared to the RFFE method were higher for events rarer than the 10% AEP and lower for events more frequent than the 10% AEP. This irregularity is not concerning as the RFFE can provide irregular results if catchment characteristics are mostly different from the nearby gauged waterways used to derive the RFFE. Additionally, the Issac gauge catchment (1071.21 km^2) is outside the RFFE recommended catchment size of 0.5-1000 km^2, hence results have lower accuracy (Figure B.2).
  - WBNM estimated peak flows for all design events are higher (11%-28%) than the WRM 2019 flood modelling report (Table B.1).
- **Eureka Ck Gauge**
  - WBNM estimated peak flows for all design events are higher (10%-37%) than the WRM 2019 flood modelling report. This is expected considering the 37% increase of the Eureka catchment (Table B.1).

TABLE B.1: COMPARISON OF WBNM DESIGN DISCHARGES TO THE WRM 2019 FLOWS

		WRM (2019) Peak Discharge (m3/s)	WRM (2019) Critical duration (hours)	WBNM Peak Discharge (m3/s)	WBNM Critical duration (hours)	Difference (%)
Isaac River at Goonyella	Catchment Area (km^2)	-		1071.12 km^2		-
	Design event (AEP%)					
	10	830	18 hr	932	18 hr	11%
	5	1167	18 hr	1363	18 hr	14%
	2	1707	18 hr	2061	18 hr	17%
	1	2079	24 hr	2616	18 hr	21%
	0.1	3808	24 hr	5291	18 hr	28%
Eureka Creek at the railway	Catchment Area (km^2)	76.4 km^2		113.78 km^2		33%
	Design event (AEP%)					
	10	140	6 hr	159	18 hr	12%
	5	180	6 hr	217	18 hr	17%
	2	256	6 hr	299	18 hr	14%
	1	299	6 hr	374	18 hr	20%
	0.1	499	6 hr	692	12 hr	28%
Eureka Creek at the GS4A	Catchment Area (km^2)	80.7 km^2		129.05 km^2		37%
	Design event (AEP%)					
	10	147	6 hr	163	18 hr	10%
	5	189	6 hr	225	18 hr	16%
	2	267	6 hr	320	18 hr	17%
	1	311	6 hr	400	18 hr	22%
	0.1	521	6 hr	728	18 hr	28%

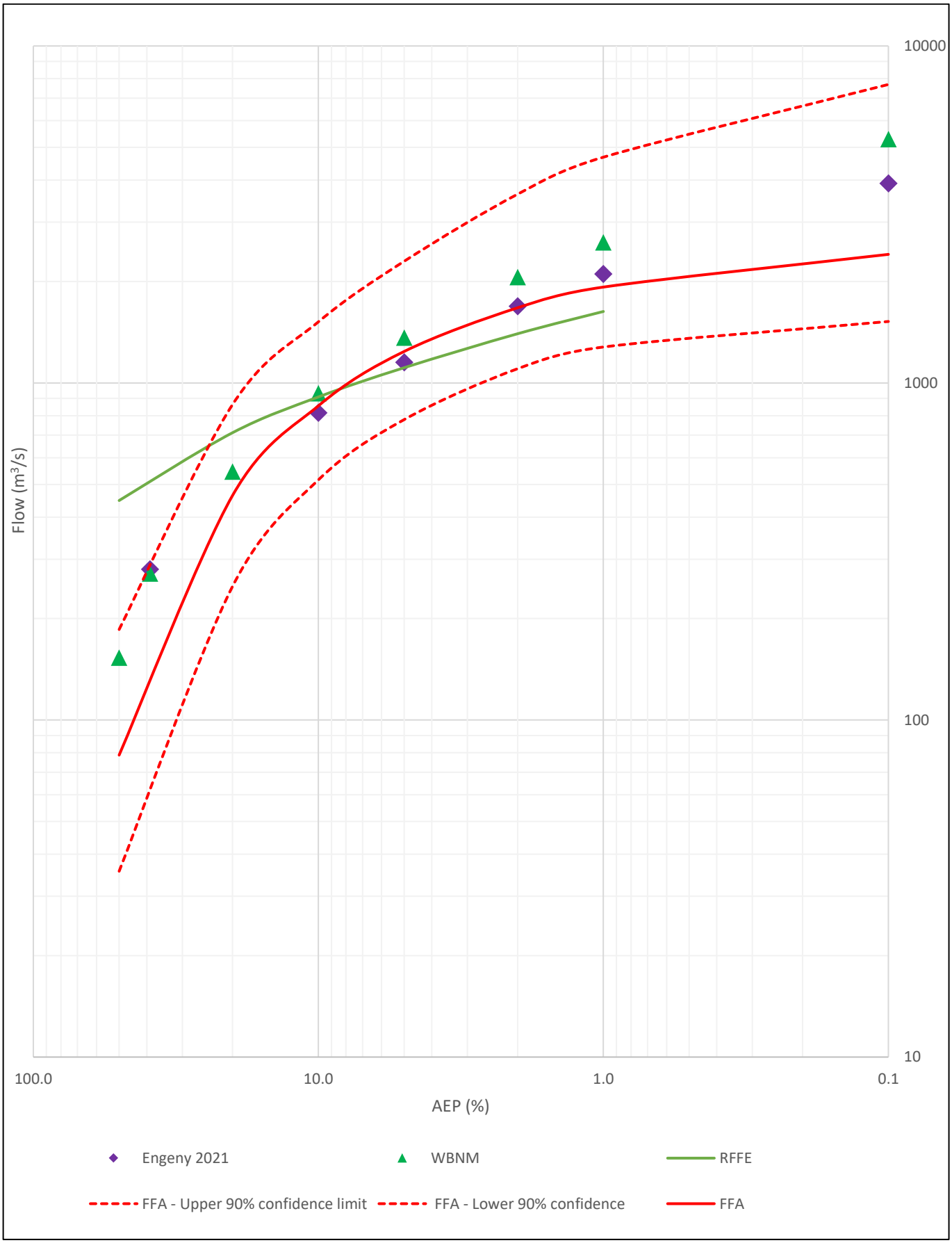

FIGURE B.2: COMPARISON OF WBNM DESIGN DISCHARGES TO THE FFA AND RFFE DESIGN DISCHARGES TO THE ISAAC RIVER GAUGE

APPENDIX C: HYDRAULIC MODEL DEVELOPMENT

MODEL EXTENT AND TOPOGRAPHY

The hydraulic model utilised the TUFLOW HPC solver. The Digital Elevation Model (DEM) used in the hydraulic model was based on the most recent PRCP landform (Version 2) provided by BHP.

A grid cell size of 4 m was selected for the TUFLOW model, which is suitable for representing the width of the diversion across multiple modelling cells.

The selected extent for the Fisher Creek TUFLOW model covers upstream of where Eureka Creek starts to the Isaac River, downstream of where Holding Paddock Creek, Fisher Creek, and Platypus Creek join into the Isaac River from the west which are all in the extent of the ML Goonyella Riverside. This was chosen to maintain a consistent modelling extent for the 0.1%AEP runs for all the GRM diversions across each of the hydraulic models. The modelling layout is shown in Figure C.1 and Figure C.2.

The proposed diversion design option was included in the model using design tins produced by 12D and merging it to the PRCP landform (Version 2).

HYDRAULIC ROUGHNESS

The hydraulic roughness has been selected based on the inspection of aerial imagery and expected treatments within the diversion as well as historical investigations into hydraulic roughness values for existing watercourse channels at GRM. The rail, which is not owned by BMA and goes to Moranbah North, was considered in the base land use mapping of the site. The adopted Manning's 'n' roughness values are summarized in TABLE C.1 below.

TABLE C.1: ADOPTED MANNING'S N ROUGHNESS

Land Use	Manning's' 'n'
Railway	0.015
Constructed Channel	0.050
Dense Vegetation	0.080
Isaac River Existing Channel	0.020
Platypus Creek Existing Channel	0.030
Holding Paddock Creek and Fisher Creek Existing Channel	0.050

MODEL INFLOWS AND BOUNDARY CONDITIONS

Boundary conditions are required in the model to define hydrology inflows, flow leaving the model domain and interfaces between the one dimensional and two-dimensional model domains. The following boundary conditions used in the models are:

- Upstream: The upstream boundary condition used a combination of 'SA' and 'BC' type boundaries, allocating flow to the defined model grid cells based on the design hydrograph from the hydrologic model (flow per unit of time) input. Total inflow hydrographs were applied to Fisher Creek, Isaac River, Holding Paddock Creek and Platypus Creek at the upstream boundaries.
- Downstream: A normal depth outflow boundary was adopted with a hydraulic grade based on the Isaac River channel grade at the downstream extent of the model. The boundary was located a sufficient distance downstream to not influence the flood behaviour near the areas of interest.

Peak flows as estimated by the WBNM hydrologic model (only for 0.1% AEP event) have been applied at various locations dependent on the diversion being assessed. The location of the model inflows (0.1% AEP) can also be seen in Figure C.1**.** As mentioned in section 6.4.1, for the 39% and 2% AEP event, constant ACARP flows were applied throughout the diversion as shown in Figure C.2**.**

596000 597000 598000 599000 600000 601000 602000 603000 604000 605000

7592000 7591000 7590000 7589000 7588000 7587000 7586000 7585000 7584000 7583000 7582000 7581000

Isaac River

Isaac River

Holding Paddock Creek

Isaac River

Legend

- Inflow
- Outflow
- Tuflow Model Boundary
- Local Catchment Inflow
- Watercourses

Hydraulic Roughness Areas

- Railway
- Fisher Design Channel
- Dense Vegetation
- Existing Watercourse Channels

BMA PRCP GRM Fisher Creek Diversion

Figure C.1
Hydraulic Model Layout - 0.1% AEP

REV.	DETAILS	DATE
1		

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GENERAL NOTES:

0 500 1,000 m

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BMA
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598000 599000 600000 601000

7586000 7585000 7584000 7583000 7582000

Holding Paddock Creek

Fisher Creek

Platypus Creek

Isaac River

Legend

- Inflow
- Outflow
- Tuflow Model Boundary
- Watercourses

Hydraulic Roughness Areas

- Railway
- Fisher Design Channel
- Dense Vegetation
- Existing Watercourse Channels

BMA PRCP GRM Fisher Creek Diversion

Figure C.2
Hydraulic Model Layout - 39% and 2% AEP

REV.	DETAILS	DATE
0		

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APPENDIX D: HYDRAULIC PARAMETER MODELLING RESULT

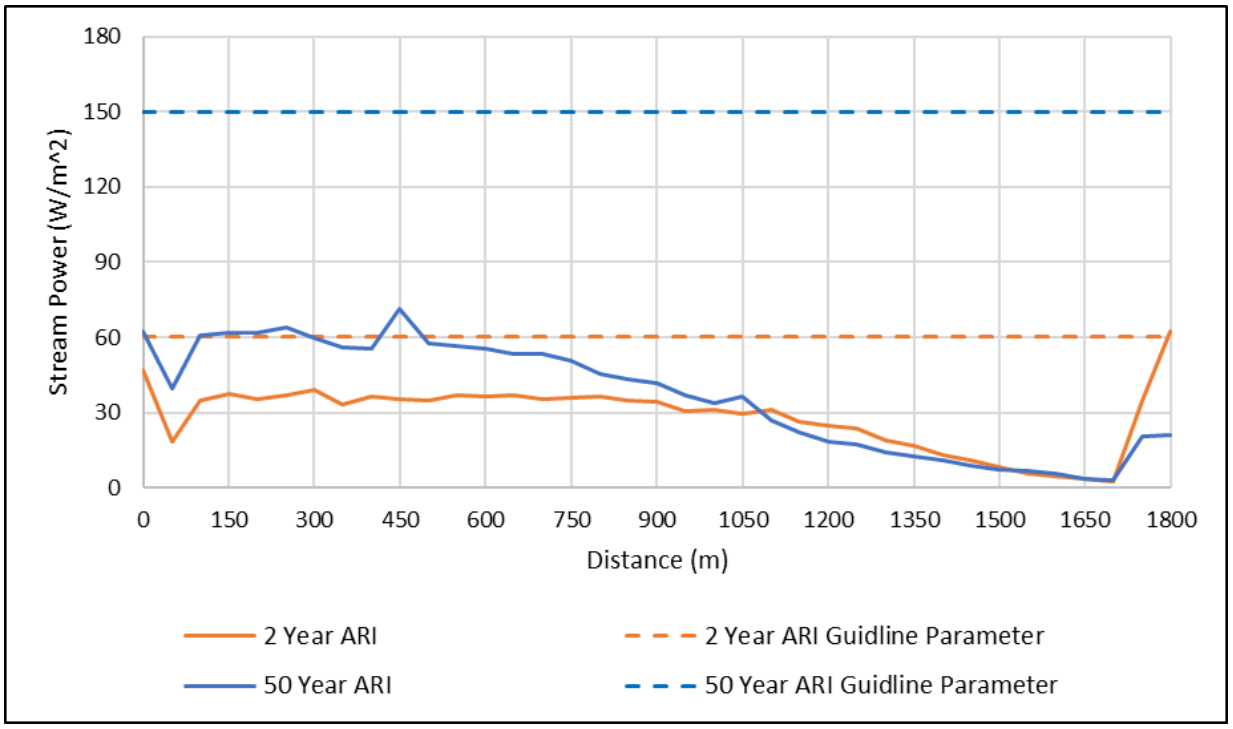

FIGURE D.1: STREAM POWER TUFLOW MODEL RESULTS

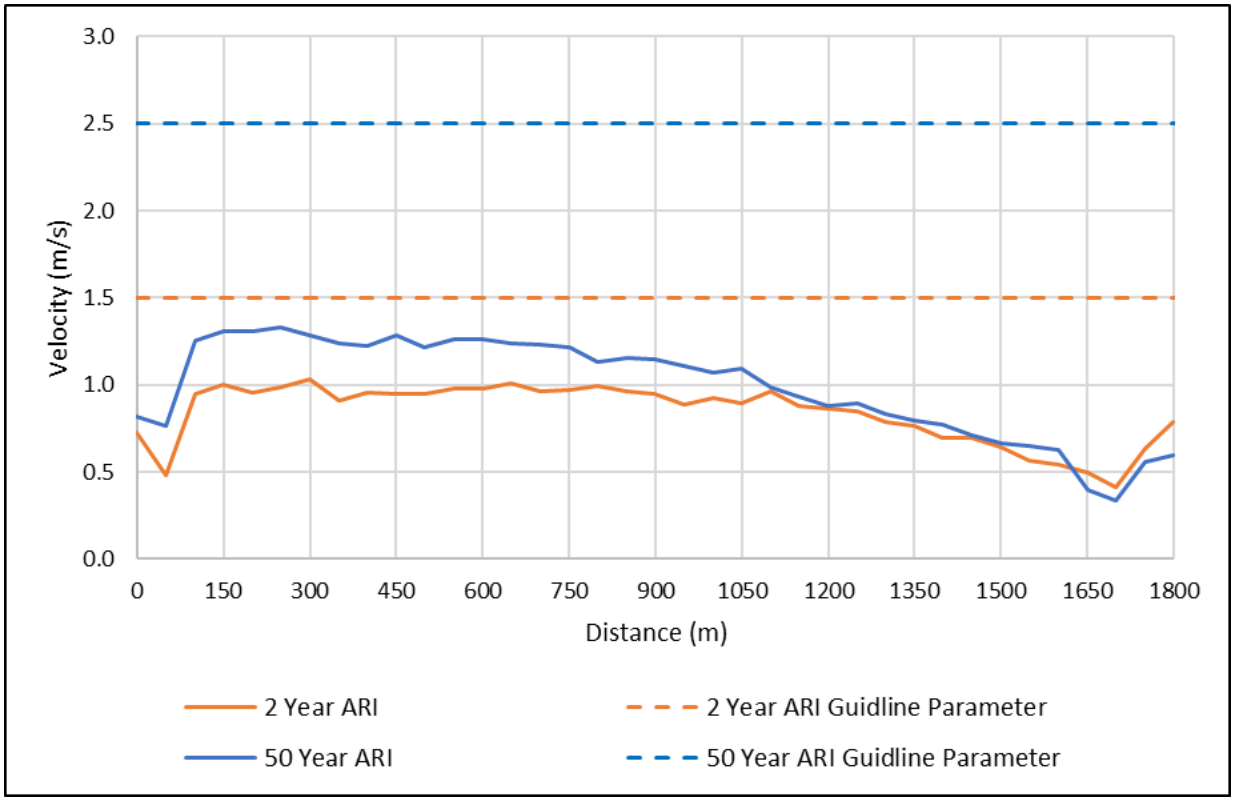

FIGURE D.2: VELOCITY TUFLOW MODEL RESULTS

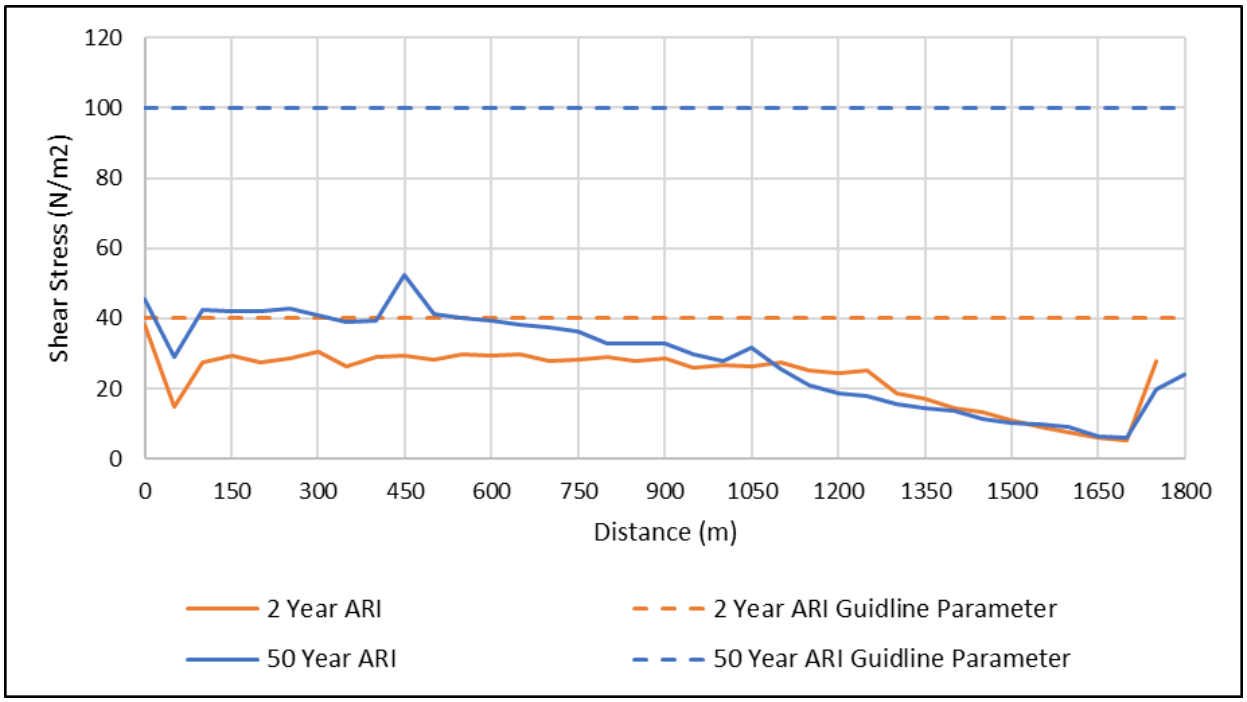

FIGURE D.3: SHEAR STRESS TUFLOW MODEL RESULTS

APPENDIX E: PREFERRED OPTION CONCEPT DESIGN DRAWINGS

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VENDOR LOGO: ENGENY								BMA BHP Mitsubishi Alliance	DRAWN			RPEQ ENGINEER	SIGNATURE		Sht Size: A1
									DRN. CHK			RPEQ No. DATE			Scale: -
									ENGINEER			PROJECT No.	DATE	DRG. No. / LEGACY DRG No.	Rev. No.
									ENG. CHK (QA)			EQUIPMENT TAG			
	A								APPROVED					STATUS: NOT FOR CONSTRUCTION - FOR REVIEW	A
	REV	DATE	DESCRIPTION	DRN	ENG	APP	DRAWING No.	TITLE							
	REVISION						REFERENCE DRAWINGS								

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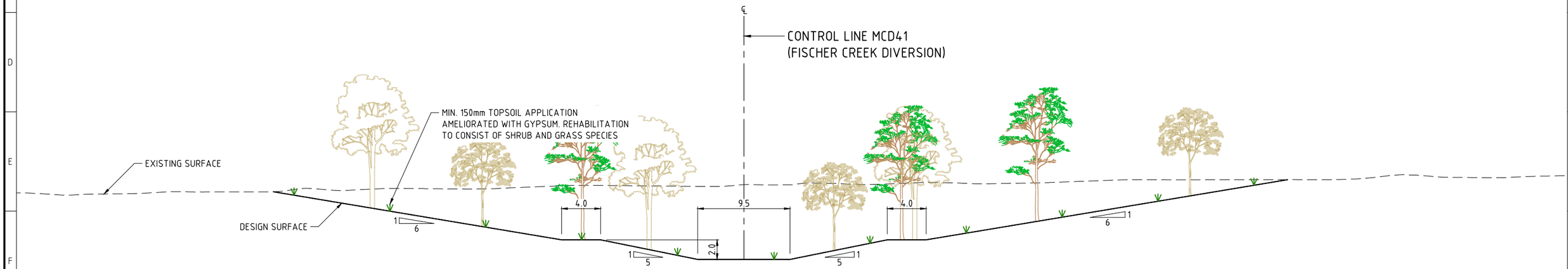

SECTION A
SCALE 1:200 0101

LEGEND

EXISTING SURFACE

DESIGN SURFACE

0 2 4 6 8 10m
SCALE 1:200 (A1)
SCALE BEFORE REDUCTION

VENDOR DRG NUMBER
QC1000-051-DWG-0201

VENDOR LOGO
ENGENY

REV	DATE	DESCRIPTION	DRN	ENG	APP
A					

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DRN. CHK		
ENGINEER		
ENG. CHK (QA)		
APPROVED		

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RPEQ ENGINEER
RPEQ No. DATE
PROJECT No.
EQUIPMENT TAG

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GOONYELLA MINE
PRCP FISCHER CREEK DIVERSION
TYPICAL SECTIONS AND DETAILS

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LEGACY DRG No.
STATUS: NOT FOR CONSTRUCTION - FOR REVIEW
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Sht Size A1
Scale –
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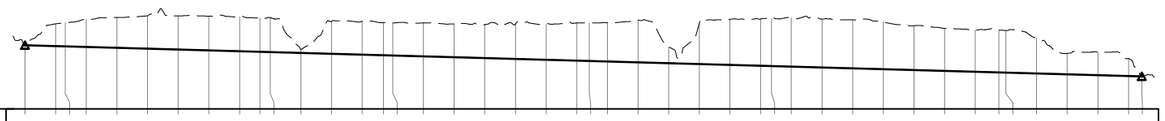

| | | |

APPENDIX F: CONCEPT DESIGN WITH PRCP LANDFORM 2 INTERACTION

598500 599000 599500 600000 600500

7584500 7584000 7583500 7583000 7582500 7582000

Legend

- Preferred Diversion Alignment
- Watercourses
- ML Boundary

PRCP Landform (mAHD)

- -15
- 50
- 100
- 200
- 250
- 300
- 350
- 420

Ramp 32

Fisher Creek

Holding Paddock Creek

PRCP residual void

ML 1763

ML 70479

Platypus Creek

Isaac River

BMA PRCP GRM Fisher Creek Diversion

Figure F.1
Fisher Creek Concept Design with PRCP Landform 2

REV.	DETAILS	DATE
0	Issue for review	04/09/2024

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APPROVED: BK | DATE: 24/09/2024

GENERAL NOTES:

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Void Closure Plan

Goonyella
Riverside/Broadmeadow
Mine

November 2024

Question today
Imagine tomorrow
Create for the future

Void Closure Plan
Goonyella Riverside/Broadmeadow Mine

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Rev	Date	Details
A	25/10/2024	Draft for comment
0	22/11/2024	Final

	Name	Date	Signature
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Reviewed/approved by:	Gareth Simpson	22/11/2024	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Acronyms, abbreviations, and terms

Acronym / abbreviation / term	Description
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AWBM	Australian Water Balance Model
BMA	BHP Mitsubishi Alliance
BRM	Broadmeadow Mine
CHPP	Coal handling and processing plant
CSM	Conceptual site model
DESI	Department of Environment, Science and Innovation
EA	Environmental Authority
FoS	Factor of Safety
GDE	Groundwater Dependent Ecosystems
GRM	Goonyella Riverside Mine
GRBM	Goonyella Riverside/Broadmeadow Mine
IPCC	Intergovernmental Panel on Climate Change
LOD	Land Outcome Document
PCM	Permian Coal Measures
MCM	Moranbah Coal Measures
MIA	Mine Infrastructure Area
ML/year	Megalitres per year
ML	Mining Lease
NUMA	Non-Use Management Area
PMF	Probable Maximum Flood
PMLU	Post-Mining Land Use
PRC plan	Progressive Rehabilitation and Closure Plan
QC	Quality Control
QLD	Queensland
RCP	Representative Concentration Pathway
TSF	Tailings Storage Facility
WBM	Water Balance Model
WQO	Water Quality Objective

1 Introduction

Goonyella Riverside/Broadmeadow Mine (GRBM) is a coal mine, located 30 kilometres (km) north of Moranbah in the Bowen Basin, Central Queensland (QLD). GRBM forms part of the Goonyella Riverside Mine Complex, consisting of Goonyella Riverside Mine (GRM), which is a large and established open cut operation and the Broadmeadow Mine (BRM), an underground longwall operation which is located within the boundaries of the GRBM (BHP, 2019). Operations at GRBM are authorised under Environmental Authority (EA) (EPML00853413) for the following Mining Leases (ML); ML1762, ML1764, ML1802, ML1900, ML700003, ML70121, ML 20193, ML70194, ML70287, ML70288, ML70289, ML70421, ML70468, ML70469, ML70478, ML70479, ML70493, ML70494.

The EA (EPML00853413) is jointly held by BHP Coal Pty Ltd, QCT Resources Pty Ltd, Mitsubishi Development Pty Ltd, Umal Consolidated Pty Ltd, QCT Mining Pty Ltd, QCT Investments Pty Ltd, and BHP Queensland Coal Investments Pty Ltd. Holders of an EA are required to submit a progressive rehabilitation and closure plan (PRC plan) that meets requirements under the *Environmental Protection Act 1994*. A Transition Notice has been issued to BMA by the Department of Environment, Science and Innovation (DESI) for GRBM, requiring a PRC plan be submitted to the administering authority by 29 November 2024.

This void closure plan presents outcomes of technical studies completed to support closure planning and achievement of residual voids that are safe and do not cause environmental harm at GRBM – specifically for the Goonyella, Broadmeadow, Isaac, R32 South, R32 East and Thiess residual voids. This void closure plan is an appendix to the GRBM PRC plan and is required by the DES *Progressive rehabilitation and closure plan (PRC plans) Guideline (version 3.01)*, hereafter referred to as the 'PRC Plan Guideline', dated 16 September 2024.

The technical studies, including the hydrogeology and rehabilitation flood modelling, have been undertaken through an iterative approach with the development of the closure landform design. These iterations have resulted in a closure landform design that includes refinements comprising partial void backfill, increased void crest off-set distances, removal of culverts and other infrastructure from watercourses/floodplains, and changes to flood protection landforms to provide increased protection from flood water. This void closure plan documents how these refinements contribute to minimising environmental harm, as it relates to the GRBM final residual voids.

1.1 Scope and objectives

The GRBM mining pits are currently in various operational stages and are pre-approved as non-use management areas (NUMAs). They will be combined in a final closure landform design as six residual voids – Goonyella, Broadmeadow, Isaac, R32 South, R32 East and Thiess (herein referred to as the GRBM residual voids).

The objective of this void closure plan is to document the rehabilitation and management approach, capturing how BMA will aim to achieve residual voids that are safe and do not cause environmental harm at closure. This void closure plan will also assist to:

- Minimise risk of the residual voids and surrounding areas within the Non-use management area (NUMA) extent
- Minimise active management of the residual voids post-closure
- Avoid unmitigated access to the NUMA by humans and livestock.

The following sections present information as required by sections 3.4 and 3.6.3 of the *PRC Plan Guideline*, specifically:

- Section 3 – Proposed residual voids
- Section 4 – Groundwater
- Section 5 – Flooding assessment
- Section 6 – Void water balance
- Section 7 – Geotechnical stability
- Section 8 – Geochemical stability
- Section 9 – Residual void management.

1.2 Application legislation and guidelines

The following applicable legislation and guidelines have informed the development of this void closure plan:

- Environmental Protection Act 1994 (QLD)
- EA (EPML00853413) dated 26 February 2024
- PRC Plan Guideline (version 3.01) dated 16 September 2024.

2 Site overview

GRBM is a conventional open-cut strip mine located approximately 30 km north of Moranbah, Queensland. Coal mining activities primarily occur within ML1763, with a small portion of mining occurring on the south-eastern portion of ML1764.

Mining involves land clearing, the removal and stockpiling of topsoil material, drilling and blasting of overburden/interburden as required, and stripping of overburden/interburden material, and mining coal using draglines and truck and shovel fleets. As mining progresses, most of the overburden/interburden material is placed in the void of the previous strips. Coal is hauled from the pits for short-term storage at the coal stockpile areas before transport and processing at coal handling and preparation plant (CHPP). Tailings and rejects from the CHPP are disposed of at a tailings storage facility (TSF) or in-pit. The coal product is transported by rail to the Hay Point Coal Terminal for export.

Operations at GRBM began in 1971. The assumed closure dates for the individual residual voids vary, based on the current projected mine plan, as follows:

- 2097 for Goonyella - utilised at the end of open-cut mining for underground access to the neighbouring BMA Red Hill Mine.
- 2061 for Broadmeadow and Isaac - utilised at the end of open-cut mining for underground access to BRM.
- 2037 for R32 South - potential operational use as water storage following final coal extraction.
- 2032 for R32 East.
- 2016 for Thiess - as per BMA instructions for modelling purposes. However, Thiess is being utilised for operational water storage. Actual rehabilitation works will be delayed until operation requirements cease.

An overview of the existing environmental site context within and surrounding GRBM is provided in the PRC plan, and therefore not repeated in this void closure plan. Timing for the residual void closure dates factors in ongoing requirements to access underground mining activities and potential for operation water storage.

3 Proposed residual voids

Residual voids are identified and authorised under Schedule E (Condition E6 and E7) of the EA (which is GRBM's Land Outcome Document (LOD)). Therefore, the six proposed GRBM residual voids are being transitioned as pre-approved NUMAs in the GRBM PRC plan.

The pits will be progressively backfilled with spoil as mining advances, with partial backfill of the final voids planned to assist with flood protection such that the proposed residual voids are not subject to inundation from floodwaters (refer to Section 5). Indicative final dimensions of the residual voids are presented in Table 3.1. A three-dimensional (3D) void design plan for all the GRBM residual voids, including the void lakes, is presented in Figure 3.1.

Table 3.1: Indicative GRBM residual void dimensions

Residual void	Indicative maximum width (m)	Indicative maximum length (m)	Indicative maximum depth (m)
Goonyella	11,630	1,270	324
Broadmeadow	2,450	430	86
Isaac	2,650	210	52
R32 South	1,030	400	79
R32 East	1,600	430	114
Thiess	3,850	390	66

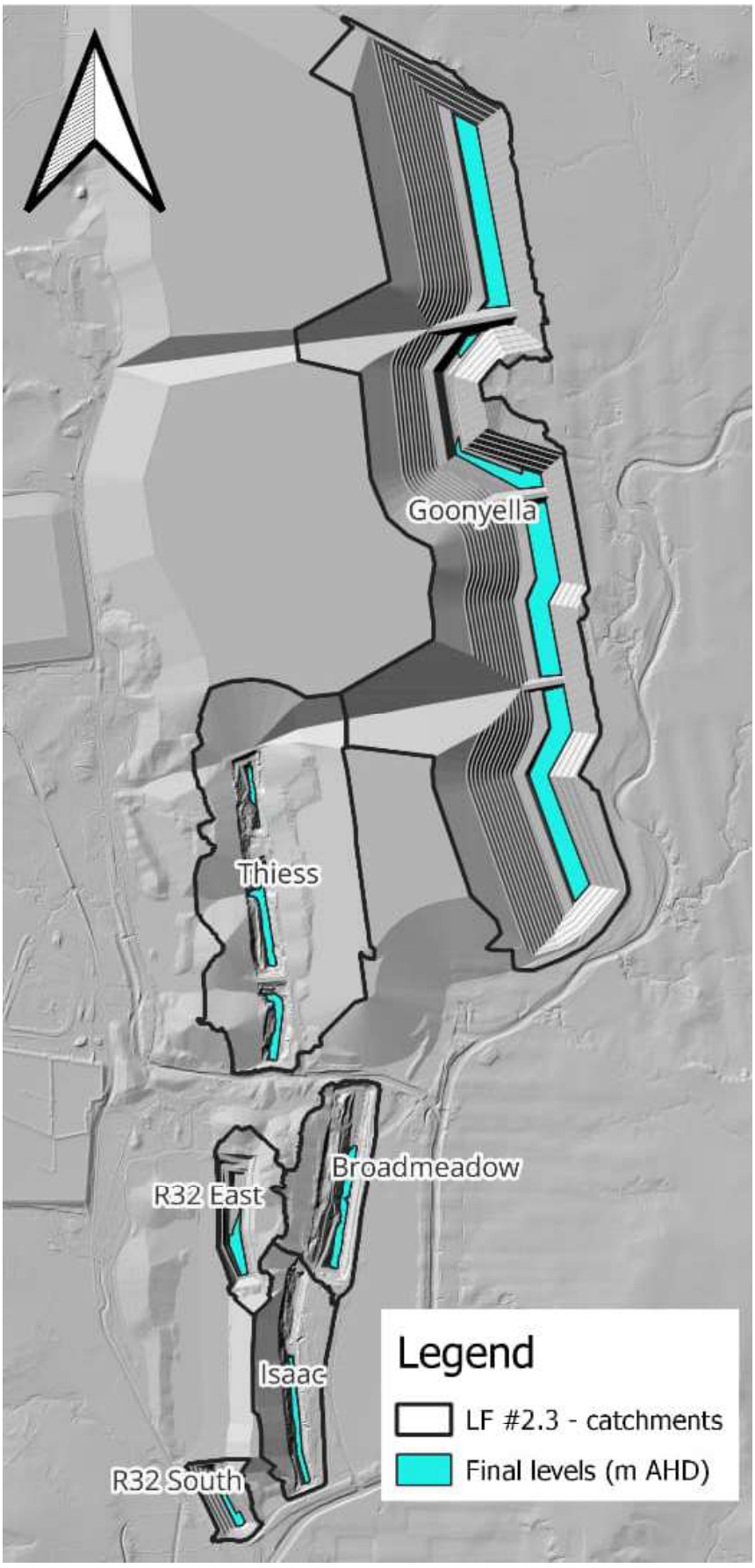


Figure 3.1: 3D void design plan: an overview of GRBM residual voids and void lakes at the end of the water balance model simulation

4 Groundwater

The hydrogeological assessment included conceptual and numerical modelling to determine groundwater interactions with void lakes, and the potential for contaminant transport from GRBM residual voids (AECOM, 2024a). The complete hydrogeological assessment, including details of the model set-up, calibration, and discussion of the results, are provided as an attachment to the PRC plan, and therefore not repeated in this void closure plan. This section summarises the hydrogeological assessment of the GRBM residual voids, as it relates to the rehabilitation and management approach to achieve residual voids that are safe and not cause environmental harm at closure.

A post-mining conceptual site model (CSM) was developed which depicts groundwater interactions with the residual voids. The model graphical representation is presented in Figure 4.1. The CSM's key findings, relevant to post-mining groundwater impacts from the closure state landform, are as follows (AECOM, 2024a):

- Residual void water level predictions including groundwater inflows for the Goonyella residual void stabilise markedly below the post-closure recovered groundwater elevations for all directly impacted hydrostratigraphic units, and below the other five residual void water levels. This groundwater sink effectively limits any migration of contaminants outside of the mining tenure.
- An inward hydraulic groundwater flow gradient within the Moranbah Coal Measures (MCM) coal seam towards three of the six residual voids develops due to:
  - Residual groundwater drawdown within the target MCM coal seams as a result of the approved mining operations.
  - Post-closure ongoing evaporative losses from the residual void lakes.
- Groundwater outflows from the Thiess and Isaac residual voids are predicted to be captured within the Goonyella residual void.
- Predicted groundwater outflows from Broadmeadow residual void during the prediction periods will reduce or cease in the long-term, as indicated by the long-term stabilisation of groundwater and residual void levels.
- The Goonyella residual void captures any infiltration of rainfall through the areas where mine waste has been or is stored (TSF, mine infrastructure areas - MIA, rejects) and spoil/backfill areas. This is supported by the particle tracking simulations.
- There is little to no additional impact on surficial aquifers, including the Isaac River alluvium, caused by the final closure state landform.
- There is little to no impact on environmental receptors such as groundwater dependent ecosystems (GDEs) caused by the final closure state landform. A single potential anthropogenic receptor (water bore) in proximity to the Goonyella residual void is expected to become dry post-closure as a result of residual mine operational dewatering activities. No other anthropogenic receptors are identified to be impacted by the final closure state landform.
- The continuous removal of groundwater through evaporation from the Goonyella residual void lake indicate that groundwater levels in proximity to the residual void will not return to a pre-mining state.

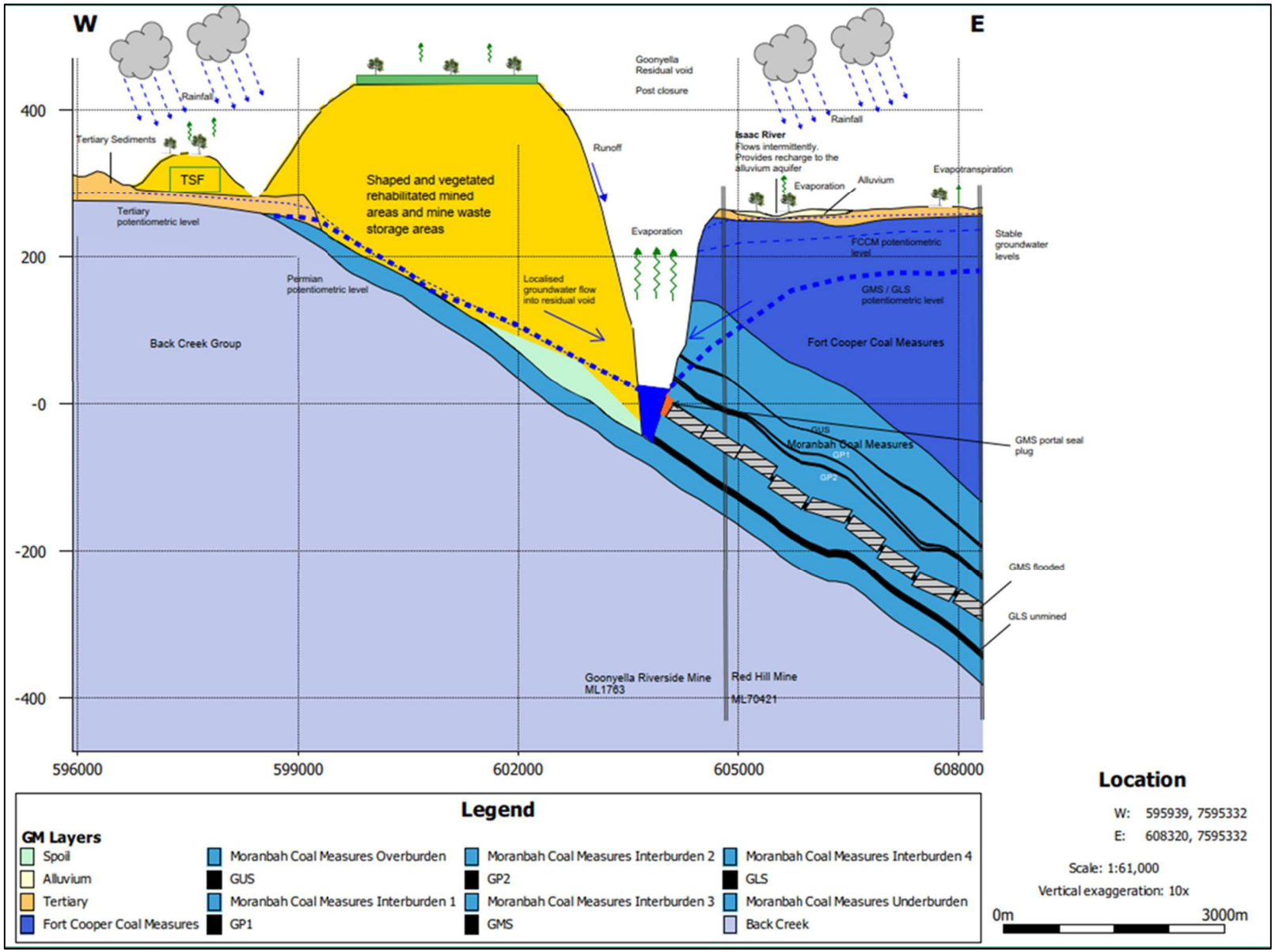


Figure 4.1 Visual depiction of the GRBM post-closure conceptual model (AECOM, 2024a)

Calibrated numerical modelling was also undertaken (AECOM, 2024a) to evaluate the potential impacts of the final closure state landforms for the GRBM residual voids on the groundwater regime. The objectives of the predictive modelling were to:

- Assess the potential groundwater-related impacts at the completion of mining and until conditions stabilise post-rehabilitation.
- Assist in demonstrating the suitability of the final landform for the post-mining land uses (i.e., evaluate the residual voids included in the final landform to determine influence on groundwater resources).
- Demonstrate that the final landforms, including the residual voids, are not causing environmental harm outside of the voids themselves or the mining tenure boundary.
- Provide an understanding of:
  - Groundwater interactions with the residual voids through simulation of the residual void lake water levels and rates of recovery, and the groundwater level and rate of recovery from mining-related drawdown in the groundwater system surrounding the voids.
  - Groundwater inflow to the final residual voids.
  - Changes in hydrogeological conditions (including groundwater levels) from the active mining to stable post-mining conditions.
- Identify areas of potential environmental or anthropogenic risk, such as impacts to water quality, private water supply bores, GDEs or surface water resources where groundwater impact mitigation/control measures may be necessary post-closure.

The final closure state landforms were replicated in the model, including the six GRBM residual voids and the spoil emplacements within the mined-out pits. The model timeframe was developed to commence at the end of mining and simulate through to 2199. The predicted end of mining groundwater level was applied as the starting heads (AECOM, 2024a). The Broadmeadow underground mine and neighbouring Red Hill Mine (RHM) underground mine have been modelled to be actively flooded at end-of-mining. The proximity of RHM to the GRBM site warrants its inclusion in the numerical groundwater model.

Goonyella residual void lake level predictions indicate the lake stabilises at a lower elevation than the post-closure recovered groundwater levels for all directly influenced hydrostratigraphic units, and below the other five GRBM residual void lake elevations. This effectively creates an inward hydraulic gradient towards the Goonyella residual void and a groundwater sink that limits the potential migration of contaminants through groundwater for the entire tenure.

The predicted equilibrium (long-term steady state) of the water table elevation adjacent to the final voids is shown in Figure 4.2 and Figure 4.3 for the Goonyella Middle Seam (GMS) and Goonyella Lower Seam (GLS), respectively. The end of the post-closure simulation (P4) is compared to the end-of-mining simulation (P3).

The groundwater levels in the water table proximal to the residual voids is predicted to remain below pre-mining groundwater levels in the long-term, driven by ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves. Long-term inwards groundwater flow gradients are maintained post-mining for four GRBM residual voids (Goonyella, Broadmeadow, Ramp 32 East and Ramp 32 South). Modelled groundwater outflow from the Thiess and Isaac residual voids is predicted to be captured within the Goonyella residual void.

The effect of the active flooding of the RHM on the groundwater drawdown to the east of the GRBM residual voids is evident in the contours for the end of the post-closure simulation. The effect of active flooding of the Broadmeadow underground mine on the GMS drawdown is less evident due to its proximity to the Broadmeadow, Isaac, and Goonyella residual voids and also the relatively deep RHM underground workings that continue to remove water from the system through evaporation and operational dewatering (RHM underground workings continue to operate following the closure of the Broadmeadow underground).

The effect of evaporative losses from the residual void lakes will maintain an inward hydraulic gradient for the tenure, which will be centred on the Goonyella residual void. This residual void will act as a terminal groundwater sink, providing long-term post-mining groundwater contaminant management.

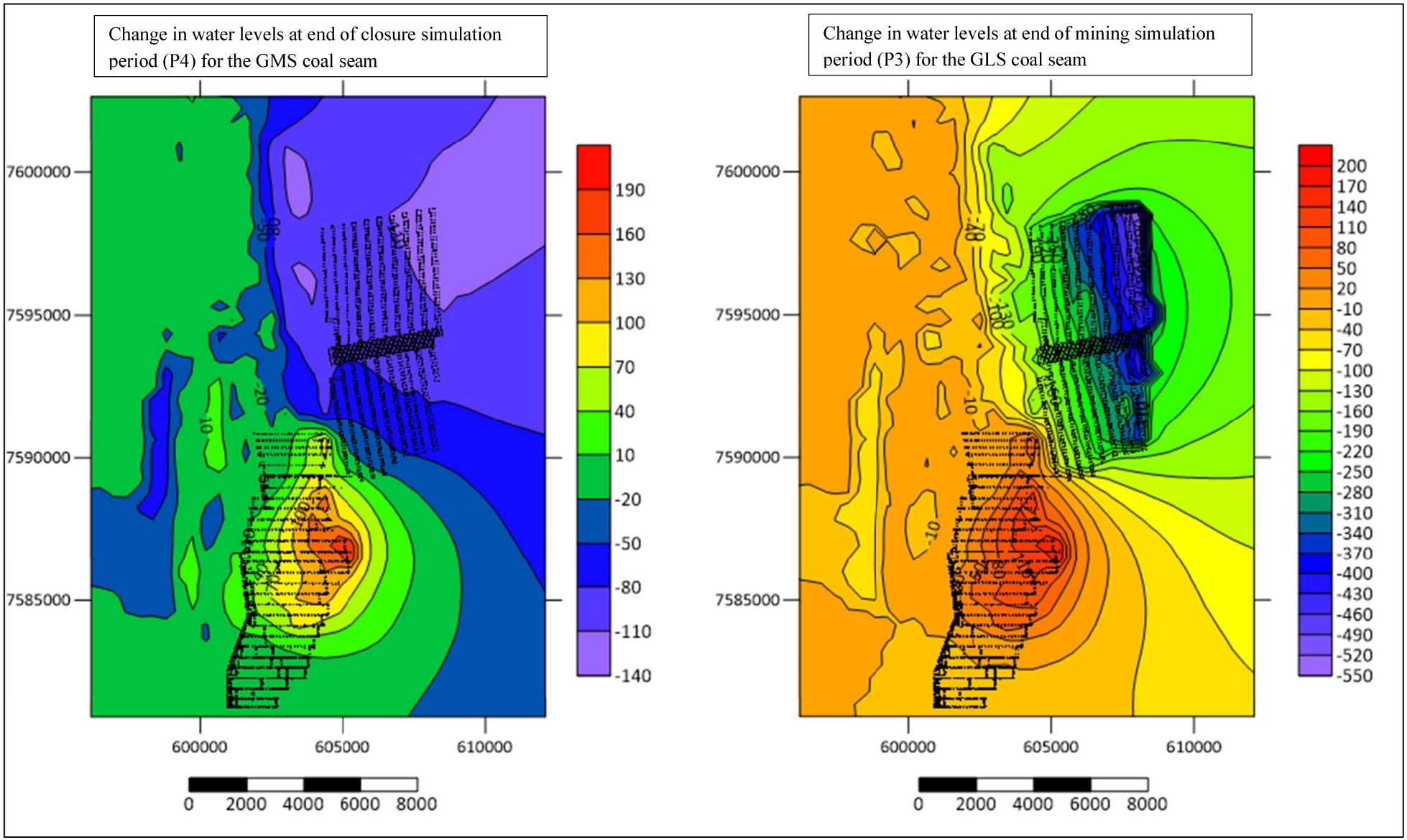


Figure 4.2 Modelled groundwater levels in the GMS at end of closure period – P4 (left) compared to the end-of-mining period – P3 (right) (AECOM, 2024a)

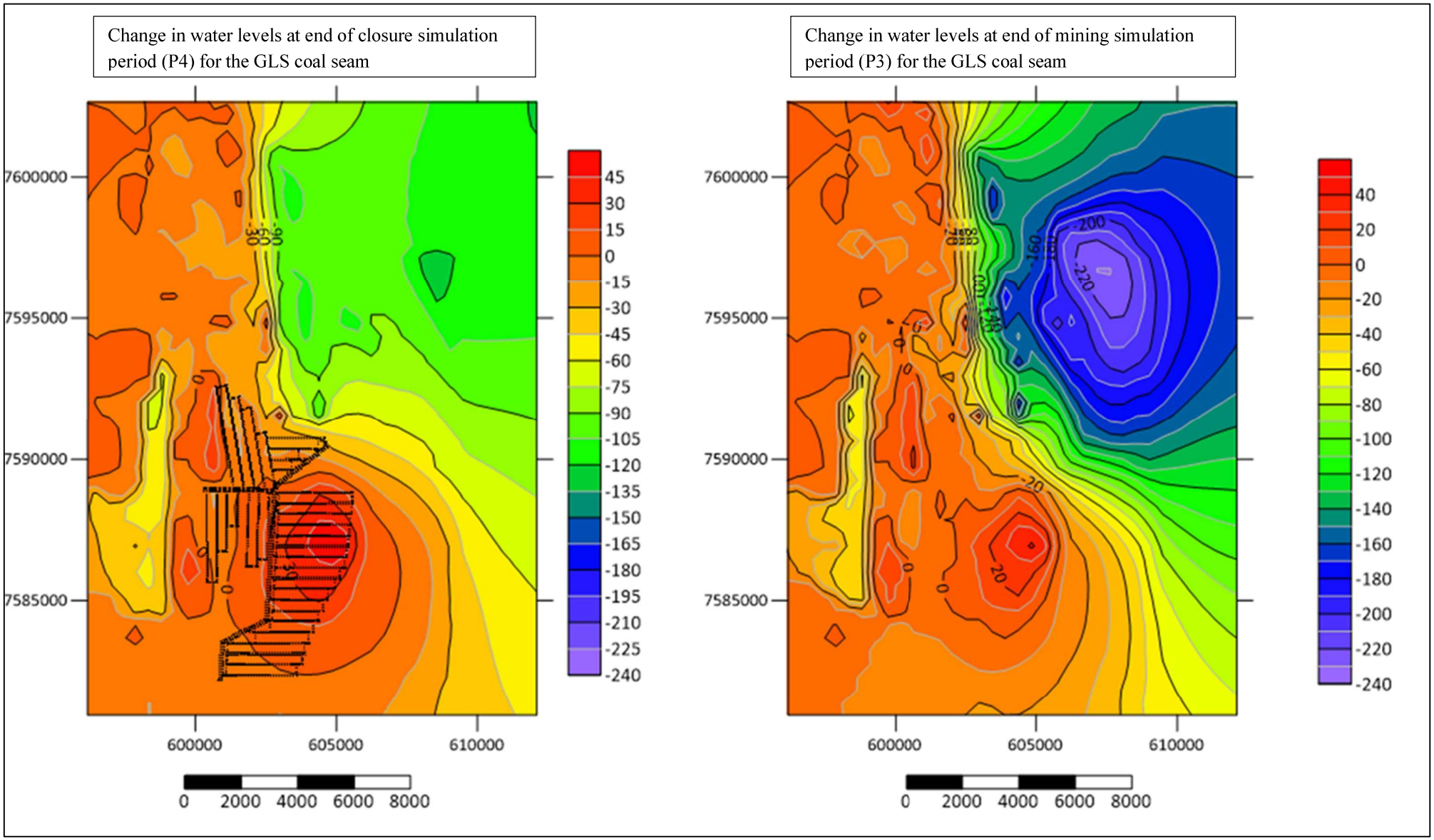


Figure 4.3 Modelled groundwater levels in the GLS at end of closure period – P4 (left) compared to the end-of-mining period – P3 (right) (AECOM, 2024a)

Post-closure, the numerical model predicted the drawdown and recovery of the groundwater levels in the alluvium, which includes surficial cover of either alluvium or Tertiary sediments (Figure 4.4). The modelled drawdown over time indicates there is no change to the zero (no drawdown) contour across the Issac River (indicated by the green cells in Figure 4.4), and ingress into the residual voids stabilises over time.

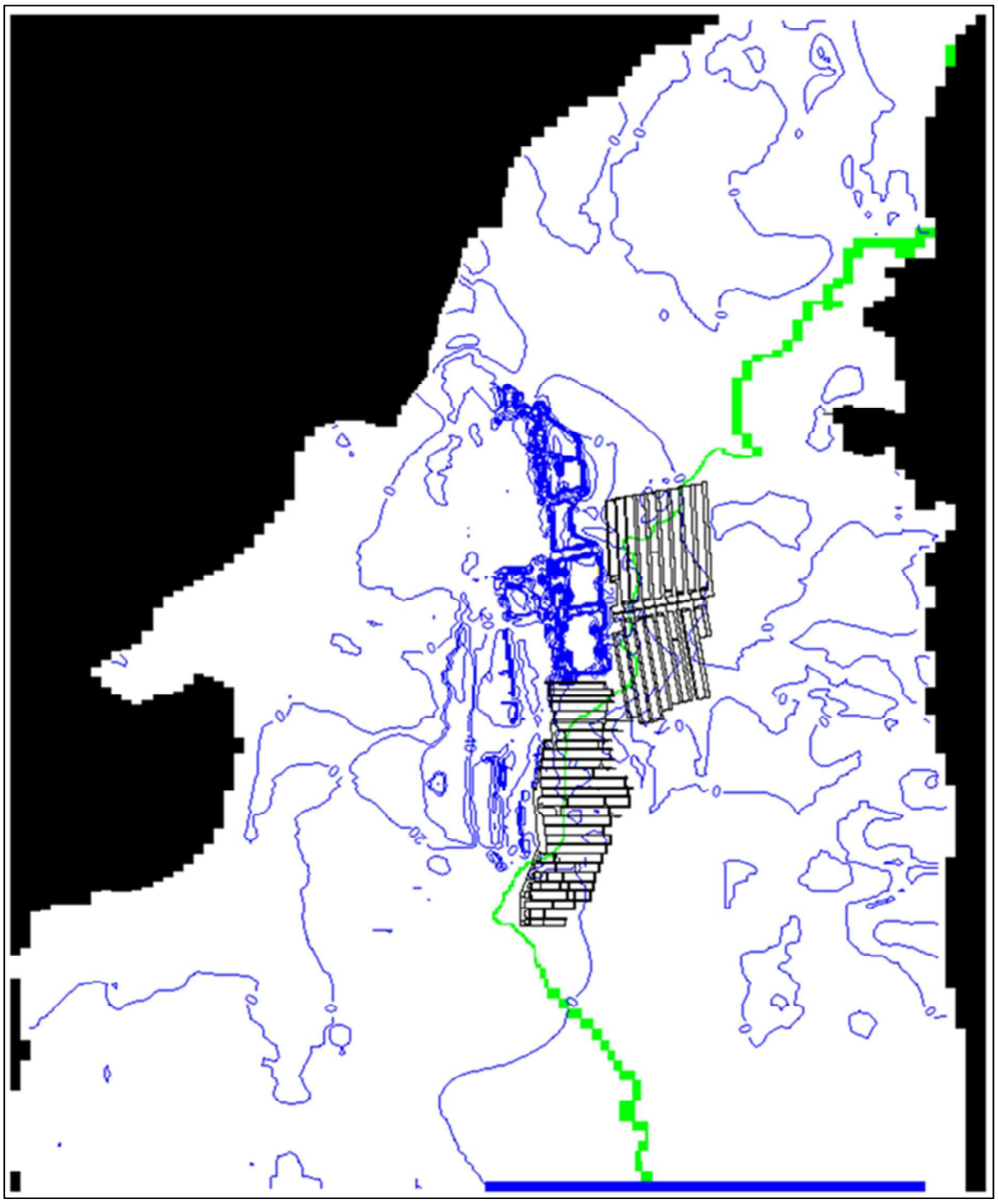


Figure 4.4 Modelled groundwater drawdown levels in the alluvium at the end of the post-closure simulation (AECOM, 2024a)

There are periods of variability in inflows and outflows from spoil and natural/unmined geology of groundwater predicted by the groundwater model for the residual voids.

Fluxes of water into the Goonyella residual void indicate that this residual void acts as a groundwater "sink", where groundwater from the surrounding spoil and natural rock, as well as from the other GRBM residual voids (where outflows are predicted), flow into the Goonyella residual void (Figure 4.5).

Fluxes of water into the Broadmeadow residual void primarily come from the spoil to the west and are maintained for the model duration, driven by evaporation from the residual void. Predictions indicate that water from Broadmeadow residual void will flow into the surrounding natural (unmined) formations due to lower groundwater levels after mining. However, once groundwater elevations reach a level that is higher than the residual void water level, the model predictions over the simulation period suggest the flux to groundwater decreases over time, and the void may eventually become a sink to both spoil and natural rock fluxes (Figure 4.6).

Fluxes of water from the Isaac and Thiess residual voids into both the surrounding spoil to the west of the void and the natural surrounding formations are predicted to occur. However these fluxes are predicted to flow into the Goonyella residual void (Figure 4.7 and Figure 4.8).

Fluxes of water into the Ramp 32 East residual void come from the surrounding natural rock with this void behaving as a groundwater sink. Groundwater fluxes out of the void are minimal and no ingress from the surrounding spoil is predicted (Figure 4.9).

Fluxes of water into the Ramp 32 South residual void originate from the natural geology, with some inflow predicted from the spoil. Similar to Ramp 32 East void, this void behaves as a groundwater sink with only groundwater inflows to the residual void (Figure 4.10).

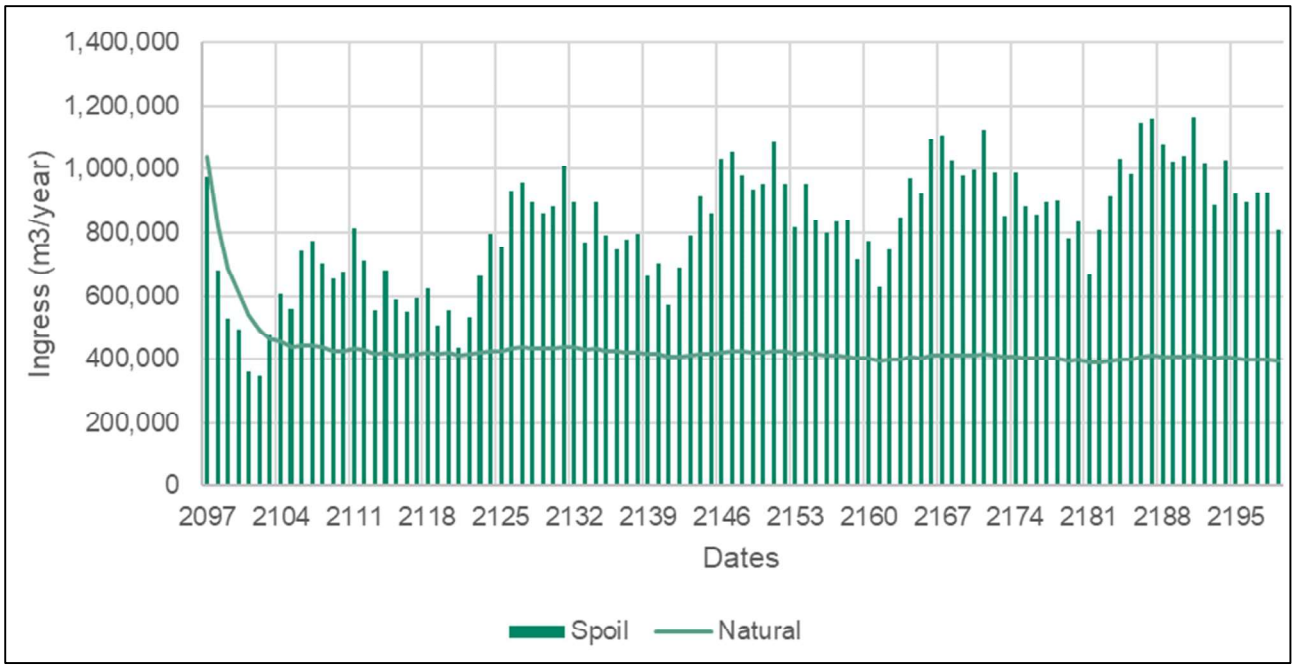


Figure 4.5 Predicted groundwater inflows to the Goonyella residual void (AECOM, 2024a)

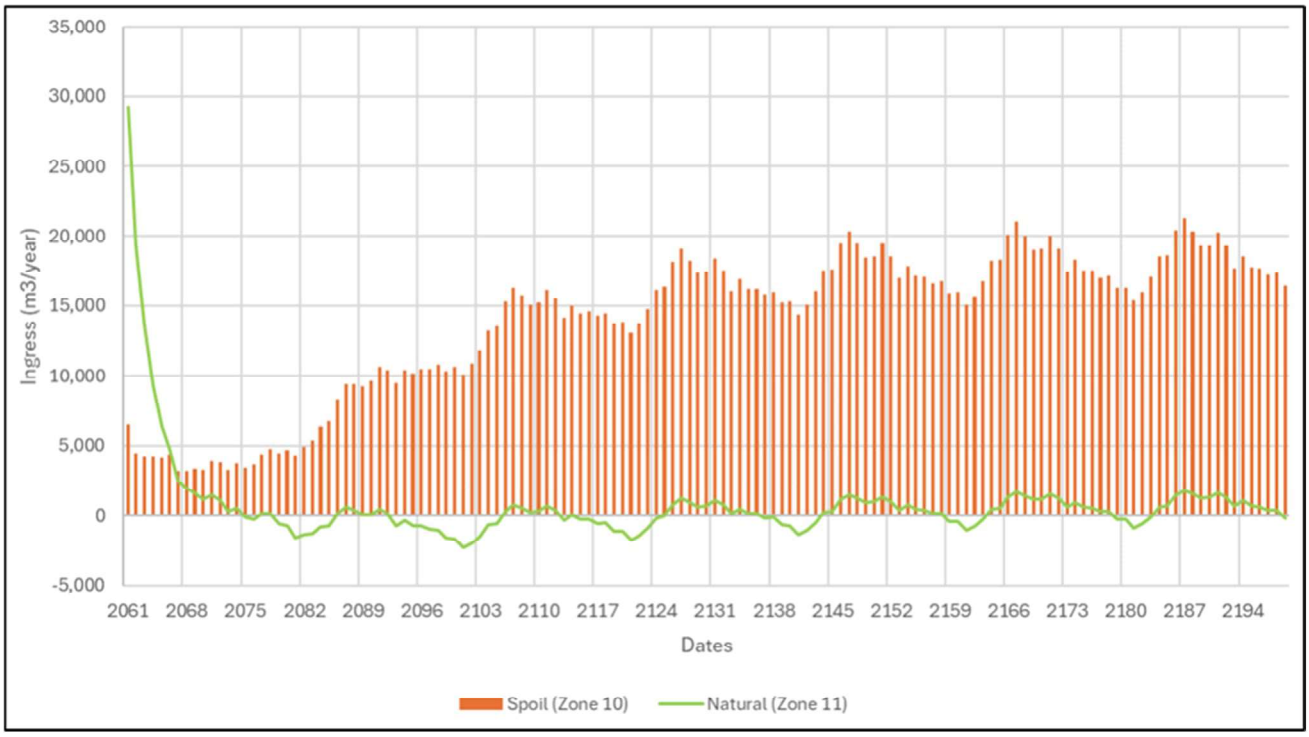


Figure 4.6 Predicted groundwater inflows to the Broadmeadow residual void (AECOM, 2024a)

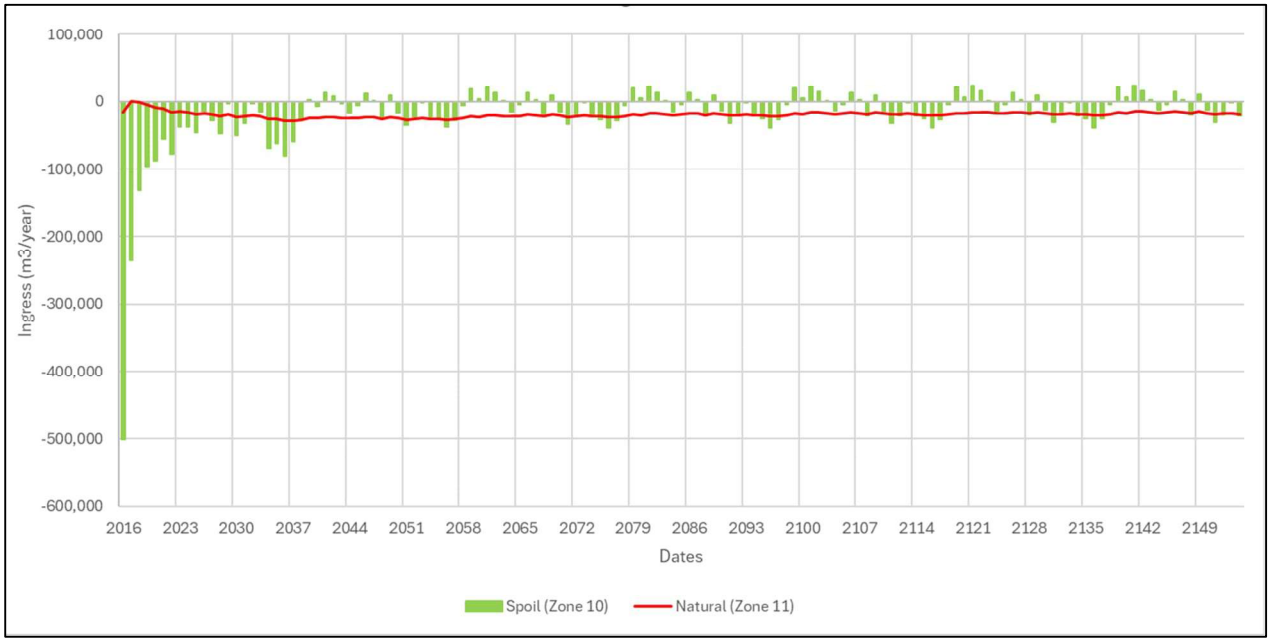


Figure 4.7 Predicted groundwater inflows to the Isaac residual void (AECOM, 2024a)

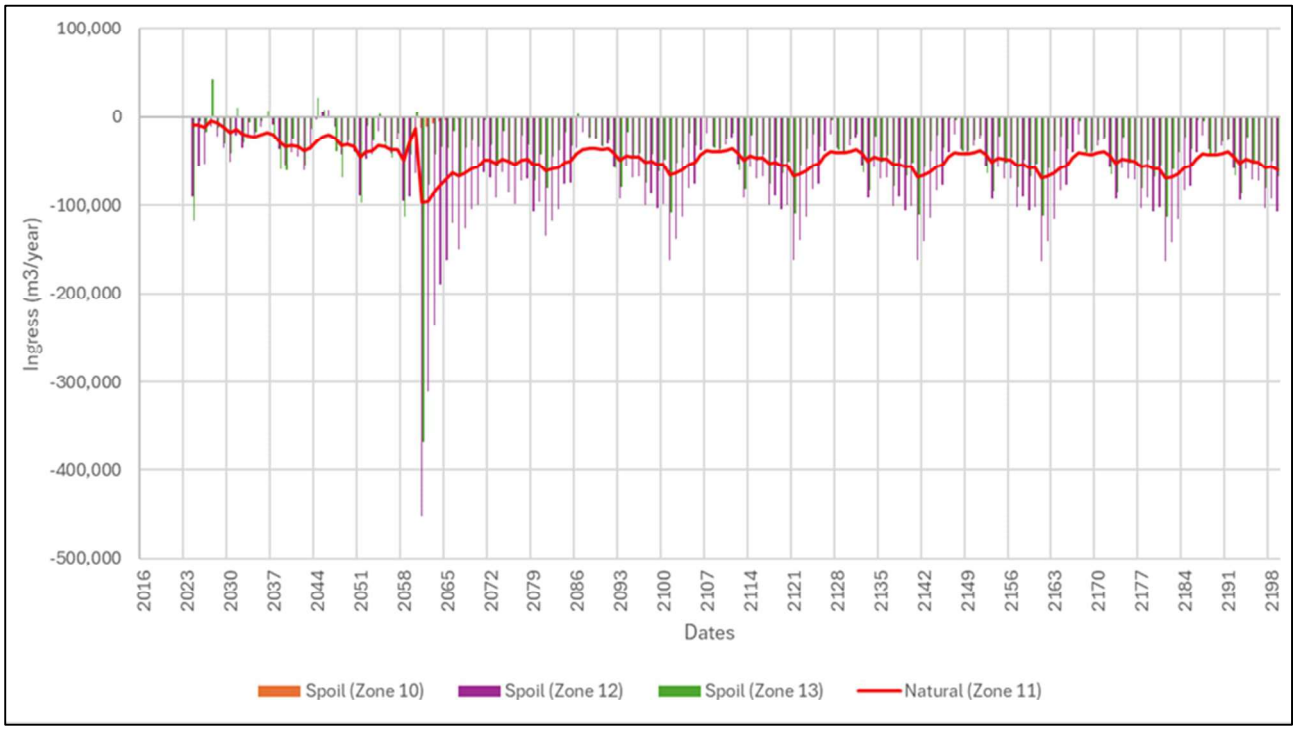


Figure 4.8 Predicted groundwater inflows to the Thiess residual void (AECOM, 2024a)

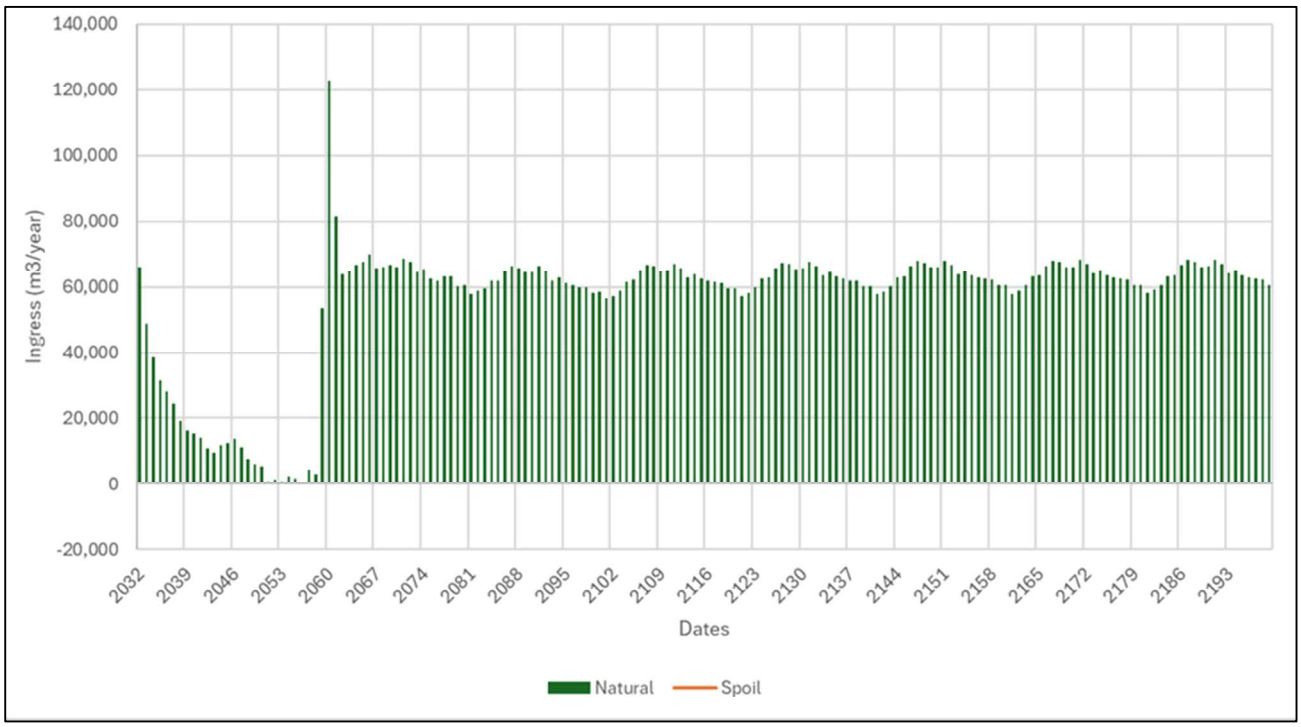


Figure 4.9 Predicted groundwater inflows to the R32 East residual void (AECOM, 2024a)

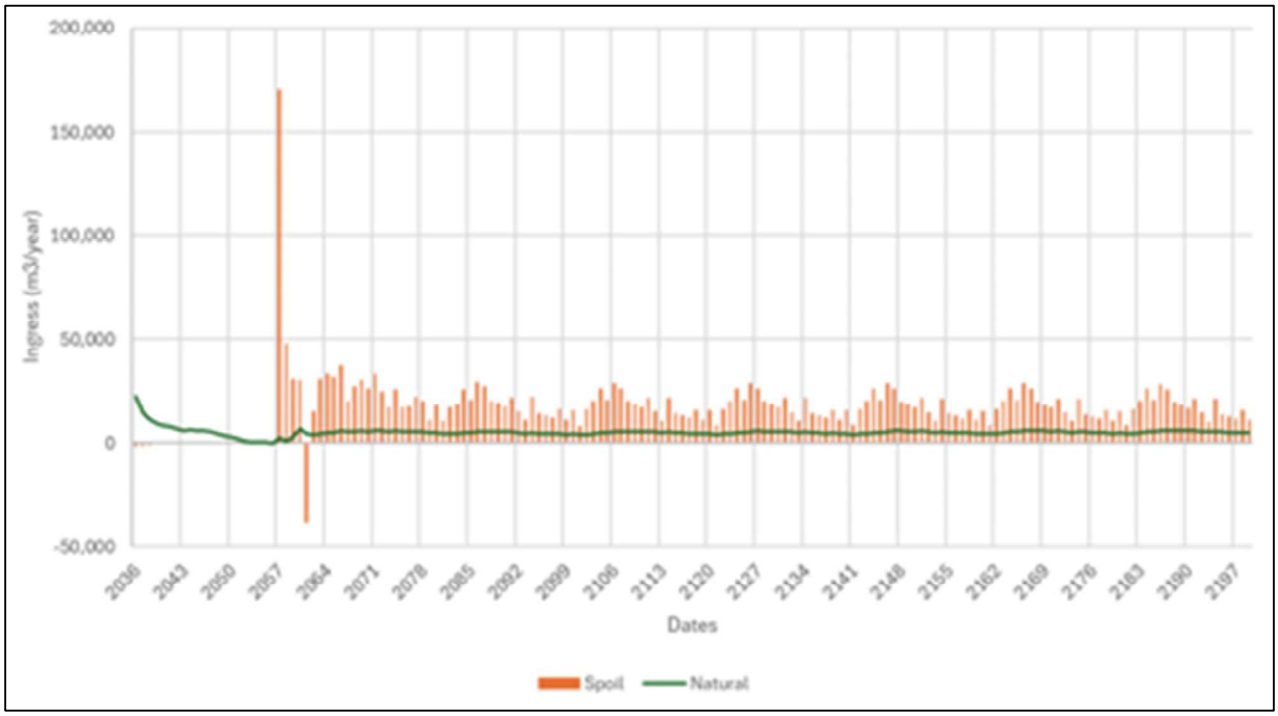


Figure 4.10 Predicted groundwater inflows to the R32 South residual void (AECOM, 2024a)

The residual voids water levels were compared to the surrounding groundwater elevations to determine the potential for the residual voids to interact with the surrounding hydrostratigraphic units (Table 4.1). The modelled groundwater elevations were determined from hydrographs positioned 100 m up gradient and down gradient (west and east) of each void and therefore are not indicative of the overall hydraulic gradient towards the voids.

Table 4.1 Modelled recovered groundwater levels in proximity to the residual voids compared to the modelled void water levels at GRBM

Residual void	Modelled recovered groundwater levels (m AHD) [1]	Modelled mean void water elevation (m AHD) [2]
Broadmeadow	143.5 - 160	155 m
Isaac	177 – 179.5	180
Theiss	187 - 203	202
Ramp 32 East	162.5 - 169	162
Ramp 32 South	173.5 - 176	173
Goonyella	20 - 36	21

[1] As indicated from hydrographs of pilot holes in the model generated to assess the groundwater elevations 100 m up gradient and down gradient (west and east) of the void (AECOM, 2024a)

[2] Section 6

The network of residual voids in the closure state landform is providing long-term management of groundwater from the mining areas. The residual void lakes, through the loss of water via evaporation, maintain an inward hydraulic gradient for the tenure centred on the Goonyella residual void, which acts as a terminal groundwater sink. Any reduction in the residual voids dimensions or increase of void catchments will change the post-mining hydrogeological conditions and reduce the effectiveness of the long-term groundwater management provided by the proposed closure state landform.

The available water quality data suggests water quality within the MCM seams ranges from moderate to brine. The GMS salinity ranges from brackish to brine, while the GLS and Back Creek Group samples indicate high salinity. The pH of the groundwater at GRBM varies, showing typically neutral to weakly alkaline pH for all formations (AECOM, 2024a).

Using the numerical groundwater model, particle tracking to analyse the water movement within the final closure state landform was completed to simulate and assess the movement and fate of water particles through the groundwater system post-mining (AECOM, 2024a).

The particle movement simulation for particles placed within and adjacent to the residual voids (Figure 4.13) indicated that groundwater at GRBM will remain within the final closure state landform (i.e., rehabilitated in-pit spoil and residual voids) in the long-term (AECOM, 2024a). Particles from the Broadmeadow, Isaac pits, Thiess, Ramp 32 East, and Ramp 32 South residual voids were predicted to migrate over time, reaching the Goonyella residual void within the 100-year particle tracking simulation period (Figure 4.11).

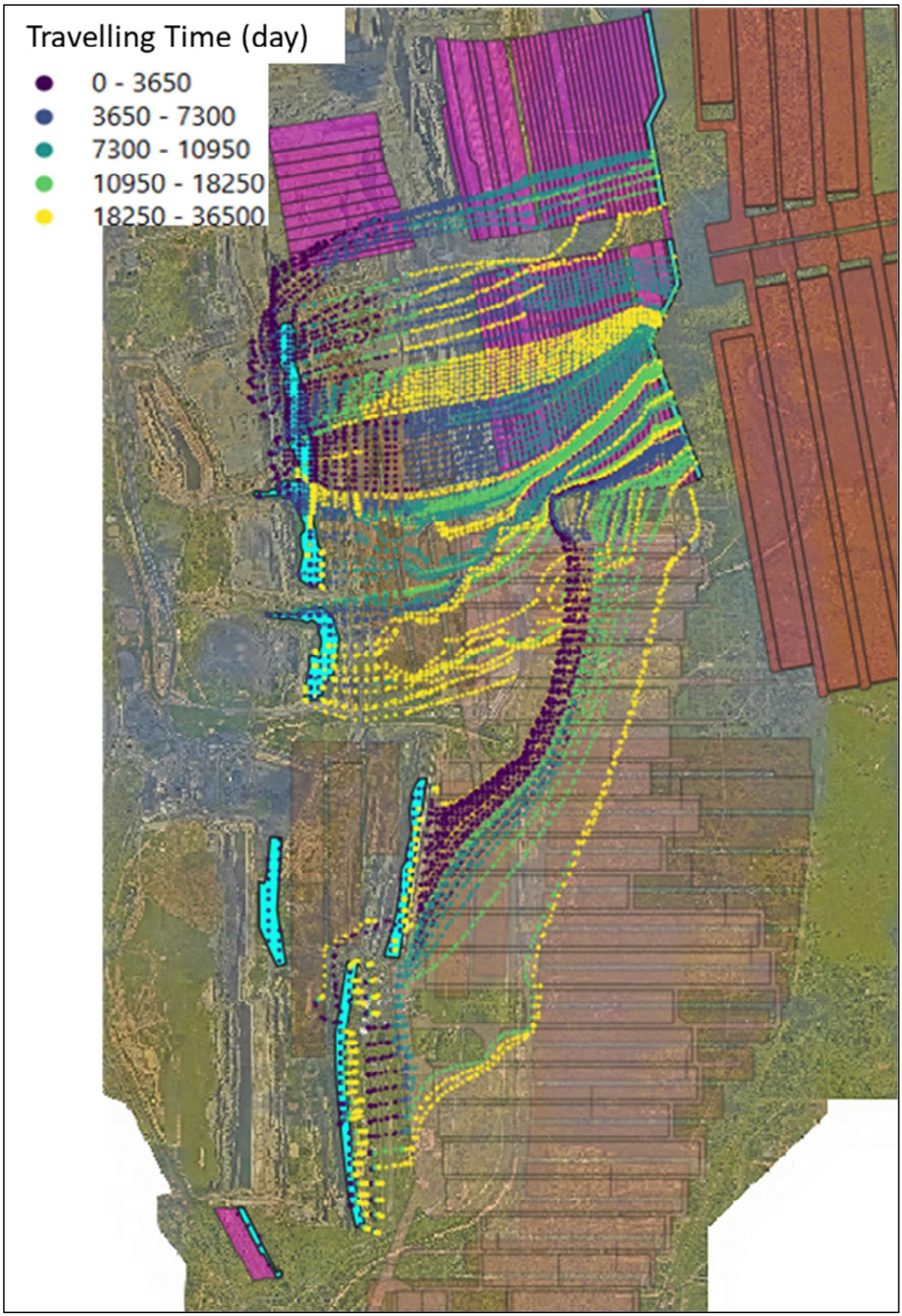


Figure 4.11 Predicted movement of particles from post-closure particle tracking simulation (AECOM, 2024a)

All modelled particles originating in the mining disturbance areas (including those within the voids themselves) are captured within the residual voids on the tenement and do not flow off-site to the receiving environment. The particles placed outside of the residual voids at the potential contaminant sources (MIA, TSFs, rejects) and spoil areas are all predicted to be captured within the residual voids.

Post-closure, particle tracking indicates that water from Broadmeadow, Thiess and Issac residual voids continue to migrate toward Goonyella residual void. All particles will reach the Goonyella Pit within the 100-year particle tracking timeframe, influenced largely by the Goonyella residual void. Particles included immediately adjacent to the Goonyella residual void indicate particle migration towards Goonyella residual void (AECOM, 2024a).

Although very minor outflows from Thiess and Isaac residual voids to the natural geology are predicted to occur, no environmental harm is expected to result beyond the mining tenure from these minor fluctuations as these outflows are re-captured within the Goonyella residual void. This absence of environmental harm is supported by the groundwater modelling, particle tracking simulation, and that no identified third-party bores or GDEs present either within the spoil areas of the residual voids or the GLS or GMS between Thiess, Isaac and Goonyella residual voids. In addition, the water quality model (see Section 8) also indicates that:

- The water quality within the Thiess and Isaac residual void lakes is unlikely to establish acidic conditions; and
- TDS for the Thiess and Isaac residual void lakes remains within the 80th percentile water quality objective (WQO) value for electrical conductivity (as TDS) for the duration of the water quality model simulation period.

As such, any potential outflows are considered to pose minimal risk to the environment if the modelled outflows were to occur.

Potential GDE sites within and adjacent to GRBM mining leases were identified using the Bureau of Meteorology GDE Atlas mapping (Figure 4.12). Some identified potential GDE sites are associated with anthropogenic sources such as dams and therefore, interpretation of potential impacts must consider the limitations of the GDE Atlas mapping.

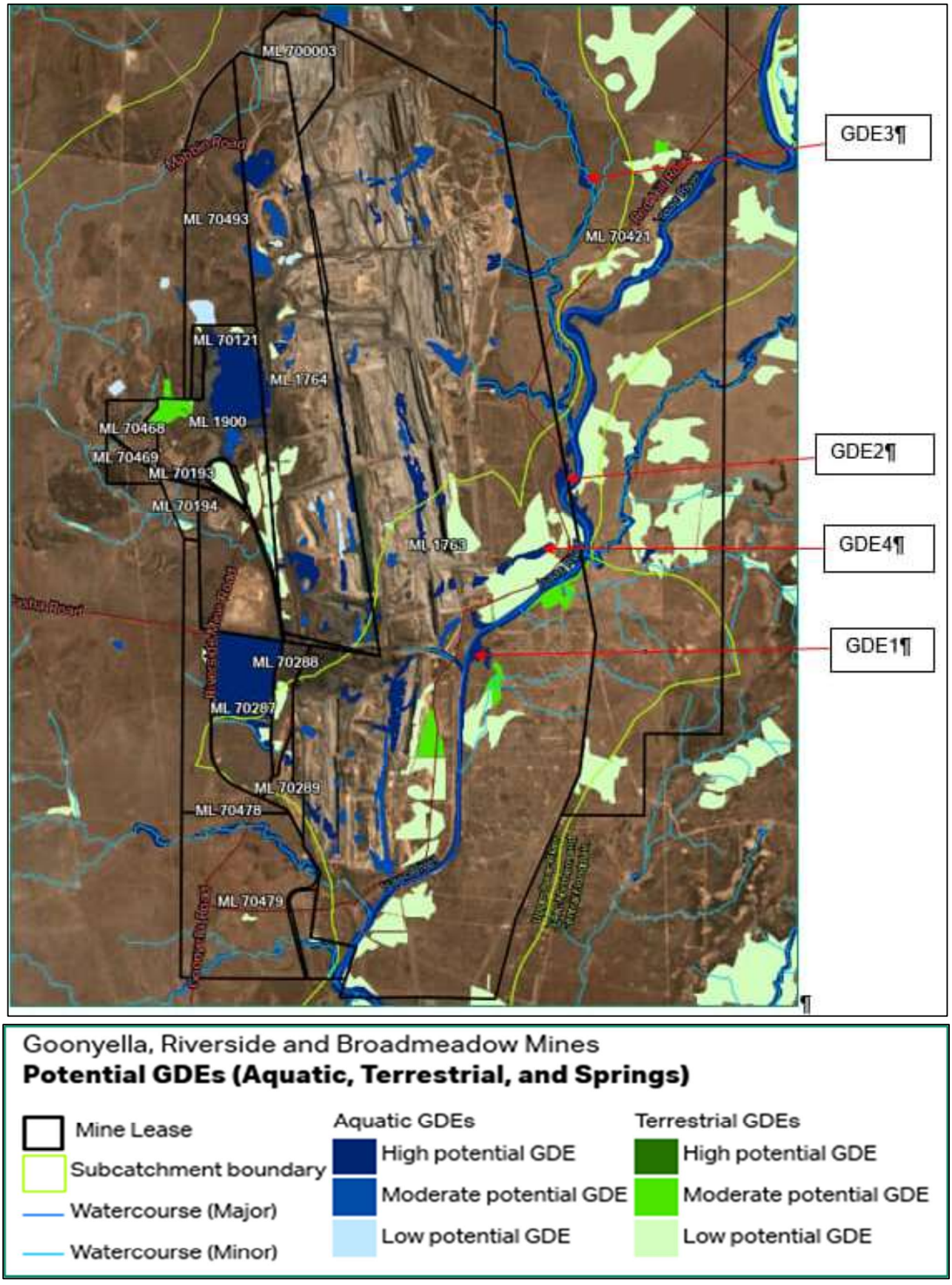


Figure 4.12: Location of potential GDEs adjacent to and within GRBM mining leases (AECOM, 2024a)

Predictive hydrographs were derived from the groundwater model for the four identified potential GDE locations. Post-closure predictions indicate no change in groundwater levels along the Isaac River. Overall, post-closure groundwater conditions, including the presence of residual void lakes, are not expected to impact the potential aquatic GDEs (AECOM, 2024a).

Predictive hydrographs were derived from the groundwater model for the three identified potential third-party water supply bores (18213, 81700 and 81696) (Figure 4.13). Three of the identified supply bores located approximately 20 km from GRBM (182311, 182312, and 132496) are located outside the active model domain and are not expected to be impacted.

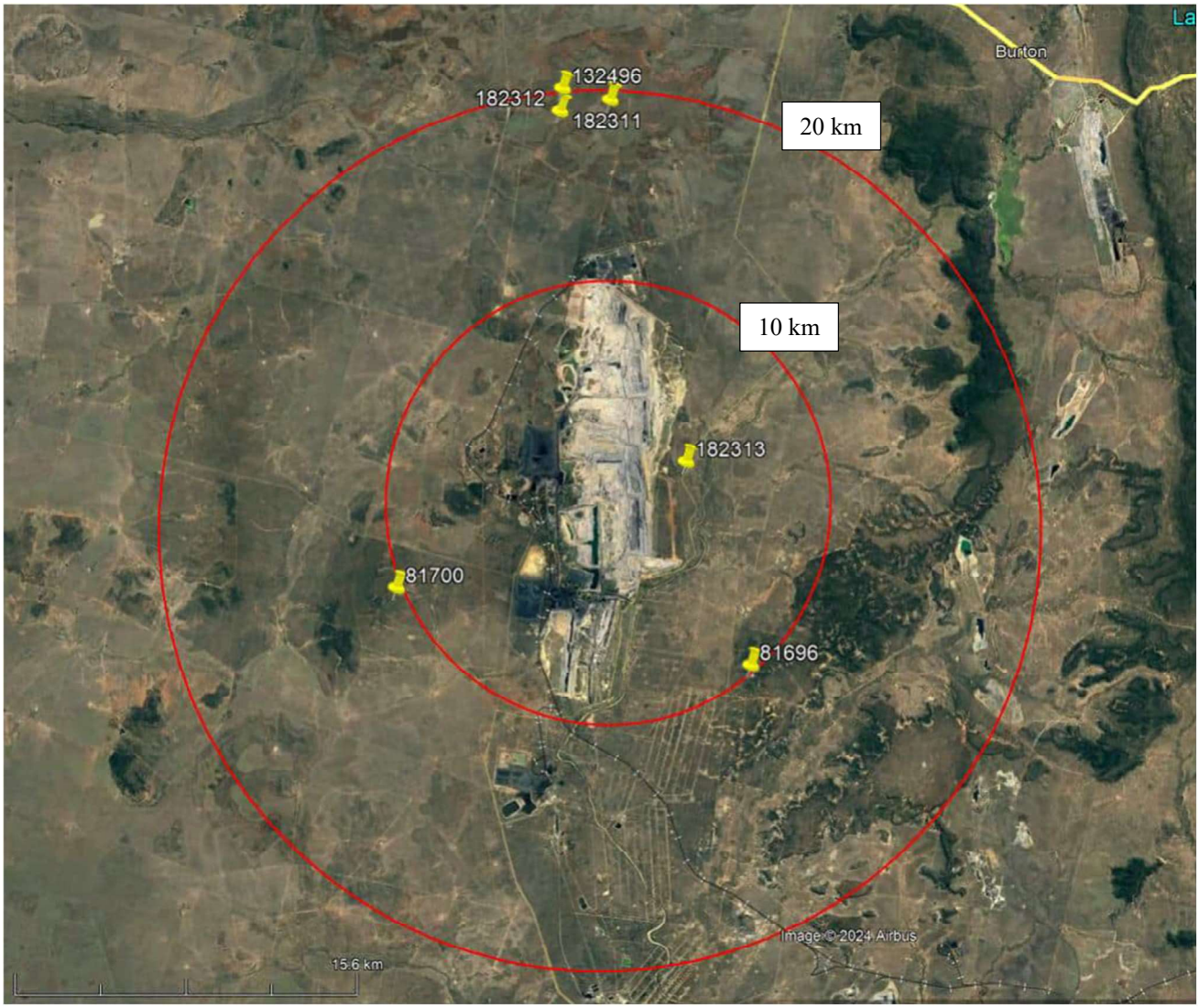


Figure 4.13 Locations of identified third-party water supply bores near GRBM (AECOM, 2024a)

The hydrographs (Figure 4.14 and Figure 4.15) for bores 81696 and 81700, respectively, indicate no predicted alteration to the bore water levels due to GRBM post-closure.

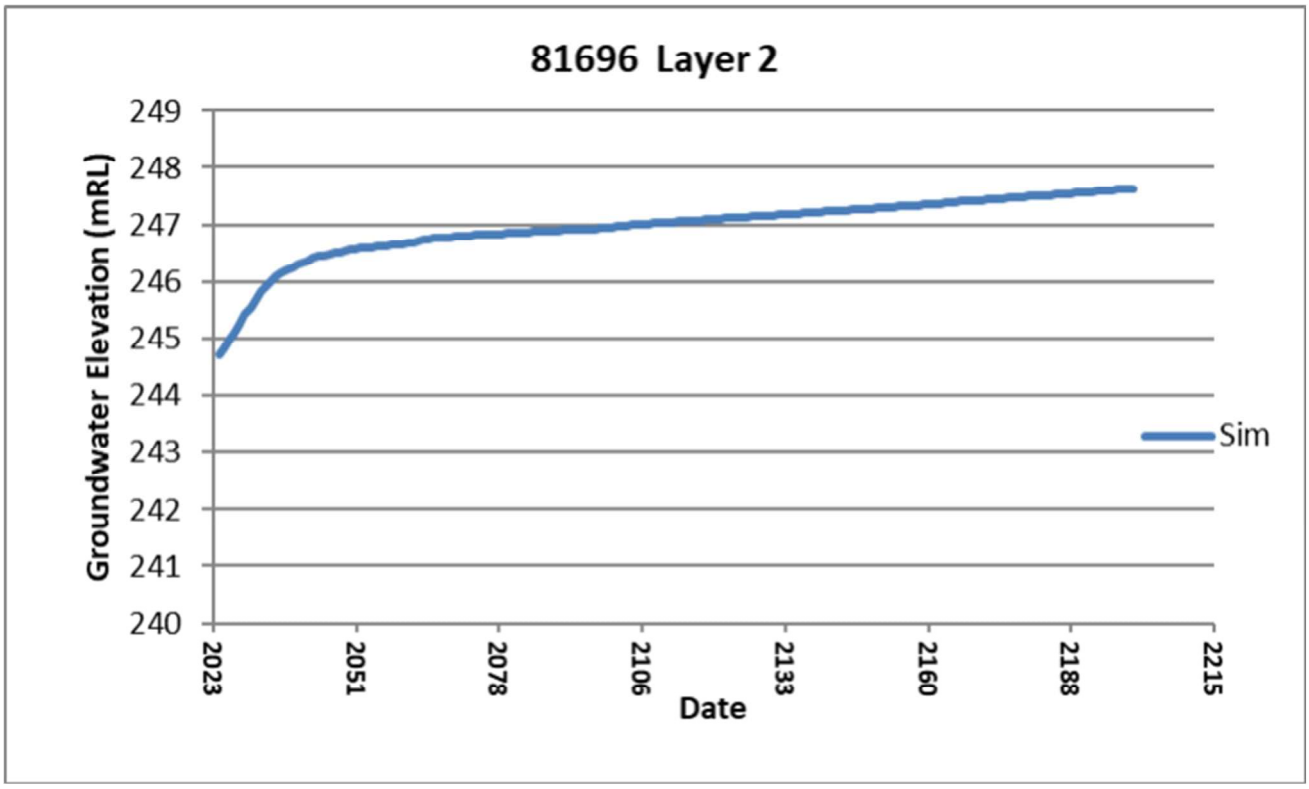


Figure 4.14 Predictive hydrographs for identified third-party water supply bore 81696 near GRBM (AECOM, 2024a)

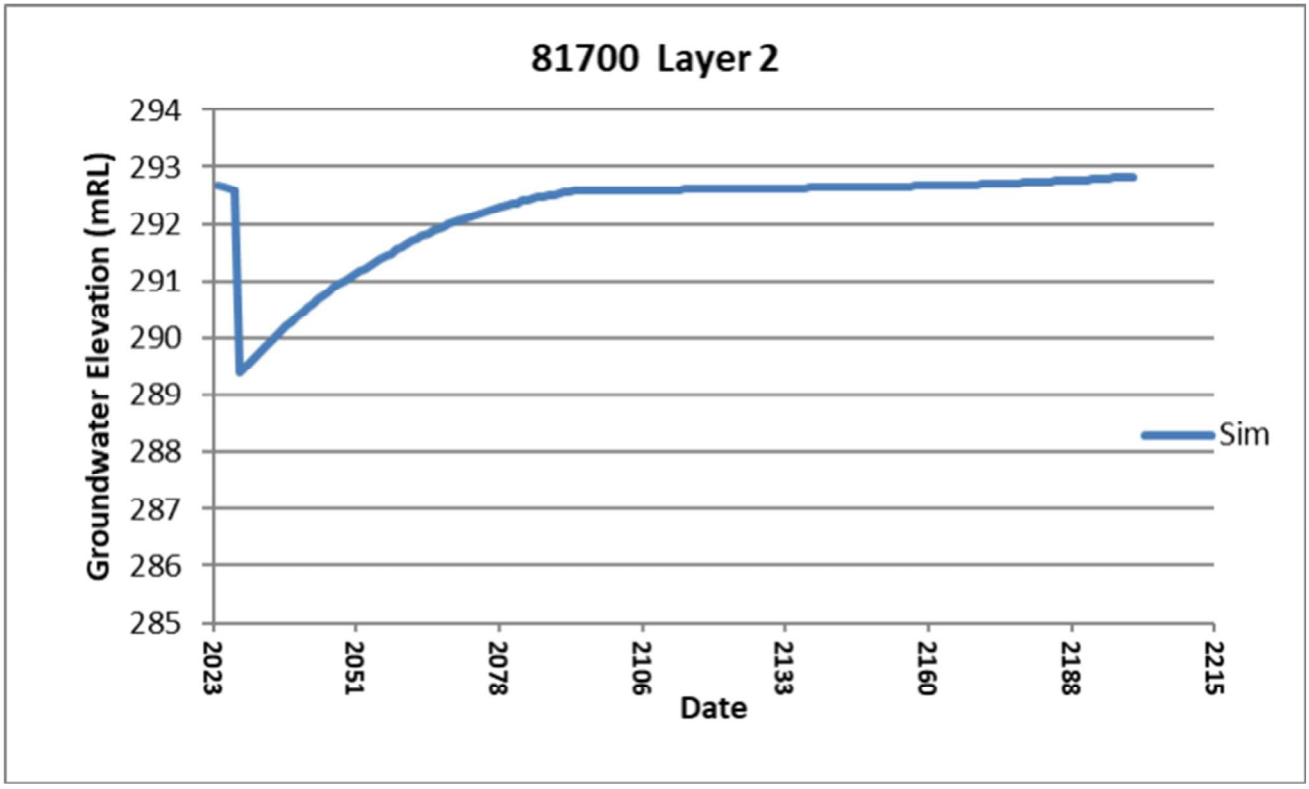


Figure 4.15 Predictive hydrographs for identified third-party water supply bore 81700 near GRBM (AECOM, 2024a)

The hydrograph (Figure 4.16) for bore 182313 shows some predicted long-term post-mining groundwater drawdown (> 5 m) as a result of approved mining activities and not closure-related. This bore is located within the mining tenure in proximity to the Goonyella residual void high-wall. Therefore, it is reasonably assumed not to be used for supply purposes either presently or in the post-mining environment.

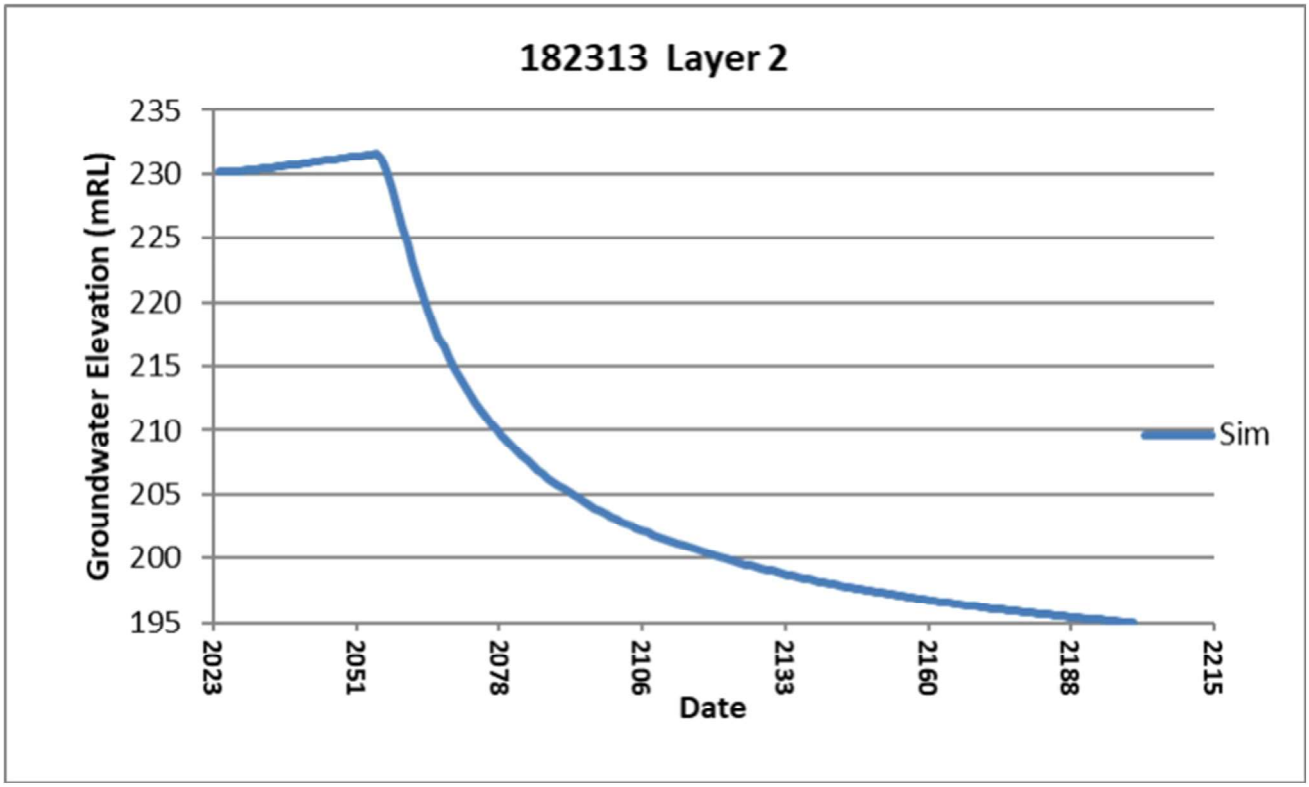


Figure 4.16 Predictive hydrographs for identified third-party water supply bore 182313 near GRBM (AECOM, 2024a)

5 Flooding Assessment

Residual void flooding assessments were completed to determine surface-water interactions, and the drainage and flooding behaviour of surface water in the vicinity of the GRBM residual voids. This section summarises the assessment findings, as relevant to void closure at GRBM. Refer to the main volume of the PRC plan for the complete voids in floodplain and closure-related rehabilitation flooding assessments.

5.1 Void in floodplains

The specific locations of the pre-approved NUMAs are not identified in the LOD (EA EPML00853413), and therefore, in accordance with the DESI PRC Plan Guideline transitional provisions, an assessment of voids in flood plains was undertaken (SLR, 2024).

The perimeters of the final void extents of the closure state landform were included in the voids in floodplain assessment in a re-constructed pre-mining topography. Any final closure landform considerations and/or final void backfill that is intended for flood protection are excluded from the assessment in accordance with the voids in flood plains information sheet (DES, 2020).

The voids in flood plain assessment of the pre-mining landform identified that all the final void's extents associated with the GRBM residual voids would be located, to some extent within the pre-mining landform flood plain of the Isaac River. For the final closure state landform, the residual void extents located within the rehabilitation area flood plain extents of the Isaac River have been reduced and refined and the landform altered to manage the flood risk at closure.

5.2 Closure state landform flooding

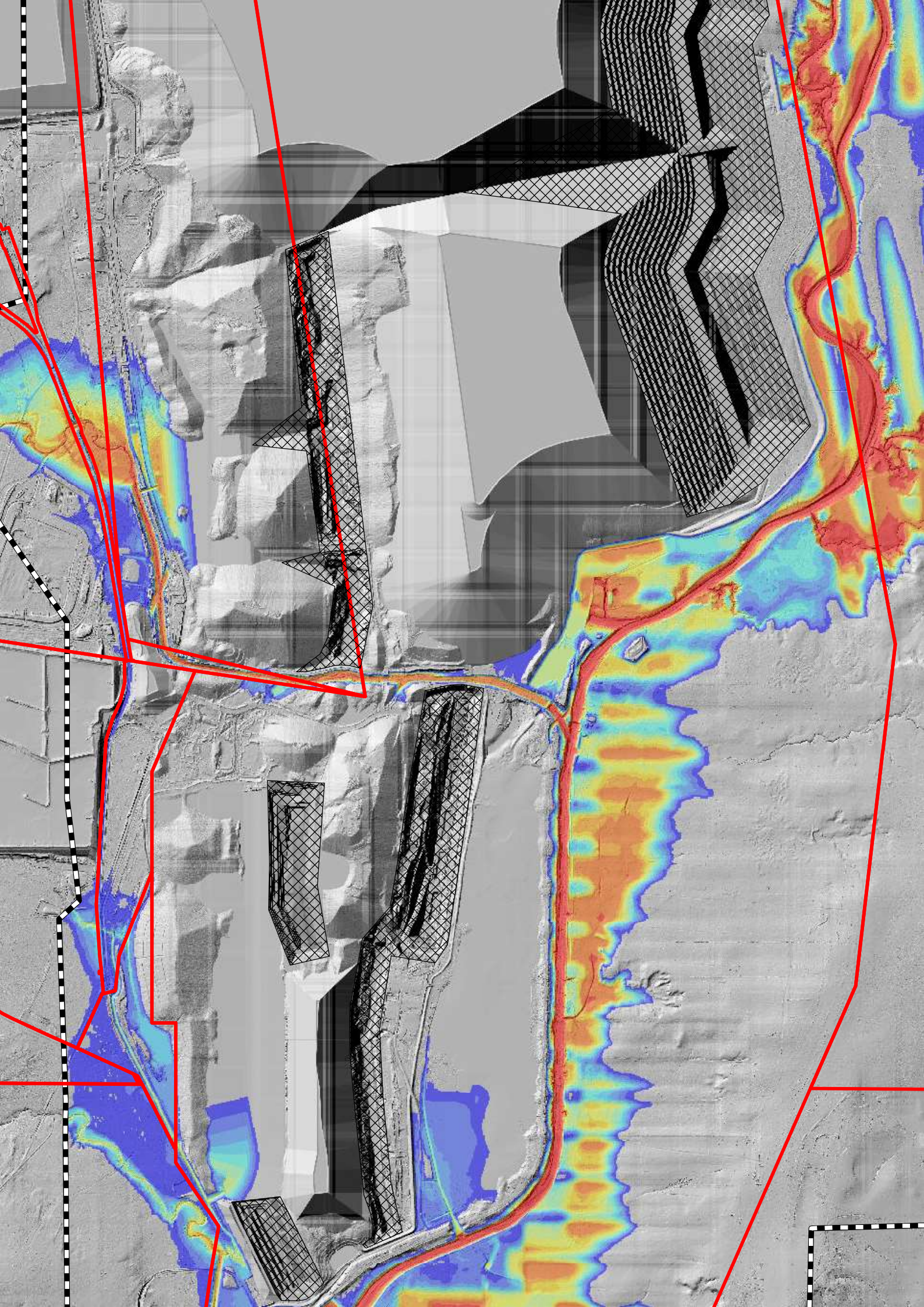
For the final closure state landform, rehabilitation flood modelling was undertaken on a range of design storm events for a range of Annual Exceedance Probability (AEP), including 0.1%, Probable Maximum Flood (PMF), and smaller events in accordance with the DES *PRC Plan Guideline* to predict the interaction of the flood events with the closure state landform.

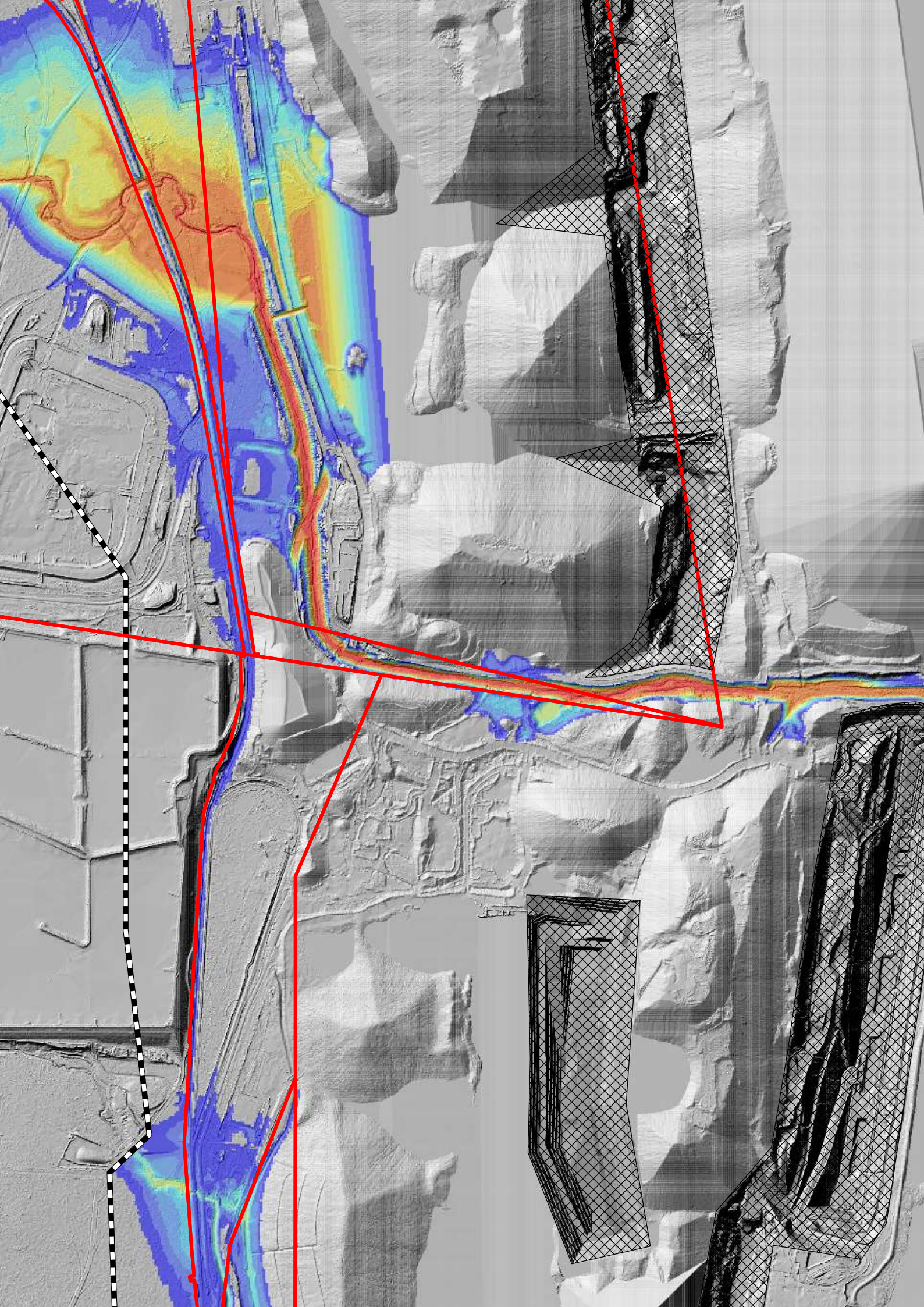
Hydrologic modelling was undertaken to develop the estimated runoff hydrographs that were used to inform the hydraulic modelling. The hydrologic modelling included the catchments of Isaac River, Eureka Creek, Platypus Creek, and Fisher Creek. To incorporate the final closure state landform, the hydrological model catchment configuration, reach lengths and storm definitions were updated.

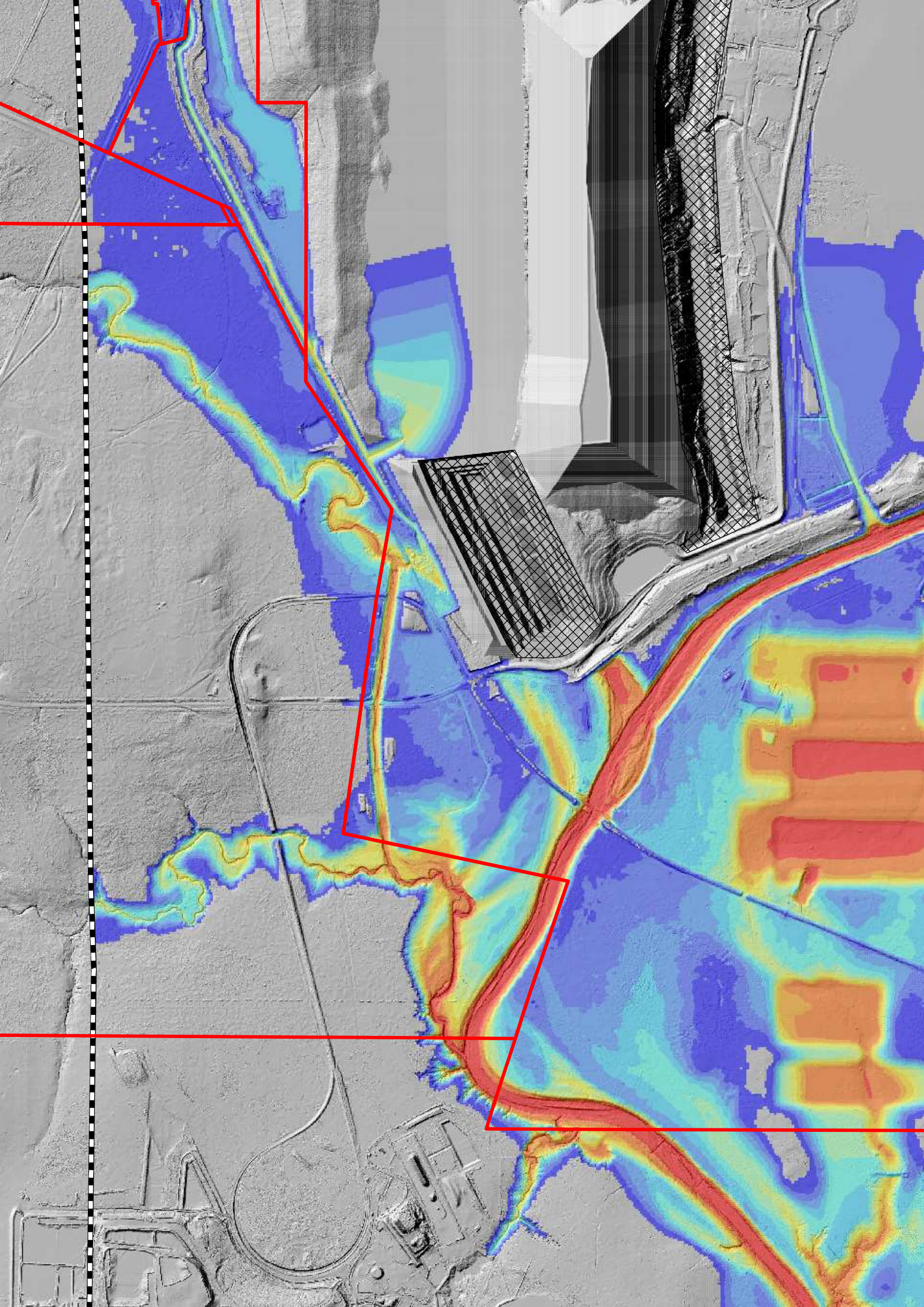
Effects of climate change through the increase in rainfall intensity were considered in the hydrological analysis. The upper climate change scenario was modelled with a 20% rainfall intensity increase (SLR, 2024).

For the final closure state landform, the pits will be partially backfilled with spoil to reduce the extent of the final voids. Spoil placement will be conducted so that the final residual voids of the NUMAs are not impacted by inundation from floodwaters up to and including the 0.1% AEP under the upper climate change scenario. The results of the hydraulic model showed the proposed GRBM residual voids are not subject to inundation from floodwaters up to and including the 0.1% AEP under the upper climate change scenario.

Figure 5.1 to Figure 5.3 show modelled peak flow depths for Isaac River, Eureka Creek, Platypus Creek and Fisher Creek for the 0.1% AEP under the upper climate change scenario.







6 Void water balance

A void water balance assessment was completed to determine the behaviour of the GRBM residual voids in their closure state. The assessment also sought to understand the inherent hydrological closure risks and to inform separate assessments relating to geotechnical and geochemical stability of the voids over time (findings from these separate assessments are presented in Section 7 and Section 8, respectively). Findings from the void water balance assessment, where relevant to void closure at GRBM, are presented below.

6.1 Water Balance Model

A water balance model (WBM) was developed using the software program GoldSim to estimate the changes in the volume of water in the final closure state landform residual voids over time in response to water inflows and outflows. The WBM adds the possible inflows and calculates the possible outflows for every step of the duration over the modelled period. The WBM for the GRBM residual voids incorporated direct rainfall, surface water runoff, groundwater interactions, and evaporation.

A model period of 234 years – from the year 2016 to 2259, with a daily time-step was selected. No operational processes (i.e., pumping or transfers to/from the assessed structures) were considered active for the period modelled.

6.1.1 Catchment areas

The conceptual final closure state landform (LF#2.3) for the GBRM residual voids was used to generate contour lines and calculate the drainage network of the area. The catchment subdivision of each void was estimated by analysing a slope map, generated using the software, QGIS. The slope map recognises zones with 'flat' zones and zones with downward slopes. This information was then used to delimitate the void catchment areas into three land use areas: natural, void, and rehabilitated. The 'natural' area was assigned as the area that will remain undisturbed, when comparing the proposed residual voids' landform and the current topography of the area. The 'void' area was assigned as the area of the residual void itself at the spill level. Finally, the 'rehabilitated' area represents the remaining catchment area of each residual void. The delimitation of each of the areas is presented in Figure 6.1 and Table 6.1.

Table 6.1: Catchment areas for each land use applied to the WBM for the GRBM residual voids

Residual void	Land use (ha)			Total (ha)
	Rehabilitated	Natural	Void	
Goonyella	743	85	1,484	**2,312**
Broadmeadow	119	0	96	**215**
Isaac	178	0	51	**229**
R32 South	17	0	39	**56**
R32 East	76	0	67	**143**
Thiess	672	0	161	**833**

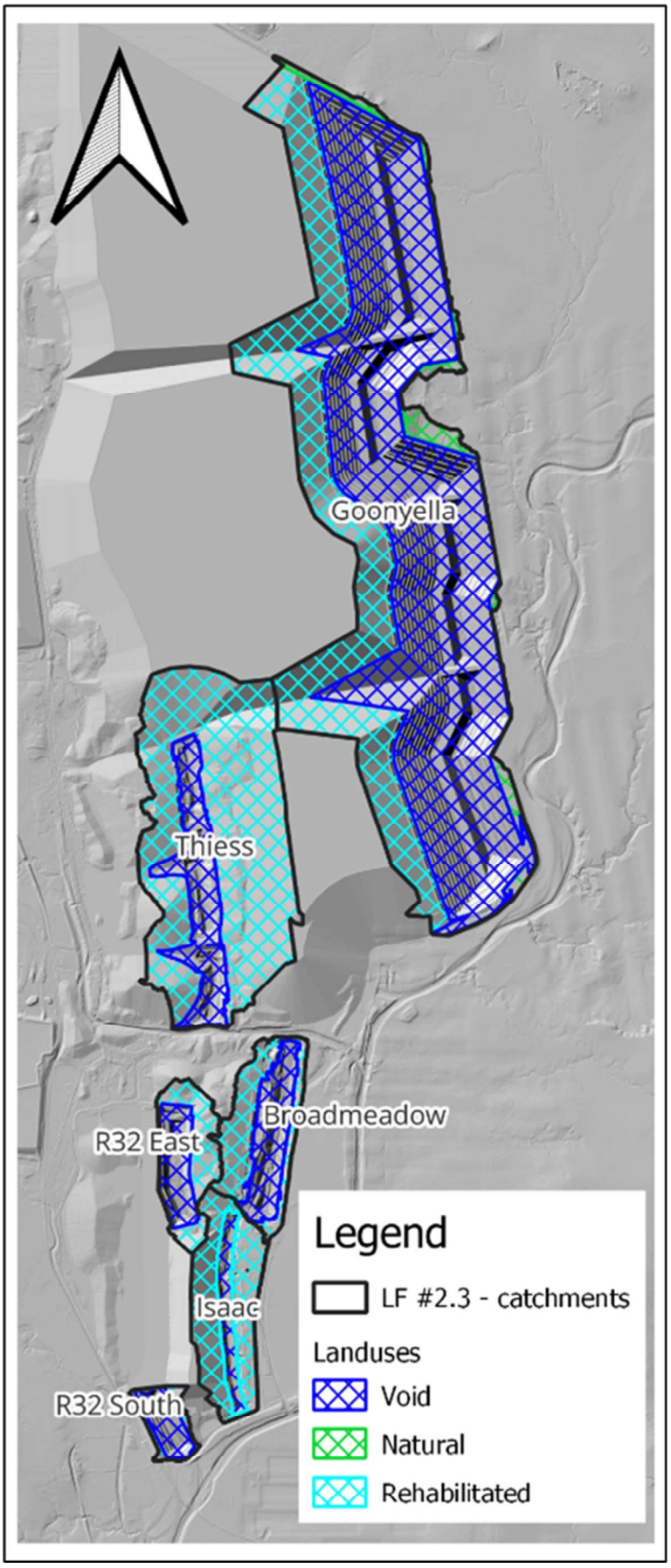


Figure 6.1 Catchment delineation into land use areas applied to the WBM of the GRBM residual voids

The final closure state landform was analysed to determine the spill elevation of each of the voids and is presented in Table 6.2.

Table 6.2: Spill elevation for the GRBM residual voids

Residual void	Spill elevation (m Australian Height Datum (AHD)
Goonyella	254
Broadmeadow	230
Isaac	230
R32 South	240
R32 East	256
Thiess	256

Stage-storage relationships, derived from the closure state landform to obtain the relationship between lake elevation and volume/surface of the lake, are presented in Figure 6.2. These relationships were used in the WBM to estimate the lake surface area and elevation from the lake volume for each time-step.

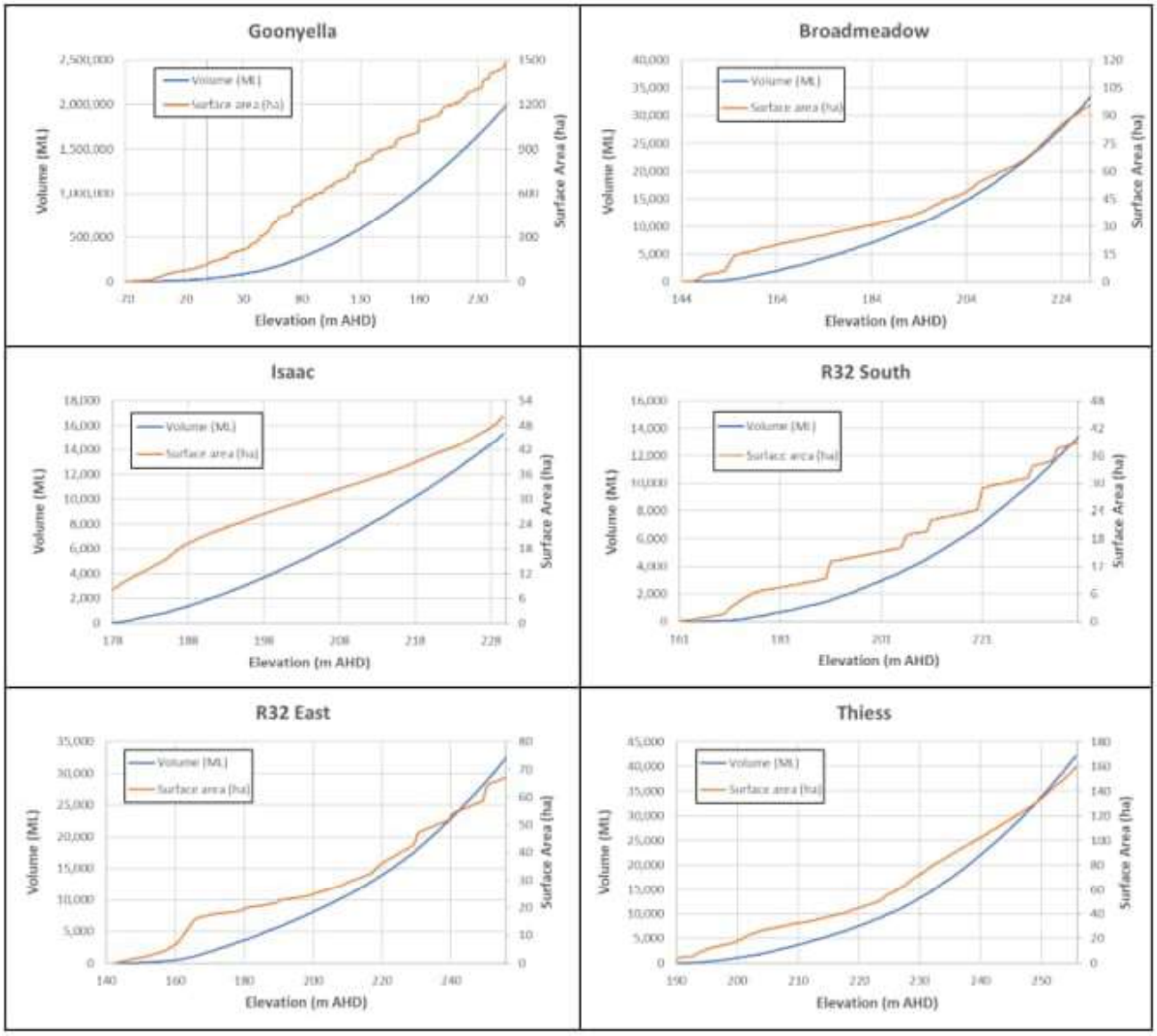


Figure 6.2: Goonyella, Broadmeadow, Isaac, R32 South, R32 East and Thiess residual void stage-storage relationship

6.1.2 *Rainfall, evaporation, and surface runoff*

The amount of surface water runoff resulting from rainfall was calculated using the Australian Water Balance Model (AWBM), a catchment WBM that relates daily rainfall and evapotranspiration to runoff and calculates losses from rainfall for flood hydrograph modelling.

The projected evaporation and rainfall data (BMA, 2023b) was applied to the AWBM to determine the surface runoff that should be input into the WBM. The AWBM contained five storages:

- Three surface storages to simulate partial areas of runoff
- One base flow storage
- One surface runoff routing storage.

The three surface storages have different capacities (small, medium, and large) for each catchment area (BMA, 2023c), as shown in Figure 6.3 and presented in Table 6.3. Each capacity is added together with fractional areas for weights, which are summarised in Table 6.4.

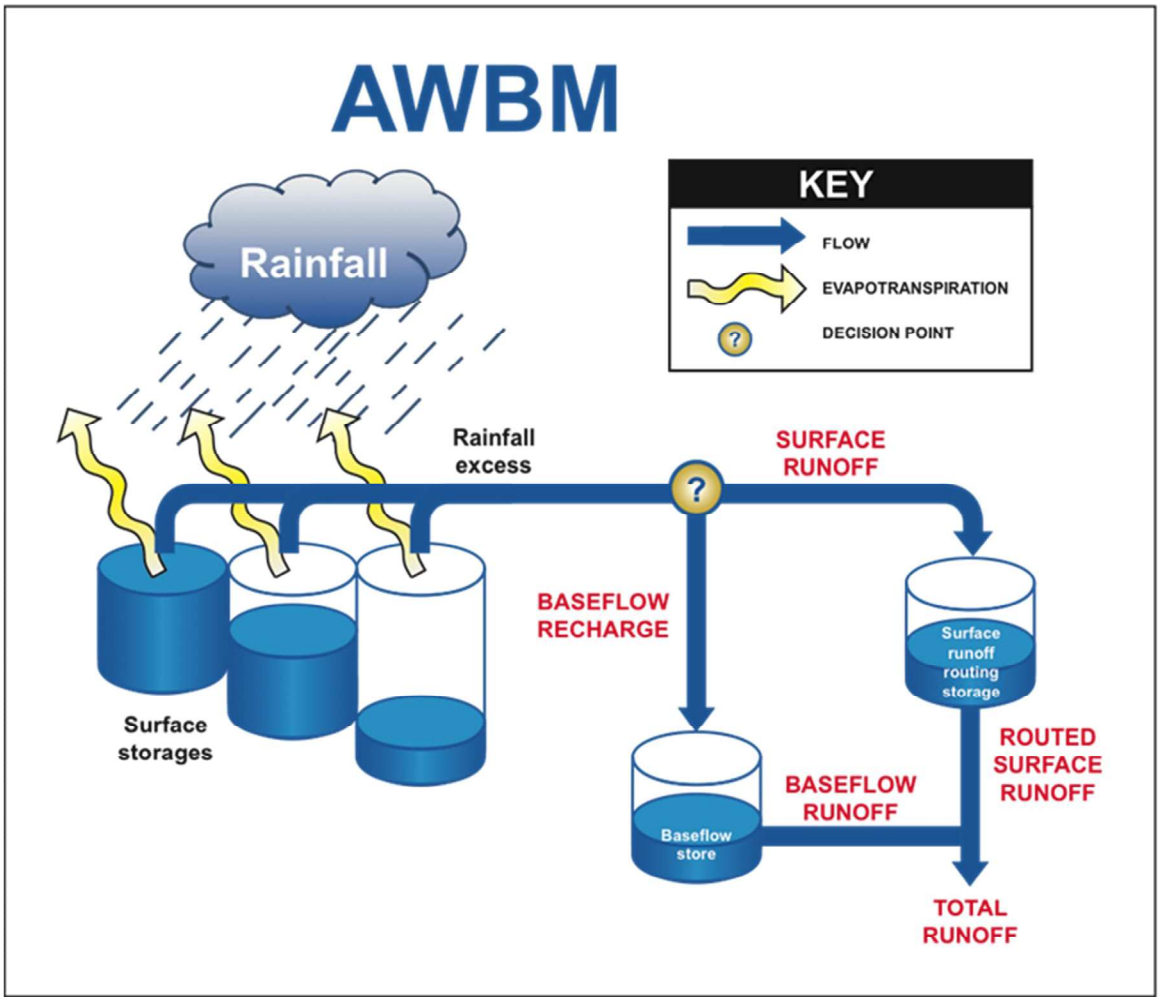


Figure 6.3: Structure of AWBM rainfall-runoff model including small, medium, and large surface storages

Table 6.3: Surface storage capacities (BMA, 2023c) applied to the WBM for GRBM

Land use	Storage capacity (mm)		
	Small	Medium	Large
Natural	10	55	115
Void	5	20	40
Rehabilitated	10	50	110

Table 6.4: Surface storage proportions (BMA, 2023c) applied to the WBM for GRBM

Land use	Small	Medium	Large
Natural	0.134	0.433	0.433
Void	0.134	0.433	0.433
Rehabilitated	0.134	0.433	0.433

Table 6.5 presents the remaining AWBM parameters (baseflow index, channel coefficient and baseflow coefficient). Surface water runoff considers flows as daily averages and does not include the effects of high-intensity and short-duration events.

Table 6.5: Baseflow and channel parameters applied to the WBM for GRBM

Land use	Baseflow index	Channel coefficient (1/day)	Baseflow coefficient
Natural	0.45	0.2	0.6
Void	0	0.1	0.6
Rehabilitated	0.25	0.075	0.7

6.1.3 Climate change considerations

To reasonably represent future climate conditions in the WBM assessment, climate change data was used from the projections of three different models (ACCESS1-0Q, GFDL-CM3Q, MPI-ESM-LRQ) evaluated under two Representative Concentration Pathway (RCP) (4.5 and 8.5), giving six climate realisations. The RCPs consist of projections of greenhouse gas concentrations (pathways) adopted by the Intergovernmental Panel on Climate Change (IPCC).

Simulations were completed for three climate realisations. These realisations were selected to represent a reasonable range of probable climate scenarios based on the climate models used, being the wetter (R3), middle (R4) and the drier (R5) climate ranges. This provides a reasonable potential range of climate impacts for each residual void. A summary of the combined pathways and models considered in each realisation (R#) of the WBM is presented in Table 6.6.

Table 6.6: Climate change scenarios considered in each realisation of the GRBM WBM

Realisation	Climate model	RCP
R3	MPI-ESM-LRQ	4.5
R4	ACCESS1-0Q	8.5
R5	GFDL-CM3Q	8.5

To cover the WBM simulation period of 234 years, the climate projections were applied from 2020 until 31 December 2259. As the climate projections data only cover the interval from 2020 to 2099, the period between January 2080 to December 2099 was repeated to act as the projected rainfall conditions beyond 2099 (as directed by BMA). This methodology is summarised in Table 6.7. To cover the WBM simulation period for Theiss residual void commencing in 2016, historical climate data was applied.

The annual mean rainfall data from the different pivotal years were calculated. Pivotal years represent the future average climate of a decade centred around them (CSIRO, 2022). The pivotal years relevant to the WBM simulation period are 2030 (projections from 2021 to 2040), 2050 (projections from 2041 to 2060), 2070 (projections from 2061 to 2080) and 2090 (projections from 2081 to 2099).

Table 6.7: Annual mean rainfall calculated for each climate realisation applied to the GRBM residual voids WBM for each simulated period

Simulation period	Mean annual precipitation (mm)		
	R3	R4	R5
2021 to 2040	597	527	508
2041 to 2060	517	572	546
2061 to 2080	530	496	529
2081 to 2099	569	593	525

The future increase in evaporation was estimated considering:

- Projected period between 2020 and 2099
- Reference period (1986 to 2005).

The result is a value of annual increase of evaporation for each realisation. This factor was applied to the monthly values of evaporation. These factors are presented in Table 6.8.

Table 6.8: Percentage increase of evaporation considered for each realisation from 2024 to 2099

	R3	R4	R5
Mean evaporation 1986-2005 (mm/yr)	1,610	1,597	1,615
2021-2040			
Mean evaporation (mm/yr)	1,617	1,717	1,739
Increase in average evaporation (%)	0.3%	6.3%	9.4%
2041-2060			
Mean evaporation (mm/yr)	1,787	1,921	1,853
Increase in average evaporation (%)	10.9%	15.4%	18.9%
2061-2080			
Mean evaporation (mm/yr)	1,843	2,105	1,979
Increase in average evaporation (%)	14.1%	22.6%	30.4%
2081-2099			
Mean evaporation (mm/yr)	1,760	2,256	2,108
Increase in average evaporation (%)	10.3%	26.7%	40.4%

6.1.4 *Groundwater inflows*

Groundwater inflows to each of the residual voids post-closure were simulated using the numerical groundwater model and time-series data of groundwater flow rates were produced (AECOM, 2024). The modelled groundwater inflow rates applied as inputs to the WBM are presented in Figure 6.4 to Figure 6.9.

Groundwater inflows to the residual voids, as discussed in Section 4, are predicted to equate to between 4 and 17% of the total volumetric inflow by the end of the post-closure simulation (AECOM, 2024a).

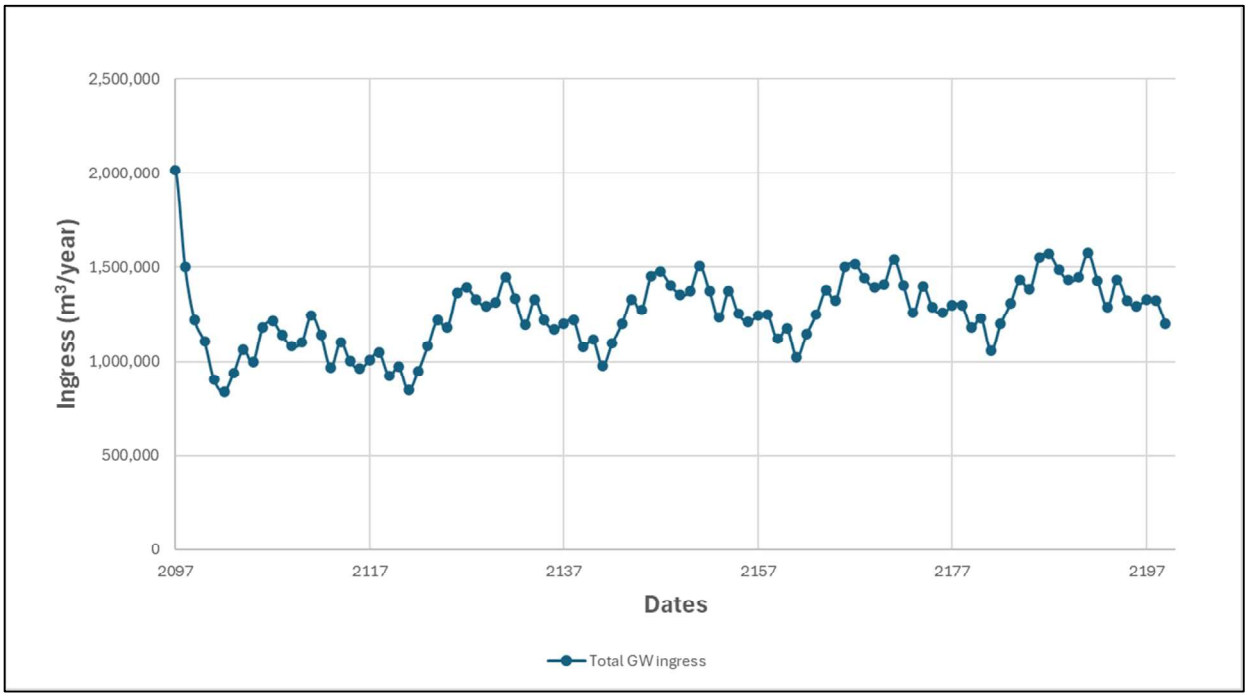


Figure 6.4: Groundwater inflows to Goonyella residual void – generated from (AECOM, 2024)

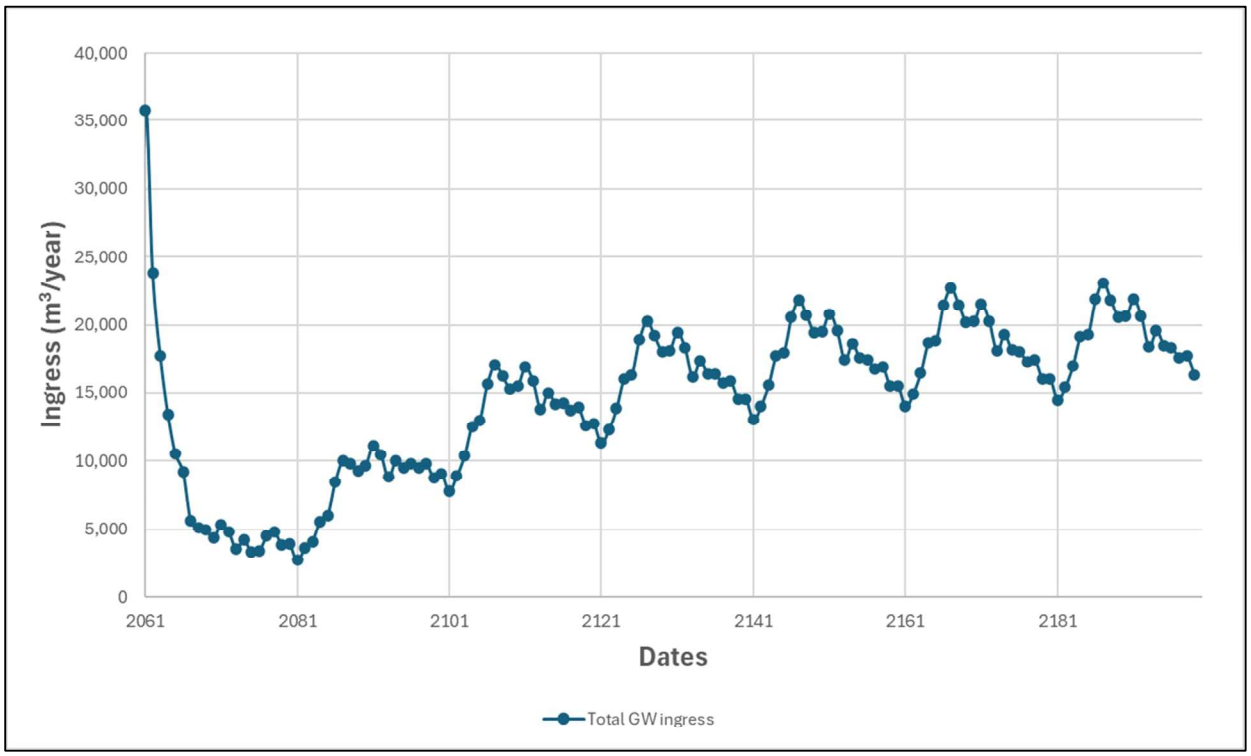


Figure 6.5: Groundwater inflows to Broadmeadow residual void – generated from (AECOM, 2024)

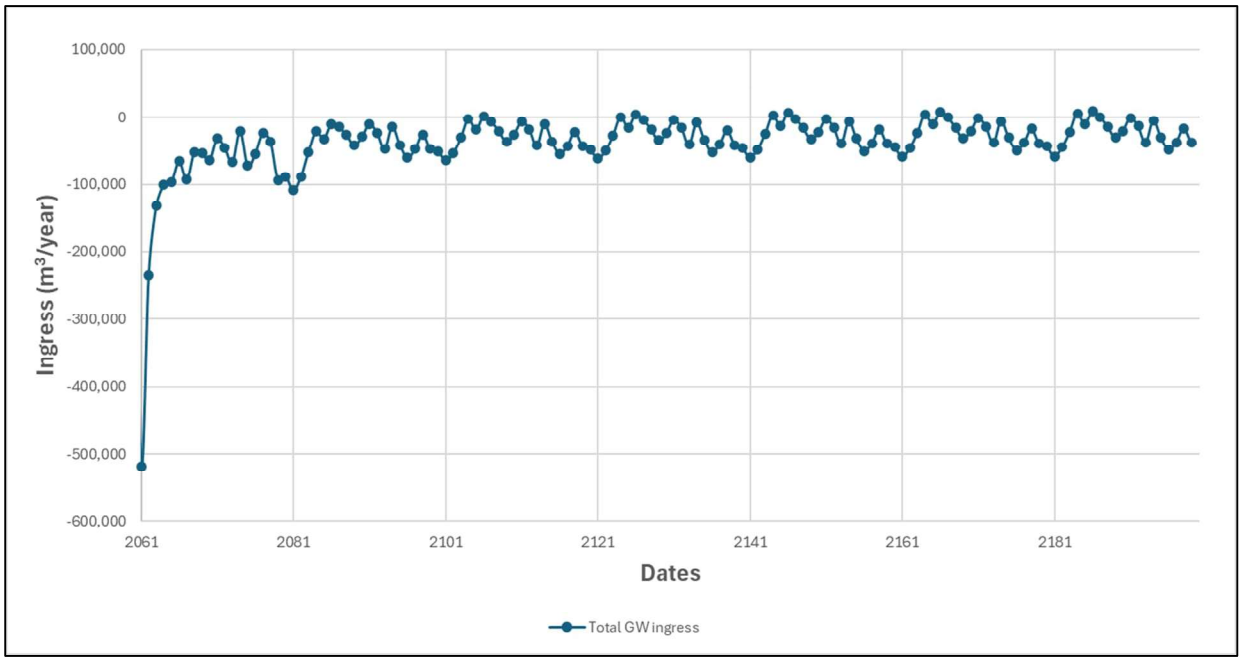


Figure 6.6: Groundwater inflows to Isaac residual void – generated from (AECOM, 2024)

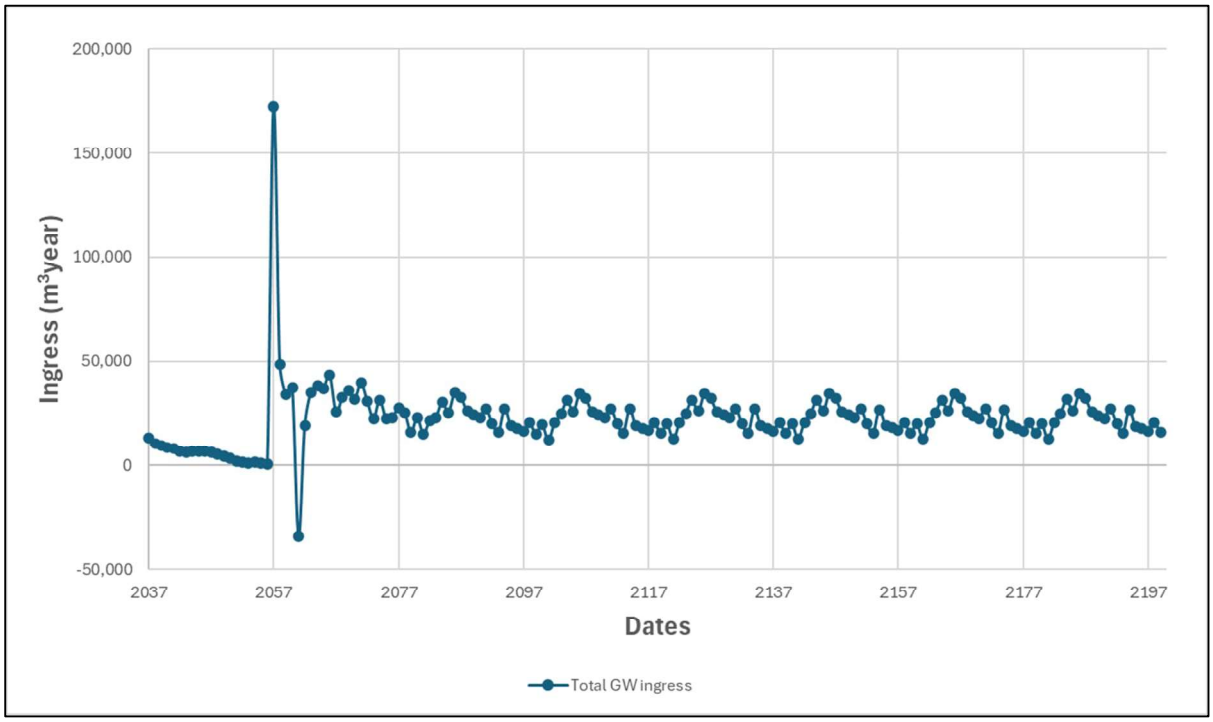


Figure 6.7: Groundwater inflows to R32 South residual voids – generated from (AECOM, 2024)

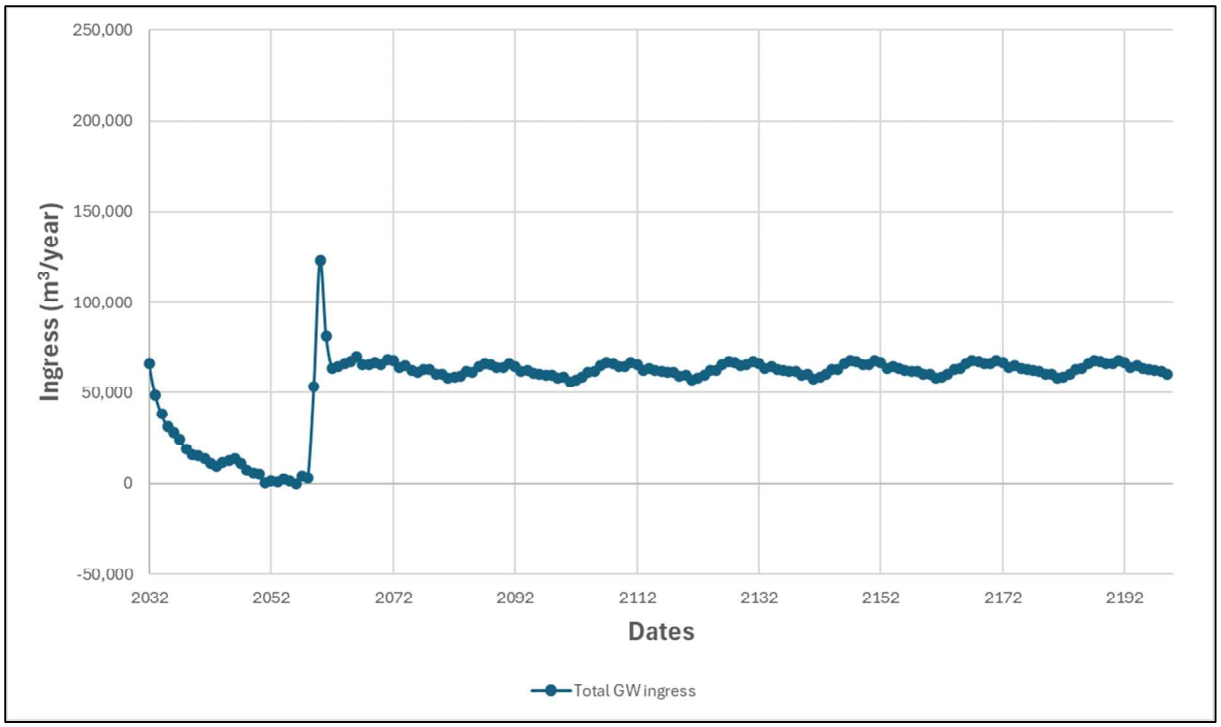


Figure 6.8: Groundwater inflows to R32 East residual void – generated from (AECOM, 2024)

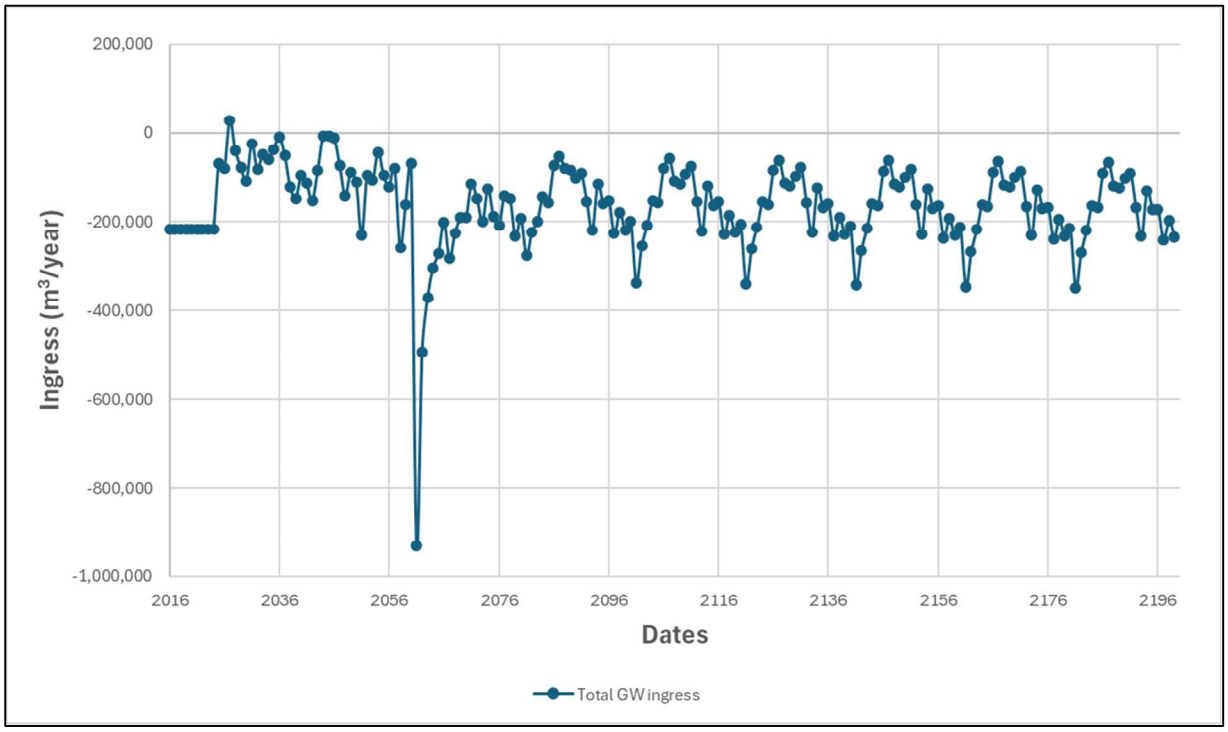


Figure 6.9: Groundwater inflows to Thiess residual voids – generated from (AECOM, 2024). The spike in outflows depicted around 2060 relate to the representation of the flooding of the underground mine in the groundwater model

6.2 Residual void water balance outcomes

6.2.1 Goonyella residual void

By 2259, the end of the simulation period, the differences between mean inflows and mean outflows reduce, and the mean water balance has reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2240 to 2259 and are presented in Figure 6.10. The mean (total) annual inflow to Goonyella residual void is 3,929 megalitres per year (ML/year) for the simulation period of 2240 to 2259, equal to the mean annual outflow for the same period. This indicates that the mean water balance for Goonyella residual void can be considered to have reached equilibrium.

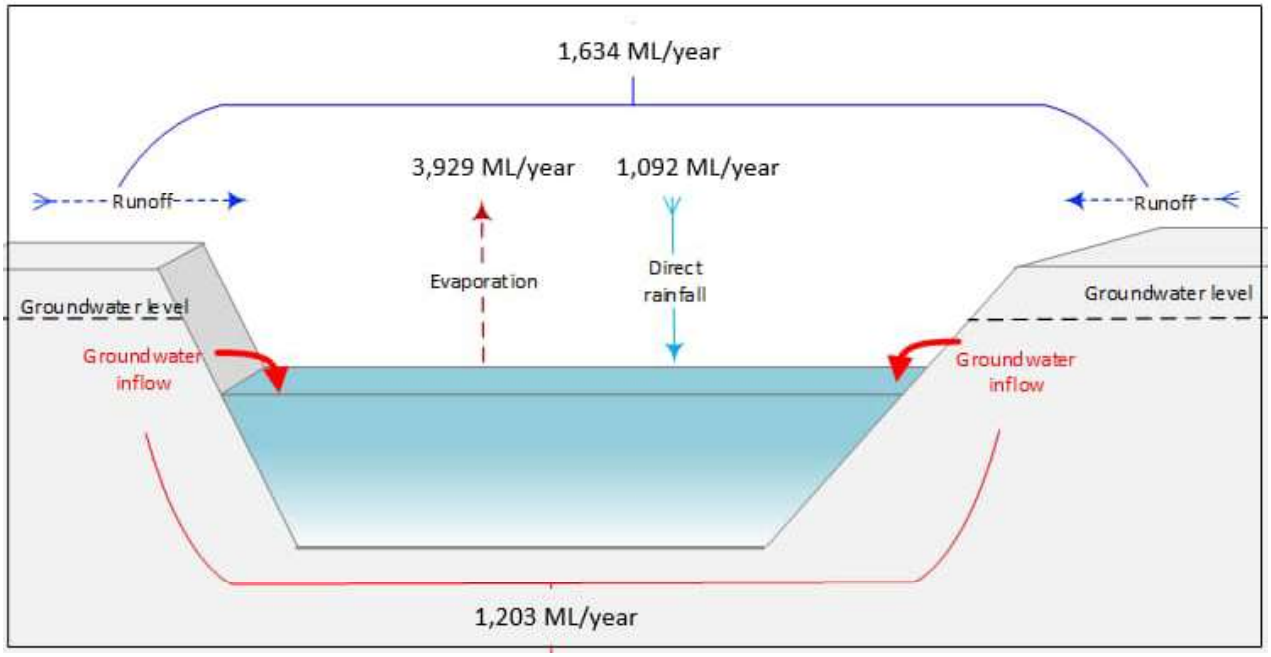


Figure 6.10: Schematic representation of average inflows/outflows simulated for the period from 2240 to 2259 – Goonyella residual void (mean volumes from all realisations – 3, 4 and 5)

The results from the WBM for Goonyella residual void indicate that, after an initial increase in void water level and volumes observed from the beginning of the simulation until the year 2200, the mean void water levels start to stabilise. The mean void water elevation reaches 21 m AHD (Figure 6.11) and the mean void water volume reaches over 69,178 megalitres (Figure 6.12) across all realisations.

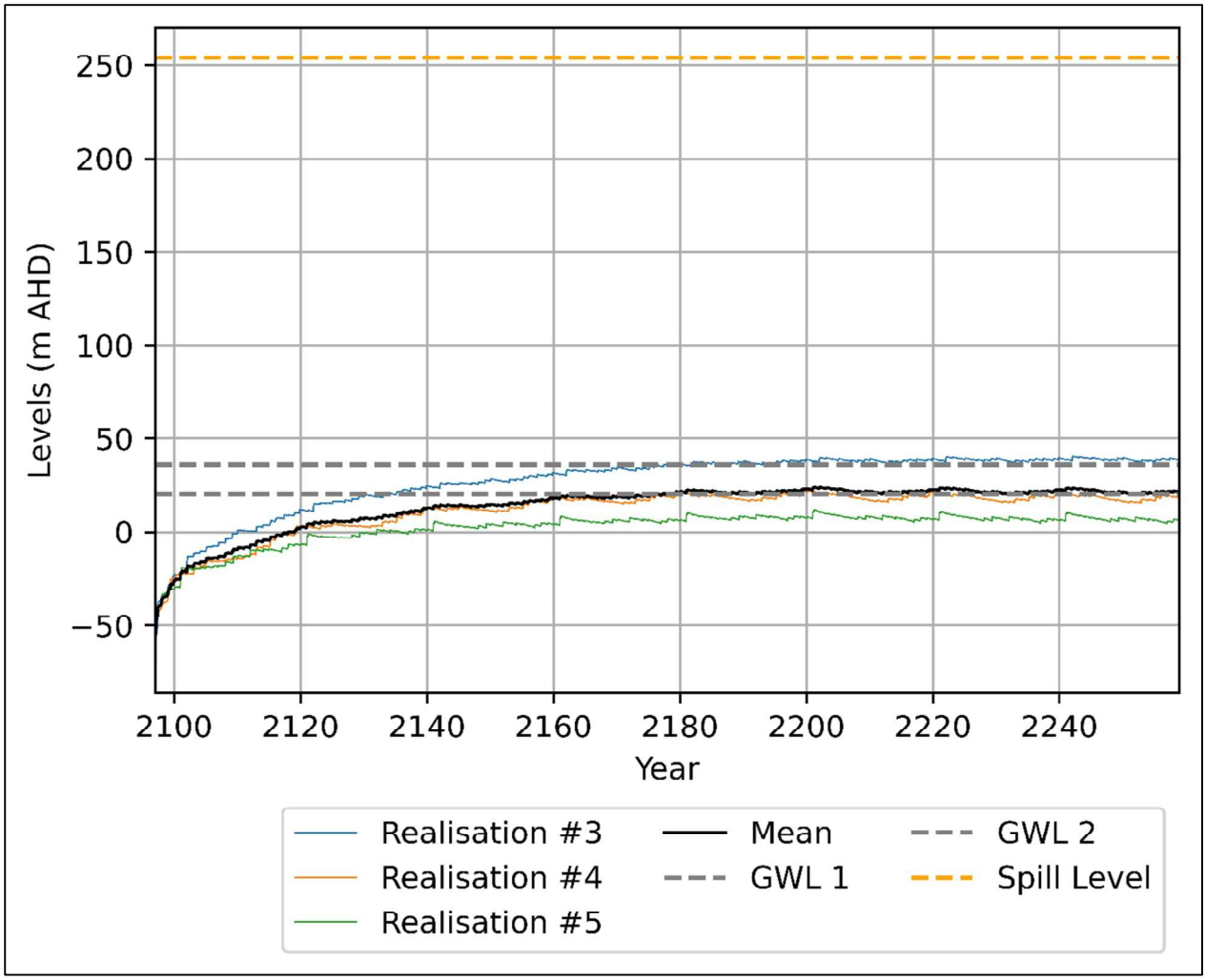


Figure 6.11: Modelled water levels in Goonyella residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (realisations 3, 4, and 5)

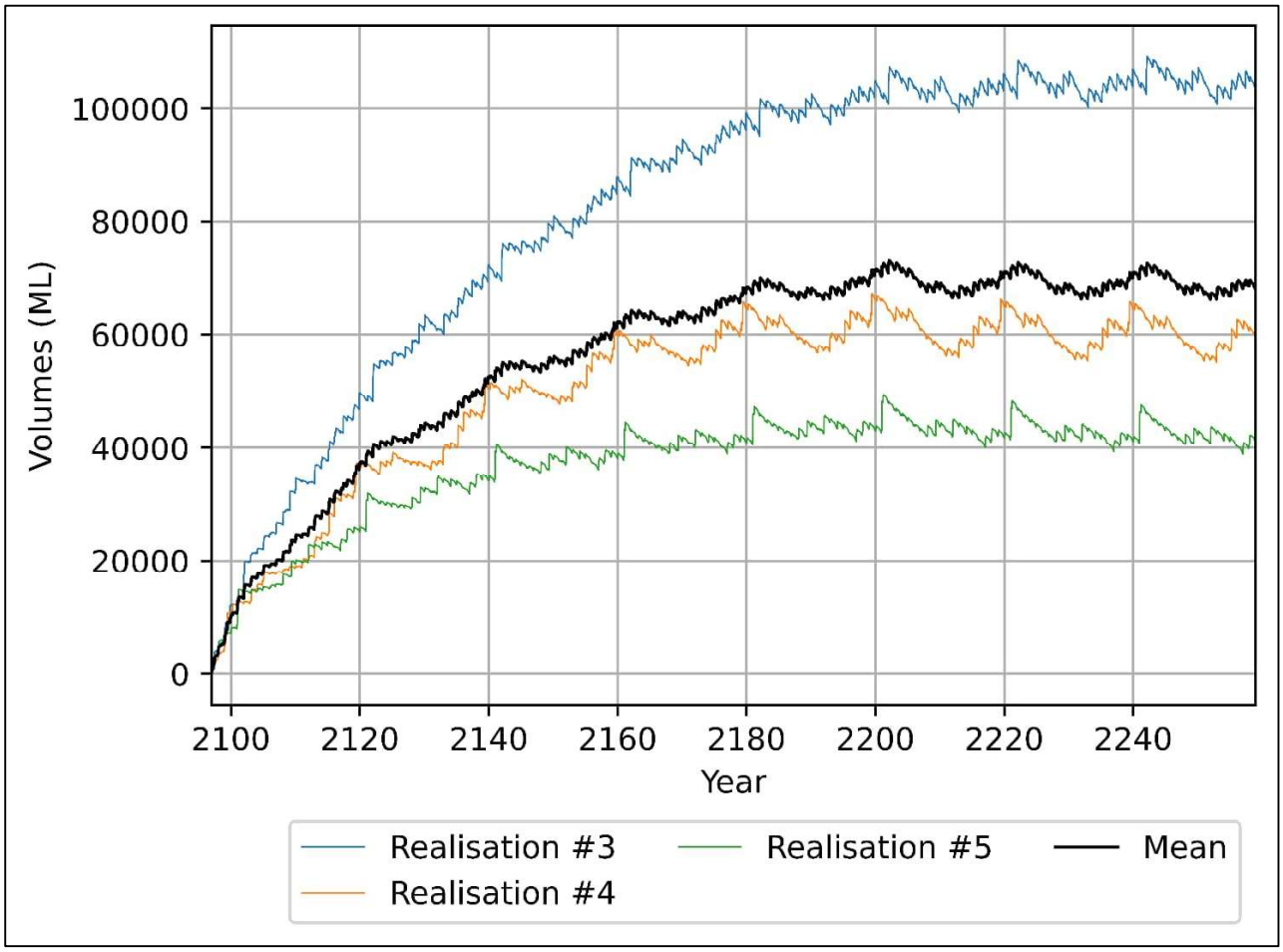


Figure 6.12: Modelled water volumes for Goonyella residual void (realisations 3, 4, and 5)

6.2.2 *Broadmeadow residual void*

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows had reduced, and the mean water balance had reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.13. The mean (total) annual inflow to Broadmeadow residual void is 218 ML/year for the simulation period of 2180 to 2199, equal to the mean annual outflow for the same period. This indicates that the mean water balance for Broadmeadow residual void can be considered to have reached equilibrium.

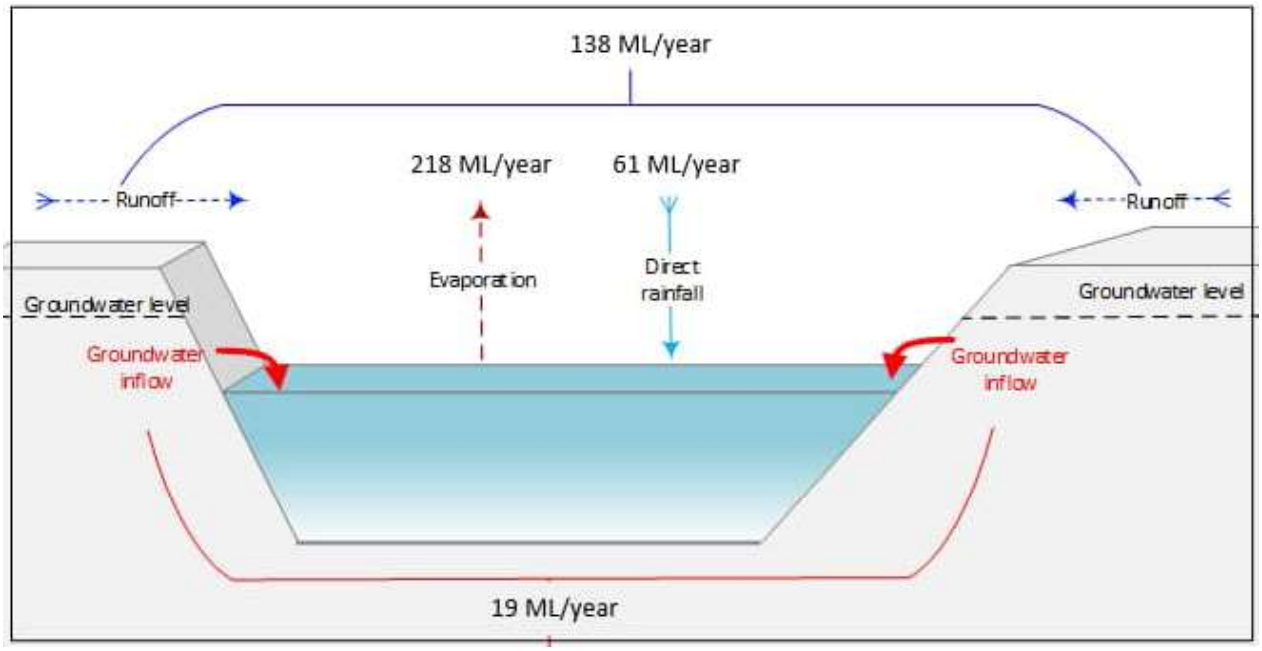


Figure 6.13: Schematic representation of average inflows/outflows simulated for period from 2180 to 2199 – Broadmeadow residual void (mean volumes from all realisations – 3,4, and 5)

The results from the WBM for Broadmeadow residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2100, the mean void water levels start to stabilise. The mean void water elevation reaches 155 m AHD (Figure 6.14) and the mean void water volume of 473 megalitres (Figure 6.15) across all realisations.

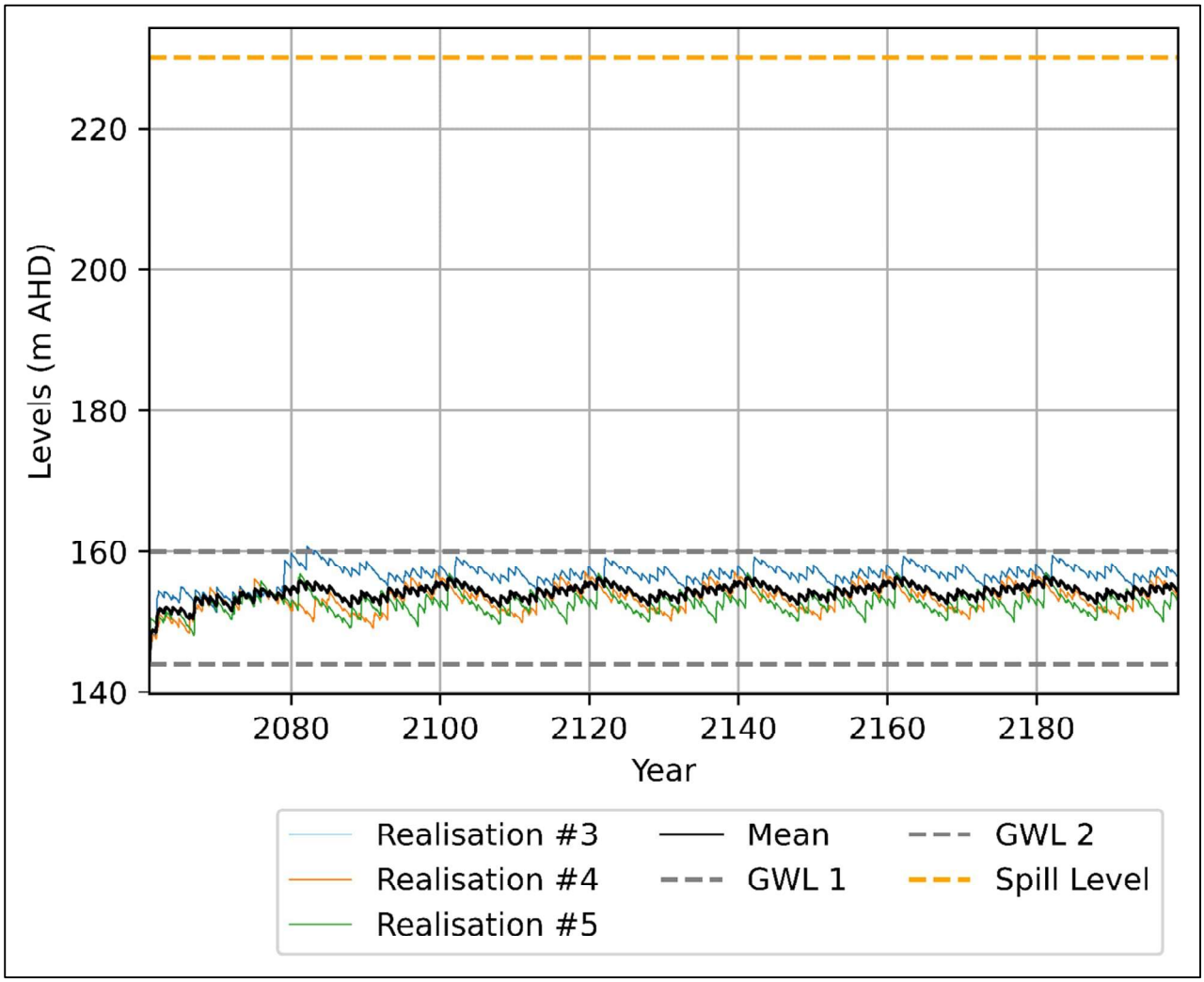


Figure 6.14: Modelled water levels in Broadmeadow residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (realisations 3, 4, and 5)

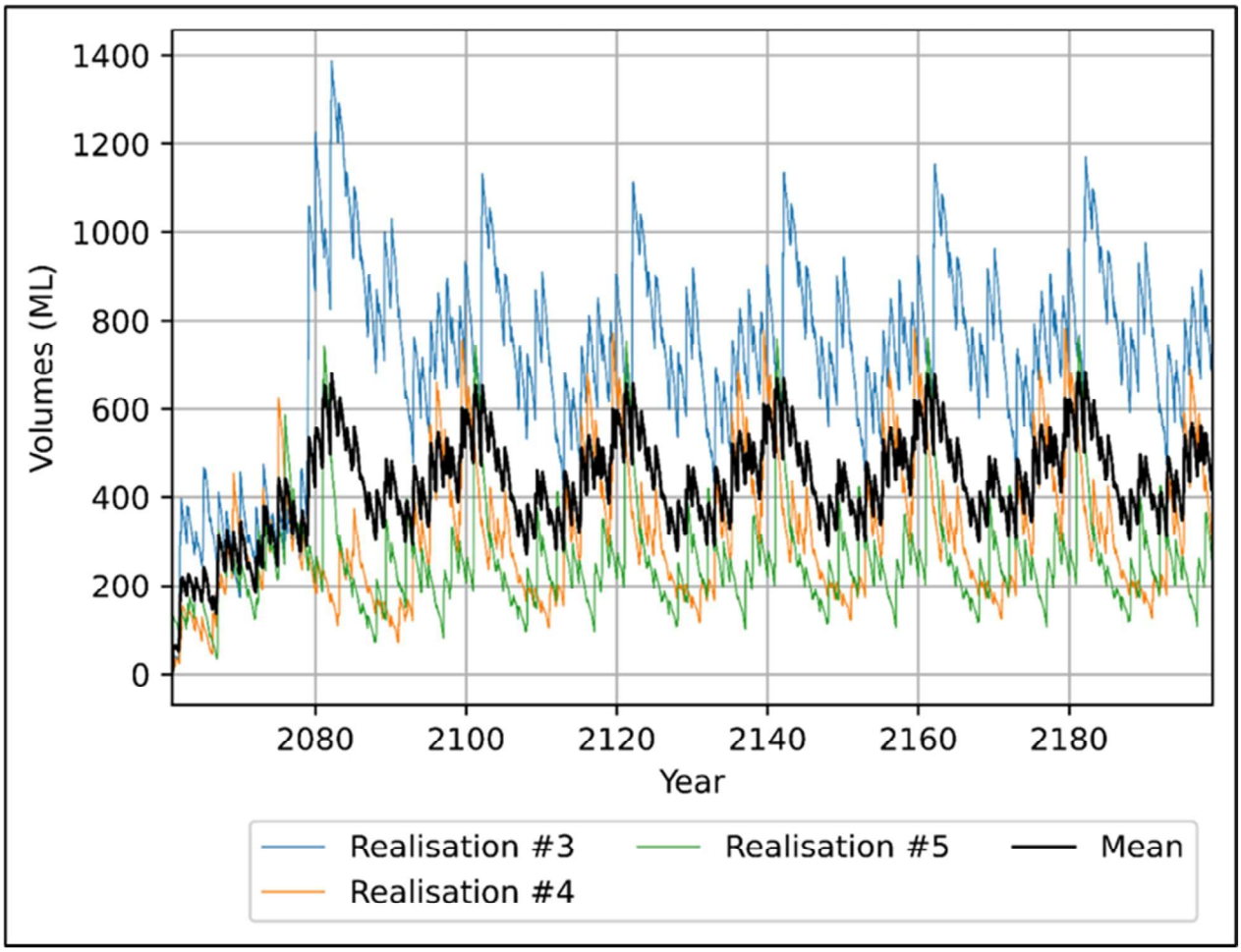


Figure 6.15: Modelled water volumes for Broadmeadow residual void (realisations 3, 4, and 5)

6.2.3 *Isaac residual void*

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows had reduced and the mean water balance had reached equilibrium The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.16. The mean (total) annual inflow to Isaac residual void is 179 ML/year for the final 20-year period, equal to the mean annual outflow for the same period. The mean annual outflows are the sum of both evaporative losses and modelled groundwater outflows. This indicates that the mean water balance for Isaac residual void can be considered to have reached equilibrium.

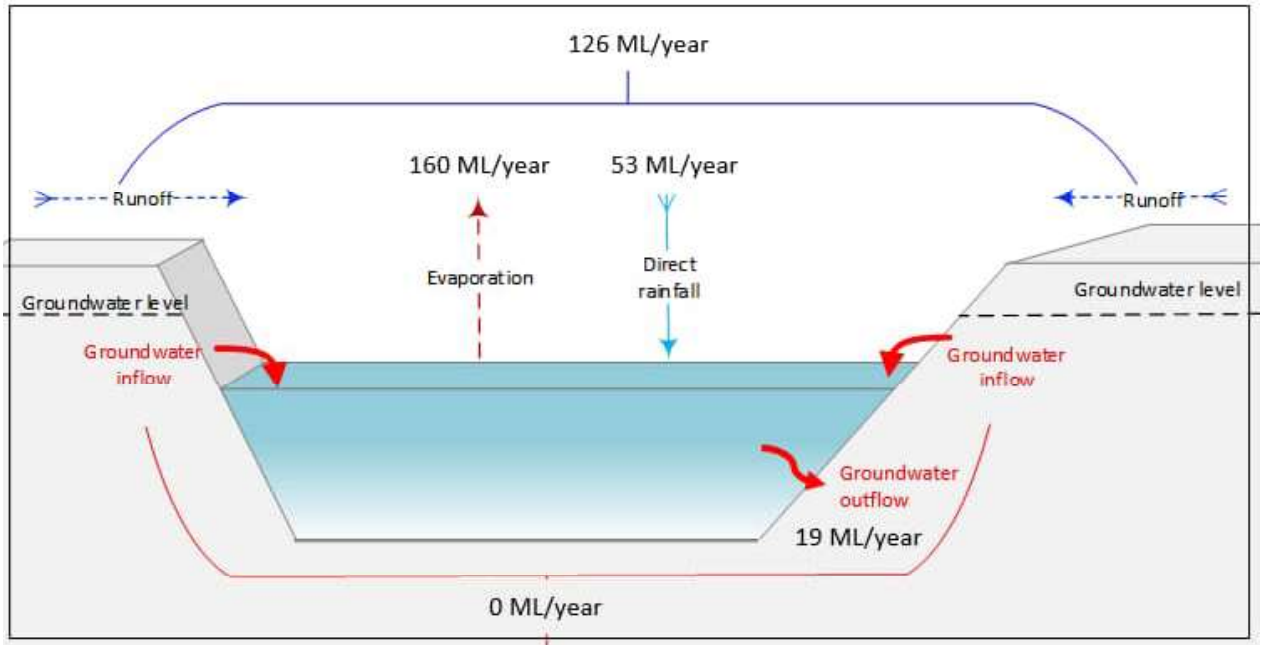


Figure 6.16: Schematic representation of average inflows/outflows simulated for the period from 2180 to 2199 – Isaac residual void (mean volumes from all realisations – 3,4 and 5)

The results from the WBM for Isaac residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2100, the mean void water levels start to stabilise. The mean void water elevation reaches 180 m AHD (Figure 6.17), and the mean void water volume of 162 megalitres (Figure 6.18) across all realisations.

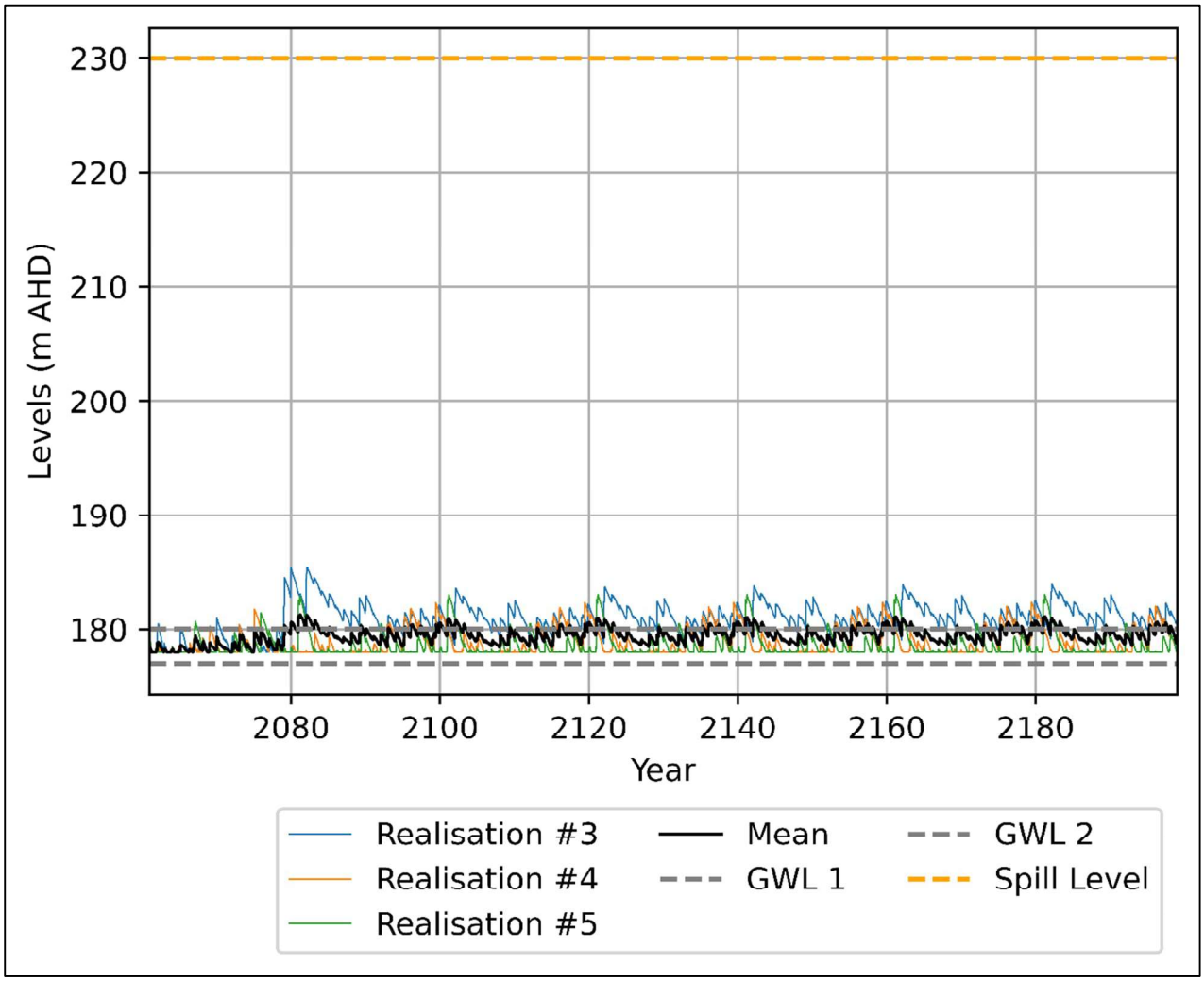


Figure 6.17: Modelled water levels in Isaac residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (GWL) (realisations 3, 4, and 5)

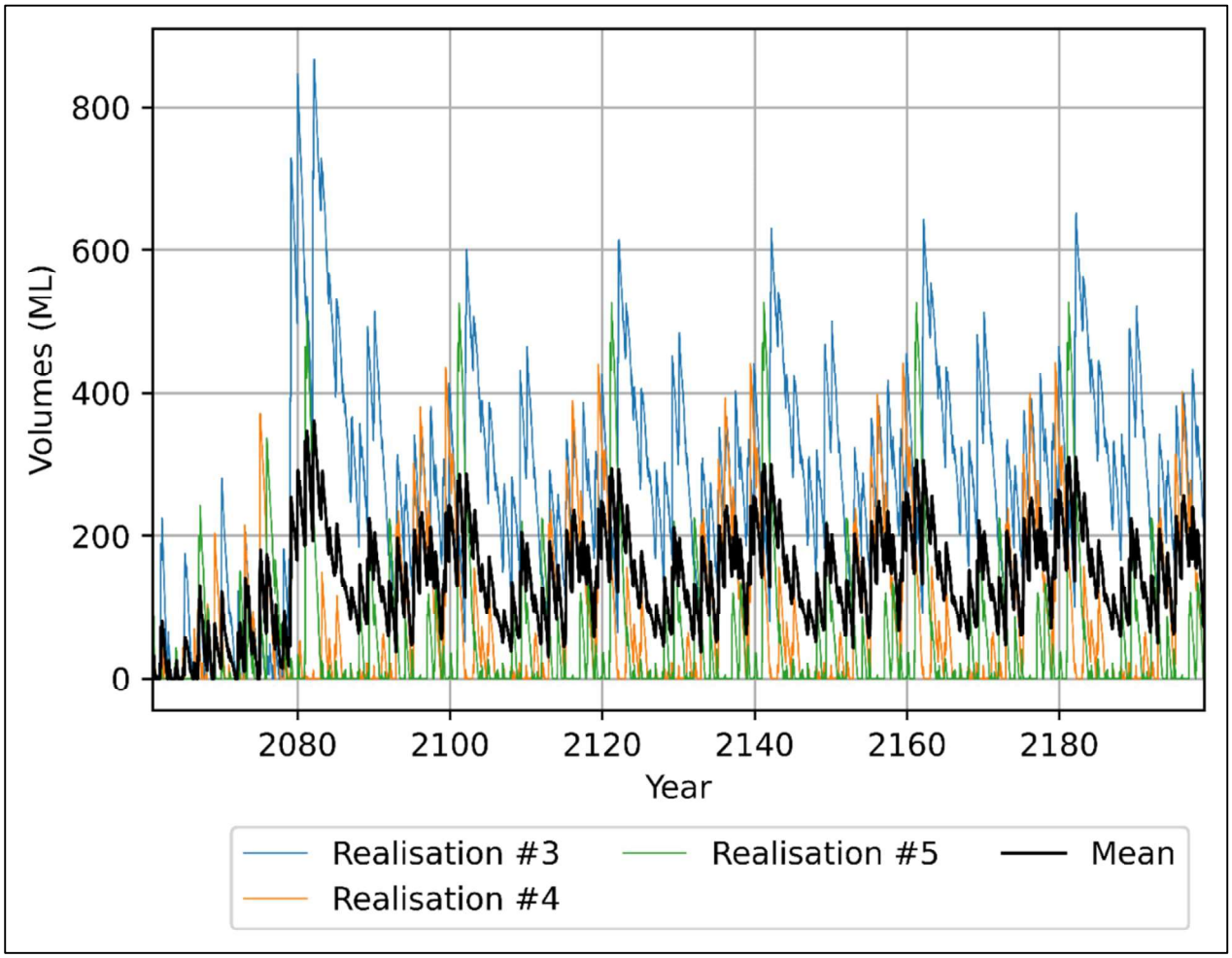


Figure 6.18: Modelled water volumes for Isaac residual void (realisations 3,4, and 5)

6.2.4 R32 South residual void

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance has reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.19. The mean (total) annual inflow to R32 South residual void is 88 ML/year for the simulation period of 2180 to 2199, equal to the mean annual outflow for the same period. This indicates that the mean water balance for R32 South residual void can be considered to have reached equilibrium.

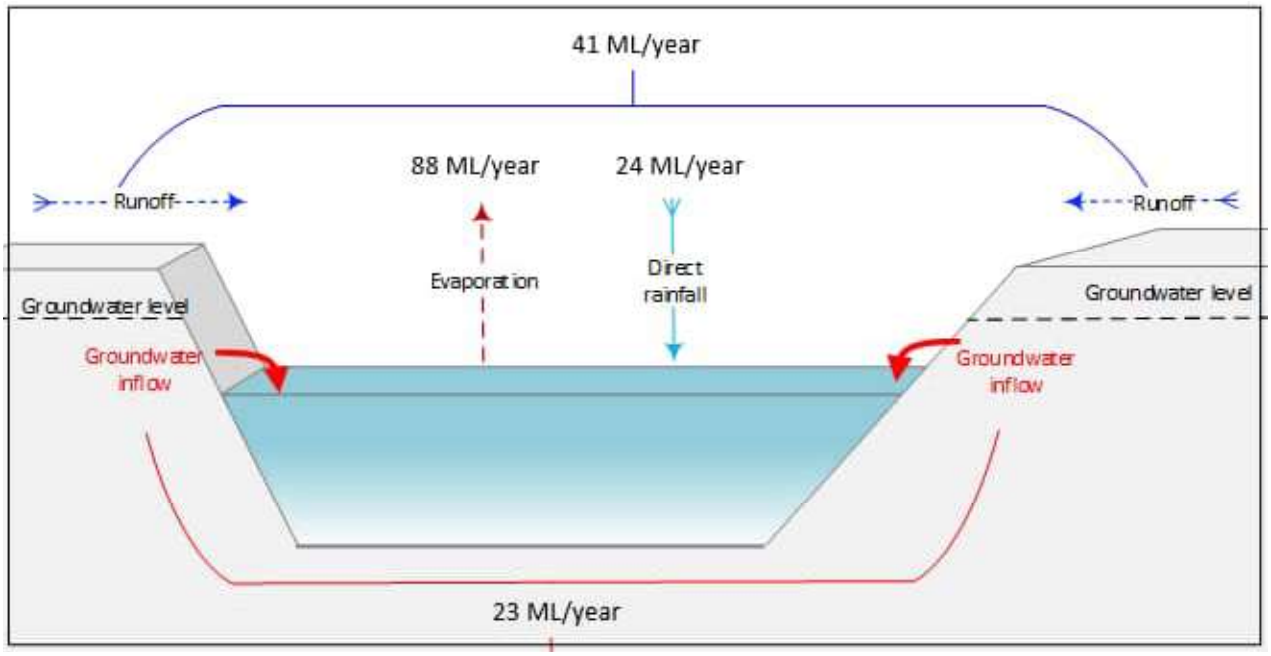


Figure 6.19: Schematic representation of average inflows/outflows simulated for the period from 2180 to 2199 – R32 South residual void (mean volumes from all realisations – 3,4 and 5)

The results from the WBM for R32 South residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2080, the mean void water levels start to stabilise. The mean void water elevation reaches 173 m AHD (Figure 6.20), and the mean void water volume of 190 megalitres (Figure 6.21) across all realisations.

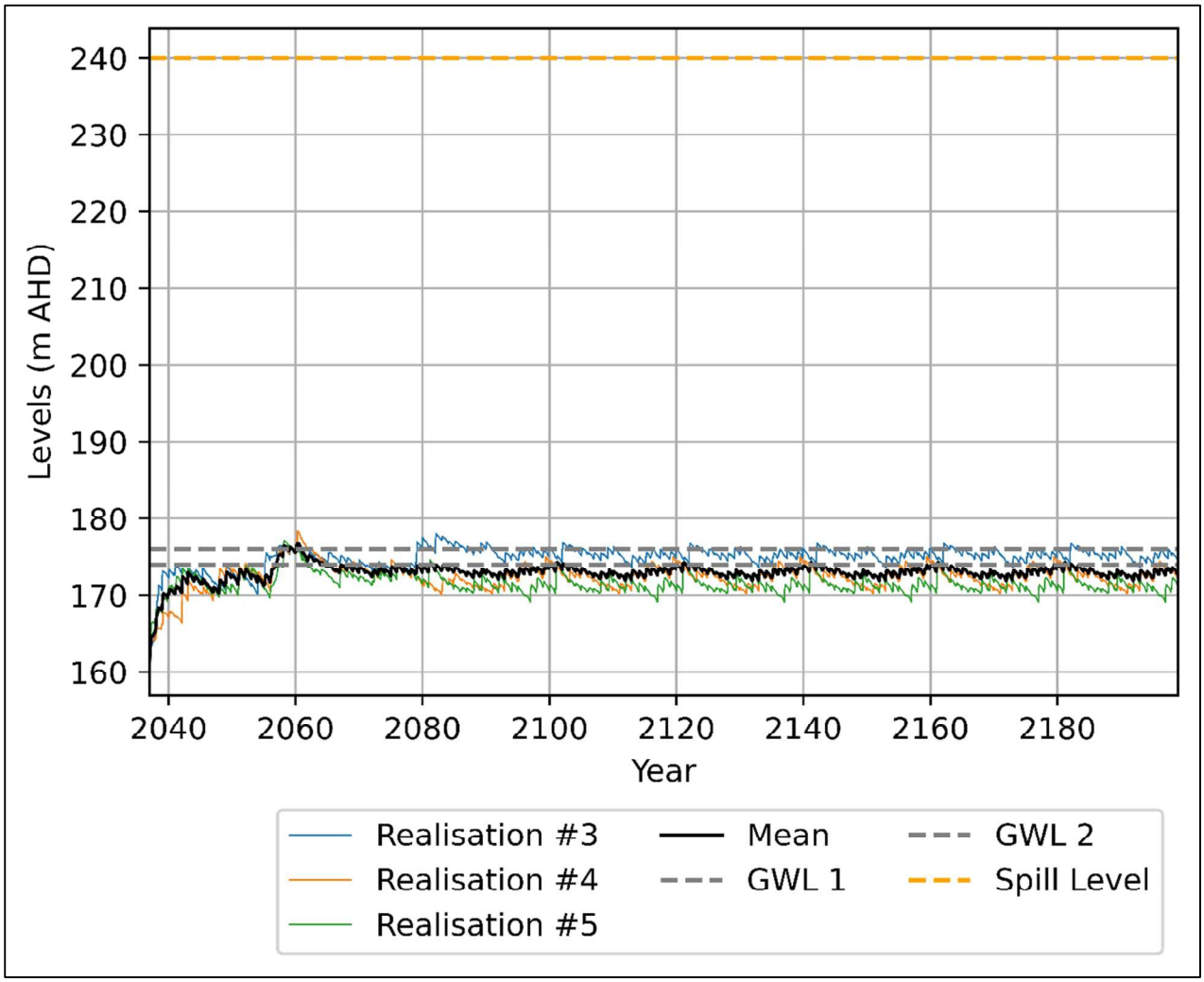


Figure 6.20: Modelled water levels in R32 South residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (realisations 3, 4, and 5)

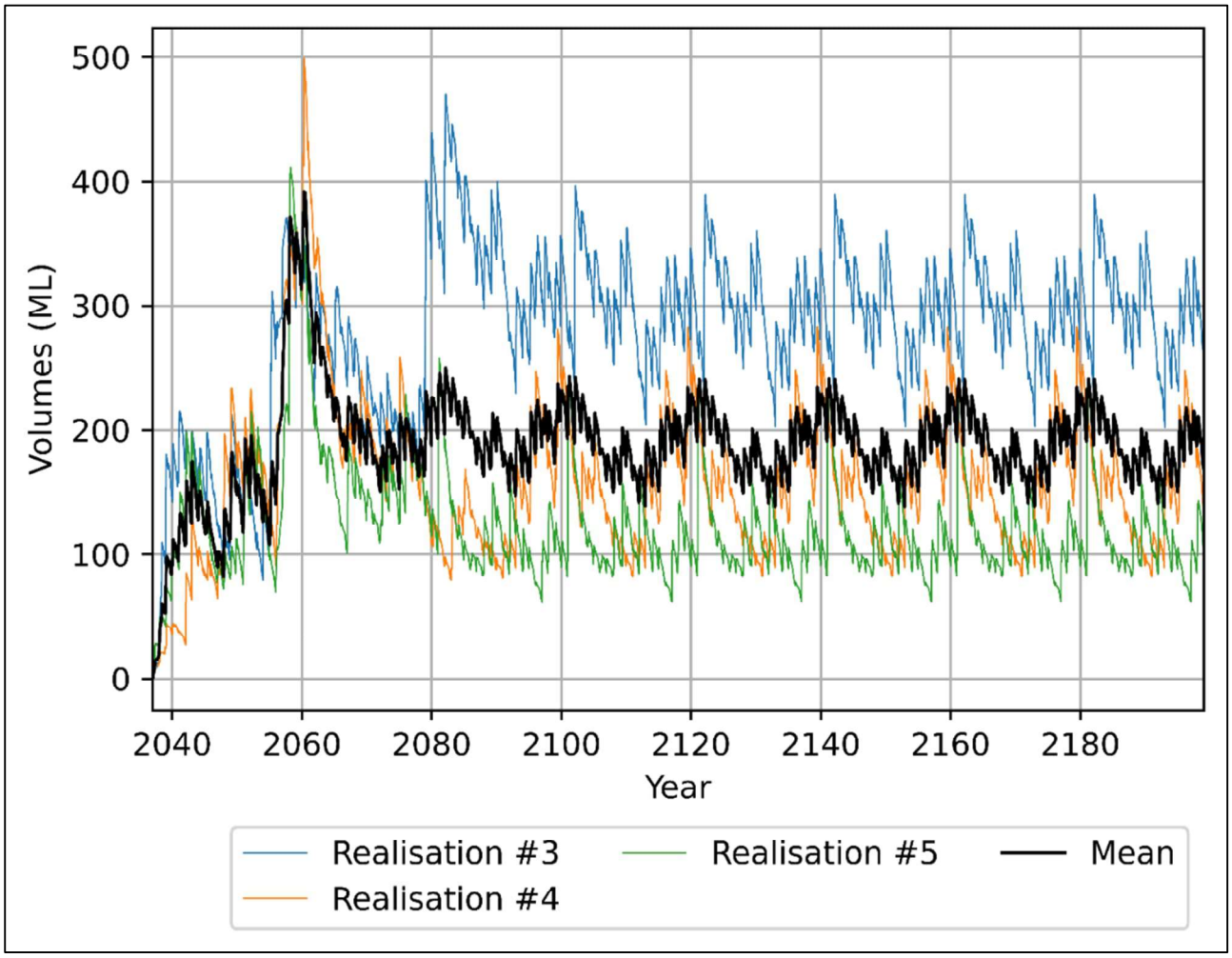


Figure 6.21: Modelled water volumes for R32 South residual void (realisations 3, 4, and 5)

6.2.5 R32 East residual void

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows had reduced, and the mean water balance had reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.22. The mean (total) annual inflow to R32 East residual void is 213 ML/year for the simulation period of 2180 to 2199, equal to the mean annual outflow for the same period. This indicates that the mean water balance for R32 South residual void can be considered to have reached equilibrium.

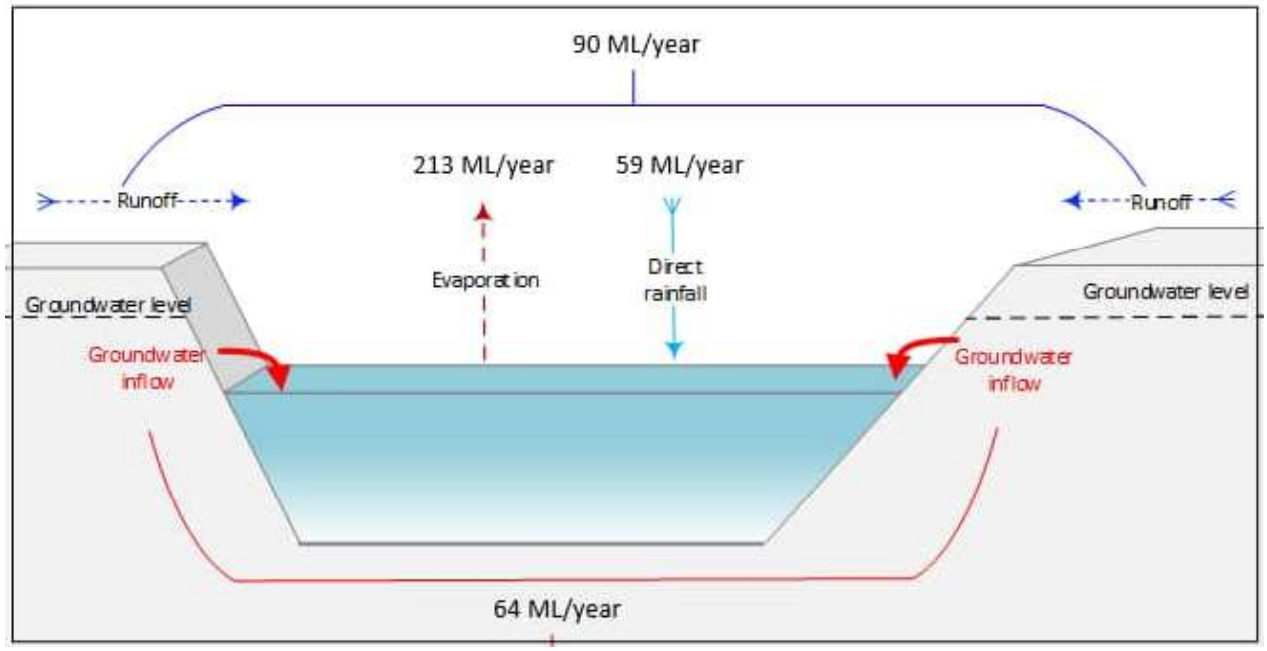


Figure 6.22: Schematic representation of average inflows/outflows simulated for the period from 2180 to 2199 – R32 East residual void (mean volumes from all realisations – 3,4 and 5)

The results from the WBM for R32 South residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2080, the mean void water levels start to stabilise. The mean void water elevation reaches 162 m AHD (Figure 6.23) and the mean void water volume of 709 megalitres (Figure 6.24) across all realisations.

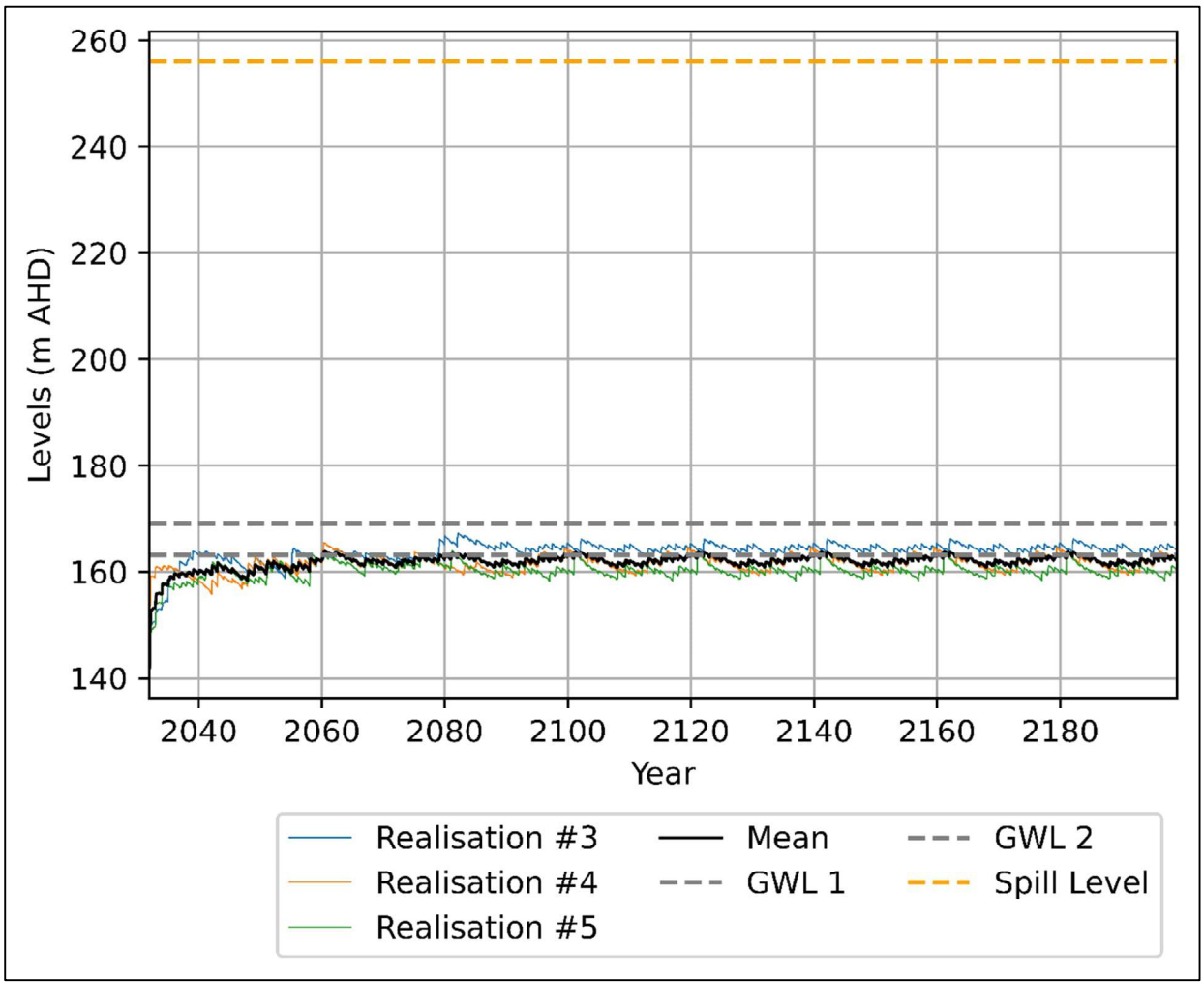


Figure 6.23: Modelled water levels in R32 East residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (realisations 3, 4, and 5)

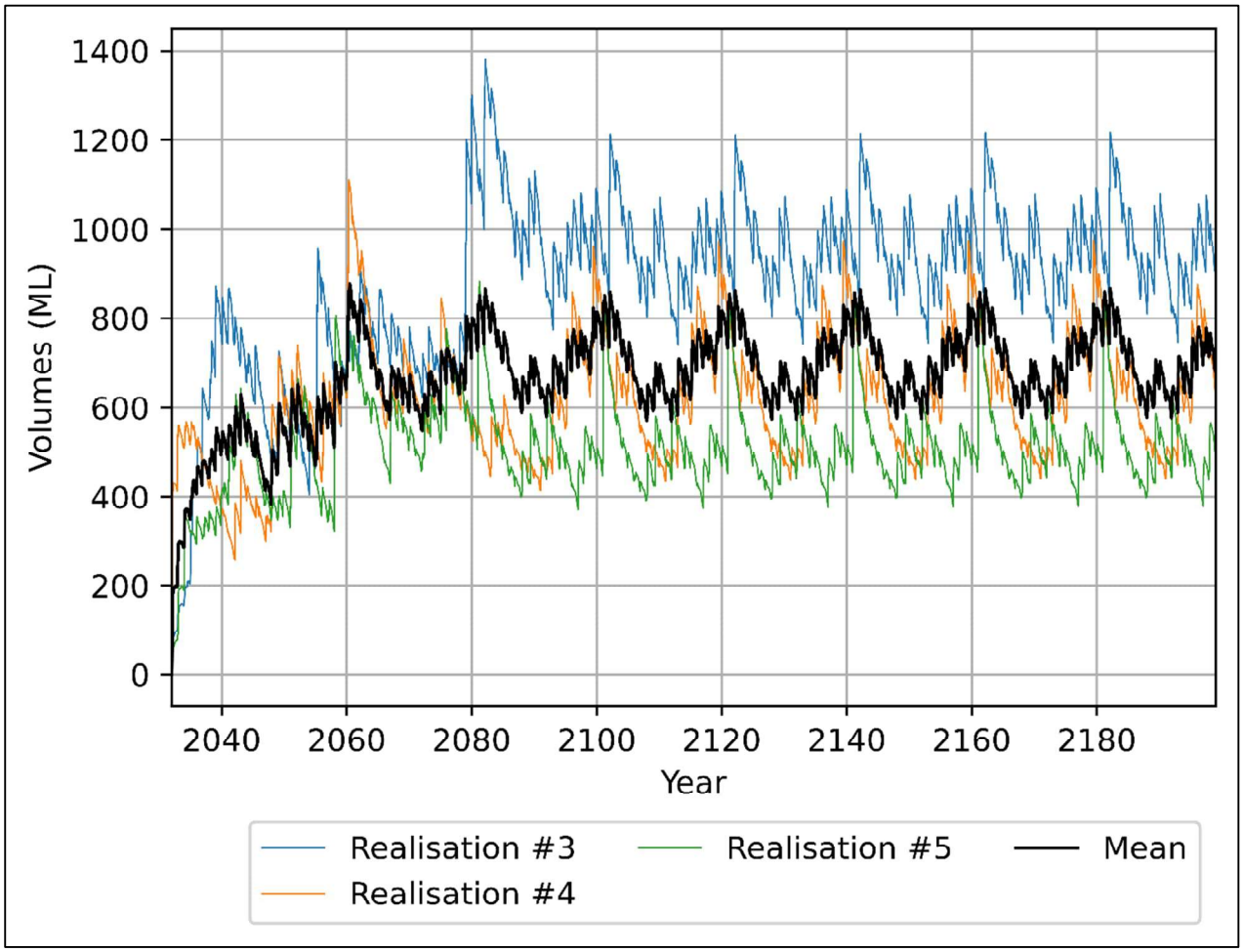


Figure 6.24: Modelled water volumes for R32 East residual void (realisations 3, 4, and 5)

6.2.6 *Thiess residual void*

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance has reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.25. The mean (total) annual inflow to R32 East residual void is 572 ML/year for the simulation period of 2180 to 2199, and the mean annual outflow is 573 ML/yr for the same period. The mean annual outflows are the sum of both evaporative losses and modelled groundwater outflows. This indicates that the mean water balance for Thiess residual void can be considered to have reached equilibrium

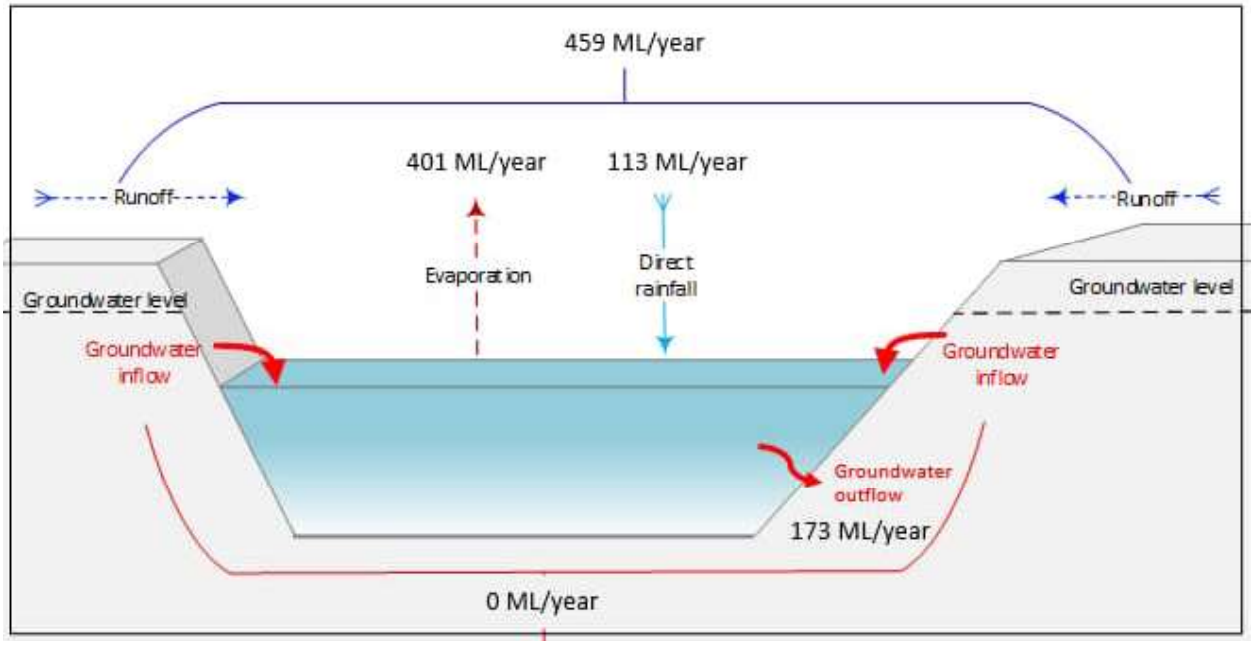


Figure 6.25: Schematic representation of average inflows/outflows simulated for the period from 2180 to 2199 – Thiess residual void (mean volumes from all realisations – 3,4 and 5)

The results from the WBM for Thiess residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2100, the mean void water levels start to stabilise. The mean void water elevation reaches 202 m AHD (Figure 6.25) and the mean void water volume of 1,869 megalitres (Figure 6.26) across all realisations.

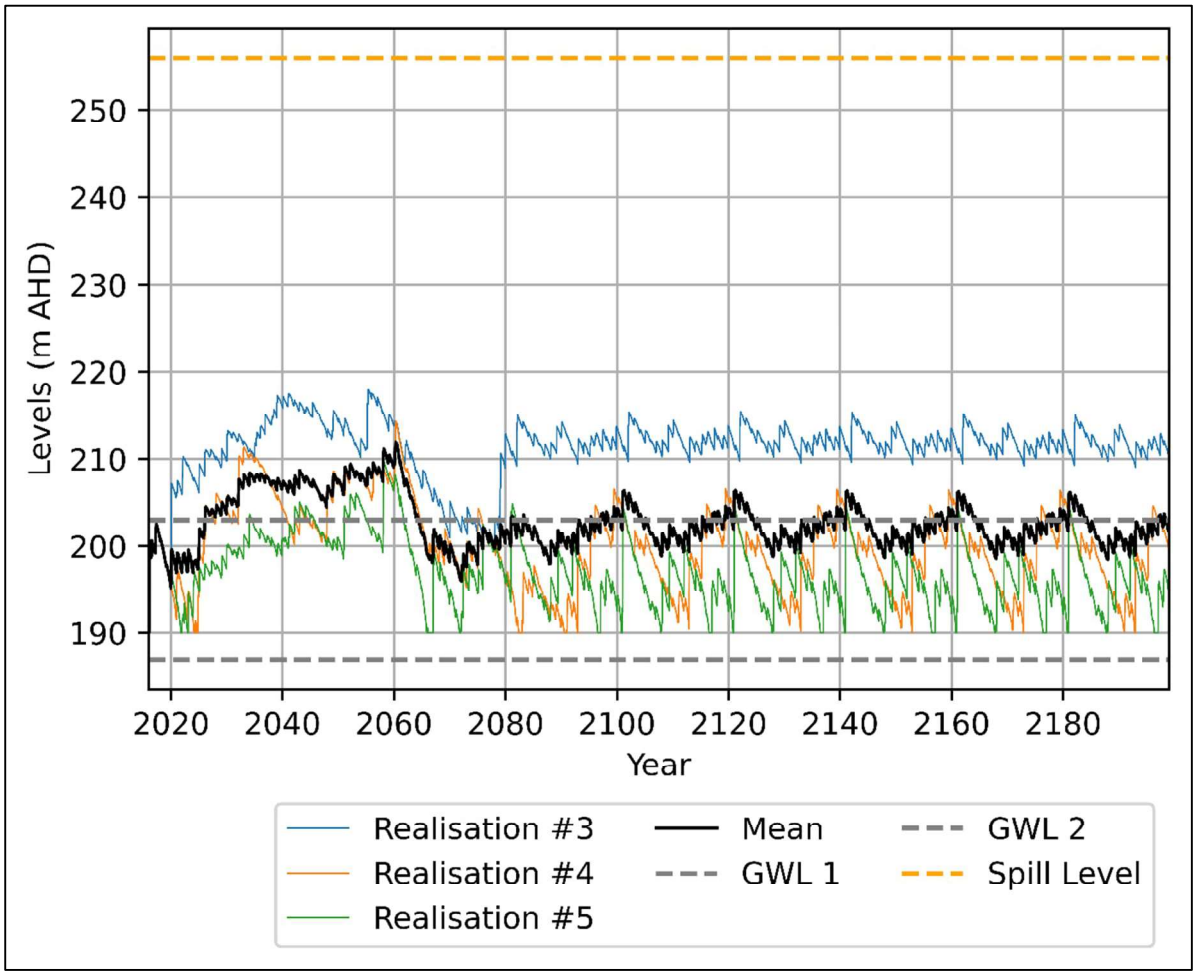


Figure 6.26: Modelled water levels in Thiess residual void compared to spill level and the recovered post-closure groundwater levels (GWL1 = downgradient, GWL2 = upgradient) (realisations 3, 4, and 5)

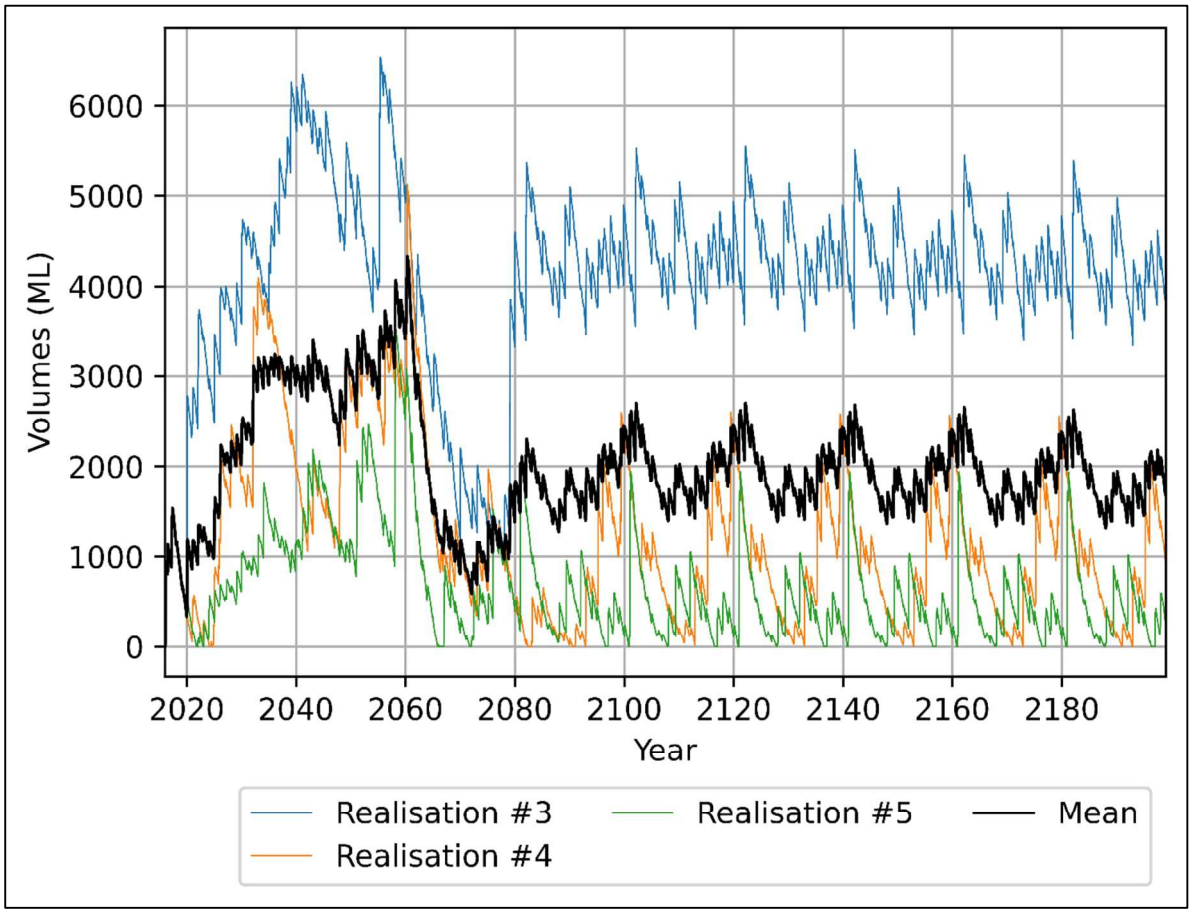


Figure 6.27: Modelled water volumes for Thiess residual void (realisations 3, 4, and 5)

7 Geotechnical stability

Geotechnical stability assessments have been completed to demonstrate that, post-closure, the conceptual void high-wall, end-wall, and low-wall slopes will all exhibit long-term geotechnical stability for the GRBM residual voids. This section presents the assessment findings relevant to void closure at GRBM.

7.1 High-wall and end-wall stability assessment

The method of limit equilibrium was selected to geotechnically assess and quantify the risk of instability for GRBM residual voids' high-walls and end-walls. Limit equilibrium compares forces on a surface with (limiting) strength if the high-wall/end-wall were at the point of failing. Defects may be included explicitly as discrete strata when known, but more often they are implicit within the strengths of broader material layers. The main disadvantage of this method is that it assumes all material along the surface can realise its peak strength at the same time; the significance of any subsequent inaccuracy depends on the load-deformation behaviour of the materials. However, the method is generally accepted by industry as a practical industry method and has therefore been adopted for the PRC plan at GRBM.

Factor of Safety (FoS) computed by limit equilibrium is essentially a ratio of the strength available to hold a slope in place divided by the loads tending to move, or destabilise, material behind the slope face. Thus, an FoS less than one indicates instability, and a value greater than one implies that the slope is stable because the capacity to resist slipping is greater than the forces promoting slipping. A FoS is a relatively coarse and simplified measure of stability that was devised to use as a design methodology. In this context, a minimum value somewhat greater than one is specified to allow for inaccuracies and uncertainties in both the method and the input data.

As a design or performance criterion, the selected minimum FoS should be appropriate to the consequences if instability did occur, which in the closure context in turn relates to land use (Martin & Stacey, 2018). A minimum FoS of 1.5 is often adopted for long-term stability of civil engineering features such as road cuttings and dam walls, that is, features with broad public access. By contrast, a FoS of 1.2 is typically applied to operational design for BMA coal mine pit walls, where stability is required for a shorter time and with limited human exposure.

Pending industry research to develop observational methods and consequence assessment for long-term pit wall stability, BMA has adopted a minimum FoS of 1.5 for closure planning. However, a too-conservative approach could lead to an unnecessary increase in void area and additional land disturbance at the potential expense of adjoining higher-value land uses. Hence, BMA is applying the minimum FoS, not to the physical crest of the pit wall but instead:

- To a distance set-back behind the crest, such that there are no environmental or third-party assets of significant value within that set-back; or
- To the final void walls, which have been located such that their computed set-back does not include any valuable assets.

This approach allows for flexibility to apply improvements in stability practice in the future and translates to both the high-walls and end-walls. At closure, all third-party assets will remain outside any identified zones of instability (i.e., a FoS equal to or less than 1.5). This constraint is illustrated in Figure 7.1. The NUMA extent will include the required set-back to achieve the minimum FoS.

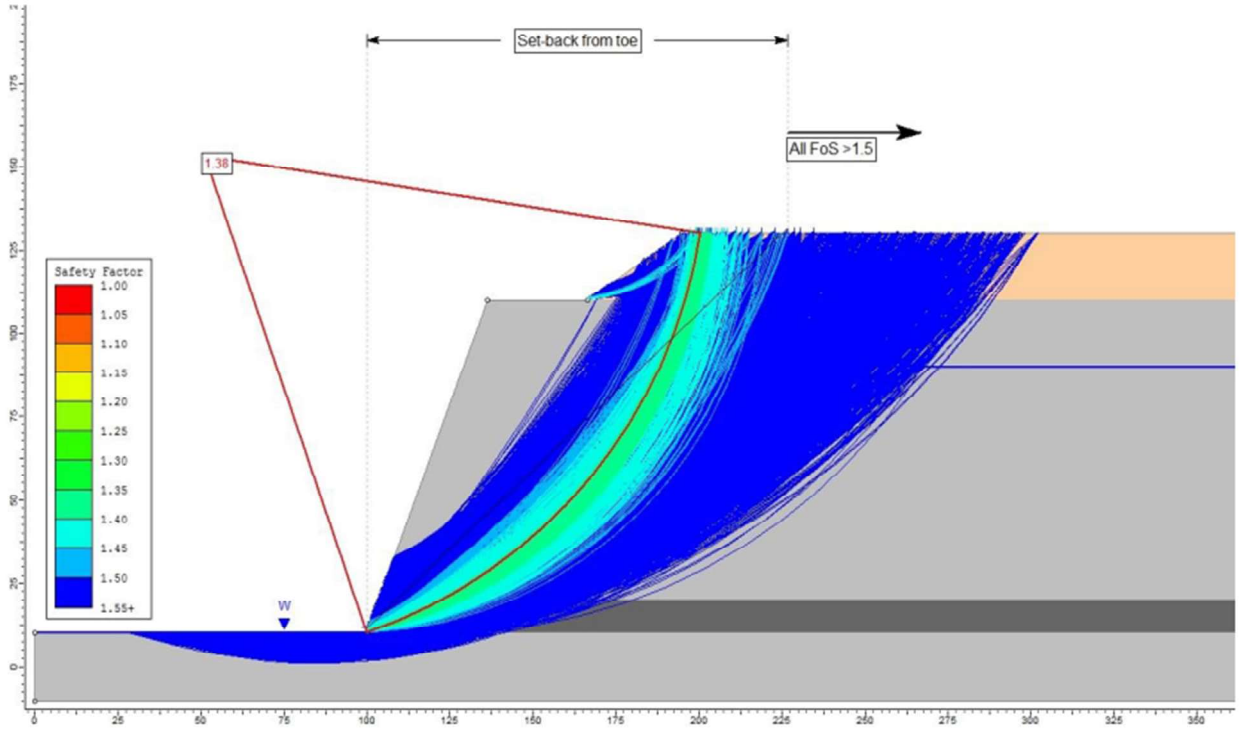


Figure 7.1: Example illustration of set-back to FoS of ≥1.5

BMA has developed a pit wall stability design tool for determining set-backs for long-term pit wall stability at BMA coal mines.

A common engineering approach, when it is anticipated that designs will be required for a large number of similar scenarios, is to undertake upfront a large number of analyses to cover the range of expected scenarios and collate the results into a design tool, for example design charts or empirical formulae or lookup tables. It is important to appreciate that such tools do not omit design analyses, it is simply that all the analyses are carried out first so that when a particular scenario is considered, the result is already available. Set-backs for long-term pit wall stability at BMA coal mines clearly lends themselves to this approach – regional geology is broadly consistent; mining methods constrain the range of efficient wall geometries; and given the number of pits and different planning horizons, there will be a large number of specific scenarios to address over time.

The key features of this design tool are summarised in Sections 7.1.1 and 7.1.2. The design tool is used for initial planning. Individual assessment of each high-wall and end-wall will be undertaken as part of the final pit detailed designs as mining approaches the final pit extents.

7.1.1 Inputs to assessment – regional

7.1.1.1 Regional geology and geotechnical (strength) properties

In the context of wall stability, the important geological boundaries are base of Tertiary and base of weathering; however, for simplicity in the design tool, Tertiary and weathered Permian rocks were treated as one material, which is a conservative approach. Stability analyses (forming the basis of the design tool) used the wall geometry and assumed strength properties summarised in Table 7.1 and Table 7.2 respectively.

Table 7.1: Wall geometry covered by the stability design tool

Aspect	Value range
Average wall angle in Tertiary overburden	35° (constant)
Depth of Tertiary/weathered overburden	1 m to 100 m
Bench width at base of Tertiary overburden	30 m (constant)
Average wall angle in Permian overburden	40° to 70°

Table 7.2: Strength properties applied in the stability design tool

	Cohesion (kPa)	Friction angle (°)	Unit weight (kN/m^3)
Tertiary/weathered	50	30	22
Fresh Permian	450	42	24
Coal	30	35	15

7.1.1.2 Effect of weathering

The effects of weathering on the character and strength of rocks and hence the long-term stability of pit walls only relates to weathering that might occur after cessation of mining, being physical degradation and chemical decomposition. Degradation depends heavily on water ingress and is largely restricted to the surface of pit walls and does not penetrate far enough to cause geotechnical instability. An exception may be when particularly moisture-sensitive rock is below the long-term void water level that is addressed by adopting saturated strength properties.

Chemical decomposition involves reactions of the actual rock minerals to form different minerals (ultimately, clay minerals) and occurs at the crystalline/molecular level at a very slow rate relative to other processes. Chemical weathering only occurs where water and other reactants can reach and therefore occurs mainly at the rock surface and along joints and bedding planes.

Both phases of weathering occur fastest in hot, wet climates – rainfall providing the necessary moisture, and high temperature promoting chemical reactions. The climate at GRBM is hot but not wet and as such only “very slight” ongoing weathering is expected. Very specific situations where even a very small amount of additional weathering might affect pit wall stability are generally localised that may only be apparent when the pit wall is excavated. Generally, these situations cannot be planned for and will be assessed and managed at the end of coal extraction at the detailed design stage for closure.

7.1.1.3 Effect of long-term erosion

Erosion is the detachment of solid particles from the soil or rock mass and the subsequent transport of those particles away from their initial location.

On high-walls and end-walls in the Bowen Basin, erosion in fresh rock is mainly limited to material that has already slaked because the intact rock is too strongly bound for particles to be readily detached. Above the base of weathering, particles are more easily detached. As particles are transported in water flow, erosion develops and progresses over time along flow lines. These are mainly perpendicular to the line of the wall. By contrast, slip failures involve surfaces that are at least sub-parallel to the line of the wall. Consequently, erosion rarely causes geomechanical instability and generally has little impact on geomechanical stability in in-situ pit wall geotechnical stability. Erosion is generally addressed through surface water and erosion control measures rather than by slope stability design. Therefore, it has not been considered further in this assessment.

7.1.2 Effect of significant hydrological events

In Bowen Basin coal mines, weathered overburden is generally susceptible to softening when saturated, especially materials containing significant clay. Water balance modelling for the proposed residual voids at GRBM predicts average and long-term void water levels many metres below the base of weathering. Consequently, void water will only contact fresh rock and so will not affect geotechnical stability of the excavated pit walls.

The most serious potential impact of severe rainfall events would be the inrush of floodwaters to the void. For the final closure state landform, spoil placement will be conducted so that the final residual voids for the NUMA will not be subject to inundation from floodwaters up to and including the 0.1% AEP climate change event with 20% increase in rainfall intensity.

A final mode of instability related to water storage is drawdown failure. This can occur when pore water pressures in the containing earth and rock have equilibrated with the water level in the storage and that water level is then lowered quicker than the containing materials can drain, causing imbalance in the pore pressures. This will not be an issue for voids which contain water passively because evaporation will not lower the water level at a rate to establish this imbalance.

7.1.3 Inputs to assessment – local

Long sections extracted from the current GRBM geological model provided void wall profile data as summarised in Table 7.3.

Table 7.3: Geotechnical profiles for the residual void walls at Goonyella Riverside Mine

Geotechnical profile parameters		Goonyella	Broadmeadow	Isaac	Thiess	R32 East	R32 South
Depth of Tertiary/ weathered overburden (m)	Average Range 90% less than	27 20-36 34	20 19-22 216	23 21-25 25	27 21-42 36	19 18-23 21	28 22-36 34
Thickness of base coal seam (m)	Average Range 90% less than	8.9 6.0-12.1 9.9	6.4 6.2-6.7 6.6	5.7 5.3-6.5 6.1	5.9 4.6-8.5 7.9	6.6 3.6-7.1 7.1	6.8 6.6-7.3 7.1
Depth of fresh overburden (m)	Average Range 90% less than	277 213-317 304	71 41-80 80	55 50-58 58	50 44-60 56	76 67-88 85	41 35-44 44
Total Wall depth (m)	Average Range 90% less than	304 242-342 328	91 62-101 100	77 74-81 80	78 73-87 80	94 89-106 103	69 65-73 72

The depth ranges for Tertiary/weathered and fresh Permian overburdens for the Goonyella, Isaac, R32 East residual voids are within the application limits for the design tool. Coal at the pit base was slightly thicker than 10 m at one end of Goonyella void, however the affected segment was less than 10% of the total pit length and, therefore was not considered significant.

Most of Broadmeadow and Thiess residual voids, except for one segment in Broadmeadow and two segments in Thiess residual voids are within the application limits for the design tool. R32 South residual void was outside the application limits of the design tool. However, for all Broadmeadow and Thiess segments and the R32 South void, the depth of fresh overburden was less than the lower limit for the design tool (50m) and therefore the pit depth was conservatively increased to meet the fresh overburden constraint.

Computations were made with an assumed wall angle of 60°. The computed set-back from the wall toe is not sensitive to the wall angle, but steeper angles are slightly more conservative as they impose greater overburden weight on the

potential slip surface. The thickness of the coal seam at the pit floor for these voids ranged up to 10 m, which is the assumed thickness in the design tool (10 m).

The design tool is used for initial planning only. Individual assessment of each high-wall and end-wall will be undertaken as part of the final pit detailed design stage required as mining approaches the final pit extents and as additional geological and geotechnical data becomes available.

The procedure for estimation of set-back distance developed in the design tool is:

1 If $D_{TW} \leq 47$m, $FoS_{TW} > 1.5$ and $S_{TW} = D_{TW}/\tan(35°)$.

2 Otherwise $S_{TW} = 2.58*D_{TW} - 41.5$.

3 $S_1 = S_{TW} + 30 + D_P/\tan(A_P)$.

4 $FoS_P = 1.208 + 0.0655/\sqrt{D_{TW}} + 13.87/\sqrt{D_P} - 0.0168A_P$; if $FoS_P > 1.5$ then $S_P = D_P/\tan(A_P) + 30 + D_{TW}/\tan(35°)$.

5 Otherwise, $S_P = 0.856*D_{TW}^{1.15} + 3.727*D_P^{0.94} + 39.35\tan(A_P)^{1.09} + 35.01\ FoS_P^{2.49} - 389$.

6 Required set-back from the wall toe = $\max(S_1, S_P)$.

Where:

- D_{TW} = depth of Tertiary/weathered overburden (m).
- D_P = depth of fresh Permian overburden (m).
- A_P = average wall angle in fresh Permian overburden (degrees).
- S_{TW} = set-back for stability in Tertiary/weathered overburden (m), measured from the toe of the weathered overburden batter.
- S_1 = set-back for the whole operational wall design (m), measured from the toe of the whole wall.
- S_P = set-back for stability of whole wall (m), at FoS = 1.5.

The set-back calculation does not consider underground access points. Stability in those areas is a focus during design and operation, but further assessment of long-term geotechnical stability will be undertaken as part of the final assessment when operations cease.

7.1.4 High-wall and end-wall stability assessment results

The results for the GRBM high-walls are summarised in Table 7.4. Set-backs for end-walls will range from the value at the end of each high-wall down to the value coinciding with the excavated wall crest as the exposed wall height reduces.

Table 7.4: Set-backs for long-term wall stability at Goonyella Riverside Mine

Geotechnical profile parameters		Goonyella	Broadmeadow	Isaac	Thiess	R32 East	R32 South
S1 (m)	Average Range 90% less than	176 140-197 189	53 41-59 58	45 43-47 46	46 42-53 49	55 51-61 59	45 42-50 48
FoS_P	Average Range 90% less than	1.05 0.99-1.16 1.01	1.86 1.77-2.18 1.77	2.09 2.03-2.17 2.04	2.13 2.01-2.17 2.07	1.82 1.69-1.91 1.72	2.17 2.17-2.18 2.17
Sp (m)	Average Range 90% less than	497 351-581 557	100 88-107 105	94 91-97 96	99 87-119 110	101 97-106 105	98 91-110 107

Geotechnical profile parameters		Goonyella	Broadmeadow	Isaac	Thiess	R32 East	R32 South
Set-back from toe of wall (m)	Average Range 90% less than	497 351-581 557	100 88-107 105	94 91-97 96	99 87-119 110	101 97-106 105	98 90-110 107

This set-back approach to long-term geotechnical stability offers several options to meet the requirements for mine closure including:

- Stop mining within the pit when the toe of each pit wall reaches at least the set-back distance away from significant permanent assets, including lease boundaries, third-party infrastructure, and Matters of State Environmental Significance.
- Move the asset in question (e.g. relocate a public road).
- Undertake a more detailed geotechnical investigation and wall stability analysis to remove some of the conservatism imposed by the design tool.
- Plan for partial backfill of the residual void. In simple terms, this would reduce the (exposed) wall depth and depth of fresh Permian overburden, reducing the set-back.
- For GRBM, the conceptual voids have been designed with the final void walls the required distance away from significant permanent third-party assets. The design will be refined with detailed individual geotechnical assessment as mining of the pits approaches the final extents. The NUMA extents include the calculated set-back distance to achieve geotechnical stability within the NUMA.
- As stated in section 7.1.3, this assessment does not apply to area around the underground access points within the voids. Stability in these areas is a focus during design and operation, but further assessment of long-term geotechnical stability will be undertaken as part of the final assessment when operations cease.

7.2 Low-wall stability assessment

The geotechnical stability of low-walls has been assessed for the GRBM residual voids with the purpose of demonstrating that, post-closure, void low-wall slopes will exhibit long-term geotechnical stability.

Stability analyses of the low-wall final closure state landform for the GRBM residual voids was undertaken using the two-dimensional (2D) limit equilibrium analysis software Slide2 (version 9.010). Cross-sections were selected that represented the interpreted critical (worst case) low-wall conditions from a stability point of view, targeting areas of greatest spoil height and steepest floor dip. R32 East residual void was not assessed as this void does not contain low-walls. The section locations for the analyses are presented in Figure 7.2 and the corresponding sections are identified as:

- Section 1 (Goonyella residual void).
- Section 2 (Thiess residual void).
- Section 3 (Broadmeadow residual void).
- Section 4 (Isaac residual void).
- Section 5 (Ramp 32 South residual void).

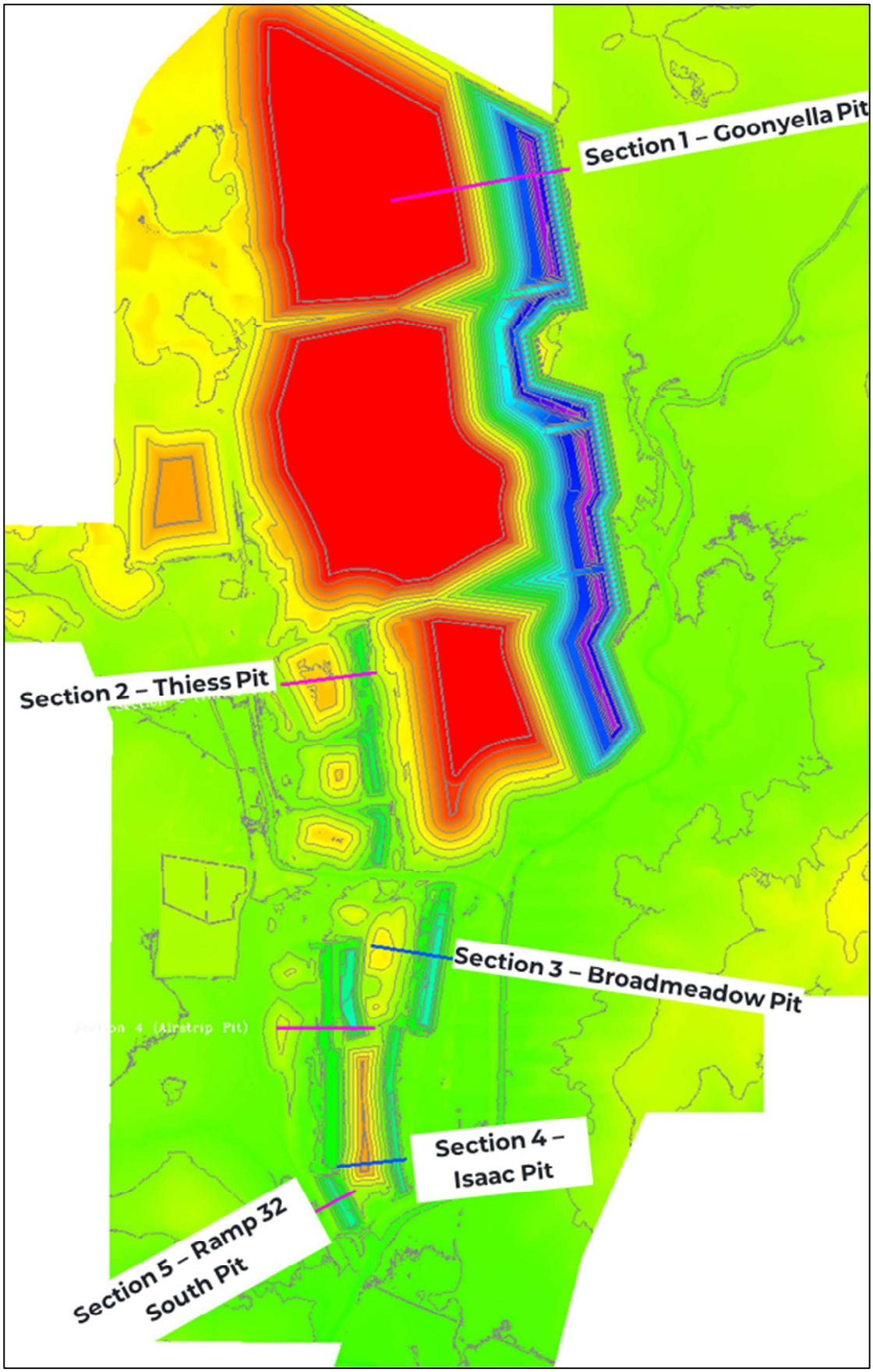


Figure 7.2: Cross-section locations for the GRBM residual voids low-wall stability analyses

For each of the cross-sections, the following analysis cases were considered:

- Slope configuration based on the 3D final closure state landform and 3D final pit floor profile. Two alternative failure mechanisms including:
  - Circular analyses using *Morgenstern-Price*.
  - Non-circular using *Sarma* and *Morgenstern-Price*, non-vertical slices.
- Alternative cases of failure extents, including:
  - Global stability: slip surfaces extending from the Post Mine Land Use (PMLU) area of the low-wall slope to the spoil toe at pit floor level.
  - Local stability: slip surfaces constrained to within the PMLU area of the low-wall slope, outside of the NUMA.

The results for the low-wall stability assessment analyses for GRBM residual voids that returned the lowest FoS are presented in Sections 7.2.1 to 7.2.5.

7.2.1 Goonyella residual void

The geotechnical stability assessment for Goonyella residual void concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was > 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.5, and depicted in Figure 7.3 and Figure 7.4.

Table 7.5: Summary of low-wall geotechnical stability analysis results for Goonyella residual void

Section	Low-wall spoil height (m)	Minimum Factor of Safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
1	400	1.62	2.32

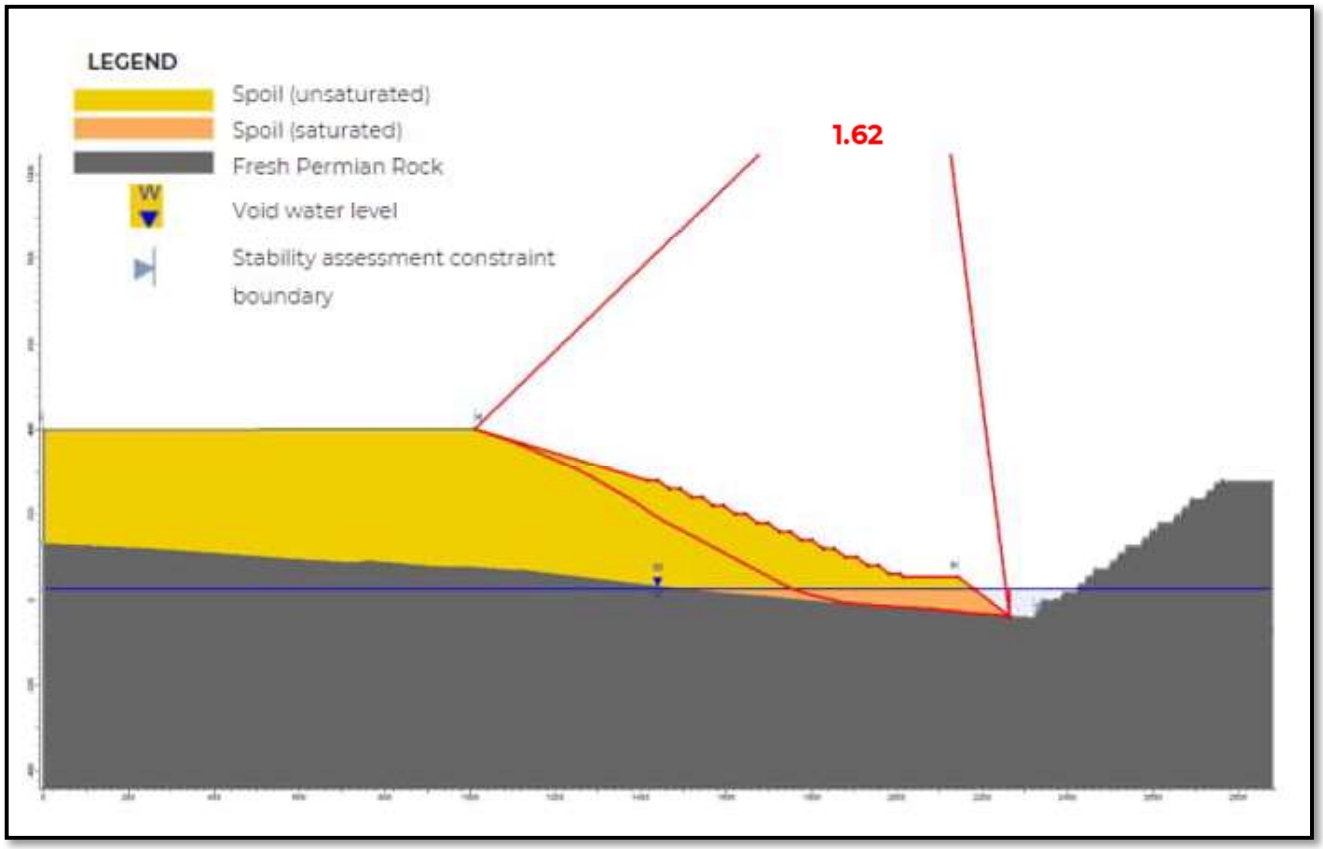


Figure 7.3: Goonyella residual void (cross-section 1) – global stability (Morgenstern-Price, non-circular)

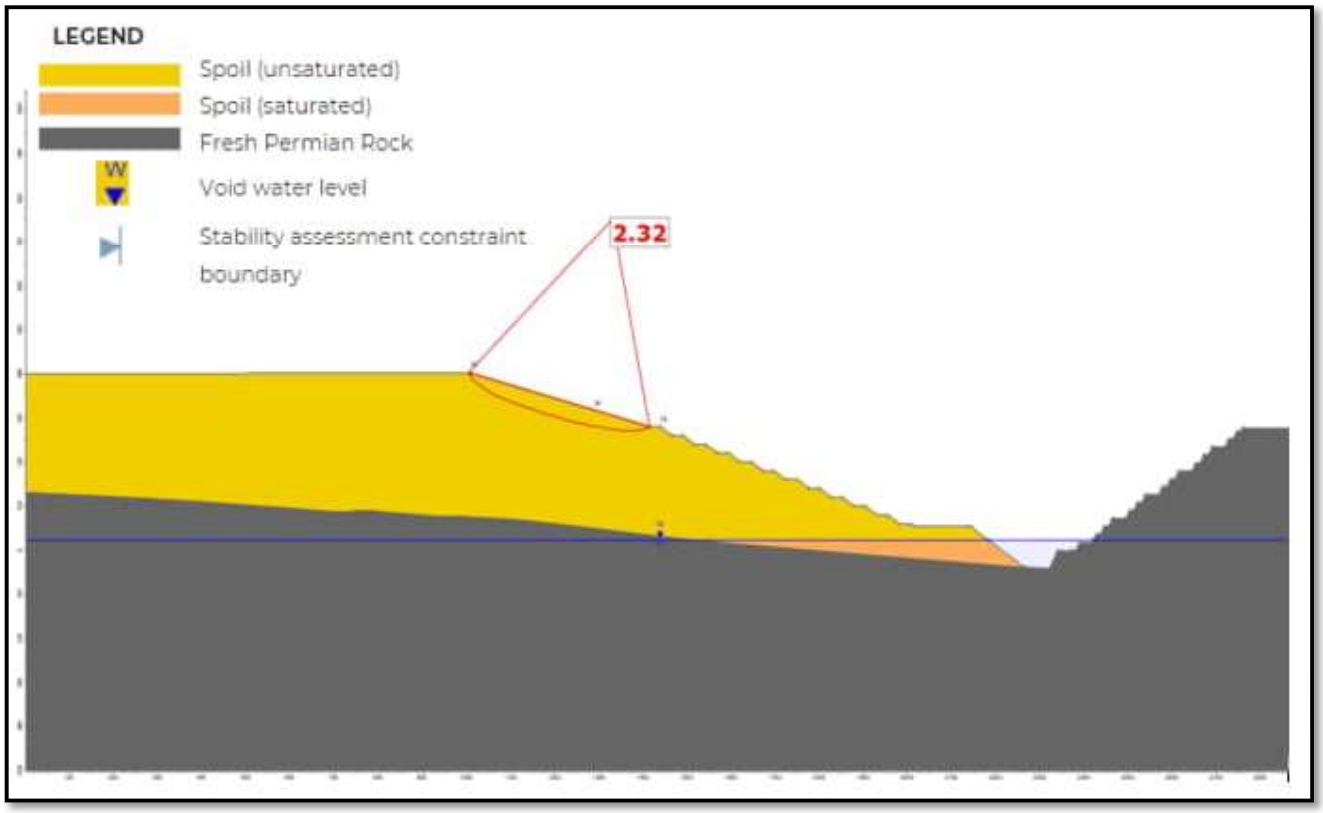


Figure 7.4: Goonyella residual void (cross-section 1) – local stability (Morgenstern-Price, non-circular)

7.2.2 *Broadmeadow residual void*

The geotechnical stability assessment for the Broadmeadow residual void concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was > 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met with the inclusion of management measures.

A summary of the analysis results is provided in Table 7.6, and depicted in Figure 7.5 and Figure 7.6.

Table 7.6: Summary of low-wall geotechnical stability analysis results for Broadmeadow residual void

Section	Low-wall spoil height (m)	Minimum Factor of Safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
3	263	2.84	4.67

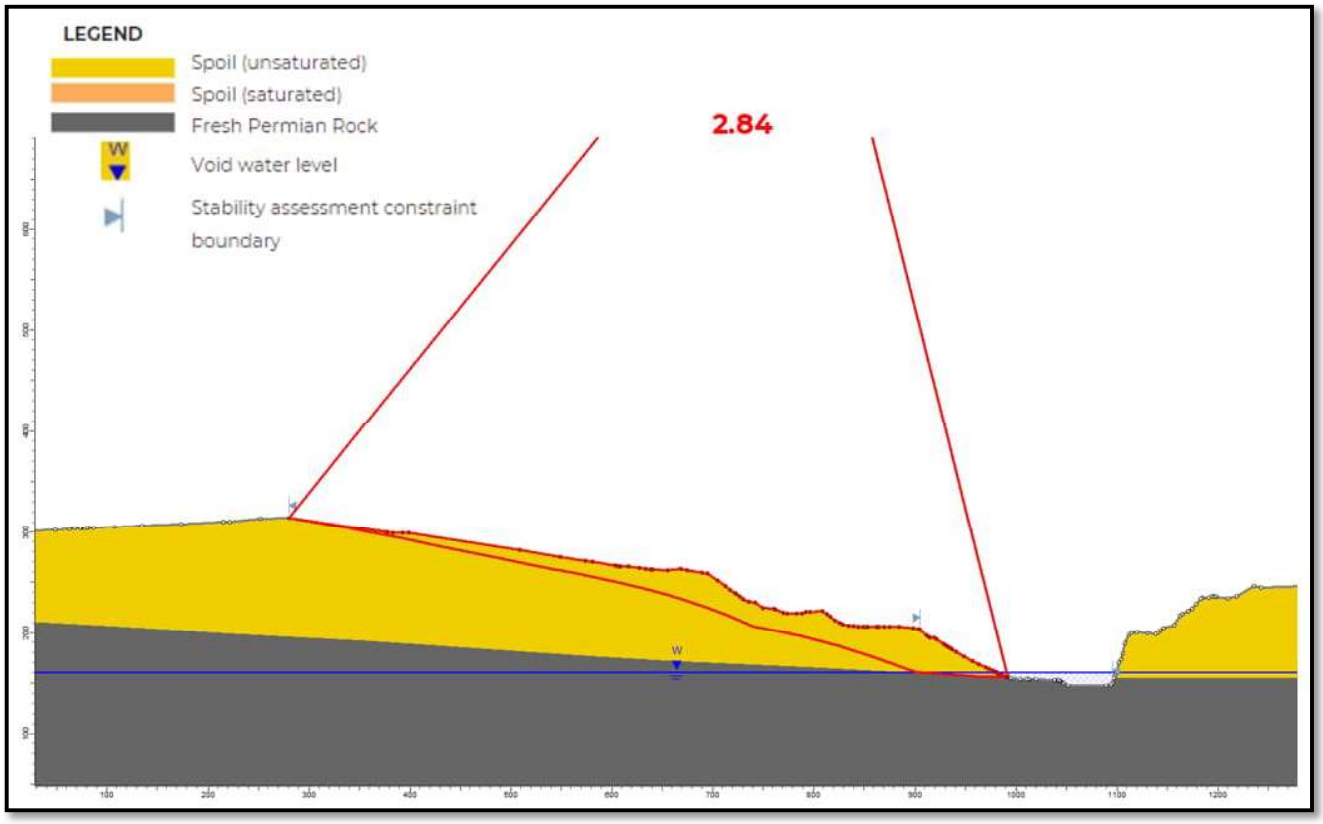


Figure 7.5: Broadmeadow residual void (cross section 3) – global stability (Morgenstern-Price, non-circular)

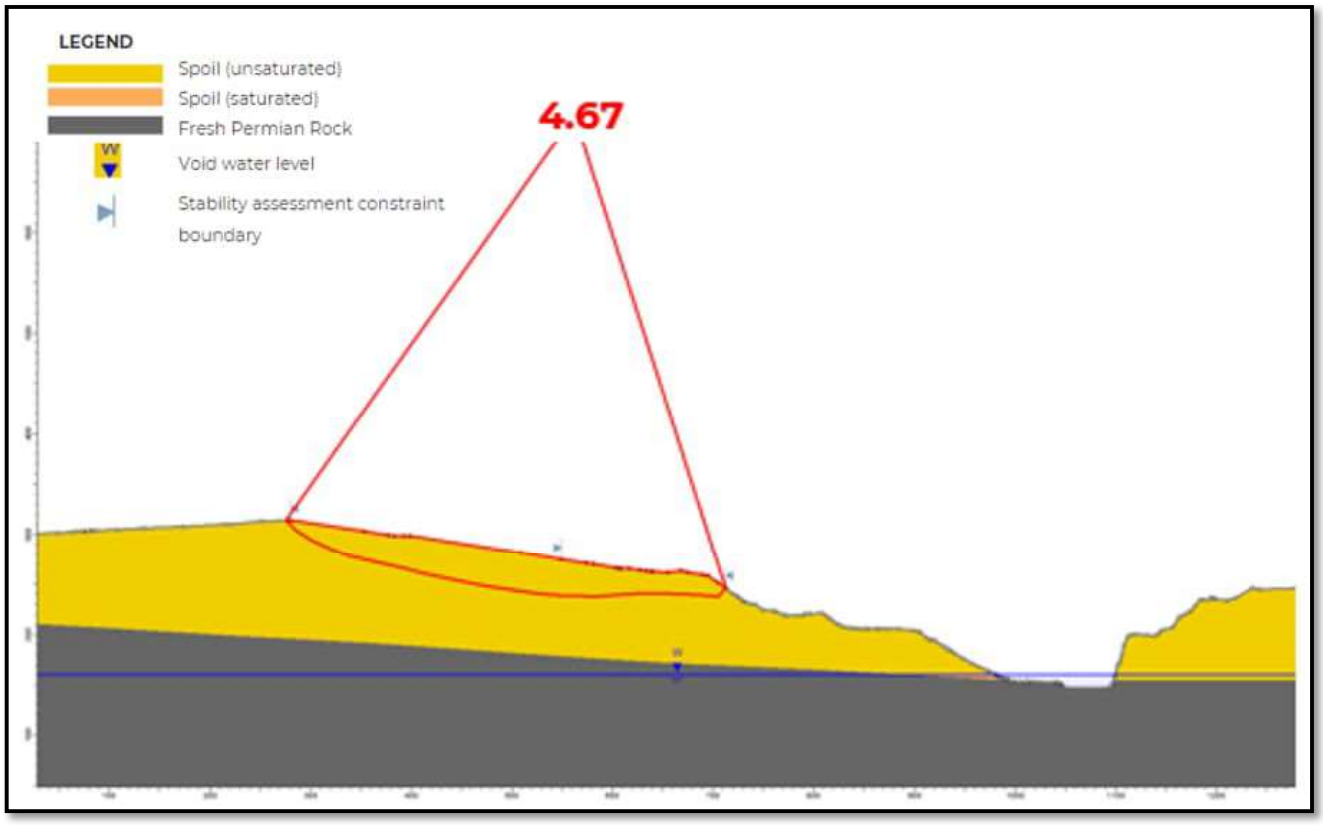


Figure 7.6: Broadmeadow residual void (cross section 3) – local stability (Morgenstern-Price, non-circular)

7.2.3 *Isaac residual void*

The geotechnical stability assessment for Isaac residual void concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was > 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.7, and depicted in Figure 7.7 and Figure 7.8.

Table 7.7: Summary of low-wall geotechnical stability analysis results for the Isaac residual void

Section	Low-wall spoil height (m)	Minimum Factor of Safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
4	340	1.79	2.38

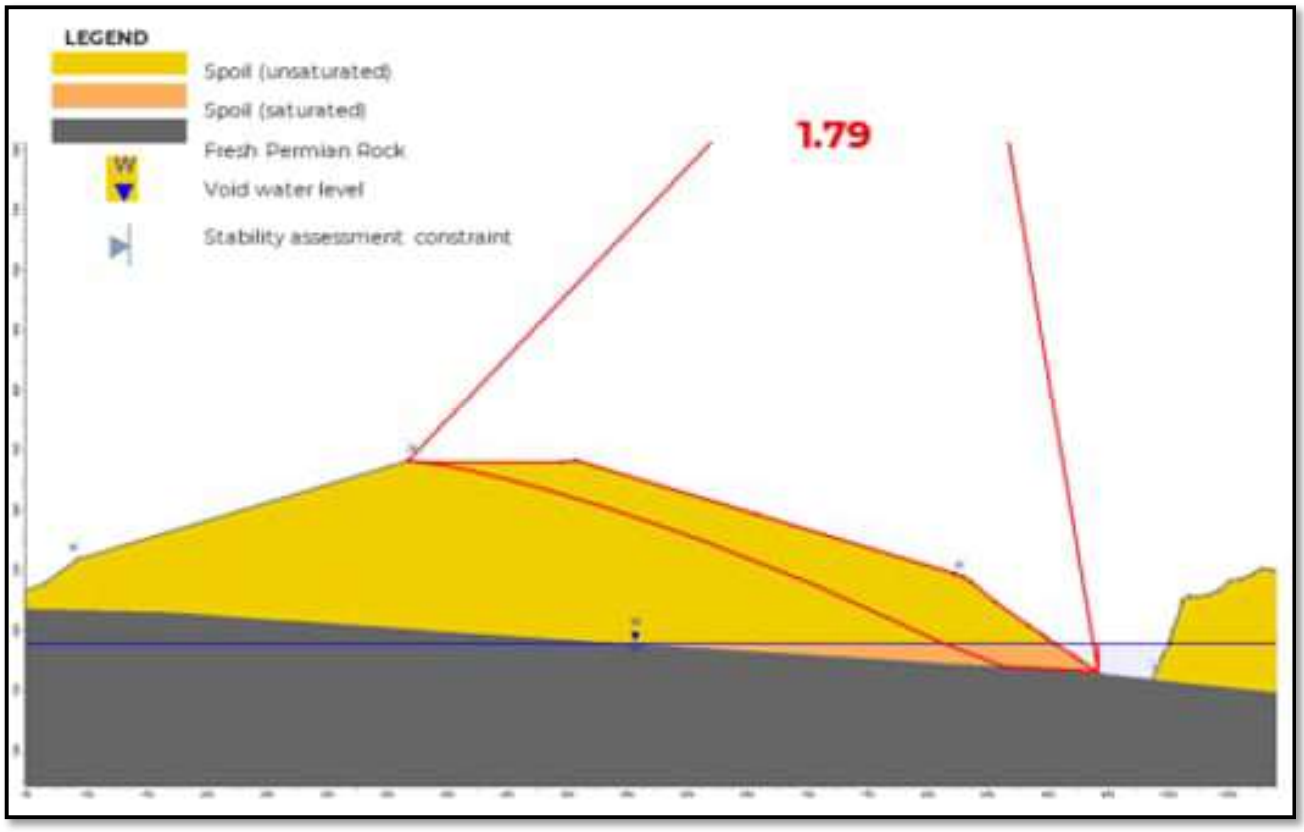


Figure 7.7: Isaac residual void (cross section 4) – global stability (Morgenstern-Price, non-circular)

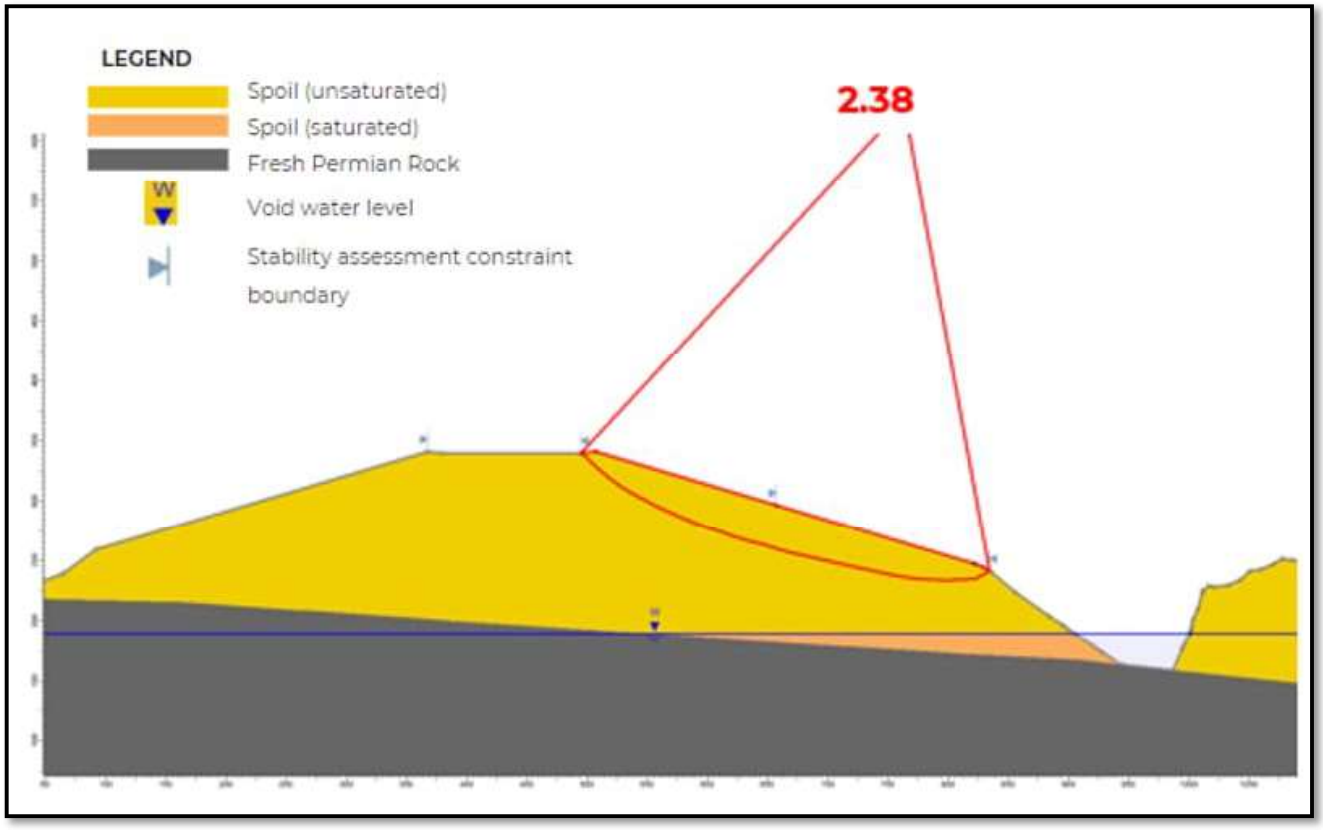


Figure 7.8: Isaac residual void (cross-section 4) – local stability (Morgenstern-Price, non-circular)

7.2.4 R32 South residual void

The geotechnical stability assessment for R32 South residual void concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was > 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results is provided in Table 7.8, and depicted in Figure 7.9 and Figure 7.10.

Table 7.8: Summary of low-wall geotechnical stability analysis results for R32 East residual void

Section	Low-wall spoil height (m)	Minimum Factor of Safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
5	250	1.96	6.81

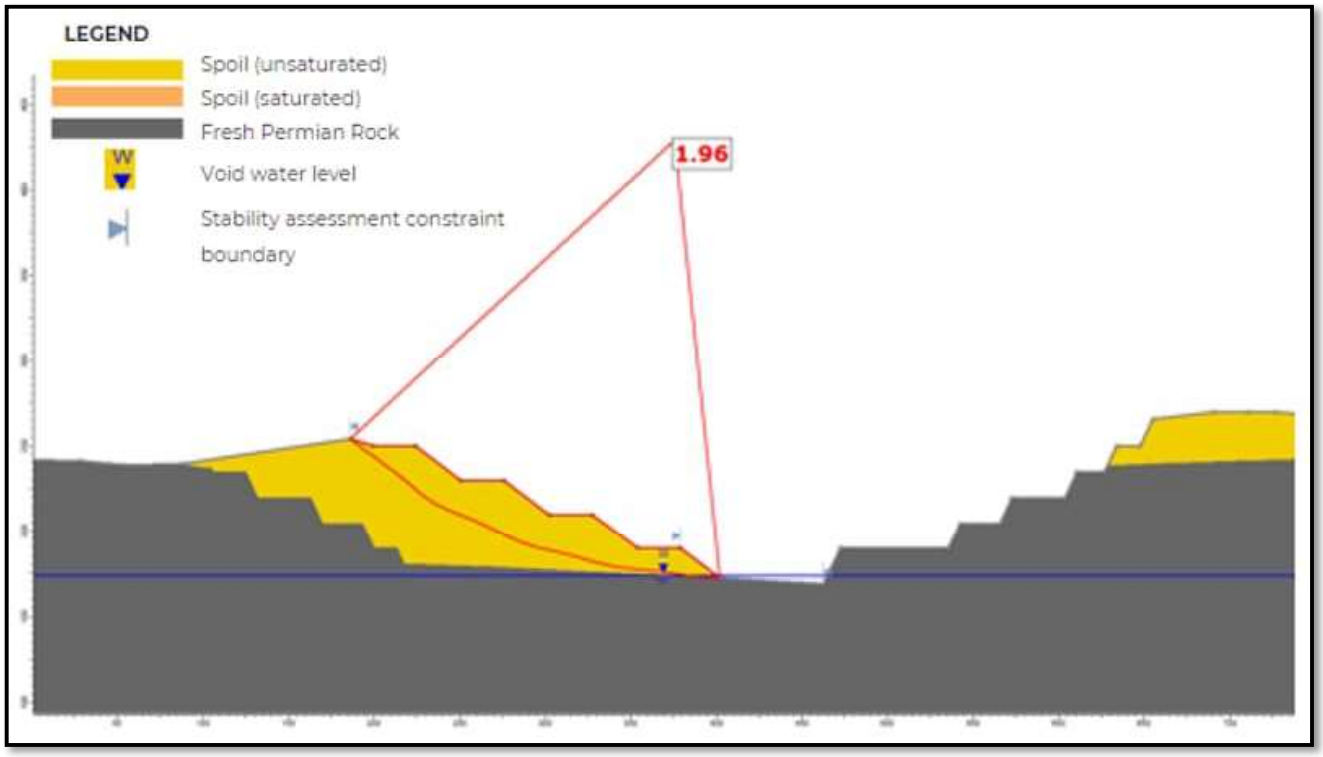


Figure 7.9: R32 South residual void (cross-section 5)– global stability (Morgenstern-Price, non-circular)

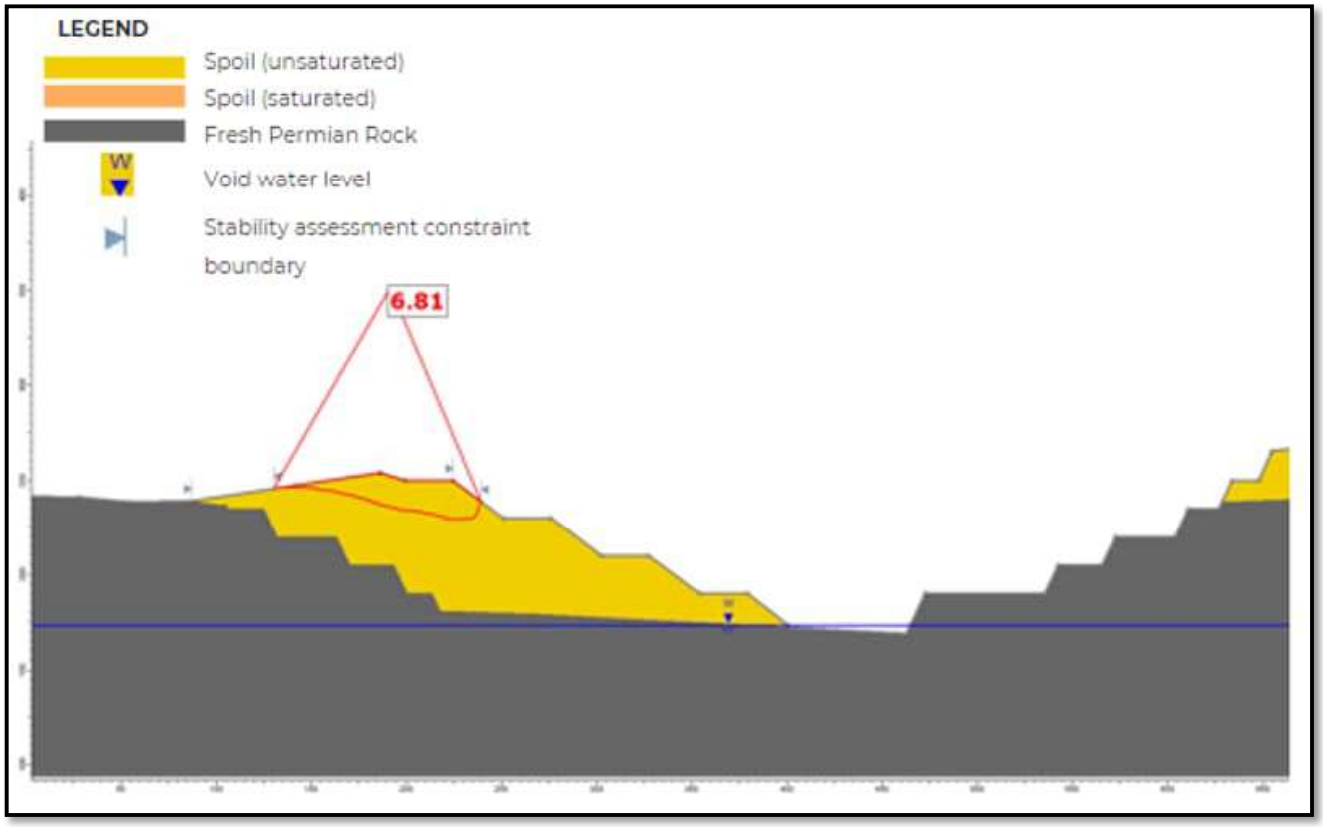


Figure 7.10: R32 South residual void (cross-section 5)– local stability (Morgenstern-Price, non-circular)

7.2.5 *Thiess residual void*

The geotechnical stability assessment for Thiess residual void concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was > 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.9, and depicted in Figure 7.11 and Figure 7.12.

Table 7.9: Summary of low-wall geotechnical stability analysis results for Thiess residual void

Section	Low-wall spoil height (m)	Minimum Factor of Safety	
		Overall slope (global stability)[a]	Slope outside NUMA (local stability)[b]
2	320	3.05	3.90

[a] Sarma non-vertical slices
[b] Morgenstern-Price, non-circular

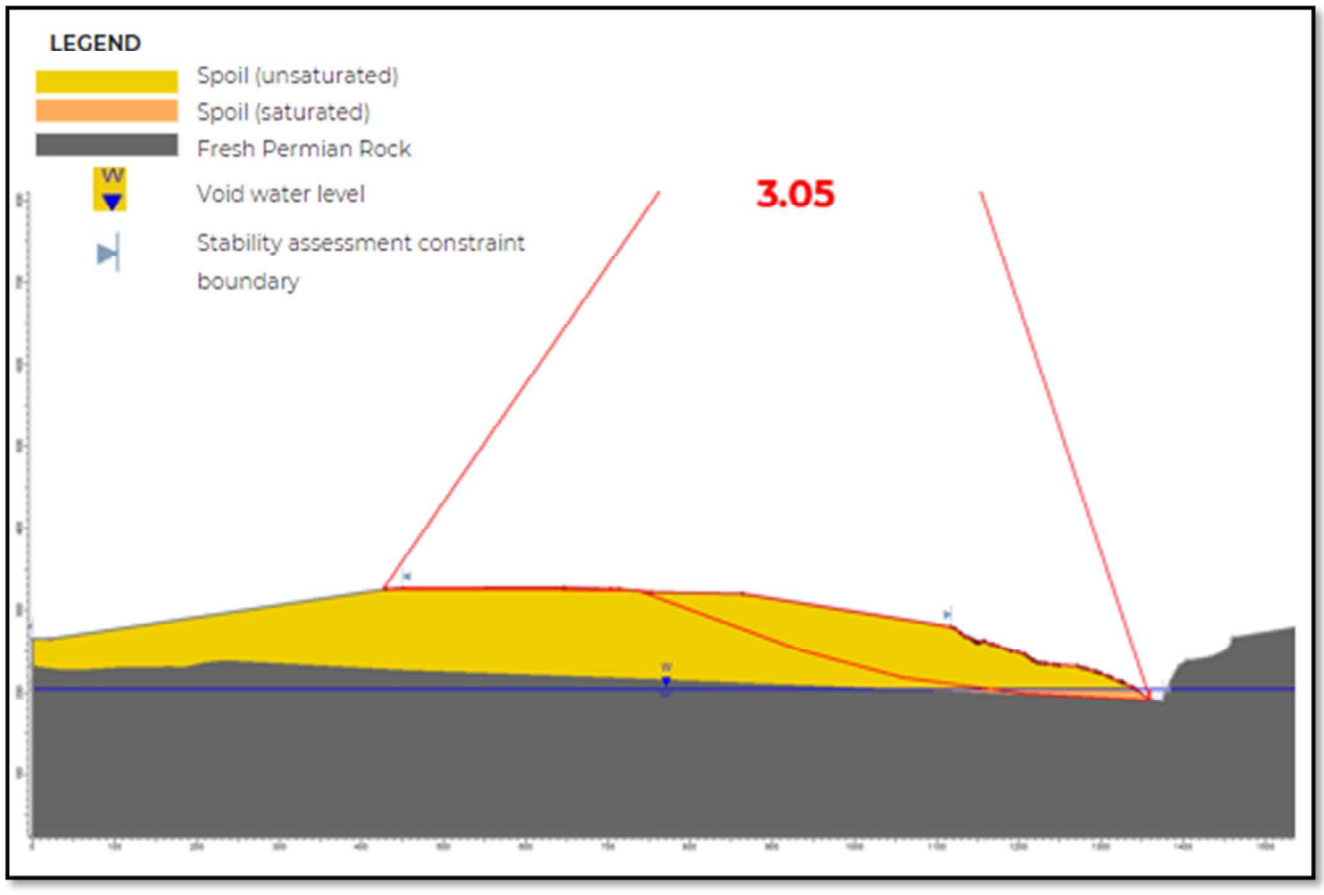


Figure 7.11 Thiess residual void (cross-section 2)– global stability (Sarma Non-vertical Slices)

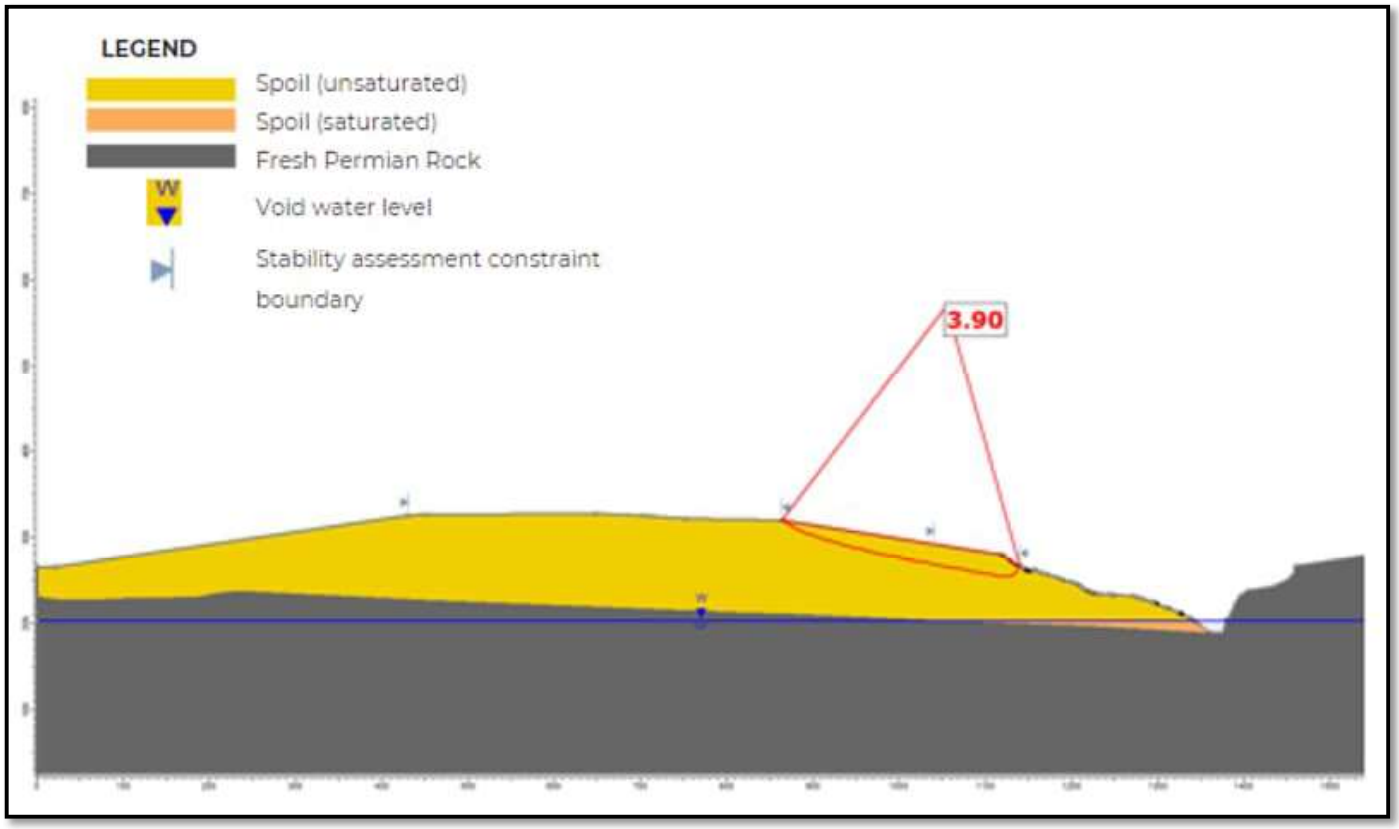


Figure 7.12: Thiess residual void (cross-section 5)– local stability (Morgenstern-Price, non-circular)

7.2.6 Assumptions

The following assumptions were made and used to inform the low-wall geotechnical stability assessments:

- The current assessment of the stability of the conceptual low-wall closure state landform at GRBM is preliminary in nature and has been based on the best inputs and assumptions available at the time of undertaking this assessment. These will be reviewed and verified over time, as mining approaches the final void limits.
- This assessment has not considered any potential effects of surface erosion on the stability of the low-wall spoil slopes.
- The agreed minimum FoS for any potential slip surfaces affecting low-wall slopes outside the NUMA is 1.5, as per the requirements of the EA Table E1.
- The equilibrium residual void lake levels assumed for the low-wall stability analyses were based on the results of the WBM (Section 6).
- Material parameters were provided by BMA and are presented in Table 7.10

Table 7.10: Material strength parameters adopted for low-wall stability analyses

Material	Bulk unit weight of intact rock (kN/m^3)	Cohesion (kPa)	Angle of friction (°)
Spoil (down dip, unsaturated)	18	40	30
Spoil (down dip, saturated)	20	23	25
Fresh Permian rock	24	450	42

- The spoil material was assumed to be homogeneous throughout, with all spoil above the void water equilibrium level assigned the same material parameters (spoil down dip, unsaturated), and all spoil below the void water equilibrium level assigned the same material parameters (spoil down dip, saturated).
- Any weak seams that might have been present within the sub-floor strata were assumed to have been treated by disrupting them with floor ripping or blasting, as required by BMA current operating procedures. Therefore, no such structures have been considered present in the current preliminary stability assessment of the conceptual low-wall slopes.
- No clay-rich spoil or mud will be present on the pit floor at the time when spoil is dumped there. Appropriate floor preparation was assumed to have been completed prior to placing the spoil on the pit floor, as required by BMA current operating procedures. Therefore no ‘weak layer’ was assumed to be present at pit floor level.

8 Geochemical stability

A geochemical assessment has been undertaken to identify the geochemical characteristics of high-wall material and mine waste materials (spoil and rejects) and model the resulting effects on long-term water quality of void lakes within the final closure state landform for the GRBM residual voids.

The objectives of the geochemical assessment were to:

- Predict the changes in water quality of GRBM residual voids in a long-term closure scenario.
- Determine, at a conceptual level (by comparison to published Water Quality Objective (WQO) specific for groundwater[1]), whether the predicted void lake water quality may impact the surrounding environment in a closure setting.
- Determine, at a conceptual level, if stratified conditions are likely to develop within the voids.

This geochemical assessment builds directly on the void water balance assessment undertaken for the GRBM residual voids (see Section 6) and covers the same timeframe: a period of 108 - 183 years post-closure (2091 through 2199) for all residual voids[2]. Within these timeframes, the water level in the void lakes reaches an equilibrium.

8.1 Water quality model

8.1.1 Geochemical materials

The geologic materials and associated mine waste materials (spoil and rejects) may react with water and release or immobilise solutes, according to their geochemical characteristics. Material interactions considered in the water quality model include:

- Highwall lithologies interacting with rainfall/runoff.
- In-pit spoil and rejects covered with non-carbonaceous interburden interacting with rainfall/runoff (infiltration of rainfall through the spoil and rejects was not included).
- Natural catchment interacting with rainfall/runoff. The natural catchment is assumed to be composed of weathered materials.

For the purposes of the geochemical assessment, the lithological materials present in the excavated walls of the GRBM residual voids, and their distribution were classified into five lithological domain groupings (Table 8.1). The relative proportions of each lithological group on current and future post-closure highwalls were derived from the stratigraphic distribution (meterage) of each material within selected drill holes.

[1] As identified in the GRBM hydrogeological assessment (AECOM, 2024a) the Isaac River Sub-basin Zone 34 WQOs (DEHP, 2011) for groundwater resources (aquatic ecosystem protection) have been considered for comparison. The values for the "deep" depth (>30 m) were selected for comparison based on the depth of the residual voids and anticipated depth to groundwater. These values are not specific to residual void lake closure objectives, and therefore should be treated as reference values only for initial benchmarking purposes.

[2] Goonyella residual void WBM was extended to 2259 to confirm equilibrium was achieved. There was no considerable change to the residual void lake level between 2199 and 2259 (refer to Section 6.2.1).

Table 8.1: Proportions of lithologies in the excavated GRBM void walls (high-wall database)

Lithology grouping	Excavated high-wall exposure (%)					
	Goonyella	Broadmeadow	Isaac	Thiess	R32 East	R32 South
Weathered, non-carbonaceous	10.3	25.2	25.2	43.9	34.4	23.0
Weathered, carbonaceous/coal	1.3	0.8	0.8	3.2	2.6	2.0
Fresh, non-carbonaceous	70.6	60.5	60.5	38.0	53.0	63.0
Fresh, carbonaceous	5.5	1.5	1.5	3.7	5.0	6.0
Coal	10.2	7.7	7.7	9.4	5.0	6.0
Unknown	2.1	4.3	4.3	1.8	0.0	0.0

8.1.2 Geochemical source terms

The geochemical source terms were derived from the BMA environmental geochemistry database. The environmental geochemistry database includes the results of analyses performed on drill core material collected at GRBM.

For the derivation of the groundwater source term, groundwater data from 2006 to 2024 that included monitoring information from 116 monitoring bores was used. No distinction was made between aquifers where groundwater bores are screened in different aquifers. The data used for the derivation of these source terms and the derived source terms are summarised in Table 8.2 and Table 8.3.

Table 8.2: Summary of data used to derive geochemical source terms for the GRBM residual voids

Source term (water balance)	Comment	n	Source
Natural catchment runoff	Represented by the average value of leachate from weathered rock of drill core samples. A ratio of non-carbonaceous/carbonaceous weathered rock was estimated based on the high-wall composition.	25	GRBM drill core database
Rehabilitated catchment runoff (in pit spoil runoff)	Represented by the average value of leachate data from fresh non-carbonaceous drill core samples, as Permian interburden was specified as the cover material for final landform.	97	GRBM drill core database
High-wall runoff	Based on the exposed lithological domains on the high-wall, the average leachate data for each lithological domain/grouping were weighted according to the proportions of high-wall exposure.	142	GRBM drill core database
Groundwater inflow	Represented by the average groundwater quality for the locations/ aquifers from the GRBM groundwater database, an equal proportion of each aquifer domain was considered. The 'pe' values were calculated based on field oxidation-reduction potential measurements.	503	GRBM groundwater database
Rainfall	Typical rainwater composition for southeastern Australia (Carroll, 1962).	-	-

Notes: '-' indicates not available; n= number of samples; pe = electron activity expressed in factors of 10: pE = -log(e-)

Table 8.3 Summary of select geochemical source terms (median results) derived from GRBM data sources

Parameter	Unit	Weathered non-carbonaceous	Weathered carbonaceous	Fresh, non-carbonaceous	Fresh, carbonaceous	Coal	Groundwater	Rainfall-runoff (natural)	Rainfall-runoff (overburden)
pH	pH units	8.0	6.7	9.4	9.5	8.9	6.4 - 7.5	7.9	9.4
Log of electron activity (pe)	-	10.1	10.1	10.1	10.1	10.1	2.65 – 4.61	10.1	10.1
Alkalinity	mg $CaCO_3$/L	111	53	248	160	185	319 - 436	107	248
Sulphate (SO4)	mg/L	210	428	93	50	11	81 – 1612	224	93
Chloride (Cl)	mg/L	381	182	84	86	36	4241 - 6278	369	84
Calcium (Ca)	mg/L	11	14	2.39	1.43	2.92	209 - 242	12	2.39
Potassium (K)	mg/L	14	16	8.82	3.66	4.17	9.8 - 23	14	8.82
Magnesium (Mg)	mg/L	11	14	1.95	1.43	2.08	181 - 495	11	1.95
Sodium (Na)	mg/L	353	288	204	151	99	2154 - 3662	349	204
Fluoride (F)	mg/L	2.36	1.98	0.713	0.959	1.00	0.00150	2.34	0.713

8.1.3 *Geochemical model approach and development*

The water quality model was run for major cations and anions per the availability of data. The results for each time-step were calculated using the geochemical modelling code PHREEQC (Parkhurst, 2013) with the Minteq.v4 thermodynamic database, derived from the MINTEQA2 version 4 database (USEPA, 1998).

The geochemical model contained the following features:

- Source-terms were mixed for annual timesteps, with inflow/outflow proportions calculated from the GoldSim water balance.
- Modelling was incremental, with the output for the void lake from the previous timestep used as the input for the next time step.
- Geochemical reactions, such as mineral precipitation/dissolution, gas exchange, and sorption.

The following assumptions apply to the water quality model:

- At all times, the void lake is fully mixed, and geochemical reactions occur within the modelled time-step. The kinetics of reactions are represented by the source-terms and were considered stable in the long-term (steady state).
- Mineral precipitates are retained within the void lake and may undergo dissolution again.
- There is no interaction between the high-wall material and spoil below the established void lake water level.
- The release of coal bed methane is not a significant process and does not drive groundwater or lake chemistry towards more reducing conditions.
- The modelled minor outflows from Isaac and Thiess residual voids (~0.06 ML/day and ~0.5 ML/day respectively) to the groundwater system have the same composition as the water in the void lake. However, evaporative losses from the GRBM residual void lakes creates an inward hydraulic gradient centred on the Goonyella residual void.
- There is no infiltration of rainfall or groundwater through the in-pit waste to the void lake.
- Stratification is assessed at a conceptual level based on a total dissolved solids (TDS) threshold. Seasonal temperature, wind patterns and other impacts on mixing are not considered.
- The geochemical model does not account for biological processes.

A model sensitivity test was performed to highlight the role of the geochemical controls (within the model) on predicted water quality. The two simulations are summarised in Table 8.4 and were performed for the mean water balance scenario.

Table 8.4: Model sensitivity simulations

Simulation	Atmospheric CO_2 equilibrium	Mineral precipitation	Surface adsorption
Base case	Equilibrium at $10^{-3.38}$ (420 ppm)*	Equilibrium	Adsorption onto ferrihydrite
No geochemical controls	No equilibrium	No equilibrium	No sorption

Note: *420 parts per million (ppm) is representative of 2024 atmospheric CO_2 concentrations. Variation with time (i.e., geochemical climate change scenarios) is not included in current model scenarios.

A conceptual level assessment of potential chemical stratification was conducted based on the evolution of TDS, which can be used to approximate the fluid density of the fully mixed void lake. Stratification assessment is provided in Section 8.2.

Quality control carried out throughout the model duration observed the log of the electron activity (pE) and mass of water remained within a suitable range.

8.2 Residual void water quality outcomes

The rehabilitation requirement in Table E1 of the EA identifies electrical conductivity (EC) as a key indicator. However, the water quality model outcomes are focused on TDS (discussion is also included for pH) as TDS is the actual measurement of the amount of total solids dissolved in water, whereas EC is a measurement of the ability of those dissolved solids to conduct electricity. Therefore, TDS is modelled within the water quality model.

The criteria for TDS were derived from the EC values referenced in Table E1 of the EA (the Isaac River Sub-basin Zone 34 WQOs) applying a 0.67 factor (considered acceptable for freshwater). The WBM and groundwater model outcomes indicate that the GRBM residual voids will create an inward hydraulic gradient centred on the Goonyella residual void creating a post-closure groundwater sink. Therefore, the comparison of the water quality model outcomes against the EC range of values from the Isaac River Sub-basin Zone 34 WQOs are for interpretive purposes only, as no modelled groundwater outflows from the modelled residual void lakes beyond the tenure boundaries are expected.

Further discussion is focused on the available modelled results for TDS (and pH) and a comparison to the corresponding published WQO specific for groundwater and the baseline groundwater quality (Table 8.5).

Table 8.5 Select WQO value screening thresholds applied to GRBM residual void lake water quality (DEHP, 2011) and baseline groundwater quality (AECOM, 2024a)

Parameter	Units	Deep groundwater (>30 m)			Baseline groundwater quality
		20th Percentile	50th Percentile	80th Percentile	Permian interburden
EC	µS/cm	3,419	6,100	16,000	7,030 – 18,800
TDS*	mg/L	2,291	4,087	10,720	4,710 – 12,596
pH	-	7.4	7.8	8.03	7.38 – 8.38

Notes: *TDS calculated from EC assuming conversion factor of 0.67

The results for the geochemical modelling for the modelled residual voids at GRBM for TDS and pH are presented for scenarios with and without geochemical controls/reactions (i.e., mineral precipitation, sorption, and gas exchange).

TDS:

Based on the outcomes of this assessment, the modelled void water quality in the GRBM residual voids is predicted to evolve through time. TDS is simulated to systematically increase over time post closure, primarily driven by evapoconcentration and the input of groundwater. The TDS concentrations retain a 20-year cyclicity from the WBM with minor seasonal variation. Brackish conditions develop in Isaac and Thiess residual voids within the modelled simulation period. Brackish to mildly saline conditions develop in Goonyella residual void. Brackish to brine (hyper-saline) conditions develop in the Broadmeadow, R32 South and R32 East residual voids.

The TDS concentrations are all modelled to increase throughout the simulation; however, the rate of TDS increase is largest within the Broadmeadow, R32 South and R32 East residual voids. Except for Thiess residual void, no residual void achieves an equilibrium TDS water quality composition by the end of the model simulation period. However, Isaac residual void also comes close to equilibrium.

Within the modelled simulation period, the predicted TDS concentrations (Figure 8.1) when compared to the 80th percentile WQO (10,720 mg/L) are as follows:

- For Thiess and Isaac residual voids, remain below the WQO.
- For Goonyella residual void, remain below the WQO for approximately the first 50 years.
- For Broadmeadow, R32 South and R32 East residual voids, become elevated above the WQO early.

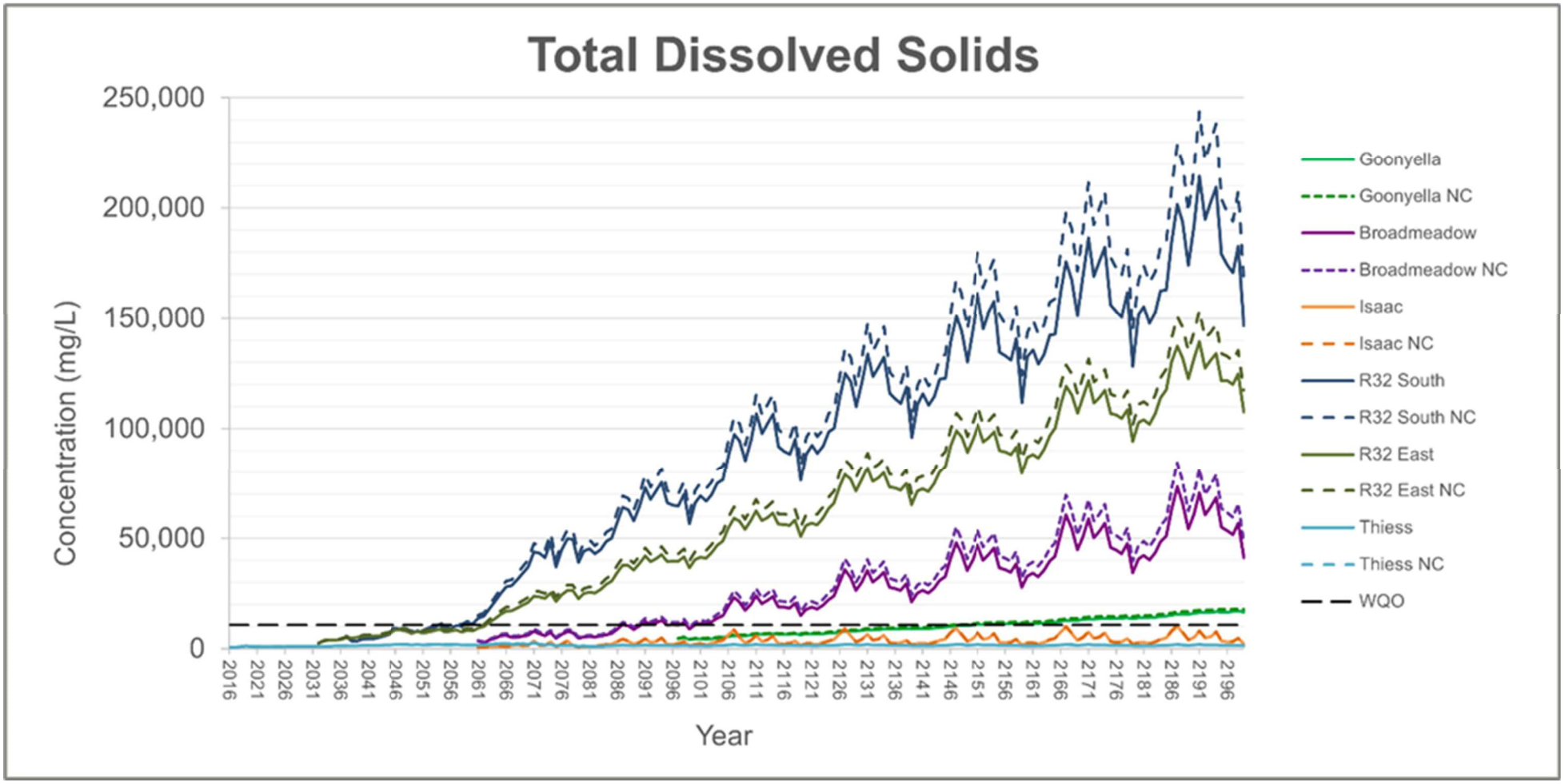


Figure 8.1: Summary of predicted TDS conditions in the GRBM residual voids (NC = no geochemical controls, WQO = 80th percentile)

pH:

Acidic conditions are unlikely to form within any of the GRBM residual voids (Figure 8.2). The modelled pH remains within the circum-neutral to alkaline range (pH 6.4 to 9.4) throughout the simulation period.

Within the modelled simulation period, the predicted pH for Isaac, Thiess and Broadmeadow residual voids surpass the 80th percentile WQO (8.03).

When geochemical controls are applied, the modelled pH for Goonyella residual void surpasses the 80th percentile WQO for pH (8.03). Without geochemical controls, Goonyella void remains below the 20th percentile WQO (7.4) for most of the simulation period.

Within the modelled simulation period, modelled pH levels in R32 South and R32 East residual voids initially surpasses the 80th percentile WQO for pH (8.03) before reducing to and remaining below the 20th percentile WQO (7.4), particularly without geochemical controls applied.

The simulation with geochemical controls results in a higher pH by the end of the simulation than without geochemical controls. The main geochemical control is CO2 degassing which raises pH, resulting in calcite/magnesite precipitation and dissolution that reduces and raises pH, respectively. These geochemical processes are driven by the input of sources of alkalinity (dissolved inorganic carbon) via surface runoff and groundwater to the void lake.

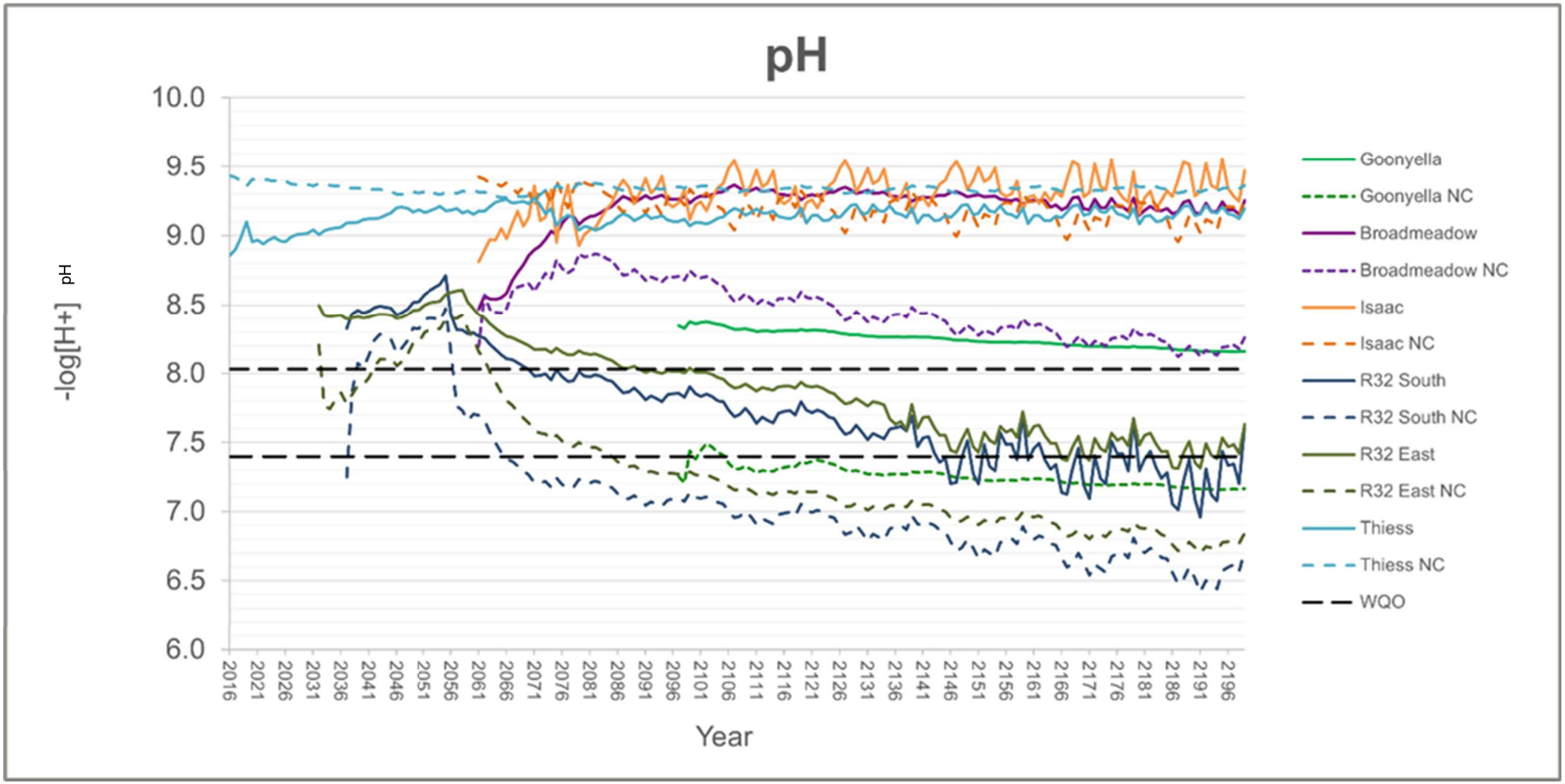


Figure 8.2: Summary of predicted pH conditions in the GRBM residual voids (NC = no geochemical controls, WQO = lower 20th to upper 80th percentile)

Stratification:

The steep sides of the voids, high TDS and the water depth present favourable conditions for stratification in all GRBM residual voids. The water of higher density (cooler or more saline) has the potential to become isolated at depth. Hydrodynamic/limnological analysis is required to assess the potential for onset of thermal/chemical stratification, and the importance of seasonal mixing processes and groundwater mixing inputs. However, as the residual voids are considered NUMAs and modelled as groundwater sinks, further stratification assessment is not warranted.

8.2.1 Qualifications

The following caveats and limitations apply to the water quality model for the GRBM residual voids:

- Available data at the time of modelling was used to represent the relevant geochemical interactions. Availability of additional data in future may result in alternative model outputs.
- The relative proportions of each lithological group on current and future post-closure highwalls were assumed to remain constant, even with the elevation of water levels.
- Water movements are based on complementary studies (groundwater and water balance). These studies constrain the model duration and the water sources.
- Screening was performed against Isaac River Sub-basin Zone 34 WQOs (DEHP, 2011) for groundwater resources (aquatic ecosystem protection). The criteria for TDS were derived from the WQO electrical conductivity value using a 0.67 factor that is considered acceptable for freshwater.

9 Residual void management

A summary of the key findings from the technical studies (presented in Sections 4 to 8) used to inform the development of residual void management measures is presented below:

- Groundwater modelling and WBM results indicate the formation of void lakes in all GRBM residual voids. Void lake levels are modelled to equilibrate below both the base of shallow geologic formations and recovered groundwater levels in the deeper geology for the Goonyella, Ramp 32 South and Ramp 32 East residual voids. Water movement out of the Broadmeadow, Thiess and Isaac residual voids through the deeper geology is predicted to be captured in the deeper Goonyella residual void.
- Continued evaporation from the void lakes will result in ongoing groundwater inflow towards the tenure with the GRBM residual voids, creating an inward hydraulic gradient centred on the Goonyella residual void.
- No additional impact beyond that which already exists at the end of mining is expected on surficial aquifers, including the shallow geological formation, and little to no impact on environmental or anthropogenic receptors (e.g. water extraction bores) is expected.
- WBM results predict that the residual voids at GRBM are at low risk of overtopping. The GRBM residual voids achieve the mean void water levels and volumes in Table 9.1 at the end of the simulation; these are well below the spill elevations for the respective voids.

Table 9.1 Mean void water levels and volumes for the GRBM residual voids

Residual void	Spill elevation (m)	Mean void water elevation (m AHD)	Mean void water volume (megalitres)
Goonyella	254	21	69,178
Broadmeadow	230	155	473
Isaac	230	180	162
R32 South	256	173	190
R32 East	240	162	709
Thiess	256	202	1,869

- The final closure state landforms have been designed such that the geotechnical stability for the low-walls of the GRBM residual voids achieved a FoS ≥1.5. Therefore, the low-walls of the final closure state landforms can be considered geotechnically stable.
- With regards to high-walls and end-walls, at closure, the NUMA extents include identified set-back zones to achieve a FoS ≥1.5. All third-party assets will remain outside of these extents.
- At closure, the GRBM residual voids will be bunded and fenced with appropriate signage erected - where restricting access to the residual voids is required to maintain safety for humans and livestock.
- The final closure state landform has been designed so that the final residual voids associated with GRBM are not subject to inundation from floodwaters up to and including the 0.1% AEP plus 20% rainfall intensity increase climate change event.

All six GRBM residual voids will be retained as NUMAs. To support attainment of NUMA voids that are safe and do not present an unacceptable risk of off-tenure environmental harm, the management strategies presented in Table 9.2 will be implemented.

Table 9.2 GRBM residual void closure context (safe, not cause environmental harm) and management considerations

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
Geotechnical stability	✓	-	— Stability outside of the NUMA extents = FoS ≥1.5 — Set-back distances for long-term pit wall stability have been defined by geotechnical analysis for all residual voids for high-walls, end-walls and low-walls. — Setbacks are included within the NUMA extent to ensure stability and that no assets (BMA, third-party, or of significant environmental value) are retained within this boundary at closure.	— As mining approaches the final limits, re-assess the geotechnical set-backs based on the latest available data. — Review and adjust the mine plan and final closure state landform, if needed, to account for any revised set-back requirements. — Use a minimum FoS≥1.5 as a guidance for ongoing void closure planning. (This may be refined over the mine life should industry research provide optimised guidance on observational methods and consequence assessment).

Void hydrology	✓	✓	— All GRBM final residual voids in the final closure state landform are not subject to inundation from floodwaters up to and including the 0.1% AEP event under the upper climate change rainfall intensity scenario based on rehabilitation flood modelling completed. — As the water levels remain well below the voids' spill points for all GRBM residual voids, the voids will not overtop and environmental harm beyond that of the void itself is not expected. Therefore, no management activities required. <u>For Goonyella residual void:</u> — After 2200, mean water levels start to stabilise, with simulated mean inflows of 3,929 ML/year being the same as mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For Broadmeadow residual void:</u> — After 2100, mean water levels start to stabilise, with simulated mean inflows of 218 ML/year being the same as mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For Isaac residual void:</u> — After 2100, mean water levels start to stabilise, with simulated mean inflows of 179 ML/year being the same as mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For R32 South residual void:</u> — After 2080, mean water levels start to stabilise, with simulated mean inflows of 88 ML/year being the same as mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For R32 East residual void:</u> — After 2080, mean water levels start to stabilise, with simulated mean inflows of 213 ML/year being the same as mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For Thiess residual void:</u>	— Residual void catchments are minimised as far as practicable and predominantly include only the low-wall areas and the voids themselves. — At cessation of mining activities, review and update the void water balance modelling, incorporating identified changes to the voids' final closure state landforms and spill point elevations, starting water levels, rainfall and evaporation, surface water runoff and groundwater inflows, and climate projections. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, then management strategies to be implemented. — Obtain certification from an appropriately qualified person that the residual voids will not cause environmental harm beyond the tenure boundary. — If necessary, identify and implement mitigation measures for appropriate protection works of landforms where floodwaters from watercourses interact with final closure state landforms.

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
			— After 2100, mean water levels start to stabilise, with simulated mean inflows of 572 ML/year being similar to the mean outflows of 573 ML/year. This indicates that the mean water balance has reached an equilibrium.	
Void hydrogeology	-	✓	— Mining-related dewatering activities have lowered groundwater levels that will result in suppression of the water table centred on the GRBM residual voids. — Void lakes are predicted to form in residual voids post-mining. Water levels in these void lakes are modelled to remain below the shallow geological units due to evaporative effects on the void lakes. — An inward hydraulic gradient is modelled to establish, centred on the Goonyella residual void. Ongoing groundwater inflow towards the tenure is expected. — Modelled outflows from Broadmeadow, Thiess and Isaac residual voids are retained within Goonyella and do not leave the tenure boundary. — The evaporative losses from the GRBM residual void lakes create a long-term inward hydraulic groundwater gradient centred on the Goonyella residual void, thereby providing long-term groundwater management for the mining disturbance areas. — Modelling, including particle tracking, indicates that infiltration of rainfall from the spoil, minor outflows from Thiess and Isaac residual voids, mine industrial area, and other disturbed areas within the tenure will migrate towards and be captured within the residual voids. Groundwater flow is not expected to flow off-tenure toward the receiving environment, minimising the risk of environmental harm due to the proposed final closure state landform.	— At cessation of mining activities, review and update the groundwater modelling, incorporating updated void WBM outputs and in-field groundwater sampling data, as required. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, management strategies are to be developed and implemented to minimise the harm. — Obtain certification from an appropriately qualified person that, upon completion of mining, residual voids do not present an unacceptable risk of environmental harm beyond the tenure boundary.

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
Void water quality	-	✓	— There are no significant sources of acid generation associated with GRBM's closure-related surface water hydrology, and acidic conditions are unlikely to develop in the voids. — TDS in all GRBM residual voids increases over time with Thiess residual void reaching an equilibrium with seasonal fluctuations. TDS in Isaac residual void almost reaches an equilibrium. — Preliminary, high-level screening base on predicted TDS levels suggest that all GBRM residual voids may become chemically stratified. — GBRM residual voids do not present an unacceptable risk of environmental harm beyond that of the mining tenures as an inward hydraulic groundwater gradient establishes, centred on the Goonyella residual void.	— At cessation of mining activities, review and update the void geochemical assessment including additional or refined data from in-pit surface water samples, surface- and groundwater samples, and biochemical modelling. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, then management strategies to be developed and implemented. — Obtain certification from an appropriately qualified person that the residual voids will not present an unacceptable risk of environmental harm beyond the tenure boundary.
Void access control	✓	-	— Access to the residual void will be restricted for humans and livestock.	On cessation of mining activities: — Construct a safety bund at the geotechnical set-back distance. — Erect fencing and signage (where required) around the perimeter of the safety bund. — Obtain certification from an appropriately qualified person that the residual void is safe to humans and livestock. — Underground access points within voids are closed in accordance with appropriately qualified person recommendations.

10 Conclusion

This void closure plan provides outcomes of technical studies completed to support closure planning and achievement of residual voids at GRBM that are safe and do not cause environmental harm– specifically the Goonyella, Broadmeadow, Isaac, R32 East, R32 South and Thiess residual voids. This void closure plan is an appendix to the GRBM PRC plan and has been complied in terms of the requirements of the *PRC Plan Guideline*.

The documented technical studies – including water balance, hydrogeological, rehabilitation flooding, geochemical and geotechnical stability modelling - have been undertaken through an iterative approach with the development of the closure state landform design. These iterations have resulted in a closure landform design that minimises the area of the voids, provides protection from flood water, and contributes to minimising environmental harm as it relates to the final residual voids.

This plan (and associated supporting technical studies) may be required to be updated should amendments to the site's PRC plan be required.

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BMA TECHNICAL SERVICES

Geotechnical considerations for closure of underground mines at BMA Broadmeadow.

REPORT: BMA-13 GRB

Date:17 October 2024

Prepared by:

Dr Ross Seedsman RPEQ

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1 INTRODUCTION

Broadmeadow Mine currently extracts the Goonyella Middle Seam (GMS) and at some time in the future will extract the Goonyella Lower Seam (GLS) (Figure 1).

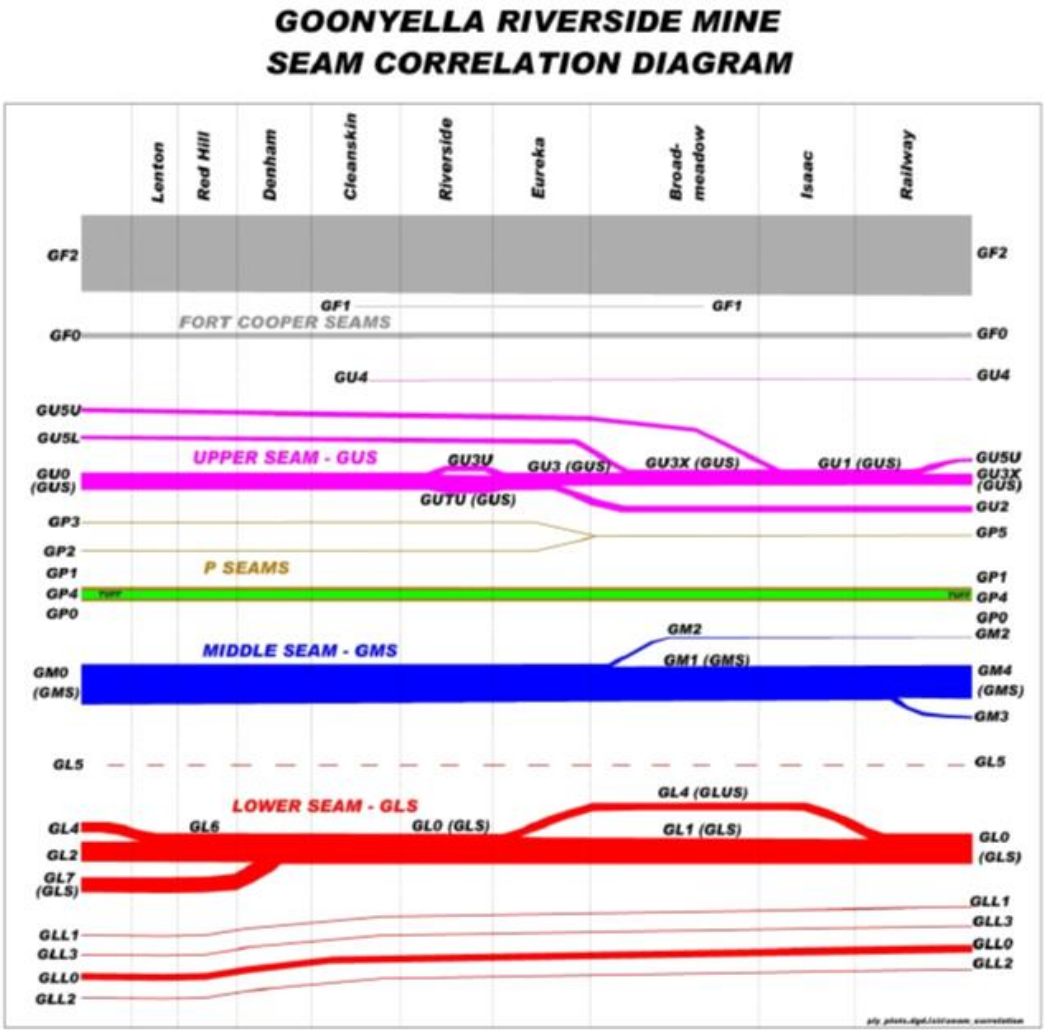


Figure 1 Seam Correlation Diagram

Broadmeadow Mine commenced longwall operations in the GMS in 2005, initially with a conventional longwall but later with a top coal caving system (TCC). The initial extracted thickness was 3.8 m but increased to a nominal 5.5 m with the TCC system (noting the thickness varies due to the caving process). The Broadmeadow longwall panels are 330 m wide (320 m wide wall plus 2 of 5 m roadway widths) and typically 2-3 km in length with chain pillars having widths that have ranged between 35 m and 45 m.

The longwalls in the GMS have retreated to the west with the mining depth decreasing from 320 m to 100 m (Figure 2). LW1-LW12 (northern panels) were punch longwalls with the gate roads driven from the Goonyella and Broadmeadow open cuts (Ramps 4 and 3). LW13 onwards (progressing to the south) are accessed by a 5-heading set of Mains. A total of 27 longwall panels are currently proposed for the GMS.

There are plans to then extract 29 longwall panels in the GLS seam with mining depths of 410 m to 110 m (Figure 3).

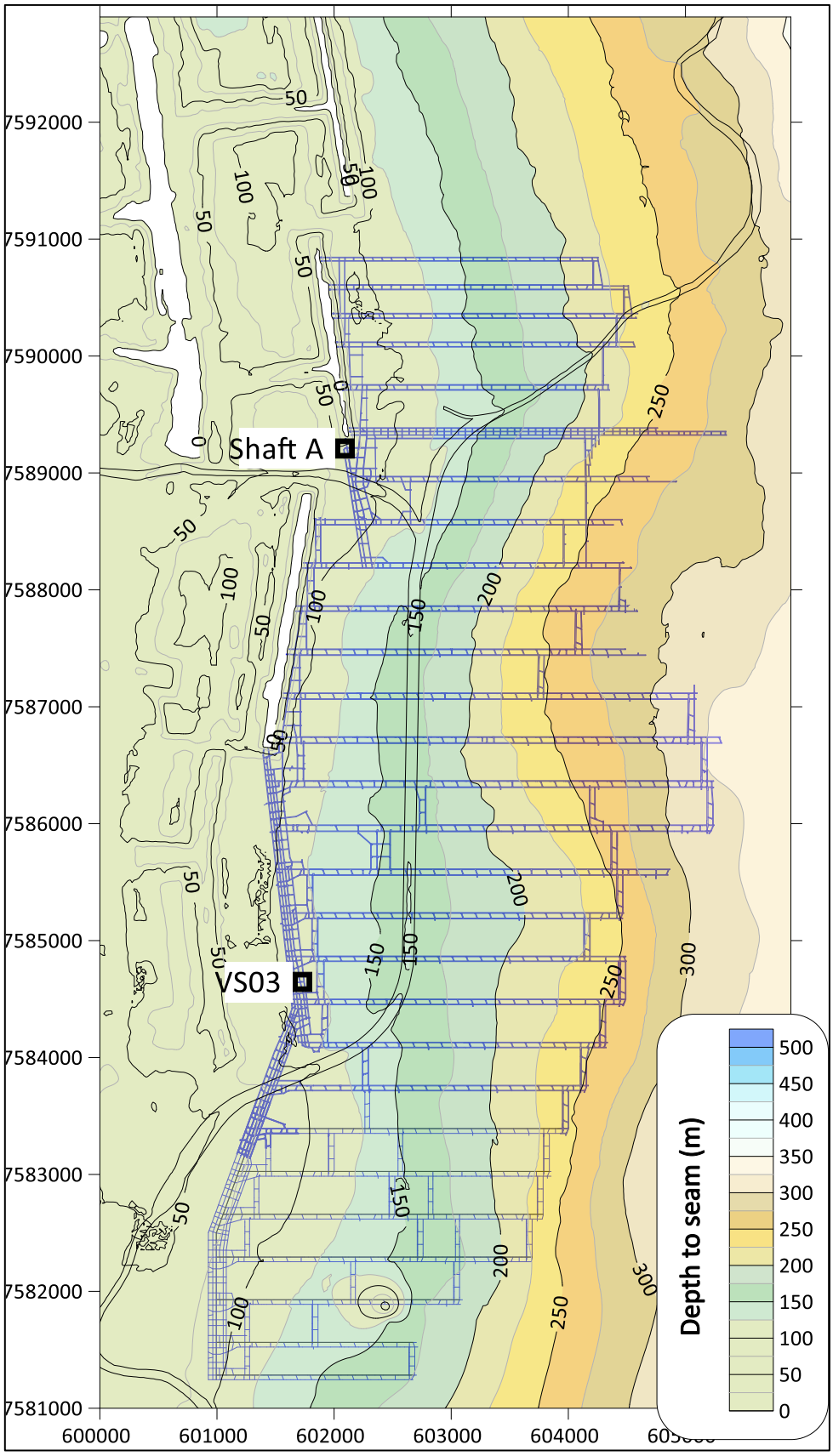


Figure 2 Mining layout for GMS with depths of cover

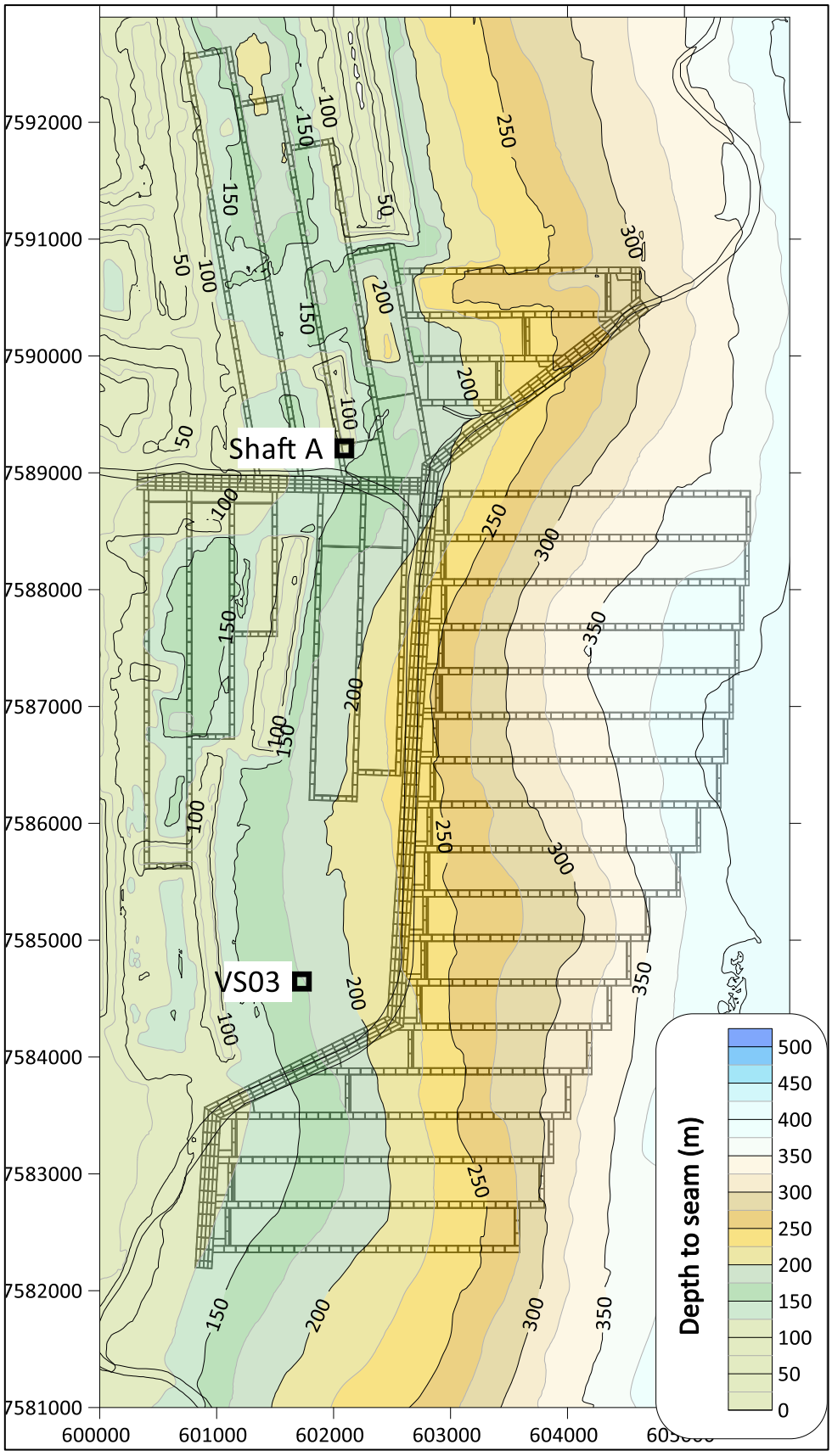


Figure 3 Mining layout for GLS with depths of cover

2 ENGINEERING GEOLOGY

2.1 Regional geology

Broadmeadow Mine is located at the mid-western fringe of the Bowen Basin in Central Queensland. In this area the late Permian coal bearing formations (Moranbah Coal Measures and overlying Fort Cooper Coal measures) are unconformably overlain by Tertiary aged sediments and basalt flows.

The Permian formations consist of fine to coarse grained sandstone of moderate to high strength, with interbeds of mudstone, siltstone and coal seams. The Tertiary sediments consist of poorly lithified sands and clays with poorly cemented sand and minor gravel lenses intercalated within widespread basalt flows. The flows infill old paleo channel drainage systems with the main channel running through the Wards Well, North Goonyella, Moranbah North and Grosvenor Coal leases, east and southeast of Broadmeadow Mine.

2.2 Surface geology

Quaternary sands and clays overlie the Tertiary deposits and are associated with more recent drainage systems (Figure 4). The main units are:

- Qrc: Colluvium and/or residual deposits, talus, scree, sheet wash; boulder, gravel, sand; may include minor alluvial or sand plane deposits.
- Czs: Sand plain, may include some residual alluvium; sand dominant, gravel, clay.

Site investigations[1] for ventilation Shaft A (Figure 2) intercepted clays and sands to a depth of 9.2 m. Both the clay and clayey sand, down to a depth of 4.2 m, were logged as being plastic with clayey properties. The silty sand, between depths of 4.4 and 9.2 m was medium dense, only had minor clay and was essentially non-plastic, collapsing following drilling and required casing.

Site investigations for ventilation shaft VS03 did not separate the Quaternary from the underlying Tertiary sediments (Figure 5). There was a large amount of core loss over the upper 16 m of the hole. Soil materials (soil clay gravel) were logged to 16.07 m and then sandstones and siltstones. The change in colour from browns to greys would appear to have been used to indicate the base of the Tertiary sequence at 16.07 m.

The compiled thickness of the Tertiary alluvials varies between 10-20 m over the Broadmeadow Mine area.

2.3 Coal Measures

The Permian coal measure rocks are interbedded sandstones mudstones and coals with laterally extensive bedding partings and orthogonal jointing whose continuity is limited by lithological units. A Geological Strength Index (GSI) of approximately 40 applies (sandstone and siltstone in similar amounts, smooth bedding planes[2]).

At Ventilation Shaft A, coal measure rocks were first encountered at a depth of approximately 14m, comprising of 11 m of extremely low strength, extremely weathered clayey sandstone with the first coal seam being intersected between depths of 25.48 - 27.0 m. Below the coal seam a further 7.6 m of generally very low strength siltstone and sandstone was intersected before medium strength siltstone was encountered at a depth of 34.65 m. Between this depth and the top of the GMS at a

[1] Douglas Partners 2014. Geotechnical Investigation, 3.6 m Diameter Ventilation Shaft. Project 80543.00.

[2] Hoek E, Marinos PG, Marinos VP.2005 Characterisation and engineering properties of tectonically undisturbed but lithologically varied sedimentary rock masses. IJRMMS, 4, 277-285.

depth of 109.68 m, there was interbedded, generally low to medium strength siltstone and high strength silty sandstone (15 - 35 MPa). Similar results are reported in analyses conducted for the underground mining operations.

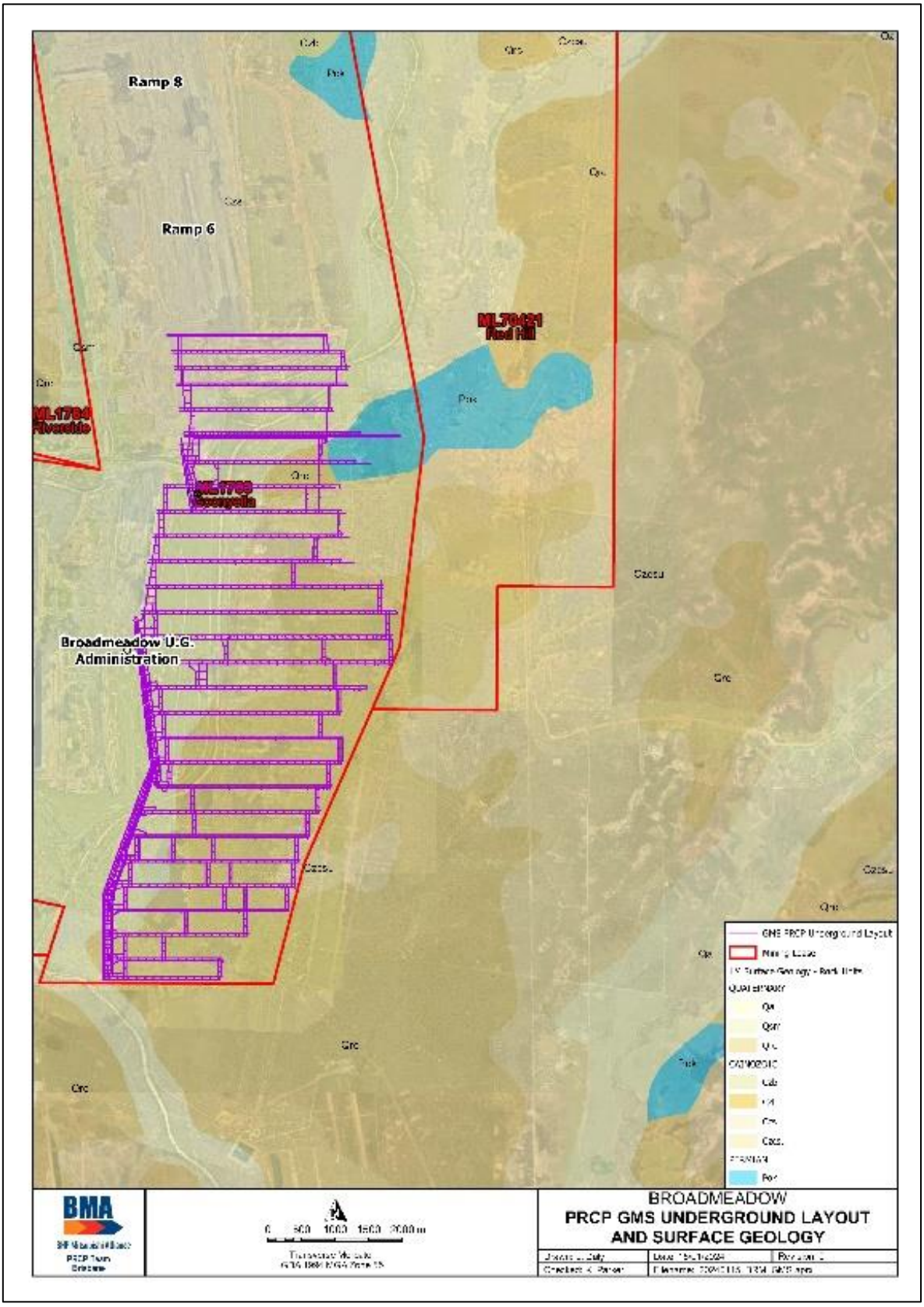


Figure 4 Surficial geology

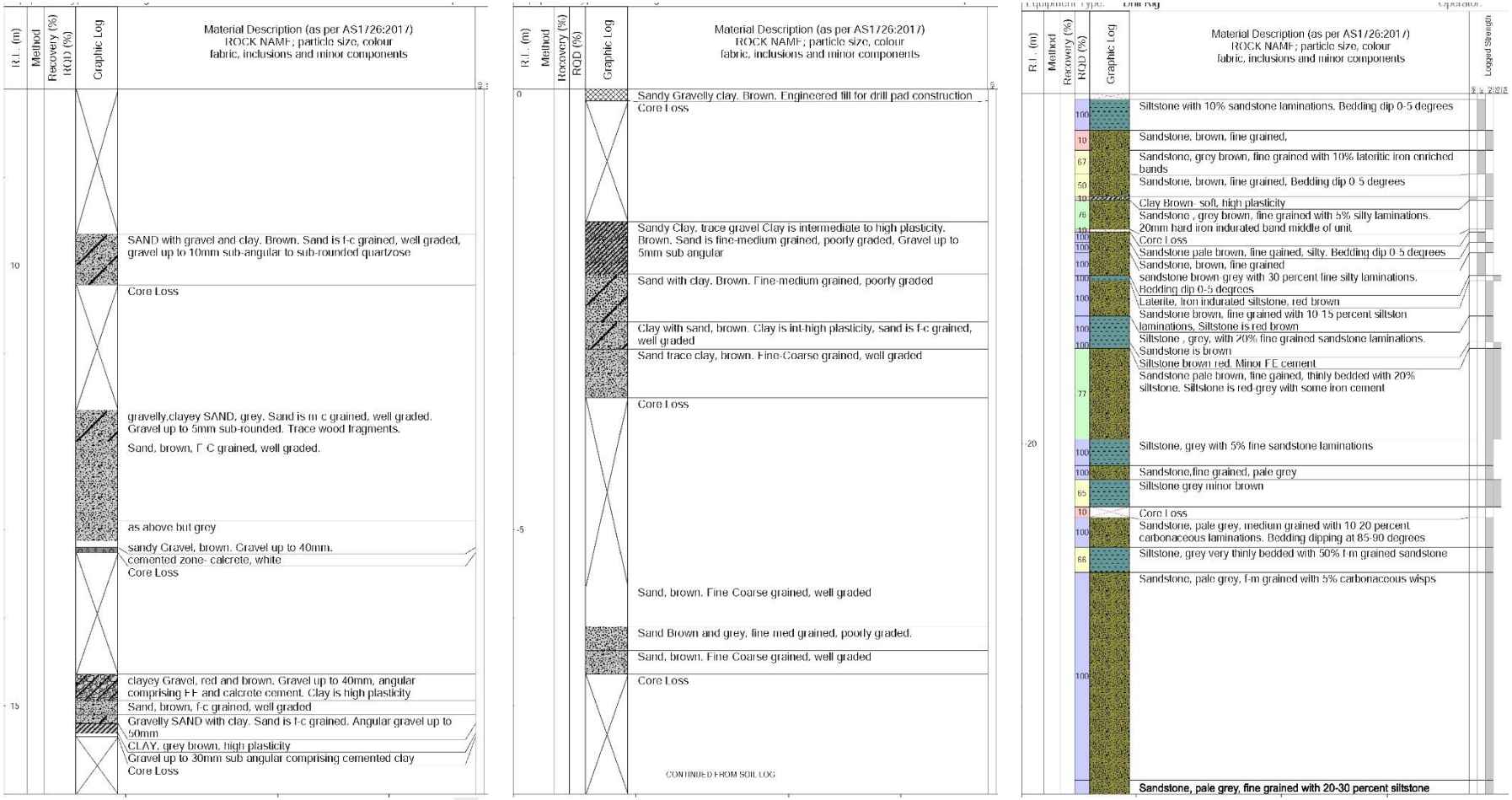


Figure 5 Quaternary and Tertiary sediments at VS03 – note large amount of core loss.

2.4 Goonyella Middle Seam

2.4.1 Coal

The working section for gate road development is 3.6-3.7 m high (Figure 6) and is located specifically to maintain a certain thickness of Ply 2 as the immediate roof. The TCC system seeks to extract a nominal thickness of 5.5 m.

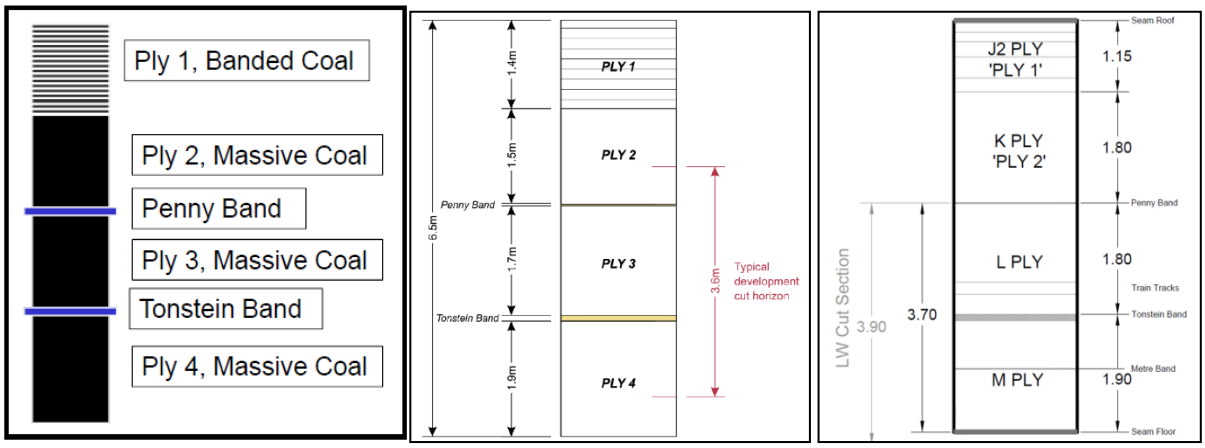


Figure 6 Details of the Goonyella Middle Seam.

2.4.2 Roof rocks

Fine grained rocks such as mudstones and siltstones have a Uniaxial Compressive Strength (UCS) of about 30 MPa. Sandstones are stronger with a UCS of about 40 MPa and with a wider range of variation (Figure 7).

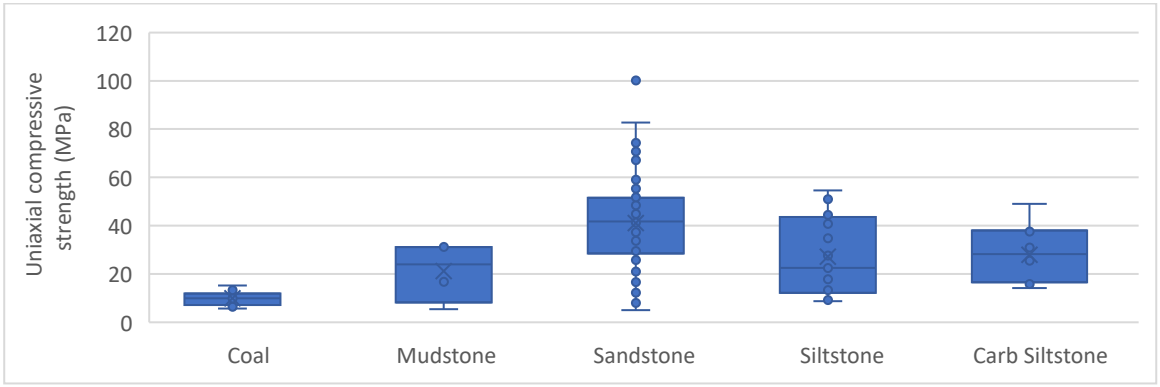


Figure 7 Range of UCS values for different lithologies.

The areal distribution of immediate roof strengths is presented in Figure 8 which is based on estimates of rock strength derived from geophysical logs. There are no low strength clayey units in the immediate roof or floor of the GMS.

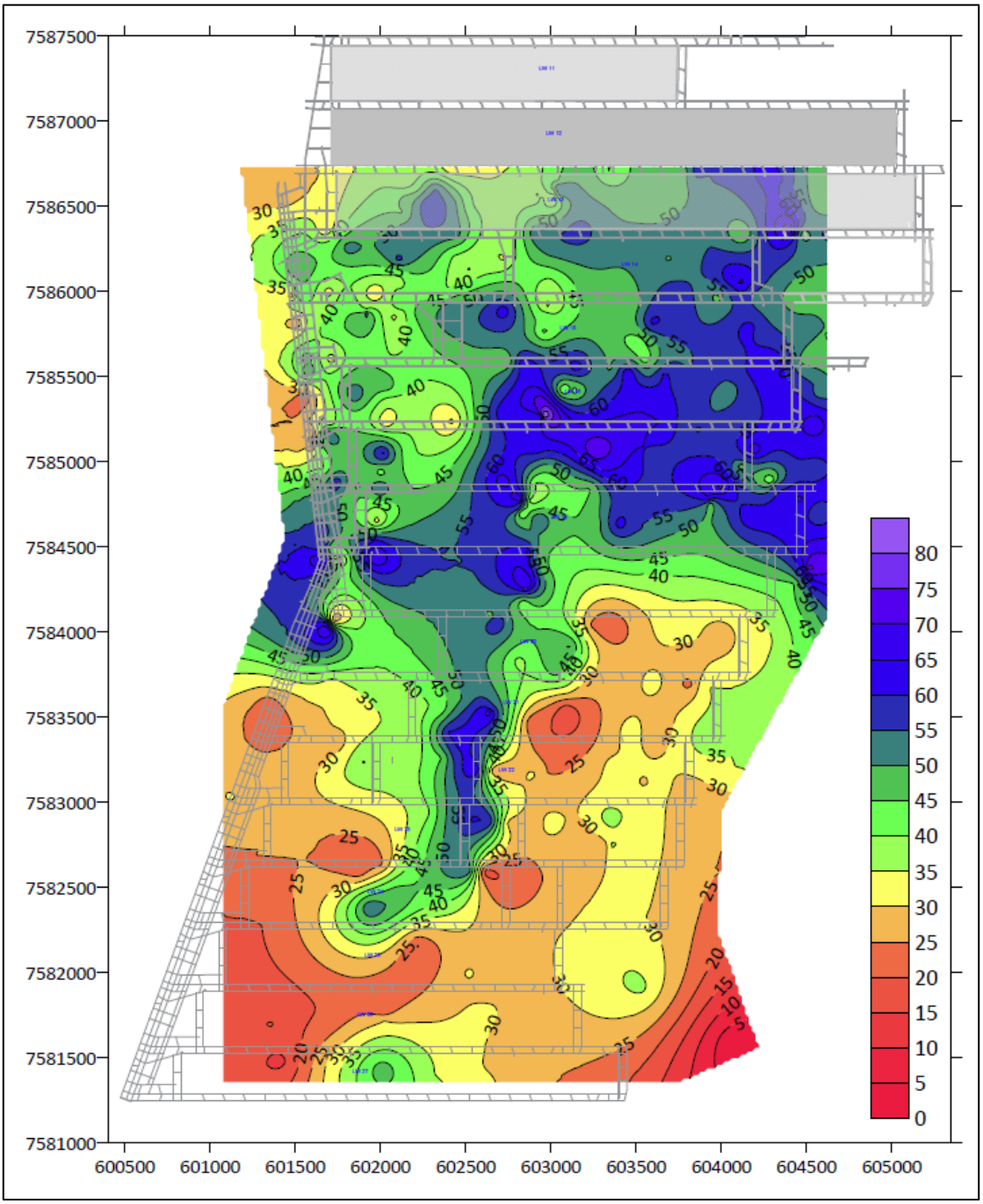


Figure 8 Sonic derived strength of the roof of GMS 2-6 m above

2.4.3 Immediate floor

The floor of the GMS consists of mudstones with no puggy clay horizons present. The compressive strengths are about 25-35 MPa.

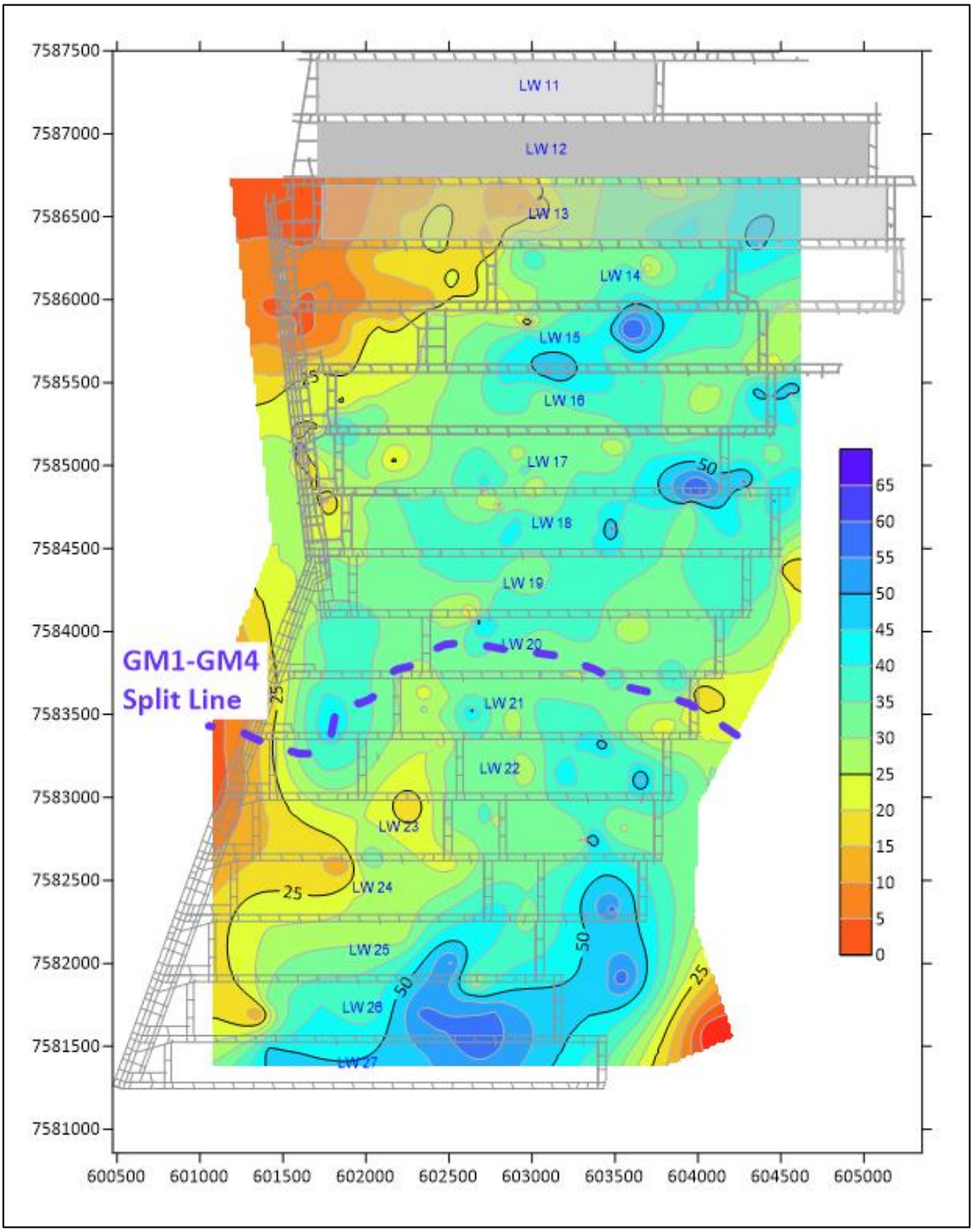


Figure 9 Sonic- derived floor strength for 1.0-2.0m interval below GM Seam

2.5 Goonyella Lower Seam

As of 2024, the geotechnical information available for the GLS has not been presented in the same way as for the GMS. There is information that compares the immediate roof and floor of the two seams which indicates that the GLS roof and floor is slightly stronger than the GMS (Table 1). It is assessed that the strength differences between the two seams are not significant and that the subsidence prediction method for the GMS seam can be validly applied to the GLS seam.

Table 1 Comparison of GMS and GLS lithologies and strengths

	Comments in BMM511c[3]
GMS roof	Siltstones – 25 MPa Sandstone 25-30 MPa Siltstone laminate sandstone 25-50 MPa Interbedded sandstone >35 MPa
GLS roof	Interbedded siltstone/sandstone 30-75 MPa Interbedded sandstone and siltstone 30-75 MPa
GMS floor	Moderate strength sandy floor Siltstone mudstone – 25-35 MPa Carbonaceous siltstone 25-35 MPa
GLS floor	Siltstone – 25-30 MPa Sandy floor 30-35 MPa Shale/sandstone floor 35-40 MPa Carbonaceous siltstone 30 MPa

3 SURFACE DEFORMATIONS DURING MINING OPERATIONS

3.1 Longwall mining

Inherent in safe and productive longwall mining is the collapse of the rock mass above the extracted coal. The geotechnical parameters of the local and regional geology (Section 2) are critical in understanding the way in which the strata above the underground mine will collapse. The collapse may extend to the surface if the width of the extraction relative to the depth of mining exceeds about 0.5. The width:depth ratio for the current and legacy longwall mines in Queensland means that the collapse extends to the surface and vertical subsidence develops progressively as the longwall advances. Maximum subsidence develops above the extraction within about 100 m of the active longwall mining face: there is also a lesser amount of vertical subsidence above the chain pillars (between the longwall panels) that develops independently of that above the longwall panel extraction (Figure 10).

There are 2 types of pillars in a longwall mining layout: mains pillars that provide access to the longwall panels and chain pillars that separate consecutive longwall panels. The mains pillars and the associated roadways are designed to be stable during the operations – both in terms of roof collapse in the roadways and stability of the pillars. The mains pillars are designed with high stability factors such that failure over the long term is unlikely and the vertical subsidence on the surface is expected to be minimal, if any. The chain pillars have lesser levels of stability and while they are designed not to collapse during longwall extraction may deform significantly and result in measurable subsidence. The collapse of the rock mass above the extracted longwalls results in the

[3] SCT 2016 Development of GMS and GLS Roadway Models for the Selection Phase of the GCOS Project.

chain pillars being confined such that on-going subsidence does not develop – subsidence is effectively complete after a few months but this depends on the rate of longwall extraction.

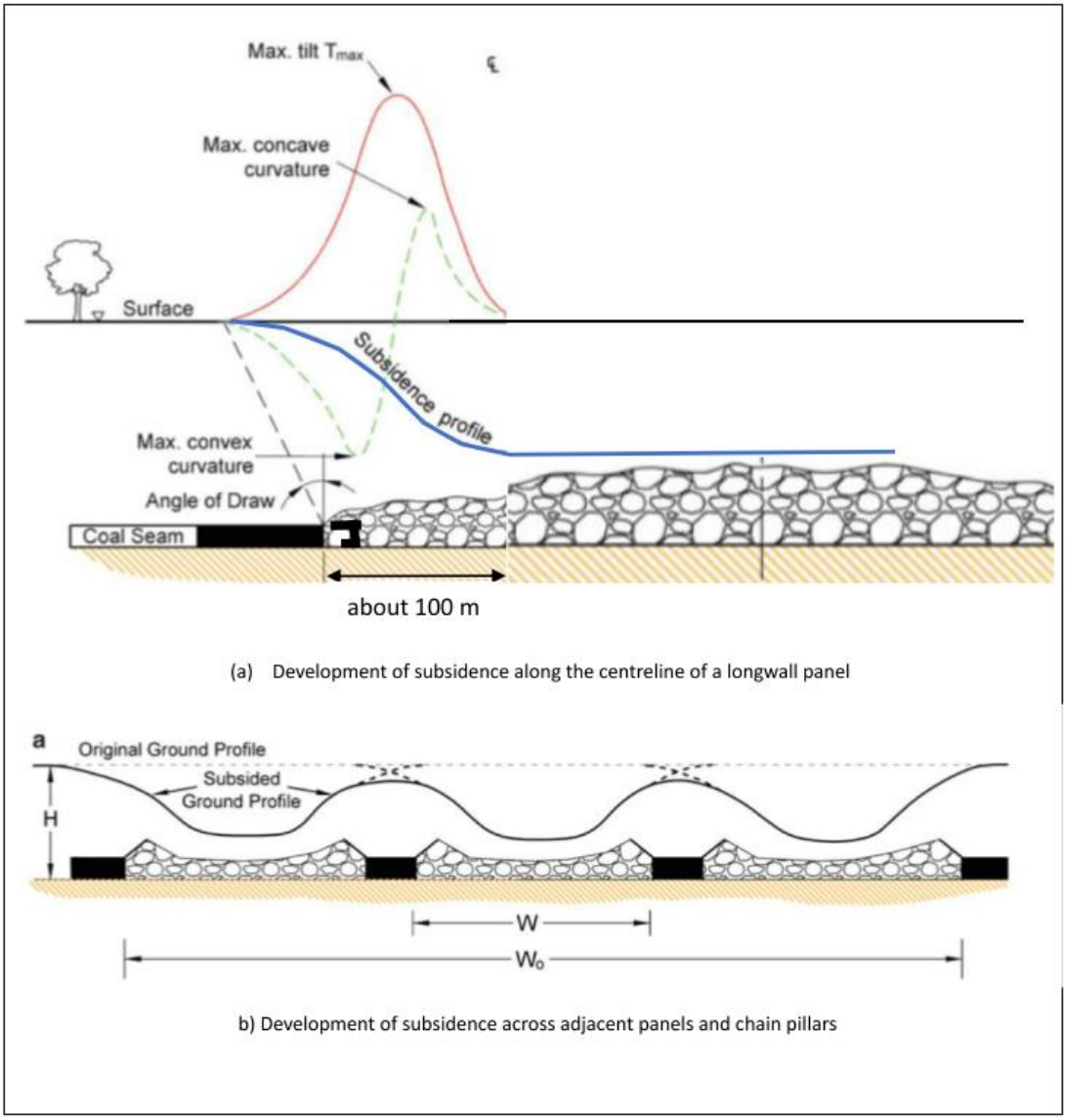


Figure 10 – Subsidence deformations (Modified from Galvin (2016)[4] Figure 10.1 and Figure 10.16)

Mining subsidence results in the following deformations and associated impacts at the surface:

- Downward vertical movements
- Change in surface slope angles
- Vertical steps and compression humps
- Surface cracking

[4] Galvin JM 2016. Ground engineering Principles and Practice for Underground Coal Mining.

3.2 Subsidence at Broadmeadow Mine

3.2.1 Above the longwall panels

The magnitude of surface subsidence directly above the longwall extraction at Broadmeadow has been well established using conventional terrestrial surveys. Surveys are completed down the centreline of each longwall panel and 3 cross lines. A peg spacing of 10 m has been used.

The crossline data for LW15 (Figure 11) shows the expected patterns for the longwall panels at Broadmeadow Mine, with the maximum vertical subsidence being 3.44m, the maximum tilt being 7.4 mm/m and the maximum tensile strain being 22.5 mm/m.

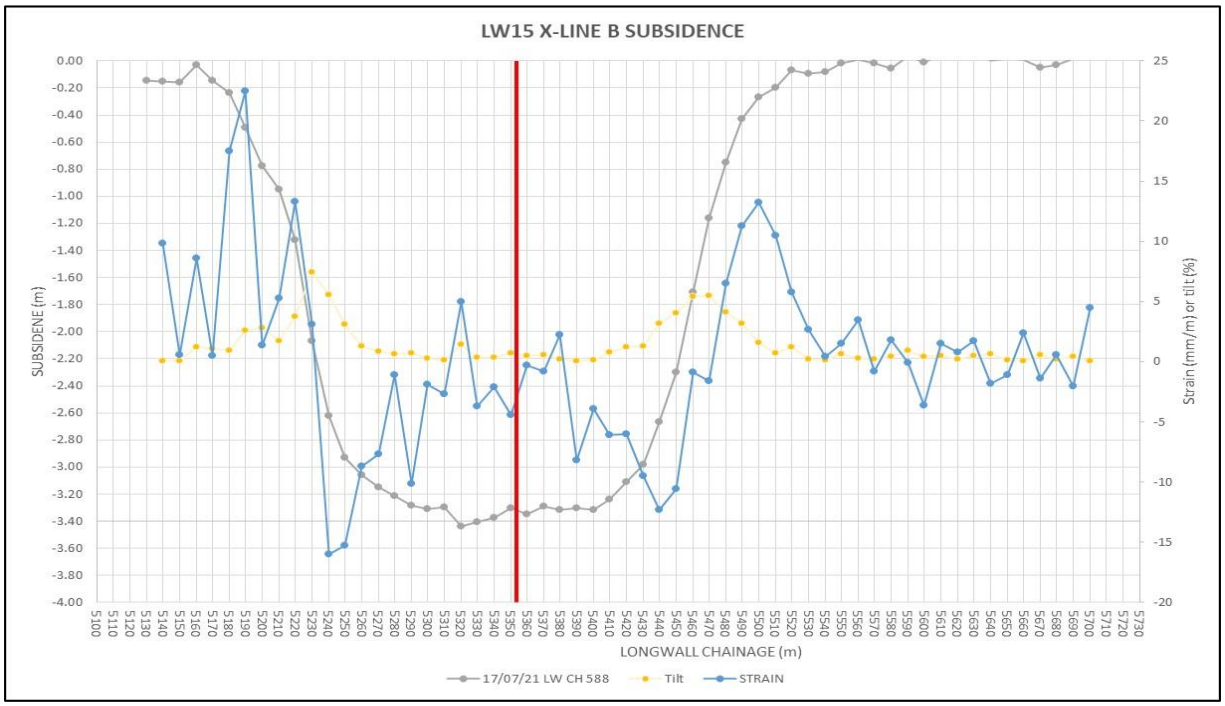


Figure 11 Example of crossline survey data used to derive prediction inputs

There are variations in the vertical subsidence measured along the centrelines of the longwalls (Figure 12). The maximum vertical subsidence recorded along LW15 centreline is 3.77 m. The bottom of the subsidence trough is not smooth – for LW15 the average subsidence between chainage 1780 and 410 is 3.4 m with a range between 3.0 - 3.77 m, with a standard variation of 0.16 m, and a coefficient of variation of 4.7%.

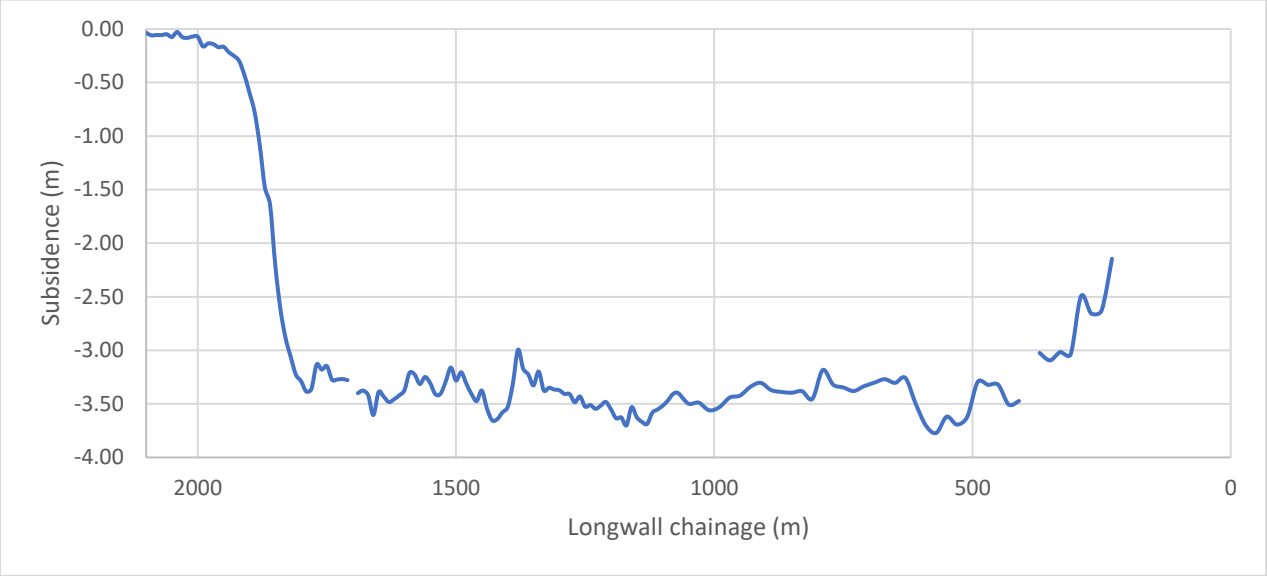


Figure 12 Example of vertical subsidence along the centreline survey of LW15

Figure 13 compiles data on the maximum vertical subsidence recorded along the surveyed centrelines for all longwalls to date. This plot highlights the fact that maximum subsidence is related to extraction thickness with the earlier conventional longwall extracting 3.8 m coal section and the TCC system extracting a thicker but variable section. There is more variability in the TCC data possibly related to variations in the amount of coal recovered in the caving process.

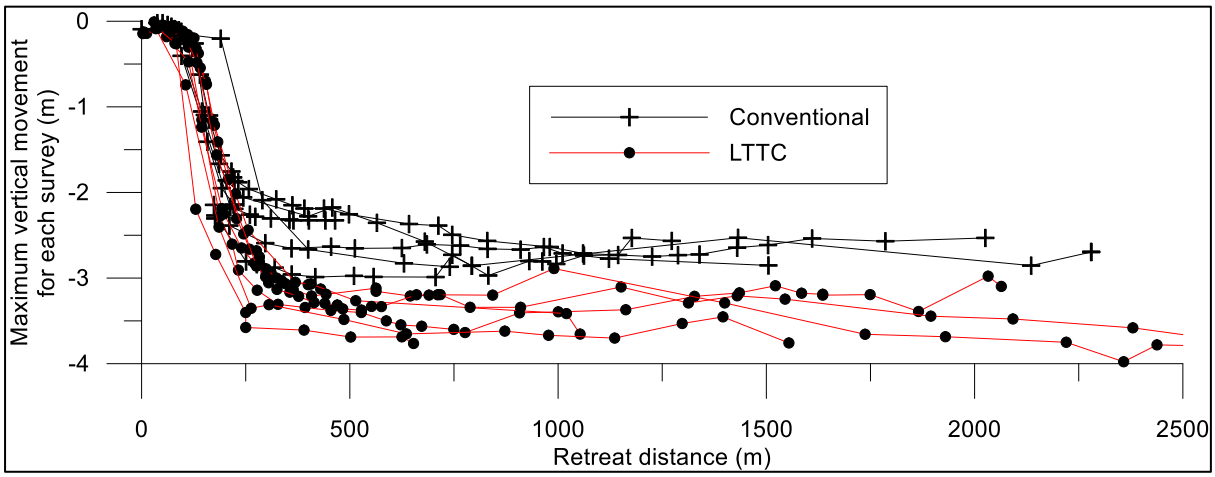


Figure 13 Compilation of centreline survey data

3.2.2 Above the chain pillars

The terrestrial surveys do not provide adequate coverage of the subsidence above the chain pillars. LIDAR surveys have given the general indication that subsidence above the chain pillars increases to the east with the greater mining depths (Figure 14). The resolution of these surveys could not detect vertical subsidence above pillars formed at depths less than about 250 m.

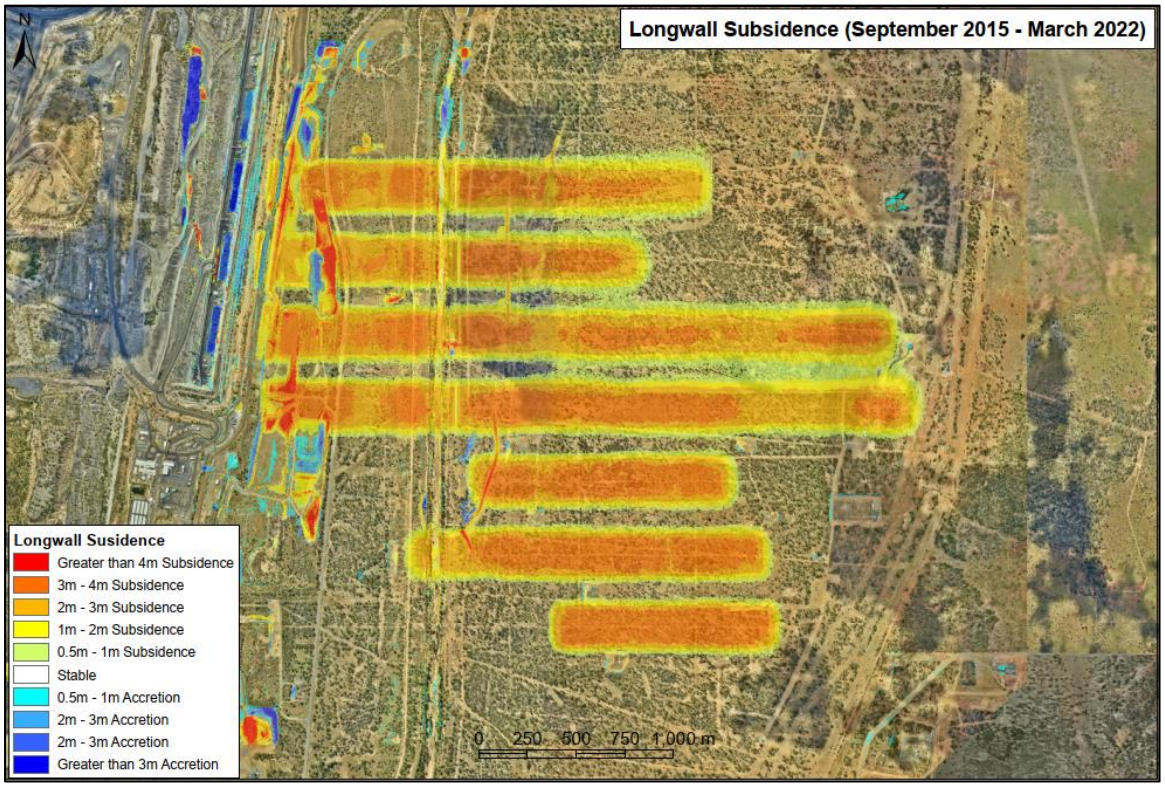


Figure 14 Example of Lidar data

3.3 Prediction and visualisation of subsidence

Inspection of the terrestrial surveys indicate that the shape of the subsidence bowl can be modelled with a gaussian influence function. The average maximum vertical subsidence over the initial longwalls was 2.8 m and this has increased to 3.4 m for the TCC panels. Relative to the extracted thickness, the maximum subsidence (Smax/T) is 0.75. The location of the maximum tilt (also the point of inflexion in the subsidence profile) relative to the extraction edge is 0.2 times the mining depth.

The prediction of future subsidence is based on the view that the overburden geology (Section 2) will not be materially different to that already encountered for GMS and that ratio of the mining depth to extraction width remains greater than 1.0.

In this report the Surface Deformation Prediction System (SDPS) influence function method[5] has been used to visualise subsidence deformations. SDPS provides 2 ways of modelling subsidence above chain pillars (Figure 15):

- One way involves the simple addition of the predicted subsidence for each longwall panel. Without calibration data, the panel addition method is more applicable for deeper mines and has been adopted for Broadmeadow. This method tends to underestimate pillar subsidence but gives a better representation of the subsidence above the extraction. Predictions were made on 20 m centres.
- The alternative way is to assume the maximum subsidence is developed over all panels and then the chain pillars are specifically introduced. This pillar reduction method works

[5] Surface Deformation Prediction System (SDPS) Software | Office of Surface Mining Reclamation and Enforcement (osmre.gov)

reasonably well for longwalls at shallow depths (individual panels are supercritical) but becomes more complicated for deeper mines (individual panels are subcritical).

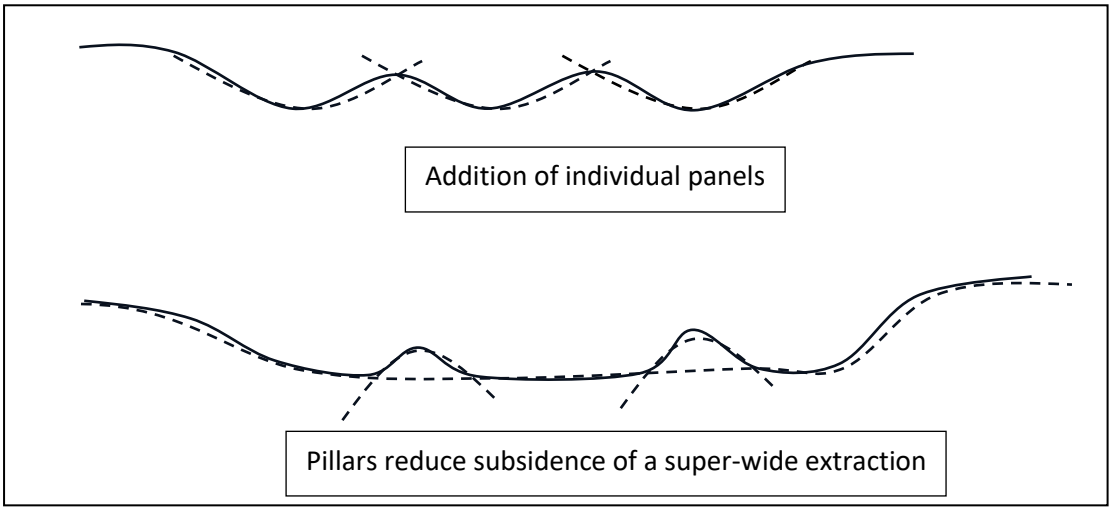


Figure 15 Two ways of modelling pillar subsidence in SDPS

SDPS has been used to visualise the vertical subsidence, tilts, and strains for both the GMS and GLS using the parameters detailed in Table 2. Note that the mathematics invoked in SDPS produces deformations down to 1 mm. A cut-off vertical deformation of 20 mm was adopted to define the onset of mining-induced displacement. As will be discussed below, there may be additional subsidence deformations when the abandoned underground workings are flooded.

Table 2 Default parameters for subsidence prediction at BMA mines

Smax/T	0.75
Edge-effect offset (distance from panel edge to inflexion point normalised to mining depth)	0.2
Angle of influence	63.4°
Factor to convert curvature to strain (metric system)	0.2

The visualisation for the end of mining of both the GMS and GLS is obtained by the addition of the vertical subsidence and horizontal strain grids. The tilts for the combined subsidence were determined by a calculus manipulation of the vertical deformations. It is recognized that the addition of the subsidence prediction for each seam may result in an underestimation of the maximum vertical subsidence and associated tilts and strains (possibly in the order of 10%). However, until calibration data is available the addition method is assessed to be suitable for the planning for mine closure.

Visualisations of vertical subsidence, tilts, and horizontal strains after the extraction of both the GMS and GLS are presented in Figure 16, Figure 17, and Figure 18 respectively. Figure 19 presents overall frequency plots of each parameter noting that there is 30.8 km^2 subsided ground. The maximum vertical subsidence is 6.75 m, the maximum change in slope is 8.25% (4.7°) and the strains range from -35 mm/m to +35 mm/m. About 30% of the subsidence area may have tensile strains in excess of 5 mm/m.

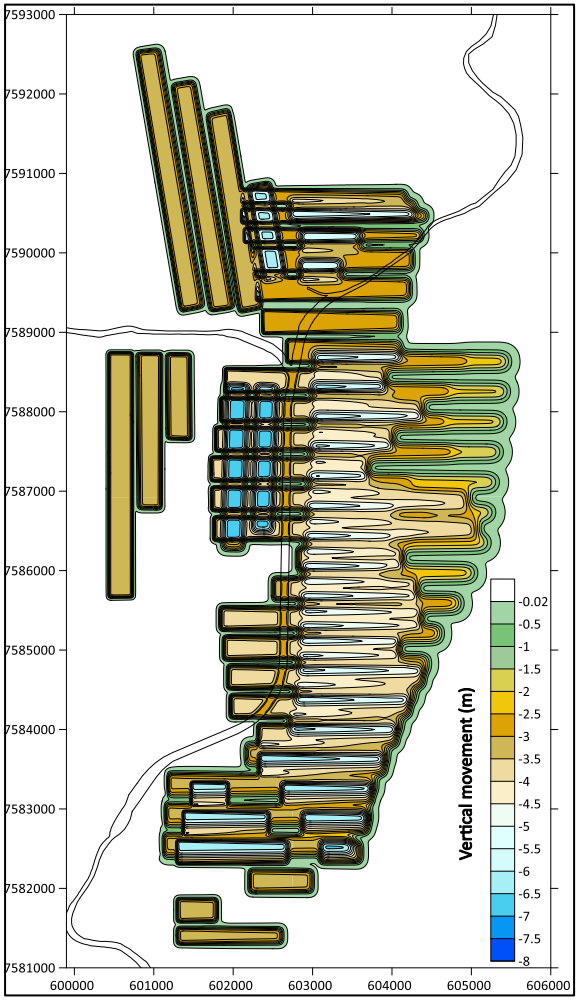


Figure 16 Visualisation of modelled vertical subsidence - both seams dry.

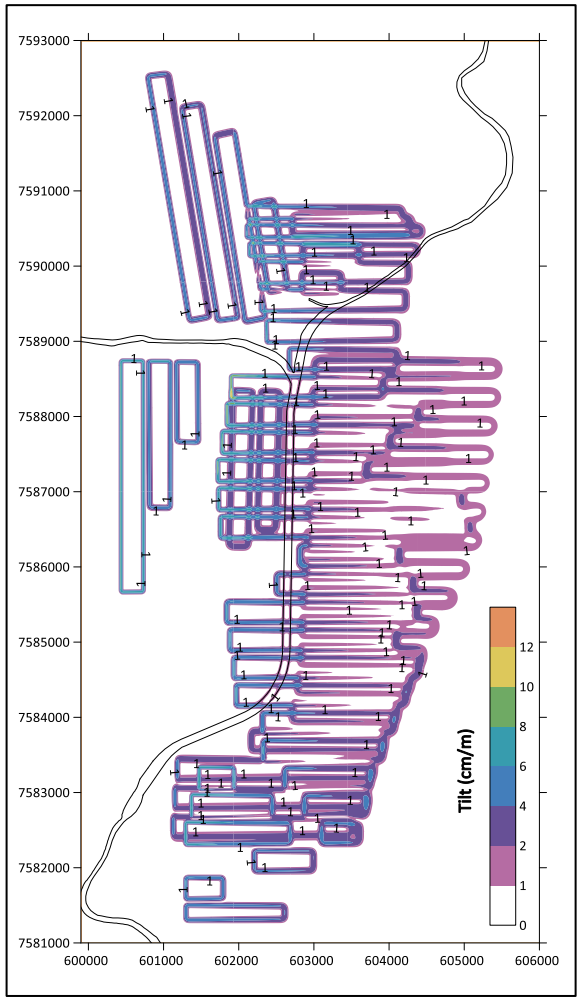


Figure 17 Visualisation of modelled tilts - both seams dry.

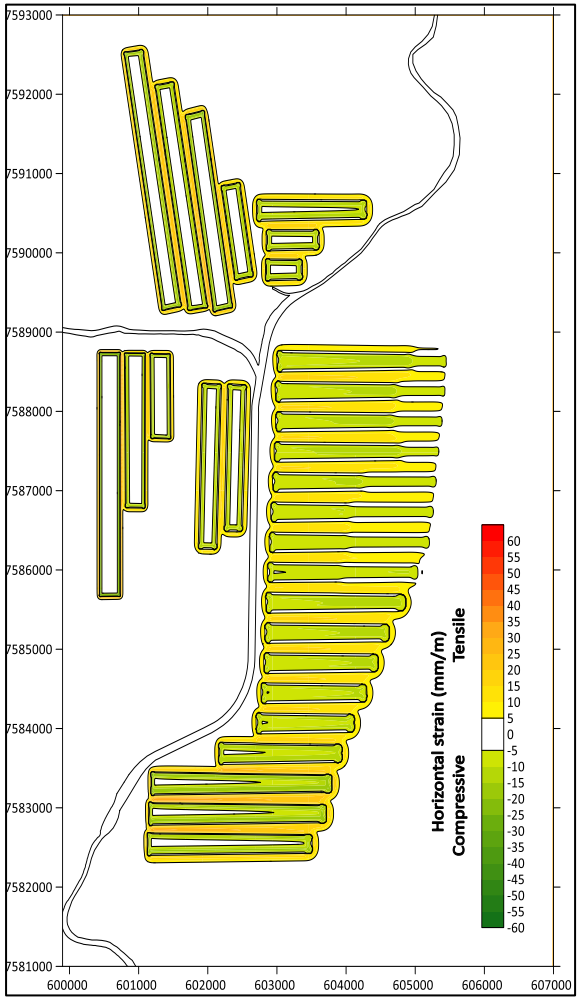


Figure 18 Visualisation of modelled strain - both seams.

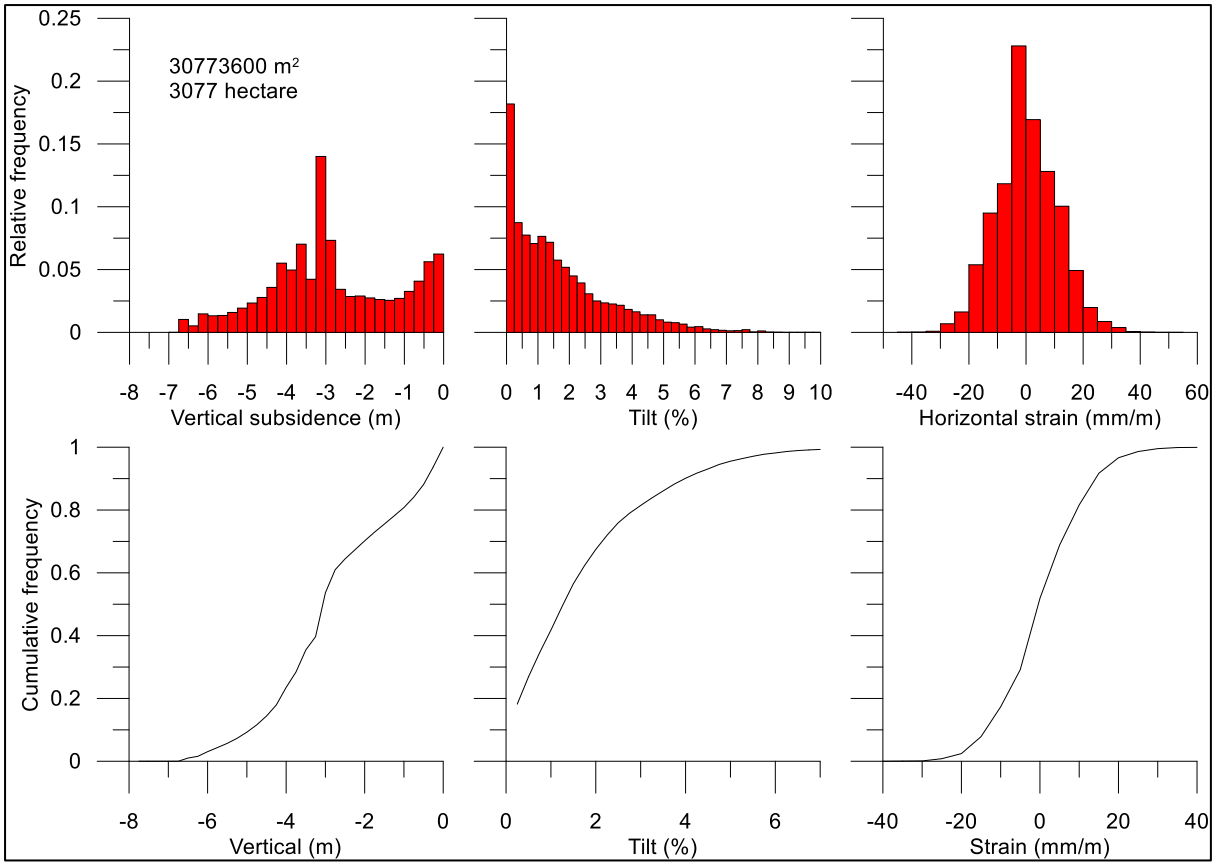


Figure 19 Frequency statistics on total area exposed to mine subsidence as defined by a prediction of vertical subsidence in excess of 20 mm both seams.

3.4 Impact of flooding of the underground workings

When the underground workings are flooded there may be a small amount of additional vertical subsidence related to the softening and consolidation of the caved rock in the presence of water. This additional subsidence after flooding is not included in the modelled results in Section 3.3.

The potential for consolidation has been identified in laboratory studies but there have been no controlled studies at the mine scale to confirm and quantify the scale of this effect. Until such information is available, it is recommended that the Smax/T values used in Table 2 be increased from 0.75 to 0.85. Figure 20 suggests that flooding will have a relatively small impact on tilts and strains.

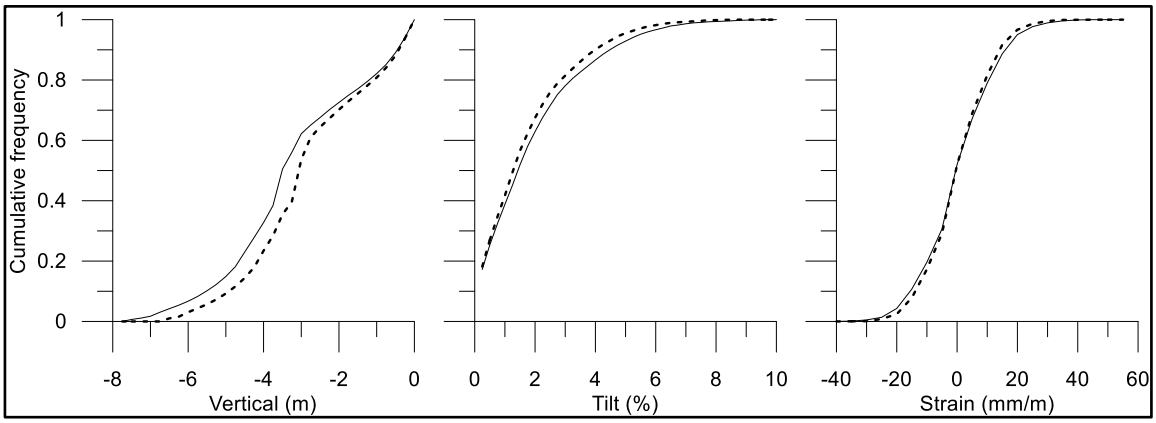


Figure 20 Impact of flooding (flooded – solid line, at mine closure -dashed line)

Flooding of the undergrounds can occur as a direct result of the mine being purposefully flooded, or over time as the groundwater recovers from operational dewatering. Flooding of the mine may temporarily reduce the stability of the pillars, but eventually their stability will be increased due to a buoyancy effect reducing the loads on the pillars.

Additional post-flooding subsidence will not occur until mining in the GLS is complete and the workings are flooded. Once the workings are flooded, any additional subsidence impacts should have developed within 12 months.

4 SUBSIDENCE DAMAGE – CRACKING

The hazards presented by subsidence at closure of longwall mines need to be considered in the context of the post-mining land use. The most problematic hazard is likely to be cracking resulting from subsidence. It is noted that the remediation of vertical steps, humps, and cracking is now addressed to some degree in progressive rehabilitation and forms a part of the day-to-day operational mining rehabilitation activities.

For longwalls such as those at Broadmeadow Mine with high width/depth ratios, cracking is to be expected at the surface (Figure 21). Open cracking may be parallel and close to the panel edges (longitudinal fracture) or parallel to the face line (arcuate fractures). There may be other longitudinal fractures distant from the panel edges.

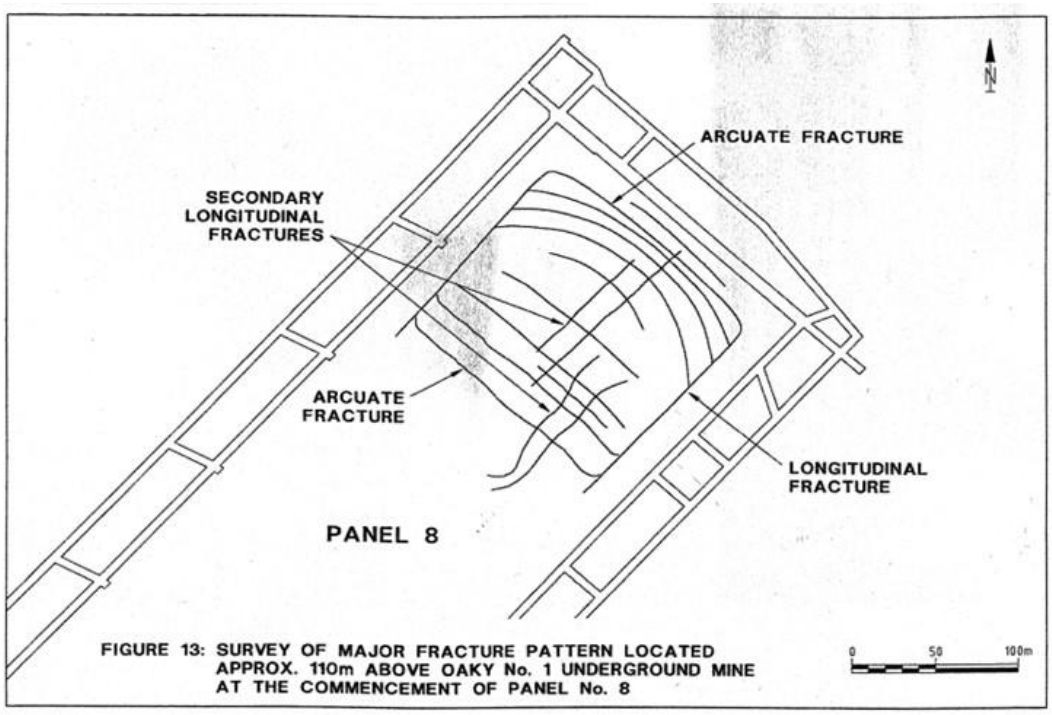


Figure 21 Longwall cracking (ACARP 2000[6])

A reconnaissance survey of subsidence cracking was conducted in July 2023 on site at Broadmeadow Mine.

[6] ACARP Project C5016 (2000) The influence of subsidence cracking on longwall extraction. Prepared by Australian Mining Engineering Consultants.

4.1 Longitudinal cracking

Longitudinal cracking was observed above LW16. The cracks can be considered to result from the onset of block rotations in response to tensile subsidence deformations. During field inspection of LW16 cracking was observed – up to 400 mm wide and at least 2.9 m deep (Figure 22).

The relationship between the width of longitudinal cracks and the predicted tensile strain depends on the spacing of the cracks. The predicted tensile strains are in part related to the spacing of the survey pegs (10 m) used in the calibration of SDPS. An upper bound estimate of the crack width (in millimeters) can be derived from tensile strain predictions (Figure 18 and Figure 19) multiplied by 10.

Assuming rigid body movements, the survey data can be used to obtain an estimate of the depth of cracking. Referring to Figure 23, the maximum strain of 13 mm/m implies a crack width of 130 mm, and this is associated with a differential tilt of 19 mm/m. The possible depth extent of the crack would be 6.8 m (0.130/0.019) at LW15. In the absence of better information, assume a crack depth of 10 m for all surfaces affected by subsidence. Adopting this depth means that the surface cracking extends through plastic clays and silty sands (Section 2.2). The silty sands would be anticipated to immediately collapse into subsidence cracks but the subsidence cracks in the clays would be metastable are only likely to collapse after rainfall.

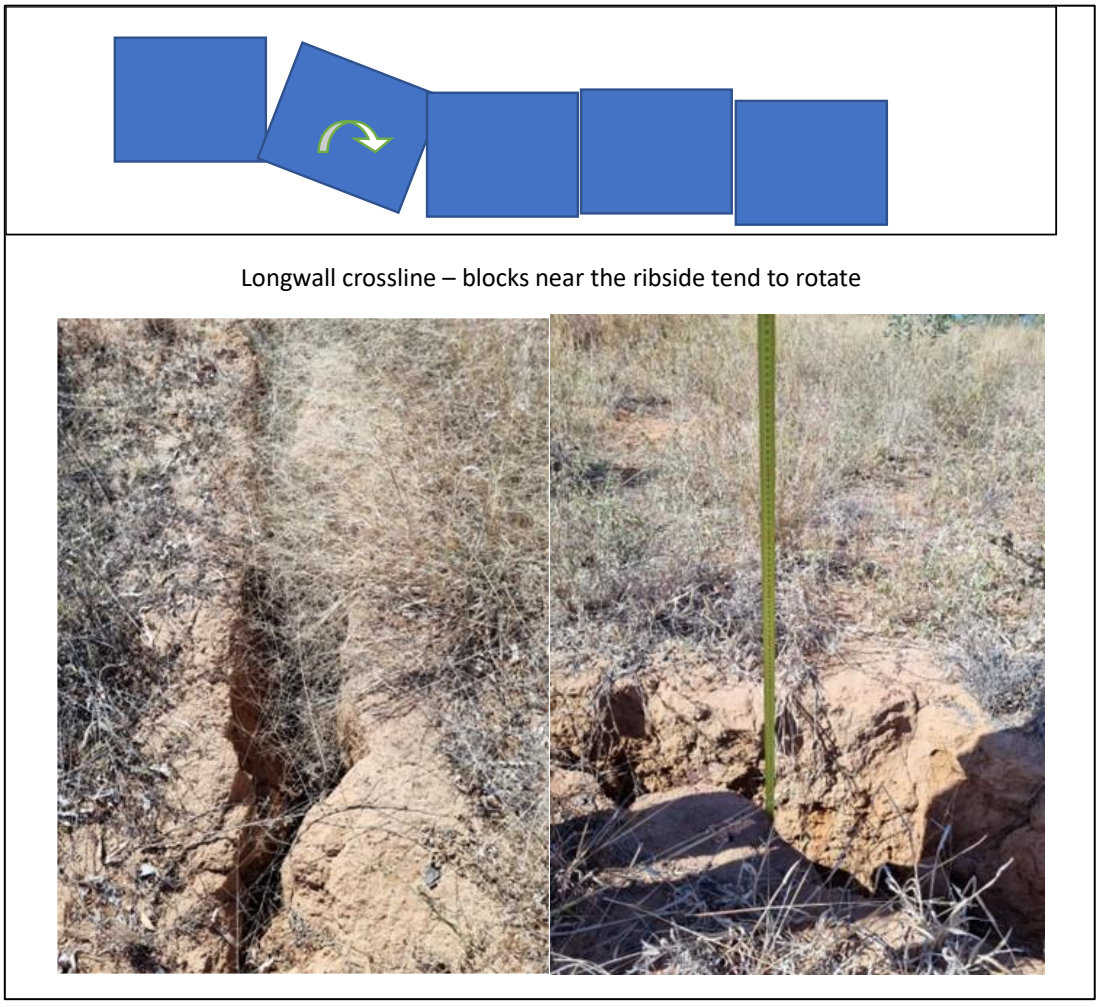


Figure 22 Longitudinal cracks

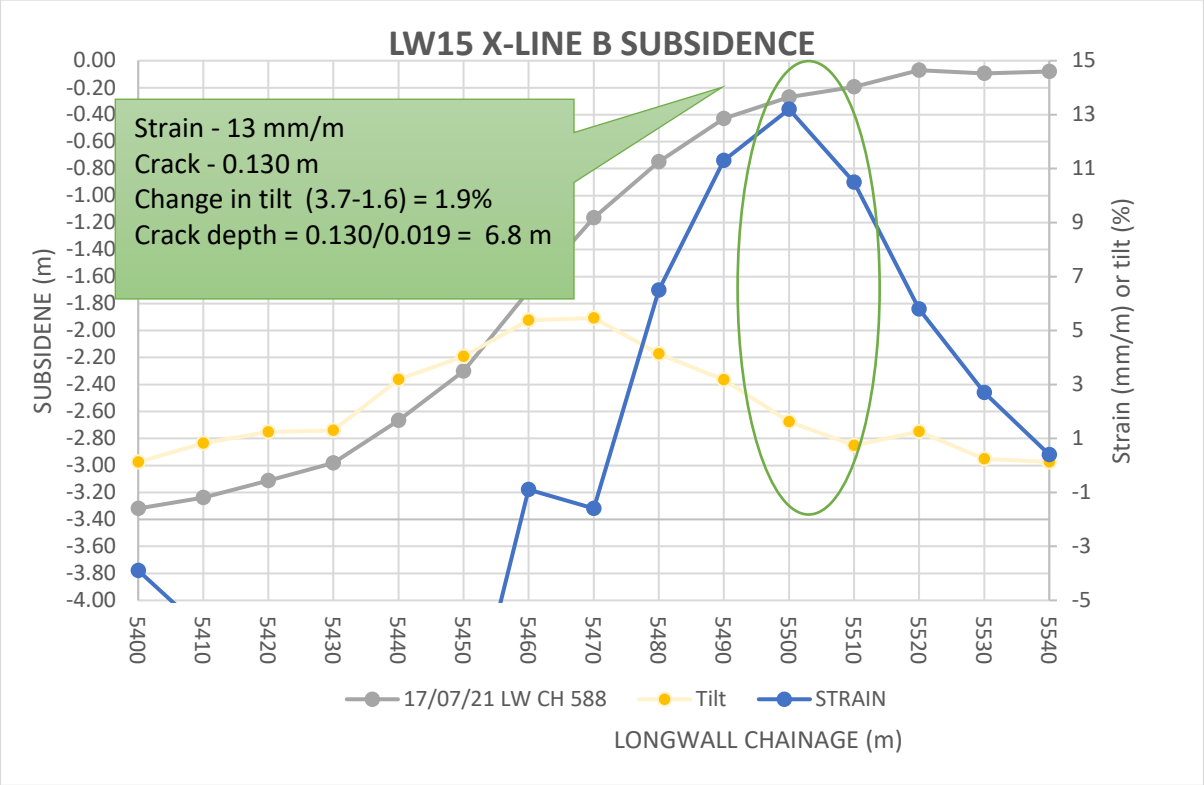


Figure 23 Detail of high strain and high tilt recorded on a subsidence cross line (for full crossline data refer to Figure 11).

4.2 Arcuate cracking

Arcuate cracking (Figure 24) was more readily found during the reconnaissance survey. The mode of formation of these cracks is more by vertical shear so the result is the formation of steps with relatively little dilation.

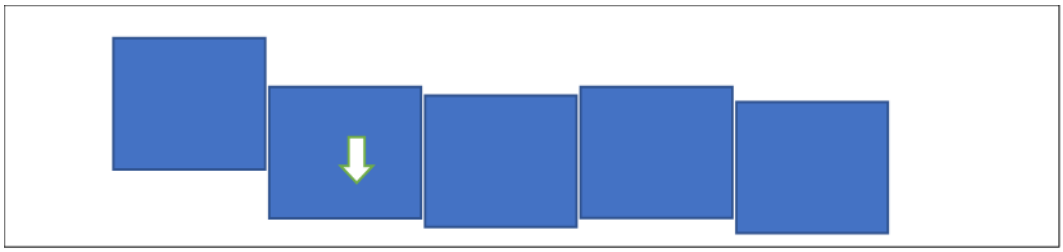
The presence of vertical steps can be interpreted from the centreline survey by calculating the vertical offset between successive pegs which are spaced at 10 m intervals (Figure 25). Most are less than 200 mm but there are some that were up to 400 mm or greater.

5 OVERBURDEN FRACTURING – HYDROGEOLOGICAL CHANGES

Longwall mining results in fracturing of the rock mass above the coal as the overburden sequence collapses/caves into the void left by the extraction of the coal. This is an intrinsic part of the mining system.

Seedsman et al (2023)[7] updated an early hydrogeological model to include estimates of hydraulic conductivity. Hydraulic conductivity within the Enhanced Conductivity Zone (ECZ) and Disrupted zone was estimated using a simple geometric model (Figure 26) for the increase in length along a given horizontal line because of downward movement and assuming a given spacing of fractures (be they joints or mining induced). The model assumes no dilation at the centreline above the Potential Consolidation Zone (PCZ). The dilation is equally distributed between the fractures and conductivity is calculated based on laminar fracture flow with smooth interfaces. The predicted conductivity is isotropic. The parameters for the PCZ were derived from large scale permeameter tests.

[7] Seedsman, R., Fellowes, M. Thoeni, K. and Fityus, S. (2023). Hydrogeological aspects of pumped hydro schemes using abandoned longwall mines. Proceedings of the 14th Australia and New Zealand Conference on Geomechanics, Cairns.



Longwall centreline – blocks move downwards (and to a lesser degree sideways) at discrete intervals

Figure 24 Acuate cracks

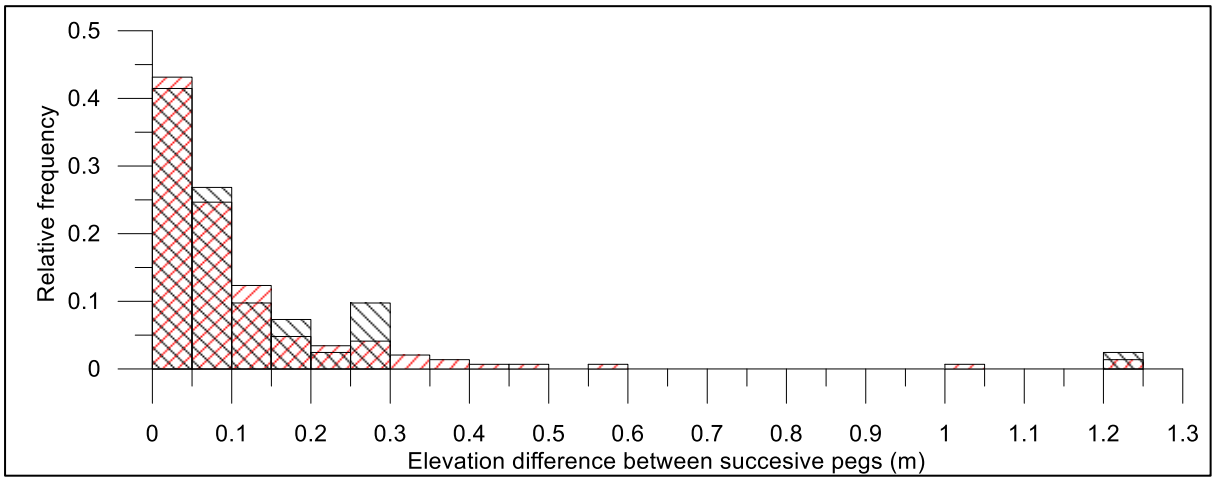


Figure 25 Evidence of vertical steps derived from the LW16 centreline survey.

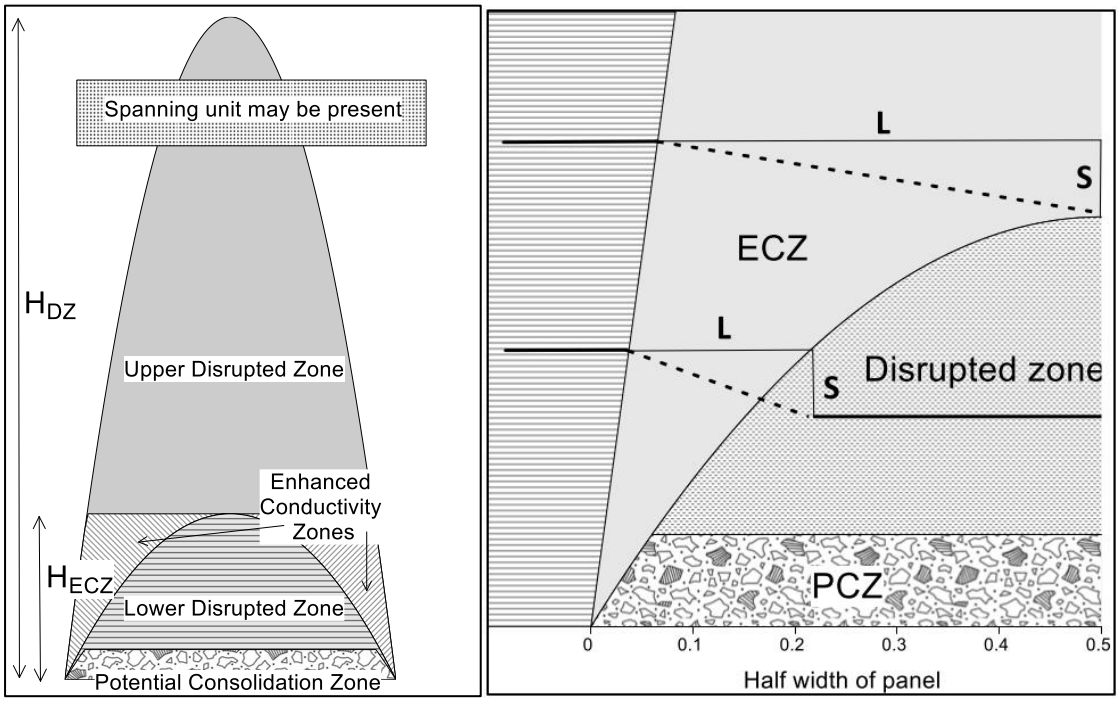


Figure 26 Basis of the geotechnical crack dilation model

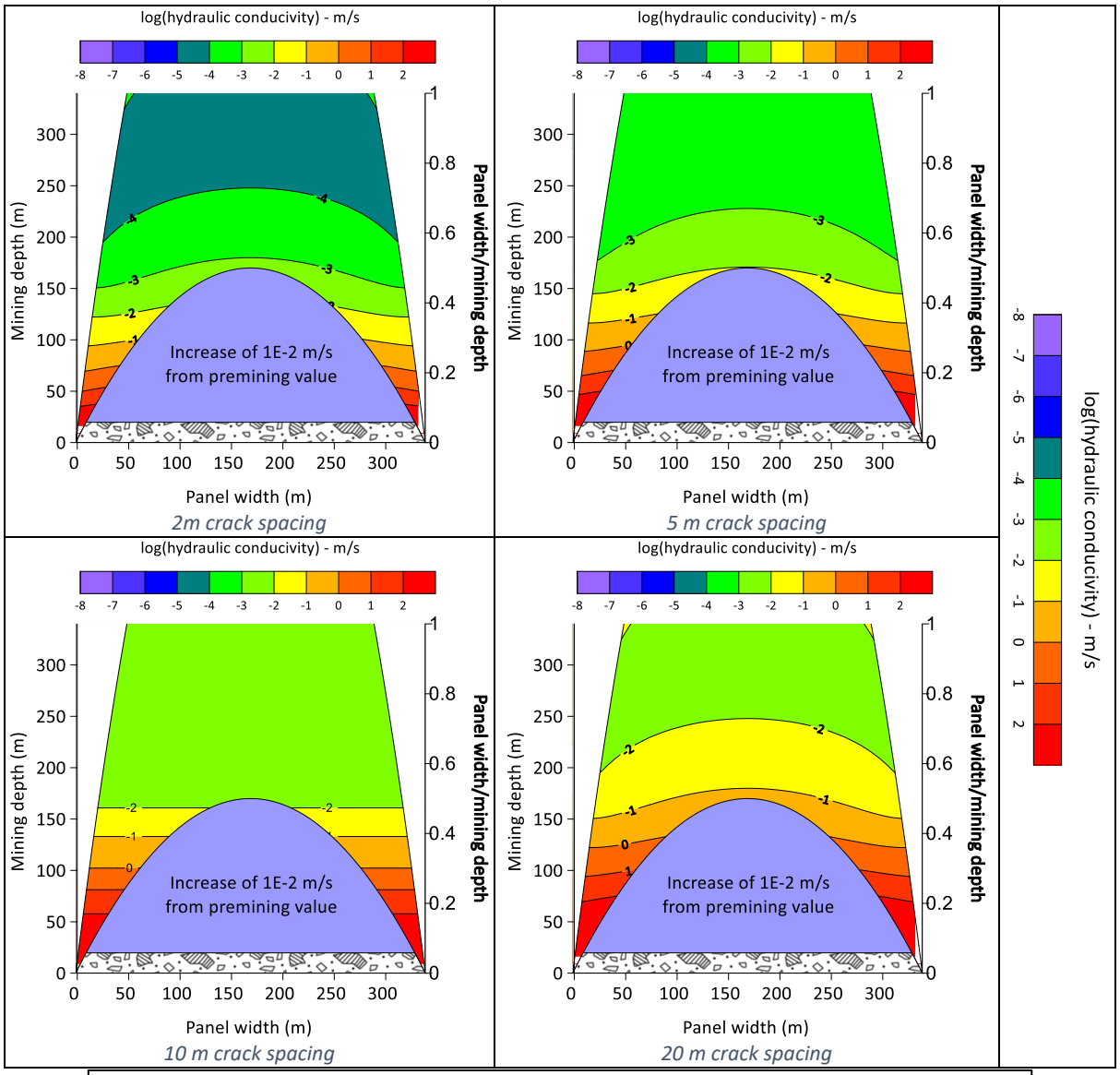
The input variables to the geotechnical model are:

- Maximum vertical subsidence, or more precisely the difference in the maximum subsidence at /near the panel centreline relative to the subsidence above the chain pillars.
- The extraction width.
- The spacing of the cracks – these may be mining-induced or the natural geological joints.

Note that the prediction is particularly sensitive to assumptions about the spacing of cracking induced by the longwall extraction. The only rock mass property used in the geotechnical model is the spacing of the joints – the rock mass is assumed to be a dilated fractured volume of rigid blocks. The geotechnical model is applicable to the Permian and Tertiary sequences but does not include the possible role of Quaternary and Recent alluvials at the surface.

Estimates of the resulting hydraulic conductivity are presented in Figure 27. The data for a crack spacing of 2 m is currently recommended for Broadmeadow Mine.

After mine flooding it is possible that conductivities in the lower portions of the Enhanced Conductivity Zones will decrease to values similar to those for the Disrupted Zone. It is anticipated that there will be lesser decreases in the upper disrupted zones



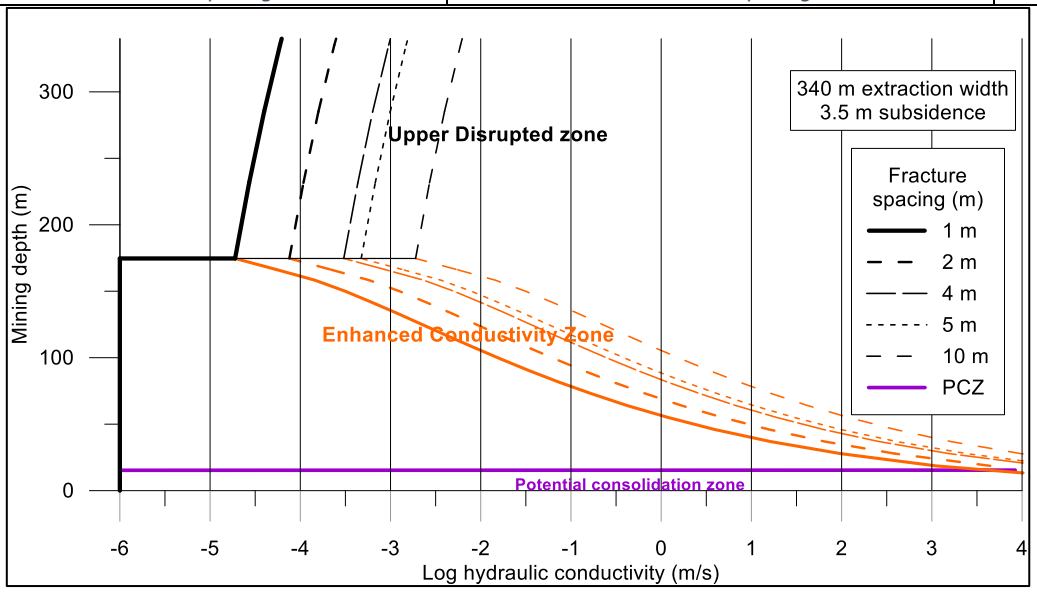


Figure 27 Hydraulic conductivity distribution depends on the spacing of fractures (340 m wide extraction, 3.5 m subsidence.

6 STABILITY ASSESSMENT

An assessment of the current and ongoing stability of the underground workings is critical to understand the subsidence risk at closure. Specifically, the possibility of pillar collapse leading to surface subsidence or roof collapse leading to pot-hole subsidence and the impacts on the post mining land use nominated for the area.

6.1 Standing pillars

6.1.1 Mains

For operational reasons the pillars in the main access roadways (Mains pillars) are typically designed with high levels of stability and a design life in excess of 50 years. Typically, Mains pillars are dimensioned with a factor of safety in excess of 2.0 and there is a conjecture that the probability of failure is better than 1:1 000 000. It is valid to assume that these mains pillars have not and will not collapse at BRM.

Specifically for the GMS seam the minimum main pillar width is 19.5 m at depths between 75 m to 105 m and these have stability factors in excess of 3.0 (Figure 28). The associated subsidence ranges are estimated from 18 mm to 32 mm.

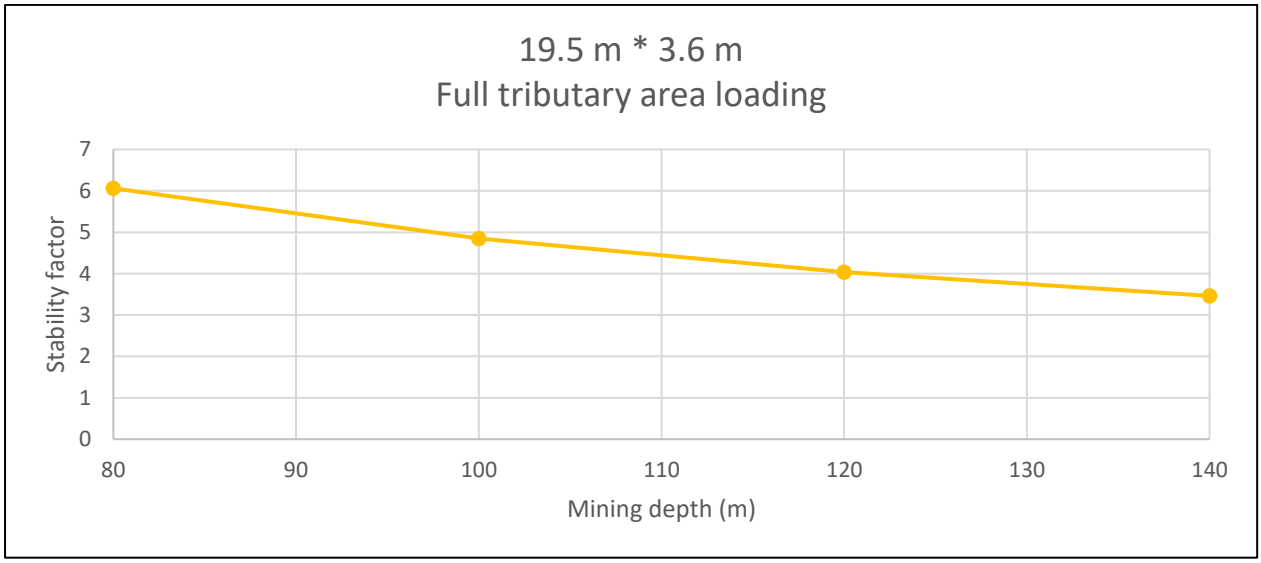


Figure 28 Stability factors for GMS mains pillars.

For the GLS seam, the 29.6 m wide pillars are planned for all depths down to 300m. Mains are aligned with the Isaac River. Figure 29 indicates that these are long-term stable and will have negligible surface subsidence associated with them.

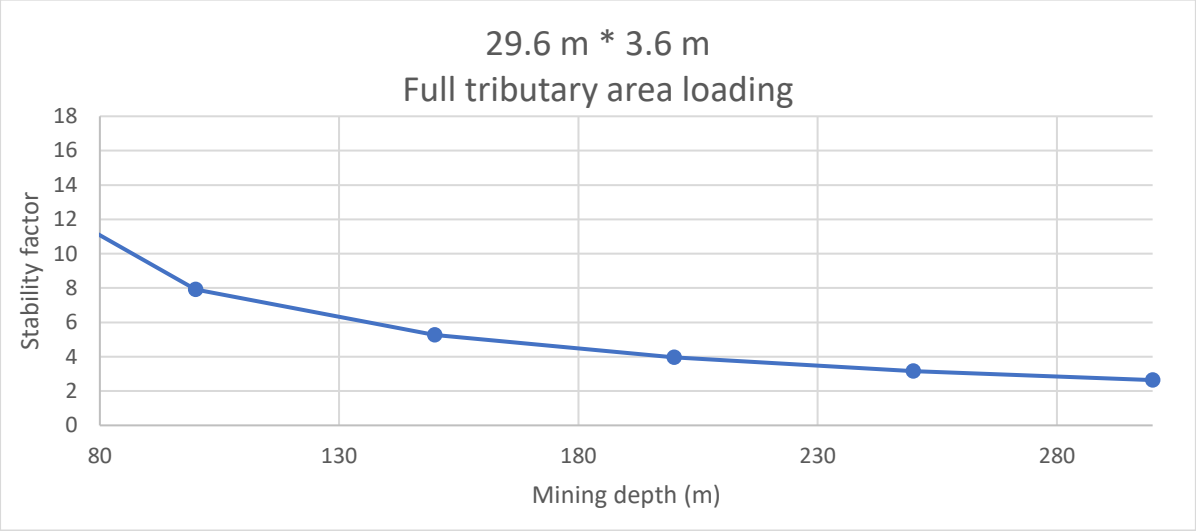


Figure 29 Stability factors for GLS mains pillars

6.1.2 Chain pillars

A number of different chain pillar widths have been used or are planned for the GMS and GLS operations. Figure 30 is a cross plot of pillar width and mining depth showing the relationship to stability and subsidence. Stability factors are in excess of about 1.5 except for one area of the GMS seam which was of limited extent and has already been extracted.

Note that the subsequent collapse of the goaf means that at mine closure the chain pillars will be laterally confined so they will have greater stability than that implied by this analysis.

An elastic (non-failure) analysis suggests surface subsidence between 400 mm and 1.4 m which is considered to be in agreement with what has been recorded to date.

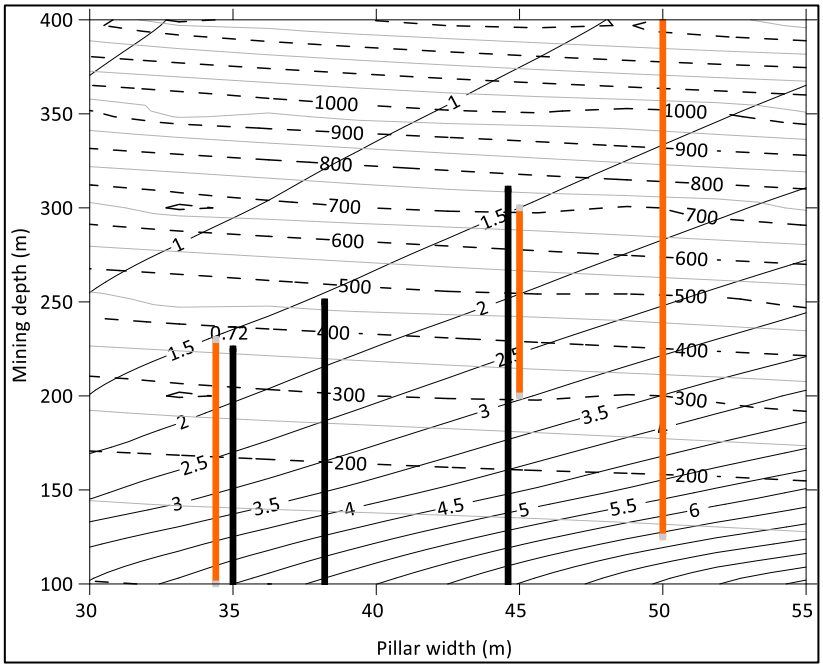


Figure 30 Range of stability factors (solid) and surface subsidence (dashed, in mm) of GMS (black) and GLS (orange) chain pillars.

6.2 Potholes

The depth of mining is such that there is no hazard of pothole subsidence outside of any NUMA associated with the highwall entries of the GMS.

6.3 Stability after mine flooding

Groundwater recovery has a possible impact on stability. Flooding of the workings can occur naturally at closure through the re-establishment of ground water or artificially with water being actively pumped into the workings. This flooding will remove oxygen from the workings and lower the potentially acid forming pollutants and displace any explosive atmosphere located within the mine.

Laboratory testing indicates there is a measurable decrease in uniaxial compressive strength on saturation of coal measure rocks. This strength reduction has the potential to impact pillar stability and it could be appropriate to consider a 10% reduction in long term pillar strength.

There is also a possibility of reduction in the floor strength of the roadways which would result in a reduction in the bearing strength of the pillar floor system (Figure 31). The reduction in roadway floor strength may be relatively small so the impact on pillar stability will be minor unless the impacted layer is very thick and initial floor stability was low. Quantification of this mechanism will require knowledge of the strength of the floor to a nominal 10 m below the mined seam – this information is needed at a 5-10 cm resolution. The material under the pillar will not lose strength as water cannot flow in this direction against the pore pressure gradient induced by the loaded pillars.

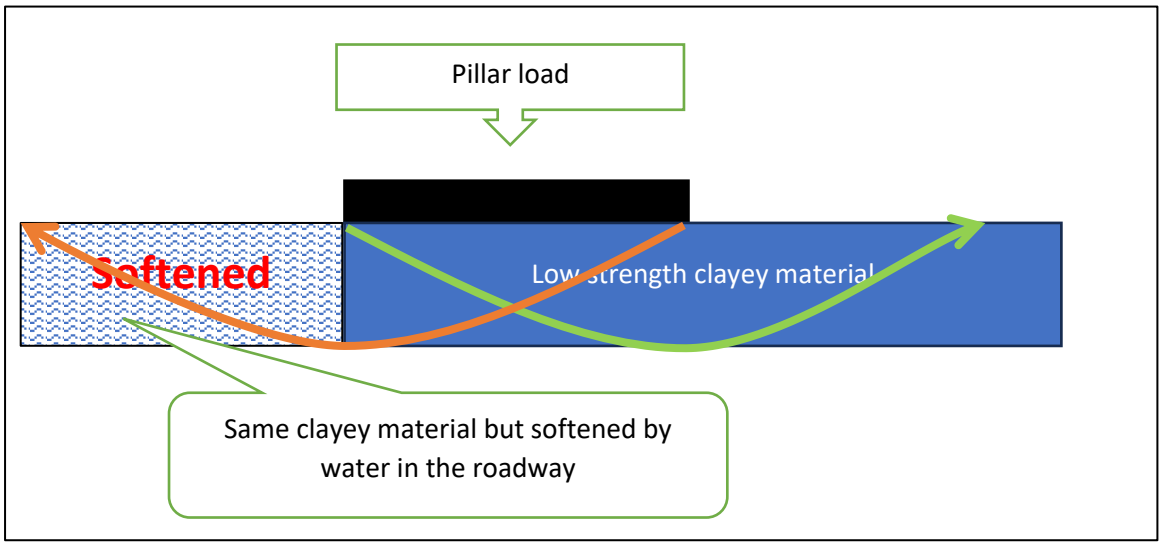


Figure 31 Softening of the floor of a roadway- strength along the green failure trajectory is greater than that along the orange trajectory.

In contrast to these reductions in strength, there will be an overall trend for an increase in stability related to a buoyancy effect as the water level rises above the coal seam. The result is that any decrease in stability will be temporary while the material at or below seam level softens and the water level is such that there is no buoyancy effect. Over time as the water level rises above the coal seam level, buoyancy will dominate and stability will increase beyond that at mine closure. It is valid to include consideration of buoyancy when using the available method to estimate pillar loading.

7 SEALING OF UNDERGROUND WORKINGS

Mine seals are used to manage or limit water and gas flows if required, as well as to control physical access to the underground mine.

Depending on their functional requirements there are three types of seals (US EPA4[8]):

- Dry seals – prevent physical access only.
- Air seals – prevent physical access without retaining water.
- Hydraulic seals – prevent physical access and retain water.

Broadmeadow Mine is downdip mining such that the mine entries are elevated with respect to the mine workings.

Due to the flooding of the underground workings and void lakes establishing in the residual voids used to access the underground workings after mining, dry seals are required at Broadmeadow Mine to prevent physical access. Their location means there will be little or no hydrostatic pressure applied to them. A corollary of this is that they need to be permeable to water.

A suitable dry seal for portals with concrete arches or culverts (as at Broadmeadow Mine) could be constructed by backfilling the concrete section and then covering further to an equal height (Figure 41).

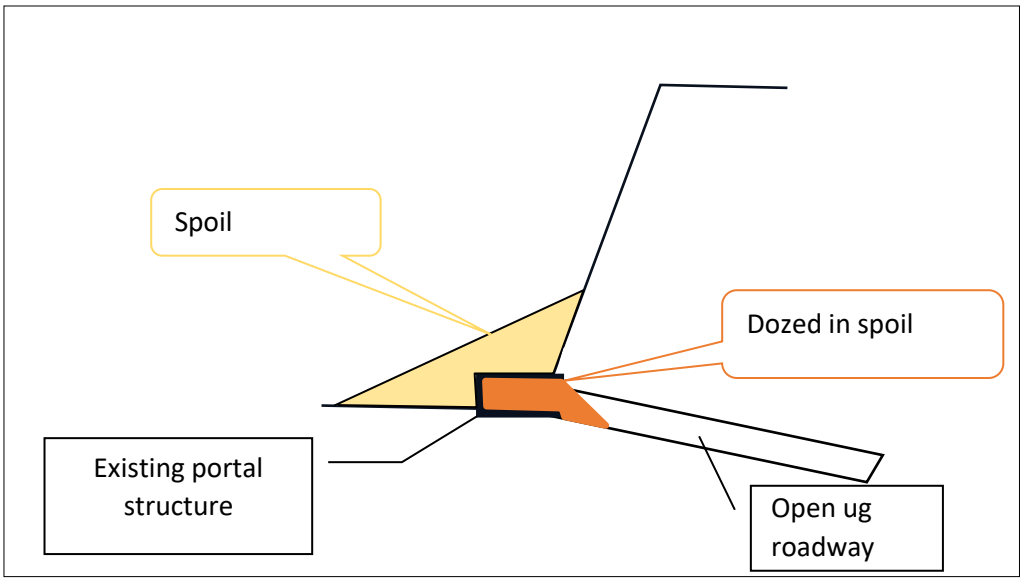


Figure 32 Concept for access (dry) seals at portals with concrete arches or culverts

8 MONITORING AFTER MINE CLOSURE

Subsidence monitoring should be conducted along a limited number of subsidence lines until the groundwater level in the underground is judged to have reached close to long-term equilibrium and then continued for another 2 years to confirm that significant movements have stopped. Broad scale mapping of the surface should be conducted at the 2-year interval to confirm that additional subsidence (if developed) has not resulted in unacceptable cracking. It is anticipated that all movements will have ceased by year 5.

[8] Inactive and abandoned underground mines – water pollution prevention and control. US Environment Protection Agency EPA-440/9-75-007

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Impact	Preventative Controls	Likelihood Basis *(chance of the risk occurring at impact level - used in the calculation of the RRR, taking into account the effectiveness of preventative controls)*	Likelihood	Likelihood Factor	RRR
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU1	Landform failure	1. Erosional instability 2. Geotechnical instability 3. Incorrect geotechnical assessment 4. Differential settlement (spoil and backfilled dams) 5. Insufficient materials to achieve design (rock, growth media) 6. Unsuitable materials used on final landform surface 7. Flooding/unplanned inundation 8. Not achieving design 9. Selection of inappropriate PMLU 10. Greater than modelled subsidence impacts 11. Destabilisation of spoil dumps from subsidence	- Erosion - Growth media loss - Failure of vegetation - Slumping and settlement - Mass movement of landform - Surface cracking	4	- Monitoring of landform stability and rehabilitation success to be undertaken post rehabilitation - Subsidence monitoring - Identify requirements for rectification works. - Complete maintenance	2	- Ongoing materials characterisation - Selective handling of materials for placement - Review the topsoil and rock material balance periodically during operations to ensure sufficient volumes for the rehabilitation needs. - No permanent berms or water management on spoil dump slopes - Landform surrounding the spoil dumps and voids to be reshaped to be free-draining where required to prevent impacts - Groundcover including vegetation to provide erosion resistance - Compliance to plan - Sufficient cover over rejects and tailings - Growth media assessment to determine amelioration and fertiliser requirements - Progressive operational subsidence management to repair initial cracks and drainage to reduce ponding to acceptable limits after initial subsidence - Final subsidence rehabilitation to repair final cracks and drainage to reduce inundation/ponding to acceptable limits after final subsidence - Suitable revegetation species in subsidence ponded areas - Flooding of underground workings	With all controls in place, including ongoing monitoring and maintenance, landform failure on a large scale for this landform is unlikely.	Unlikely	0.1	3
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU2	Alteration of hydrogeological conditions	1. Release of contaminants to groundwater 2. Change in groundwater flow, recharge and/or discharge characteristics resulting in changes to the hydrogeological system 3. Drawdown and alteration of groundwater flow due to void lakes acting as a sink driven by evaporation from the lakes 4. Maintaining dewatered conditions within aquifers 5. Change of aquifer availability/properties resulting from resource removal and subsidence	- Groundwater chemistry altered rendering it not suitable for extraction and/or to support the PMLU, or reduction of groundwater quality within the Isaac alluvials - Groundwater quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the site is located - Unfavourable geochemical or contaminants reporting to shallow and deep groundwater systems - Reduction of groundwater height within surrounding extraction bores - Degradation of terrestrial and aquatic groundwater dependant ecosystems (GDEs) - Dewatering of coal seams and other lithologies that have potential for AMD generation resulting in transport of contaminant of concern to ground and groundwater resources	5	- Assessment and remediation of impacted material, where appropriate - Development and approval of a Site Management Plan to assist with on-going management and restriction to future land use activities where appropriate - Implementation of management controls and monitoring programs outlined in an approved Site Management Plan - Re-establishment of impacted ecosystems - Decommissioning of impacted supply bores and re-instatement in suitable location - Regular updating of groundwater models to continue to improve the understanding of groundwater and the affects from mining operations	3	- All imported hazardous materials are to be stored and used in accordance with relevant standards and removed from site on completion of mining - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Contaminated land investigation to be undertaken at the completion of operations to identify contamination that has the potential to cause impacts to groundwater - Implementation of remediation and/or management plans as required to reduce potential groundwater impact risks - Mine affected water dams to be decommissioned (including investigation for potential contamination and groundwater impacts) - Groundwater monitoring to be undertaken in accordance with EA/PRCP conditions - Future tailings disposal options to be assessed for potential release of contaminants to waters including groundwater and control/approvals put in place - Installation of relevant groundwater monitoring bores - Analysis of data and development of site-specific groundwater quality limits - Revisiting and updating the groundwater models every five years (commencing from 2050) - Residual void catchments to be designed and created to establish sinks that provide for the collection of seepage from former operational areas, tailing storage facilities and spoil dumps - Landforms constructed to minimise the potential for flooding of the residual voids - Landforms designed to minimise contaminant generation and transport - Modelling of groundwater and fate and transport to understand the impacts associated with landforms/activities	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the post-mining land use is unlikely due to alternation of hydrogeological conditions.	Unlikely	0.1	10

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Impact	Preventative Controls	Likelihood Basis *(chance of the risk occurring at impact level - used in the calculation of the RRR, taking into account the effectiveness of preventative controls)*	Likelihood	Likelihood Factor	RRR
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU3	Alteration of surface water systems	1. Release of contaminants to surface water resources 2. Changes to alignments and ecosystems of drainage lines and watercourses 3. Changes to hydraulic flows 4. Changes to flood patterns/distribution 5. Alteration of surface water infiltration rates 6. Surface water flows over unvegetated/disturbed soils where rehabilitation has not re-established 7. Overland discharges from neighbouring landforms and rehabilitated areas 8. Watercourses and drainage lines not attaining successful rehabilitated state 9. Changes to surface water flows due to subsidence 10. Changes in vegetation due to ponding 11. Unfavourable climatic conditions and/or weather events	- Surface water chemistry altered rendering it not suitable for PMLU - Degradation of ecosystems and land uses connected to surface water flows and floodplains on and down gradient of the mine - Sedimentation of downstream surface water drainage lines resulting in changes to their hydraulic properties and impacting ecosystems - Surface water quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the mine is located - Accelerated erosion rates from surface water flows in disturbed areas and degraded ecosystems - Reduction in rehabilitation success rates due to reduced surface water quality - Alteration of soil properties associated with contaminants/inundation, including erodibility and geotechnical qualities - Alteration in vegetation due to change in surface run off - Vegetation failure due to inundation in subsidence areas - Reduction in land capability of PMLU in subsidence ponded areas (woodland habitat and/or grazing)	4	- Surface water monitoring data to be collected in accordance with the EA. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Any loss of hazardous contaminants that cause contaminated land/environmental harm will be reported and investigated as appropriate - Remedial works will be undertaken where releases from site result in impacts to surface waters, which may include alteration of the landforms, implementation of a Site Management Plan, implementation of additional controls/measures that reduce the potential for surface water impacts and/or re-establishment of impacted ecosystems where appropriate - Subsidence monitoring and rectification works - Undertake maintenance of rehabilitation and subsidence areas	3	- All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Surface water monitoring to be undertaken in accordance with EA conditions - Installation of monitoring equipment at the relevant surface water monitoring locations - Analysis of data and development of site-specific surface water quality limits for relevant watercourses - Rehabilitation and monitoring of disturbed reaches of watercourses undertaken - Mine affected water dams to be decommissioned and areas rehabilitated - A contaminated land investigation will be undertaken at the completion of operations and remediation works undertaken as appropriate - Landforms constructed to minimise the potential for flooding of the residual voids - Tailings and other waste disposal facilities appropriately covered - Progressive operational subsidence management - Final landform that limits the inundation/ponding of water to acceptable limits within subsidence areas to enable surface water movement to Isaac River at mine closure	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the post-mining land use is unlikely due to alternation of surface water conditions	Unlikely	0.1	10
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU4	Watercourse diversion not achieving closure objectives	1. Hydrologic characteristics of surface water and groundwater systems not representative of natural reaches 2. Hydraulic characteristics not representative of natural reaches 3. Geomorphic instability (bank erosion) 4. Seepage to/from residual voids impacting on stability 5. Sediment transport regime is not in equilibrium with and/or representative of the natural reaches 6. Poor riparian vegetation diversity and cover 7. High percentage of weeds/ invasive species 8. Poor water quality from runoff from surrounding landforms and rehabilitated areas 9. Failure of landforms impacting the performance of the diversion 10. Subsidence impacts to watercourse 11. Unfavourable climatic conditions and/or weather events	- Sediment regime impacts within diversion/subsided areas and downstream reaches resulting in changes to hydraulic properties - Surface water chemistry altered rendering it not suitable for PMLU - Degradation of downstream ecosystems and land uses connected to surface water flows and floodplains - Surface water quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the mine is located - Accelerated rates of erosion and instability of the diversion or watercourse banks causing landform instability, damage to rehabilitation areas and alteration of watercourse hydraulics - Changes to environmental flows and flood regimes impacting on surrounding land users and environmental receptors	5	- Surface water and watercourse monitoring data to be collected. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Rehabilitated landforms that do not attain a stable state to be investigated, repaired, revegetated and/or redesigned	3	- Watercourse diversion monitoring to relevant IDC standard and maintenance during the operational phase - Monitoring and maintenance of subsidence impacted areas as per EA during operations - Diversion remediation designs in accordance with the DNRME 2019 hydraulic design criteria for permanent diversions - Diversion design to include growth media assessment and revegetation species aligned to growth media, landforms and PMLU - Mine infrastructure that interacts with the watercourses during operations will be removed prior to closure (e.g. culverts) - Rehabilitation of surrounding landforms	With all controls in place, including ongoing monitoring and maintenance, inability of watercourses to meet closure objectives is unlikely as realignment of the watercourses is proposed.	Unlikely	0.1	10

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Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU5	Contaminated land impacting on environmental receptors, rehabilitation and attainment of PMLUs	1.Discharges and accumulation of hazardous contaminants (including emerging contaminants) from operational activities. 2. Licensed activities such as disposal of tailing, rejects, general and other wastes.	- Contaminants present within soil or water resulting in an unacceptable risk to the environment or PMLU - Alteration of soil chemistry that impacts on structural characteristics - Contaminants reducing the soil suitability for rehabilitation species - Requirement for on-going management and restriction of land uses	4	- Investigate and remediate contamination incidents - Implement a Site Management Plan to manage impacts, where required - Removal of primary or secondary sources - Restrict site usage - Undertake ongoing monitoring to manage contaminated land risks	3	- Management of operational activities to limit any potential contamination, all stored hazardous materials and infrastructure, that have a reasonable potential to release contaminants, will be appropriately recycled or disposed - Cleaning up of spills upon identification - Contaminated land investigation to be undertaken prior to closure and areas of contamination remediated and/or managed as appropriate - On-going surface water and groundwater monitoring providing an indication of contamination - Shallow rooted species for PMLUs with higher risk of contamination to allow for capping or other engineered controls. - Create landforms that include strong groundwater sinks to manage migration of contaminants off site	The contaminated land investigation and remediation/management works will aim to render the site suitable for the intended PMLUs and reduce the potential for any environmental harm. With operational sources of hazardous materials removed from site, tailings facilities covered and contained, any landfill materials capped and managed, the likelihood of contaminated land impacts preventing attainment of closure criteria is possible.	Possible	0.3	30
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU6	Flooding influences on rehabilitation and final landforms	1. Water inundation of landforms 2. Saturation of materials within landforms 3. Velocities of floodwaters on rehabilitated landforms 4. Inaccurate modelling 5. Surface inundation due to subsidence 6. Unfavourable climatic conditions and/or weather events	- Reduction in geotechnical stability of landforms causing failure of the landforms - Erosion of landform and sedimentation - Mobilisation of any contaminants contained within the landforms and impacts to downstream water and groundwater quality - Alteration of terrestrial ecology through introduction of weeds, sedimentation, or damage to select rehabilitation species - Introduction of weeds and impacts to rehabilitation vegetation establishment - Loss of flood waters/environmental flows to residual voids - Vegetation failure in subsidence inundated areas - Reduction in land capability of PMLU in subsidence ponded areas (woodland habitat and/or grazing)	3	- Assessment of landform failure and required rectification works upon safe access to site immediately after the flood event. Assessment to include identification of measures that would limit potential for on-going impacts. - Re-engineering of landforms to mitigate future failures followed by re-construction of landforms, and rehabilitation works. - Assessment of downstream impacts and undertake remediation/rehabilitation as required to re-establish drainage line hydraulics and ecosystems in liaison with the administering authority. - Monitoring of landform stability and rehabilitation success to be undertaken	2	- Removal of infrastructure from watercourses - Decommissioning of dams - Remediation of contaminated material where required - Design of landforms within flood extents that are stable and able to withstand flooding and water velocities - Establishment of vegetation suitable for the environment and reduces erosion risks - Progressive operational subsidence management to repair initial cracks and drainage to reduce inundation/ponding to acceptable limits after initial subsidence and final subsidence rehabilitation after final subsidence - Suitable revegetation species in subsidence ponded areas - Subsidence monitoring	Flood modelling indicates post-mining landform design does not result in inundation of residual voids and velocities outside of the watercourses and diversions are unlikely to impact rehabilitated landforms. Preventative controls include decommissioning of dams and culverts that could contribute to, or impact flood conditions.	Unlikely	0.1	3
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU7	Rehabilitated landforms result in alteration of flood hydrology upstream and downstream	1. Changes to drainage network hydraulics. 2. Artificial landforms and subsidence areas reducing or increasing flood extent and changing velocities/flows. 3. Changes to vegetation cover and soil type which alter runoff and infiltration rates.	- Increasing/decreasing of flood extents, frequency and severity - Degradation of ecosystems due to altered flows, flood extent, duration or frequency - Infrastructure damage - Health and safety risks to on-site and off-site land users associated with increased flood heights, velocities and frequency	4	- Due to the off-site nature of the impacts, which occur during significant flood events, available mitigating controls at the time of the impact are limited due to safety and accessibility restrictions. After flooding has reseeded, landform design and alteration could be undertaken to reduce possible future events.	3	- Removal of infrastructure that would adversely interfere with stream hydraulics (e.g. culverts) and decommissioning of dams - Establishment of landforms that are stable and provide appropriate level of flood protection to the residual voids - Undertake monitoring and maintenance works where required to maintain landforms - Rehabilitated landforms to limit inundation/ponding to acceptable limits - Monitoring of subsidence and rectification works as required	With preventative controls implemented, identified impacts associated with alteration of flood hydrology are possible due to loss of flows associated with subsidence and residual void catchments.	Possible	0.3	30
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU8	Insufficient or inappropriate growth media and rock resources required for rehabilitation activities	1. Insufficient growth media and rock quantities of suitable quality 2. Unstable/unsuitable material (erosive, dispersive, saline materials) 3. Weed infestation (soil is already infested with weed seeds) 4. Insufficient placement depth and surface treatment 5. Incorrect growth media and rock characterisation and amelioration 6. Inappropriate topsoil and rock stockpiling and management 7. Selection of inappropriate PMLU	- Erosion - Growth media loss - Topsoil deficit - Failure of vegetation (poor vegetation growth or incorrect vegetation affecting PMLU)	4	- Monitoring of rehabilitation success to confirm stability and identify requirements for rectification works. - Repair erosion areas, retest growth media and revegetate.	2	- Topsoil surveys and mapping - Review the topsoil, growth media and rock resources periodically during operations to ensure sufficient volumes for the rehabilitation needs. - Final landform design based on available materials. - Undertake rehabilitation planning and preparation in accordance with the specific requirements for growth media, rock, seed and management for the PMLU - Management of topsoil and rock stockpiles and application during rehabilitation - Growth media assessment to determine ameliorant and physical treatments - Amelioration and physical treatments applied as per assessment - Selective handling of materials for placement	With all controls in place, including ongoing monitoring and maintenance, insufficient or inappropriate growth media and rock for use on rehabilitation is unlikely.	Unlikely	0.1	3

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Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU9	Insufficient management of mineral waste	1. Poor material characterisation 2. Geochemistry not correctly defined for materials stored in permanent landforms (i.e. tailings, rejects, spoil) leading to an incorrect assessment of their potential for AMD and salinity generation and transport. 3. Inappropriate placement of adverse material 4. Poor landform execution 5. Inappropriate management strategy/cover 6. Generation and release of AD/SD/NMD and salinity from coal during operation accumulating in groundwater, surface water, soils 7. Knowledge base gap in geochemical data for tailings and rejects	- Release of contaminates to surface and groundwater from rehabilitated landforms. - Vegetation failure - Water cannot be used by end user - Geochemical reactivity and impacts associated with incorrect drain down in TSFs	5	- Monitoring of rehabilitation success to confirm stability and identify requirements for rectification works. - Maintenance and rectification works undertaken - Goonyella residual void is acting as sinks for groundwater therefore capturing potential AMD / salinity impacted seepage from TSF/spoil piles/reject stockpiles - Spoil materials have excess buffering capacity (i.e.. acid neutralising capacity in excess of acid generating capacity)	1	- Material characterisation during operations in line with BHP Materials Management Standard - Ongoing sampling of tailings and rejects from processing plant - Appropriate material placement and selective handling during operations - Remove and/or cover tailings and rejects - Detailed cover design for tailings and rejects completed prior to installation - Install tailings and rejects cover as per detailed design - Appropriate water quality monitoring for surface and groundwater to enable tracking of processes affecting water quality during operation and into closure - Undertaking appropriate fate and transport modelling during operations, pending of risk profile of landform - Sonic drilling to collect additional tailings data and monitoring of boreholes to address hydrogeochemical knowledge base gaps for TSFs - Geochemical static and kinetic testing and additional waste characterisation of tailings and rejects to address knowledge base gaps - Update hydrogeochemical modelling and develop detailed cover design	With all controls in place, including ongoing monitoring and maintenance, insufficient management of mineral waste is unlikely.	Unlikely	0.1	1
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU10	Failure of, or inappropriate engineered cover design	1. Poor material characterisation 2. Geochemistry not correctly defined for materials stored in permanent landforms (i.e. tailings, rejects, spoil) leading to an incorrect assessment of their potential for AMD and salinity generation and transport. 3. Erosional instability 4. Geotechnical instability 5. Insufficient materials to achieve cover design 6. Unsuitable materials used on cover design 7. Not achieving design specifications 8. Knowledge base gap in geochemical and geotechnical data for tailings and rejects to inform cover design 9. Livestock impact stability of cover	- Release of contaminates to surface and/or groundwater from rehabilitated landforms. - Poor vegetation establishment - Erosion - Failure or collapse of structure, including cover	5	- Surface water and groundwater monitoring data to be collected in accordance with the EA. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Rehabilitation monitoring and identification of maintenance - Complete maintenance	2	- Material characterisation during operations (outcomes stored into Geological database) in line with BHP Materials Management Standard - Ongoing sampling of tailings and rejects from processing plant - Tailings and rejects material appropriately disposed on-site - In-situ geochemical and geotechnical monitoring of landforms - Detailed cover design developed based on data collected once tailings deposition and drying or rejects dumping is complete - Installation of cover conducted in accordance with cover design (documented compliance to plan) - Modelling of cover performance - Restrict livestock from areas with a cover	With all controls in place, including ongoing monitoring and maintenance, failure of cover is unlikely.	Unlikely	0.1	3
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU11	Inadequate and/or inappropriate revegetation	1. Unfavourable climatic conditions and/or weather events 2. Incorrect species mix 3. Poor seed quality 4. Weed contaminated seed 5. Poor quality growth media or seed bed preparation 6. Erosion 7. Land contaminants 8. Leucaena infestations 9. Subsidence related ponding causing vegetation dieback and loss of groundcover	- Exposed soils due to poor vegetation establishment and growth, resulting in enhanced erosion rates. - Increased weed establishment and growth. - Reduction in land capability of PMLU (woodland habitat and/or grazing) - Need for ongoing corrective action - soil sampling and analysis, amelioration and re-vegetation. - Reduced fauna habitat due to loss of existing vegetation - Extensive leucaena management may be intrusive impacting existing rehabilitation progression	3	- Monitoring of rehabilitation - Monitoring of subsidence areas and repair of surface cracks - Rectification works undertaken e.g. repair erosion areas or ponded areas, retest materials, review seed mix and revegetate	1	- Growth media assessment to determine ameliorant and physical treatments - Amelioration and physical treatments applied as per assessment - Management of seed selection, provenance and quality - Plant at optimal time of year - Revegetation species aligned to growth media, landforms, subsidence and PMLU - Progressive operational subsidence management to repair initial cracks and drainage to reduce ponding to acceptable limits after initial subsidence and final rehabilitation after final subsidence	With all controls in place, including revegetating with species aligned to growth media, landforms, subsidence and PMLUs, as well as ongoing monitoring and maintenance, inadequate or inappropriate revegetation is unlikely.	Unlikely	0.1	1
Stable condition for land described as a post-mining land (cattle grazing, grassland, woodland habitat, watercourse) use is not achieved	PMLU12	Deterioration of built infrastructure conditions	1. Potential soil contamination around mine industrial areas 2. Inadequate sealing of surface underground infrastructure (shaft, holes, etc)	- Reduced soil fertility to support PMLU land capability - Potential contamination of surface water runoff affecting integrity of local catchments. - Inability to achieve PMLU	2	- Undertake a preliminary contaminated land assessment prior to the completion of the approved activities, identify if any areas require a further Detailed Site Investigation and remediation plan developed if required - Conduct ongoing maintenance - Mapping of below ground infrastructure remaining at closure	1	- Clean up and remediate contamination during operational period. - Surface infrastructure not being retained on-site to be decommissioned and removed, and underlying land rehabilitated - Undertake contaminated land assessment and remediation/management where required post mining - Capping and sealing of surface underground infrastructure (shaft, holes etc)	With all controls in place, including ongoing monitoring and maintenance, deterioration of built infrastructure is unlikely.	Unlikely	0.1	1

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NUMAs do not achieve safe, structurally stable condition or cause environmental harm off tenure.	NUMA1	Void walls do not achieve geotechnical stability	1. Geotechnical instability 2. Geochemical instability 3. Increase/decrease in predicted void water levels 4. Incorrect geotechnical assessment	- Failure of void walls leads to instability beyond NUMA extent	4	- Geotechnical monitoring - Completing designs and assessments - Identify requirements for rectification works.	1	- Geotechnical assessment and final void wall design - Pit floor treatments as required to improve low wall stability. - Geotechnical monitoring during operations - Updated geotechnical assessment to be completed as mining approaches final limits and wall design and NUMA extent adjusted if required - NUMA extents designed at the required FoS limit - Bunding or equivalent landform, fencing and signage placed at FoS limit - Install physical barrier to underground access points - Minimum distance of 50m between the residual void crest and the toe of the safety bund, where against a tenure boundary - Minimum 25m distance between the residual void low-wall crest within the NUMA and the Safety bund or equilivent landform	With all controls in place, including ongoing monitoring and maintenance, wall failure beyond the NUMA limit is unlikely.	Unlikely	0.1	1
NUMAs do not achieve safe, structurally stable condition or cause environmental harm off tenure.	NUMA2	Uncontrolled access to NUMA	1. Inappropriate design, management and construction of safety bund or equivalent landform 2. Inadequate/poorly maintained fencing and signage	- Unmanaged access to NUMA by people or livestock	4	- Compliance checks as part of monitoring	1	- Safety bunding or equivalent landform, fencing and signage placed at FoS limit, where required to prevent access - Geotech modelling completed to determine FoS limit - Install physical barrier to underground access points	With all controls in place, including ongoing monitoring and maintenance, failure of bunding, fencing and signage is unlikely.	Unlikely	0.1	1
NUMAs do not achieve safe, structurally stable condition or cause environmental harm off tenure.	NUMA3	Uncontrolled flooding into voids	1. Flood mitigation is not installed or incorrect construction 2. Incorrect flood modelling 3. Climate change impacts are different to those used to inform landform design	- Uncontrolled capture of flood waters - Altered/changed alignment of watercourses and drainage lines - Removal of downstream environmental flows - Filling of residual void with water and interconnecting groundwater units - Geotechnical instability of residual void - Contamination of clean surface water flows, within residual void - Contamination of groundwater resources	4	- Compliance checks as part of monitoring	2	- Flood modelling including climate change scenarios - Void flood mitigation designed to 0.1% AEP flood event - Void flood mitigation (partial backfill and/or landforms) installed - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, uncontrolled flooding into the voids is unlikely.	Unlikely	0.1	3
NUMAs do not achieve safe, structurally stable condition or cause environmental harm off tenure.	NUMA4	Water in the void causes environmental harm outside of the mining tenure	1. Groundwater outflow seepage not identified by groundwater modelling 2. Lack of groundwater quality data to support water quality assessment 3. Overtopping or interconnection of the void lake with shallow groundwater water units 4. Flooding of underground	- Reduction in surface and/or groundwater quality beyond the mining leases - Degradation of GDEs - Changes to the chemistry of shallow groundwater units - Groundwater extraction/use off site impacted	5	- Groundwater monitoring - Water quality monitoring - Design for flooding	3	- Up to date groundwater and void lake water balance modelling - Void flood mitigation designed to 0.1% AEP flood event - Void flood mitigation (partial backfill and/or landforms) installed - Containment of potential sediment as a result of erosion from the low-wall within the residual void - Landform design to enable to ensure inward hydraulic gradient towards Goonyella residual void. - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, any water in voids causing environmental harm outside of mining tenure will be managed through engineering controls.	Unlikely	0.1	10