Permit

Environmental Protection Act 1994

Environmental authority EPML00865013

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

Environmental authority number: EPML00865013

Environmental authority takes effect on 29 June 2023

Environmental authority holder(s)

Name(s)	Registered address
BHP COAL PTY LTD	Level 14, 480 Queen Street BRISBANE CITY QLD 4000
QCT Management Pty Limited	Level 13, 123 Eagle Street BRISBANE QLD 4001
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
QCT MINING PTY. LTD.	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
QCT INVESTMENT PTY. LTD.	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
BHP Queensland Coal Investments 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	ML1782 ML70126 ML70127 ML70325 ML70328 ML70350 ML70369 ML70370 ML70410
Ancillary 08 - Chemical Storage 1: Storing a total of 50t or more of chemicals of dangerous goods class 1 or class 2, division 2.3 under subsection (1)(a)	ML1782 ML70126 ML70127 ML70325 ML70328 ML70350 ML70369 ML70370 ML70410
Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t	ML1782 ML70126 ML70127 ML70325 ML70328 ML70350 ML70369 ML70370 ML70410
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (b-i) more than 100 but not more than 1500EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme	ML1782 ML70126 ML70127 ML70325 ML70328 ML70350 ML70369 ML70370 ML70410

Queensland Government

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-on 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 *Sustainable Planning Act 2009* 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.

Alison Cummings
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Date issued: 29 June 2023

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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)

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; a) that such measures, plant and equipment are maintained in a proper condition; b) that such measures, plant and equipment are operated in a proper manner; and c) 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.

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 for 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: a) 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 b) 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 c) 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 d) Australian Standard *AS3580.9.11 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 beta attenuation monitors*. *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.

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: a) the type of waste disposed of, treated, or reprocessed; and b) 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: a) segregation of the wastes; b) storage of the wastes; c) transport of the wastes; and d) monitoring and reporting matters concerning the wastes; f) how the waste will be managed 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; and k) staff training.
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 **D7** (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; a) vegetation; b) water or sediment containing hydrocarbons; c) fuels, oils, lubricants and coolants; d) bulk rubber; e) inert waste; f) poly-pipe and other plastic; g) fibreglass; h) treated and untreated timber; and i) asphalt.
D5	**Waste disposal** Unless otherwise specified in conditions **D6** and **D7**, 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: a) in spoil emplacements; and b) in regulated structures in accordance with **Schedule G: Structures** of this environmental authority; and c) in pits or voids; and d) in dedicated rejects emplacements; and b) tailings and water or sediment containing hydrocarbons: a) in regulated structures in accordance with **Schedule G: Structures** of this environmental authority; and b) 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; b) inert waste; c) poly-pipe and other plastic; d) fibreglass; e) treated and untreated timber; f) asphalt; and g) asbestos. These types of waste may be disposed of: a) in pits or voids; b) in spoil emplacements; and c) left in situ below ground level.

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-mining land	Native bushland characteristics	Species richness Trees Shrubs Grasses	 ≥2 ≥3 ≥4

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
	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	Maintain a Rehabilitation Management Plan, detailing the rehabilitation of disturbed area to approved acceptance criteria. The rehabilitation management plan must, at a minimum: a) map existing areas of rehabilitation; b) develop design criteria for rehabilitation of disturbed areas; c) detail rehabilitation methods applied to areas; d) identify success factors for areas; e) detail future rehabilitation actions to be completed on areas; f) identify three (3) reference and three (3) rehabilitation sites to be used to develop rehabilitation success criteria; g) contain landform design criteria including end of mine design; h) detail how landform design will be consistent with the surrounding topography; i) specify future planned rehabilitation methods for disturbed areas; j) explain planned native vegetation rehabilitation areas and corridors; k) describe rehabilitation monitoring and maintenance requirements to be applied to all areas of disturbance; l) itemise revegetation criteria; m) describe end of mine landform design plan and post mining land uses across the mine; n) specify spoil characteristics, soil analysis, soil separation for use on rehabilitation; o) include a cost benefit analysis / triple bottom line assessment (or an alternative assessment method) of the proposed final landform design criteria and alternatives; and p) identify potential problems and how they will be addressed.
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	Maintain an investigation into residual voids proposing acceptance criteria to meet the outcomes in condition **E6** and landform design criteria. The investigation must at a minimum include the following: 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 study of void capability to support native flora and fauna; e) develop design criteria for rehabilitation of final voids; and f) a proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes. These studies will be undertaken during the life of the mine and will include detailed research and modelling.
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	**Acid Rock Drainage and Leachate Management** Subject to the release limits defined in **Schedule F: Water**, all reasonable and practicable measures must be implemented to prevent hazardous leachate being directly or indirectly released or likely to be released as a result of the activity to any groundwater or water course.

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	Notwithstanding any other condition of this environmental authority, the environmental authority holder may commence the release of mine affected water to waters in accordance with a written approval provided by the administering authority.
F3	Any release of mine affected water in accordance with condition **F2** must comply with the conditions of the written approval.
F4	Any release of mine affected water in accordance with condition **F2** must cease immediately if directed to do so in writing by the administering authority.
F5	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)**.
F6	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 **F33** to **F34** 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	654503	7481569	Horseshoe Dam	Discharge pipe intake	Rolf Creek
RP2	652482	7482650	Browns Dam	Dam spillway	Rolf Creek
RP3	650762	7491528	Ramp 6 Fill Point Dam	Discharge pipe intake	Scott Creek
RP4	652807	7491703	Price Pit / Gilbert Pit (Ramp 50 Dam)	Discharge pipe intake	Scott Creek
RP5	649525	7482615	Area Dam	Dam spillway	Scott Creek
RP6	647905	7497318	Suttles Bend Dam	Discharge pipe intake	Stephens Creek
RP7	648713	7497808	Lotus Dam	Discharge pipe intake	Stephens Creek

F7	The release of mine affected water to waters in accordance with condition **F5** 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 monitoring of pH, EC and flow during active release. Where real time monitoring is not available, daily sampling during active release as soon as possible after commencement of active release, when safe access permits^
pH (pH units)	6.5 (minimum) 9.0 (maximum)	
Sulphate (SO_4^{2-})	N/A – correlated with EC	As soon as possible after commencement of active release, when safe access permits, and weekly thereafter. For successive releases from the same site under similar circumstances, only one sample per week is required^.

NOTES:
^ Generally during daylight hours only

F8	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 **F8** 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.*
F9	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 **F9(2)(b)**, no further reporting is required for subsequent trigger events for that quality characteristic.*

Table F3 (Release Contaminant Trigger Investigation Levels)

Quality Characteristic	Trigger Level (µg/L)	Comment of Trigger Level	Monitoring Frequency
Aluminium	372	For aquatic ecosystem protection, based on 80th percentile of 42 upstream samples	Release Point: Within one week prior to commencement of release or as soon as practicable after commencement of release and weekly thereafter^. Receiving Water: Weekly and prior to cessation of release.
Chromium	1	For aquatic ecosystem protection, based on SMD guideline	
Copper	3	For aquatic ecosystem protection, based on 80th percentile of 42 upstream samples	
Iron	484	For aquatic ecosystem protection, based on 80th percentile of 42 upstream samples	
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	
Silver	1	For aquatic ecosystem protection, based on LOR for ICPMS	
Uranium	1	For aquatic ecosystem protection, based on LOR for ICPMS	
Vanadium	18	For aquatic ecosystem protection, based on 80th percentile of 42 upstream samples	
Ammonia	900	For aquatic ecosystem protection, based on SMD guideline	
Nitrate	1100	For aquatic ecosystem protection, based on ambient QLD WQ Guidelines (2006) for TN	
Petroleum hydrocarbons (C6-C9)	20		
Petroleum hydrocarbons (C10-C36)	100		
Fluoride (total)	2000	Protection of livestock and short-term irrigation guideline	

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.
^ When safe to do so and access permits. Generally during daylight hours.

F10	If an exceedance in accordance with condition **F9(2)(b)** is identified, the environmental authority holder must notify the administering authority within **twenty-four (24) hours** of receiving the result.
F11	**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)**.
F12	Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with condition **F5** 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)**.

F13	The 80th percentile of electrical conductivity (EC) values recorded at the downstream monitoring points specified in **Table F6 (Receiving Waters Upstream Background and Downstream Monitoring Points)** must not exceed 2,000 µS/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 and includes both the duration of release and any lag time between release point/s and downstream monitoring points.*
F14	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)**.
F15	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^
Scott Creek	RP3 RP4 RP5	Scott Creek Downstream or Scott Creek Upstream (Alternative site)	653010 649926	7492596 7489893	>1 m^3/s	Continuous (minimum daily)
Stephens Creek	RP6 RP7	Stephens Creek Downstream or Stephens Creek Upstream (Alternative site)	650361 640576	7496841 7498430		
Rolf Creek	RP1 RP2	Rolf Creek Downstream	673653	7487296		

Note:
^ Assumes access to real time telemetry monitoring with up to 15 minute polling of data. Where access is not available, daily records will be calculated.
 # When the downstream flow gauge falls below the minimum flow trigger of 1m^3/s, a 6 week tail flow period commences.

F16	**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).

F17	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 **F16**. 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 **F16** and **F17** and **F18** and **F19**, provided the relevant details of the release are included within the notification provided in accordance with conditions **F16** and **F17** and **F18** and **F19**.*
F18	Within **twenty-eight (28) days** of notification under condition **F17**, the environmental authority holder must provide the administrating authority via WaTERS the following information in writing: a) confirmation of: a) the release commencement date and time; b) the release cessation date and time; c) receiving water(s) including the natural flow rate; d) 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.
F19	**Release notification – potentially affected stakeholder** If written approval is given by the administering authority, the environmental authority holder must notify all potentially affected stakeholders on commencement (**within 2 hours**) of releasing mine affected water in accordance with the written approval as per condition **F2**. Notification must include the following information: a) release commencement date/time; b) release location (release point/s); c) release rate; d) receiving waters for the release; e) receiving water flow rate; f) water quality of the release including salinity and pH; and g) estimated duration of the release.
F20	**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.

F21	The environmental authority holder must, within **twenty-eight (28) days** of the notification provided in accordance with condition **F20**, 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.
F22	**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)**.
F23	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 **F23(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 monitoring of pH, EC, and flow during active or passive release. Where real time monitoring is not available, daily sampling during active or passive release as soon as possible after commencement of release, when safe access permits^
Electrical Conductivity (µS/cm)	2,000	
Sulphate (SO_4^{2-})	1,000	As soon as possible after commencement of active release, when safe access permits, and weekly thereafter

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			
UMP1	Scott Creek Upstream	649926	7489914
UMP2	Sandy Creek Upstream	650216	7489443
UMP3	Stephens Creek Upstream	640611	7498453
Downstream Monitoring Points			
DMP1	Scott Creek Downstream	653010	7492596
DMP2	Stephens Creek Downstream	650361	7496841
DMP3	Rolf Creek	673653	7487296
DMP4	Stephens Creek Downstream (alternative)	648991	7496421

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

F24	**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 Scott, Stephens and Rolf Creeks and connected or surrounding waterways within **eight (8) 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.
F25	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.

F26	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions **F24** and **F25** 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.
F27	**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

F28	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.

F29	If the responsibility for mine affected water is given or transferred to another person in accordance with conditions **F27** or **F28**: 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.
F30	**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 **F30** 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.*
F31	The release of any contaminants as permitted by this environmental authority, directly or indirectly to waters, other than internal water management infrastructure that is installed and operated in accordance with a Water Management Plan that complies with conditions **F33** to **F34** inclusive: a) must not produce any visible discolouration of receiving waters; and b) must not produce any slick or other visible or odorous evidence of oil, grease or petrochemicals nor contain visible floating oil, grease, scum, litter or other objectionable matter.

F32	**Annual water monitoring reporting** The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format with each annual return: a) the date on which the sample was taken; b) the time at which the sample was taken; c) the monitoring point at which the sample was taken; d) the measured or estimated daily quantity of mine affected water released from all release points; e) the release flow rate at the time of sampling for each release point; f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority; and g) water quality monitoring data must be provided to the administering authority in the specified electronic format upon request.
F33	**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, as a minimum, 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: a) a study of the source of contaminants; b) a water balance model for the site; c) a water management system for the site; d) measures to manage and prevent saline drainage; e) measures to manage and prevent acid rock drainage; f) contingency procedures for emergencies; and g) a program for monitoring and review of the effectiveness of the Water Management Plan.
F34	The Water Management Plan must be reviewed each calendar year by an appropriately qualified person(s).
F35	**Saline drainage** The environmental authority holder must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of saline drainage.

F36	**Acid rock drainage** The environmental authority holder must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of acid rock drainage.
F37	**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.
F38	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 **F37**; and b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with conditions **F33** to **F34** inclusive, for the purpose of ensuring water does not become mine affected water.
F39	The maintenance and cleaning of any vehicles, plant or equipment must not be carried out in areas from which contaminants can be released into any receiving waters.
F40	Any spillage of wastes, contaminants or other materials must be cleaned up as quickly as practicable to minimise the release of wastes, contaminants or materials to any stormwater drainage system or receiving waters.
RR1	Conditions F24 to F26 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 F24 to F26.

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: a) floodwaters from entering the regulated dam from any watercourse or drainage line; and b) 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: a) the recommendations section of the annual inspection report; and b) 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: a) it no longer contains contaminants that will migrate into the environment; and b) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and c) 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: a) groundcover, that is not a declared pest species is established and self-sustaining b) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and c) the maintenance requirements for rehabilitated land are 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 1500 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 of five samples collected	1000	Colonies per 100mL	Maximum

Schedule I: Groundwater	
Condition number	**Condition**
I1	**Groundwater** The holder of this environmental authority must not release contaminants to groundwater.
I2	**Groundwater Monitoring and Management Program** A Groundwater Monitoring and Management Program must be: a) developed by an appropriately qualified person; and b) implemented by the environmental authority holder for all stages of mining activities.
I3	The Groundwater Monitoring and Management Program required by condition **I2** must: a) identify potential groundwater impacts due to the mining activities; b) include a site conceptual groundwater model; c) describe the sampling and monitoring methodology; d) detail an appropriate quality assurance and quality control program; and e) provide the process for notifying the administering authority and investigating exceedances in accordance with conditions **I4-I5**.
I4	**Groundwater monitoring** Groundwater quality and standing water levels must be monitored: a) at the locations and at the frequencies specified in **Table I1 (Groundwater Monitoring Program)**; and b) for the characteristics specified in **Table I2 (Groundwater Trigger Levels)**.
I5	If the groundwater contaminant trigger levels defined in **Table I2 (Groundwater Trigger Levels)** are exceeded on three (3) consecutive monitoring occasions, the environmental authority holder must complete an investigation into the potential for environmental harm and notify the administering authority within twenty (20) business days of receiving the analysis results.

I6	The Groundwater Monitoring and Management Program must be reviewed by **31 November 2023** and thereafter every **two (2) years** by an appropriately qualified person. The review report must: a) analyse the results of groundwater monitoring to: i. describe any impacts to groundwater levels and groundwater quality due to the mining activity; ii. determine trends in groundwater levels and groundwater quality; b) assess the adequacy of the Groundwater Monitoring and Management Program; and c) provide recommendations to the environmental authority holder to address the findings of parts (a) and (b) of the review.
I7	Within **twenty (20) business days** of receiving the review report, the environmental authority holder must provide to the administering authority: a) the review report; b) if applicable, any actions being taken by the environmental authority holder to address the recommendations of the review report; and c) if action is not being taken to address a recommendation, the environmental authority holder must provide justification for not taking action.
I8	Annual groundwater monitoring data must be submitted to the administering authority via WaTERS by 30 September each calendar year.
I9	**Bore construction** The construction, management, 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.

Table I1 (Groundwater Monitoring Program)

Monitoring Location	Easting (GDA94)	Northing (GDA94)	Monitoring Frequency
Interpretation Bores			
P3	649758	7489756.3	6 monthly
Compliance Bores			
P2A_R[1, 2]	650914.1	7483162.7	6 monthly
RN 43060	663843.4	7482400.7	6 monthly
P6R[3]	650218.3	7496665.8	6 monthly
RN 38547	654266.62	7494832.06	6 monthly
RN 43062	658070.4	7487766.1	6 monthly

NOTES:

1. Replaces bore P2.
2. Bore P2A_R was installed in March 2021. Trigger values have not yet been developed due to limited available data set. The replacement bore will continue to be monitored and trigger levels will be developed where applicable once an adequate data set is obtained.
3. Replaces bore P6.

Table I2 (Groundwater Trigger Levels)

Quality Characteristic	Units	Trigger Levels					
		P3	P2A_R	RN43060	P6R	RN38547	RN 43062
Water Level	RL	Monitored for interpretive purposes only – no triggers apply	TBC[1]	Fluctuations in excess of 2m per year excluding changes from pumping of licenced bores			
pH	pH units			6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Electrical Conductivity	µS/cm			15,820	7,450	7,450	11,520
Sulphate	mg/L			318	520	520	520
Dissolved Aluminium	mg/L			0.41	0.055	0.078	0.48
Dissolved Antimony	mg/L			0.0090	0.0090	0.0090	0.0090
Dissolved Arsenic	mg/L			0.013	0.013	0.013	0.013
Dissolved Iron	mg/L			16	7.2	0.7	4.9
Dissolved Mercury	mg/L			0.00060	0.00060	0.00060	0.00060

Quality Characteristic	Units	Trigger Levels					
		P3	P2A_R	RN43060	P6R	RN38547	RN 43062
Dissolved Molybdenum	mg/L			0.034	0.034	0.034	0.034
Dissolved Selenium	mg/L			0.020	0.011	0.011	0.011
Dissolved Silver	mg/L			0.056	0.0010	0.0010	0.39
Total recoverable hydrocarbons C6-C10	µg/L			20	20	20	20
Total recoverable hydrocarbons >C10 - C40	µg/L			100	100	100	100

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 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 into 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, nematicide, 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 workplace 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 home or other building or part of a building; or

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

c) a watercraft in a marina.

Effluent means treated wastewater 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 17 November 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 landowner.

$L_{A10,\ adj,\ 10\ mins}$ 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.

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) means the following types of water:

   i. pit water, tailings dam water, processing plant water;

   ii. 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;

   iii. 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 such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;

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

   v. groundwater from the mine's dewatering activities; or

   vi. a mix of mine affected water (under any of paragraphs i to v) and other water.

b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:

   i. land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or

   ii. land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:

      a. areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site;

      b. evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or

   iii. both.

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).

Potentially Affected Stakeholders includes (but should not be limited to)

a) a local landholder whose property is riparian, downstream of the release point specified point specified in Table F1 of the environmental authority and is determined by the environmental authority holder to be potentially impacted by mine affected water releases; or

b) a landholder or other party nominated by the administering authority; and

c) the relevant local government authority; and

d) the operator of a downstream water storage that supplies raw water to a local government or any other water user located between the nearest monitoring location listed in Table F1 or Table F2 of the operational policy and the release points specified in Table F1 of the environmental authority; and

e) does not include a landholder or other party who by written agreement with the environmental authority holder has declined to be notified for the purpose of this condition.

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 landform 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.

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

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 Mitsui Coal Pty Ltd
Level 14, 480 Queen Street
BRISBANE CITY QLD 4000

Email: Mark.garrahy@bhp.com; Trudy.mazucco@bhp.com

Attention: Mark Garrahy & Trudy Mazucco
Our reference: EPML00865013

Transition Notice for a PRC plan

1 Environmental authority details

Environmental authority EPML00865013 dated 29 July 2020 issued to BHP Coal Pty Ltd, QCT Resources Pty Limited, Mitsubishi Development Pty Ltd, Umal Consolidated Pty Ltd, QCT MINING PTY. LTD., QCT INVESTMENT PTY. LTD., BHP Queensland Coal Investments Pty Ltd.

Land description: ML1782, ML70126, ML70127, ML70325, ML70328, ML70350, ML70369, ML70370, ML70410.

2 Required action

The holder(s) of environmental authority EPML00865013 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 **1 October 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 is/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–

(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.

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

Queensland Government

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

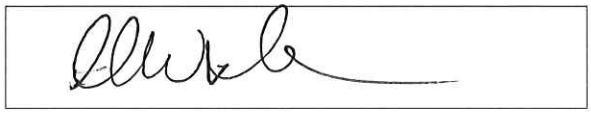
As detailed in section 2 of this notice, your PRC plan and associated PRCP schedule is required to address the relevant legislative requirements.

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 completed 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, please contact Jeremy Wheeler on telephone (07) 4987 9329.



Signature

27/05/2021

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	20 May 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 – Norwich Park Mine

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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 – Norwich Park Mine. 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: EPML000865013

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

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

Introduction	Norwich Park Mine (NPM) is an open cut strip mine, and forms part of the BMA Central Region mine complex. The mine is located 25 km south of the town of Dysart in the Bowen Basin, Central Queensland. The mine sits within the Isaac Regional Council (IRC) Area. Mining operations commenced in 1979 and, although the mine is currently in care-and-maintenance (since 2012) mine planning indicates a remaining LoA of more than 50 years. The site comprises the following Mining Leases (MLs): ML 70410, ML 70369, ML 70370, ML 70325, ML 70328, ML 70126, ML 70127, ML 1782, ML70350 Mining operations uses a combination of dragline and truck/shovel equipment to extract coking coal.

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.

	The joint holders of Environmental Authority EPML00865013 include: BHP Coal Pty Ltd; BHP Queensland Coal Investments Pty Ltd; Mitsubishi Development Pty Ltd; QCT Investments Pty Ltd; QCT Mining Pty Ltd; QCT Resources Pty Ltd; and Umal Consolidated Pty Ltd.

PRCP Requirement	BHP information submission for review
Rehabilitation Planning Part	
Project Description	The mining process involved land clearing, the removal and stockpiling of topsoil material, drilling and blasting of overburden as required, and stripping of overburden material utilising a combination of draglines and truck/shovel. The majority of the overburden material is placed in the void of the previous strips. Product coal is transported by rail to the Hay Point Coal Terminal for export.
Mining Activities	The activities at NPM include: Open cut mining; • Spoil dumps and in-ramp reject dumps; • Tailings storage facilities (TSFs); • Coal handling and preparation plant (CHPP); Mine water dams; • Coal stockpile areas; • Run-of-mine (ROM) area; and • Haul roads and laydown areas. NPM has no underground workings.
Existing Rehabilitation	Rehabilitation has been completed routinely at NPM each year, with 727 ha re-profiled, topsoiled and seeded to date.
PMLUs	The predominant pre-mining land use at NPM was cattle grazing. Cropping has not been practiced in the area due to generally significant moisture, workability and fertility limitations. As per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*, BHP has transitional arrangements for NPM 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 NPM. 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 assessed for each void at NPM. 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. The PRC Plan will also demonstrate how no environmental harm will be caused beyond the transitioned NUMAs.

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PRCP Requirement	BHP information submission for review
Voids in Floodplains	As the location 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 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.

PRCP Requirement	BHP information submission for review
Rehabilitation and Management Methodology	
Hydrogeology	The development of the rehabilitation and management methodologies for NPM relating to groundwater will utilise the existing groundwater monitoring network and monitoring data to complete the following: • Develop a numerical hydrogeological model where appropriate; • Prepare a hydrological conceptual model for the point of closure; and • Development of groundwater criteria.
Flooding	NPM spans across four stream catchments – Downs Creek, Stephens Creek, Rolf Creek and Roper Creek. All natural watercourses and tributaries that meander through the mine site are ephemeral. They experience short periods of flow during and immediately after rainfall events. Springs are reported to occur within the headwaters of the streams at the contact of the Permian sandstone and overlying Tertiary basalt. As per the *BHP PRCP Flood Modelling Position – 23072020* memo, BHP will use a risk-based approach to determine if flood modelling is required. 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 NPM will include: • Topsoil quality, quantity, treatments and management; • Availability, quality and quantity of any other capping material required; and • Strategies to address any deficits.
Waste Characterisation	Mine waste at NPM includes: • Overburden / interburden; • Coarse rejects; and • Tailings. Historic, pre-2019, geochemical and physical (sodicity and dispersivity) characterisation test work will represent the smaller fraction of the data available for assessing the geochemical risk posed by key mine waste domain and landforms. 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 NPM. In addition to the historic samples listed in *BHP PRCP Geochem DES Update 26082020*, the following additional data are currently available: • 41 samples collected from Old TSF in November 2020

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<table>
<tr><th>PRCP Requirement</th><th>BHP information submission for review</th></tr>
<tr><td></td><td>
Overburden/interburden drilling are planned for FY22. Samples collected from this field campaign are expected 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).
• 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 PRCP will detail the waste categories to ensure problematic waste, based on both chemical and physical behaviour, is managed at NPM. Conceptual waste categories at NPM are shown in the table below but modification may be made in the PRCP 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></tr>
<tr><td>Landform Design</td><td>The main structures of the NPM final landform include spoil dumps, rejects dumps, final voids and tailings storage facilities. The PRCP will include the</td></tr>
</table>

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PRCP Requirement	BHP information submission for review
	detail for landform design as per the *BHP PRCP Landform and Rehabilitation DES memo Final 28082020*.
Cover Design	A risk-based approach will be used to determine areas that may require a cover design.
Water Management	As described within the BHP 25 September 2020 Groundwater scope memo, BHP had indicated that Norwich Park groundwater modelling could be forward loaded to meet DES indicated timelines, if required. The groundwater modelling to be completed on the DES indicated timeline would have been based on existing/historical data only. Given that the requested submission date of October 2024 is now being considered by DES it is noted that additional data to that detailed above will be included in the groundwater modelling. A drilling/monitoring well installation program is ongoing to close out current data gaps, and additional wells have recently been installed with further additional wells planned to be installed. The additional data from the new wells would allow, within the October 2024 timeframe, the development of a groundwater model that would provide a model output with a higher level of confidence. A Preliminary Site Investigation (PSI) and Stage 1 of a Detailed Site Investigation will be completed within the October 2024 timeframe. Further contaminated land investigations, prioritised on a risk-based approach, will be undertaken across the BMA Queensland portfolio of sites. Where appropriate these investigations will include subsequent stages of DSI investigations, risk assessment and modelling of contaminant plumes. 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 NPM: • Stephens Creek; • Downs Creek; • Lotus Creek; and • Rolf 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.
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	NPM TSFs include: Old TSF and Ramp 5 TSF.

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PRCP Requirement	BHP information submission for review
	These facilities comprise the following: • Down Slope Turkey's Nest Dams (Old TSF): this is an above ground facility with partial perimeter embankments. These facilities typically have a depth of tailings of less than 20 m and have been deposited in such a manner that supernatant water is collected in a decant pond at one edge of the facility. This means that the existing tailings surface is not only shaped to shed water towards the decant pond, but ongoing settlement accentuates this drainage, thereby minimising the need for cover material. • In-Pit (Ramp 5 TSF) – this is a disused mining void that has been partially filled with tailings. The relatively level pit floor will result in small differential settlement. However, as the pit has only been partially filled with tailings, management of surface runoff is important, as free drainage may not be able to be achieved. The PRC Plan will include the detail for TSFs as per the *BHP Coal Tailings PRCP Final 30062020 memo*.
Voids	There are currently six pits including Lotus, Campbell, Gilbert, Roper and Leichhardt. All are in care-and-maintenance. Voids at NPM 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 each final void at NPM. The PRCP 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 the following where sufficient time and data are available: • 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 flood modelling. Note that as discussed above for water management, contaminated land detailed site investigations and fate and transport modelling for the entire site is unlikely to be completed within the indicated timelines. As the results of these investigations may impact on the water quality within the void, the void water quality predictions maybe incomplete and require additional development post-PRC Plan and Schedule submission.
Underground Mining	There is no current underground mining at NPM.
Infrastructure	The main on-site infrastructure at NPM includes: CHPP, 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.). 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.

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PRCP Requirement	BHP information submission for review
Risk assessment	
Risk Assessment	To be completed as part of the PRC Plan.
Rehabilitation Trails and Monitoring and Maintenance	Rehabilitation trials will be conducted throughout the life of mine but will not be including 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 Requirement	BHP information submission for review
PRCP Schedule	
PRCP Schedule	To be completed as part of the PRC Plan.

Other matters for consideration		
Study Timelines	**Study required**	**Due date**
	Flood interaction studies	August 2024
	Diversions	September 2021
	Groundwater	August 2024
	Stakeholder engagement	February 2022
	Landform & rehabilitation design	April 2023
	Geochemistry	July 2022
	TSFs	September 2022
	Voids	April 2023
Consolidation, report writing, and submission		**October 2024**

Recommendations

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

Kind regards

Trudy Mazucco
Principal Closure Planning
0475 300 433

CONFIDENTIAL

Appendix 1: Norwich Park Mine – Supporting Maps

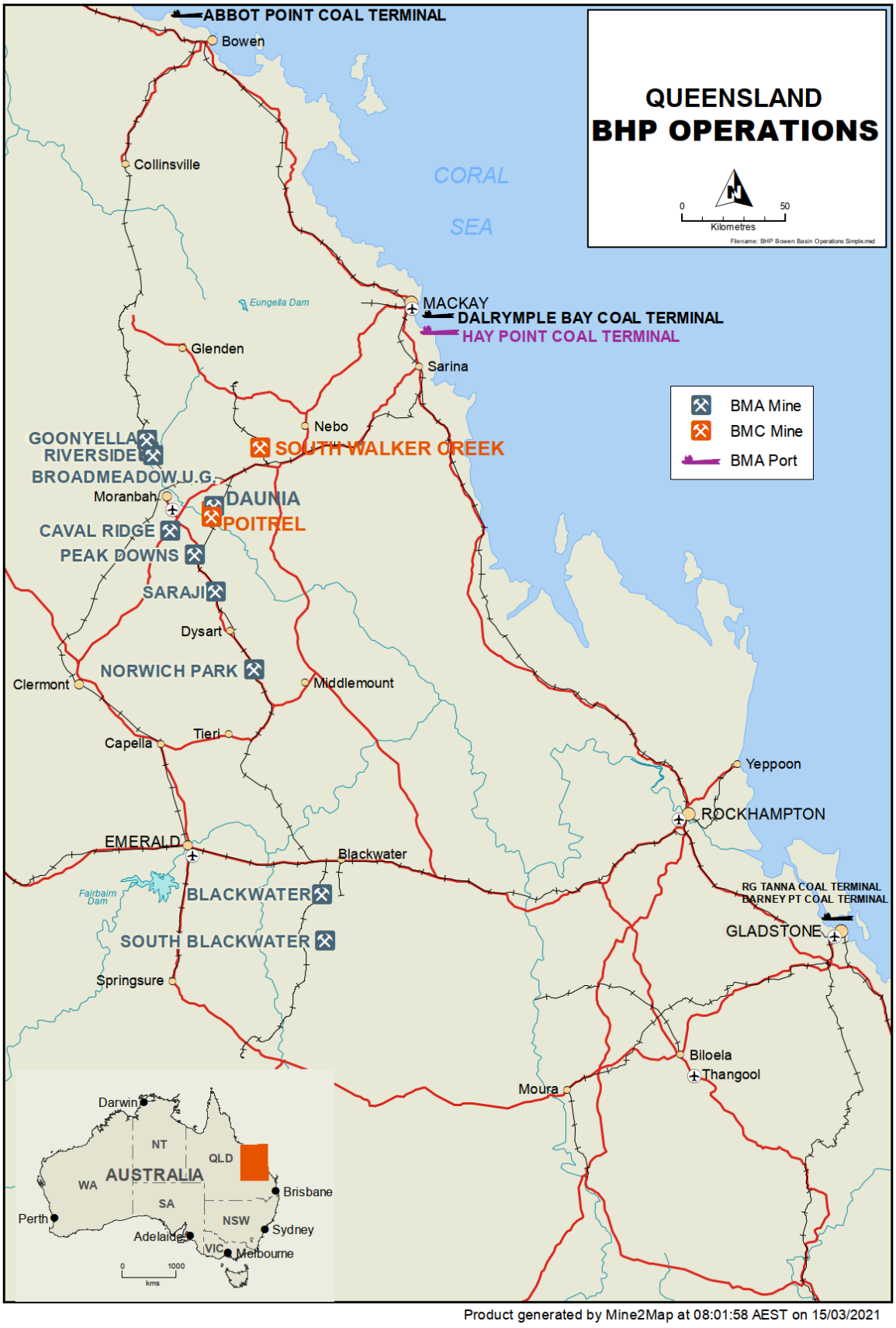

Figure 1: BHP Operations in Queensland

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.

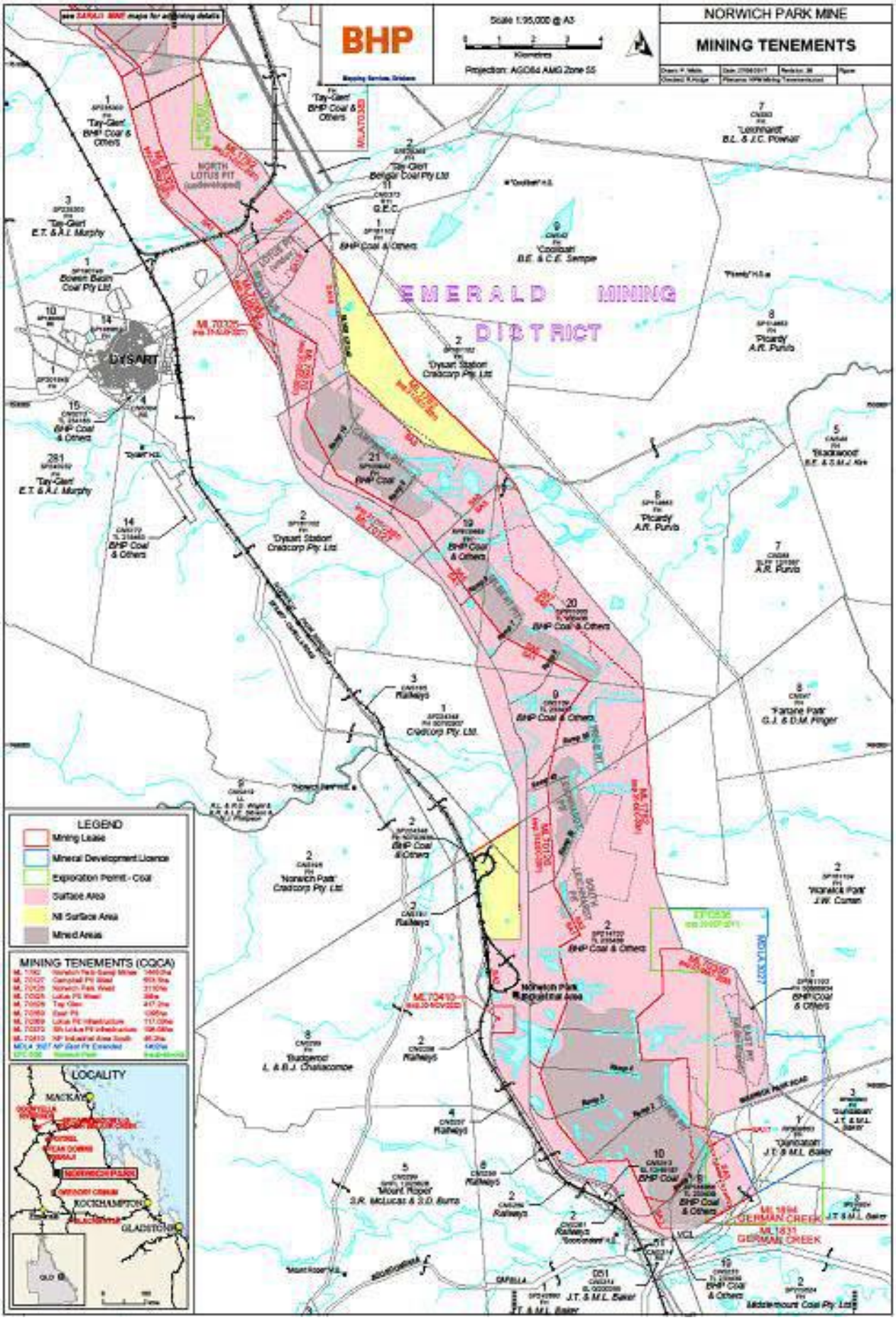

Figure 2: Norwich Park Mine mining tenements and operational land

Saraji South Mine

Transitional PRC Plan Hydrogeology Assessment

BMA

480 Queen St
Brisbane QLD 4000 Australia

Prepared by:

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SLR Project No.: 620.31444.00000

27 September 2024

Revision: 4.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
V4.0	27 September 2024	Daniel Ashton	Derwin Lyons	Derwin Lyons
V3.0	28 August 2024	Daniel Ashton	Derwin Lyons	Derwin Lyons
v2.0	24 July 2024	Daniel Ashton Jade Darvell	Derwin Lyons	Derwin Lyons
v1.0	12 July 2023	Daniel Ashton Gabrielle Killalea	Derwin Lyons	Derwin Lyons
	Click to enter a date.			

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 BMA (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.

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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1.0 Introduction

1.1 Background

SLR Consulting Australia Pty Ltd (SLR) has been engaged by BM Alliance Coal Operations Pty Ltd (BMA) to undertake a hydrogeological assessment supporting the Norwich Park Mine (NPM) (operationally known as Saraji South Mine, SSM) Progressive Rehabilitation and Closure Plan (PRC Plan). 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 3.00, effective 4 April 2023) - "the Guideline" and will be integrated into the design of the rehabilitation strategies and selection of post mining land uses (PMLUs) and Non-use Management Areas (NUMAs) within the SSM PRC Plan.

SSM is located immediately to the south of BMA's Saraji Mine and the western SSM Environmental Authority (EA) boundary is approximately 5 kilometres (km) to the east of Dysart and 86 km to the north-east of Emerald (**Figure 1-1**).

SSM operates under EA EPML00865013, and the area covered by EA EPML00865013 is approximately 16,138ha. The following mining leases intersect the EA (**Figure 1-1**):

- Saraji Norwich Park Mine – ML1782 (part)
- Tay Glen – ML70328 (part)
- Lotus Pit Infrastructure – ML70369
- South Lotus Pit Infrastructure – ML70370
- Lotus Pit West – ML70325
- Campbell Pit West – ML70127
- Norwich Park West – ML70126
- East Pit – ML70350
- Norwich Park Industrial Area South – ML70410

For the purposes of this report:

- The "SSM Area" is synonymous with the EA boundary described above and shown on **Figure 1-1**.
- The "Study Area" for this investigation includes the area covered by the EA boundary that includes SSM mining operations, and the area approximately 10 km immediately around this zone that includes areas where the groundwater environment may influence or be influenced by activities on site.

Mining commenced at SSM in 1979, and has included the extraction of coking and steaming coal through open cut strip mining from a series of pits (**Figure 1-2**). In 2012 the mine was placed in care and maintenance with select mine pit voids utilised as water storage. In 2022, limited extraction of coal from the northern pit voids recommenced with coal processing currently occurring at the Saraji Mine to the north.

Mine voids within the SSM Area (and the ML they are within):

- Lotus Pit (ML1782, ML70325, ML70369, ML70370)
- Campbell Pit (ML1782, ML70127)
- Gilbert Pit (ML1782, ML70126)
- Price Pit (ML1782)
- Leichhardt Pit (ML1782, ML70126)
- Roper Pit (ML1782, ML70126)
- East Pit (ML70350)

BMA have advised that during the period of care and maintenance at SSM (2011 to 2022), only limited activities that were required by the EA were undertaken. Therefore, the groundwater data collected at SSM in the period prior to the development of the hydrogeological assessment and numerical groundwater model, is limited. A program of groundwater monitoring infrastructure installation and monitoring has been implemented from 2020. However, there has been insufficient time within the PRCP notice period for BMA to compete all installation works and undertake monitoring for durations that would normally be used to support the development of a numerical groundwater model. On-going works and assessment of additional groundwater data is required to further reduce the uncertainty within the numerical model and improve the understanding of

groundwater characteristics, particularly within the area including and surrounding the Roper residual voids referred to as the ‘Roper Study Area. The Roper Study Area contains landforms that are likely to be hydrogeologically interconnected including: in-pit tailings storage; out of pit tailings dams; ramp reject disposal areas; mine affected water dams; ramp voids; and multiple residual voids. The complex hydrogeology within the Roper Study Area will require additional assessment and detailed technical studies to enable further development of the numerical groundwater model, which is required to understand any contaminant migration and inform an appropriate closure strategy for the area.

BMA for the PRC Plan development has implemented a specific Roper Study Area (refer **Figure 1-1**) with dedicated Rehabilitation Milestones (RM). More detailed assessment is required within this area to derive a closure strategy that provides for stable PMLUs and NUMAs that are safe, structurally stable and do not present an unacceptable risk of causing environmental harm to surrounding areas. At completion of the detailed assessments, the PRC Plan and PRC schedule will be amended, where required, to provide an appropriate closure outcome for the Roper Study Area. Although the Roper Study Area has been included within the underlying model build, the Hydrogeological Assessment results presented in this report are only for the area of SSM outside of the Roper Study Area. Upon completion of further detailed assessment, the groundwater model in the proximity of the Roper Study Area will need to be updated.

1.2 PRC Plan Final Landform

The post-mining final SSM landform relevant to this hydrogeological assessment was provided by BMA and is shown as **Figure 1-3**. This is a preliminary final landform provided for the timely commencement of this hydrogeological assessment, however there are no fundamental changes in the final landform presented in the PRC Plan that would affect this assessment. The final landform contains multiple residual final voids.

Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
Mining Lease, DNRME, 2023
Watercourse, DNRME, 2022
Roads, DoR, 2021

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Surrounding Coal Mine
- Watercourse
- Major Road
- Railway
- SSM Mine Lease
- BMA Mine Lease
- SSM EA Boundary
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

PROJECT LOCATION

SLR

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FIGURE 1-1

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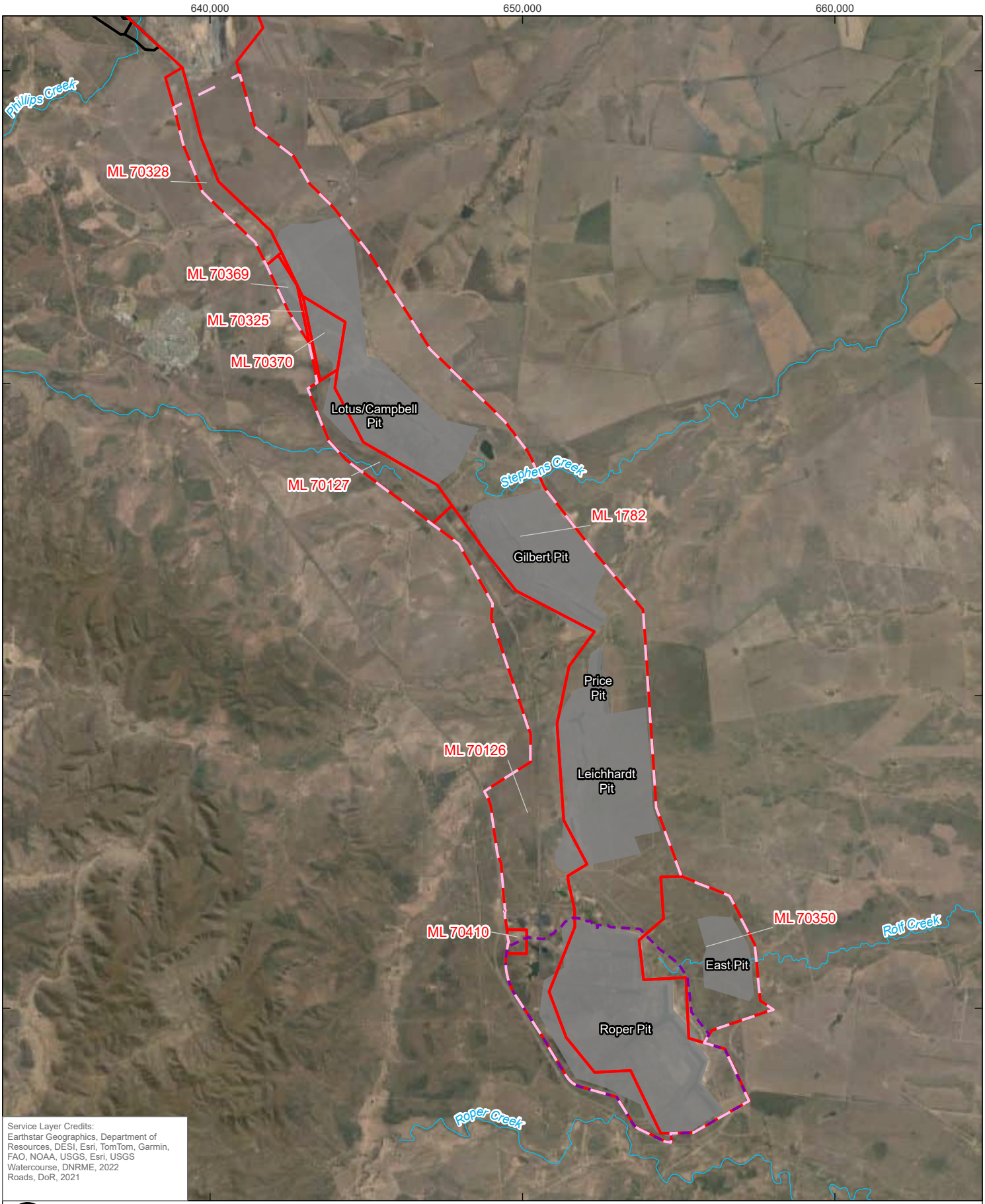

Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS Watercourse, DNRME, 2022 Roads, DoR, 2021

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Watercourse
- SSM Mine Lease
- BMA Mine Lease
- SSM EA Boundary
- Pit Extent
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

MINING AREAS

SLR

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FIGURE 1-2

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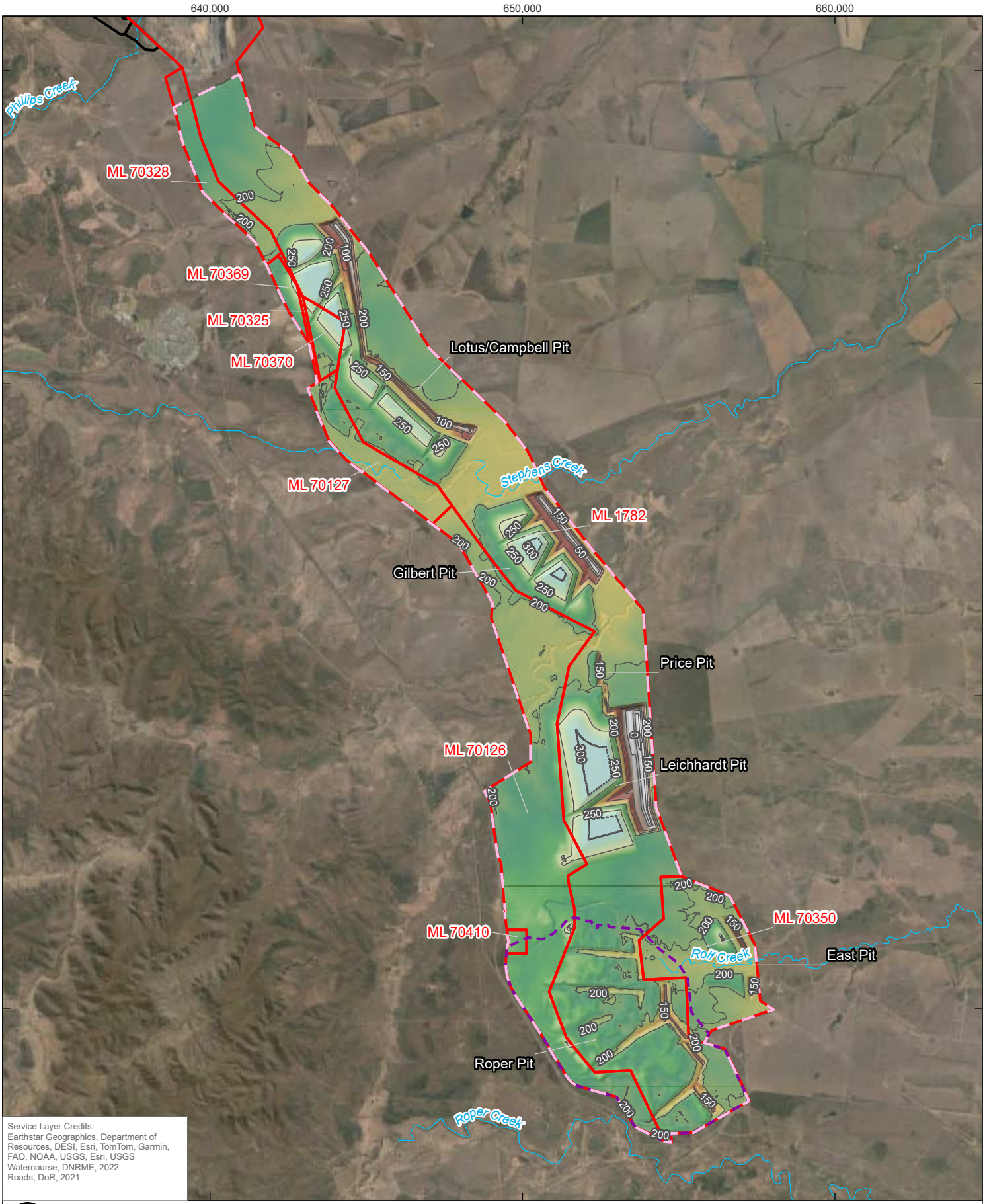
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650,000
660,000
7,510,000
7,500,000
7,490,000
7,480,000
Phillips Creek
ML 70328
ML 70369
ML 70325
ML 70370
Lotus/Campbell Pit
ML 70127
Stephens Creek
ML 1782
Gilbert Pit
Price Pit
ML 70126
Leichhardt Pit
ML 70410
ML 70350
Roff Creek
East Pit
Roper Pit
Roper Creek
Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS Watercourse, DNRME, 2022 Roads, DoR, 2021
0
2.5
5
km
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:160,000 at A4
Project Number: 620.314444.00000
Date Drawn: 28-Aug-2024
Drawn by: AS
LEGEND
Topographic Contour (mAHD)
Watercourse
SSM Mine Lease
BMA Mine Lease
SSM EA Boundary
Roper Study Area
Elevation (mAHD)
301
-80
SARAJI SOUTH MINE
TRANSITIONAL PRCP
POST MINING LANDFORM
SLR
DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.
FIGURE 1-3
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1.3 Objectives

The main objective of the hydrogeological assessment is to assess the potential groundwater related impacts at SSM 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 final landform for the intended PLMUs with respect of the SSM groundwater system. As such, the key specific objectives adopted in this assessment from which to demonstrate this suitability are:

- That the final landform is non-polluting with respect to groundwater:
  - Final voids are demonstrated to be sinks for groundwater, including groundwater contained within spoil.
  - Final void lake levels remain below shallow groundwater bearing units, i.e. there is sufficient freeboard to negate risk of void water discharge to any shallow groundwater system.
- That there are minimal 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.

1.4 Guideline Criteria

As discussed in **Section 1.1**, this hydrogeology assessment is undertaken consistent with the Guideline: Progressive Rehabilitation and Closure Plans (ESR/2019/4964). A cross reference between the relevant Guideline requirements with respect of groundwater and specific components of this assessment is provided in **Table 1-1**.

Table 1-1 Guideline Requirements

Guideline Requirement	Section of this Report
Section 3.6.1 General rehabilitation practices – Hydrogeology	
Determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	Section 4.3
Locating groundwater recharge and discharge locations locally and regionally	Section 4.3
Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	Section 4.4
Current and potential future uses of groundwater including existing groundwater extraction bores	Section 4.5
Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	Section 4.2
The development of potentiometric mapping and hydro stratigraphic cross sections	Section 5.0 Section 7.2.5 Section 8.0
Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage.	Section 7.0

2.0 Physical Setting

2.1 Climate

The climate at the Study Area is sub-tropical with higher temperatures, higher rainfall and higher evaporation occurring over the summer months (December to February). The closest Bureau of Meteorology (BoM) weather station is located at Dysart Post Office (35278), approximately 3 km to the west of the SSM Area. This Dysart Post Office weather station operated between 1988 and 2006. The nearest weather station with a longer data record is Booroondarra (station 35109) located at the southern extent of the SSM Area. The Booroondarra weather station has been in operation since 1929 and has a continuous record with only a few occasional months of missing data. **Table 2-1** provides the details of the nearby operational weather stations.

Table 2-1 Operational BoM Weather Stations near to SSM

Name	Site Number	Date Commenced	Easting (GDA94z55)	Northing (GDA94z55)	Elevation (mAHD[1])	Operational Status	Distance from SSM
Dysart Post Office	35278	1988	637975	7501644	200	Closed - 2006	3 km W
Dysart Station	35092	1956	639057	7498467	183	Closed - 2008	4 km W
Booroondarra	35109	1929	652913	7475845	200	Open	1 km S

1. mAHD = metres Australian Height Datum

SILO Grid point data (Latitude: -22.65, Longitude: 148.45) was used to assess long-term rainfall trends in the vicinity of SSM. This dataset is interpolated from quality checked observational timeseries data collected at nearby stations by the BoM. Data from January 1970 until January 2024 was used to assess the long-term rainfall trends in the vicinity of the SSM Area. From this data, the average annual site rainfall is 607.8 millimetres (mm). The highest annual rainfall was recorded for 2010, with 1,198.4 mm falling that year. The minimum annual rainfall occurred in 2018 with 249.1 mm. Monthly averages for the Booroondarra station discussed as well as the SILO grid point are listed in **Table 2-2**. Low relative annual rainfall was measured at the Dysart Post Office station, owing to the relatively short time period this was in operation aligning with relatively low precipitation.

Table 2-2 Average Monthly Rainfall

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dysart Post Office	91.5	85.6	46.0	28.5	37.1	23.1	7.8	30.0	9.6	43.4	48.1	115.4	523.6
Dysart Station	105.5	103.7	60.4	38.7	42.0	23.4	28.1	18.8	13.7	34.7	58.9	94.2	601.7
Booroondarra	111.8	95.8	71.6	33.4	36.3	24.2	23.4	23.4	15.5	38.2	54.3	95.7	623.5
SILO Grid Point Data	109.4	90.4	63.6	32.1	34.3	24.1	25.0	21.5	16.3	36.1	61.8	93.2	607.7

2. Source: **http://www.bom.gov.au/climate/data/index.shtml**
3. Note: SILO Grid point data coordinates are Latitude: -22.65 and Longitude: 148.45.

Rainfall trends for the SSM Area since 1970 are indicated by analysis of the Cumulative Rainfall Departure (CRD) trend for monthly rainfall data (**Figure 2-1**). Positive gradients on this curve (rising limbs) confirm wetter climatic conditions than normal, while negative gradients (falling limbs) indicate dry conditions. Average rainfall conditions are inferred during periods of stable residual mass. **Figure 2-1** shows that, over the past 50 years, the wettest periods occurred during 1973-1979, and in 2010-2011. The driest periods were 1991-1998 and 2001-2007. As shown by the declining trend in the

CRD, recently between 2017 and 2022 SSM experienced drier than average conditions before wetter than average conditions prevailed between 2022 and the present.

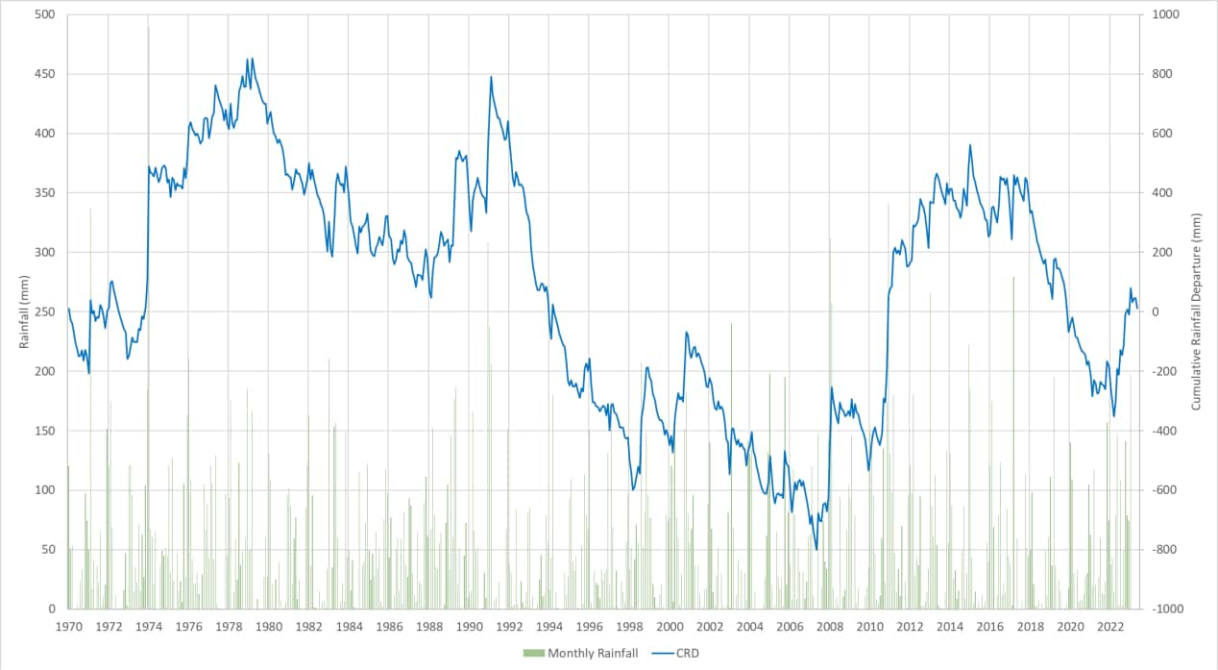


Figure 2-1 Long term Monthly Rainfall and Cumulative Rainfall Departure from mean monthly rainfall at SILO data point Lat: -22.65 and Long: 148.45.

The CRD performs an additional service: if rainfall recharge is a significant source of groundwater, the temporal variability in recorded groundwater levels can be expected to mimic the pattern of this curve. That is, natural fluctuations in the groundwater table result from temporal changes in rainfall recharge to groundwater systems. Typically, changes in groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall, illustrated by the rainfall CRD. Groundwater hydrographs showing the relationship between rainfall and groundwater levels are assessed in **Section 4.0**.

Actual and potential evapotranspiration (ET) have been taken from BoM's Australia wide interpolation dataset at the locations of the weather stations (BoM, 2023). The potential ET in the district is about 2,385 mm/year according to BoM (2023) (**Table 2-3**). The definition of potential ET is: *"… the ET that would take place, under the condition of unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average"*. For example, this represents the ET which would occur over a very large wetland or large irrigated area, with a never-ending water inflow. Further to this, where the water table approaches the ground surface, ET can also approach the potential ET value.

Table 2-3 Average Monthly Potential Evapotranspiration

PE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Booroondarra	250	209	216	179	147	121	135	166	207	252	259	269	2,410
SILO Grid Point Data	246	206	214	176	145	122	136	168	207	249	254	263	2,385

4. PE = Potential Evapotranspiration

The actual ET in the district is about 1,027 mm/year according to BoM (2023) (**Table 2-4**). The definition for actual ET is: "*... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average*". For example, this represents the predicted ET that is occurring over a large area of land under the existing (mean) rainfall conditions.

Table 2-4 Average Monthly Actual Evapotranspiration

PE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Booroondarra	129	114	108	78	49	35	40	60	81	104	117	130	1,046
SILO Grid Point Data	128	112	108	76	49	34	39	60	80	101	113	127	1,027

5. AE = Actual Evapotranspiration

Figure 2-2 shows that the average potential monthly ET exceeds the average monthly rainfall over the entire year, often by more than double. Average actual ET is slightly greater than average rainfall for all months.

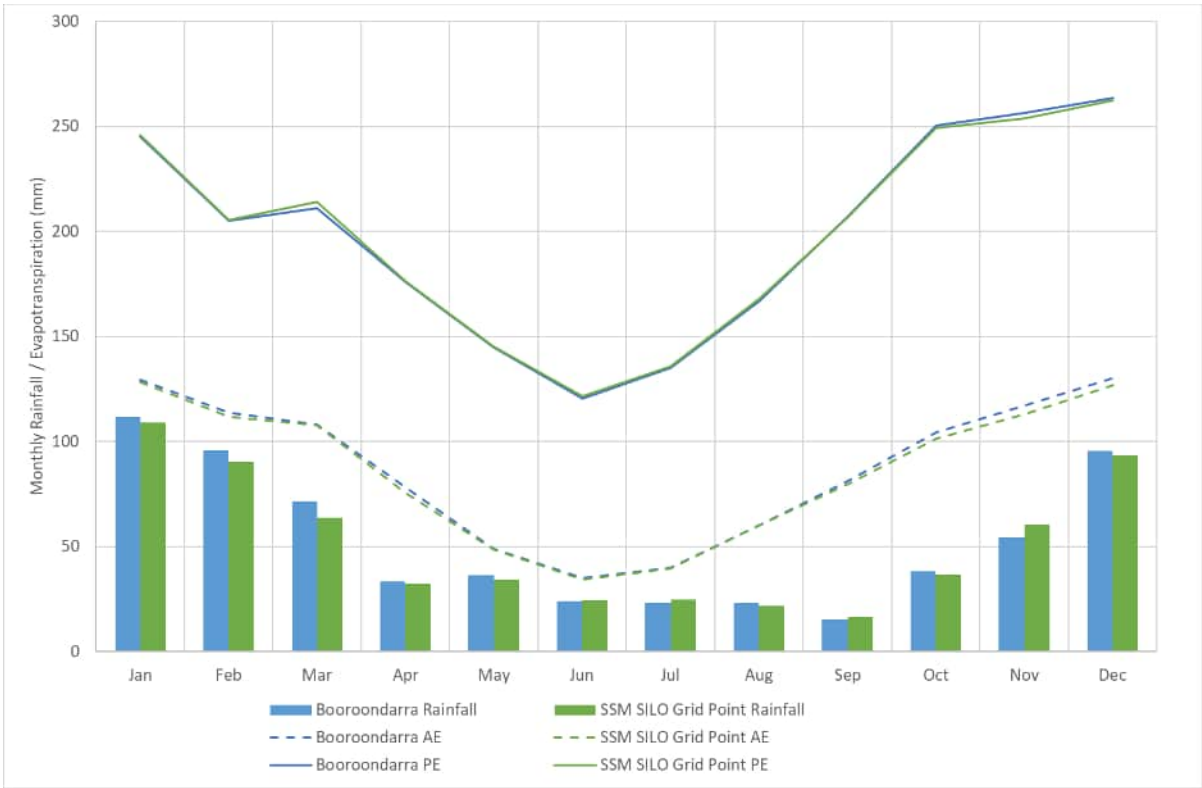


Figure 2-2 Average Monthly Rainfall and Evapotranspiration at Nearby Weather Stations

2.2 Topography and Drainage

SSM is located in the Isaac Connors surface water catchment, a sub-catchment of the upper Fitzroy Basin. The topography of the SSM Area is relatively flat with gentle undulation (average elevation of 195 mAHD), with an overall easterly gradient of less than 1% from the Harrow Range in the west to the Isaac River in the east (BMA, 2006). Land within the SSM Area has been essentially cleared for mining purposes, with substantial alteration to the surface profile with activities over time (AGE, 2004). Alteration to stream courses has been associated with mining activities, including route diversion and damming.

All watercourses and tributaries within and in the vicinity of SSM are highly ephemeral and only flow briefly after rainfall. After significant rainfall, water remains in shallow, non-flowing pools, which are utilised as livestock water sources (AGE, 2014a).

The Isaac River, located approximately 20 km northeast of SSM at its closest point, is the major drainage feature of the region and flows from northwest to southeast (**Figure 2-3**). Drainage across SSM includes a number of ephemeral tributary stream catchments that have formed as a part of the Isaac River catchment (AGE, 2014a). These ephemeral creeks traverse the SSM lease area from

generally west to east. The creeks from the north to the south of the lease area are Lotus/Downs Creek, Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek.

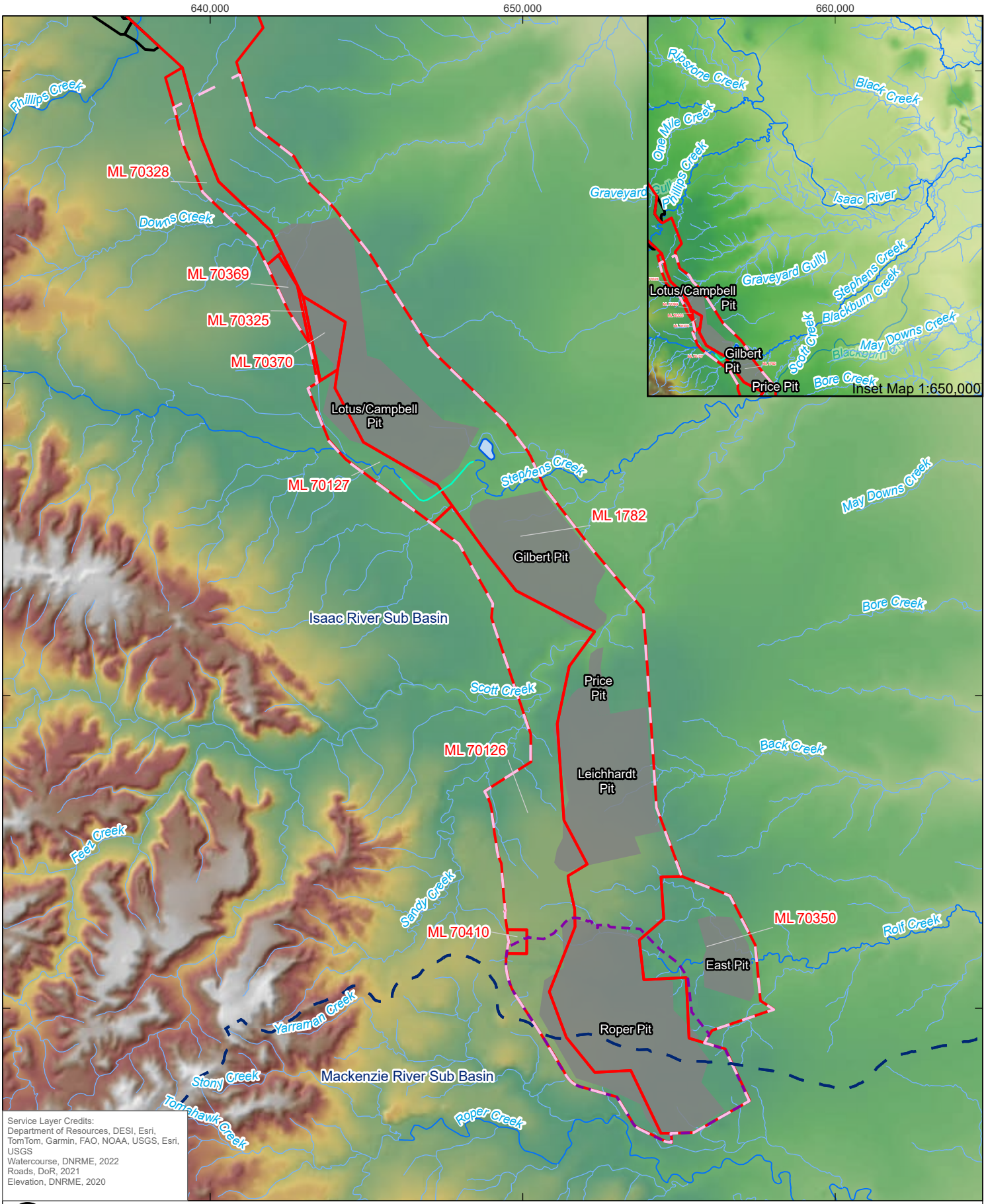
Stephens Creek is a primary drainage feature in the Study Area (**Figure 2-3**). The course of Stephens Creek within the SSM Area runs adjacent to Gilbert Pit before abruptly meandering north to Lotus Pit as it traverses the site from west to east (AGE, 2014b). Stephens Creek passes within approximately 150 m of Lotus Pit and approximately 100 m of Gilbert Pit. An AGE (2014b) investigation showed that at the apex of the meander between both pits, standing pools were a permanent feature of the creek, irrespective of seasonality. LiDAR imagery collected in August 2013 returned water levels from 175.4 mAHD to 175.0 mAHD for these standing pools (AGE, 2014b). The elevation of the creek channel terraces incised between Gilbert Pit and Lotus Pit is approximately 179.5 mAHD, approximately 6 m below the level of the flood plain (185.5 mAHD) (AGE, 2014b). Diversion of Stephens Creek in the early 1990's was conducted to allow for mining operations in Campbell Pit to expand. The embankment known as Suttles Bend Dam is an impasse to surface drainage along the original Stephens Creek watercourse to the southwest and consequently stores mine affected water (AGE, 2014b).

Scott Creek is a secondary drainage feature in the Study Area and runs from southwest to northeast across SSM before draining eastwards (**Figure 2-3**). The course of Scott Creek within the SSM Area has been diverted to run between Gilbert Pit and Price Pit (**Figure 1-3**)(AGE, 2014a). Scott Creek passes within 100 m of Price Pit North and approximately 85 m of Gilbert Pit. The elevation of the creek channel incised adjacent to Price Pit North is approximately 175.5 mAHD, with the channel bed approximately 15 m below the surrounding floodplain level at 190 mAHD (AGE, 2014a). Feez Creek and Little Roper Creek drain flow into Scott Creek 10km and 20km southwest of SSM respectively. The confluence of Scott Creek to Stephens Creek is approximately 7.2 km northeast of Gilbert Pit.

Rolf Creek is another secondary drainage feature in the Study Area and runs from east to northeast across SSM before draining eastwards (**Figure 2-3**). The course of Rolf Creek within the SSM begins at the north of Roper pit (within 30 m of the pit boundary), running directly through the middle of the proposed East Pit before draining to the northeast. The elevation of the creek channel incised adjacent to Roper Pit ranges between ~193 mAHD and ~201 mAHD near the highwall, to ~183 mAHD some 3.8 km east of the pit at Ramp 5 (AGE, 2014a). The confluence of Rolf Creek to May Downs Creek is approximately 34 km northeast of East Pit.

Roper Creek is the only drainage feature in the Study Area that runs from west to southeast, draining into the Mackenzie River catchment south of SSM, i.e. the next major Fitzroy Basin surface catchment south of the Isaac Connors catchment. The course of Roper Creek runs immediately south of Roper Pit (within ~30 m of the pit boundary), before draining to the southeast. The elevation of the creek channel incised adjacent to Roper Pit ranges between ~200 mAHD near the highwall, to ~185 mAHD some 1.4 km south of the pit (AGE, 2014c).

Lotus Dam, located south east of Lotus/Campbell Pit, was constructed in 2010 for storage of mine affected water and is the nominated controlled release point for EA MIN100760208, discharging into Stephens Creek.



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TOPOGRAPHY AND DRAINAGE

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FIGURE 2-3

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2.3 SSM Mining

This section outlines the historical mine progression, care and maintenance activities, and future mining plan at SSM, as relevant to assessing the effect of SSM on the groundwater system post-closure. This is considered important since post-closure groundwater conditions will in part be dictated by the conditions that are present as a result of existing mining activities at the time of closure.

2.3.1 Historical Mining Activities (pre-2012)

SSM began operations in 1979 with open pit dragline mining in Roper Pit targeting the D seam of the Moranbah Coal Measures (also termed Dysart Seam). Other pits were opened up progressively over approximately the next 30 years until the operations were placed on care and maintenance in May 2012 (**Table 2-5**). A visual representation of the pre-2012 SSM mine progression is shown in **Figure 2-4**.

In all pits, spoil was deposited to the west of mine void adjacent to the pit ramps. The primary mine operations area including stockpile, workshops, coal processing facility and Tailings Dam are located immediately northwest of Roper Pit.

Table 2-5 Details of mine progression at SSM pre-2012

Pit name	Mining Commenced	Target Seam
East Pit	Approved future mining	H Seams
Campbell Pit	1999	D Seam
Gilbert Pit	1987	D Seam
Leichhardt Pit	2005	D Seam
Roper Pit	1979	D Seam
Price Pit	2002	H Seams
Lotus Pit	2011	H Seams

Prior to the excavation of Campbell Pit, Stephens Creek was diverted to the south around the planned mining area. This feature is now partially fed by Lotus Dam discharge from the authorised release point.

2.3.2 Care and Maintenance (2012 – 2022)

Following the site being placed on care and maintenance, the residual voids located within SSM were incorporated into the BMA active water network, which comprises water management at SSM, as well as Caval Ridge, Peak Downs and Saraji mines. In this network, the SSM voids receive and store excess mine affected water from other BMA sites during wet periods and recycle the water by supplying BMA operations during drought conditions. A summary of water holding locations at SSM is presented in **Table 2-6** with volume estimates based on BMA water storage area register data, and locations for these are presented in **Figure 2-5**. The formation of pit void lakes during the care & maintenance phase is considered indicative of how the hydrologic system might behave in the long-term post-closure, as relevant to the PRC Plan.

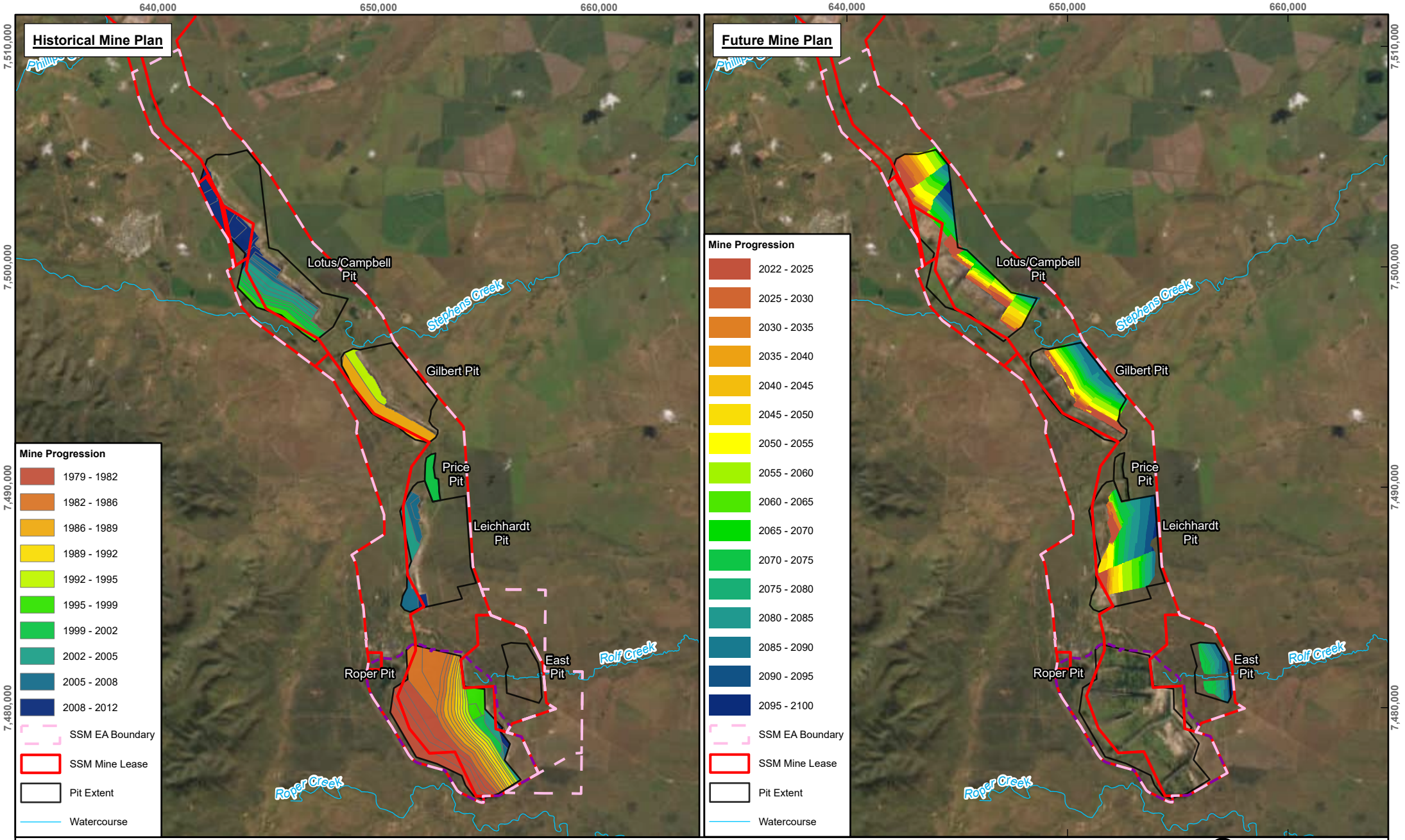
In January 2014, ad-hoc monitoring of water quality in Scott Creek identified brackish to moderately saline water at pools in the channel close to Price Pit. Subsequent investigation into the source of the anomalously saline water identified potential pathways for seepage out of the water stored in the Price Pit lake (AGE 2014a, JBS&G 2021). These investigations identified that the water level was maintained above the maximum operating level of 174.5 mAHD for extended periods between 2012 and 2013. This maximum operating level is below the capacity of the dam 187 mAHD, but selected due to the bed level of Scott Creek adjacent to Price Pit North at 174.5 mAHD (AGE, 2014a).

Table 2-6 Water Storage Areas at SSM

Water Storage Name	Pit	Capacity (ML)	Minimum (mAHD)	Date Minimum Measured	Maximum (mAHD)	Date Maximum Measured
Area Dam			220.9	14-06-2018	223.1	26-04-2017
Browns Dam		142	212.0	02-02-2021	216.0	26-04-2017
Horseshoe Dam		51	191.1	28-08-2018	192.8	26-04-2017
Ramp 64	Leichhardt		148.4	07-01-2019	158.7	09-05-2019
Ramp 65	Leichhardt		155.6	07-05-2021	159.1	10-07-2017
Ramp 66	Leichhardt		173.1	07-05-2021	176.3	26-04-2017
Little Murphy Dam		408	217.1	02-01-2020	222.9	14-06-2018
Lotus Dam		1057	185.4	04-01-2021	187.5	10-07-2017
Murphy Dam		2022	214.8	05-05-2022	222.1	14-06-2018
Old Tailings Dam		434	220.6	04-06-2021	223.6	29-07-2019
Ramp 54	Lotus		166.7	02-04-2021	172.6	12-03-2018
Ramp 56N	Campbell		123.5	08-06-2023	131.9	30-03-2020
Ramp 56S	Campbell		124.1	05-08-2021	131.9	30-03-2020
Ramp 58	Campbell		123.8	04-06-2021	131.9	30-03-2020
Ramp 59	Gilbert		126.5	26-04-2017	129.9	08-06-2023
Ramp 6 Fill Point Dam		167	180.7	02-01-2020	188.2	26-04-2017
Ramp 61 S	Gilbert		128.5	11-08-2017	130.6	06-04-2023
Ramp 62	Gilbert		128.4	26-04-2017	130.5	06-04-2023
Ramp 63 N	Price	5298	179.1	02-01-2020	184.9	26-04-2017
Ramp 63 S	Price	1914	179.2	02-01-2020	184.9	26-04-2017
Ramp 67 Tailings Pit	Roper	7307	178.1	02-06-2022	182.9	26-04-2017
Ramp 68 Mine Water Storage	Roper		178.0	02-06-2022	182.7	11-08-2017
Ramp 69 Mine Water Storage	Roper		168.1	02-09-2021	181.2	26-04-2017
Ramp 70 Mine Water Storage	Roper		166.3	06-01-2018	170.5	08-06-2023
Ramp 71 Mine Water Storage	Roper		149.7	26-04-2017	165.1	02-02-2023
Suttles Bend Dam		73	178.7	26-04-2017	178.7	26-04-2017

2.3.3 Current and Future Mining

Mining at SSM recommenced in 2022 at the northern extent of SSM (Lotus/Campbell pits). The current mine plan, with polygons indicating timing for mine strip extraction is provided as **Figure 2-4**. Currently, planned extractive mining operation is anticipated to continue to 2097.



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Watercourse
SSM Mine Lease
Pit Extent
SSM EA Boundary
Roper Study Area

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MINING ACTIVITIES AT SSM

FIGURE 2-4

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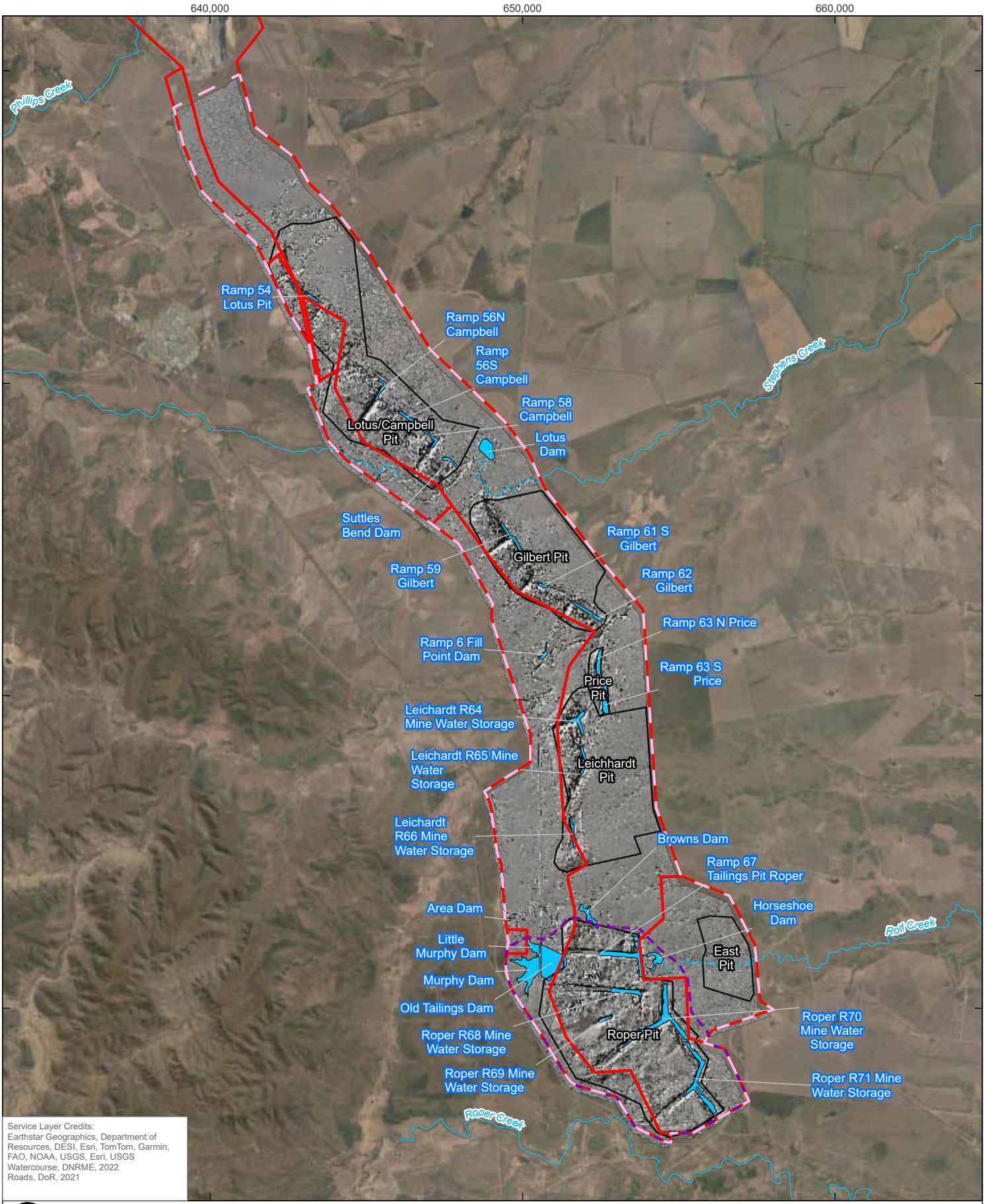

0 2.5 5 km

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LEGEND

- Watercourse
- Water Storage Area
- SSM EA Boundary
- SSM Mine Lease
- Pit Extent
- Roper Study Area

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WATER STORAGE AREAS

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3.0 Geology

3.1 Regional Geology

SSM is located in the northern part of the Bowen Basin, a foreland sedimentary basin of approximately 200,000 km^2 (**Figure 3-1**). The Bowen Basin is a north-northwest to south-southeast oriented basin and contains the largest coal reserves in Australia. The southern half of the Bowen Basin is covered by the Surat Basin, and the Galilee Basin exists to the west (Geoscience Australia, 2017).

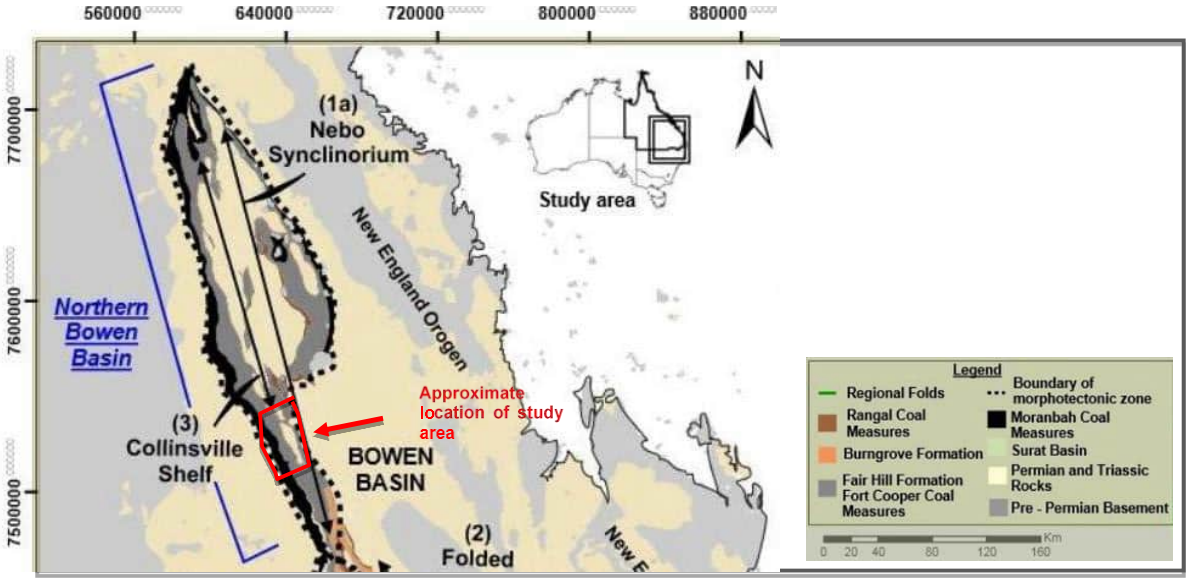


Figure 3-1 Regional geology of the Bowen Basin (after Dickens and Malone, 1973)

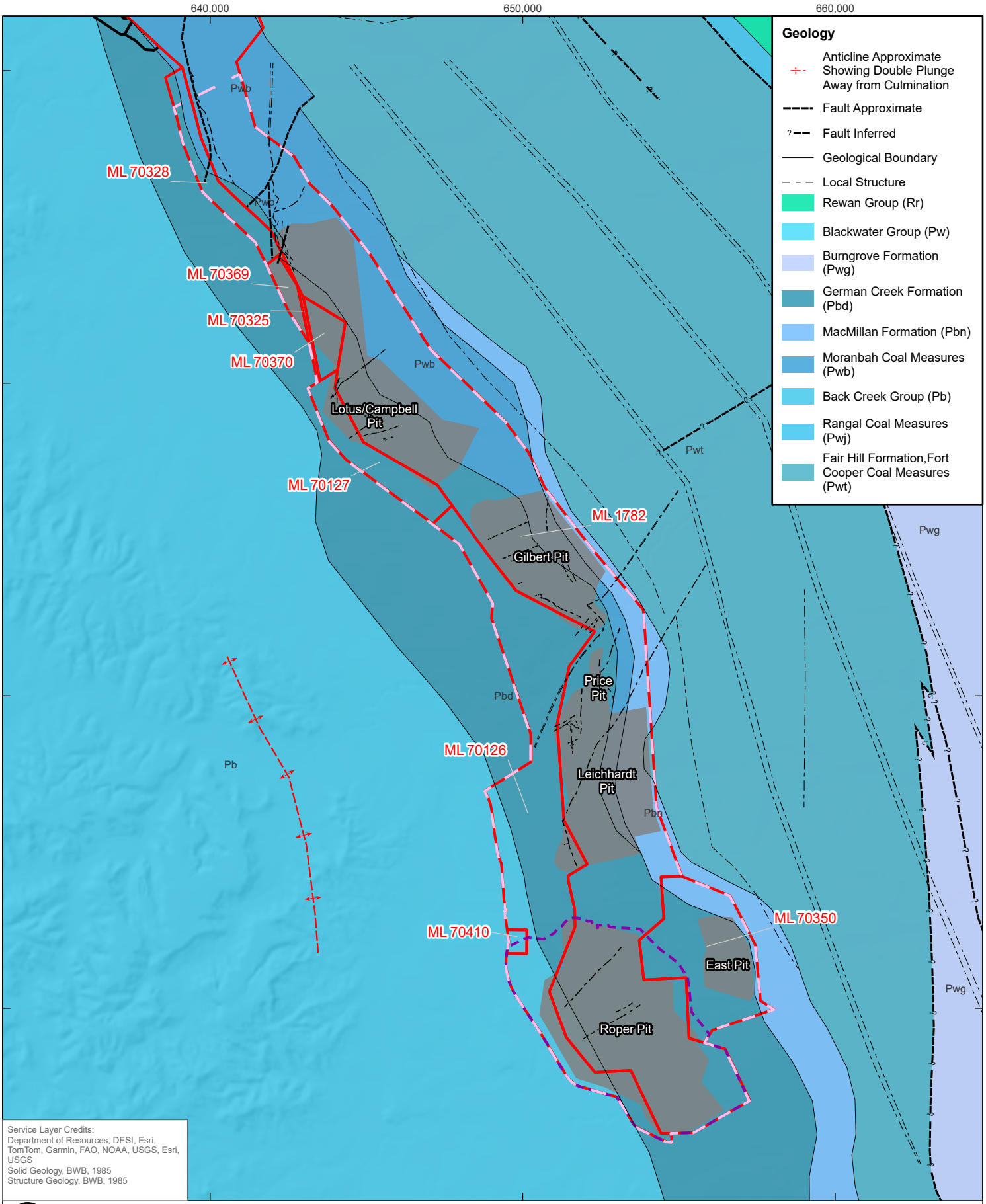
Basin geology within the Collinsville Shelf includes the basal Permian aged Back Creek Group, which generally comprises of generally fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is conformably overlain by the Blackwater Group, which includes the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures. The economic coal seams at SSM are contained in the Moranbah Coal Measures. The Permian strata occur at outcrop on the eastern and western edges of the Basin and are unconformably overlain by the Triassic aged consolidated sedimentary rocks of the Rewan Group.

The Permian and Triassic units are covered by a thin veneer of unconsolidated to semi-consolidated Cainozoic sediments (undifferentiated Tertiary to Quaternary alluvium and colluvium, and unconsolidated to semi-consolidated Tertiary sedimentary formations), as well as Tertiary aged basalt flows. The alluvial sediments are localised along surface water features (i.e., Lotus/Downs Creek, Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek).

The generalised regional stratigraphy is summarised in **Table 3-1**.

Table 3-1 Regional Stratigraphy

Period		Stratigraphic Unit		Description	Mapped Distribution	Mapped Max Thickness in and near to the SSM Area (m)
Cainozoic		Quaternary alluvium (Qa)		Flood plain alluvium comprising clay, silt, sand and gravel.	Surficial cover localised along Stephens Creek, Scott Creek and Back Creek	~ 20
		"Regolith" – older alluvium, colluvium and other Q/T sediments in floodplains, alluvial fans, and high terraces (Qr, Qr\b and TQa) For the purposes of defining hydrogeological units in this assessment, 'regolith' also includes the upper weathered portion of the Permian bedrock strata where present		Shallow unconsolidated and semi-consolidated sediments and weathered units outside of Quaternary alluvium (Qa), comprising colluvial and residual deposits of poorly sorted clay, silt, sand, gravel and black soils, silts and muds derived from weathered basalts.	Surficial cover throughout the SSM Area. TQa coverage throughout SSM Area extending eastwards until overlain by Qa deposits and pinching out on Tu contacts. Qr distributed in areas to the west of SSM, associated with weathering of Back Creek Group by watercourses traversing area	~ 20
		Duaringa Formation (Tu)		Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Forms primary surficial cover unit in the SSM Area, with significant sequences of highly weathered silt/clay/sand and basalt profiles.	~ 50
Triassic		Rewan Group (Rr) (Rewan Formation and Sagittarius Sandstone)		Rewan Formation: green lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base).	Within regional stratigraphy however outcrops outside of the Study Area, 11km to the east of the SSM Area.	~840
Permian	Late	Blackwater Group	Fort Cooper Coal Measures (Pwt)	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff.	Subcrops along total eastern extent of SSM Area and extends directly to the east.	~350
			Moranbah Coal Measures (Pwb)	Quartzose to sub-labile locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone and coal.	Within/underlies the whole of the SSM Area.	~ 400
	Early to Middle	Back Creek Group		Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite.	Within/underlies all of the SSM Area; Outcrops west of the SSM Area.	~400



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SOLID GEOLOGY

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FIGURE 3-2

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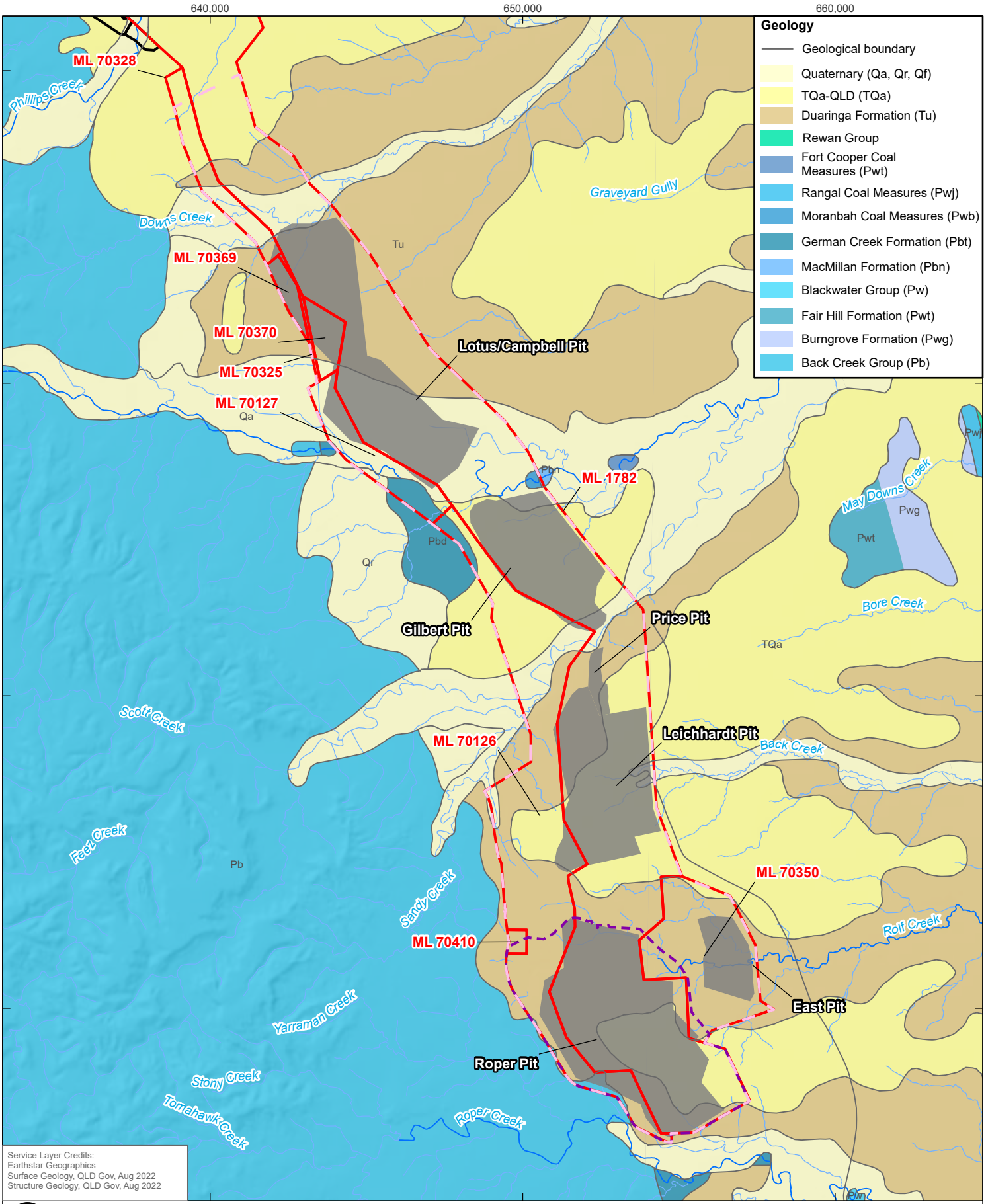

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FIGURE 3-3

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3.2 Local Geology

The stratigraphic profile within the SSM Area comprises three distinct units:

- Cainozoic sediments
  - Quaternary alluvium
  - Tertiary alluvium, colluvium, and regolith (including weathered Tertiary basalt); and
- Permian coal measures.

3.2.1 Cainozoic

3.2.1.1 Quaternary Alluvium

State (Queensland Government) Detailed Surface Geology (SDSG) mapping (**Figure 3-3**) shows Quaternary Alluvium associated with Stephens Creek, Scott Creek, and Rolf Creek, with relatively large lateral extent. Site based investigations (AGE 2004, AGE 2014a, AGE 2014b, AGE 2014c) have found that the regionally mapped extent is not correct with Quaternary Alluvium distribution relatively limited to where stream erosion has incised into Tertiary material (**Figure 3-4**). These lenses are comprised of unconsolidated clays to boulder sized material, with thicknesses ranging between 1-2m (AGE, 2004).

Figure 3-4 Ephemeral stream bed looking downstream (left) and upstream (right) near Price Pit showing localised deposition of sediment in creek channel (AGE 2014)

3.2.1.2 Tertiary Sediments and Regolith

SDSG mapping shows Tertiary-Quaternary alluvium (TQa) deposits distributed across SSM and the surrounding area. TQa is defined as a *poorly consolidated or unconsolidated alluvial deposit in an ancestral valley, which has been dissected by more recent channel activity*. SDSG mapping shows that the TQa deposits extend eastwards from SSM and are indicative of flood plain material associated with watercourses traversing the area. The inferred extent of the surficial material is presented in **Figure 3-3**. AGE (2014a) report Tertiary sediments comprising of an intercalation of unconsolidated clay and sand to semi-unconsolidated clay, sandy clay, silty clay, sand, and gravel sediments, where clay predominates within the sequence. Thicknesses of approximately 45 m are reported across SSM for the Tertiary unit, increasing to 54 m in the western portion of the site (AGE, 2014c). The generally dry and hard unconsolidated basal sediments are mostly densely compacted, comprising of coarse-grained sands and fine gravels (AECOM, 2019). The thickness of these sediments varies across the site, unconformably sitting on the erosional surface that forms the top of the underlying Permian sequence (AGE, 2014a; AGE, 2004).

Close to Price Pit, in association with Scott Creek, BMA drill logs indicate varying depths of 1 to 3 m for Tertiary cover, comprising of soils up to 1 m thick and firm dry clays up to 3 m thick (AGE, 2014a).

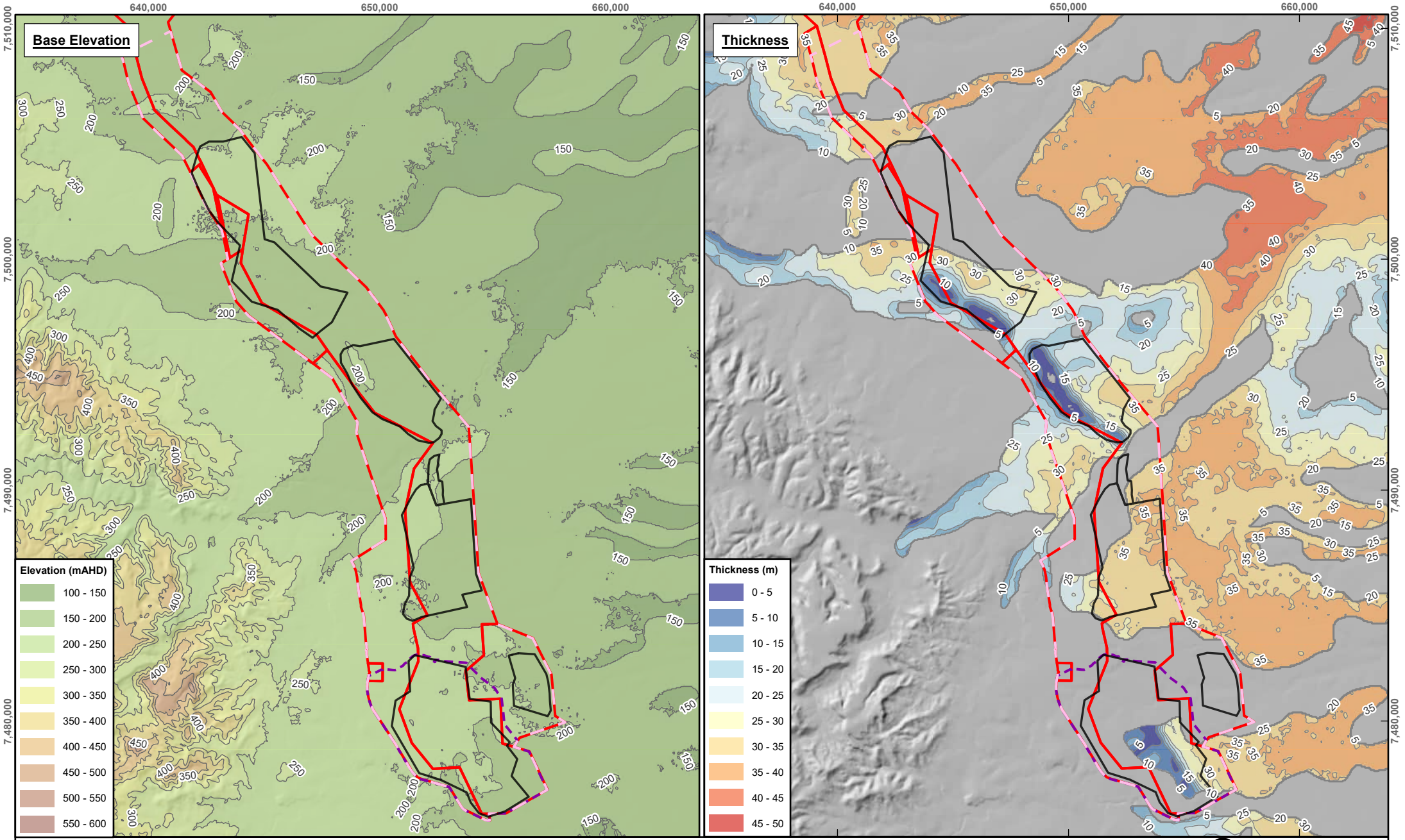
The thickest Tertiary sediments are found to the south of SSM at Leichhardt Pit and Roper Pit, consisting of poorly interconnected aquifers of variable permeability and limited storage potential (AGE, 2014c). Lower permeability clayey horizons are considered to limit drainage between these aquifers (AGE, 2014c).

SDSG mapping shows the Duaringa Formation (Tu) covering a significant proportion of SSM, with the Lotus, Price, Leichhardt, Roper, and East Pits intersecting this unit. Tu is defined as mudstone, sandstone conglomerate, siltstone, oil shale, lignite, and basalt (Withnall et al., 2009). This mapping is supported by groundwater bore drilling logs from the SSM Area.

The other undifferentiated surficial material covering much of the Study Area comprises unconsolidated undifferentiated sediments (regolith), including colluvium and residual deposits (Qr) derived from weathering of the underlying Permian strata.

In many recent relevant hydrogeological studies, the surficial Tertiary aged sediments and other weathering derived material outside of mapped Quaternal Alluvium (Qa) has been collectively termed ‘regolith’, since these sediments essentially function as a single hydrogeological unit. The extent and thickness of the regolith material is presented in **Figure 3-5** interpolated from the site geological data and regional modelling completed based on CSIRO Soil and Landscape Grid of Australia (CSIRO, 2015) data. SDSG mapping shows surficial regolith deposits to be localised in the west of the SSM area (**Figure 3-3**), indicative of weathering of the Permian Back Creek Group by water courses as they traverse these locations.

Based on BMA drill logs, the regolith in the SSM Area comprises of interbedded sequences of sandstone and siltstone, dominated by highly weathered medium to coarse, low strength sandstone and moderate strength, medium to fine grained sandstone (AGE, 2014a). The regolith material is generally 6 m to 20 m thick, with the depth of weathering extending into the underlying Permian coal measures (AGE, 2014a).



Scale: 1:210,000 at A4
Coordinate System: GDA 1994 MGA Zone 55

Date Drawn: 28-Aug-2024
Project Number: 620.314444

Elevation Contour (mAHD)
Thickness Contour (m)

SSM Mine Lease
SSM EA Boundary
Pit Extent
Roper Study Area

SLR

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SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION AND THICKNESS OF SURFICIAL UNITS

FIGURE 3-5

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F3_5_Surficial_Units_01

3.2.2 Permian Coal Measures (Blackwater Group)

Permian coal-bearing sedimentary rocks of the Blackwater Group form the main economic resource of the numerous mines in the Study Area. In decreasing depth (age) order, the major coal measures in the Study Area include the:

- Moranbah Coal Measures;
- Fort Cooper Coal Measures; and
- Rangal Coal Measures

3.2.2.1 Moranbah Coal Measures

The Moranbah Coal Measures consist of laterally persistent sandstone, siltstone, claystone, mudstone, and coal sedimentary sequences dipping 3° to 6° towards the east (AGE, 2014a). These coal measures subcrop at SSM on the western limb of the Bowen Basin and are also mined at Saraji Mine immediately north of SSM. These seams constitute the economic deposits of coal that are targeted by mining operations at SSM.

The predominance of sandstone, siltstone and claystone inter and overburden is reported to vary across SSM. AGE (2004) summarised the below variations in pit lithology encountered in the Permian unit:

- Roper Pit: Sandstone and carbonaceous claystone interlaminated with sandy siltstone;
- Leichhardt Pit: Siltstone with some thick sandstone beds and minor claystone;
- Gilbert Pit: Thick, massive sandstone beds; and
- Campbell Pit: Massive sandstone

Geological assessment of the Permian formations concluded that the weathering horizon extends to a depth ranging between about 2 to 12 mbGL (metres below Ground Level) with the deepest weathering horizon corresponding with the thickest sequence of Tertiary formation (Dames and Moore, 1975).

There are two main coal seams (each comprised of multiple plies) within the Moranbah Coal Measures mined at SSM; in order of increasing depth these are known as the Harrow Creek (H) seams and the Dysart (D) seams. All seams split and recombine along the mine. These main coal seams subcrop on the western part of the SSM (AGE, 2014a). **Figure 3-6** presents a schematic of the coal seams along the mine. It should be noted that the Fort Cooper Coal Measures are not present within the SSM Area, instead subcropping immediately east of the SSM Area boundary (described further in **Section 3.2.2.2** and as shown in **Figure 3-3**). A brief description of Moranbah Coal Measures coal sequence at SSM includes:

- The Pisces (P) group seams are within the stratigraphic package of SSM however do not occur at sufficient thickness or quality to be considered for mining. Modelled depth and thickness of this seam group is presented in **Figure 3-7**.
- The main Harrow Creek (H) group seams of interest include the Harrow Creek Upper (H16), Harrow Creek Lower (H33 and H32). The H16 is up to 4.8 m thick, the H33 seam up to 2.4 m thick and the H32 up to 1.1 m thick (AGE, 2014a). Modelled depth and thickness of this seam group is presented in **Figure 3-8**.
- The main Dysart (D) group seams of interest include the Dysart Upper (D58 and D59) seam and Dysart Lower (D35) seam. The D35 seam is generally the target coal seam across SSM (AGE, 2014c). Where coalesced, the Dysart Lower seam is typically 4 m thick. The Dysart Upper seams D58 and D59 are 1.1 m to 0.6 m thick respectively. Modelled depth and thickness of this seam group is presented in **Figure 3-9**.

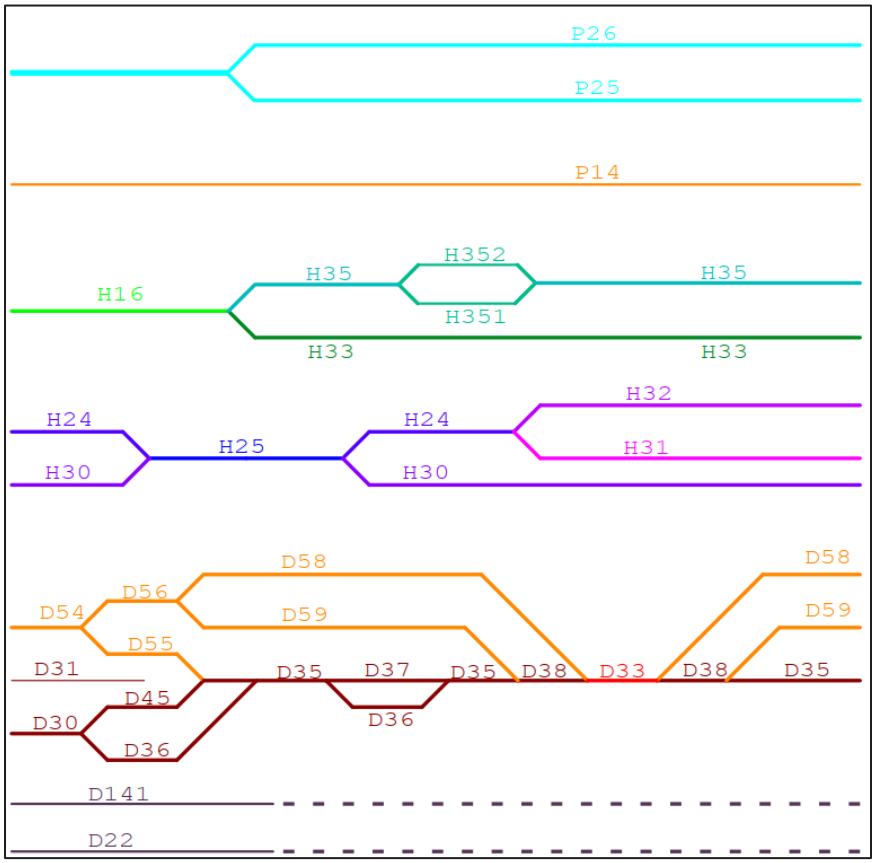


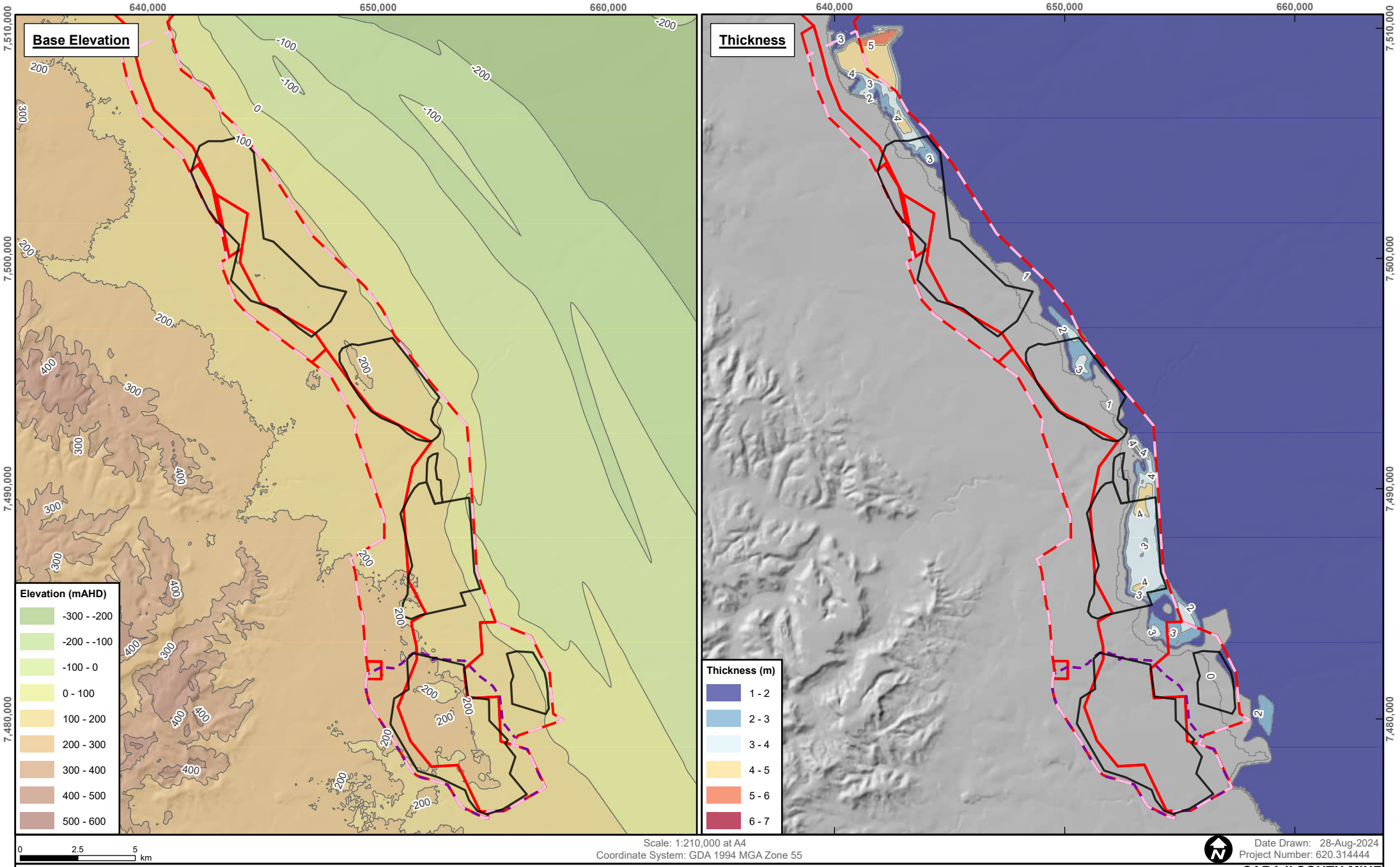
Figure 3-6 Schematic Split Diagram of Moranbah Coal Measures Coal Seams at SSM (JB Mining Services, 2012)

3.2.2.2 Fort Cooper Coal Measures

The Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures and subcrop east of SSM but are not present within the SSM Area. Regionally, the formation has a maximum thickness of approximately 350 m (HydroSimulations, 2018) and drill logs indicate the Fort Cooper Coal Measures comprise lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous (cherty) mudstone. Primary coal seams within the Fort Cooper Coal Measures are the S seam (3 to 4 m thick) and the R seam (1 to 2 m thick) (BMA, 2020). The two seams are not found in the SSM lease and only adjacent to the eastern margins.

3.2.2.3 Rangal Coal Measures

Where they occur further east of SSM, the youngest Blackwater Group coal measures, the Rangal Coal Measures, overlie the Fort Cooper Coal Measures. The transition between the Rangal Coal Measures and the Fort Cooper Coal Measures is marked by the Yarrabee Tuff which immediately overlies the Vermont Lower Seam. The Yarrabee Tuff is a basin-wide marker bed comprised of weak, brown tuffaceous claystone, with an average thickness of 0.7 m. The Rangal Coal Measures comprise light grey, cross-bedded, fine to medium grained labile and well cemented sandstones, grey siltstones, mudstones, shale and coal seams. The non-coal portions of the sequence are predominantly sandstones, siltstones, mudstone and shales, referred to as interburden in the mining context. This unit is outside of the SSM groundwater system considered in this hydrogeology assessment.



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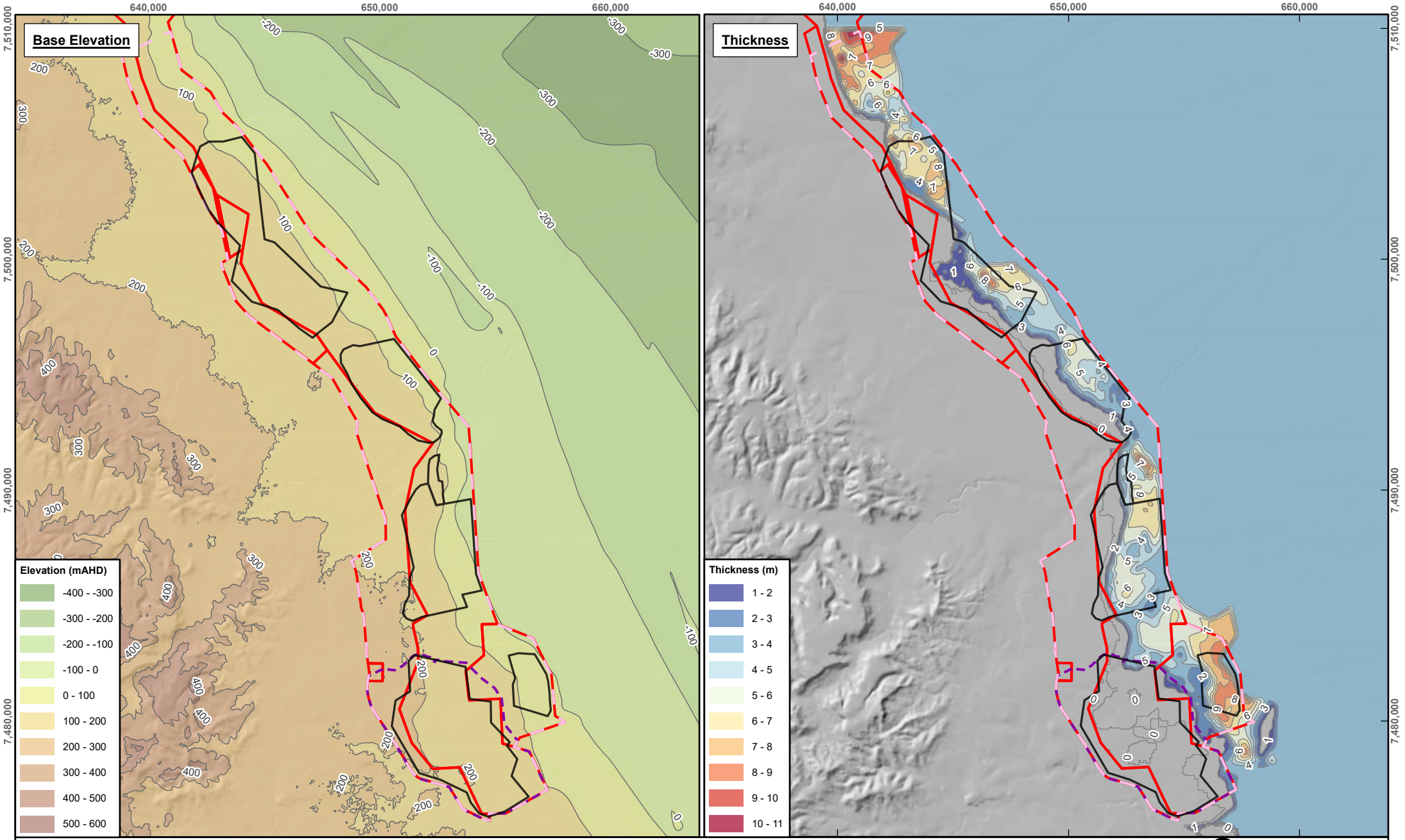
SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION OF THE P SEAM AND THICKNESS OF THE P SEAM

FIGURE 3-7

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F3_7_P_Seam_Thickness_01



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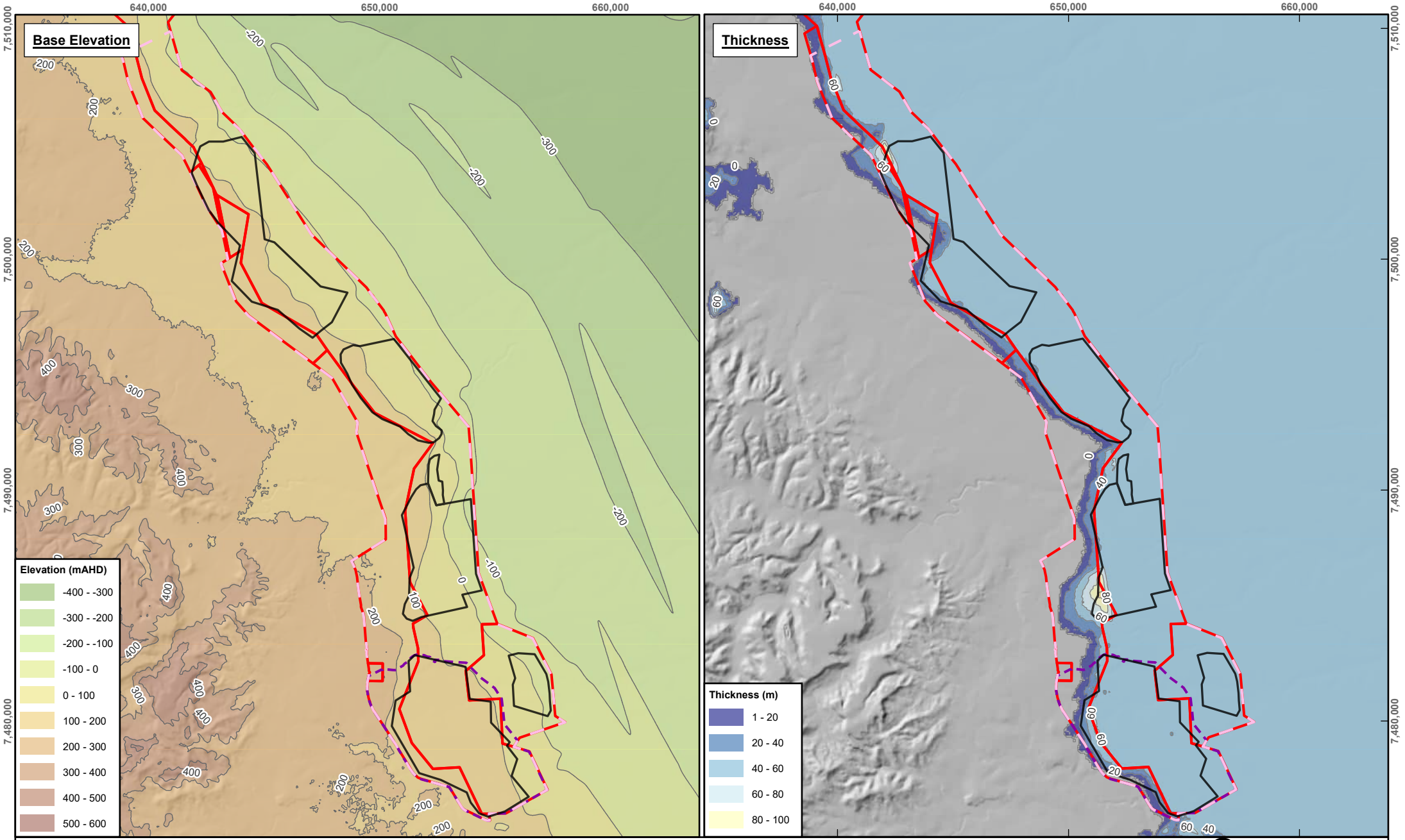
SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION OF THE H SEAM AND THICKNESS OF THE H SEAM

FIGURE 3-8

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F3_8_H_Seam_Thickness_01



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SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION OF THE D SEAM AND THICKNESS OF THE D SEAM

FIGURE 3-9

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F3_9_D_Seam_Thickness_01

3.2.3 Back Creek Group

Along the western margin of SSM is the Back Creek Group comprising the German Creek Formation and other undifferentiated sandstone, siltstone and shale packages. As shown in the stratigraphic sequence represented in **Table 3-1**, this unit is considered basal for the groundwater system at SSM. The formation consists of early to late Permian interbedded sandstone, siltstone, carbonaceous shale with minor coal seams. The contact between this unit and the overlying formations dips 3° to 6° towards the east, in line with the regional syncline.

3.2.4 Structural Geology

The Bowen Basin was subject to significant tectonic compression from the eastern side at the end of coal deposition in the late Triassic. The compression from the eastern side caused major thrust faulting, which resulted in the commercial viability of mining the coal deposits across the region.

SSM is located within the regional Western Foreland structural domain of the Bowen Basin, located approximately 20 km west of the Jellinbah Fault Zone.

All units of the Permian sequence generally dip from west to east at an average of 4° in the vicinity of SSM, towards the axis of a local syncline that is truncated by the north-south trending Isaac Thrust Fault.

Faults at SSM strike predominantly east northeast- west southwest at the Lotus, Campbell, Roper and Gilbert Pits (**Figure 3-2**). In between the Gilbert and Leichhardt pits is a pair of large northeast-southwest striking faults that dislocate the entire stratigraphic package. The Price and Leichhardt pits display north-south striking structures together with the site wide east northeast- west southwest structures.

The detail on hydrogeological influence of the structural geology features present in the SSM Area is discussed in detail in **Section 4.2.3**.

4.0 Hydrogeology

Based on the understanding of the geological setting presented in **Section 3.0** the hydrogeological regime relevant to SSM comprises the following key hydrogeological units:

- Cainozoic sediments
  - Quaternary alluvium – unconfined aquifer (sporadically water-bearing strata of permeable unconsolidated sand or gravel) localised to major ephemeral drainage line channels at SSM along Downs Creek, Scott Creek and Rolf Creek;
  - Quaternary to Tertiary non-alluvial sediments and weathered units (collectively termed 'regolith' in many recent relevant regional studies) – unconfined unit with limited saturation at SSM and in the Study Area.
- Permian coal measures with:
  - Low permeability interburden and overburden units with aquitard properties; and
  - Coal seams that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

The coal seams within the Moranbah Coal Measures are the primary aquifer at SSM. The coal seams can be characterised as confined aquifers, with the H Seam and D Seam forming the main aquifer units locally. The Moranbah Coal Measures overburden and interburden act as aquitards and are typically dry, or very low yielding.

This section discusses each of the hydrogeological units relevant to SSM, covering hydraulic properties, groundwater occurrence, hydraulic gradients, recharge, discharge, groundwater quality, and water use.

4.1 SSM Groundwater Monitoring

Whilst mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004, approximately 25 years after the commencement of mining. The SSM groundwater monitoring network currently comprises a total of 51 monitoring sites consisting of 33 active sites, 7 decommissioned inactive sites and 11 locations that are not consistently monitored (i.e. historic monitoring points no longer actively routinely monitored).

The monitoring network was first established in 2004 following the issue of an EA (MIM800126503, Environmental Protection Agency, 17 September 2003) (AGE, 2004), and expanded further in AGE (2014c), AGE (2018), GHD (2021a), and BHP (2021). Much of this work was completed in order to identify the nature of groundwater interaction with mine void and water storages. The hydrostatic units monitored in the network include:

- Quaternary Alluvium (2 monitoring bores);
- Tertiary sediments (19 monitoring bores);
- Tertiary weathered basalt (1 monitoring bore);
- the P Seam of the Moranbah Coal Measures (3 monitoring bores);
- the H Seam of the Moranbah Coal Measures (5 monitoring bores);
- the D seam of the Moranbah Coal Measures (4 monitoring bores);
- the interburden/overburden of the Moranbah Coal Measures (9 monitoring bores);
- Fort Cooper Coal Measures (2 monitoring bores); and
- 3 bores with unknown screen details (all inactive).

Groundwater data collection from this network has been undertaken since 2004. The bore details for the current monitoring network are summarised in **Table 4-1** and shown graphically in **Figure 4-1**. This network includes 13 sites where bores are installed in different hydrogeological features across the vertical profile, providing information on vertical gradients in chemistry and hydrostatic pressure

within the aquifer sequence. No vibrating wire piezometers (VWPs) have been installed on site. Water pressure loggers were installed in ten monitoring bores late 2021, monitoring groundwater level through 2022 (**Table 4-2**). This data is presented with the manual groundwater level dips in **Section 4.3**.

Table 4-1 SSM Groundwater Monitoring Network Details

Bore ID	Easting (GDA94)	Northing (GDA94)	Surface Elevation (mAHD)	Screen Top Elevation (mAHD)	Screen Base Elevation (mAHD)	Monitored Unit	Install Date	Bore Status	WL Data Availability	WQ Data Availability
38547	654098	7495068	182.63	No data	No data	Permian (FCCM[1])	15-09-1972	Active	2011-2023	2011-2020
43060	663900	7482826	170.02	No data	No data	Tertiary	01-02-1973	Active	2011-2023	2011-2020
43062	659415	7488033	179.66	No data	No data	Permian (FCCM)	01-02-1973	Active	2011-2023	2011-2020
MB20NPM01A	643394	7505494	188.74[+]	No data	No data	No data	No data	No data		
MB20NPM02P	643391	7505498	188.66[+]	89.16	83.16	Permian (MCM[2] H Seam)	No data	Active	2022	
MB20NPM03A	650324	7496839	180.38	177.38	174.38	Alluvium	07-12-2020	Active	2022	
MB20NPM04P	650338	7496838	183.28	101.28	98.28	Permian (MCM H Seam)	05-12-2020	Active	2021-2022	
MB20NPM05A	653471	7493056	184.52	170.52	166.52	Tertiary	09-12-2020	Active	2021-2023	
MB20NPM06T	653469	7493063	184.91[+]	151.91	144.81	Tertiary	02-03-2021	Active	2021-2023	
MB20NPM07A	656939	7479625	194.01[+]	163.01	154.01	Permian (MCM IB/OB[3])	04-02-2021	Active	2021-2023	
MB20NPM08P	656952	7479625	193.52[+]	142.52	139.52	Permian (MCM P Seam)	26-03-2021	Active	2021-2023	
MBL01A	652545	7488003	209.85[+]	47.35	41.35	Permian (MCM D Seam)	17-03-2014	No data	2014	2014
MBL01B	652541	7488007	209.81	166.21	160.21	Tertiary	19-03-2014	No data	2014	2014
MBP001A	652782	7491808	188.46	159.46	155.46	Permian (MCM IB/OB)	11-12-2018	Active	2018-2022	2018-2020
MBP001B	652778	7491810	188.32	115.62	106.32	Permian (MCM D Seam)	10-12-2018	Active	2018-2022	2018-2020
MBP002A	652810	7491432	190.91	182.91	175.91	Tertiary	10-12-2018	Active	2018-2022	2018-2020
MBP002B	652808	7491427	191	173	168.5	Permian (MCM IB/OB)	09-12-2018	Active	2018-2019	2018-2020
MBP003A	652157	7491547	187.15	165.15	157.15	Permian (MCM IB/OB)	05-12-2018	Active	2018-2019	2018-2020
MBP003B	652158	7491552	187.36	156.36	147.36	Permian (MCM IB/OB)	04-12-2018	Active	2018-2019	2018-2020
MBP004A	652380	7491536	188.54	177.54	170.54	Permian (MCM IB/OB)	06-12-2018	Active	2018-2022	2018-2020
MBP004B	652381	7491542	188.53	167.53	160.53	Permian (MCM H Seam)	06-12-2018	Active	2018-2022	2018-2020
MBP005A	652525	7491909	187	164	159	Permian (MCM IB/OB)	08-12-2018	Active	2018-2022	2018-2020
MBP005B	652523	7491904	187.26	131.26	124.26	Permian (MCM H Seam)	07-12-2018	Active	2018-2022	2018-2020
MBR01A	655738	7479095	206.67[+]	112.67	106.67	Permian (MCM D Seam)	11-03-2014	No data	2014	2014
MBR01B	655738	7479098	206.68[+]	167.18	161.18	Tertiary	13-03-2014	No data	Dry (2014)	
MBR02A	656144	7478203	206.10[+]	114.10	108.10	Permian (MCM D Seam)	14-03-2014	No data	2014	2014
MBR02B	656145	7478197	206.14[+]	173.14	167.14	Tertiary	15-03-2014	No data	Dry (2014)	
NPMMB01_01	643395	7505495	188.69[+]	146.19	140.19	Permian (MCM P Seam)	No data	Active	2022	
NPMMB02_01	649880	7489940	196.38[+]	127.38	121.38	Permian (MCM IB/OB)	15-02-2021	Active	2021-2023	
NPMMB02_02	649869	7489940	196.33	122.33	116.33	Tertiary Basalt	19-02-2021	Active	2021-2023	
NPMMB03_01	650329	7496838	181.38	165.18	159.18	Permian (MCM IB/OB)	06-12-2020	Active	2021-2022	
NPMMB06_01	653440	7487474	201.64	154.49	148.49	Tertiary	06-02-2021	Active	2022-2023	
NPMMB06_03	653438	7487481	201.88	116.38	113.38	Permian (MCM P Seam)	29-01-2021	Active	2022-2023	
NPMMB07_01							14-12-2020	Inactive		
NPMMB08_01	650987	7483198	223.82[+]	194.82	188.82	Tertiary	13-02-2021	Active	2021-2022	
P2	651008	7483333	221.65	213.15	210.15		01-04-2004	Inactive	2004-2013	2010-2012
P2A	651026	7483343	221.80	203.80	192.80	Tertiary	2013	Inactive	2013-2020	2013-2018

Bore ID	Easting (GDA94)	Northing (GDA94)	Surface Elevation (mAHD)	Screen Top Elevation (mAHD)	Screen Base Elevation (mAHD)	Monitored Unit	Install Date	Bore Status	WL Data Availability	WQ Data Availability
P2A_R	651026	7483343	222.05+	192.05	187.05	Tertiary	14-12-2020	Active	2022-2023	
P3	649872	7489937	196.01	175.01	172.01	Tertiary	28-04-2004	Active	2004-2020	2005-202
P6	650330	7496846	181.18	172.38	167.18	Alluvium	15-04-2004	Inactive	2004-2014	2005-2014
P6R	650356	7496833	181.37	175.37	141.37	Permian (MCM H Seam)	2015	Active	2015-2020	2015-2021
P7	650958	7483035	228.70+			Tertiary	No data	Inactive	2023	
P7R	650955	7483035	229.03+	223.03	205.53	Tertiary	No data	Active	Dry	
P8	650987	7483109	226.66+			Tertiary	No data	Inactive	Dry	
P8R	650988	7483126	226.20+	220.20	202.20	Tertiary	No data	Active	Dry	
P9	650914	7483118	227.33+			Tertiary	No data	Inactive	Dry	
P9R	650914	7483118	227.33+	221.33	203.43	Tertiary	No data	Active	Dry	
P10	651036	7482966	228.78+	No data	No data	Tertiary	No data	No data	Dry	

+ Indicates surface RL sourced from LiDAR

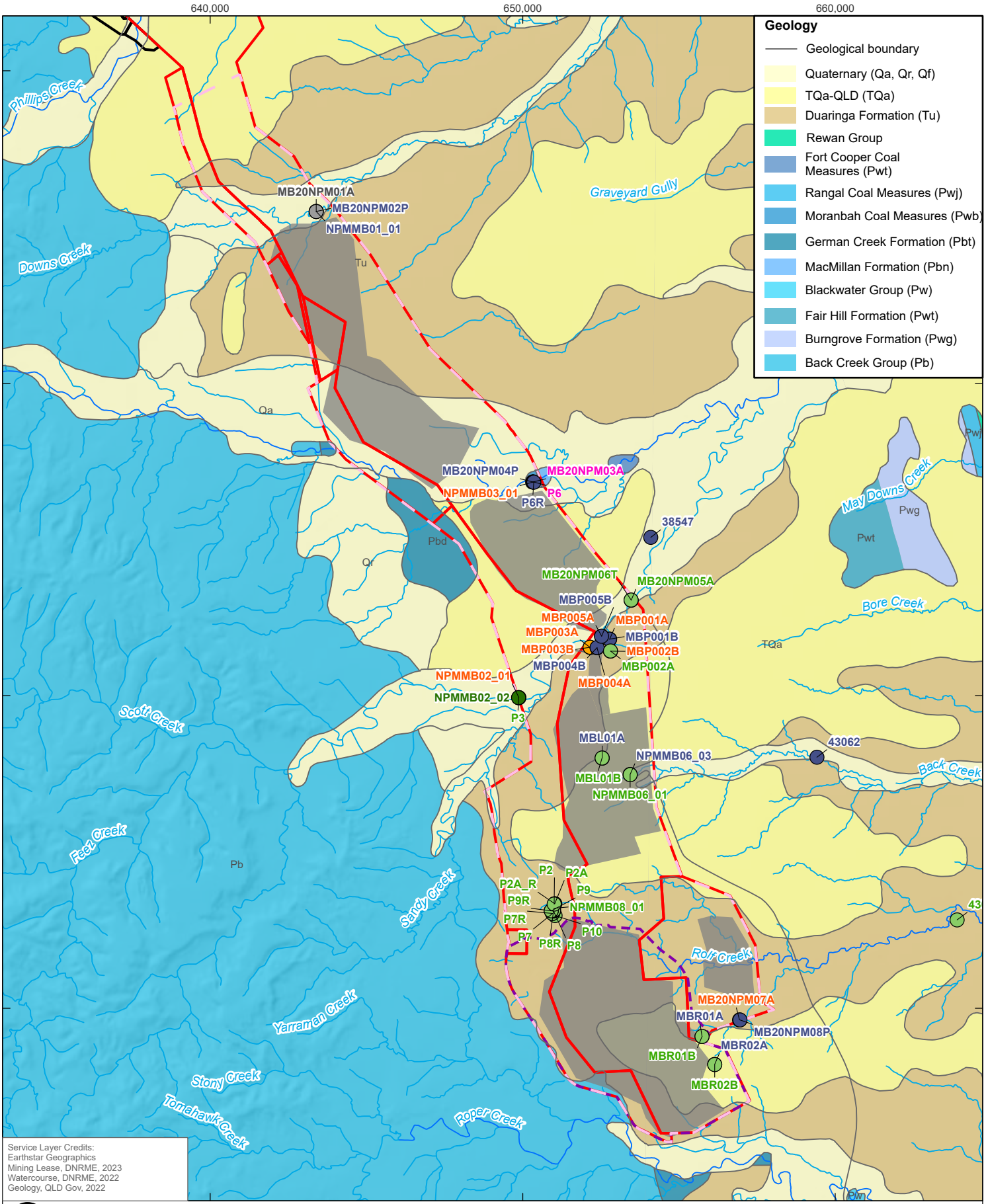
[1] Fort Cooper Coal Measures

[2] Moranbah Coal Measures

[3] Interburden/Overburden

Table 4-2 Summary of groundwater level logging data availability

Bore ID	Start of Logger Record	End of Logger Record	Frequency
MB20NPM07A	21-09-2021	22-05-2023	1 hour
MB20NPM06T	21-09-2021	06-12-2023	1 hour
MB20NPM05A	21-09-2021	06-12-2023	1 hour
MB20NPM04P	22-09-2021	06-12-2023	12 hours
MB20NPM08P	21-09-2021	06-06-2023	12 hours
NPMB02-01	22-09-2021	05-12-2023	12 hours
NPMB02-02	22-09-2021	05-12-2023	12 hours
NPMB03-01	22-09-2021	06-12-2023	12 hours
NPMMB08-01	21-09-2021	05-12-2023	12 hours
P2AR	21-09-2021	05-12-2023	12 hours
NPMB06-01	21-09-2021	06-12-2023	12 hours
MB20NPM03A	22-09-2021	11-11-2022	4 hours



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

SARAJI SOUTH MINE TRANSITIONAL PRCP

SSM GROUNDWATER MONITORING NETWORK

SLR

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FIGURE 4-1

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_1_Groundwater_Monitoring_Network_01

4.2 Hydraulic Properties

SSM site groundwater hydraulic testing is available from slug (rising and falling head) tests performed on monitoring network bores completed by AGE (2014a) and BHP (2021). This section presents a summary of the available field hydraulic data, and a comparison to externally reported hydraulic properties that BMA has access to through its regional data sharing agreement with neighbouring sites.

4.2.1 Hydraulic Data

The database of available field results for horizontal (Kh) and vertical (Kv) hydraulic conductivity is presented graphically as **Figure 4-2**. Tests from the SSM Area are provided as a separate classification on the plot. The data are also presented separately for each test method as results can vary based on the type of testing and analysis undertaken.

Figure 4-2 shows that the hydraulic conductivity of the alluvium is variable, ranging from 1 x 10^{-2} to almost 101 metres per day (m/day), which reflects the heterogeneous nature of the alluvial sediments. There is no hydraulic testing data available for the alluvium in the SSM monitoring network, though extensive testing from the region provides reasonable ranges for groundwater modelling applications. Pumping tests of the Isaac River alluvium conducted in 2019 as part of the Moorvale South Project assessment reported hydraulic conductivity values in the range of 2.1 – 2.7 m/day (Golder, 2019).

Broadly termed the Regolith unit in previous relevant studies, the Tertiary aquifer consists of highly weathered basalts and clay rich sediments that have been found to behave similarly in the groundwater system to the weathered Permian outcrops. Hydraulic testing of the unit within SSM also found hydraulic conductivity to be highly variable, in line with regional values, with SSM slug testing hydraulic conductivity ranging from 0.03 m/d to 6.5 m/d.

The coal seams of the Permian coal measures generally record higher hydraulic conductivity than the majority of the interburden/overburden. Interburden/overburden testing shows a hydraulic conductivity of at least an order of magnitude less than that of coal seams at similar depths, typically less than 1 x 10^{-4} m/day. This is due to the dual porosity of the coal seams, with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats), which supports the concept of the coal seams themselves forming the dominant groundwater zones of the Permian units.

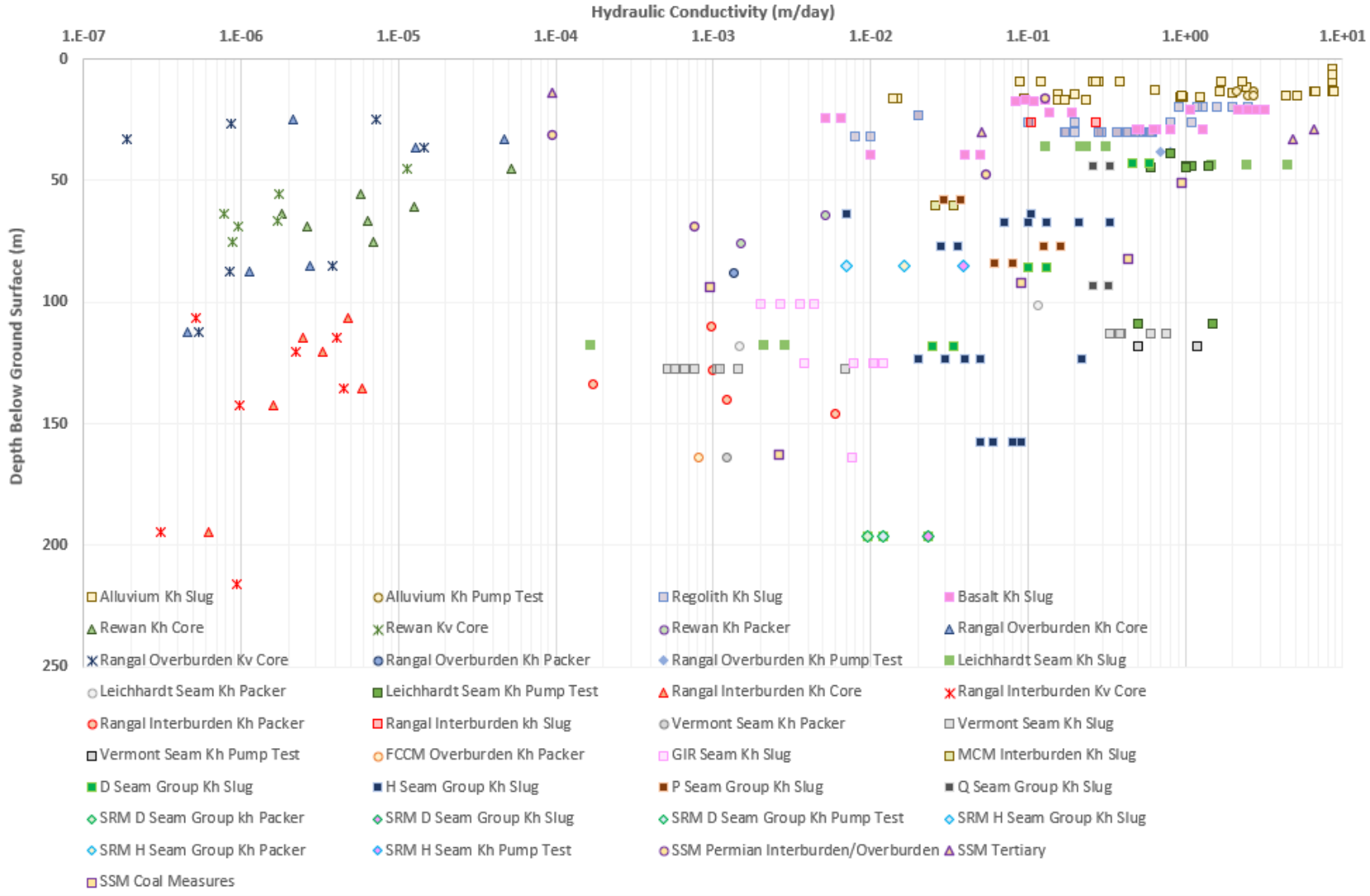


Figure 4-2 Summary of all regional hydraulic testing results

4.2.2 Hydraulic Conductivity Ranges

A histogram of the spread of horizontal hydraulic conductivity (Kh) from the field testing at SSM, as well as at other nearby sites, is presented in **Figure 4-3**. The results are compared to the range of documented values for each relevant unit, as presented within a literature review previously completed by HydroSimulations (2018) based on several other studies within the Bowen Basin.

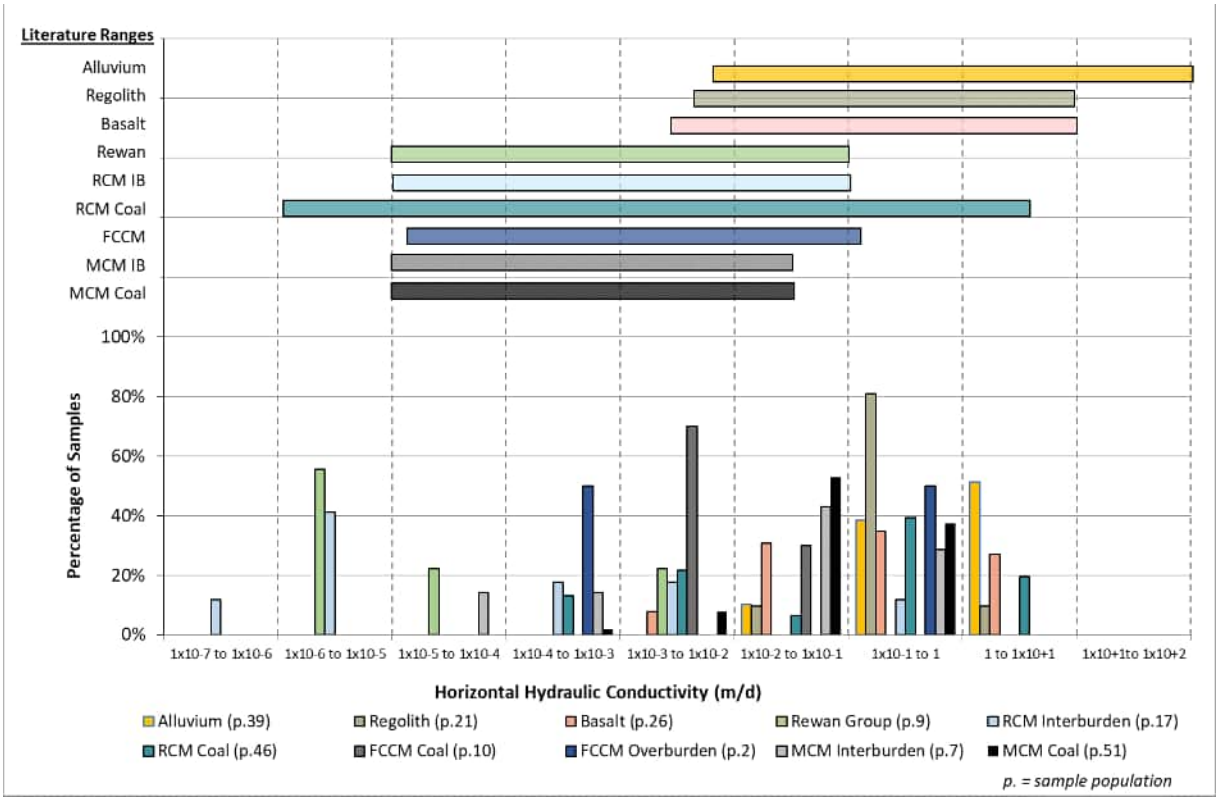


Figure 4-3 Histogram of Horizontal Hydraulic Conductivity Distribution

The comparison shows that the field results for alluvium, Tertiary sediments, and Moranbah Coal Measures interburden within the Study Area and immediate surrounds, fall within the range of field data collected through other studies across the Bowen Basin, with just one measurement greater than the literature range for Moranbah Coal Measures interburden. As established in conceptualisation work completed for study area along strike to the north, hydraulic testing results for the coal seams of Moranbah Coal Measures in the SSM Area recorded higher hydraulic conductivity than previously identified in literature for that unit (SLR, 2023a). Review of **Figure 4-2** shows that within the Moranbah Coal Measures the higher values are attributed to the H seam where hydraulic conductivities are generally an order of magnitude greater than measured within the P and D coal seams. These testing results from SSM are consistent with H seam observations adjacent to the Study Area along strike (SLR, 2023a).

4.2.3 Faulting

As discussed in **Section 3.2.3**, there are numerous faults trending northwest-southeast within Permian strata across SSM and surrounding area.

As identified by Jourde *et al*. (2002), faulting can result in higher permeabilities within strata parallel with the fault plane, and lower permeabilities within strata perpendicular to the fault plane. However, this can also be dependent on whether faults are currently active (Paul *et al.*, 2009). Faulting has been inactive within the Bowen Basin for over 140 million years (Clark *et al.*, 2011), indicating that the fault zones are less likely to act as conduits to flow; this relates to filling of the fractured pore spaces over time through hydrothermal alteration and mineralisation (Uysal *et al.*, 2000).

Downhole hydraulic testing was also conducted in the Permian coal measures for the Winchester South Project north-northwest of SSM (SLR, 2020). Fault zones were confirmed to be intersected at these drill holes due to the presence of fracturing, calcite infills, and slickensides in core obtained from the drill holes, all of which are considered an indicative marker of faulting. Testing results showed relatively low hydraulic conductivity values ranging from 6.9×10^{-5} to 2.1×10^{-3} m/day, and in line with those presented in **Figure 4-4**. These properties indicate that the faulting zones intercepted and tested are 'healed' and not pathways for preferential groundwater flow, given their hydraulic conductivities are generally lower than the adjacent Permian coal seams.

Laboratory geotechnical analysis of core samples of interburden immediately above and below coal seams proximal to a fault zone has previously been undertaken in support of groundwater assessments in the Study Area (SLR, 2020). The samples recorded vertical hydraulic conductivity of 50% to 160% of horizontal hydraulic conductivity; i.e. although some samples show a typical Kv of somewhat less than Kh, some samples also suggest greater Kv than Kh, which may be indicative of preferential vertical flow pathways associated with faulting. However, it was also noted that these areas of increased Kv are limited vertically, with samples collected from the same drill hole at horizons further above and below the fault zone (interburden and Rewan Group) returning a lower Kv of between 11% and 76% of Kh. This highlights the limitations of bore scale test methods (such as core or slug testing) that may bias results compared to methods that yield more aquifer scale estimates of hydraulic properties, such as pumping tests.

The impact of faults on groundwater flow within the Study Area was also assessed as part of the Bowen Gas Project (Arrow Energy, 2012). Kinnon (2010) assessed the movement of water and gas across a series of faults in the Bowen Basin using stable isotope and water quality analysis to assess zones of potential recharge, water mixing and flow pathways. Higher gas production rates were also observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of the major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a horizontal permeability barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin.

Based on a detailed literature review of the effect of faulting on groundwater flow, Coffey (2014) developed a conceptual model for fault zone hydraulic characterisation in the Bowen Basin (**Figure 4-4**), largely based on Jourde *et al.* (2002) and Flodin *et al.* (2001). This conceptualisation provided a means of inferring hydraulic conductivities of the fault core and the fault damage zone from regional hydraulic conductivity, with the fault core typically one to three orders of magnitude lower conductivity than the regional host rock, and the damage zone approximately an order of magnitude higher.

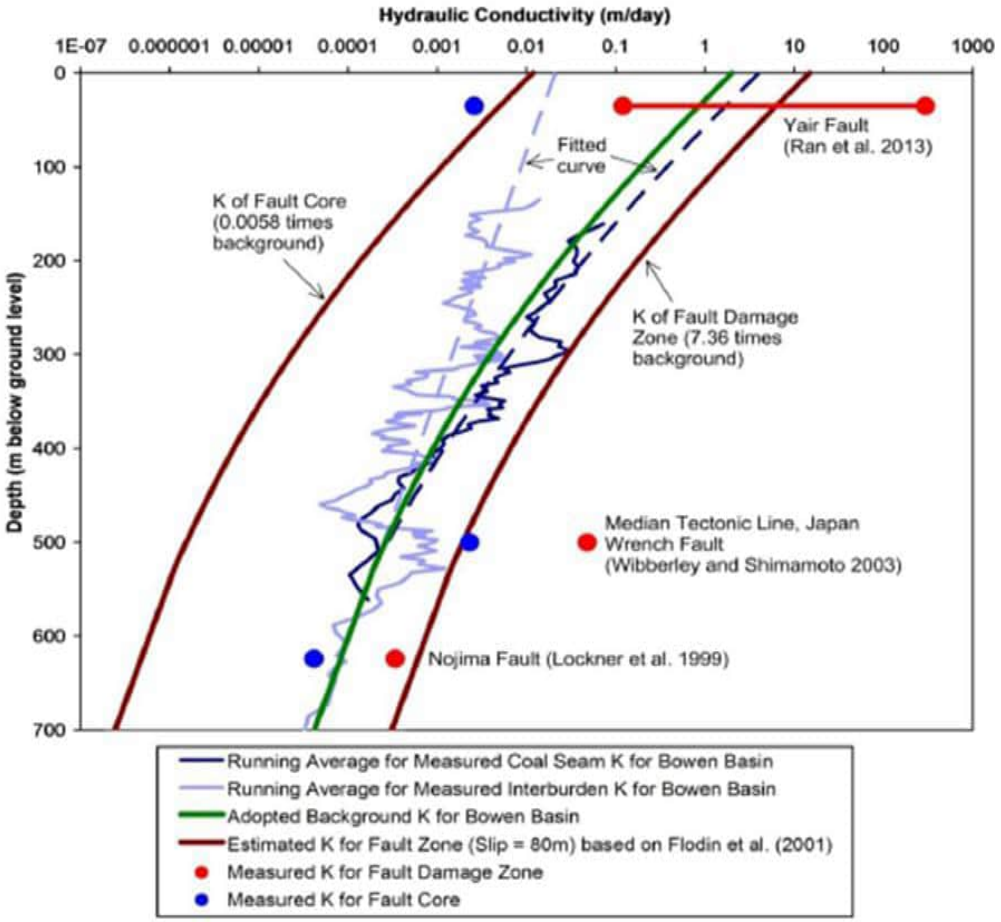


Figure 4-4 Faulting Conceptual Model Developed by Coffey (2014)

4.3 Groundwater Distribution, Flow, Recharge and Discharge

4.3.1 Alluvium

4.3.1.1 Distribution and Flow

Despite significant areas delineated as Quaternary alluvium in the Queensland regional detailed surface mapping (DNRME, 2017), site investigations have repeatedly noted that surface cover is Tertiary aged colluvium (i.e. regolith), with alluvial material limited to within surface water channels where they have eroded into the Tertiary profile. That is, the actual distribution of Quaternary alluvium in the SSM Area is deemed to be significantly more restricted than is mapped in the public surface geology. BMA drilling investigations at SSM from 2014 to 2021 failed to identify significant lenses of shallow alluvial material to install monitoring bores, and thus there are only two locations where alluvial monitoring was installed, bores P6 and MB20NPM03A north of Gilbert Pit adjacent to Stephens Creek (refer **Figure 4-1**).

P6 was installed in an alluvial sand lens north of Gilbert Pit adjacent to Stephens Creek. The alluvium in this bore was initially saturated and monitored from 2004 to 2009 before it ran dry and was replaced by P6R, however due to a lack of saturation in the shallow alluvium, this bore was installed in the underlying Permian coal seam water table aquifer (**Figure 4-5**). Alluvium monitoring in this area was re-instated in 2020 with the installation of MB20NPM03A, however no saturation has been observed (i.e. the alluvium is deemed to be 'dry').

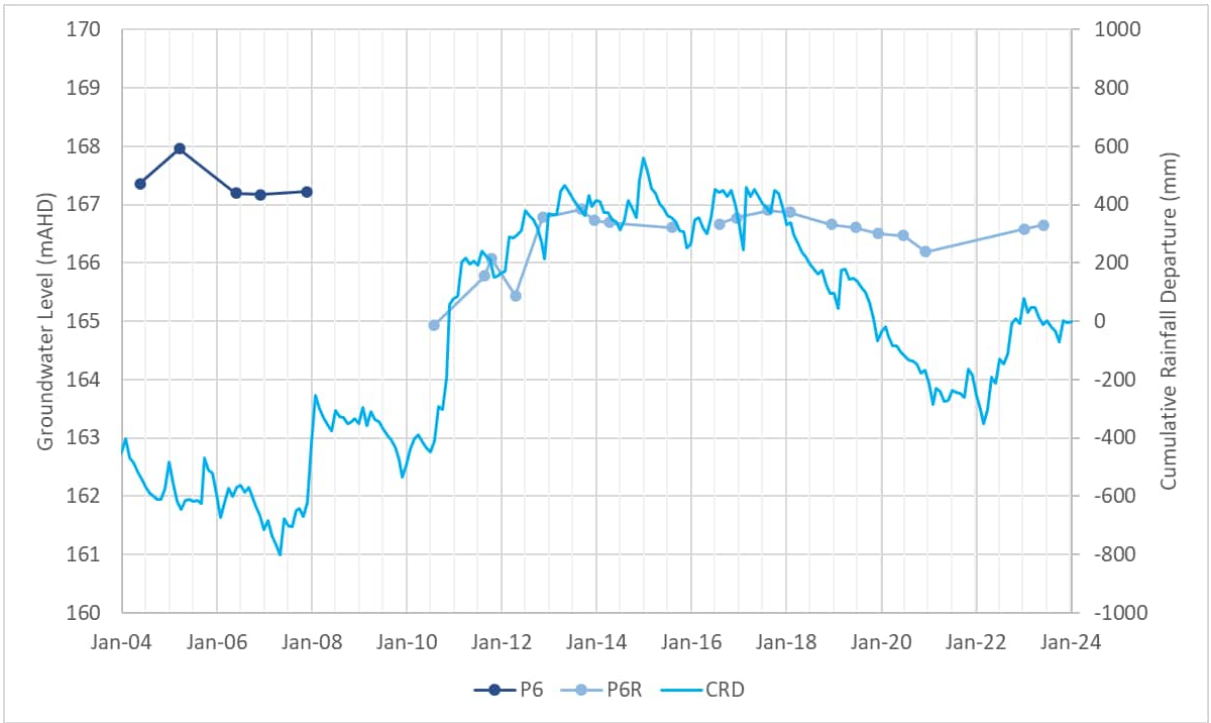


Figure 4-5 Alluvium water level monitoring bore P6 hydrograph with coal seam bore P6R for comparison

4.3.1.2 Recharge and Discharge

Recharge to the alluvium is considered to be mostly from stream flow or flooding (losing streams), with direct infiltration of rainfall also occurring where there are no substantial clay barriers in the shallow subsurface.

4.3.2 Regolith

4.3.2.1 Distribution and Flow

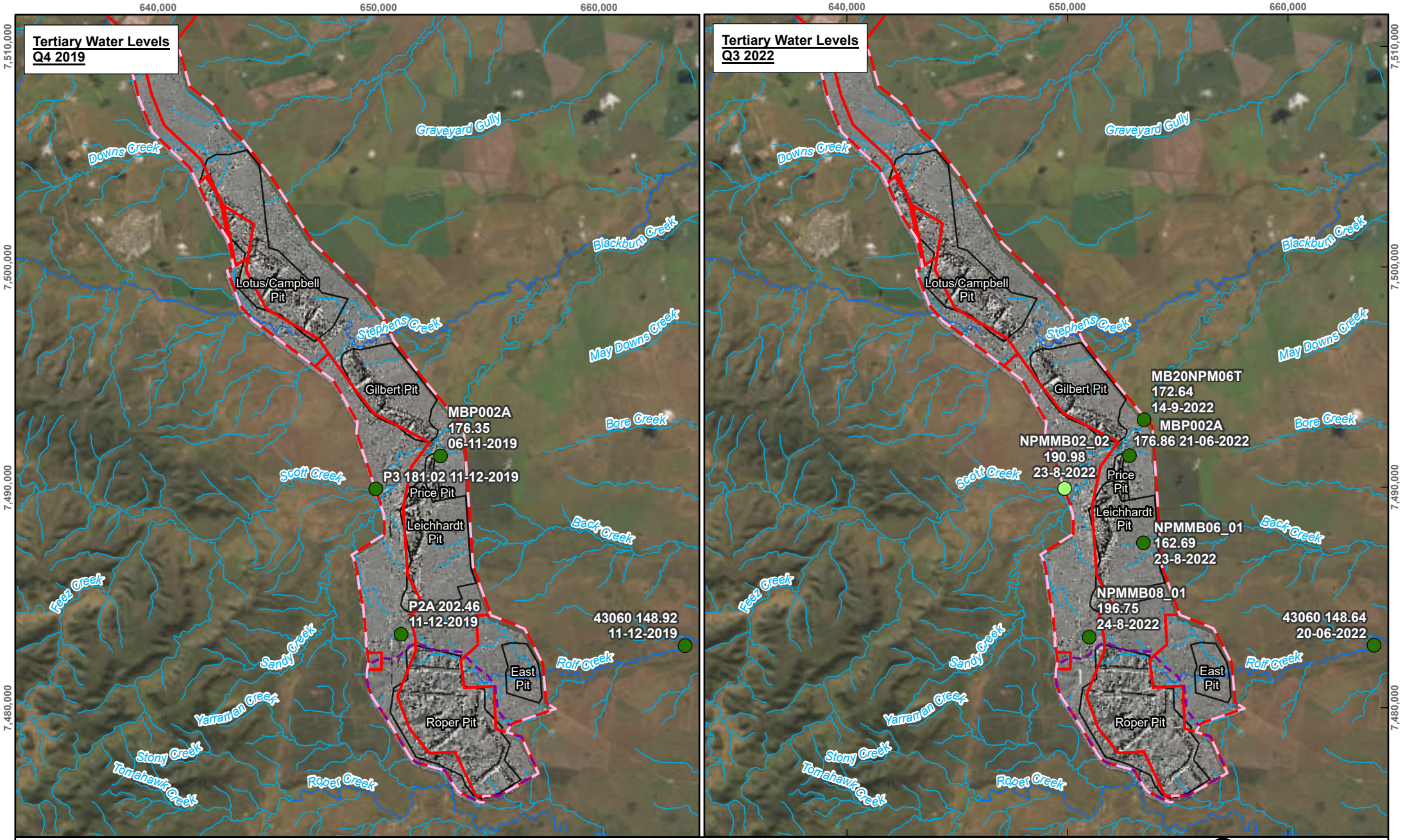
Across the SSM site, the Tertiary sediments and weathered strata (i.e. collectively the 'regolith' in a hydrogeological sense) are generally considered to form the water table aquifer, with saturation commonly displayed in coarse lenses of clayey sand and weathered material between 20-35 mbGL. Ten Tertiary monitoring bores are located in a cluster north of Roper Pit in the south of SSM (refer **Figure 4-1**), originally constructed to monitor the mine infrastructure area and, excepting P2 and one water level measured at P7, have been dry since construction. Bore P3 is located adjacent to Scott Creek on the western boundary of ML70126, and 43060 is located approximately 9 km to the east of the Roper Pit mining area. The remaining Tertiary monitoring bores are spread along the eastern margin of existing mine voids from Roper Pit in the south to Campbell Pit in the north (**Figure 4-6**). Hydrographs of water level measurements available for these monitoring locations are split between **Figure 4-7** and **Figure 4-8.**

Bore 43060 is screened within a Tertiary aged sand layer. Groundwater elevations have varied during the monitoring period, fluctuating between approximately 147.97 mAHD and 149.04 mAHD. A strong correlation with the CRD is evident at 43060, indicating the rise and fall of groundwater levels are a direct response to changes in climate/rainfall.

Installed adjacent to historical mine infrastructure area, P2, P2A and P2AR are a series of bores located in a cluster north of Roper Pit in the south of SSM that have replaced one another as each runs dry. Contrasting with the other shallow groundwater monitoring in this area, the successive re-installation of monitoring at progressively deeper levels has tracked the mine-related water level decline within the shallow water table aquifer (**Figure 4-8**). P2AR is the only active bore, as both P2

and P2A have been decommissioned. All three bores have been screened in Tertiary aged clayey sand, though at deepening screen depths, with the currently active P2AR screened between 30 and 35 mbGL. The water level hydrograph from these monitoring points shows water levels at these bores are largely separated from the climatic trend.

Bore P3 is screened within a Tertiary aged sand layer. Water levels in this bore have shown general consistency with the climatic trend indicated by the CRD plot, with a dampened and somewhat delayed elevation change coinciding with periods of rainfall excess and deficiency (**Figure 4-7**). Since August 2017, groundwater levels at P3 have steadily decreased, following the trend in the CRD.



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TERTIARY WATER LEVELS

FIGURE 4-6

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_6_Tertiary_Water_Levels_01

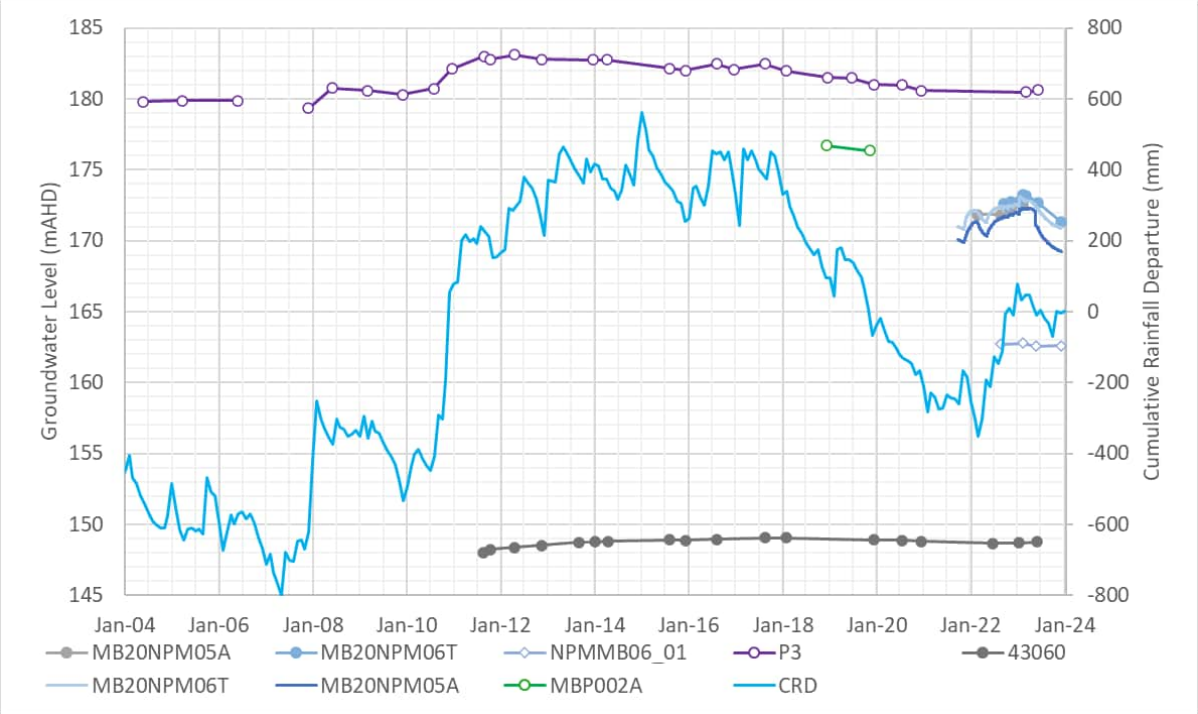


Figure 4-7 SSM Monitoring Bore Hydrographs – Tertiary bores 145 to 185 mAHD

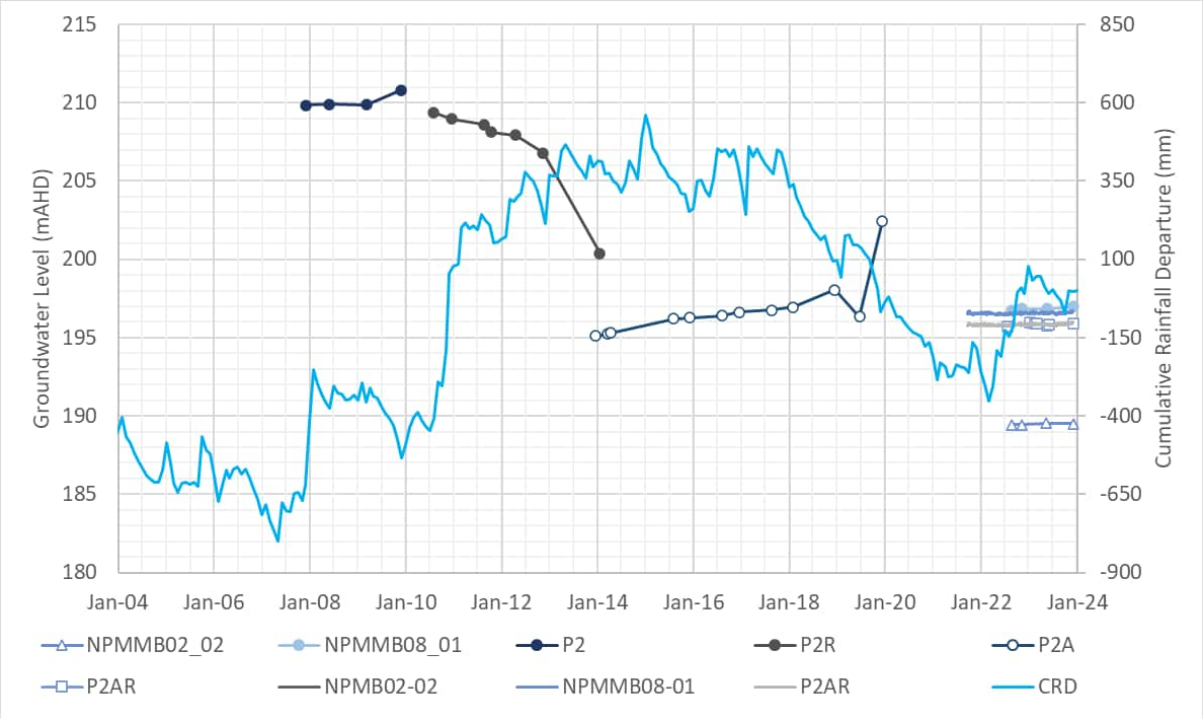


Figure 4-8 SSM Monitoring Bore Hydrographs – Tertiary bores 185 to 215 mAHD

Located east of Gilbert Pit and adjacent to Scott Creek, two paired bores MB20NPM05A and MB20NPM06T are screened within Tertiary aged sediments and regolith, separated by approximately 15 vertical metres. Automated level loggers installed at these two locations show relatively immediate response to rainfall (**Figure 4-9**). Data from these two bores indicates an upwards hydraulic gradient of approximately 0.8 m/15 m (~5%).

As displayed in **Figure 4-8**, NPMMB02_02 is screened within Tertiary aged basalt. Despite limited data, a slight response to rain events in 2022 suggests groundwater level fluctuations at NPMMB02_02 are partially correlated to the CRD.

Although when considered spatially the data is relatively limited, with relatively few monitoring bores across a large area, the available monitoring suggests that groundwater flow within the Tertiary sediments is expected to be a subdued reflection of the topography, with flow from west to east, with local scale modification around existing mine pit voids. This is consistent with the outcomes of other recent relevant studies in the Study Area (e.g. SLR, 2021).

4.3.2.2 Recharge and Discharge

As discussed in **Section 3.2.1**, the Tertiary and regolith material comprises low hydraulic conductivity strata (i.e., clay and claystone), which somewhat restricts rainfall recharge. This is shown by the general limited response to climatic conditions in monitoring bores. This is consistent with the outcomes of other recent relevant studies in the Study Area (e.g. SLR, 2020). This lack of response in monitoring bores within the Study Area may also be due to rainfall being insufficient to wet the unsaturated zone above the water table as well as providing vertical groundwater flow towards the water table. Bores MB20NPM06T and MB20NPM05A are installed in sand lenses at approximately 25-30 mbGL that appear to show more rapid reaction to surface water recharge events (**Figure 4-9**). Some or all of this recharge is likely to be associated with the losing condition ephemeral surface drainage (Scott Creek) near to these bores. The rate of groundwater level rise recorded following rainfall events is generally marginally greater at MB20NPM06T than MB20NPM05A, suggesting a higher specifical yield at the shallower MB20NPM05A bore.

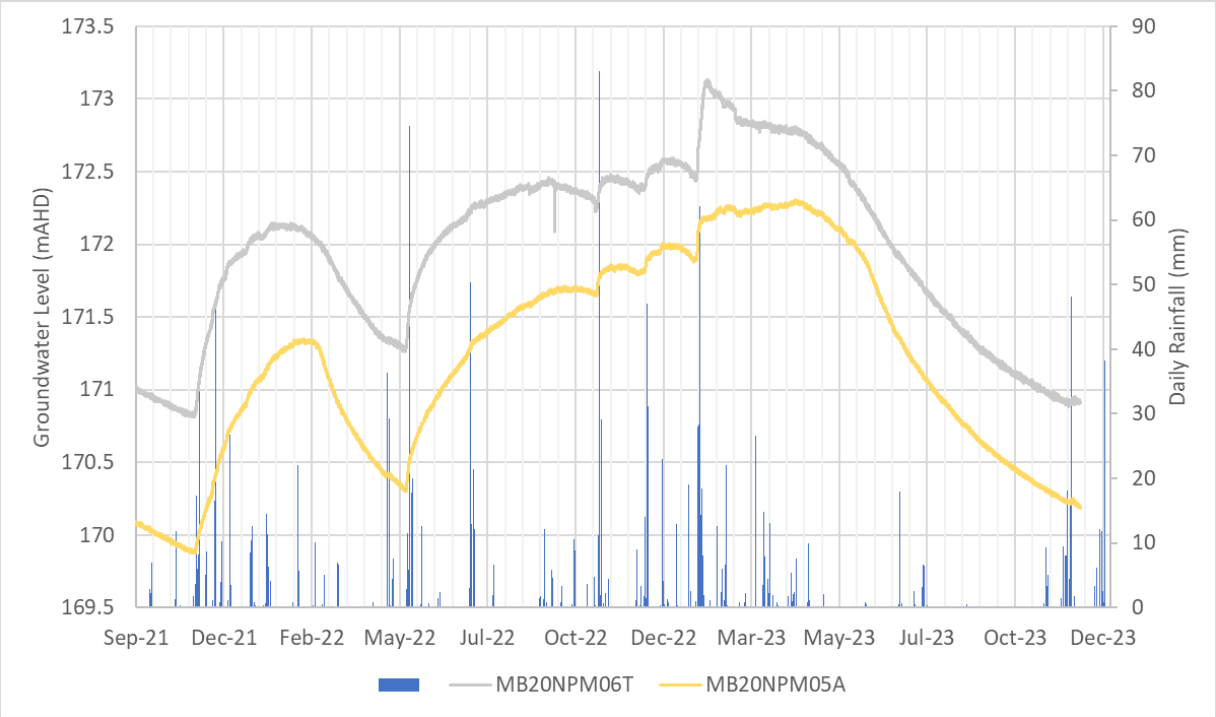


Figure 4-9 SSM Monitoring Bore Hydrographs – MB20NPM06T and MB20NPM05A water level logging plotted with rainfall

Groundwater discharge occurs primarily via evapotranspiration, with some baseflow to streams from the regolith under wet climatic conditions. Previous investigations reported to DES (AGE 2014a,

JSB&G 2021) have indicated that there may be potential for recharge to the Tertiary unit through mine voids at high water storage levels; that is, where void storage (lake) levels are above the base of the Tertiary units.

Vertical seepage through the Tertiary sediments and regolith is limited by the underlying low hydraulic conductivity of the Blackwater Group overburden and other aquitards, such that the Tertiary sediments and regolith effectively form a perched groundwater system above the Permian.

4.3.3 Permian Coal Measures

4.3.3.1 Distribution and Flow

The coal seams of the Moranbah Coal Measures subcrop throughout the western area of SSM, and outcrop to surface in the mine voids where surficial cover has been removed. Groundwater occurrence within the Permian coal measures is largely restricted to the more permeable coal seams that exhibit secondary porosity through fractures and cleats (**Section 3.2.2**). Regionally groundwater flow is to the east, consistent with local topography (AECOM, 2019). Differences in piezometric heads within the confined coal seam aquifers of the Moranbah Coal Measures drive groundwater flow eastwards across the Bowen Basin, from the slightly more elevated outcrop and subcrop areas on the western flank of the Basin to the less elevated subcrop areas on the eastern flank (AECOM, 2019). However, mining activities throughout the region have created locally modified groundwater flow systems within the Permian coal measures that are superimposed on these regional flow gradients. Mine voids at SSM are expected to be long term sinks for groundwater flow within the Permian Coal Measures, with local groundwater flow directions towards the mine voids.

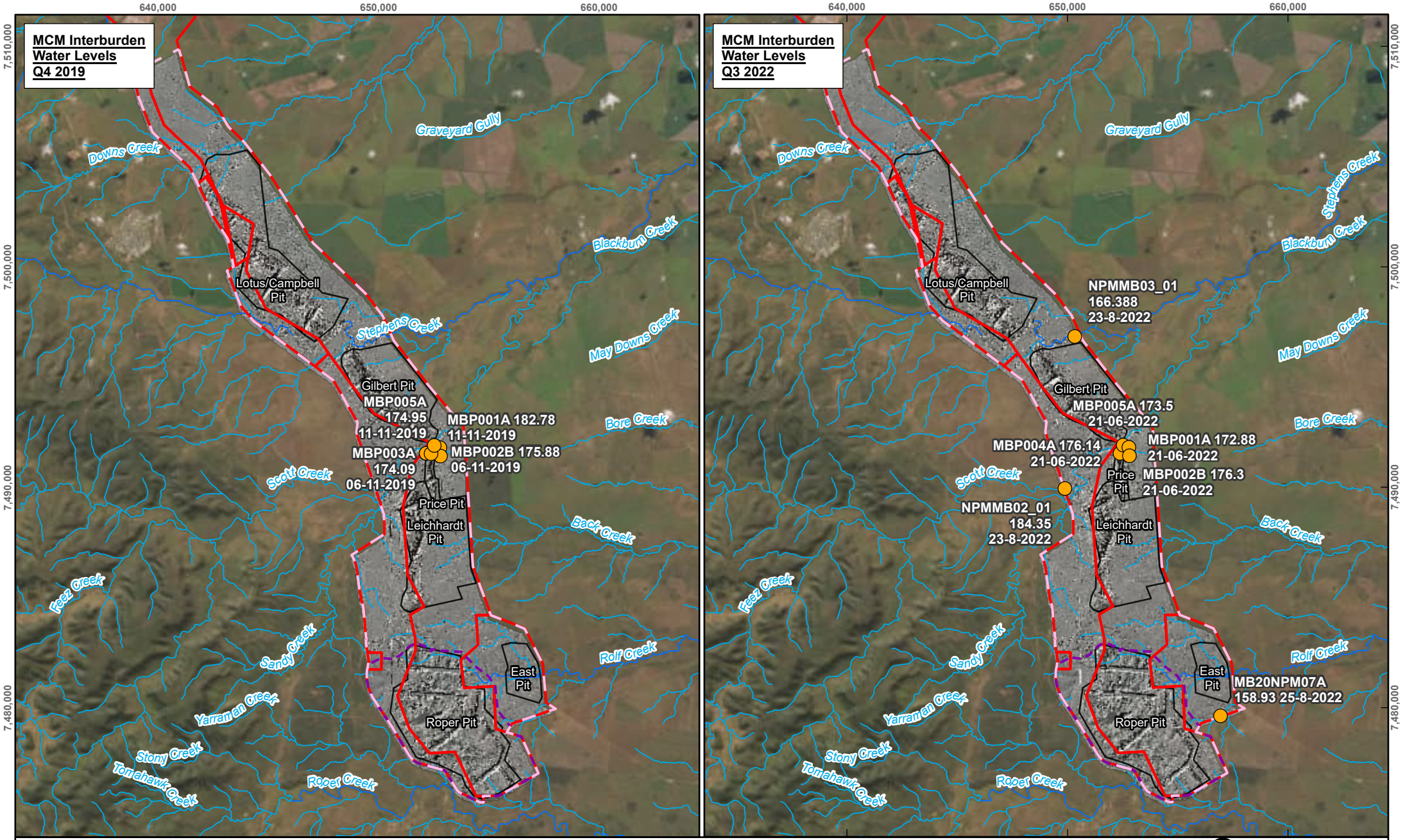
While mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004. Pre-mining potentiometric surface maps for the coal measures therefore cannot be generated due to the absence of data prior to mining, and neither can assessment of groundwater system response to the first ~25 years of SSM mining.

Groundwater data for the Permian coal measures since 2004 are broken into observations associated with the coal seams, and those associated with the overburden and interburden. Two time slices are presented in the following figures that correspond to pre-wet season groundwater levels in Q4 2019 and Q3 2022 (**Figure 4-10** and **Figure 4-11**). **Figure 4-12** shows hydrographs of Permian monitoring with water levels between 150 and 170 mAHD, and **Figure 4-13** shows monitoring with water levels between 170 and 190 mAHD. **Figure 4-14** presents water levels for Permian coal seam monitoring in 2014 in the south of the SSM Area, and **Figure 4-15** presets water level logger data recorded over a two-year period for two bores located just north of Gilbert Pit. Interburden locations are indicated by open, non-filled markers. Coal seam monitoring is indicated by closed, filled markers.

NPMMB02_01, and NPMMB03_01 all screened in the interburden. NPMMB02_01 shows relatively minor response to above average rainfall, with groundwater levels increasing following Q4 2022 wet season. NPMMB03_01 has shown no response, with water levels remaining stable across both monitoring rounds.

MB20NPM04P is screened within the H33 coal seam north of Gilbert Pit. This is paired with bore NPMMB03-01 which is screened much higher in the formation, near the weathered zone interface with Tertiary material. Groundwater levels at these two bores indicate an upwards hydraulic gradient of approximately 3.5 m / 64 m (~5%). Water levels show that the Permian coal is confined and both the interburden and coal seams show relatively minor reaction to rainfall and climatic input. This relatively muted reaction to rainfall is mirrored in P6R, 43062 and 38547.

Overall, the Permian monitoring data does not indicate significant mining related effects on the Permian groundwater system. This may in part however, be related to the sporadic temporal availability of Permian monitoring data, with much of that data only being available during the recent period of SSM care and maintenance and not during the earlier active mining phase at SSM.



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PERMIAN INTERBURDEN WATER LEVELS

FIGURE 4-10

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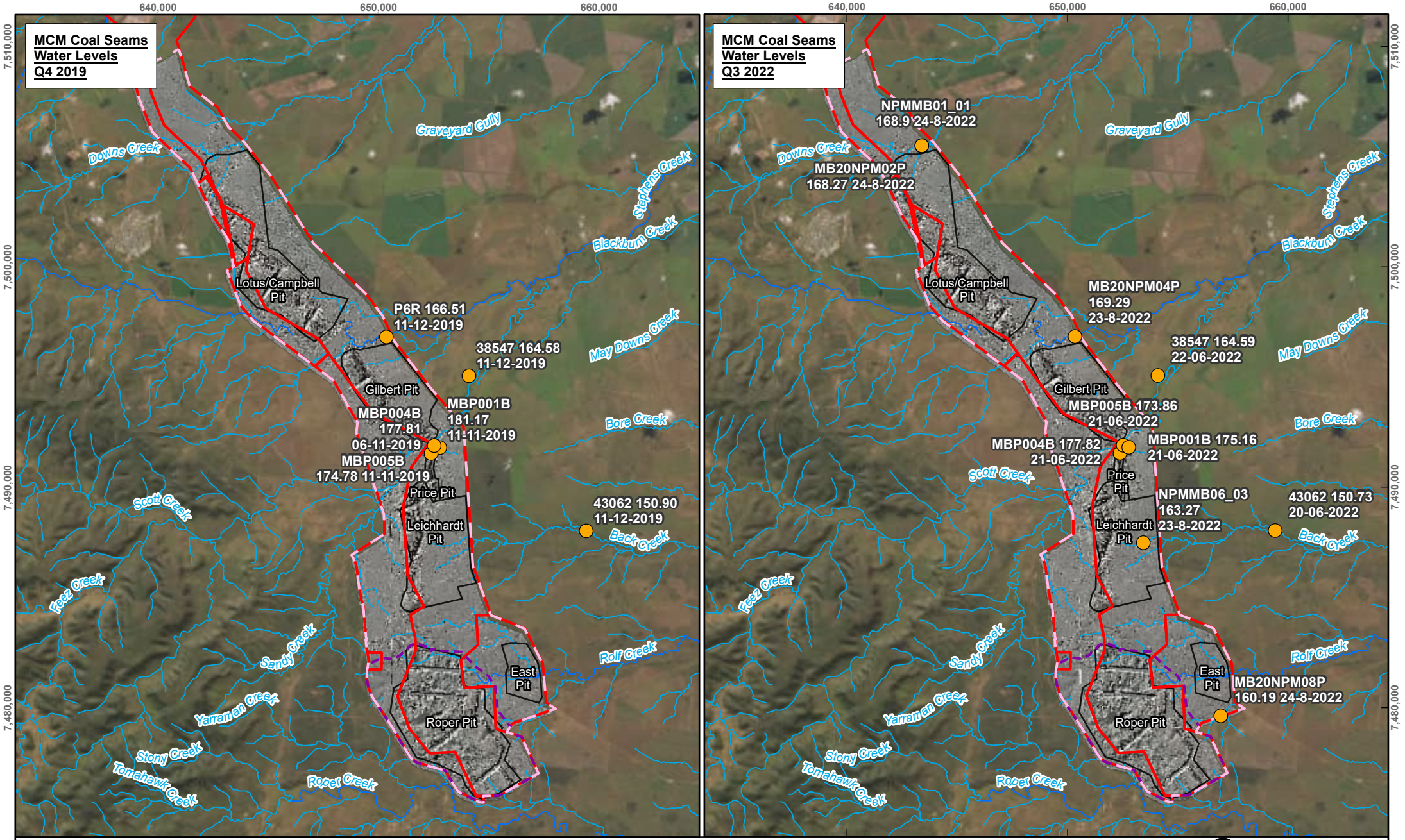

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PERMIAN COAL SEAMS WATER LEVELS

FIGURE 4-11

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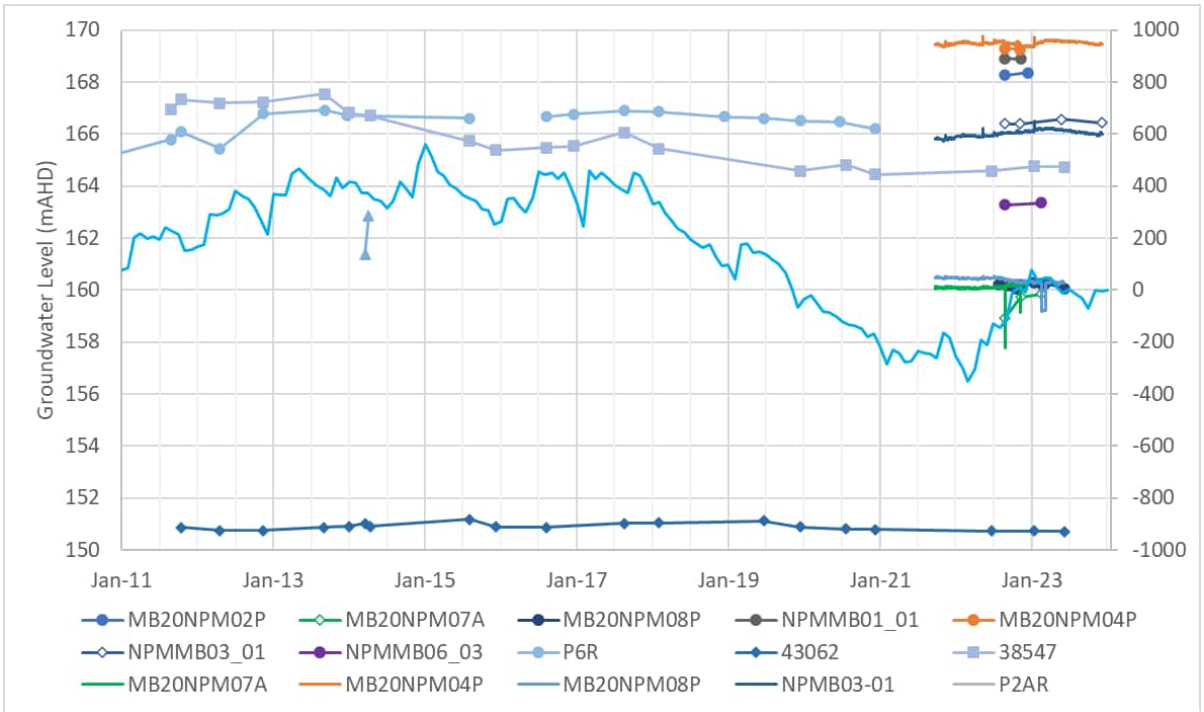

Figure 4-12 SSM Monitoring Bore Hydrographs – Permian bores 150 to 170 mAHD. Interburden/overburden with open markers, Coal seams with solid markers.

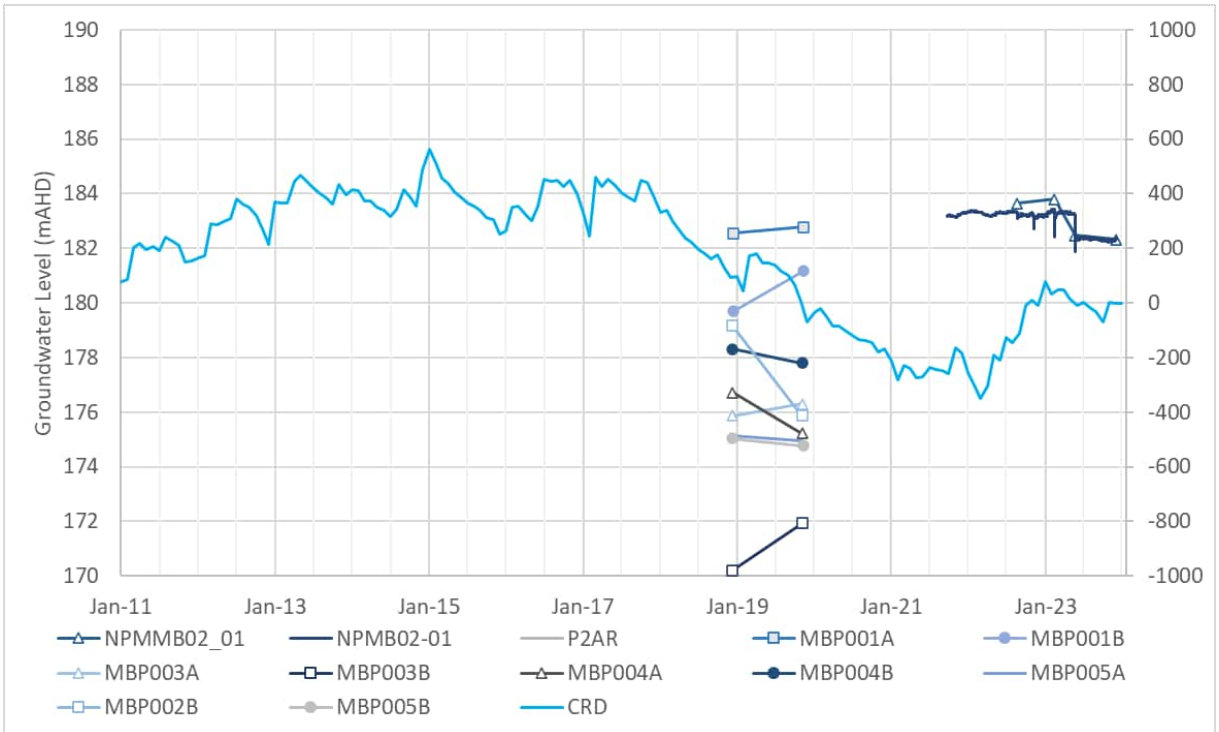

Figure 4-13 SSM Monitoring Bore Hydrographs – Permian bores 170 to 190 mAHD. Interburden/overburden with open markers, Coal seams with solid markers

Figure 4-14 SSM Monitoring Bore Hydrographs – Permian bores MBR01A and MBR02A. Interburden/overburden with open markers, coal seams with solid markers

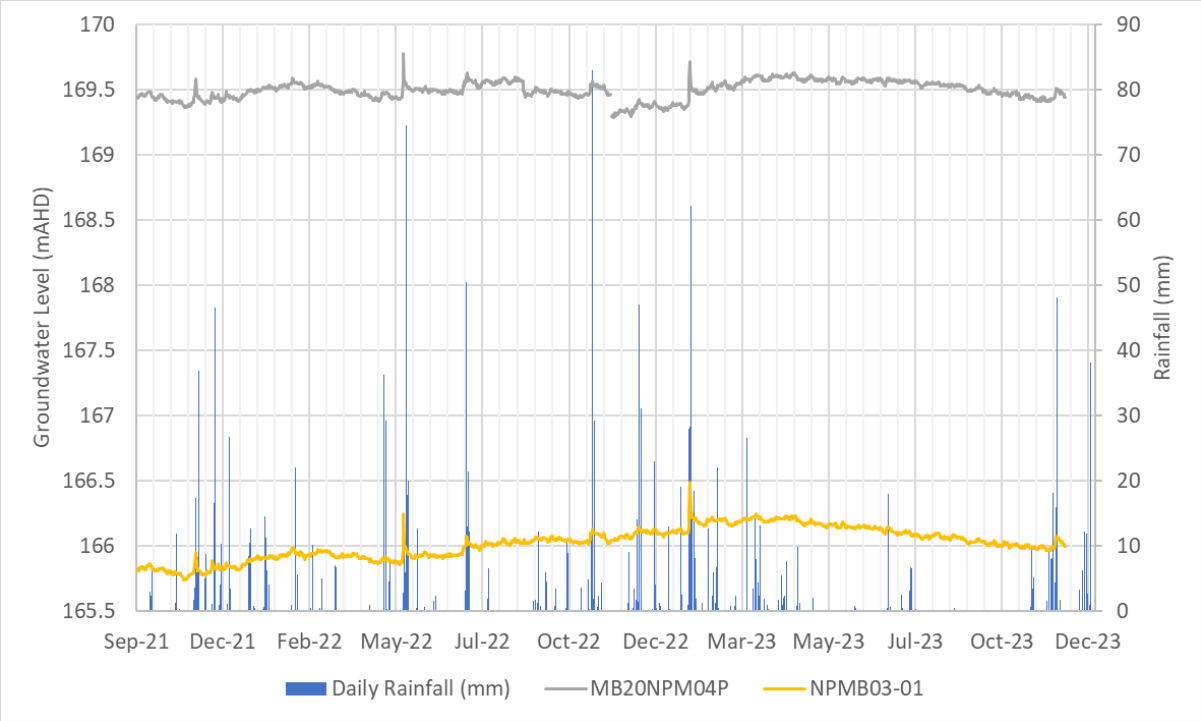

Figure 4-15 Water level logging data for Permian monitoring MB20NPM04P (H Seam) and NPM03-01 (Interburden)

4.3.3.2 Recharge and Discharge

Recharge to the Permian coal measures coal seams, before mining, occurred where the seams were present at outcrop and subcrop. Hydrograph analysis shows little to no reaction in water levels to significant rainfall events, suggesting that these units are insulated from direct recharge pathways. Using the CMB method, a recharge rate for the weathered Permian units was calculated as 0.1 mm/year by SLR (2021). Due to the low hydraulic conductivity of the interburden material, groundwater largely flows horizontally within the coal measures, along the bedding plane of the coal seams themselves, resulting in confined conditions that are observed in many of the paired groundwater monitoring locations. Local groundwater discharge from the Permian coal measures occurs via inflow to, and evaporation from, the walls and floors of mine pit areas as discussed in **Section 4.5.1.1**.

4.4 Baseline Water Quality

4.4.1 Water Type

The proportions of the major anions and cations were used to determine the hydrochemical facies of groundwaters sampled at SSM. The anion-cation balance from the SSM monitoring bores is shown on the Durov plots, with monitoring bores have been split on the basis of aquifer type, with **Figure 4-16** displaying alluvium bores, **Figure 4-17** displaying Tertiary bores, and **Figure 4-18** displaying Permian Coal Measures bores. As shown on **Figure 4-18**, the Permian bores are symbolised by monitored unit, including: cross symbol (FCCM), square symbol (MCM overburden/interburden) and diamond symbol (MCM coal).

The results for these monitoring bores generally indicate that Na, Cl and HCO_3 are the dominant water chemistry signatures in groundwater across SSM.

Alluvium monitoring at P6 and MB20NPM03A displays a wide range of water type, with MB20NPM03A showing a moderate salinity and HCO_3 enriched water reflective of recharge to the shallow systems, but P6 showing a broad range of water types from similar to MB20NPM03A to one that is consistent with a saline evapoconcentrated Na-Cl type water.

Monitoring bores screened within the Tertiary predominantly recorded Na-Mg-Cl type waters, with minor variances in HCO_3 and SO_4 ion proportions. Moderately saline waters were generally returned, however, P2A and 43060 displayed significantly higher salinities than were typical across this aquifer, and strongly concentrated Na-Cl signatures. This is indicative of natural salinisation of shallow groundwater through low recharge and long term evapoconcentration. Bore 43060 is located approximately 9 km east of the mining area and is not expected to display influence of any groundwater impacts that may have occurred due to mining activities at SSM. Lower salinity concentrations were observed at MB20NPM05A and MB20NPM06T, with these likely to be receiving meteoric recharge rather than flushing of concentrated water.

Monitoring bores screened within the Permian consistently record mixed/intermediate type waters with moderate salinity. Strong similarities exist between the Tertiary and Permian in regard to their hydrochemical characteristics. These similarities suggest there may be some pathways for interaction, with historical recharge pathways to the Permian formation occurring through Tertiary subcrop and regolith zone.

Within the Permian coal measures (interburden), monitoring bores recorded predominantly Na-Cl and Na-Mg water types. Bores that were shallower demonstrate relatively higher proportions of SO_4 ions, with deeper bores returning higher proportions of HCO_3 ions (in exemption to MBP001A, which returned higher Ca ions). This is likely due to interactions between groundwater and the weathered aquifer material in the shallow formations. Highly saline groundwater samples are reflective of strongly concentrated Na-Cl-type waters that are likely the result of progressive evapoconcentration and flushing into the shallow groundwater system.

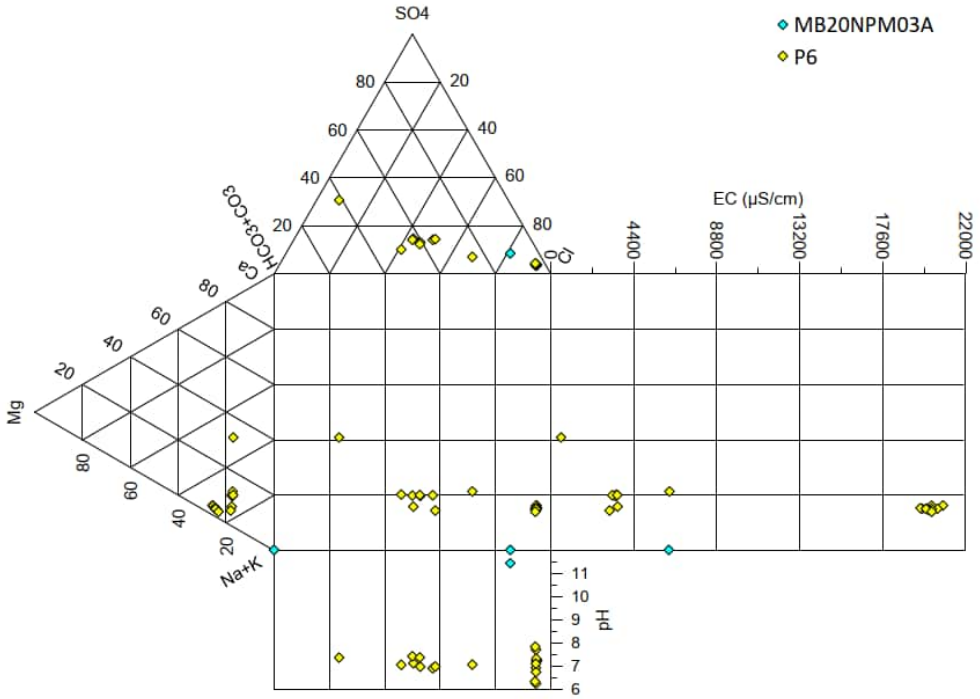

Figure 4-16 Alluvium Durov Plot

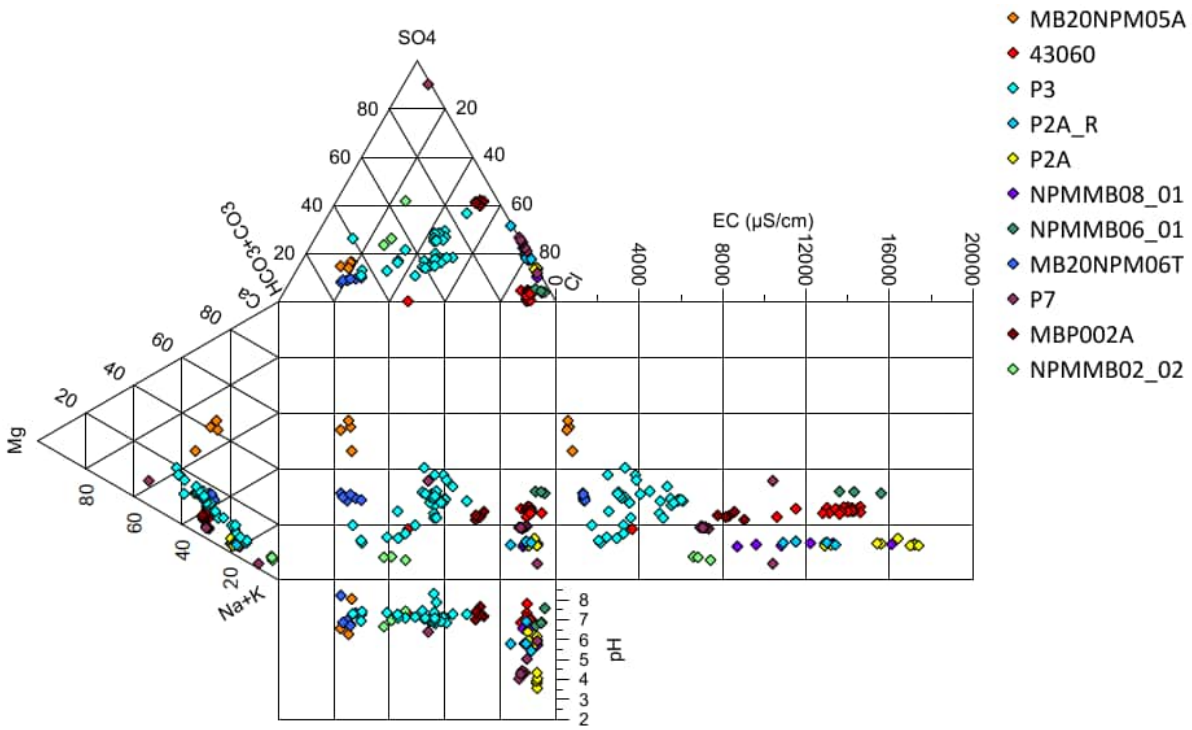

Figure 4-17 Tertiary Durov Plot

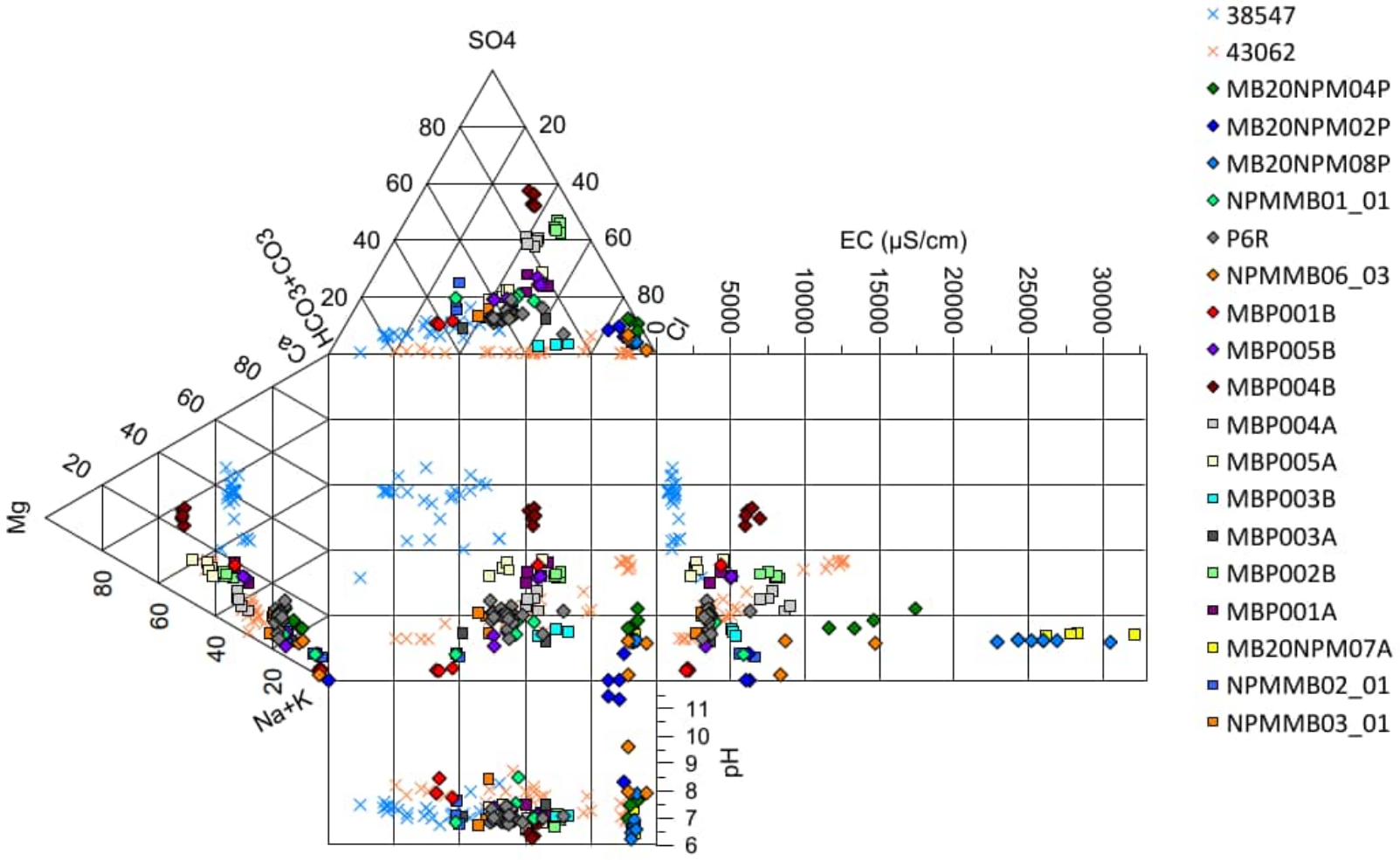

Figure 4-18 Permian Bore Durov Plot

4.4.2 Salinity

Salinity is a key constraint to water management and groundwater use by receptors and can be described by total dissolved solid (TDS) concentrations. **Figure 4-19** presents the TDS data associated with waters screened in the various geological horizons for SSM monitoring bores. Salinity ranges represented on **Figure 4-19** are defined by the Food and Agriculture Organization of the United Nations (FAO).

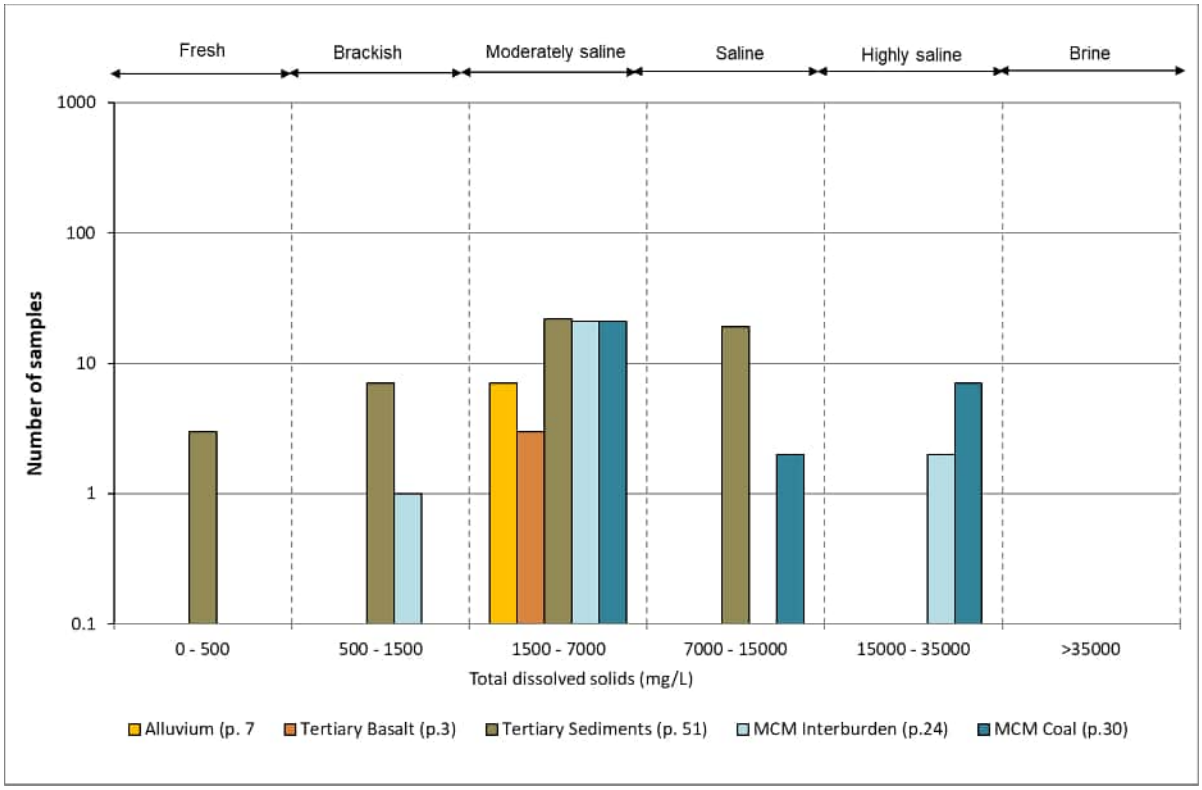

Figure 4-19FAO (2013) Salinity Ranking by Unit – SSM and surrounding area

The graph shows that water within the alluvium is moderately saline with an average TDS of 2,045 mg/L, though it should be noted this data is from bore P6 between 2010 and 2014 and there is no more recent data available for the alluvium as there was no saturated alluvium encountered in monitoring bores.

Tertiary sediments samples show fresh to saline water quality, ranging between 377 mg/L to 11,600 mg/L, with a mean value of 4,808 mg/L. One Tertiary bore screened in weathered basalt displays water quality in line with the broader Tertiary/Regolith aquifer, with three samples displaying a range between 4,384 and 4,847 mg/L.

Water within the Moranbah Coal Measures is generally saline within the coal seams and moderately saline to saline in the interburden units but can range between brackish and highly saline. Coal seam units of the Moranbah Coal Measures record an average TDS of 7,982 mg/L, ranging between 1,514 mg/L and 19,200mg/L. The interburden units of the Permian coal measures record an average TDS of 4,747 mg/L, ranging between 1,280 mg/L and 21,353 mg/L.

4.4.3 Beneficial Groundwater Use (Environmental Values)

SSM lies in the southern portion of the Isaac Connors Groundwater Management Area (GMA) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011. Within the Isaac Connors GMA, alluvial groundwater is managed as Groundwater Unit 1 and water within the hard rock aquifers as Groundwater Unit 2 (sub-artesian aquifers). The far southern area of SSM lies within the Highlands Groundwater Management Area, where, similar to the Isaac Connors 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 both GMAs.

Groundwater resources in the SSM Area are also scheduled under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019, predominantly as Isaac Groundwaters of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1310), although the very southern part of the SSM Area crosses approximately 2.6 km into the Mackenzie Groundwaters scheduled area. The legislated environmental values (EVs) for both the Isaac Groundwaters and Mackenzie Groundwaters are:

- Biological integrity of aquatic ecosystems;
- Human use EVs:
    - Suitability of water supply for irrigation;
    - Farm water supply/use;
    - Stock watering;
    - Primary recreation (Isaac Groundwaters);
    - Drinking water supply;
    - Industrial Use (Mackenzie Groundwaters)
    - Cultural and spiritual values.

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 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 WQ1310 WQOs for groundwater at SSM are shown in **Table 4-3.**

Table 4-3 Water Quality Objectives for Isaac & Mackenzie River Sub-basin Environmental Values

Water Quality Indicator	Unit	ADWG Guidelines[1]		Isaac River Sub-basin EVs[2]			Mackenzie River Sub-basin EVs[4]		
		Health	Aesthetic	Irrigation	Stock	Aquatic 95% spp[3]	Irrigation[6]	Stock	Aquatic 95% spp[3]
pH	-		6.5 to 8.5			6.5 to 8.5			6.5 to 8.5
Aluminium	mg/L		0.2	5	5	0.055	5		0.055
Calcium	mg/L				1000				
Chloride	mg/L		250						
Magnesium	mg/L				2000				
Manganese	mg/L	0.5	0.1			1.9			1.9
Sodium	mg/L		180						
Sulfate	mg/L				1000				
Zinc	mg/L		3	2		0.008	2	20	0.008
Arsenic	mg/L	0.01		0.1	0.5	0.024	0.1	0.5	0.024
Cadmium	mg/L	0.002		0.001	0.01	0.0002	0.001	0.01	0.0002
Chromium	mg/L	0.05		0.1	1	0.001	0.1	1	0.001
Cobalt	mg/L			0.05	1		0.05	1	
Copper	mg/L	2	1	0.2	1[5]	0.0014	0.2	1[5]	0.0014
Lead	mg/L	0.01		2	0.1	0.0034	2	0.1	0.0034
Mercury	mg/L	0.001		0.02	0.002	0.0006	0.02	0.002	0.0006
Nickel	mg/L	0.02		0.2	1	0.011	0.2	1	0.011
Selenium	mg/L	0.01		0.02	0.02	0.005	0.02	0.02	0.005
Silver	mg/L	0.1				0.05			0.05

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).
4. Table 2, Table 9, Table 10 and Table 11 of Mackenzie River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed
5. Figure quoted for cattle.
6. Long term trigger value

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 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 (**Figure 4-20**). The applicable Chemistry Zones for SSM are:

- Isaac Groundwaters:
  - Zone 5 (**Table 4-4**): Alluvial sequence – Low salinity, balanced cations, HCO_3;
  - Zone 23 (**Table 4-5**): Alluvial Sequence – Moderate salinity, Na > Mg > Ca, Cl (SO_4 above average); and
  - Zone 34 (Table 4-6): Sodic Sequence – Saline, Na, Cl.
- Mackenzie Groundwaters:

- Zone 34 (Table 4-7): 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 4-4** to **Table 4-7**.The management intent of each WQO zone is to maintain each of 20th, 50th and 80th percentile values.

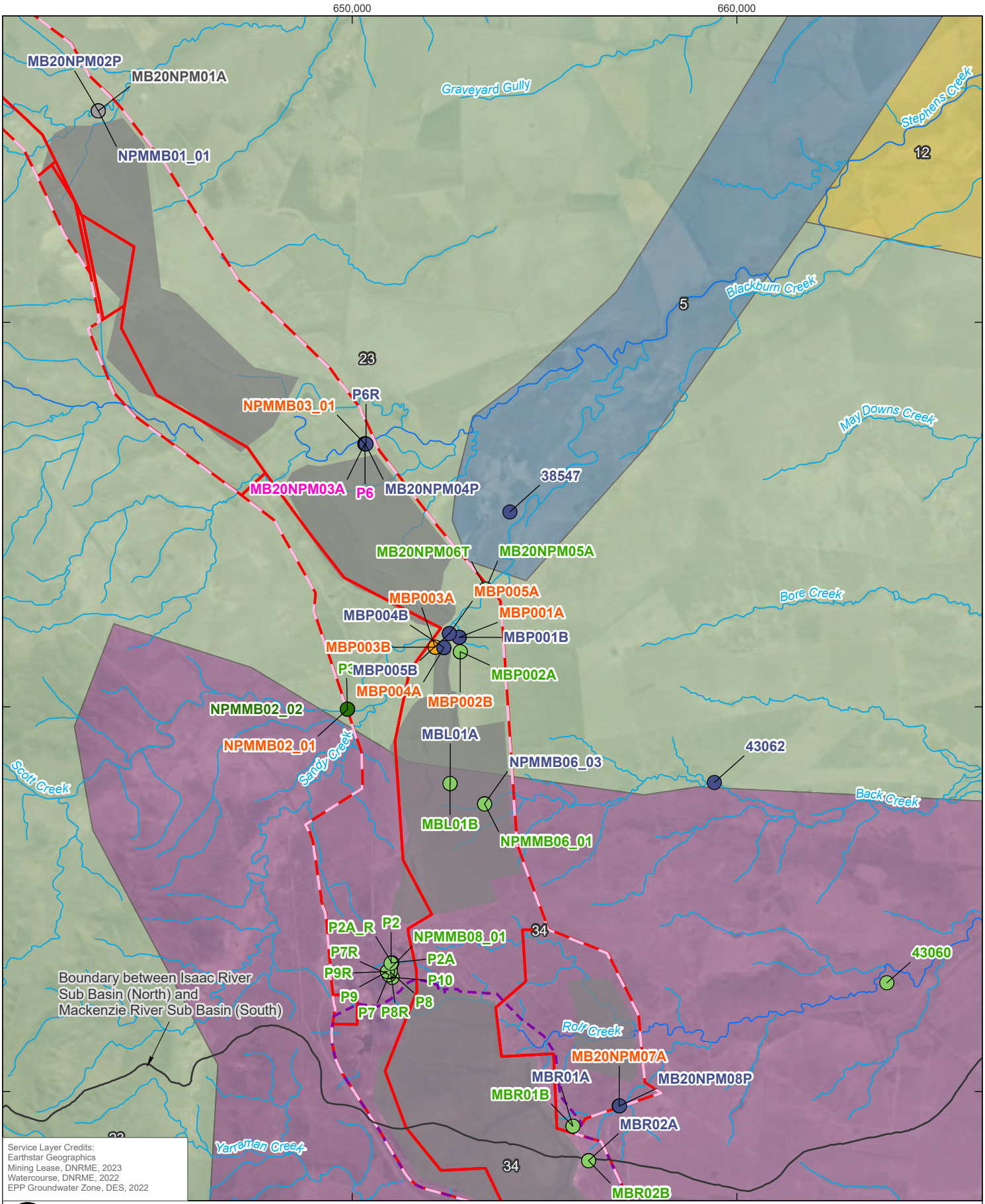

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FIGURE 4-20

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Table 4-4 Isaac River Sub-basin Zone 5 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	633	680	750	914	2400	4219
Hardness	mg/L as CaCO3	182	286	322	273	475	594
pH	-	7.39	7.7	7.82	7.73	7.9	8
Alkalinity	mg/L	242	280	417	429	516	591
Ca	mg/L	35	60	75	43	55	61
Mg	mg/L	23	24	38	39	82	109
Na	mg/L	44	68	195	100	350	684
Cl	mg/L	53	80	137	41	381	860
SO_4	mg/L	5	21	45	20	173	319
HCO_3	mg/L	294	342	506	517	621	713
NO_3	mg/L	0.38	3.2	9.89	ID	ID	ID
SiO_2	mg/L	17	23	33	ID	ID	ID
F	mg/L	0.127	0.2	1.01	0.183	0.335	0.41
Fe	mg/L	0	0.01	0.02	ID	ID	ID
Mn	mg/L	0	0.07	0.203	ID	ID	ID
Zn	mg/L	ID	ID	ID	ID	ID	ID
Cu	mg/L	ID	ID	ID	ID	ID	ID
SAR	-	1.09	2	6.89	2.44	7.1	12.18
RAH	meq/L	0.18	1.06	4	0.87	1.09	3.78

Table 4-5 Isaac River Sub-basin Zone 23 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	3333	3850	4506	2496	3465	7450
Hardness	mg/L as CaCO3	461	793	1146	350	1098	1621
pH	-	7.6	7.75	8.45	7.51	7.8	7.99
Alkalinity	mg/L	445	650	903	233	463	618
Ca	mg/L	51	100	223	50	138	260
Mg	mg/L	70	140	185	55	165	244
Na	mg/L	501	561	599	312	587	1106
Cl	mg/L	558	750	989	553	851	1930
SO_4	mg/L	50	95	832	42	100	520
HCO_3	mg/L	543	793	1091	282	565	753
NO_3	mg/L	0	0.5	1.65	0	0	2.25
SiO_2	mg/L	13	21	48	20	47	54
F	mg/L	0.68	0.8	1.2	0.149	0.37	1.02
Fe	mg/L	0.006	0.035	0.085	0.014	0.04	0.382
Mn	mg/L	0.02	0.035	0.176	0	0.025	0.34
Zn	mg/L	ID	ID	ID	ID	ID	ID
Cu	mg/L	ID	ID	ID	ID	ID	ID
SAR	-	5.71	8.4	14.36	5.5	10.45	13
RAH	meq/L	1.83	2.85	9.36	0	0.73	10.83

Table 4-6 Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	498	2150	8910	3419	6100	16000
Hardness	mg/L as CaCO3	163	674	2228	359	919	3208
pH	-	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	1500	480	1100	2565
Cl	mg/L	171	1309	3185	753	1900	5905
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

Table 4-7 Mackenzie River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	498	2150	8910	3419	6100	16000
Hardness	mg/L as CaCO3	163	674	2228	359	919	3208
pH	-	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	1500	480	1100	2565
Cl	mg/L	171	1309	3185	753	1900	5905
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 possible utilisation of groundwater resources within the SSM area, available water quality data have been compared to the:

- Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed (Isaac River EVs)
- Mackenzie River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed (Mackenzie River EVs)
- Fitzroy Basin Zones 5, 23 and 34 groundwater quality objectives for deep and shallow water;
- Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011);
- ANZECC (2000) guidelines for aquatic ecosystems, irrigation (long-term and short-term) and stock water supply.

While the long-term groundwater dataset is somewhat incomplete due to changes in monitoring, management, and access issues over time, there is approximately 12 months of sampling for most active bores with complete suite of analysis. For many groundwater samples, dissolved metals laboratory analysis was carried out at sensitivities that prevented clear comparison with guideline values due to relatively high limit of reporting.

Chemistry time series from P6 and isolated samples at MB20NPM03A indicates that alluvial groundwater in the SSM Area, where very sporadically present, may be generally suitable for livestock water supply and for short-term irrigation. However, this is based on sporadic saturation in

the alluvium monitoring bores, and including results from a bore that is no longer monitored, having been decommissioned and replaced, and these values may not reflect regionally characteristic groundwater chemistry. The lack of consistent saturation in the alluvium limits:

- collection of a robust monitoring data set, and
- most beneficial uses..

Summary results indicate that, where water is present within the Tertiary sediments, it exhibits a wide chemical profile, though considered collectively it is not considered a suitable groundwater resource for Isaac River Stock EV (sulfate, selenium), drinking water or aquatic ecosystems. The water within Tertiary sediments was found to exceed the Zone 34 and Zone 23 Fitzroy Plan WQO (Shallow and Deep considering depth of Tertiary in some areas) for EC, bicarbonate, chloride, sodium, magnesium, sulfate, and iron. Very low pH values are observed in some bores (P7, historical measurements at P2A)

Comparison of results to the EPP Water and Wetland Biodiversity WQO guideline levels indicates the Moranbah Coal Measures (inter/overburden and coal) exceed guideline values for irrigation, drinking water or aquatic ecosystems, though there was a wide range of values.

Water chemistry analysis showed values exceeding Isaac River Stock EV (sulfate, and total dissolved material), drinking water (sodium, chloride, aluminium) or aquatic ecosystems (range of metals including aluminium, chromium, nickel, and selenium). The water within the Permian coal formations were found to exceed the Zone 23 Fitzroy Plan WQO (Deep) for EC, calcium, bicarbonate, chloride, sodium, magnesium, sulfate, and iron. Bore 38547 lies east of SSM within Fitzroy Plan WQO Zone 5 (Deep) and although the water quality at this bore is better than other Permian monitoring locations, samples have exceeded WQO values for EC, calcium, magnesium, sodium, chloride, sulfate, bicarbonate, and iron.

4.5 Groundwater Receptors

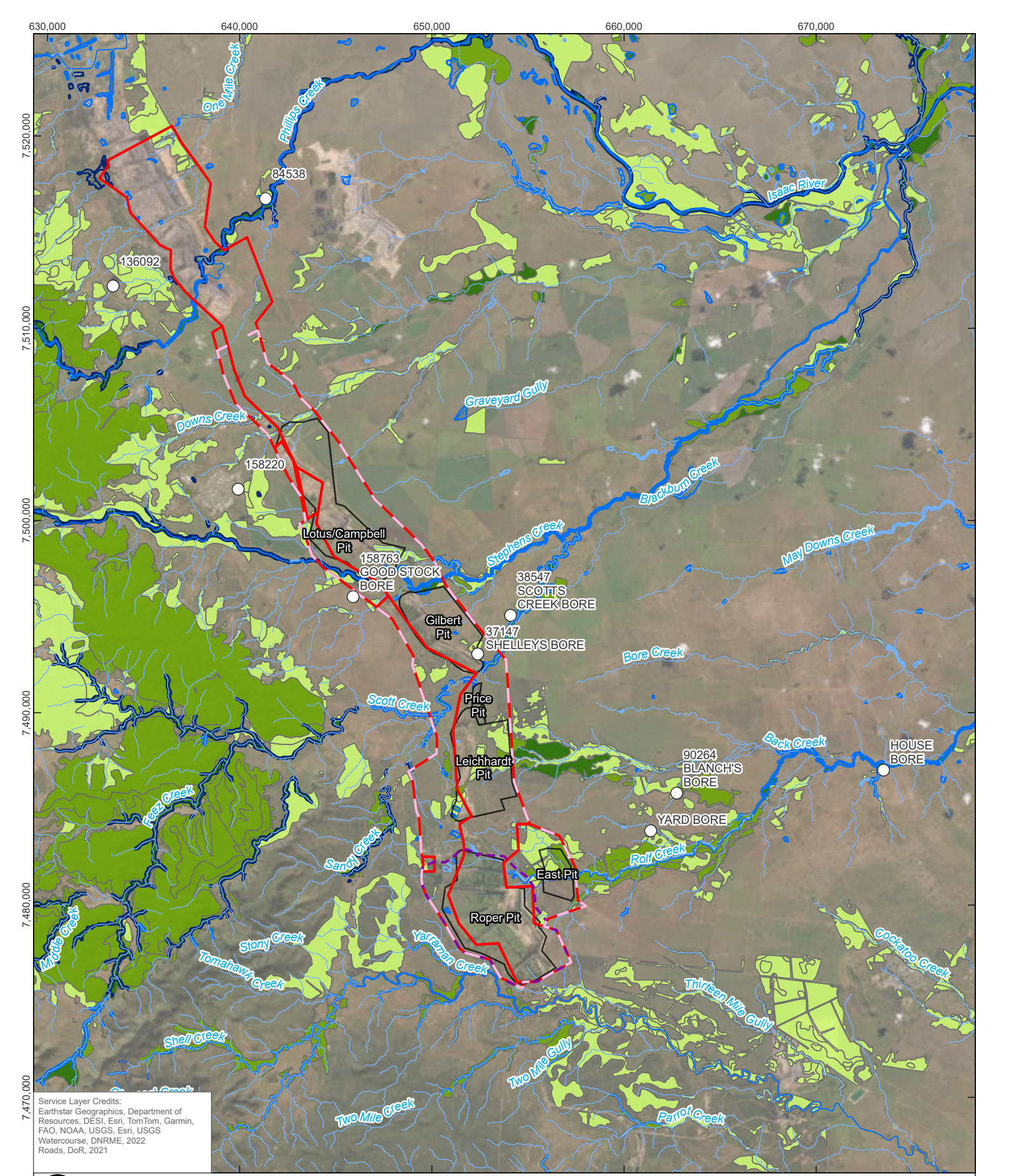
4.5.1 Anthropogenic

A search of the Queensland Government's Groundwater Bore Database (GWBD) and the Bureau of Meteorology's National Groundwater Information System (NGIS) was carried out for registered bores within 5 km of the SSM Area. These are summarised in **Table 4-8** and the water supply locations are shown on **Figure 4-21**.The search indicated that there are 82 registered bores, of which 53 bores (66%) are used for groundwater monitoring and investigations, and only 9 bores (11%) are used for water supply. The remainder of bores have an unknown use or resulted from exploration activities.

Table 4-8 Registered use of Groundwater Bores within the Study Area

Use	Count	Percent of Total
Groundwater monitoring (mine monitoring, water resource investigation etc)	54	66
Water Supply	9	11
Unknown	19	23
Total	82	100

Anecdotal reporting in previous SSM technical studies suggests that groundwater yields are low and of poor quality, with property owners in the area relying primarily on dams that can be constructed readily in the Tertiary clay material and/or on the McKenzie River pipeline for their water supply (GHD, 2021b). Where properties have bores they are nearly all constructed in the Permian coal seams and not in the Tertiary sands and gravel, confirming the localised occurrence and limited saturation of the Tertiary aquifers.



Service Layer Credits: Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS Watercourse, DNRME, 2022 Roads, DoR, 2021

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:250,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Potential Water Supply Bore
- Major Watercourse
- Minor Watercourse
- SSM Mine Lease
- Pit Extent
- SSM EA Boundary
- Roper Study Area

Aquatic GDE

- High potential GDE
- Moderate potential GDE
- Low potential GDE

Terrestrial GDE

- High potential GDE
- Moderate potential GDE
- Low potential GDE

SARAJI SOUTH MINE TRANSITIONAL PRCP

POTENTIAL GDES AND REGISTERED BORES

SLR

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FIGURE 4-21

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AGE (2004) documents that a bore census near to SSM was undertaken in 2004, identifying that there were three bores that were in private extractive use (**Figure 4-21**) (**Table 4-9**). Two of these, Blanch's Bore and House Bore, were reported to be 12 km and 18 km east of SSM adjacent to Rolf Creek, respectively. Both were noted to be accessing the Tertiary aquifer, though the GWBD contradicts this report as Blanch's Bore is classified as Permian (GHD, 2021b). A third bore named House Bore, was identified in the census 10 km east of SSM as being used for domestic purposes.

Table 4-9 Summary of water supply bores and bore census data (modified per AGE, 2004)

Local Bore Name	Bore RN	Easting	Northing	Ground Level (mAHD)	Depth (m)	Role identified	Inferred Aquifer
SHELLEYS BORE	37147	652385[1]	7493059[1]	-	36	Water supply	Tertiary
SCOTTS CREEK BORE	38547	654098[1]	7495068	-	34	Water supply	Tertiary
-	84538	641354[1]	7516737[1]	-	109.7	Water supply	Permian
-	136092	633416[1]	7512196[1]	-	22	Water supply	Tertiary
-	158220	639923[1]	7501629[1]	-	66.5	Water supply	Tertiary
GOOD STOCK BORE	158763	645904[1]	7496037[1]	-	148	Water supply	Permian
Yard Bore	-	661387[2]	7483865[2]	187	60	Stock Watering	Tertiary
Blanch's Bore	90264	662740[2]	7485824[2]	171	39	Stock Watering	Permian
House Bore	-	673504[2]	7487021[2]	146	~30	Domestic and stock	Tertiary

1. From registed bore database, GDA94z55
2. No co-ordinate projection system provided in AGE 2004, assumed GDA94z55

There were no water entitlements for groundwater identified in the Water Entitlements Database Queensland, within or surrounding the SSM Area, indicating groundwaters in this area are not used for activities requiring a license such as irrigation or industrial purposes.

4.5.1.1 Mine Pit Inflows

During active mining operations, groundwater inflows to active pit voids are generally small in volume and do not typically need to be actively managed via advance dewatering or other groundwater management methods. Evaporation from the pit walls and floors accounts for most of the groundwater. Where small volumes of groundwater inflow require management within the active mine pits, this is generally managed via the use of in-pit sumps to capture water. The water is then used for dust suppression purposes or circulated via the Mine water management system for use in coal washing.

During the care and maintenance phase of SSM operations between 2012 and 2022, voids were used as water storage hubs for nearby BHP operations, with pit lakes developing in the undisturbed mine voids. With the formation of these lakes, groundwater inflows to the voids would have reduced as the head gradient between the voids and the surrounding groundwater system reduced. Previous investigations note that some of the mine voids were used as active mine water management by the local BHP operations (AGE 2014a).

4.5.2 Environmental

4.5.2.1 Groundwater Dependent Ecosystems

A groundwater dependant ecosystem (GDE) is one in which the plant and/or animal community is dependent on the availability of groundwater to maintain its structure and function. The GDE Atlas is a national scale broadbrush tool that classifies ecosystems based on the potential for dependence on groundwater through multiple lines of scientific evidence (BOM, 2017). 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; or
- 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).

Desktop mapping of potential aquatic and terrestrial GDEs in the GDE Atlas indicates that areas with possible high, moderate, and low potential for groundwater interaction occur in the vicinity of SSM (BoM, 2017). Isolated areas of high and moderate potential GDEs occur within SSM, with low potential GDEs identified predominantly around the SSM boundaries.

Surface ecosystems on and adjacent SSM that may be reliant on the surface expression of groundwater are shown in **Figure 4-21**. The desktop GDE mapping (BOM, 2017) indicates:

- East of SSM, terrestrial riparian vegetation associated with the downstream extent of Stephens Creek, Rolf Creek, Scott Creek and Back Creek are mapped as having a moderate potential to high potential for dependence on subsurface expression of groundwater.
- Aquatic habitat associated with the upstream areas of Stephens Creek, Scott Creek, and Sandy Creek are mapped as having a high potential to be dependent surface expression of groundwater.

All other terrestrial vegetation and aquatic habitat within and adjacent SSM, is broadly mapped as having a low to moderate potential of being associated with the presence of groundwater (BoM, 2017).

5.0 Conceptual Site Model

A conceptual site model (CSM) of the groundwater regime has been developed based on the review of the hydrogeological information for SSM presented in the above report sections.

5.1 General

SSM is located within the northern part of the Bowen Basin, which comprises Permian aged coal measures that have been folded into a syncline structure that strikes in a north-west to south-east direction. The geology of SSM comprises the stratified sequences of the Moranbah Coal Measures at the westernmost extent of the syncline that dip towards the east. Mining at SSM targets the coal seams of the Moranbah Coal Measures, that occur at subcrop, and increase in depth towards the east. Surficial cover at SSM includes some alluvium associated with minor tributaries of the Isaac River, being Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek. This alluvium is highly localised to within and immediately around the incised channel for these surface water features. Surficial cover at SSM outside of these creek lines consists predominantly of a Tertiary aged package of clays, sands and weathered Basalt units, underlain by weathering derived regolith.

While mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004. Assessment of groundwater system response to the first ~25 years of SSM mining is therefore not possible. Regardless, groundwater monitoring and investigations at SSM since 2004, as well as other relevant studies for nearby sites, indicate that the main hydrogeological features at SSM include:

- Cainozoic sediments
    - Quaternary alluvium – unconfined aquifer (sporadically water-bearing strata of permeable unconsolidated sand or gravel) highly localised to incised channels of the major ephemeral drainage line channels at SSM along Downs Creek, Scott Creek and Rolf Creek;
    - Quaternary to Tertiary non-alluvial sediments and weathered units (collectively termed ‘regolith’ in many recent relevant regional studies) – unconfined unit with limited saturation at SSM and in the Study Area.
- Permian coal measures with:
    - Low permeability Interburden and overburden units with aquitard properties; and
    - Coal seams that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

Alluvium associated with the creek lines at SSM is poorly developed, spatially constrained to surface water channels by incised weathering into the Tertiary material and regolith. Saturation has been observed to be inconsistent across site with most groundwater drilling targeting alluvium, failing to find saturated alluvial sediments. All current alluvial monitoring is dry. Historical measurements of saturation in alluvium at a single bore that found saturation have shown water levels around 14 mbGL and typically significantly disconnected from the streambed elevation. 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 and recharge to the alluvium is considered to be primarily from stream flow or flooding, with direct infiltration of rainfall also occurring rapidly 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.

Water quality data for the alluvium within the broader Study Area indicates it can be fresh to saline and highly spatially and temporally variable. Groundwater sampling from SSM shows the limited saturation on site (one bore) is moderately saline. Regionally, alluvium is suitable for stock water supply and irrigation but is not suitable for drinking water and freshwater aquatic ecosystems, though there is understood to be little groundwater utilisation in the Study Area. Based on previous ecological

studies, it was identified that riparian vegetation has a low likelihood of dependence on alluvial groundwater.

Tertiary-Quaternary aged sediments and weathering derived Regolith present across SSM forms the base of the unconfined shallow groundwater system. The groundwater flow processes are similar to those of the alluvium; however the fluxes are expected to be significantly lower due to the dominance of clay within the sediments. Within the Study Area, near surface water features, saturation has been detected within the Tertiary material at depths of around 25 mbGL to 45 mbGL. Water quality data for the Tertiary sediments and Regolith indicates it is generally moderately saline but can be fresh to saline. Water is generally of moderate quality and has the potential to be used for limited stock, or irrigation purposes, depending on the local chemistry.

In the Permian strata, groundwater is encountered mainly in the coal seams, and occasionally in the sandstone/siltstone units of lower hydraulic conductivity. As with the rest of the Bowen Basin, the coal seams are the main groundwater bearing units within the Permian sequences, with low hydraulic conductivity interburden generally confining the individual seams. The coal seams are dual porosity in nature with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats). Hydraulic conductivity of the coal decreases with depth due to increasing overburden pressure reducing the aperture of fractures. Vertical movement of groundwater (including recharge) is limited by the confining interburden layers, meaning that groundwater flow is primarily horizontal through the seams with recharge only occurring at subcrop.

Review of fault behaviour within the Bowen Basin has identified that faults in the Permian strata can increase vertical hydraulic conductivity parallel to the fault trace and reduce it perpendicular to the fault trace. However, any increases in vertical hydraulic conductivity are limited to small vertical horizons (<20 m) and are variable between faults dependent on localised hydrothermal activity and mineralisation in-filling pore spaces. Previous hydraulic testing of faults in the Bowen Basin indicate that faulting zones intercepted are not pathways for preferential flow.

Regionally, groundwater within the Permian coal measures flows in a south-easterly direction, but the flow system is significantly modified by mining activities. Review of water quality data indicates water within the Permian coal measures is generally saline at SSM but can range between brackish to highly saline. Groundwater within the coal measures at SSM is generally considered unsuitable for all stock types.

5.2 End of Mining

An understanding of the hydrogeological system response to mining, and conditions at the end of mining, is considered important in the context of defining the starting conditions for the post-mining assessment described later in this report. A visual representation of the end of mining CSM is provided in **Figure 5-1**, noting the general conceptualisation features discussed above. Note that the post-mining CSM of the SSM hydrogeological system is related to the area outside of the Roper Study Area, with the Roper Study Area to be subject to future local scale study as described in **Section 1.1**. Based on an understanding of hydrogeological mechanisms and response to mining observed in the site monitoring data, and modelled in other local studies, key outcomes relevant to the assessment of potential groundwater impacts at the end of mining are likely to be:

- Groundwater drawdown within the Moranbah Coal Measures, associated with passive dewatering into the SSM mine pits, results in inwards hydraulic flow gradients in the coal measures.
- Mine pits capture any seepage from spoil emplacements.
- Limited groundwater level drawdown in the Tertiary formations due to low hydraulic conductivity of these zones and poor lateral connection and no impact to alluvial aquifers.
- Limited potential for groundwater level drawdown impacts to potential terrestrial GDEs along Stephens Creek and Rolf Creek, where the water table in the regolith material may be accessed by deeper rooted riparian species and may be subject to relatively small drawdowns
- Little to no impact on aquatic environmental receptors.

- No impact on anthropogenic receptors.

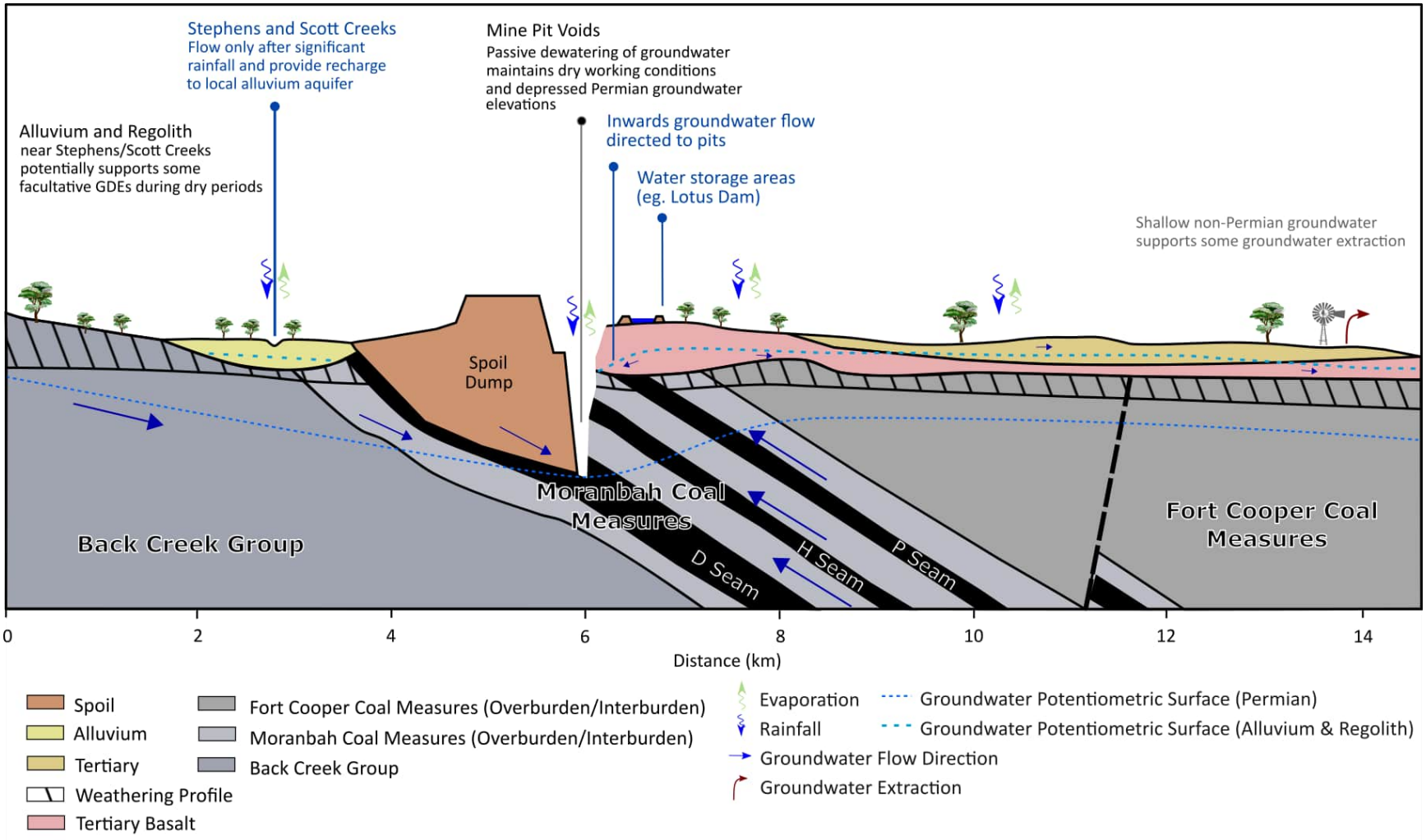


Figure 5-1 Conceptual Model of SSM Groundwater System – End of Mining

6.0 Potential Impacts

Potential Impacts associated with shallow sources of potential groundwater contamination at SSM 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 site groundwater system.

6.1 Groundwater System at End of Mining

The potential impacts to the groundwater system post-closure, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining. Therefore, it is important to understand the nature of the groundwater system at the conclusion of mining immediately prior to the closure period, noting that the features discussed below are relevant for areas of the site outside of the Roper Study Area where further studies are required. Based on the observed response during the care and maintenance period, the following points are relevant as an indication of the predicted response of the SSM groundwater system to end of mining impacts:

- Groundwater drawdown within the Moranbah Coal Measures, associated with passive dewatering into the SSM mine pits, results in inwards hydraulic flow gradients in the coal measures. The magnitude of this drawdown will be most significant in the immediate vicinity of the pits, but extend northwards, eastwards and southwards of SSM by several kilometres and interact with drawdown from nearby mines.
- Mine pits capture any seepage from spoil emplacements due to the hydraulic gradient orientated towards the mine void.
- No observed groundwater level drawdown of the alluvium due to the limited extent of continuous alluvial lenses.
- Limited groundwater level drawdown in the Tertiary formations due to low hydraulic conductivity of these zones and poor lateral connection.
- Limited potential for groundwater level drawdown impacts to potential terrestrial GDEs along Stephens Creek and Rolf Creek, where the water table in the regolith material may be accessed by deeper rooted riparian species and may be subject to relatively small drawdowns.
- Little to no impact on aquatic environmental receptors.
- No reported impact on anthropogenic receptors.

6.2 Groundwater System Post Mining

The remainder of this report evaluates the potential post mining impacts on the groundwater system through numerical groundwater modelling work based on the above conceptual model of SSM. The evaluation presented in the remainder of this report includes:

- Assessment of residual void lake formation in the post-mining period, and whether lake levels stabilise below the pre-mining groundwater elevations and any shallow post-Permian strata, including the base of surficial weathering and shallow hydrostratigraphic units (i.e. alluvium and Tertiary sediments/Regolith).
- Assessment of potential for continued groundwater drawdown within the Moranbah Coal Measures, resulting in continued inwards hydraulic flow gradients in the coal measures in the post-mining period.
- Whether residual voids continue to capture any seepage from spoil emplacements in the post-mining period.
- The extent of impact on surficial aquifers in the post-mining period.

- The extent of impact on environmental receptors in the post-mining period.
- The extent of impact on anthropogenic receptors in the post-mining period.

7.0 Groundwater Modelling

Numerical groundwater modelling was undertaken in support of the hydrogeological assessment for the PRC Plan to evaluate the potential impacts of the proposed PRC Plan's Final Landform on the groundwater regime. This section provides a summary of the design and development of the SSM numerical groundwater model. Full details of the SSM numerical groundwater model developed for this hydrogeological assessment are included in the technical modelling report (SLR, 2024).

The objectives of the groundwater modelling were to:

- Assess the nature (timing and elevation) of void water level recovery (i.e. time to reach post mining equilibrium and definition of that equilibrium level), and associated groundwater fluxes to/from voids.
- Assess the groundwater levels at post mining equilibrium in all relevant hydrogeologic units, and associated impacts on current and potential future receptors (drawdown, water quality and groundwater flow direction).
- Assess impacts to alluvial and Tertiary hosted groundwater and any identified potential receptors.
- Assess the influence on potential groundwater receptors associated with surface drainage lines.

7.1 Model Details

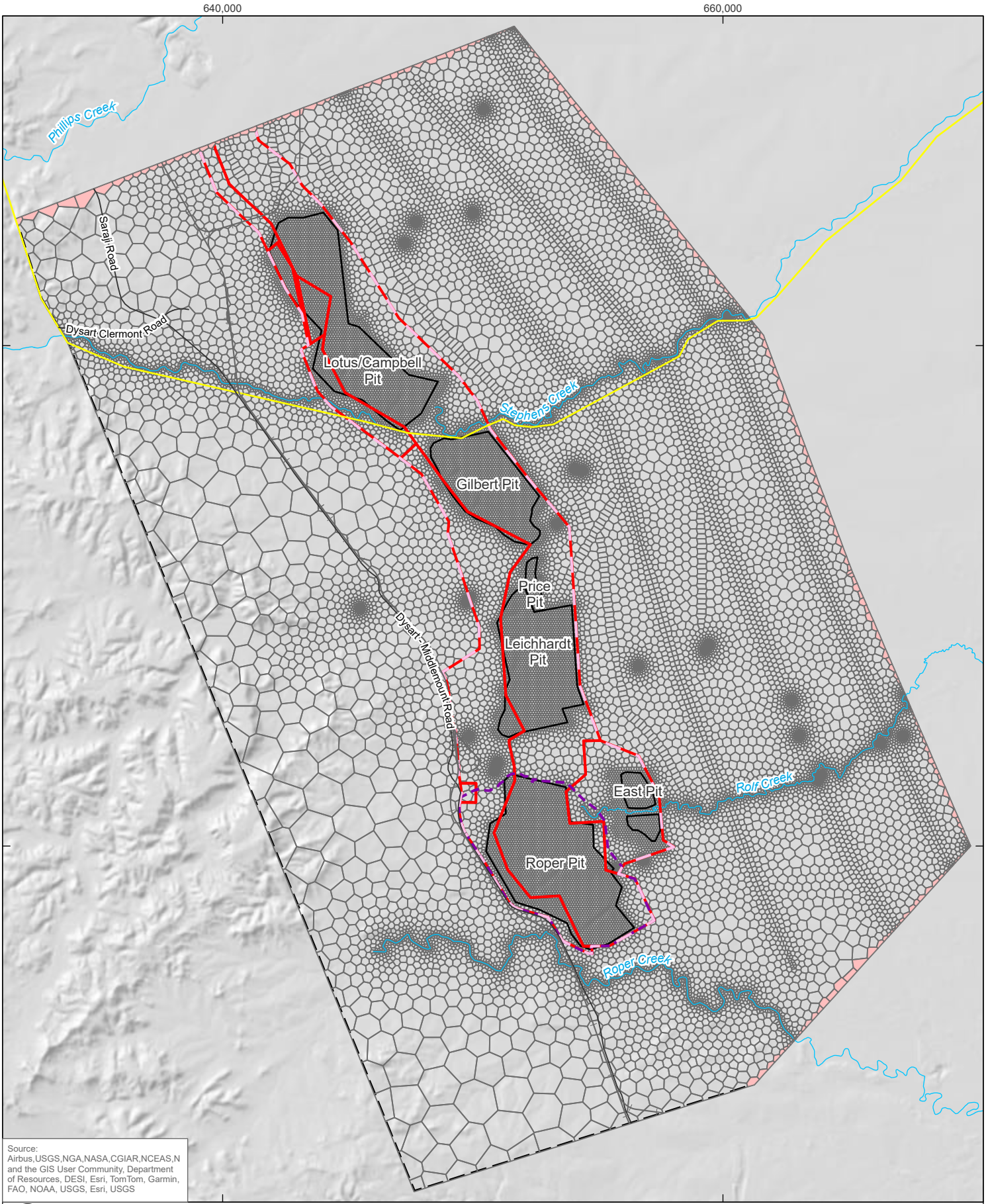
7.1.1 Model Design

MODFLOW-USG Transport was used as the model code (Panday et al. 2013). MODFLOW-USG is a recent version of industry standard MODFLOW code and was determined to be the most suitable modelling code for accomplishing the model objectives. MODFLOW-USG optimises the model grid and increases numerical stability by using unstructured, variably sized cells. These cells take any polygonal shape, with variable size constraints allowing for refinement in areas of interest.

MODFLOW-USG is also able to simulate unsaturated conditions, allowing progressive mine dewatering and post mining rewetting to be represented by the model. For the SSM model, vadose zone properties have been excluded, and the unsaturated zone was simulated using the upstream-weighting method.

The groundwater model extent is shown in **Figure 7-1**. The model domain is intended to place boundary conditions sufficiently distant from the SSM site to allow the extent of potential impacts from mining activities on the groundwater system to be assessed. At its widest extents, the model is approximately 25 km west-east by 43 km north-south. The model domain was selected based on the following considerations:

- The western boundary is represented by the outcrop boundary of the Back Creek Group, which is considered the regional low permeability basement for the purpose of this modelling.
- The northern boundary contains the primary geological unit being targeted by the SSM site and is approximately 4 km away from the proposed open cut mine areas. This northern section overlaps with the Saraji East version of BMA's central Bowen Basin regional groundwater model (SLR, 2022a)
- The southern boundary is set approximately 8 km south of the SSM site and is expected to be far outside the range of predicted SSM related drawdown.
- The eastern boundary is set along the SSM fault approximately 11 km east of the SSM area and is expected to be far outside the range of predicted SSM related drawdown.



Source: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,N and the GIS User Community, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Railway
- Major Road
- Watercourse
- Model Boundary
- Model Grid
- SSM Pit Extent
- General Head Boundary
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area
- Central Bowen Basin Regional Model Boundary

SARAJI SOUTH MINE TRANSITIONAL PRCP

MODEL MESH AND BOUNDARY CONDITIONS

SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

FIGURE 7-1

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_1_Model Mesh and Boundary Conditions

The following features have been included in the grid design:

- Open cut mine areas for the SSM are represented with a 100 m Voronoi cell size constraint.
- Faults are represented using a 200 m Voronoi cell constraint.
- Alluvium areas are represented by irregular shaped Voronoi cells with resolution in a range of 100 m and 300m.

Model layering is based on a simplified representation of the SSM site geological model. The major coal seams considered for the model layering were: D seam, H seam, P seam and Q seam. The regions between these seams are interburden layers. Outside of the SSM geological model extents, and average seam thickness (sampled across the geological model extents) was applied regionally. Where the model boundary overlaps with the existing Saraji East version of BMA's central Bowen Basin regional groundwater model (SLR, 2022a), the layer structure from the southern part of the central Bowen Basin regional model was adopted.

Structural trend data was extrapolated from the geological models using the neighbouring "Saraji East groundwater model" to the north (SLR, 2023b) as well as publicly available solid geology mapping. The layering and average thicknesses used are summarised in **Table 7-1**.

Table 7-1 Model Layers and Thickness

Model Layer	Formation	Unit	Average Thickness (m)
1	Alluvium, colluvium, Tertiary basalt	Surface cover – alluvium, colluvium and Tertiary basalt	32
2	Tertiary sediments, Tertiary basalt, Regolith	Tertiary and minor Triassic Clematis Group, weathered Permian, Tertiary basalt	30
3	Fort Cooper Coal Measures	Fort Cooper overburden	53.0
4		Fort Cooper seams (combined)	62.7
5		Fort Cooper underburden	72.5
6	Moranbah Coal Measures	Q Seam	1.0
7		Interburden	46.2
8		P Seam	1.9
9		Interburden	43.6
10		H Seam	3.7
11		Interburden	52.8
12		D Seam	5.1
13		Base of Model - aquitard	100

Further detail on geological structure representation, time discretisation, model stressors and boundary conditions are detailed in **Appendix A**.

7.1.2 Model Calibration

A detailed description of the calibration procedure is provided in **Appendix A**. The numerical model includes a steady state and a transient calibration (1990 to 2023). In all, 261 target heads were established for 53 bores from the SSM area. Historical mining at SSM 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. Calibration of the model was carried out with the objective being to replicate the groundwater levels measured in SSM monitoring network. The calibration statistics were calculated for each

realisation and the realisation that produced the lowest Scaled Root Mean Square error (SRMS) was considered to be the best-calibrated model, in accordance with Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The model variables included in the calibration were:

- Aquifer parameters including horizontal and vertical hydraulic conductivity, specific storage and specific yield.
- Stresses including recharge rates.
- Boundary conditions including evapotranspiration (EVT) rate, EVT extinction depth, and General Head Boundary (GHB) conductance factor (excluding the northern GHB area covered by the Saraji East numerical groundwater model).
- Faults horizontal and vertical hydraulic conductivity, specific storage, and specific yield.
- Horizontal and vertical hydraulic conductivity, specific storage, and specific yield of spoils.

Groundwater level calibration targets were selected where:

- Valid information on bore construction or geology information was available for the site.
- Targets were manually reviewed to ensure the measurements were realistic.

Calibration target observations and resultant residual data summary is presented in **Table 7-2**. Calibration statistics were calculated from the calibration ensemble including 120 realisations. The RMS error calculated for the Base Model realisation is 3.4 m, equating to a 4.2% scaled root mean square (SRMS) error, which is within the recommended range (i.e. 10%) in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). Calibrated hydraulic parameters were shown to be all within the range of available field data (**Section 4.2**).

Table 7-2 Model Calibration Targets and Residual

Model Layer	Formation	Unit	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
1	Alluvium, colluvium, Tertiary basalt	Surface cover	-0.1	0.3	5	1
2	Tertiary sediments, Tertiary basalt	Tertiary and minor Triassic Clematis, weathered Permian, Tertiary basalt	0.7	3.1	133	32
3*	Fort Cooper Coal Measures	Fort Cooper overburden	-	-	-	-
4		Fort Cooper seams (combined)	-0.2	0.6	38	2
5		Fort Cooper underburden	0.0	2.1	11	2
6*	Moranbah Cooper Coal Measures	Q Seam	-	-	-	-
7		Interburden	2.3	2.3	11	2
8		P Seam	1.4	2.3	12	3
9		Interburden	0.5	0.5	3	1
10		H Seam	-0.2	1.4	30	3
11		Interburden	-3.1	8.0	3	2
12		D Seam	-3.6	3.6	7	4
13		Interburden	0.4	0.4	8	1

*There are no observation bores in Layes 3 and 6.

7.1.3 Model Performance and Limitations

The Australian Government's Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling* (Peeters and Middlemis, 2023) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

Peeters and Middlemis (2023) state that simulation models are developed as simplified representations of 'real world' systems that are usually history-matched to measured data, albeit affected to some degree by the various sources of uncertainty outlined above. Peeters and Middlemis (2023) further describe that models are continuously refined with new data, conceptualisations and processes, to investigate the effects of management options on future eventualities.

The four sources of scientific uncertainty identified by Peeters and Middlemis (2023) have been qualitatively assessed with regards to key aspects of the SSM numerical model adopted for this groundwater assessment, as presented in **Table 7-3**.

Overall, the model captures depressurisation due to active mining. The model is numerically stable with no mass balance error. The model shows a reasonable fit between observed and modelled groundwater levels. A depth dependence function was used for hydraulic conductivity, with the calibrated values showing a good fit to observed data. Overall, the model is considered fit for purpose based on the data provided and the project timeframe.

In case of future use of the model, updates could be conducted to further refine the model if it was deemed that an increase in model confidence level was required, but the applicability of this would be dependent on the purpose of the future modelling and availability of data to inform future changes. As it stands, the current model is deemed fit for purpose for this assessment.

Table 7-3 Groundwater Model and Data Limitations

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose	The model has an unstructured Voronoi grid that includes detailed cell refinement around the SSM site, major modelled faults and along drainage features.
	Layers	Fit for purpose	Representation of alluvium and other geologic units based on CSIRO depth to regolith surface (Wilford et, al., 2016) and SSM-derived information from the study area including drilling data.
	Conceptualisation – Geological Structure	Fit for purpose	The local structure of the geology is based on detailed data at SSM where available, including a SSM developed site geology model. Geological mapping has identified several large faults throughout the model domain. Faults have been included as separate (i.e. individual for each fault) hydraulic parameter zones and calibrated to fit measured water level data across the model domain.
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose	The Moranbah Coal Measures outcrop within the numerical model domain and as such they receive direct recharge like the Alluvium and Tertiary in the model. A specific recharge zone was attributed to the drainage lines, to represent infiltration recharge via the creek bed during flooding events. Mine pits that were flooded in 2011 are represented using a constant head boundary based on site measurements.
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose improvements possible	For the extent and thickness of alluvium and regolith within the model domain, a combination of site geological model (SSM geological model - base of weathering), regional geological mapping and the CSIRO depth to regolith surface (Wilford et, al., 2016) was used. Any additional data or study on alluvium extent and thickness in the SSM area should be reviewed and captured (where relevant) in future updates of the model.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose, future improvements possible	Field testing of hydraulic conductivity (horizontal and to a lesser extent vertical) has been conducted in the SSM and the neighbouring Saraji/Saraji East Mine area. Hydraulic conductivity test results from the wider Bowen Basin were also considered. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model. Further hydraulic conductivity tests and measurements of storage properties can improve model calibration and refine model predictions but are not deemed required for the current impact assessment.
	Spoil Properties	Fit for purpose, future improvements possible	Limited site-specific data is available for the spoil. Spoil parameter calibration ranges were estimated based on previous studies at other sites.
	Rivers	Fit for purpose, future improvements possible	All watercourses within the model domain are minor ephemeral creeks. They are represented in the model via specific recharge zone, to reproduce infiltration recharge via the creek bed during flooding

Type	Part	Status	Comment
			events. A refinement along the riverbeds was also performed to capture the variation in the evapotranspiration surface along the watercourses).
	Recharge	Fit for purpose, future improvements possible	Recharge zonation is based on mapped surface geology and calibrated recharge rates. Calibration ranges were based on site data analysis and literature values.
Measurement Error	Observation Data Quality	Fit for purpose	Bore logs and construction details available for most site bores, and long-term site water level data available for various units. 261 target heads were established for 53 bores from the SSM area.
	Temporal spread	Fit for purpose, future improvements possible	Timeseries water level data from the site used for calibration contains at least one observation in every modelled aquifer, except for the Q Seam and the Fort Cooper Coal Measures overburden. Data is available from 1990, although most of the data covers the period 2010 – 2023.
Scenario Uncertainties	Calibration	Fit for purpose	A steady state calibration to initial heads at each bore was performed followed by a transient calibration to observed drawdowns up to 2023.
Future stresses/ conditions	Predictive	Fit for purpose	Model prediction period covers all 2023 onwards SSM approved mining activity and accounts for post mining rehabilitation (i.e. PRC Plan final landform)
	Sensitivity and uncertainty	Fit for purpose	Postmining simulation of surface water lakes in all the final voids was conducted via an iterative process whereby groundwater fluxes to and from the lakes were estimated using the MODFLOW groundwater model and surface water fluxes were simulated using a GoldSim rainfall/runoff model. Final lake levels were obtained after the two models converged and the results of this final set of lake levels were used to estimate postmining groundwater impacts in the groundwater assessment component of the SSM PRCP.

7.2 PRC Plan Landform Model

Post-mining groundwater impacts at SSM were investigated for the purposes of the PRC Plan's hydrogeology assessment with a numerical groundwater recovery model for the final landform as outlined in **Section 1.2**.

7.2.1 Model Setup

The recovery stress periods of the overall model setup commence from the end of mining at SSM and were run for 578 years over 32 model stress periods. The recovery stress period setup is shown in **Table 7-4**.

Table 7-4 Recovery Model Stress Periods

Recovery Stress Periods	Recovery Stress Period Duration (Years)	Starting Year (Post-Mining at SSM)	Ending Year (Post-Mining at SSM)
1 – 18	1	1	18
19-22	5	19	38
23-26	10	39	78
27-28	50	79	178
29-32	100	179	578

The PRC Plan's proposed final landform was replicated in the recovery model, including areas of spoil emplacement and the proposed residual voids. The distribution of modelled spoil emplacement is shown on **Figure 1-3**. At the mining at SSM, all the drain cells (representing SSM pit dewatering in areas of active mining) were removed from pits. Then the properties of the residual void cells were converted to values representative of void values. That is, the void cells were assigned high horizontal and vertical hydraulic conductivities (1,000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, specific storage of 5.0×10^{-6} m^{-1}), to simulate free water movement within the residual void. This approach is often referred to as a 'high-K' lake.

Climate related boundary conditions (i.e. recharge and ET) in the recovery model were set constant for the duration of the recovery. Recharge and ET were not applied to the final voids in the groundwater model as the WSP (2024) water balance model used iteratively with the groundwater model accounts for these boundary conditions.

7.2.2 Integration with Residual Void Water Balance Model

Figure 7-2 presents a conceptual diagram of the post-mining modelling setup adopted for this hydrogeological assessment. As shown in **Figure 7-2** , the residual voids will accumulate water over time due to direct rainfall, surface water runoff and groundwater inflow from both spoil and natural rock as groundwater levels recover. Whilst the numerical groundwater model can reliably account for the groundwater inflow component, the surface components of direct rainfall, surface water runoff, as well as evaporative loss from the void lake, are considered to be better accounted for within a surface water balance model. This is due to the inherently more refined nature of simulating those surface components within a water balance model, as compared to a numerical groundwater model.

The groundwater model was therefore used to predict the following fluxes to the residual voids:

- Groundwater inflow to the pit shell from the surrounding geology, including inflow from the natural geology to the spoil backfill and inflow from the natural geology directly to the residual voids; and
- Groundwater inflow originating from the indirect catchment (i.e. areas of spoil backfill that receive rainfall recharge that then flows through the spoil into the residual voids).

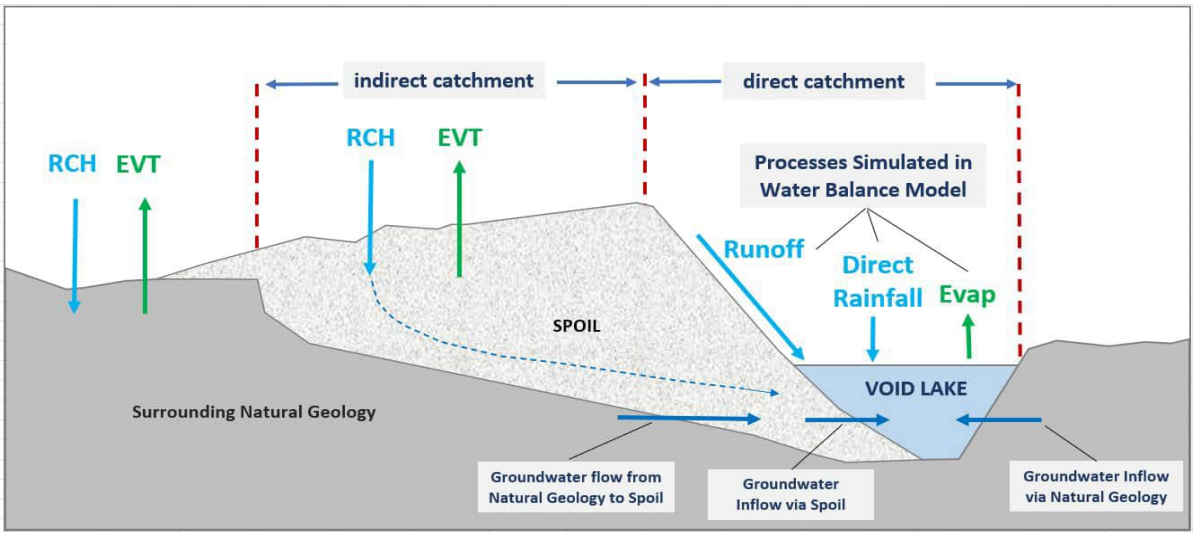


Figure 7-2 Residual Void Recovery Model Conceptual Diagram

Void water levels were not predicted by the groundwater model but were estimated by the balance between groundwater inflow and the direct rainfall and rainfall runoff from the surrounding catchment against the evaporation loss from the lake surface through iterative surface water balance modelling (WSP, 2024). The WSP (2024) surface water balance modelling included climate sensitivity and three climate scenarios reported therein were adopted for the groundwater model as instructed by BMA and shown in **Table 7-5**. Three sets of groundwater model predictions were generated for this hydrogeology assessment based on the three climate scenarios.

Table 7-5 Climate Scenarios Modelled

Climate Scenario	Climate Model	IPCC RCP Scenario[1]	WSP (2024) Realisation
Wetter	ACCESS1-0Q	4.5	R#1
Mid	MPI-ESM-LRQ	4.5	R#3
Drier	MPI-ESM-LRQ	8.5	R#6

1. Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP), refer https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/RCPs.html

The iterative modelling approach was undertaken in a stepwise manner as follows, for each climate scenario:

1. The water balance model for the residual void and depressed landforms prepared by WSP (2024) was first run.
2. The daily surface water inflows were combined with predicted groundwater fluxes to the residual void and depressed landforms from the groundwater model, to produce a surrogate water balance model at a lower temporal resolution (i.e., matching the stress period setup of the groundwater model).
3. The predicted void and depressed landform lake levels from the surrogate water balance model were applied as constant head boundary conditions in the groundwater model, and the groundwater model was re-run to obtain updated groundwater fluxes to the lakes.
4. The surrogate water balance model was re-run with the updated groundwater fluxes, resulting in a new set of predicted lake levels.
5. Steps 3 and 4 were repeated until the time series of predicted lake levels for the residual void and depressed landforms stopped changing substantially between iterations.

6. The converged groundwater fluxes obtained from running the groundwater model and surrogate water balance model in tandem were supplied to the WSP (2024) water balance model.
7. The resulting void lake levels calculated by the WSP (2024) water balance model were compared with the lake levels estimated by the surrogate water balance model to evaluate agreement between the two models.
8. As the lake levels produced by the two water balance models were very similar, the models were determined to have converged, and the results of the groundwater model and the WSP (2024) water balance model were adopted for reporting the PRCP.

The assessment of the iterative model outputs between the groundwater model and the water balance model indicates the northern three SSM voids achieved an appropriate level of convergence for the purpose of this assessment. However, the alignment of the models for Roper and East Pit residual voids did not achieve the same level of convergence. Reasonable efforts to align the models has been completed including development of an auto iterator, to better define the starting point, combined with numerous model iterations. The PRC Plan's approach to the area containing the Roper residual voids includes the implementation of a 'Roper Study Area' and an additional remediation milestone (RM) that provides for additional studies to be completed to inform the further development of the closure landform. The additional data produced for the Roper Study Area will provide for further development of the groundwater and water balance models by providing additional data on groundwater and revised landform designs. Based on this, the PRC Plan will also be amended where required. Furthermore, the East Pit residual voids are located down dip from the Roper residual voids and changes to the Roper residual voids will impact the hydrogeology and void lakes within the East Pit residual voids. Therefore, the long-term hydrogeology of East Pit residual voids, due to the uncertainty of the Roper Study Area closure landform, is also uncertain. Any remodelling of the Roper residual voids will require consideration/inclusion of the East Pit residual voids. However, as reflected in the PRC Plan schedule, East Pits are an approved future mining opportunity that will not be commenced prior to the completion of Roper Pit studies and any associated amendment of the PRC Plan. Therefore, prior to the mining of East Pits, the hydrogeology will have been restudied and included in any PRC Plan amendments. The potential for improvement in alignment of the models is acknowledged by BMA.

Given the continued uncertainty pertaining to the final landform for the Roper Study Area, and the reasons discussed in **Section 1.1**, the following discussion of modelling outcomes are presented only for the area of SSM outside of the Roper Study Area.

7.2.3 Residual Void Lake Recovery

Figure 7-3 through **Figure 7-7** provide a graphical representation of the final simulated recovery of water levels in the residual voids, based on the iterative groundwater and surface water balance modelling. Of note, there is only an approximate 0 to 27 m range in equilibrium lake elevations between the three climate scenarios. It should be noted that, as predicted groundwater inflow to the voids is only approximately 10% to 20% of the total volumetric inflow to the voids (see **Section 7.2.2**), within the water balance model the surface water fluxes are the dominant driver for the estimated void water levels and associated trends, rather than the predicted groundwater inflow volumes. The exception to this is where groundwater inflows to the East 1 and East 2 residual voids account for approximately 50% of the total volumetric inflow to these two residual voids (noting that the hydrologic behaviour of the East Pit residual voids remains subject to change based on outcomes of further studies in the Roper Study Area as discussed in **Section 7.2.2** above).

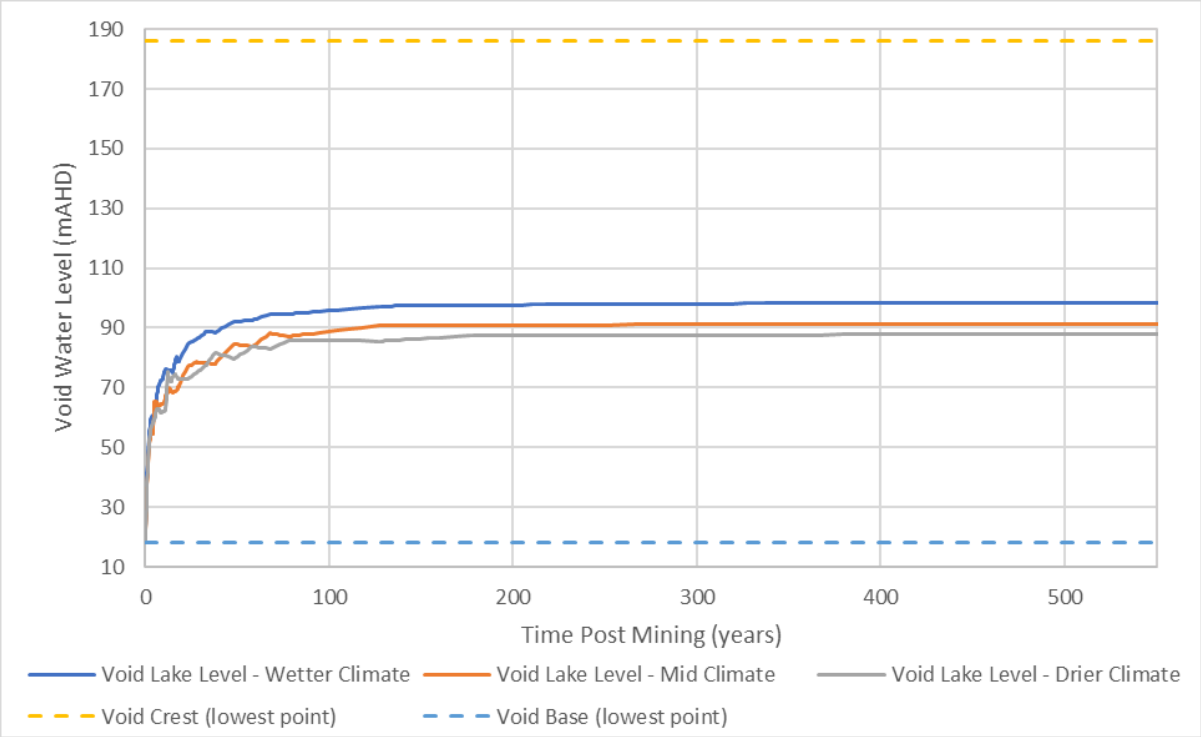


Figure 7-3 Simulated Void Water Level Recovery – Lotus/Campbell Void (based on WSP, 2024)

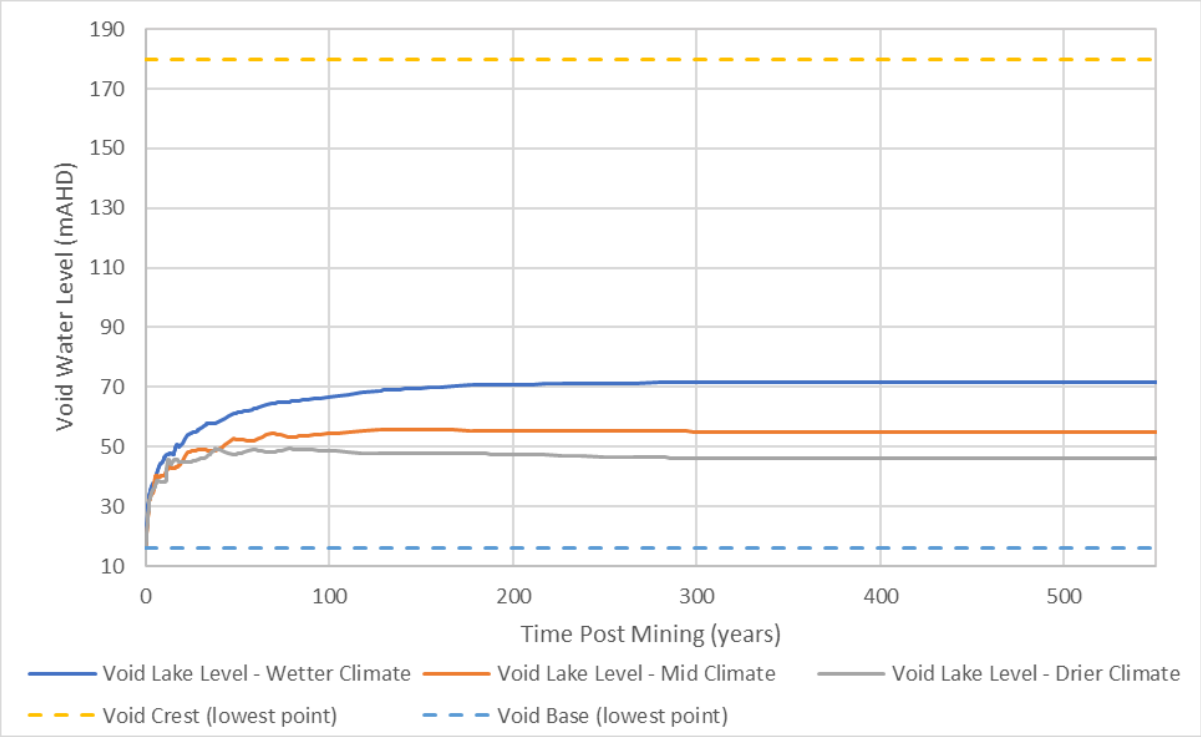


Figure 7-4 Simulated Void Water Level Recovery – Gilbert Void (based on WSP, 2024)

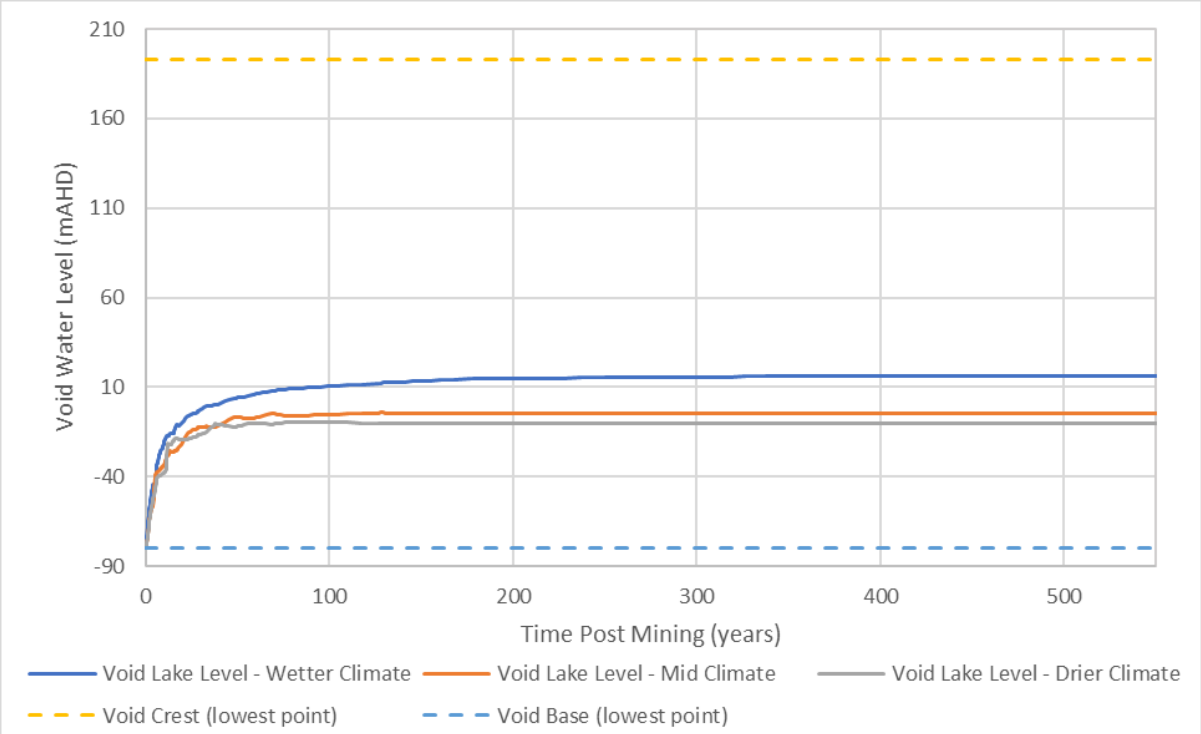


Figure 7-5 Simulated Void Water Level Recovery – Price/ Leichhardt Void (based on WSP, 2024)

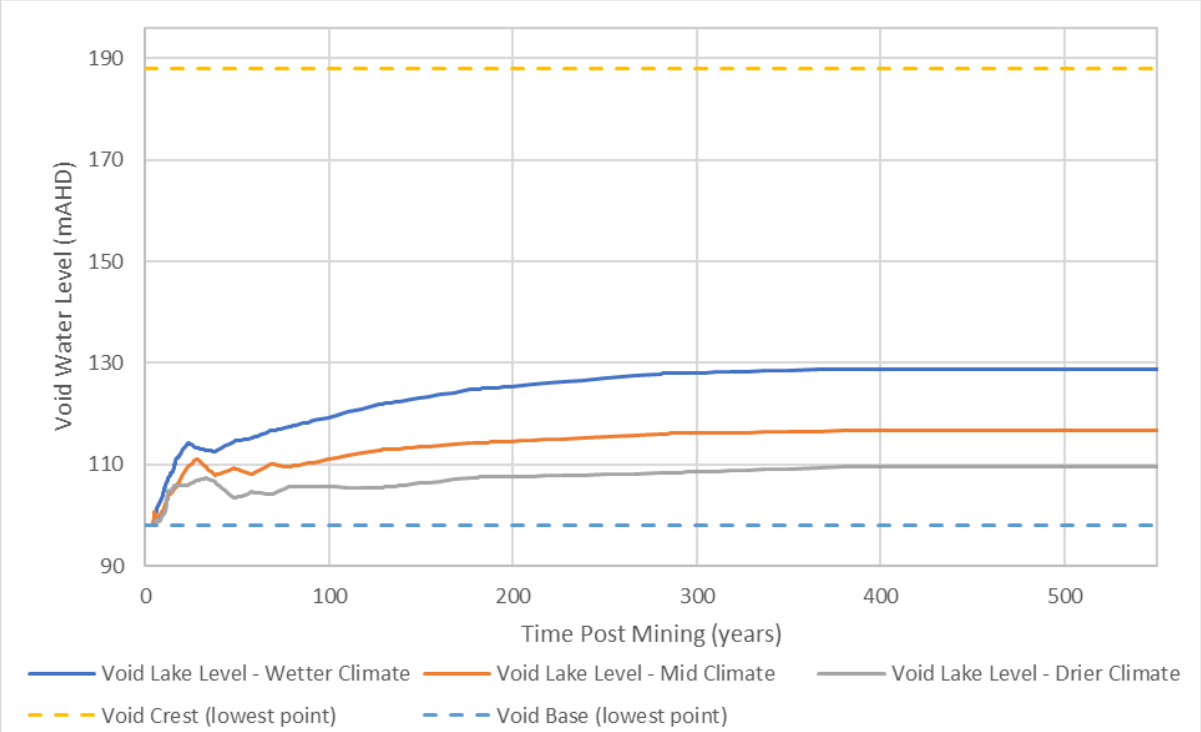


Figure 7-6 Simulated Void Water Level Recovery – East 1 Void (based on WSP, 2024)

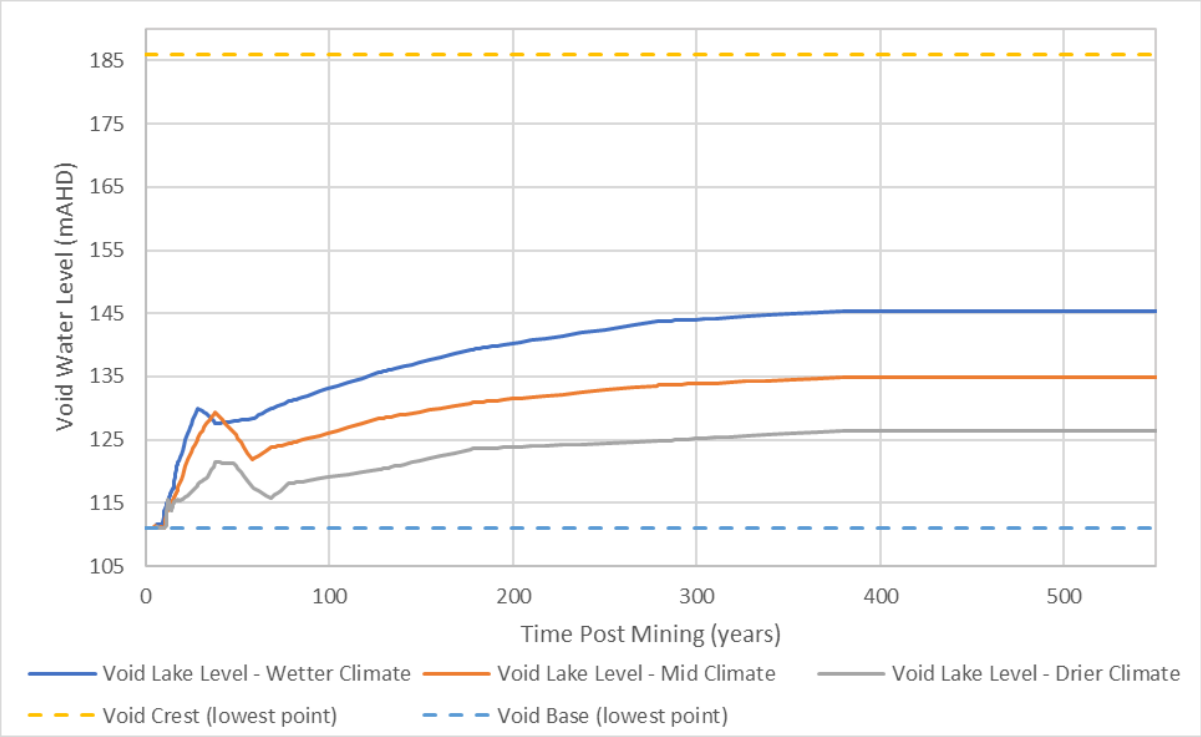


Figure 7-7 Simulated Void Water Level Recovery – East 2 Void (based on WSP, 2024)

Figure 7-3 through **Figure 7-7** show that the residual void water level recovery is a process that takes decades with the recovery rate declining as the lakes reach equilibrium conditions. The majority of recovery in the voids is achieved within the first 100 years, and equilibrium water level conditions are reached after approximately 50 to 300 years for all climate scenarios represented in the groundwater model. The predicted equilibrated water levels in the residual voids are shown in **Table 7-6**.

Table 7-6 Equilibrated Water Levels in the Residual Voids (based on WSP, 2024)

Climate Scenario	Residual Void	Initial water level (mAHD)	Approximate time to equilibrium (years)	Equilibrium water level (mAHD)
Wetter	Lotus/Campbell	18	115	98
	Gilbert	16	110	71
	Price/Leichhardt	-80	167	16
	East 1	98	247	129
	East 2	111	252	145
Mid	Lotus/Campbell	18	115	91
	Gilbert	16	110	55
	Price/Leichhardt	-80	167	-5
	East 1	98	247	116
	East 2	111	252	135
Drier	Lotus/Campbell	18	115	88
	Gilbert	16	110	46
	Price/Leichhardt	-80	167	-11
	East 1	98	247	109
	East 2	111	252	126

The freeboard for each of the residual voids (i.e. the difference in elevation between the long-term water levels in the residual voids and the landform crest elevation) is as shown in **Table 7-7**. Predicted void lake levels remain significantly below the surface ‘spill’ level for each of the residual voids.

Table 7-7 Predicted Freeboard in the Residual Voids at Equilibrium

Climate Scenario	Residual Void	Freeboard (m)
Wetter	Lotus/Campbell	88
	Gilbert	109
	Price/Leichhardt	177
	East 1	59
	East 2	41
Mid	Lotus/Campbell	95
	Gilbert	125
	Price/Leichhardt	198
	East 1	72
	East 2	51
Drier	Lotus/Campbell	98
	Gilbert	134
	Price/Leichhardt	204
	East 1	79
	East 2	60

The difference in elevation between the long-term water levels in the residual voids and the lowest point of the base of the shallow geologic formations (weathered regolith; model Layer 2) adjacent to the voids is shown in **Table 7-8**. Predicted residual void lake levels remain significantly below the base of the shallow geologic formations for Lotus/Campbell, Gilbert, and Price/Leichhardt residual voids, even with the temporal fluctuations in void water levels predicted by the WSP (2024) water balance model. That is, there is never the potential for a flux of water to leave the residual voids and enter the shallow/unconsolidated geologic formations.

Table 7-8 Predicted Difference between Residual Void Water Levels and Shallow Formations

Climate Scenario	Residual Void	Lowest Elevation of Base of Model Layer 2 Adjacent Void (mAHD)	Difference Between Void Lake Level and Lowest Elevation of Base of Model Layer 2 Adjacent Void (m)[1]	
			Start of Post-Mining	Post-Mining Equilibrium
Wetter	Lotus/Campbell	155.3	137.3	57.3
	Gilbert	150.6	134.6	79.6
	Price/Leichhardt	163.2	243.2	147.2
	East 1	152.0	54.0	23.0
	East 2	155.1	44.1	10.1
Mid	Lotus/Campbell	155.3	137.3	64.3
	Gilbert	150.6	134.6	95.6
	Price/Leichhardt	163.2	243.2	168.2
	East 1	152.0	54.0	36.0
	East 2	155.1	44.1	20.1
Drier	Lotus/Campbell	155.3	137.3	67.3
	Gilbert	150.6	134.6	104.6
	Price/Leichhardt	163.2	243.2	174.2
	East 1	152.0	54.0	43.0
	East 2	155.1	44.1	29.1

1. A positive number means the base of Model Layer 2 is that many metres higher than the void lake level

7.2.4 Residual Void Groundwater Inflow

The final predicted groundwater inflows to the residual voids from the groundwater model are shown on **Figure 7-8** through **Figure 7-12**, with inflows partitioned between that which flows into the residual voids through spoil, and that which flows into the residual voids through surrounding natural geological formations.

In approximately the first 50 years post-mining, groundwater levels are predicted to remain suppressed, particularly within the spoil around each residual void that is yet to saturate to a significant degree. During this time, groundwater fluxes to the voids are largely controlled by the difference between the predicted spoil groundwater levels and the predicted WSP (2024) residual void lake levels that rise and fall periodically (refer **Figure 7-3** through **Figure 7-7**) according to:

- Day-on-day climatic simulation within the WSP (2024) water balance model; and
- How the daily timestep water balance results are translated to the groundwater model's more simplified stress period setup.

For the mid-climate scenario, periods of variable groundwater inflow and outflow are predicted by the groundwater model in the first 39 years post-mining at Lotus/Campbell void, 13 years post-mining at Gilbert void, 14 years post-mining at East 1 void, and 39 years post-mining at East 2 void. Note that Price/Leichhardt void does not show periods of net variable groundwater inflow and outflow, maintaining net groundwater inflow and outflow fluxes, respectively, at all times of the mid-climate scenario simulation.

Over these periods, rainfall derived surface water captured in the residual voids (per the WSP water balance model) is predicted to move into the spoil, as the groundwater levels in the surrounding in-pit spoil backfill (and natural geological formations) slowly recover from mining activities. All predicted outflows from the Lotus/Campbell, Gilbert, and Price/Leichhardt residual voids over this time are to

the spoil, that is, there is no net predicted outflow from these voids to the natural geological formations in the whole post-mining duration.

It is noted that any form of further backfilling of residual voids above the groundwater level as a means to attempt to limit this early post-closure void water discharge will likely result in poorer environmental outcomes, as water in the backfilled voids will have a hydraulic head gradient toward the surrounding groundwater system. This will facilitate discharge outwards to the surrounding environment, in the absence of the hydraulic control (sink) caused by a relatively deep void lake that is maintained by evaporation in the long term (SLR, 2022b).

Simulation results indicate that there are predicted outflows from East 1 and East 2 voids to natural geological formations within the first 15 years post-mining.

As groundwater levels in the spoil and natural geology recover to elevations above some of the void lakes and lake levels stabilise, the direction of flow out of those void lakes stabilises and long-term groundwater inflow to the lakes is established after 24 years post-mining at Lotus/Campbell void, 6 years post-mining at Gilbert void, 14 years post-mining at East 1 void, and 39 years post-mining at East 2 void for the mid-climate scenario. Model results indicate that this inflow comes mostly via the spoil, originating mainly as local rainfall recharge applied to the spoil.

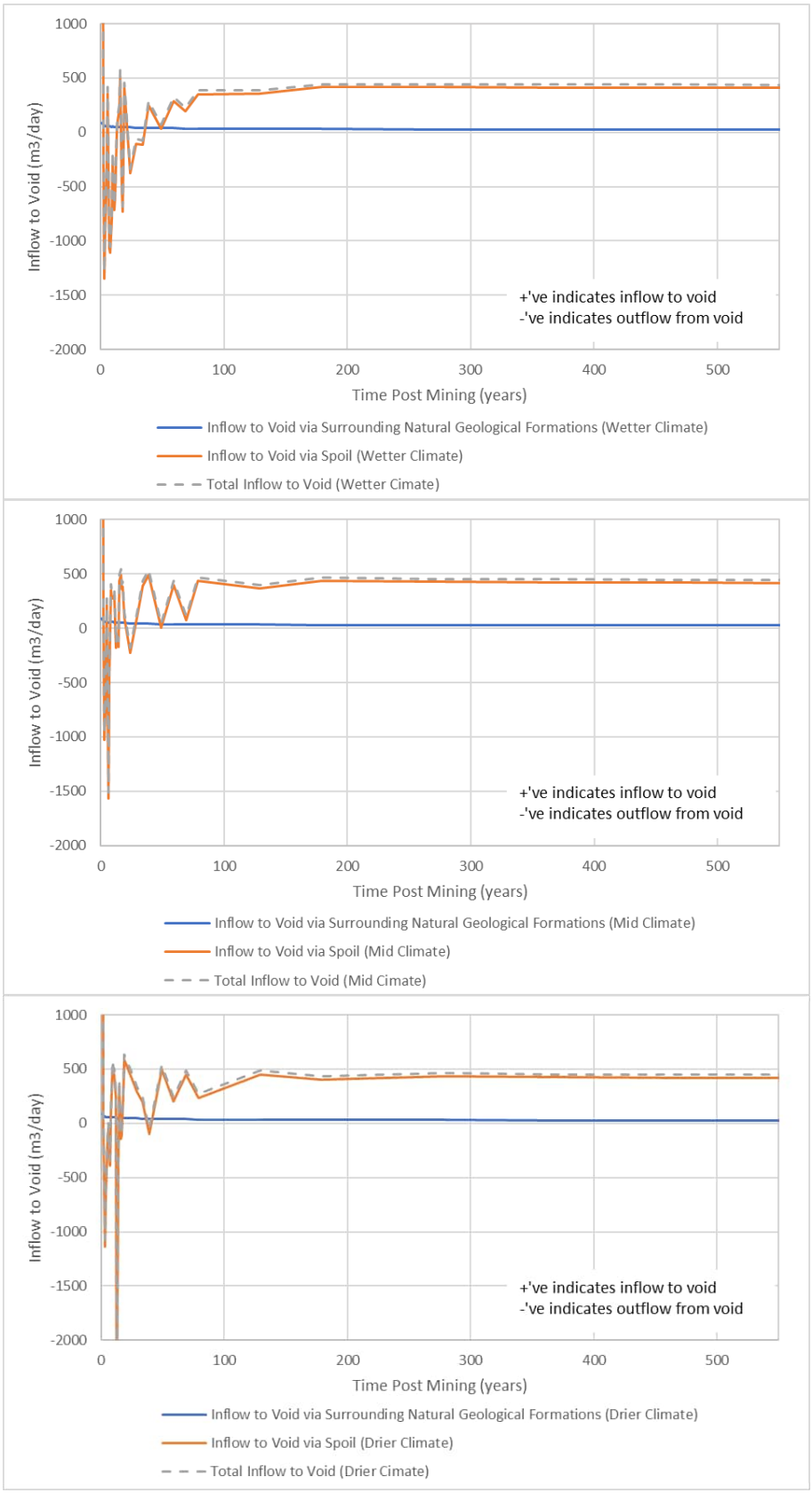


Figure 7-8 Predicted Void Groundwater Inflows – Lotus\Campbell Void

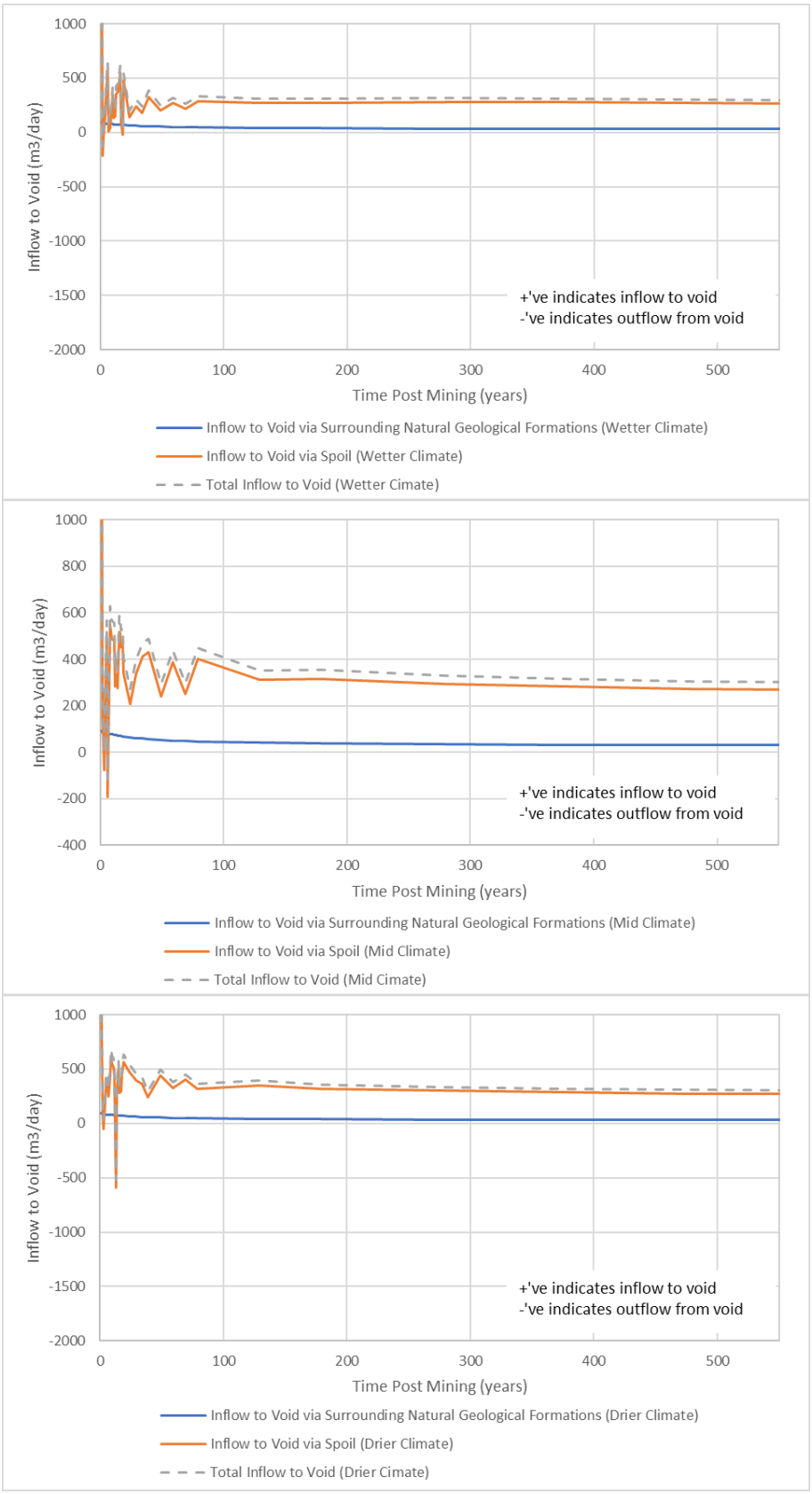


Figure 7-9 Predicted Void Groundwater Inflows – Gilbert Void

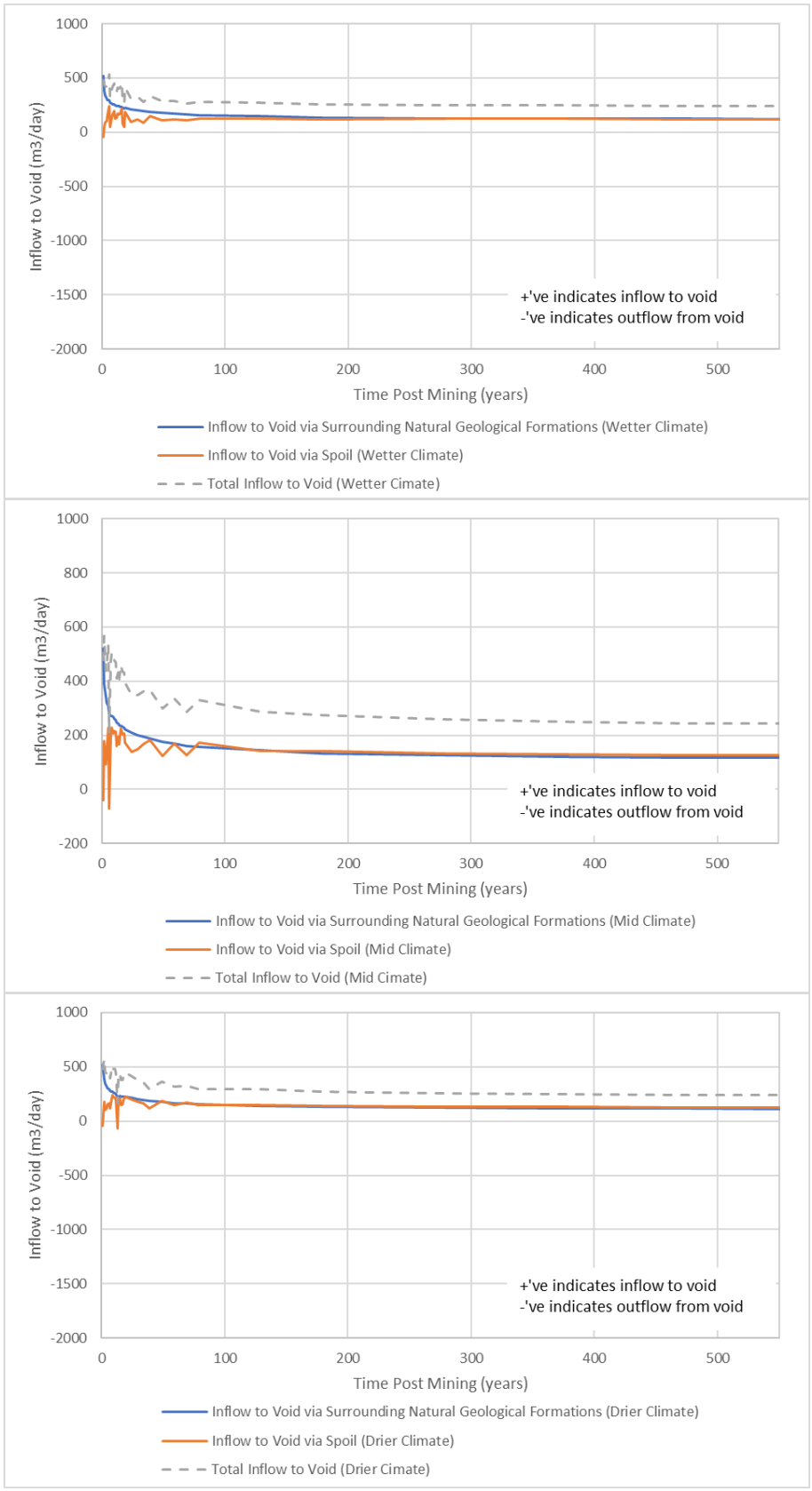


Figure 7-10 Predicted Void Groundwater Inflows – Price\Leichhardt Void

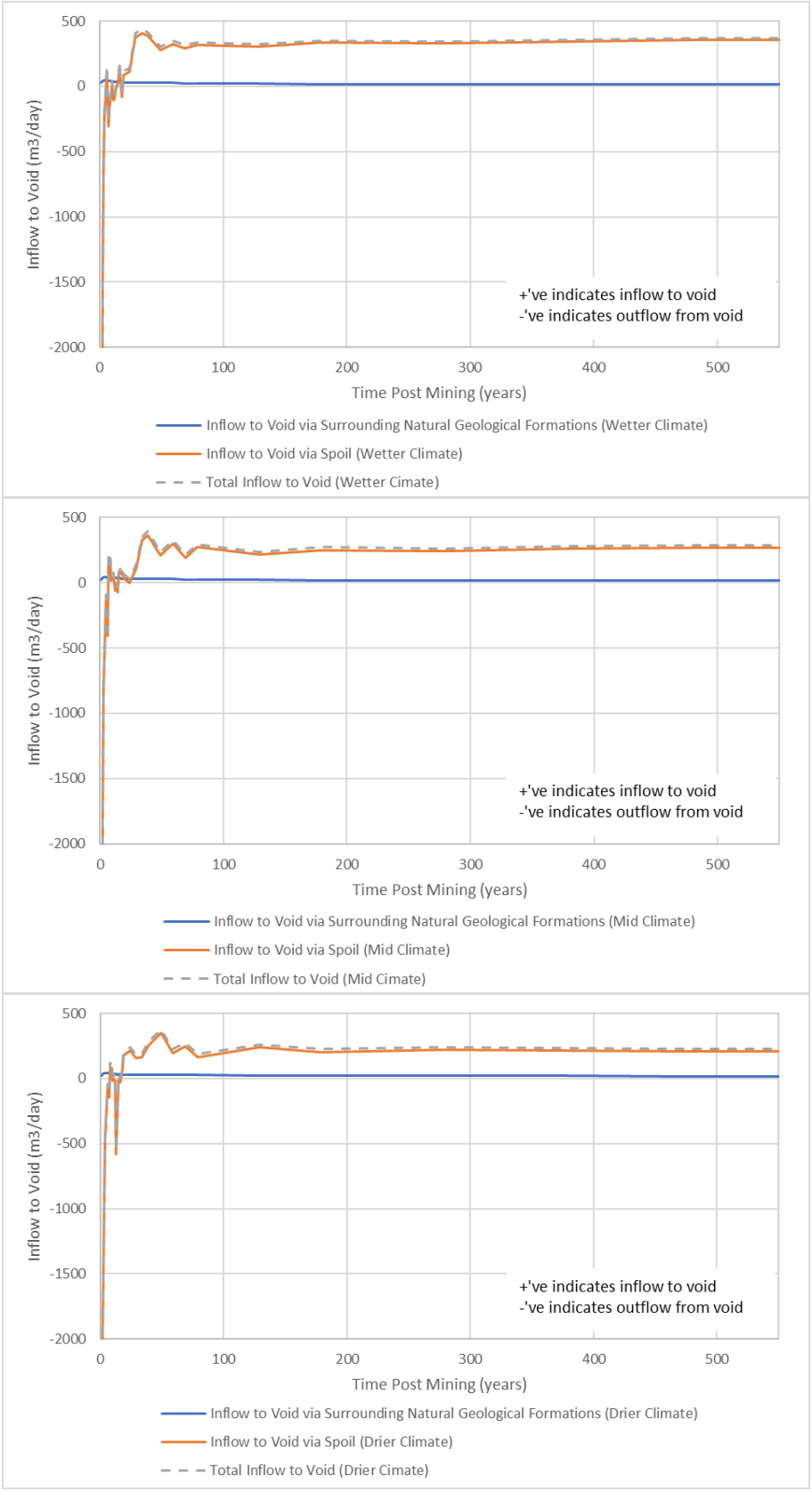


Figure 7-11 Predicted Void Groundwater Inflows – East 1 Void

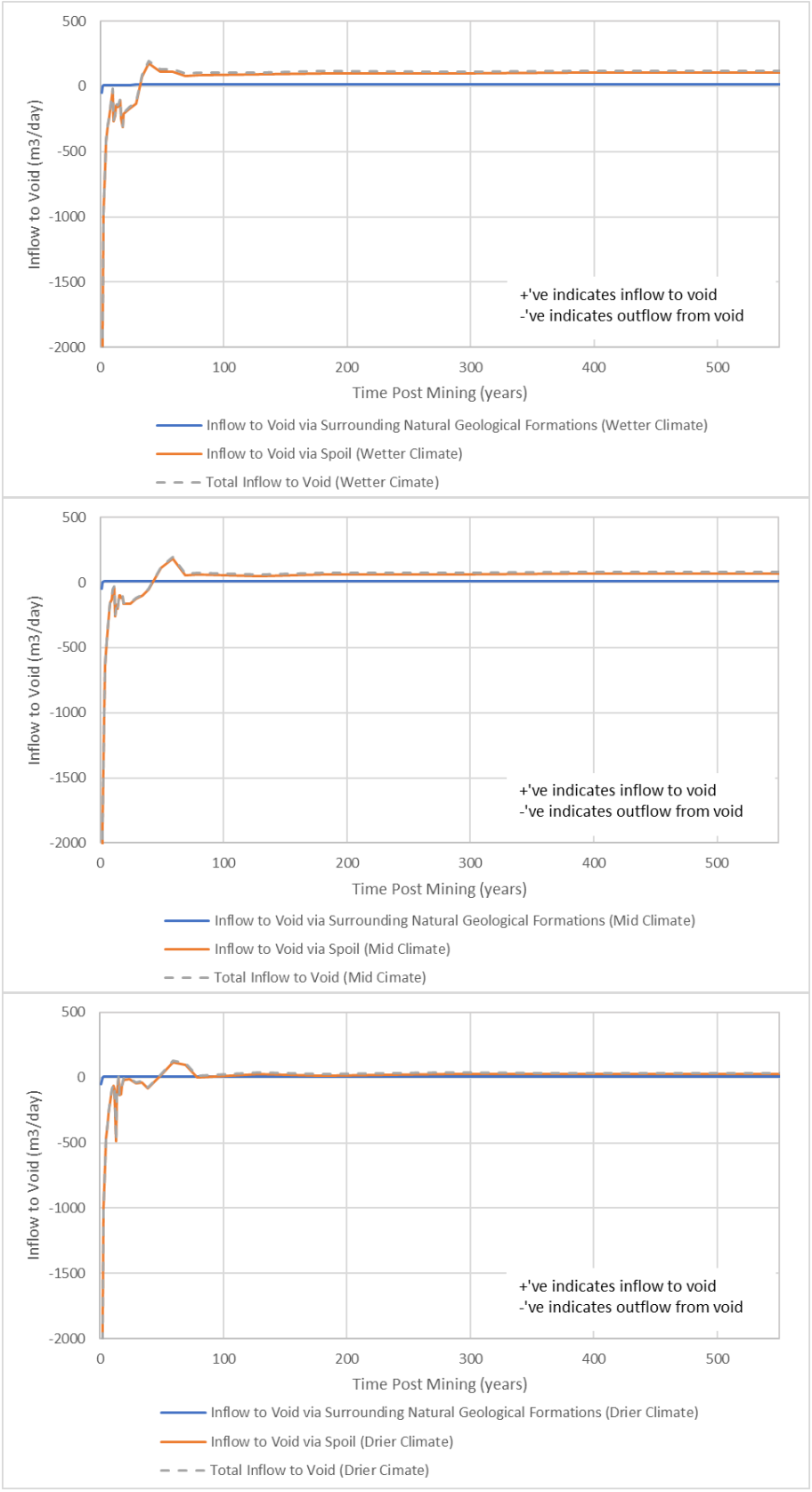


Figure 7-12 Predicted Void Groundwater Inflows – East2 Void

Predicted equilibrium groundwater inflows to each of the voids for the three climate scenarios are presented in **Table 7-9**. Model results indicate that, for the Lotus/Campbell, Gilbert, and East 1 and 2 residual voids, more than 79% of the long term groundwater inflow to the voids comes via the spoil, with between 2% and 29% of this inflow originating as local recharge applied to the spoil, and between 71% and 98% coming from natural geological formations before moving through the spoil into the residual void lakes. Price/Leichhardt residual void is distinct in having a much lower contribution to the void from spoil, with approximately 50% of total inflows occurring from the natural geological formations directly rather than through the spoil.

As previously discussed, except for the East voids, the equilibrium groundwater inflows to each of the voids shown in **Table 7-9** represent approximately 10% to 20% of the total volumetric inflow to each residual void's water balance (WSP, 2024), that is, groundwater volumetric contribution to the residual voids are very small in comparison to surface water (rainfall and runoff) contribution. Groundwater inflow to the East 1 and East 2 residual voids accounts for approximately 50% of the total volumetric inflow to these two residual voids (noting again that the hydrologic behaviour of the East Pit residual voids remains subject to change based on outcomes of further studies in the Roper Study Area as discussed in **Section 7.2.2**).

Table 7-9 Equilibrium Groundwater Inflow to the Residual Voids

Climate Scenario	Residual Void	Equilibrium Inflow Rate – Spoil (m^3/day)[1]			Equilibrium Inflow Rate – Natural Geological Formations (m^3/day)[3]	Equilibrium Inflow Rate – Total (m^3/day)
		From Natural Geological Formations into Spoil	From Rainfall Recharge on Spoil	Total Inflow from Spoil to Residual Void[2]		
Wetter	Lotus/Campbell	289.2	118.7	409.0	26.4	435.3
	Gilbert	201.6	62.5	265.5	30.6	296.1
	Price/Leichhardt	53.3	66.1	119.9	120.6	240.5
	East 1	346.0	7.9	353.9	12.6	366.5
	East 2	102.0	5.8	107.8	12.4	120.3
Mid	Lotus/Campbell	295.6	118.7	415.3	27.7	443.1
	Gilbert	205.4	62.5	269.4	31.6	300.9
	Price/Leichhardt	58.6	66.1	125.3	116.8	242.1
	East 1	261.2	7.9	269.2	17.3	286.4
	East 2	64.7	5.8	70.5	12.2	82.7
Drier	Lotus/Campbell	299.0	118.7	418.5	27.7	446.3
	Gilbert	208.2	62.5	271.8	30.8	302.7
	Price/Leichhardt	60.0	66.1	126.6	111.6	238.2
	East 1	202.8	7.9	210.8	18.1	228.9
	East 2	21.3	5.8	27.1	7.0	34.2

Notes:

1. Includes a component of groundwater from natural geological formations that moves into spoil, and a component of groundwater derived from local recharge on spoil, before discharging to the residual void lakes; refer **Figure 7-2**.
2. Any volumetric discrepancy between total inflow from spoil and the sum of the spoil inflow components is related to small ongoing residual changes in spoil storage occurring in the model as well as losses to evapotranspiration through spoil and rounding errors. Such discrepancies are typically less than 1% of the total spoil inflow.
3. Directly from natural geological formations into residual void lakes.

7.2.5 Predicted Groundwater Levels

Groundwater level predictions and associated discussion presented herein is focussed primarily on the Mid Climate scenario with the Drier and Wetter scenario's reported as sensitivities.

7.2.5.1 Mid Climate Scenario

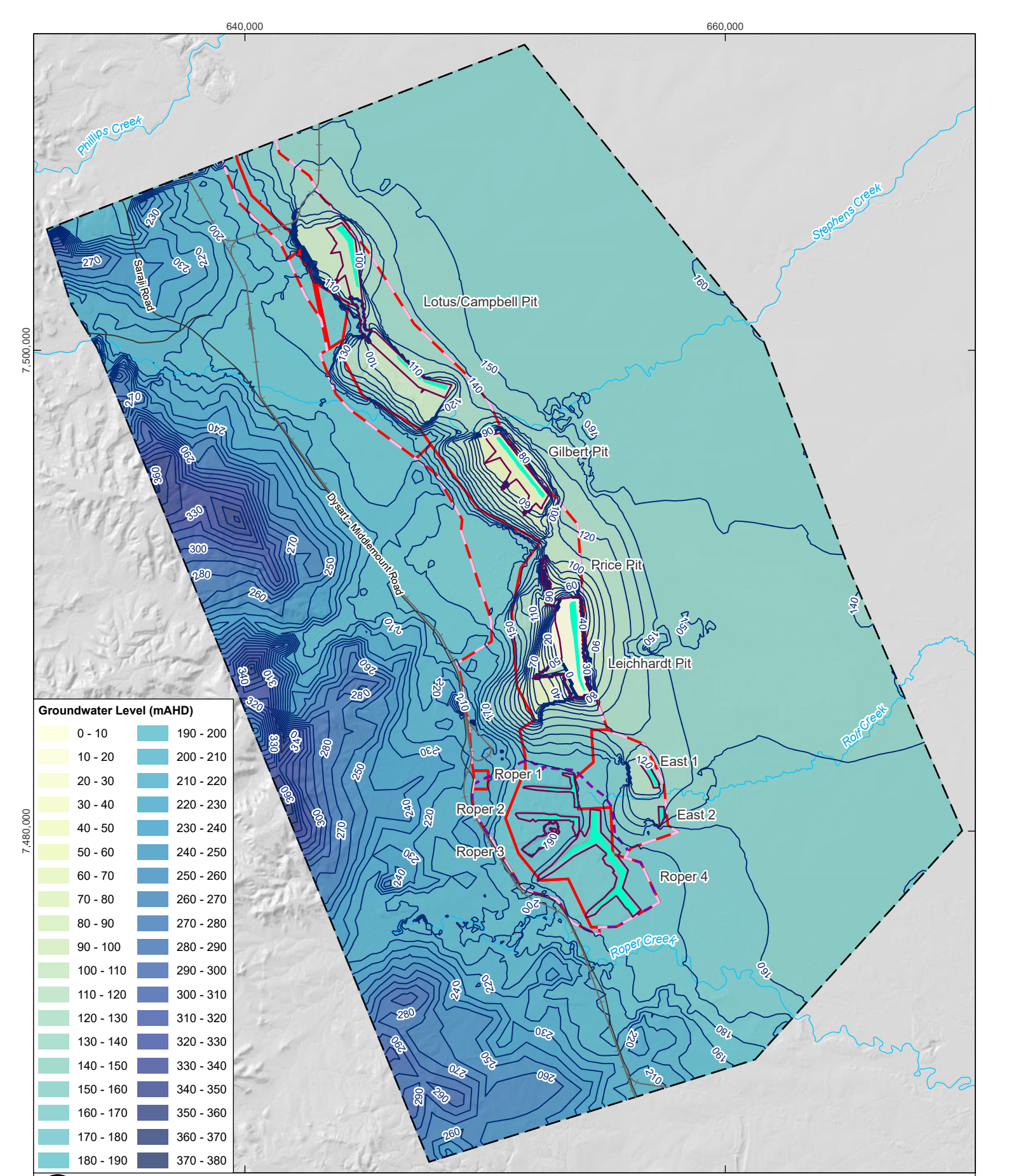
Groundwater Levels – General

The predicted equilibrium water table elevation adjacent the residual voids is shown on **Figure 7-13** for the Mid Climate scenario. Predicted groundwater levels for the Fort Cooper Coal Seams, Q, P, H and D Seams of the Permian Coal Measures (model layers 4, 6, 8, 10, and 12, respectively) outside of the residual voids are shown on **Figure 7-14** through to **Figure 7-18**, again at equilibrium for the Mid Climate scenario.

Groundwater levels surrounding the final voids are controlled by the predicted residual void lake levels, which in turn are controlled by the rate of evaporation from the void lakes balancing mostly surface inflows and some groundwater inflows to the lakes (WSP, 2024), including a component of groundwater that moves out of the natural geological formations into the residual voids via the spoil (refer **Table 7-9**). The conceptual relationship between these components is displayed in **Figure 7-2**. That is, predicted groundwater levels are a function of predicted lake levels, which as discussed in **Section 7.2.2** are dominantly controlled by surface water fluxes and maintained by evaporation.

The water table is predicted to remain depressed in the immediate vicinity of the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids in the long term, driven by the ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves. That is, long term inwards groundwater flow gradients are maintained post-mining for the water table at these voids.

Predicted groundwater levels for the Fort Cooper Seams, Q, P, H and D Seams of the Permian Coal Measures indicate again that groundwater levels in the Permian sequence are predicted to remain depressed in the immediate vicinity of the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids in the long term, driven by the ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves. The Fort Cooper Coal seam is predicted to remain 'dry' in the long term across most of the SSM Area, with some saturation present in the east of the Price/Leichhardt void. The Q seam is predicted to remain 'dry' in the long term across most of the SSM Area, with some saturation present in the east and south of the East 1 and East 2 voids. The P Seam is predicted to remain unsaturated across much of the SSM Area, however remains saturated along the eastern margin of the SSM Area, east of the residual voids. Flow gradients towards the East 1, East 2, and Price/Leichhardt voids are apparent in the P Seam. The H Seam is predicted to remain unsaturated across much of the SSM Area, except along the eastern margin, east of the residual voids, where it remains saturated. Flow gradients towards the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids are evident in the P Seam. D Seam levels show saturation across most of the SSM Area, with groundwater gradients showing discharge to mine voids (except in the case of Roper Study Area).



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Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	RB

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PREDICTED WATER TABLE ELEVATION – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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FIGURE 7-13

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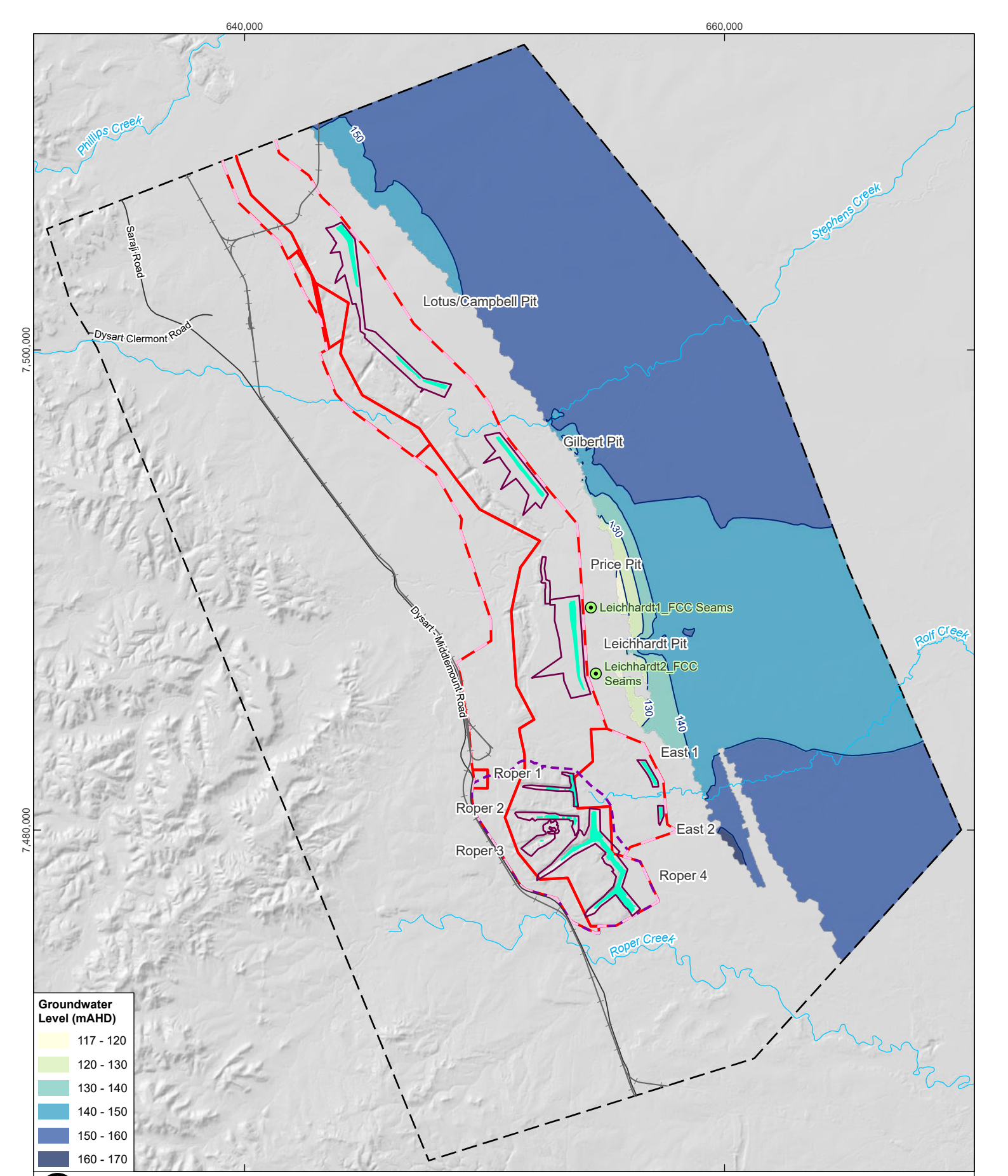

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SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED GROUNDWATER LEVELS IN THE FORT COOPER SEAMS (LAYER 4) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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FIGURE 7-14

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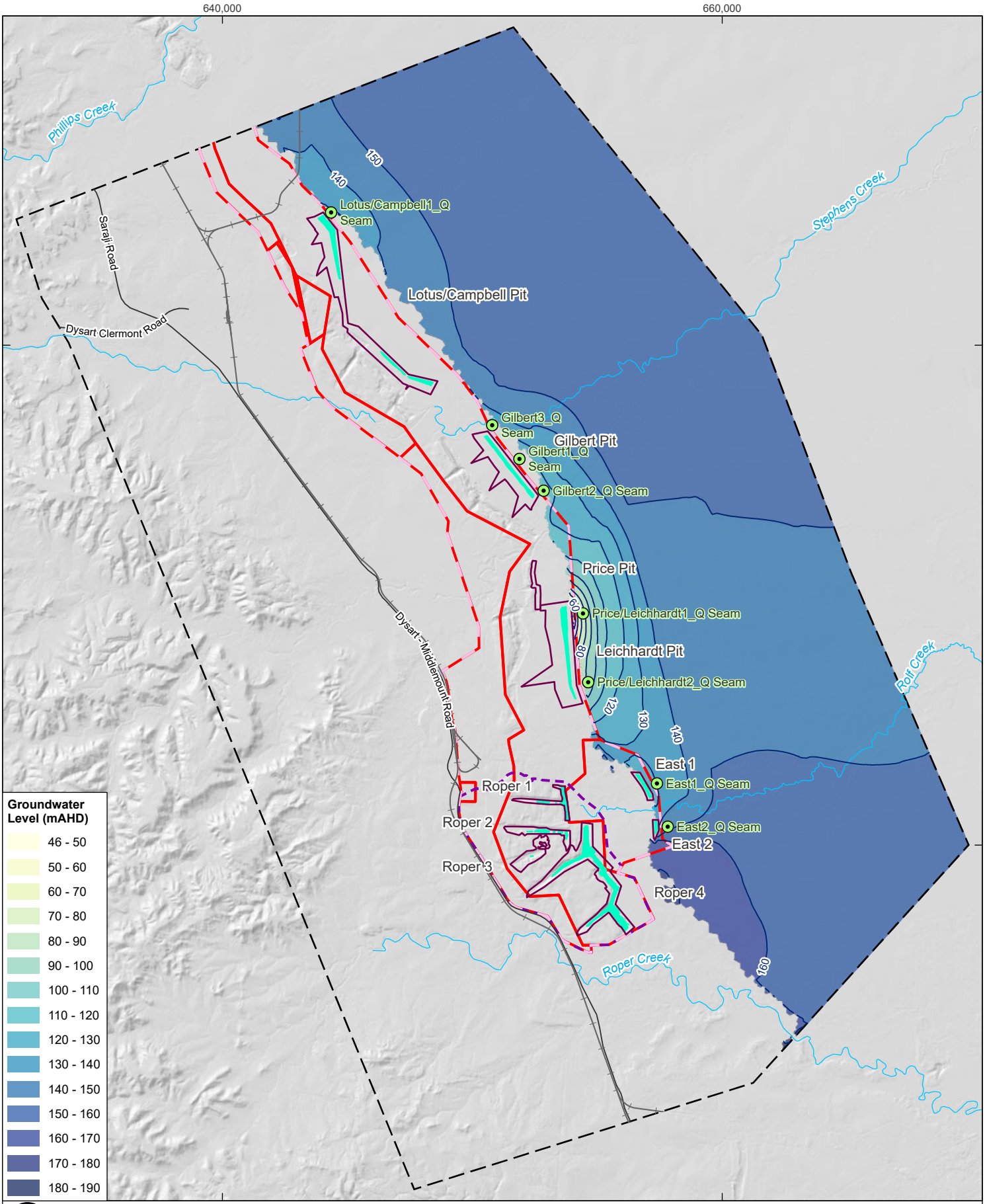

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Project Number:	620.314444.00000
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PREDICTED GROUNDWATER LEVELS IN THE Q SEAM (LAYER 6) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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FIGURE 7-15

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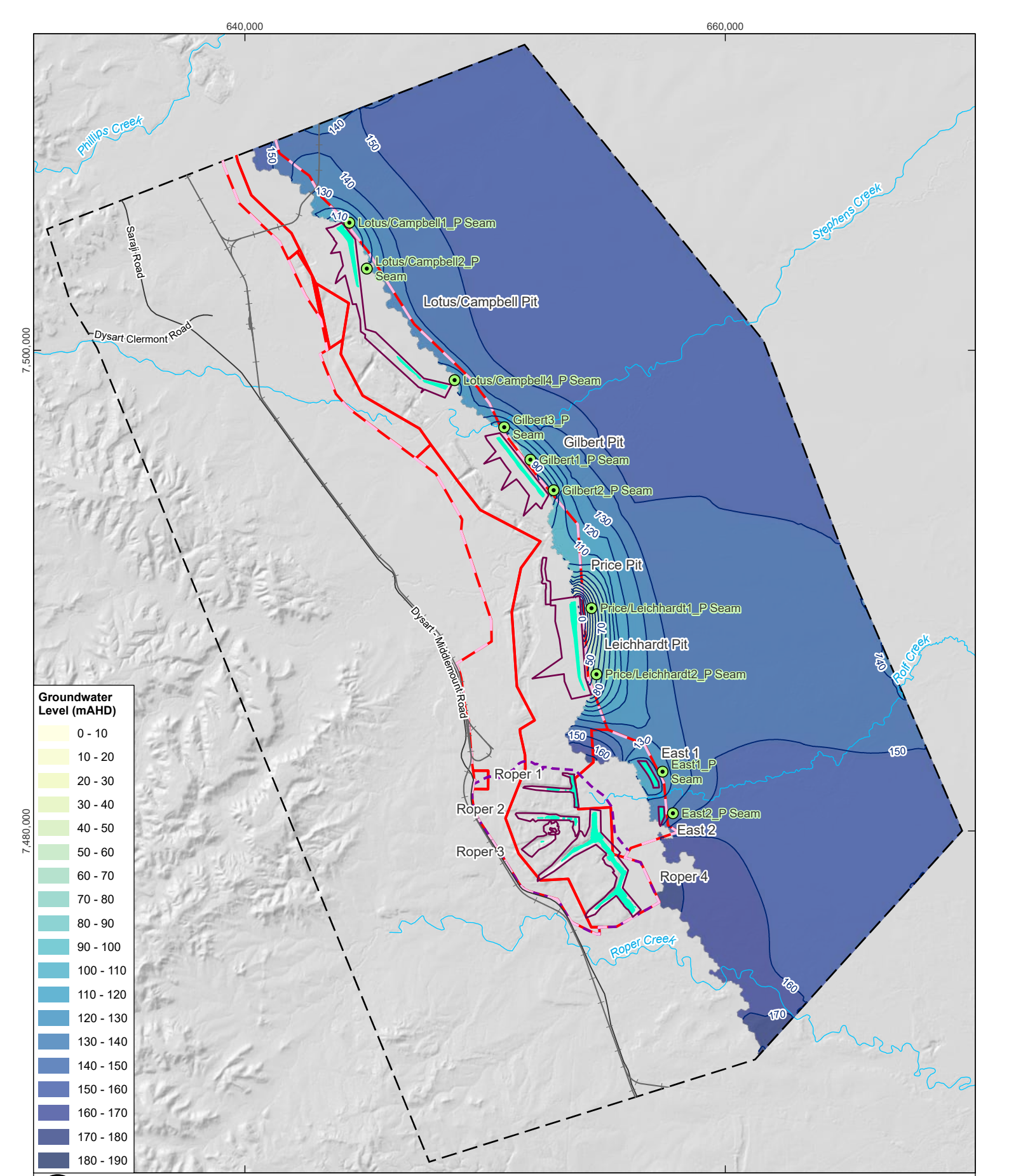

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PREDICTED GROUNDWATER LEVELS IN THE P SEAM (LAYER 8) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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FIGURE 7-16

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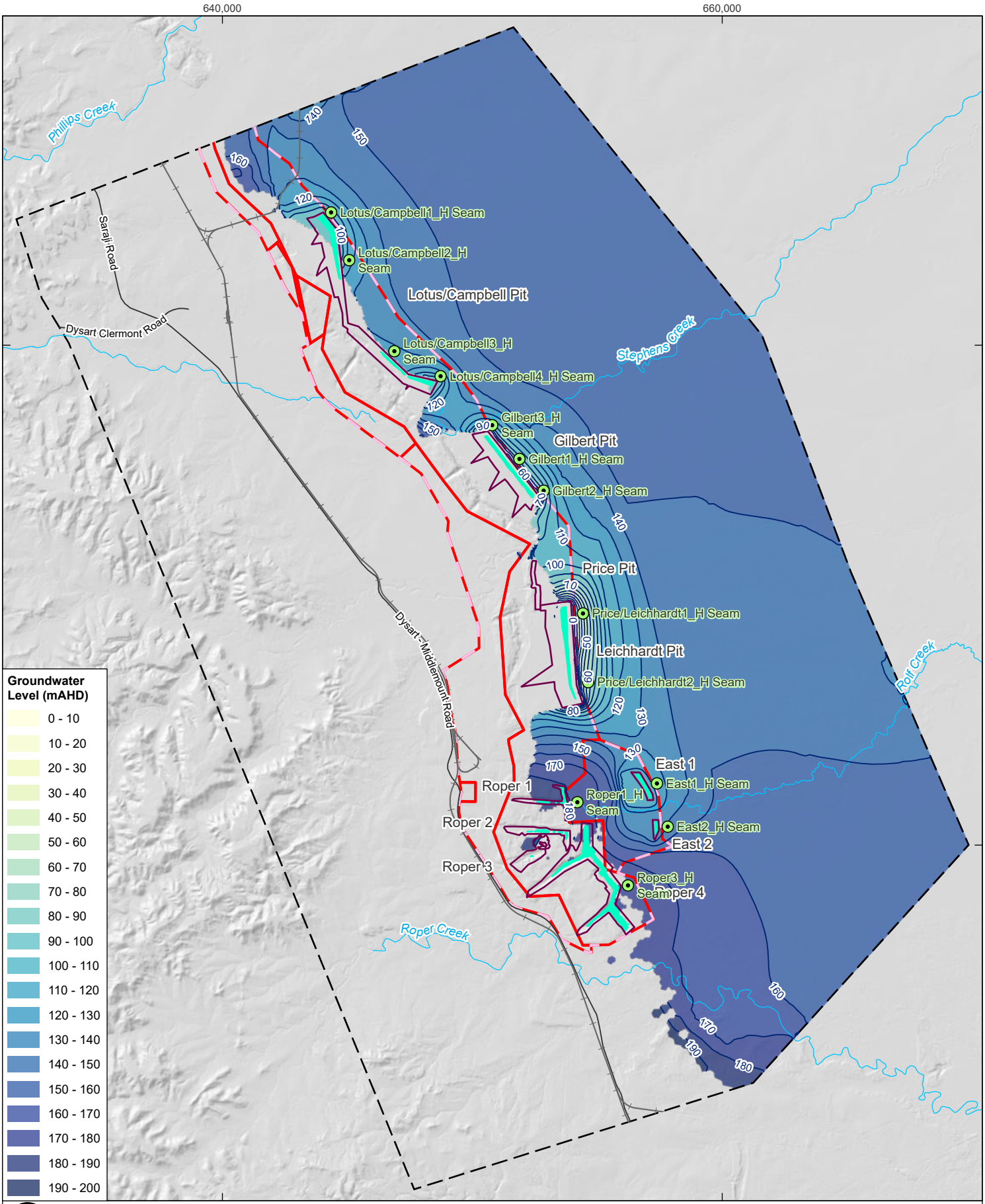

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Drawn by:	RB

LEGEND

- Hydrograph Location
- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary

SARAJI SOUTH MINE GROUNDWATER MODELLING TECHNICAL REPORT

PREDICTED GROUNDWATER LEVELS IN THE H SEAM (LAYER 10) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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FIGURE 7-17

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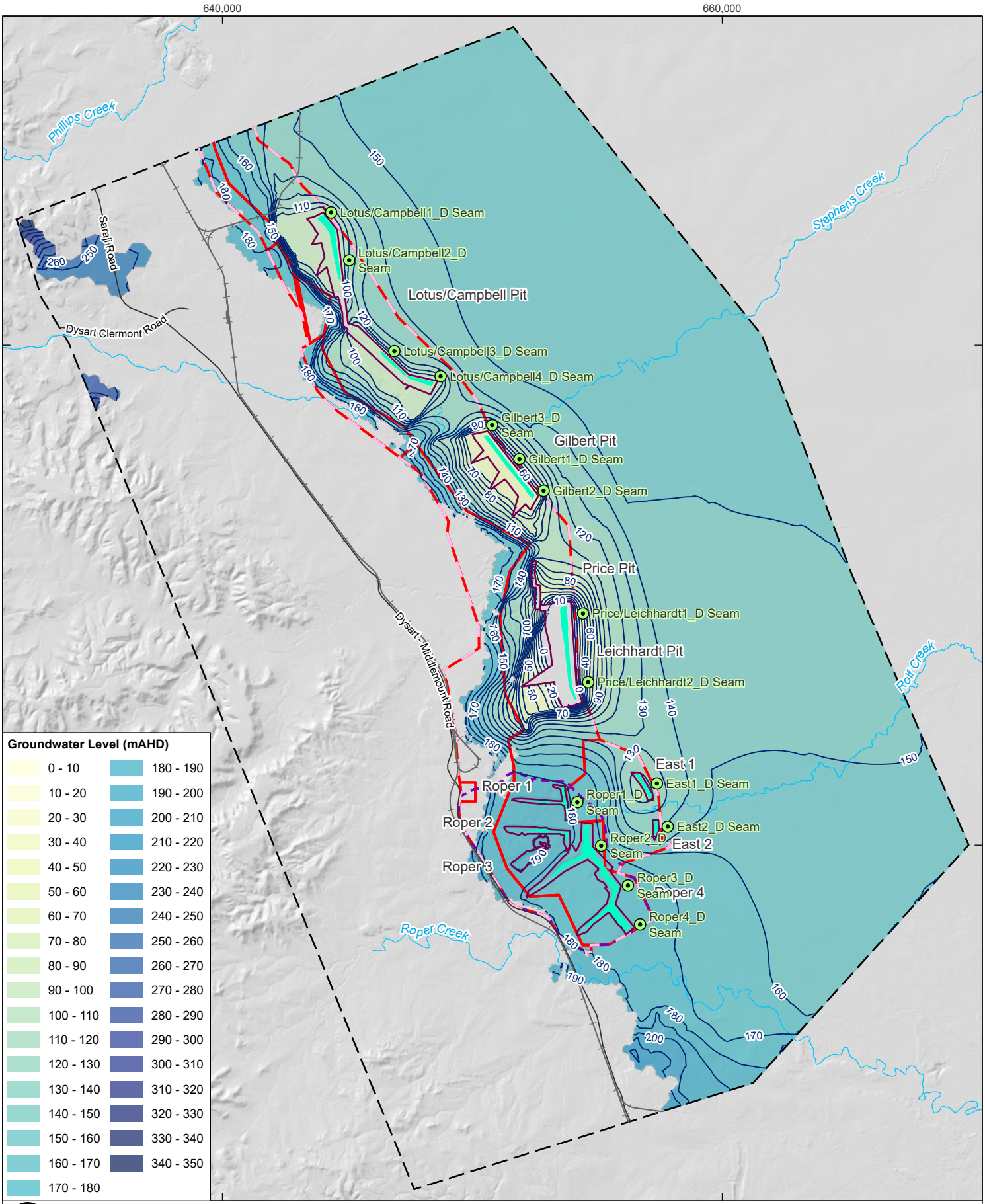

LEGEND

- Hydrograph Location
- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

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PREDICTED GROUNDWATER LEVELS IN THE D SEAM (LAYER 12) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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FIGURE 7-18

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Predictive hydrographs showing the change in groundwater levels over time for the Fort Cooper Seams, Q, P, H and D Seams of the Permian Coal Measures just outside (east) of the residual voids are shown in **Figure 7-19** through **Figure 7-31** with the hydrograph locations shown in **Figure 7-13** through to **Figure 7-18**. Given their relatively significant north-south strike length, four sets of predictive hydrographs have been generated for Lotus/Campbell and Roper voids, three sets for Gilbert void, and two sets for Price/Leichhardt void, as shown in the figures. In **Figure 7-19** through **Figure 7-31**, the green line represents the groundwater level in the related model layer.

The hydrographs demonstrate that the vast majority of groundwater level drawdown in the Permian Coal Measures occurs as a result of extractive mining operations. The hydrographs demonstrate very little effect on groundwater levels from the residual void inflow flux variability in the early post-closure period as shown and discussed in **Section 7.2.4**. The hydrographs show:

- For the Lotus/Campbell residual void:
    - The Fort Cooper Seam does not exist at the Lotus/Campbell residual void because the Fort Cooper Seam layer is pinched out at this location.
    - At the northern end of the residual void (hydrograph site Lotus/Campbell 1), lake levels are predicted to recover to within approximately 12 m of the predicted P Seam groundwater elevation just outside the void, within approximately 10 m of the predicted H Seam groundwater elevation just outside the void, and within approximately 10 m of the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 45 m above the void lake level.
    - At the central end of the residual void (hydrograph site Lotus/Campbell 2), lake levels are predicted to recover to approximately 23 m below the predicted H Seam groundwater elevation just outside the void, and approximately 19 m of the predicted D Seam groundwater elevation just outside the void. The P Seam is predicted to remain dry with its base more than 45 m above the void lake level. The Q Seam does not exist at the central end of the residual void (hydrograph site Lotus/Campbell 2) because the Q Seam layer is pinched out at this location.
    - At the central end of the residual void (hydrograph site Lotus/Campbell 3), lake levels are predicted to recover to approximately 35 m below the predicted H Seam groundwater elevation just outside the void, and approximately 25 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam and P Seam do not exist at the central end of the residual void (hydrograph site Lotus/Campbell 3) because the Q Seam and P Seam layers are pinched out at this location.
    - At the southern end of the residual void (hydrograph site Lotus/Campbell 4), lake levels are predicted to recover to approximately 32 m below the predicted P Seam groundwater elevation just outside the void, approximately 16 m below the predicted H Seam groundwater elevation just outside the void, and approximately 13 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam does not exist at the southern end of the residual void (hydrograph site Lotus/Campbell 4) because the Q Seam layer is pinched out at this location
- For the Gilbert residual void:
    - The Fort Cooper Seam does not exist at the Gilbert residual void because the Fort Cooper Seam layer is pinched out at this location.
    - At the northern end of the residual void (hydrograph site Gilbert 1), lake levels are predicted to recover to approximately 35 m below the predicted P Seam groundwater elevation just outside the void, approximately 31 m below the predicted H Seam groundwater elevation just outside the void, and approximately 26 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 79 m above the void lake level.
    - At the central end of the residual void (hydrograph site Gilbert 2), lake levels are predicted to recover to approximately 57 m below the predicted Q Seam groundwater elevation just outside the void, approximately 33 m below the predicted P Seam groundwater elevation

just outside the void, approximately 30 m below the predicted H Seam groundwater elevation just outside the void, and approximately 29 m below the predicted D Seam groundwater elevation just outside the void.

- At the southern end of the residual void (hydrograph site Gilbert 3), lake levels are predicted to recover to approximately 47 m below the predicted P Seam groundwater elevation just outside the void, approximately 42 m below the predicted H Seam groundwater elevation just outside the void, and approximately 34 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 91 m above the void lake level.

- For the Price/Leichhardt residual void:
  - At the northern end of the residual void (hydrograph site Price/Leichhardt 1), lake levels are predicted to recover to approximately 83 m below the predicted Q Seam groundwater elevation just outside the void, approximately 47 m below the predicted P Seam groundwater elevation just outside the void, approximately 46 m below the predicted H Seam groundwater elevation just outside the void, and approximately 46 m below the predicted D Seam groundwater elevation just outside the void. The Fort Cooper Seam is predicted to remain dry with its base more than 141 m above the void lake level.
  - At the southern end of the residual void (hydrograph site Price/Leichhardt 2), lake levels are predicted to recover to approximately 100 m below the predicted Q Seam groundwater elevation just outside the void, approximately 75 m below the predicted P Seam groundwater elevation just outside the void, approximately 72 m below the predicted H Seam groundwater elevation just outside the void, and approximately 63 m below the predicted D Seam groundwater elevation just outside the void. The Fort Cooper Seam is predicted to remain dry with its base more than 170 m above the void lake level.
- For the East 1 residual void, lake levels are predicted to recover to:
  - Approximately 13 m below the predicted Q Seam groundwater elevation just outside the void, and
  - Approximately 7 m of the predicted P Seam groundwater elevation just outside the void
  - Approximately 7 m of the predicted H Seam groundwater elevation just outside the void
  - Approximately 7 m of the predicted D Seam groundwater elevation just outside the void.
  - The Fort Cooper Seam does not exist at the East 1 residual void because the Fort Cooper Seam layer is geologically cropped out at this location.
  - .
- For the East 2 residual void, lake levels are predicted to recover to:
  - Approximately 11 m of the predicted Q Seam groundwater elevation just outside the void
  - Approximately 6 m of the predicted P Seam groundwater elevation just outside the void
  - Approximately 5 m of the predicted H Seam groundwater elevation just outside the void
  - Approximately 5 m of the predicted D Seam groundwater elevation just outside the void.
  - The Fort Cooper Seam does not exist at the East 2 residual void because the Fort Cooper Seam layer is geologically cropped out at this location.

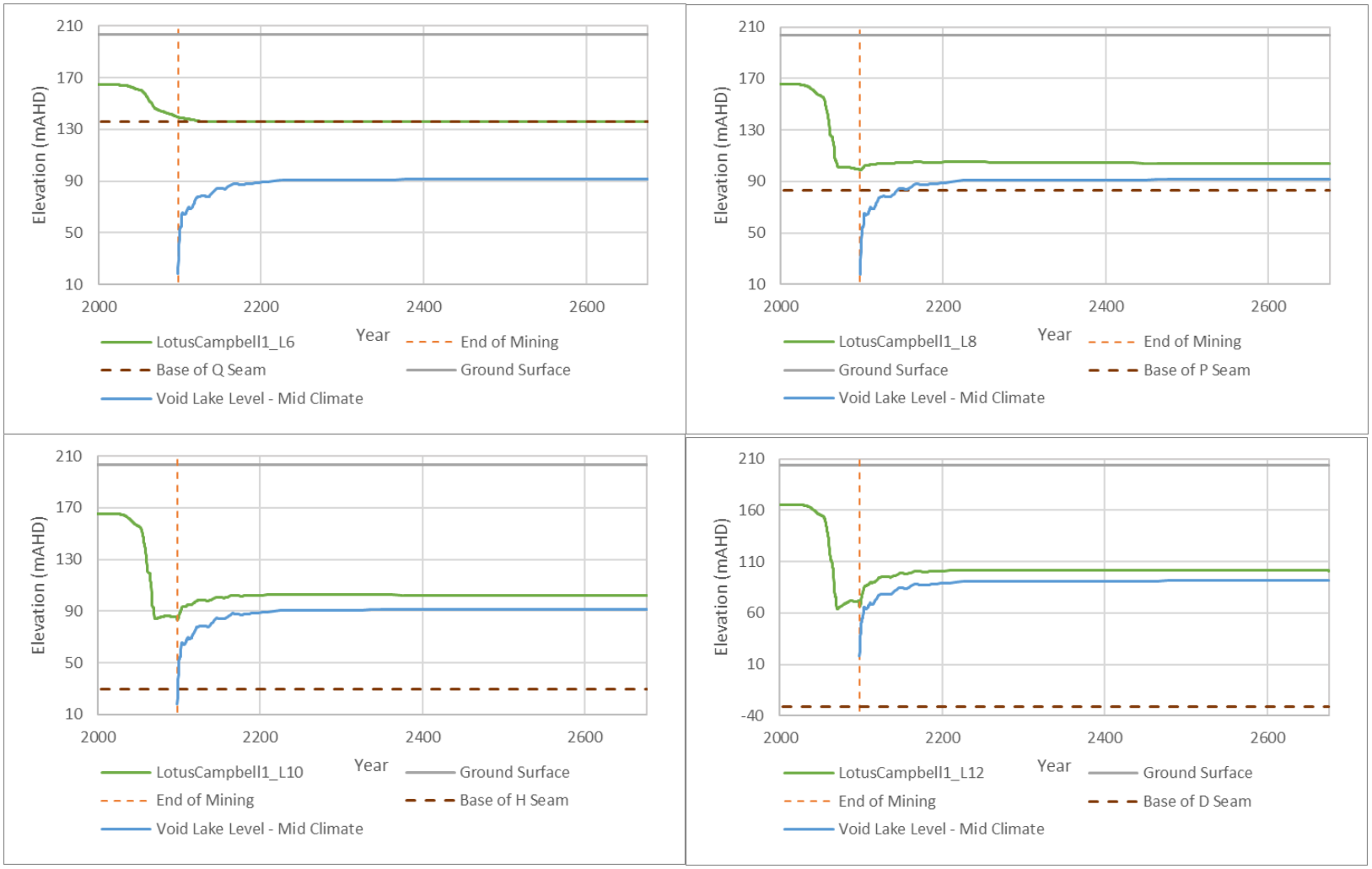


Figure 7-19 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (north)

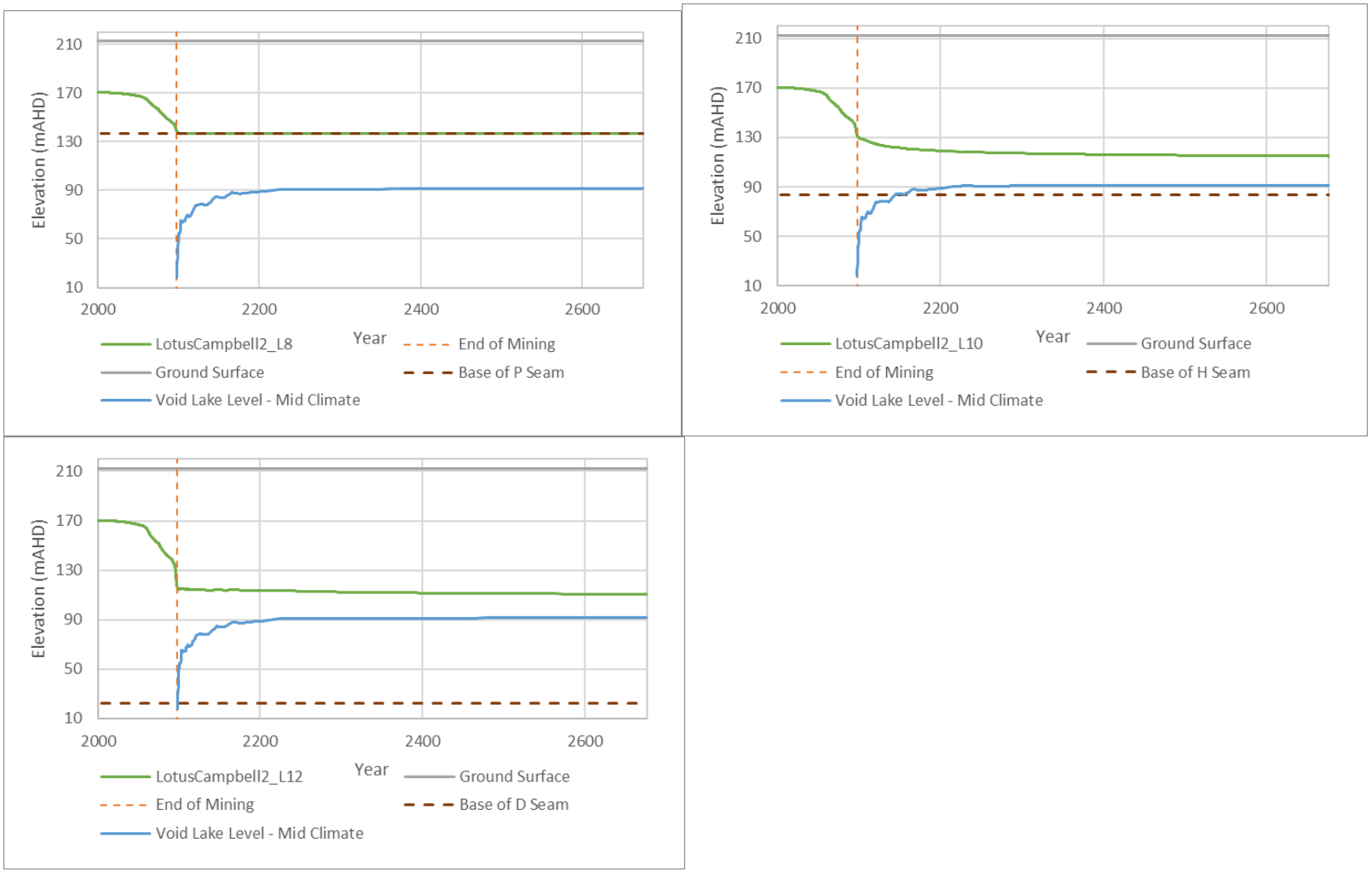


Figure 7-20 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (centre1)

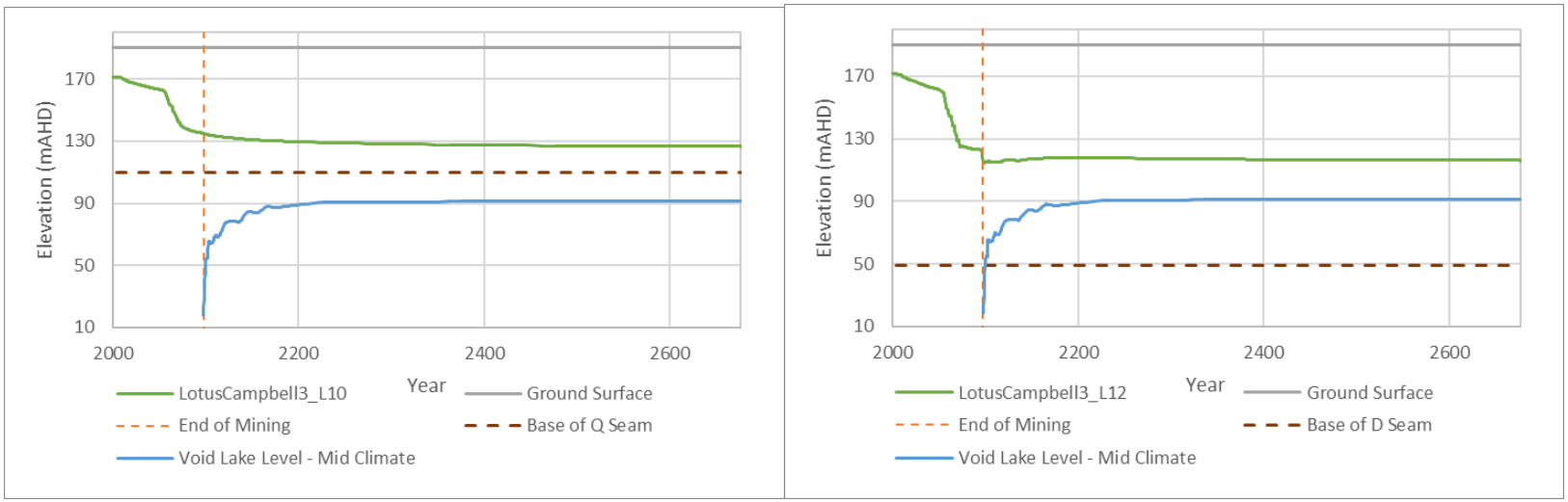


Figure 7-21 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (centre2)

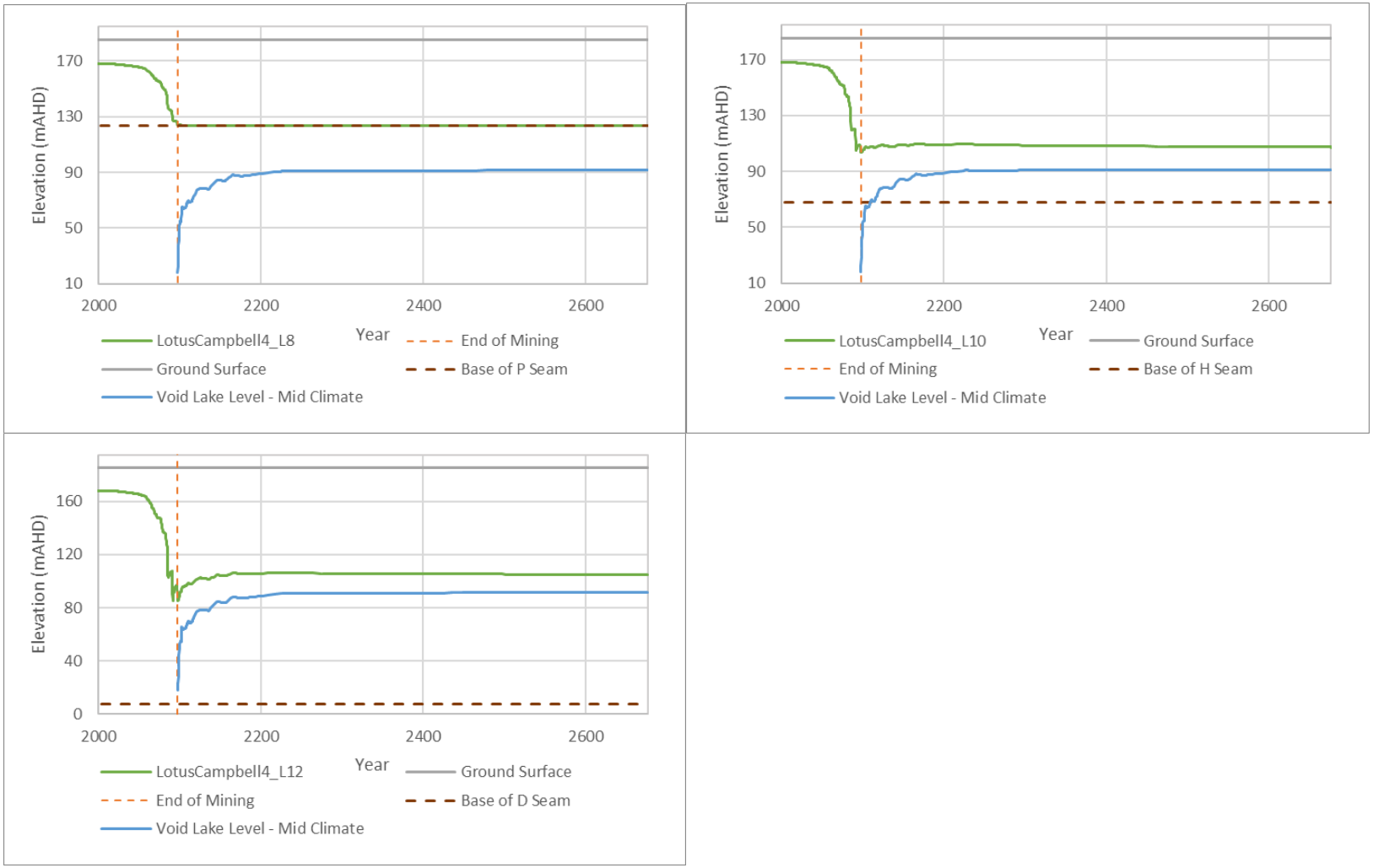


Figure 7-22 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (south)

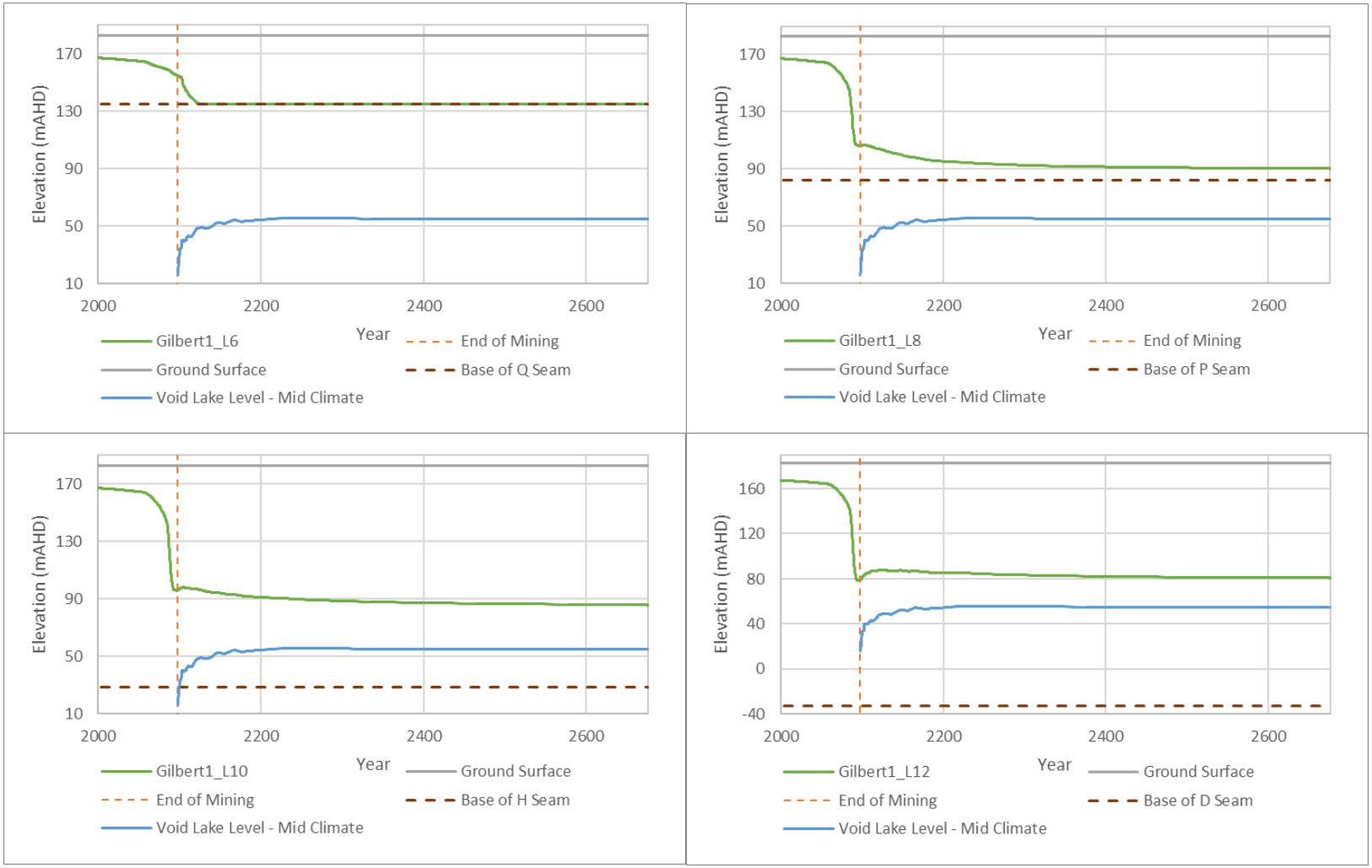


Figure 7-23 Coal Measures Predictive Hydrographs adjacent Gilbert Void (north)

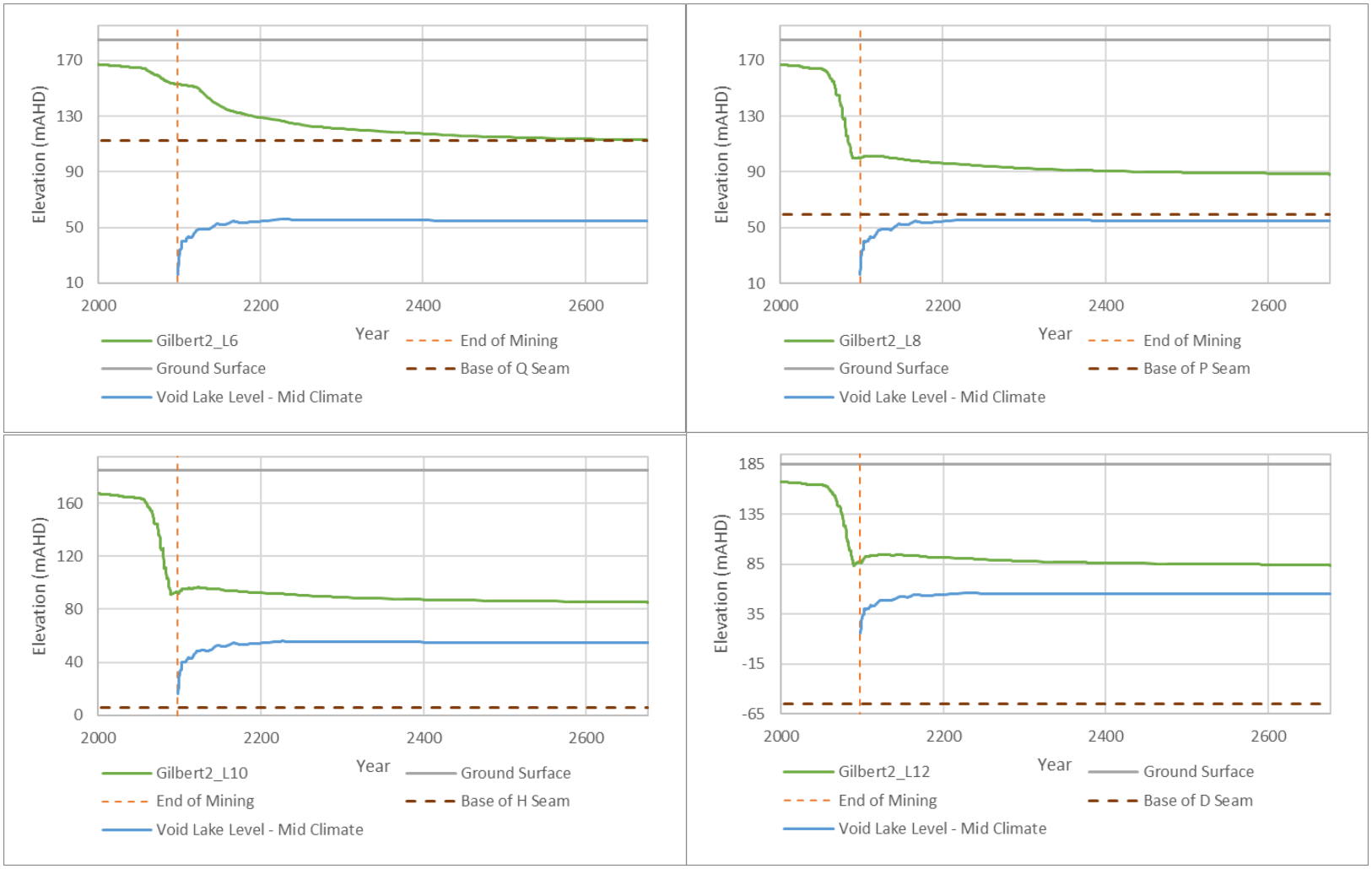


Figure 7-24 Coal Measures Predictive Hydrographs adjacent Gilbert Void (centre)

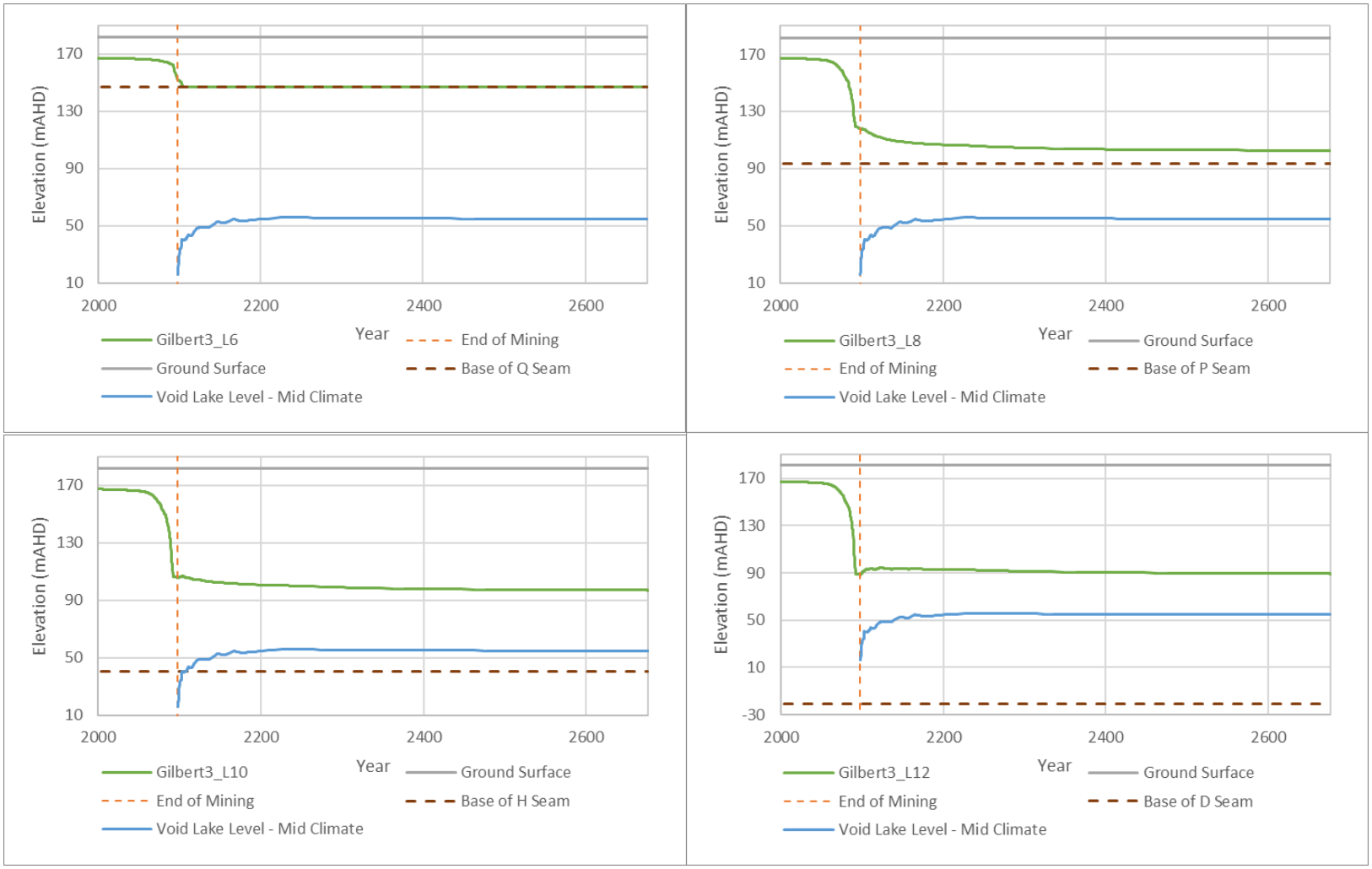


Figure 7-25 Coal Measures Predictive Hydrographs adjacent Gilbert Void (south)

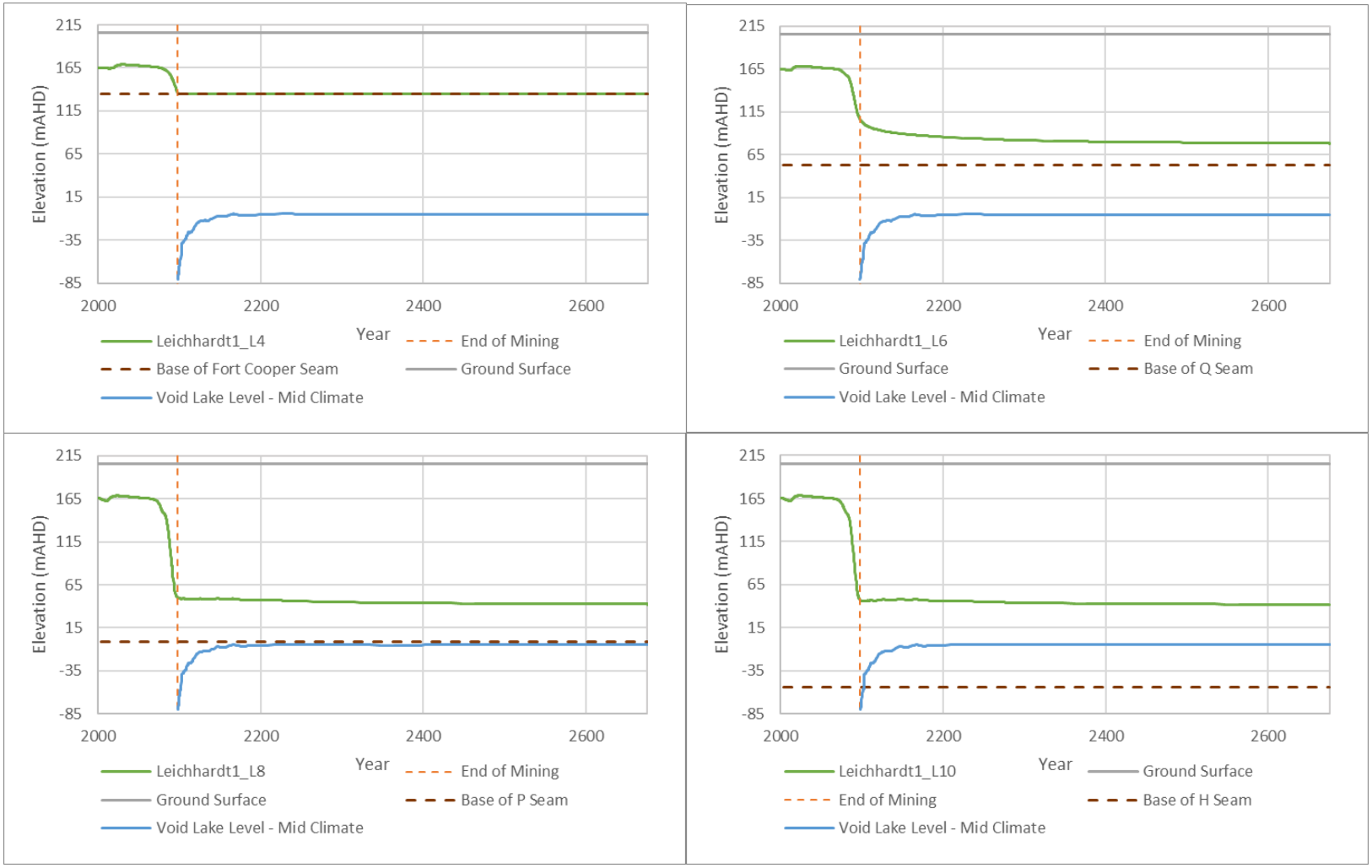


Figure 7-26 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (north)

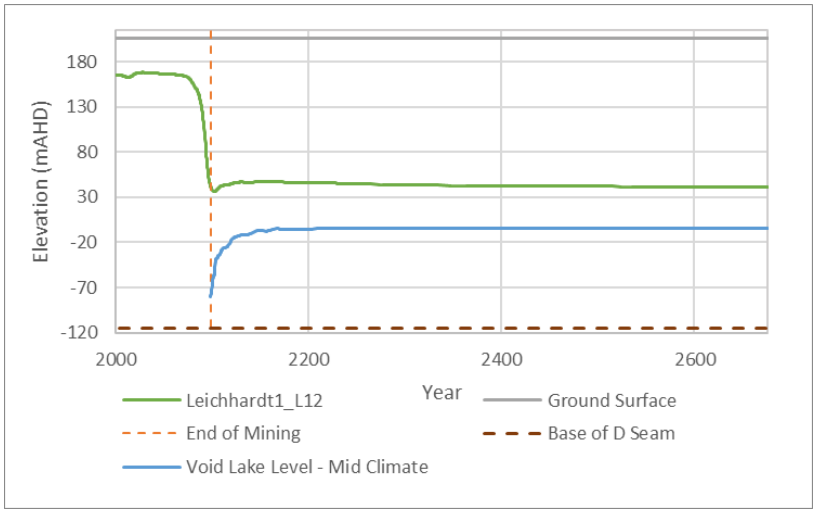


Figure 7-27 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (north) (cont.)

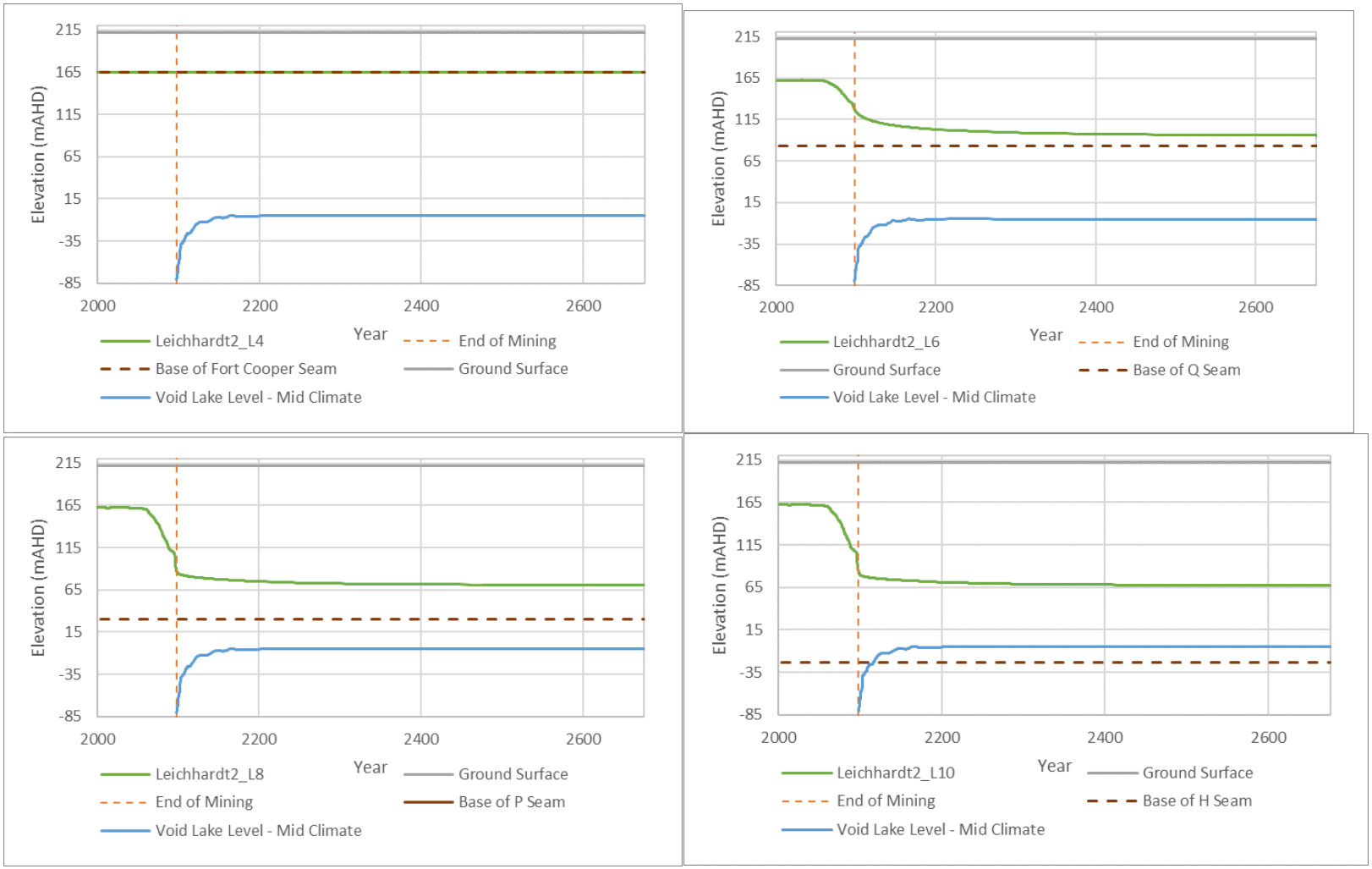


Figure 7-28 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (south)

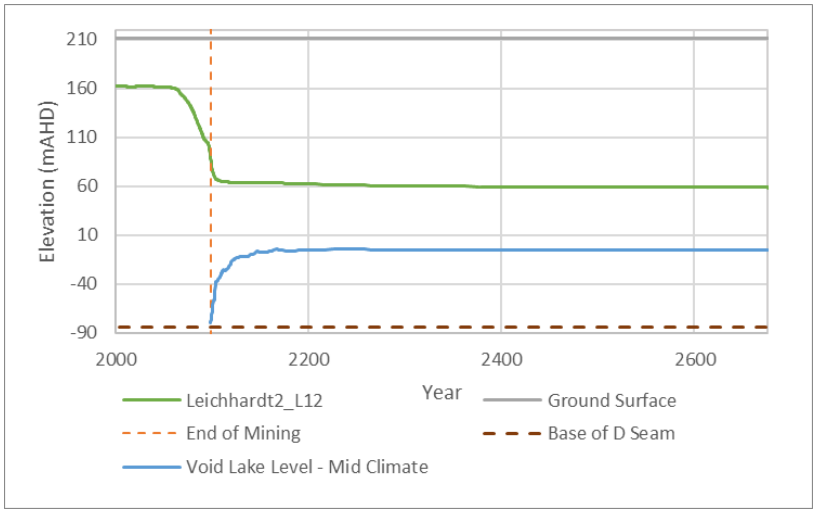


Figure 7-29 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (south) (cont.)

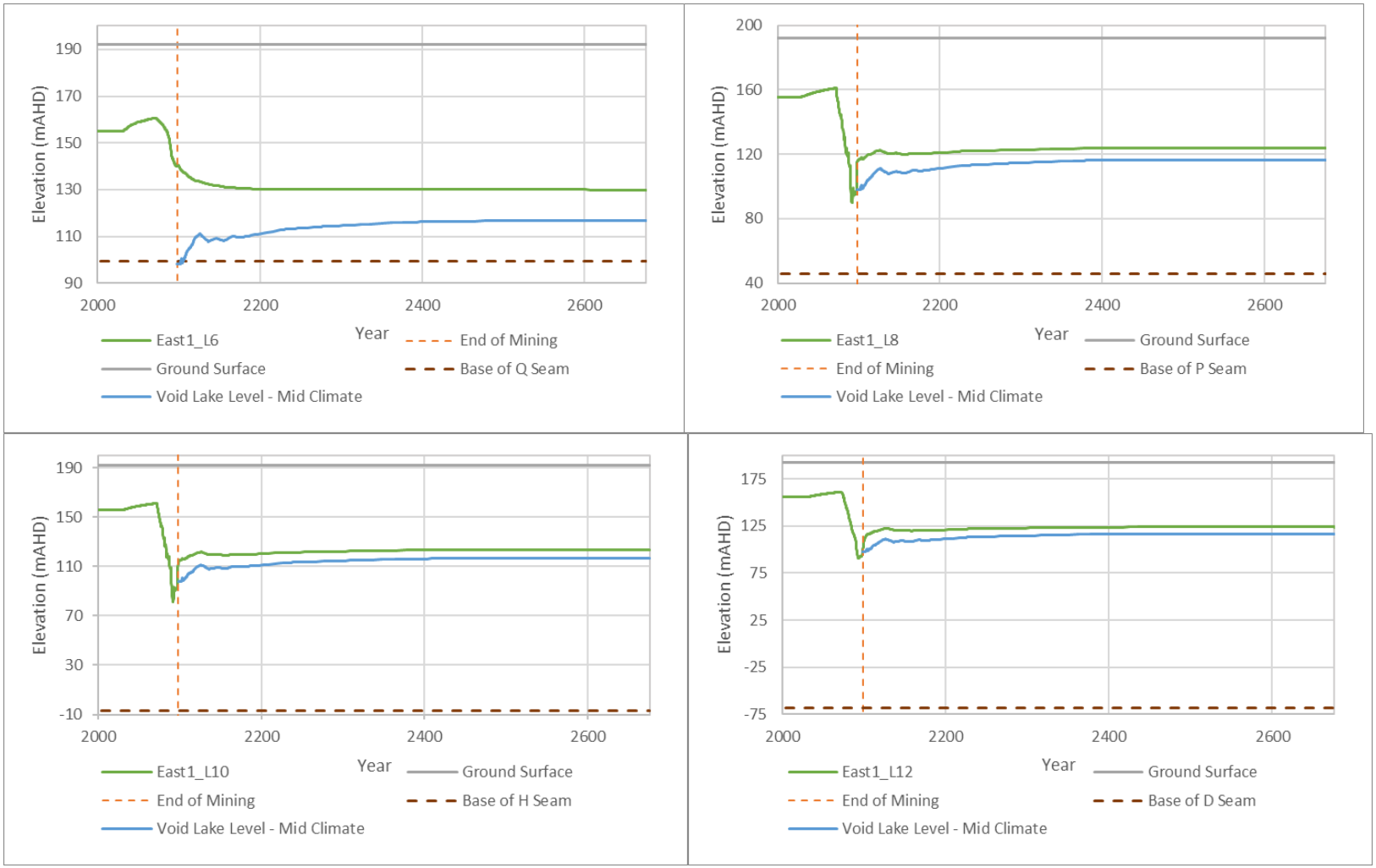


Figure 7-30 Coal Measures Predictive Hydrographs Adjacent East 1 Void

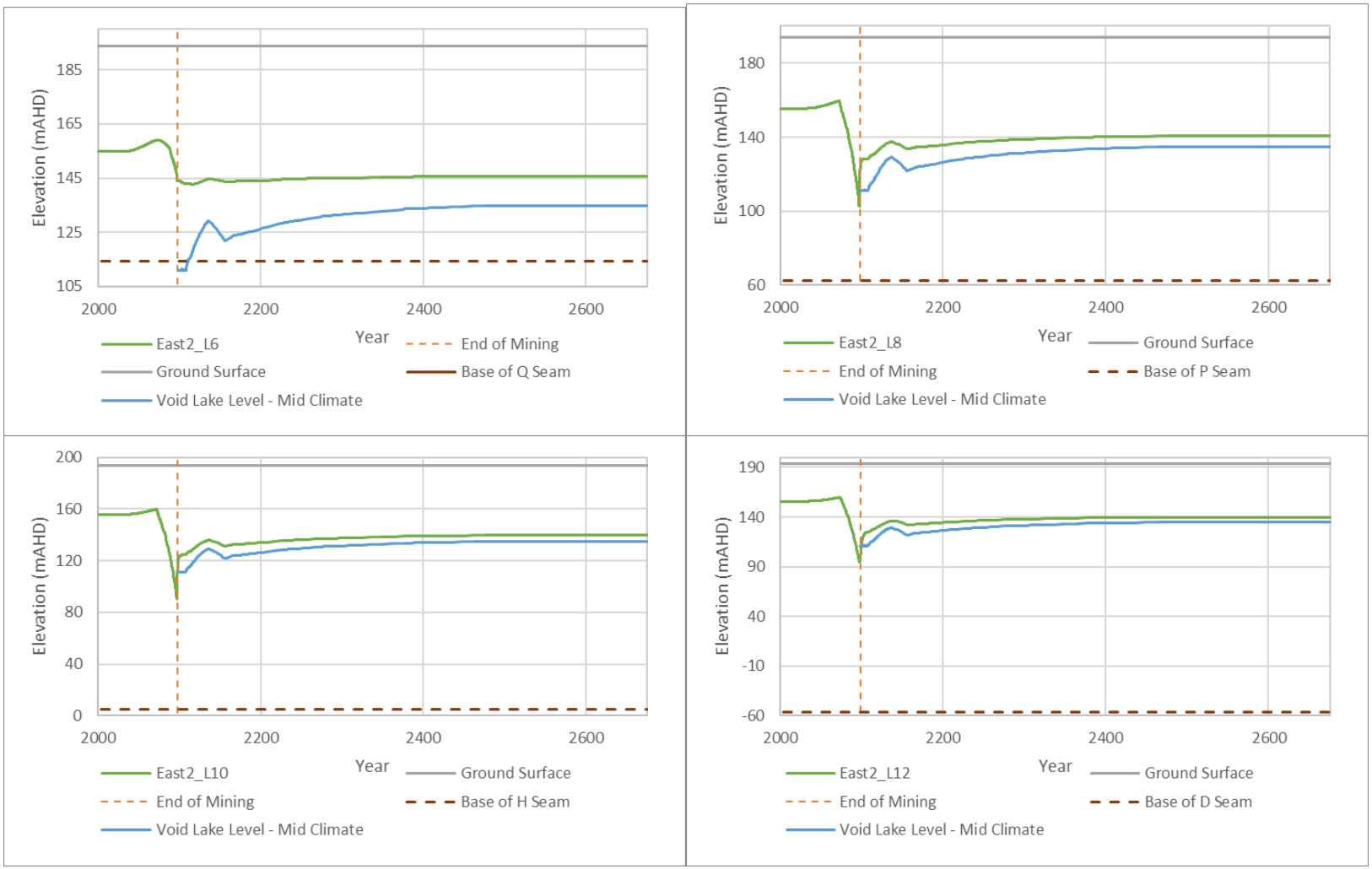
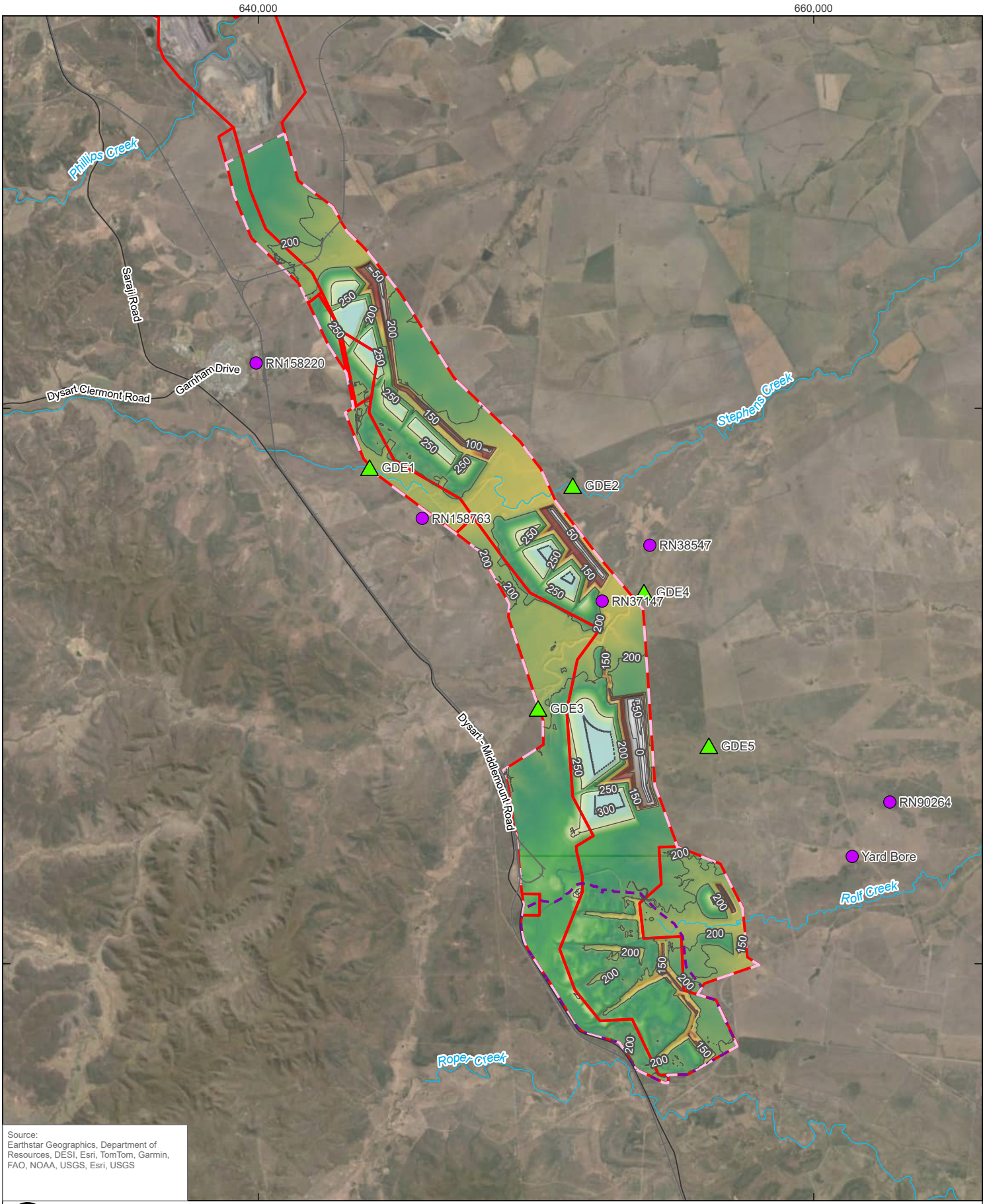


Figure 7-31 Coal Measures Predictive Hydrographs Adjacent East 2 Void

7.2.5.2 Groundwater Level Impacts to Potential Receptors

Predictive hydrographs have been derived from the groundwater model to understand the nature of likely groundwater level change in the interpreted source aquifer for identified potential natural and anthropogenic groundwater receptors in the vicinity of the SSM Area. The aim of the hydrographs is to assess the potential for additional impacts to these potential receptors in the period post-mining, i.e. identify additional potential impacts beyond those that have occurred during already approved mining operations that may be attributable to the PRC Plan's proposed final landform. **Figure 7-32** provides the locations of identified potential receptors, and the corresponding hydrographs.

Predictive hydrographs for the water table at the potential GDE sites identified in and adjacent to the SSM Area are provided as **Figure 7-33** and **Figure 7-34** for the mid climate scenario. The hydrographs also indicate that much of the water table drawdown in the vicinity of the potential GDEs is predicted to occur prior to the end of mining (i.e. associated with approved SSM mining operations), with any additional drawdown occurring over the post-mining period continuing the drawdown trends that commence prior to the end of mining. The shape of the hydrographs suggests that the additional drawdown impacts that occur in the post-mining period are residual impacts from approved previous active mining activities (i.e. a time lag from active mining), rather than new impacts caused by the PRC Plan's landform design; i.e. suggesting that the final landform is not contributing significantly to additional impacts at the potential GDE locations. Note there is no difference in the hydrographs for the drier or wetter climate scenarios.


640,000
660,000
7,500,000
7,480,000
Phillips Creek
Saraji Road
Dysart Clermont Road
Gernham Drive
Stephens Creek
Dysart - Middlemount Road
Rolf Creek
Rope Creek
RN158220
RN158763
RN38547
RN37147
RN90264
Yard Bore
GDE1
GDE2
GDE3
GDE4
GDE5
Source:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
0
2.5
5
km
LEGEND
Hydrograph Location
Bore
GDE
Topographic Contour (mAHD)
Railway
Major Road
Watercourse
SSM Mine Lease
SSM EA Boundary
Elevation (mAHD)
301
-80
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:180,000 at A4
Project Number: 620.314444.00000
Date Drawn: 21-Aug-2024
Drawn by: RB
SARAJI SOUTH MINE
GROUNDWATER MODELLING
TECHNICAL REPORT
POTENTIAL RECEPTOR
PREDICTIVE HYDROGRAPH
LOCATIONS
SLR
DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.
FIGURE 7-32
Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_MOD_F3_41_Potential Receptor Predictive Hydrograph Locations

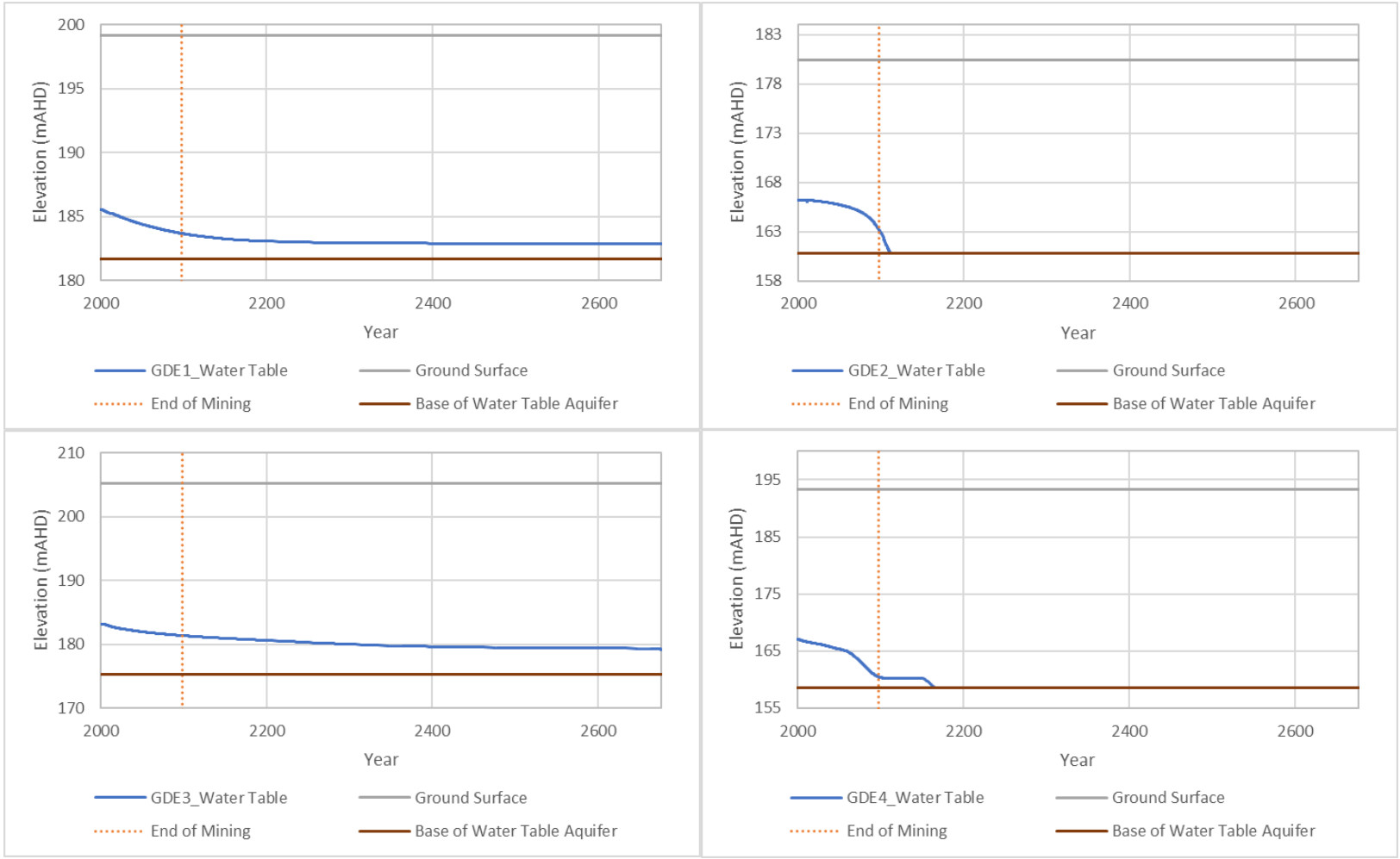


Figure 7-33 Water Table Hydrographs at Potential GDEs

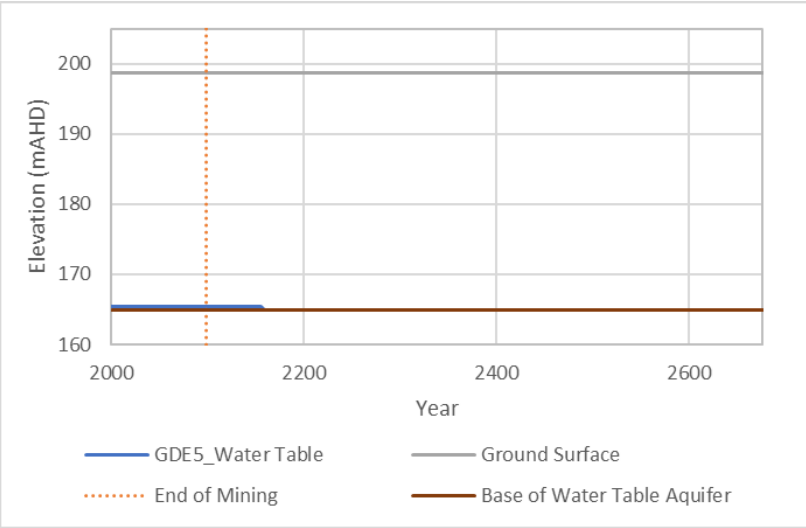


Figure 7-34 Water Table Hydrographs at Potential GDEs (cont.)

Predictive hydrographs for the identified third party water supply bores with sufficient information to attribute a source aquifer (see **Table 4-8** in **Section 4.5.1**) are provided as **Figure 7-35** for the mid climate scenario. Some long-term post mining groundwater drawdown of less than 5 m is predicted at bores RN37861, RN43060, RN43794, RN90017, RN158220, RN158763, and RN90264, located in the Fort Cooper Coal Measures, between 1 and 3 km east of the Gilbert, Price/Leichhardt and Lotus Campbell voids. For the bores RN38547, RN43061, RN89469, RN89470, and RN90014, a relatively significant amount of drawdown is predicted in the long term post-mining noting that it takes hundreds of years for the maximum drawdown to occur, which is well beyond the expected service life of a groundwater bore. This drawdown is considered to be mostly related to a time lag from during-mining impacts, plus also regional scale influences represented in the model (i.e. other mining activities) given the bore accesses groundwater from geological units not present across the majority of the SSM Area. The maximum drawdown at this bore is greater than the relevant 5 m drawdown 'bore trigger threshold' for consolidated aquifers (i.e. the Fort Cooper Coal Measures) identified in Chapter 3 of the *Water Act 2000*, i.e. the threshold at which drawdown impacts may need to be further investigated for the purposes of determining any requirement to 'make good' a bore impairment.

Note there is no difference in the hydrographs for the drier or wetter climate scenarios.

The bores RN84538, RN136092, and the unregistered House Bore are located outside the model boundary, and therefore have not been included in the model assessment.

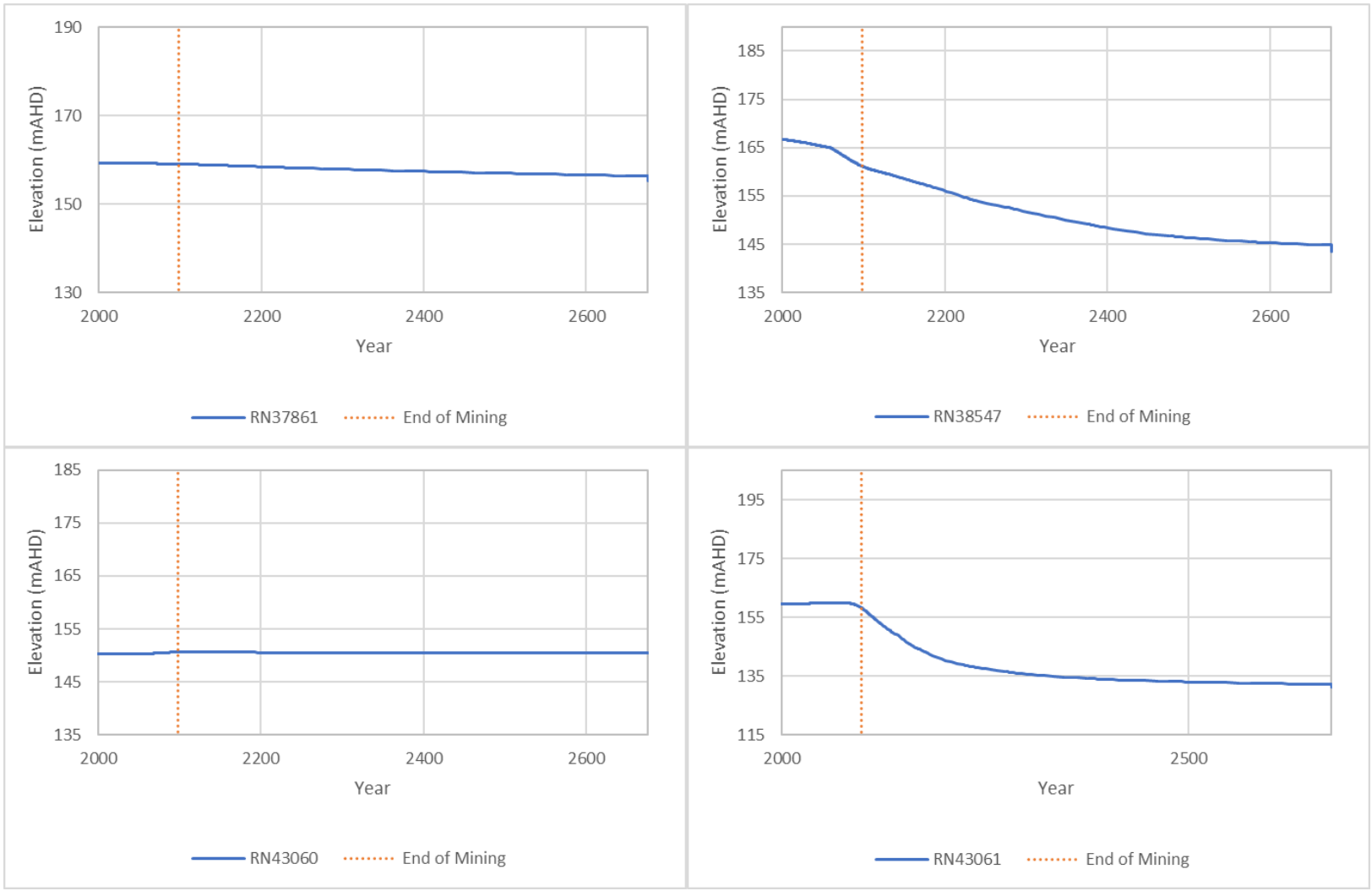


Figure 7-35 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer

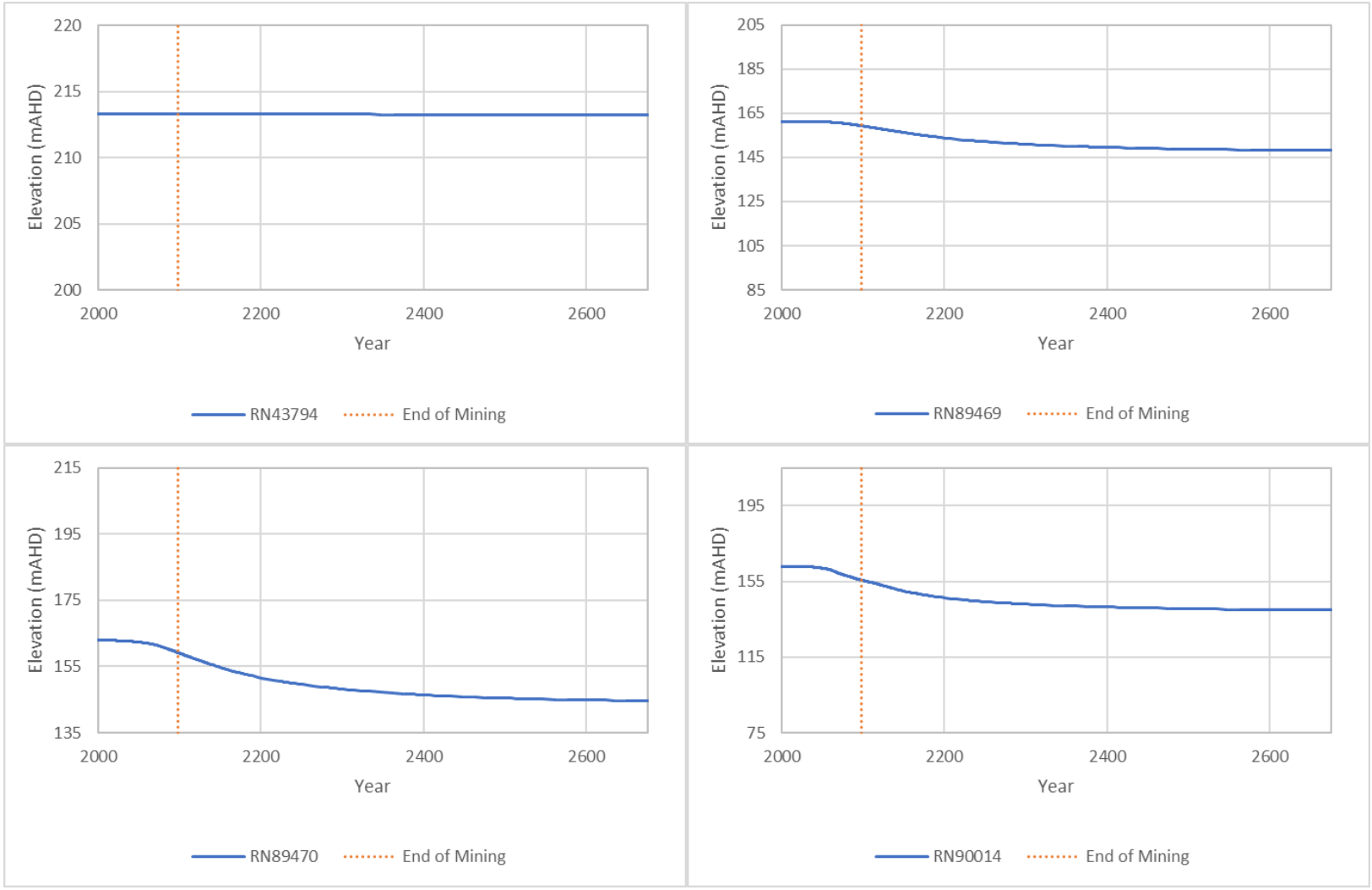


Figure 7 46 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer (cont.)

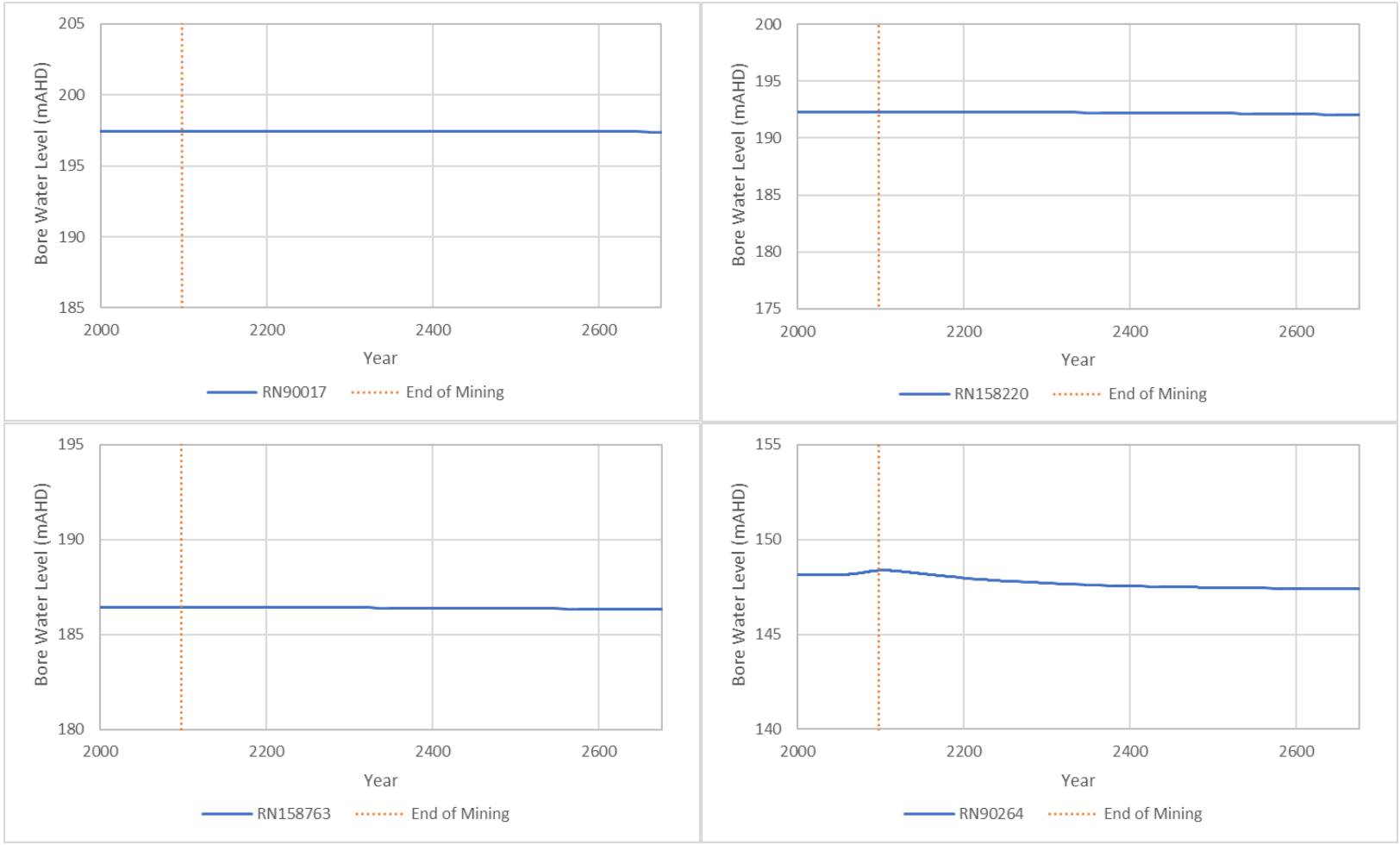


Figure 7 46 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer (cont.)

7.2.6 Flow Path Simulation

An analysis of the water movement within the final landform was undertaken to simulate and assess the movement and fate of water particles through the groundwater system post-mining. A number of particles were placed on the final landform and within the residual voids in the recovery groundwater model and the mod-PATH3DU code (S.S. Papadopulos & Associates, 2018) was used to simulate particle pathways along the groundwater flow field during recovery (i.e. 578 years). To run the mod-PATH3DU code the transient head outputs from the groundwater flow model were used by mod-PATH3DU to simulate particle flow path lines.

Figure 7-36 shows the initial location of particles on the final landform. The particles were placed at the surface of the model and released at the start of the post-mining simulation, with the movement of the particles then recorded during the post-mining simulation. It should be noted that the mod-PATH3DU code automatically moves the particle from the model surface to the shallowest saturated layer at the commencement of the simulation. As shown on **Figure 7-36**, for many of the particles, this represents the Permian layers (including areas of spoil backfill in model layers that represent Permian units pre-mining) as the shallow layers (Layers 1 and 2) are unsaturated across much of the SSM Area at the commencement of the post-mining simulation. Locations where the model predicts saturation in the shallow groundwater system (i.e. Layer 2) at the end of mining.

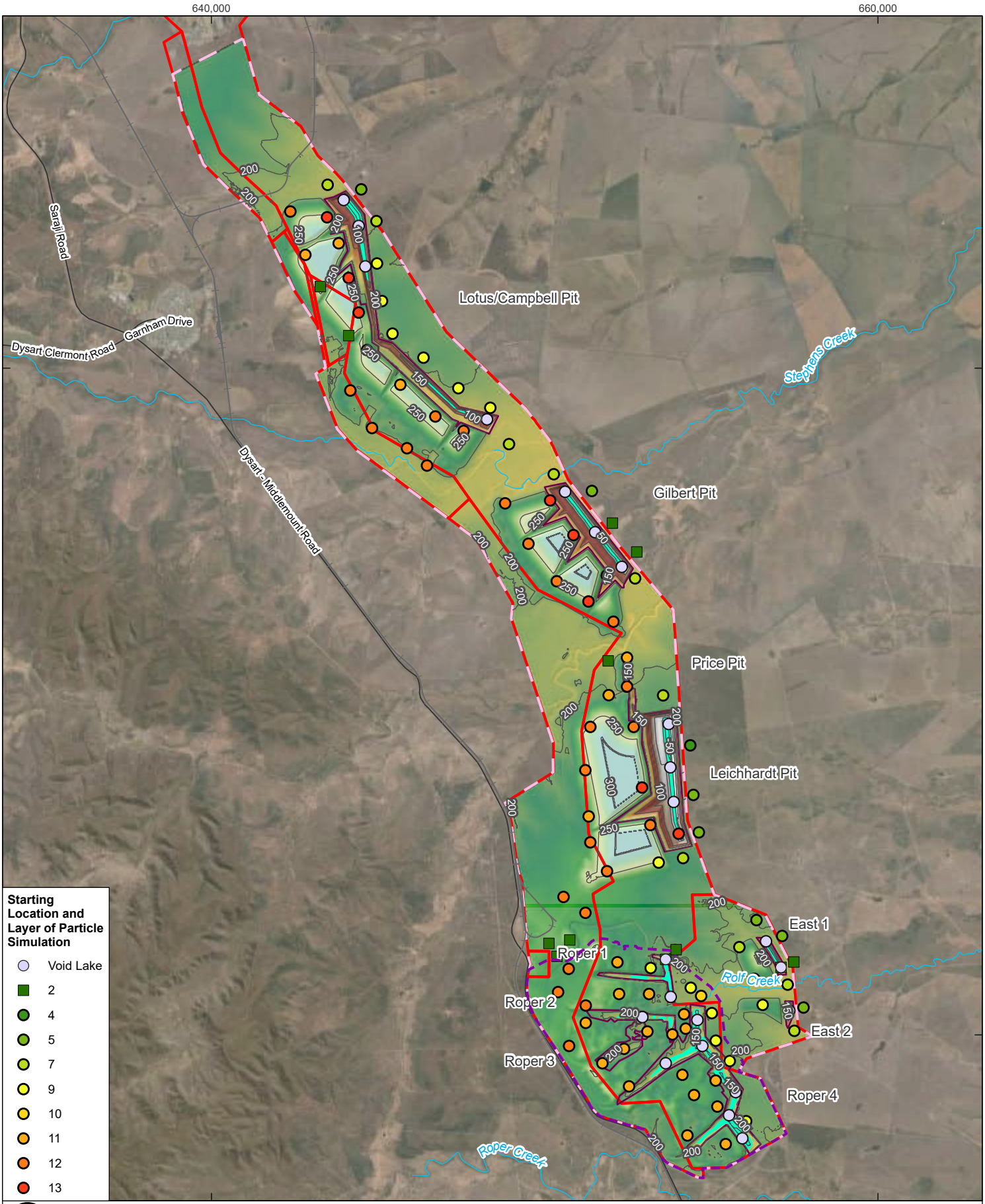
7.2.6.1 Mid Climate Scenario

Figure 7-37 shows the predicted movement of water particles in the 578-year recovery simulation of the final landform for the Mid Climate scenario. The colours along the predicted particle flow paths provides the model layer the particle was simulated to be moving through, with the green to red scale classification representing particles moving from shallow to deep model layers.

The colour changes along the paths on **Figure 7-37** indicate that particles situated within the shallower saturated layers at the beginning of the post-mining simulation generally move progressively toward deeper layers representing the Permian coal measures (or backfilled spoil where the coal measures has been mined out) over the post-mining period. The flow path analysis indicates the particles generally move toward the void lakes, with many of the particles captured in the voids. No particles are shown to move significantly away from the SSM Area to the broader receiving environment.

Overall, the particle movement simulation indicates that groundwater on SSM, including that flowing through spoil of the final landform and that beneath the mine area, would remain within the final landform (e.g. backfilled spoil and voids) in the long term for all mine voids except for the Roper Pits. As noted in Hydrogeological Assessment introduction, the Roper Study Area requires further investigations and development of the closure landform. For all other mine voids, particle movement simulation shows that no groundwater originating from the SSM is predicted to flow to the receiving environment, i.e. the voids would remain groundwater sinks and groundwater would not flow from the residual voids off-site. The figure below shows that this may not be the case for the Roper pits, though PMLU and final landforms will be developed to address this potential risk as part of future separate studies for the Roper Study Area.

Given that the particle pathlines are simulated from the start of recovery, they generally follow predicted head gradients. However, the particle directions at times appear to be contrary to the head contours/gradients shown on **Figure 7-37**. It should be noted that the contours shown on **Figure 7-37** only represents the final head pattern when the aquifer has reached an equilibrium and hence does not necessarily show the transient head changes occurring during the 578-year recovery simulation, given the recovery simulation commences from the first year post-mining. For example, head gradients will change over the 578 years of recovery simulation as void lake levels stabilise and the groundwater system recovers partially from mining.



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:150,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Topographic Contour (mAHD)
- Railway
- Major Road
- Watercourse
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

Elevation (mAHD)

301

-80

SARAJI SOUTH MINE TRANSITIONAL PRCP

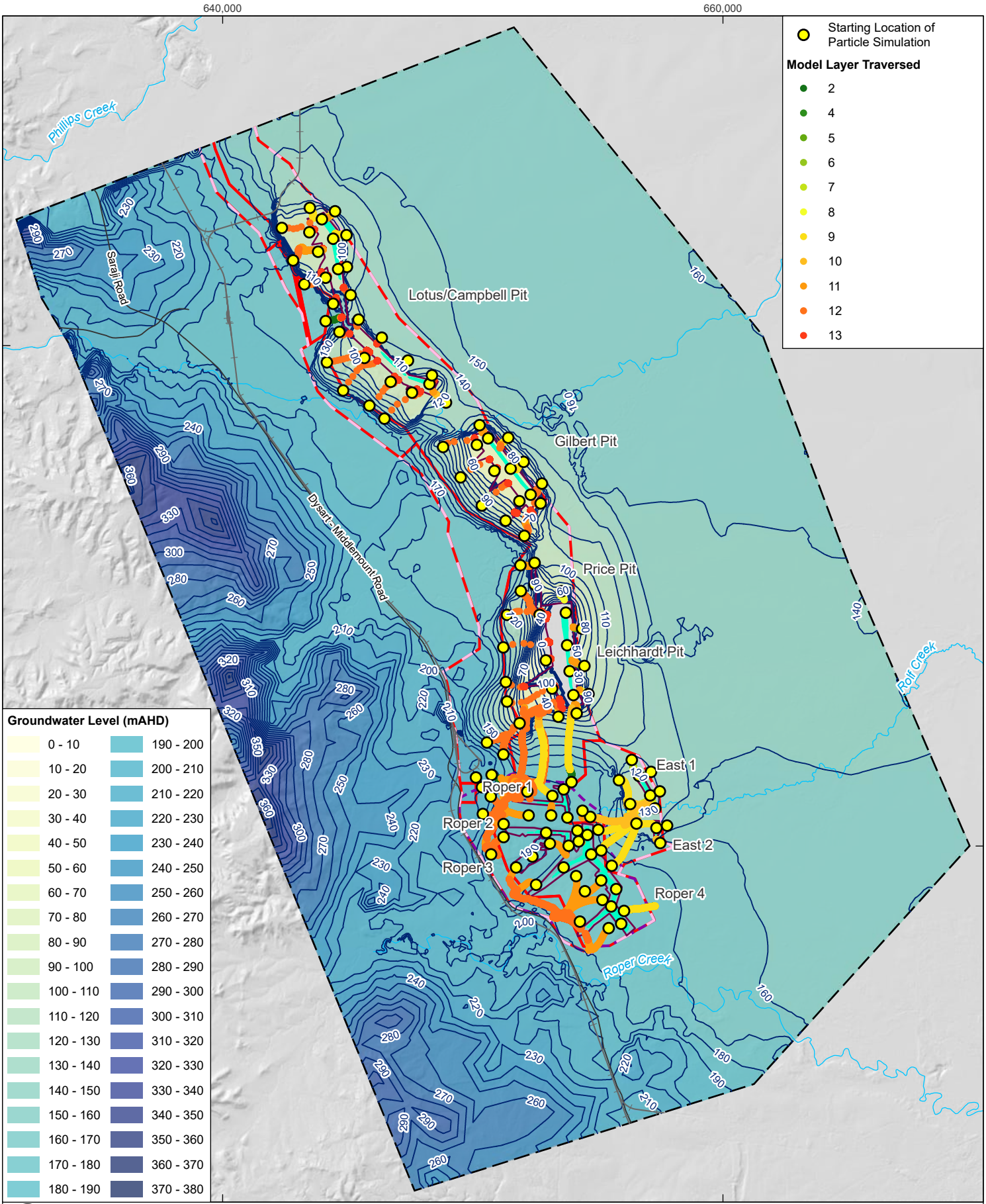
STARTING LOCATION OF PARTICLES

SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

FIGURE 7-36

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_35_Starting Location of Particles



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED MOVEMENT OF PARTICLES (MID CLIMATE SCENARIO)

SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

FIGURE 7-37

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_36_Predicted Movement of Particles (Mid Climate Scenario)

8.0 Conceptual Site Model – Post Mining

8.1 General Overview

A visual representation of the post-mining CSM based on the results of this Hydrogeological Assessment is provided as **Figure 8-1**, noting the features discussed in **Section 5.0** above. Based on an understanding of hydrogeological mechanisms and response to mine closure modelled in local studies, key features relevant to the discussion of potential groundwater impacts (excluding the Roper Study Area) post-mining are likely to be:

- Residual void lake formation, with lake levels stabilising significantly below the pre-mining groundwater elevations and any shallow post-Permian strata, including the base of surficial weathering and shallow hydrostratigraphic units (i.e. alluvium and Tertiary sediments/Regolith).
- Residual groundwater drawdown within the Moranbah Coal Measures, associated with time lag of discharge to mine voids during mining, and long-term evaporative discharge from the void lakes, resulting in continued inwards hydraulic flow gradients in the coal measures.
- Voids continue to capture any seepage from spoil emplacements.
- Little to no impact on surficial aquifers, with predicted water level influence showing decline caused by approved mining impacts prior to closure.
- Little to no impact on environmental receptors, with predicted water level influence showing decline caused by approved mining impacts prior to closure.
- No impact on anthropogenic receptors, with predicted water level influence dominated by approved mining impacts prior to closure, and showing recovery post-mining.

Note that the nature of groundwater interaction associated with the Roper Study Area will be examined in more detail during subsequent investigations, per the discussion provided in **Section 1.1**.

8.2 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 8-2**.

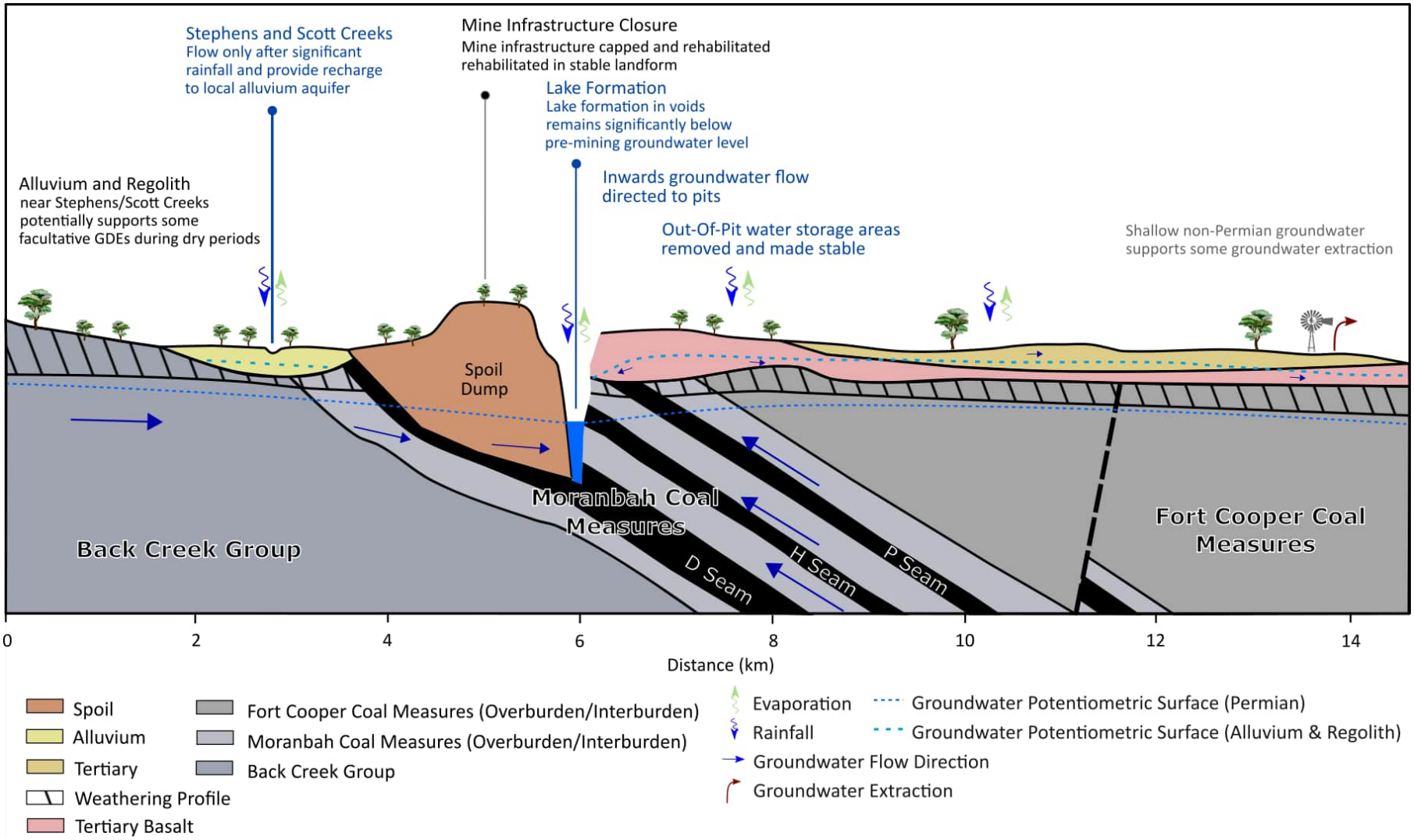


Figure 8-1 Conceptual Model of SSM Groundwater System – Post Closure

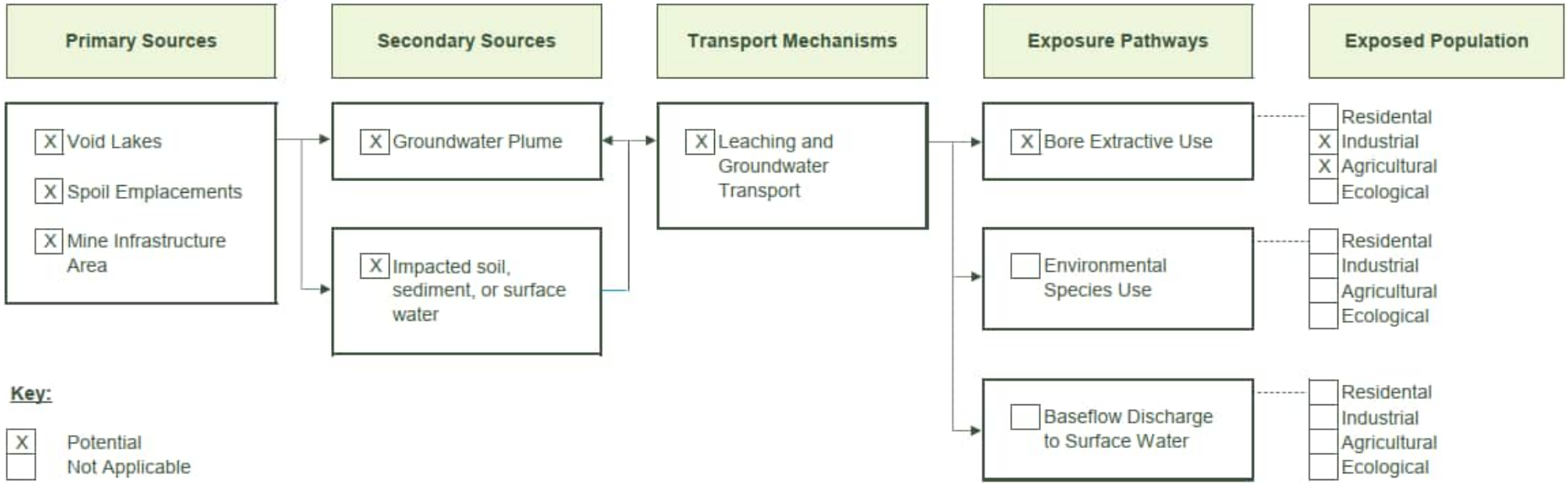


Figure 8-2 Source-Pathway-Receptor Presentation of CSM

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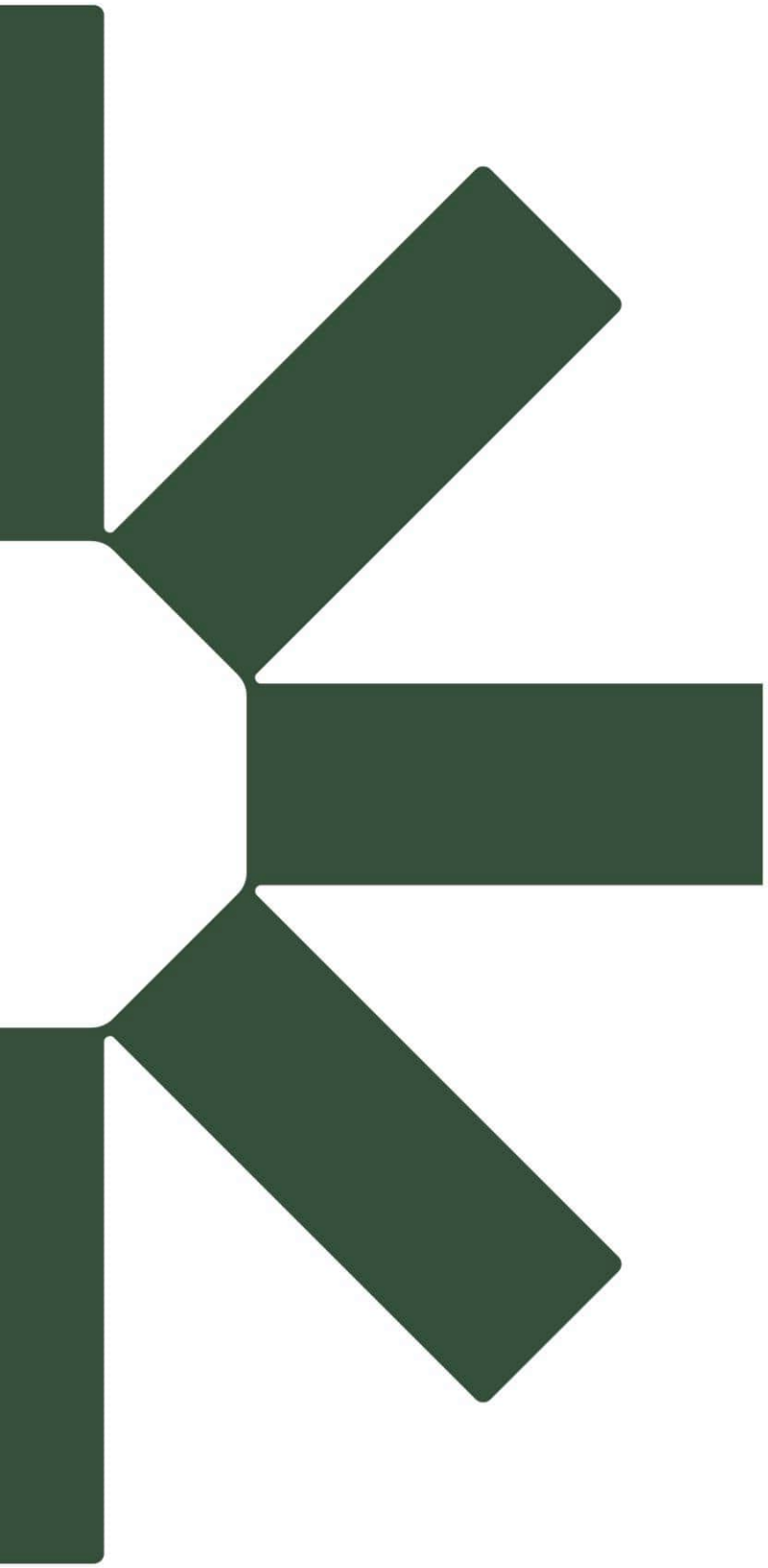

Making Sustainability Happen

Saraji South Mine

Transitional PRC Plan Hydrogeology Assessment

BMA

480 Queen St
Brisbane QLD 4000 Australia

Prepared by:

SLR Consulting Australia Pty Ltd

Level 16, 175 Eagle Street, Brisbane, QLD, Australia, 4000

SLR Project No.: 620.31444.00000

27 September 2024

Revision: 4.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
V4.0	27 September 2024	Daniel Ashton	Derwin Lyons	Derwin Lyons
V3.0	28 August 2024	Daniel Ashton	Derwin Lyons	Derwin Lyons
v2.0	24 July 2024	Daniel Ashton Jade Darvell	Derwin Lyons	Derwin Lyons
v1.0	12 July 2023	Daniel Ashton Gabrielle Killalea	Derwin Lyons	Derwin Lyons
	Click to enter a date.			

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 BMA (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.

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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1.0 Introduction

1.1 Background

SLR Consulting Australia Pty Ltd (SLR) has been engaged by BM Alliance Coal Operations Pty Ltd (BMA) to undertake a hydrogeological assessment supporting the Norwich Park Mine (NPM) (operationally known as Saraji South Mine, SSM) Progressive Rehabilitation and Closure Plan (PRC Plan). 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 3.00, effective 4 April 2023) - "the Guideline" and will be integrated into the design of the rehabilitation strategies and selection of post mining land uses (PMLUs) and Non-use Management Areas (NUMAs) within the SSM PRC Plan.

SSM is located immediately to the south of BMA's Saraji Mine and the western SSM Environmental Authority (EA) boundary is approximately 5 kilometres (km) to the east of Dysart and 86 km to the north-east of Emerald (**Figure 1-1**).

SSM operates under EA EPML00865013, and the area covered by EA EPML00865013 is approximately 16,138ha. The following mining leases intersect the EA (**Figure 1-1**):

- Saraji Norwich Park Mine – ML1782 (part)
- Tay Glen – ML70328 (part)
- Lotus Pit Infrastructure – ML70369
- South Lotus Pit Infrastructure – ML70370
- Lotus Pit West – ML70325
- Campbell Pit West – ML70127
- Norwich Park West – ML70126
- East Pit – ML70350
- Norwich Park Industrial Area South – ML70410

For the purposes of this report:

- The "SSM Area" is synonymous with the EA boundary described above and shown on **Figure 1-1**.
- The "Study Area" for this investigation includes the area covered by the EA boundary that includes SSM mining operations, and the area approximately 10 km immediately around this zone that includes areas where the groundwater environment may influence or be influenced by activities on site.

Mining commenced at SSM in 1979, and has included the extraction of coking and steaming coal through open cut strip mining from a series of pits (**Figure 1-2**). In 2012 the mine was placed in care and maintenance with select mine pit voids utilised as water storage. In 2022, limited extraction of coal from the northern pit voids recommenced with coal processing currently occurring at the Saraji Mine to the north.

Mine voids within the SSM Area (and the ML they are within):

- Lotus Pit (ML1782, ML70325, ML70369, ML70370)
- Campbell Pit (ML1782, ML70127)
- Gilbert Pit (ML1782, ML70126)
- Price Pit (ML1782)
- Leichhardt Pit (ML1782, ML70126)
- Roper Pit (ML1782, ML70126)
- East Pit (ML70350)

BMA have advised that during the period of care and maintenance at SSM (2011 to 2022), only limited activities that were required by the EA were undertaken. Therefore, the groundwater data collected at SSM in the period prior to the development of the hydrogeological assessment and numerical groundwater model, is limited. A program of groundwater monitoring infrastructure installation and monitoring has been implemented from 2020. However, there has been insufficient time within the PRCP notice period for BMA to compete all installation works and undertake monitoring for durations that would normally be used to support the development of a numerical groundwater model. On-going works and assessment of additional groundwater data is required to further reduce the uncertainty within the numerical model and improve the understanding of

groundwater characteristics, particularly within the area including and surrounding the Roper residual voids referred to as the ‘Roper Study Area. The Roper Study Area contains landforms that are likely to be hydrogeologically interconnected including: in-pit tailings storage; out of pit tailings dams; ramp reject disposal areas; mine affected water dams; ramp voids; and multiple residual voids. The complex hydrogeology within the Roper Study Area will require additional assessment and detailed technical studies to enable further development of the numerical groundwater model, which is required to understand any contaminant migration and inform an appropriate closure strategy for the area.

BMA for the PRC Plan development has implemented a specific Roper Study Area (refer **Figure 1-1**) with dedicated Rehabilitation Milestones (RM). More detailed assessment is required within this area to derive a closure strategy that provides for stable PMLUs and NUMAs that are safe, structurally stable and do not present an unacceptable risk of causing environmental harm to surrounding areas. At completion of the detailed assessments, the PRC Plan and PRC schedule will be amended, where required, to provide an appropriate closure outcome for the Roper Study Area. Although the Roper Study Area has been included within the underlying model build, the Hydrogeological Assessment results presented in this report are only for the area of SSM outside of the Roper Study Area. Upon completion of further detailed assessment, the groundwater model in the proximity of the Roper Study Area will need to be updated.

1.2 PRC Plan Final Landform

The post-mining final SSM landform relevant to this hydrogeological assessment was provided by BMA and is shown as **Figure 1-3**. This is a preliminary final landform provided for the timely commencement of this hydrogeological assessment, however there are no fundamental changes in the final landform presented in the PRC Plan that would affect this assessment. The final landform contains multiple residual final voids.

Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
Mining Lease, DNRME, 2023
Watercourse, DNRME, 2022
Roads, DoR, 2021

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Surrounding Coal Mine
- Watercourse
- Major Road
- Railway
- SSM Mine Lease
- BMA Mine Lease
- SSM EA Boundary
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

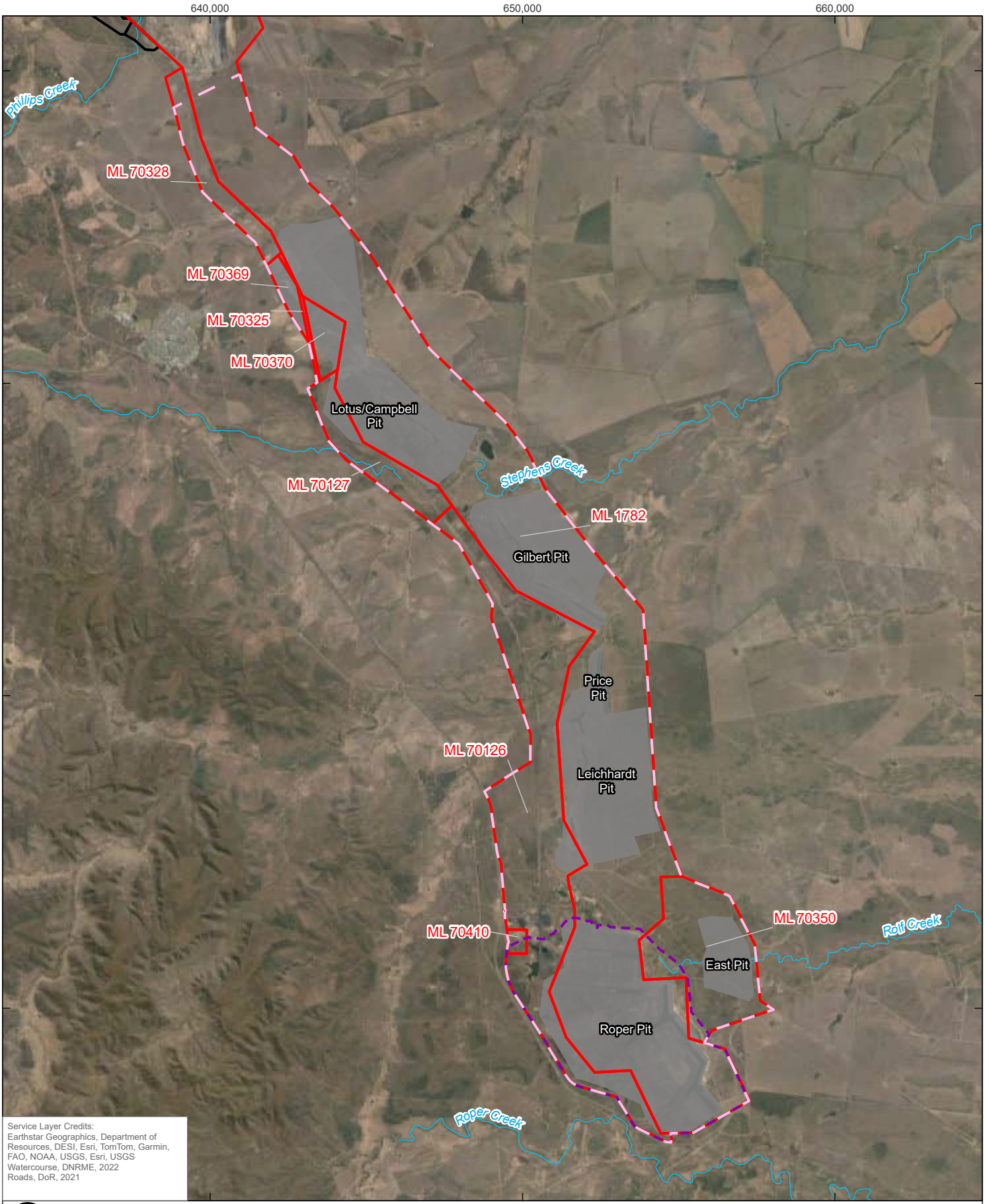
PROJECT LOCATION

SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

FIGURE 1-1

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F1_1_Project_Location_01



Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS Watercourse, DNRME, 2022 Roads, DoR, 2021

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Watercourse
- SSM Mine Lease
- BMA Mine Lease
- SSM EA Boundary
- Pit Extent
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

MINING AREAS

SLR

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FIGURE 1-2

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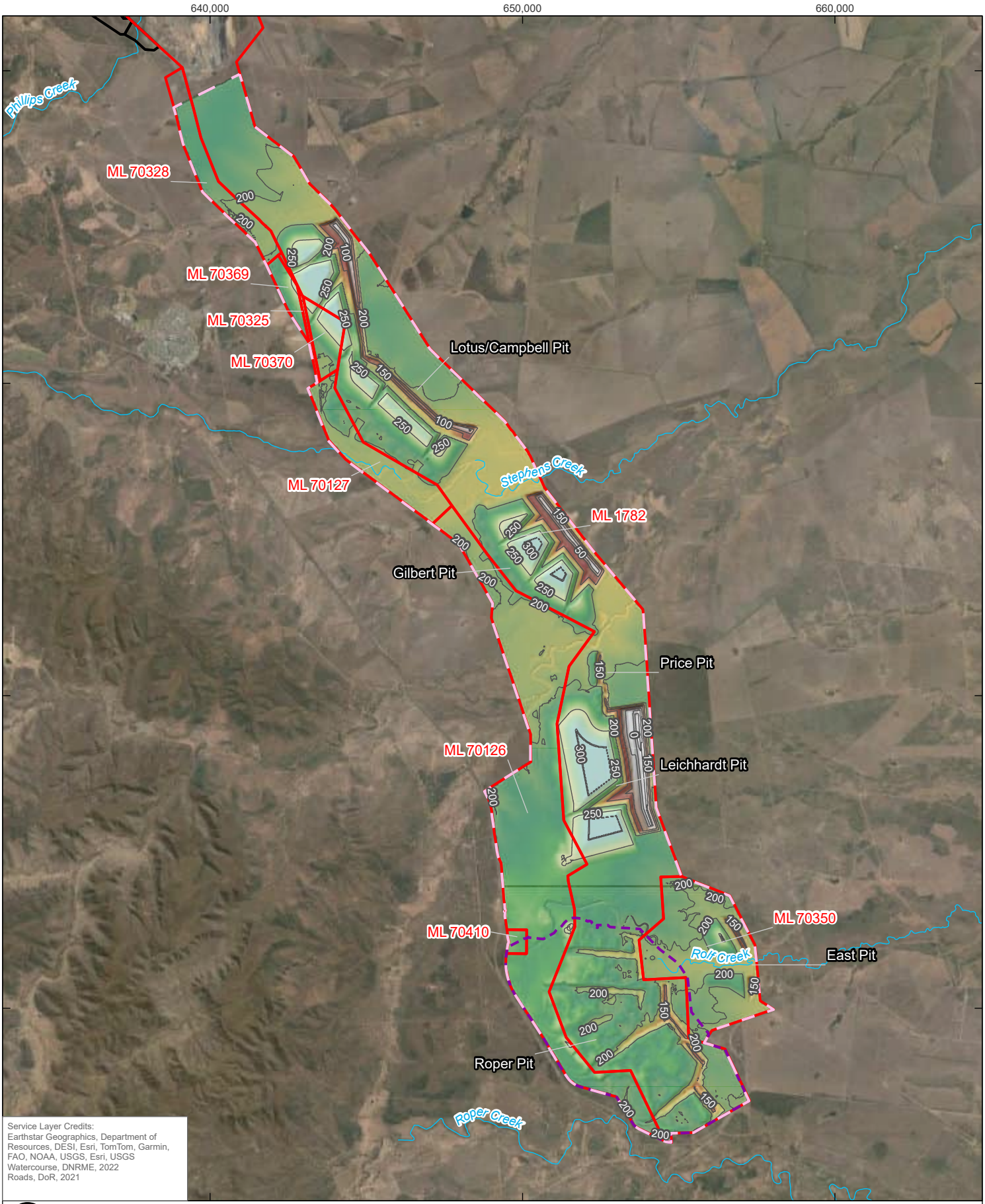
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Phillips Creek
ML 70328
ML 70369
ML 70325
ML 70370
Lotus/Campbell Pit
ML 70127
Stephens Creek
ML 1782
Gilbert Pit
Price Pit
ML 70126
Leichhardt Pit
ML 70410
ML 70350
Roff Creek
East Pit
Roper Pit
Roper Creek
Service Layer Credits:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS Watercourse, DNRME, 2022 Roads, DoR, 2021
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Scale: 1:160,000 at A4
Project Number: 620.314444.00000
Date Drawn: 28-Aug-2024
Drawn by: AS
LEGEND
Topographic Contour (mAHD)
Watercourse
SSM Mine Lease
BMA Mine Lease
SSM EA Boundary
Roper Study Area
Elevation (mAHD)
301
-80
SARAJI SOUTH MINE
TRANSITIONAL PRCP
POST MINING LANDFORM
SLR
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FIGURE 1-3
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1.3 Objectives

The main objective of the hydrogeological assessment is to assess the potential groundwater related impacts at SSM 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 final landform for the intended PLMUs with respect of the SSM groundwater system. As such, the key specific objectives adopted in this assessment from which to demonstrate this suitability are:

- That the final landform is non-polluting with respect to groundwater:
  - Final voids are demonstrated to be sinks for groundwater, including groundwater contained within spoil.
  - Final void lake levels remain below shallow groundwater bearing units, i.e. there is sufficient freeboard to negate risk of void water discharge to any shallow groundwater system.
- That there are minimal 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.

1.4 Guideline Criteria

As discussed in **Section 1.1**, this hydrogeology assessment is undertaken consistent with the Guideline: Progressive Rehabilitation and Closure Plans (ESR/2019/4964). A cross reference between the relevant Guideline requirements with respect of groundwater and specific components of this assessment is provided in **Table 1-1**.

Table 1-1 Guideline Requirements

Guideline Requirement	Section of this Report
Section 3.6.1 General rehabilitation practices – Hydrogeology	
Determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	Section 4.3
Locating groundwater recharge and discharge locations locally and regionally	Section 4.3
Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	Section 4.4
Current and potential future uses of groundwater including existing groundwater extraction bores	Section 4.5
Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	Section 4.2
The development of potentiometric mapping and hydro stratigraphic cross sections	Section 5.0 Section 7.2.5 Section 8.0
Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage.	Section 7.0

2.0 Physical Setting

2.1 Climate

The climate at the Study Area is sub-tropical with higher temperatures, higher rainfall and higher evaporation occurring over the summer months (December to February). The closest Bureau of Meteorology (BoM) weather station is located at Dysart Post Office (35278), approximately 3 km to the west of the SSM Area. This Dysart Post Office weather station operated between 1988 and 2006. The nearest weather station with a longer data record is Booroondarra (station 35109) located at the southern extent of the SSM Area. The Booroondarra weather station has been in operation since 1929 and has a continuous record with only a few occasional months of missing data. **Table 2-1** provides the details of the nearby operational weather stations.

Table 2-1 Operational BoM Weather Stations near to SSM

Name	Site Number	Date Commenced	Easting (GDA94z55)	Northing (GDA94z55)	Elevation (mAHD[1])	Operational Status	Distance from SSM
Dysart Post Office	35278	1988	637975	7501644	200	Closed - 2006	3 km W
Dysart Station	35092	1956	639057	7498467	183	Closed - 2008	4 km W
Booroondarra	35109	1929	652913	7475845	200	Open	1 km S

1. mAHD = metres Australian Height Datum

SILO Grid point data (Latitude: -22.65, Longitude: 148.45) was used to assess long-term rainfall trends in the vicinity of SSM. This dataset is interpolated from quality checked observational timeseries data collected at nearby stations by the BoM. Data from January 1970 until January 2024 was used to assess the long-term rainfall trends in the vicinity of the SSM Area. From this data, the average annual site rainfall is 607.8 millimetres (mm). The highest annual rainfall was recorded for 2010, with 1,198.4 mm falling that year. The minimum annual rainfall occurred in 2018 with 249.1 mm. Monthly averages for the Booroondarra station discussed as well as the SILO grid point are listed in **Table 2-2**. Low relative annual rainfall was measured at the Dysart Post Office station, owing to the relatively short time period this was in operation aligning with relatively low precipitation.

Table 2-2 Average Monthly Rainfall

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dysart Post Office	91.5	85.6	46.0	28.5	37.1	23.1	7.8	30.0	9.6	43.4	48.1	115.4	523.6
Dysart Station	105.5	103.7	60.4	38.7	42.0	23.4	28.1	18.8	13.7	34.7	58.9	94.2	601.7
Booroondarra	111.8	95.8	71.6	33.4	36.3	24.2	23.4	23.4	15.5	38.2	54.3	95.7	623.5
SILO Grid Point Data	109.4	90.4	63.6	32.1	34.3	24.1	25.0	21.5	16.3	36.1	61.8	93.2	607.7

2. Source: **http://www.bom.gov.au/climate/data/index.shtml**
3. Note: SILO Grid point data coordinates are Latitude: -22.65 and Longitude: 148.45.

Rainfall trends for the SSM Area since 1970 are indicated by analysis of the Cumulative Rainfall Departure (CRD) trend for monthly rainfall data (**Figure 2-1**). Positive gradients on this curve (rising limbs) confirm wetter climatic conditions than normal, while negative gradients (falling limbs) indicate dry conditions. Average rainfall conditions are inferred during periods of stable residual mass. **Figure 2-1** shows that, over the past 50 years, the wettest periods occurred during 1973-1979, and in 2010-2011. The driest periods were 1991-1998 and 2001-2007. As shown by the declining trend in the

CRD, recently between 2017 and 2022 SSM experienced drier than average conditions before wetter than average conditions prevailed between 2022 and the present.

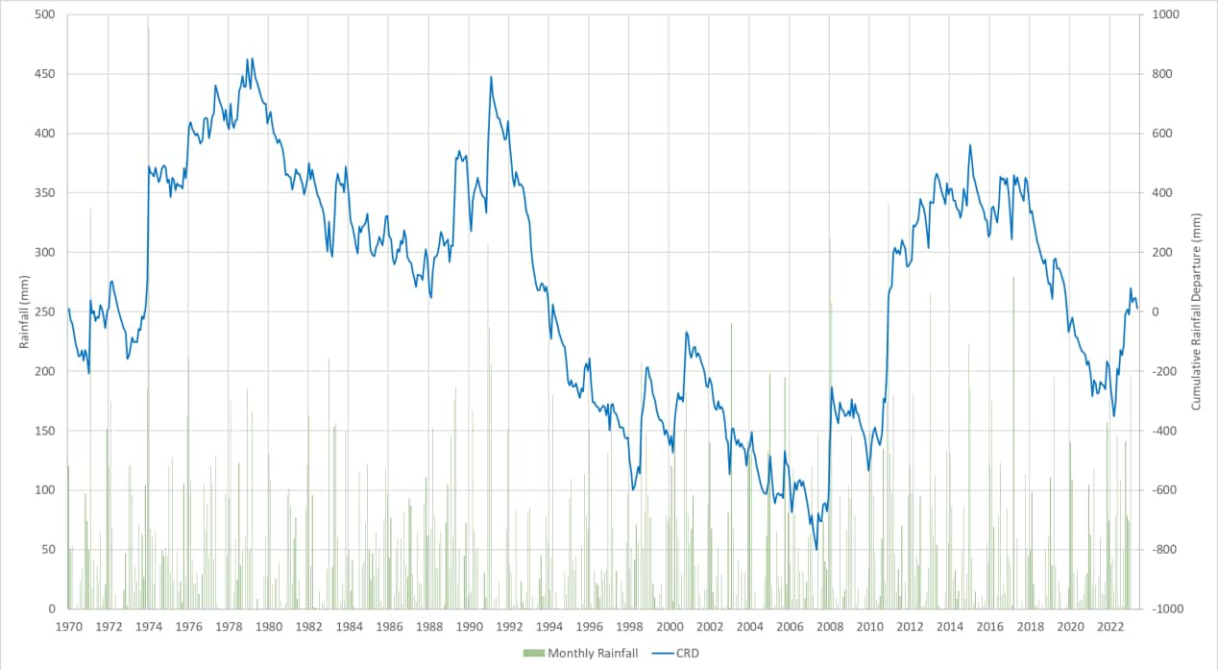


Figure 2-1 Long term Monthly Rainfall and Cumulative Rainfall Departure from mean monthly rainfall at SILO data point Lat: -22.65 and Long: 148.45.

The CRD performs an additional service: if rainfall recharge is a significant source of groundwater, the temporal variability in recorded groundwater levels can be expected to mimic the pattern of this curve. That is, natural fluctuations in the groundwater table result from temporal changes in rainfall recharge to groundwater systems. Typically, changes in groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall, illustrated by the rainfall CRD. Groundwater hydrographs showing the relationship between rainfall and groundwater levels are assessed in **Section 4.0**.

Actual and potential evapotranspiration (ET) have been taken from BoM's Australia wide interpolation dataset at the locations of the weather stations (BoM, 2023). The potential ET in the district is about 2,385 mm/year according to BoM (2023) (**Table 2-3**). The definition of potential ET is: *"… the ET that would take place, under the condition of unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average"*. For example, this represents the ET which would occur over a very large wetland or large irrigated area, with a never-ending water inflow. Further to this, where the water table approaches the ground surface, ET can also approach the potential ET value.

Table 2-3 Average Monthly Potential Evapotranspiration

PE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Booroondarra	250	209	216	179	147	121	135	166	207	252	259	269	2,410
SILO Grid Point Data	246	206	214	176	145	122	136	168	207	249	254	263	2,385

4. PE = Potential Evapotranspiration

The actual ET in the district is about 1,027 mm/year according to BoM (2023) (**Table 2-4**). The definition for actual ET is: "*... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average*". For example, this represents the predicted ET that is occurring over a large area of land under the existing (mean) rainfall conditions.

Table 2-4 Average Monthly Actual Evapotranspiration

PE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Booroondarra	129	114	108	78	49	35	40	60	81	104	117	130	1,046
SILO Grid Point Data	128	112	108	76	49	34	39	60	80	101	113	127	1,027

5. AE = Actual Evapotranspiration

Figure 2-2 shows that the average potential monthly ET exceeds the average monthly rainfall over the entire year, often by more than double. Average actual ET is slightly greater than average rainfall for all months.

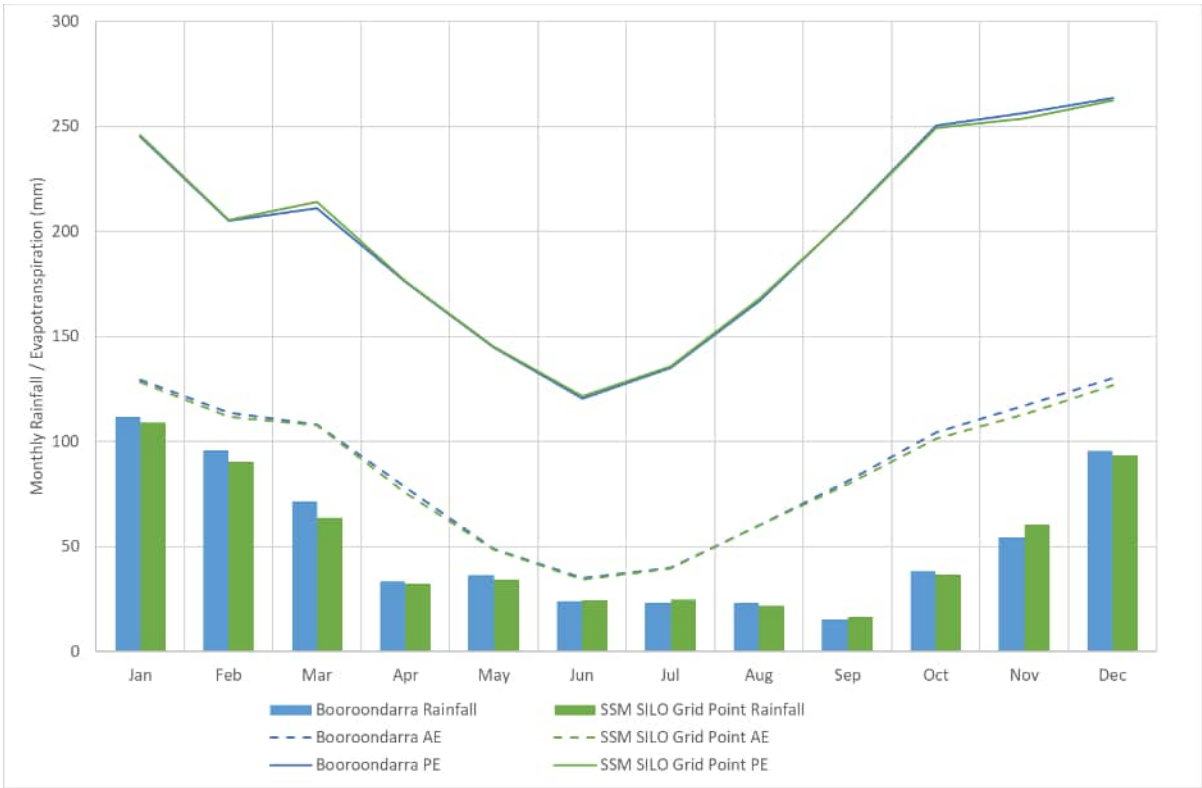


Figure 2-2 Average Monthly Rainfall and Evapotranspiration at Nearby Weather Stations

2.2 Topography and Drainage

SSM is located in the Isaac Connors surface water catchment, a sub-catchment of the upper Fitzroy Basin. The topography of the SSM Area is relatively flat with gentle undulation (average elevation of 195 mAHD), with an overall easterly gradient of less than 1% from the Harrow Range in the west to the Isaac River in the east (BMA, 2006). Land within the SSM Area has been essentially cleared for mining purposes, with substantial alteration to the surface profile with activities over time (AGE, 2004). Alteration to stream courses has been associated with mining activities, including route diversion and damming.

All watercourses and tributaries within and in the vicinity of SSM are highly ephemeral and only flow briefly after rainfall. After significant rainfall, water remains in shallow, non-flowing pools, which are utilised as livestock water sources (AGE, 2014a).

The Isaac River, located approximately 20 km northeast of SSM at its closest point, is the major drainage feature of the region and flows from northwest to southeast (**Figure 2-3**). Drainage across SSM includes a number of ephemeral tributary stream catchments that have formed as a part of the Isaac River catchment (AGE, 2014a). These ephemeral creeks traverse the SSM lease area from

generally west to east. The creeks from the north to the south of the lease area are Lotus/Downs Creek, Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek.

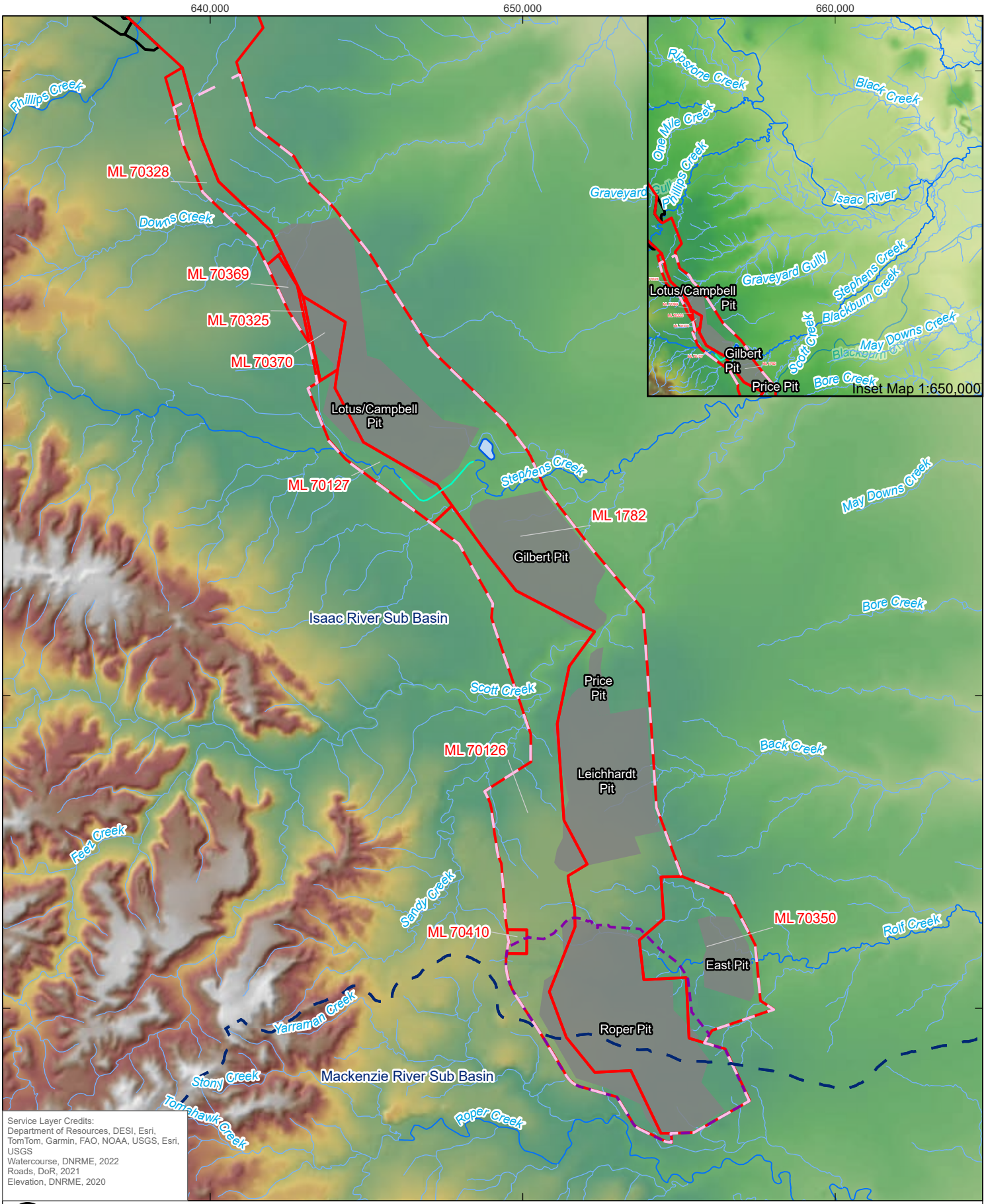
Stephens Creek is a primary drainage feature in the Study Area (**Figure 2-3**). The course of Stephens Creek within the SSM Area runs adjacent to Gilbert Pit before abruptly meandering north to Lotus Pit as it traverses the site from west to east (AGE, 2014b). Stephens Creek passes within approximately 150 m of Lotus Pit and approximately 100 m of Gilbert Pit. An AGE (2014b) investigation showed that at the apex of the meander between both pits, standing pools were a permanent feature of the creek, irrespective of seasonality. LiDAR imagery collected in August 2013 returned water levels from 175.4 mAHD to 175.0 mAHD for these standing pools (AGE, 2014b). The elevation of the creek channel terraces incised between Gilbert Pit and Lotus Pit is approximately 179.5 mAHD, approximately 6 m below the level of the flood plain (185.5 mAHD) (AGE, 2014b). Diversion of Stephens Creek in the early 1990's was conducted to allow for mining operations in Campbell Pit to expand. The embankment known as Suttles Bend Dam is an impasse to surface drainage along the original Stephens Creek watercourse to the southwest and consequently stores mine affected water (AGE, 2014b).

Scott Creek is a secondary drainage feature in the Study Area and runs from southwest to northeast across SSM before draining eastwards (**Figure 2-3**). The course of Scott Creek within the SSM Area has been diverted to run between Gilbert Pit and Price Pit (**Figure 1-3**)(AGE, 2014a). Scott Creek passes within 100 m of Price Pit North and approximately 85 m of Gilbert Pit. The elevation of the creek channel incised adjacent to Price Pit North is approximately 175.5 mAHD, with the channel bed approximately 15 m below the surrounding floodplain level at 190 mAHD (AGE, 2014a). Feez Creek and Little Roper Creek drain flow into Scott Creek 10km and 20km southwest of SSM respectively. The confluence of Scott Creek to Stephens Creek is approximately 7.2 km northeast of Gilbert Pit.

Rolf Creek is another secondary drainage feature in the Study Area and runs from east to northeast across SSM before draining eastwards (**Figure 2-3**). The course of Rolf Creek within the SSM begins at the north of Roper pit (within 30 m of the pit boundary), running directly through the middle of the proposed East Pit before draining to the northeast. The elevation of the creek channel incised adjacent to Roper Pit ranges between ~193 mAHD and ~201 mAHD near the highwall, to ~183 mAHD some 3.8 km east of the pit at Ramp 5 (AGE, 2014a). The confluence of Rolf Creek to May Downs Creek is approximately 34 km northeast of East Pit.

Roper Creek is the only drainage feature in the Study Area that runs from west to southeast, draining into the Mackenzie River catchment south of SSM, i.e. the next major Fitzroy Basin surface catchment south of the Isaac Connors catchment. The course of Roper Creek runs immediately south of Roper Pit (within ~30 m of the pit boundary), before draining to the southeast. The elevation of the creek channel incised adjacent to Roper Pit ranges between ~200 mAHD near the highwall, to ~185 mAHD some 1.4 km south of the pit (AGE, 2014c).

Lotus Dam, located south east of Lotus/Campbell Pit, was constructed in 2010 for storage of mine affected water and is the nominated controlled release point for EA MIN100760208, discharging into Stephens Creek.



SARAJI SOUTH MINE TRANSITIONAL PRCP

TOPOGRAPHY AND DRAINAGE

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

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FIGURE 2-3

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2.3 SSM Mining

This section outlines the historical mine progression, care and maintenance activities, and future mining plan at SSM, as relevant to assessing the effect of SSM on the groundwater system post-closure. This is considered important since post-closure groundwater conditions will in part be dictated by the conditions that are present as a result of existing mining activities at the time of closure.

2.3.1 Historical Mining Activities (pre-2012)

SSM began operations in 1979 with open pit dragline mining in Roper Pit targeting the D seam of the Moranbah Coal Measures (also termed Dysart Seam). Other pits were opened up progressively over approximately the next 30 years until the operations were placed on care and maintenance in May 2012 (**Table 2-5**). A visual representation of the pre-2012 SSM mine progression is shown in **Figure 2-4**.

In all pits, spoil was deposited to the west of mine void adjacent to the pit ramps. The primary mine operations area including stockpile, workshops, coal processing facility and Tailings Dam are located immediately northwest of Roper Pit.

Table 2-5 Details of mine progression at SSM pre-2012

Pit name	Mining Commenced	Target Seam
East Pit	Approved future mining	H Seams
Campbell Pit	1999	D Seam
Gilbert Pit	1987	D Seam
Leichhardt Pit	2005	D Seam
Roper Pit	1979	D Seam
Price Pit	2002	H Seams
Lotus Pit	2011	H Seams

Prior to the excavation of Campbell Pit, Stephens Creek was diverted to the south around the planned mining area. This feature is now partially fed by Lotus Dam discharge from the authorised release point.

2.3.2 Care and Maintenance (2012 – 2022)

Following the site being placed on care and maintenance, the residual voids located within SSM were incorporated into the BMA active water network, which comprises water management at SSM, as well as Caval Ridge, Peak Downs and Saraji mines. In this network, the SSM voids receive and store excess mine affected water from other BMA sites during wet periods and recycle the water by supplying BMA operations during drought conditions. A summary of water holding locations at SSM is presented in **Table 2-6** with volume estimates based on BMA water storage area register data, and locations for these are presented in **Figure 2-5**. The formation of pit void lakes during the care & maintenance phase is considered indicative of how the hydrologic system might behave in the long-term post-closure, as relevant to the PRC Plan.

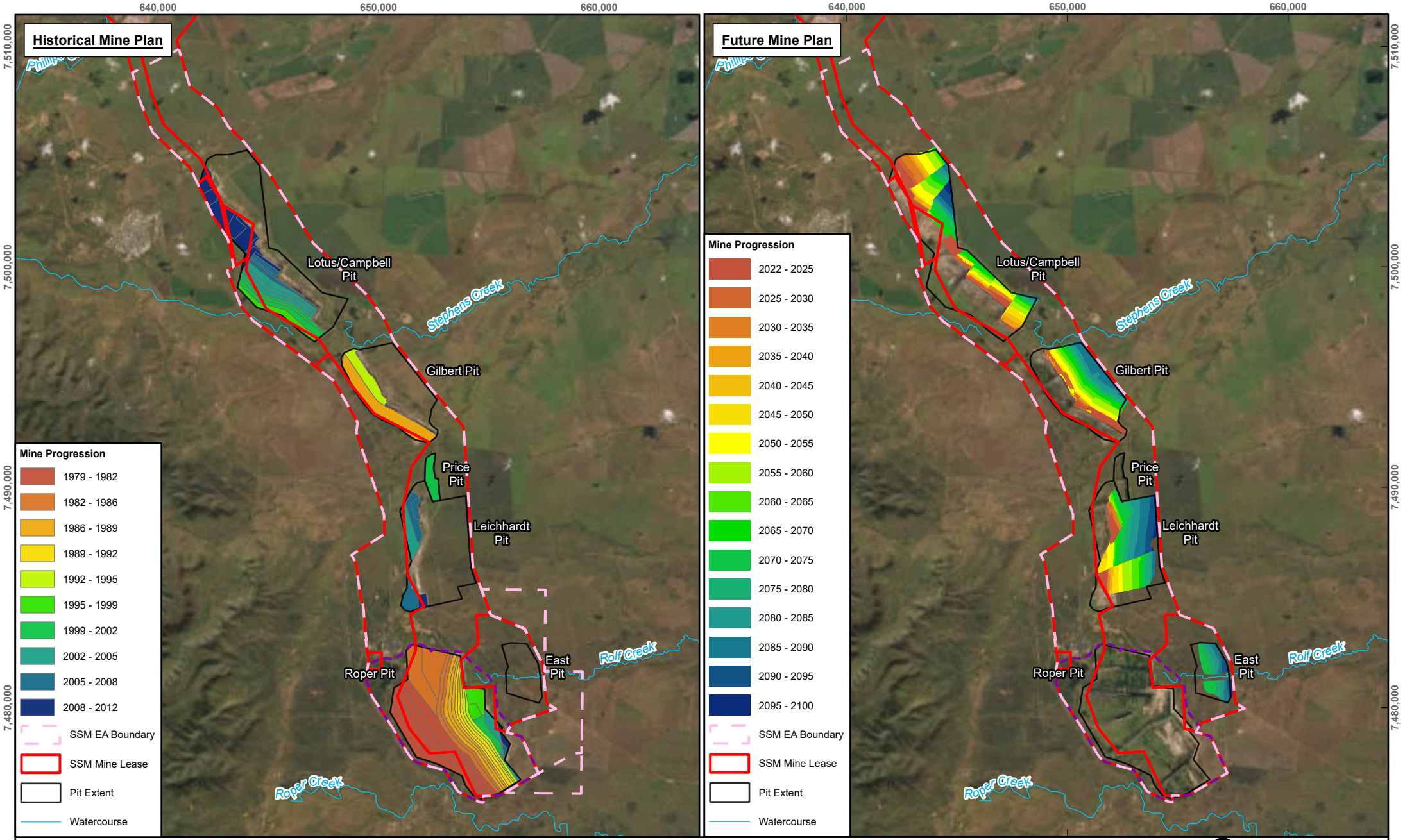
In January 2014, ad-hoc monitoring of water quality in Scott Creek identified brackish to moderately saline water at pools in the channel close to Price Pit. Subsequent investigation into the source of the anomalously saline water identified potential pathways for seepage out of the water stored in the Price Pit lake (AGE 2014a, JBS&G 2021). These investigations identified that the water level was maintained above the maximum operating level of 174.5 mAHD for extended periods between 2012 and 2013. This maximum operating level is below the capacity of the dam 187 mAHD, but selected due to the bed level of Scott Creek adjacent to Price Pit North at 174.5 mAHD (AGE, 2014a).

Table 2-6 Water Storage Areas at SSM

Water Storage Name	Pit	Capacity (ML)	Minimum (mAHD)	Date Minimum Measured	Maximum (mAHD)	Date Maximum Measured
Area Dam			220.9	14-06-2018	223.1	26-04-2017
Browns Dam		142	212.0	02-02-2021	216.0	26-04-2017
Horseshoe Dam		51	191.1	28-08-2018	192.8	26-04-2017
Ramp 64	Leichhardt		148.4	07-01-2019	158.7	09-05-2019
Ramp 65	Leichhardt		155.6	07-05-2021	159.1	10-07-2017
Ramp 66	Leichhardt		173.1	07-05-2021	176.3	26-04-2017
Little Murphy Dam		408	217.1	02-01-2020	222.9	14-06-2018
Lotus Dam		1057	185.4	04-01-2021	187.5	10-07-2017
Murphy Dam		2022	214.8	05-05-2022	222.1	14-06-2018
Old Tailings Dam		434	220.6	04-06-2021	223.6	29-07-2019
Ramp 54	Lotus		166.7	02-04-2021	172.6	12-03-2018
Ramp 56N	Campbell		123.5	08-06-2023	131.9	30-03-2020
Ramp 56S	Campbell		124.1	05-08-2021	131.9	30-03-2020
Ramp 58	Campbell		123.8	04-06-2021	131.9	30-03-2020
Ramp 59	Gilbert		126.5	26-04-2017	129.9	08-06-2023
Ramp 6 Fill Point Dam		167	180.7	02-01-2020	188.2	26-04-2017
Ramp 61 S	Gilbert		128.5	11-08-2017	130.6	06-04-2023
Ramp 62	Gilbert		128.4	26-04-2017	130.5	06-04-2023
Ramp 63 N	Price	5298	179.1	02-01-2020	184.9	26-04-2017
Ramp 63 S	Price	1914	179.2	02-01-2020	184.9	26-04-2017
Ramp 67 Tailings Pit	Roper	7307	178.1	02-06-2022	182.9	26-04-2017
Ramp 68 Mine Water Storage	Roper		178.0	02-06-2022	182.7	11-08-2017
Ramp 69 Mine Water Storage	Roper		168.1	02-09-2021	181.2	26-04-2017
Ramp 70 Mine Water Storage	Roper		166.3	06-01-2018	170.5	08-06-2023
Ramp 71 Mine Water Storage	Roper		149.7	26-04-2017	165.1	02-02-2023
Suttles Bend Dam		73	178.7	26-04-2017	178.7	26-04-2017

2.3.3 Current and Future Mining

Mining at SSM recommenced in 2022 at the northern extent of SSM (Lotus/Campbell pits). The current mine plan, with polygons indicating timing for mine strip extraction is provided as **Figure 2-4**. Currently, planned extractive mining operation is anticipated to continue to 2097.



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Coordinate System: GDA 1994 MGA Zone 55

Date Drawn: 28-Aug-2024
Project Number: 620.314444

Watercourse
SSM Mine Lease
Pit Extent
SSM EA Boundary
Roper Study Area

SLR

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SARAJI SOUTH MINE TRANSITIONAL PRCP

MINING ACTIVITIES AT SSM

FIGURE 2-4

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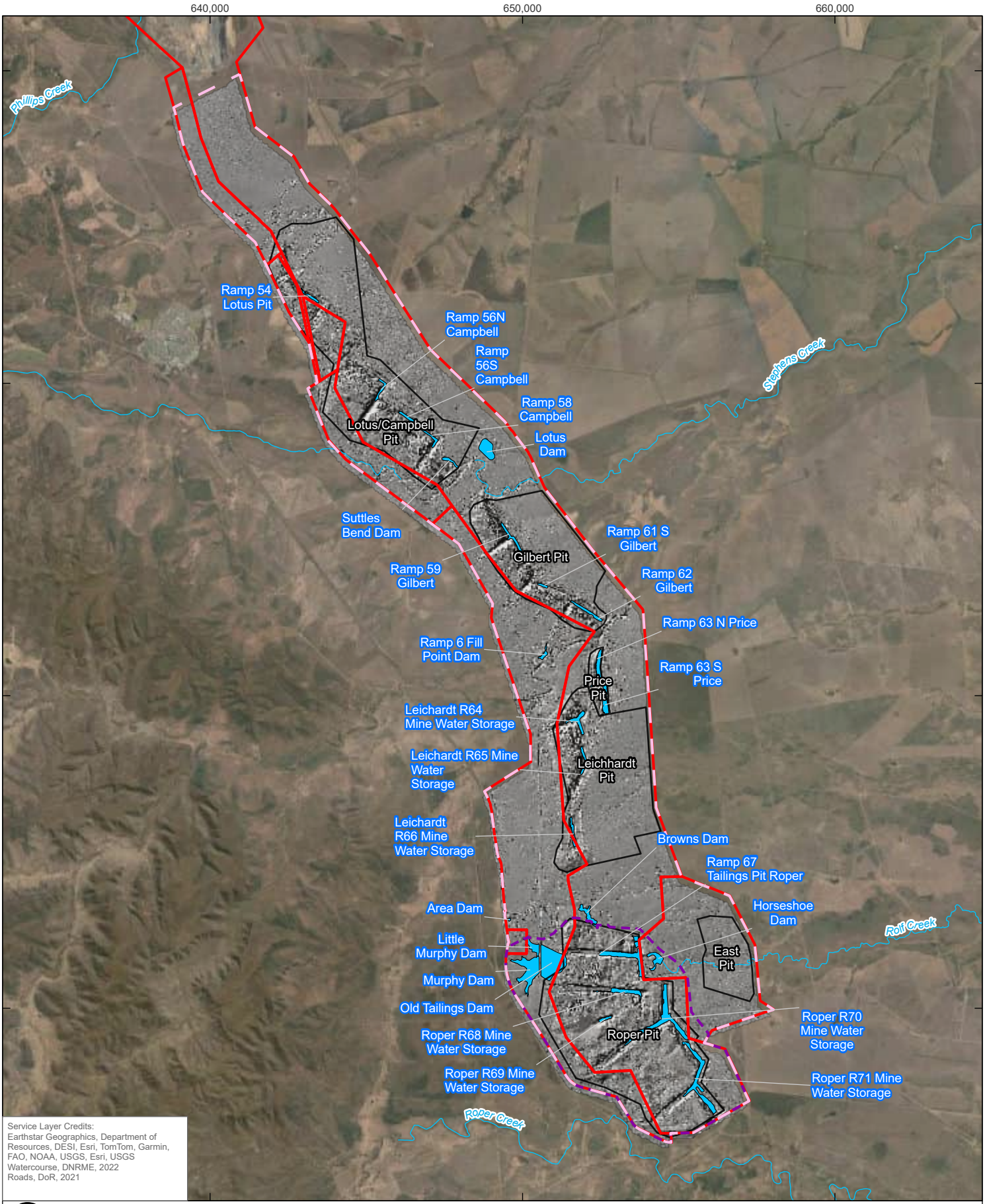

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Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Watercourse
- Water Storage Area
- SSM EA Boundary
- SSM Mine Lease
- Pit Extent
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

WATER STORAGE AREAS

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FIGURE 2-5

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3.0 Geology

3.1 Regional Geology

SSM is located in the northern part of the Bowen Basin, a foreland sedimentary basin of approximately 200,000 km^2 (**Figure 3-1**). The Bowen Basin is a north-northwest to south-southeast oriented basin and contains the largest coal reserves in Australia. The southern half of the Bowen Basin is covered by the Surat Basin, and the Galilee Basin exists to the west (Geoscience Australia, 2017).

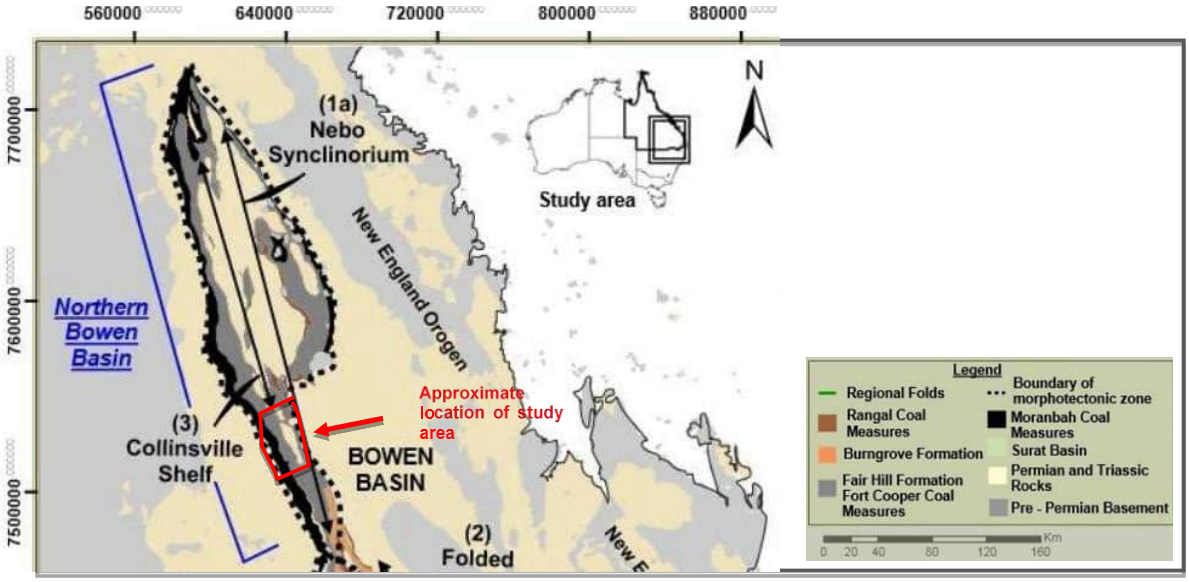


Figure 3-1 Regional geology of the Bowen Basin (after Dickens and Malone, 1973)

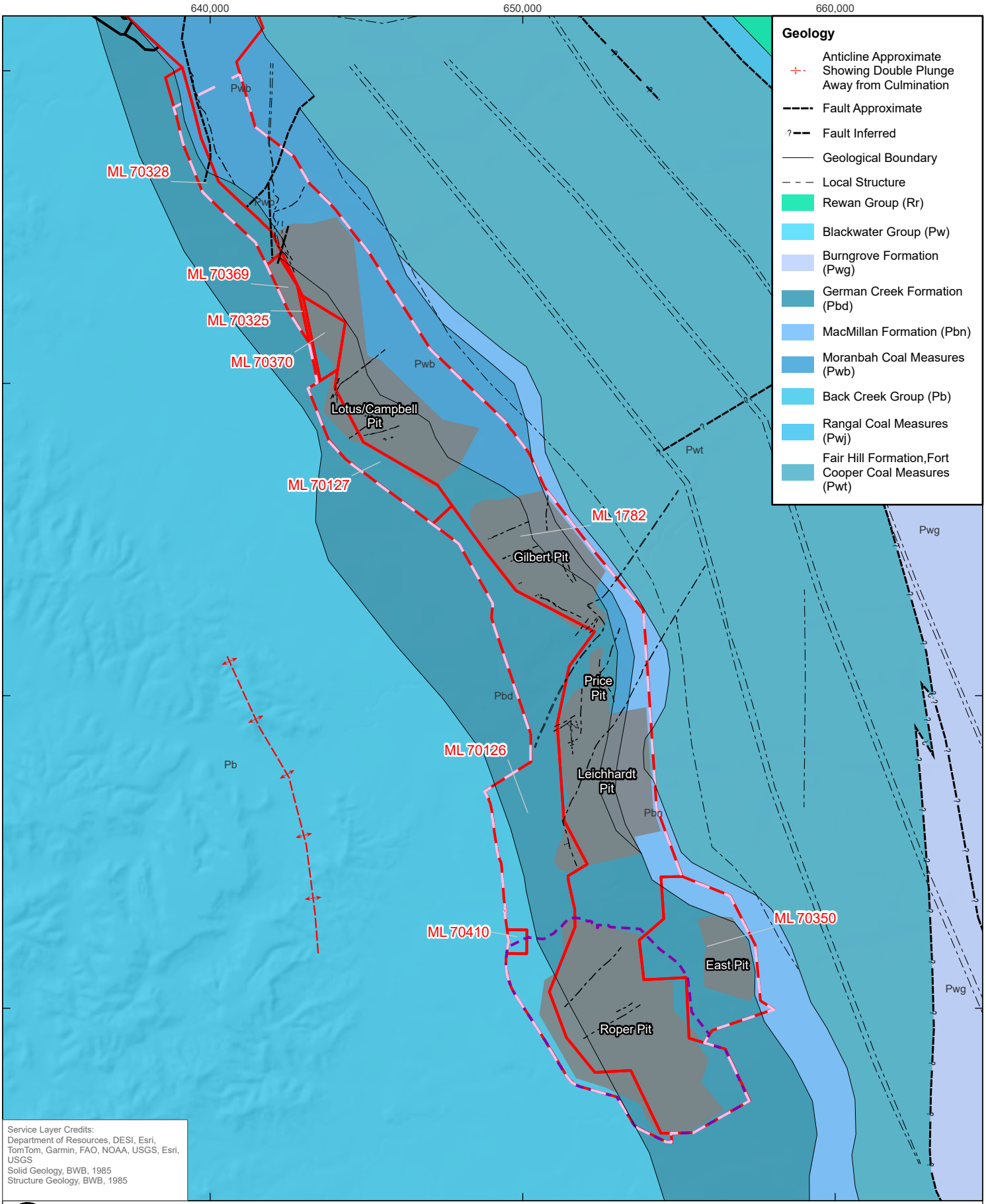
Basin geology within the Collinsville Shelf includes the basal Permian aged Back Creek Group, which generally comprises of generally fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is conformably overlain by the Blackwater Group, which includes the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures. The economic coal seams at SSM are contained in the Moranbah Coal Measures. The Permian strata occur at outcrop on the eastern and western edges of the Basin and are unconformably overlain by the Triassic aged consolidated sedimentary rocks of the Rewan Group.

The Permian and Triassic units are covered by a thin veneer of unconsolidated to semi-consolidated Cainozoic sediments (undifferentiated Tertiary to Quaternary alluvium and colluvium, and unconsolidated to semi-consolidated Tertiary sedimentary formations), as well as Tertiary aged basalt flows. The alluvial sediments are localised along surface water features (i.e., Lotus/Downs Creek, Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek).

The generalised regional stratigraphy is summarised in **Table 3-1**.

Table 3-1 Regional Stratigraphy

Period		Stratigraphic Unit		Description	Mapped Distribution	Mapped Max Thickness in and near to the SSM Area (m)
Cainozoic		Quaternary alluvium (Qa)		Flood plain alluvium comprising clay, silt, sand and gravel.	Surficial cover localised along Stephens Creek, Scott Creek and Back Creek	~ 20
		"Regolith" – older alluvium, colluvium and other Q/T sediments in floodplains, alluvial fans, and high terraces (Qr, Qr\b and TQa) For the purposes of defining hydrogeological units in this assessment, 'regolith' also includes the upper weathered portion of the Permian bedrock strata where present		Shallow unconsolidated and semi-consolidated sediments and weathered units outside of Quaternary alluvium (Qa), comprising colluvial and residual deposits of poorly sorted clay, silt, sand, gravel and black soils, silts and muds derived from weathered basalts.	Surficial cover throughout the SSM Area. TQa coverage throughout SSM Area extending eastwards until overlain by Qa deposits and pinching out on Tu contacts. Qr distributed in areas to the west of SSM, associated with weathering of Back Creek Group by watercourses traversing area	~ 20
		Duaringa Formation (Tu)		Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Forms primary surficial cover unit in the SSM Area, with significant sequences of highly weathered silt/clay/sand and basalt profiles.	~ 50
Triassic		Rewan Group (Rr) (Rewan Formation and Sagittarius Sandstone)		Rewan Formation: green lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base).	Within regional stratigraphy however outcrops outside of the Study Area, 11km to the east of the SSM Area.	~840
Permian	Late	Blackwater Group	Fort Cooper Coal Measures (Pwt)	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff.	Subcrops along total eastern extent of SSM Area and extends directly to the east.	~350
			Moranbah Coal Measures (Pwb)	Quartzose to sub-labile locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone and coal.	Within/underlies the whole of the SSM Area.	~ 400
	Early to Middle	Back Creek Group		Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite.	Within/underlies all of the SSM Area; Outcrops west of the SSM Area.	~400



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

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SOLID GEOLOGY

SLR

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FIGURE 3-2

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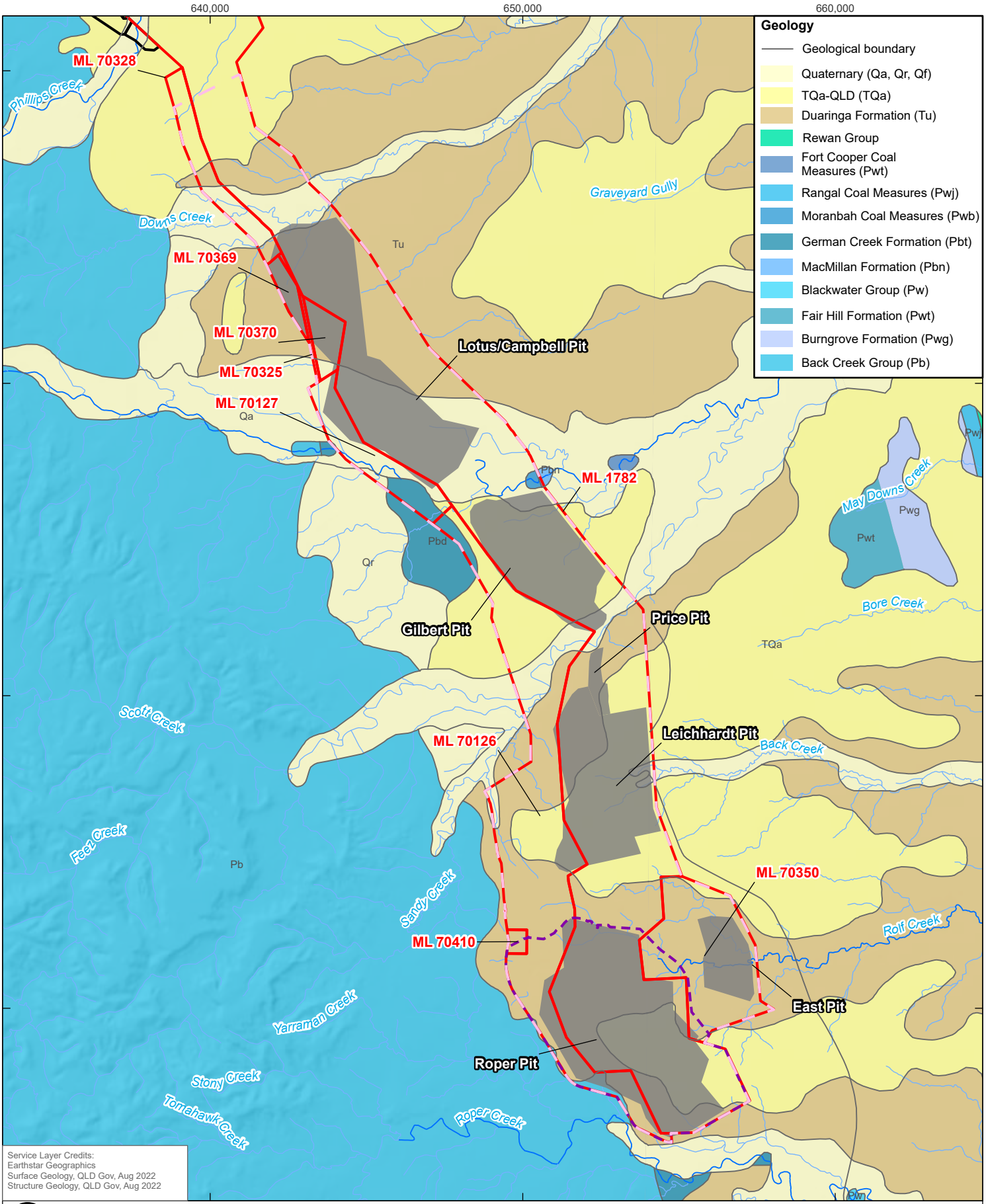

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
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SURFACE GEOLOGY

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FIGURE 3-3

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3.2 Local Geology

The stratigraphic profile within the SSM Area comprises three distinct units:

- Cainozoic sediments
  - Quaternary alluvium
  - Tertiary alluvium, colluvium, and regolith (including weathered Tertiary basalt); and
- Permian coal measures.

3.2.1 Cainozoic

3.2.1.1 Quaternary Alluvium

State (Queensland Government) Detailed Surface Geology (SDSG) mapping (**Figure 3-3**) shows Quaternary Alluvium associated with Stephens Creek, Scott Creek, and Rolf Creek, with relatively large lateral extent. Site based investigations (AGE 2004, AGE 2014a, AGE 2014b, AGE 2014c) have found that the regionally mapped extent is not correct with Quaternary Alluvium distribution relatively limited to where stream erosion has incised into Tertiary material (**Figure 3-4**). These lenses are comprised of unconsolidated clays to boulder sized material, with thicknesses ranging between 1-2m (AGE, 2004).

Figure 3-4 Ephemeral stream bed looking downstream (left) and upstream (right) near Price Pit showing localised deposition of sediment in creek channel (AGE 2014)

3.2.1.2 Tertiary Sediments and Regolith

SDSG mapping shows Tertiary-Quaternary alluvium (TQa) deposits distributed across SSM and the surrounding area. TQa is defined as a *poorly consolidated or unconsolidated alluvial deposit in an ancestral valley, which has been dissected by more recent channel activity*. SDSG mapping shows that the TQa deposits extend eastwards from SSM and are indicative of flood plain material associated with watercourses traversing the area. The inferred extent of the surficial material is presented in **Figure 3-3**. AGE (2014a) report Tertiary sediments comprising of an intercalation of unconsolidated clay and sand to semi-unconsolidated clay, sandy clay, silty clay, sand, and gravel sediments, where clay predominates within the sequence. Thicknesses of approximately 45 m are reported across SSM for the Tertiary unit, increasing to 54 m in the western portion of the site (AGE, 2014c). The generally dry and hard unconsolidated basal sediments are mostly densely compacted, comprising of coarse-grained sands and fine gravels (AECOM, 2019). The thickness of these sediments varies across the site, unconformably sitting on the erosional surface that forms the top of the underlying Permian sequence (AGE, 2014a; AGE, 2004).

Close to Price Pit, in association with Scott Creek, BMA drill logs indicate varying depths of 1 to 3 m for Tertiary cover, comprising of soils up to 1 m thick and firm dry clays up to 3 m thick (AGE, 2014a).

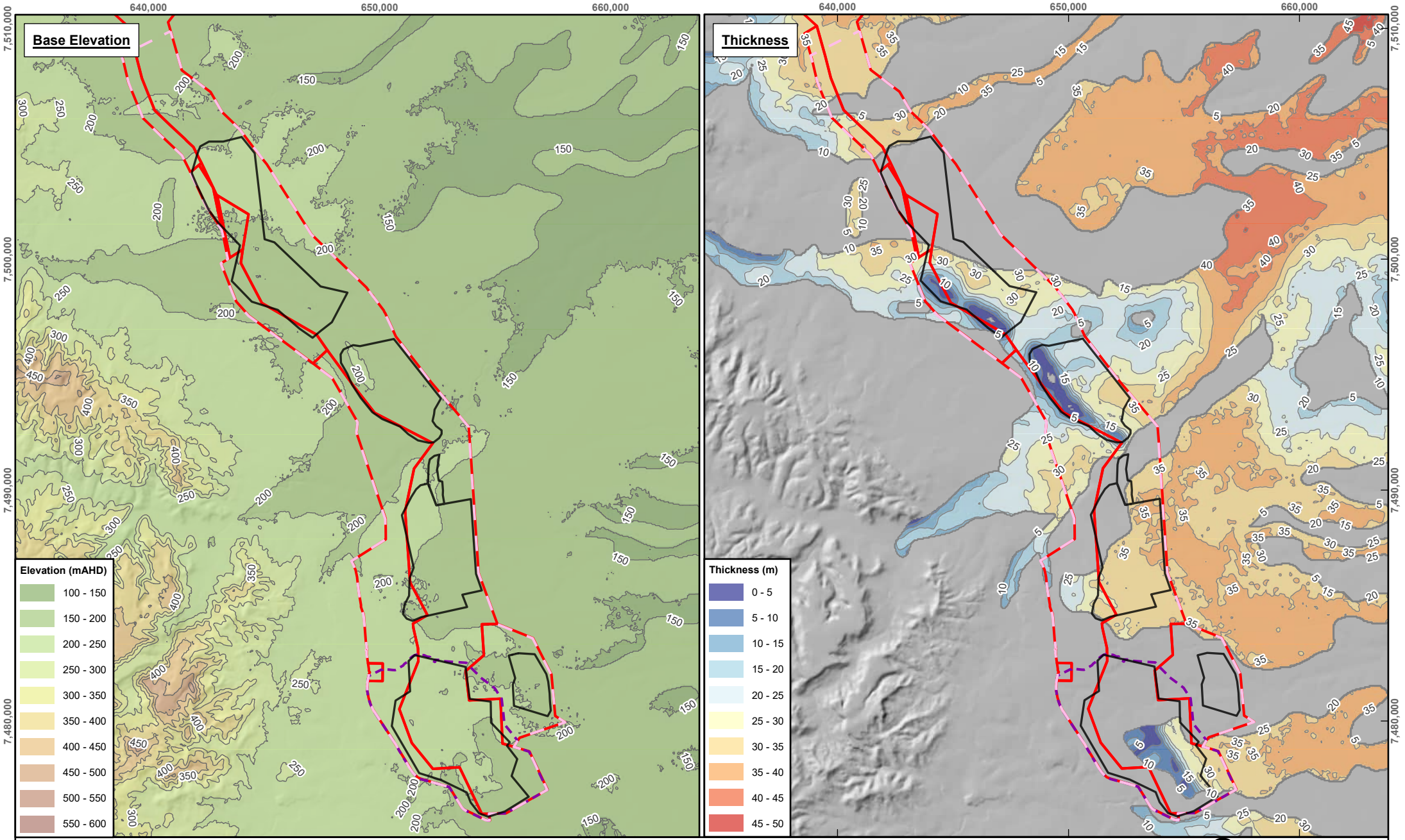
The thickest Tertiary sediments are found to the south of SSM at Leichhardt Pit and Roper Pit, consisting of poorly interconnected aquifers of variable permeability and limited storage potential (AGE, 2014c). Lower permeability clayey horizons are considered to limit drainage between these aquifers (AGE, 2014c).

SDSG mapping shows the Duaringa Formation (Tu) covering a significant proportion of SSM, with the Lotus, Price, Leichhardt, Roper, and East Pits intersecting this unit. Tu is defined as mudstone, sandstone conglomerate, siltstone, oil shale, lignite, and basalt (Withnall et al., 2009). This mapping is supported by groundwater bore drilling logs from the SSM Area.

The other undifferentiated surficial material covering much of the Study Area comprises unconsolidated undifferentiated sediments (regolith), including colluvium and residual deposits (Qr) derived from weathering of the underlying Permian strata.

In many recent relevant hydrogeological studies, the surficial Tertiary aged sediments and other weathering derived material outside of mapped Quaternal Alluvium (Qa) has been collectively termed ‘regolith’, since these sediments essentially function as a single hydrogeological unit. The extent and thickness of the regolith material is presented in **Figure 3-5** interpolated from the site geological data and regional modelling completed based on CSIRO Soil and Landscape Grid of Australia (CSIRO, 2015) data. SDSG mapping shows surficial regolith deposits to be localised in the west of the SSM area (**Figure 3-3**), indicative of weathering of the Permian Back Creek Group by water courses as they traverse these locations.

Based on BMA drill logs, the regolith in the SSM Area comprises of interbedded sequences of sandstone and siltstone, dominated by highly weathered medium to coarse, low strength sandstone and moderate strength, medium to fine grained sandstone (AGE, 2014a). The regolith material is generally 6 m to 20 m thick, with the depth of weathering extending into the underlying Permian coal measures (AGE, 2014a).



Scale: 1:210,000 at A4
Coordinate System: GDA 1994 MGA Zone 55

Date Drawn: 28-Aug-2024
Project Number: 620.314444

Elevation Contour (mAHD)
Thickness Contour (m)

SSM Mine Lease
SSM EA Boundary
Pit Extent
Roper Study Area

SLR

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SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION AND THICKNESS OF SURFICIAL UNITS

FIGURE 3-5

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3.2.2 Permian Coal Measures (Blackwater Group)

Permian coal-bearing sedimentary rocks of the Blackwater Group form the main economic resource of the numerous mines in the Study Area. In decreasing depth (age) order, the major coal measures in the Study Area include the:

- Moranbah Coal Measures;
- Fort Cooper Coal Measures; and
- Rangal Coal Measures

3.2.2.1 Moranbah Coal Measures

The Moranbah Coal Measures consist of laterally persistent sandstone, siltstone, claystone, mudstone, and coal sedimentary sequences dipping 3° to 6° towards the east (AGE, 2014a). These coal measures subcrop at SSM on the western limb of the Bowen Basin and are also mined at Saraji Mine immediately north of SSM. These seams constitute the economic deposits of coal that are targeted by mining operations at SSM.

The predominance of sandstone, siltstone and claystone inter and overburden is reported to vary across SSM. AGE (2004) summarised the below variations in pit lithology encountered in the Permian unit:

- Roper Pit: Sandstone and carbonaceous claystone interlaminated with sandy siltstone;
- Leichhardt Pit: Siltstone with some thick sandstone beds and minor claystone;
- Gilbert Pit: Thick, massive sandstone beds; and
- Campbell Pit: Massive sandstone

Geological assessment of the Permian formations concluded that the weathering horizon extends to a depth ranging between about 2 to 12 mbGL (metres below Ground Level) with the deepest weathering horizon corresponding with the thickest sequence of Tertiary formation (Dames and Moore, 1975).

There are two main coal seams (each comprised of multiple plies) within the Moranbah Coal Measures mined at SSM; in order of increasing depth these are known as the Harrow Creek (H) seams and the Dysart (D) seams. All seams split and recombine along the mine. These main coal seams subcrop on the western part of the SSM (AGE, 2014a). **Figure 3-6** presents a schematic of the coal seams along the mine. It should be noted that the Fort Cooper Coal Measures are not present within the SSM Area, instead subcropping immediately east of the SSM Area boundary (described further in **Section 3.2.2.2** and as shown in **Figure 3-3**). A brief description of Moranbah Coal Measures coal sequence at SSM includes:

- The Pisces (P) group seams are within the stratigraphic package of SSM however do not occur at sufficient thickness or quality to be considered for mining. Modelled depth and thickness of this seam group is presented in **Figure 3-7**.
- The main Harrow Creek (H) group seams of interest include the Harrow Creek Upper (H16), Harrow Creek Lower (H33 and H32). The H16 is up to 4.8 m thick, the H33 seam up to 2.4 m thick and the H32 up to 1.1 m thick (AGE, 2014a). Modelled depth and thickness of this seam group is presented in **Figure 3-8**.
- The main Dysart (D) group seams of interest include the Dysart Upper (D58 and D59) seam and Dysart Lower (D35) seam. The D35 seam is generally the target coal seam across SSM (AGE, 2014c). Where coalesced, the Dysart Lower seam is typically 4 m thick. The Dysart Upper seams D58 and D59 are 1.1 m to 0.6 m thick respectively. Modelled depth and thickness of this seam group is presented in **Figure 3-9**.

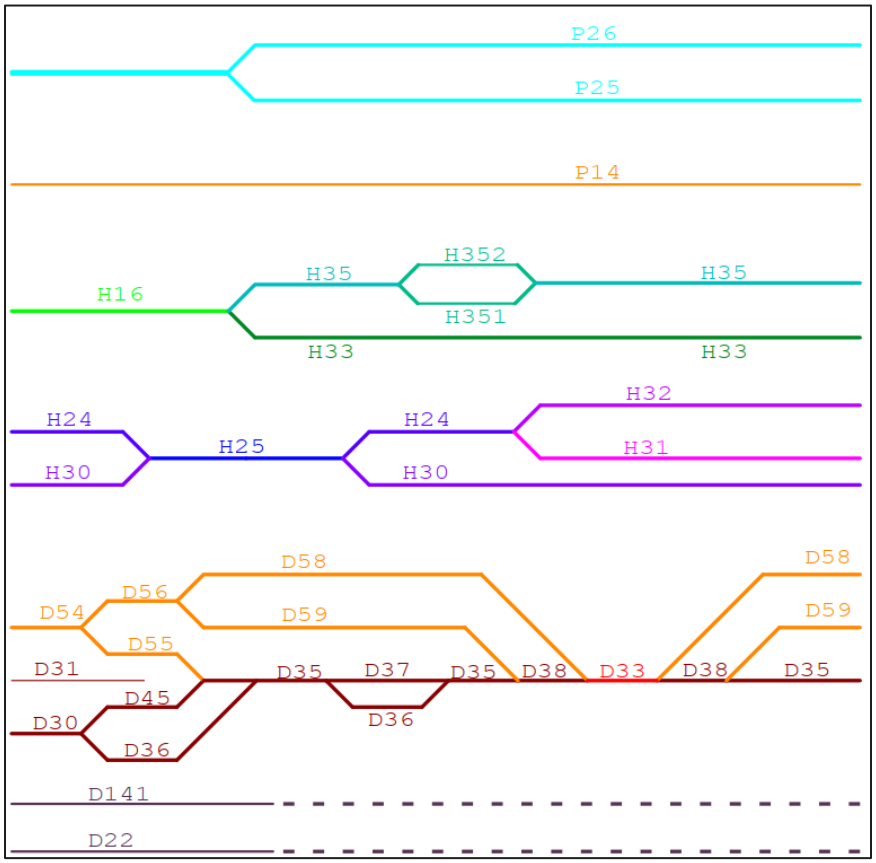


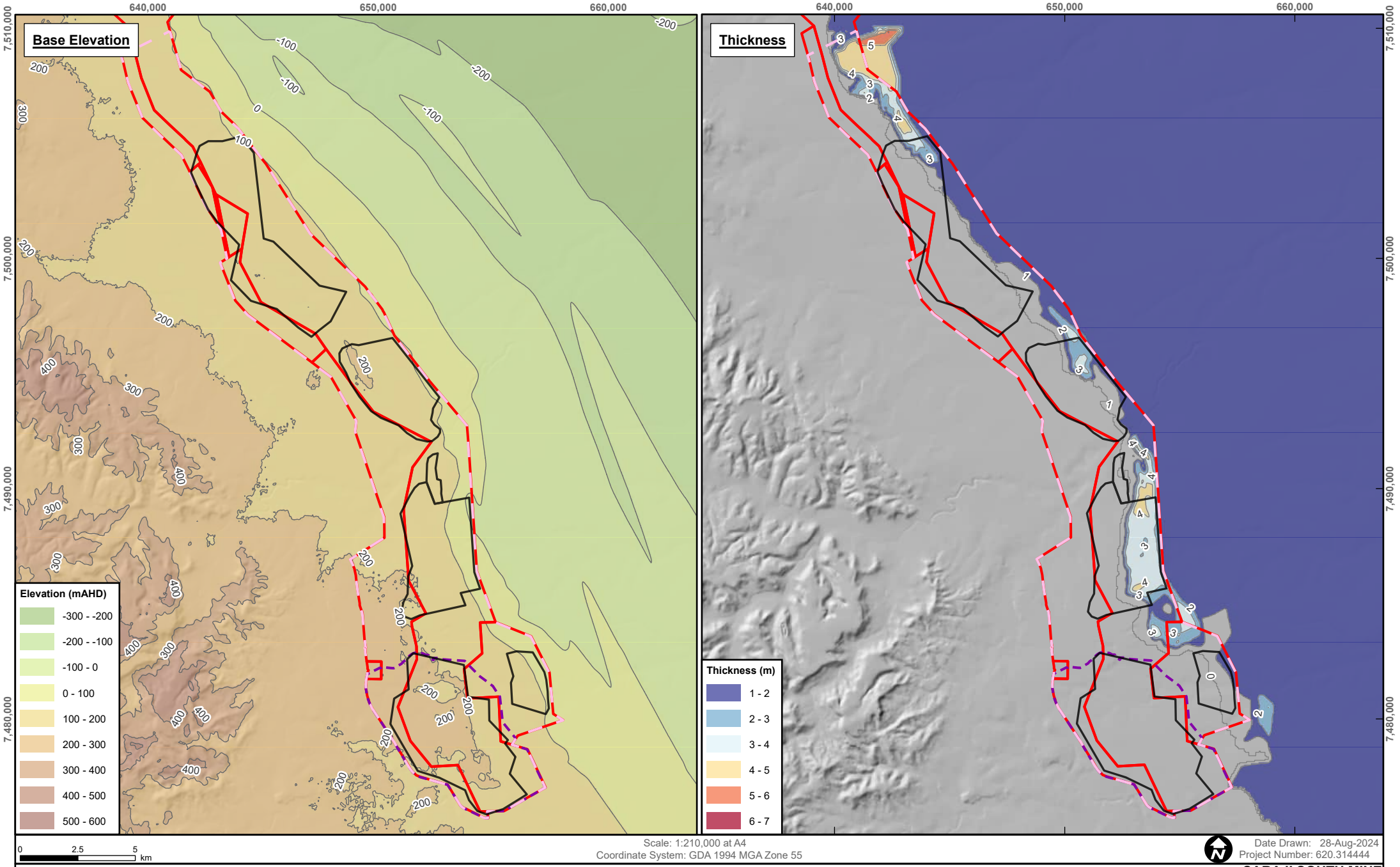
Figure 3-6 Schematic Split Diagram of Moranbah Coal Measures Coal Seams at SSM (JB Mining Services, 2012)

3.2.2.2 Fort Cooper Coal Measures

The Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures and subcrop east of SSM but are not present within the SSM Area. Regionally, the formation has a maximum thickness of approximately 350 m (HydroSimulations, 2018) and drill logs indicate the Fort Cooper Coal Measures comprise lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous (cherty) mudstone. Primary coal seams within the Fort Cooper Coal Measures are the S seam (3 to 4 m thick) and the R seam (1 to 2 m thick) (BMA, 2020). The two seams are not found in the SSM lease and only adjacent to the eastern margins.

3.2.2.3 Rangal Coal Measures

Where they occur further east of SSM, the youngest Blackwater Group coal measures, the Rangal Coal Measures, overlie the Fort Cooper Coal Measures. The transition between the Rangal Coal Measures and the Fort Cooper Coal Measures is marked by the Yarrabee Tuff which immediately overlies the Vermont Lower Seam. The Yarrabee Tuff is a basin-wide marker bed comprised of weak, brown tuffaceous claystone, with an average thickness of 0.7 m. The Rangal Coal Measures comprise light grey, cross-bedded, fine to medium grained labile and well cemented sandstones, grey siltstones, mudstones, shale and coal seams. The non-coal portions of the sequence are predominantly sandstones, siltstones, mudstone and shales, referred to as interburden in the mining context. This unit is outside of the SSM groundwater system considered in this hydrogeology assessment.



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BASE ELEVATION OF THE P SEAM AND THICKNESS OF THE P SEAM

FIGURE 3-7

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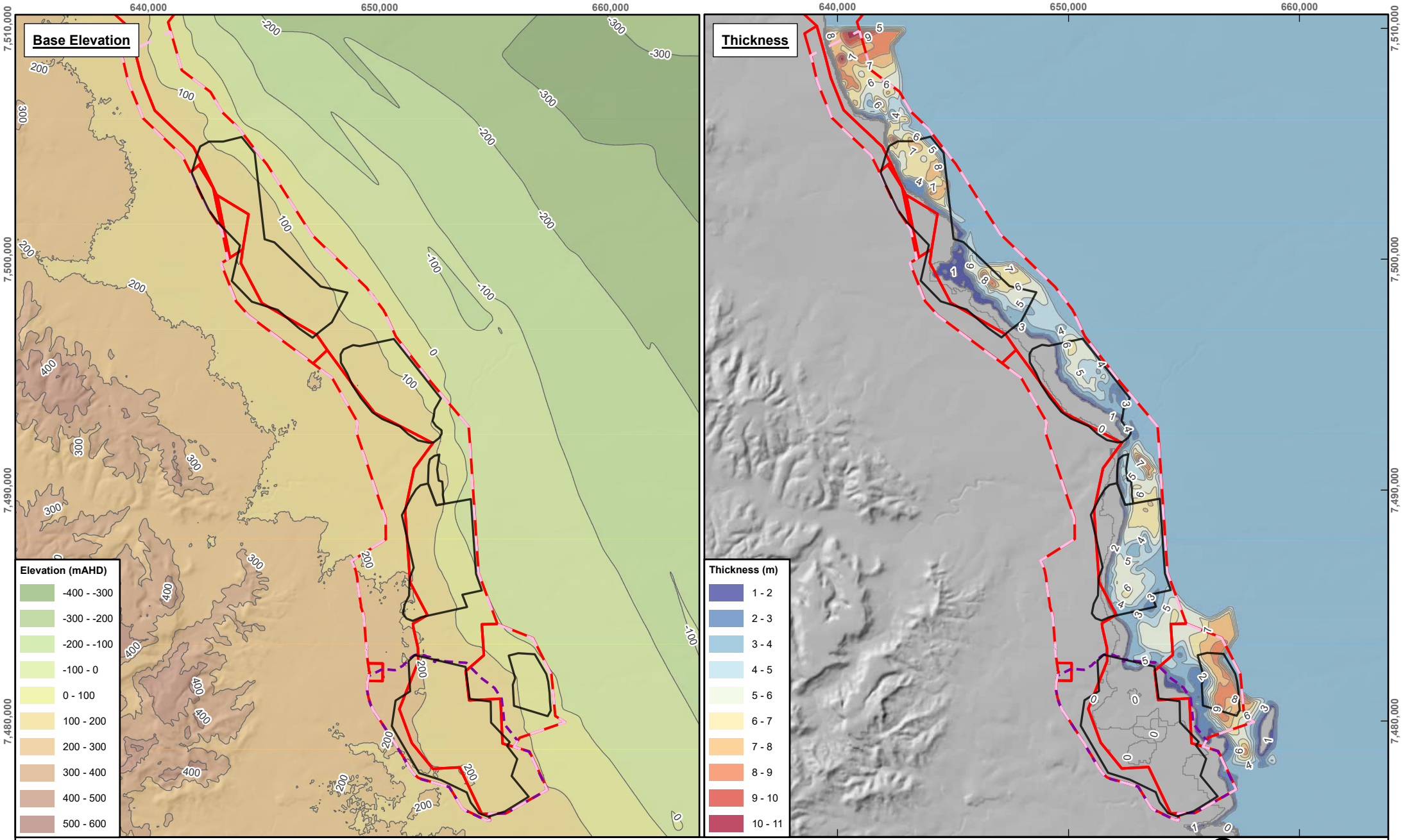

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SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION OF THE H SEAM AND THICKNESS OF THE H SEAM

FIGURE 3-8

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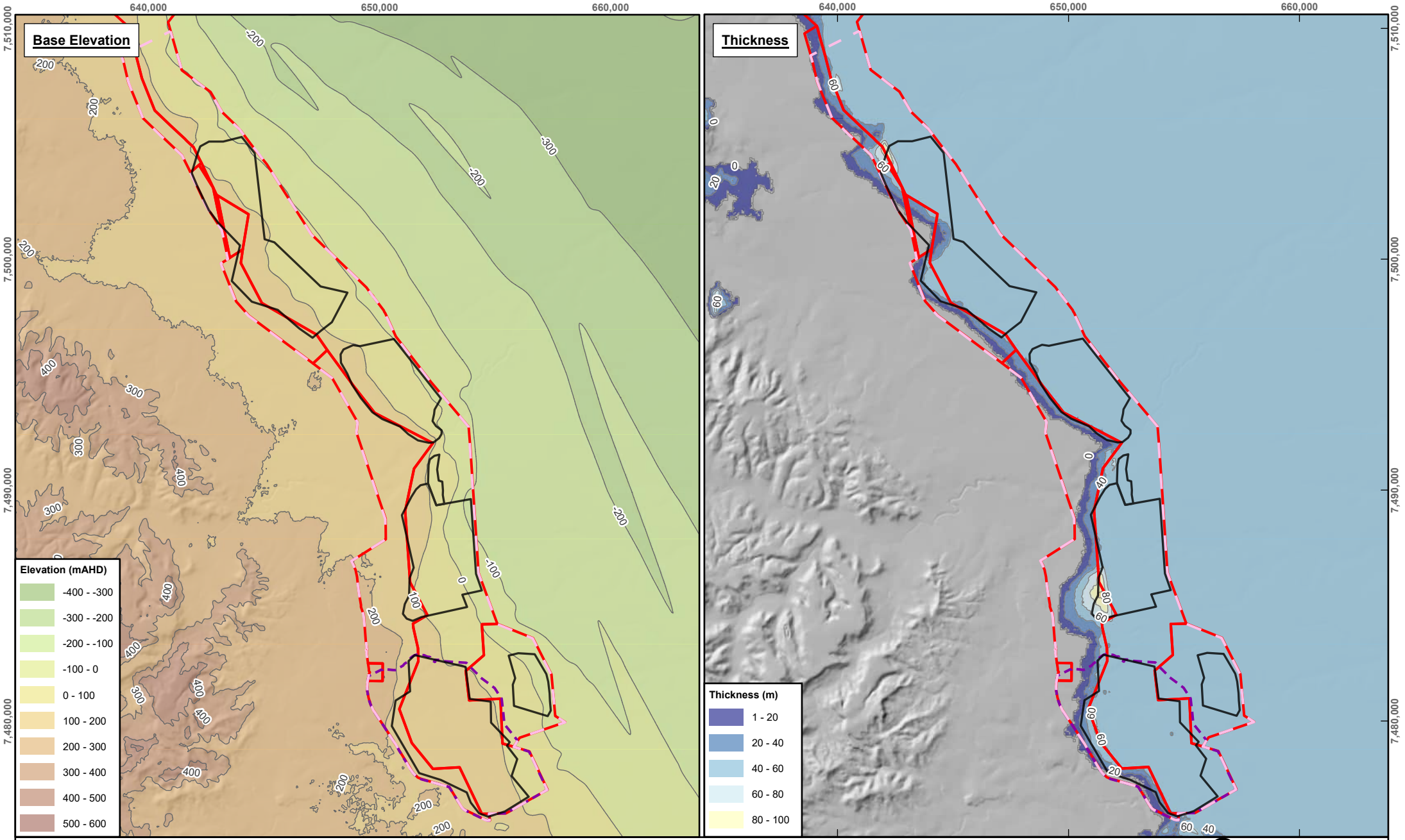

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SARAJI SOUTH MINE TRANSITIONAL PRCP

BASE ELEVATION OF THE D SEAM AND THICKNESS OF THE D SEAM

FIGURE 3-9

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3.2.3 Back Creek Group

Along the western margin of SSM is the Back Creek Group comprising the German Creek Formation and other undifferentiated sandstone, siltstone and shale packages. As shown in the stratigraphic sequence represented in **Table 3-1**, this unit is considered basal for the groundwater system at SSM. The formation consists of early to late Permian interbedded sandstone, siltstone, carbonaceous shale with minor coal seams. The contact between this unit and the overlying formations dips 3° to 6° towards the east, in line with the regional syncline.

3.2.4 Structural Geology

The Bowen Basin was subject to significant tectonic compression from the eastern side at the end of coal deposition in the late Triassic. The compression from the eastern side caused major thrust faulting, which resulted in the commercial viability of mining the coal deposits across the region.

SSM is located within the regional Western Foreland structural domain of the Bowen Basin, located approximately 20 km west of the Jellinbah Fault Zone.

All units of the Permian sequence generally dip from west to east at an average of 4° in the vicinity of SSM, towards the axis of a local syncline that is truncated by the north-south trending Isaac Thrust Fault.

Faults at SSM strike predominantly east northeast- west southwest at the Lotus, Campbell, Roper and Gilbert Pits (**Figure 3-2**). In between the Gilbert and Leichhardt pits is a pair of large northeast-southwest striking faults that dislocate the entire stratigraphic package. The Price and Leichhardt pits display north-south striking structures together with the site wide east northeast- west southwest structures.

The detail on hydrogeological influence of the structural geology features present in the SSM Area is discussed in detail in **Section 4.2.3**.

4.0 Hydrogeology

Based on the understanding of the geological setting presented in **Section 3.0** the hydrogeological regime relevant to SSM comprises the following key hydrogeological units:

- Cainozoic sediments
  - Quaternary alluvium – unconfined aquifer (sporadically water-bearing strata of permeable unconsolidated sand or gravel) localised to major ephemeral drainage line channels at SSM along Downs Creek, Scott Creek and Rolf Creek;
  - Quaternary to Tertiary non-alluvial sediments and weathered units (collectively termed 'regolith' in many recent relevant regional studies) – unconfined unit with limited saturation at SSM and in the Study Area.
- Permian coal measures with:
  - Low permeability interburden and overburden units with aquitard properties; and
  - Coal seams that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

The coal seams within the Moranbah Coal Measures are the primary aquifer at SSM. The coal seams can be characterised as confined aquifers, with the H Seam and D Seam forming the main aquifer units locally. The Moranbah Coal Measures overburden and interburden act as aquitards and are typically dry, or very low yielding.

This section discusses each of the hydrogeological units relevant to SSM, covering hydraulic properties, groundwater occurrence, hydraulic gradients, recharge, discharge, groundwater quality, and water use.

4.1 SSM Groundwater Monitoring

Whilst mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004, approximately 25 years after the commencement of mining. The SSM groundwater monitoring network currently comprises a total of 51 monitoring sites consisting of 33 active sites, 7 decommissioned inactive sites and 11 locations that are not consistently monitored (i.e. historic monitoring points no longer actively routinely monitored).

The monitoring network was first established in 2004 following the issue of an EA (MIM800126503, Environmental Protection Agency, 17 September 2003) (AGE, 2004), and expanded further in AGE (2014c), AGE (2018), GHD (2021a), and BHP (2021). Much of this work was completed in order to identify the nature of groundwater interaction with mine void and water storages. The hydrostatic units monitored in the network include:

- Quaternary Alluvium (2 monitoring bores);
- Tertiary sediments (19 monitoring bores);
- Tertiary weathered basalt (1 monitoring bore);
- the P Seam of the Moranbah Coal Measures (3 monitoring bores);
- the H Seam of the Moranbah Coal Measures (5 monitoring bores);
- the D seam of the Moranbah Coal Measures (4 monitoring bores);
- the interburden/overburden of the Moranbah Coal Measures (9 monitoring bores);
- Fort Cooper Coal Measures (2 monitoring bores); and
- 3 bores with unknown screen details (all inactive).

Groundwater data collection from this network has been undertaken since 2004. The bore details for the current monitoring network are summarised in **Table 4-1** and shown graphically in **Figure 4-1**. This network includes 13 sites where bores are installed in different hydrogeological features across the vertical profile, providing information on vertical gradients in chemistry and hydrostatic pressure

within the aquifer sequence. No vibrating wire piezometers (VWPs) have been installed on site. Water pressure loggers were installed in ten monitoring bores late 2021, monitoring groundwater level through 2022 (**Table 4-2**). This data is presented with the manual groundwater level dips in **Section 4.3**.

Table 4-1 SSM Groundwater Monitoring Network Details

Bore ID	Easting (GDA94)	Northing (GDA94)	Surface Elevation (mAHD)	Screen Top Elevation (mAHD)	Screen Base Elevation (mAHD)	Monitored Unit	Install Date	Bore Status	WL Data Availability	WQ Data Availability
38547	654098	7495068	182.63	No data	No data	Permian (FCCM[1])	15-09-1972	Active	2011-2023	2011-2020
43060	663900	7482826	170.02	No data	No data	Tertiary	01-02-1973	Active	2011-2023	2011-2020
43062	659415	7488033	179.66	No data	No data	Permian (FCCM)	01-02-1973	Active	2011-2023	2011-2020
MB20NPM01A	643394	7505494	188.74[+]	No data	No data	No data	No data	No data		
MB20NPM02P	643391	7505498	188.66[+]	89.16	83.16	Permian (MCM[2] H Seam)	No data	Active	2022	
MB20NPM03A	650324	7496839	180.38	177.38	174.38	Alluvium	07-12-2020	Active	2022	
MB20NPM04P	650338	7496838	183.28	101.28	98.28	Permian (MCM H Seam)	05-12-2020	Active	2021-2022	
MB20NPM05A	653471	7493056	184.52	170.52	166.52	Tertiary	09-12-2020	Active	2021-2023	
MB20NPM06T	653469	7493063	184.91[+]	151.91	144.81	Tertiary	02-03-2021	Active	2021-2023	
MB20NPM07A	656939	7479625	194.01[+]	163.01	154.01	Permian (MCM IB/OB[3])	04-02-2021	Active	2021-2023	
MB20NPM08P	656952	7479625	193.52[+]	142.52	139.52	Permian (MCM P Seam)	26-03-2021	Active	2021-2023	
MBL01A	652545	7488003	209.85[+]	47.35	41.35	Permian (MCM D Seam)	17-03-2014	No data	2014	2014
MBL01B	652541	7488007	209.81	166.21	160.21	Tertiary	19-03-2014	No data	2014	2014
MBP001A	652782	7491808	188.46	159.46	155.46	Permian (MCM IB/OB)	11-12-2018	Active	2018-2022	2018-2020
MBP001B	652778	7491810	188.32	115.62	106.32	Permian (MCM D Seam)	10-12-2018	Active	2018-2022	2018-2020
MBP002A	652810	7491432	190.91	182.91	175.91	Tertiary	10-12-2018	Active	2018-2022	2018-2020
MBP002B	652808	7491427	191	173	168.5	Permian (MCM IB/OB)	09-12-2018	Active	2018-2019	2018-2020
MBP003A	652157	7491547	187.15	165.15	157.15	Permian (MCM IB/OB)	05-12-2018	Active	2018-2019	2018-2020
MBP003B	652158	7491552	187.36	156.36	147.36	Permian (MCM IB/OB)	04-12-2018	Active	2018-2019	2018-2020
MBP004A	652380	7491536	188.54	177.54	170.54	Permian (MCM IB/OB)	06-12-2018	Active	2018-2022	2018-2020
MBP004B	652381	7491542	188.53	167.53	160.53	Permian (MCM H Seam)	06-12-2018	Active	2018-2022	2018-2020
MBP005A	652525	7491909	187	164	159	Permian (MCM IB/OB)	08-12-2018	Active	2018-2022	2018-2020
MBP005B	652523	7491904	187.26	131.26	124.26	Permian (MCM H Seam)	07-12-2018	Active	2018-2022	2018-2020
MBR01A	655738	7479095	206.67[+]	112.67	106.67	Permian (MCM D Seam)	11-03-2014	No data	2014	2014
MBR01B	655738	7479098	206.68[+]	167.18	161.18	Tertiary	13-03-2014	No data	Dry (2014)	
MBR02A	656144	7478203	206.10[+]	114.10	108.10	Permian (MCM D Seam)	14-03-2014	No data	2014	2014
MBR02B	656145	7478197	206.14[+]	173.14	167.14	Tertiary	15-03-2014	No data	Dry (2014)	
NPMMB01_01	643395	7505495	188.69[+]	146.19	140.19	Permian (MCM P Seam)	No data	Active	2022	
NPMMB02_01	649880	7489940	196.38[+]	127.38	121.38	Permian (MCM IB/OB)	15-02-2021	Active	2021-2023	
NPMMB02_02	649869	7489940	196.33	122.33	116.33	Tertiary Basalt	19-02-2021	Active	2021-2023	
NPMMB03_01	650329	7496838	181.38	165.18	159.18	Permian (MCM IB/OB)	06-12-2020	Active	2021-2022	
NPMMB06_01	653440	7487474	201.64	154.49	148.49	Tertiary	06-02-2021	Active	2022-2023	
NPMMB06_03	653438	7487481	201.88	116.38	113.38	Permian (MCM P Seam)	29-01-2021	Active	2022-2023	
NPMMB07_01							14-12-2020	Inactive		
NPMMB08_01	650987	7483198	223.82[+]	194.82	188.82	Tertiary	13-02-2021	Active	2021-2022	
P2	651008	7483333	221.65	213.15	210.15		01-04-2004	Inactive	2004-2013	2010-2012
P2A	651026	7483343	221.80	203.80	192.80	Tertiary	2013	Inactive	2013-2020	2013-2018

Bore ID	Easting (GDA94)	Northing (GDA94)	Surface Elevation (mAHD)	Screen Top Elevation (mAHD)	Screen Base Elevation (mAHD)	Monitored Unit	Install Date	Bore Status	WL Data Availability	WQ Data Availability
P2A_R	651026	7483343	222.05+	192.05	187.05	Tertiary	14-12-2020	Active	2022-2023	
P3	649872	7489937	196.01	175.01	172.01	Tertiary	28-04-2004	Active	2004-2020	2005-202
P6	650330	7496846	181.18	172.38	167.18	Alluvium	15-04-2004	Inactive	2004-2014	2005-2014
P6R	650356	7496833	181.37	175.37	141.37	Permian (MCM H Seam)	2015	Active	2015-2020	2015-2021
P7	650958	7483035	228.70+			Tertiary	No data	Inactive	2023	
P7R	650955	7483035	229.03+	223.03	205.53	Tertiary	No data	Active	Dry	
P8	650987	7483109	226.66+			Tertiary	No data	Inactive	Dry	
P8R	650988	7483126	226.20+	220.20	202.20	Tertiary	No data	Active	Dry	
P9	650914	7483118	227.33+			Tertiary	No data	Inactive	Dry	
P9R	650914	7483118	227.33+	221.33	203.43	Tertiary	No data	Active	Dry	
P10	651036	7482966	228.78+	No data	No data	Tertiary	No data	No data	Dry	

+ Indicates surface RL sourced from LiDAR

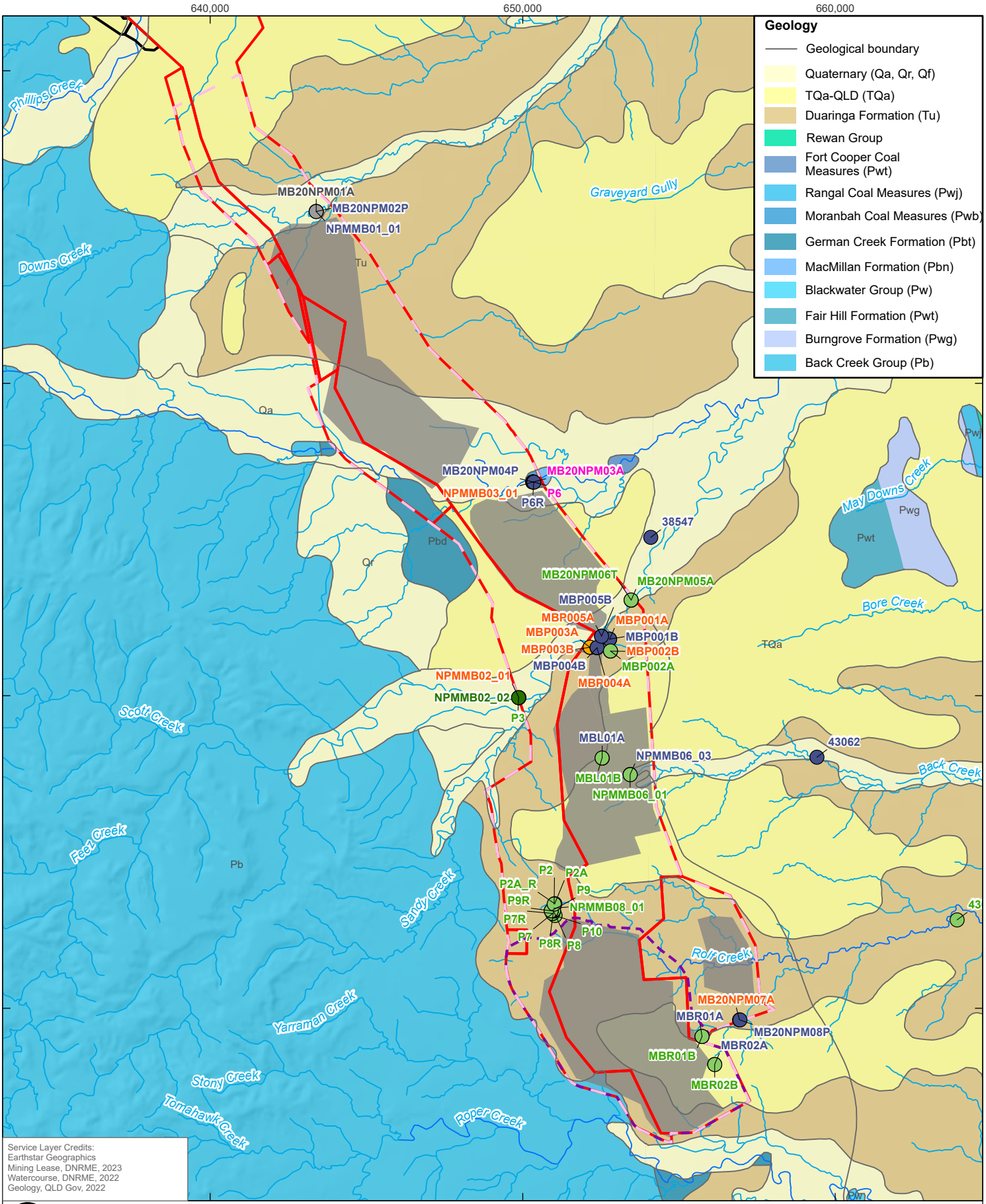
[1] Fort Cooper Coal Measures

[2] Moranbah Coal Measures

[3] Interburden/Overburden

Table 4-2 Summary of groundwater level logging data availability

Bore ID	Start of Logger Record	End of Logger Record	Frequency
MB20NPM07A	21-09-2021	22-05-2023	1 hour
MB20NPM06T	21-09-2021	06-12-2023	1 hour
MB20NPM05A	21-09-2021	06-12-2023	1 hour
MB20NPM04P	22-09-2021	06-12-2023	12 hours
MB20NPM08P	21-09-2021	06-06-2023	12 hours
NPMB02-01	22-09-2021	05-12-2023	12 hours
NPMB02-02	22-09-2021	05-12-2023	12 hours
NPMB03-01	22-09-2021	06-12-2023	12 hours
NPMMB08-01	21-09-2021	05-12-2023	12 hours
P2AR	21-09-2021	05-12-2023	12 hours
NPMB06-01	21-09-2021	06-12-2023	12 hours
MB20NPM03A	22-09-2021	11-11-2022	4 hours



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:160,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

SARAJI SOUTH MINE TRANSITIONAL PRCP

SSM GROUNDWATER MONITORING NETWORK

SLR

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FIGURE 4-1

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_1_Groundwater_Monitoring_Network_01

4.2 Hydraulic Properties

SSM site groundwater hydraulic testing is available from slug (rising and falling head) tests performed on monitoring network bores completed by AGE (2014a) and BHP (2021). This section presents a summary of the available field hydraulic data, and a comparison to externally reported hydraulic properties that BMA has access to through its regional data sharing agreement with neighbouring sites.

4.2.1 Hydraulic Data

The database of available field results for horizontal (Kh) and vertical (Kv) hydraulic conductivity is presented graphically as **Figure 4-2**. Tests from the SSM Area are provided as a separate classification on the plot. The data are also presented separately for each test method as results can vary based on the type of testing and analysis undertaken.

Figure 4-2 shows that the hydraulic conductivity of the alluvium is variable, ranging from 1 x 10^{-2} to almost 101 metres per day (m/day), which reflects the heterogeneous nature of the alluvial sediments. There is no hydraulic testing data available for the alluvium in the SSM monitoring network, though extensive testing from the region provides reasonable ranges for groundwater modelling applications. Pumping tests of the Isaac River alluvium conducted in 2019 as part of the Moorvale South Project assessment reported hydraulic conductivity values in the range of 2.1 – 2.7 m/day (Golder, 2019).

Broadly termed the Regolith unit in previous relevant studies, the Tertiary aquifer consists of highly weathered basalts and clay rich sediments that have been found to behave similarly in the groundwater system to the weathered Permian outcrops. Hydraulic testing of the unit within SSM also found hydraulic conductivity to be highly variable, in line with regional values, with SSM slug testing hydraulic conductivity ranging from 0.03 m/d to 6.5 m/d.

The coal seams of the Permian coal measures generally record higher hydraulic conductivity than the majority of the interburden/overburden. Interburden/overburden testing shows a hydraulic conductivity of at least an order of magnitude less than that of coal seams at similar depths, typically less than 1 x 10^{-4} m/day. This is due to the dual porosity of the coal seams, with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats), which supports the concept of the coal seams themselves forming the dominant groundwater zones of the Permian units.

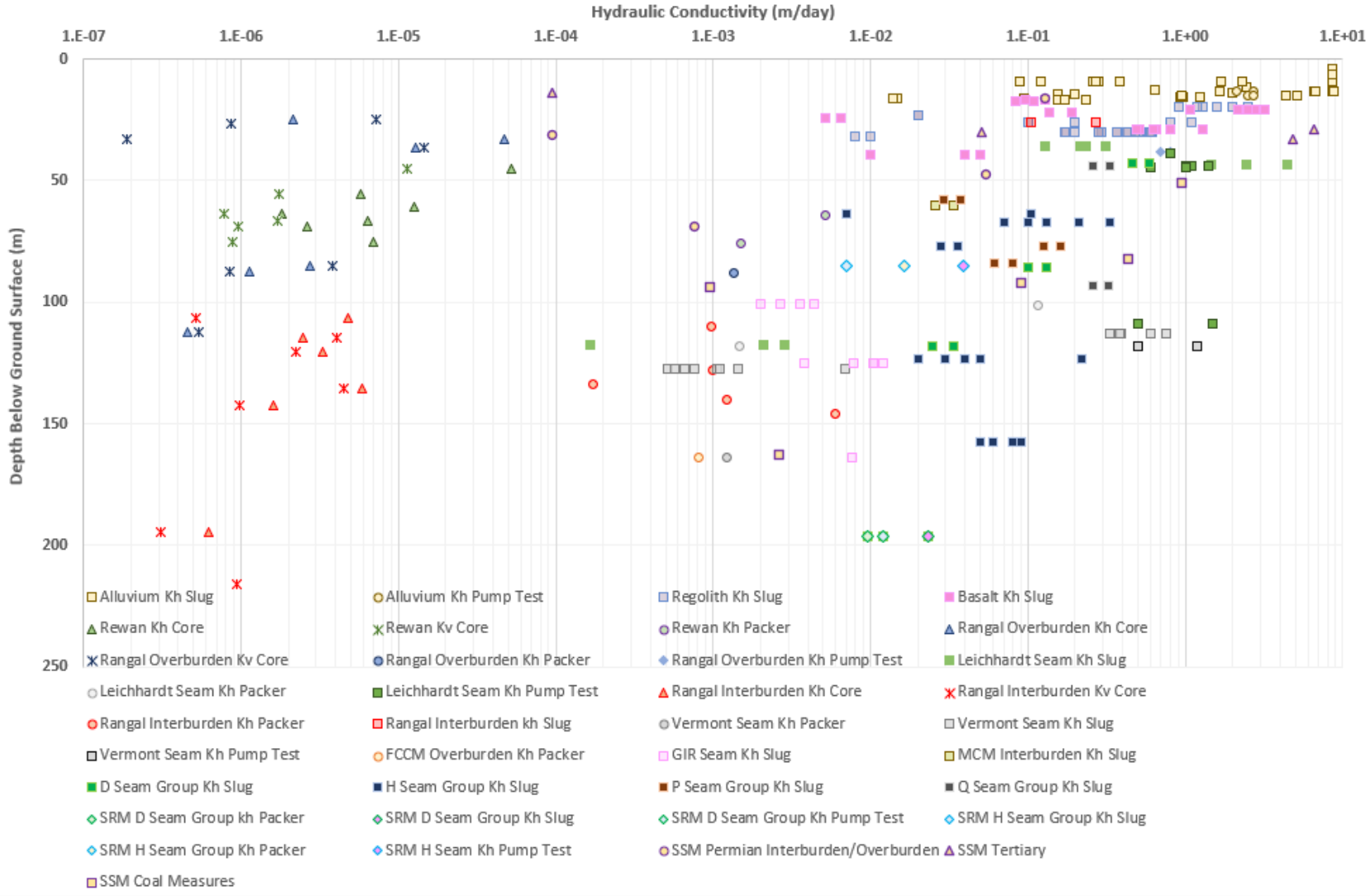


Figure 4-2 Summary of all regional hydraulic testing results

4.2.2 Hydraulic Conductivity Ranges

A histogram of the spread of horizontal hydraulic conductivity (Kh) from the field testing at SSM, as well as at other nearby sites, is presented in **Figure 4-3**. The results are compared to the range of documented values for each relevant unit, as presented within a literature review previously completed by HydroSimulations (2018) based on several other studies within the Bowen Basin.

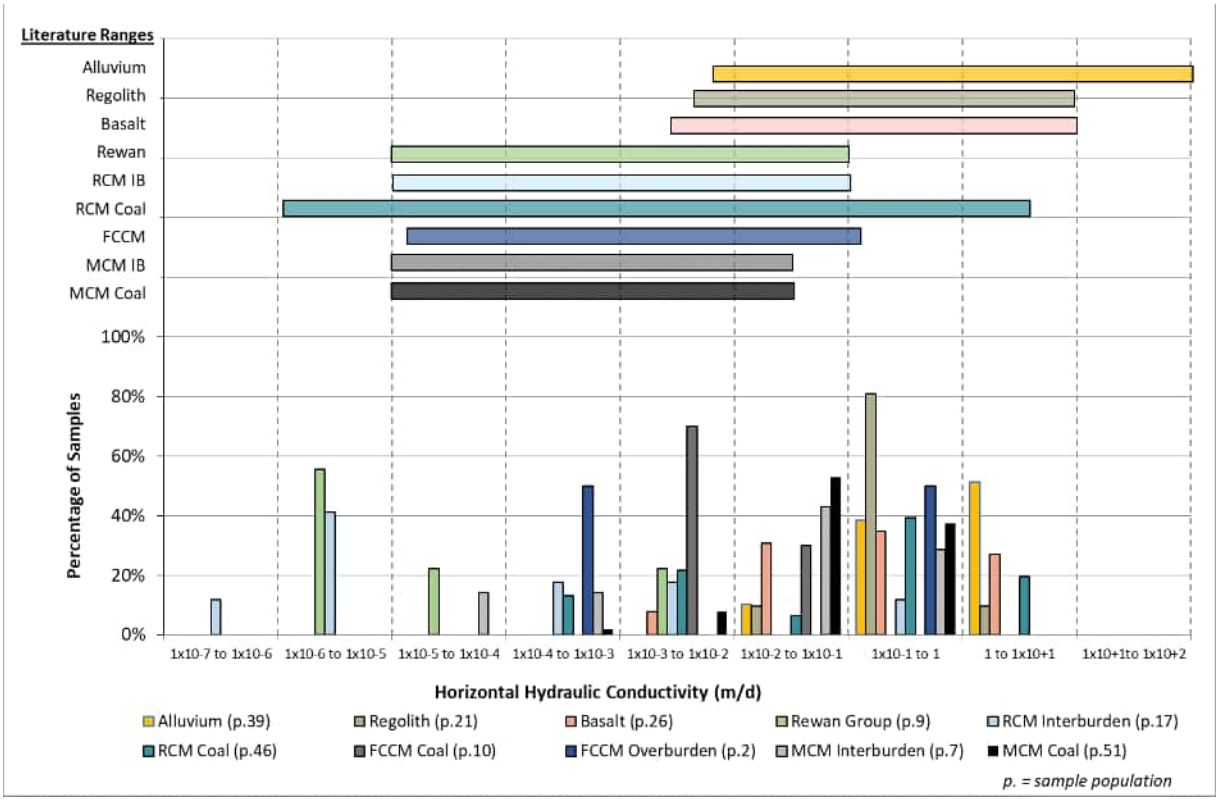


Figure 4-3 Histogram of Horizontal Hydraulic Conductivity Distribution

The comparison shows that the field results for alluvium, Tertiary sediments, and Moranbah Coal Measures interburden within the Study Area and immediate surrounds, fall within the range of field data collected through other studies across the Bowen Basin, with just one measurement greater than the literature range for Moranbah Coal Measures interburden. As established in conceptualisation work completed for study area along strike to the north, hydraulic testing results for the coal seams of Moranbah Coal Measures in the SSM Area recorded higher hydraulic conductivity than previously identified in literature for that unit (SLR, 2023a). Review of **Figure 4-2** shows that within the Moranbah Coal Measures the higher values are attributed to the H seam where hydraulic conductivities are generally an order of magnitude greater than measured within the P and D coal seams. These testing results from SSM are consistent with H seam observations adjacent to the Study Area along strike (SLR, 2023a).

4.2.3 Faulting

As discussed in **Section 3.2.3**, there are numerous faults trending northwest-southeast within Permian strata across SSM and surrounding area.

As identified by Jourde *et al*. (2002), faulting can result in higher permeabilities within strata parallel with the fault plane, and lower permeabilities within strata perpendicular to the fault plane. However, this can also be dependent on whether faults are currently active (Paul *et al.*, 2009). Faulting has been inactive within the Bowen Basin for over 140 million years (Clark *et al.*, 2011), indicating that the fault zones are less likely to act as conduits to flow; this relates to filling of the fractured pore spaces over time through hydrothermal alteration and mineralisation (Uysal *et al.*, 2000).

Downhole hydraulic testing was also conducted in the Permian coal measures for the Winchester South Project north-northwest of SSM (SLR, 2020). Fault zones were confirmed to be intersected at these drill holes due to the presence of fracturing, calcite infills, and slickensides in core obtained from the drill holes, all of which are considered an indicative marker of faulting. Testing results showed relatively low hydraulic conductivity values ranging from 6.9×10^{-5} to 2.1×10^{-3} m/day, and in line with those presented in **Figure 4-4**. These properties indicate that the faulting zones intercepted and tested are 'healed' and not pathways for preferential groundwater flow, given their hydraulic conductivities are generally lower than the adjacent Permian coal seams.

Laboratory geotechnical analysis of core samples of interburden immediately above and below coal seams proximal to a fault zone has previously been undertaken in support of groundwater assessments in the Study Area (SLR, 2020). The samples recorded vertical hydraulic conductivity of 50% to 160% of horizontal hydraulic conductivity; i.e. although some samples show a typical Kv of somewhat less than Kh, some samples also suggest greater Kv than Kh, which may be indicative of preferential vertical flow pathways associated with faulting. However, it was also noted that these areas of increased Kv are limited vertically, with samples collected from the same drill hole at horizons further above and below the fault zone (interburden and Rewan Group) returning a lower Kv of between 11% and 76% of Kh. This highlights the limitations of bore scale test methods (such as core or slug testing) that may bias results compared to methods that yield more aquifer scale estimates of hydraulic properties, such as pumping tests.

The impact of faults on groundwater flow within the Study Area was also assessed as part of the Bowen Gas Project (Arrow Energy, 2012). Kinnon (2010) assessed the movement of water and gas across a series of faults in the Bowen Basin using stable isotope and water quality analysis to assess zones of potential recharge, water mixing and flow pathways. Higher gas production rates were also observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of the major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a horizontal permeability barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin.

Based on a detailed literature review of the effect of faulting on groundwater flow, Coffey (2014) developed a conceptual model for fault zone hydraulic characterisation in the Bowen Basin (**Figure 4-4**), largely based on Jourde *et al.* (2002) and Flodin *et al.* (2001). This conceptualisation provided a means of inferring hydraulic conductivities of the fault core and the fault damage zone from regional hydraulic conductivity, with the fault core typically one to three orders of magnitude lower conductivity than the regional host rock, and the damage zone approximately an order of magnitude higher.

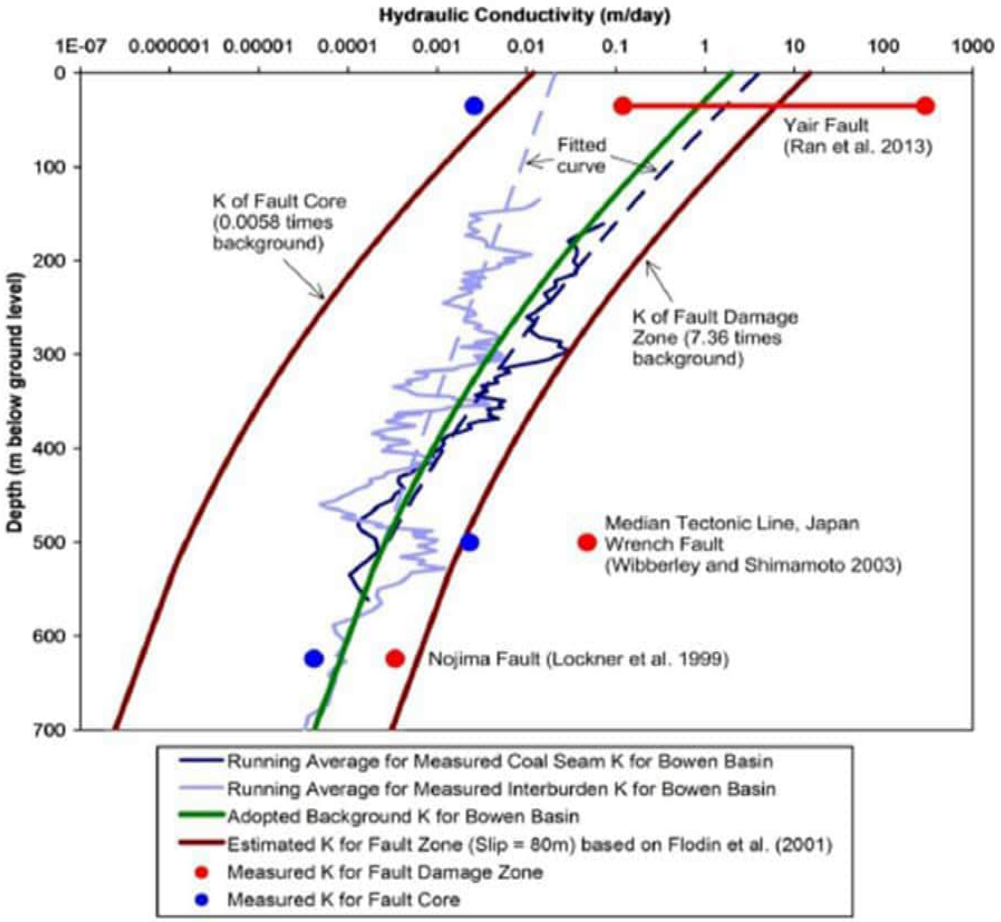


Figure 4-4 Faulting Conceptual Model Developed by Coffey (2014)

4.3 Groundwater Distribution, Flow, Recharge and Discharge

4.3.1 Alluvium

4.3.1.1 Distribution and Flow

Despite significant areas delineated as Quaternary alluvium in the Queensland regional detailed surface mapping (DNRME, 2017), site investigations have repeatedly noted that surface cover is Tertiary aged colluvium (i.e. regolith), with alluvial material limited to within surface water channels where they have eroded into the Tertiary profile. That is, the actual distribution of Quaternary alluvium in the SSM Area is deemed to be significantly more restricted than is mapped in the public surface geology. BMA drilling investigations at SSM from 2014 to 2021 failed to identify significant lenses of shallow alluvial material to install monitoring bores, and thus there are only two locations where alluvial monitoring was installed, bores P6 and MB20NPM03A north of Gilbert Pit adjacent to Stephens Creek (refer **Figure 4-1**).

P6 was installed in an alluvial sand lens north of Gilbert Pit adjacent to Stephens Creek. The alluvium in this bore was initially saturated and monitored from 2004 to 2009 before it ran dry and was replaced by P6R, however due to a lack of saturation in the shallow alluvium, this bore was installed in the underlying Permian coal seam water table aquifer (**Figure 4-5**). Alluvium monitoring in this area was re-instated in 2020 with the installation of MB20NPM03A, however no saturation has been observed (i.e. the alluvium is deemed to be 'dry').

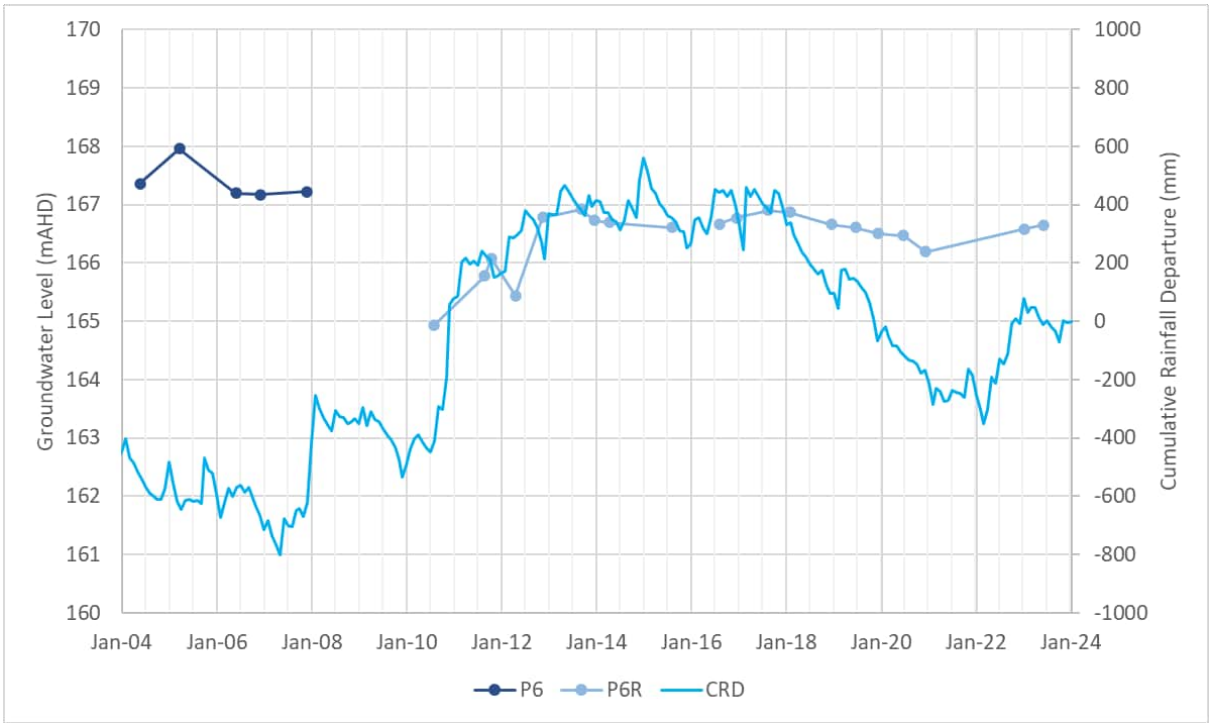


Figure 4-5 Alluvium water level monitoring bore P6 hydrograph with coal seam bore P6R for comparison

4.3.1.2 Recharge and Discharge

Recharge to the alluvium is considered to be mostly from stream flow or flooding (losing streams), with direct infiltration of rainfall also occurring where there are no substantial clay barriers in the shallow subsurface.

4.3.2 Regolith

4.3.2.1 Distribution and Flow

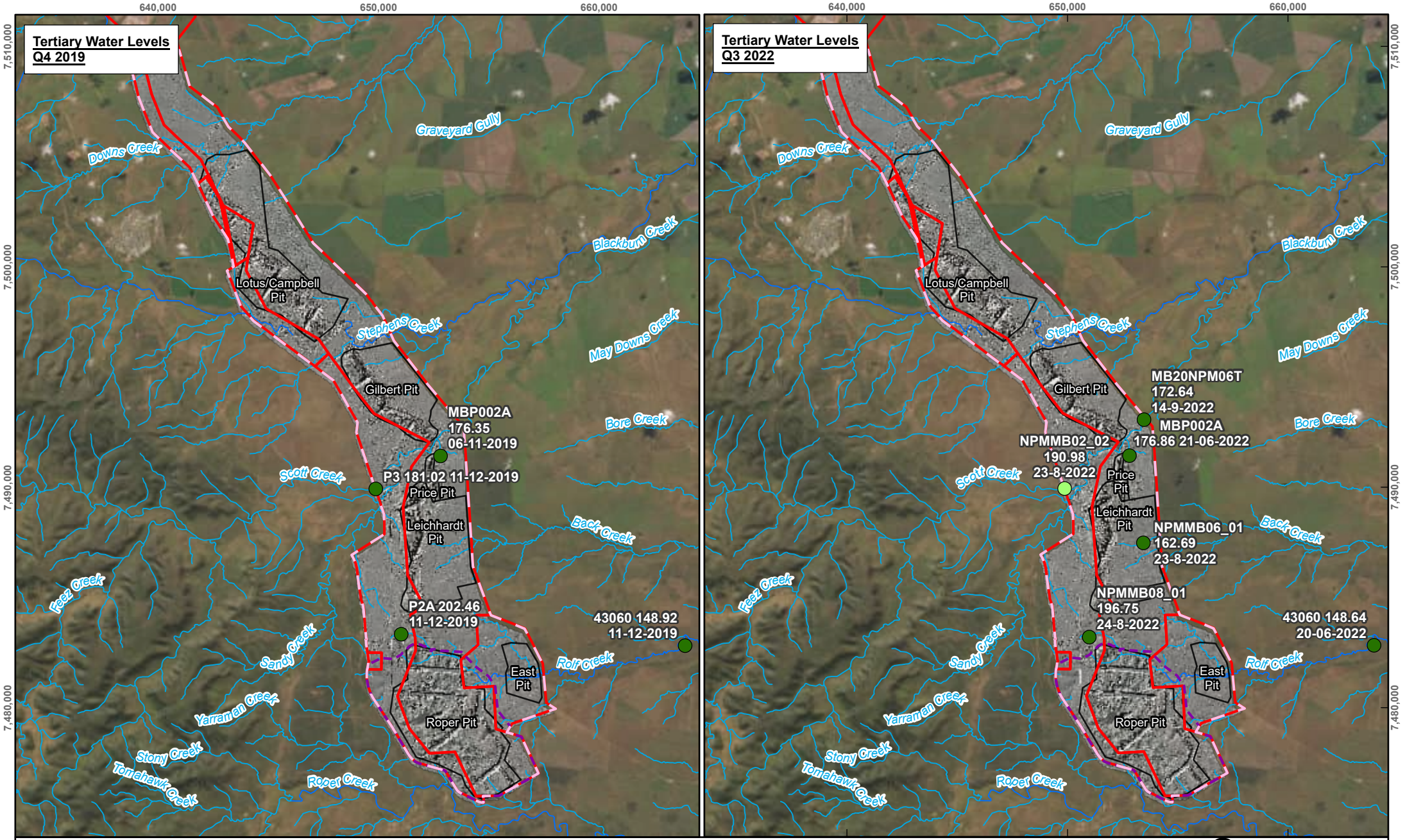
Across the SSM site, the Tertiary sediments and weathered strata (i.e. collectively the 'regolith' in a hydrogeological sense) are generally considered to form the water table aquifer, with saturation commonly displayed in coarse lenses of clayey sand and weathered material between 20-35 mbGL. Ten Tertiary monitoring bores are located in a cluster north of Roper Pit in the south of SSM (refer **Figure 4-1**), originally constructed to monitor the mine infrastructure area and, excepting P2 and one water level measured at P7, have been dry since construction. Bore P3 is located adjacent to Scott Creek on the western boundary of ML70126, and 43060 is located approximately 9 km to the east of the Roper Pit mining area. The remaining Tertiary monitoring bores are spread along the eastern margin of existing mine voids from Roper Pit in the south to Campbell Pit in the north (**Figure 4-6**). Hydrographs of water level measurements available for these monitoring locations are split between **Figure 4-7** and **Figure 4-8.**

Bore 43060 is screened within a Tertiary aged sand layer. Groundwater elevations have varied during the monitoring period, fluctuating between approximately 147.97 mAHD and 149.04 mAHD. A strong correlation with the CRD is evident at 43060, indicating the rise and fall of groundwater levels are a direct response to changes in climate/rainfall.

Installed adjacent to historical mine infrastructure area, P2, P2A and P2AR are a series of bores located in a cluster north of Roper Pit in the south of SSM that have replaced one another as each runs dry. Contrasting with the other shallow groundwater monitoring in this area, the successive re-installation of monitoring at progressively deeper levels has tracked the mine-related water level decline within the shallow water table aquifer (**Figure 4-8**). P2AR is the only active bore, as both P2

and P2A have been decommissioned. All three bores have been screened in Tertiary aged clayey sand, though at deepening screen depths, with the currently active P2AR screened between 30 and 35 mbGL. The water level hydrograph from these monitoring points shows water levels at these bores are largely separated from the climatic trend.

Bore P3 is screened within a Tertiary aged sand layer. Water levels in this bore have shown general consistency with the climatic trend indicated by the CRD plot, with a dampened and somewhat delayed elevation change coinciding with periods of rainfall excess and deficiency (**Figure 4-7**). Since August 2017, groundwater levels at P3 have steadily decreased, following the trend in the CRD.



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TERTIARY WATER LEVELS

FIGURE 4-6

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_6_Tertiary_Water_Levels_01

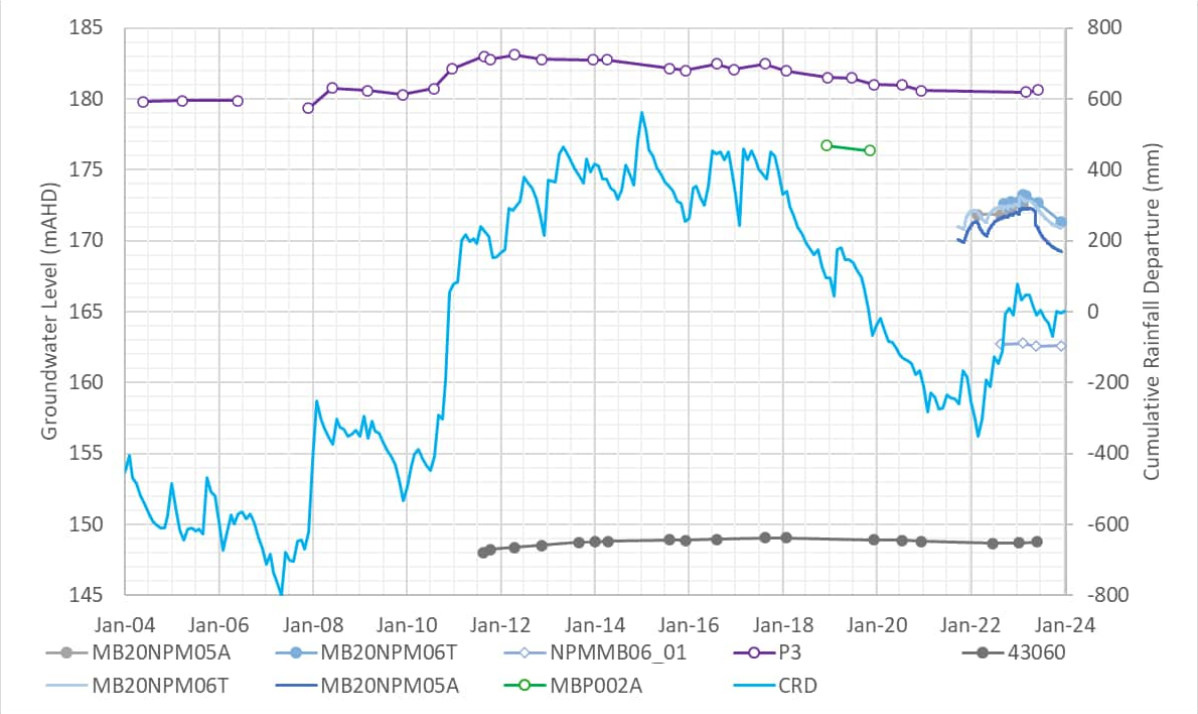


Figure 4-7 SSM Monitoring Bore Hydrographs – Tertiary bores 145 to 185 mAHD

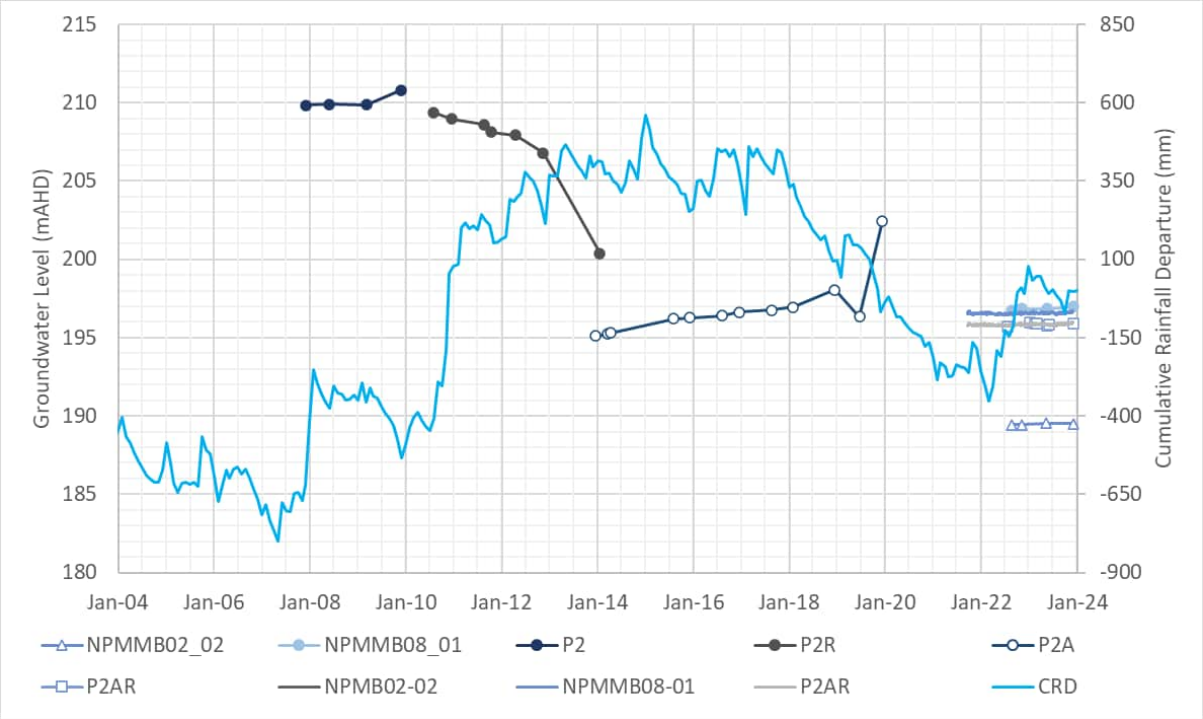


Figure 4-8 SSM Monitoring Bore Hydrographs – Tertiary bores 185 to 215 mAHD

Located east of Gilbert Pit and adjacent to Scott Creek, two paired bores MB20NPM05A and MB20NPM06T are screened within Tertiary aged sediments and regolith, separated by approximately 15 vertical metres. Automated level loggers installed at these two locations show relatively immediate response to rainfall (**Figure 4-9**). Data from these two bores indicates an upwards hydraulic gradient of approximately 0.8 m/15 m (~5%).

As displayed in **Figure 4-8**, NPMMB02_02 is screened within Tertiary aged basalt. Despite limited data, a slight response to rain events in 2022 suggests groundwater level fluctuations at NPMMB02_02 are partially correlated to the CRD.

Although when considered spatially the data is relatively limited, with relatively few monitoring bores across a large area, the available monitoring suggests that groundwater flow within the Tertiary sediments is expected to be a subdued reflection of the topography, with flow from west to east, with local scale modification around existing mine pit voids. This is consistent with the outcomes of other recent relevant studies in the Study Area (e.g. SLR, 2021).

4.3.2.2 Recharge and Discharge

As discussed in **Section 3.2.1**, the Tertiary and regolith material comprises low hydraulic conductivity strata (i.e., clay and claystone), which somewhat restricts rainfall recharge. This is shown by the general limited response to climatic conditions in monitoring bores. This is consistent with the outcomes of other recent relevant studies in the Study Area (e.g. SLR, 2020). This lack of response in monitoring bores within the Study Area may also be due to rainfall being insufficient to wet the unsaturated zone above the water table as well as providing vertical groundwater flow towards the water table. Bores MB20NPM06T and MB20NPM05A are installed in sand lenses at approximately 25-30 mbGL that appear to show more rapid reaction to surface water recharge events (**Figure 4-9**). Some or all of this recharge is likely to be associated with the losing condition ephemeral surface drainage (Scott Creek) near to these bores. The rate of groundwater level rise recorded following rainfall events is generally marginally greater at MB20NPM06T than MB20NPM05A, suggesting a higher specifical yield at the shallower MB20NPM05A bore.

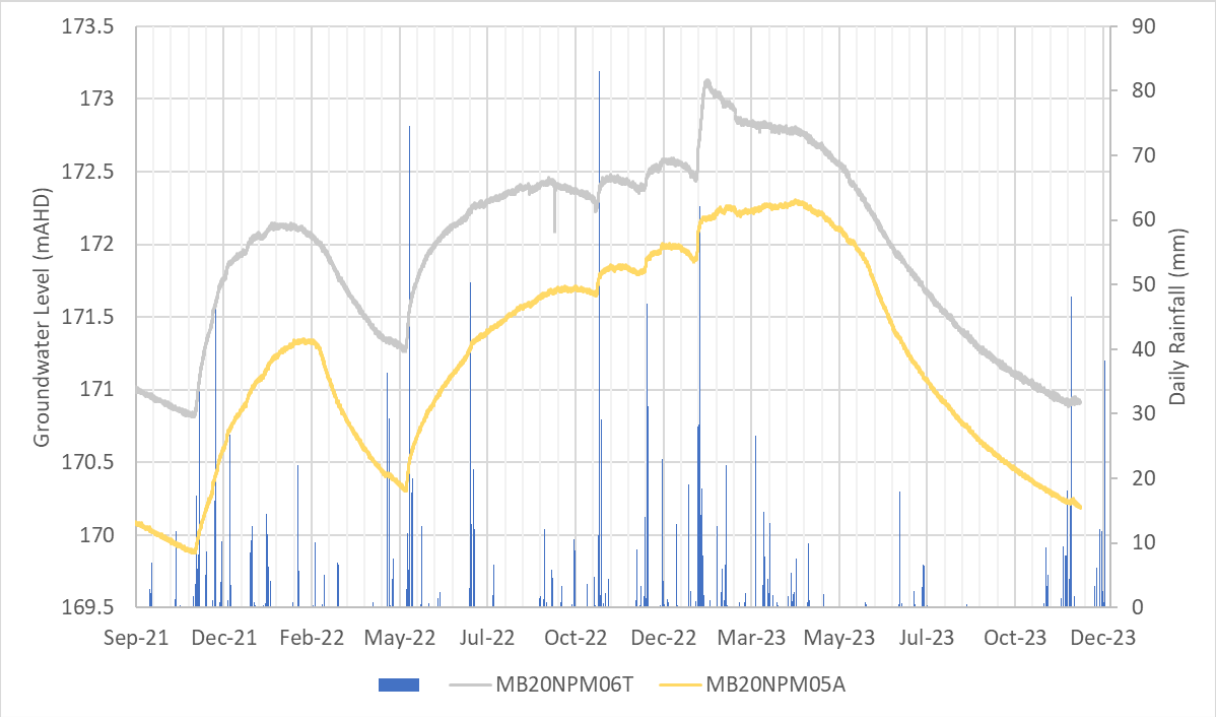


Figure 4-9 SSM Monitoring Bore Hydrographs – MB20NPM06T and MB20NPM05A water level logging plotted with rainfall

Groundwater discharge occurs primarily via evapotranspiration, with some baseflow to streams from the regolith under wet climatic conditions. Previous investigations reported to DES (AGE 2014a,

JSB&G 2021) have indicated that there may be potential for recharge to the Tertiary unit through mine voids at high water storage levels; that is, where void storage (lake) levels are above the base of the Tertiary units.

Vertical seepage through the Tertiary sediments and regolith is limited by the underlying low hydraulic conductivity of the Blackwater Group overburden and other aquitards, such that the Tertiary sediments and regolith effectively form a perched groundwater system above the Permian.

4.3.3 Permian Coal Measures

4.3.3.1 Distribution and Flow

The coal seams of the Moranbah Coal Measures subcrop throughout the western area of SSM, and outcrop to surface in the mine voids where surficial cover has been removed. Groundwater occurrence within the Permian coal measures is largely restricted to the more permeable coal seams that exhibit secondary porosity through fractures and cleats (**Section 3.2.2**). Regionally groundwater flow is to the east, consistent with local topography (AECOM, 2019). Differences in piezometric heads within the confined coal seam aquifers of the Moranbah Coal Measures drive groundwater flow eastwards across the Bowen Basin, from the slightly more elevated outcrop and subcrop areas on the western flank of the Basin to the less elevated subcrop areas on the eastern flank (AECOM, 2019). However, mining activities throughout the region have created locally modified groundwater flow systems within the Permian coal measures that are superimposed on these regional flow gradients. Mine voids at SSM are expected to be long term sinks for groundwater flow within the Permian Coal Measures, with local groundwater flow directions towards the mine voids.

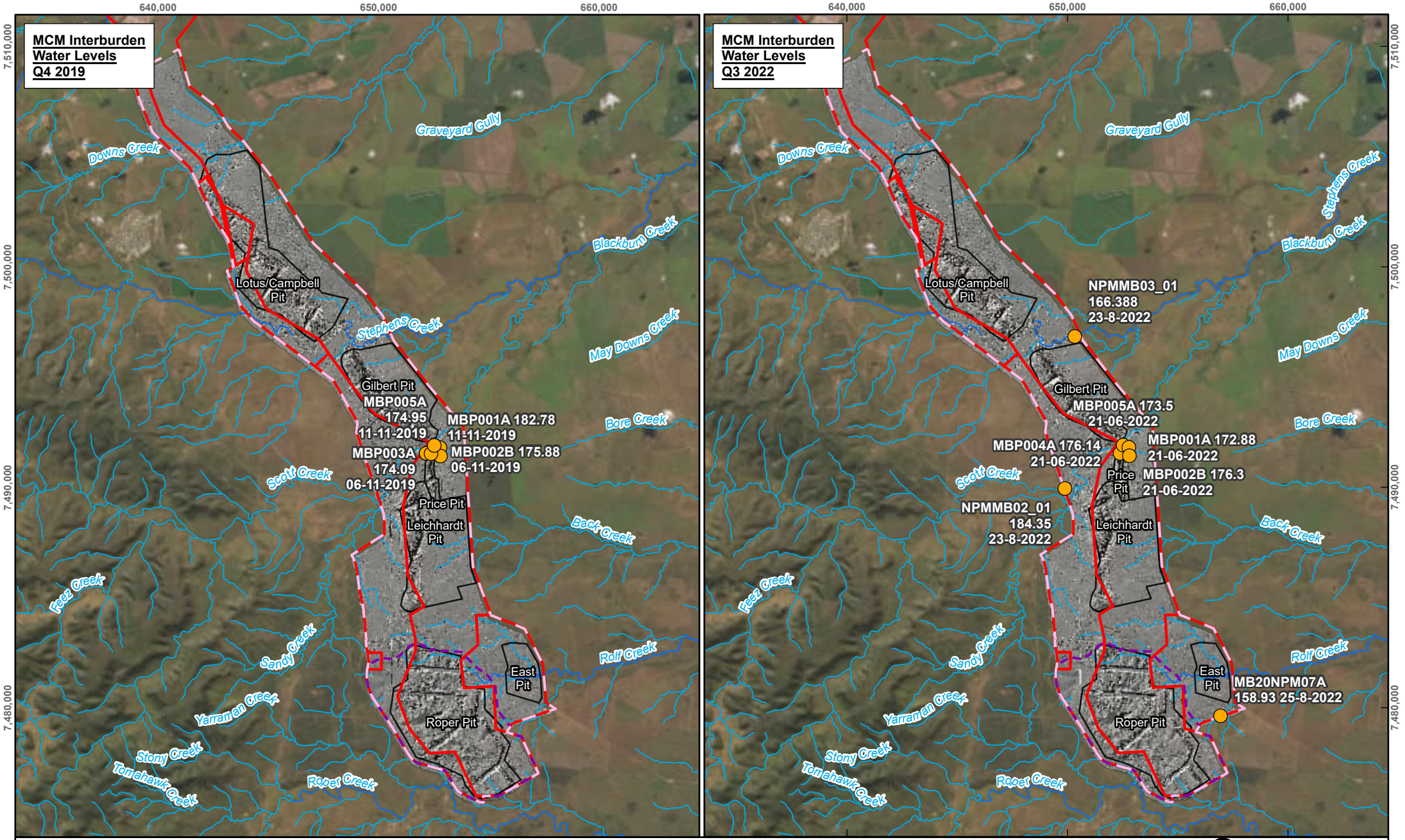
While mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004. Pre-mining potentiometric surface maps for the coal measures therefore cannot be generated due to the absence of data prior to mining, and neither can assessment of groundwater system response to the first ~25 years of SSM mining.

Groundwater data for the Permian coal measures since 2004 are broken into observations associated with the coal seams, and those associated with the overburden and interburden. Two time slices are presented in the following figures that correspond to pre-wet season groundwater levels in Q4 2019 and Q3 2022 (**Figure 4-10** and **Figure 4-11**). **Figure 4-12** shows hydrographs of Permian monitoring with water levels between 150 and 170 mAHD, and **Figure 4-13** shows monitoring with water levels between 170 and 190 mAHD. **Figure 4-14** presents water levels for Permian coal seam monitoring in 2014 in the south of the SSM Area, and **Figure 4-15** presets water level logger data recorded over a two-year period for two bores located just north of Gilbert Pit. Interburden locations are indicated by open, non-filled markers. Coal seam monitoring is indicated by closed, filled markers.

NPMMB02_01, and NPMMB03_01 all screened in the interburden. NPMMB02_01 shows relatively minor response to above average rainfall, with groundwater levels increasing following Q4 2022 wet season. NPMMB03_01 has shown no response, with water levels remaining stable across both monitoring rounds.

MB20NPM04P is screened within the H33 coal seam north of Gilbert Pit. This is paired with bore NPMMB03-01 which is screened much higher in the formation, near the weathered zone interface with Tertiary material. Groundwater levels at these two bores indicate an upwards hydraulic gradient of approximately 3.5 m / 64 m (~5%). Water levels show that the Permian coal is confined and both the interburden and coal seams show relatively minor reaction to rainfall and climatic input. This relatively muted reaction to rainfall is mirrored in P6R, 43062 and 38547.

Overall, the Permian monitoring data does not indicate significant mining related effects on the Permian groundwater system. This may in part however, be related to the sporadic temporal availability of Permian monitoring data, with much of that data only being available during the recent period of SSM care and maintenance and not during the earlier active mining phase at SSM.



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PERMIAN INTERBURDEN WATER LEVELS

FIGURE 4-10

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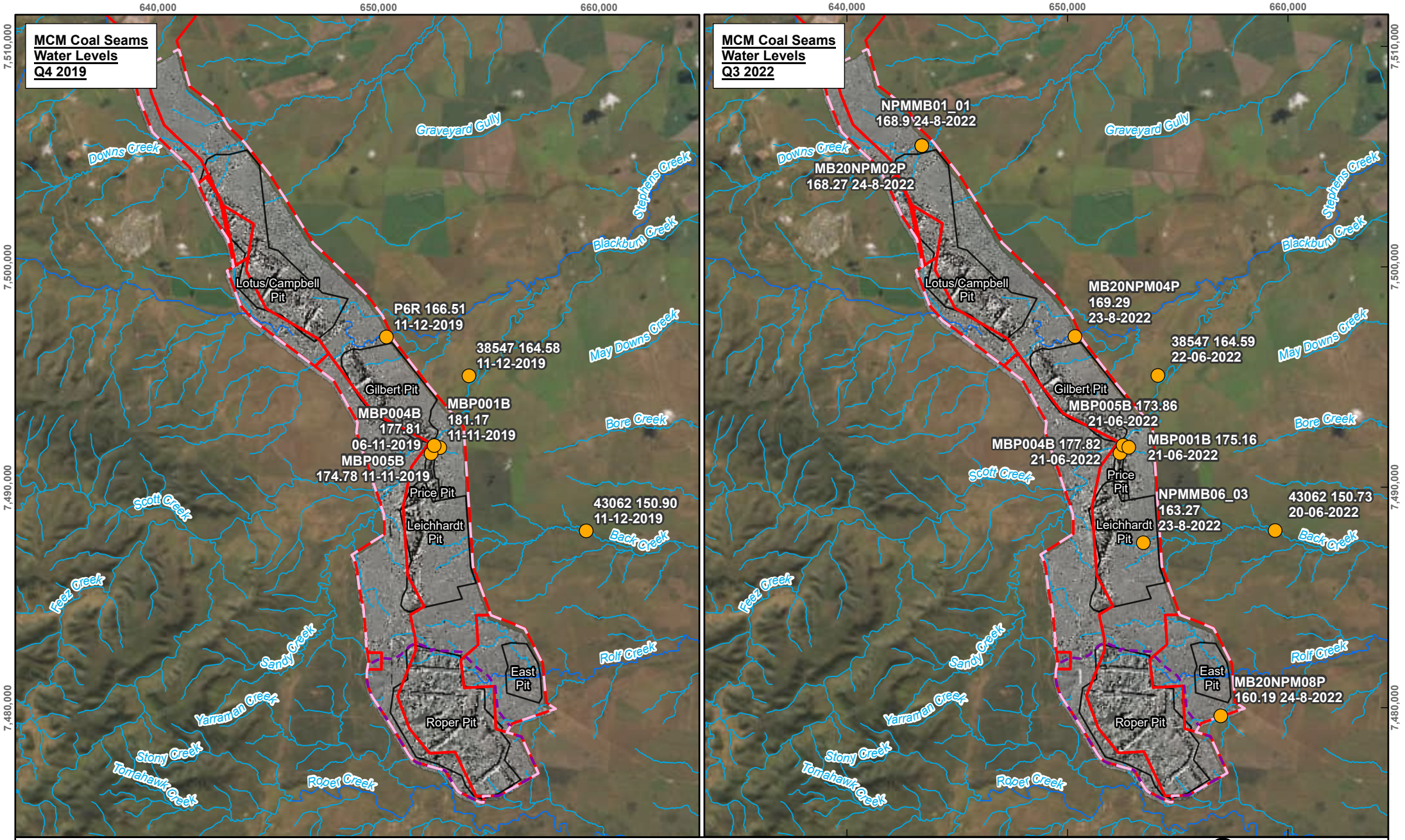

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PERMIAN COAL SEAMS WATER LEVELS

FIGURE 4-11

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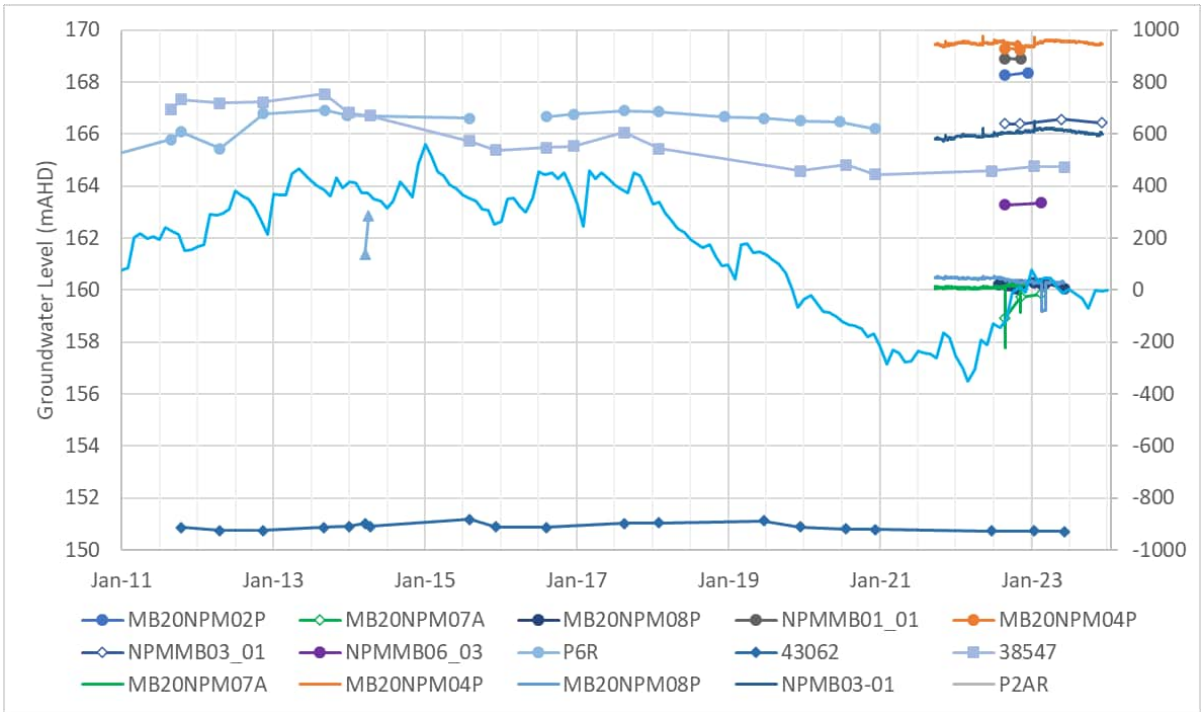

Figure 4-12 SSM Monitoring Bore Hydrographs – Permian bores 150 to 170 mAHD. Interburden/overburden with open markers, Coal seams with solid markers.

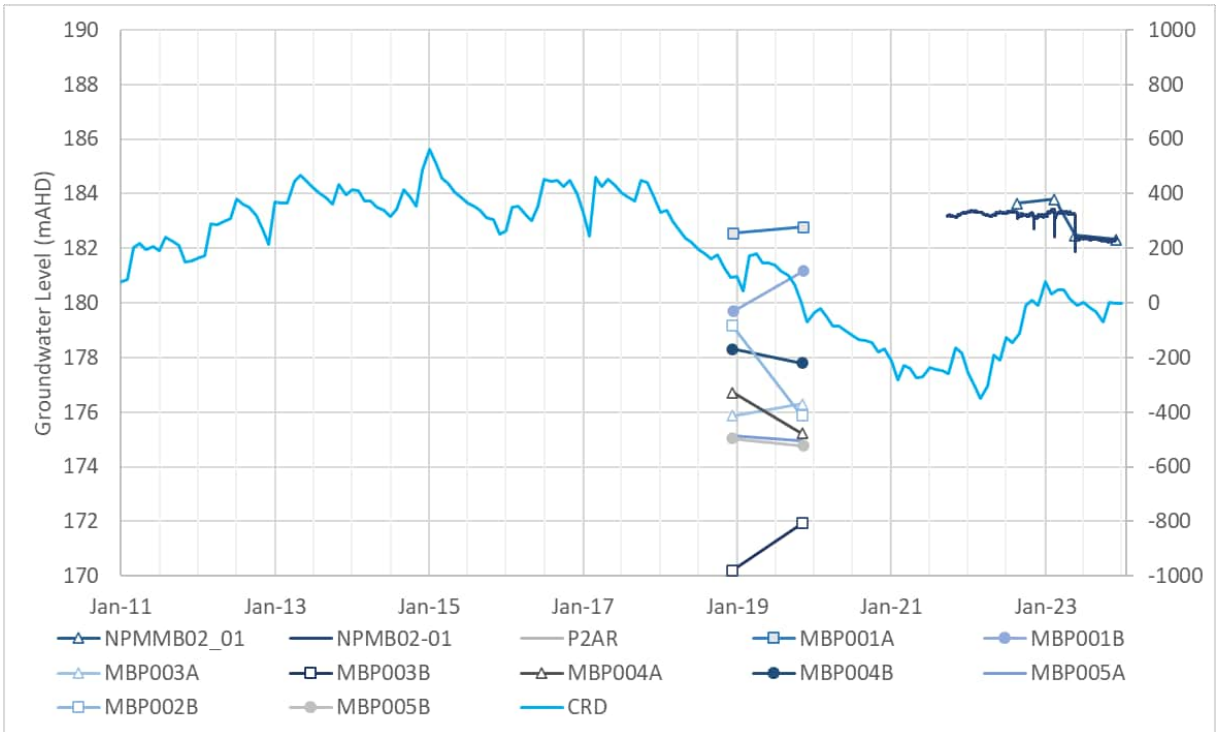

Figure 4-13 SSM Monitoring Bore Hydrographs – Permian bores 170 to 190 mAHD. Interburden/overburden with open markers, Coal seams with solid markers

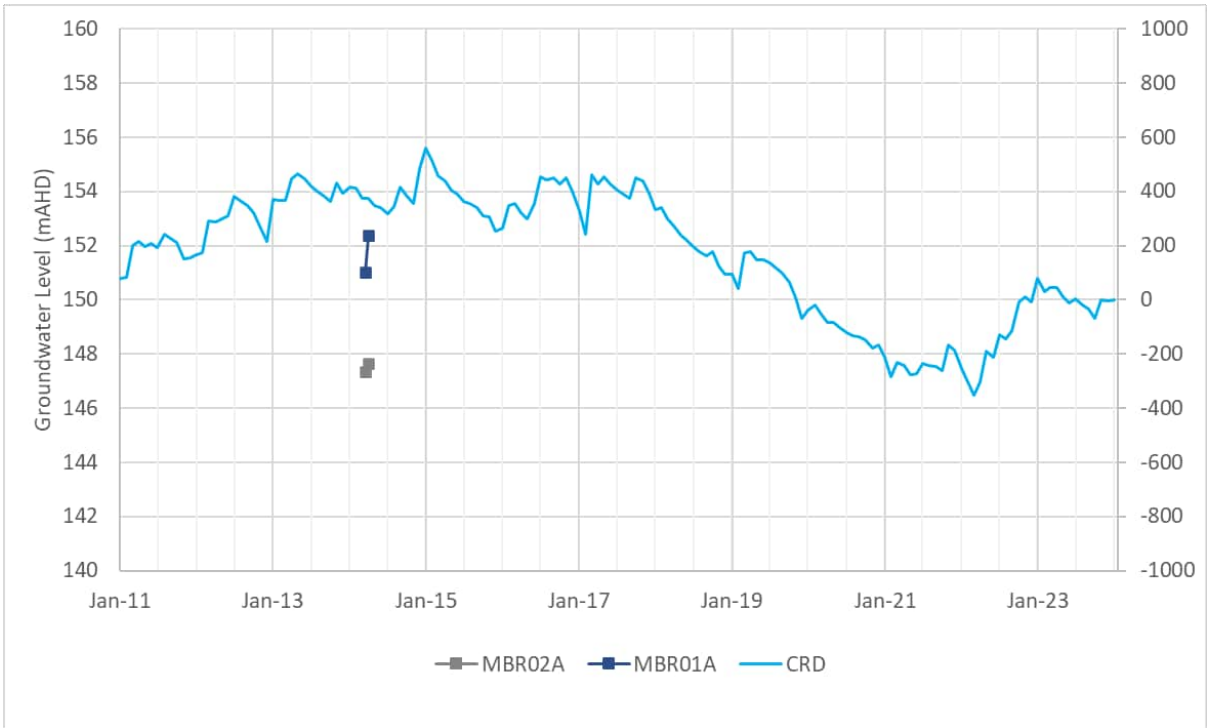

Figure 4-14 SSM Monitoring Bore Hydrographs – Permian bores MBR01A and MBR02A. Interburden/overburden with open markers, coal seams with solid markers

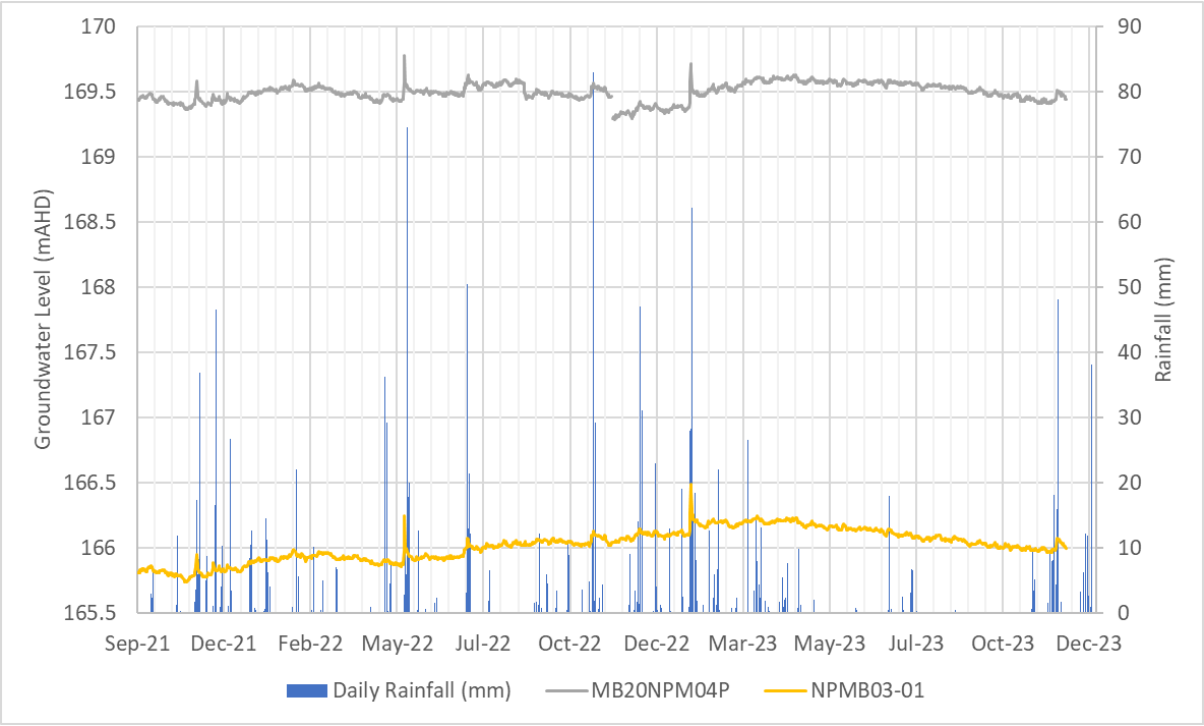

Figure 4-15 Water level logging data for Permian monitoring MB20NPM04P (H Seam) and NPM03-01 (Interburden)

4.3.3.2 Recharge and Discharge

Recharge to the Permian coal measures coal seams, before mining, occurred where the seams were present at outcrop and subcrop. Hydrograph analysis shows little to no reaction in water levels to significant rainfall events, suggesting that these units are insulated from direct recharge pathways. Using the CMB method, a recharge rate for the weathered Permian units was calculated as 0.1 mm/year by SLR (2021). Due to the low hydraulic conductivity of the interburden material, groundwater largely flows horizontally within the coal measures, along the bedding plane of the coal seams themselves, resulting in confined conditions that are observed in many of the paired groundwater monitoring locations. Local groundwater discharge from the Permian coal measures occurs via inflow to, and evaporation from, the walls and floors of mine pit areas as discussed in **Section 4.5.1.1**.

4.4 Baseline Water Quality

4.4.1 Water Type

The proportions of the major anions and cations were used to determine the hydrochemical facies of groundwaters sampled at SSM. The anion-cation balance from the SSM monitoring bores is shown on the Durov plots, with monitoring bores have been split on the basis of aquifer type, with **Figure 4-16** displaying alluvium bores, **Figure 4-17** displaying Tertiary bores, and **Figure 4-18** displaying Permian Coal Measures bores. As shown on **Figure 4-18**, the Permian bores are symbolised by monitored unit, including: cross symbol (FCCM), square symbol (MCM overburden/interburden) and diamond symbol (MCM coal).

The results for these monitoring bores generally indicate that Na, Cl and HCO_3 are the dominant water chemistry signatures in groundwater across SSM.

Alluvium monitoring at P6 and MB20NPM03A displays a wide range of water type, with MB20NPM03A showing a moderate salinity and HCO_3 enriched water reflective of recharge to the shallow systems, but P6 showing a broad range of water types from similar to MB20NPM03A to one that is consistent with a saline evapoconcentrated Na-Cl type water.

Monitoring bores screened within the Tertiary predominantly recorded Na-Mg-Cl type waters, with minor variances in HCO_3 and SO_4 ion proportions. Moderately saline waters were generally returned, however, P2A and 43060 displayed significantly higher salinities than were typical across this aquifer, and strongly concentrated Na-Cl signatures. This is indicative of natural salinisation of shallow groundwater through low recharge and long term evapoconcentration. Bore 43060 is located approximately 9 km east of the mining area and is not expected to display influence of any groundwater impacts that may have occurred due to mining activities at SSM. Lower salinity concentrations were observed at MB20NPM05A and MB20NPM06T, with these likely to be receiving meteoric recharge rather than flushing of concentrated water.

Monitoring bores screened within the Permian consistently record mixed/intermediate type waters with moderate salinity. Strong similarities exist between the Tertiary and Permian in regard to their hydrochemical characteristics. These similarities suggest there may be some pathways for interaction, with historical recharge pathways to the Permian formation occurring through Tertiary subcrop and regolith zone.

Within the Permian coal measures (interburden), monitoring bores recorded predominantly Na-Cl and Na-Mg water types. Bores that were shallower demonstrate relatively higher proportions of SO_4 ions, with deeper bores returning higher proportions of HCO_3 ions (in exemption to MBP001A, which returned higher Ca ions). This is likely due to interactions between groundwater and the weathered aquifer material in the shallow formations. Highly saline groundwater samples are reflective of strongly concentrated Na-Cl-type waters that are likely the result of progressive evapoconcentration and flushing into the shallow groundwater system.

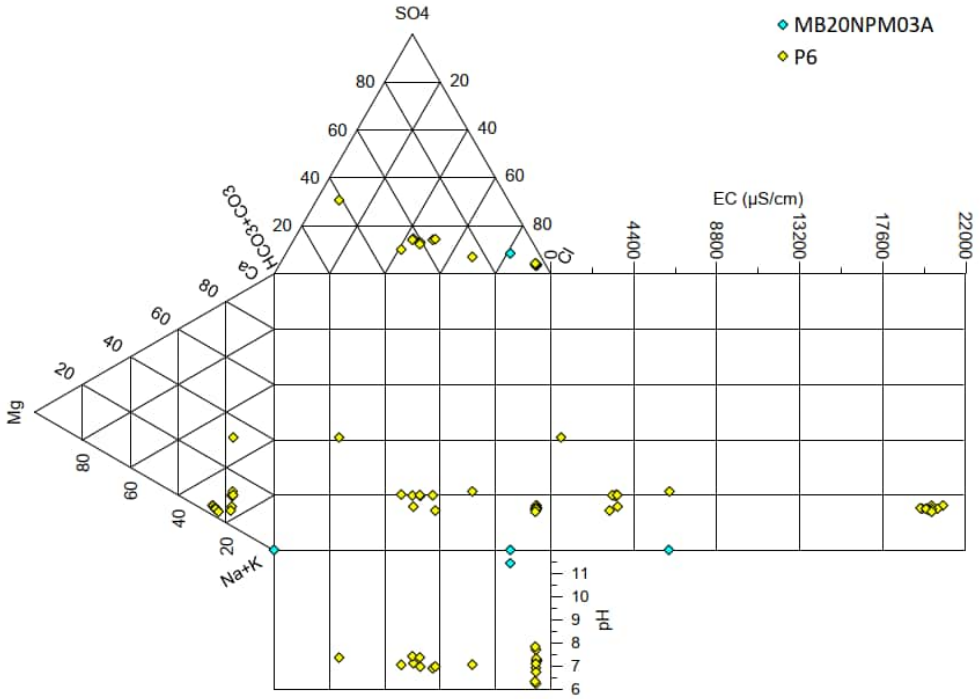

Figure 4-16 Alluvium Durov Plot

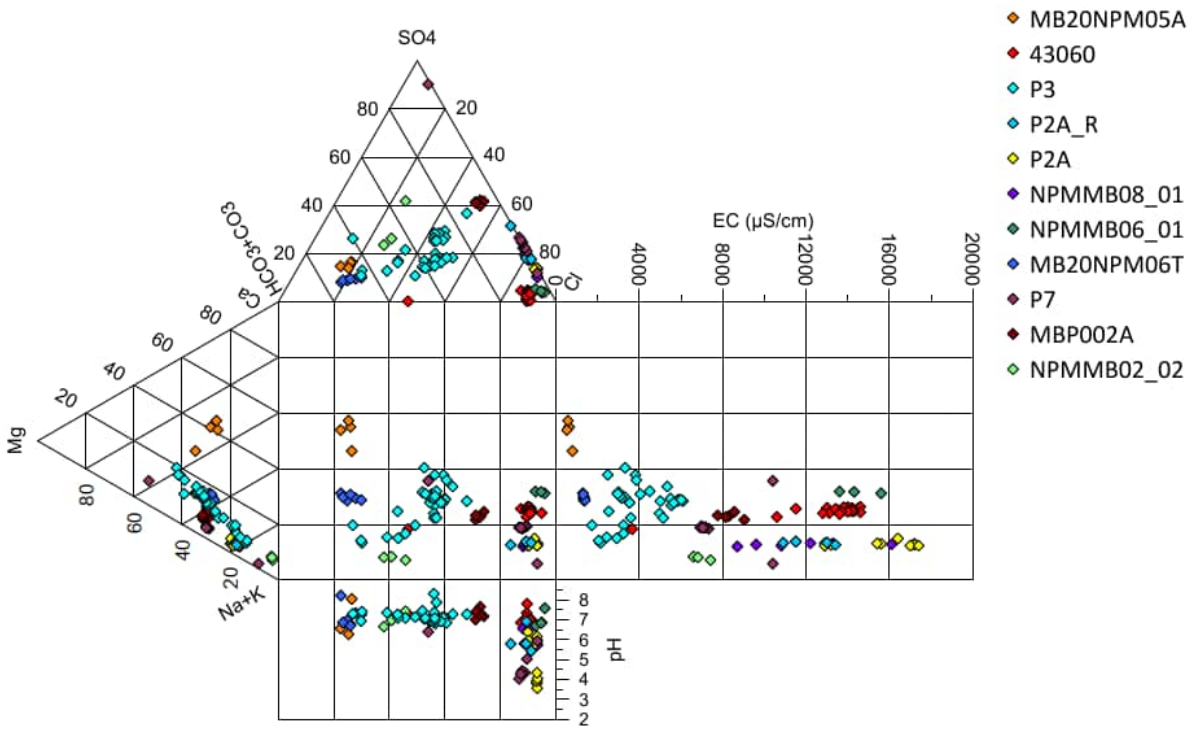

Figure 4-17 Tertiary Durov Plot

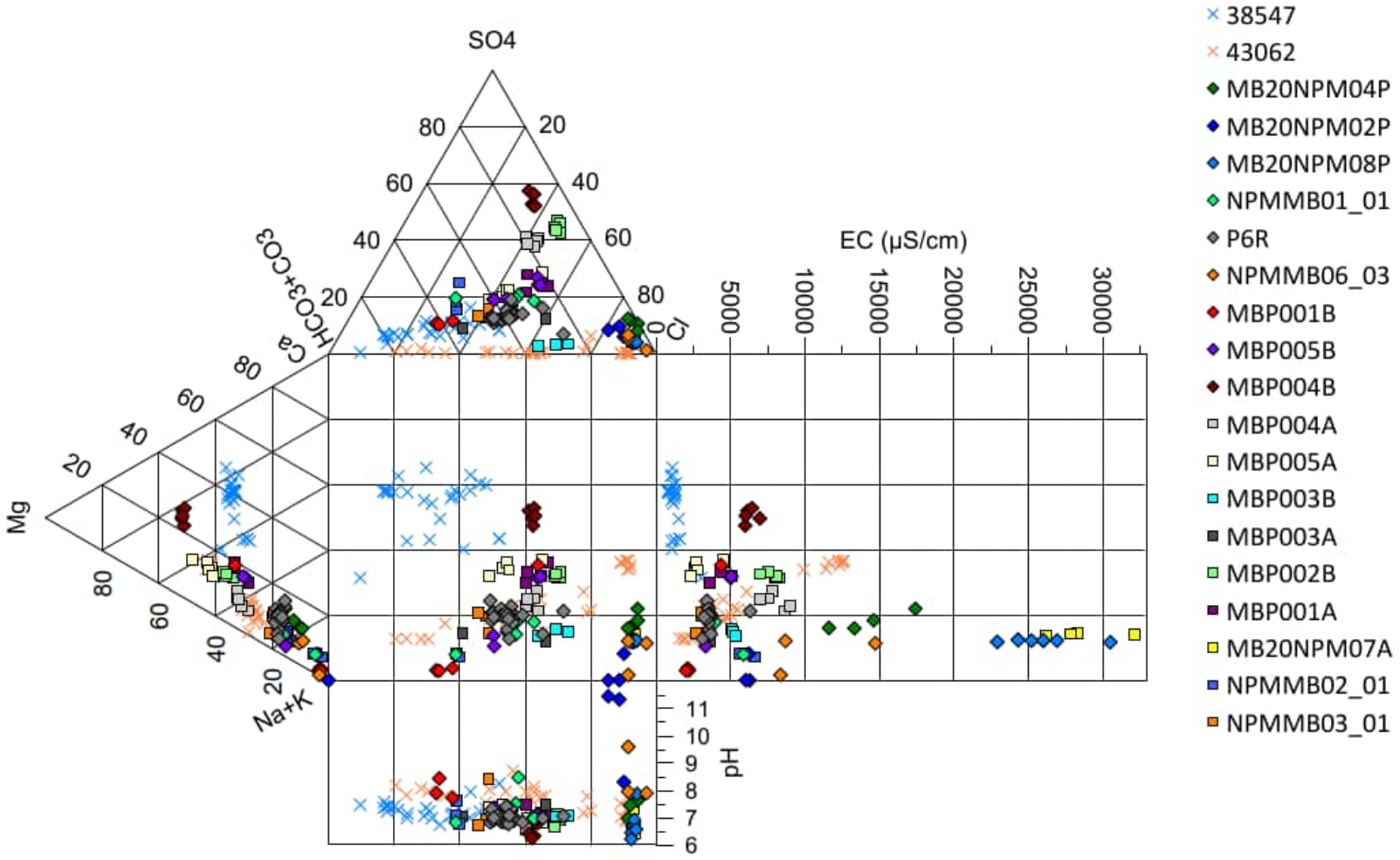

Figure 4-18 Permian Bore Durov Plot

4.4.2 Salinity

Salinity is a key constraint to water management and groundwater use by receptors and can be described by total dissolved solid (TDS) concentrations. **Figure 4-19** presents the TDS data associated with waters screened in the various geological horizons for SSM monitoring bores. Salinity ranges represented on **Figure 4-19** are defined by the Food and Agriculture Organization of the United Nations (FAO).

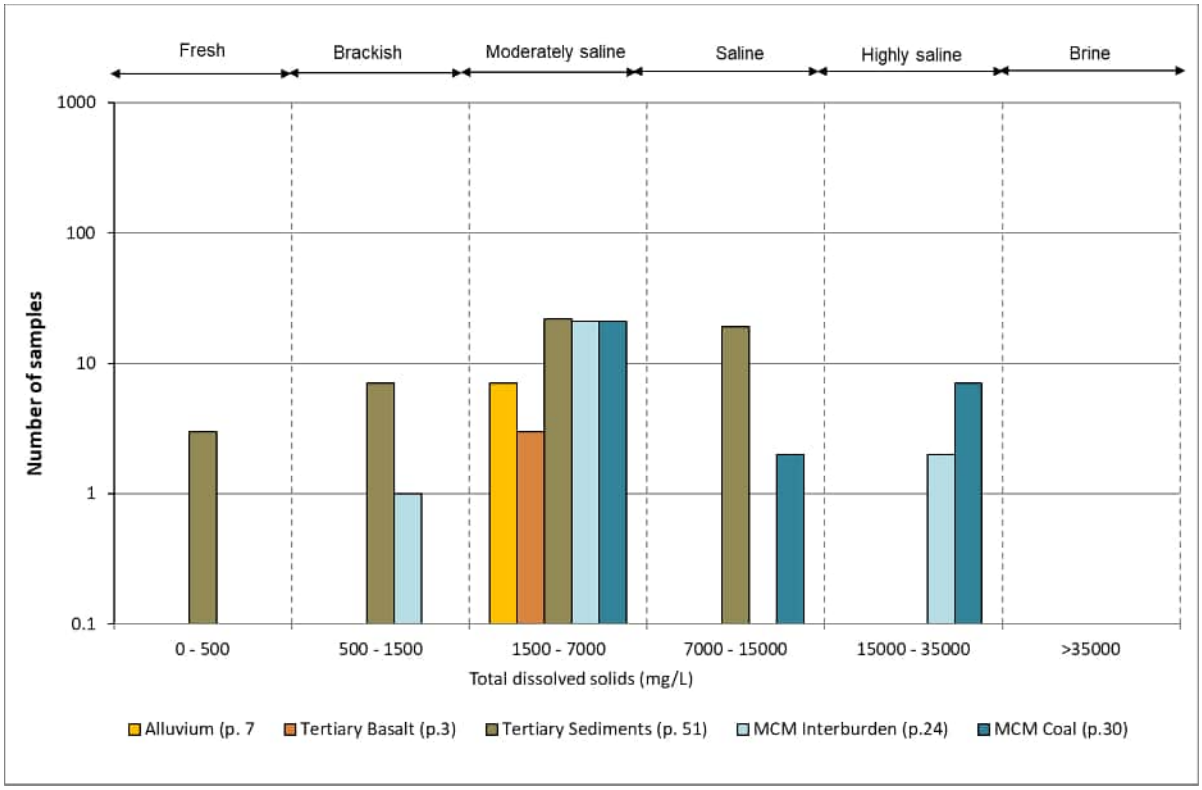

Figure 4-19FAO (2013) Salinity Ranking by Unit – SSM and surrounding area

The graph shows that water within the alluvium is moderately saline with an average TDS of 2,045 mg/L, though it should be noted this data is from bore P6 between 2010 and 2014 and there is no more recent data available for the alluvium as there was no saturated alluvium encountered in monitoring bores.

Tertiary sediments samples show fresh to saline water quality, ranging between 377 mg/L to 11,600 mg/L, with a mean value of 4,808 mg/L. One Tertiary bore screened in weathered basalt displays water quality in line with the broader Tertiary/Regolith aquifer, with three samples displaying a range between 4,384 and 4,847 mg/L.

Water within the Moranbah Coal Measures is generally saline within the coal seams and moderately saline to saline in the interburden units but can range between brackish and highly saline. Coal seam units of the Moranbah Coal Measures record an average TDS of 7,982 mg/L, ranging between 1,514 mg/L and 19,200mg/L. The interburden units of the Permian coal measures record an average TDS of 4,747 mg/L, ranging between 1,280 mg/L and 21,353 mg/L.

4.4.3 Beneficial Groundwater Use (Environmental Values)

SSM lies in the southern portion of the Isaac Connors Groundwater Management Area (GMA) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011. Within the Isaac Connors GMA, alluvial groundwater is managed as Groundwater Unit 1 and water within the hard rock aquifers as Groundwater Unit 2 (sub-artesian aquifers). The far southern area of SSM lies within the Highlands Groundwater Management Area, where, similar to the Isaac Connors 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 both GMAs.

Groundwater resources in the SSM Area are also scheduled under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019, predominantly as Isaac Groundwaters of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1310), although the very southern part of the SSM Area crosses approximately 2.6 km into the Mackenzie Groundwaters scheduled area. The legislated environmental values (EVs) for both the Isaac Groundwaters and Mackenzie Groundwaters are:

- Biological integrity of aquatic ecosystems;
- Human use EVs:
    - Suitability of water supply for irrigation;
    - Farm water supply/use;
    - Stock watering;
    - Primary recreation (Isaac Groundwaters);
    - Drinking water supply;
    - Industrial Use (Mackenzie Groundwaters)
    - Cultural and spiritual values.

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 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 WQ1310 WQOs for groundwater at SSM are shown in **Table 4-3.**

Table 4-3 Water Quality Objectives for Isaac & Mackenzie River Sub-basin Environmental Values

Water Quality Indicator	Unit	ADWG Guidelines[1]		Isaac River Sub-basin EVs[2]			Mackenzie River Sub-basin EVs[4]		
		Health	Aesthetic	Irrigation	Stock	Aquatic 95% spp[3]	Irrigation[6]	Stock	Aquatic 95% spp[3]
pH	-		6.5 to 8.5			6.5 to 8.5			6.5 to 8.5
Aluminium	mg/L		0.2	5	5	0.055	5		0.055
Calcium	mg/L				1000				
Chloride	mg/L		250						
Magnesium	mg/L				2000				
Manganese	mg/L	0.5	0.1			1.9			1.9
Sodium	mg/L		180						
Sulfate	mg/L				1000				
Zinc	mg/L		3	2		0.008	2	20	0.008
Arsenic	mg/L	0.01		0.1	0.5	0.024	0.1	0.5	0.024
Cadmium	mg/L	0.002		0.001	0.01	0.0002	0.001	0.01	0.0002
Chromium	mg/L	0.05		0.1	1	0.001	0.1	1	0.001
Cobalt	mg/L			0.05	1		0.05	1	
Copper	mg/L	2	1	0.2	1[5]	0.0014	0.2	1[5]	0.0014
Lead	mg/L	0.01		2	0.1	0.0034	2	0.1	0.0034
Mercury	mg/L	0.001		0.02	0.002	0.0006	0.02	0.002	0.0006
Nickel	mg/L	0.02		0.2	1	0.011	0.2	1	0.011
Selenium	mg/L	0.01		0.02	0.02	0.005	0.02	0.02	0.005
Silver	mg/L	0.1				0.05			0.05

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).
4. Table 2, Table 9, Table 10 and Table 11 of Mackenzie River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed
5. Figure quoted for cattle.
6. Long term trigger value

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 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 (**Figure 4-20**). The applicable Chemistry Zones for SSM are:

- Isaac Groundwaters:
  - Zone 5 (**Table 4-4**): Alluvial sequence – Low salinity, balanced cations, HCO_3;
  - Zone 23 (**Table 4-5**): Alluvial Sequence – Moderate salinity, Na > Mg > Ca, Cl (SO_4 above average); and
  - Zone 34 (Table 4-6): Sodic Sequence – Saline, Na, Cl.
- Mackenzie Groundwaters:

- Zone 34 (Table 4-7): 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 4-4** to **Table 4-7**.The management intent of each WQO zone is to maintain each of 20th, 50th and 80th percentile values.

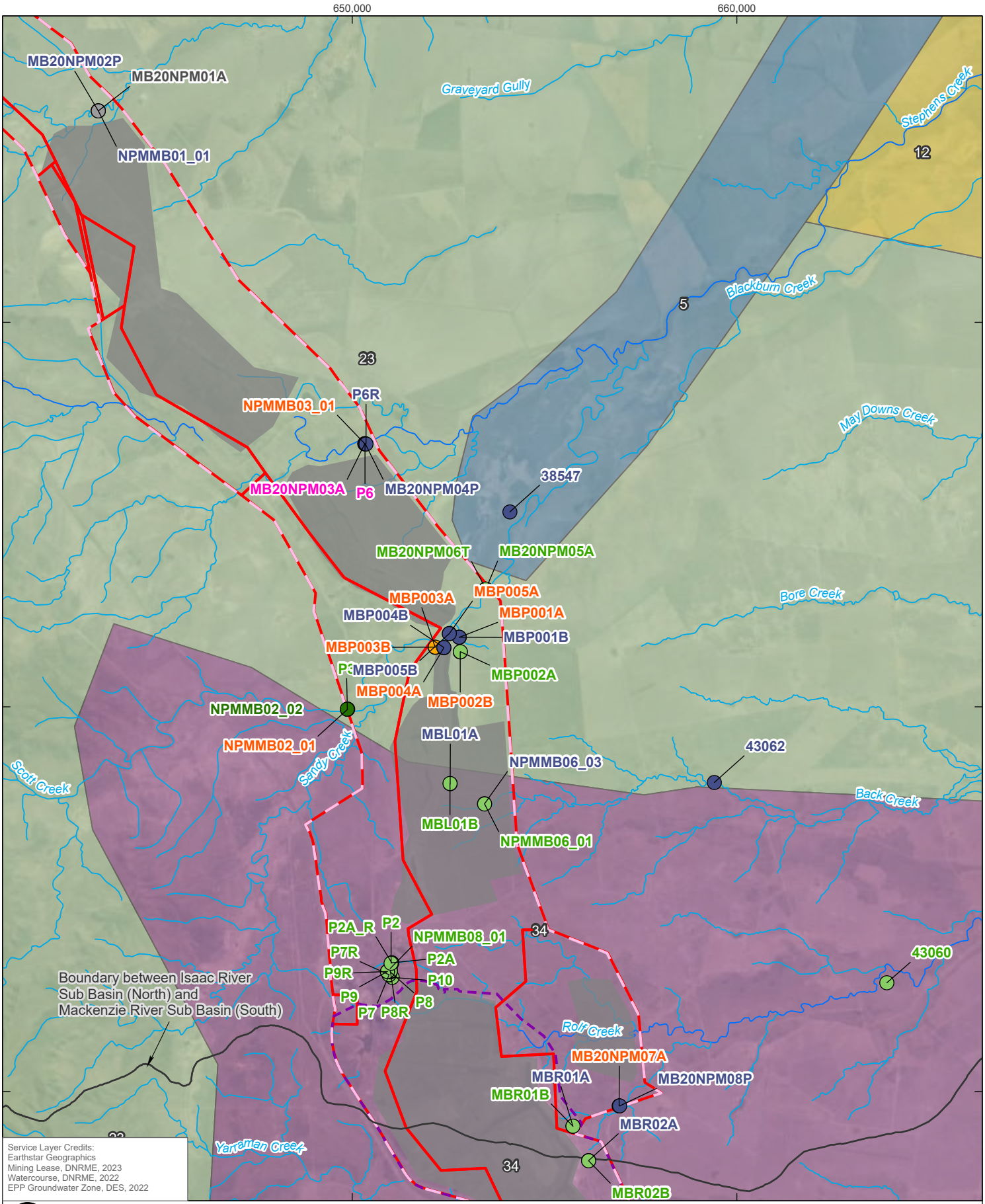

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FIGURE 4-20

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_20_Water_Quality_Objective_Zones_01

Table 4-4 Isaac River Sub-basin Zone 5 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	633	680	750	914	2400	4219
Hardness	mg/L as CaCO3	182	286	322	273	475	594
pH	-	7.39	7.7	7.82	7.73	7.9	8
Alkalinity	mg/L	242	280	417	429	516	591
Ca	mg/L	35	60	75	43	55	61
Mg	mg/L	23	24	38	39	82	109
Na	mg/L	44	68	195	100	350	684
Cl	mg/L	53	80	137	41	381	860
SO_4	mg/L	5	21	45	20	173	319
HCO_3	mg/L	294	342	506	517	621	713
NO_3	mg/L	0.38	3.2	9.89	ID	ID	ID
SiO_2	mg/L	17	23	33	ID	ID	ID
F	mg/L	0.127	0.2	1.01	0.183	0.335	0.41
Fe	mg/L	0	0.01	0.02	ID	ID	ID
Mn	mg/L	0	0.07	0.203	ID	ID	ID
Zn	mg/L	ID	ID	ID	ID	ID	ID
Cu	mg/L	ID	ID	ID	ID	ID	ID
SAR	-	1.09	2	6.89	2.44	7.1	12.18
RAH	meq/L	0.18	1.06	4	0.87	1.09	3.78

Table 4-5 Isaac River Sub-basin Zone 23 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	3333	3850	4506	2496	3465	7450
Hardness	mg/L as CaCO3	461	793	1146	350	1098	1621
pH	-	7.6	7.75	8.45	7.51	7.8	7.99
Alkalinity	mg/L	445	650	903	233	463	618
Ca	mg/L	51	100	223	50	138	260
Mg	mg/L	70	140	185	55	165	244
Na	mg/L	501	561	599	312	587	1106
Cl	mg/L	558	750	989	553	851	1930
SO_4	mg/L	50	95	832	42	100	520
HCO_3	mg/L	543	793	1091	282	565	753
NO_3	mg/L	0	0.5	1.65	0	0	2.25
SiO_2	mg/L	13	21	48	20	47	54
F	mg/L	0.68	0.8	1.2	0.149	0.37	1.02
Fe	mg/L	0.006	0.035	0.085	0.014	0.04	0.382
Mn	mg/L	0.02	0.035	0.176	0	0.025	0.34
Zn	mg/L	ID	ID	ID	ID	ID	ID
Cu	mg/L	ID	ID	ID	ID	ID	ID
SAR	-	5.71	8.4	14.36	5.5	10.45	13
RAH	meq/L	1.83	2.85	9.36	0	0.73	10.83

Table 4-6 Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	498	2150	8910	3419	6100	16000
Hardness	mg/L as CaCO3	163	674	2228	359	919	3208
pH	-	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	1500	480	1100	2565
Cl	mg/L	171	1309	3185	753	1900	5905
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

Table 4-7 Mackenzie River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) (DEHP, 2011)

Water Quality Indicator	Unit	Shallow Groundwater (<30m)			Deep Groundwater (>30m)		
		20th Percentile	50th percentile	80th Percentile	20th Percentile	50th percentile	80th Percentile
EC	µS/cm	498	2150	8910	3419	6100	16000
Hardness	mg/L as CaCO3	163	674	2228	359	919	3208
pH	-	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	1500	480	1100	2565
Cl	mg/L	171	1309	3185	753	1900	5905
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 possible utilisation of groundwater resources within the SSM area, available water quality data have been compared to the:

- Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed (Isaac River EVs)
- Mackenzie River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed (Mackenzie River EVs)
- Fitzroy Basin Zones 5, 23 and 34 groundwater quality objectives for deep and shallow water;
- Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011);
- ANZECC (2000) guidelines for aquatic ecosystems, irrigation (long-term and short-term) and stock water supply.

While the long-term groundwater dataset is somewhat incomplete due to changes in monitoring, management, and access issues over time, there is approximately 12 months of sampling for most active bores with complete suite of analysis. For many groundwater samples, dissolved metals laboratory analysis was carried out at sensitivities that prevented clear comparison with guideline values due to relatively high limit of reporting.

Chemistry time series from P6 and isolated samples at MB20NPM03A indicates that alluvial groundwater in the SSM Area, where very sporadically present, may be generally suitable for livestock water supply and for short-term irrigation. However, this is based on sporadic saturation in

the alluvium monitoring bores, and including results from a bore that is no longer monitored, having been decommissioned and replaced, and these values may not reflect regionally characteristic groundwater chemistry. The lack of consistent saturation in the alluvium limits:

- collection of a robust monitoring data set, and
- most beneficial uses..

Summary results indicate that, where water is present within the Tertiary sediments, it exhibits a wide chemical profile, though considered collectively it is not considered a suitable groundwater resource for Isaac River Stock EV (sulfate, selenium), drinking water or aquatic ecosystems. The water within Tertiary sediments was found to exceed the Zone 34 and Zone 23 Fitzroy Plan WQO (Shallow and Deep considering depth of Tertiary in some areas) for EC, bicarbonate, chloride, sodium, magnesium, sulfate, and iron. Very low pH values are observed in some bores (P7, historical measurements at P2A)

Comparison of results to the EPP Water and Wetland Biodiversity WQO guideline levels indicates the Moranbah Coal Measures (inter/overburden and coal) exceed guideline values for irrigation, drinking water or aquatic ecosystems, though there was a wide range of values.

Water chemistry analysis showed values exceeding Isaac River Stock EV (sulfate, and total dissolved material), drinking water (sodium, chloride, aluminium) or aquatic ecosystems (range of metals including aluminium, chromium, nickel, and selenium). The water within the Permian coal formations were found to exceed the Zone 23 Fitzroy Plan WQO (Deep) for EC, calcium, bicarbonate, chloride, sodium, magnesium, sulfate, and iron. Bore 38547 lies east of SSM within Fitzroy Plan WQO Zone 5 (Deep) and although the water quality at this bore is better than other Permian monitoring locations, samples have exceeded WQO values for EC, calcium, magnesium, sodium, chloride, sulfate, bicarbonate, and iron.

4.5 Groundwater Receptors

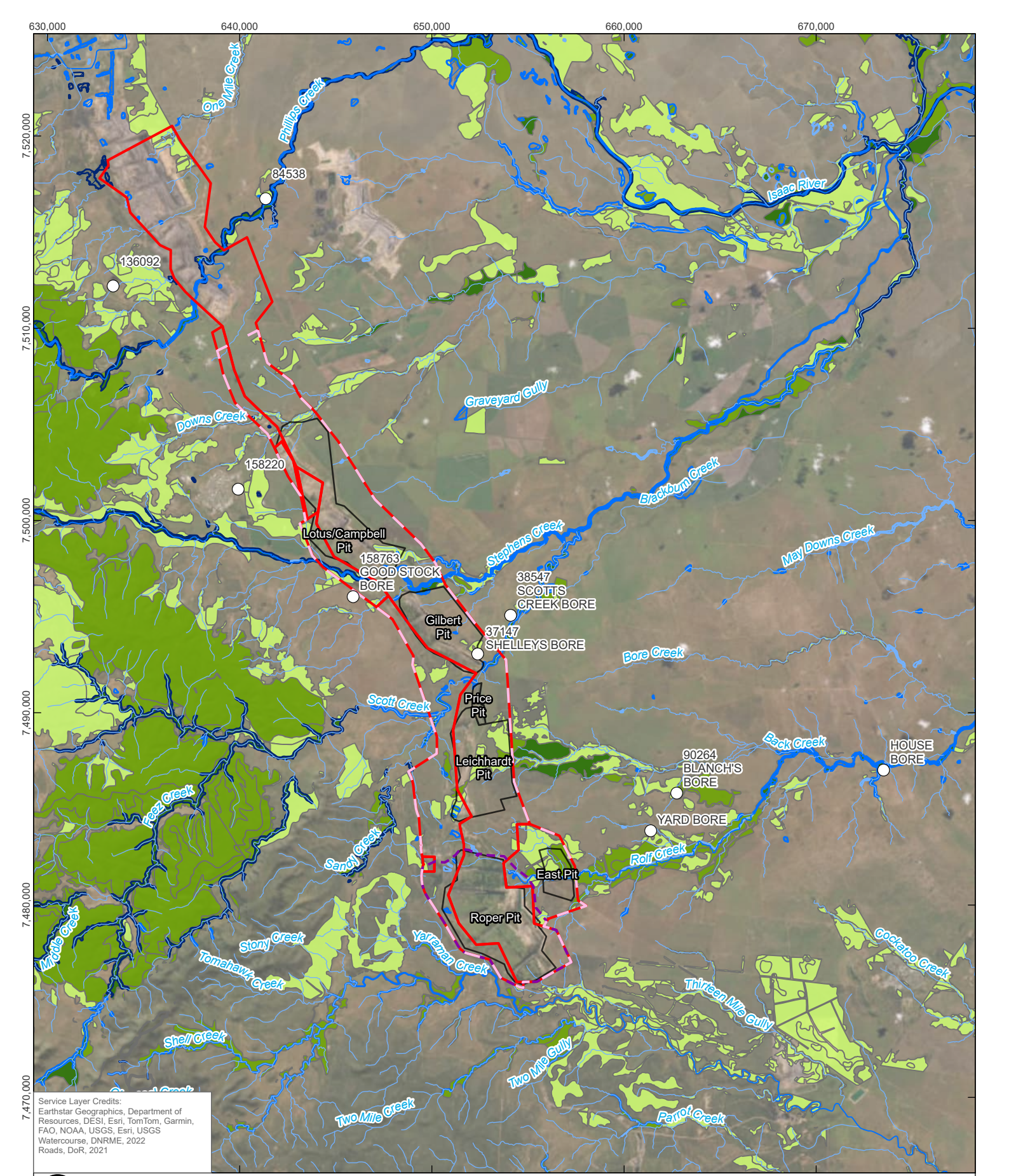
4.5.1 Anthropogenic

A search of the Queensland Government's Groundwater Bore Database (GWBD) and the Bureau of Meteorology's National Groundwater Information System (NGIS) was carried out for registered bores within 5 km of the SSM Area. These are summarised in **Table 4-8** and the water supply locations are shown on **Figure 4-21**.The search indicated that there are 82 registered bores, of which 53 bores (66%) are used for groundwater monitoring and investigations, and only 9 bores (11%) are used for water supply. The remainder of bores have an unknown use or resulted from exploration activities.

Table 4-8 Registered use of Groundwater Bores within the Study Area

Use	Count	Percent of Total
Groundwater monitoring (mine monitoring, water resource investigation etc)	54	66
Water Supply	9	11
Unknown	19	23
Total	82	100

Anecdotal reporting in previous SSM technical studies suggests that groundwater yields are low and of poor quality, with property owners in the area relying primarily on dams that can be constructed readily in the Tertiary clay material and/or on the McKenzie River pipeline for their water supply (GHD, 2021b). Where properties have bores they are nearly all constructed in the Permian coal seams and not in the Tertiary sands and gravel, confirming the localised occurrence and limited saturation of the Tertiary aquifers.



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0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:250,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Potential Water Supply Bore
- Major Watercourse
- Minor Watercourse
- SSM Mine Lease
- Pit Extent
- SSM EA Boundary
- Roper Study Area

Aquatic GDE

- High potential GDE
- Moderate potential GDE
- Low potential GDE

Terrestrial GDE

- High potential GDE
- Moderate potential GDE
- Low potential GDE

SARAJI SOUTH MINE TRANSITIONAL PRCP

POTENTIAL GDES AND REGISTERED BORES

SLR

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FIGURE 4-21

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F4_21_Potential_GDEs_and_Registered_Bores_01

AGE (2004) documents that a bore census near to SSM was undertaken in 2004, identifying that there were three bores that were in private extractive use (**Figure 4-21**) (**Table 4-9**). Two of these, Blanch's Bore and House Bore, were reported to be 12 km and 18 km east of SSM adjacent to Rolf Creek, respectively. Both were noted to be accessing the Tertiary aquifer, though the GWBD contradicts this report as Blanch's Bore is classified as Permian (GHD, 2021b). A third bore named House Bore, was identified in the census 10 km east of SSM as being used for domestic purposes.

Table 4-9 Summary of water supply bores and bore census data (modified per AGE, 2004)

Local Bore Name	Bore RN	Easting	Northing	Ground Level (mAHD)	Depth (m)	Role identified	Inferred Aquifer
SHELLEYS BORE	37147	652385[1]	7493059[1]	-	36	Water supply	Tertiary
SCOTTS CREEK BORE	38547	654098[1]	7495068	-	34	Water supply	Tertiary
-	84538	641354[1]	7516737[1]	-	109.7	Water supply	Permian
-	136092	633416[1]	7512196[1]	-	22	Water supply	Tertiary
-	158220	639923[1]	7501629[1]	-	66.5	Water supply	Tertiary
GOOD STOCK BORE	158763	645904[1]	7496037[1]	-	148	Water supply	Permian
Yard Bore	-	661387[2]	7483865[2]	187	60	Stock Watering	Tertiary
Blanch's Bore	90264	662740[2]	7485824[2]	171	39	Stock Watering	Permian
House Bore	-	673504[2]	7487021[2]	146	~30	Domestic and stock	Tertiary

1. From registed bore database, GDA94z55
2. No co-ordinate projection system provided in AGE 2004, assumed GDA94z55

There were no water entitlements for groundwater identified in the Water Entitlements Database Queensland, within or surrounding the SSM Area, indicating groundwaters in this area are not used for activities requiring a license such as irrigation or industrial purposes.

4.5.1.1 Mine Pit Inflows

During active mining operations, groundwater inflows to active pit voids are generally small in volume and do not typically need to be actively managed via advance dewatering or other groundwater management methods. Evaporation from the pit walls and floors accounts for most of the groundwater. Where small volumes of groundwater inflow require management within the active mine pits, this is generally managed via the use of in-pit sumps to capture water. The water is then used for dust suppression purposes or circulated via the Mine water management system for use in coal washing.

During the care and maintenance phase of SSM operations between 2012 and 2022, voids were used as water storage hubs for nearby BHP operations, with pit lakes developing in the undisturbed mine voids. With the formation of these lakes, groundwater inflows to the voids would have reduced as the head gradient between the voids and the surrounding groundwater system reduced. Previous investigations note that some of the mine voids were used as active mine water management by the local BHP operations (AGE 2014a).

4.5.2 Environmental

4.5.2.1 Groundwater Dependent Ecosystems

A groundwater dependant ecosystem (GDE) is one in which the plant and/or animal community is dependent on the availability of groundwater to maintain its structure and function. The GDE Atlas is a national scale broadbrush tool that classifies ecosystems based on the potential for dependence on groundwater through multiple lines of scientific evidence (BOM, 2017). 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; or
- 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).

Desktop mapping of potential aquatic and terrestrial GDEs in the GDE Atlas indicates that areas with possible high, moderate, and low potential for groundwater interaction occur in the vicinity of SSM (BoM, 2017). Isolated areas of high and moderate potential GDEs occur within SSM, with low potential GDEs identified predominantly around the SSM boundaries.

Surface ecosystems on and adjacent SSM that may be reliant on the surface expression of groundwater are shown in **Figure 4-21**. The desktop GDE mapping (BOM, 2017) indicates:

- East of SSM, terrestrial riparian vegetation associated with the downstream extent of Stephens Creek, Rolf Creek, Scott Creek and Back Creek are mapped as having a moderate potential to high potential for dependence on subsurface expression of groundwater.
- Aquatic habitat associated with the upstream areas of Stephens Creek, Scott Creek, and Sandy Creek are mapped as having a high potential to be dependent surface expression of groundwater.

All other terrestrial vegetation and aquatic habitat within and adjacent SSM, is broadly mapped as having a low to moderate potential of being associated with the presence of groundwater (BoM, 2017).

5.0 Conceptual Site Model

A conceptual site model (CSM) of the groundwater regime has been developed based on the review of the hydrogeological information for SSM presented in the above report sections.

5.1 General

SSM is located within the northern part of the Bowen Basin, which comprises Permian aged coal measures that have been folded into a syncline structure that strikes in a north-west to south-east direction. The geology of SSM comprises the stratified sequences of the Moranbah Coal Measures at the westernmost extent of the syncline that dip towards the east. Mining at SSM targets the coal seams of the Moranbah Coal Measures, that occur at subcrop, and increase in depth towards the east. Surficial cover at SSM includes some alluvium associated with minor tributaries of the Isaac River, being Stephens Creek, Scott Creek, Rolf Creek, and Roper Creek. This alluvium is highly localised to within and immediately around the incised channel for these surface water features. Surficial cover at SSM outside of these creek lines consists predominantly of a Tertiary aged package of clays, sands and weathered Basalt units, underlain by weathering derived regolith.

While mining at SSM began in 1979, the first groundwater monitoring bores were not established until 2004. Assessment of groundwater system response to the first ~25 years of SSM mining is therefore not possible. Regardless, groundwater monitoring and investigations at SSM since 2004, as well as other relevant studies for nearby sites, indicate that the main hydrogeological features at SSM include:

- Cainozoic sediments
    - Quaternary alluvium – unconfined aquifer (sporadically water-bearing strata of permeable unconsolidated sand or gravel) highly localised to incised channels of the major ephemeral drainage line channels at SSM along Downs Creek, Scott Creek and Rolf Creek;
    - Quaternary to Tertiary non-alluvial sediments and weathered units (collectively termed ‘regolith’ in many recent relevant regional studies) – unconfined unit with limited saturation at SSM and in the Study Area.
- Permian coal measures with:
    - Low permeability Interburden and overburden units with aquitard properties; and
    - Coal seams that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

Alluvium associated with the creek lines at SSM is poorly developed, spatially constrained to surface water channels by incised weathering into the Tertiary material and regolith. Saturation has been observed to be inconsistent across site with most groundwater drilling targeting alluvium, failing to find saturated alluvial sediments. All current alluvial monitoring is dry. Historical measurements of saturation in alluvium at a single bore that found saturation have shown water levels around 14 mbGL and typically significantly disconnected from the streambed elevation. 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 and recharge to the alluvium is considered to be primarily from stream flow or flooding, with direct infiltration of rainfall also occurring rapidly 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.

Water quality data for the alluvium within the broader Study Area indicates it can be fresh to saline and highly spatially and temporally variable. Groundwater sampling from SSM shows the limited saturation on site (one bore) is moderately saline. Regionally, alluvium is suitable for stock water supply and irrigation but is not suitable for drinking water and freshwater aquatic ecosystems, though there is understood to be little groundwater utilisation in the Study Area. Based on previous ecological

studies, it was identified that riparian vegetation has a low likelihood of dependence on alluvial groundwater.

Tertiary-Quaternary aged sediments and weathering derived Regolith present across SSM forms the base of the unconfined shallow groundwater system. The groundwater flow processes are similar to those of the alluvium; however the fluxes are expected to be significantly lower due to the dominance of clay within the sediments. Within the Study Area, near surface water features, saturation has been detected within the Tertiary material at depths of around 25 mbGL to 45 mbGL. Water quality data for the Tertiary sediments and Regolith indicates it is generally moderately saline but can be fresh to saline. Water is generally of moderate quality and has the potential to be used for limited stock, or irrigation purposes, depending on the local chemistry.

In the Permian strata, groundwater is encountered mainly in the coal seams, and occasionally in the sandstone/siltstone units of lower hydraulic conductivity. As with the rest of the Bowen Basin, the coal seams are the main groundwater bearing units within the Permian sequences, with low hydraulic conductivity interburden generally confining the individual seams. The coal seams are dual porosity in nature with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats). Hydraulic conductivity of the coal decreases with depth due to increasing overburden pressure reducing the aperture of fractures. Vertical movement of groundwater (including recharge) is limited by the confining interburden layers, meaning that groundwater flow is primarily horizontal through the seams with recharge only occurring at subcrop.

Review of fault behaviour within the Bowen Basin has identified that faults in the Permian strata can increase vertical hydraulic conductivity parallel to the fault trace and reduce it perpendicular to the fault trace. However, any increases in vertical hydraulic conductivity are limited to small vertical horizons (<20 m) and are variable between faults dependent on localised hydrothermal activity and mineralisation in-filling pore spaces. Previous hydraulic testing of faults in the Bowen Basin indicate that faulting zones intercepted are not pathways for preferential flow.

Regionally, groundwater within the Permian coal measures flows in a south-easterly direction, but the flow system is significantly modified by mining activities. Review of water quality data indicates water within the Permian coal measures is generally saline at SSM but can range between brackish to highly saline. Groundwater within the coal measures at SSM is generally considered unsuitable for all stock types.

5.2 End of Mining

An understanding of the hydrogeological system response to mining, and conditions at the end of mining, is considered important in the context of defining the starting conditions for the post-mining assessment described later in this report. A visual representation of the end of mining CSM is provided in **Figure 5-1**, noting the general conceptualisation features discussed above. Note that the post-mining CSM of the SSM hydrogeological system is related to the area outside of the Roper Study Area, with the Roper Study Area to be subject to future local scale study as described in **Section 1.1**. Based on an understanding of hydrogeological mechanisms and response to mining observed in the site monitoring data, and modelled in other local studies, key outcomes relevant to the assessment of potential groundwater impacts at the end of mining are likely to be:

- Groundwater drawdown within the Moranbah Coal Measures, associated with passive dewatering into the SSM mine pits, results in inwards hydraulic flow gradients in the coal measures.
- Mine pits capture any seepage from spoil emplacements.
- Limited groundwater level drawdown in the Tertiary formations due to low hydraulic conductivity of these zones and poor lateral connection and no impact to alluvial aquifers.
- Limited potential for groundwater level drawdown impacts to potential terrestrial GDEs along Stephens Creek and Rolf Creek, where the water table in the regolith material may be accessed by deeper rooted riparian species and may be subject to relatively small drawdowns
- Little to no impact on aquatic environmental receptors.

- No impact on anthropogenic receptors.

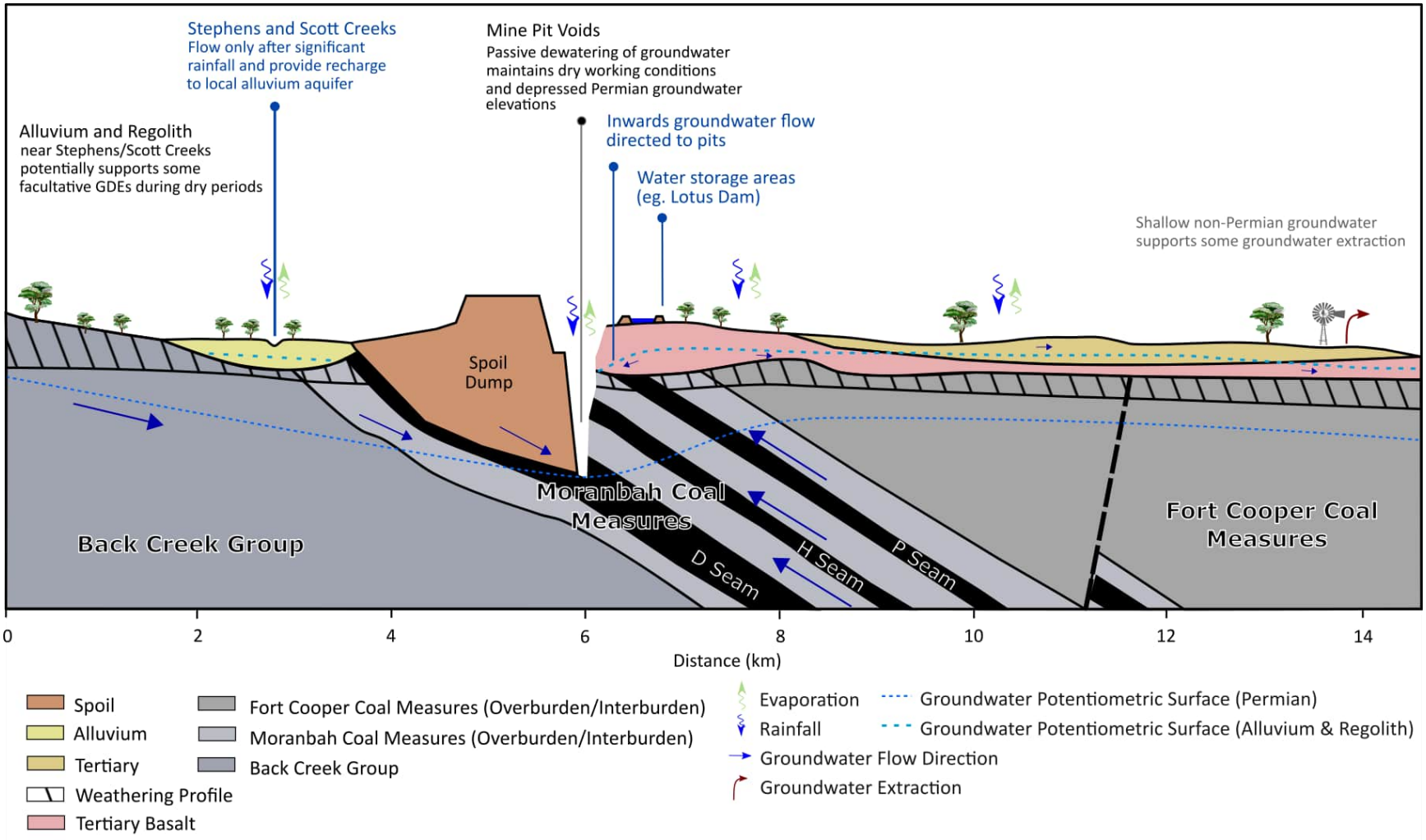


Figure 5-1 Conceptual Model of SSM Groundwater System – End of Mining

6.0 Potential Impacts

Potential Impacts associated with shallow sources of potential groundwater contamination at SSM 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 site groundwater system.

6.1 Groundwater System at End of Mining

The potential impacts to the groundwater system post-closure, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining. Therefore, it is important to understand the nature of the groundwater system at the conclusion of mining immediately prior to the closure period, noting that the features discussed below are relevant for areas of the site outside of the Roper Study Area where further studies are required. Based on the observed response during the care and maintenance period, the following points are relevant as an indication of the predicted response of the SSM groundwater system to end of mining impacts:

- Groundwater drawdown within the Moranbah Coal Measures, associated with passive dewatering into the SSM mine pits, results in inwards hydraulic flow gradients in the coal measures. The magnitude of this drawdown will be most significant in the immediate vicinity of the pits, but extend northwards, eastwards and southwards of SSM by several kilometres and interact with drawdown from nearby mines.
- Mine pits capture any seepage from spoil emplacements due to the hydraulic gradient orientated towards the mine void.
- No observed groundwater level drawdown of the alluvium due to the limited extent of continuous alluvial lenses.
- Limited groundwater level drawdown in the Tertiary formations due to low hydraulic conductivity of these zones and poor lateral connection.
- Limited potential for groundwater level drawdown impacts to potential terrestrial GDEs along Stephens Creek and Rolf Creek, where the water table in the regolith material may be accessed by deeper rooted riparian species and may be subject to relatively small drawdowns.
- Little to no impact on aquatic environmental receptors.
- No reported impact on anthropogenic receptors.

6.2 Groundwater System Post Mining

The remainder of this report evaluates the potential post mining impacts on the groundwater system through numerical groundwater modelling work based on the above conceptual model of SSM. The evaluation presented in the remainder of this report includes:

- Assessment of residual void lake formation in the post-mining period, and whether lake levels stabilise below the pre-mining groundwater elevations and any shallow post-Permian strata, including the base of surficial weathering and shallow hydrostratigraphic units (i.e. alluvium and Tertiary sediments/Regolith).
- Assessment of potential for continued groundwater drawdown within the Moranbah Coal Measures, resulting in continued inwards hydraulic flow gradients in the coal measures in the post-mining period.
- Whether residual voids continue to capture any seepage from spoil emplacements in the post-mining period.
- The extent of impact on surficial aquifers in the post-mining period.

- The extent of impact on environmental receptors in the post-mining period.
- The extent of impact on anthropogenic receptors in the post-mining period.

7.0 Groundwater Modelling

Numerical groundwater modelling was undertaken in support of the hydrogeological assessment for the PRC Plan to evaluate the potential impacts of the proposed PRC Plan's Final Landform on the groundwater regime. This section provides a summary of the design and development of the SSM numerical groundwater model. Full details of the SSM numerical groundwater model developed for this hydrogeological assessment are included in the technical modelling report (SLR, 2024).

The objectives of the groundwater modelling were to:

- Assess the nature (timing and elevation) of void water level recovery (i.e. time to reach post mining equilibrium and definition of that equilibrium level), and associated groundwater fluxes to/from voids.
- Assess the groundwater levels at post mining equilibrium in all relevant hydrogeologic units, and associated impacts on current and potential future receptors (drawdown, water quality and groundwater flow direction).
- Assess impacts to alluvial and Tertiary hosted groundwater and any identified potential receptors.
- Assess the influence on potential groundwater receptors associated with surface drainage lines.

7.1 Model Details

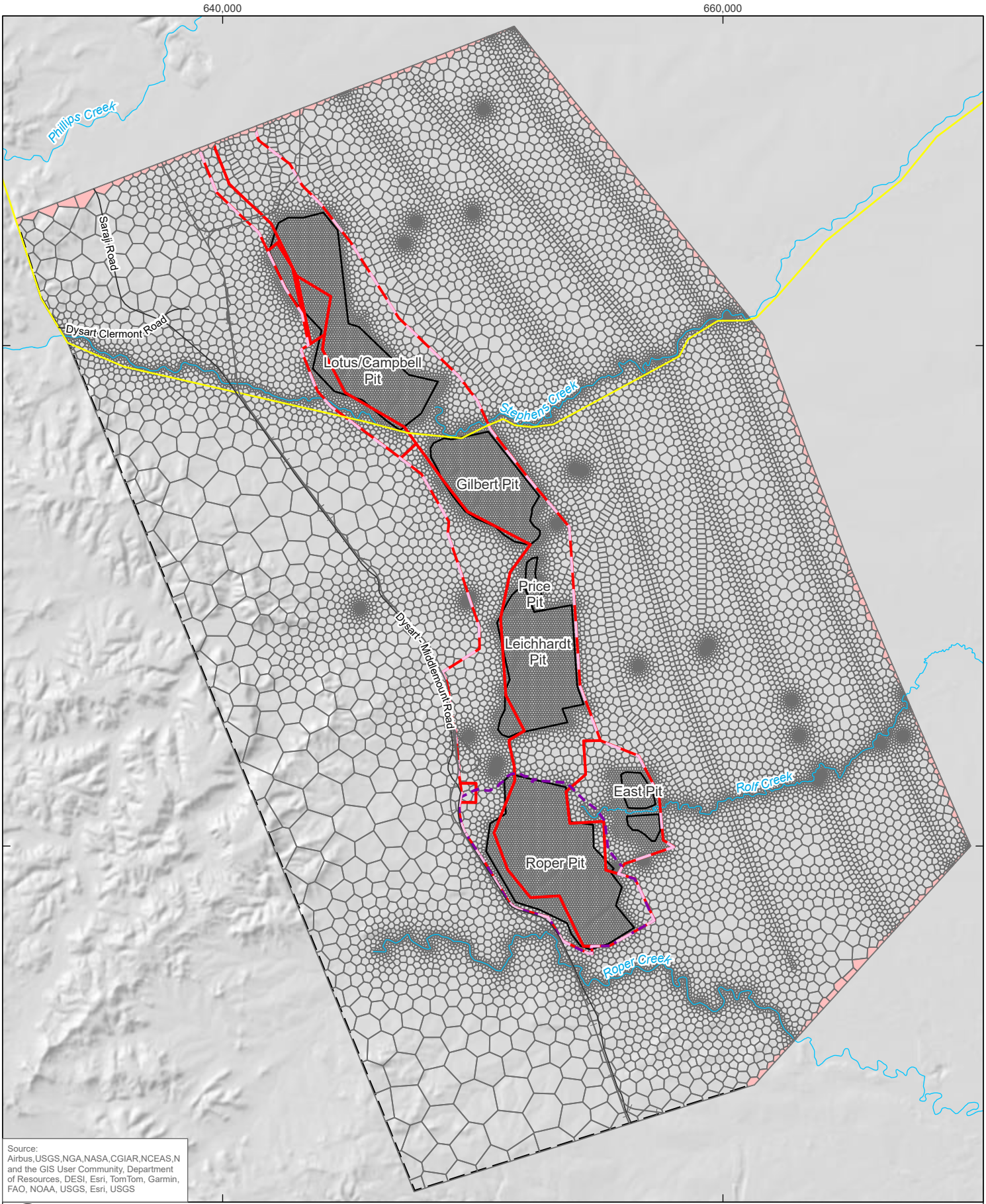
7.1.1 Model Design

MODFLOW-USG Transport was used as the model code (Panday et al. 2013). MODFLOW-USG is a recent version of industry standard MODFLOW code and was determined to be the most suitable modelling code for accomplishing the model objectives. MODFLOW-USG optimises the model grid and increases numerical stability by using unstructured, variably sized cells. These cells take any polygonal shape, with variable size constraints allowing for refinement in areas of interest.

MODFLOW-USG is also able to simulate unsaturated conditions, allowing progressive mine dewatering and post mining rewetting to be represented by the model. For the SSM model, vadose zone properties have been excluded, and the unsaturated zone was simulated using the upstream-weighting method.

The groundwater model extent is shown in **Figure 7-1**. The model domain is intended to place boundary conditions sufficiently distant from the SSM site to allow the extent of potential impacts from mining activities on the groundwater system to be assessed. At its widest extents, the model is approximately 25 km west-east by 43 km north-south. The model domain was selected based on the following considerations:

- The western boundary is represented by the outcrop boundary of the Back Creek Group, which is considered the regional low permeability basement for the purpose of this modelling.
- The northern boundary contains the primary geological unit being targeted by the SSM site and is approximately 4 km away from the proposed open cut mine areas. This northern section overlaps with the Saraji East version of BMA's central Bowen Basin regional groundwater model (SLR, 2022a)
- The southern boundary is set approximately 8 km south of the SSM site and is expected to be far outside the range of predicted SSM related drawdown.
- The eastern boundary is set along the SSM fault approximately 11 km east of the SSM area and is expected to be far outside the range of predicted SSM related drawdown.



Source: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,N and the GIS User Community, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Railway
- Major Road
- Watercourse
- Model Boundary
- Model Grid
- SSM Pit Extent
- General Head Boundary
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area
- Central Bowen Basin Regional Model Boundary

SARAJI SOUTH MINE TRANSITIONAL PRCP

MODEL MESH AND BOUNDARY CONDITIONS

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FIGURE 7-1

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_1_Model Mesh and Boundary Conditions

The following features have been included in the grid design:

- Open cut mine areas for the SSM are represented with a 100 m Voronoi cell size constraint.
- Faults are represented using a 200 m Voronoi cell constraint.
- Alluvium areas are represented by irregular shaped Voronoi cells with resolution in a range of 100 m and 300m.

Model layering is based on a simplified representation of the SSM site geological model. The major coal seams considered for the model layering were: D seam, H seam, P seam and Q seam. The regions between these seams are interburden layers. Outside of the SSM geological model extents, and average seam thickness (sampled across the geological model extents) was applied regionally. Where the model boundary overlaps with the existing Saraji East version of BMA's central Bowen Basin regional groundwater model (SLR, 2022a), the layer structure from the southern part of the central Bowen Basin regional model was adopted.

Structural trend data was extrapolated from the geological models using the neighbouring "Saraji East groundwater model" to the north (SLR, 2023b) as well as publicly available solid geology mapping. The layering and average thicknesses used are summarised in **Table 7-1**.

Table 7-1 Model Layers and Thickness

Model Layer	Formation	Unit	Average Thickness (m)
1	Alluvium, colluvium, Tertiary basalt	Surface cover – alluvium, colluvium and Tertiary basalt	32
2	Tertiary sediments, Tertiary basalt, Regolith	Tertiary and minor Triassic Clematis Group, weathered Permian, Tertiary basalt	30
3	Fort Cooper Coal Measures	Fort Cooper overburden	53.0
4		Fort Cooper seams (combined)	62.7
5		Fort Cooper underburden	72.5
6	Moranbah Coal Measures	Q Seam	1.0
7		Interburden	46.2
8		P Seam	1.9
9		Interburden	43.6
10		H Seam	3.7
11		Interburden	52.8
12		D Seam	5.1
13		Base of Model - aquitard	100

Further detail on geological structure representation, time discretisation, model stressors and boundary conditions are detailed in **Appendix A**.

7.1.2 Model Calibration

A detailed description of the calibration procedure is provided in **Appendix A**. The numerical model includes a steady state and a transient calibration (1990 to 2023). In all, 261 target heads were established for 53 bores from the SSM area. Historical mining at SSM 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. Calibration of the model was carried out with the objective being to replicate the groundwater levels measured in SSM monitoring network. The calibration statistics were calculated for each

realisation and the realisation that produced the lowest Scaled Root Mean Square error (SRMS) was considered to be the best-calibrated model, in accordance with Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The model variables included in the calibration were:

- Aquifer parameters including horizontal and vertical hydraulic conductivity, specific storage and specific yield.
- Stresses including recharge rates.
- Boundary conditions including evapotranspiration (EVT) rate, EVT extinction depth, and General Head Boundary (GHB) conductance factor (excluding the northern GHB area covered by the Saraji East numerical groundwater model).
- Faults horizontal and vertical hydraulic conductivity, specific storage, and specific yield.
- Horizontal and vertical hydraulic conductivity, specific storage, and specific yield of spoils.

Groundwater level calibration targets were selected where:

- Valid information on bore construction or geology information was available for the site.
- Targets were manually reviewed to ensure the measurements were realistic.

Calibration target observations and resultant residual data summary is presented in **Table 7-2**. Calibration statistics were calculated from the calibration ensemble including 120 realisations. The RMS error calculated for the Base Model realisation is 3.4 m, equating to a 4.2% scaled root mean square (SRMS) error, which is within the recommended range (i.e. 10%) in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). Calibrated hydraulic parameters were shown to be all within the range of available field data (**Section 4.2**).

Table 7-2 Model Calibration Targets and Residual

Model Layer	Formation	Unit	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
1	Alluvium, colluvium, Tertiary basalt	Surface cover	-0.1	0.3	5	1
2	Tertiary sediments, Tertiary basalt	Tertiary and minor Triassic Clematis, weathered Permian, Tertiary basalt	0.7	3.1	133	32
3*	Fort Cooper Coal Measures	Fort Cooper overburden	-	-	-	-
4		Fort Cooper seams (combined)	-0.2	0.6	38	2
5		Fort Cooper underburden	0.0	2.1	11	2
6*	Moranbah Cooper Coal Measures	Q Seam	-	-	-	-
7		Interburden	2.3	2.3	11	2
8		P Seam	1.4	2.3	12	3
9		Interburden	0.5	0.5	3	1
10		H Seam	-0.2	1.4	30	3
11		Interburden	-3.1	8.0	3	2
12		D Seam	-3.6	3.6	7	4
13		Interburden	0.4	0.4	8	1

*There are no observation bores in Layes 3 and 6.

7.1.3 Model Performance and Limitations

The Australian Government's Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling* (Peeters and Middlemis, 2023) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

Peeters and Middlemis (2023) state that simulation models are developed as simplified representations of 'real world' systems that are usually history-matched to measured data, albeit affected to some degree by the various sources of uncertainty outlined above. Peeters and Middlemis (2023) further describe that models are continuously refined with new data, conceptualisations and processes, to investigate the effects of management options on future eventualities.

The four sources of scientific uncertainty identified by Peeters and Middlemis (2023) have been qualitatively assessed with regards to key aspects of the SSM numerical model adopted for this groundwater assessment, as presented in **Table 7-3**.

Overall, the model captures depressurisation due to active mining. The model is numerically stable with no mass balance error. The model shows a reasonable fit between observed and modelled groundwater levels. A depth dependence function was used for hydraulic conductivity, with the calibrated values showing a good fit to observed data. Overall, the model is considered fit for purpose based on the data provided and the project timeframe.

In case of future use of the model, updates could be conducted to further refine the model if it was deemed that an increase in model confidence level was required, but the applicability of this would be dependent on the purpose of the future modelling and availability of data to inform future changes. As it stands, the current model is deemed fit for purpose for this assessment.

Table 7-3 Groundwater Model and Data Limitations

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose	The model has an unstructured Voronoi grid that includes detailed cell refinement around the SSM site, major modelled faults and along drainage features.
	Layers	Fit for purpose	Representation of alluvium and other geologic units based on CSIRO depth to regolith surface (Wilford et, al., 2016) and SSM-derived information from the study area including drilling data.
	Conceptualisation – Geological Structure	Fit for purpose	The local structure of the geology is based on detailed data at SSM where available, including a SSM developed site geology model. Geological mapping has identified several large faults throughout the model domain. Faults have been included as separate (i.e. individual for each fault) hydraulic parameter zones and calibrated to fit measured water level data across the model domain.
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose	The Moranbah Coal Measures outcrop within the numerical model domain and as such they receive direct recharge like the Alluvium and Tertiary in the model. A specific recharge zone was attributed to the drainage lines, to represent infiltration recharge via the creek bed during flooding events. Mine pits that were flooded in 2011 are represented using a constant head boundary based on site measurements.
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose improvements possible	For the extent and thickness of alluvium and regolith within the model domain, a combination of site geological model (SSM geological model - base of weathering), regional geological mapping and the CSIRO depth to regolith surface (Wilford et, al., 2016) was used. Any additional data or study on alluvium extent and thickness in the SSM area should be reviewed and captured (where relevant) in future updates of the model.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose, future improvements possible	Field testing of hydraulic conductivity (horizontal and to a lesser extent vertical) has been conducted in the SSM and the neighbouring Saraji/Saraji East Mine area. Hydraulic conductivity test results from the wider Bowen Basin were also considered. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model. Further hydraulic conductivity tests and measurements of storage properties can improve model calibration and refine model predictions but are not deemed required for the current impact assessment.
	Spoil Properties	Fit for purpose, future improvements possible	Limited site-specific data is available for the spoil. Spoil parameter calibration ranges were estimated based on previous studies at other sites.
	Rivers	Fit for purpose, future improvements possible	All watercourses within the model domain are minor ephemeral creeks. They are represented in the model via specific recharge zone, to reproduce infiltration recharge via the creek bed during flooding

Type	Part	Status	Comment
			events. A refinement along the riverbeds was also performed to capture the variation in the evapotranspiration surface along the watercourses).
	Recharge	Fit for purpose, future improvements possible	Recharge zonation is based on mapped surface geology and calibrated recharge rates. Calibration ranges were based on site data analysis and literature values.
Measurement Error	Observation Data Quality	Fit for purpose	Bore logs and construction details available for most site bores, and long-term site water level data available for various units. 261 target heads were established for 53 bores from the SSM area.
	Temporal spread	Fit for purpose, future improvements possible	Timeseries water level data from the site used for calibration contains at least one observation in every modelled aquifer, except for the Q Seam and the Fort Cooper Coal Measures overburden. Data is available from 1990, although most of the data covers the period 2010 – 2023.
Scenario Uncertainties	Calibration	Fit for purpose	A steady state calibration to initial heads at each bore was performed followed by a transient calibration to observed drawdowns up to 2023.
Future stresses/ conditions	Predictive	Fit for purpose	Model prediction period covers all 2023 onwards SSM approved mining activity and accounts for post mining rehabilitation (i.e. PRC Plan final landform)
	Sensitivity and uncertainty	Fit for purpose	Postmining simulation of surface water lakes in all the final voids was conducted via an iterative process whereby groundwater fluxes to and from the lakes were estimated using the MODFLOW groundwater model and surface water fluxes were simulated using a GoldSim rainfall/runoff model. Final lake levels were obtained after the two models converged and the results of this final set of lake levels were used to estimate postmining groundwater impacts in the groundwater assessment component of the SSM PRCP.

7.2 PRC Plan Landform Model

Post-mining groundwater impacts at SSM were investigated for the purposes of the PRC Plan's hydrogeology assessment with a numerical groundwater recovery model for the final landform as outlined in **Section 1.2**.

7.2.1 Model Setup

The recovery stress periods of the overall model setup commence from the end of mining at SSM and were run for 578 years over 32 model stress periods. The recovery stress period setup is shown in **Table 7-4**.

Table 7-4 Recovery Model Stress Periods

Recovery Stress Periods	Recovery Stress Period Duration (Years)	Starting Year (Post-Mining at SSM)	Ending Year (Post-Mining at SSM)
1 – 18	1	1	18
19-22	5	19	38
23-26	10	39	78
27-28	50	79	178
29-32	100	179	578

The PRC Plan's proposed final landform was replicated in the recovery model, including areas of spoil emplacement and the proposed residual voids. The distribution of modelled spoil emplacement is shown on **Figure 1-3**. At the mining at SSM, all the drain cells (representing SSM pit dewatering in areas of active mining) were removed from pits. Then the properties of the residual void cells were converted to values representative of void values. That is, the void cells were assigned high horizontal and vertical hydraulic conductivities (1,000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, specific storage of 5.0×10^{-6} m^{-1}), to simulate free water movement within the residual void. This approach is often referred to as a 'high-K' lake.

Climate related boundary conditions (i.e. recharge and ET) in the recovery model were set constant for the duration of the recovery. Recharge and ET were not applied to the final voids in the groundwater model as the WSP (2024) water balance model used iteratively with the groundwater model accounts for these boundary conditions.

7.2.2 Integration with Residual Void Water Balance Model

Figure 7-2 presents a conceptual diagram of the post-mining modelling setup adopted for this hydrogeological assessment. As shown in **Figure 7-2** , the residual voids will accumulate water over time due to direct rainfall, surface water runoff and groundwater inflow from both spoil and natural rock as groundwater levels recover. Whilst the numerical groundwater model can reliably account for the groundwater inflow component, the surface components of direct rainfall, surface water runoff, as well as evaporative loss from the void lake, are considered to be better accounted for within a surface water balance model. This is due to the inherently more refined nature of simulating those surface components within a water balance model, as compared to a numerical groundwater model.

The groundwater model was therefore used to predict the following fluxes to the residual voids:

- Groundwater inflow to the pit shell from the surrounding geology, including inflow from the natural geology to the spoil backfill and inflow from the natural geology directly to the residual voids; and
- Groundwater inflow originating from the indirect catchment (i.e. areas of spoil backfill that receive rainfall recharge that then flows through the spoil into the residual voids).

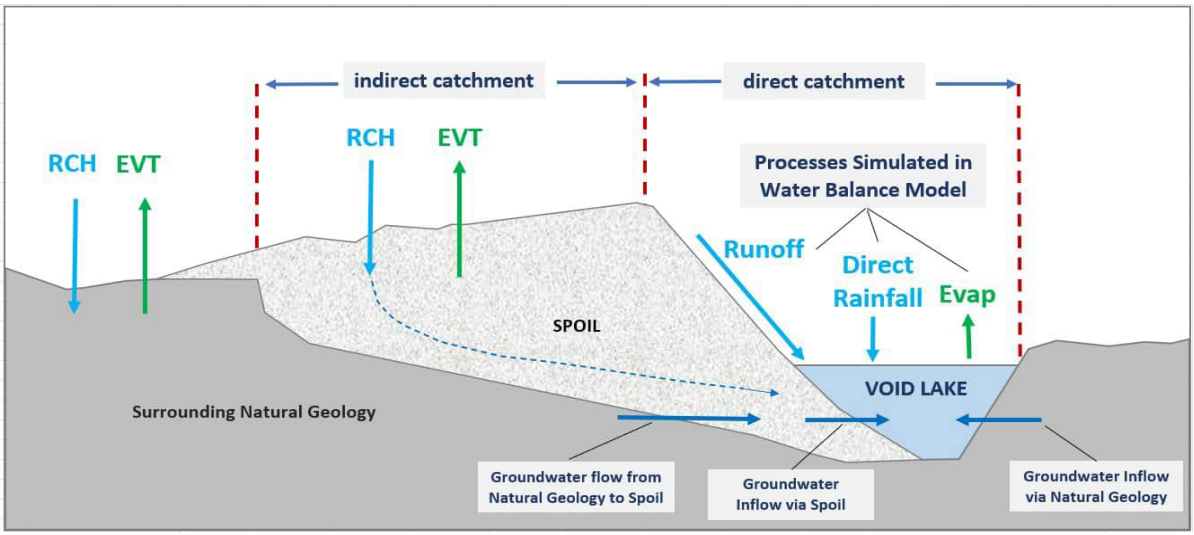


Figure 7-2 Residual Void Recovery Model Conceptual Diagram

Void water levels were not predicted by the groundwater model but were estimated by the balance between groundwater inflow and the direct rainfall and rainfall runoff from the surrounding catchment against the evaporation loss from the lake surface through iterative surface water balance modelling (WSP, 2024). The WSP (2024) surface water balance modelling included climate sensitivity and three climate scenarios reported therein were adopted for the groundwater model as instructed by BMA and shown in **Table 7-5**. Three sets of groundwater model predictions were generated for this hydrogeology assessment based on the three climate scenarios.

Table 7-5 Climate Scenarios Modelled

Climate Scenario	Climate Model	IPCC RCP Scenario[1]	WSP (2024) Realisation
Wetter	ACCESS1-0Q	4.5	R#1
Mid	MPI-ESM-LRQ	4.5	R#3
Drier	MPI-ESM-LRQ	8.5	R#6

1. Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP), refer https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/RCPs.html

The iterative modelling approach was undertaken in a stepwise manner as follows, for each climate scenario:

1. The water balance model for the residual void and depressed landforms prepared by WSP (2024) was first run.
2. The daily surface water inflows were combined with predicted groundwater fluxes to the residual void and depressed landforms from the groundwater model, to produce a surrogate water balance model at a lower temporal resolution (i.e., matching the stress period setup of the groundwater model).
3. The predicted void and depressed landform lake levels from the surrogate water balance model were applied as constant head boundary conditions in the groundwater model, and the groundwater model was re-run to obtain updated groundwater fluxes to the lakes.
4. The surrogate water balance model was re-run with the updated groundwater fluxes, resulting in a new set of predicted lake levels.
5. Steps 3 and 4 were repeated until the time series of predicted lake levels for the residual void and depressed landforms stopped changing substantially between iterations.

6. The converged groundwater fluxes obtained from running the groundwater model and surrogate water balance model in tandem were supplied to the WSP (2024) water balance model.
7. The resulting void lake levels calculated by the WSP (2024) water balance model were compared with the lake levels estimated by the surrogate water balance model to evaluate agreement between the two models.
8. As the lake levels produced by the two water balance models were very similar, the models were determined to have converged, and the results of the groundwater model and the WSP (2024) water balance model were adopted for reporting the PRCP.

The assessment of the iterative model outputs between the groundwater model and the water balance model indicates the northern three SSM voids achieved an appropriate level of convergence for the purpose of this assessment. However, the alignment of the models for Roper and East Pit residual voids did not achieve the same level of convergence. Reasonable efforts to align the models has been completed including development of an auto iterator, to better define the starting point, combined with numerous model iterations. The PRC Plan's approach to the area containing the Roper residual voids includes the implementation of a 'Roper Study Area' and an additional remediation milestone (RM) that provides for additional studies to be completed to inform the further development of the closure landform. The additional data produced for the Roper Study Area will provide for further development of the groundwater and water balance models by providing additional data on groundwater and revised landform designs. Based on this, the PRC Plan will also be amended where required. Furthermore, the East Pit residual voids are located down dip from the Roper residual voids and changes to the Roper residual voids will impact the hydrogeology and void lakes within the East Pit residual voids. Therefore, the long-term hydrogeology of East Pit residual voids, due to the uncertainty of the Roper Study Area closure landform, is also uncertain. Any remodelling of the Roper residual voids will require consideration/inclusion of the East Pit residual voids. However, as reflected in the PRC Plan schedule, East Pits are an approved future mining opportunity that will not be commenced prior to the completion of Roper Pit studies and any associated amendment of the PRC Plan. Therefore, prior to the mining of East Pits, the hydrogeology will have been restudied and included in any PRC Plan amendments. The potential for improvement in alignment of the models is acknowledged by BMA.

Given the continued uncertainty pertaining to the final landform for the Roper Study Area, and the reasons discussed in **Section 1.1**, the following discussion of modelling outcomes are presented only for the area of SSM outside of the Roper Study Area.

7.2.3 Residual Void Lake Recovery

Figure 7-3 through **Figure 7-7** provide a graphical representation of the final simulated recovery of water levels in the residual voids, based on the iterative groundwater and surface water balance modelling. Of note, there is only an approximate 0 to 27 m range in equilibrium lake elevations between the three climate scenarios. It should be noted that, as predicted groundwater inflow to the voids is only approximately 10% to 20% of the total volumetric inflow to the voids (see **Section 7.2.2**), within the water balance model the surface water fluxes are the dominant driver for the estimated void water levels and associated trends, rather than the predicted groundwater inflow volumes. The exception to this is where groundwater inflows to the East 1 and East 2 residual voids account for approximately 50% of the total volumetric inflow to these two residual voids (noting that the hydrologic behaviour of the East Pit residual voids remains subject to change based on outcomes of further studies in the Roper Study Area as discussed in **Section 7.2.2** above).

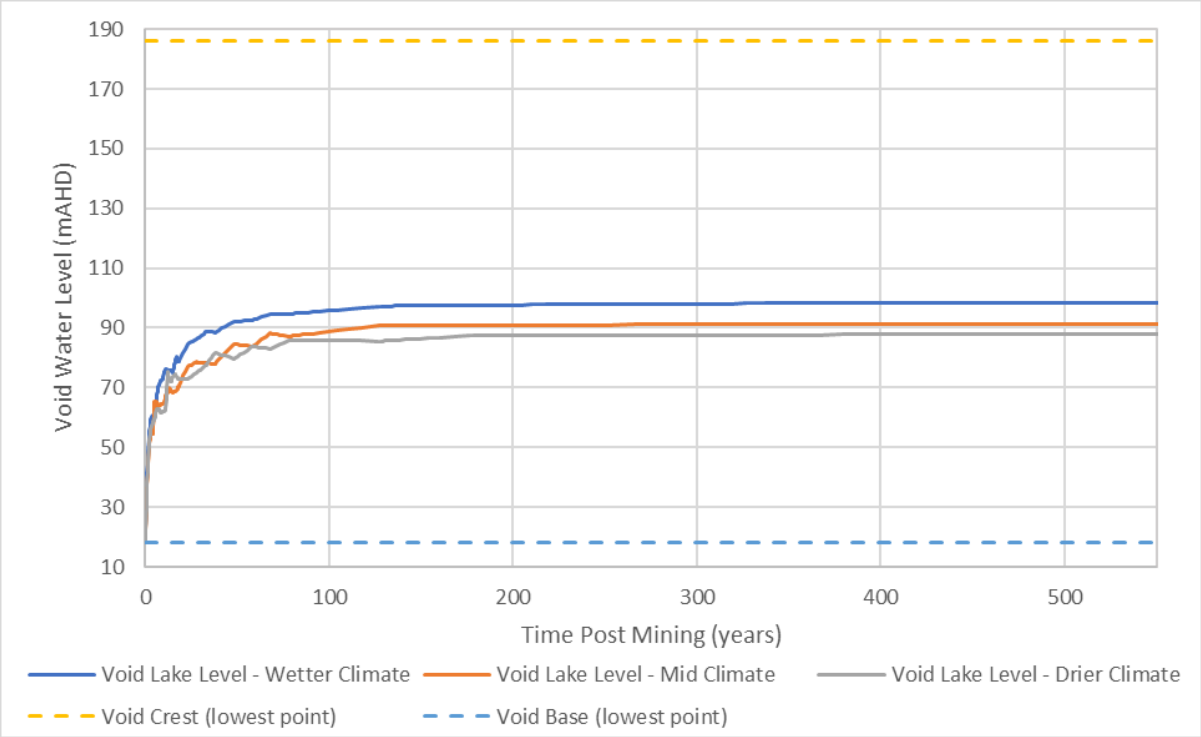


Figure 7-3 Simulated Void Water Level Recovery – Lotus/Campbell Void (based on WSP, 2024)

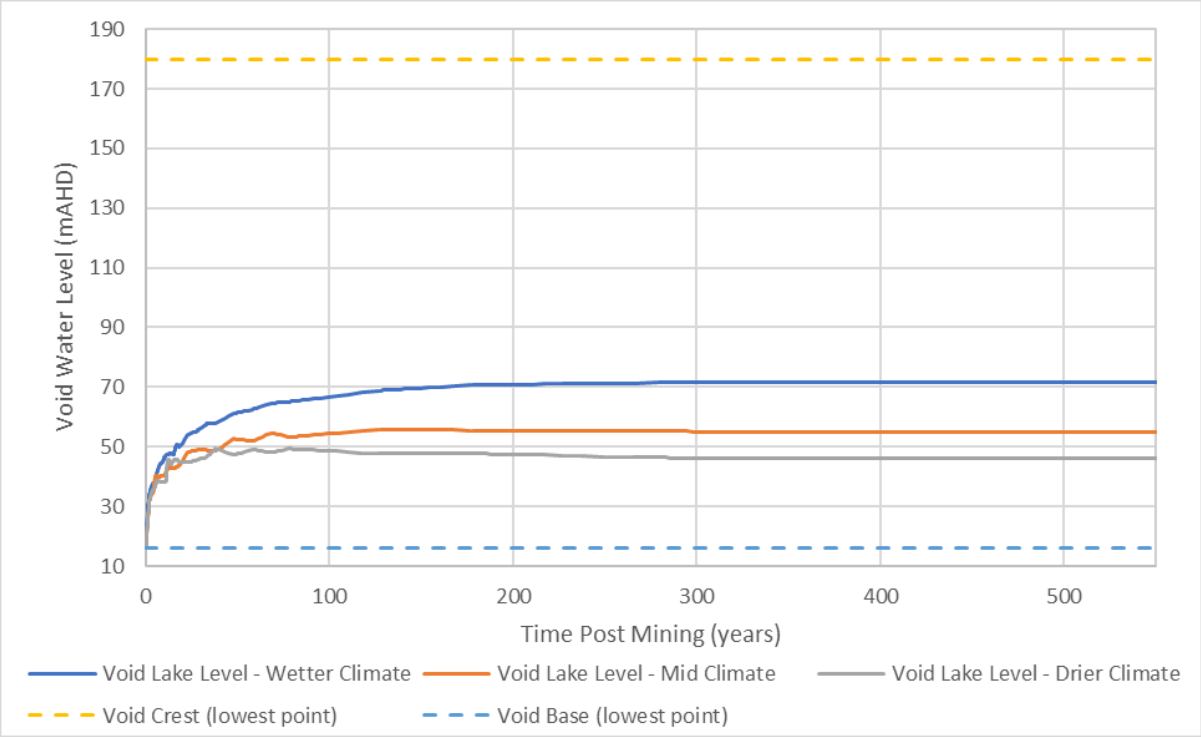


Figure 7-4 Simulated Void Water Level Recovery – Gilbert Void (based on WSP, 2024)

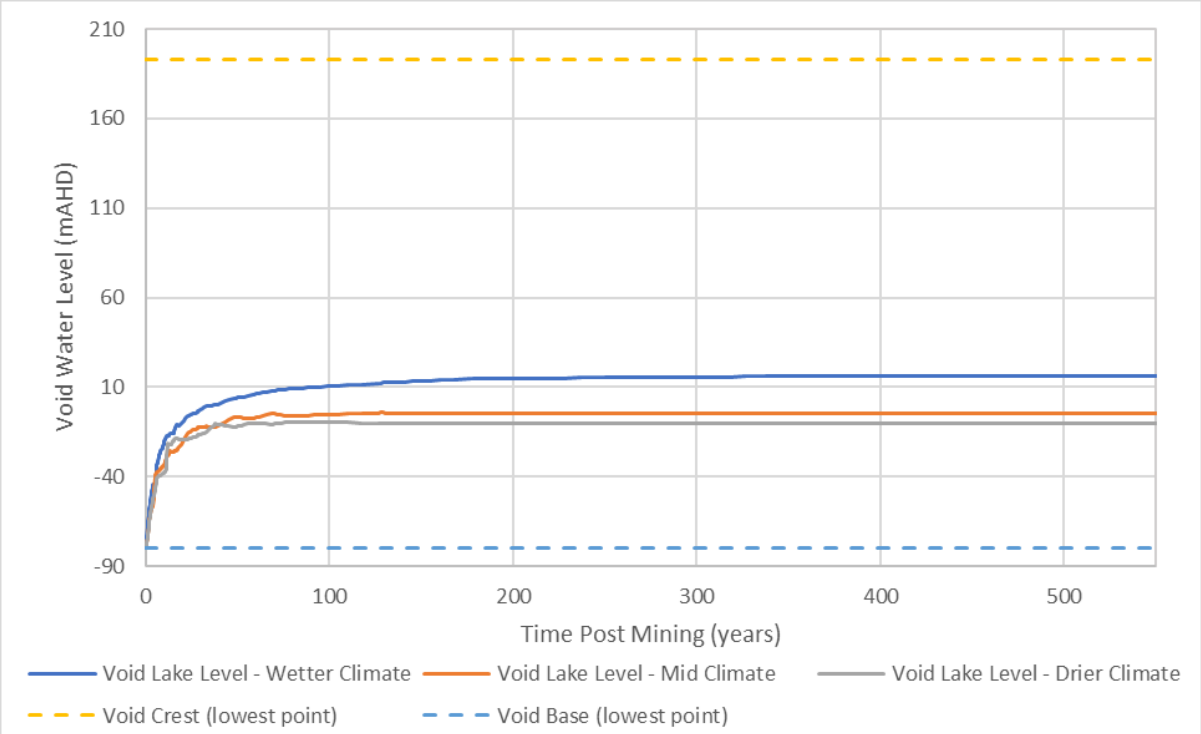


Figure 7-5 Simulated Void Water Level Recovery – Price/ Leichhardt Void (based on WSP, 2024)

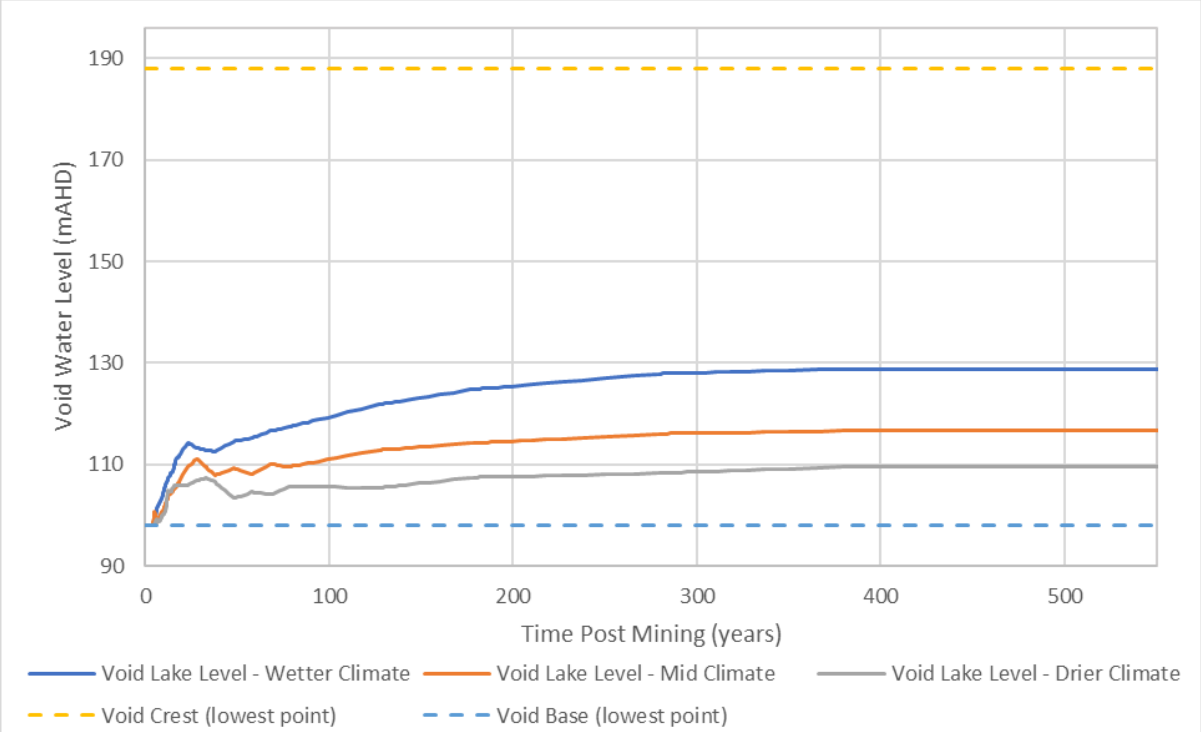


Figure 7-6 Simulated Void Water Level Recovery – East 1 Void (based on WSP, 2024)

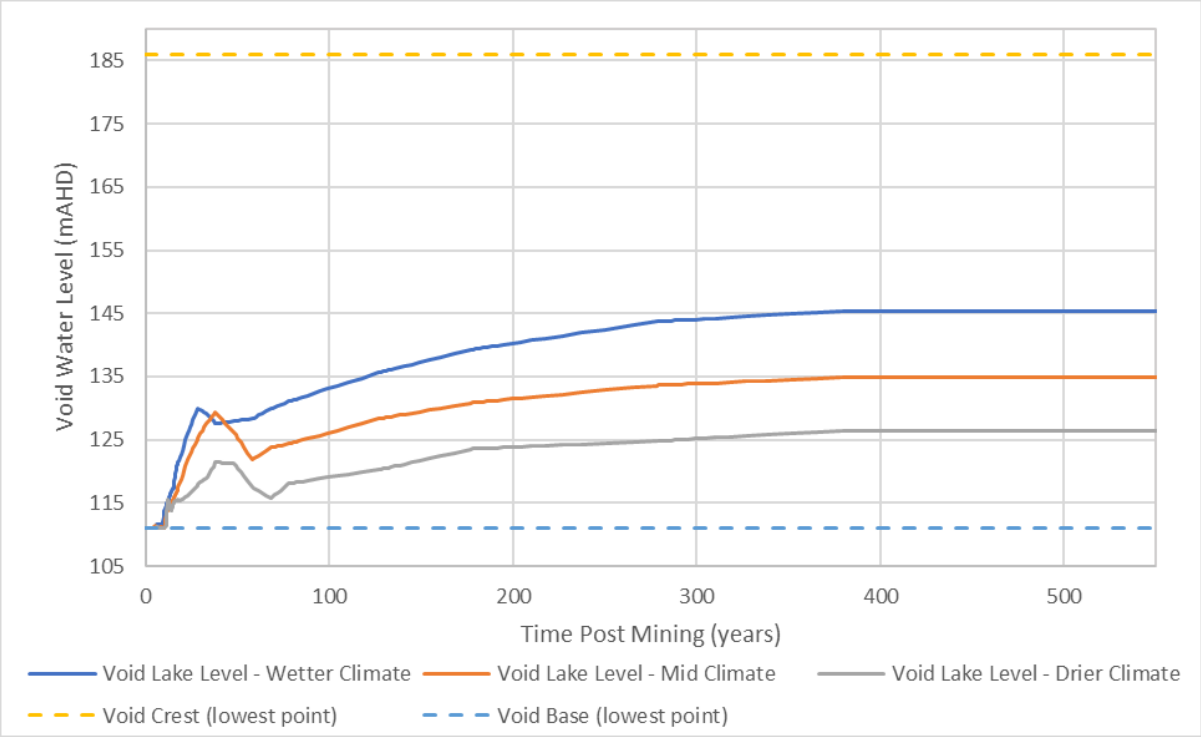


Figure 7-7 Simulated Void Water Level Recovery – East 2 Void (based on WSP, 2024)

Figure 7-3 through **Figure 7-7** show that the residual void water level recovery is a process that takes decades with the recovery rate declining as the lakes reach equilibrium conditions. The majority of recovery in the voids is achieved within the first 100 years, and equilibrium water level conditions are reached after approximately 50 to 300 years for all climate scenarios represented in the groundwater model. The predicted equilibrated water levels in the residual voids are shown in **Table 7-6**.

Table 7-6 Equilibrated Water Levels in the Residual Voids (based on WSP, 2024)

Climate Scenario	Residual Void	Initial water level (mAHD)	Approximate time to equilibrium (years)	Equilibrium water level (mAHD)
Wetter	Lotus/Campbell	18	115	98
	Gilbert	16	110	71
	Price/Leichhardt	-80	167	16
	East 1	98	247	129
	East 2	111	252	145
Mid	Lotus/Campbell	18	115	91
	Gilbert	16	110	55
	Price/Leichhardt	-80	167	-5
	East 1	98	247	116
	East 2	111	252	135
Drier	Lotus/Campbell	18	115	88
	Gilbert	16	110	46
	Price/Leichhardt	-80	167	-11
	East 1	98	247	109
	East 2	111	252	126

The freeboard for each of the residual voids (i.e. the difference in elevation between the long-term water levels in the residual voids and the landform crest elevation) is as shown in **Table 7-7**. Predicted void lake levels remain significantly below the surface ‘spill’ level for each of the residual voids.

Table 7-7 Predicted Freeboard in the Residual Voids at Equilibrium

Climate Scenario	Residual Void	Freeboard (m)
Wetter	Lotus/Campbell	88
	Gilbert	109
	Price/Leichhardt	177
	East 1	59
	East 2	41
Mid	Lotus/Campbell	95
	Gilbert	125
	Price/Leichhardt	198
	East 1	72
	East 2	51
Drier	Lotus/Campbell	98
	Gilbert	134
	Price/Leichhardt	204
	East 1	79
	East 2	60

The difference in elevation between the long-term water levels in the residual voids and the lowest point of the base of the shallow geologic formations (weathered regolith; model Layer 2) adjacent to the voids is shown in **Table 7-8**. Predicted residual void lake levels remain significantly below the base of the shallow geologic formations for Lotus/Campbell, Gilbert, and Price/Leichhardt residual voids, even with the temporal fluctuations in void water levels predicted by the WSP (2024) water balance model. That is, there is never the potential for a flux of water to leave the residual voids and enter the shallow/unconsolidated geologic formations.

Table 7-8 Predicted Difference between Residual Void Water Levels and Shallow Formations

Climate Scenario	Residual Void	Lowest Elevation of Base of Model Layer 2 Adjacent Void (mAHD)	Difference Between Void Lake Level and Lowest Elevation of Base of Model Layer 2 Adjacent Void (m)[1]	
			Start of Post-Mining	Post-Mining Equilibrium
Wetter	Lotus/Campbell	155.3	137.3	57.3
	Gilbert	150.6	134.6	79.6
	Price/Leichhardt	163.2	243.2	147.2
	East 1	152.0	54.0	23.0
	East 2	155.1	44.1	10.1
Mid	Lotus/Campbell	155.3	137.3	64.3
	Gilbert	150.6	134.6	95.6
	Price/Leichhardt	163.2	243.2	168.2
	East 1	152.0	54.0	36.0
	East 2	155.1	44.1	20.1
Drier	Lotus/Campbell	155.3	137.3	67.3
	Gilbert	150.6	134.6	104.6
	Price/Leichhardt	163.2	243.2	174.2
	East 1	152.0	54.0	43.0
	East 2	155.1	44.1	29.1

1. A positive number means the base of Model Layer 2 is that many metres higher than the void lake level

7.2.4 Residual Void Groundwater Inflow

The final predicted groundwater inflows to the residual voids from the groundwater model are shown on **Figure 7-8** through **Figure 7-12**, with inflows partitioned between that which flows into the residual voids through spoil, and that which flows into the residual voids through surrounding natural geological formations.

In approximately the first 50 years post-mining, groundwater levels are predicted to remain suppressed, particularly within the spoil around each residual void that is yet to saturate to a significant degree. During this time, groundwater fluxes to the voids are largely controlled by the difference between the predicted spoil groundwater levels and the predicted WSP (2024) residual void lake levels that rise and fall periodically (refer **Figure 7-3** through **Figure 7-7**) according to:

- Day-on-day climatic simulation within the WSP (2024) water balance model; and
- How the daily timestep water balance results are translated to the groundwater model's more simplified stress period setup.

For the mid-climate scenario, periods of variable groundwater inflow and outflow are predicted by the groundwater model in the first 39 years post-mining at Lotus/Campbell void, 13 years post-mining at Gilbert void, 14 years post-mining at East 1 void, and 39 years post-mining at East 2 void. Note that Price/Leichhardt void does not show periods of net variable groundwater inflow and outflow, maintaining net groundwater inflow and outflow fluxes, respectively, at all times of the mid-climate scenario simulation.

Over these periods, rainfall derived surface water captured in the residual voids (per the WSP water balance model) is predicted to move into the spoil, as the groundwater levels in the surrounding in-pit spoil backfill (and natural geological formations) slowly recover from mining activities. All predicted outflows from the Lotus/Campbell, Gilbert, and Price/Leichhardt residual voids over this time are to

the spoil, that is, there is no net predicted outflow from these voids to the natural geological formations in the whole post-mining duration.

It is noted that any form of further backfilling of residual voids above the groundwater level as a means to attempt to limit this early post-closure void water discharge will likely result in poorer environmental outcomes, as water in the backfilled voids will have a hydraulic head gradient toward the surrounding groundwater system. This will facilitate discharge outwards to the surrounding environment, in the absence of the hydraulic control (sink) caused by a relatively deep void lake that is maintained by evaporation in the long term (SLR, 2022b).

Simulation results indicate that there are predicted outflows from East 1 and East 2 voids to natural geological formations within the first 15 years post-mining.

As groundwater levels in the spoil and natural geology recover to elevations above some of the void lakes and lake levels stabilise, the direction of flow out of those void lakes stabilises and long-term groundwater inflow to the lakes is established after 24 years post-mining at Lotus/Campbell void, 6 years post-mining at Gilbert void, 14 years post-mining at East 1 void, and 39 years post-mining at East 2 void for the mid-climate scenario. Model results indicate that this inflow comes mostly via the spoil, originating mainly as local rainfall recharge applied to the spoil.

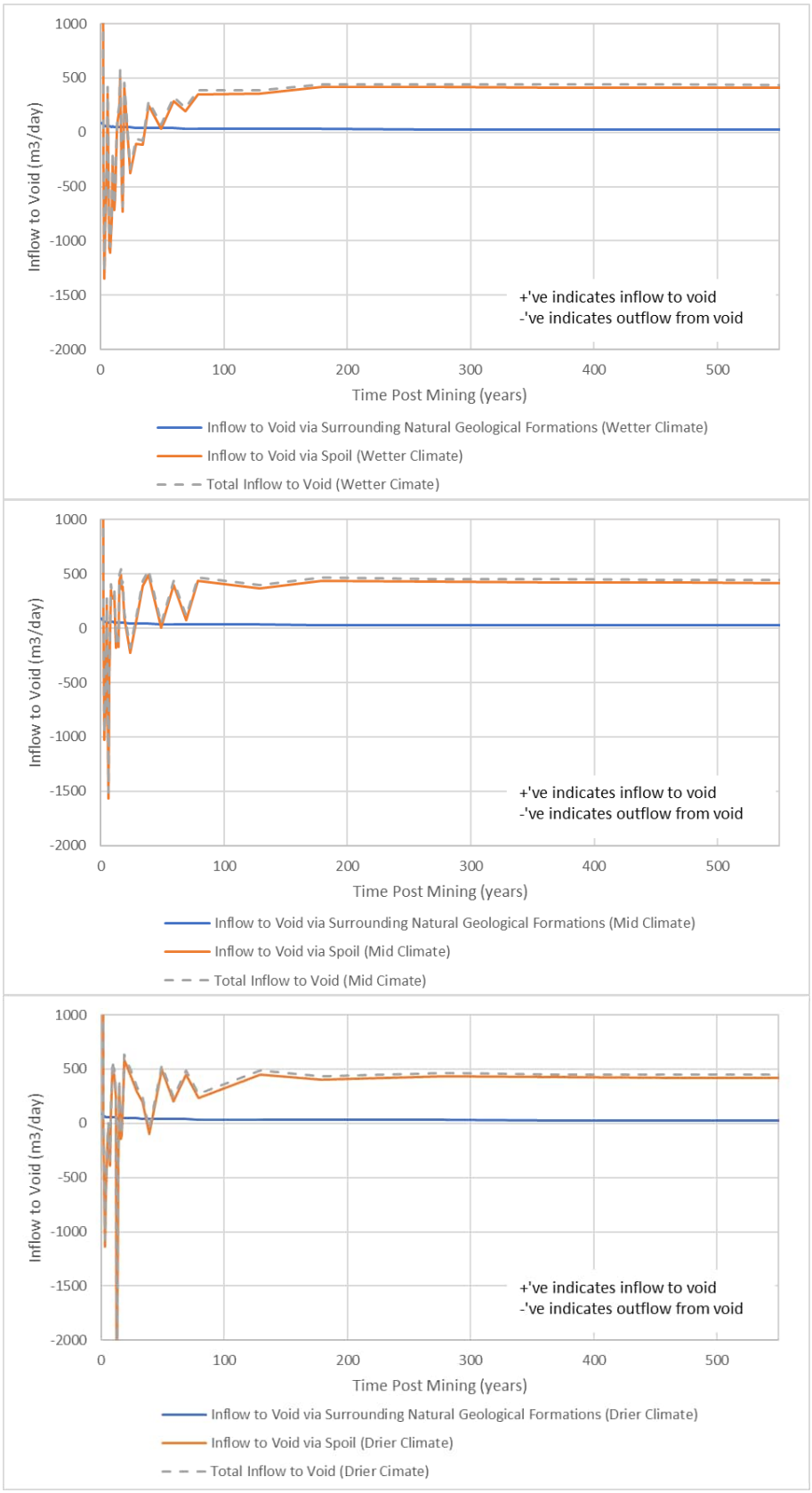


Figure 7-8 Predicted Void Groundwater Inflows – Lotus\Campbell Void

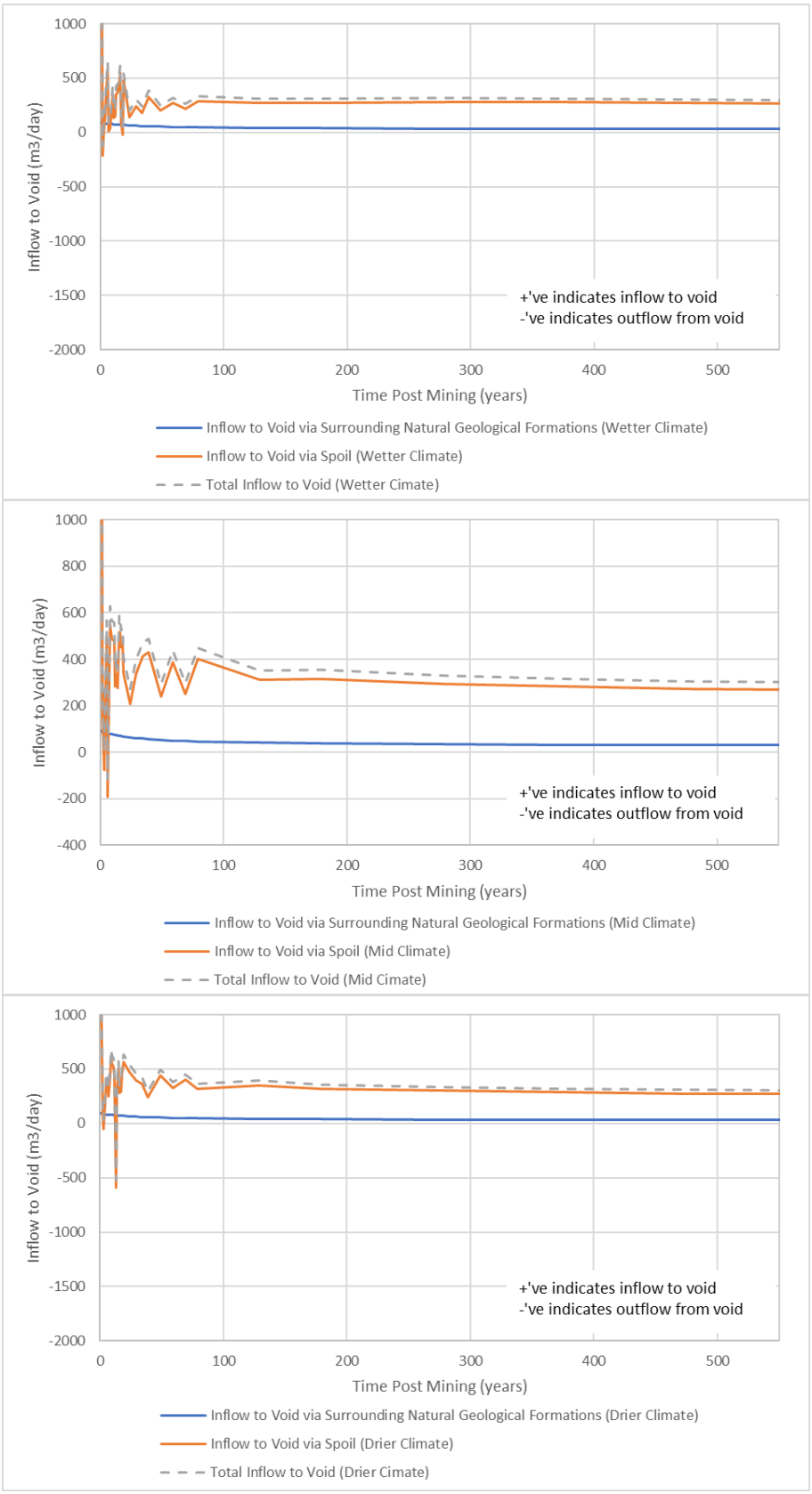


Figure 7-9 Predicted Void Groundwater Inflows – Gilbert Void

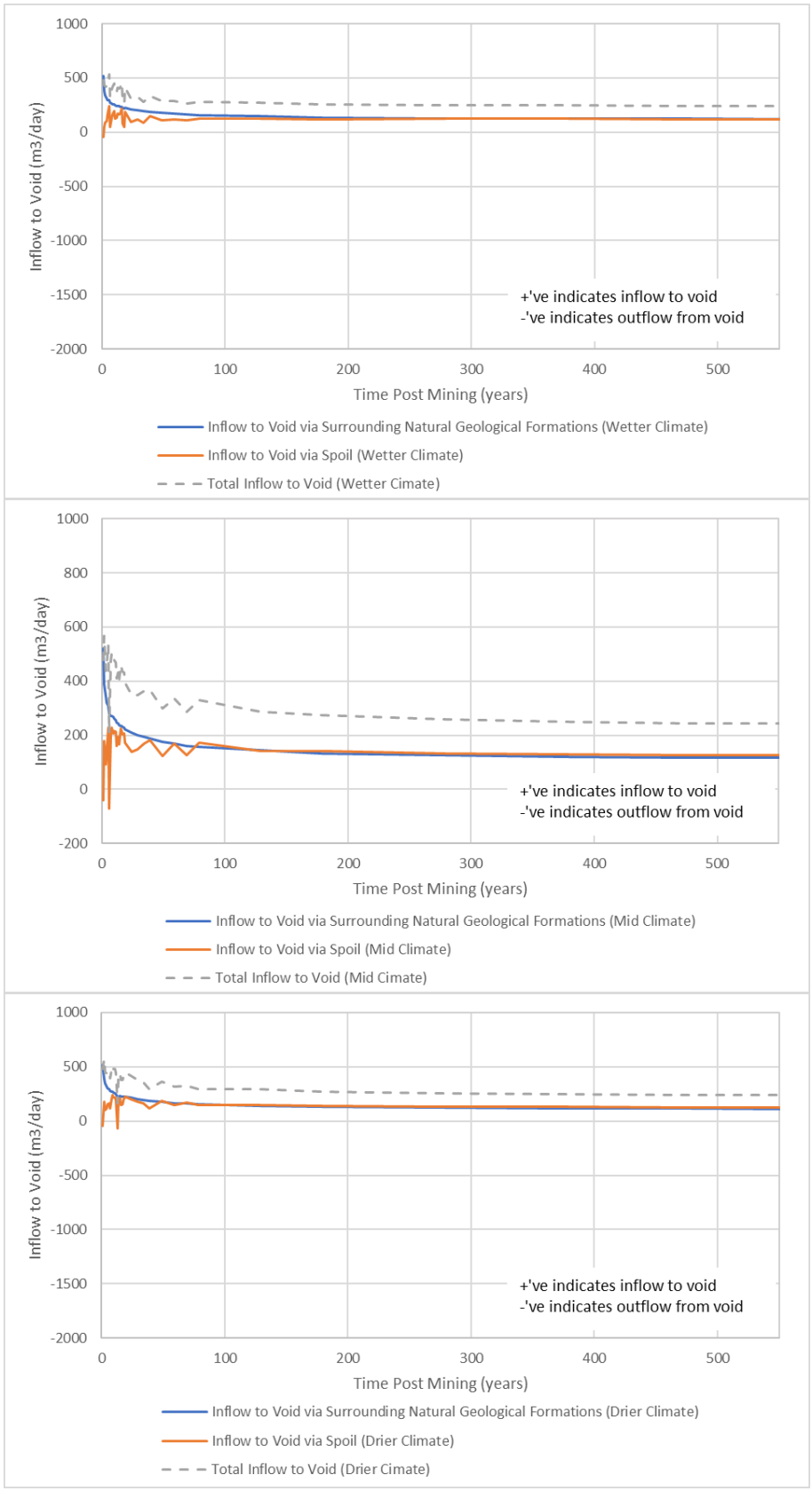


Figure 7-10 Predicted Void Groundwater Inflows – Price\Leichhardt Void

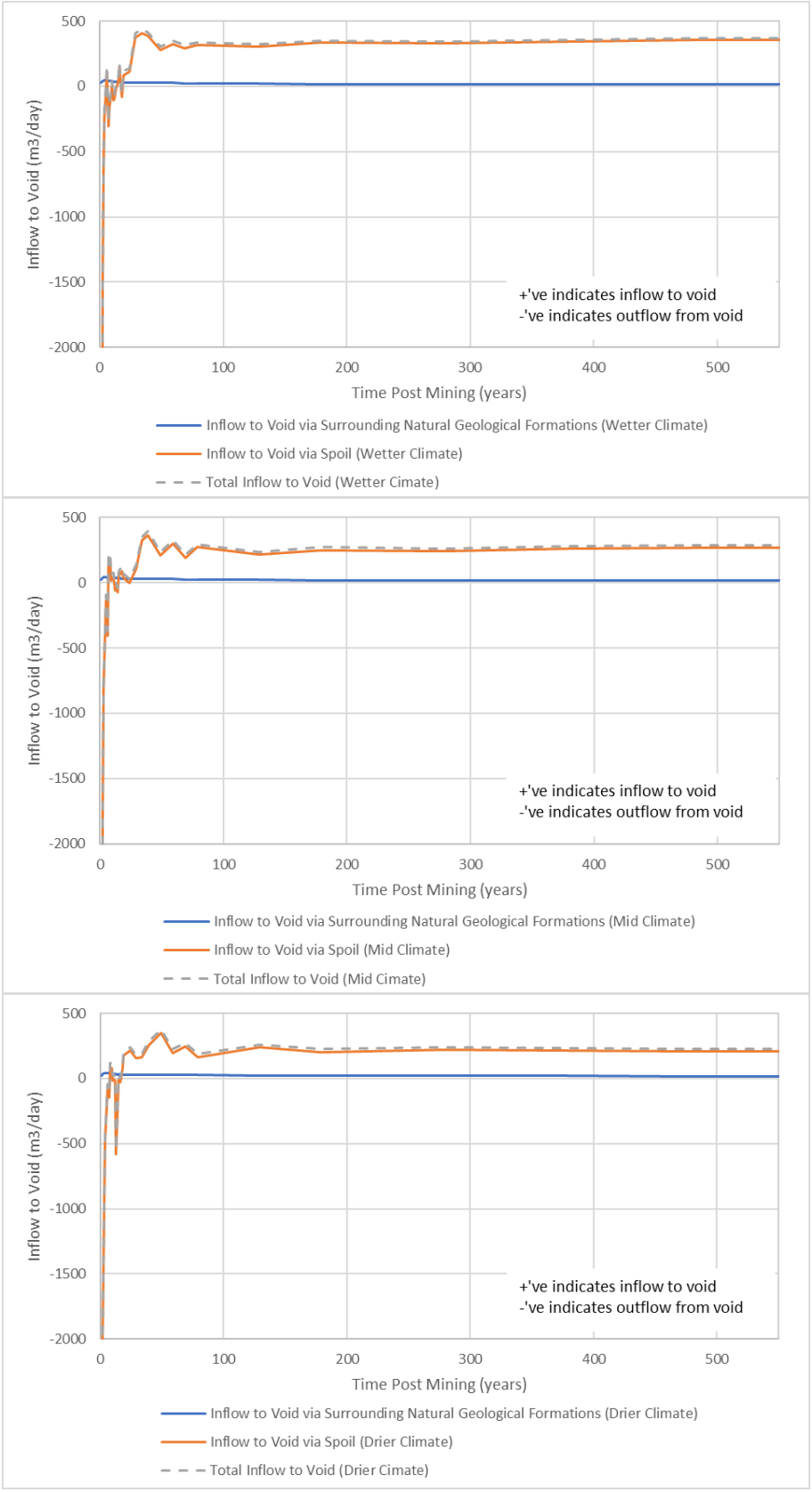


Figure 7-11 Predicted Void Groundwater Inflows – East 1 Void

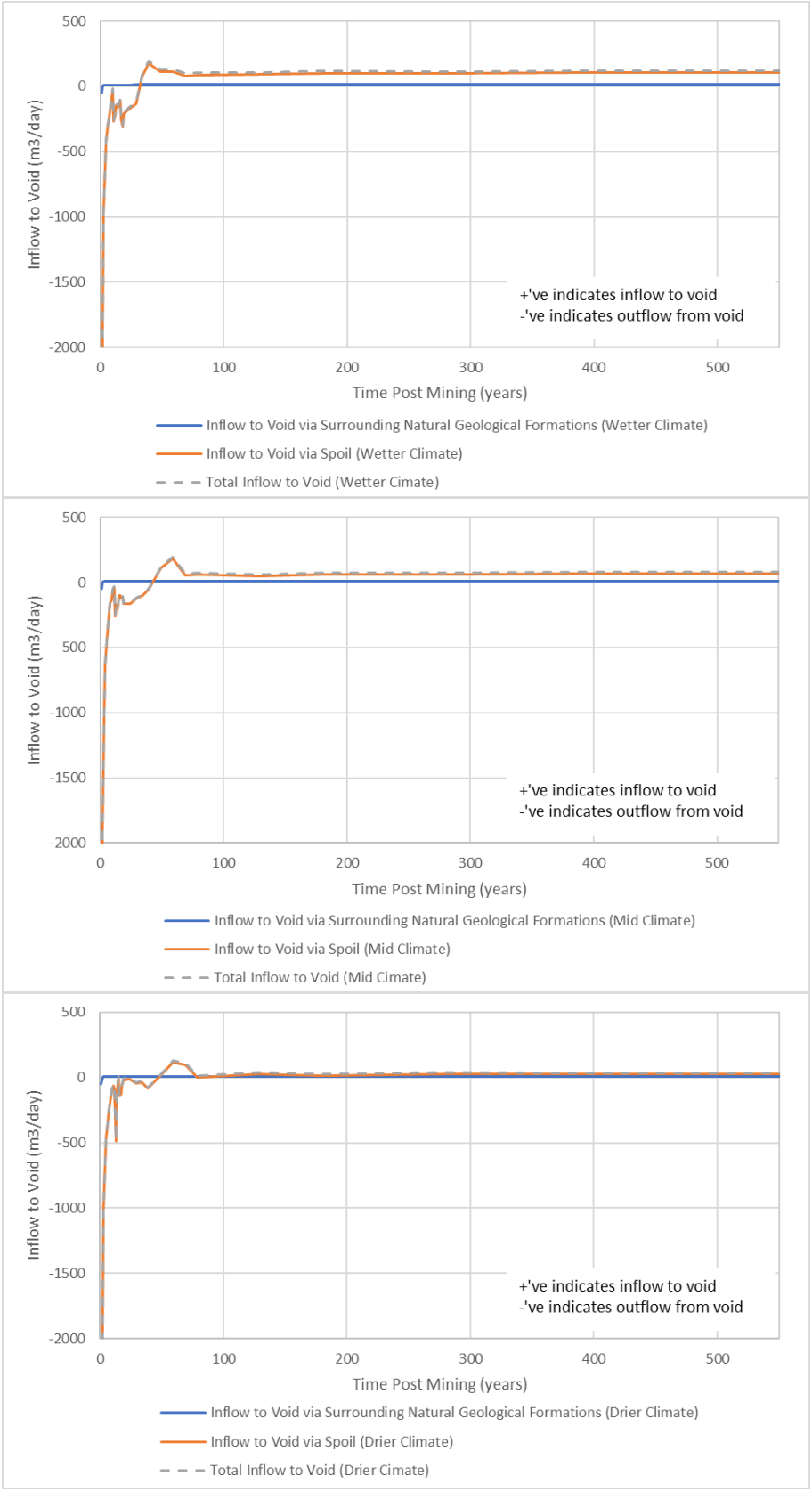


Figure 7-12 Predicted Void Groundwater Inflows – East2 Void

Predicted equilibrium groundwater inflows to each of the voids for the three climate scenarios are presented in **Table 7-9**. Model results indicate that, for the Lotus/Campbell, Gilbert, and East 1 and 2 residual voids, more than 79% of the long term groundwater inflow to the voids comes via the spoil, with between 2% and 29% of this inflow originating as local recharge applied to the spoil, and between 71% and 98% coming from natural geological formations before moving through the spoil into the residual void lakes. Price/Leichhardt residual void is distinct in having a much lower contribution to the void from spoil, with approximately 50% of total inflows occurring from the natural geological formations directly rather than through the spoil.

As previously discussed, except for the East voids, the equilibrium groundwater inflows to each of the voids shown in **Table 7-9** represent approximately 10% to 20% of the total volumetric inflow to each residual void's water balance (WSP, 2024), that is, groundwater volumetric contribution to the residual voids are very small in comparison to surface water (rainfall and runoff) contribution. Groundwater inflow to the East 1 and East 2 residual voids accounts for approximately 50% of the total volumetric inflow to these two residual voids (noting again that the hydrologic behaviour of the East Pit residual voids remains subject to change based on outcomes of further studies in the Roper Study Area as discussed in **Section 7.2.2**).

Table 7-9 Equilibrium Groundwater Inflow to the Residual Voids

Climate Scenario	Residual Void	Equilibrium Inflow Rate – Spoil (m^3/day)[1]			Equilibrium Inflow Rate – Natural Geological Formations (m^3/day)[3]	Equilibrium Inflow Rate – Total (m^3/day)
		From Natural Geological Formations into Spoil	From Rainfall Recharge on Spoil	Total Inflow from Spoil to Residual Void[2]		
Wetter	Lotus/Campbell	289.2	118.7	409.0	26.4	435.3
	Gilbert	201.6	62.5	265.5	30.6	296.1
	Price/Leichhardt	53.3	66.1	119.9	120.6	240.5
	East 1	346.0	7.9	353.9	12.6	366.5
	East 2	102.0	5.8	107.8	12.4	120.3
Mid	Lotus/Campbell	295.6	118.7	415.3	27.7	443.1
	Gilbert	205.4	62.5	269.4	31.6	300.9
	Price/Leichhardt	58.6	66.1	125.3	116.8	242.1
	East 1	261.2	7.9	269.2	17.3	286.4
	East 2	64.7	5.8	70.5	12.2	82.7
Drier	Lotus/Campbell	299.0	118.7	418.5	27.7	446.3
	Gilbert	208.2	62.5	271.8	30.8	302.7
	Price/Leichhardt	60.0	66.1	126.6	111.6	238.2
	East 1	202.8	7.9	210.8	18.1	228.9
	East 2	21.3	5.8	27.1	7.0	34.2

Notes:

1. Includes a component of groundwater from natural geological formations that moves into spoil, and a component of groundwater derived from local recharge on spoil, before discharging to the residual void lakes; refer **Figure 7-2**.
2. Any volumetric discrepancy between total inflow from spoil and the sum of the spoil inflow components is related to small ongoing residual changes in spoil storage occurring in the model as well as losses to evapotranspiration through spoil and rounding errors. Such discrepancies are typically less than 1% of the total spoil inflow.
3. Directly from natural geological formations into residual void lakes.

7.2.5 Predicted Groundwater Levels

Groundwater level predictions and associated discussion presented herein is focussed primarily on the Mid Climate scenario with the Drier and Wetter scenario's reported as sensitivities.

7.2.5.1 Mid Climate Scenario

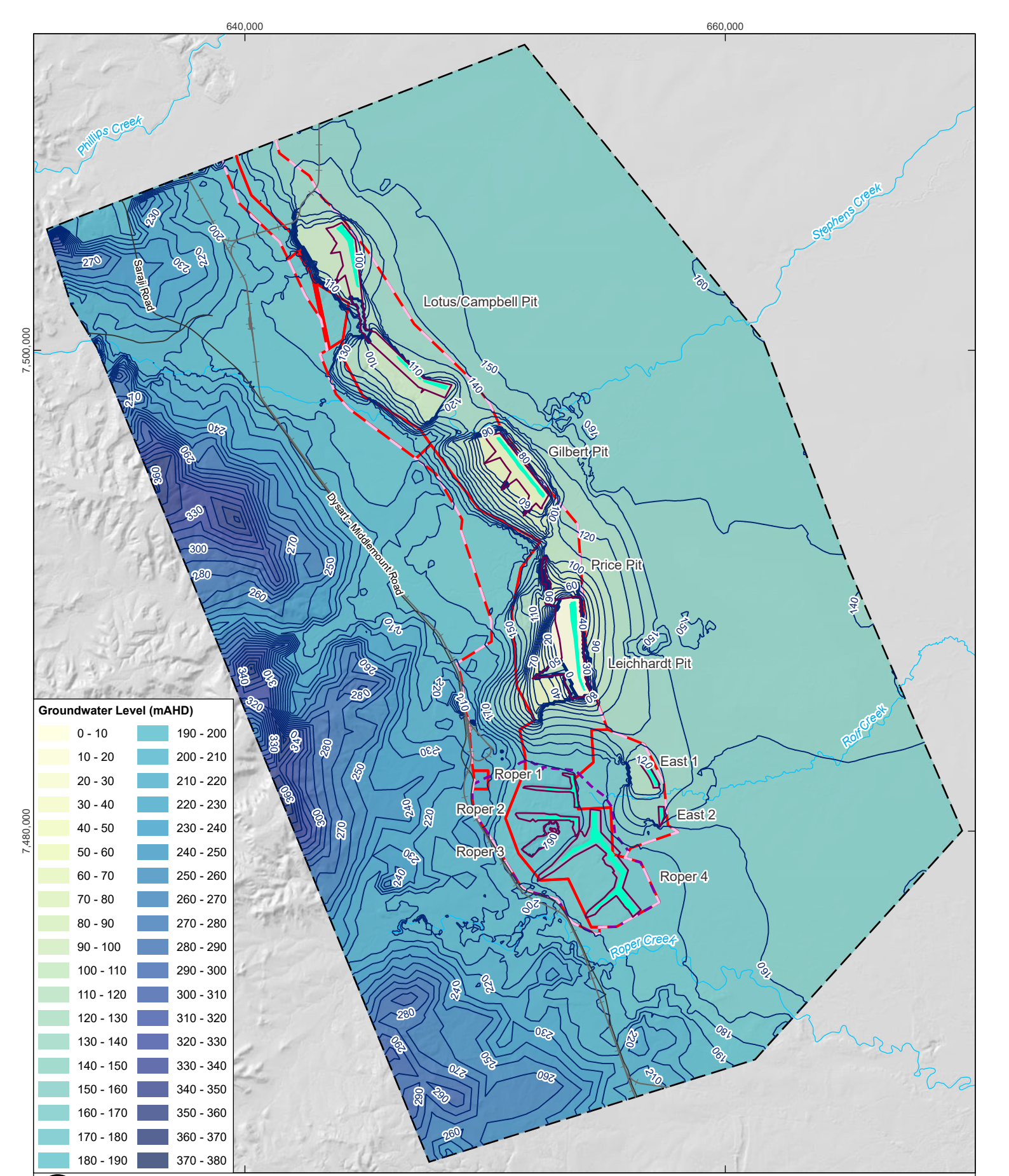
Groundwater Levels – General

The predicted equilibrium water table elevation adjacent the residual voids is shown on **Figure 7-13** for the Mid Climate scenario. Predicted groundwater levels for the Fort Cooper Coal Seams, Q, P, H and D Seams of the Permian Coal Measures (model layers 4, 6, 8, 10, and 12, respectively) outside of the residual voids are shown on **Figure 7-14** through to **Figure 7-18**, again at equilibrium for the Mid Climate scenario.

Groundwater levels surrounding the final voids are controlled by the predicted residual void lake levels, which in turn are controlled by the rate of evaporation from the void lakes balancing mostly surface inflows and some groundwater inflows to the lakes (WSP, 2024), including a component of groundwater that moves out of the natural geological formations into the residual voids via the spoil (refer **Table 7-9**). The conceptual relationship between these components is displayed in **Figure 7-2**. That is, predicted groundwater levels are a function of predicted lake levels, which as discussed in **Section 7.2.2** are dominantly controlled by surface water fluxes and maintained by evaporation.

The water table is predicted to remain depressed in the immediate vicinity of the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids in the long term, driven by the ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves. That is, long term inwards groundwater flow gradients are maintained post-mining for the water table at these voids.

Predicted groundwater levels for the Fort Cooper Seams, Q, P, H and D Seams of the Permian Coal Measures indicate again that groundwater levels in the Permian sequence are predicted to remain depressed in the immediate vicinity of the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids in the long term, driven by the ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves. The Fort Cooper Coal seam is predicted to remain 'dry' in the long term across most of the SSM Area, with some saturation present in the east of the Price/Leichhardt void. The Q seam is predicted to remain 'dry' in the long term across most of the SSM Area, with some saturation present in the east and south of the East 1 and East 2 voids. The P Seam is predicted to remain unsaturated across much of the SSM Area, however remains saturated along the eastern margin of the SSM Area, east of the residual voids. Flow gradients towards the East 1, East 2, and Price/Leichhardt voids are apparent in the P Seam. The H Seam is predicted to remain unsaturated across much of the SSM Area, except along the eastern margin, east of the residual voids, where it remains saturated. Flow gradients towards the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, and East 2 voids are evident in the P Seam. D Seam levels show saturation across most of the SSM Area, with groundwater gradients showing discharge to mine voids (except in the case of Roper Study Area).



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Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	RB

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED WATER TABLE ELEVATION – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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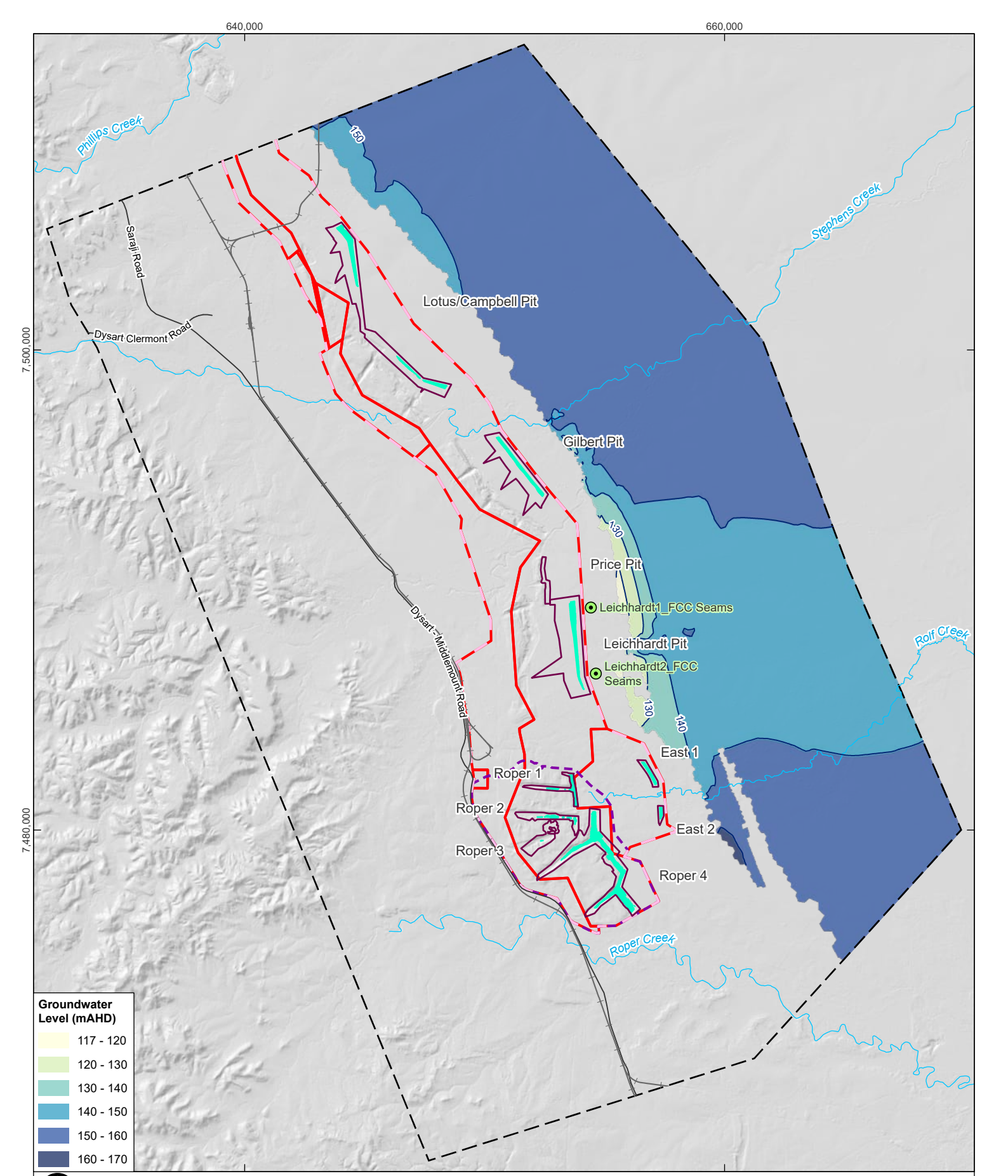
FIGURE 7-13

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_13_Predicted Water Table Elevation – Post-Mining Equilibrium (Mid Climate Scenario)



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Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	RB

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED GROUNDWATER LEVELS IN THE FORT COOPER SEAMS (LAYER 4) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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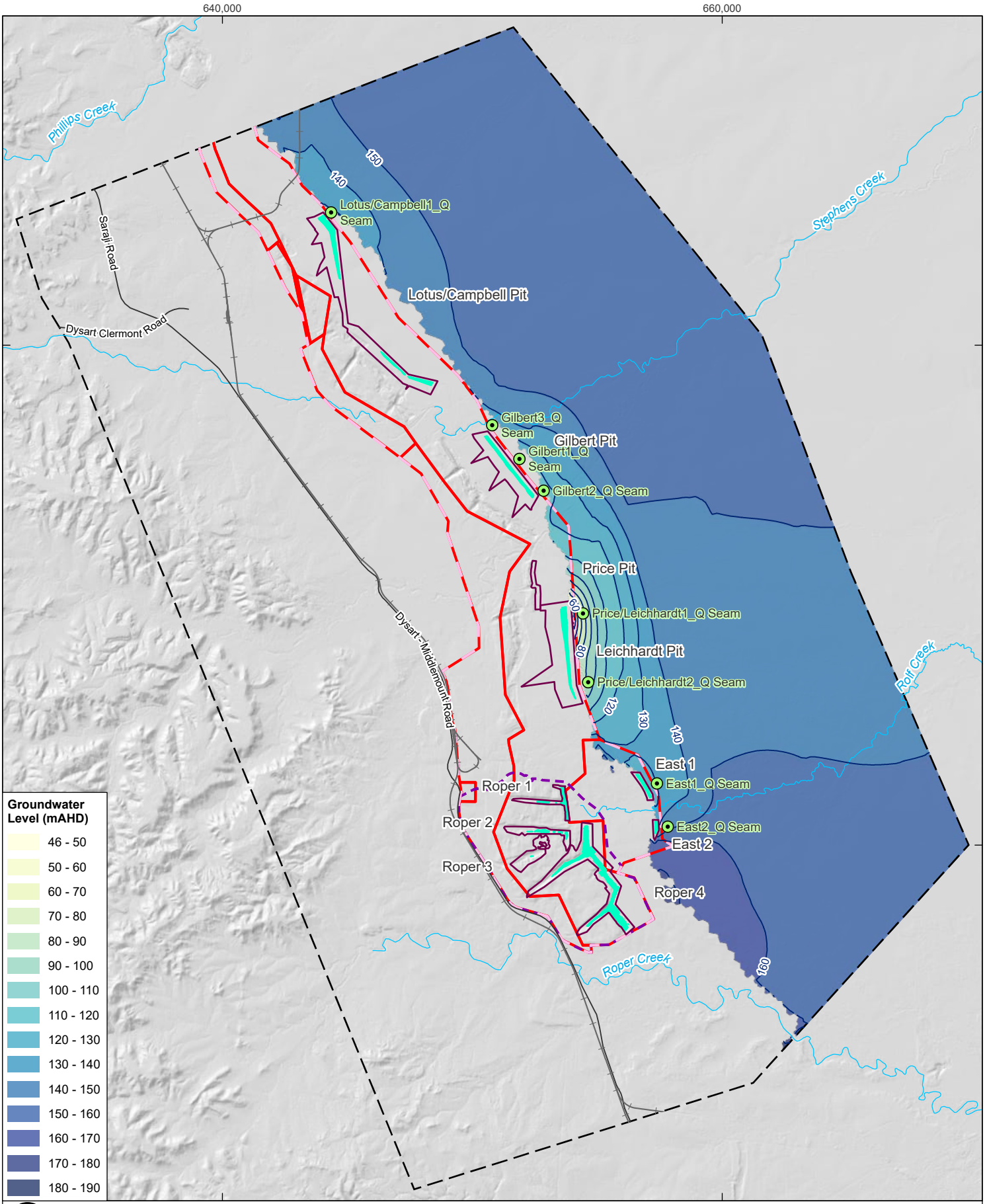
FIGURE 7-14

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_14_Predicted Groundwater Levels in the Fort Cooper Seams (Layer 4) – Post-Mining Equilibrium (Mid Climate Scenario)



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED GROUNDWATER LEVELS IN THE Q SEAM (LAYER 6) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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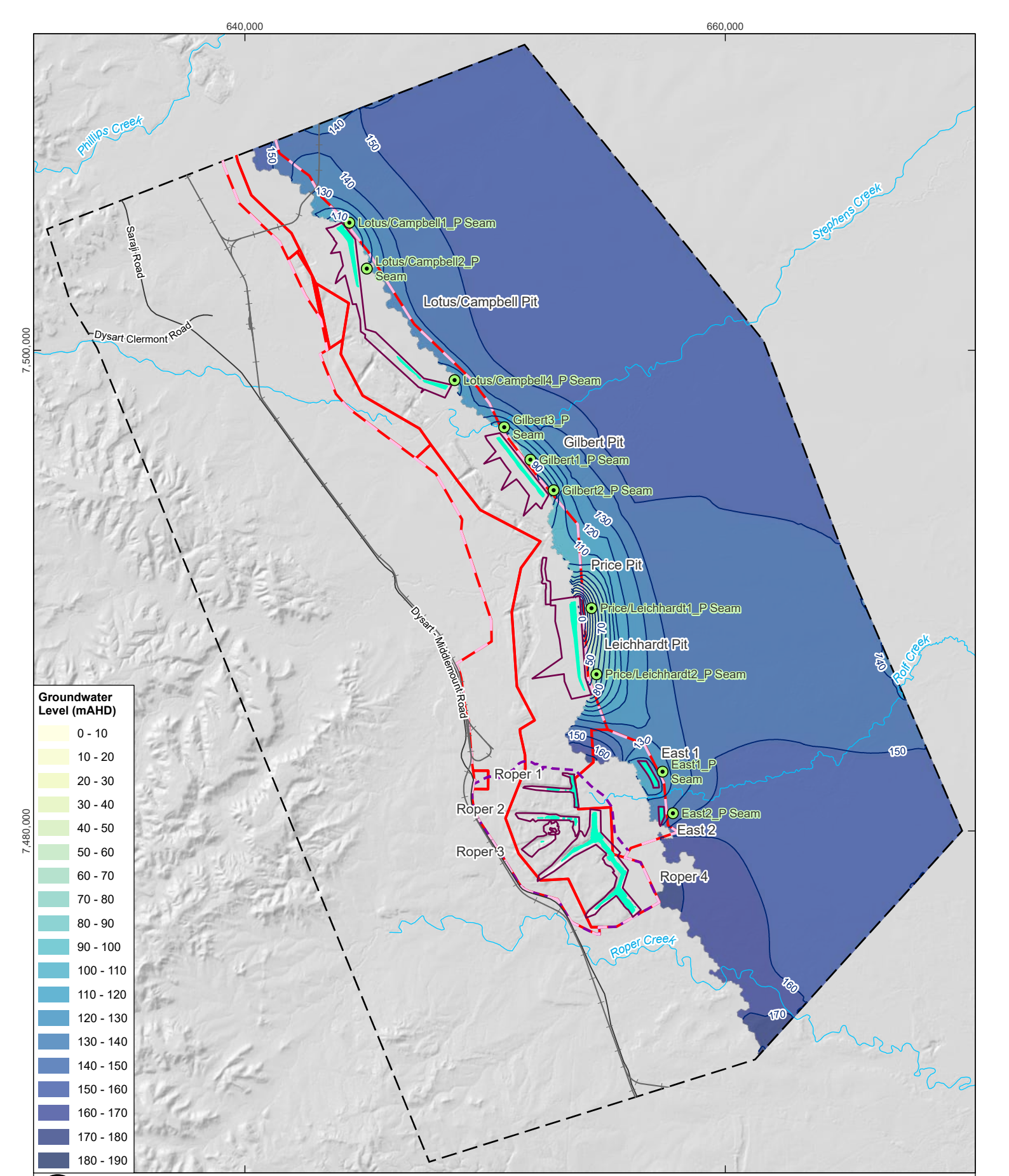
FIGURE 7-15

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_15_Predicted Groundwater Levels in the Q Seam (Layer 6) – Post-Mining Equilibrium (Mid Climate Scenario)



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED GROUNDWATER LEVELS IN THE P SEAM (LAYER 8) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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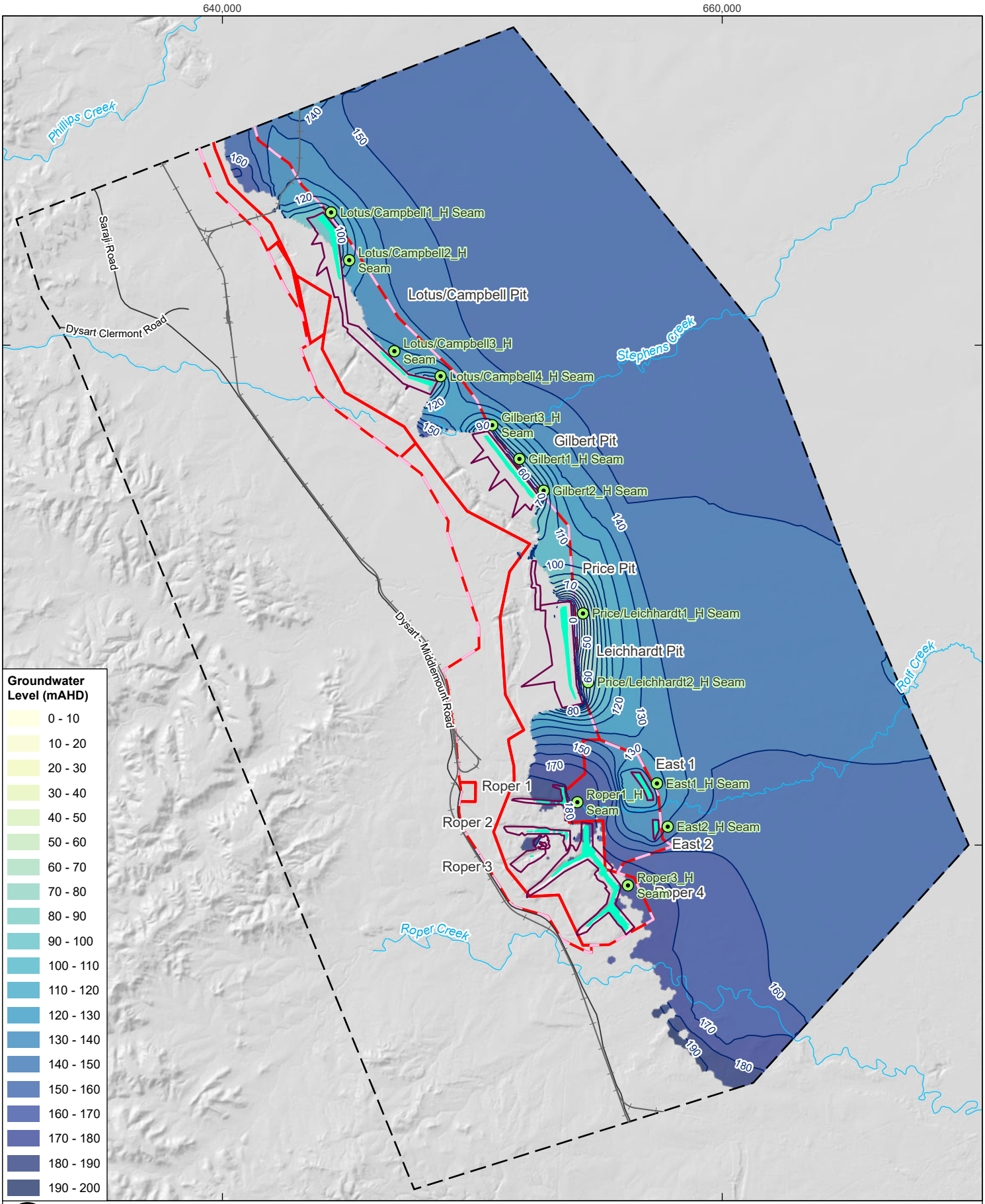
FIGURE 7-16

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_16_Predicted Groundwater Levels in the P Seam (Layer 8) – Post-Mining Equilibrium (Mid Climate Scenario)



Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	30-May-2024
Drawn by:	RB

LEGEND

- Hydrograph Location
- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary

SARAJI SOUTH MINE GROUNDWATER MODELLING TECHNICAL REPORT

PREDICTED GROUNDWATER LEVELS IN THE H SEAM (LAYER 10) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

SLR

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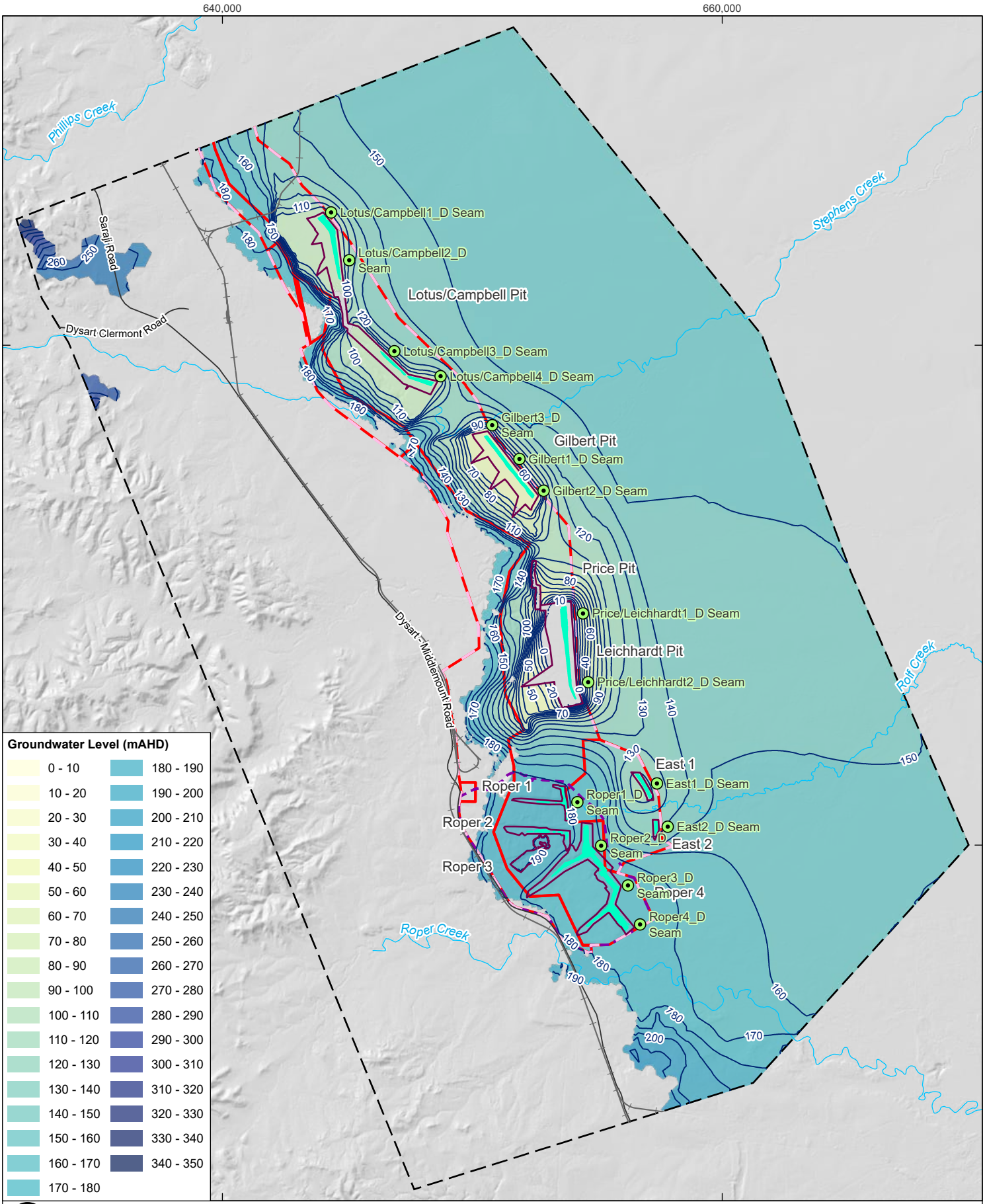
FIGURE 7-17

Path: \\au.slr.local\Corporate\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_MOD_F3_25_Predicted Groundwater Levels in the H Seam (Layer 10) – Post-Mining Equilibrium (Mid Climate Scenario)



LEGEND

- Hydrograph Location
- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED GROUNDWATER LEVELS IN THE D SEAM (LAYER 12) – POST-MINING EQUILIBRIUM (MID CLIMATE SCENARIO)

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FIGURE 7-18

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_17_Predicted Groundwater Levels in the D Seam (Layer 12) – Post-Mining Equilibrium (Mid Climate Scenario)

Predictive hydrographs showing the change in groundwater levels over time for the Fort Cooper Seams, Q, P, H and D Seams of the Permian Coal Measures just outside (east) of the residual voids are shown in **Figure 7-19** through **Figure 7-31** with the hydrograph locations shown in **Figure 7-13** through to **Figure 7-18**. Given their relatively significant north-south strike length, four sets of predictive hydrographs have been generated for Lotus/Campbell and Roper voids, three sets for Gilbert void, and two sets for Price/Leichhardt void, as shown in the figures. In **Figure 7-19** through **Figure 7-31**, the green line represents the groundwater level in the related model layer.

The hydrographs demonstrate that the vast majority of groundwater level drawdown in the Permian Coal Measures occurs as a result of extractive mining operations. The hydrographs demonstrate very little effect on groundwater levels from the residual void inflow flux variability in the early post-closure period as shown and discussed in **Section 7.2.4**. The hydrographs show:

- For the Lotus/Campbell residual void:
    - The Fort Cooper Seam does not exist at the Lotus/Campbell residual void because the Fort Cooper Seam layer is pinched out at this location.
    - At the northern end of the residual void (hydrograph site Lotus/Campbell 1), lake levels are predicted to recover to within approximately 12 m of the predicted P Seam groundwater elevation just outside the void, within approximately 10 m of the predicted H Seam groundwater elevation just outside the void, and within approximately 10 m of the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 45 m above the void lake level.
    - At the central end of the residual void (hydrograph site Lotus/Campbell 2), lake levels are predicted to recover to approximately 23 m below the predicted H Seam groundwater elevation just outside the void, and approximately 19 m of the predicted D Seam groundwater elevation just outside the void. The P Seam is predicted to remain dry with its base more than 45 m above the void lake level. The Q Seam does not exist at the central end of the residual void (hydrograph site Lotus/Campbell 2) because the Q Seam layer is pinched out at this location.
    - At the central end of the residual void (hydrograph site Lotus/Campbell 3), lake levels are predicted to recover to approximately 35 m below the predicted H Seam groundwater elevation just outside the void, and approximately 25 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam and P Seam do not exist at the central end of the residual void (hydrograph site Lotus/Campbell 3) because the Q Seam and P Seam layers are pinched out at this location.
    - At the southern end of the residual void (hydrograph site Lotus/Campbell 4), lake levels are predicted to recover to approximately 32 m below the predicted P Seam groundwater elevation just outside the void, approximately 16 m below the predicted H Seam groundwater elevation just outside the void, and approximately 13 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam does not exist at the southern end of the residual void (hydrograph site Lotus/Campbell 4) because the Q Seam layer is pinched out at this location
- For the Gilbert residual void:
    - The Fort Cooper Seam does not exist at the Gilbert residual void because the Fort Cooper Seam layer is pinched out at this location.
    - At the northern end of the residual void (hydrograph site Gilbert 1), lake levels are predicted to recover to approximately 35 m below the predicted P Seam groundwater elevation just outside the void, approximately 31 m below the predicted H Seam groundwater elevation just outside the void, and approximately 26 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 79 m above the void lake level.
    - At the central end of the residual void (hydrograph site Gilbert 2), lake levels are predicted to recover to approximately 57 m below the predicted Q Seam groundwater elevation just outside the void, approximately 33 m below the predicted P Seam groundwater elevation

just outside the void, approximately 30 m below the predicted H Seam groundwater elevation just outside the void, and approximately 29 m below the predicted D Seam groundwater elevation just outside the void.

- At the southern end of the residual void (hydrograph site Gilbert 3), lake levels are predicted to recover to approximately 47 m below the predicted P Seam groundwater elevation just outside the void, approximately 42 m below the predicted H Seam groundwater elevation just outside the void, and approximately 34 m below the predicted D Seam groundwater elevation just outside the void. The Q Seam is predicted to remain dry with its base more than 91 m above the void lake level.

- For the Price/Leichhardt residual void:
  - At the northern end of the residual void (hydrograph site Price/Leichhardt 1), lake levels are predicted to recover to approximately 83 m below the predicted Q Seam groundwater elevation just outside the void, approximately 47 m below the predicted P Seam groundwater elevation just outside the void, approximately 46 m below the predicted H Seam groundwater elevation just outside the void, and approximately 46 m below the predicted D Seam groundwater elevation just outside the void. The Fort Cooper Seam is predicted to remain dry with its base more than 141 m above the void lake level.
  - At the southern end of the residual void (hydrograph site Price/Leichhardt 2), lake levels are predicted to recover to approximately 100 m below the predicted Q Seam groundwater elevation just outside the void, approximately 75 m below the predicted P Seam groundwater elevation just outside the void, approximately 72 m below the predicted H Seam groundwater elevation just outside the void, and approximately 63 m below the predicted D Seam groundwater elevation just outside the void. The Fort Cooper Seam is predicted to remain dry with its base more than 170 m above the void lake level.
- For the East 1 residual void, lake levels are predicted to recover to:
  - Approximately 13 m below the predicted Q Seam groundwater elevation just outside the void, and
  - Approximately 7 m of the predicted P Seam groundwater elevation just outside the void
  - Approximately 7 m of the predicted H Seam groundwater elevation just outside the void
  - Approximately 7 m of the predicted D Seam groundwater elevation just outside the void.
  - The Fort Cooper Seam does not exist at the East 1 residual void because the Fort Cooper Seam layer is geologically cropped out at this location.
  - .
- For the East 2 residual void, lake levels are predicted to recover to:
  - Approximately 11 m of the predicted Q Seam groundwater elevation just outside the void
  - Approximately 6 m of the predicted P Seam groundwater elevation just outside the void
  - Approximately 5 m of the predicted H Seam groundwater elevation just outside the void
  - Approximately 5 m of the predicted D Seam groundwater elevation just outside the void.
  - The Fort Cooper Seam does not exist at the East 2 residual void because the Fort Cooper Seam layer is geologically cropped out at this location.

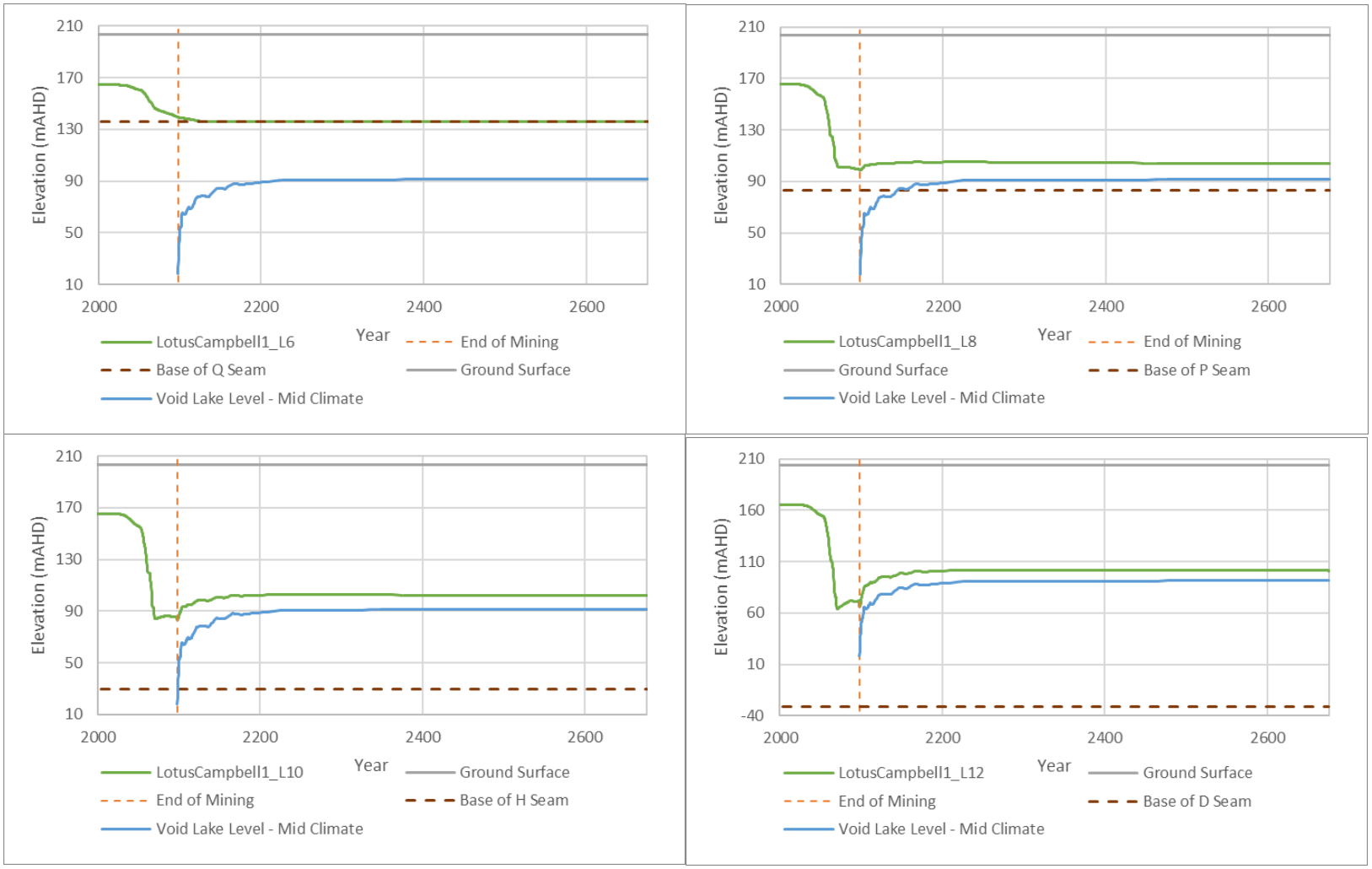

Figure 7-19 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (north)

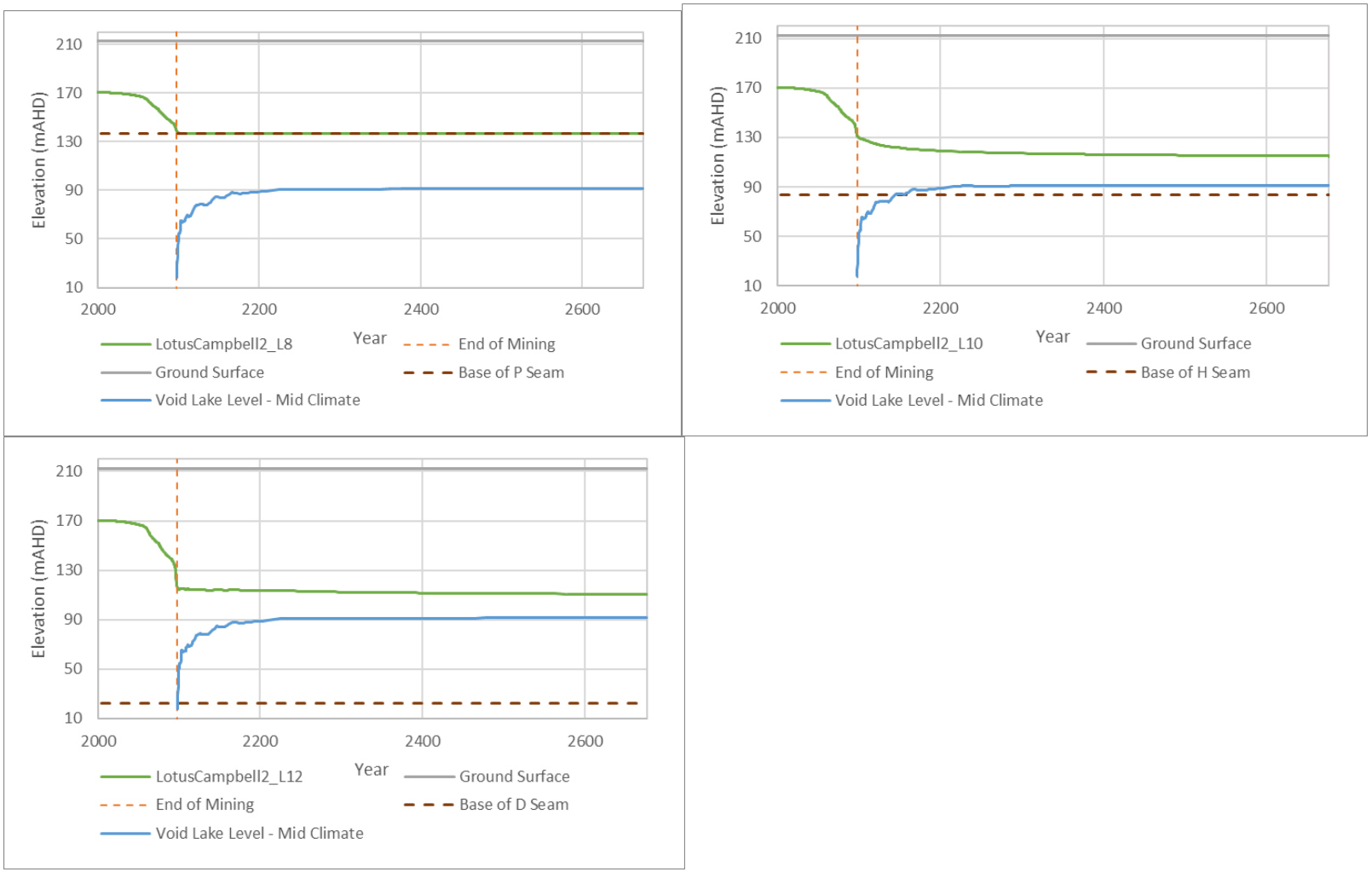

Figure 7-20 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (centre1)

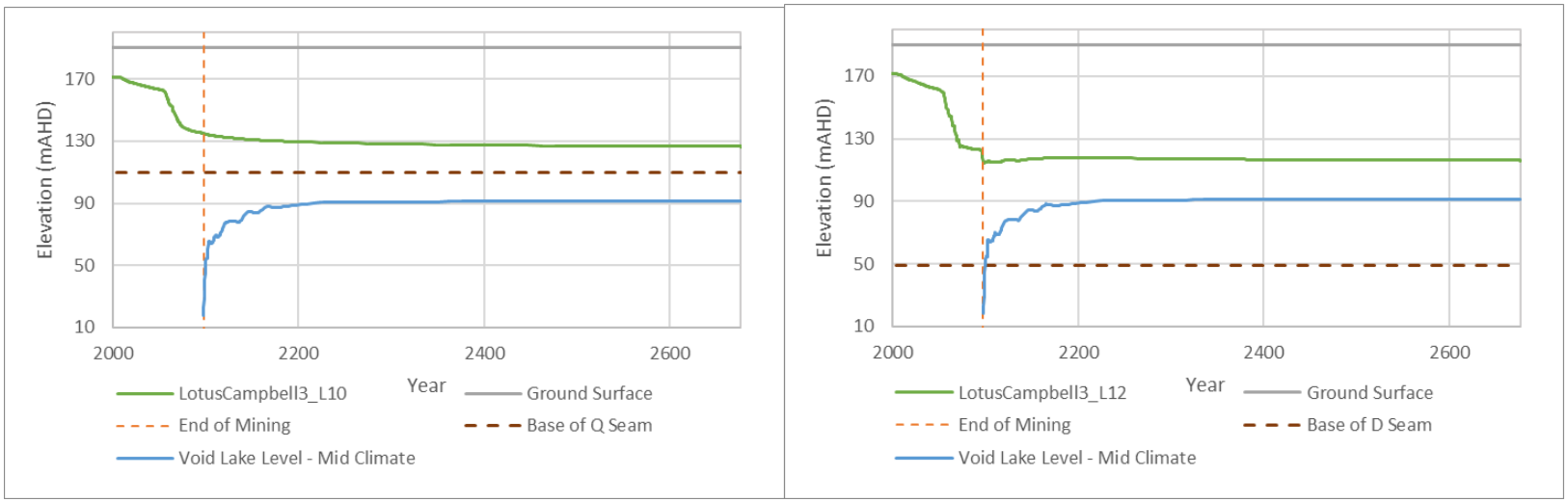

Figure 7-21 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (centre2)

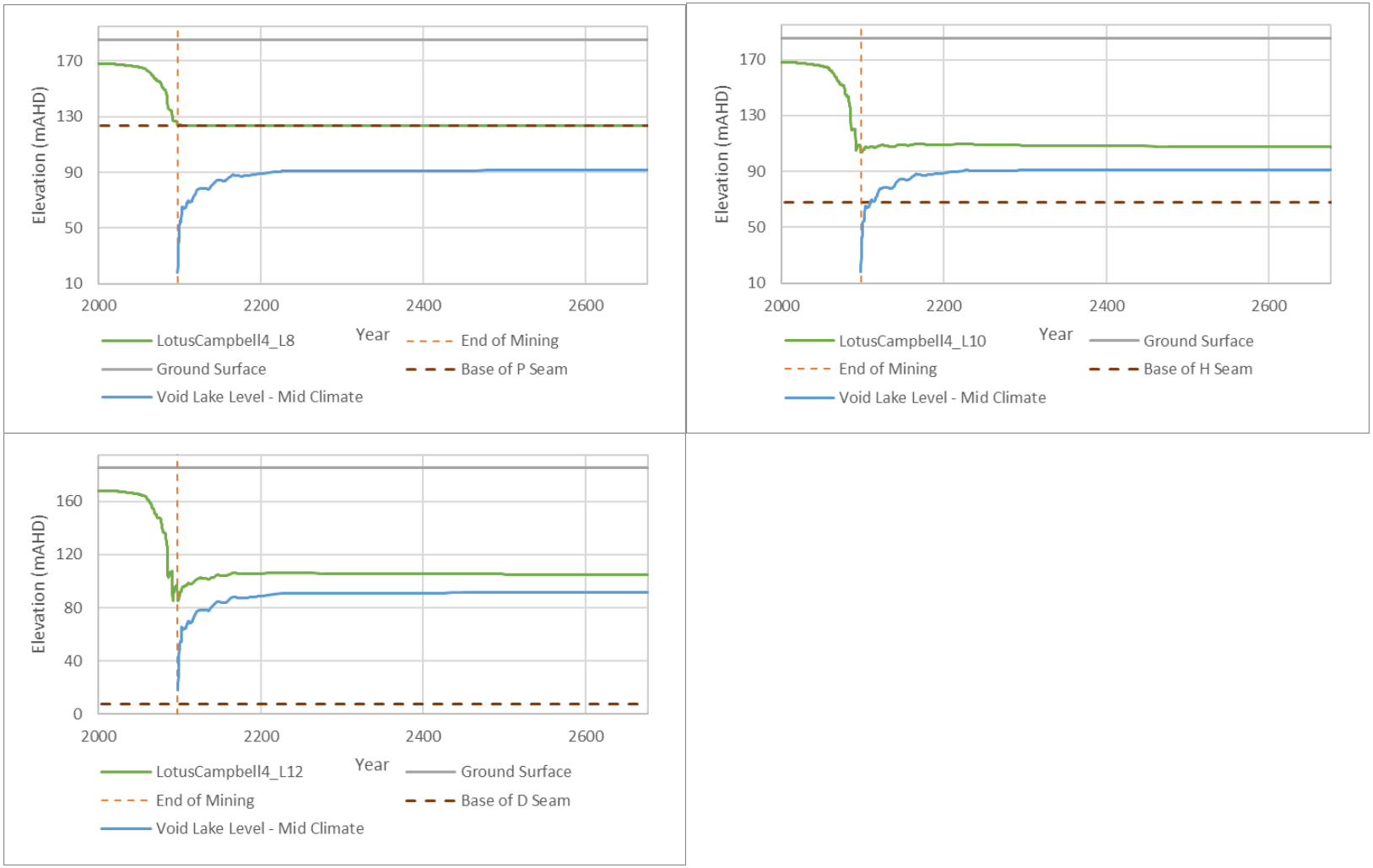

Figure 7-22 Coal Measures Predictive Hydrographs adjacent Lotus\Campbell Void (south)

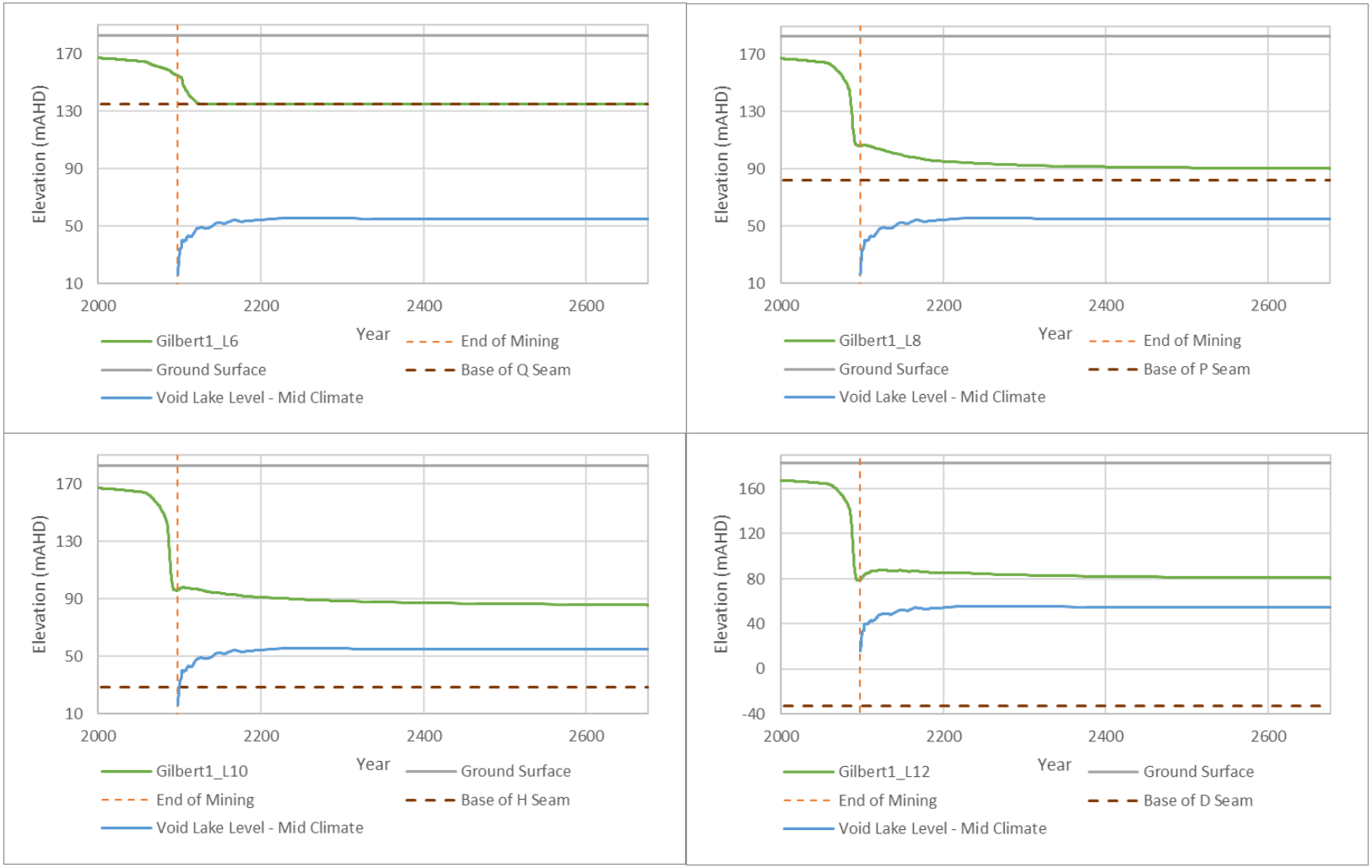

Figure 7-23 Coal Measures Predictive Hydrographs adjacent Gilbert Void (north)

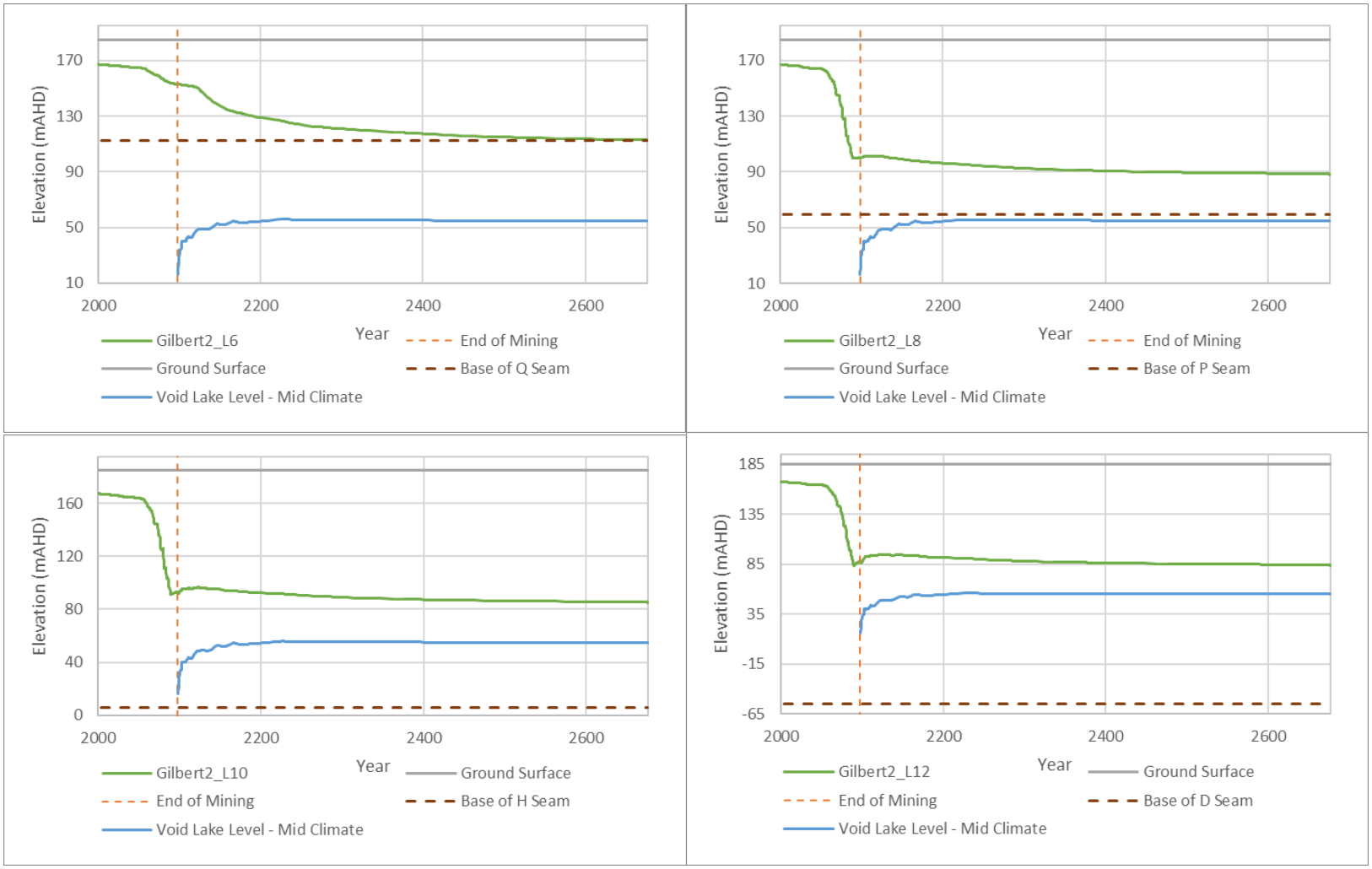

Figure 7-24 Coal Measures Predictive Hydrographs adjacent Gilbert Void (centre)

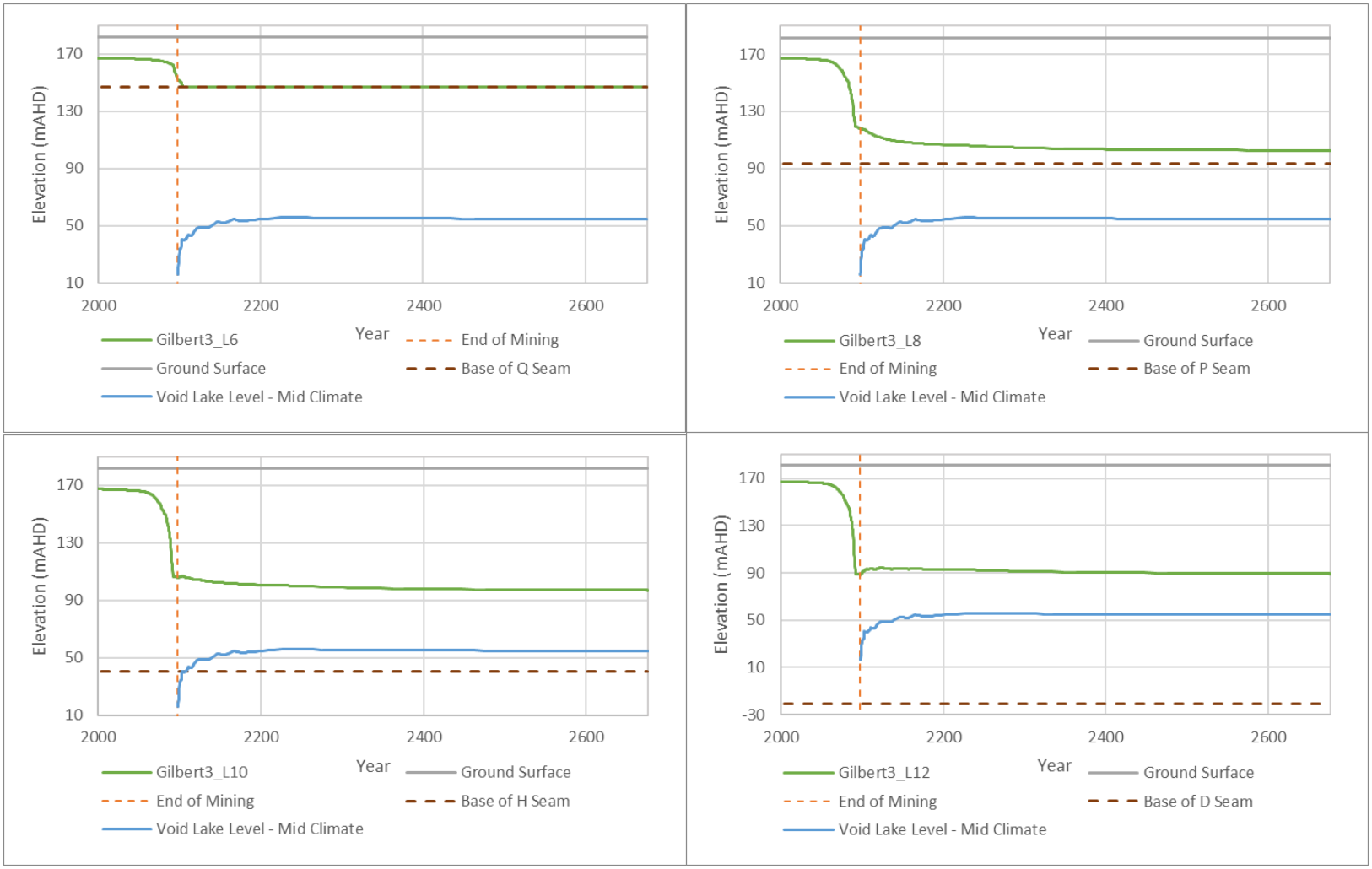

Figure 7-25 Coal Measures Predictive Hydrographs adjacent Gilbert Void (south)

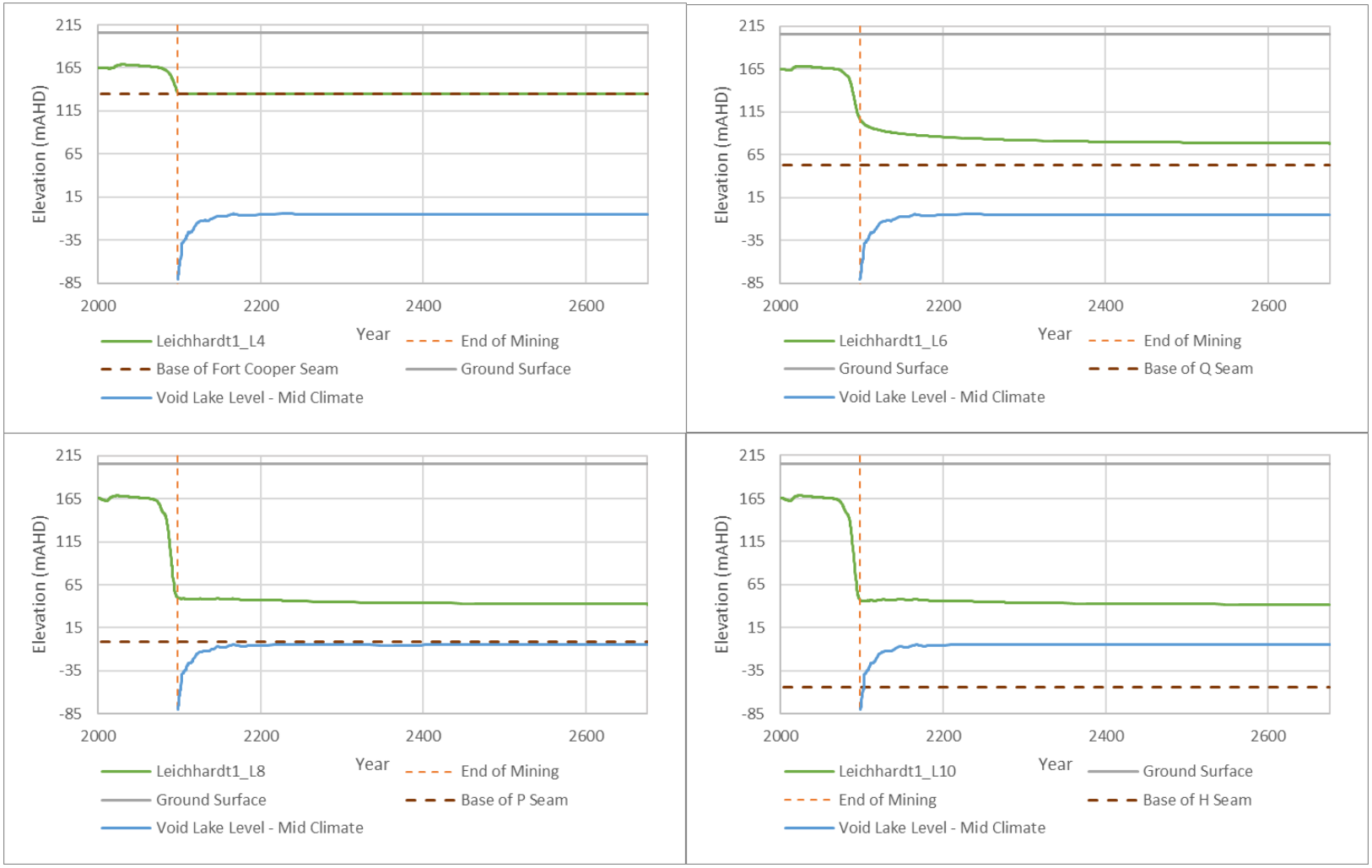

Figure 7-26 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (north)

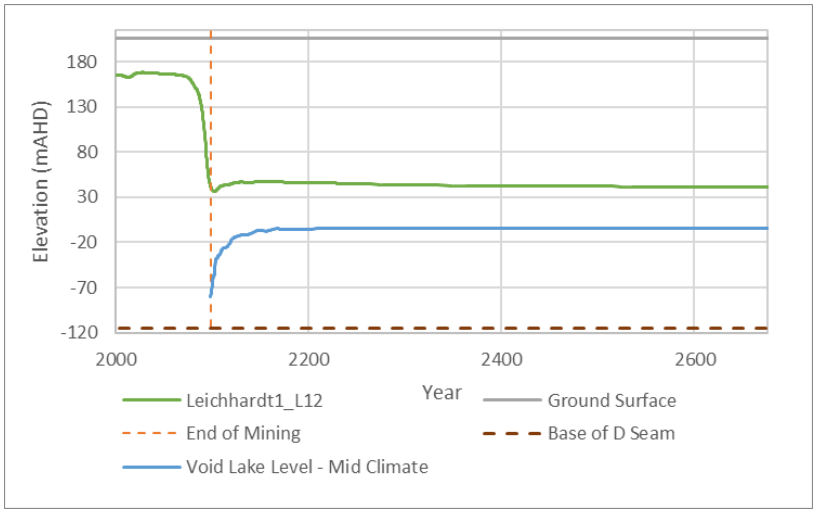

Figure 7-27 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (north) (cont.)

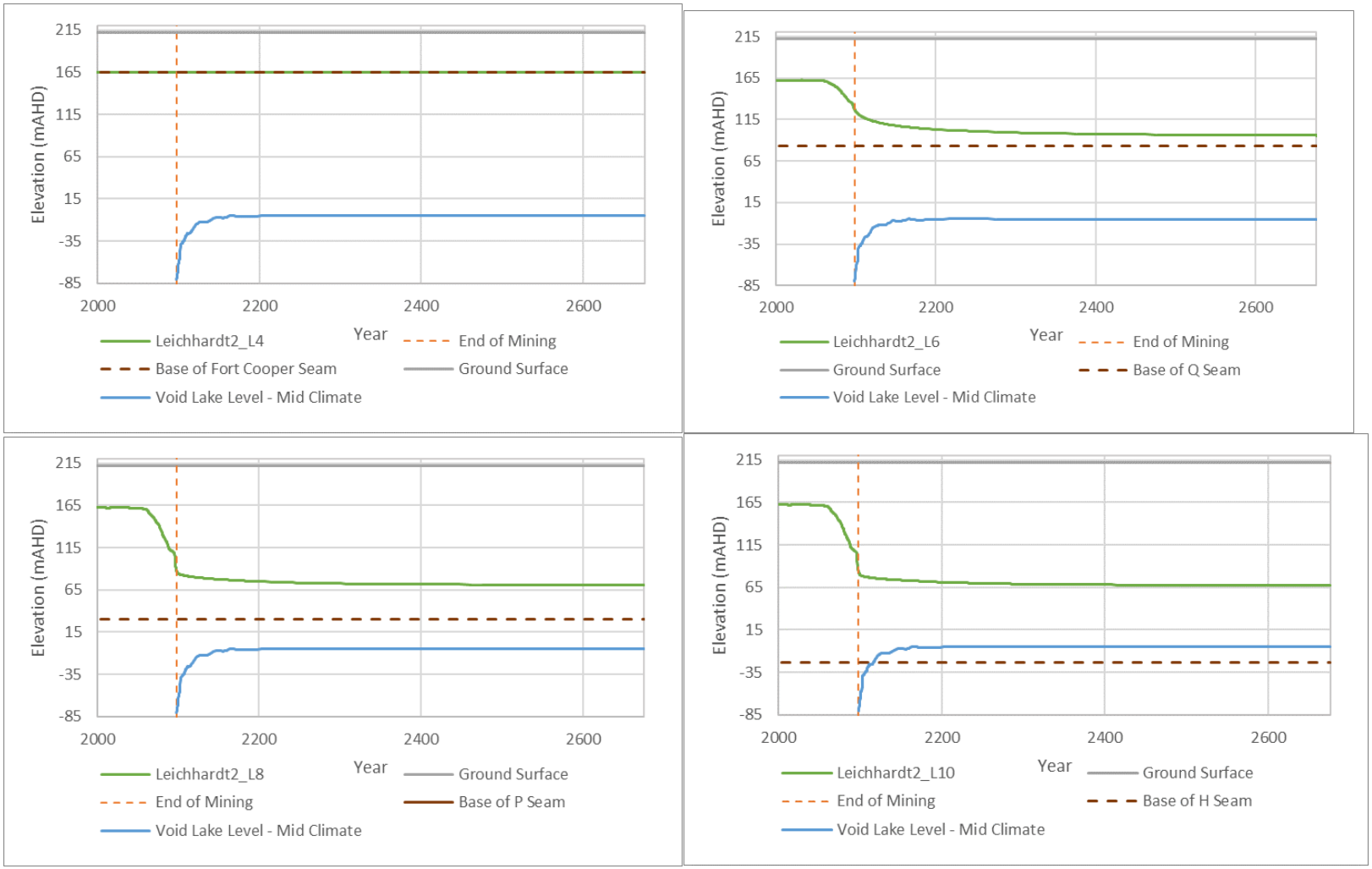

Figure 7-28 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (south)

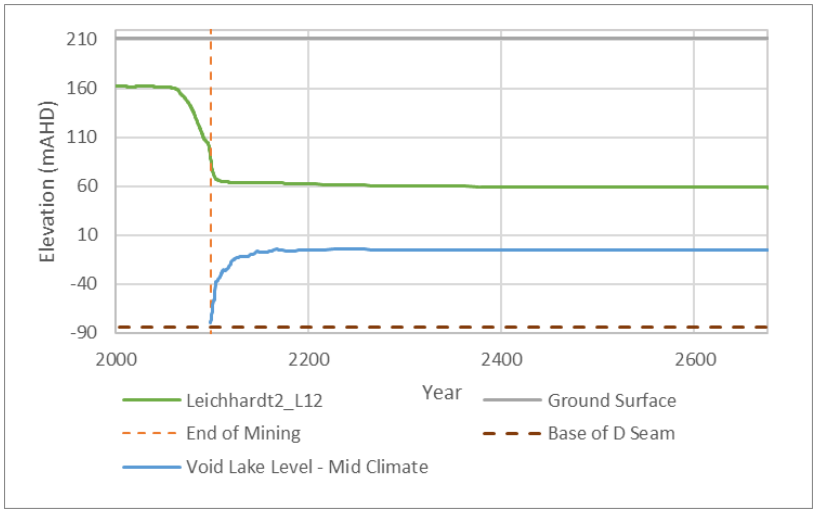

Figure 7-29 Coal Measures Predictive Hydrographs adjacent Price\Leichhardt Void (south) (cont.)

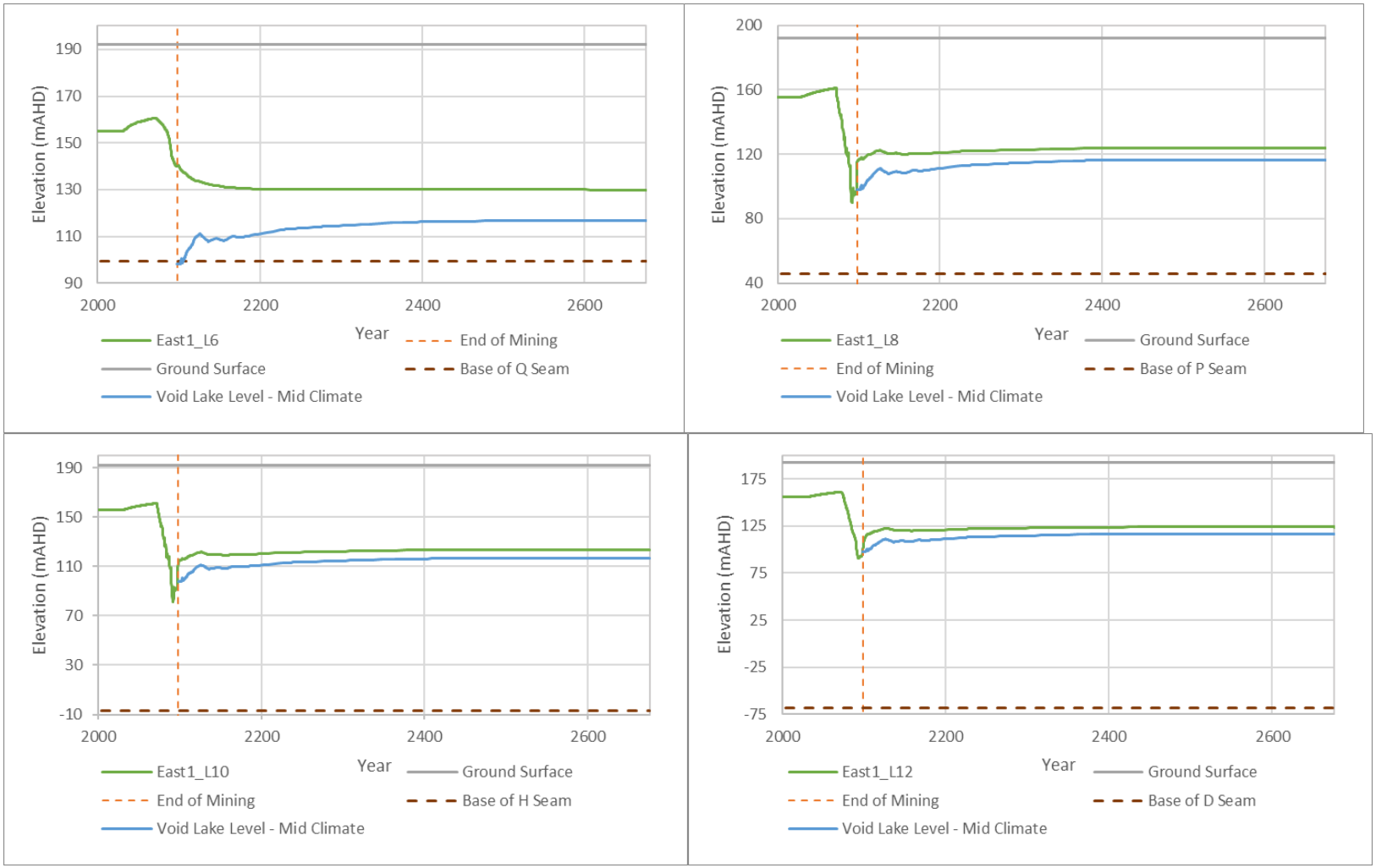

Figure 7-30 Coal Measures Predictive Hydrographs Adjacent East 1 Void

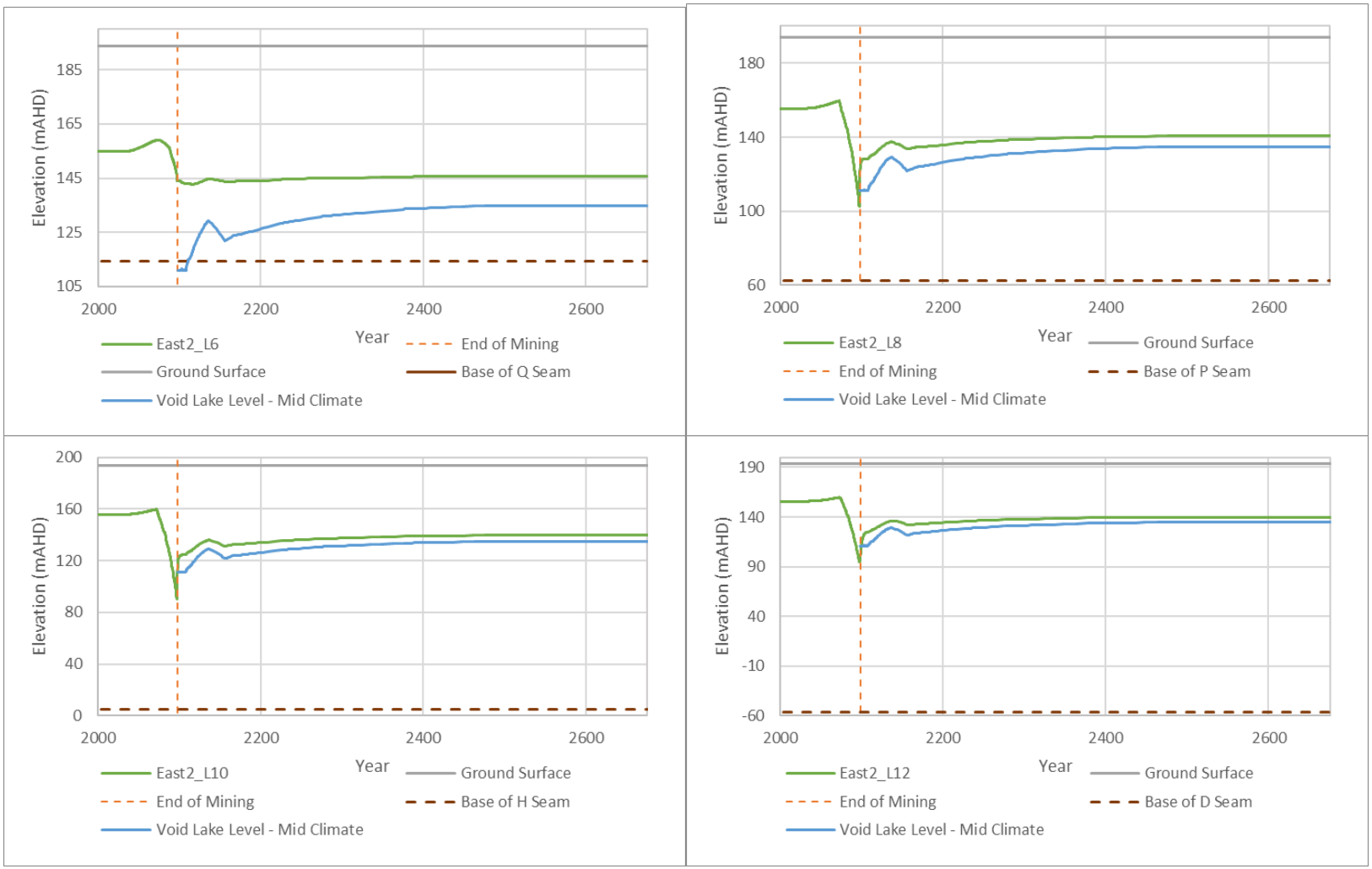

Figure 7-31 Coal Measures Predictive Hydrographs Adjacent East 2 Void

7.2.5.2 Groundwater Level Impacts to Potential Receptors

Predictive hydrographs have been derived from the groundwater model to understand the nature of likely groundwater level change in the interpreted source aquifer for identified potential natural and anthropogenic groundwater receptors in the vicinity of the SSM Area. The aim of the hydrographs is to assess the potential for additional impacts to these potential receptors in the period post-mining, i.e. identify additional potential impacts beyond those that have occurred during already approved mining operations that may be attributable to the PRC Plan's proposed final landform. **Figure 7-32** provides the locations of identified potential receptors, and the corresponding hydrographs.

Predictive hydrographs for the water table at the potential GDE sites identified in and adjacent to the SSM Area are provided as **Figure 7-33** and **Figure 7-34** for the mid climate scenario. The hydrographs also indicate that much of the water table drawdown in the vicinity of the potential GDEs is predicted to occur prior to the end of mining (i.e. associated with approved SSM mining operations), with any additional drawdown occurring over the post-mining period continuing the drawdown trends that commence prior to the end of mining. The shape of the hydrographs suggests that the additional drawdown impacts that occur in the post-mining period are residual impacts from approved previous active mining activities (i.e. a time lag from active mining), rather than new impacts caused by the PRC Plan's landform design; i.e. suggesting that the final landform is not contributing significantly to additional impacts at the potential GDE locations. Note there is no difference in the hydrographs for the drier or wetter climate scenarios.

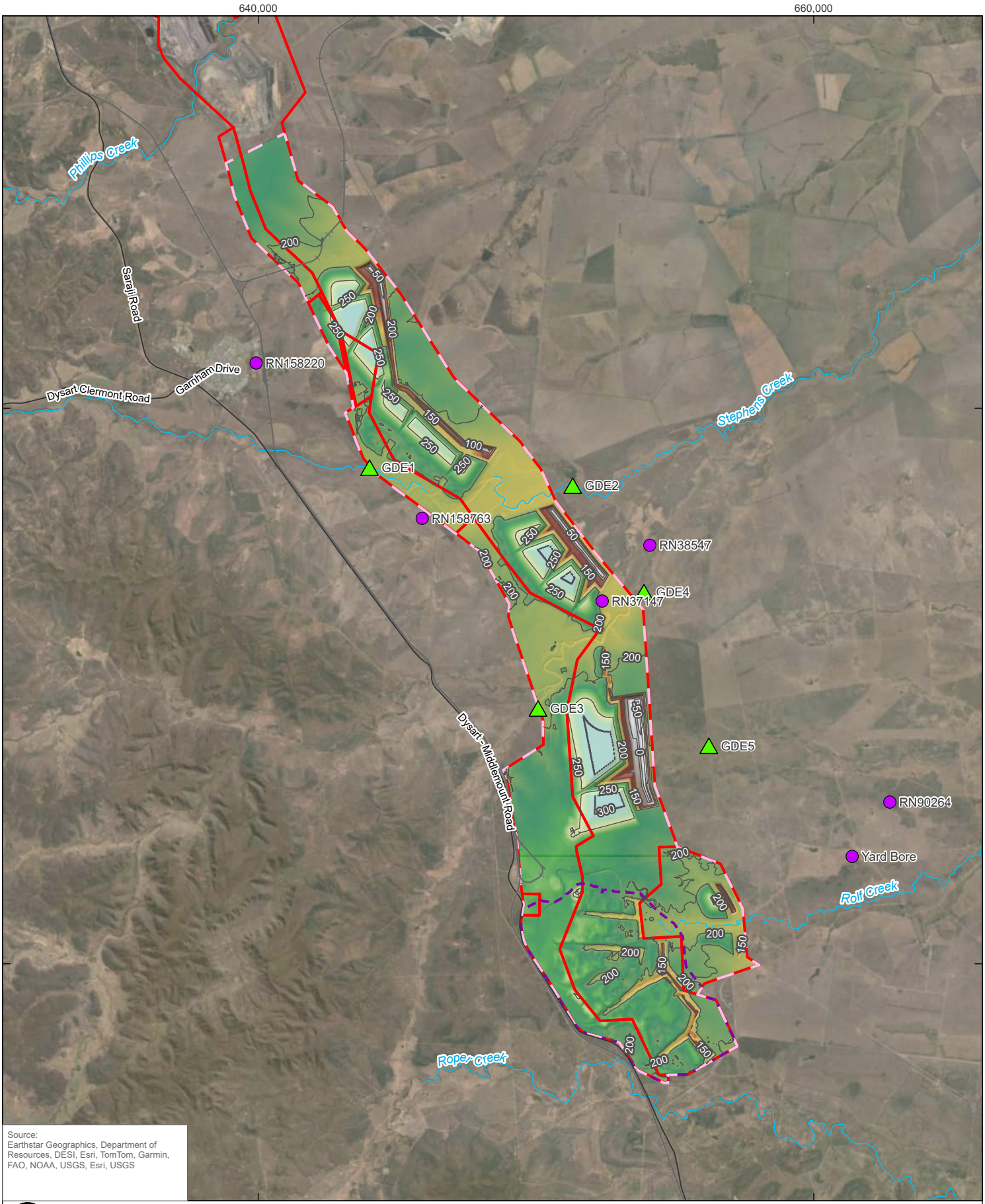
640,000
660,000
7,500,000
7,480,000
Phillips Creek
Saraji Road
Dysart Clermont Road
Gernham Drive
Stephens Creek
Dysart - Middlemount Road
Rolf Creek
Rope Creek
RN158220
RN158763
RN38547
RN37147
RN90264
Yard Bore
GDE1
GDE2
GDE3
GDE4
GDE5
Source:
Earthstar Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
0
2.5
5
km
LEGEND
Hydrograph Location
Bore
GDE
Topographic Contour (mAHD)
Railway
Major Road
Watercourse
SSM Mine Lease
SSM EA Boundary
Elevation (mAHD)
301
-80
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:180,000 at A4
Project Number: 620.314444.00000
Date Drawn: 21-Aug-2024
Drawn by: RB
SARAJI SOUTH MINE
GROUNDWATER MODELLING
TECHNICAL REPORT
POTENTIAL RECEPTOR
PREDICTIVE HYDROGRAPH
LOCATIONS
SLR
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FIGURE 7-32
Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_MOD_F3_41_Potential Receptor Predictive Hydrograph Locations

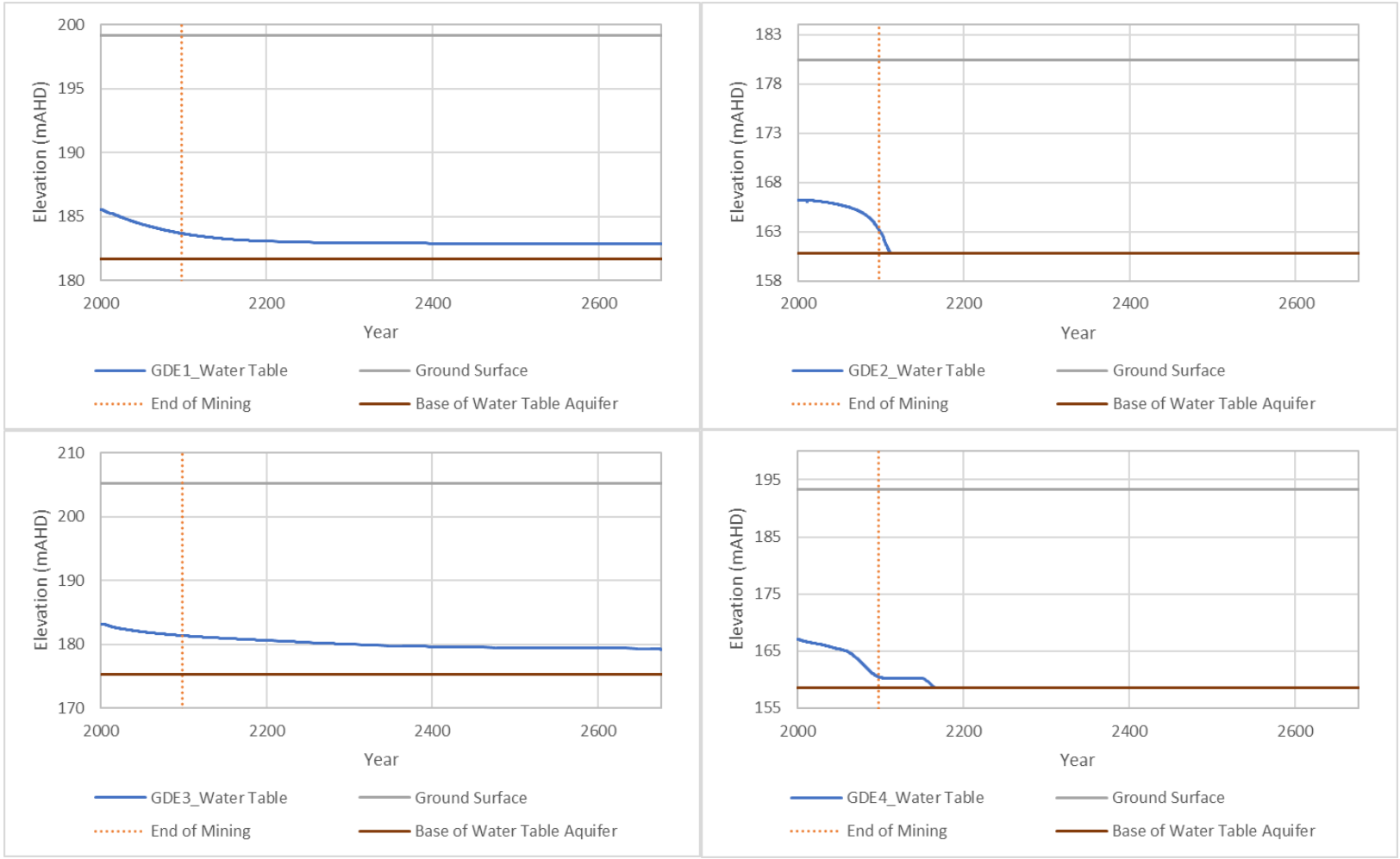


Figure 7-33 Water Table Hydrographs at Potential GDEs

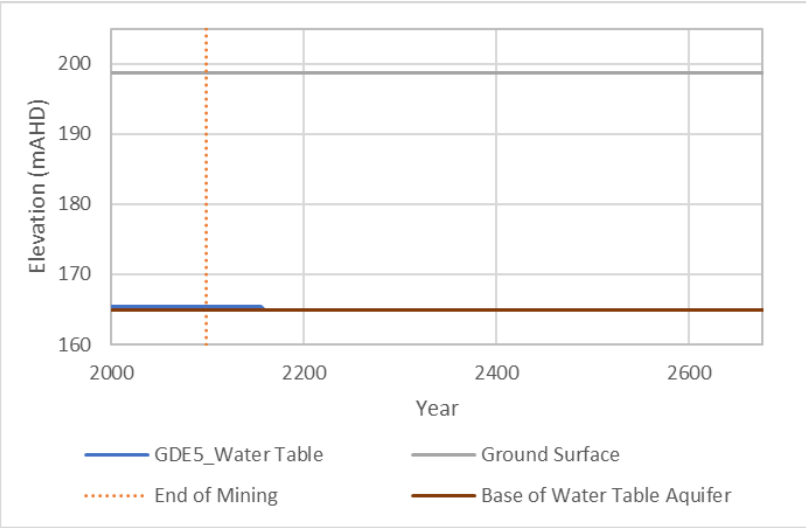


Figure 7-34 Water Table Hydrographs at Potential GDEs (cont.)

Predictive hydrographs for the identified third party water supply bores with sufficient information to attribute a source aquifer (see **Table 4-8** in **Section 4.5.1**) are provided as **Figure 7-35** for the mid climate scenario. Some long-term post mining groundwater drawdown of less than 5 m is predicted at bores RN37861, RN43060, RN43794, RN90017, RN158220, RN158763, and RN90264, located in the Fort Cooper Coal Measures, between 1 and 3 km east of the Gilbert, Price/Leichhardt and Lotus Campbell voids. For the bores RN38547, RN43061, RN89469, RN89470, and RN90014, a relatively significant amount of drawdown is predicted in the long term post-mining noting that it takes hundreds of years for the maximum drawdown to occur, which is well beyond the expected service life of a groundwater bore. This drawdown is considered to be mostly related to a time lag from during-mining impacts, plus also regional scale influences represented in the model (i.e. other mining activities) given the bore accesses groundwater from geological units not present across the majority of the SSM Area. The maximum drawdown at this bore is greater than the relevant 5 m drawdown 'bore trigger threshold' for consolidated aquifers (i.e. the Fort Cooper Coal Measures) identified in Chapter 3 of the *Water Act 2000*, i.e. the threshold at which drawdown impacts may need to be further investigated for the purposes of determining any requirement to 'make good' a bore impairment.

Note there is no difference in the hydrographs for the drier or wetter climate scenarios.

The bores RN84538, RN136092, and the unregistered House Bore are located outside the model boundary, and therefore have not been included in the model assessment.

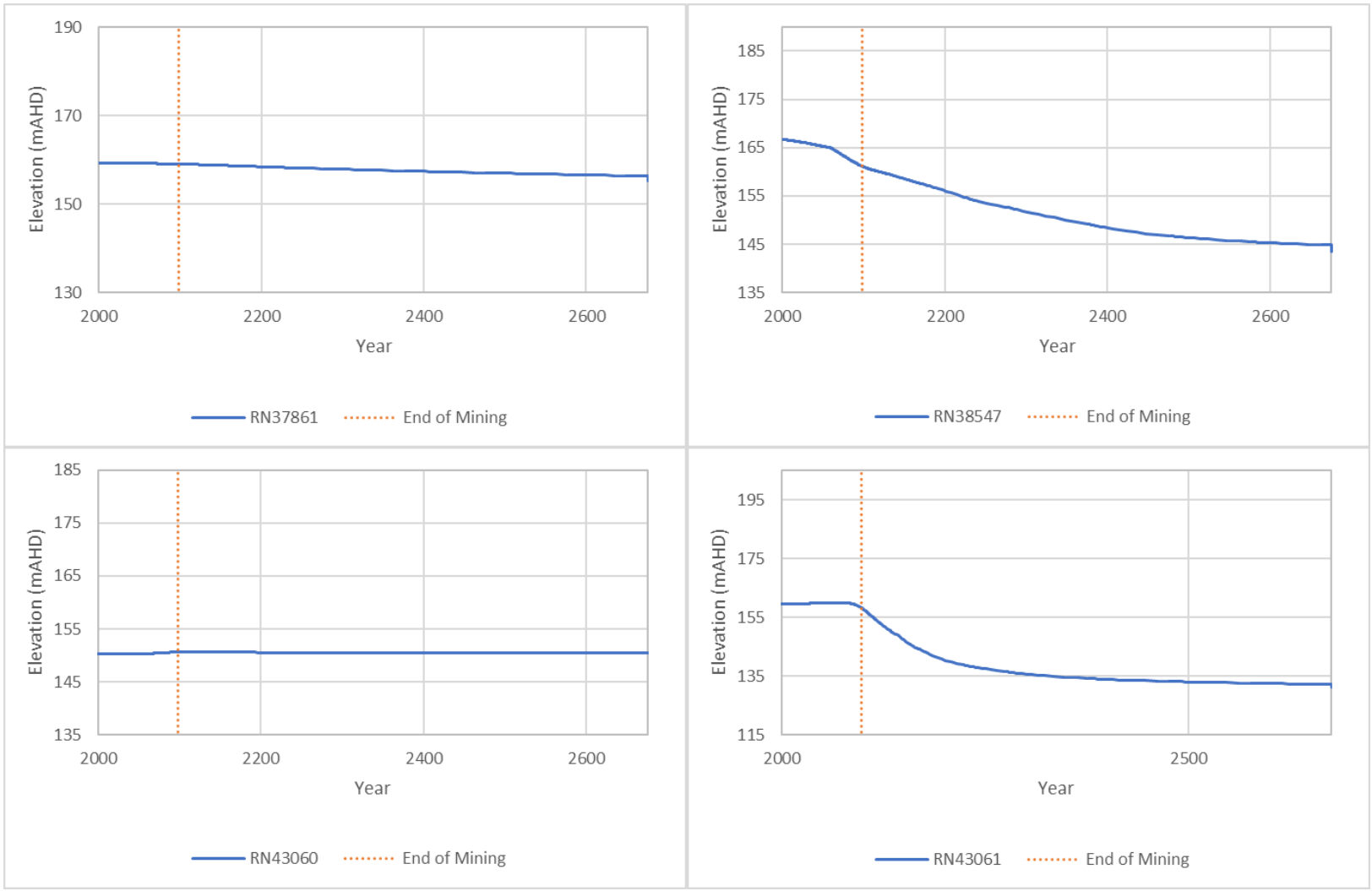


Figure 7-35 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer

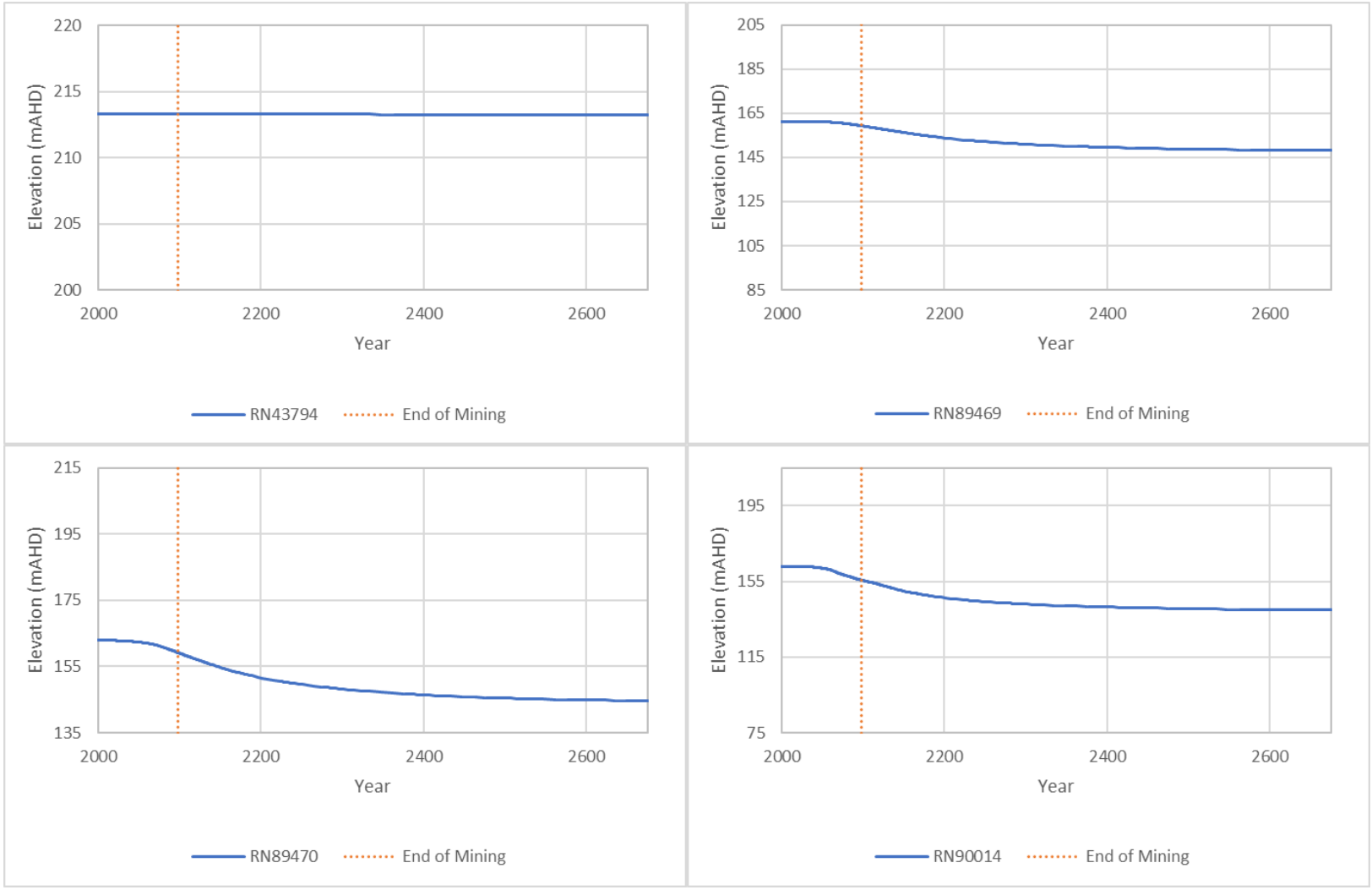


Figure 7 46 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer (cont.)

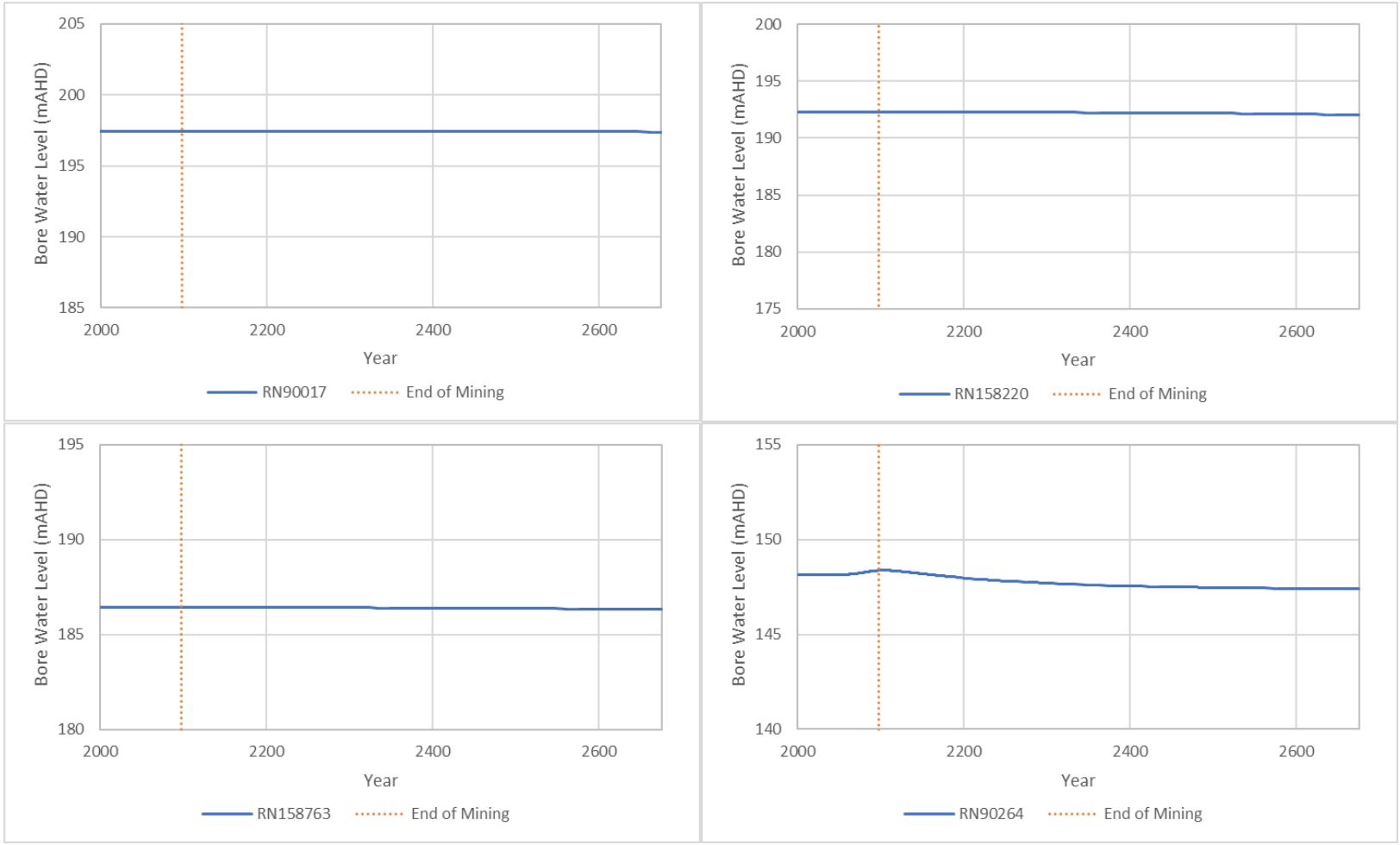


Figure 7 46 Hydrographs for Surveyed Third Party Supply Bores with Attributable Source Aquifer (cont.)

7.2.6 Flow Path Simulation

An analysis of the water movement within the final landform was undertaken to simulate and assess the movement and fate of water particles through the groundwater system post-mining. A number of particles were placed on the final landform and within the residual voids in the recovery groundwater model and the mod-PATH3DU code (S.S. Papadopulos & Associates, 2018) was used to simulate particle pathways along the groundwater flow field during recovery (i.e. 578 years). To run the mod-PATH3DU code the transient head outputs from the groundwater flow model were used by mod-PATH3DU to simulate particle flow path lines.

Figure 7-36 shows the initial location of particles on the final landform. The particles were placed at the surface of the model and released at the start of the post-mining simulation, with the movement of the particles then recorded during the post-mining simulation. It should be noted that the mod-PATH3DU code automatically moves the particle from the model surface to the shallowest saturated layer at the commencement of the simulation. As shown on **Figure 7-36**, for many of the particles, this represents the Permian layers (including areas of spoil backfill in model layers that represent Permian units pre-mining) as the shallow layers (Layers 1 and 2) are unsaturated across much of the SSM Area at the commencement of the post-mining simulation. Locations where the model predicts saturation in the shallow groundwater system (i.e. Layer 2) at the end of mining.

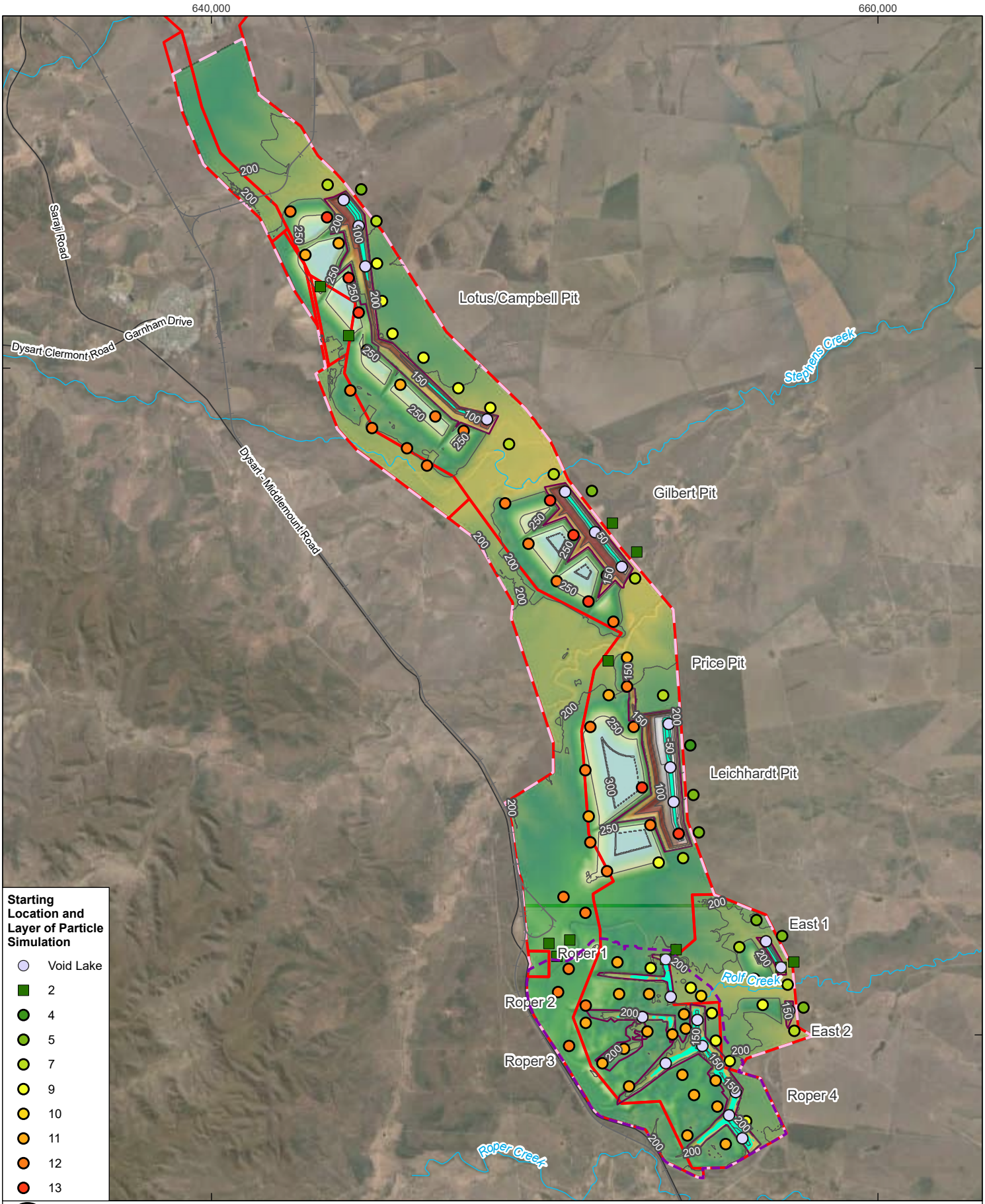
7.2.6.1 Mid Climate Scenario

Figure 7-37 shows the predicted movement of water particles in the 578-year recovery simulation of the final landform for the Mid Climate scenario. The colours along the predicted particle flow paths provides the model layer the particle was simulated to be moving through, with the green to red scale classification representing particles moving from shallow to deep model layers.

The colour changes along the paths on **Figure 7-37** indicate that particles situated within the shallower saturated layers at the beginning of the post-mining simulation generally move progressively toward deeper layers representing the Permian coal measures (or backfilled spoil where the coal measures has been mined out) over the post-mining period. The flow path analysis indicates the particles generally move toward the void lakes, with many of the particles captured in the voids. No particles are shown to move significantly away from the SSM Area to the broader receiving environment.

Overall, the particle movement simulation indicates that groundwater on SSM, including that flowing through spoil of the final landform and that beneath the mine area, would remain within the final landform (e.g. backfilled spoil and voids) in the long term for all mine voids except for the Roper Pits. As noted in Hydrogeological Assessment introduction, the Roper Study Area requires further investigations and development of the closure landform. For all other mine voids, particle movement simulation shows that no groundwater originating from the SSM is predicted to flow to the receiving environment, i.e. the voids would remain groundwater sinks and groundwater would not flow from the residual voids off-site. The figure below shows that this may not be the case for the Roper pits, though PMLU and final landforms will be developed to address this potential risk as part of future separate studies for the Roper Study Area.

Given that the particle pathlines are simulated from the start of recovery, they generally follow predicted head gradients. However, the particle directions at times appear to be contrary to the head contours/gradients shown on **Figure 7-37**. It should be noted that the contours shown on **Figure 7-37** only represents the final head pattern when the aquifer has reached an equilibrium and hence does not necessarily show the transient head changes occurring during the 578-year recovery simulation, given the recovery simulation commences from the first year post-mining. For example, head gradients will change over the 578 years of recovery simulation as void lake levels stabilise and the groundwater system recovers partially from mining.



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:150,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Topographic Contour (mAHD)
- Railway
- Major Road
- Watercourse
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

Elevation (mAHD)

301

-80

SARAJI SOUTH MINE TRANSITIONAL PRCP

STARTING LOCATION OF PARTICLES

SLR

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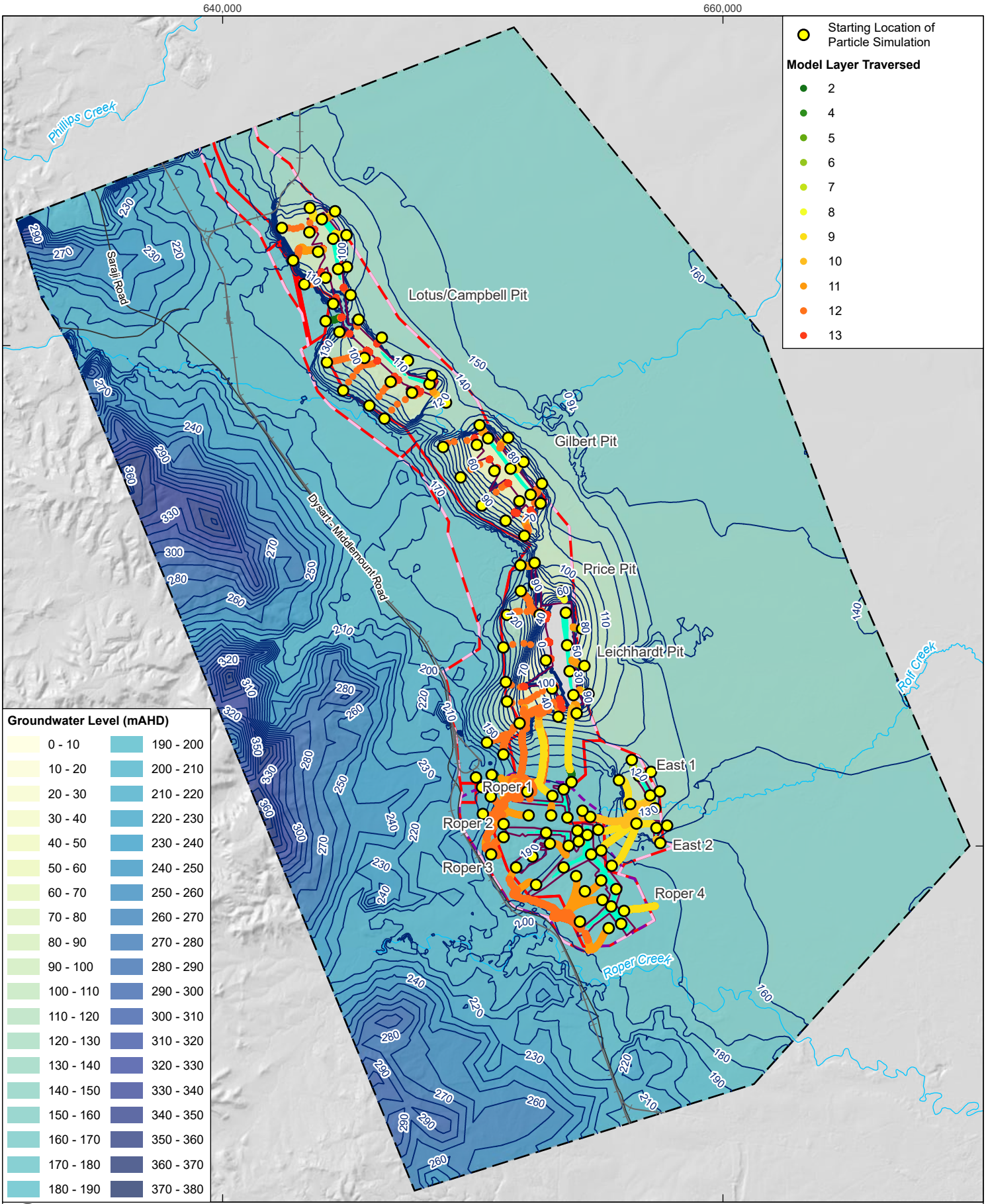
FIGURE 7-36

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_35_Starting Location of Particles



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:200,000 at A4
Project Number:	620.314444.00000
Date Drawn:	28-Aug-2024
Drawn by:	AS

LEGEND

- Railway
- Major Road
- Watercourse
- Model Boundary
- Groundwater Contour (mAHD)
- Void Extent
- Void Lake
- SSM Mine Lease
- SSM EA Boundary
- Roper Study Area

SARAJI SOUTH MINE TRANSITIONAL PRCP

PREDICTED MOVEMENT OF PARTICLES (MID CLIMATE SCENARIO)

SLR

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FIGURE 7-37

Path: H:\Projects-SLR\620-BNE\620-BNE\620.31444.00000 PDM & SSM PRCPs GW\03 SLR Data\01 CADGIS\GIS\SSM Report Figures\SSM Report Figures.aprx\620314444_CON_F7_36_Predicted Movement of Particles (Mid Climate Scenario)

8.0 Conceptual Site Model – Post Mining

8.1 General Overview

A visual representation of the post-mining CSM based on the results of this Hydrogeological Assessment is provided as **Figure 8-1**, noting the features discussed in **Section 5.0** above. Based on an understanding of hydrogeological mechanisms and response to mine closure modelled in local studies, key features relevant to the discussion of potential groundwater impacts (excluding the Roper Study Area) post-mining are likely to be:

- Residual void lake formation, with lake levels stabilising significantly below the pre-mining groundwater elevations and any shallow post-Permian strata, including the base of surficial weathering and shallow hydrostratigraphic units (i.e. alluvium and Tertiary sediments/Regolith).
- Residual groundwater drawdown within the Moranbah Coal Measures, associated with time lag of discharge to mine voids during mining, and long-term evaporative discharge from the void lakes, resulting in continued inwards hydraulic flow gradients in the coal measures.
- Voids continue to capture any seepage from spoil emplacements.
- Little to no impact on surficial aquifers, with predicted water level influence showing decline caused by approved mining impacts prior to closure.
- Little to no impact on environmental receptors, with predicted water level influence showing decline caused by approved mining impacts prior to closure.
- No impact on anthropogenic receptors, with predicted water level influence dominated by approved mining impacts prior to closure, and showing recovery post-mining.

Note that the nature of groundwater interaction associated with the Roper Study Area will be examined in more detail during subsequent investigations, per the discussion provided in **Section 1.1**.

8.2 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 8-2**.

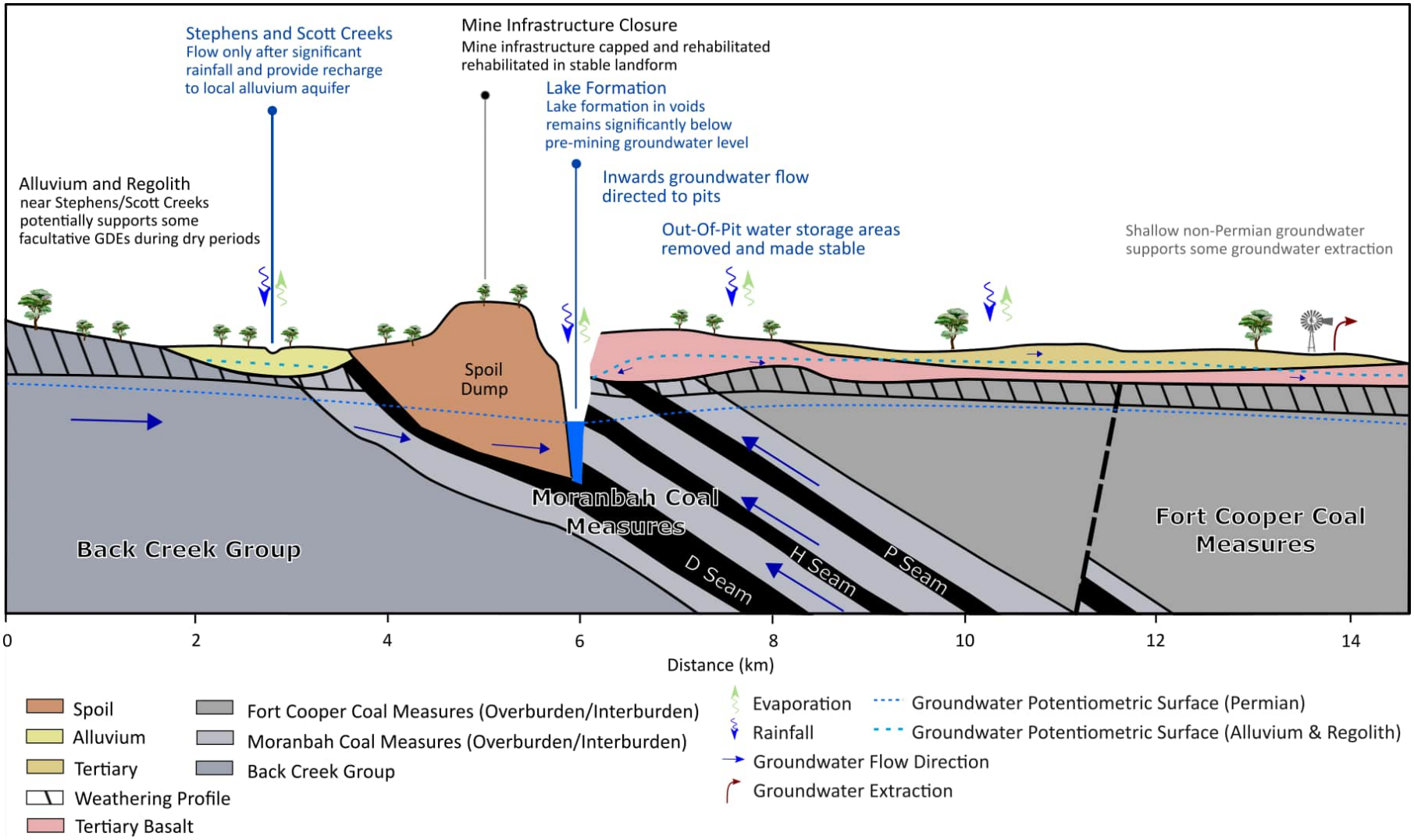

Figure 8-1 Conceptual Model of SSM Groundwater System – Post Closure

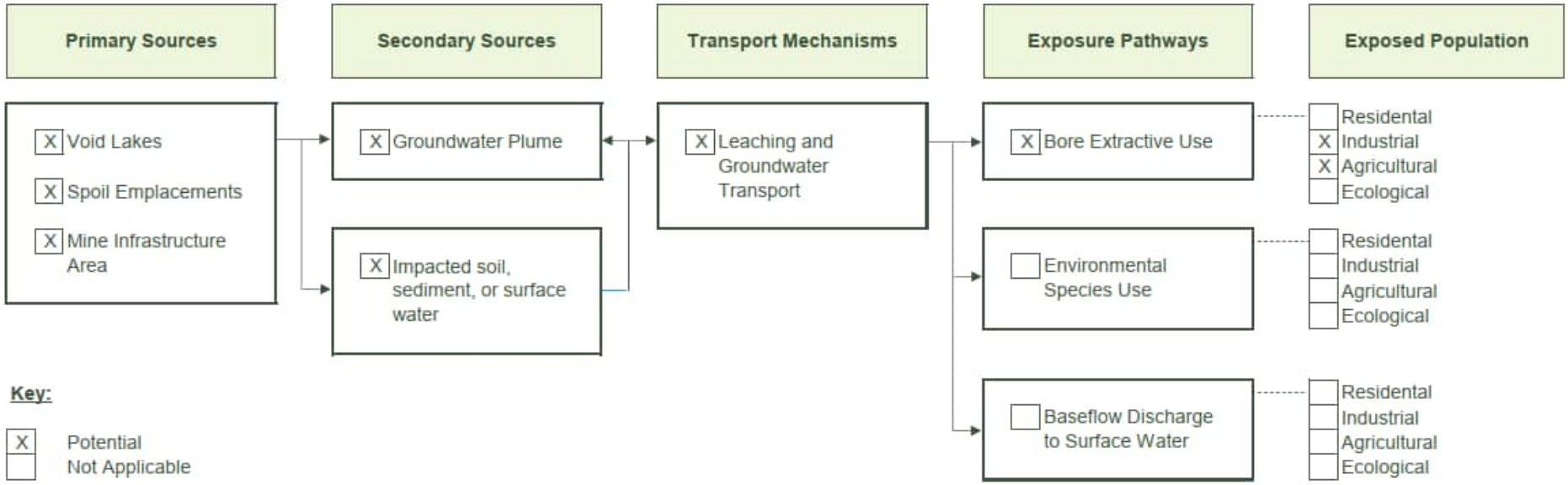

Figure 8-2 Source-Pathway-Receptor Presentation of CSM

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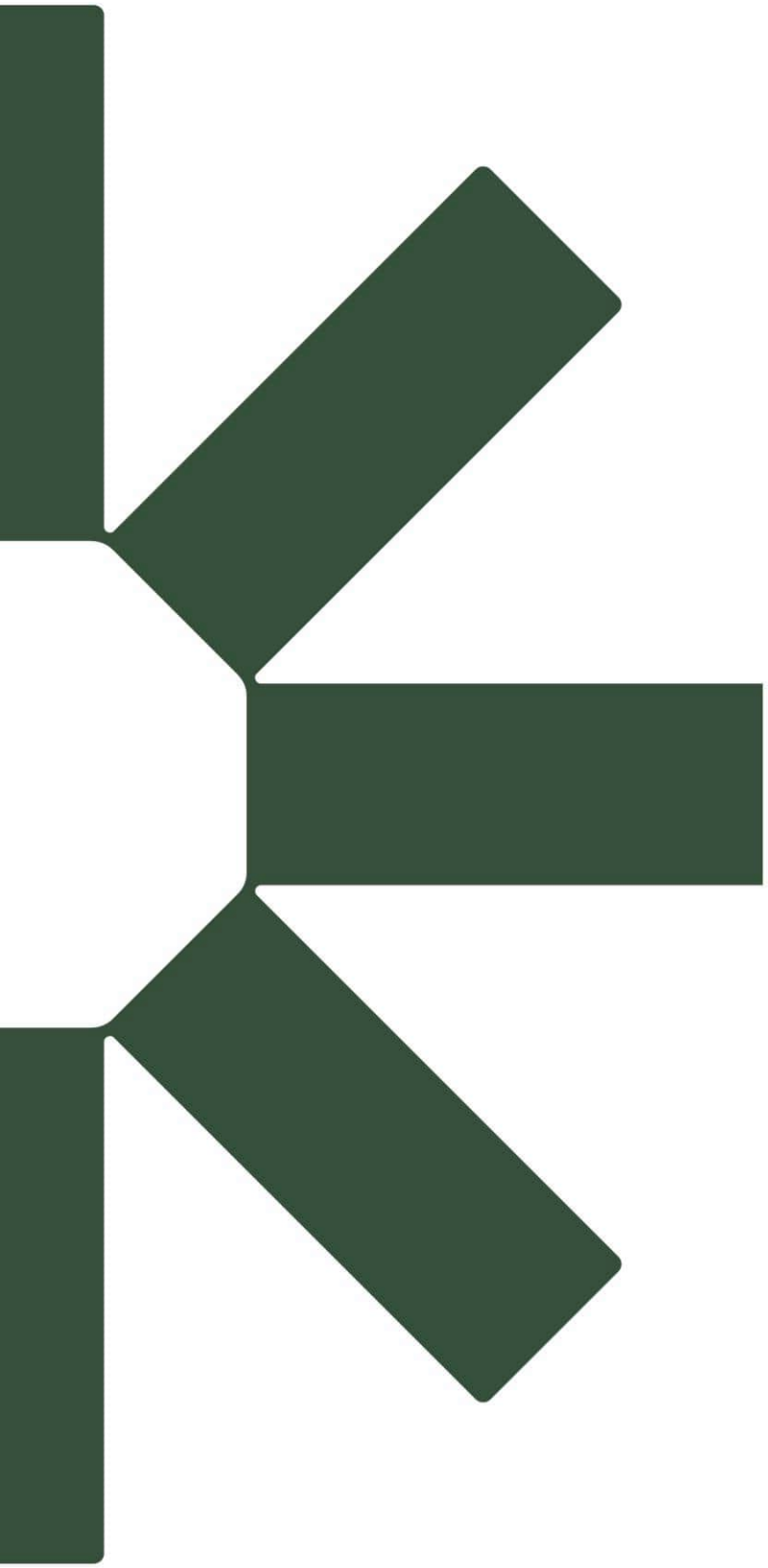

Making Sustainability Happen

SARAJI SOUTH MINE – MATERIAL CHARACTERISATION STUDY

March 2023

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Project Number: 1447.21a6

Report Title: Saraji South Mine – Material Characterisation Study

Client: BHP Mitsubishi Alliance

Review History

Version	Prepared by	Reviewed by	Date
Draft A	L. McGrath	E. Howard	27/03/2023
Rev 1	L. McGrath	BHP	15/06/2023
Rev 2	L. McGrath	BHP	10/07/2023
Rev 3	L. McGrath	BHP	31/07/2023

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1 INTRODUCTION

BHP Mitsubishi Alliance (BMA) has engaged Landloch to provide a material characterisation study of potential growth media at the Saraji South Mine (SSM). This covers all materials assessed below, both stockpiled and/or in situ. To ensure rehabilitation success, materials planned to be placed near the surface of rehabilitated landforms (including soils and waste materials) need to be assessed for their suitability to support the vegetation required to meet the post-mining land use (PMLU).

This study will evaluate the quality of soil and waste materials and their suitability for use as growth media in rehabilitation.

1.1 Project description

SSM, previously known as Norwich Park Mine, is a coal mine operated by BMA located approximately 25 km south of Dysart in the Bowen Basin, Central Queensland. Mining activities commenced in 1979, before entering a period of care and maintenance. Open cut strip mining operations at SSM recommenced in 2022. The current pits extend over a strike length of 19 km including Lotus, Campbell, Gilbert, Roper, Price and Leichhardt.

1.2 Scope of work

The scope of work involved the following tasks:

1. Review previous soil, waste, and land assessments undertaken at SSM.
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. Topsoil stockpile sampling and analysis to fill the gaps identified.
5. Soil survey and land suitability assessment of unmined areas to the east of the existing pits.
6. Collate existing and newly acquired soil and spoil characterisation data.
7. Interpret data, characterise materials, and prepare this report.

2 DESKTOP REVIEW

2.1 Climate

The mine is situated in Queensland's sub-tropical climate zone, which is characterised by high summer temperatures, warm dry winters, and a distinct wet and dry season.

Average monthly maximum temperatures range from 24°C to 27°C in winter, and from 33°C to 36°C in summer. Summer temperatures can exceed 40°C for short periods. Average monthly minimum temperatures range from 8°C to 10°C in winter and from 20°C to 22°C in summer. Rainfall is concentrated through the summer with approximately 75% of yearly rainfall occurring between November and March. The median annual rainfall for the area is 636 mm. Rainfall events are often associated with

short-lived, intense thunderstorms. These high intensity rainfall events can produce high runoff rates and can produce conditions conducive to erosion. (Bureau of Meteorology 2023).

2.2 Topography

The topography of SSM consists of predominantly flat (low gradient) areas, with several creeks passing through the mining lease. The prominent creeks include Stephens Creek, Downs Creek, Lotus Creek, and Rolf Creek, all of which are part of the Isaac and Fitzroy River catchments. Most of the terrain within these catchments is undulating, with minor steep areas in the upper catchments.

2.3 Regional geology

Geoscience Australia mapping of the mine identifies three major geological units. Descriptions of each geological unit are provided in Table 1.

Table 1: Geological units and descriptions for SSM (Geoscience Australia 2022).

Geological unit	Description
Qrc – Colluvium	Residual deposits, sheetwash, talus, scree; boulder, gravel, sand; may include minor alluvial or sand plain deposits, local calcrete and reworked laterite.
Po – Sandstone	Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate.
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.

2.4 Waste materials

The waste materials at SSM consist of overburden/interburden materials (spoil), coal rejects and tailings.

2.4.1 Spoil material

The material at SSM consists of tertiary/weathered materials and fresh Permian materials.

Based on regional geology characteristics and spoil analysis data over the life of the mine overburden/interburden geology at SSM can be broadly classified into:

- Tertiary/weathered materials – unconsolidated Cainozoic (Tertiary) and Quaternary calcareous sediments consisting of clays, sands, petroreticulite, and ferricrete. These weathered materials are typically sodic, highly erodible, and prone to clay dispersion. They are known to have varying levels of salinity, but their main constraint is their high erosion risk. Minor inclusions of tertiary basalt may be present and occur as relatively pure *in situ* fresh/weathered Tertiary basalt rock.

- Fresh Permian materials – Permian shales, sandstones, siltstones, and mudstones. Carbonaceous zones are present close to the coal seams. The physical and chemical properties of these materials are highly variable. They are generally sodic, alkaline, and non-saline, although there are some materials with elevated salinity levels, and some carbonaceous strata maybe acidic (refer to the PRC Plan Waste Characterisation section). Erosion risk varies based on physical properties and sodicity, but generally the sandstones are more competent and resistant to weathering and erosion than are the siltstones and mudstones. The predominantly fresh, medium to coarse grained, grey sandstone material is more resistant to short term weathering and is potentially more beneficial to rehabilitation.

Characterisation studies were undertaken by B.R. Emmerton (2004) and GT Environmental Services (2000). Generally, spoil materials at SSM were found to be:

- Non-acid forming, with acid neutralising capacity (ANC). Some potentially acid forming (PAF) material occurs in the stratigraphic unit, but the excess ANC means acid and metalliferous drainage (AMD) would not be considered a significant issue in the mixed spoil material;
- Slightly acidic (Tertiary) to strongly alkaline (Permian);
- Sodic to strongly sodic and dispersive;
- Moderately to highly saline; and
- Low fertility, but significant responses to nitrogen and phosphorus fertilisers.

GT Environmental Services Pty Ltd (2000) concluded in the spoil characterisation review that the weathered Tertiary spoil alone would be difficult to establish stable rehabilitation cover due to chemistry and stability limitations. The unweathered Permian wastes were reported to be better suited for use on rehabilitated batter slopes and would provide a higher quality growth medium due to a less hostile chemistry and susceptibility to erosion.

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 materials that is more suitable for use as a growth medium.

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 mapping

Regional soils mapping of the mine indicates the presence of four broad soil groups (State of Queensland 2022):

- CC21 – Vertosols;
- Kd7 – Vertosol;
- MM7 – Vertosols or Dermosols; and
- Ub83 – Sodosols.

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)
CC21	Gilgaied cracking clays	Vertosol
Kd7	Deep dark clays	Vertosol
MM7	Dark and yellow friable earths with friable brown soils	Vertosol, Dermosol
Ub83	Sandy duplex soils with moderately deep A horizons	Sodosol

2.5.2 Recoverable soils

A soil survey was undertaken at the mine in August 2009 by Soil Mapping and Monitoring PL in association with B.R Emmerton PL. The survey assessed 121 sites over 1,115 ha and was considered the most representative of stockpiled topsoil at the mine. Six soil types were identified in the Lotus Pit area and nine within the Roper Pit area, and a total of 15 soil mapping units (SMUs) were identified (Soil Mapping and Monitoring 2010). A summary of all SMUs is provided in Table 3. The dominant soils are consistent with the alluvial Plains Land Resource Area, specifically the Rolleston, Adelong and Lascelles Agricultural Management Units as described in the Land Management Manual for the Central Highlands (Bourne and Tuck 1993).

A soil map displaying broad ASC soil types for the SSM area is provided in Figure A11 (Appendix A). A portion of the soils data used to generate this map was collected by Landloch during the 2023 survey conducted as part of this study. The mapping units are a synthesis of soils data and mapping sourced from that assessment and existing soil assessments for the mine area in figures A8 – A10, East Pit Project EIS BMA (2006) and Soil Mapping and Monitoring (2010), along with existing land systems information sourced from the Queensland Globe online spatial data system (State of Queensland 2023) and regional land resource assessments completed by Burgess (2003). The map is Landloch's interpretation of the available soils information.

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 4,509,587 m^3 (in April 2023). Locations of topsoil stockpiles on SSM are presented in Figure 1.

Table 3: Summary details of the SMUs developed in the previous soil assessments for the mine site.

SMU	Soil Details	Vegetation Description	ASC	pH_w* (pH Units)	$EC_{1:5}$ (dS/m)*	Exchangeable Sodium Percentage (ESP)* (%)	Grazing Suitability Class
1	Hard setting to moderately self-mulching, brown to red-brown cracking clay over unconsolidated, calcareous sediments below 0.6-1.2m	Ironbark – bloodwood – ghost gum or mountain coolibah open woodland	Brown Vertosol	7.7	0.074	<1	2/3
2	Strongly self-mulching, black cracking clay with well-developed linear gilgai (VI 0.1–0.3 m) over unconsolidated, calcareous sediments below 0.8-1.2m	Mountain coolibah open woodland grading to grassland on lower slopes	Black Vertosol	8.4	0.125	<1	2
3	Weakly to strongly self-mulching, brown or red cracking clay over unconsolidated, calcareous sediments below 0.5-1.0m	Shrubby brigalow scrub	Brown Vertosol	7.7	0.033	<1	2
4	Strongly self-mulching, black cracking clay with weakly developed gilgai (VI 0.05–0.1 m) over unconsolidated, calcareous sediments below 1.1-1.5 m	Brigalow – yellowwood scrub	Black Vertosol	8.5	0.253	6	2
5	Strongly self-mulching (silty), black cracking clay over buried alluvial layers below 1.2- >1.5m	Coolibah woodland	Black Vertosol	8.3	0.223	6	2
6	Strongly self-mulching, black cracking clay over buried alluvial layers below 1.5m	Brigalow scrub	Black Vertosol	8.5	0.322	8	2
7	Sandy surfaced, bleached, brown (to grey), sodic texture contrast soil with coarse columnar structure; over *in situ* deeply weathered Tertiary sediments below 1.3m	Poplar box – bulloak woodland	Brown Sodosol	9.5	0.543	32	4/5
8	Sandy surfaced, bleached, brown (to grey), sodic texture contrast soil with coarse columnar structure; over *in situ* deeply weathered Tertiary sediments below 1.3m	Brigalow – Dawson Gum scrub	Brown Sodosol	9.2	0.57	31.4	4/5

SMU	Soil Details	Vegetation Description	ASC	pH_w* (pH Units)	$EC_{1:5}$ (dS/m)*	Exchangeable Sodium Percentage (ESP)* (%)	Grazing Suitability Class
9	Firm to hard setting, grey sodic cracking clay; over unconsolidated fine sandy clay sediments or reworked acidic Tertiary clay >1.5m; non-gilgaied to variable shallow melonhole (VI 0.2–0.5m)	Brigalow scrub	Grey Vertosol/ Dermosol	8.8	0.532	25	3
10	Hard setting to weakly self-mulching, grey, sodic cracking clay with strongly developed melonhole gilgai (VI 0.5–1.5 m); over reworked acidic Tertiary clay from 0.6–>1.5 m	Brigalow scrub	Grey Vertosol	8.9	0.38	17	3
11	Sandy surfaced, sporadically bleached, mottled, brown, sodic texture contrast soil with coarse columnar structure; over unconsolidated sandy clay sediments >1.5m	Shrubby poplar box woodland	Brown Sodosol	9.2	0.392	30	4
12	Sandy clay loam surfaced, brown, sodic texture contrast soil with coarse columnar structure; over unconsolidated sandy clay sediments >1.5m	Shrubby brigalow – Dawson Gum scrub	Brown Sodosol	9.6	0.518	38	4
13	Hard setting, firm or weakly self-mulching, black, grey or brown cracking clay; over unconsolidated sandy clay sediments >1.5m; non-gilgaied to variable shallow melonhole (VI 0.2–0.5m)	Shrubby brigalow scrub	Black or Brown Vertosol	9.6	0.313	19	3
14	A firm to moderately self-mulching, black (to grey) cracking clay with variable melonhole gilgai (VI <0.6m); over unconsolidated reactive clay sediments >1.5m	Brigalow scrub	Black Vertosol	9.1	0.287	11	3
15	Thick, fine sandy surfaced (0.5–1.0 m), bleached, mottled, grey or brown texture contrast soil on older relict alluvium	Moreton Bay ash – bloodwood – narrow leaved ironbark woodland	Brown Chromosol	-	-	-	3

*Analysis at 0.3–0.6 m depth.

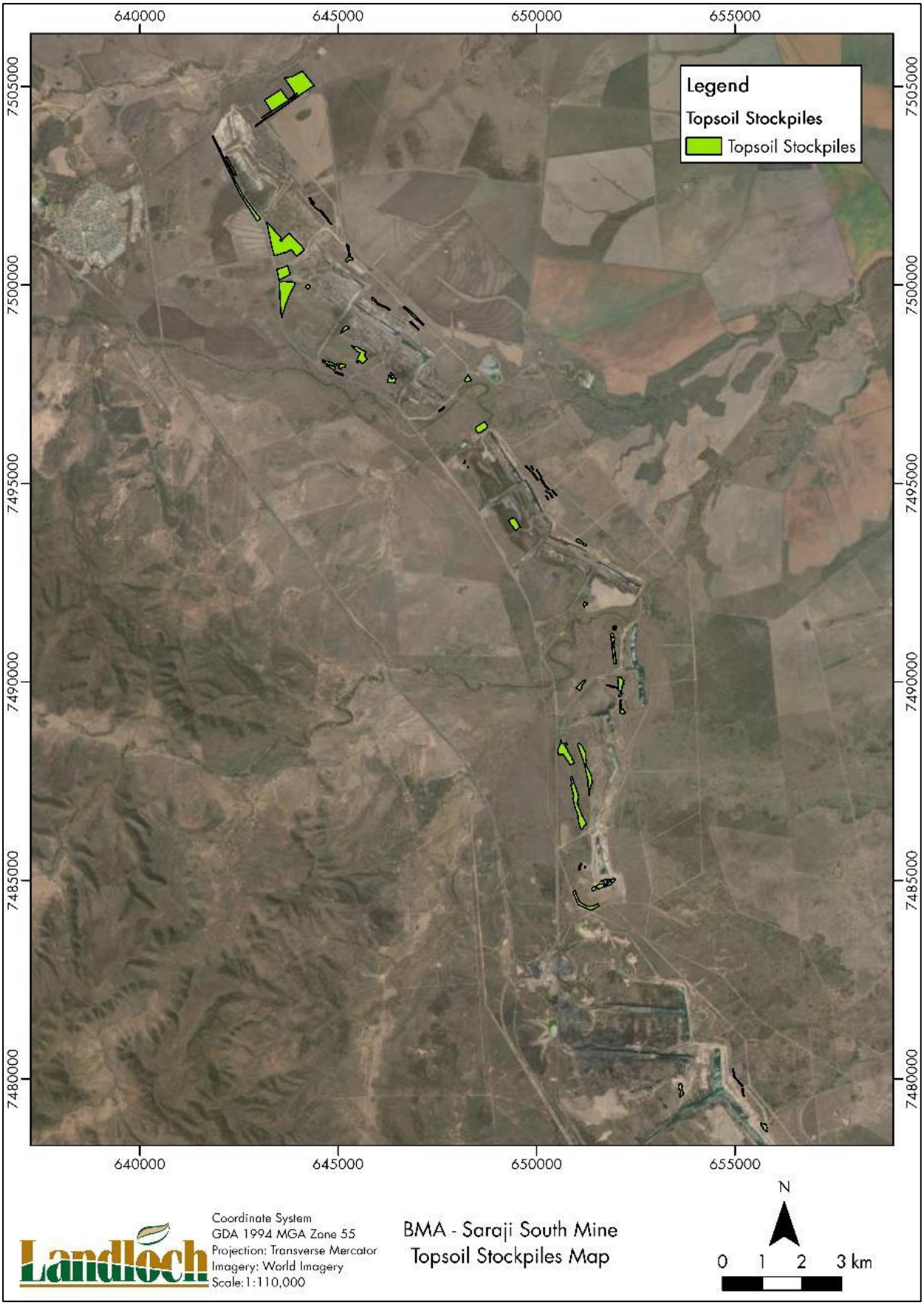

Figure 1: Stockpiled topsoil materials across the SSM.

2.6 Post-mining land use

BMA's rehabilitation objectives for SSM are to create a safe, stable, non-polluting, and sustainable landscape with PMLUs in accordance with the EA:

- Cattle grazing
- Woodland habitat
- Water storage
- Watercourse

The predominant pre-mining land use was cattle grazing.

2.7 Revegetation methodology

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 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;
- Expected growth media amelioration activities.

More details on revegetation can be found in the relevant section of the PRC Plan.

3 MATERIAL CHARACTERISATION METHODOLOGY

3.1 Materials

Soils and spoil materials were targeted for consideration as potential growth media. When considering the growth media at SSM, 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 work. 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 spoil as a potential growth media. All 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 5 and 12 September 2022. Site conditions were dry across SSM at the time of the field program. For the month preceding the field program, the Bureau of Meteorology's Booroondarra weather station (29 km south-east of Dysart) recorded less than 5 mm of rainfall.

3.2.2 Sampling plan and intensity

The soil sampling plan is listed in Table 4 and the stockpile sampling locations are shown in Figures A2–A4 (Appendix A).

The sample density adopted is consistent with a 'high (detailed)' intensity (McKenzie *et al.* 2008), assuming soil will be placed at an average depth of 0.1 – 0.15 m at rehabilitation. Using these criteria, Table 5 shows the sampling density on a stockpile volume basis. Stockpile location details are provided in Table B1 (Appendix B).

Table 4: Soil stockpile sampling program.

Stockpile ID	Area (ha)	Sampling Sites	Stockpile ID	Area (ha)	Sampling Sites
410706	4.8	2	410925	5.0	2
410717	1.5	1	410940	1.8	1
410728	1.2	1	410950	9.7	4
410732	1.7	1	410958	9.0	3
410740	7.5	3	410966	43.7	11
410742	3.0	1	410969	2.0	1
410751	1.5	1	410972	10.2	4
410753	0.5	1	410973	13.7	5
410760	1.4	1	410976	2.1	1
410767	0.6	1	410989	2.8	1
410790	1.3	1	411004	1.6	1
410791	2.3	1	411008	1.0	1
410799	34.4	9	411010	4.4	2
410801	6.8	3	411080	5.7	2
410879	1.8	1	411081	3.1	1
410884	2.7	1	411101	17.6	6
410891	1.7	1	411259	1.3	1

Table 5: Sample density for soil stockpiles.

Soil Volume (m^3)	Reinstatement Coverage (ha)	Total Samples	Sampling Density	Sampling Density	Survey Scale
4,509,587	3,006*	308	1 sample/ 14,641 m^3	1 sample/ 9.7 ha	1:25,000

* Based on a replacement depth of 0.15m

3.2.3 Sample collection

Samples and descriptions of materials were taken from test pits. Depth of excavation was to the base of the stockpile, or to the limit of excavation (~3–5 m). Samples were collected from the stockpiles 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 about the collected materials were recorded in the field. Sampling included composite and discrete samples. 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) accreditation. 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	77	231

3.3 Spoil materials

Geochemical and physical characterisation data for the spoil materials were collated from multiple assessments previously conducted for the project. Information was primarily sourced from the detailed *Spoil Characterisation and Review Report* (GT Environmental 2000) that assessed and summarised spoil data from 50 existing technical reports, trials, and assessments relevant to the mine. Additional information sources included:

- B.R. Emmerton Pty Ltd overburden characterisation and geochemical assessment as part of the *East Pit Project Environmental Impact Statement* (BMA 2006);
- Spoil data collected and analysed to inform Landloch's landform erodibility study as part of the PRC plan development; and
- Internal BMA spoil monitoring data.

4 FINDINGS

4.1 Soil stockpiles

A total of 308 samples were collected from 34 locations within the soil stockpiles. A total of 77 samples were analysed for the topsoil suite and another 231 samples were analysed for the basic suite. Their locations and characterisation of soil types are provided in Figures A2–A8 (Appendix A) and laboratory data are presented in Tables B4 and B5 (Appendix B). Stockpiled soil for use in rehabilitation were categorised into two soil management groups: 1) clay soils, and 2) Sand and loam soils. A summary of key chemical and physical properties is presented in Table 7. Topsoil within each soil management group is summarised in the sections below. Detailed descriptions of soil in each stockpile are provided in Table B3 (Appendix B).

Table 7: Summary of key chemical and physical properties for topsoils at SSM.

Analysis	Clay Soils	Sand and Loam Soils
Chemical Properties		
pH_w (pH Units)	Slightly to strongly alkaline (7.9 – 8.8)	Neutral (6.6 – 7.4)
$EC_{1:5}$ (dS/m)	Low to moderate (0.11 – 0.39)	Very low (0.02 – 0.05)
Exchangeable sodium percentage (ESP) (%)	Non-sodic to sodic (1.4 – 10.6)	Non-sodic to sodic (3.9 – 10.2)
Total N (mg/kg)	Low (537 – 1,087)	Very low (<300)
Available P (mg/kg)	Low (6 – 10)	Low (6)
Available K (mg/kg)	Very low to low (39 – 157)	Very low to low (46 – 171)
Total Organic Carbon (TOC) (%)	Low to moderate (0.63 – 1.46)	Low (0.15 – 0.45)
Effective Cation Exchange Capacity (ECEC) (meg/100g)	Moderate to high (23 – 66)	Low (<4)
Ca/Mg (ratio)	Strongly imbalanced to low (0.9 – 1.9)	Low to adequate (1.1 – 4.5)
Physical Properties		
Clay content (%)	>35	5 – 25
Rock content (%)	<10	nil
Dispersion (EAT)	Dispersive to slaking (2 – 5)	Slightly dispersive (3b)
Permeability	Low	Moderate
Associated regional soil	CC21, Kd7 (Vertosol) and MM7 (Dermososl/Vertosol)	Ub83 (Sodosol)
Associated SMU	1, 2, 3, 4, 5, 6, 9, 10, 13 and 14	7, 8, 11, 12 and 15

Note: Chemical properties for clay topsoil are based on average 10th and 90th percentile values for all stockpile samples analysed. Chemical properties for sand and loam topsoil are based on minimum and maximum values due to the limited sampling size.

4.1.1 Clay soils

Figures 2 to 5 are representative of clay topsoils at SSM. Clay soils account for 95% of samples assessed across SSM. Generally, these soils have relatively similar properties but occasionally minor inclusions of sands and loams were noted at varying stockpile depths. This is likely a result of topsoils from smaller texture contrast soil units being stripped simultaneously with the more dominant vertosols. The soils are generally dark brown, reddish brown or black in colour with occasional mottling, and have textures ranging from light to heavy clay. Gravel content is generally less than 10% with gravel size being less than 60 mm in diameter. The soils often have vertic properties making them susceptible to slaking and dispersion, thereby increasing the risk of erosion.

Figure 2: Soil material excavated at sampling site 410973d.

Figure 3: Soil profile at sampling site 410950c.

Figure 4: Soil material at stockpile 410976.

Figure 5: Vegetation cover on topsoil stockpile 410950.

Stockpiled clay soils are occasionally sodic and there is potential for saline lenses to occur. In comparison to the other soils available, clay soils would be the preferred option for revegetation on areas of low erosion risk, such as low gradient areas on the tops of spoil dumps where higher quality vegetation establishment and performance is required. If 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.

The main requirement for this soil is to ensure that its chemical fertility is managed to ensure vigorous vegetation growth in the initial stage of rehabilitation, and maintenance of suitable levels of surface groundcover in the longer term. Any sodicity issues will also need to be addressed by incorporating gypsum prior to rehabilitation.

4.1.2 Sand and loam soils

Figures 6 to 9 are representative of sand and loam topsoils at SSM. Lighter textured sand and loam soils account for less than 5% of samples assessed. These soils are concentrated around the southern pit areas. These materials have a degree of variability, but due to the limited volumes present, have been grouped together to aid their management. They are generally brown to reddish brown in colour and have textures that range from loamy sand to sandy clay loam. No gravels are present. The soils are susceptible to slaking and dispersion, thereby increasing the risk of erosion.

Figure 6: Soil material at stockpile 411080 (sampling site A).

Figure 7: Soil profile at stockpile 411080 (sampling site B).

Figure 8: Soil material at stockpile 410753.

Figure 9: Vegetation cover on topsoil stockpile 411080.

The soil at stockpile 410753 is sodic and is likely a result of collecting a portion of sodic subsoil together with topsoil during the initial stripping. All other samples are non-sodic.

The sand and loam soils would require different methods to rehabilitate than the clay soils. When this soil is to be used in rehabilitation, its chemical and physical limitations will need to be managed.

4.1.3 Stockpiles with limitations

Stockpiles 410706, 410972 and 411081 have elevated salts in portions of the stockpiles, particularly chloride based salts. These soils are pale in colour and at stockpile 410706, contains considerable gravel (Figure 10). Groundcover observations (Table B2, Appendix B) indicate that limited vegetation had established across the stockpiles at the time of sampling (Figure 11). The chemical and physical properties indicate a portion of these stockpile is likely to be subsoil or spoil material.

It is recommended that this material is excluded from use as a primary growth media where possible. If the stockpiled material is required for use as a growth medium, additional sampling is recommended to identify and separate the area of saline soil present.

Figure 10: Coarse angular gravel present at stockpile 410706 (red circle).

Figure 11: Limited vegetation cover has established in the vicinity of sampling site 410972a.

4.2 Undisturbed (natural) ground

A total of 52 natural ground sites were described during the soil survey of undisturbed areas at SSM (Landloch Pty Ltd, 2023). These were situated to the east of the current disturbance footprint, in areas designated for stripping in the future. Details of this survey are available in the *Saraji South Mine: Soils and Land Suitability Assessment* report. A summary of the soil profile classes identified, the key soil properties and recovery details are provided in the following sections.

4.2.1 Soil profile classes

The soil profile classes (SPCs) identified as part of the survey were:

- B1: Brigalow cracking clay (Vertosol);
- B2: Uniform brigalow cracking clays with melon holes (Vertosol);
- D1: Shallow poplar box duplex sandy loam (Sodosol);
- D3v: Gradational sandy loams (Sodosol).

The key features of each SPC are summarised in table 8 below.

Table 8: Summary of key features for all SPCs identified in the soil survey of natural ground (Landloch Pty Ltd, 2023).

SPC	Key Features
B1 (Brigalow cracking clay)	• Uniformly textured soil profiles. Typical depths are >1.5m • Topsoil fertility rating is *low to moderate*; total N: high; available P: moderate; available K: low; and organic carbon: moderate. The CEC indicates the topsoil has high potential to supply nutrients. • Field tests indicate topsoil has potential to be dispersive. • Subsoils have high alkalinity, salinity and sodicity.
B2 (Uniform brigalow cracking clays with melon holes)	• Uniformly textured soil profiles. Typical depths are 1 m overlying a highly weathered sandstone saprolite. • Topsoil fertility rating is *low to moderate;* total N: high; available P: low to moderate; available K: low; and organic carbon: moderate. The CEC indicates the topsoil has high potential to supply nutrients. • Subsoils are generally alkaline with moderate salinity and sodicity. Field tests indicate potential to be dispersive when disturbed.
D1 (Shallow poplar box duplex sandy loam)	• Sandy clay loam topsoils generally 150 mm deep. • Topsoil material has the potential to be dispersive when disturbed. • Topsoil fertility rating is *low to moderate:* total N: low to moderate; available P: low to moderate; available K: very low to low; and organic carbon: low to moderate. • Texture contrast soils with highly alkaline, sodic, and moderately saline subsoils.
D3v (Gradational sandy loams)	• Deep sandy loam topsoils with neutral pH. • Topsoil fertility is *low*: total N: low; available P: moderate; available K: low; and organic carbon: low. • Field test indicate that the topsoil has the potential to be dispersive when disturbed. • Subsoils are moderately alkaline, moderately saline and sodic.

4.2.2 Potential topsoil recovery depths and volumes

The depth of topsoil stripping and growth media volumes was determined by considering the quality of the soils available to be recovered, and the potential to support PMLUs.

A summary of the topsoil available in undisturbed areas at SSM is provided in table 9.

Table 9: Summary of topsoil depths and volumes available for recovery in undisturbed areas at SSM (Landloch Pty Ltd, 2023).

SPC	Area (Ha)	Topsoil (m)	Volume (m3)	Marginal Topsoil (Limitation)	Volume (m3)
B1	199	**0 – 0.3** Light to medium clay	**597,000**	**0.3 – 0.6 m** Light to medium clay (High alkalinity & ESP)	**597,000**
B2	421	**0 – 0.4** Light to medium clay	**1,684,000**	**0.4 – 0.6** Light to medium clay (Moderate alkalinity & ESP)	**842,000**
D1	410	**0 – 0.1** Sandy clay loam	**410,000**	**Nil** (Very high ESP, Salinity, and ESP)	**0**
D3v	11	**0 – 0.3** Sandy loam	**33,000**	**0.3 – 0.5** Clayey Sand (ESP)	**22,000**

4.3 Spoil materials

From the previous assessments detailed in Section 3.3, spoil material characteristics were found to be heterogeneous within each spoil type and across sampling areas. For this reason, spoil materials are categorised into two management groups which have broad similarities:

- Permian materials; and
- Weathered Tertiary materials.

A summary of key chemical and physical properties is presented in Table 10. Each spoil management group is described in further detail in the following sections.

Table 10: Summary of key chemical and physical properties for spoils at SSM.

Analysis	Permian	Tertiary
Chemical Properties		
pH_w	Neutral to strongly alkaline (6.5 – 9.6, but can be highly acidic)	Moderately acidic to neutral (4.3 – 6.5, but can be strongly alkaline)
$EC_{1:5}$ (dS/m)	Moderate to extreme (0.3 – 2.5)	Low to extreme (0.14 – 2.5)
ANC (H_2SO_4/t)	Low to high (3 – 82)	N/A
Potentially Acid Forming (PAF)	Minor potential to occur	Unlikely
ECEC	Low – adequate	Very low
ESP (%)	Sodic to strongly sodic (10 – 40)	Sodic to strongly sodic (10 – 40). More likely to be extreme
Ca/Mg (ratio)	Very low to adequate (0.3 – 1.7)	Very low (<0.5)

Analysis	Permian	Tertiary
Fertility	Low N, P and K	Very low N, P and K
Physical Properties		
Clay content (%)	25 – 45	35 – 65
Rock content (%)	Up to 74%	10 – 20
Estimated Permeability	Moderate	Low
Dispersion potential	Moderate to high	High to extreme
Dispersion risk	High	Very high

4.3.1 Permian materials

Permian materials at SSM can vary depending on the strata location and degree of weathering. Generally, Permian materials are rocky and consist primarily of sandstone, with clay content in the fine fraction ranging from 25–45% and the coarse rock fraction being up to 75% of the mass of the material. Permian materials have low to moderate water holding capacity. Permeability is likely to increase depending on the volume and composition of rock present. It is generally grey in colour. The material ranges from moderately to highly dispersive and can be saline. A minor proportion is PAF but they present a very low risk for rehabilitation when mixed with the surrounding alkaline materials. Figure 12 is representative of fresh Permian sandstone spoil at SSM.

Of the two spoil management groups, Permian materials 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.

Figure 12: Fresh Permian sandstone material present at the mine. Large-sized, competent rock is present throughout the stockpile.

4.3.2 Weathered Tertiary materials

Weathered Tertiary materials are a highly weathered material containing small portions of fragile (low durability) rock. It has a clay content of 35–65%, resulting in moderate to high water holding capacity. It is typically pale brown to pale orange in colour. The materials are often highly saline and strongly sodic. Compared to Permian materials, the weathered Tertiary material is more susceptible to slaking and dispersion. The is often high variability in the physical nature of this material across SSM (Figure 13).

Figure 13: Weathered Tertiary spoil mixed with weathered Permian spoil stockpiled at the mine.

Placement of this material close to the final rehabilitated surface is not recommended due to its susceptibility to erosion and potential toxicities to plant growth. However, targeted testing may identify suitable Tertiary materials that could potentially be mixed with more competent rock to form a marginal secondary growth medium where required.

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

micronutrients 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 consider the desired PMLU and vegetation. 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 substrate or substrate surrogate. It may be a spoil material that is capped with the primary growth medium (if the spoil is suitable) or may be an intermediate layer of ameliorated spoil placed on unameliorated spoil material and then capped with primary growth media.

The main purpose of the secondary growth medium is to increase the soil water storage capacity of the profile in which the vegetation grows, 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 11.

5.4 Fertiliser and ameliorants

Fertiliser and amelioration rates for spoil materials are dependent on the intended PMLU for a rehabilitated area. For example, cattle grazing requires 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 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 11: Recommended fertiliser and ameliorant treatments for materials and growth media suitability classification.

Material	Limitations	Amendments	Suitability Class	
			Primary (1)	Secondary (2)
Clay soils	• Sometimes strongly alkaline • Often sodic and sometimes dispersive • Susceptible to slaking • Occasionally highly saline • Low N, P, K and Ca • Sometimes low TOC	• 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	1B	2A
Sand and loam soils	• Sometimes sodic and dispersive • Low ability to retain nutrients • Very low N, P, K and TOC • Sometimes low 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	1B	2A
Natural Ground SPCs B1 and B2 topsoil	• Susceptible to slaking	Amendments should be assessed after stripping.	1A	2A
Natural Ground SPCs B1, B2 and D3v upper subsoil	• Sometimes strongly alkaline • Often sodic and sometimes dispersive • Susceptible to slaking	Amendments should be assessed after stripping.	1B	2A
Natural Ground SPC D1 and D3v topsoil	• Susceptible to slaking • Low N and Ca • Sometimes low P, K, S and TOC	Amendments should be assessed after stripping.	1B	2A
Natural Ground SPC D1 upper subsoil	• Sometimes strongly alkaline • Sodic and dispersive • Susceptible to slaking • Sometimes saline	Amendments should be assessed after stripping.	1C/D	2C
Permian materials	• Often strongly alkaline • Occasionally PAF • Moderate to high salinity • Sodic to strongly sodic and dispersive • Rock content up to 75% • Low fertility	• Gypsum: due to heterogeneity between spoil samples, rates should be calculated for broad spoil areas after placement • Bury all saline material to a depth greater than 2 m below the surface	1C/D	2B/C

Material	Limitations	Amendments	Suitability Class	
			Primary (1)	Secondary (2)
		• If to be used as a primary growth media further assessment by an appropriately qualified person is required to determine amelioration required		
Weathered Tertiary materials	• Often highly acidic • Often high salinity • Sodic to strongly sodic and dispersive • Low permeability • Very low fertility • Low ability to retain nutrients	• Most material is not suitable for placement in the upper soil profile Where no alternative is available: • Mix with competent rock. • Gypsum: due to heterogeneity between spoil samples, rates should be calculated for broad spoil areas after placement for rehabilitation. • Bury all saline material to a depth greater than 2 m below the surface.	1D	2C/D

Notes: 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; Class D – Not Suitable: Severe limitations to plant growth.

5.4.1 Fertiliser

A balanced NPK fertiliser such as Crop King (CK) 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 depth at SSM is approximately 610 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, previous soil and spoil assessments, and other SSM project-related documents.

6.1 Soil stockpiles

Generally, the stockpiled soil is considered to be of adequate quality for use as a primary growth media. 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 sodicity and low fertility.

Amelioration of sodicity requires the thorough incorporation of gypsum. Due to the high degree of heterogeneity in measured sodicity within stockpiles, gypsum rates should be calculated for individual stockpiles prior to use in rehabilitation.

It is noted that chemical fertility of the stockpiled soils is quite low. A balanced NPK fertiliser or compost should be applied during rehabilitation to provide a starter source of nutrients for initial vegetation growth. Additional subsequent applications may be required to maintain adequate fertility levels and ensure vegetation is established in the long-term.

Amelioration products and application rates should be assessed by an appropriately qualified person prior to use for rehabilitation and to complement the desired PMLU.

6.2 Spoil materials

Generally, Permian materials have the highest potential to be used as secondary growth media through varying degrees of amelioration. If competent, fresh Permian materials can be reliably sourced, it could be placed in the upper soil profile on sloped areas to reduce erosion potential. Where possible, placement of weathered Tertiary materials in the upper soil profile should be avoided.

Where topsoil availability is limited, a topsoil/Permian 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, this method is recommended to be trialled in select areas to assess chemical and physical properties and the overall viability before being applied to the broader rehabilitation.

Due to the high degree of heterogeneity in the spoil materials, the summarised laboratory data should only be considered a guide to their suitability. Targeted sampling of spoil materials planned for use in the upper soil profile (i.e. primary or secondary growth media) should be conducted prior to rehabilitation.

Chemical fertility of all spoil materials is low and would benefit from an application of a balanced NPK fertiliser or compost if the material is to be covered with less than 30 cm of primary growth media.

6.3 Growth media for PMLU

Physical and chemical properties of the soil and spoil materials available on site meet the requirements to establish the PMLU for rehabilitated areas of cattle grazing, woodland habitat or watercourse. It is recommended that the growth media is 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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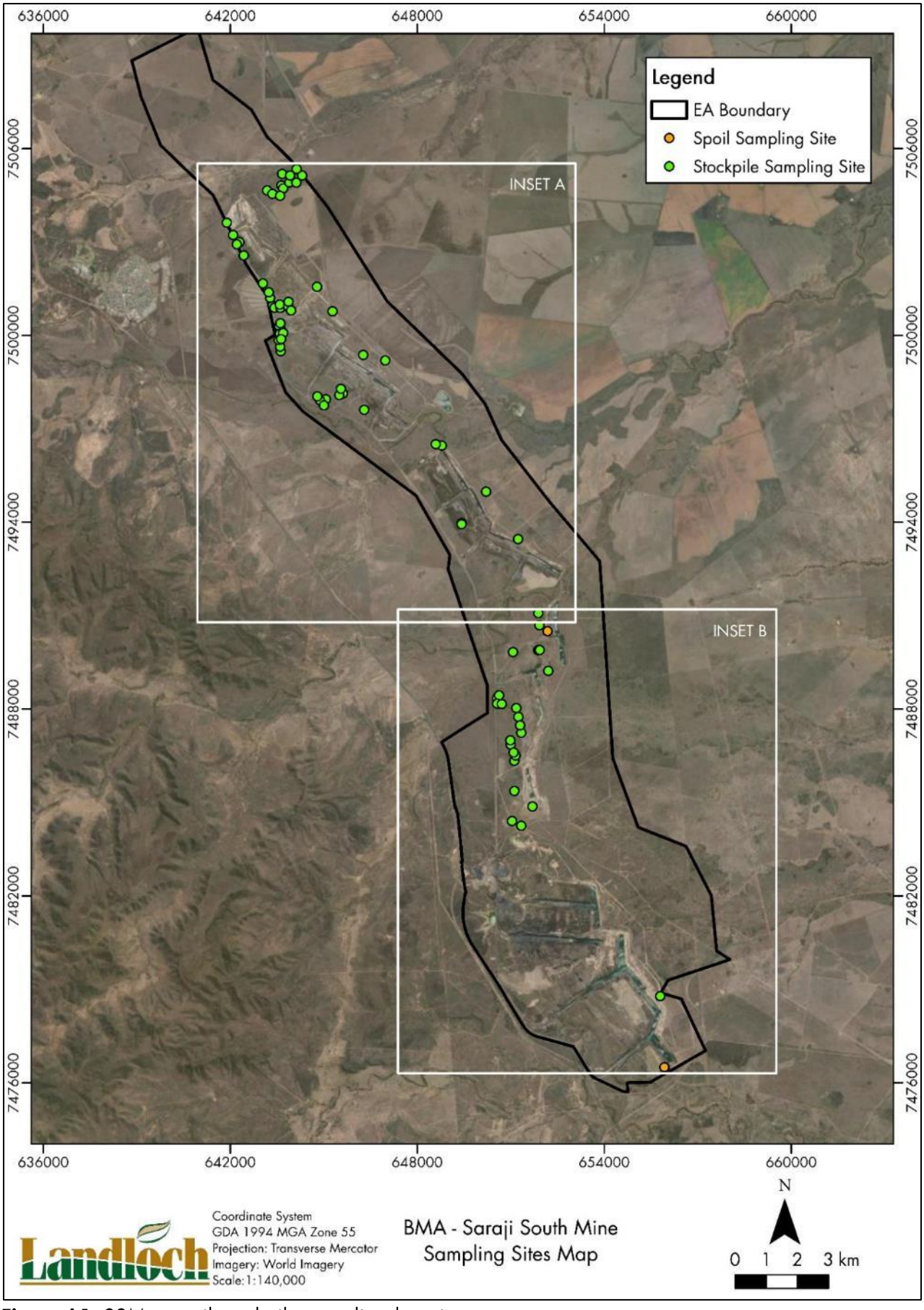

Figure A1: SSM topsoil stockpile sampling locations.

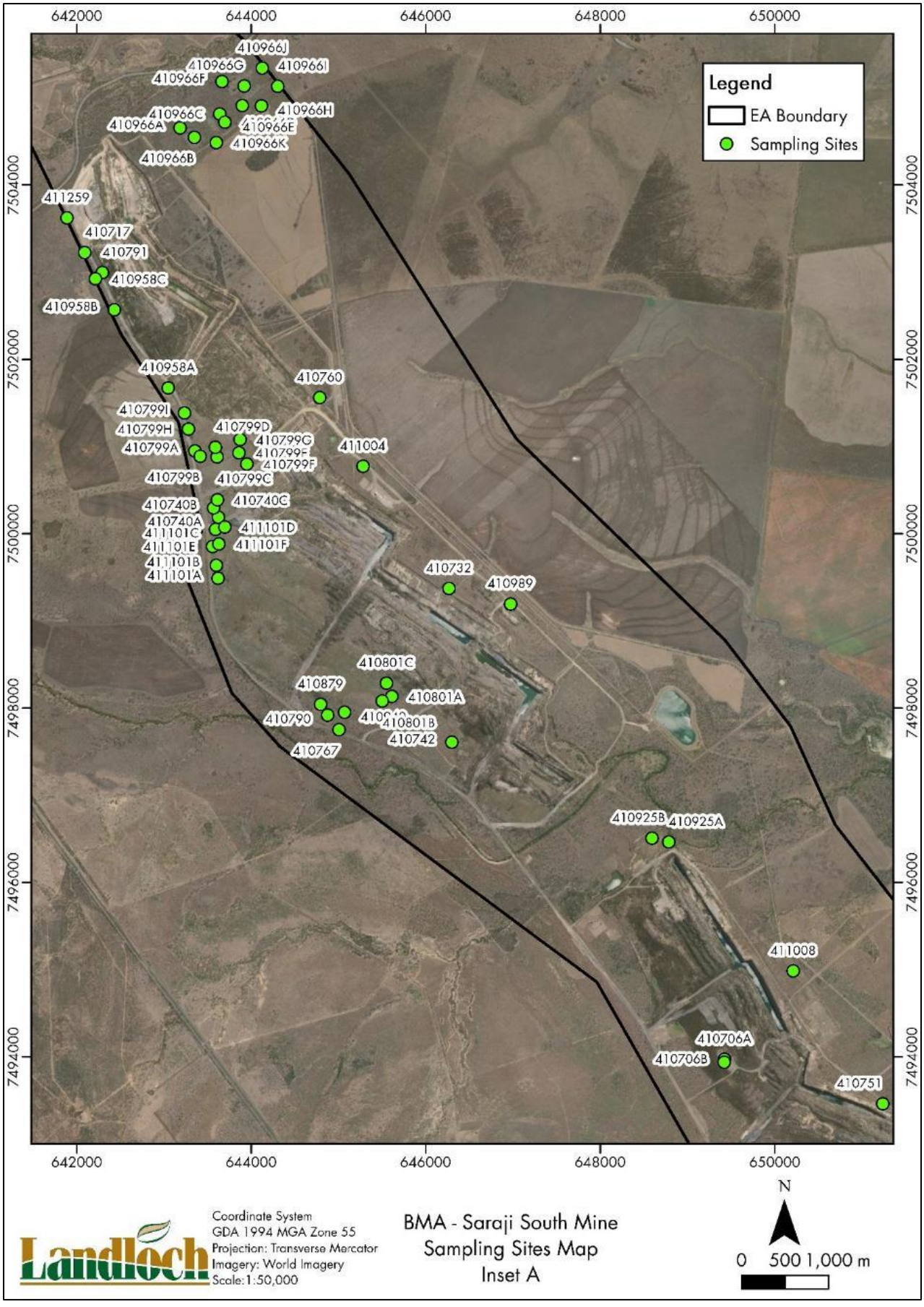

Figure A2: SSM soil stockpile sampling locations in the northern mine area (Insert A).

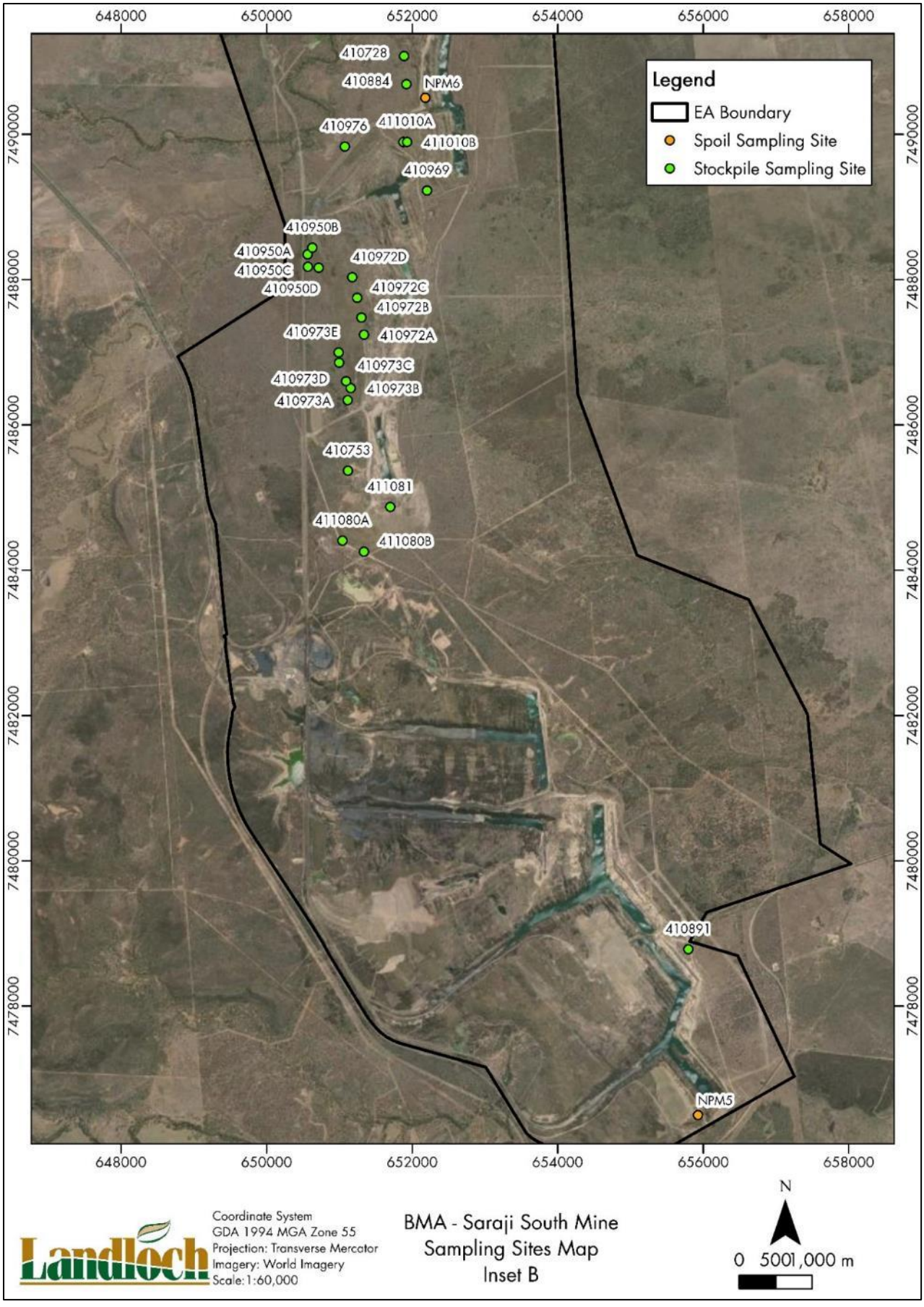

Figure A3: SSM soil stockpile sampling locations in the southern mine area (Insert B).

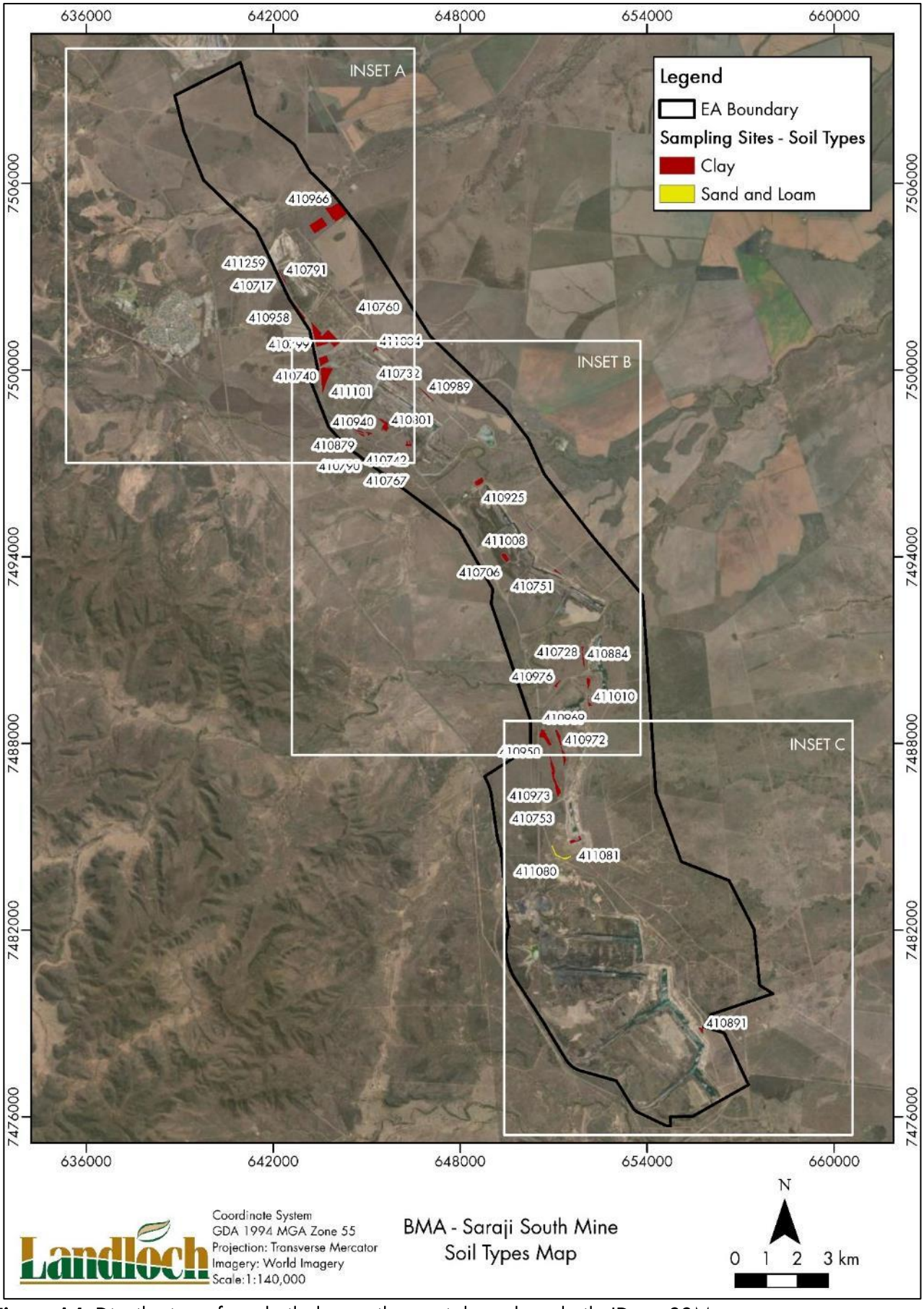

Figure A4: Distribution of stockpiled topsoil materials and stockpile IDs at SSM.

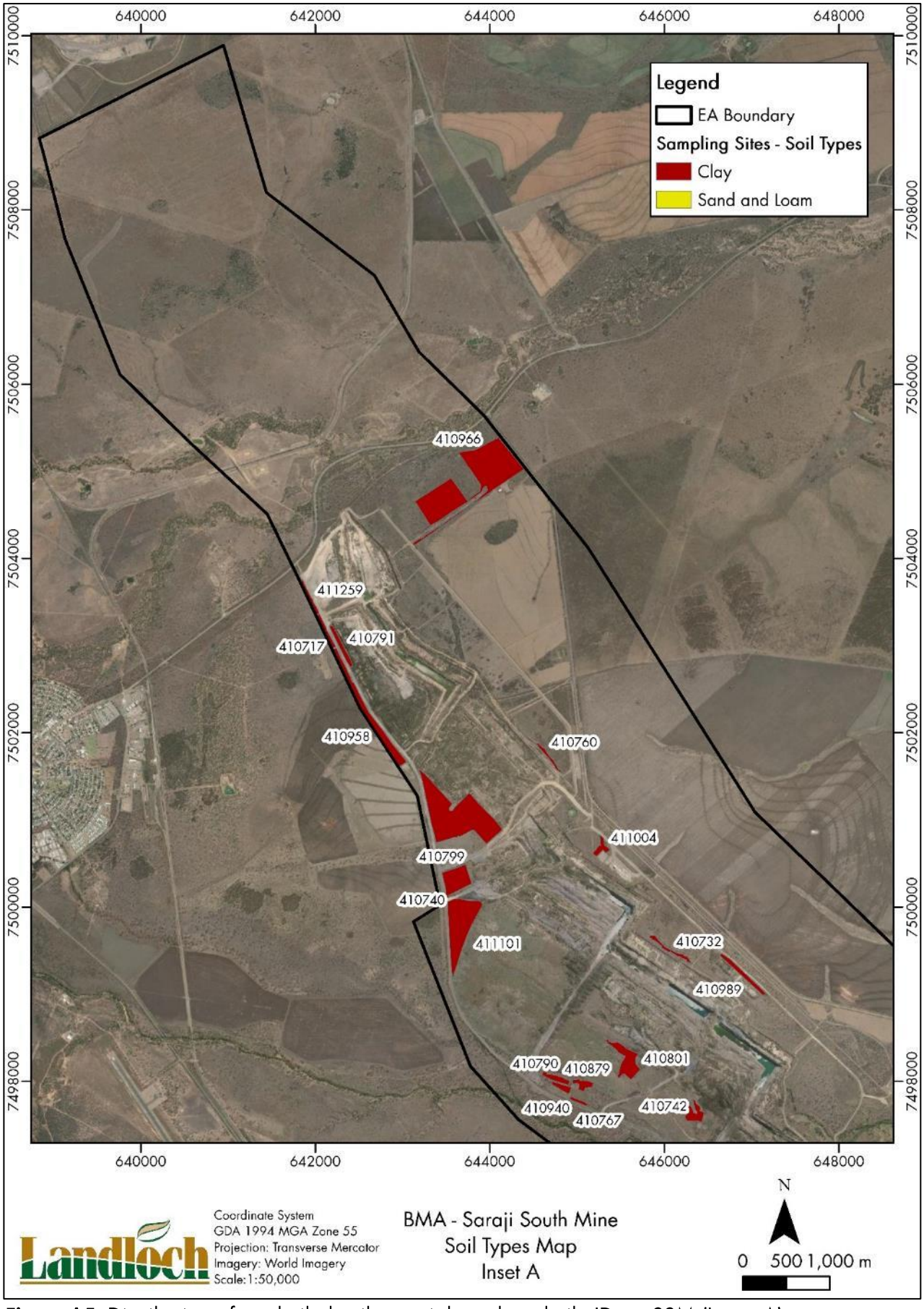

Figure A5: Distribution of stockpiled soil materials and stockpile IDs at SSM (Insert A).

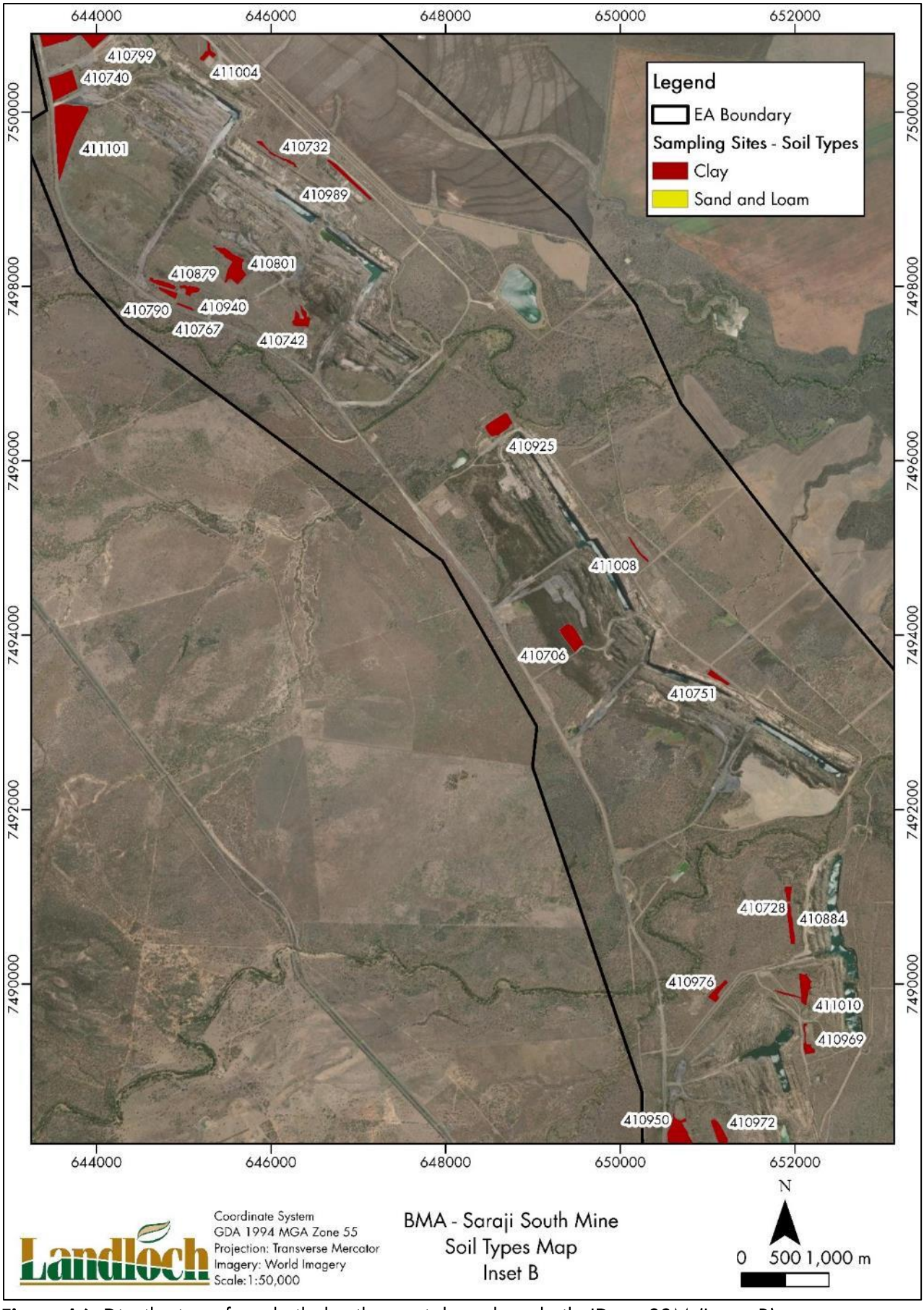

Figure A6: Distribution of stockpiled soil materials and stockpile IDs at SSM (Insert B).

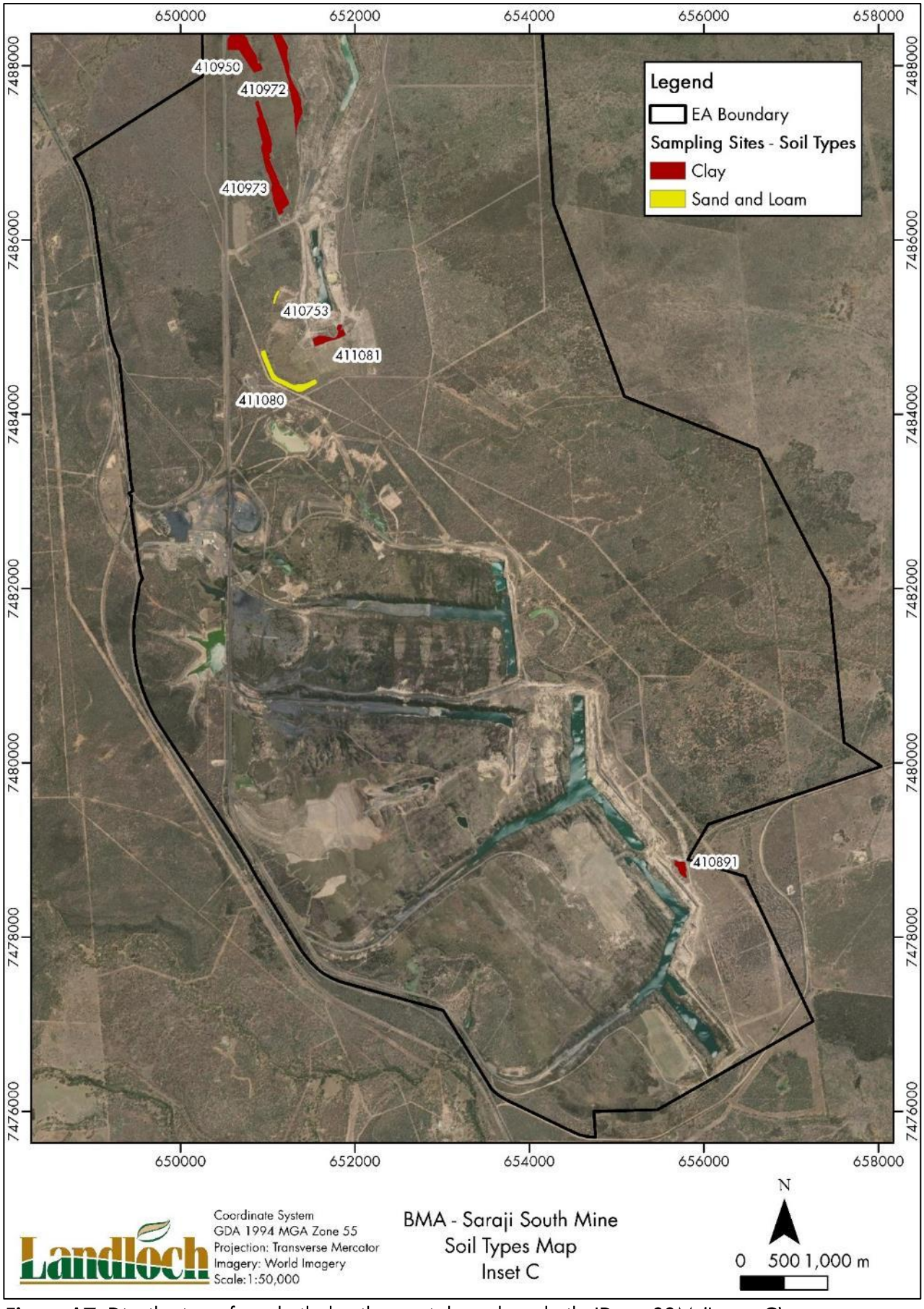

Figure A7: Distribution of stockpiled soil materials and stockpile IDs at SSM (Insert C).

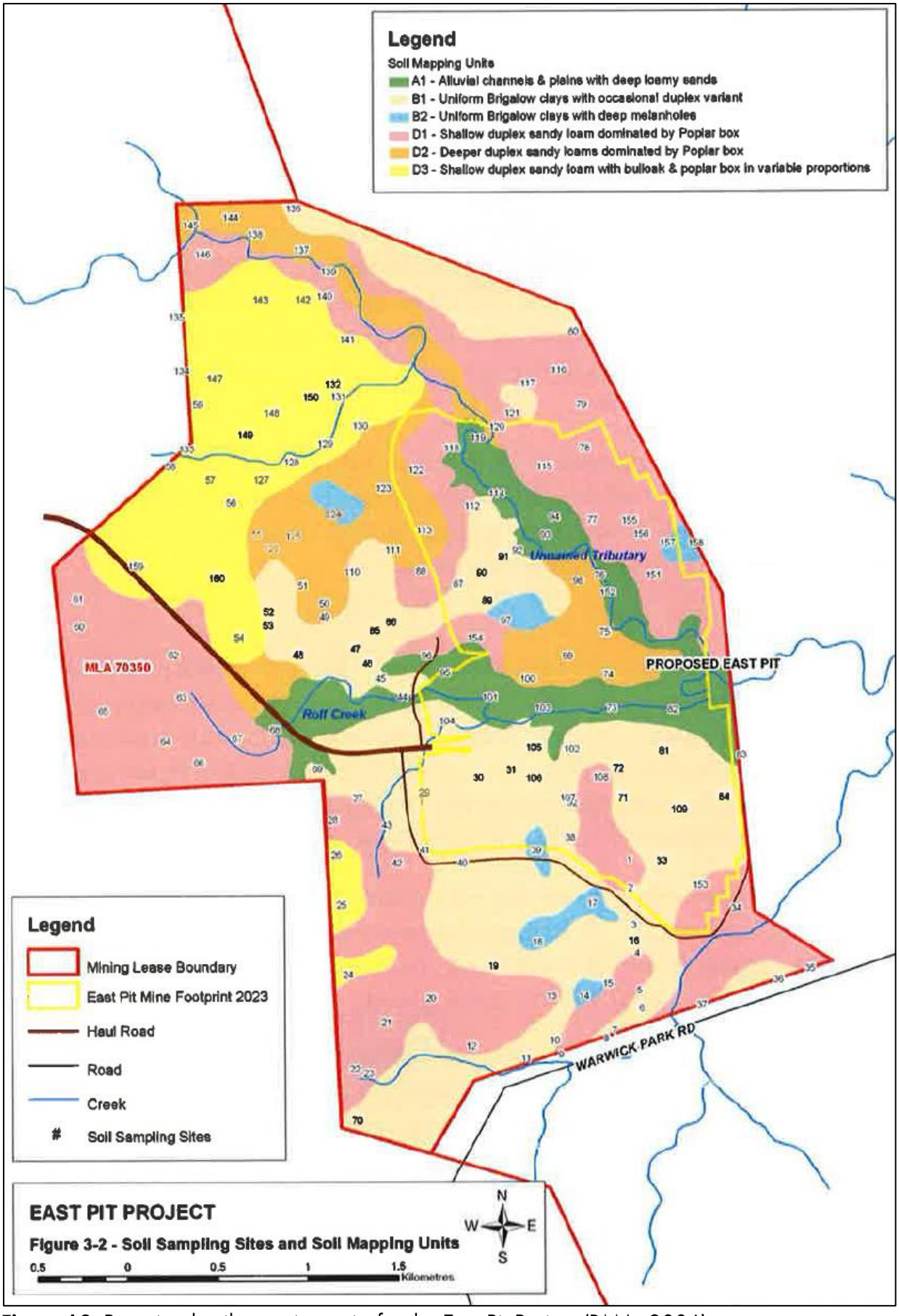

Figure A8: Pre mined soil mapping units for the East Pit Project (BMA, 2006).

Figure A9: Pre mined soil mapping units for the Lotus Pit (Soil Mapping and Monitoring Pty Ltd, 2010).

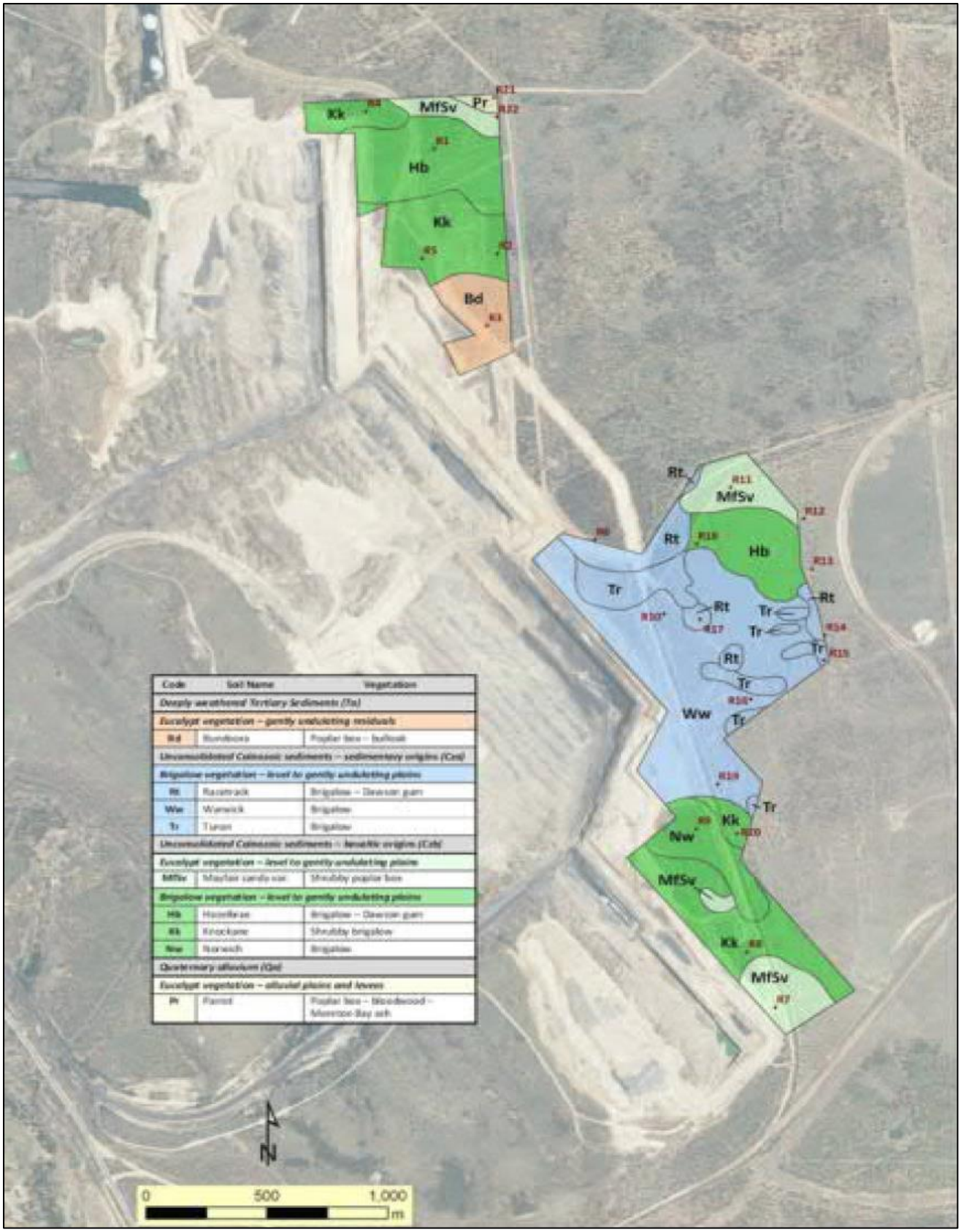

Figure A10: Pre mined soil mapping units for the Roper Pit (Soil Mapping and Monitoring Pty Ltd, 2010)

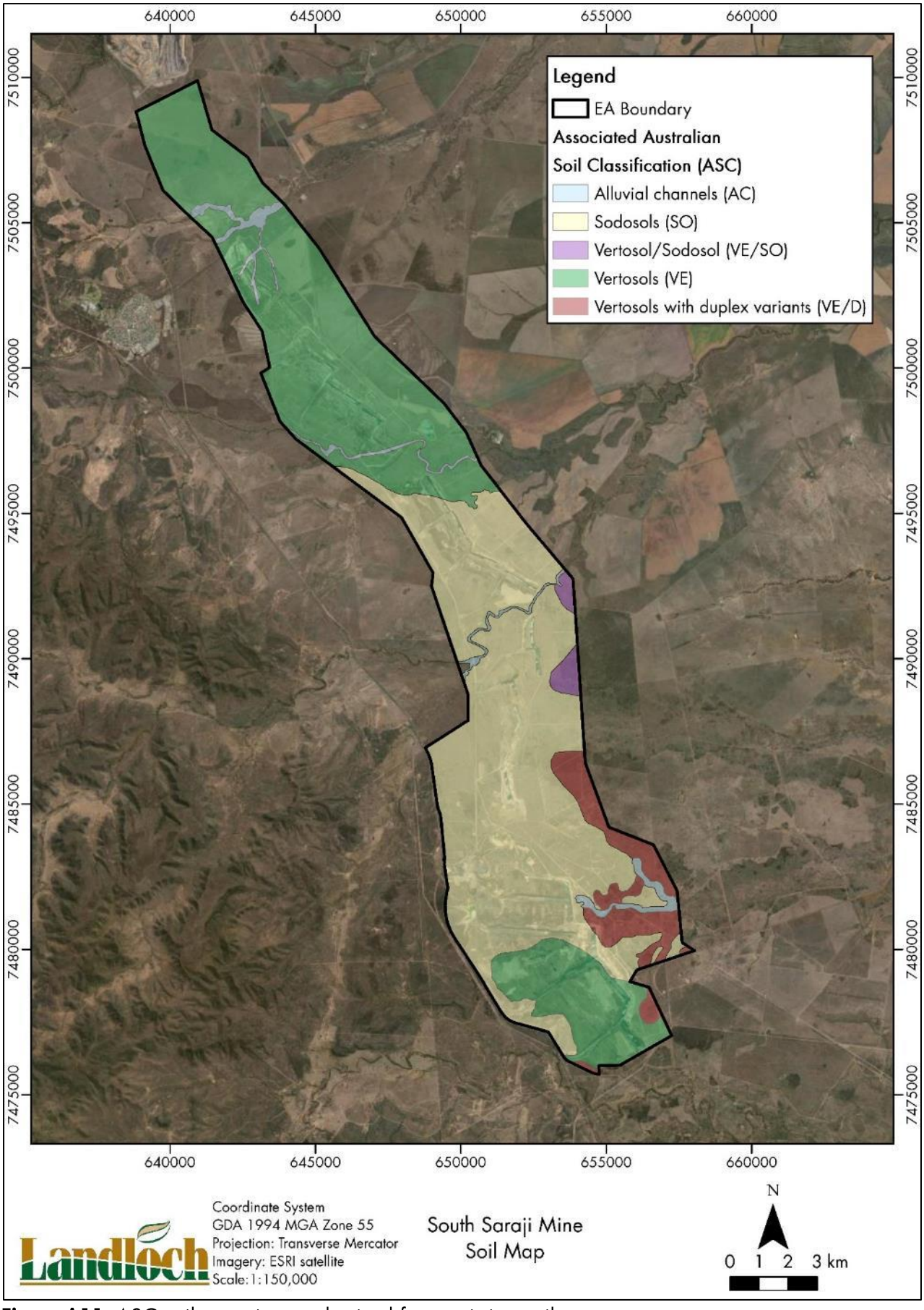

Figure A11: ASC soil mapping synthesised from existing soil assessments.

APPENDIX B: DATA TABLES

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Table B1: Sampling site locations.

Site ID	Type	UTM	Easting	Northing	Latitude	Longitude
410717	Topsoil stockpile	55	642093	7503225	-22.5720005	148.3821044
410728	Topsoil stockpile	55	651889	7491077	-22.68099976	148.4785405
410732	Topsoil stockpile	55	646267	7499371	-22.6060009	148.423056
410940	Topsoil stockpile	55	645070	7497950	-22.61899948	148.4115363
410742	Topsoil stockpile	55	646300	7497608	-22.62199974	148.4235422
410751	Topsoil stockpile	55	651239	7493459	-22.6590004	148.4719855
410760	Topsoil stockpile	55	644785	7501561	-22.58699989	148.408437
410790	Topsoil stockpile	55	644876	7497918	-22.61899948	148.4096584
410791	Topsoil stockpile	55	642294	7502993	-22.5739994	148.3840805
410972D	Topsoil stockpile	55	651179	7488032	-22.70800018	148.4719202
410879	Topsoil stockpile	55	644796	7498042	-22.61800003	148.4088631
410884	Topsoil stockpile	55	651923	7490688	-22.68400002	148.4789076
410891	Topsoil stockpile	55	655798	7478781	-22.79100037	148.517801
410969	Topsoil stockpile	55	652206	7489226	-22.6970005	148.4818051
410973A	Topsoil stockpile	55	651115	7486340	-22.72299957	148.4714669
410989	Topsoil stockpile	55	646973	7499193	-22.6079998	148.4299396
411004	Topsoil stockpile	55	645282	7500773	-22.59399986	148.4133447
411008	Topsoil stockpile	55	650213	7494984	-22.64599991	148.4618532
411080A	Topsoil stockpile	55	651042	7484406	-22.74099922	148.4709432
411259	Topsoil stockpile	55	641890	7503622	-22.56800079	148.3800964
410706A	Topsoil stockpile	55	649426	7493972	-22.65500069	148.4542947
410706B	Topsoil stockpile	55	649422	7493937	-22.65500069	148.4542578
410740A	Topsoil stockpile	55	643625	7500188	-22.59900093	148.397278
410740B	Topsoil stockpile	55	643569	7500295	-22.59799957	148.3967295
410740C	Topsoil stockpile	55	643613	7500387	-22.59700012	148.3971432
410972C	Topsoil stockpile	55	651246	7487749	-22.71100044	148.4726045
410973D	Topsoil stockpile	55	650998	7486857	-22.71899986	148.4702756
410799A	Topsoil stockpile	55	643356	7500950	-22.59199905	148.3945944
410799B	Topsoil stockpile	55	643415	7500888	-22.59300041	148.3951771
410799C	Topsoil stockpile	55	643609	7500881	-22.59300041	148.3970604
410799D	Topsoil stockpile	55	643590	7500991	-22.59199905	148.3968659
410799E	Topsoil stockpile	55	643860	7500928	-22.59199905	148.3994965
410799F	Topsoil stockpile	55	643950	7500799	-22.59399986	148.400387
410799G	Topsoil stockpile	55	643872	7501079	-22.5909996	148.3996034
410799H	Topsoil stockpile	55	643280	7501200	-22.59000015	148.393836
410799I	Topsoil stockpile	55	643237	7501384	-22.58799934	148.3933935
410801A	Topsoil stockpile	55	645613	7498132	-22.61700058	148.4168041
410801B	Topsoil stockpile	55	645503	7498080	-22.61800003	148.4157363
410801C	Topsoil stockpile	55	645551	7498285	-22.61599922	148.4161922
410925A	Topsoil stockpile	55	648786	7496463	-22.63199997	148.4478312
410950A	Topsoil stockpile	55	650565	7488346	-22.70499992	148.4659144
410950B	Topsoil stockpile	55	650629	7488440	-22.70499992	148.4665259
410950C	Topsoil stockpile	55	650569	7488176	-22.70700073	148.4659663
410950D	Topsoil stockpile	55	650716	7488163	-22.70700073	148.4674043
410958A	Topsoil stockpile	55	643048	7501671	-22.58600044	148.391536
410958B	Topsoil stockpile	55	642431	7502568	-22.57799911	148.3854518
410958C	Topsoil stockpile	55	642214	7502922	-22.57500076	148.383311
410966A	Topsoil stockpile	55	643186	7504655	-22.55900002	148.3926025
410966B	Topsoil stockpile	55	643350	7504546	-22.55999947	148.3942132
410966C	Topsoil stockpile	55	643641	7504815	-22.55699921	148.3970134
410966D	Topsoil stockpile	55	643698	7504720	-22.55800056	148.3975797
410966E	Topsoil stockpile	55	643898	7504910	-22.55599976	148.3994998
410966F	Topsoil stockpile	55	643666	7505186	-22.55400085	148.397224
410966G	Topsoil stockpile	55	643920	7505136	-22.55400085	148.399698

Site ID	Type	UTM	Easting	Northing	Latitude	Longitude
410966H	Topsoil stockpile	55	644118	7504907	-22.55599976	148.4016396
410966I	Topsoil stockpile	55	644305	7505132	-22.55400085	148.4034434
410966J	Topsoil stockpile	55	644127	7505341	-22.55200005	148.4016925
410966K	Topsoil stockpile	55	643600	7504485	-22.55999947	148.3966503
410972A	Topsoil stockpile	55	651338	7487242	-22.71500015	148.4735513
410972B	Topsoil stockpile	55	651304	7487477	-22.71299934	148.4731949
410973B	Topsoil stockpile	55	651157	7486506	-22.72200012	148.4718531
410973C	Topsoil stockpile	55	651093	7486602	-22.72100067	148.4712278
411010A	Topsoil stockpile	55	651882	7489894	-22.69099998	148.4785895
411010B	Topsoil stockpile	55	651932	7489895	-22.69099998	148.4790719
411101A	Topsoil stockpile	55	643621	7499488	-22.60499954	148.3973008
411101B	Topsoil stockpile	55	643600	7499637	-22.60400009	148.3970909
411101C	Topsoil stockpile	55	643591	7500049	-22.60000038	148.3969655
411101D	Topsoil stockpile	55	643698	7500077	-22.60000038	148.3979995
411101E	Topsoil stockpile	55	643557	7499853	-22.60199928	148.396648
411101F	Topsoil stockpile	55	643630	7499882	-22.60199928	148.3973578
410973E	Topsoil stockpile	55	650990	7486995	-22.71800041	148.4701871
411081	Topsoil stockpile	55	651701	7484870	-22.73699951	148.4773087
410925B	Topsoil stockpile	55	648595	7496506	-22.63199997	148.4459694
411080B	Topsoil stockpile	55	651340	7484254	-22.74200058	148.4738557
410976	Topsoil stockpile	55	651076	7489830	-22.69199944	148.4707487
410753	Topsoil stockpile	55	651119	7485368	-22.73200035	148.4715973
410767	Topsoil stockpile	55	645007	7497751	-22.62100029	148.4109499

Table B2: Ground observations and surface descriptions.

Site ID	Groundcover	Veg/Litter (%)	Cracks (width)	Cracks (depth)	Stoniness (cover)	Stoniness (size)	Surface Cover
410717	80-100%	100/0	5-10mm	<10mm			Firm
410728			<5mm	<10mm	<2%	2-6mm	Firm
410732		100/0	5-10mm	<10mm			Self Mulching
410940	80-100%	80/20	<5mm	<10mm	<2%	<20mm	Self Mulching
410742	80-100%	80/20					Firm
410751	80-100%	80/20	5-10mm	10-20mm			Crusting
410760	80-100%	100/0	5-10mm	<10mm		<20mm	Self Mulching
410790	80-100%	60/40					Firm
410791	80-100%	100/0			<2%	2-6mm	Firm
410972D	80-100%	80/20					Firm
410879	80-100%	80/20	<5mm	<10mm	<2%	<20mm	Self Mulching
410884	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410891	80-100%	100/0	5-10mm	10-20mm	<2%	2-6mm	Firm
410969	80-100%	80/20					Firm
410973A	80-100%	80/20	5-10mm	<10mm	<2%	<20mm	Crusting
410989	80-100%	100/0			2-10%	<60mm	Firm
411004	80-100%	100/0					
411008	80-100%	80/20					Firm
411080A			<5mm	<10mm	<2%	2-6mm	
411259	80-100%	100/0	5-10mm	<10mm	<2%	2-6mm	Firm
410706A	60-80%	80/20	<5mm	<10mm	<2%	<60mm	Firm
410706B	60-80%	60/40	<5mm	<10mm	<2%	2-6mm	Firm
410740A	80-100%	100/0	5-10mm	<10mm			Firm
410740B		100/0					Firm
410740C	80-100%	80/20					Firm
410972C	80-100%	100/0					Firm
410973D	80-100%	80/20					Firm
410799A	80-100%	80/20	<5mm	<10mm	<2%	2-6mm	Firm
410799B	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799C	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799D	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799E	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799F	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799G	80-100%	0/100	<5mm	<10mm	<2%	2-6mm	Firm
410799H	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410799I	80-100%	100/0	<5mm				Firm
410801A	80-100%	100/0					Firm
410801B			5-10mm	<10mm			Self Mulching
410801C	80-100%	100/0					Soft
410925A	80-100%						Firm
410950A	80-100%	80/20			<2%	2-6mm	Firm
410950B	80-100%	100/0					Firm
410950C	80-100%	100/0				2-6mm	Firm
410950D	80-100%	100/0					Firm
410958A	80-100%	100/0	5-10mm	10-20mm	2-10%	2-6mm	Firm
410958B	80-100%	100/0	5-10mm	<10mm	<2%		Firm
410958C	80-100%	100/0	5-10mm	<10mm	<2%	2-6mm	Firm
410966A	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410966B	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410966C	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Firm
410966D	80-100%	100/0					Firm
410966E	80-100%	100/0					
410966F	80-100%	100/0					Firm
410966G	80-100%	100/0	<5mm	<10mm	<2%	2-6mm	Self Mulching

Site ID	Groundcover	Veg/Litter (%)	Cracks (width)	Cracks (depth)	Stoniness (cover)	Stoniness (size)	Surface Cover
410966H	80-100%	100/0					Firm
410966I	80-100%	100/0					Firm
410966J	80-100%	100/0	5-10mm	<10mm	2-10%	<60mm	Self Mulching
410966K	80-100%	100/0					Soft
410972A	20-40%	60/40	5-10mm	<10mm	50-90%	<200mm	Crusting
410972B	80-100%	100/0	5-10mm	<10mm			Crusting
410973B	80-100%	80/20					
410973C	80-100%	80/20					Firm
411010A	80-100%	100/0	<5mm	<10mm	2-10%	2-6mm	Firm
411010B	80-100%	100/0	<5mm	<10mm	<2%	<20mm	Firm
411101A	80-100%	100/0					Firm
411101B	80-100%	80/20					Firm
411101C	80-100%	100/0	<5mm	<10mm			Firm
411101D	80-100%	100/0					Firm
411101E	80-100%	100/0	<5mm	<10mm			Firm
411101F	80-100%	100/0					Firm
410973E	80-100%	100/0					Firm
411081	20-40%	60/40	5-10mm	<10mm		<2000mm	Crusting
410925B	80-100%	80/20	5-10mm	10-20mm	<2%	2-6mm	Crusting
411080B							
410976					<2%	2-6mm	
410753	80-100%	80/20	5-10mm	<10mm			Firm
410767	80-100%	80/20					Firm

Table B3: Morphological description of stockpiled soil materials.

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
410891	5/09/2022	0.5	LOAM		Light Clay	Grey	Brown		Grab
		1.5	LOAM		Light Clay	Grey	Brown		Grab
		2.5	LOAM		Light Clay	Grey	Brown		Grab
411080A	5/09/2022	0.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
		1.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
		2.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
411080B	5/09/2022	0.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
		1.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
		2.5	SAND		Sandy Loam	Pale Yellow	Pale Brown		Grab
410976	5/09/2022	0.5	CLAY		Medium Heavy Clay	Black	Dark Brown	coarse fragments 2-6 in 1 and 2 (5%). 6-20 in lower depth	Grab
		1.5	CLAY		Medium Heavy Clay	Black	Dark Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Black	Dark Brown		Grab
410728	5/09/2022	0.5	CLAY		Medium Clay	Black			Grab
		1	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Red			Grab
410884	5/09/2022	0.5	CLAY		Medium Heavy Clay	Black	Dark Brown		Grab
		1.5	CLAY		Medium Heavy Clay	Black	Dark Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Black	Dark Brown		Grab
411010A	5/09/2022	0.5	CLAY		Medium Clay	Black	Dark Brown		Grab
		1.5	CLAY		Medium Clay	Black	Dark Brown		Grab
		2.5	CLAY		Medium Clay	Black	Dark Brown		Grab
411010B	5/09/2022	0.5	CLAY		Medium Clay	Black	Dark Brown		Grab
		1.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
410706A	5/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		1.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		2.5	CLAY		Light Medium Clay	Brown	Grey		Grab
410706B	5/09/2022	0.5	CLAY		Medium Clay	Brown	Pale Brown		Grab
		1.5	CLAY		Medium Clay	Brown			Grab
		2.5	CLAY		Medium Clay	Pale Brown	Grey		Grab
410950a	6/09/2022	0.5	CLAY		Light Clay	Brown	Red		Grab
		1.5	CLAY		Light Clay	Brown	Red		Grab
		2.5	CLAY		Light Medium Clay	Brown	Red		Grab
410950b	6/09/2022	0.5	CLAY		Medium Clay	Brown		carbonates	Grab
		1.25	CLAY		Medium Clay	Brown			Grab
		2	CLAY		Medium Clay	Brown			Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
419050c	6/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410950d	6/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Red	carbonates present	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Light Medium Clay	Dark Brown			Grab
411101a	6/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Grey			Grab
		1.5	CLAY		Medium Heavy Clay	Dark Grey			Grab
		2.5	CLAY		Medium Heavy Clay	Dark Grey			Grab
411101b	6/09/2022	0.5	CLAY		Light Clay	Red	Brown	various mix of soil	Grab
		1.5	CLAY		Medium Clay	Dark Grey			Grab
		2.5	CLAY		Medium Heavy Clay	Dark Grey			Grab
411101c	6/09/2022	0.5	CLAY		Light Medium Clay	Dark Grey	Brown		Grab
		1.5	CLAY		Medium Clay	Dark Grey	Brown		Grab
		2.5	CLAY		Medium Clay	Dark Grey	Brown		Grab
411101d	6/09/2022	0.5	CLAY		Medium Clay	Dark Grey	Brown		Grab
		1.5	CLAY		Medium Clay	Dark Grey	Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Grey	Brown		Grab
411101e	6/09/2022	0.5	CLAY		Medium Clay	Brown	Grey		Grab
		1.5	CLAY		Medium Clay	Brown	Grey		Grab
		2.5	CLAY		Medium Clay	Brown	Grey		Grab
411101f	6/09/2022	0.5	CLAY		Medium Clay				Grab
		1.5	CLAY		Light Medium Clay				Grab
		2.5	CLAY		Medium Clay				Grab
410740a	6/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Grey	Small amounts of carbonate	Grab
		1.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
		2	CLAY		Medium Clay	Dark Brown	Grey		Grab
410740b	6/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
		1.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
410740c	6/09/2022	0.5	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410799A	7/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown	Brown		Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown	Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown	Brown		Grab
410799B	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown			Grab
		1.75	CLAY		Medium Clay	Dark Brown			Grab
		2	CLAY		Medium Clay	Brown			Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
410799C	7/09/2022	0.5	CLAY		Medium Clay	Dark Brown		Some carbonates	Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Brown			Grab
410799D	7/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown		compacted at 2 m, but bottom of pile reached.	Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		2	CLAY		Medium Clay	Brown			Grab
410799E	7/09/2022	0.5	CLAY		Medium Heavy Clay	Brown			Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
410799F	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Brown		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Brown		Grab
		2.5	CLAY		Light Medium Clay	Brown	Pale Brown		Grab
410799G	7/09/2022	0.5	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2	CLAY		Medium Clay	Pale Brown			Grab
410799H	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
		2.5	CLAY		Light Medium Clay	Dark Brown	Pale Yellow		Grab
410799I	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		2 pits dug. first not deep enough, ran into material change. data from both pits.	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Light Medium Clay	Dark Brown			Grab
410958A	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		Reached bottom of pile	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Light Medium Clay	Dark Brown			Grab
410958B	7/09/2022	0.5	CLAY		Medium Clay	Dark Brown		Digger restricted at 1.5m. Carbonates present	Grab
		1	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
410958C	7/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		2.5	CLAY		Heavy Clay	Black			Grab
410791	7/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown			Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410717	7/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Brown	Carbonates present	Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
411259	7/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		1.5	CLAY		Medium Clay	Brown	Pale Brown		Grab
		2	CLAY		Medium Clay	Dark Brown			Grab
410966A	8/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown	Carbonates present	Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown		Grab
410966B	8/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown	Carbonates present	Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown	Pale Brown		Grab
410966C	8/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		1.5	CLAY		Medium Clay	Dark Brown	Brown		Grab
		2.5	CLAY		Medium Clay	Black	Dark Brown		Grab
410966D	8/09/2022	0.5	CLAY		Light Clay	Dark Brown	Red		Grab
		1.75	CLAY		Light Medium Clay	Pale Grey			Grab
		2	CLAY		Medium Clay	Dark Brown			Grab
410966e	8/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Pale Brown	Carbonates present in all depth layers	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
410966f	8/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		Carbonates present in all depth layers, (< 2mm diameter).	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410966g	8/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		Carbonates present in all depth layers, (< 2mm diameter).	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410966h	10/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown			Grab
		1.25	CLAY		Light Medium Clay	Dark Brown			Grab
		2	CLAY		Light Medium Clay	Dark Brown			Grab
410966i	10/09/2022	0.5	CLAY	SAND	Sandy Clay Loam	Dark Brown	Pale Red	Small stones present. < 6 mm in diameter and 2% total in top layer (0.5 - 1m)	Grab
		1.5	CLAY	SAND	Sandy Clay Loam	Dark Brown	Pale Red		Grab
		2.5	CLAY	LOAM	Light Clay	Dark Brown	Pale Red		Grab
410966j	10/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		2.5	CLAY	SAND	Light Medium Clay	Dark Brown	Pale Red	Clay was sandy to touch for depth of 2.5 to 3 m	Grab
410966k	10/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		2.5	CLAY	SAND	Light Medium Clay	Brown	Red	Sandy to touch.	Grab
410760	10/09/2022	0.5	CLAY	SAND	Medium Clay	Dark Brown	Pale Red		Grab
		1.5	CLAY	SAND	Medium Clay	Dark Brown	Pale Red		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown	Grey		Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
411004	10/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		Carbonates present throughout all depths.	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		2.5	CLAY		Light Medium Clay	Dark Brown			Grab
410732	10/09/2022	0.5	CLAY		Medium Clay	Dark Brown		Carbonates throughout all depths < 5mm in diameter.	Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410989	10/09/2022	0.5	CLAY		Medium Clay	Dark Brown		Carbonates throughout all depths. < 3mm in diameter.	Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410801a	10/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Grey		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Grey		Grab
		2.5	CLAY		Light Medium Clay	Dark Brown	Grey		Grab
410801b	10/09/2022	0.5	CLAY		Medium Clay	Grey	Brown		Grab
		1.5	CLAY		Medium Clay	Grey	Brown		Grab
		2.5	CLAY		Medium Clay	Grey	Brown		Grab
410801c	10/09/2022	0.5	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY		Medium Clay	Dark Brown			Grab
		2	CLAY		Medium Heavy Clay	Dark Brown			Grab
410742	11/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown		Carbonates throughout all depths. < 3mm in diameter.	Grab
		1l5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		2.5	CLAY		Medium Clay	Dark Brown			Grab
410790	11/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Grey	Carbonates throughout all depths. < 3mm in diameter.	Grab
		1.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
410879	11/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown	Grey	Carbonates throughout all depths. < 3mm in diameter.	Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown	Grey		Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown	Grey		Grab
410940	11/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown	Grey	Very small amount of carbonates 0.5-1m. < 2mm diameter.	Grab
		1.25	CLAY		Medium Heavy Clay	Dark Brown	Grey		Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown	Grey		Grab
410767	11/09/2022	0.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		1.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
		2.5	CLAY		Medium Heavy Clay	Dark Brown			Grab
410925a	11/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Red		Grab
		1.5	CLAY		Medium Clay	Dark Brown	Red		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Grey	Carbonates present in this layer.	Grab
410925b	11/09/2022	0.5	CLAY	SAND	Light Clay	Brown	Red		Grab
		1.5	CLAY	SAND	Light Clay	Brown	Red		Grab
		2.5	CLAY	SAND	Light Clay	Brown	Red		Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
410925c	11/09/2022	0.5	CLAY		Medium Clay	Red	Brown	checks- variable soil in area	Grab
410925d	11/09/2022	0.5	CLAY		Light Medium Clay	Red	Brown	checks- variable soil in area	Grab
411008	11/09/2022	0.5	CLAY		Medium Clay	Dark Brown			Grab
		1.5	CLAY	SAND	Medium Clay	Dark Brown			Grab
		2.5	CLAY	SAND	Light Medium Clay	Dark Brown		Clay was sandy to touch.	Grab
410751	11/09/2022	0.5	CLAY		Medium Heavy Clay	Grey	Dark Brown		Grab
		1.5	CLAY		Heavy Clay	Grey	Dark Brown		Grab
		2.5	CLAY		Heavy Clay	Grey	Dark Brown		Grab
410969	11/09/2022	0.5	CLAY		Light Medium Clay	Brown	Red	Carbonates present throughout all depths.	Grab
		1.5	CLAY		Light Medium Clay	Brown	Red		Grab
		2.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
410973a	11/09/2022	0.5	CLAY		Light Medium Clay	Brown	Red		Grab
		1.5	CLAY		Light Medium Clay	Brown	Red		Grab
		2.5	CLAY		Light Medium Clay	Brown	Red		Grab
410973b	12/09/2022	0.5	CLAY		Light Medium Clay	Brown	Red	Very small amount of carbonates in all depths.	Grab
		1.5	CLAY		Light Medium Clay	Brown	Red	one large rock in this layer.	Grab
		2.5	CLAY		Light Medium Clay	Brown	Grey		Grab
410973c	12/09/2022	0.5	CLAY		Light Clay	Brown	Pale Red	Sandy loam with clay feel. Ribboned to 10mm	Grab
		1.5	CLAY	SAND	Light Clay	Brown	Red		Grab
		2.5	CLAY	SAND	Light Clay	Brown	Red		Grab
410973d	12/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Red	Carbonates in all depths. Less than 2% present in each layer.	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Red		Grab
		2.5	CLAY		Light Medium Clay	Dark Brown	Red		Grab
410973e	12/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown		No stones observed in any depth (layer).	Grab
		1.5	CLAY		Light Medium Clay	Dark Brown			Grab
		2.5	CLAY		Light Medium Clay	Dark Brown			Grab
411081	12/09/2022	0.5	CLAY	LOAM	Clay Loam	Brown	Pale Red		Grab
		1.5	CLAY	LOAM	Clay Loam	Brown	Pale Red		Grab
		2.5	CLAY	LOAM	Clay Loam	Pale Red	Brown		Grab
410972a	12/09/2022	0.5	CLAY		Light Medium Clay	Brown	Pale Red		Grab
		1.5	CLAY		Light Medium Clay	Brown	Pale Red		Grab
		2.5	CLAY		Light Medium Clay	Brown	Pale Red		Grab
410972b.1	12/09/2022	0.5	CLAY		Medium Clay	Dark Brown	Grey	Three 0.5m samples taken at three stockpiles close in proximity	Grab
410972b.2		0.5	CLAY		Medium Clay	Dark Brown	Grey		Grab
410972b.3		0.5	CLAY		Medium Clay	Dark Brown	Grey		Grab

Site ID	Date	Sample Depth (m)	Texture Group 1°	Texture Group 2°	Texture Field	Colour (rapid)		Comments	Sample Type
						Primary	Secondary		
410972c	12/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
		2	CLAY		Light Medium Clay	Dark Brown	Pale Red		Grab
410972d	12/09/2022	0.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
		1.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
		2.5	CLAY		Light Medium Clay	Dark Brown	Pale Brown		Grab
410753	12/09/2022	0.5	LOAM	SAND	Loamy Sand	Pale Brown	Pale Red		Grab
		1.5	LOAM	SAND	Clayey Sand	Pale Brown	Pale Red		Grab
		2 .5	LOAM	CLAY	Medium Clay	Pale Brown	Pale Red		Grab

Table B4: Laboratory analysis data for clay soils. Part 1 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-4		221739-16		221739-20		221739-24		221739-28		221739-32	
	Sample ID	410891		410976		410728		410884		411010A		411010B	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	LMC		LMC		LMC		MC		MC		LMC	
Analyses	**Unit**												
pH - Water	pH units	7.26	*Neutral*	8.62	*H.Alk*	8.69	*H.Alk*	8.72	*H.Alk*	8.13	*M.Alk*	8.15	*M.Alk*
Electrical Conductivity	dS/m	0.16	*L.Sal*	0.11	*VL.Sal*	0.08	*VL.Sal*	0.11	*VL.Sal*	0.27	*M.Sal*	0.19	*L.Sal*
Chloride	mg/kg	32	*VL.Sal*	20	*VL.Sal*	13	*VL.Sal*	41	*VL.Sal*	86	*VL.Sal*	146.0	*L.Sal*
Total Nitrogen - Kjeldahl	mg/kg	1012	*L*	849	*L*	680	*L*	755	*L*	887	*L*	886	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	161	*	134	*	188	*	130	*	250	*	147	*
Phosphorus - Colwell extr	mg/kg	25.2	*L*	7.76	*L*	<5.00	*FALSE*	<5.00	*FALSE*	7.38	*L*	<5.00	*FALSE*
Potassium - Colwell ext	mg/kg	94.7	*VL*	67.9	*VL*	82.0	*VL*	75	*VL*	91	*VL*	62.3	*VL*
Sulphur - KCl	mg/kg	16.5	*H*	6.3	*L*	4.5	*L*	5.2	*L*	13.1	*H*	6.5	*L*
Organic Carbon	%	0.89	*L*	1.17	*M*	0.78	*L*	1.00	*M*	1.21	*M*	1.15	*M*
Copper	mg/kg	0.48	*M*	0.48	*M*	0.78	*M*	0.58	*M*	0.74	*M*	0.66	*M*
Iron	mg/kg	46.6	*	8.4	*	13.6	*	10.40	*	14.50	*	16.70	*
Manganese	mg/kg	10.50	*M*	4.94	*M*	4.4	*M*	3.54	*M*	12.90	*M*	9.62	*M*
Zinc	mg/kg	0.30	*L*	<0.20	*FALSE*	<0.20	*FALSE*	<0.20	*FALSE*	0.34	*L*	<0.20	*FALSE*
Boron	mg/kg	0.29	*VL*	0.77	*L*	0.89	*L*	1.51	*M*	0.39	*VL*	0.75	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	15.0	*M*	31.9	*H*	35.6	*H*	47.8	*VH*	37.8	*H*	42.9	*VH*
Ex Calcium Percent	%	60.51	*L*	56.95	*L*	59.04	*L*	51.38	*L*	55.70	*L*	56.63	*L*
Ex Magnesium Percent	%	31.89	*H*	38.87	*H*	38.01	*H*	44.66	*H*	39.69	*H*	38.71	*H*
Ex Potassium Percent	%	0.41	*L*	0.36	*L*	0.81	*L*	0.37	*L*	0.61	*L*	0.40	*L*
Ex Sodium Percent	%	7.04	*Sodic*	3.75	*N.Sodic*	2.07	*N.Sodic*	3.54	*N.Sodic*	3.93	*N.Sodic*	4.21	*N.Sodic*
Ex Aluminium Percent	%	0.15	*VL*	0.07	*VL*	0.06	*VL*	0.05	*VL*	0.06	*VL*	0.05	*VL*
Exchangeable Calcium	meq/100g	9.08	*M*	18.17	*H*	21.05	*VH*	24.56	*VH*	21.05	*VH*	24.27	*VH*
Exchangeable Magnesium	meq/100g	4.78	*H*	12.40	*VH*	13.55	*VH*	21.35	*VH*	15.00	*VH*	16.59	*VH*
Exchangeable Potassium	meq/100g	0.06	*VL*	0.12	*VL*	0.29	*L*	0.18	*VL*	0.23	*L*	0.17	*VL*
Exchangeable Sodium	meq/100g	1.06	*H*	1.20	*H*	0.74	*H*	1.69	*H*	1.49	*H*	1.80	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.9	*LowCa*	1.5	*LowCa*	1.6	*LowCa*	1.2	*LowCa*	1.4	*LowCa*	1.5	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	7	*Stable*	5	*Slaking*	5	*Slaking*	7	*Stable*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 2 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-36		221739-40		221739-44		221739-48		221739-52		221739-56	
	Sample ID	410706A		410706B		410950a		410950b		419050c		410950d	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	LMC		LMC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.5	*H.Alk*	8.21	*M.Alk*	7.85	*L.Alk*	8.52	*H.Alk*	8.24	*M.Alk*	8.16	*M.Alk*
Electrical Conductivity	dS/m	0.37	*M.Sal*	0.59	*H.Sal*	0.44	*M.Sal*	0.15	*L.Sal*	0.1	*VL.Sal*	0.17	*L.Sal*
Chloride	mg/kg	117.0	*L.Sal*	717.0	*H.Sal*	105	*L.Sal*	27	*VL.Sal*	31	*VL.Sal*	11.4	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	995	*L*	1198	*L*	994	*L*	946	*L*	705	*L*	739	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	185	*	265	*	227	*	239	*	111	*	165	*
Phosphorus - Colwell extr	mg/kg	5.36	*L*	5.42	*L*	<5.00	*FALSE*	7.88	*L*	<5.00	*FALSE*	6.1	*L*
Potassium - Colwell ext	mg/kg	76.5	*VL*	66	*VL*	181	*M*	96	*VL*	86	*VL*	119.0	*VL*
Sulphur - KCl	mg/kg	74.5	*VH*	47.0	*VH*	141.0	*VH*	14.5	*H*	4.0	*L*	6.2	*L*
Organic Carbon	%	1.64	*M*	2.49	*H*	1.51	*M*	1.4	*M*	0.93	*L*	1.1	*M*
Copper	mg/kg	0.47	*M*	0.48	*M*	0.66	*M*	1.28	*M*	1.32	*M*	1.04	*M*
Iron	mg/kg	14.60	*	9.16	*	14.70	*	10.00	*	11.60	*	15.80	*
Manganese	mg/kg	6.67	*M*	4.58	*M*	8.42	*M*	3.12	*M*	5.02	*M*	4.26	*M*
Zinc	mg/kg	0.41	*L*	0.28	*VL*	0.22	*VL*	0.30	*L*	1.90	*M*	0.56	*L*
Boron	mg/kg	0.73	*L*	0.75	*L*	<0.20	*FALSE*	0.69	*L*	1.17	*M*	0.83	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	22.1	*M*	25.4	*H*	49.6	*VH*	57.0	*VH*	48.1	*VH*	46.0	*VH*
Ex Calcium Percent	%	50.44	*L*	45.70	*L*	65.91	*Normal*	62.66	*L*	51.86	*L*	68.18	*Normal*
Ex Magnesium Percent	%	39.97	*H*	45.12	*H*	30.93	*H*	34.92	*H*	45.21	*H*	29.74	*H*
Ex Potassium Percent	%	0.74	*L*	0.59	*L*	0.56	*L*	0.42	*L*	0.33	*L*	0.68	*L*
Ex Sodium Percent	%	8.75	*Sodic*	8.50	*Sodic*	2.56	*N.Sodic*	1.96	*N.Sodic*	2.55	*N.Sodic*	1.35	*N.Sodic*
Ex Aluminium Percent	%	0.10	*VL*	0.09	*VL*	0.04	*VL*	0.04	*VL*	0.05	*VL*	0.05	*VL*
Exchangeable Calcium	meq/100g	11.13	*H*	11.62	*H*	32.68	*VH*	35.74	*VH*	24.92	*VH*	31.36	*VH*
Exchangeable Magnesium	meq/100g	8.82	*VH*	11.47	*VH*	15.33	*VH*	19.92	*VH*	21.73	*VH*	13.68	*VH*
Exchangeable Potassium	meq/100g	0.16	*VL*	0.15	*VL*	0.28	*L*	0.24	*L*	0.16	*VL*	0.31	*M*
Exchangeable Sodium	meq/100g	1.93	*H*	2.16	*VH*	1.27	*H*	1.12	*H*	1.23	*H*	0.62	*M*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.3	*LowCa*	1.0	*LowCa*	2.1	*LowCa*	1.8	*LowCa*	1.1	*LowCa*	2.3	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	4	*Slaking*	5	*Slaking*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 3 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-60		221739-64		221739-68		221739-72		221739-76		221739-80	
	Sample ID	411101a		411101b		411101c		411101d		411101e		411101f	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.31	*M.Alk*	8.27	*M.Alk*	8.08	*M.Alk*	7.79	*L.Alk*	8.28	*M.Alk*	7.83	*L.Alk*
Electrical Conductivity	dS/m	0.2	*L.Sal*	0.21	*L.Sal*	0.18	*L.Sal*	0.18	*L.Sal*	0.21	*L.Sal*	0.38	*M.Sal*
Chloride	mg/kg	67	*VL.Sal*	55.9	*VL.Sal*	32.4	*VL.Sal*	41.5	*VL.Sal*	95	*VL.Sal*	214	*L.Sal*
Total Nitrogen - Kjeldahl	mg/kg	668	*L*	1049	*L*	817	*L*	850	*L*	623	*L*	811	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	122	*	334	*	135	*	164	*	111	*	168	*
Phosphorus - Colwell extr	mg/kg	10.3	*L*	5.36	*L*	5.36	*L*	5.61	*L*	<5.00	*FALSE*	<5.00	*FALSE*
Potassium - Colwell ext	mg/kg	99.7	*VL*	119.0	*VL*	129	*L*	86	*VL*	63	*VL*	114	*VL*
Sulphur - KCl	mg/kg	17.2	*H*	9.3	*M*	17.4	*H*	30.2	*VH*	15.6	*H*	19.0	*H*
Organic Carbon	%	0.99	*L*	1.62	*M*	1.34	*M*	1.26	*M*	1.28	*M*	1.06	*M*
Copper	mg/kg	1.3	*M*	1.24	*M*	1.46	*M*	1.32	*M*	1.18	*M*	1.30	*M*
Iron	mg/kg	20.50	*	17.70	*	25.5	*	24.70	*	17.30	*	16.3	*
Manganese	mg/kg	5.50	*M*	5.74	*M*	9.42	*M*	8.96	*M*	4.78	*M*	4.9	*M*
Zinc	mg/kg	0.62	*L*	0.62	*L*	0.66	*L*	0.66	*L*	0.64	*L*	0.58	*L*
Boron	mg/kg	1.39	*M*	0.83	*L*	0.97	*L*	0.67	*L*	1.41	*M*	1.87	*M*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	46.8	*VH*	55.7	*VH*	41.7	*VH*	45.5	*VH*	48.3	*VH*	50.2	*VH*
Ex Calcium Percent	%	56.15	*L*	69.83	*Normal*	60.33	*L*	61.32	*L*	56.25	*L*	57.85	*L*
Ex Magnesium Percent	%	38.22	*H*	27.83	*H*	35.74	*H*	35.73	*H*	38.36	*H*	36.77	*H*
Ex Potassium Percent	%	0.70	*L*	0.61	*L*	0.78	*L*	0.51	*L*	0.40	*L*	0.65	*L*
Ex Sodium Percent	%	4.89	*N.Sodic*	1.69	*N.Sodic*	3.10	*N.Sodic*	2.38	*N.Sodic*	4.94	*N.Sodic*	4.69	*N.Sodic*
Ex Aluminium Percent	%	0.05	*VL*	0.04	*VL*	0.05	*VL*	0.05	*VL*	0.05	*VL*	0.04	*VL*
Exchangeable Calcium	meq/100g	26.30	*VH*	38.89	*VH*	25.17	*VH*	27.89	*VH*	27.18	*VH*	29.03	*VH*
Exchangeable Magnesium	meq/100g	17.90	*VH*	15.50	*VH*	14.91	*VH*	16.25	*VH*	18.53	*VH*	18.45	*VH*
Exchangeable Potassium	meq/100g	0.33	*M*	0.34	*M*	0.33	*M*	0.23	*L*	0.19	*VL*	0.33	*M*
Exchangeable Sodium	meq/100g	2.29	*VH*	0.94	*H*	1.29	*H*	1.08	*H*	2.39	*VH*	2.35	*VH*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.5	*LowCa*	2.5	*LowCa*	1.7	*LowCa*	1.7	*LowCa*	1.5	*LowCa*	1.6	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 4 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-84		221739-88		221739-92		221739-96		221739-100		221739-104	
	Sample ID	410740a		410740b		410740c		410799A		410799B		410799C	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.21	*M.Alk*	8.46	*M.Alk*	8.36	*M.Alk*	8.26	*M.Alk*	7.75	*L.Alk*	8.47	*M.Alk*
Electrical Conductivity	dS/m	0.14	*L.Sal*	0.2	*L.Sal*	0.13	*L.Sal*	0.12	*L.Sal*	0.11	*VL.Sal*	0.13	*L.Sal*
Chloride	mg/kg	54.3	*VL.Sal*	140.0	*L.Sal*	50	*VL.Sal*	30.7	*VL.Sal*	29.1	*VL.Sal*	47.3	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	739	*L*	614	*L*	658	*L*	772	*L*	984	*L*	823	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	160	*	174	*	134	*	108	*	818	*	760	*
Phosphorus - Colwell extr	mg/kg	6.49	*L*	<5.00	*FALSE*	<5.00	*FALSE*	<5.00	*FALSE*	10.2	*L*	9.3	*L*
Potassium - Colwell ext	mg/kg	69	*VL*	74.3	*VL*	70	*VL*	68.0	*VL*	100	*VL*	72	*VL*
Sulphur - KCl	mg/kg	7.7	*L*	9.0	*M*	6.5	*L*	7.7	*L*	4.7	*L*	7.4	*L*
Organic Carbon	%	1	*M*	0.86	*L*	0.89	*L*	1.29	*M*	1.13	*M*	1.07	*M*
Copper	mg/kg	1.24	*M*	1.22	*M*	1.18	*M*	1.14	*M*	1.24	*M*	1.10	*M*
Iron	mg/kg	16.60	*	13.10	*	16.10	*	15.90	*	18.30	*	13.70	*
Manganese	mg/kg	6.38	*M*	4.9	*M*	5.4	*M*	5.82	*M*	7.62	*M*	4.60	*M*
Zinc	mg/kg	0.60	*L*	0.58	*L*	0.60	*L*	0.58	*L*	0.62	*L*	0.58	*L*
Boron	mg/kg	1.29	*M*	1.65	*M*	1.21	*M*	0.93	*L*	0.81	*L*	1.01	*M*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	50.0	*VH*	54.5	*VH*	53.3	*VH*	49.9	*VH*	72.9	*VH*	56.7	*VH*
Ex Calcium Percent	%	59.48	*L*	56.58	*L*	57.95	*L*	60.32	*L*	59.25	*L*	58.75	*L*
Ex Magnesium Percent	%	36.90	*H*	38.73	*H*	38.96	*H*	36.86	*H*	39.01	*H*	38.29	*H*
Ex Potassium Percent	%	0.46	*L*	0.31	*L*	0.40	*L*	0.36	*L*	0.42	*L*	0.39	*L*
Ex Sodium Percent	%	3.12	*N.Sodic*	4.34	*N.Sodic*	2.66	*N.Sodic*	2.41	*N.Sodic*	1.28	*N.Sodic*	2.54	*N.Sodic*
Ex Aluminium Percent	%	0.04	*VL*	0.04	*VL*	0.04	*VL*	0.04	*VL*	0.03	*VL*	0.04	*VL*
Exchangeable Calcium	meq/100g	29.72	*VH*	30.82	*VH*	30.87	*VH*	30.10	*VH*	43.20	*FALSE*	33.31	*VH*
Exchangeable Magnesium	meq/100g	18.43	*VH*	21.09	*VH*	20.75	*VH*	18.39	*VH*	28.44	*FALSE*	21.71	*VH*
Exchangeable Potassium	meq/100g	0.23	*L*	0.17	*VL*	0.21	*L*	0.18	*VL*	0.31	*M*	0.22	*L*
Exchangeable Sodium	meq/100g	1.56	*H*	2.37	*VH*	1.42	*H*	1.20	*H*	0.93	*H*	1.44	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.6	*LowCa*	1.5	*LowCa*	1.5	*LowCa*	1.6	*LowCa*	1.5	*LowCa*	1.5	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 5 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-108		221739-112		221739-116		221739-120		221739-124		221739-128	
	Sample ID	410799D		410799E		410799F		410799G		410799H		410799I	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		LMC		LMC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.21	*M.Alk*	7.85	*L.Alk*	7.89	*L.Alk*	8.27	*M.Alk*	8.35	*M.Alk*	8.02	*M.Alk*
Electrical Conductivity	dS/m	0.18	*L.Sal*	0.25	*M.Sal*	0.10	*VL.Sal*	0.4	*M.Sal*	0.18	*L.Sal*	0.16	*L.Sal*
Chloride	mg/kg	144.0	*L.Sal*	191.0	*L.Sal*	12.6	*VL.Sal*	589.0	*M.Sal*	88.0	*VL.Sal*	58.3	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	833	*L*	1091	*L*	1456	*L*	400	*VL*	671	*L*	1531	*M*
Total Phosphorus - Nitric/Perchloric	mg/kg	112	*	161	*	226	*	260	*	144	*	130	*
Phosphorus - Colwell extr	mg/kg	6.6	*L*	12.1	*L*	11.9	*L*	8.6	*L*	8.9	*L*	9.3	*L*
Potassium - Colwell ext	mg/kg	85	*VL*	84	*VL*	158	*L*	104	*VL*	72	*VL*	156	*L*
Sulphur - KCl	mg/kg	13.7	*H*	9.9	*M*	8.3	*M*	6.4	*L*	6.7	*L*	11.1	*M*
Organic Carbon	%	1.07	*M*	1.28	*M*	1.58	*M*	0.69	*L*	0.95	*L*	1.48	*M*
Copper	mg/kg	1.14	*M*	0.88	*M*	0.84	*M*	0.84	*M*	0.82	*M*	0.86	*M*
Iron	mg/kg	15.40	*	8.64	*	6.28	*	6.58	*	6.00	*	6.04	*
Manganese	mg/kg	5.06	*M*	1.90	*L*	1.66	*L*	1.48	*L*	1.70	*L*	2.16	*M*
Zinc	mg/kg	0.60	*L*	0.56	*L*	0.58	*L*	0.54	*L*	0.54	*L*	0.58	*L*
Boron	mg/kg	1.47	*M*	1.27	*M*	0.93	*L*	3.15	*H*	1.43	*M*	0.99	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	66.4	*VH*	58.4	*VH*	57.1	*VH*	67.5	*VH*	68.1	*VH*	66.7	*VH*
Ex Calcium Percent	%	53.02	*L*	54.50	*L*	63.26	*L*	44.17	*L*	57.63	*L*	61.00	*L*
Ex Magnesium Percent	%	43.93	*H*	41.80	*H*	34.95	*H*	49.28	*H*	39.49	*H*	36.95	*H*
Ex Potassium Percent	%	0.24	*L*	0.37	*L*	0.78	*L*	0.18	*L*	0.31	*L*	0.65	*L*
Ex Sodium Percent	%	2.77	*N.Sodic*	3.29	*N.Sodic*	0.97	*N.Sodic*	6.33	*Sodic*	2.54	*N.Sodic*	1.37	*N.Sodic*
Ex Aluminium Percent	%	0.03	*VL*	0.04	*VL*	0.04	*VL*	0.03	*VL*	0.03	*VL*	0.03	*VL*
Exchangeable Calcium	meq/100g	35.18	*VH*	31.83	*VH*	36.13	*VH*	29.81	*VH*	39.22	*VH*	40.67	*FALSE*
Exchangeable Magnesium	meq/100g	29.15	*FALSE*	24.42	*FALSE*	19.96	*VH*	33.26	*FALSE*	26.88	*FALSE*	24.63	*FALSE*
Exchangeable Potassium	meq/100g	0.16	*VL*	0.22	*L*	0.45	*M*	0.12	*VL*	0.21	*L*	0.44	*M*
Exchangeable Sodium	meq/100g	1.84	*H*	1.92	*H*	0.56	*M*	4.27	*VH*	1.73	*H*	0.91	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.2	*LowCa*	1.3	*LowCa*	1.8	*LowCa*	0.9	*LowCa*	1.5	*LowCa*	1.7	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 6 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-132		221739-136		221739-140		221739-144		221739-148		221739-152	
	Sample ID	410958A		410958B		410958C		410791		410717		411259	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	LMC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.34	*M.Alk*	7.37	*Neutral*	8	*M.Alk*	8.48	*M.Alk*	7.87	*L.Alk*	8.68	*H.Alk*
Electrical Conductivity	dS/m	0.10	*VL.Sal*	0.12	*L.Sal*	0.09	*VL.Sal*	0.11	*VL.Sal*	0.24	*M.Sal*	0.14	*L.Sal*
Chloride	mg/kg	27.2	*VL.Sal*	20.4	*VL.Sal*	49.9	*VL.Sal*	51.6	*VL.Sal*	172.0	*L.Sal*	21.0	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	720	*L*	739	*L*	736	*L*	794	*L*	816	*L*	780	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	145	*	148	*	102	*	154	*	171	*	149	*
Phosphorus - Colwell extr	mg/kg	10.0	*L*	6.1	*L*	7.6	*L*	6.3	*L*	6.9	*L*	7.3	*L*
Potassium - Colwell ext	mg/kg	79	*VL*	74	*VL*	89	*VL*	90	*VL*	65	*VL*	61	*VL*
Sulphur - KCl	mg/kg	6.8	*L*	7.3	*L*	6.2	*L*	4.0	*VL*	9.9	*M*	7.8	*L*
Organic Carbon	%	1.05	*M*	0.98	*L*	1.59	*M*	0.97	*L*	0.86	*L*	1.04	*M*
Copper	mg/kg	0.86	*M*	0.8	*M*	0.78	*M*	0.8	*M*	0.78	*M*	0.78	*M*
Iron	mg/kg	4.70	*	4.92	*	7.34	*	5.76	*	6.32	*	4.96	*
Manganese	mg/kg	1.46	*L*	1.58	*L*	1.68	*L*	1.70	*L*	1.98	*L*	1.62	*L*
Zinc	mg/kg	0.54	*L*	0.54	*L*	0.54	*L*	0.54	*L*	0.54	*L*	0.54	*L*
Boron	mg/kg	0.99	*L*	1.45	*M*	1.25	*M*	1.69	*M*	1.07	*M*	0.95	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	69.6	*VH*	66.6	*VH*	58.8	*VH*	66.8	*VH*	56.4	*VH*	62.8	*VH*
Ex Calcium Percent	%	55.08	*L*	58.86	*L*	60.63	*L*	54.31	*L*	54.09	*L*	55.89	*L*
Ex Magnesium Percent	%	43.26	*H*	38.62	*H*	36.37	*H*	43.02	*H*	42.41	*H*	41.03	*H*
Ex Potassium Percent	%	0.29	*L*	0.36	*L*	0.28	*L*	0.29	*L*	0.40	*L*	0.29	*L*
Ex Sodium Percent	%	1.34	*N.Sodic*	2.13	*N.Sodic*	2.68	*N.Sodic*	2.36	*N.Sodic*	3.07	*N.Sodic*	2.76	*N.Sodic*
Ex Aluminium Percent	%	0.03	*VL*	0.03	*VL*	0.04	*VL*	0.03	*VL*	0.04	*VL*	0.04	*VL*
Exchangeable Calcium	meq/100g	38.33	*VH*	39.23	*VH*	35.66	*VH*	36.26	*VH*	30.51	*VH*	35.07	*VH*
Exchangeable Magnesium	meq/100g	30.10	*FALSE*	25.73	*FALSE*	21.39	*VH*	28.72	*FALSE*	23.93	*VH*	25.75	*FALSE*
Exchangeable Potassium	meq/100g	0.20	*L*	0.24	*L*	0.17	*VL*	0.19	*VL*	0.22	*L*	0.18	*VL*
Exchangeable Sodium	meq/100g	0.93	*H*	1.42	*H*	1.57	*H*	1.57	*H*	1.73	*H*	1.73	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.3	*LowCa*	1.5	*LowCa*	1.7	*LowCa*	1.3	*LowCa*	1.3	*LowCa*	1.4	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 7 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-156		221739-160		221739-164		221739-168		221739-172		221739-176	
	Sample ID	410966A		410966B		410966C		410966D		410966e		410966f	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.62	*H.Alk*	8.59	*H.Alk*	8.33	*M.Alk*	8.42	*M.Alk*	8.67	*H.Alk*	8.54	*H.Alk*
Electrical Conductivity	dS/m	0.12	*L.Sal*	0.16	*L.Sal*	0.12	*L.Sal*	0.1	*VL.Sal*	0.19	*L.Sal*	0.16	*L.Sal*
Chloride	mg/kg	31.2	*VL.Sal*	15.3	*VL.Sal*	61.6	*VL.Sal*	12.1	*VL.Sal*	78.2	*VL.Sal*	35.9	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	917	*L*	984	*L*	1010	*L*	943	*L*	607	*L*	877	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	150	*	141	*	131	*	90	*	125	*	137	*
Phosphorus - Colwell extr	mg/kg	6.5	*L*	7.2	*L*	6.0	*L*	7.8	*L*	6.9	*L*	6.4	*L*
Potassium - Colwell ext	mg/kg	82	*VL*	79	*VL*	74	*VL*	79	*VL*	86	*VL*	62	*VL*
Sulphur - KCl	mg/kg	7.6	*L*	10.8	*M*	8.7	*M*	5.8	*L*	5.3	*L*	10.8	*M*
Organic Carbon	%	0.96	*L*	1.07	*M*	1.14	*M*	1.32	*M*	0.88	*L*	0.91	*L*
Copper	mg/kg	0.81	*M*	0.82	*M*	0.76	*M*	0.70	*M*	0.76	*M*	0.84	*M*
Iron	mg/kg	6.56	*	6.64	*	5.98	*	4.80	*	6.10	*	5.88	*
Manganese	mg/kg	1.89	*L*	1.88	*L*	1.74	*L*	1.62	*L*	2.06	*M*	1.60	*L*
Zinc	mg/kg	0.57	*L*	0.56	*L*	0.56	*L*	0.54	*L*	0.54	*L*	0.54	*L*
Boron	mg/kg	0.37	*VL*	1.25	*M*	1.19	*M*	<0.20	*FALSE*	1.21	*M*	0.31	*VL*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	58.8	*VH*	55.9	*VH*	54.8	*VH*	50.3	*VH*	66.4	*VH*	62.5	*VH*
Ex Calcium Percent	%	58.67	*L*	59.60	*L*	65.03	*Normal*	71.20	*Normal*	56.85	*L*	60.27	*L*
Ex Magnesium Percent	%	38.77	*H*	36.45	*H*	33.10	*H*	27.65	*H*	39.81	*H*	36.78	*H*
Ex Potassium Percent	%	0.38	*L*	0.41	*L*	0.40	*L*	0.46	*L*	0.27	*L*	0.36	*L*
Ex Sodium Percent	%	2.14	*N.Sodic*	3.50	*N.Sodic*	1.44	*N.Sodic*	0.65	*N.Sodic*	3.04	*N.Sodic*	2.55	*N.Sodic*
Ex Aluminium Percent	%	0.04	*VL*	0.04	*VL*	0.04	*VL*	0.04	*VL*	0.03	*VL*	0.04	*VL*
Exchangeable Calcium	meq/100g	34.52	*VH*	33.33	*VH*	35.66	*VH*	35.83	*VH*	37.78	*VH*	37.65	*VH*
Exchangeable Magnesium	meq/100g	22.81	*VH*	20.38	*VH*	18.15	*VH*	13.92	*VH*	26.45	*FALSE*	22.98	*VH*
Exchangeable Potassium	meq/100g	0.23	*L*	0.23	*L*	0.22	*L*	0.23	*L*	0.18	*VL*	0.23	*L*
Exchangeable Sodium	meq/100g	1.26	*H*	1.96	*H*	0.79	*H*	0.33	*M*	2.02	*VH*	1.59	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.5	*LowCa*	1.6	*LowCa*	2.0	*LowCa*	2.6	*LowCa*	1.4	*LowCa*	1.6	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	5	*Slaking*	4	*Slaking*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 8 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-180		221739-184		221739-188		221739-192		221739-196		221739-200	
	Sample ID	410966g		410966h		410966i		410966j		410966k		410760	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		MC		LMC		LMC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.69	*H.Alk*	8.57	*H.Alk*	8.56	*H.Alk*	8.19	*M.Alk*	8.29	*M.Alk*	8.39	*M.Alk*
Electrical Conductivity	dS/m	0.13	*L.Sal*	0.1	*VL.Sal*	0.14	*L.Sal*	0.13	*L.Sal*	0.13	*L.Sal*	0.21	*L.Sal*
Chloride	mg/kg	8.0	*VL.Sal*	45.0	*VL.Sal*	27.6	*VL.Sal*	5.4	*VL.Sal*	23.0	*VL.Sal*	116.0	*L.Sal*
Total Nitrogen - Kjeldahl	mg/kg	989	*L*	810	*L*	789	*L*	1492	*L*	1359	*L*	1458	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	82	*	195	*	149	*	243	*	236	*	208	*
Phosphorus - Colwell extr	mg/kg	6.0	*L*	8.8	*L*	5.7	*L*	12.2	*L*	6.2	*L*	6.7	*L*
Potassium - Colwell ext	mg/kg	83	*VL*	83	*VL*	90	*VL*	149	*L*	138	*L*	105	*VL*
Sulphur - KCl	mg/kg	9.8	*M*	6.0	*L*	7.0	*L*	6.9	*L*	6.1	*L*	13.4	*H*
Organic Carbon	%	1.21	*M*	0.97	*L*	0.92	*L*	1.51	*M*	1.39	*M*	1.25	*M*
Copper	mg/kg	0.8	*M*	0.76	*M*	0.84	*M*	0.70	*M*	0.74	*M*	0.94	*M*
Iron	mg/kg	5.98	*	5.08	*	4.56	*	5.10	*	16.70	*	14.30	*
Manganese	mg/kg	1.54	*L*	1.58	*L*	1.82	*L*	2.10	*M*	5.94	*M*	8.14	*M*
Zinc	mg/kg	0.54	*L*	0.52	*L*	0.54	*L*	0.62	*L*	0.34	*L*	0.36	*L*
Boron	mg/kg	1.03	*M*	0.81	*L*	1.38	*M*	0.51	*L*	<0.20	*FALSE*	0.39	*VL*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	69.8	*VH*	54.1	*VH*	64.4	*VH*	56.5	*VH*	58.1	*VH*	63.9	*VH*
Ex Calcium Percent	%	63.29	*L*	62.50	*L*	60.40	*L*	69.67	*Normal*	74.37	*Normal*	60.33	*L*
Ex Magnesium Percent	%	33.64	*H*	34.96	*H*	37.14	*H*	28.95	*H*	24.85	*H*	36.39	*H*
Ex Potassium Percent	%	0.31	*L*	0.45	*L*	0.38	*L*	0.65	*L*	0.55	*L*	0.50	*L*
Ex Sodium Percent	%	2.73	*N.Sodic*	2.05	*N.Sodic*	2.04	*N.Sodic*	0.69	*N.Sodic*	0.20	*N.Sodic*	2.75	*N.Sodic*
Ex Aluminium Percent	%	0.03	*VL*	0.04	*VL*	0.03	*VL*	0.04	*VL*	0.04	*VL*	0.03	*VL*
Exchangeable Calcium	meq/100g	44.20	*FALSE*	33.79	*VH*	38.92	*VH*	39.34	*VH*	43.18	*FALSE*	38.58	*VH*
Exchangeable Magnesium	meq/100g	23.49	*VH*	18.90	*VH*	23.93	*VH*	16.34	*VH*	14.43	*VH*	23.27	*VH*
Exchangeable Potassium	meq/100g	0.21	*L*	0.24	*L*	0.24	*L*	0.37	*M*	0.32	*M*	0.32	*M*
Exchangeable Sodium	meq/100g	1.90	*H*	1.11	*H*	1.31	*H*	0.39	*M*	0.11	*L*	1.76	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.9	*LowCa*	1.8	*LowCa*	1.6	*LowCa*	2.4	*LowCa*	3.0	*LowCa*	1.7	*LowCa*
Emerson Aggregate	Class	4	*Slaking*	5	*Slaking*	5	*Slaking*	4	*Slaking*	4	*Slaking*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 9 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-204		221739-208		221739-212		221739-216		221739-220		221739-224	
	Sample ID	411004		410732		410989		410801a		410801b		410801c	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		LMC		LMC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.53	*H.Alk*	8.58	*H.Alk*	8.19	*M.Alk*	8.79	*H.Alk*	8.29	*M.Alk*	8.72	*H.Alk*
Electrical Conductivity	dS/m	0.14	*L.Sal*	0.12	*L.Sal*	0.14	*L.Sal*	0.24	*M.Sal*	0.30	*M.Sal*	0.13	*L.Sal*
Chloride	mg/kg	57.6	*VL.Sal*	21.7	*VL.Sal*	32.9	*VL.Sal*	24.7	*VL.Sal*	283.0	*L.Sal*	19.4	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	1015	*L*	701	*L*	735	*L*	558	*L*	569	*L*	629	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	223	*	175	*	138	*	159	*	111	*	173	*
Phosphorus - Colwell extr	mg/kg	6.1	*L*	7.4	*L*	5.9	*L*	6.6	*L*	<5	*FALSE*	5.5	*L*
Potassium - Colwell ext	mg/kg	92	*VL*	99	*VL*	73	*VL*	100	*VL*	81	*VL*	103	*VL*
Sulphur - KCl	mg/kg	8.6	*M*	16.1	*H*	10.1	*M*	48.6	*VH*	47.2	*VH*	16.0	*H*
Organic Carbon	%	1.06	*M*	0.85	*L*	1.18	*M*	0.89	*L*	0.8	*L*	0.92	*L*
Copper	mg/kg	0.7	*M*	0.80	*M*	0.64	*M*	0.70	*M*	0.8	*M*	1.02	*M*
Iron	mg/kg	11.50	*	9.38	*	9.09	*	14.30	*	12.00	*	16.80	*
Manganese	mg/kg	8.42	*M*	5.44	*M*	7.29	*M*	6.10	*M*	6.26	*M*	7.08	*M*
Zinc	mg/kg	0.30	*L*	0.34	*L*	0.27	*VL*	0.34	*L*	0.30	*L*	2.40	*M*
Boron	mg/kg	1.10	*M*	0.77	*L*	0.87	*L*	1.25	*M*	1.17	*M*	1.11	*M*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	57.0	*VH*	56.5	*VH*	56.7	*VH*	49.2	*VH*	51.6	*VH*	52.3	*VH*
Ex Calcium Percent	%	60.50	*L*	54.91	*L*	53.60	*L*	43.88	*L*	45.36	*L*	49.26	*L*
Ex Magnesium Percent	%	37.00	*H*	41.50	*H*	43.50	*H*	49.12	*H*	47.52	*H*	44.65	*H*
Ex Potassium Percent	%	0.46	*L*	0.49	*L*	0.39	*L*	0.65	*L*	0.53	*L*	0.55	*L*
Ex Sodium Percent	%	2.00	*N.Sodic*	3.06	*N.Sodic*	2.47	*N.Sodic*	6.30	*Sodic*	6.55	*Sodic*	5.50	*N.Sodic*
Ex Aluminium Percent	%	0.04	*VL*	0.04	*VL*	0.04	*VL*	0.05	*VL*	0.04	*VL*	0.04	*VL*
Exchangeable Calcium	meq/100g	34.50	*VH*	31.05	*VH*	30.42	*VH*	21.59	*VH*	23.40	*VH*	25.78	*VH*
Exchangeable Magnesium	meq/100g	21.10	*VH*	23.47	*VH*	24.68	*FALSE*	24.17	*FALSE*	24.52	*FALSE*	23.37	*VH*
Exchangeable Potassium	meq/100g	0.26	*L*	0.28	*L*	0.22	*L*	0.32	*M*	0.27	*L*	0.29	*L*
Exchangeable Sodium	meq/100g	1.14	*H*	1.73	*H*	1.40	*H*	3.10	*VH*	3.38	*VH*	2.88	*VH*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.6	*LowCa*	1.3	*LowCa*	1.2	*LowCa*	0.9	*LowCa*	1.0	*LowCa*	1.1	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	5	*Slaking*	5	*Slaking*	4	*Slaking*	5	*Slaking*	5	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 10 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-228		221739-232		221739-236		221739-240		221739-244		221739-248	
	Sample ID	410742		410790		410879		410940		ID: 410767		410925a	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	MC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.77	*H.Alk*	9.2	*E.Alk*	8.66	*H.Alk*	8.78	*H.Alk*	8.81	*H.Alk*	8.52	*H.Alk*
Electrical Conductivity	dS/m	0.18	*L.Sal*	0.24	*M.Sal*	0.20	*L.Sal*	0.18	*L.Sal*	0.49	*M.Sal*	0.36	*M.Sal*
Chloride	mg/kg	57.6	*VL.Sal*	32.6	*VL.Sal*	65.5	*VL.Sal*	45.1	*VL.Sal*	393.0	*M.Sal*	306.0	*M.Sal*
Total Nitrogen - Kjeldahl	mg/kg	799	*L*	836	*L*	794	*L*	535	*L*	823	*L*	672	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	200	*	260	*	246	*	108	*	321	*	307	*
Phosphorus - Colwell extr	mg/kg	7.1	*L*	10.1	*L*	7.1	*L*	8.0	*L*	7.4	*L*	10.6	*L*
Potassium - Colwell ext	mg/kg	204	*M*	207	*M*	235	*M*	127	*L*	203	*M*	182	*M*
Sulphur - KCl	mg/kg	15.9	*H*	16.0	*H*	25.2	*VH*	9.1	*M*	42.9	*VH*	46.9	*VH*
Organic Carbon	%	1.03	*M*	0.82	*L*	0.9	*L*	0.75	*L*	1.08	*M*	0.78	*L*
Copper	mg/kg	1.04	*M*	1.14	*M*	1.06	*M*	0.8	*M*	1.24	*M*	1.04	*M*
Iron	mg/kg	17.20	*	22.00	*	18.50	*	18.50	*	23.80	*	20.50	*
Manganese	mg/kg	5.76	*M*	7.04	*M*	5.74	*M*	7.48	*M*	6.18	*M*	7.14	*M*
Zinc	mg/kg	0.38	*L*	0.44	*L*	0.36	*L*	0.30	*L*	0.36	*L*	0.40	*L*
Boron	mg/kg	0.77	*L*	0.85	*L*	0.21	*VL*	1.35	*M*	2.67	*H*	1.13	*M*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	61.8	*VH*	39.2	*H*	56.6	*VH*	47.0	*VH*	45.6	*VH*	37.3	*H*
Ex Calcium Percent	%	50.31	*L*	35.70	*L*	54.76	*L*	47.59	*L*	36.60	*L*	52.58	*L*
Ex Magnesium Percent	%	41.24	*H*	50.87	*H*	38.86	*H*	45.90	*H*	49.09	*H*	39.03	*H*
Ex Potassium Percent	%	1.00	*L*	1.24	*Normal*	1.12	*Normal*	0.58	*L*	1.23	*Normal*	1.27	*Normal*
Ex Sodium Percent	%	7.42	*Sodic*	12.13	*Sodic*	5.22	*N.Sodic*	5.88	*N.Sodic*	13.03	*Sodic*	7.06	*Sodic*
Ex Aluminium Percent	%	0.04	*VL*	0.06	*VL*	0.04	*VL*	0.05	*VL*	0.05	*VL*	0.06	*VL*
Exchangeable Calcium	meq/100g	31.08	*VH*	14.01	*H*	31.00	*VH*	22.36	*VH*	16.69	*H*	19.59	*H*
Exchangeable Magnesium	meq/100g	25.48	*FALSE*	19.97	*VH*	21.99	*VH*	21.57	*VH*	22.38	*VH*	14.54	*VH*
Exchangeable Potassium	meq/100g	0.62	*M*	0.49	*M*	0.64	*M*	0.27	*L*	0.56	*M*	0.47	*M*
Exchangeable Sodium	meq/100g	4.59	*VH*	4.76	*VH*	2.95	*VH*	2.76	*VH*	5.94	*VH*	2.63	*VH*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.2	*LowCa*	0.7	*LowCa*	1.4	*LowCa*	1.0	*LowCa*	0.7	*LowCa*	1.3	*LowCa*
Emerson Aggregate	Class	5	*Slaking*	2	*Disp.*	5	*Slaking*	4	*Slaking*	4	*Slaking*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 11 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-252		221739-258		221739-262		221739-266		221739-270		221739-274	
	Sample ID	410925b		411008		410751		410969		410973a		410973b	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	LC		MC		LMC		LMC		LMC		LMC	
Analyses	**Unit**												
pH - Water	pH units	8.72	*H.Alk*	8.70	*H.Alk*	8.68	*H.Alk*	8.13	*M.Alk*	8.74	*H.Alk*	8.81	*H.Alk*
Electrical Conductivity	dS/m	0.15	*L.Sal*	0.16	*L.Sal*	0.81	*H.Sal*	0.21	*L.Sal*	0.40	*M.Sal*	0.19	*L.Sal*
Chloride	mg/kg	77.5	*VL.Sal*	31.2	*VL.Sal*	589.0	*M.Sal*	156.0	*L.Sal*	402.0	*M.Sal*	69.1	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	392	*VL*	826	*L*	530	*L*	921	*L*	650	*L*	521	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	112	*	122	*	213	*	146	*	102	*	101	*
Phosphorus - Colwell extr	mg/kg	7.3	*L*	8.4	*L*	8.1	*L*	7.1	*L*	8.7	*L*	6.5	*L*
Potassium - Colwell ext	mg/kg	88	*VL*	72	*VL*	190	*M*	96	*VL*	27	*VL*	12	*VL*
Sulphur - KCl	mg/kg	12.4	*H*	11.5	*M*	201.0	*VH*	10.3	*M*	16.7	*H*	7.9	*L*
Organic Carbon	%	0.34	*EL*	0.81	*L*	0.56	*VL*	1.09	*M*	0.75	*L*	0.46	*VL*
Copper	mg/kg	0.58	*M*	0.5	*M*	0.95	*M*	0.84	*M*	0.74	*M*	0.42	*M*
Iron	mg/kg	15.60	*	22.60	*	35.60	*	24.30	*	20.50	*	20.10	*
Manganese	mg/kg	7.58	*M*	10.70	*M*	11.10	*M*	11.70	*M*	13.10	*M*	9.70	*M*
Zinc	mg/kg	0.38	*L*	0.46	*L*	0.38	*L*	0.32	*L*	0.32	*L*	0.32	*L*
Boron	mg/kg	0.89	*L*	1.13	*M*	3.31	*H*	0.59	*L*	1.59	*M*	0.87	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	11.2	*L*	21.9	*M*	41.3	*VH*	45.3	*VH*	26.1	*H*	22.0	*M*
Ex Calcium Percent	%	51.51	*L*	58.85	*L*	47.89	*L*	56.02	*L*	40.68	*L*	50.62	*L*
Ex Magnesium Percent	%	35.87	*H*	34.74	*H*	36.15	*H*	40.59	*H*	44.33	*H*	40.78	*H*
Ex Potassium Percent	%	1.76	*Normal*	0.71	*L*	1.27	*Normal*	0.40	*L*	0.27	*L*	0.17	*L*
Ex Sodium Percent	%	10.66	*Sodic*	5.60	*N.Sodic*	14.64	*H.Sodic*	2.94	*N.Sodic*	14.64	*H.Sodic*	8.33	*Sodic*
Ex Aluminium Percent	%	0.20	*VL*	0.10	*VL*	0.05	*VL*	0.05	*VL*	0.09	*VL*	0.10	*VL*
Exchangeable Calcium	meq/100g	5.78	*M*	12.89	*H*	19.79	*H*	25.36	*VH*	10.63	*H*	11.12	*H*
Exchangeable Magnesium	meq/100g	4.03	*H*	7.61	*H*	14.93	*VH*	18.38	*VH*	11.58	*VH*	8.96	*VH*
Exchangeable Potassium	meq/100g	0.20	*VL*	0.16	*VL*	0.53	*M*	0.18	*VL*	0.07	*VL*	0.04	*VL*
Exchangeable Sodium	meq/100g	1.20	*H*	1.23	*H*	6.05	*FALSE*	1.33	*H*	3.83	*VH*	1.83	*H*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	1.4	*LowCa*	1.7	*LowCa*	1.3	*LowCa*	1.4	*LowCa*	0.9	*LowCa*	1.2	*LowCa*
Emerson Aggregate	Class	2	*Disp.*	4	*Slaking*	4	*Slaking*	5	*Slaking*	4	*Slaking*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 12 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-278		221739-282		221739-286		221739-290		221739-294		221739-298	
	Sample ID	410973c		410973d		410973e		411081		410972a		410972b	
	Sample Depth (m)	composite		composite		composite		composite		composite		composite	
	Field Texture	LC		MC		MC		MC		MC		MC	
Analyses	**Unit**												
pH - Water	pH units	8.14	*M.Alk*	8.48	*M.Alk*	7.76	*L.Alk*	9.30	*E.Alk*	8.64	*H.Alk*	9.00	*E.Alk*
Electrical Conductivity	dS/m	0.12	*L.Sal*	0.17	*L.Sal*	0.20	*L.Sal*	0.81	*H.Sal*	0.90	*H.Sal*	0.25	*M.Sal*
Chloride	mg/kg	52.2	*VL.Sal*	60.2	*VL.Sal*	192.0	*L.Sal*	1000.0	*H.Sal*	1480.0	*H.Sal*	101.0	*L.Sal*
Total Nitrogen - Kjeldahl	mg/kg	327	*VL*	2129	*M*	660	*L*	<50	*FALSE*	<50	*FALSE*	270	*VL*
Total Phosphorus - Nitric/Perchloric	mg/kg	100	*	130	*	144	*	694	*	201	*	147	*
Phosphorus - Colwell extr	mg/kg	6.6	*L*	10.4	*L*	9.9	*L*	7.2	*L*	7.6	*L*	5.2	*L*
Potassium - Colwell ext	mg/kg	39	*VL*	18	*VL*	17	*VL*	35	*VL*	17	*VL*	26	*VL*
Sulphur - KCl	mg/kg	8.4	*M*	8.4	*M*	17.8	*H*	11.9	*M*	9.4	*M*	8.8	*M*
Organic Carbon	%	0.4	*VL*	1.29	*M*	0.62	*L*	0.11	*EL*	0.23	*EL*	0.42	*VL*
Copper	mg/kg	0.36	*M*	0.66	*M*	0.6	*M*	0.2	*L*	0.24	*L*	0.48	*M*
Iron	mg/kg	22.80	*	34.00	*	29.10	*	9.00	*	10.30	*	14.30	*
Manganese	mg/kg	9.34	*M*	11.30	*M*	13.00	*M*	2.20	*M*	2.56	*M*	5.12	*M*
Zinc	mg/kg	0.28	*VL*	0.32	*L*	0.34	*L*	0.36	*L*	0.32	*L*	0.28	*VL*
Boron	mg/kg	0.83	*L*	1.19	*M*	0.75	*L*	0.80	*L*	0.61	*L*	2.07	*H*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	14.2	*M*	20.9	*M*	20.0	*M*	45.0	*VH*	34.0	*H*	36.6	*H*
Ex Calcium Percent	%	42.69	*L*	52.36	*L*	50.08	*L*	20.82	*L*	18.80	*L*	40.60	*L*
Ex Magnesium Percent	%	46.24	*H*	39.59	*H*	41.36	*H*	49.35	*H*	51.24	*H*	49.88	*H*
Ex Potassium Percent	%	0.46	*L*	0.18	*L*	0.19	*L*	0.17	*L*	0.09	*L*	0.10	*L*
Ex Sodium Percent	%	10.46	*Sodic*	7.76	*Sodic*	8.26	*Sodic*	29.61	*H.Sodic*	29.80	*H.Sodic*	9.36	*Sodic*
Ex Aluminium Percent	%	0.16	*VL*	0.11	*VL*	0.11	*VL*	0.05	*VL*	0.07	*VL*	0.06	*VL*
Exchangeable Calcium	meq/100g	6.07	*M*	10.97	*H*	10.02	*H*	9.37	*M*	6.40	*M*	14.87	*H*
Exchangeable Magnesium	meq/100g	6.58	*H*	8.29	*VH*	8.28	*VH*	22.21	*VH*	17.43	*VH*	18.27	*VH*
Exchangeable Potassium	meq/100g	0.07	*VL*	0.04	*VL*	0.04	*VL*	0.08	*VL*	0.03	*VL*	0.04	*VL*
Exchangeable Sodium	meq/100g	1.49	*H*	1.63	*H*	1.65	*H*	13.33	*FALSE*	10.14	*FALSE*	3.43	*VH*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*	0.02	*VH*
Calcium/Magnesium Ratio	-	0.9	*LowCa*	1.3	*LowCa*	1.2	*LowCa*	0.4	*P.Unstab*	0.4	*P.Unstab*	0.8	*LowCa*
Emerson Aggregate	Class	2	*Disp.*	3b	*Slight Disp*	5	*Slaking*	2	*Disp.*	2	*Disp.*	4	*Slaking*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B4: Laboratory analysis data for clay soils. Part 13 of 13.

TABLE B4. Laboratory Results ALL SITES													
	Lab No	221739-302		221739-306		**Mean**		**10%ile**		**90%ile**		**Min**	**Max**
	Sample ID	410972c		410972d									
	Sample Depth (m)	composite		composite									
	Field Texture	MC		LMC									
Analyses	**Unit**												
pH - Water	pH units	9.04	*E.Alk*	8.36	*M.Alk*	*8.4*	*M.Alk*	*7.9*	*L.Alk*	*8.8*	*H.Alk*	*7.3*	*9.3*
Electrical Conductivity	dS/m	0.28	*M.Sal*	0.14	*L.Sal*	*0.22*	*M.Sal*	*0.11*	*L.Sal*	*0.39*	*M.Sal*	*0.08*	*0.90*
Chloride	mg/kg	59.5	*VL.Sal*	37.9	*VL.Sal*	*132*	*L.Sal*	*19*	*VL.Sal*	*299*	*L.Sal*	*5*	*1480*
Total Nitrogen - Kjeldahl	mg/kg	263	*VL*	601	*L*	*828*	*L*	*537*	*L*	*1087*	*L*	*263*	*2129*
Total Phosphorus - Nitric/Perchloric	mg/kg	386	*	89	*	*193*	*	*108*	*	*264*	*	*82*	*818*
Phosphorus - Colwell extr	mg/kg	7.9	*L*	5.6	*L*	*8*	*L*	*6*	*L*	*10*	*L*	*5*	*25*
Potassium - Colwell ext	mg/kg	41	*VL*	49	*VL*	*92*	*VL*	*39*	*VL*	*157*	*L*	*12*	*235*
Sulphur - KCl	mg/kg	14.9	*H*	6.4	*L*	*18.05*	*H*	*6.04*	*L*	*39.09*	*VH*	*3.95*	*201.00*
Organic Carbon	%	0.65	*L*	0.79	*L*	*1.02*	*M*	*0.63*	*L*	*1.46*	*M*	*0.11*	*2.49*
Copper	mg/kg	0.42	*M*	0.68	*M*	*0.84*	*M*	*0.48*	*M*	*1.24*	*M*	*0.20*	*1.46*
Iron	mg/kg	13.30	*	17.60	*	*14*	*	*6*	*	*24*	*	*5*	*47*
Manganese	mg/kg	4.32	*M*	7.10	*M*	*5.50*	*M*	*1.63*	*L*	*10.26*	*M*	*1.46*	*13.10*
Zinc	mg/kg	0.44	*L*	0.30	*L*	*0.51*	*L*	*0.30*	*L*	*0.62*	*L*	*0.22*	*2.40*
Boron	mg/kg	1.07	*M*	1.37	*M*	*1.10*	*M*	*0.59*	*L*	*1.59*	*M*	*0.21*	*3.31*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	*	*	*	*	*	*	*	*
Cation Exchange Capacity	meq/100g	40.7	*VH*	41.0	*VH*	*48.6*	*VH*	*23.1*	*M*	*66.6*	*VH*	*11.2*	*72.9*
Ex Calcium Percent	%	36.85	*L*	50.01	*L*	*54.5*	*L*	*43.0*	*L*	*63.3*	*L*	*18.8*	*74.4*
Ex Magnesium Percent	%	52.15	*H*	46.21	*H*	*39.7*	*H*	*33.3*	*H*	*48.6*	*H*	*24.8*	*52.2*
Ex Potassium Percent	%	0.19	*L*	0.27	*L*	*0.5*	*L*	*0.2*	*L*	*0.8*	*L*	*0.1*	*1.8*
Ex Sodium Percent	%	10.76	*Sodic*	3.45	*N.Sodic*	*5.2*	*N.Sodic*	*1.4*	*N.Sodic*	*10.6*	*Sodic*	*0.2*	*29.8*
Ex Aluminium Percent	%	0.05	*VL*	0.05	*VL*	*0.1*	*VL*	*0.0*	*VL*	*0.1*	*VL*	*0.0*	*0.2*
Exchangeable Calcium	meq/100g	15.02	*H*	20.53	*VH*	*27.0*	*VH*	*11.0*	*H*	*38.9*	*VH*	*5.8*	*44.2*
Exchangeable Magnesium	meq/100g	21.25	*VH*	18.97	*VH*	*19.2*	*VH*	*9.7*	*VH*	*25.7*	*FALSE*	*4.0*	*33.3*
Exchangeable Potassium	meq/100g	0.08	*VL*	0.11	*VL*	*0.2*	*L*	*0.1*	*VL*	*0.4*	*M*	*0.0*	*0.6*
Exchangeable Sodium	meq/100g	4.38	*VH*	1.42	*H*	*2.2*	*VH*	*0.9*	*H*	*4.1*	*VH*	*0.1*	*13.3*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	*0.0*	*VH*	*0.0*	*VH*	*0.0*	*VH*	*0.0*	*0.0*
Calcium/Magnesium Ratio	-	0.7	*LowCa*	1.1	*LowCa*	*1.4*	*LowCa*	*0.9*	*	*1.9*	*	*0.4*	*3.0*
Emerson Aggregate	Class	3b	*Slight Disp*	5	*Slaking*	*	*	*	*	*	*	*	*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Table B5: Laboratory analysis data for sand and loam soils.

TABLE B5. Laboratory Resul ALL SITES															
	Lab No	221739-310		221739-8		221739-12		**Mean**		**10%ile**		**90%ile**		**Min**	**Max**
	Sample ID	410753		411080A		411080B									
	Sample Depth (m)	composite		composite		composite									
	Field Texture	SCL		LS		LS									
Analyses	**Unit**														
pH - Water	pH units	7.43	*L.Alk*	6.60	*Neutral*	6.75	*Neutral*	*6.9*	*Neutral*	*6.6*	*Neutral*	*6.7*	*Neutral*	*6.6*	*6.8*
Electrical Conductivity	dS/m	0.05	*VL.Sal*	0.04	*VL.Sal*	0.02	*VL.Sal*	*0.04*	*VL.Sal*	*0.02*	*VL.Sal*	*0.04*	*VL.Sal*	*0.02*	*0.04*
Chloride	mg/kg	32.9	*VL.Sal*	15.7	*VL.Sal*	7.0	*VL.Sal*	*19*	*VL.Sal*	*8*	*VL.Sal*	*15*	*VL.Sal*	*7*	*16*
Total Nitrogen - Kjeldahl	mg/kg	71	*VL*	289.0	*VL*	263	*VL*	*208*	*VL*	*266*	*VL*	*286*	*VL*	*263*	*289*
Total Phosphorus - Nitric/Perchloric	mg/kg	63	*	81.0	*	52	*	*65*	*	*55*	*	*78*	*	*52*	*81*
Phosphorus - Colwell extr	mg/kg	5.7	*L*	5.9	*L*	<5.00	*FALSE*	*6*		*6*		*6*		*6*	*6*
Potassium - Colwell ext	mg/kg	46	*VL*	171.00	*H*	114	*L*	*110*		*120*		*165*		*114*	*171*
Sulphur - KCl	mg/kg	<3.00	*VH*	3.4	*VL*	<3.00	*VH*	*3.41*	*VL*	*3.41*	*VL*	*3.41*	*VL*	*3.41*	*3.41*
Organic Carbon	%	0.15	*EL*	0.45	*VL*	0.31	*EL*	*0.30*	*EL*	*0.32*	*EL*	*0.44*	*VL*	*0.31*	*0.45*
Copper	mg/kg	0.42	*M*	0.26	*L*	0.34	*M*	*0.34*	*M*	*0.27*	*L*	*0.33*	*M*	*0.26*	*0.34*
Iron	mg/kg	24.80	*	33.90	*	11.10	*	*23*	*	*13*	*	*32*	*	*11*	*34*
Manganese	mg/kg	5.12	*M*	5.02	*M*	4.22	*M*	*4.79*	*M*	*4.30*	*M*	*4.94*	*M*	*4.22*	*5.02*
Zinc	mg/kg	0.28	*VL*	<0.20	*FALSE*	0.90	*M*	*0.59*	*M*	*0.90*	*M*	*0.90*	*M*	*0.90*	*0.90*
Boron	mg/kg	0.37	*VL*	<0.20	*FALSE*	<0.20	*FALSE*	*0.37*	*VL*	*#NUM!*	*#NUM!*	*#NUM!*	*#NUM!*	*0.00*	*0.00*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	*	*	*	*	*	*	*	*
Cation Exchange Capacity	meq/100g	3.6	*VL*	2.8	*VL*	2.6	*VL*	*3.0*	*VL*	*2.6*	*VL*	*2.8*	*VL*	*2.6*	*2.8*
Ex Calcium Percent	%	45.50	*L*	69.90	*Normal*	65.10	*Normal*	*60.2*	*L*	*65.6*	*Normal*	*69.4*	*Normal*	*65.1*	*69.9*
Ex Magnesium Percent	%	41.05	*H*	15.48	*H*	24.37	*H*	*27.0*	*H*	*16.4*	*H*	*23.5*	*H*	*15.5*	*24.4*
Ex Potassium Percent	%	2.58	*Normal*	9.77	*H*	5.74	*H*	*6.0*	*H*	*6.1*	*H*	*9.4*	*H*	*5.7*	*9.8*
Ex Sodium Percent	%	10.25	*Sodic*	4.0	*N.Sodic*	3.91	*N.Sodic*	*6.1*	*Sodic*	*3.9*	*N.Sodic*	*4.0*	*N.Sodic*	*3.9*	*4.0*
Ex Aluminium Percent	%	0.62	*VL*	0.80	*VL*	0.87	*VL*	*94.1*	*FALSE*	*0.8*	*VL*	*0.9*	*VL*	*0.8*	*0.9*
Exchangeable Calcium	meq/100g	1.64	*VL*	1.95	*VL*	1.67	*VL*	*1.7*	*VL*	*1.7*	*VL*	*1.9*	*VL*	*1.7*	*1.9*
Exchangeable Magnesium	meq/100g	1.48	*M*	0.43	*L*	0.62	*L*	*0.8*	*L*	*0.5*	*L*	*0.6*	*L*	*0.4*	*0.6*
Exchangeable Potassium	meq/100g	0.09	*VL*	0.27	*L*	0.15	*VL*	*0.2*	*VL*	*0.2*	*VL*	*0.3*	*L*	*0.1*	*0.3*
Exchangeable Sodium	meq/100g	0.37	*M*	0.11	*L*	0.10	*L*	*0.2*	*L*	*0.1*	*L*	*0.1*	*L*	*0.1*	*0.1*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.02	*VH*	0.02	*VH*	*0.0*	*VH*	*0.0*	*VH*	*0.0*	*VH*	*0.0*	*0.0*
Calcium/Magnesium Ratio	-	1.1	*LowCa*	4.5	*Balanced*	2.7	*LowCa*	*2.8*	*LowCa*	*2.9*	*	*4.3*	*	*2.7*	*4.5*
Emerson Aggregate	Class	3b	*Slight Disp*	3b	*Slight Disp*	3b	*Stable*	*	*	*	*	*	*	*	*

	Highly acidic		Extremely alkaline		High salinity		Sodic		Strongly sodic

Saraji South Mine (SSM) 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, community and economic development and rehabilitation planning. BMA holds a project-wide Native Title Project Agreement with BBAC on behalf of Barada Barna peoples. The Agreement was signed in August 2024. This includes meetings and correspondence through the BBAC-BMA Relationship Committee and regular Barada Barna & BMA Closure Planning Working Group meetings. Businesses owned by BBAC and/ or their members are currently involved in rehabilitation works at BMA.	Letter, via email to BBAC Chair	4/07/2024	Queensland Government requirements for mine rehabilitation and closure planning PRCP inclusions Asset location Environmental Authority held for SSM PRCP submission date Mining leases within the EA area and approved activities (open cut coal mining) 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 Inclusion of voids as non-use management areas Commitment to future engagement in PRC planning Invitation to seek information or discussion about PRCP Contacts for further information	No issues raised, 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 & Barada Barna Aboriginal Corporation Indigenous Land Use 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 ILUA. Barada Barna People's interest in environmental management and mine rehabilitation will be progressed as part of ongoing engagement with them.	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.
Local Government	Mayor and Councillors CEO Executive Manager of Advocacy and External Affairs Manager Galilee and Bowen Basin Operations	Isaac Regional Council	BMA has regular meetings with Council, and meets with Councillors and officers as needed on specific issues. BMA has provided briefings and updates to Council on the PRCPs for each BMA asset.	Letter to stakeholders provided to Council, via email	21/06/2024	As above	No enquiries received or issues raised following the PRCP letter. Issues discussed during previous meetings with IRC have identified the key principal is cooperation to get the best outcome for communities, industry and Council. Interest in rehabilitation. Potential innovative approach to end of life and long term futures post mining.	Engagement processes for the PRCP are based on a strategic approach to consultation with Council, to minimise demands on Council's time and maximise the value derived from consultation.	IRC will require ongoing engagement regarding PRC planning for SSM. PRC planning updates will be provided at regular meetings between BMA and 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 SSM project area as relevant. BMA will engage with IRC to plan for any other use of or impacts on Council assets (e.g. waste management faculties) during the closure process. BMA will work with Council and other stakeholders in future PRCP consultations to identify and implement social value opportunities.
Underlying landowners	Company Manager and Estate Manager	Private grazing business	Land parcels within ML1782, ML70369, ML70370 and ML70126 are owned by a grazing company, which also holds agistment licensees within the MLs, and is an adjacent landowner. BMA and the company's manager engage on commercial and contractual issues on as needed basis.	Letter, via email	1/07/2024	As above	No enquiries received or issues raised.	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 post-mining land use (PMLU) e.g. grazing, woodland, water courses, or managed as a non-use management area (NUMA).	BMA will continue to consult with underlying landowners and seek their inputs on SSM's rehabilitation schedule and approved PMLUs.
	Family partnership members	Private grazing business	Family partnership members are the owners of a small section of land within ML1782, hold an agistment licence over BMA-owned land, and are adjacent landowners.	Letter, via post	25/06/2024	As above	As above	As above	As above	As above
	Mayor and Councillors CEO Executive Manager of Advocacy and External Affairs Manager Galilee and Bowen Basin Operations	IRC	IRC is the owner of Golden Mile Road, Warwick Park Road, Silver K Road and Picardy Road within SSM's EA area. There is also a stock route (classified as minor and unused) aligned with Golden Mile Road within the EA area. BMA has regular meetings with Council, and meets with Councillors and officers as needed on specific issues.	Letter to stakeholders provided to Council, via email	1/07/2024	As above	As above	IRC road reserves within the EA area will need to be considered in PRC planning. Prior information and consultation will be required with IRC regarding the future use of roads and road reserves within the EA area.	BMA will engage with IRC regarding any impacts on Golden Mile Road, Warwick Park Road, Silver K Road and/or Picardy Road as part of the progressive rehabilitation and closure process, and will update IRC on PRC planning regularly.	BMA will engage with IRC regarding any impacts on Golden Mile Road, Warwick Park Road, Silver K Road and/or Picardy Road as part of the progressive rehabilitation and closure process, and will update IRC on PRC planning regularly.
	Manager Project Planning and Corridor Management	Department of Transport and Main Roads (DTMR)	State of Queensland via DTMR owns land for the SSM rail loop within ML70126. BMA engages with DTMR on commercial and contractual issues on as needed basis.	Letter, via email	1/07/2024	As above	Acknowledgement of letter received. No enquiries received or issues raised.	As above	BMA will engage with DTMR regarding any effects of rehabilitation or closure works on the SSM rail loop, and engage with DTMR prior to SSM's closure.	BMA will continue to consult with DTMR regarding land used for rail assets, as and when affected by rehabilitation and/or closure.
Licensees and lessees of BMA land	Family partnership members	Private grazing business	BMA engages with licensees regarding licence terms and conditions, and matters relating to land use management from time to time. The family partnership members are also adjacent landowners.	Letter, via post	25/06/2024	As above	No enquiries received or issues raised.	Landowners' interest in use of the land for grazing was considered in framing PMLUs.	BMA will continue to consult with licensees and lessees regarding licence and lease agreements as and when affected by rehabilitation and/or closure.	BMA will continue to consult with licensees and lessees regarding licence and lease agreements as and when affected by rehabilitation and/or closure.
	Family partnership members	Private grazing business	BMA engages with licensees regarding licence terms and conditions, and matters relating to land use management from time to time.	Letter, via email	1/07/2024	As above	As above	As above	As above	As above
	Owner	Private grazing business	As above	Letter, via email	1/07/2024	As above	As above	As above	As above	As above
	Family partnership members	Private grazing business	As above	Letter, via email	1/07/2024	As above	As above	As above	As above	As above
Adjacent and nearby landholders (within 5 km)	Family partnership members	Private grazing business	As above, and as for Row 8.	Letter, via post	25/06/2024	As above	No feedback or enquiries were received. BMA's regular engagements with adjacent landowners 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.	BMA will keep adjacent landholders updated if there are substantive future changes to the PRCP.	BMA will keep adjacent landholders updated if there are substantive future changes to the PRCP.

Saraji South Mine (SSM) 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**
	Family partnership members	Private grazing business	As above, and as for Row 11.	Letter, via post	25/06/2024	As above	As above	As above	As above	As above
	Family partnership members	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Owner	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Family partnership members	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Family partnership members	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Family partnership members	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Owner	Private grazing business	As above	As above	1/07/2024	As above	As above	As above	As above	As above
	Company manager	Agriculture company	As above	As above	1/07/2024	As above	As above	As above	As above	As above
Dysart community	Dysart residents, businesses and community groups	Residents, community groups and businesses	BMA communicates with Dysart residents and businesses through stakeholder meetings, community events and forums, media and social media, and Community Connect, a regular newsletter.	Letter, via mail to all premises and post office boxes in Dysart Information provided through Community Connect newsletter	15/07/2024 - 19/07/24 10/06/24 - 16/06/24	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will continue to provide information about PRC planning to Dysart community members, and consider their feedback in future PRCP development.	BMA will provide community updates on PRC planning, and seek the involvement of community members and groups in understanding community aspirations for rehabilitation, PMLU and economic transformation, as part of portfolio-wide engagement.
	STAC Members	Dysart STAC	The Smart Transformation Project including the Moranbah and Dysart Smart Transformation Advisory Councils (STACs) was established by BMA in 2019. Dysart STAC members include local community members, business owners, and service providers, as well as senior BMA personnel. The STACs meet every two months to consider a range of issues and priorities related to the future and sustainability of the communities and economies of Moranbah and Dysart.	Letter, via email	12/07/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will continue to provide information about PRC planning to Dysart STAC members, and consider their feedback in future PRCP development.	BMA will continue to provide information about PRC planning to Dysart 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 from 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 establishment of the Isaac Business Chamber and attended its launch event.	Letter, via email	15/07/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep the Isaac Business Council updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRC planning to Isaac Business Chamber, and consider their feedback in future PRCP development.
SSM personnel and suppliers	Personnel	SSM	BMA communicates with its personnel on a continual basis through toolbox talks, emails, safety meetings, 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 or enquiries were received.	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 PRC planning and rehabilitation.
	Business owners	SSM 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 or enquiries were received.	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 PRC planning and rehabilitation.
Utility owners	CEO	IRC	As per previous entries for IRC - Row 6 and Row 9	Letter to stakeholders provided to Council, via email	21/06/2024	As per previous entry for IRC	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will maintain correspondence with IRC regarding progressive rehabilitation activities as they affect Golden Mile Road, Warwick Park Road, Silver K Road and/or Picardy Road, and undertake consultation regarding crossing/interface agreements, if required.	BMA will work with IRC to develop an agreement addressing any closure/rehabilitation impacts affecting Council roads, as relevant.

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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**
	Senior Designer, Mackay/Whitsunday District,	Program Delivery & Operations Branch, Infrastructure Management & Delivery Division, Queensland Rail (QR)	Engagement with QR is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	20/06/2024	Queensland Government requirements for mine rehabilitation and closure planning PRCP inclusions Asset location Environmental Authority held for SSM PRCP submission date Mining leases within the EA area and approved activities (open cut coal mining) 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 PMLU options Inclusion of voids as non-use management areas Commitment to future engagement in PRC planning Invitation to seek information or discussion about PRCP Contacts for further information	No feedback or enquiries were received.	Prior information and consultation will be required with QR regarding the decommissioning of rail infrastructure within the EA area.	BMA will advise QR of any substantive changes to closure planning or the rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will maintain engagement with QR regarding its progressive rehabilitation activities as they affect QR assets, and undertake engagement regarding the decommissioning of rail infrastructure prior to its closure, in accordance with agreements between BMA and QR at the time.
	Senior Business Analyst, Network Asset Management	Aurizon Network	Engagement with Aurizon is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As above	No feedback or enquiries were received.	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 PRC planning processes for SSM.	BMA will maintain engagement with Aurizon Network regarding its progressive rehabilitation activities as they affect rail assets, and undertake engagement regarding the decommissioning of rail infrastructure prior to its closure, in accordance with agreements between BMA and Aurizon Network at the time.
	Major Customer Manager	Ergon Energy Corporation Ltd	Engagement with Ergon Energy is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	20/06/2024	As above	Acknowledgement of letter received. No enquiries received or issues raised.	Prior information and consultation will be required with Ergon Energy regarding the decommissioning/future use of power easements within the EA.	BMA will maintain correspondence with Ergon Energy regarding progressive rehabilitation activities as they affect Ergon Energy assets.	BMA will maintain correspondence with Ergon Energy regarding progressive rehabilitation activities, and undertake consultation regarding crossing/interface agreements, if required. BMA will advise and consult Ergon Energy regarding any impacts of the closure/rehabilitation activity that may affect Ergon Energy's asset.
	Property Services and Management Team Leader	Powerlink	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 above	No feedback or enquiries were received.	Prior information and consultation will be required with Powerlink regarding the decommissioning/future use of power easements within the EA.	BMA will maintain correspondence with Powerlink regarding progressive rehabilitation activities as they affect Powerlink assets.	BMA will maintain correspondence with Powerlink regarding progressive rehabilitation activities, and undertake consultation regarding crossing/interface agreements, if required. BMA will advise and consult Powerlink regarding any impacts of the closure/rehabilitation activity that may affect Powerlink's assets.
Adjacent and nearby mining interests	Legal Counsel	Bowen Basin Coal Pty Ltd)	Lake Vermont Coal Mine is located approximately 5 km to the east of SSM. Engagement with Bowen Basin 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 above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep Bowen Basin Coal updated as the PRCP is implemented and revised.	BMA will keep Bowen Basin Coal updated if there are substantive future changes to the PRCP.
	General Manager	Middlemount Coal Pty Ltd	Middlemount Coal Pty Ltd.'s MLs are within 5 km of BMA's MLs to the south. Engagement with Middlemount Coal is via routine statutory and commercial correspondence.	Letter, via email	20/06/2024	As above	Acknowledgement of letter received. No enquiries received or issues raised.	No feedback or enquiries were received.	BMA will keep Middlemount Coal Pty Ltd. updated as the PRCP is implemented and revised.	BMA will keep Middlemount Coal 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 (German Creek) Pty Ltd	Anglo American Australia (German Creek) Pty Ltd holds adjoining MLs to the south. Engagement with Anglo American Australia is via routine statutory and commercial correspondence.	Letter, via email	14/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep Anglo American Australia (German Creek) Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Anglo American Australial (German Creek) Pty Ltd updated if there are substantive future changes to the PRCP.
	Director, Legal Counsel	Queensland Coking Coal Pty Ltd and Vitrinite Pty. Ltd.	BMA has not had specific engagement with Queensland Coking Coal/Vitrinite regarding SSM.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep Queensland Coking Coal Pty Ltd (Vitrinite) updated as the PRCP is implemented and revised.	BMA will keep Queensland Coking Coal Pty Ltd (Vitrinite) updated if there are substantive future changes to the PRCP.
	Tenement Manager	Scap Exploration Pty Ltd	BMA has not had specific engagement with Scap Exploration Pty Ltd regarding SSM.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep Scap Exploration Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Scap Exploration Pty Ltd updated if there are substantive future changes to the PRCP.
	Tenement Manager	Boardwalk Sienna Pty Ltd	BMA has not had specific engagement with Boardwalk Sienna Pty Ltd regarding SSM.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will keep Boardwalk Sienna Pty Ltd updated as the PRCP is implemented and revised.	BMA will keep Boardwalk Sienna Pty Ltd updated if there are substantive future changes to the PRCP.
	Chief Executive Officer	Bengal Coal Pty Ltd	Bengal Coal has an ML granted for the Dysart East Project, but there has been no development to date. BMA has not had specific engagement with Bengal Coal	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will update Bengal Coal Pty Ltd. on any substantive future changes to the PRCP.	BMA will advise Bengal Coal Pty Ltd if there are any substantive changes to the closure and rehabilitation schedule in future iterations of the PRCP.
Petroleum tenement holders	Principal Commercial Advisor	Bow CSG Pty Ltd	Bow CSG hold an Authority to Prospect and Petroleum Commercial Area which include land within the EA area. BMA's MLs were granted prior to the enactment of the Mineral and Energy Resources (Common Provisions) Act 2014, and BMA holds gaseous hydrocarbons rights, so there is no requirement to notify Bow CSG Pty. Ltd. of activities within the coal MLs. Bow CSG Pty Ltd (as authorised holder representatives) are considered in the PRCP consultation plan as an adjacent tenement holder. BMA and Bow CSG communicate regarding tenure issues on an as-needed basis.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise Bow CSG Pty. Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will advise Bow CSG Pty. Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRC planning processes for SSM.
	Principal Commercial Advisor	Arrow CSG (ATP 364) Pty Ltd	Arrow CSG (ATP 364) Pty Ltd holds an Adjacent Authority to Prospect (ATP). BMA and Arrow CSG (ATP 364) Pty Ltd communicate regarding tenure issues on an as-needed basis.	Letter, via email	19/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise Arrow CSG (ATP 364) Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will advise Arrow CSG (ATP 364) Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRC planning processes for SSM.

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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**
	Principal Commercial Advisor	CH4 Pty Ltd (Arrow Energy)	CH4 Pty. Ltd holds an Adjacent Authority to Prospect (ATP). BMA and CH4 Pty Ltd (Arrow Energy) communicate regarding tenure issues on an as-needed basis.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise CH4 Pty Ltd (Arrow Energy) of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will advise CH4 Pty Ltd (Arrow Energy) of any substantive changes to closure or rehabilitation schedule as part of future PRC planning processes for SSM.
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	6/05/2021	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-lodgement meeting	45551	SSM site overview What aspects of SSM are the same as previous approved BMA site PRCPs What aspects of SSM are different	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.
	Director General, Agriculture and Fisheries	Department of Agriculture and Fisheries	Bundoora State Forest is located 5 km south-west of ML70126. The Department of Agriculture and Fisheries is the key stakeholder for State Forests. Specific consultation regarding SSM has not previously occurred.	Letter, via email	15/07/2024	Queensland Government requirements for mine rehabilitation and closure planning PRCP inclusions Asset location Environmental Authority held for SSM PRCP submission date Mining leases within the EA area and approved activities (open cut coal mining) 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 PMLU options Inclusion of voids as non-use management areas Commitment to future engagement in PRC planning Invitation to seek information or discussion about PRCP Contacts for further information	Acknowledgement of letter received. No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise the Director General, Agriculture and Fisheries of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will advise the Director General, Agriculture and Fisheries of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.
	Regional Director, Mackay	DESI - Queensland Parks and Wildlife and Partnerships	Coolibah Nature Reserve is located 5-6 km north-east of SSM, and Norwich Park Nature Refuge is located adjacent to SSM. Department of Environment Science and Innovation (QPWSP) is the key stakeholder for these reserves. Specific consultation regarding SSM's PRC planning has not previously occurred.	Letter, via post	25/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise the Regional Director Mackay - Queensland Parks and Wildlife and Partnerships of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will advise the Regional Director Mackay - Queensland Parks and Wildlife and Partnerships of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.
	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 above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will update the DDG Georesources on any future changes to the PRCP.	BMA will provide updates on PRC planning 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, Rockhampton, on an as needed basis, and meets and corresponds with Department of Resources regarding resource development commitments.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will provide updates on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Director Native Title Services and Coal Hub, Rockhampton as requested.
	Deputy Director-General Lands Division,	Department of Resources	BMA corresponds with the Deputy Director-General, Land Division regarding impacts on unallocated state land on an as needed basis.	Letter, via email	20/06/2024	As above	No feedback or enquiries were received.	No feedback or enquiries were received.	BMA will advise the DDG, Lands Division, Department of Resources, of any substantive changes to the closure or rehabilitation schedule as part of future PRC planning processes for SSM.	BMA will provide updates on PRC planning to the DDG, Lands Division, Department of Resources, 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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Member for Burdekin on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Member's office as requested.

Saraji South Mine (SSM) 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**
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Shadow Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Shadow Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Shadow Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Shadow Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Shadow Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Shadow Minister's office as requested.
	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Shadow Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Shadow Minister's office as requested.
Federal Government	Chief of Staff/Secretary	Office of the Minister and Dep. Sec. Environment Protection, Department of Climate Change, Energy, the Environment and Water (DCCEEW)	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	No feedback or enquiries received to date.	No feedback or enquiries received to date.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.	BMA will provide updates on PRC planning to the Minister's office as requested.

NORWICH PARK MINE

Transitional Progressive Rehabilitation and Closure Plan
Voids in Floodplain Assessment

Prepared for:

BHP Metcoal Holdings Pty Ltd

SLR Ref: 620.30403.00000-R01
Version No: -v2.0
August 2024

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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 Metcoal Holdings Pty Ltd (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.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.30403.00000-R01-v2.0	5 August 2024	HM	MD	HM
620.30403.00000-R01-v1.0	10 June 2022	HM	MD	MD

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Appendix B TUFLOW Model Results – Norwich Park Model
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Appendix F TUFLOW Model Results – Roper Creek Model – Flow Sensitivity Assessment

1 Introduction

SLR was engaged by BHP in March 2021 to undertake floodplain modelling at Norwich Park Mine (NPM). The modelling was undertaken to inform the Transitional Progressive Rehabilitation and Closure Plan (PRCP) for Norwich Park.

Norwich Park Mine is located in Central Queensland, approximately 20 kilometres north-west of Middlemount, and immediately south of Saraji Mine. Norwich Park is located within the catchment of the Isaac River. Two local watercourses traverse the site, Stephens Creek and Scott Creek, while a third watercourse, Roper Creek, is located directly south of Norwich Park EA boundary. Nine final voids are proposed within NPM as follows:

- R9 Pit located north of Stephens Creek;
- R6 Pit located between Stephens Creek and Scott Creek;
- R50 Pit located south of Scott Creek;
- R0B, R0C, R0D, R0E, R0F Pits not located nearby known watercourses; and
- R0A Pit located north of Roper Creek.

Figure 1 illustrates the location of Norwich Park Mine and key surrounding features.

The assessment detailed in this document was undertaken specifically to address the voids in flood plain modelling as part of the PRCP requirements for NPM.

1.1 Aims and Objectives

Norwich Park Mine requires a PRCP to be completed in accordance with NPM's Environmental Authority (EA), (No. EPML00562013). The EA is held by the Central Queensland Coal Associates Joint Venture (CQCA JV). The EA relates to NPM on Mining Leases (ML) 70410, 70369, 70370, 70325, 70328, 70126, 70127, 1782 and 70350. As part of the PRCP for NPM, it is proposed to incorporate nine final voids as Non-Use Management Areas (NUMAs). **Figure 1** illustrates the location and extent of the proposed final voids at NPMs.

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). The study includes watercourses classified as stream order four or higher, and their contributing tributaries.
- 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.

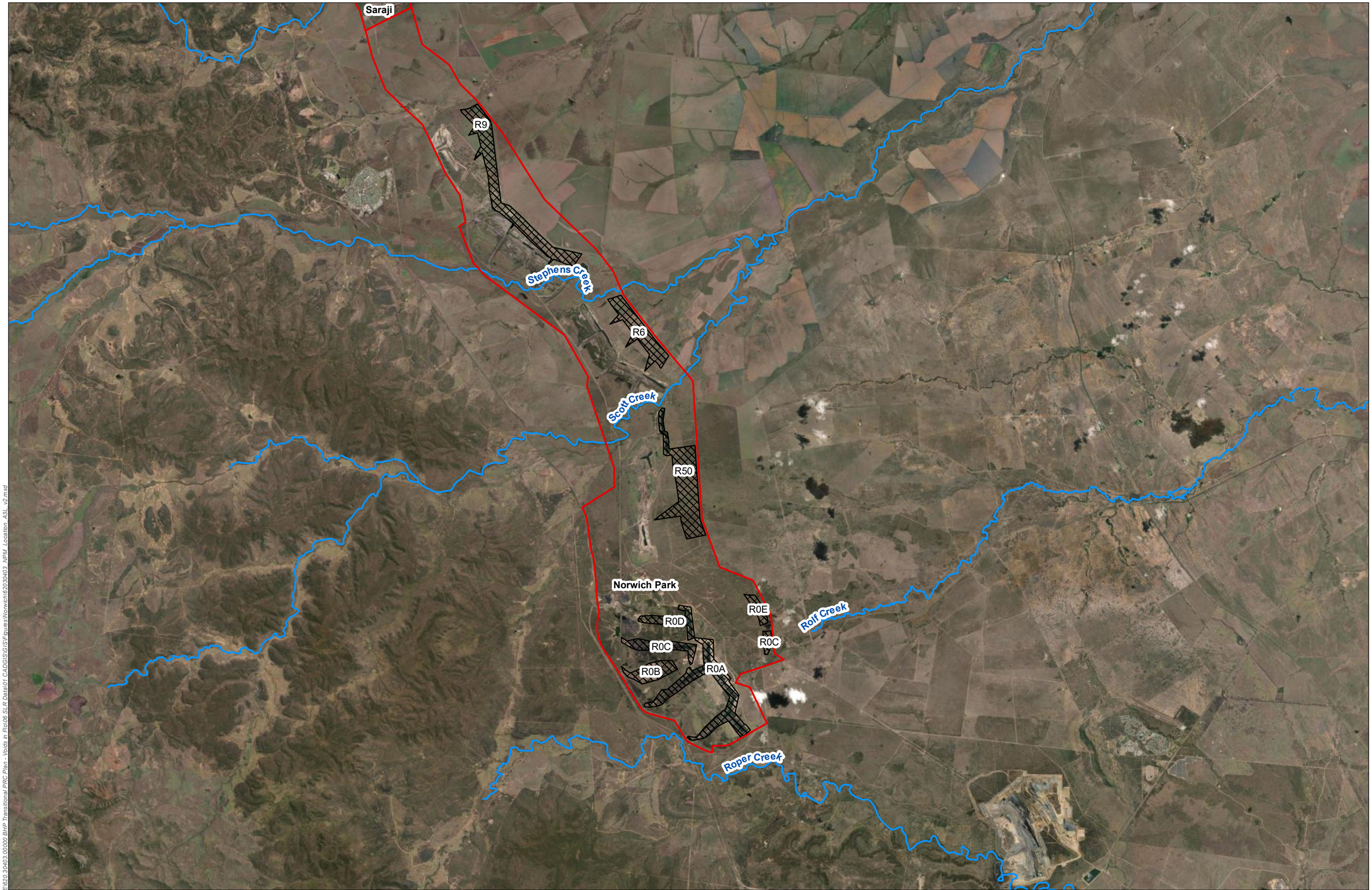
- Produce a Voids in Floodplain Model Report detailing the methodology and findings of the above assessments, including all relevant mapping of flood extents, levels and depths. GIS data and models will also be provided as an output of this assessment.

The assessments detailed in this report were undertaken and reviewed by appropriately qualified persons.

1.2 Input Data

Data for the assessment was provided by BHP and included pre-mining topographic data, design surface data for the PRCP landform, aerial imagery and previous flood studies for NPM.

Further data was obtained for use in the assessment from public sources, including additional topographic data, rainfall data, catchment specific hydrologic data and stream flow data. Further detail on the data utilised in the assessment is provided in **Section 3.**



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0 2 4 6 8 10 Kilometers

18-Apr-2024 Scale: 1:160,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- Final Void Extent
- EA Boundary
- Watercourse

Transition PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Project Location

Figure 1

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*', Department of Environment and Science, March 2021 (PRCP Guideline);
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, March 2020 (Voids in Flood Plains Information Sheet); and
- *'Australian Rainfall and Runoff (2019)'* (ARR).

In addition to the documentation listed above, the assessment was undertaken in accordance with the methodology that was agreed between BHP and DES during the pre-lodgement workshop for PRCPs (**Appendix A**).

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**. SLR has assumed all source data to be fit for purpose and sufficiently accurate for the purpose of this assessment.
- Floodplain modelling was undertaken only for relevant watercourses as defined in the Voids in Floodplain Information Sheet, i.e. watercourses with a stream order of 4 or higher under the Strahler stream order classification system.
- Generation of the model landform for the assessment was undertaken in accordance with the Voids in Flood Plains Information Sheet. Due to the requirement to include artificial features outside of the subject Mine Lease, the modelled floodplain may differ from the true pre-mining floodplain in areas where adjacent artificial features affect a relevant watercourse.
- The hydraulic models were based on 1 Second Derived SRTM topographic data in some areas due to the limited extent of available LiDAR Data. SRTM data for the site has a vertical accuracy of +/- 5-10m. The accuracy of the model results are limited to the accuracy of the adopted topographic data.
- Consideration was made as to the potential effects of groundwater on the floodplain extent. It was considered that groundwater will have no significant impact on the extent of the floodplain. An initial rainfall loss of 0 mm was adopted in the hydrologic studies. This assumption represents fully saturated catchment conditions (i.e. soil stores at the surface were full), which was considered to be a conservative approach. It was considered that the occurrence of elevated baseflow conditions of the relevant watercourses would have no impact on peak flood levels, particularly in a 0.1% AEP event.

1.5 Document Structure

The structure of this report is set out as follows:

- **Section 2** - Relevant legislation and guidelines;

- **Section 3** - Data review and gap analysis, including details of the model landform development methodology and results;
- **Section 4** - Hydrologic modelling of the Isaac River and local Norwich Park and Roper Creek catchments, including calibration methodology;
- **Section 5** - Hydraulic modelling of relevant watercourses including Stephens Creek, Scott Creek and Roper Creek, including results and outcomes of the floodplain modelling in relation to the proposed final voids; and
- **Section 6** – Consideration of groundwater effects on the Floodplain extent.
- **Section 7** – Summary of the study and conclusions.
- **Section 8** – Limitations of this assessment.

Details of each component of the assessment are provided below.

2 Legislation and Guidelines

2.1 Relevant 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.

2.2 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 1** are applicable to the project.

Table 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 Norwich Park Mine includes nine final voids which are proposed to be developed as NUMAs. Therefore, floodplain assessment is required.	PRCP Guideline Section 3.4

Requirement	Application to the Project	Source
Floodplains associated with a stream order 4 or greater are required to be modelled.	The following watercourses are of Strahler stream order 4 or greater and may affect the proposed voids: - Stephens Creek; - Scott Creek; and - Roper Creek Therefore, the above Creeks are relevant watercourses and floodplain modelling was undertaken for each.	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 time of modelling, are located outside of the mining tenure boundary.	A Digital Elevation Model (DEM) of the area was created to be used as the model landform for the assessment. 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, based on available data.	Voids in Flood Plains Information 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

2.3 Definitions and Terminology

Table 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 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 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 – (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

Term	Definition	Source
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 Data Review and Gap Analysis

3.1 Available Data

A data package was provided to SLR by BHP for use in the assessment. The package included:

- Pre-mining topography for the adjacent Saraji Mine (2 meter interval contour data date unknown);
- Proposed PRCP NUMA landform DEM including final voids;
- Norwich Park aerial imagery (date unknown);
- Norwich Park Mine GIS datasets; and
- GIS data containing watercourses with Strahler Stream Order 4 or greater.

Additional data was obtained from publicly available sources including:

- Queensland road, rail and place names GIS datasets (DR, 2021); and
- Historic gauged stream flow data for the Goonyella and Deverill Stream Gauges (DNRM);
- GIS data containing watercourses for all Strahler Stream Orders (DR); and
- 1 second SRTM Derived Hydrological Elevation Model topographic data (Geoscience Australia).

The provided data was analysed for suitability for the purposes of this assessment. The outcomes of the review are detailed below.

3.2 Watercourses

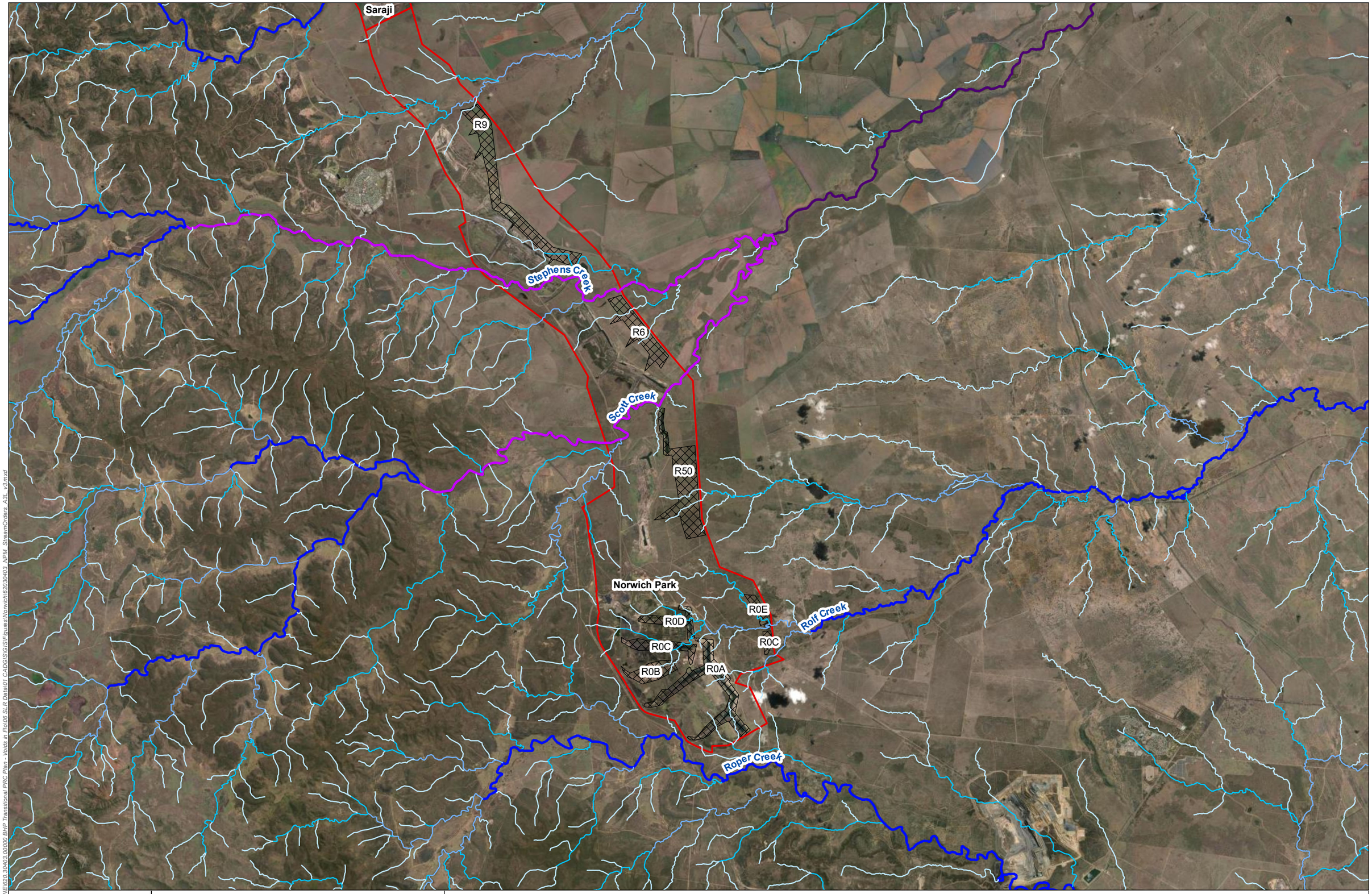
A review of the existing watercourses in the vicinity of NPM was undertaken using hydrologic streamline data sourced from DR. The dataset contained Strahler Stream Order classifications for each watercourse, which ranged from order 1 to order 7 within the extent of the data, as illustrated in **Figure 2**. The reviewed showed that the following watercourses are of Strahler stream order 4 or greater and may affect the proposed voids:

- Stephens Creek;
- Scott Creek; and
- Roper Creek

Therefore, the above Creeks are relevant watercourses and floodplain modelling was undertaken for each.

Preliminary review of the above watercourses in relation to the proposed voids showed that Stephens Creek, and Scott Creek traverse directly adjacent to A, B and C Pits and therefore floodplain modelling of these systems is required.

Roper Creek is located approximately 700m south of F Pit outside of Norwich Park EA boundary. However, given the critical flood event for the assessment is the 0.1% AEP event, it was considered conservative to also undertake floodplain modelling of Roper Creek.



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0 2 4 6 8 10 Kilometers

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Legend

Final Void Extent

EA Boundary

Strahler Stream Order

1 5

2 6

3

4

Transition PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

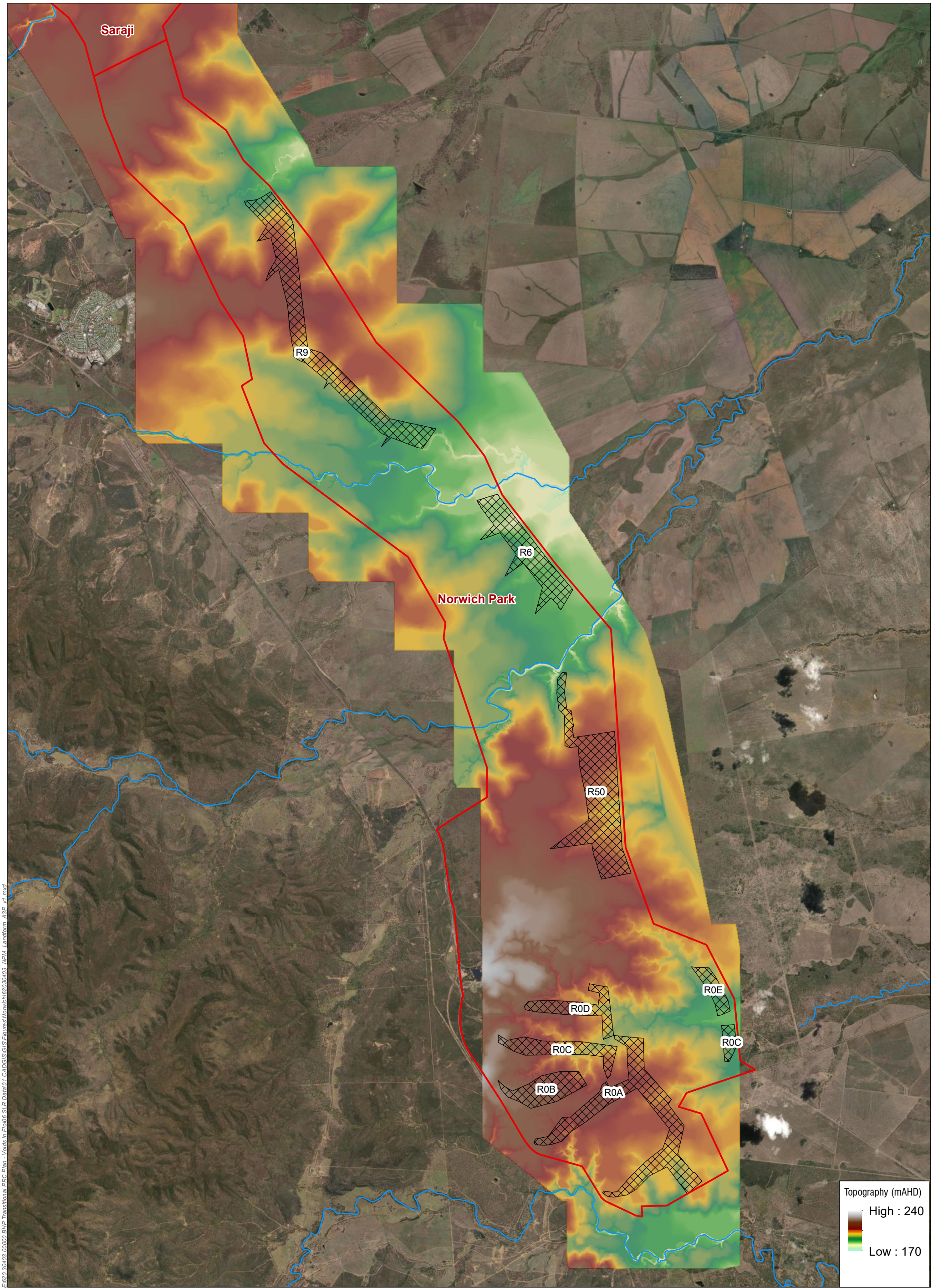
Watercourses
Strahler Stream Order Classification

Figure 2

3.3 Landforms

The pre-mining contour data for Norwich Park was processed into a 2 metre spaced DEM. As a result of the raw topographic data being contour lines at 2 m elevation intervals, the resulting DEM does not necessarily represent the true pre-mining topography in all locations, and is not ideal for use in hydraulic modelling. However, given the lack of alternative pre-mining topographic data, the DEM was adopted for use in the assessment.

The resulting pre-mining model DEM is illustrated in **Figure 3**.



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0 1 2 3 4 5 Kilometers

18-Apr-2024 Scale:1:100,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- Watercourse

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park
Model Landform

FIGURE 3

3.4 Artificial Features

Existing and proposed artificial features within the model domain were identified based on the available information at the time of the assessment. A summary of the identified artificial features and relevant details are provided in **Table 3.** Consideration was made for each artificial feature to determine if the feature was necessary to include in the hydrologic and hydraulic models, based on the feature's respective influence on 0.1% AEP flooding conditions in the vicinity of the voids.

Table 3 Artificial Features

Artificial Feature / Description	Source	Hydraulic model inclusion status
On-tenure		
Golden Mile Road	Department of Resources (DR)	All on lease artificial features not included in model as per EP Regulation requirements.
Norwich Park Pits	PRCP Landform DEM (BHP).	
Norwich Park OOPD	PRCP Landform DEM (BHP).	
Stephens Creek Diversion	BHP	
Lake Vermont Balloon Loop Railway	DR	
Norwich Park Balloon Loop Railway	DR	
Norwich Park Railway Station	DR	
Silver K Road	DR	
Warwick Park Road	DR	
Picardy Road	DR	
Site Roads and Tracks	DR	
Off-tenure		
Site Roads and Tracks Haul Road	BHP	Not included – no material effect on 0.1% AEP flood levels in vicinity of voids.
Dysart Middlemount Road	DR	
Booroondarra Capella Road	DR	
Picardy Road	DR	
Golden Mile Road	DR	
Warwick Park Road	DR	
Dysart Bypass Road	DR	
Saraji Road	DR	
Goonyella System Railway	DR	
Dysart Railway Siding Point	DR	
Stephens Railway Siding Point	DR	
Norwich Park Junction Railway Siding Point	DR	
Town of Dysart	DR	Included in hydrologic model

Based on the review of information available at the time of the assessment, no other artificial features are known to exist or are proposed outside of the NPM ML that will influence flooding conditions in the vicinity of the voids. The incorporation of the model landform DEM into the hydraulic model is outlined in **Section 5.3.1**.

4 Hydrologic Modelling

4.1 Software

Hydrologic modelling was undertaken to estimate runoff hydrographs at various locations throughout the catchments of Stephens Creek, Scott Creek and Roper Creek. The model was developed using the Watershed Bounded Network Model Version 2019 (WBNM). WBNM is an industry standard rainfall-runoff routing software package.

4.2 Model Setup

4.2.1 Approach

The catchments of Stephens Creek, Scott Creek and Roper Creek are tributaries of the Isaac River. To encompass the above catchments, a WBNM model of the Isaac River to the immediately upstream of its junction with Devlin Creek was developed.

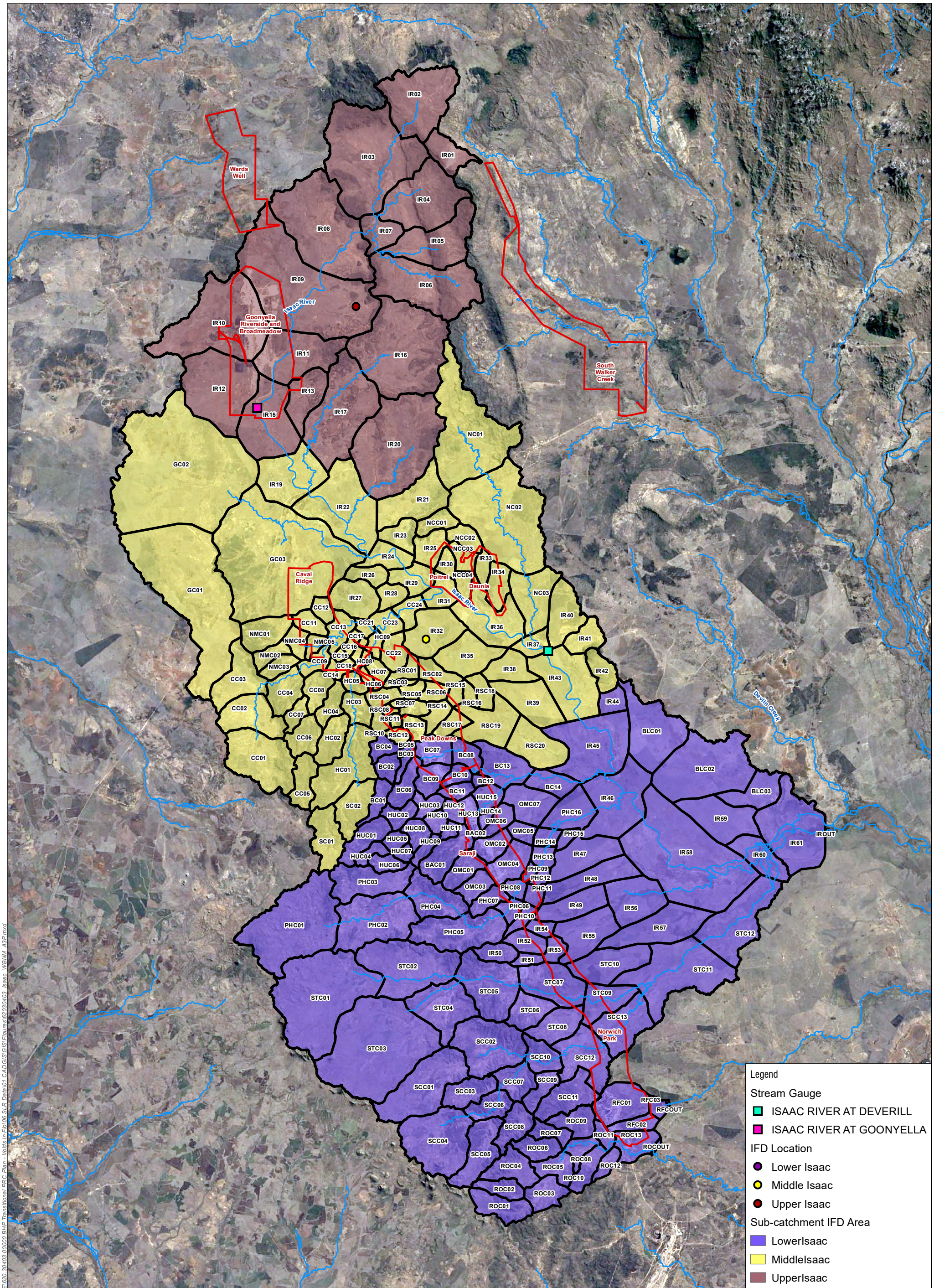
An additional factor contributing to developing the model to include the wider Isaac River catchment was to allow the model to be calibrated against the results of a Flood Frequency Analysis (FFA) undertaken at the nearest suitable location(s), being the Goonyella (130414A) and Deverill (130410A) stream gauges. This was considered appropriate given the 0.1% AEP flood event is the critical event for the assessment and the long period of record at the gauges provides the best estimation of peak flows with this exceedance probability. Further detail on the model calibration process is provided in **Section 4.3**.

4.2.2 Catchment Details

The Isaac River model covers a catchment area of approximately 8300 km^2, of which sub-catchments were delineated using hydrologically enforced 1 second SRTM 30 metre DEM terrain data sourced from Geoscience Australia. The model extent and sub-catchment delineation are illustrated in **Figure 4**.

4.2.3 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). Spatial variability of IFD data was accounted for by sourcing data separately for the upper catchment, middle catchment and lower catchment of the model area. Each sub-catchment was allocated the IFD data of each relevant IFD location based on proximity, as illustrated in **Figure 4.**



Legend

Stream Gauge
- ISAAC RIVER AT DEVERILL
- ISAAC RIVER AT GOONYELLA

IFD Location
- Lower Isaac
- Middle Isaac
- Upper Isaac

Sub-catchment IFD Area
- LowerIsaac
- MiddleIsaac
- UpperIsaac

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0 10 20 Kilometers

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Legend
- WBNM Sub-catchments
- EA Boundary
- Watercourse

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

WBNM Layout
Isaac River Model

FIGURE 4

H:\Projects-SLR\620-BNE\620-BNE\620.30403.00000 BHP Transitional PRC Plan - Voids in Flp\06 SLR Data\01 CAD\GIS\GIS\Figures\620303403 Isaac WBNM A3P.mxd

4.2.4 Losses

Storm rainfall loss data for the catchment was obtained from the ARR data hub. The initial and continuing losses are provided in **Table 4**. Based on the ARR Data Hub data, an initial loss of 0 mm was adopted as for the 0.1% AEP event.

Table 4 Rainfall Losses

Global Storm Loss	Loss
Initial loss (pervious)	0 mm
Continuing loss (pervious)	1.0 mm/h

4.2.5 Lag Parameter

A catchment lag parameter of 1.90 was adopted in the WBNM model. The WBNM documentation recommends a lag parameter value between 1.40 and 1.80 where possible, however if reliable calibration data is available the lag parameter should be adjusted to provide accurate calibration of the model, as was the case for this assessment.

4.2.6 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.

4.2.7 Aerial Reduction Factor

Aerial reduction factors were applied to the model based on the catchment area draining to the Deverill gauge (refer **Section 4.3.1**), which is approximately 4090 km^2.

4.3 Calibration

4.3.1 Flood Frequency Analysis

A FFA was undertaken using recorded streamflow data sourced from the Department of Regional Development, Manufacturing and Water (DRDMW). Two gauge locations exist on the Isaac River within the catchment of the area of assessment, located at Goonyella (130414A) and Deverill (130410A). The locations of the gauges are illustrated in **Figure 4.**

The Goonyella gauge has continuous streamflow records beginning in 1983 (38 years), while the Deverill gauge has records beginning in 1968 (53 years). It was noted during the analysis that the catchment to the Deverill gauge, including the Goonyella gauge, has been modified significantly by various mining operations since approximately 2002. The WBNM model was developed based on SRTM topographic data which generally predates 2002, therefore streamflow data from 2003 onwards was excluded from the Deverill gauge data in the FFA. With these records excluded, a total of 35 years data was available for use from the Deverill gauge, which was considered sufficient to produce an estimate of flows for the 0.1% AEP. The full 38 years of record was adopted for the Goonyella gauge, given excluding the post-2002 flows would leave only 20 years of data, which was considered insufficient.

For both gauges, a Log-Pearson III (LP3) flood frequency distribution to the annual maximum data series. For each gauge, low flow outliers were excluded from the data series using the Grubbs Beck Test method, prior to fitting the distribution.

4.3.2 Calibration Results

Results of the flood frequency analysis, in comparison to the results of the WBNM hydrologic model, are illustrated in **Figure 5** and **Figure 6.**

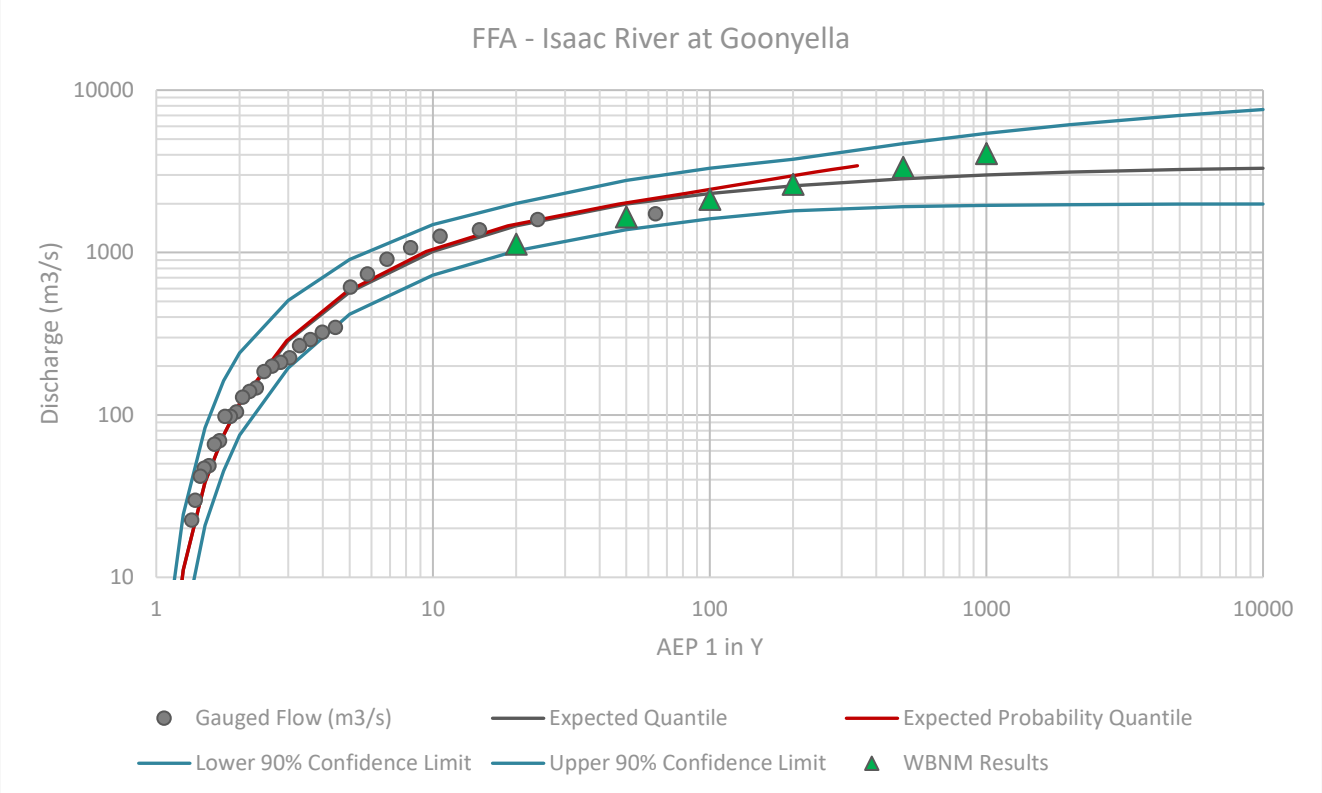


Figure 5 Flood Frequency Analysis Results – Isaac River at Goonyella Gauge

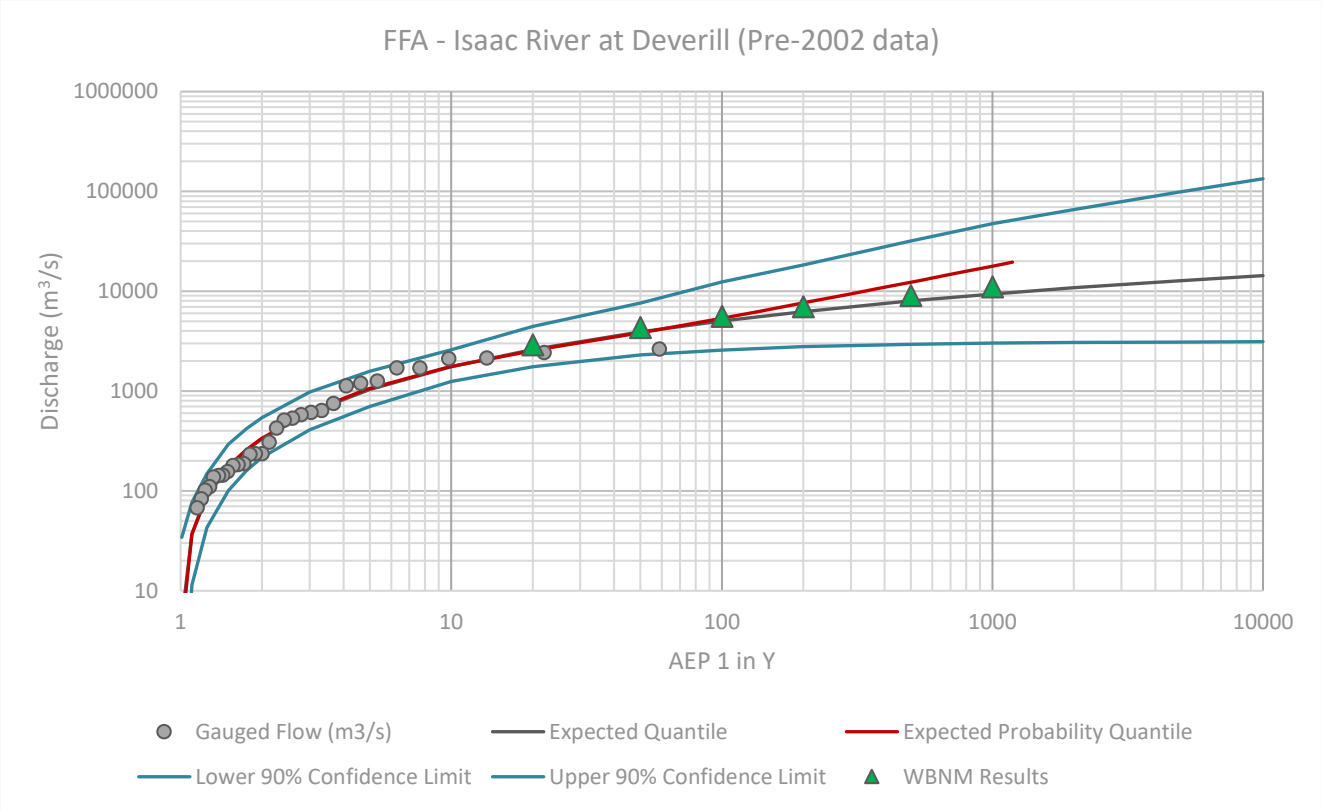


Figure 6 Flood Frequency Analysis Results – Isaac River at Deverill Gauge

The WBNM model results were compared against previous modelling of the catchment undertaken by others, as illustrated in **Table 5**. The following studies were reviewed and referenced:

- *'Winchester South Project Environmental Impact Statement – Surface Water and Flooding Assessment'*, WRM, 20 May 2021 (WRM 1)
- *'Goonyella and Broadmeadow Hydraulic Assessment',* WRM, 2 August 2019 (WRM 2)
- *'G200s Project – Flood Modelling Report'*, Alluvium, September 2016 (Alluvium)

Table 5 WBNM Model Results – Comparison to previous assessments

Isaac River Location	1% AEP				0.1% AEP			
	SLR WBNM	WRM 1	WRM 2	Alluvium	SLR WBNM	WRM 1	WRM 2	Alluvium
Goonyella (m^3/s)	2,130	-	2,079	-	4,078	-	3,808	-
Deverill (m^3/s)	5,589	5,051	-	4,500	11,023	10,009	-	7,500

As illustrated by the above, the WBNM model produced results in line with the results of the FFAs, particularly with the results of the Deverill gauge data. The model results are also generally consistent with the results of the reviewed analyses by others. Therefore, the model was considered suitable for use for the purposes of this assessment.

4.4 Norwich Park Sub-model

A sub-model of the Isaac River hydrologic model was developed for the Norwich Park area, including the catchments of Stephens Creek and Scott Creek. The model was required for the following reasons:

- Revision of sub-catchment delineation based on the Model Landform DEM; and
- Application of Aerial Reduction Factors relevant to the local catchment area of 1,197 km^2.

All other model parameters were retained from the Isaac River model. The model extent and sub-catchment delineation of the Norwich Park sub-model are illustrated in **Figure 7**.

As detailed in Section 4.3.1, the Isaac River model was developed based on SRTM topographic data, which generally pre-dates mining activities throughout much of the Isaac catchment and thus typically represents pre-mining catchments. Therefore, the catchment area within the NPM ML was generally consistent between the Isaac River model and NPM sub-model. There was no resulting change in catchment area for the relevant watercourses, as illustrated in **Table 6**.

The results of the sub-model were compared to the results of the Isaac River model at the outflow points of sub-catchment STC09 and SCC13 (refer **Figure 7**), shown in **Table 6**.

Table 6 Norwich Park WBNM Model Results Comparison

Model	0.1% AEP Discharge (m^3/s)	Aerial Reduction Factor	Catchment Area (km^2)
STC09			
Isaac River model	1,892	0.82	669 km^2
Norwich Park Sub-model	2,430	0.88	669 km^2
SCC13			
Isaac River model	1,736	0.82	528 km^2
Norwich Park Sub-model	2,249	0.88	528 km^2

Based on the above, the Norwich Park sub-model was deemed suitable for use in the assessment.

4.5 Roper Creek Sub-model

A sub-model of the Isaac River hydrologic model was also developed for the Roper Creek catchment. The sub-model was developed to account for:

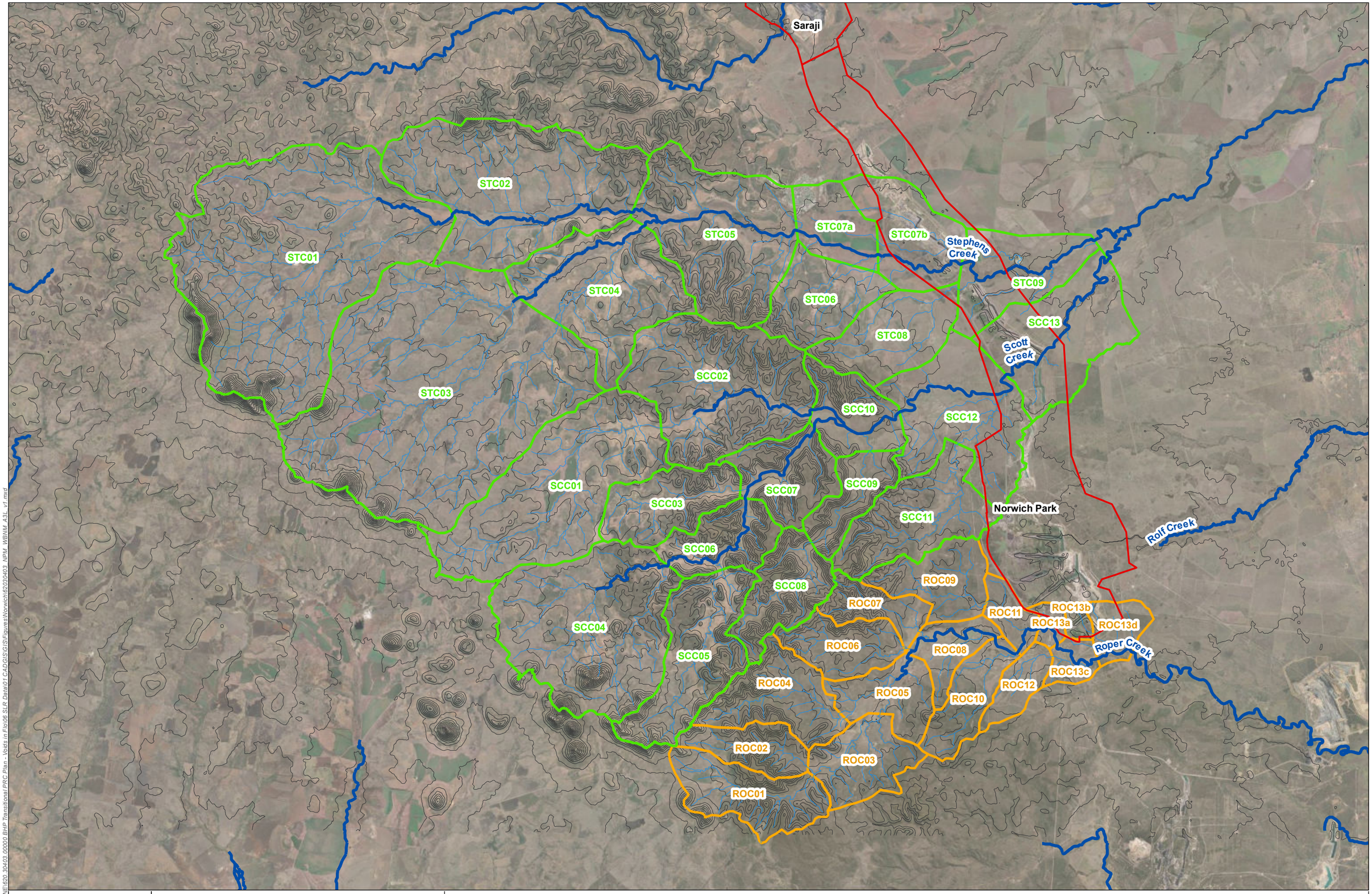
- Revision of sub-catchment delineation based on the Roper Creek Model Landform DEM ; and
- Account for Aerial Reduction Factors applicable to the 236 km^2 catchment area.

All other model parameters were retained from the Isaac River model. The model extent and sub-catchment delineation of the Roper Creek sub-model are illustrated in **Figure 7**.

The results of the sub-model for the critical storm duration of 9 hours were compared to the results of the Isaac River model at the outflow point of sub-catchment ROC13 (refer **Figure 7**), shown in **Table 7**. The results show that the sub-model produces a higher peak flow than the Isaac River model, which is attributed to increased Aerial Reduction Factor that is appropriate for the local Roper Creek catchment area.

Table 7 Roper Creek WBNM Model Results Comparison

Model	0.1% AEP Peak Discharge (m^3/s)	Aerial Reduction Factor	Catchment Area (km^2)
Isaac River model	977	0.68	236 km^2
Roper Creek Sub-model	1,331	0.86	236 km^2



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0 2 4 6 8 10 Kilometers

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Legend

- EA Boundary
- Norwich Park WBNM Sub-catchments
- Roper Creek WBNM Sub-catchments
- Stream Order 4 or Greater
- Watercourse
- SRTM 30m Contours

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

WBNM Layout
Norwich Park and Roper Creek Sub-Models

Figure 7

5 Hydraulic Modelling

5.1 Software

A hydraulic model of the catchment was developed for the purpose of assessing pre-mining flood extents.

The industry standard hydrodynamic modelling software TUFLOW (build 2020-10-AA) was utilised for the hydraulic modelling. The sub-grid sampling (SGS) feature of TUFLOW suited the modelling required for the assessment. SGS provides an increased definition of model terrain and flow conveyance, enabling model resolution to be improved without significant increases in model runtimes.

5.2 Models

Two hydraulic models were developed as part of this assessment:

- **Norwich Park Model** -The primary model covering the catchments including Stephens Creek and Scott Creek. These relevant watercourses represent the highest risk of floodplain interaction with the proposed final voids; and
- **Roper Creek Model** - A model was developed for the Roper Creek catchment located to the south of the site. As discussed in **Section 3.2**, Roper Creek presents a low risk in terms of void inundation. For this reason, and lack of available detailed data, the modelling was undertaken with conservative assumptions and less detail than the Norwich Park model.

Details of the respective model assumptions, methodology and results are provided below.

5.3 Norwich Park

5.3.1 Topography

The model landform DEM as detailed in **Section 3** was utilised as the topography for the model. The DEM for the model area is shown in **Figure 10**. Drainage features of this DEM were reinforced using gully lines to ensure reasonable conveyance.

5.3.2 Model Grid Cell Size

A grid cell size of 10 metres was adopted for the model. In combination with a 1 metre SGS sampling distance, this was considered to provide adequate model resolution for the purposes of the analysis undertaken, while providing a reasonable runtime.

5.3.3 Hydraulic Roughness

Hydraulic roughness across the model area was assessed based on the supplied aerial imagery from 1986. This was the most suitable available imagery for the area and was considered a reasonable representation of the pre-mining land use. The Manning's roughness values adopted for the various land use types within the model domains are shown in **Table 8** and in **Figure 11**.

Table 8 TUFLOW Model Manning's Roughness Values

Land Use	Manning's n Value
Sparse Vegetation	0.06
Dense Vegetation	0.08
Creek Beds	0.02

5.3.4 Downstream Boundary

The downstream boundaries for the TUFLOW model were positioned on Stephens Creek and Scott Creek approximately 6km upstream of the Creeks confluence. Stage-discharge relationships based on the topography gradient at these locations of 0.1% was applied. The location and extent of the downstream boundaries is shown in **Figure 10**.

Sensitivity analysis was carried out on the downstream model boundary, by reducing the flood surface gradient of the stage-discharge relationship to 0.01%. The results of the sensitivity analysis are outlined in Section **5.5.**

5.3.5 Model Inflows

Flow hydrographs for the model were extracted from the Norwich Park WBNM sub-model for each sub-catchment. These hydrographs were applied as inflow boundaries, as either total or local inflows where relevant, to the hydraulic model at appropriate locations, as shown in **Figure 10**.

Flows produced by the WBNM at the outlet of sub-catchments STC09 and SCC13 were compared with the results of the hydraulic model at the downstream boundaries. This was undertaken for the critical duration event and indicates that the TUFLOW model calculates similar flows and the general shape of the hydrographs were similar. **Figure 8** and **Figure 9** illustrates these comparisons.

Sensitivity analysis was undertaken on the inflow boundaries. For the analysis, flows were increased by a factor of 20%. The results of the sensitivity analysis are outlined Section **5.5.**

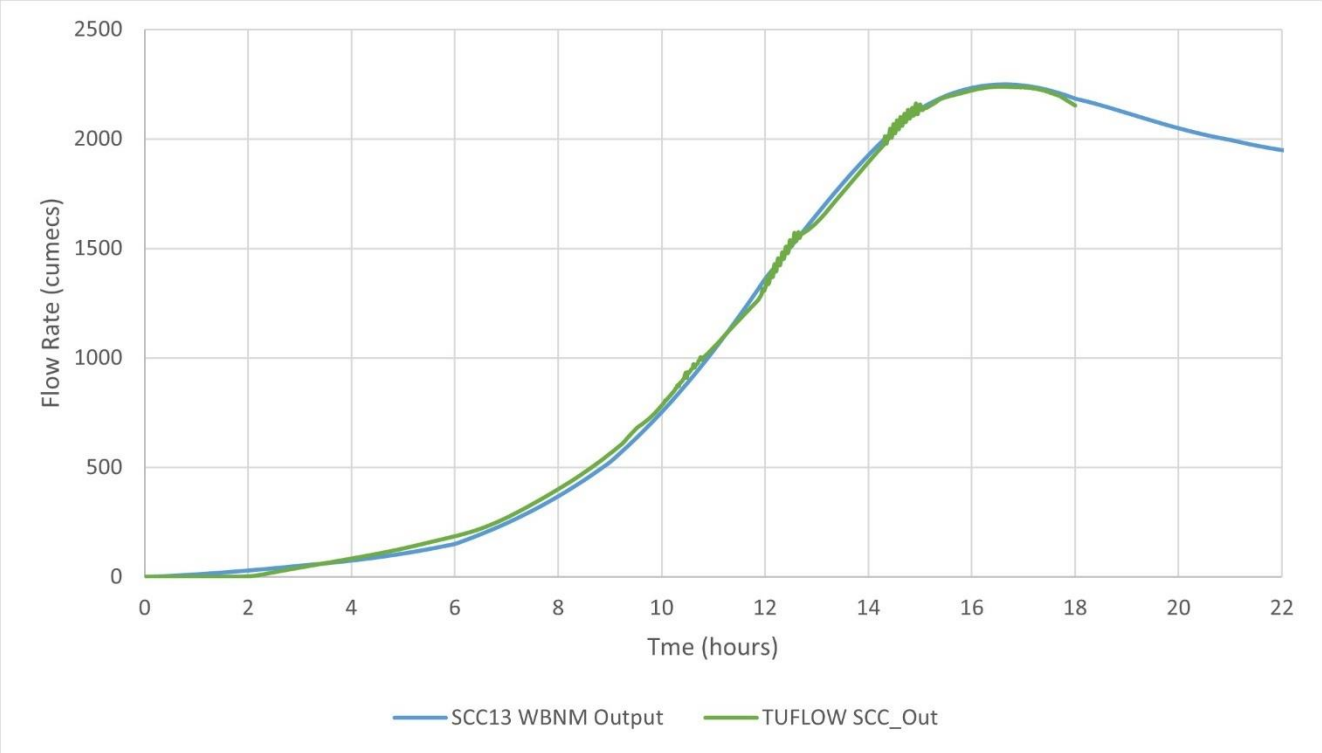

Figure 8 24 hour 0.1% AEP WBNM and TUFLOW Results Comparison (Stephens Creek)

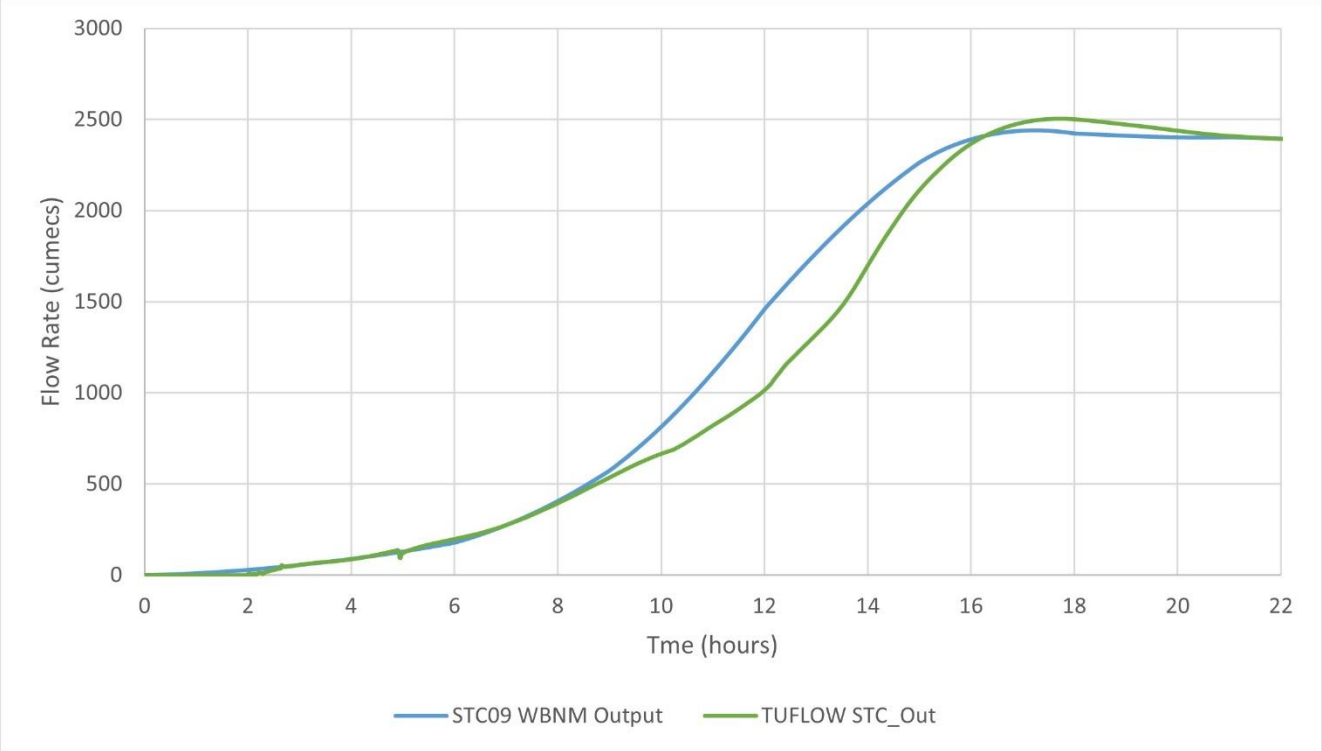

Figure 9 24 hour 0.1% AEP WBNM and TUFLOW Results Comparison (Scott Creek)

5.3.6 Critical Storm Durations

In accordance with the recommendations of ARR, a suite of design storm events was simulated in the hydraulic models for the 0.1% AEP event and durations between 1 and 72 hours. The results of the various storm durations were cross-referenced to determine the critical duration for the focal point of the model, i.e. the proposed void locations. The results showed that the 24 hour storm duration was the critical event.

STC07|Tot

STC09|Loc

Norwich Park

SCC13|Loc

SCC12|Tot

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0 1,000 2,000 3,000 4,000 Meters

08-Jun-2022 Scale: 1:60,000

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Legend

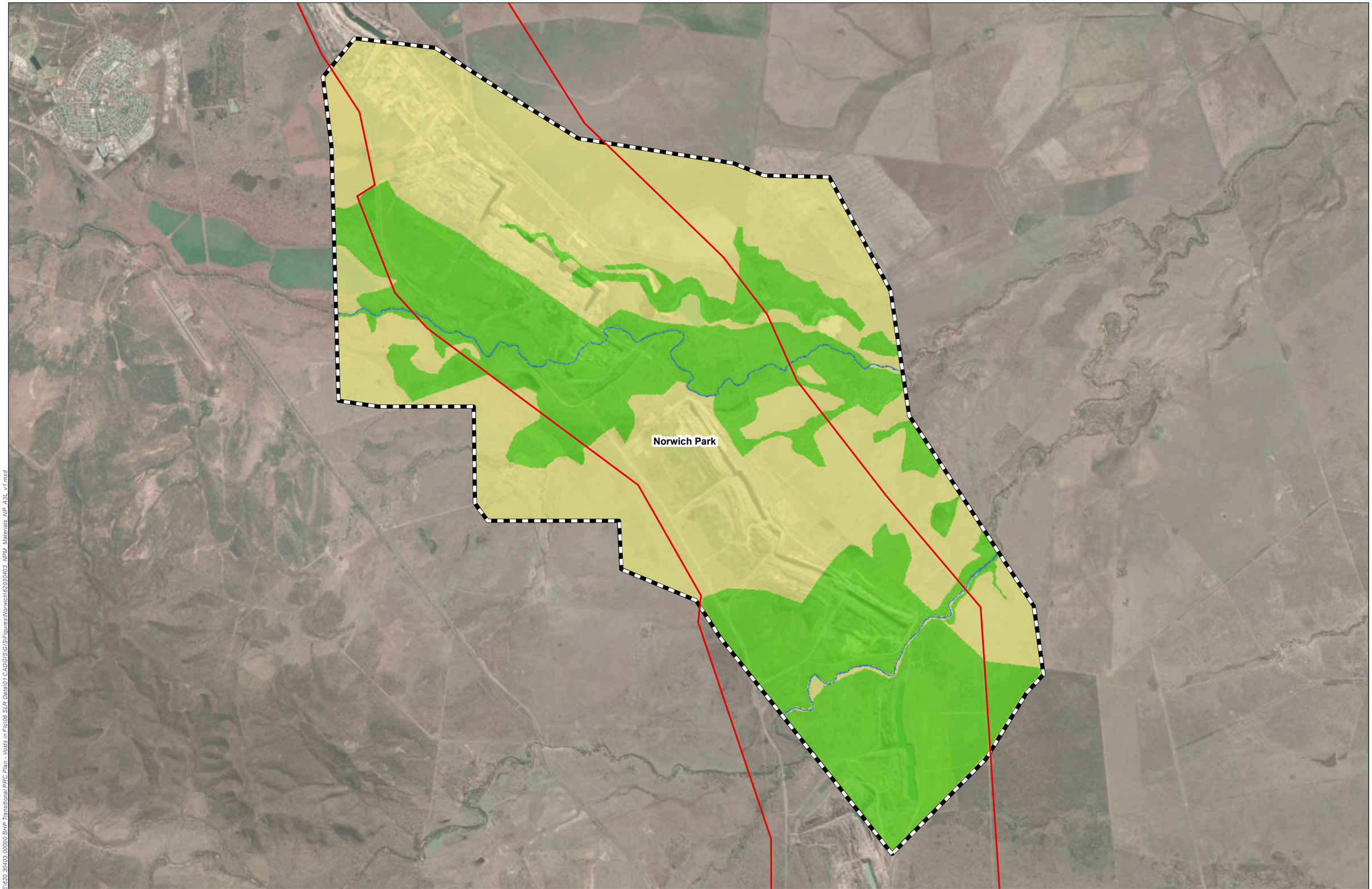
- EA Boundary
- Downstream Boundary
- Upstream Inflow
- Local Inflows
- Gully Points
- Gully Line
- TUFLOW Model Extent

Topography (m AHD)
High : 214.002
Low : 155.716

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

TUFLOW Model Layout
Norwich Park Model

Figure 10



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0 1,000 2,000 3,000 4,000 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

EA Boundary

TUFLOW Model Extent

Manning's n Value

0.08

0.02

0.06

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

TUFLOW Model Norwich Park
Hydraulic Roughness

Figure 11

5.4 Roper Creek

5.4.1 Topography

The model landform DEM as detailed in **Section 3** was utilised as the topography for the model. The 2m pre-mining contour data was considered to be an appropriate representation of the topography of Roper Creek, given the area is effectively unchanged from natural conditions.

Preliminary model results showed the 2m pre-mining contour data did not cover the full extent of the 0.1% AEP floodplain to the south of Roper Creek. Therefore, SRTM topographic data was utilised to extend the model DEM to incorporate the floodplain storage area not covered by the 2m pre-mining contour data.

Drainage features of this DEM were reinforced using gully lines to ensure reasonable conveyance.

The DEM for the model area is shown in **Figure 13**.

5.4.2 Model Grid Cell Size

A grid cell size of 10 metres was adopted for the model. In combination with a 1 metre SGS sampling distance.

5.4.3 Hydraulic Roughness

A Manning's n value of 0.06 was applied across the model domain, as a conservative approach based on review of aerial imagery of the area.

5.4.4 Downstream Boundary

A stage-discharge relationship based on the topography gradient at this location of 0.1% was applied.

5.4.5 Model Inflows

The flow hydrograph for the catchment area draining to sub-catchment ROC11 (refer **Figure 4**), was extracted from the Isaac River hydrologic model and applied as the upstream inflow boundary condition.

Source area inflows was also applied for a tributary of Roper Creek. The source area inflow was located at the downstream extent of the tributary, given the assessment was undertaken to investigate the Roper Creek floodplain.

Sensitivity analysis was undertaken on the inflow boundaries. For the analysis , flows were increased by a factor of 20%. The results of the sensitivity analysis are outlined **Section 5.5.**

5.4.6 Verification

Flows produced by the WBNM at the outlet of sub-catchment ROC13 were compared with the results of the hydraulic model at the downstream boundary. This was undertaken for the critical duration event and indicates that the TUFLOW model calculates similar flows and the general trends of the hydrographs were similar. **Figure 12** illustrates these comparisons.

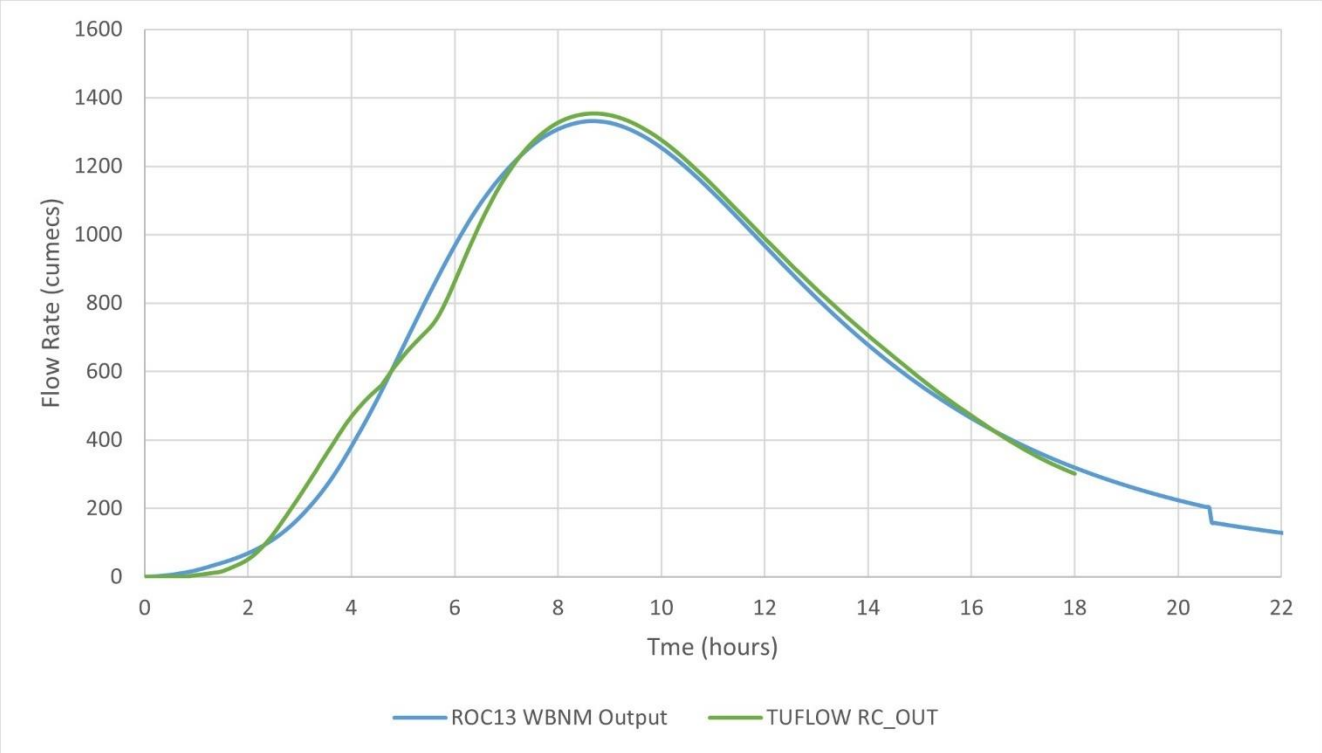

Figure 12 9 hour 0.1% AEP WBNM and TUFLOW Results Comparison (Roper Creek)

5.4.7 Critical Storm Duration

In accordance with the recommendations of ARR, a suite of design storm events was simulated in the hydraulic models for the 0.1% AEP event and durations between 1 and 72 hours. The results of the various storm durations were cross-referenced to determine the critical duration for the focal point of the model, i.e. the proposed void locations. The results showed that the 9 hour storm duration was the critical event.

5.5 Results

5.5.1 Norwich Park

The results of the Norwich Park TUFLOW model for peak water surface levels and depths for the 0.1% AEP event are illustrated in **Appendix B**. The results illustrate the proposed NUMA voids are generally located outside of the modelled floodplain for Stephens Creek and Scott Creek.

At three locations, as shown in **Figure 14**, the proposed footprints of the R9, R50 and R6 Voids encroach into the floodplains of Stephens and Scott Creeks respectively.

Model sensitivity analyses were undertaken as described in **Section 5.3**. The results of the sensitivity analyses are illustrated in **Appendices C and D**. Details of the results are as follows:

- An increase of flows by a magnitude of 20% results does not significantly change the inundation extent of Stephens Creek and the R9, R50 and R6 voids are subject to inundation which is consistent with the base model scenario. The inundation footprint of Scott Creek is increased, and the southern extent of the R6 void is subject to a larger area of inundation than the base model scenario. The results of the sensitivity assessment show breakout flow path occurs on the northern floodplain of Scott Creek. This flowpath occurs in an area of the model landform with sparse contour density and therefore may be overstated in the model results.
- The results of the tailwater sensitivity assessment showed that a reduction in the adopted flood gradient at the downstream model boundary did not result in a material change to the flood inundation extent in the vicinity of the voids.

The results of the hydraulic model are heavily dependant on the underlying model landform DEM. As detailed in Section **3.3**, the landform DEM was created using the provided pre-mining 2m contour data, and is therefore limited in accuracy and may not adequately represent the true pre-mining topography in some areas.

5.5.2 Roper Creek

The results of the Roper Creek TUFLOW model for peak water surface levels and depths for the 0.1% AEP event are illustrated in **Appendix E**. As shown in **Figure 16** the results illustrate the proposed NUMA voids are entirely located outside of the modelled floodplain for Roper Creek.

The results of the model sensitivity analysis showed that a 20% increase in flow magnitude did not materially alter the floodplain extent and the footprint of the proposed voids are located outside the modelled floodplain extent. The results of the sensitivity assessment are illustrated in **Appendix F**.

As detailed in Section **5.4**, SRTM topographic data was used to supplement the base 2m pre-mining contour data in the Roper Creek model DEM. Review of the model results showed that the floodplain extends only marginally into the area of the model DEM that is formed by the SRTM data, and the peak flood levels and inundation extent is not significantly affected by the incorporation of the SRTM data.

Norwich Park

ROC11|Tot

ROC13a|Loc

ROC12|Loc

ROC13d|Loc

ROC13c|Loc

ROC13b|Loc

2m Contour Topographic Data

SRTM Topographic Data

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SLR
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0 250 500 750 1,000 Meters

08-Jun-2022 Scale: 1:20,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

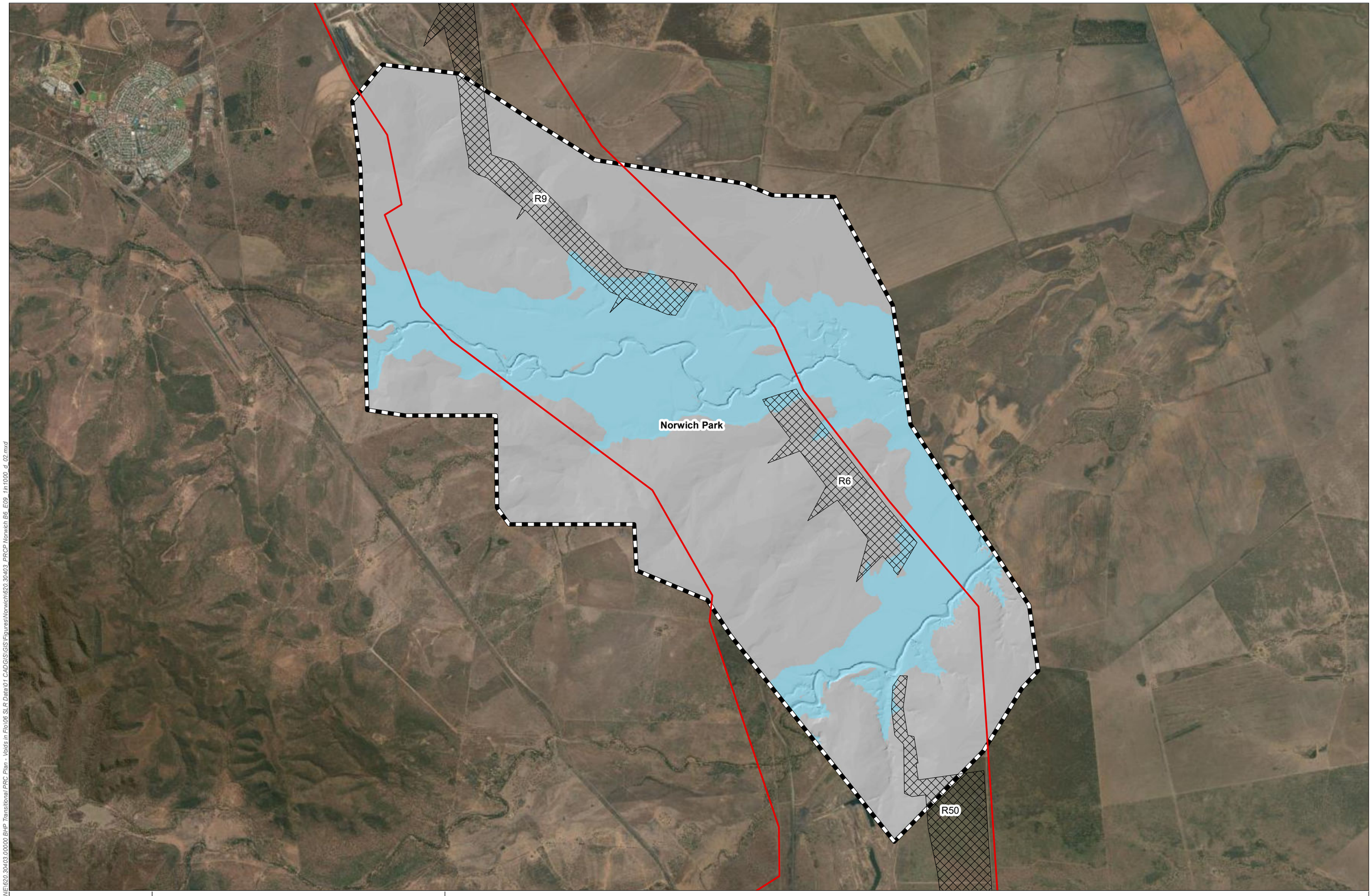
- EA Boundary
- Downstream Boundary
- Upstream Inflow
- Local Inflows
- Gully Points
- Gully Line
- TUFLOW Model Extent

Topography (m AHD)
High : 222.795
Low : 178

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

TUFLOW Model Layout
Roper Creek Model

Figure 13



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0 1,000 2,000 3,000 4,000 Meters

05-Aug-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

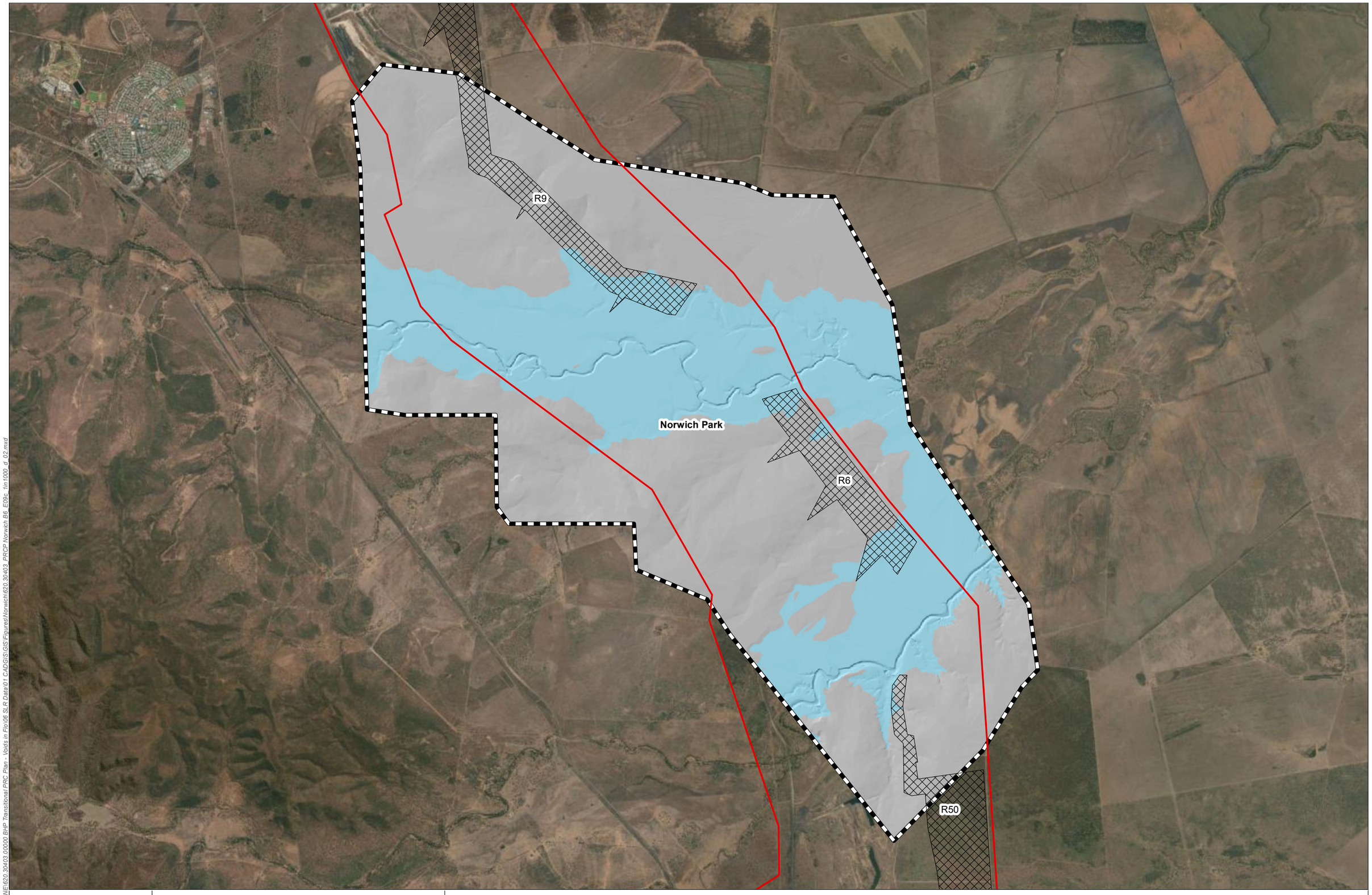
Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent
- Floodplain Extent

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model
Floodplain Extent - 0.1% AEP

Figure 14



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0 1,000 2,000 3,000 4,000 Meters

05-Aug-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent
- Floodplain Extent

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Inflow Sensitivity Assessment
Floodplain Extent - 0.1% AEP

Figure 15

R0A

Norwich Park

R0A

0 200 400 600 800 1,000 Meters

05-Aug-2024 Scale: 1:20,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

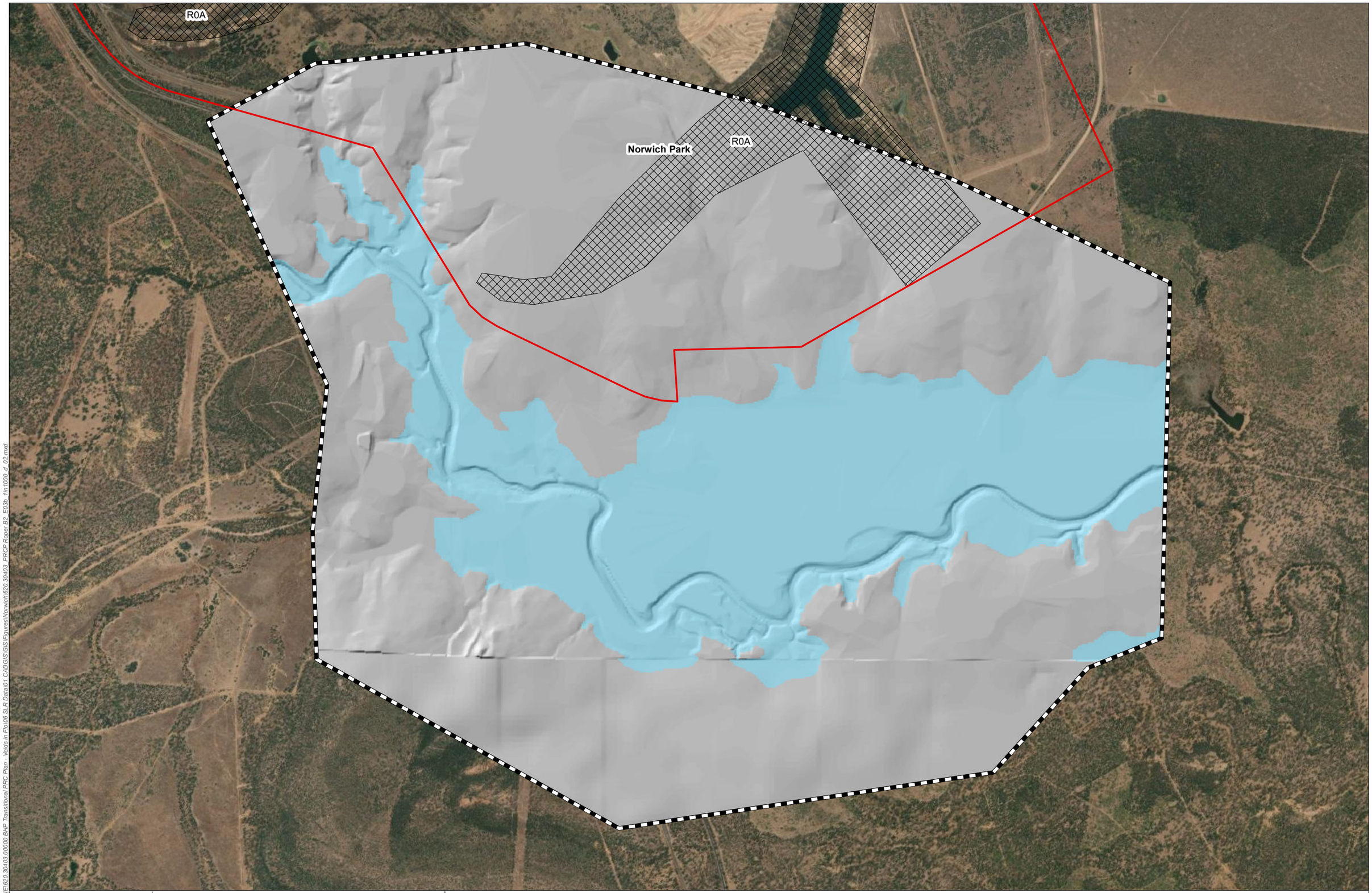
- EA Boundary
- Final Void Extent
- TUFLOW Model Extent
- Floodplain Extent

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Roper Creek
Peak Flood Depths - 0.1% AEP

Figure 16

H:\Projects-SLR\620-BNE\620.30403.00000 BHP Transitional PRC Plan - Voids in Flo\06 SLR Data\01 CAD\GIS\GIS\Figures\Norwich\620.30403_PRCP Roper B2_E03_1in1000_d_02.mxd



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0 200 400 600 800 1,000
Meters

05-Aug-2024 Scale: 1:20,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent
- Floodplain Extent

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Roper Creek - Inflow Sensitivity Assessment
Peak Flood Depths - 0.1% AEP

Figure 17

6 Summary

As part of the PRCP for Norwich Park Mine, it is proposed to incorporate nine 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 including BoM, DRDMW and Geoscience Australia. The data was reviewed and modified for use where appropriate. Model landforms were developed to account for artificial features outside of the ML where relevant, and pre-mining topography within the ML based on the information available at the time of the study.

A hydrologic assessment was undertaken for the portion of the Isaac River catchment that encompasses the Mine and the relevant watercourses. The model was calibrated against the results of Flood Frequency Analyses undertaken using data obtained at Goonyella and Deverill stream gauge stations located on the Isaac River.

A sub-model of the Isaac River hydrologic model was developed for the local Norwich Park Mine covering the catchments of the relevant watercourses in the area being Stephens Creek, Scott Creek and Roper Creek.

Hydraulic models were developed for Roper Creek and the Norwich Park Mine area. Hydrographs from extracted from the hydrologic models at relevant locations were applied as inflows to the hydraulic models.

The results of the hydraulic models provided the predicted 0.1% AEP flood event inundation extent. Predicted peak flood levels and depths were also produced by the hydraulic models. The results showed that the R9 and R6 NUMA voids are located inside the floodplain of Stephens and Scott Creeks respectively.

Sensitivity analyses was undertaken using the hydraulic model. The results of the analyses showed that a 20% increase in flows in Scott Creek causes a significant increase in the floodplain extent in the area of the southern arm of the R6 void.

7 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 Norwich Park 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

Pre-lodgement BHP/DES Workshop for PRCPs – Floodplain modelling and flood risks – Memorandum

Voids in flood plains

The PRCP guideline Section 3.4 outlines considerations to be included for PRC plan submissions relating specifically to voids in flood plains. Table 1 lists the key points that will be considered based on the guideline for flood modelling for voids and subsequent inclusion in the PRC plan submissions for relevant BHP sites.

Table 1: Guideline considerations for Voids in Floodplains

Guideline Considerations	**BHP PRCP Deliverables**
Voids located in floodplain to be rehabilitated to a stable condition	✓
Sites with a void proposed as a NUMA will have flood plain modelling*	✓
Flood plain modelled with peak water level 0.1% AEP	✓
Flood plain modelled for relevant watercourse – stream order 4 or higher including permanent diversions	✓
Modelling carried out under the ARR	✓
Modelling to exclude any *artificial features* for the land within the tenure boundary	✓
Modelling to include catchment data outside of the tenure including all existing and approved artificial features (as per Information Sheet)	BHP to use best endeavours
Modelling to include the location of the watercourse after the temporary diversions has been removed (as per Information Sheet)	Modelling to include watercourse classified as stream order 4 or higher, or current approved permanent diversions (stream order 4 or higher). Temporary diversions are not included in this modelling.
Flood plain model report developed by an appropriately qualified person	✓
Flood model report to contain:	
Details provided of the data used to develop the model in accordance with section 4.13.3. of the ARR	✓
Identification of all *artificial features* proposed or present within the tenure boundary	✓
Identification of all watercourses within the immediate catchment with the Strahler method of stream ordering applied	✓
Identification of any approved permanent watercourse diversions within the tenure boundaries and the relevant approval of the diversion	✓
Consideration of how groundwater may impact the flood plain extent	✓
A hydrologic model	Model report only
A hydraulic model	Model report only
Model assumptions and limitations	✓
Model calibration and sensitivity analysis	✓
Spatial data outlining the extent of the flood plain.	✓

* Unless the conditions of the applicability to transitional PRC plans are met for where flood plain modelling is not required.

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The PRCP Guideline Section 3.4 describes that “Flood plain modelling is required for all sites with a void proposed as a NUMA” with “the level modelled as the peak water level 0.1% AEP for a relevant watercourse”.

BHP will complete flood plain modelling in accordance with the ARR, and a model report for all sites with a void proposed as a NUMA. In accordance with the EP Regulation, the flood plain will be treated as the land where 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 0.1% Annual Exceedance Probability (AEP) for a relevant watercourse under the Australian Rainfall and Runoff Guideline (2019).

Artificial Feature

The PRCP Guideline details flood plain modelling must “exclude any artificial features for the land within the tenure boundary”. An artificial feature is detailed as:

> ***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.*

The DES have advised that the intent of the policy is that flood plain modelling must be based on pre-mining state. Therefore, temporary structures including those that will require a level of maintenance after the land is surrendered within the tenure boundary, will not be included in the flood plain modelling. Additionally, a feature that does not form part of the natural landform and interferes or affects a relevant water course or the natural flow of water on the land will not be included in the flood plain modelling. In accordance with the definition of artificial feature, the structures or features that will not be included in the flood plain modelling may include::

- final dumps
- final voids
- final subsidence
- creek diversions (in the current temporary approved state)

If a watercourse diversion over the course of the future mine life requires further approval, then new information will be provided at that point.

Whilst the DES have confirmed their position, BHP maintain that this may result in an impracticable application of the flood plain modelling, and could fail to ensure the relevant risks associated with flood plains are properly addressed and managed.

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Relevant Watercourse

BHP have confirmed with the DES and both are in agreement that the flood plain modelling will include the relevant watercourses, as defined under the EP Regulation:

> ***Relevant watercourse*** *means—*
> *(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 licence or proposed water licence under the Water Act 2000;*
> *the watercourse as permanently diverted.*

The DES have advised that the statement in the information sheet regarding "The application for voids in the flood plain of streams with a stream order of three and lower are still assessed against the decision criteria in the EP Act and may be refused", is in relation to rehabilitation practices for flooding.

Spatial Extent of Modelling

The information sheet details the need for considering catchment data outside of the relevant tenure in determining the extent of the flood plain model and final mapped flood plain extent.

As the spatial extent of data that is required for each catchment and model is a highly technical matter. The DES and BHP are in agreement that BHP will default to the expert judgement of those performing the flood modelling in determining this extent.

With respect to artificial features outside of the tenure boundary, the information sheet details that the flood plain model includes a combination of data:

- within the mining tenure boundary, to exclude any artificial features;
- outside of the mining tenure boundary to include all existing and approved artificial features.

BHP is unclear on what is intended, because it potentially results in an unrealistic hybrid scenario containing both past and future features being modelled. For example, BMA's Saraji Mine PRCP *must not* include flood modelling with Saraji's artificial features, but also *must* include the artificial features on the adjacent BMA Peak Downs Mine. BHP has several sites this will be relevant to and foreshadows that this requirement may result in flood plain modelling results that appear unusual when compared between PRCP's. This is because every site will likely need to be modelled separately and will produce flood plain modelling results that could well differ in the flood plain extent shown in an adjacent site's PRCP. Further afield, an example is the Burton Gorge Dam operated by Peabody upstream of BMA's Goonyella Riverside Mine on the Isaac River that will be included in the model.

Nonetheless, BHP will use best endeavours to obtain information on artificial features outside of the mining tenure boundary for inclusion in the flood plain modelling. In addition to this, the flood plain modelling undertaken by BHP will include artificial features obtained outside of the mining tenure boundary based on current as at time of modelling.

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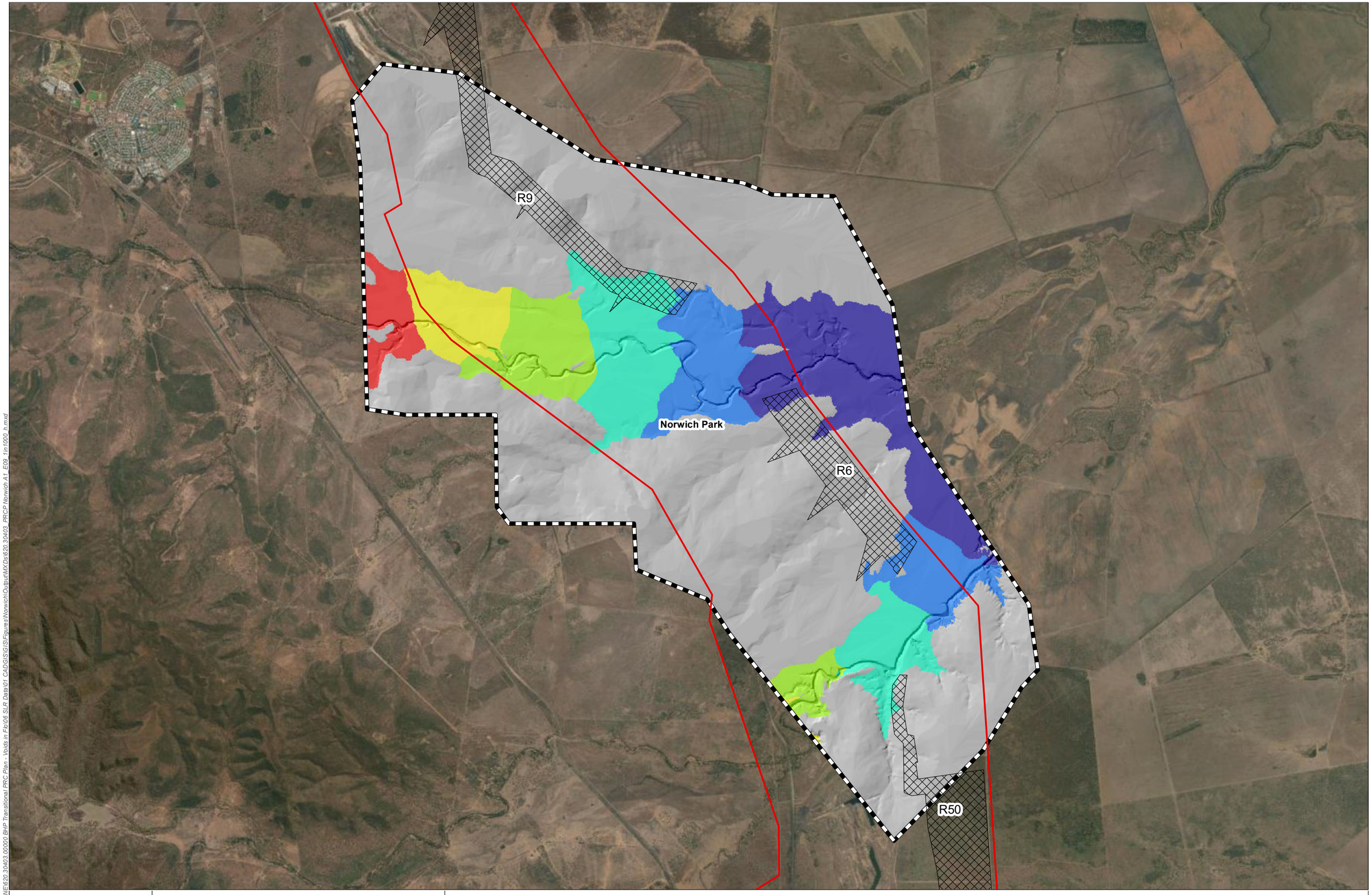
APPENDIX B

TUFLOW Model Results – Norwich Park Model



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0 1,000 2,000 3,000 4,000 Meters

05-Aug-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

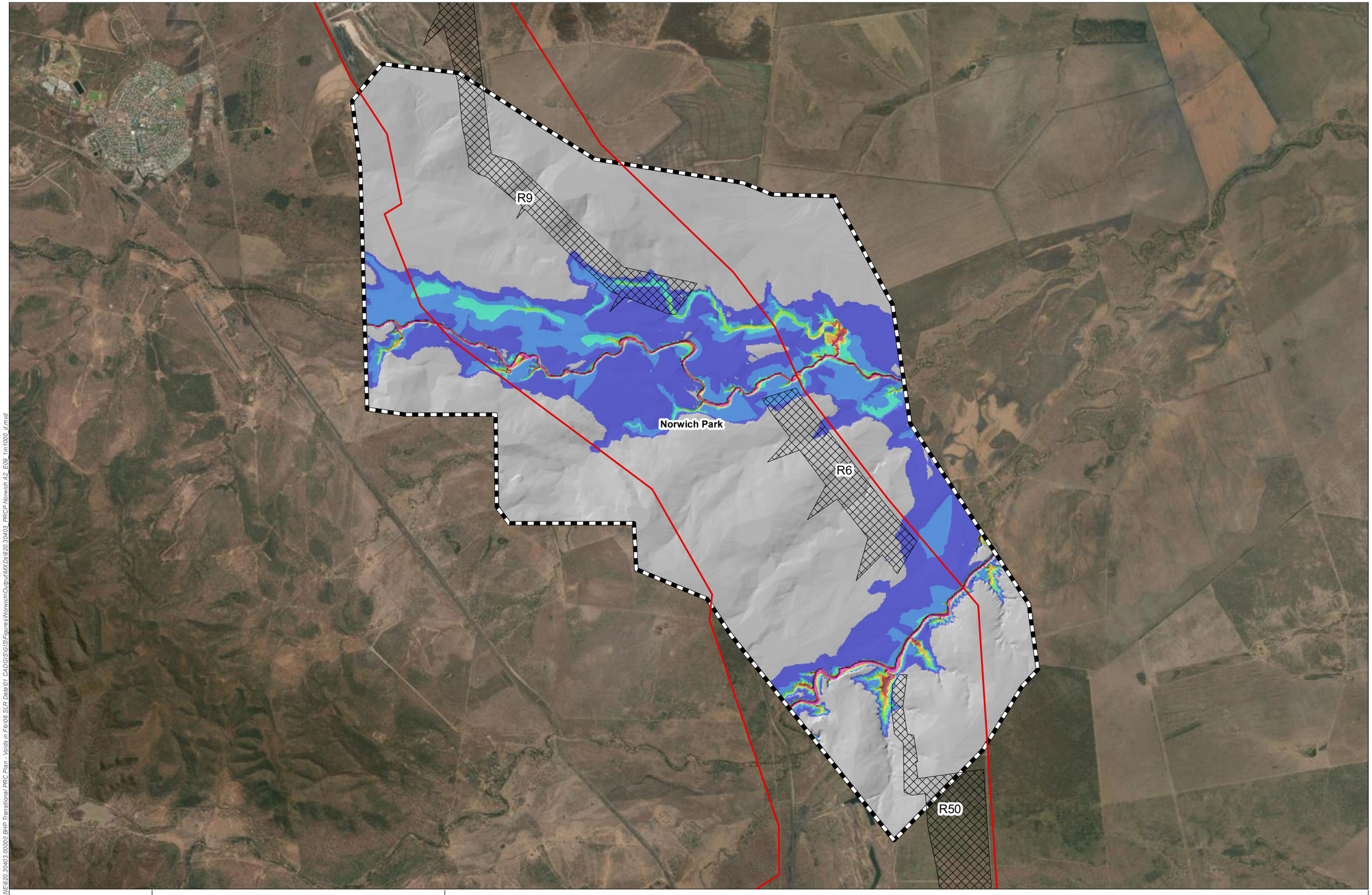
Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model
Peak Flood Levels - 0.1% AEP

Appendix B1



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0 1,000 2,000 3,000 4,000 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model
Peak Flood Depths - 0.1% AEP

Appendix B2

R6

Norwich Park

R50

0 500 1,000 1,500 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 187
- 187 - 189
- 189 - 191
- 191 - 193
- 193 - 195
- >195

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Scott Creek
Peak Flood Levels - 0.1% AEP

Appendix B3

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R6

Norwich Park

R50

0 500 1,000 1,500 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Scott Creek
Peak Flood Depths - 0.1% AEP

Appendix B4

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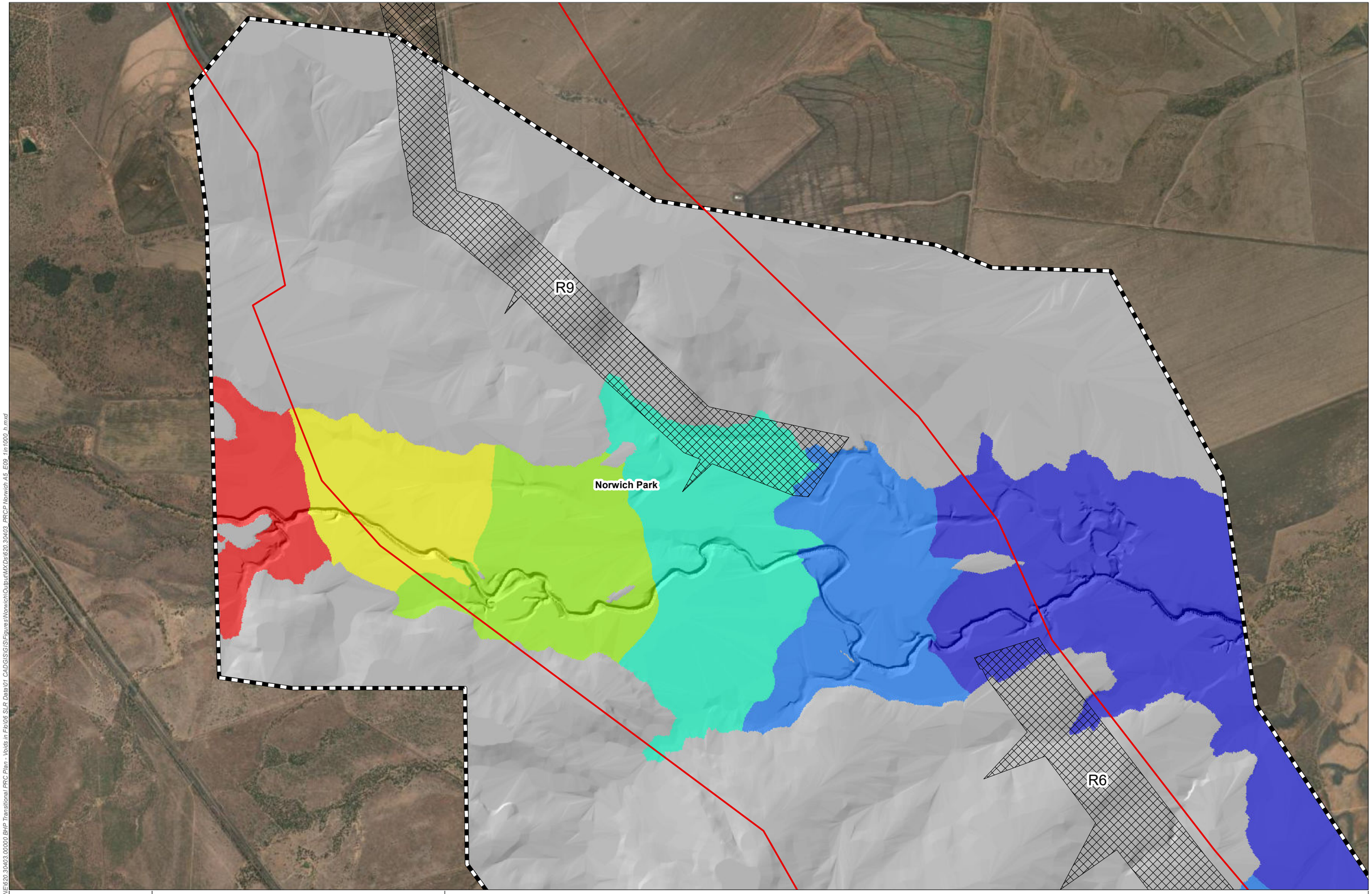

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Stephens Creek
Peak Flood Levels - 0.1% AEP

Appendix B5

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R9

Norwich Park

R6

0 400 800 1,200 1,600 2,000 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Stephens Creek
Peak Flood Depths - 0.1% AEP

Appendix B6

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APPENDIX C

TUFLOW Model Results – Norwich Park Model – Flow Sensitivity Assessment

R9

Norwich Park

R6

R50

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

0 1,000 2,000 3,000 4,000 Meters

05-Aug-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

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Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario
Peak Flood Levels - 0.1% AEP

Appendix C1

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R9

Norwich Park

R6

R50

0 1,000 2,000 3,000 4,000 Meters

05-Aug-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario
Peak Flood Depths - 0.1% AEP

Appendix C2

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R6

Norwich Park

R50

0 500 1,000 1,500 Meters

05-Aug-2024 Scale: 1:25,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 187
- 187 - 189
- 189 - 191
- 191 - 193
- 193 - 195
- >195

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario - Scott Creek Peak Flood Levels - 0.1% AEP

Appendix C3

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R6

Norwich Park

R50

0 500 1,000 1,500 Meters

05-Aug-2024 Scale: 1:25,000

Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario - Scott Creek
Peak Flood Depths - 0.1% AEP

Appendix C4

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R9

Norwich Park

R6

0 400 800 1,200 1,600 2,000 Meters

05-Aug-2024 Scale: 1:33,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario - Stephens Creek Peak Flood Levels - 0.1% AEP

Appendix C5

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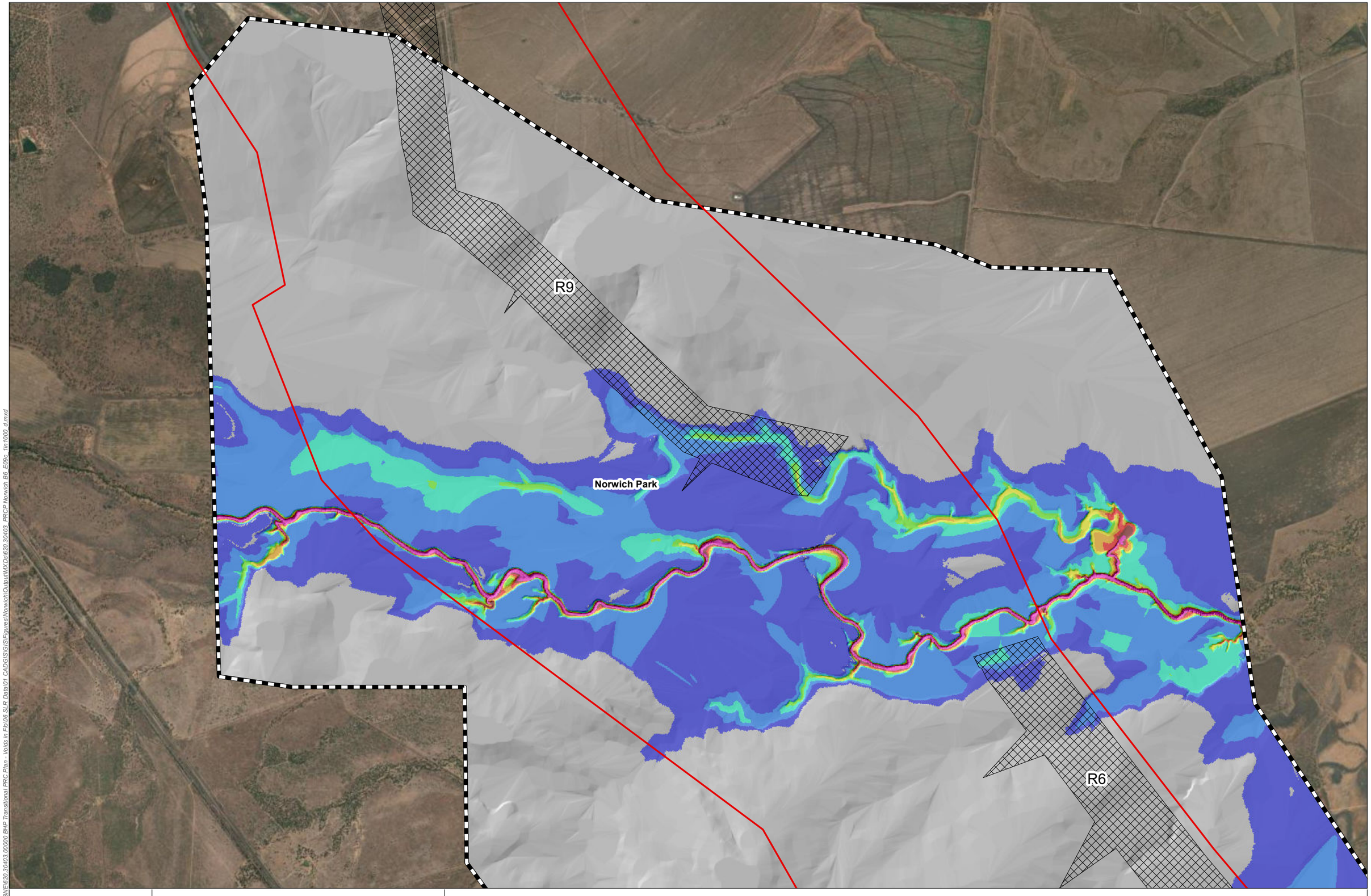

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SLR
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05-Aug-2024 Scale: 1:33,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

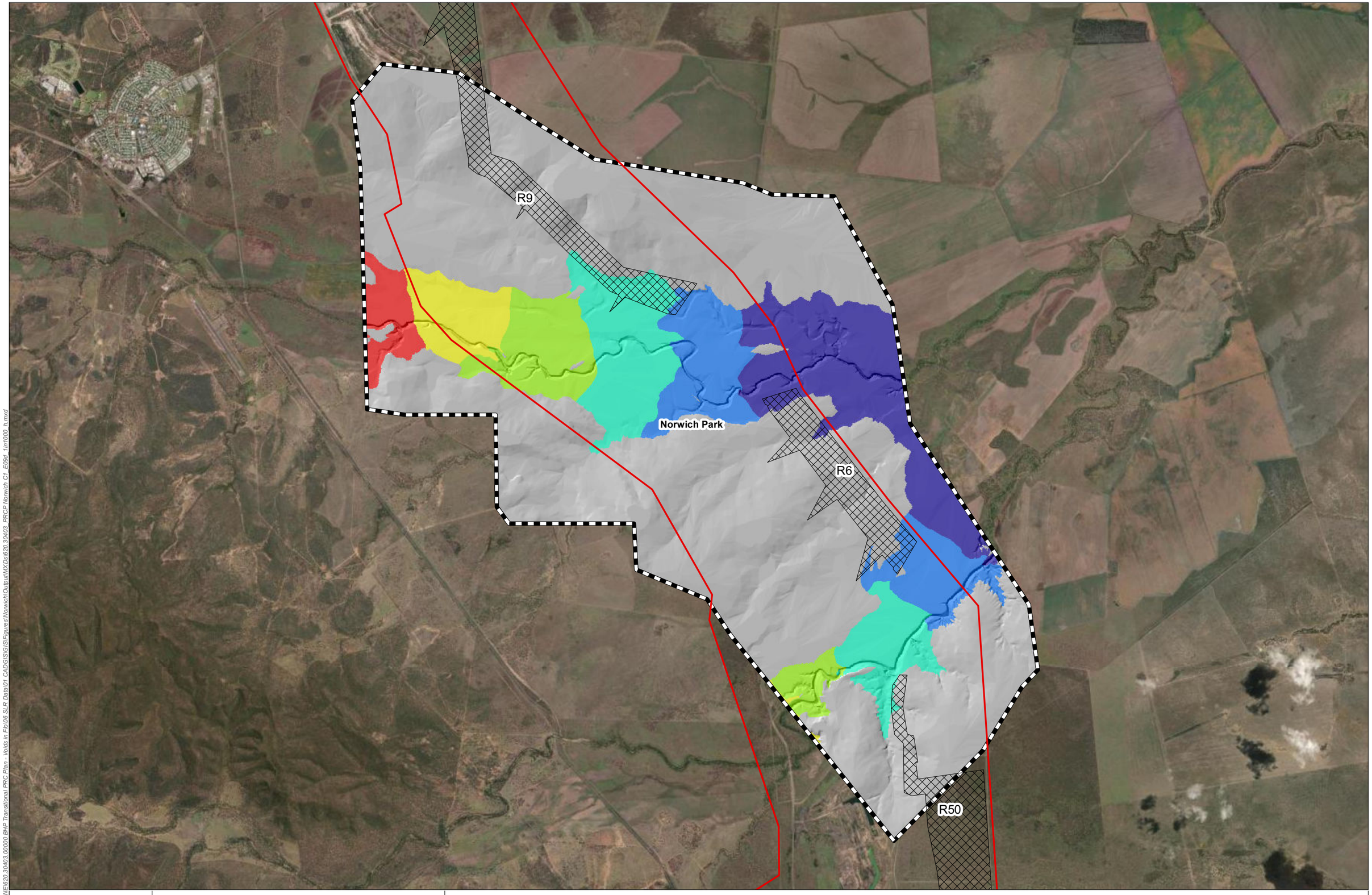
Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - 20% Flow Increase Sensitivity Scenario - Stephens Creek
Peak Flood Depths - 0.1% AEP

Appendix C6

APPENDIX D

TUFLOW Model Results – Norwich Park Model – Tailwater Sensitivity Assessment



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SLR
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0 1,000 2,000 3,000 4,000 Meters

18-Apr-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Levels - 0.1% AEP

Appendix D1

R9

Norwich Park

R6

R50

0 1,000 2,000 3,000 4,000 Meters

18-Apr-2024 Scale: 1:63,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Depths - 0.1% AEP

Appendix D2

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R6

Norwich Park

R50

0 500 1,000 1,500 Meters

18-Apr-2024 Scale: 1:25,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 187
- 187 - 189
- 189 - 191
- 191 - 193
- 193 - 195
- >195

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Levels - 0.1% AEP

Appendix D3

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R6

Norwich Park

R50

0 500 1,000 1,500 Meters

18-Apr-2024 Scale: 1:25,000

Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Depths - 0.1% AEP

Appendix D4

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R9

Norwich Park

R6

0 400 800 1,200 1,600 2,000 Meters

18-Apr-2024 Scale: 1:33,000

Sheet Size : A3 AGD 1966 AMG Zone 55

SLR
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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Level (m AHD)

- <185
- 185 - 188
- 188 - 191
- 191 - 194
- 194 - 197
- 197 - 200
- >200

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Levels - 0.1% AEP

Appendix D5

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R9

Norwich Park

R6

0 400 800 1,200 1,600 2,000 Meters

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Legend

- Final Void Extent
- TUFLOW Model Extent
- EA Boundary

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Norwich Park Model - Tailwater Sensitivity Scenario
Peak Flood Depths - 0.1% AEP

Appendix D6

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APPENDIX E

TUFLOW Model Results – Roper Creek Model

R0A

Norwich Park

R0A

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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Level (m AHD)

- <184
- 184 - 186
- 186 - 188
- 188 - 190
- 190 - 192
- 192 - 194
- >194

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Roper Creek Model
Peak Flood Levels - 0.1% AEP

Appendix E1

R0A

Norwich Park

R0A

0 200 400 600 800 1,000 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

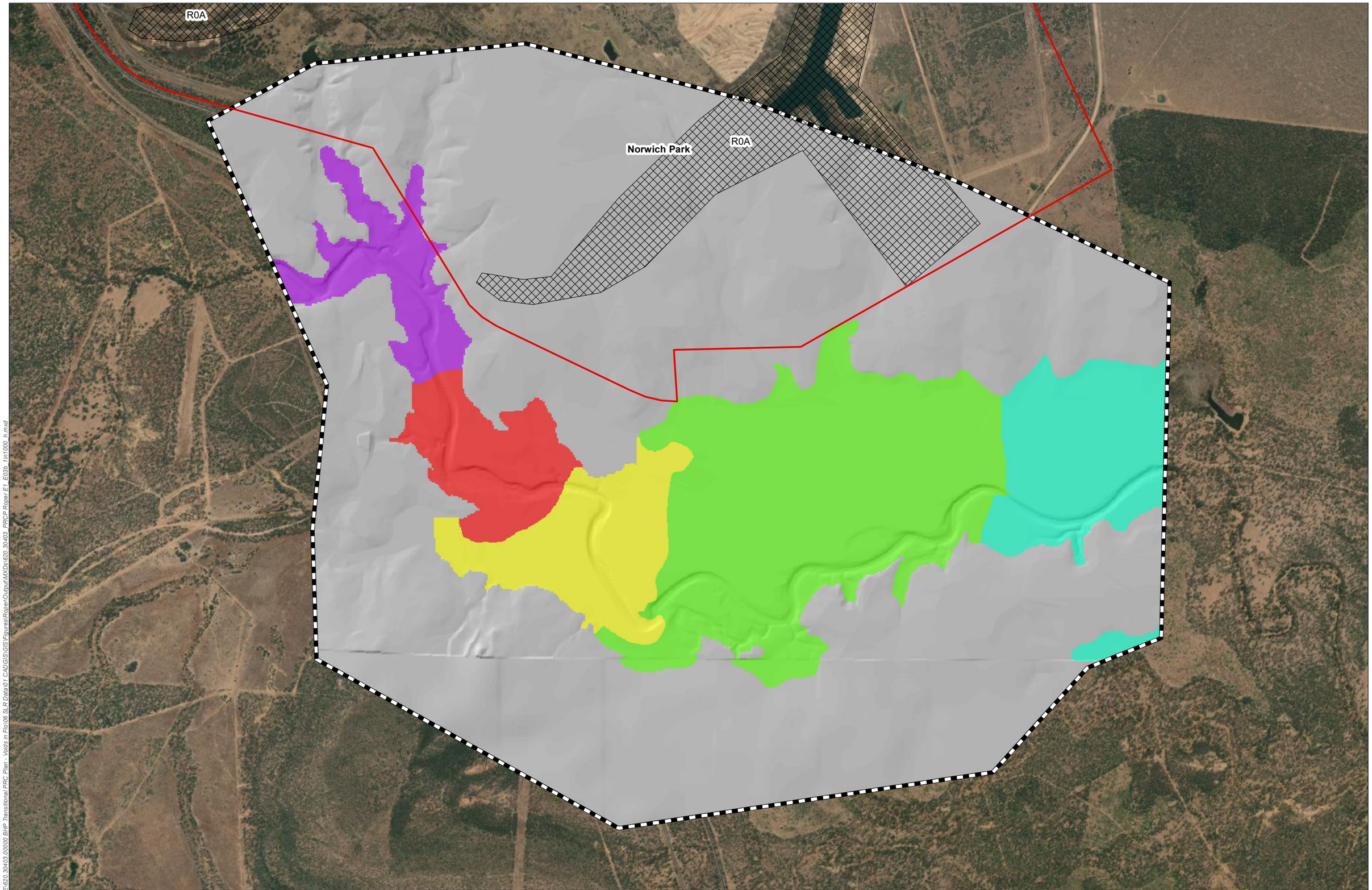
Roper Creek Model
Peak Flood Depths - 0.1% AEP

Appendix E2

H:\Projects-SLR\620-BNE\620.30403.00000 BHP Transitional PRC Plan - Voids in Flo\06 SLR Data\01 CAD\GIS\GIS\Figures\Roper\Output\MXDs\620.30403_PRCP Roper D2_E03_1in1000_d.mxd

APPENDIX F

TUFLOW Model Results – Roper Creek Model – Flow Sensitivity Assessment



0 200 400 600 800 1,000 Meters

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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Level (m AHD)

- <184
- 184 - 186
- 186 - 188
- 188 - 190
- 190 - 192
- 192 - 194
- >194

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Roper Creek Model
Peak Flood Levels - 0.1% AEP

Appendix F1

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R0A

Norwich Park

R0A

0 200 400 600 800 1,000 Meters

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Sheet Size : A3 AGD 1966 AMG Zone 55

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Legend

- EA Boundary
- Final Void Extent
- TUFLOW Model Extent

Depth (m)

< 1	4 - 5	> 8
1 - 2	5 - 6	
2 - 3	6 - 7	
3 - 4	7 - 8	

Transitional PRC Plan - Voids in Floodplain Modelling
Norwich Park Mine

Roper Creek Model
Peak Flood Depths - 0.1% AEP

Appendix F2

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WMS

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REHABILITATION FLOOD MODELLING – SARAJI SOUTH (NORWICH PARK) MINE

AUGUST 2024

PREPARED FOR

BHP Mitsubishi Alliance (BMA)

Details	
Title	Rehabilitation Flood Modelling – Saraji South (Norwich Park) Mine
Prepared for	BHP Mitsubishi Alliance (BMA)
Document Name	10749-R01-SarajiSouthRehabFloodModelling-2.docx

Document Control					
Revision	**Author**	**Reviewer**	**Approved for Issue**		
			Name	**Signature**	**Report Date**
0	MAL & ATO	BLB	B. Boulton		26/10/2023
1	MAL & ATO	BLB	B. Boulton		27/03/2024
2	MAL & ATO	BLB	B. Boulton		05/08/2024

Revision Status	
Revision	**Description**
0	Draft report
1	Updated report after client review
2	Updated report with 'Consideration of Roper Study Area'

Cover Image: Norwich Park (known operationally as Saraji South) Mine. Source https://www.flickr.com/photos/beyondcoalandgas/28308874224/ (visited July 2023).

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In preparing this report, WMS has assumed that all data, reports, and any other information provided to us by the Client, on behalf of the Client, or by third parties is complete and accurate, unless stated otherwise.

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
ARR	Australian Rainfall & Runoff
BMA	BHP Mitsubishi Alliance
DEM	Digital Elevation Model
DES	Department of Environment and Science
EA	Environmental Authority
FFA	Flood Frequency Analysis
FRP	Flooding Risk Profile
GSDM	Generalised Short-Duration Method
GTSMR	Revised Generalised Tropical Storm Method
LiDAR	Light Detection and Ranging
NUMA	Non-use Management Area
PMC	Pre-mining conditions
PMF	Probable Maximum Flood
QRT	Quantile Regression Technique
PRC	Progressive Rehabilitation and Closure
RCP	Representative Concentration Pathway (climate change emissions scenario)
RFFE	Regional Flood Frequency Estimation
SRM	Saraji Mine
SSM	Saraji South Mine
SRTM	Shuttle Radar Topography Mission

1 INTRODUCTION

1.1 PROJECT BACKGROUND

BHP Mitsubishi Alliance (BMA) is Australia's largest producer and supplier of seaborne metallurgical coal, and it operates several mines within the Bowen Basin. As such, BMA are subject to the Queensland Government's Mined Land Rehabilitation Policy, which ensures that land disturbed by mining activities is rehabilitated progressively to a safe and stable landform as it becomes available. The rehabilitation must minimise the risks of environmental impacts and reduce cumulative areas of disturbed land throughout the life of a site.

To comply with the Queensland Government's Mined Land Rehabilitation Policy and the Environmental Protection (Rehabilitation Reform) Amendment Regulation 2019, BMA are required to develop Progressive Rehabilitation and Closure (PRC) Plans for the Norwich Park mine, known operationally as Saraji South Mine (SSM). The PRC plans detail how and where activities will be carried out to allow the progressive rehabilitation of the land to a stable condition. Because SSM is a pre-existing mine for which BMA already hold an Environmental Authority (EA)/Land Outcome Document, the 'transitional' provisions provided for within the Mineral and Energy Resources (Financial Provisioning) Act 2018 (MERFP Act) apply to the SSM PRC plan.

This rehabilitation flood modelling report has been prepared to inform the development of the SSM transitional PRC plan. The completed scope specifically aims to address the 'Flooding' requirements outlined in Section 3.6.1 – General Rehabilitation Practices of the Department of Environment and Science (DES) 2021 Guideline – Progressive rehabilitation and closure plans (PRC plans). The scope of this assessment does not include voids in floodplain modelling, which has been completed under separate cover.

This report has been prepared and reviewed by appropriately qualified engineers in accordance with DES PRC Guideline's definition of an appropriately qualified person - *"a person who has professional qualifications, training, skills and experience relevant to the subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods and literature"*.

1.2 PROJECT OBJECTIVES AND SCOPE

The objective of the project has been to deliver the supporting information pertaining to flooding that is considered by the administering authority to be necessary for underpinning the development of rehabilitation and management methodologies for SSM.

The project was divided into several phases. The scope of each phase is briefly outlined below.

Preliminaries

- Kick Off Meeting; and
- Collection and review of available data such as:
  - BMA available LiDAR data, contour data and aerial imagery for mining lease areas;
  - Existing flood models and data;
  - Pre-mining landform; and
  - Preliminary landform designs.

Hydrologic Modelling

- Preliminary assessment of the landform design and existing voids in floodplain models;
- Required updates to catchment characterisation and delineation based on pre- and post-mining landforms;
- Model calibration (if/where data is available);
- Rerunning of hydrologic models in accordance with Australian Rainfall & Runoff (ARR) 2019 guidelines;
- Modelling of the 39%, 2%, 1%, 0.1% Annual Exceedance Probability (AEP) and Probable Maximum Flood (PMF) events as well as climate change scenarios; and
- Selection of critical design storm events.

Hydraulic Modelling

- Development/update of TUFLOW 1D/2D hydraulic models in accordance with ARR2019 guidelines for pre- and post-mining conditions;
- Simulation of all required scenarios (pre- and post-mining) and design storm events (39%, 2%, 1%, 0.1% AEP and PMF events, as well as climate change scenarios);
- Processing of simulation results;
- Flood assessment including a detailed understanding of the following:
  - Drainage and flooding behaviours in the vicinity of the voids;
  - Potential extent of flooding and any interactions with the voids;
  - Drainage and flooding behaviours over backfilled material; and
  - Assessment of any alteration to flows upstream and downstream.
- Development of a flooding risk profile using the BHP established qualitative risk method.

Reporting and Mapping

- Documentation of study approach, methodology, inputs and outcomes;
- Floodplain mapping for all modelled scenarios and events showing peak flood results, including water levels, depths, velocities and stream power; and
- Workshop with BMA – Results Briefing.

Project Finalisation

- Finalisation of report based on comments and feedback received from BMA on draft report; and
- Handover of final report, all study materials and model files.

1.3 STUDY AREA

SSM is an open pit coal mine located immediately south of the Saraji Mine (SRM). The mine's western EA boundary is approximately 5 km east of Dysart and 86 km northeast of Emerald, in Queensland's Bowen Basin.

Mining operations commenced at SSM in 1979. targeting the Dysart and Harrow Creek Coal Seams. Mining has included the extraction of coking and steaming coal through open cut strip mining. In 2012 the mine was placed in care and maintenance and select voids utilised as water storage until 2022 when limited extraction of coal from the northern voids recommenced with coal processing currently occurring at the Saraji Mine to the north.

Upon project initiation five main watercourses were identified to be crossing/adjacent to SSM: Stephens Creek, Scotts Creek, Downs Creek, Rolf Creek and Roper Creek. Review of the PRC landform design showed that Roper Creek catchments were unlikely to undergo changes as part of the PRC process and further modelling of the watercourse was not deemed necessary for the purposes of this study. Further details regarding the consideration of Roper Creek and the PRC Landform Design are outlined in Section 1.5.

All study watercourses flow generally from west to east through or adjacent to the mine lease boundary and between mining pits. All watercourses have been or will be diverted from their original alignment to allow access to coal reserves. The catchments that feed the watercourses are located to the west of SSM and are defined by highlands and ranges with the catchment land use comprising of natural wooded areas and grassland.

The study area and key waterways are illustrated in Figure 1-1.

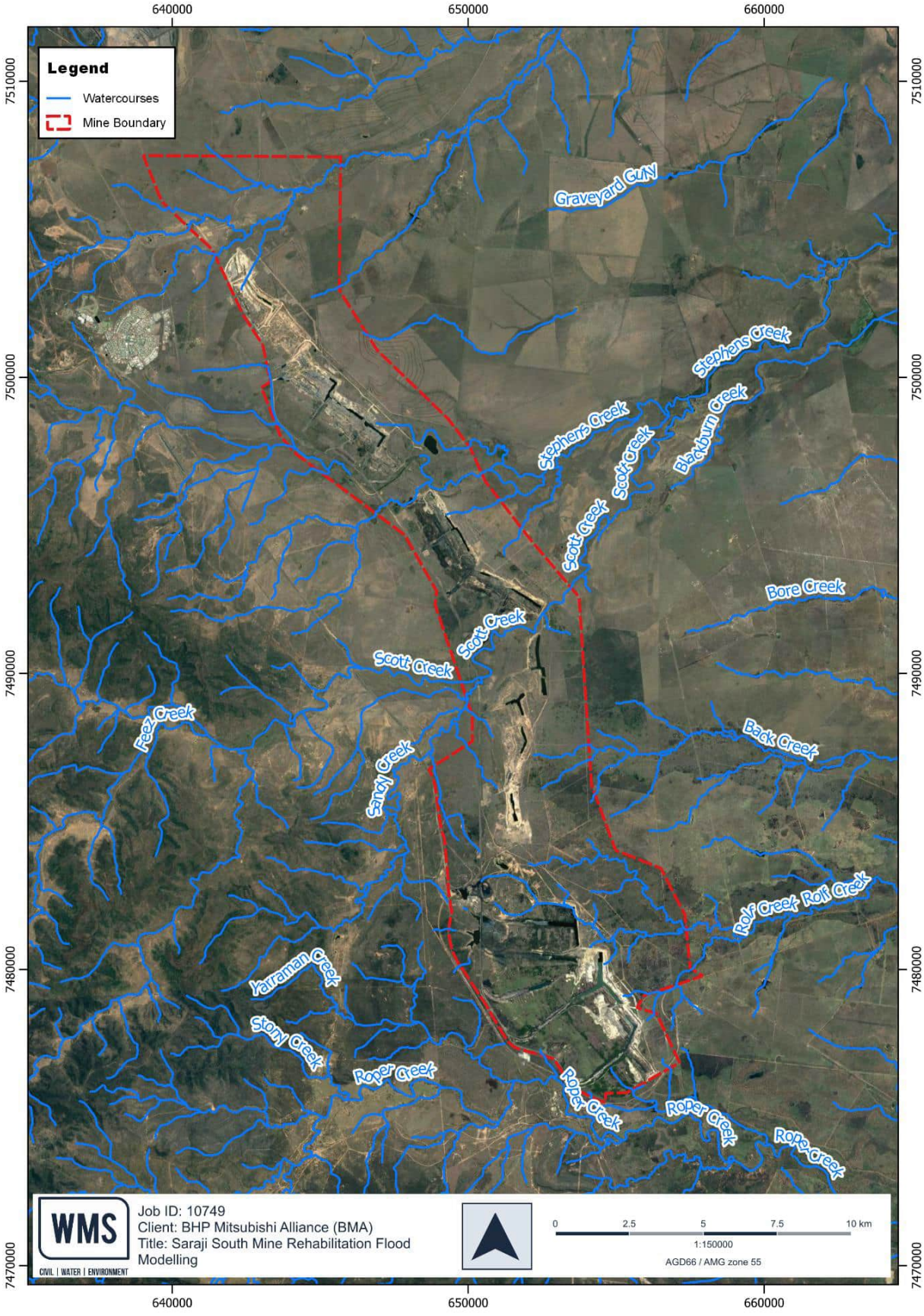

Figure 1-1 Saraji South Mine Study Area

1.4 PRC LANDFORM DESIGN

The proposed PRC landform design provided by BMA (file name: *prcp_npm_lf1_1_modelled_dem_agd66z55_20230825.asc*) is illustrated in Figure 1-2.

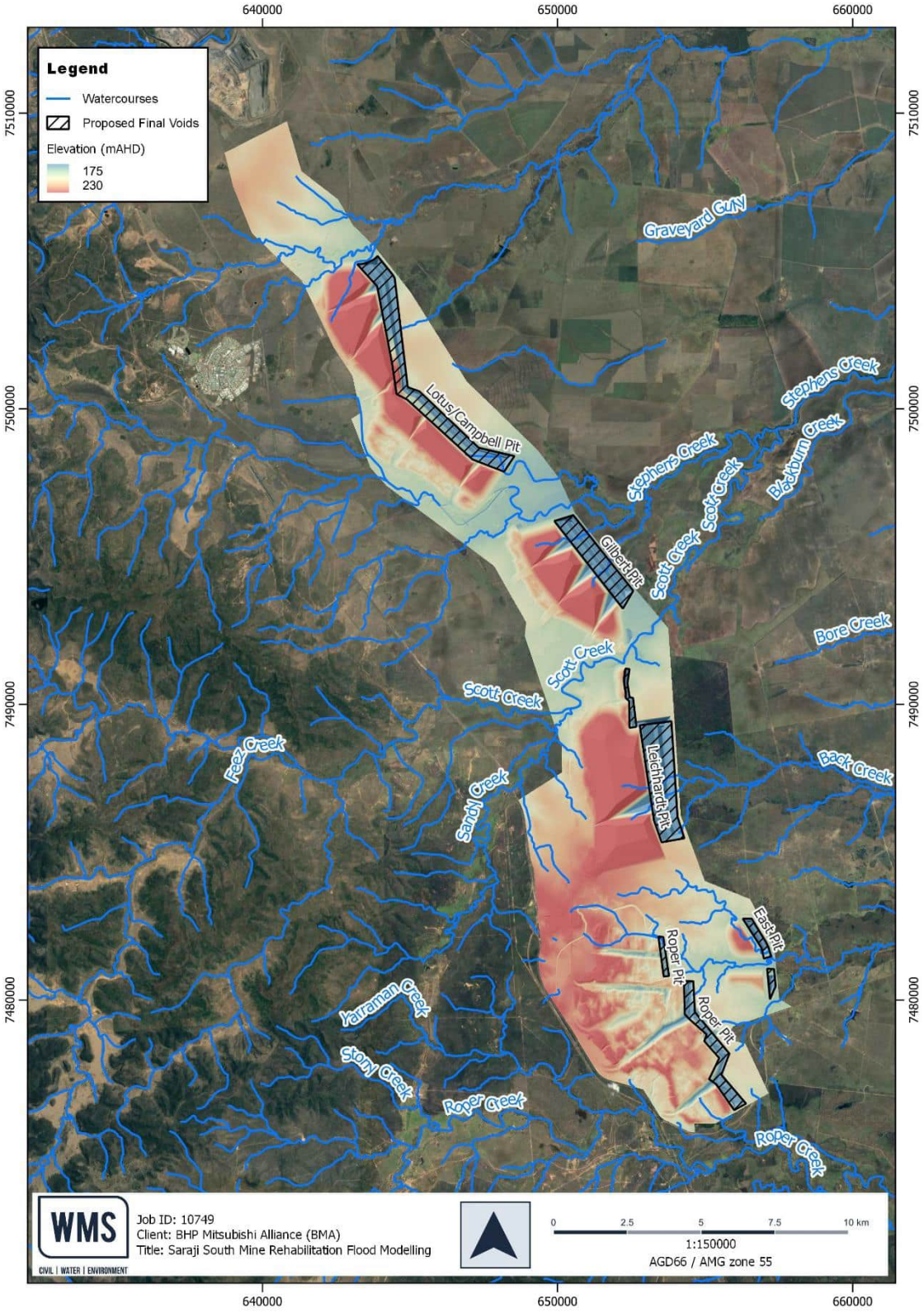

Figure 1-2 Saraji South Mine PRC Landform Design

1.5 CONSIDERATION OF ROPER CREEK MODELLING

Upon inspection of the SSM PRC Landform Design Surface it was apparent that no significant landform features are proposed in the vicinity of Roper Creek. Flood modelling completed as part of the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020) demonstrates that Roper Creek poses a negligible risk to the current PRC Landform Design for SSM. Figure 1-3 illustrates the 0.1% AEP Climate Change flood extent from the WRM study, in the vicinity of the landform design. The following can be noted:

- The Roper Creek flood extent crosses into the mining lease area in the 0.1% Climate Change event at a water level of approximately 197.2 m AHD.
- Under PRC conditions the flood waters would be prevented from entering further into the mine lease area by the decommissioned haul road, the lowest point of which is approximately 3 m above the Flood Study 0.1% AEP Climate Change flood level.
- The Roper Creek catchment is predominantly outside of the mining lease area. Catchment characteristics are not changing under PRC conditions, so flood levels estimates are not anticipated to change.

WMS met with BMA on 6 June 2023 for a project progress meeting. The value in reassessing Roper Creek as part of the PRC modelling works was discussed at this meeting. BMA and WMS agreed that further modelling of the watercourse would not be required.

1.6 CONSIDERATION OF ROPER STUDY AREA

BMA have advised that, at the time of the preparation of this rehabilitation flood assessment, further technical studies were required in the area containing the Roper residual voids to close out data gaps required to inform the development of a closure landform. As these investigations cannot be completed by BMA within the PRC Plan notice period, BMA have implemented a Roper Study Area (Figure 1-4) with dedicated Rehabilitation Milestones (RM). Due to the reasonable uncertainty around the final landforms within the Roper Study Area, the results of the flood modelling in the proximity of the Roper Voids can be considered indicative only. Upon completion of the required additional technical studies within the Roper Study Area and finalisation of the landform design, reassessment of the flooding will be required.

1.7 KEY ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations are applicable to the data used for the investigation, modelling results and mapping deliverables. The modelling results should therefore be viewed in light of these limitations.

Table 1-1 Key Assumptions and Limitations

Assumptions	
1	Gauge and calibration data associated with the Stephens Creek and Scott Creek calibration undertaken as part of the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020) was not available to WMS. It is understood from BMA that the existing calibrated model is fit for purpose and no further calibration is required as part of this project.
Limitations	
1	There is limited historical/gauged data for the catchments that contribute to SSM with the exception of Stephens Creek and Scott Creek. As such, the models developed for Downs Creek and Rolf Creek as part of this assessment have not been calibrated to historical data. Appropriate validation has been carried out in place of calibration.
2	The pre-mining surface provided by BMA for use in the modelling of pre-mining conditions was derived from 2 m interval topographic contours, resulting in a very course digital surface. As such, pre-mining modelling results should not be relied upon for anything more than a general check against the PRC model results, and the limitations of the underlying source data should be considered when interpreting the results.
3	There was limited high-resolution topographic data available for some models. Areas of the Stephens Creek and Scotts Creek models, downstream of the mine have been constrained due to this absence of reliable data. Some 'glass-walling' is presented in the mapping as a result. For Rolf Creek, topography immediately downstream of the mine utilises low-resolution SRTM data, which may reduce accuracy of the modelled flood levels near the downstream ends of the PRC mine voids. It is understood from BMA that no better data is available at the locations identified.
4	The modelling reflects BMA's Stage 3 PRC Landform Design and its supporting available information at the time of report issue. Any ongoing changes to the design or supporting information may require revision of the study findings.

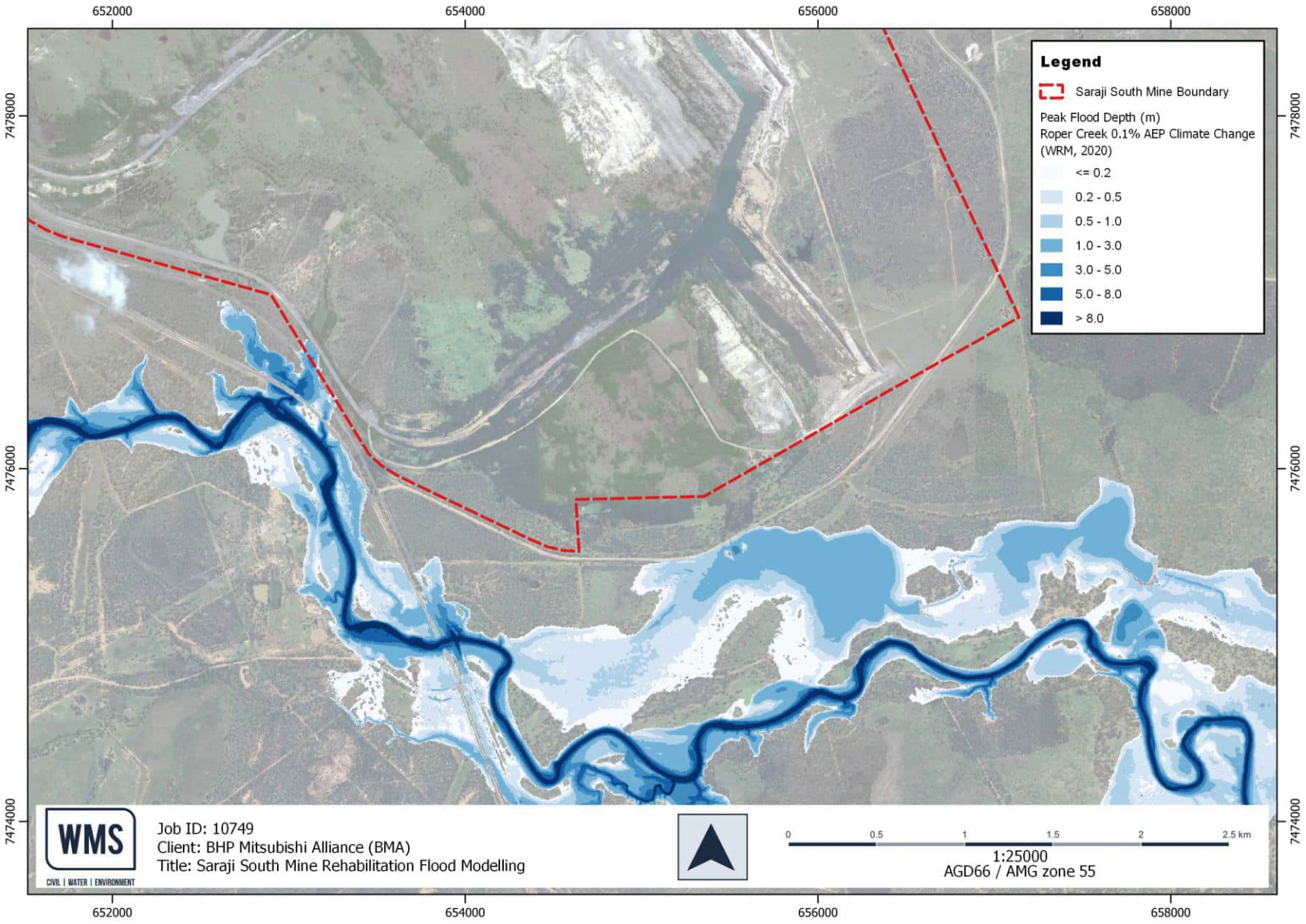

Figure 1-3 Roper Creek 0.1% AEP Climate Change Event (WRM, 2020)

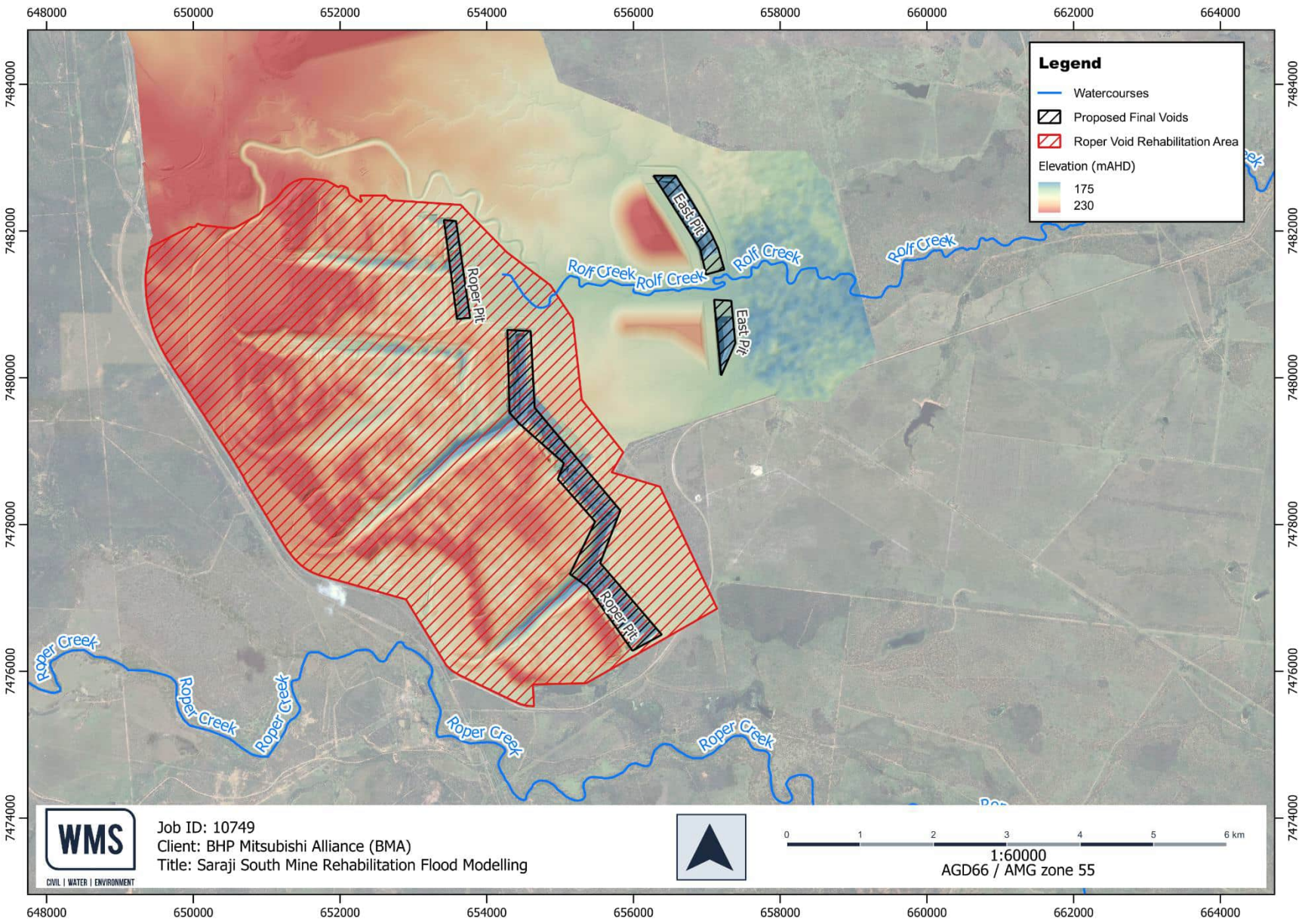

Figure 1-4 Roper Study Area

2 INPUT DATA

Data for the current assessment was provided by BMA and included topographic data, design surface data for the PRC landform, aerial imagery and previous studies and models. Further data was obtained for use in the assessment from public sources, including additional topographic data, rainfall data and catchment specific hydrologic data.

Further detail on the data utilised in the assessment is provided below.

2.1 PREVIOUS STUDIES

Several flood studies have been previously undertaken for the SSM study area. BMA provided WMS with a copy of the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020), which is summarised below. The report was reviewed at the start of this assessment to gain a better understanding of the study area and its key hydrologic and hydraulic features. Furthermore, the hydrologic and hydraulic models developed as part of the WRM study were provided to WMS to be used as a basis for the modelling in this assessment.

2.1.1 Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)

WRM was engaged by BMA to undertake a flood study for Stephens Creek, Scott Creek, Downs Creek and Roper Creek at SSM. The purpose of the flood study was to define baseline flood conditions at the existing mine site and assess the flood risk imposed by the study creeks, including flood risk assessments of existing mine infrastructure to determine if the mine infrastructure provides adequate flood immunity for the pits.

Hydrologic modelling of the study creek catchments was undertaken to estimate design peak discharges. Hydrologic modelling was undertaken based on the latest best practice guidelines outlined in ARR2019. The hydrologic and hydraulic models were calibrated to the Stephens Creek and Scott Creek upstream gauging stations, which are the only two gauging stations located in the study area.

2.1.2 Existing Models

As part of their 2020 study, WRM developed XPRAFTS hydrologic models of the Stephens Creek, Scott Creek, Downs Creek and Roper Creek catchments. The Stephens Creek and Scott Creek models were calibrated to the December 2010 and March 2017 events. The calibrated hydrologic models were used to estimate the 10%, 5%, 1% and 0.1% AEP design discharges for the study creeks in the vicinity of SSM. These design discharge estimates were validated against flood frequency analysis (FFA) results.

WRM also developed TUFLOW hydraulic models for Stephens Creek, Scott Creek, Downs Creek and Roper Creek. The TUFLOW model was verified against the existing rating curve developed at the Stephens Creek upstream gauge and Scott Creek upstream gauge. The calibrated model was then used to estimate flooding characteristics in the study creeks for the 1% and 0.1% AEP. Design discharge hydrographs from the calibrated XPRAFTS model were used as inflows to the TUFLOW model.

The existing models developed as part of the 2020 WRM study were provided to WMS are summarised in Table 2-1. These models were used as a starting point for this assessment and were modified/updated where required.

As no pre-existing model was available for Rolf Creek at the time of this assessment, a new XP-RAFTS/TUFLOW model was developed by WMS for that watercourse.

Further details on model updates and new model build are provided in Section 4.

Table 2-1 Existing SSM Models Provided to WMS

Model Name	Hydrologic Model Software	Hydraulic Model Software	Hydraulic Model Grid Resolution (m)	Source
Stephens Creek	XPRAFTS	TUFLOW	4	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)
Scotts Creek	XPRAFTS	TUFLOW	5	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)
Downs Creek	XPRAFTS	TUFLOW	5	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)
Roper Creek	XPRAFTS	TUFLOW	5	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)

2.2 TOPOGRAPHY

Topography data within the study area was available in the form of several digital elevation models (DEMs) that were provided by BMA. These are summarised in Table 2-2. The SSM PRC Landform Design Surface forms the basis of the PRC assessment with other surfaces used to supplement the design where terrain was required outside the area of interest. The Saraji South Mine Pre-Mining Surface was the best available surface representative of pre-mining conditions. This surface was used for the PMC assessment. The pre-mining surface is poor quality and the PMC model results should therefore be viewed as indicative only.

Table 2-2 Available Digital Elevation Models

DEM Name	Terrain Conditions	Area Covered	Resolution (m)	Date Surveyed/Created	Source
Saraji South Mine PRC Landform Design Surface	Design	SSM	1	25/08/2023	BMA
Saraji South Mine Existing Surface – LiDAR	Existing	SSM	1	July 2022	BMA
1 second SRTM Derived Hydrological Digital Elevation Model	Existing	SSM and surrounds	~30	2009	Geoscience Australia
Saraji Mine Pre-Mining Surface	Pre-Mining	SSM	1	2022	SLR[1]

[1] The SSM pre-mining surface was built by SLR based on 2 m interval contour data provided by BMA as part of the SSM Voids in Floodplain Assessment.

2.3 AERIAL IMAGERY

Aerial imagery of the SSM area captured in March 2023 was used within the mine extent, and online imagery services (i.e. Google Satellite, Queensland Globe) were used for the wider study area. The aerial was used to assist in the parametrisation of the models and gain an appreciation of the site characteristics, but neither the PRC or PMC scenarios of this study are indicative of present-day conditions.

3 HYDROLOGIC MODELLING

As previously mentioned, hydrologic models for Stephens Creek, Scotts Creek and Downs Creek were adopted from the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020). These models were provided to WMS and used as the basis for hydrologic modelling in this assessment. A new XPRAFTS model was developed to derive flows at Rolf Creek. The key parameters of the provided models remained unchanged unless there was a justifiable reason to alter them. To incorporate the PRC landform, updates were made to the models' catchment configuration, reach lengths and storm definitions. The latest BHP climate change scenarios were also incorporated into each hydrologic model.

The following sections present the key details and parameters of the hydrologic modelling following the updates.

3.1 MODELLING SOFWARE

The existing models provided to WMS were developed using XPRAFTS, an industry standard modelling package that is widely used in hydrologic studies across Australia. A high-level review was carried out on the received models and they were deemed fit for purpose and appropriate for use in this assessment. For consistency, the new Rolf Creek hydrologic model was also developed on XPRAFTS.

3.2 CATCHMENT DELINEATION

For Stephens Creek, Scotts Creek and Downs Creek, the catchment delineation developed as part of the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020) was updated to reflect the PRC conditions based on the SSM PRC Landform Design. The catchment delineation was modified near the areas surrounding the mine, which have been or will be subject to major changes due to the mining activities. As the upper reaches of the catchments are outside the mining lease, these have not changed significantly and will remain generally unchanged after mine closure.

For the development of the Rolf Creek XPRAFTS model, catchment delineation was undertaken based on the SSM PRC Landform Design where available, and based on 1 second SRTM Derived topography data downstream of the mine where the catchment was not covered by the PRC Landform Design.

The PRC catchment delineations for all watercourses of interest are presented in Figure 3-1 through to Figure 3-4, and a summary of key catchment parameters is provided in Table 3-1.

Table 3-1 PRC Catchments Parameters

Model	Scenario	Number of Sub-catchments	Total Catchment Area (km^2)	Adopted Fraction Impervious
Stephens Creek	PRC	32	659	0%
Scotts Creek	PRC	17	502	0%
Downs Creek	PRC	10	54	0%
Rolf Creek	PRC	10	42	0%

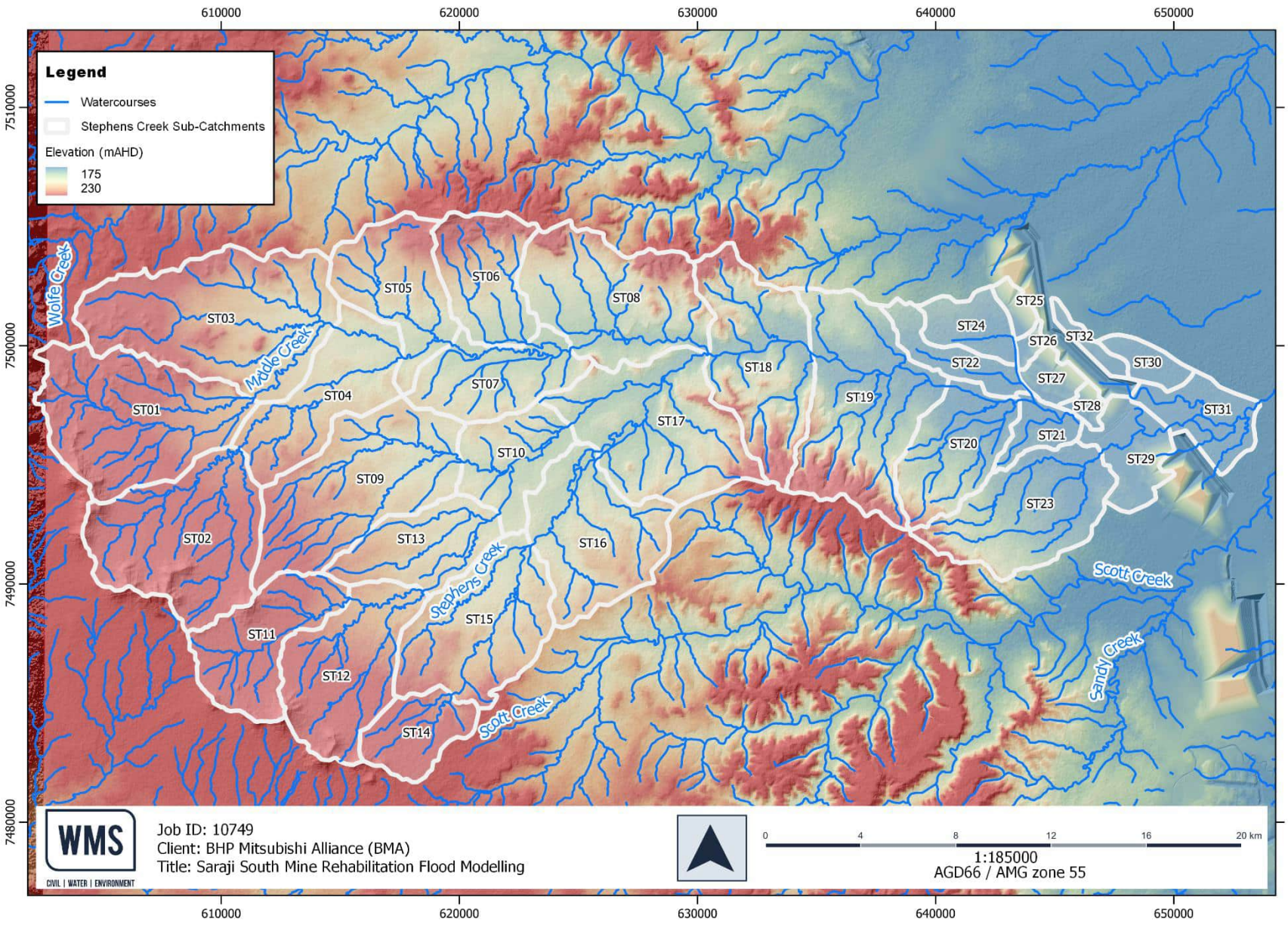

Figure 3-1 Stephens Creek PRC Catchment Delineation

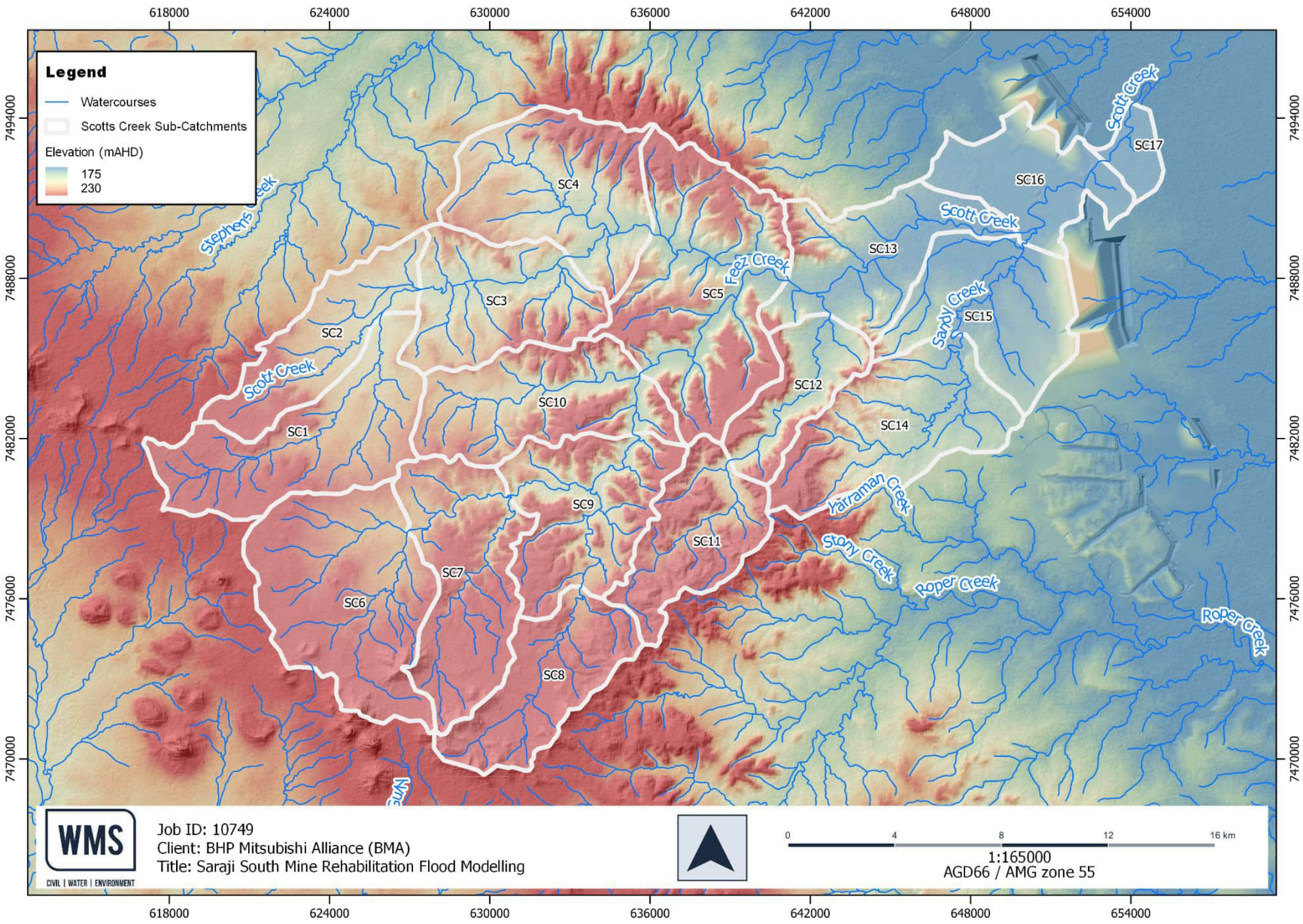

Figure 3-2 Scotts Creek PRC Catchment Delineation

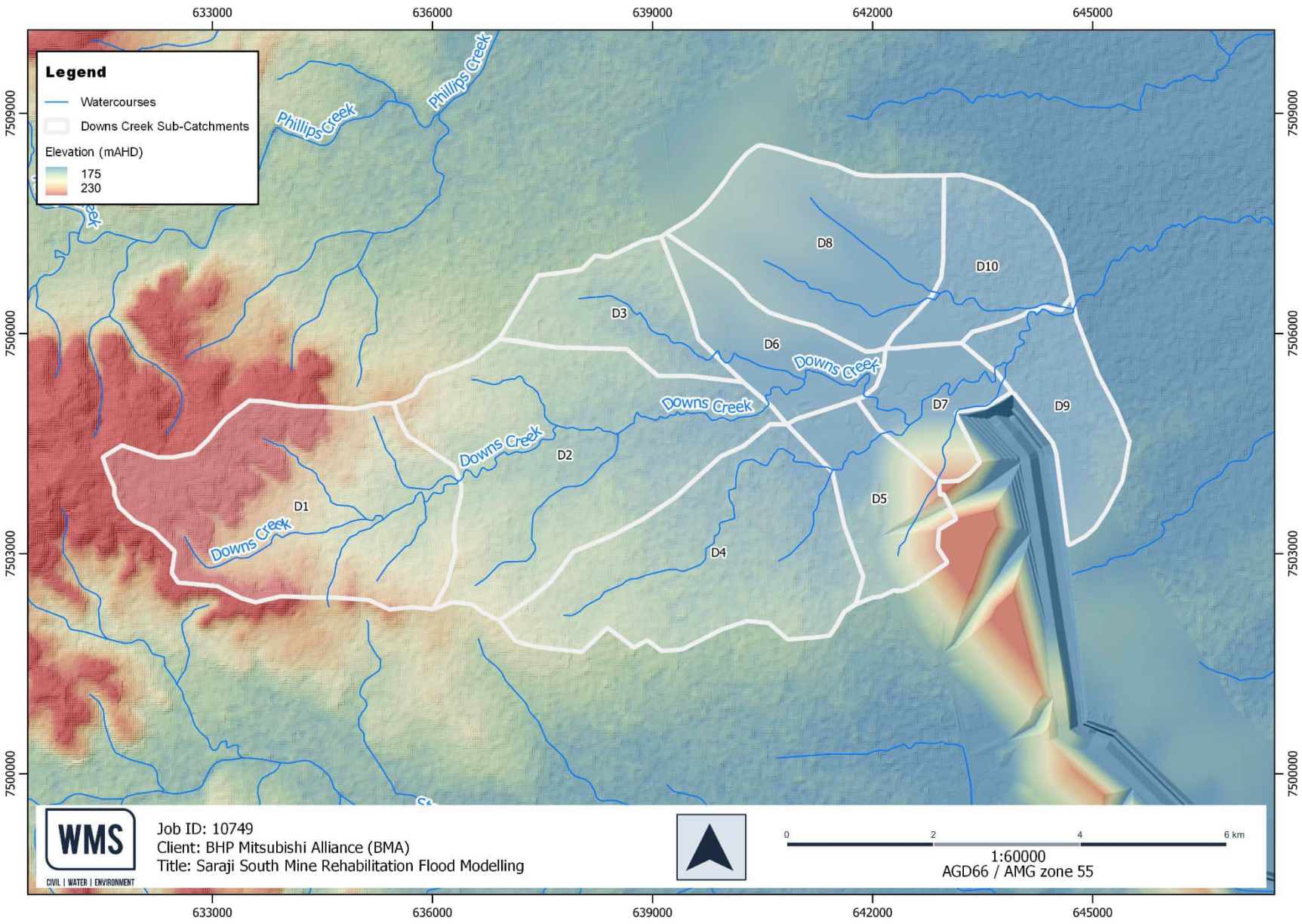

Figure 3-3 Downs Creek PRC Catchment Delineation

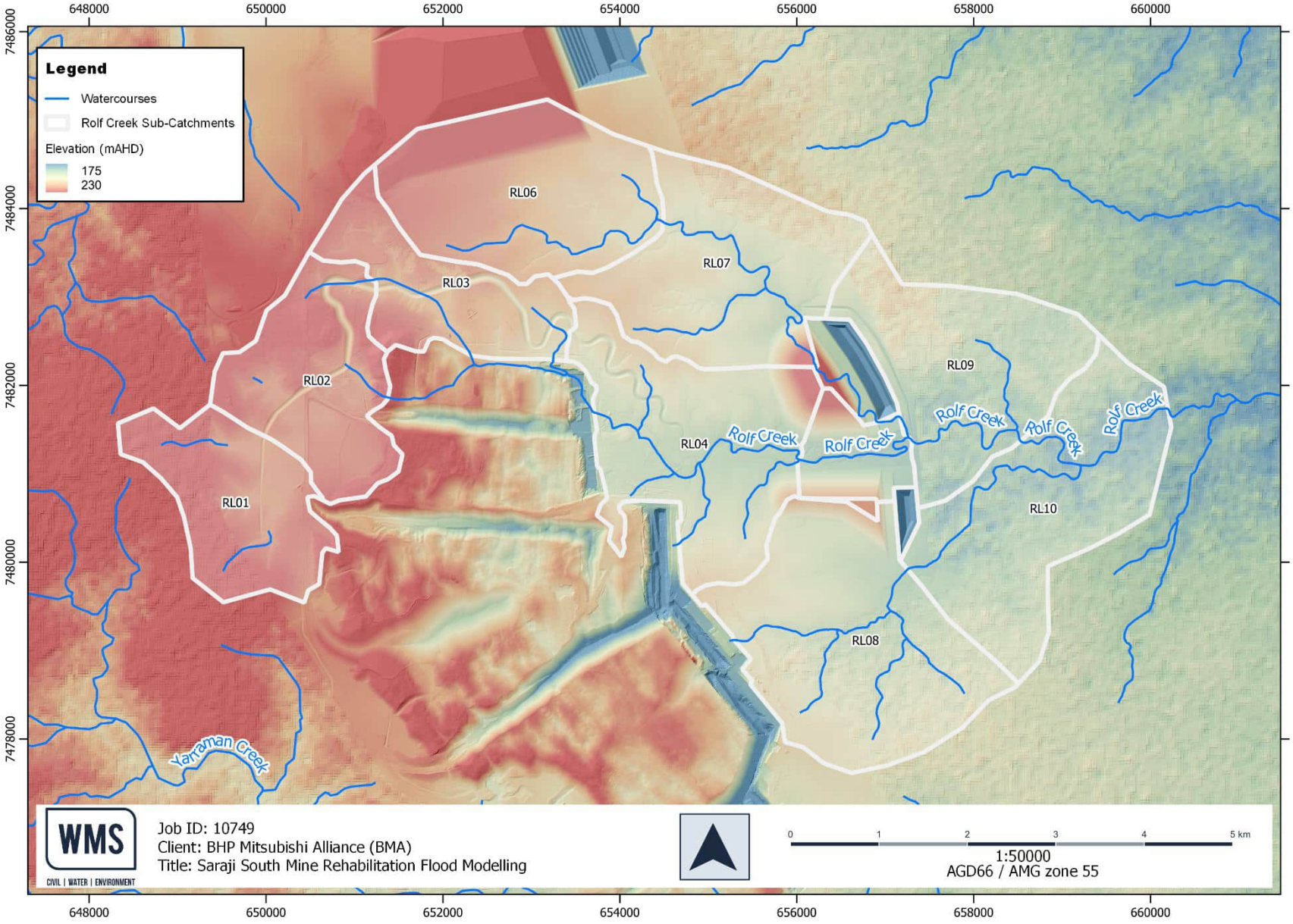

Figure 3-4 Rolf Creek PRC Catchment Delineation

3.3 DESIGN RAINFALL

The ARR BOM design rainfall, available through the online ARR Data Hub, was defined in XPRAFTS based on the catchment centroid locations. The design rainfalls were consistent with the rainfall totals used in previous modelling as part of the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020), Design rainfall for the 39%, 2%, 1%, 0.1% AEP events is shown in Table 3-2.

Table 3-2 ARR2019 BOM Design Rainfall

Duration	Rainfall Totals (mm) per Annual Exceedance Probability (AEP)			
	39% AEP	2% AEP	1% AEP	0.1% AEP
15min	21.9	41.3	45.6	70.1
30min	31.0	59.1	65.4	101
45min	36.4	70.4	78.1	120
60min	40.2	78.6	87.5	135
90min	45.4	90.5	101.0	156
120min	49.1	99.2	111.0	171
180min	54.3	112.0	126.0	194
270min	59.9	126.0	142.0	219
360min	64.2	136.0	155.0	238
540min	71.1	153.0	175.0	268
720min	76.6	167.0	190.0	293
1080min	85.4	188.0	216.0	332
1440min	92.6	206.0	237.0	364

3.4 PMP AND EXTREME RAINFALL

Probable Maximum Precipitation (PMP) is the rainfall used as input in the hydrologic model to generate PMF hydrographs, and is not available through the BOM website. To calculate PMP, the Generalised Short-Duration Method (GSDM) was used. This method is based on an analysis of convective thunderstorms and is appropriate for durations up to 6 hours. The GSDM PMP rainfall calculation procedure followed the instructions detailed in 'The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method' (BoM, 2003).

Where potential existed for PMF critical durations to exceed the 6-hour duration, the revised Generalised Tropical Storm Method (GTSMR) was used. The GTSMR is appropriate to calculate PMP rainfall totals for durations greater than 24 hours, in areas of Australia affected by tropical storms and includes the majority of the continent with the exception of the southeast. For durations between 6 hours and 24 hours, the PMP rainfall totals were determined by interpolation between the GSDM and GTSMR estimates.

All watercourses were subsequently found to have PMF critical durations of 6 hours or less. The GSDM PMP rainfall totals are summarised in Table 3-3.

Table 3-3 PMP Design Rainfall

Duration	Rainfall Totals (mm) per Model			
	Stephens Creek	Scott Creek	Downs Creek	Rolf Creek
15min	110	110	160	170
30min	160	170	240	250
45min	200	210	300	310
60min	240	260	360	370
90min	320	340	470	480
120min	370	390	540	550
180min	450	480	660	670
270min	535	560	780	800
360min	590	620	870	890

3.5 TEMPORAL PATTERNS

For flood events up to and including the 1% AEP, East Coast (North) ARR Data Hub temporal patterns were adopted. Point temporal patterns were adopted for all storm durations where total catchment areas were less than 75 km^2 (i.e. for Downs Creek and Rolf Creek). Where that was exceeded (i.e. for Stephens Creek and Scott Creek) areal temporal patterns were adopted for storm durations of 12 hours or longer.

For the larger events (i.e. 0.1% AEP and PMF), historical temporal patterns from the paper *'Growth curves and temporal patterns of short duration design storms for extreme events'* (Jordan, P., 2005) were adopted. This methodology is in line with ARR Guidelines, which recommend the use of Jordan temporal patterns for extreme event modelling.

3.6 RAINFALL LOSSES

Rainfall loss values used in the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020) were maintained for consistency. The rainfall losses used in the 2020 WRM study were selected to achieve the best match between the XPRAFTS design discharges and the design discharges estimated by the FFA at the Stephens Creek upstream gauge, as part of the calibration procedure undertaken. The WRM study included losses for the 10%, 5%, 1% and 0.1% AEP events. The same losses were applied to all catchments for the PRC modelling.

Losses for the 39% and 2% AEP events had to be determined as these events were not part of the 2020 WRM study scope. In a similar manner to the WRM study, losses for the 39% and 2% AEP events were selected through an iterative process to achieve an appropriate match between the XPRAFTS peak flows and the FFA flows at the Stephens Creek gauge.

For the PMF event, initial and continuing loss values of 0 mm and 1 mm/h were adopted, respectively, in accordance with ARR2019 Guidelines (Book 8, Section 6.4).

A summary of all adopted losses is provided in Table 3-4. It should be noted that:

- For events between 10% and 1% AEP, initial losses decrease with increases in event magnitude, as the catchments are likely to be more saturated prior to the design rainfall burst.
- The exception to the above is the 39% AEP event, where initial loss decreased with a decrease in event magnitude. This was likely a result of very low rainfall depths in the 39% AEP event being 'consumed' by higher losses.

Table 3-4 Adopted Rainfall Losses

Event	Source	Initial Loss (mm)	Continuing Loss (mm/h)
39% AEP	WMS 'calibration' to Stephens Creek FFA	40	1.7
10% AEP	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)	80	1.7
5% AEP	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)	75	1.7
2% AEP	WMS 'calibration' to Stephens Creek FFA	70	1.7
1% AEP	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)	40	1.7
0.1% AEP	Flood Study and Levee Assessment – Norwich Park Mine (WRM, 2020)	0	1.7
PMF	ARR 2019, Book 8, Section 6.4	0	1.0

3.7 AREAL REDUCTION FACTORS

Areal reduction factors (ARF) are multipliers applied to the design rainfall to account for increased spatial variability that occurs over larger catchments. ARFs are calculated using region specific parameters and the total catchment area upstream of the study site. They vary across different storm durations and different design AEPs. Calculation of storm ARF within the SSM catchments is based on ARF parameters for the Semi-arid Inland QLD zone and catchment areas outlined in Table 3-5. For each watercourse the ARF areas are indicative of the catchment areas upstream of the PRC pit locations.

Table 3-5 ARF Areas

Model	ARF Area (km^2)
Stephens Creek	619.0
Scott Creek	476.0
Downs Creek	38.6
Rolf Creek	3.2

3.8 HYDROLOGY STORAGE AND CHANNEL ROUTING

Hydrology storage and channel routing parameters remained unchanged from those used in the *Flood Study and Levee Assessment – Norwich Park Mine* (WRM, 2020). Channel routing was determined using the Muskingum method, using a channel velocity of 0.9 m/s to 1.1 m/s and a constant 'x' storage coefficient of 0.25.

3.9 CLIMATE CHANGE ASSESSMENT

A climate change assessment was undertaken for the 1% AEP and 0.1% AEP events events in accordance with the *Guideline for Climate Change Adaptation in Mine Water Planning and Hydrologic Assessments* (BHP, 2023). The climate change scenarios include:

- 2061 – 2099 period, RCP 2.6 50th percentile (6% rainfall intensity increase)
- 2061 – 2099 period, RCP 4.5 50th percentile (11% rainfall intensity increase)
- 2061 – 2099 period, RCP 4.5 90th percentile (20% rainfall intensity increase)

3.10 CRITICAL DURATION ASSESSMENT

A critical duration assessment was carried out in the hydrology models for all events in accordance with ARR2019 guidelines. A range of durations were simulated for each event. The range of durations was typically between 30 mins and 48 hours but varied somewhat depending on the watercourse study area.

For each duration an ensemble of 10 temporal patterns was simulated as outlined in Section 3.5. Peak flows from the 10 temporal patterns were ranked and the event above median selected as representative of each duration. The critical durations were determined based on the highest median peak flow. The assessments were carried out at the hydrological node immediately upstream of the future pit locations in each study area. The critical duration event and durations either side of the critical were taken forward for hydraulic modelling in TUFLOW. The additional storms were taken forward as the critical duration can vary between hydrological and hydraulic results.

The flood level surfaces from the hydraulic models were interrogated to confirm the critical duration event. The identified critical durations were found to produce the highest flood levels at key areas at the pit locations and through the landform gullies. The final critical durations confirmed by hydraulic modelling are listed in Table 3-6.

Table 3-6 Critical Duration Summary

Model	Event	Critical Duration (h)	Temporal Pattern
Stephens Creek	39%	24	3
	2%	18	3
	1%	12	8
	0.1%	9	1
	PMF	6	5
Scotts Creek	39%	18	9
	2%	18	3
	1%	12	4
	0.1%	9	1
	PMF	6	5
Downs Creek	39%	18	9
	2%	6	6
	1%	6	6
	0.1%	3	5
	PMF	3	4
Rolf Creek	39%	9	10
	2%	6	2
	1%	6	6
	0.1%	3	4
	PMF	3	4

3.11 PEAK FLOW VALIDATION

To assess the appropriateness of hydraulic model flows, peak flows at the critical locations upstream of the pits were compared to results from the hydrologic models, to the WRM results, and to peak flows estimated using the following methods:

- Regional Flood Frequency Estimation Model (RFFE): the RFFE requires the catchment centroid and outlet coordinates, and the catchment area. The RFFE transfers flood frequency characteristics from a group of stream gauged catchments to the location of interest. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).
- Quantile Regression Technique (QRT): the QRT uses a number of gauged catchments in a selected region from which the historical flood records are collected and used in a flood frequency analysis to provide flood quantities. These results and corresponding catchment characteristics are used in a regression analysis, which provides an equation that best describes the relationship between the two sets of data. This equation can then be used to estimate design flows for ungagged locations. The QRT analysis for Queensland included all suitable stream gauging stations in the state and the equations developed predict design flows based on catchment area and the rainfall intensity. The QRT for Queensland is appropriate for small and medium sized catchments up to 1000 km².

A summary of the peak flow validation is provided in Table 3-7. The hydraulic model peak flows are generally in line with the flows from other sources. It is important to note that the WRM flows, including the FFA flows, were taken from the main inflow points of the models rather than from immediately upstream of the pits. Therefore, some differences are expected due to variations in hydraulic conditions along the model terrain. It should be noted that hydraulic peak flows for Rolf Creek are overall higher than hydrologic peak flows, likely due to Rolf Creek being a relatively channelised watercourse with limited storage or areas where flows break out into the floodplain.

Table 3-7 Peak Flow Validation Summary

Model	Event	Peak Flow (m^3/s)					
		Hydrologic Model (XPRAFTS)	Hydraulic Model (TUFLOW)	QRT	RFFE	FFA (WRM, 2020)	WRM Hydrologic Model (WRM, 2020)
Stephens Creek	39%	342	339	144	-	300	-
	2%	1310	1307	1242	1090	929	-
	1%	1776	1765	1553	1270	1030	1490
	0.1%	2857	2887	-	-	-	2898
	PMF	9639	9891	-	-	-	-
Downs Creek	39%	51	48	18	-	-	-
	2%	168	161	204	100	-	-
	1%	247	251	264	122	-	209
	0.1%	447	431	-	-	-	381
	PMF	2065	2294	-	-	-	-
Scotts Creek	39%	337	348	119	-	300	-
	2%	1259	1206	1052	856	998	-
	1%	1740	1725	1320	1010	1080	1523
	0.1%	2802	2688	-	-	-	2619
	PMF	9914	9820	-	-	-	-
Rolf Creek	39%	13	13	9	-	-	-
	2%	53	58	110	52.8	-	-
	1%	84	93	144	66	-	-
	0.1%	144	178	-	-	-	-
	PMF	609	732	-	-	-	-

4 HYDRAULIC MODELLING

Four TUFLOW 2D hydraulic models were developed to determine flood behaviour around the PRC landform and pits. TUFLOW is widely used in Australia for flooding and drainage studies. The latest TUFLOW release available at the time this study was completed was used (2023-03-AA). The latest versions of TUFLOW incorporate the HPC (Heavily Parallelised Compute) model run engine. TUFLOW HPC is an explicit solver for the full 2D Shallow Water Equations, including a sub-grid scale eddy viscosity model. HPC can be used in GPU (Graphics Processing Unit) mode to improve simulation speed. TUFLOW HPC GPU was used for this assessment.

4.1 MODEL RESOLUTION, EXTENT AND TOPOGRAPHY

Layouts and key features of each hydraulic model are presented in Figure 4-1, Figure 4-2, Figure 4-3 and Figure 4-4.

Relatively fine grid cell sizes have been selected for the SSM PRC modelling to allow for detailed representation of the channel and floodplain flow paths. These cell sizes are consistent with previous modelling carried out for SSM and are summarised in Table 4-1.

Table 4-1 Model 2D Cell Sizes

Model	Cell Size (m)
Stephens Creek	5
Scotts Creek	5
Downs Creek	5
Rolf Creek	5

The model extent was delineated to capture all flood events and their anticipated wetted areas upstream, downstream and throughout the PRC landform design and pits. The PRC design surface was supplied by BMA and incorporated into the model. Additional topographic layers were used to supplement the surface at areas on the periphery of the modelled floodplain that had not been incorporated into the design. These surfaces are noted in Section 2.2.

Culvert and road underpasses have been removed from the decommissioned mine area. This is consistent with the BMA approach to the PRC plan final landform, which removes engineered structures that would require on-going maintenance post relinquishment. As such, 1D structures were removed from the active mine site and the topography reviewed at the structure locations. At these locations topography was lowered to the watercourse or drain invert levels using terrain modifiers if it was determined that the watercourse had not already been modified in the landform design. This was to allow the free passage of flow in the absence of the watercourse structures. Structures outside the mine lease area but within the modelled flood extent were retained.

4.2 BOUNDARY CONDITIONS

4.2.1 Inflow Boundaries and Initial Conditions

The hydrographs extracted from the XPRAFTS models were applied to the TUFLOW model as 2D boundary conditions. Two types of inflow boundaries were used:

- '2d_bc' Lines

  '2d_bc' lines were used to apply the hydrographs for the sub-catchments located outside the model extent. These inflows are applied to the model edges and include total flow hydrographs for the main watercourses in each modelled area.

- '2d_sa' Polygons

  '2d_sa' polygons were used to apply the local hydrographs for the sub-catchments located within the model extent. The polygons were positioned at appropriate locations along the watercourse, consistent with the hydrology model package, and within their respective local sub-catchments.

4.2.2 Outflow Boundaries

Downstream boundaries were applied to the TUFLOW model to allow flow to exit the study area. All downstream boundaries were based on a water profile slopes. The downstream boundaries were all positioned more than a kilometre downstream from the future pit locations and perpendicular to the main watercourses.

Pit outflow boundaries were positioned along the wetted perimeter of the pits to extract flow from the model. Outflow rates were based on steep water profiles to approximate the overtopping of pits at the floodplain periphery.

4.3 HYDRAULIC ROUGHNESS

The hydraulic roughness (Manning's 'n') values used in the model are outlined in Table 4-2. Values are within the ranges recommended by ARR 2019 Guidelines.

The delineation of land use was based on identifiable features within the PRC topography and inspection of existing aerial imagery. Revegetation and post mining land use (PMLU) planning as part of the PRC plan was under development at the time of this study. BMA have advised the PMLUs will be transitioned from the current EA and dominated by woodland habitat, with selected areas rehabilitated for beef cattle grazing and watercourses. Grazing will generally be adopted in relatively flat areas such as the mine industrial areas, coal handling and processing plant, stockpile pads, out of pit tailings dams and mine water dams. Grazing areas will be revegetated with pastures and woodland habitat and watercourse areas rehabilitated with a mixture of trees, shrubs and grasses suitable for the specific environment. Due to this future variability of PMLU, sensitivity testing has been carried out on the hydraulic roughness values as outlined in Section 4.4.

Table 4-2 Adopted Hydraulic Roughness Values per Land Use

Land Use	Adopted Manning's 'n'
Creek Bed	0.04
Heavy Vegetation	0.09
Light Vegetation	0.65
Roads	0.02
Grass	0.045

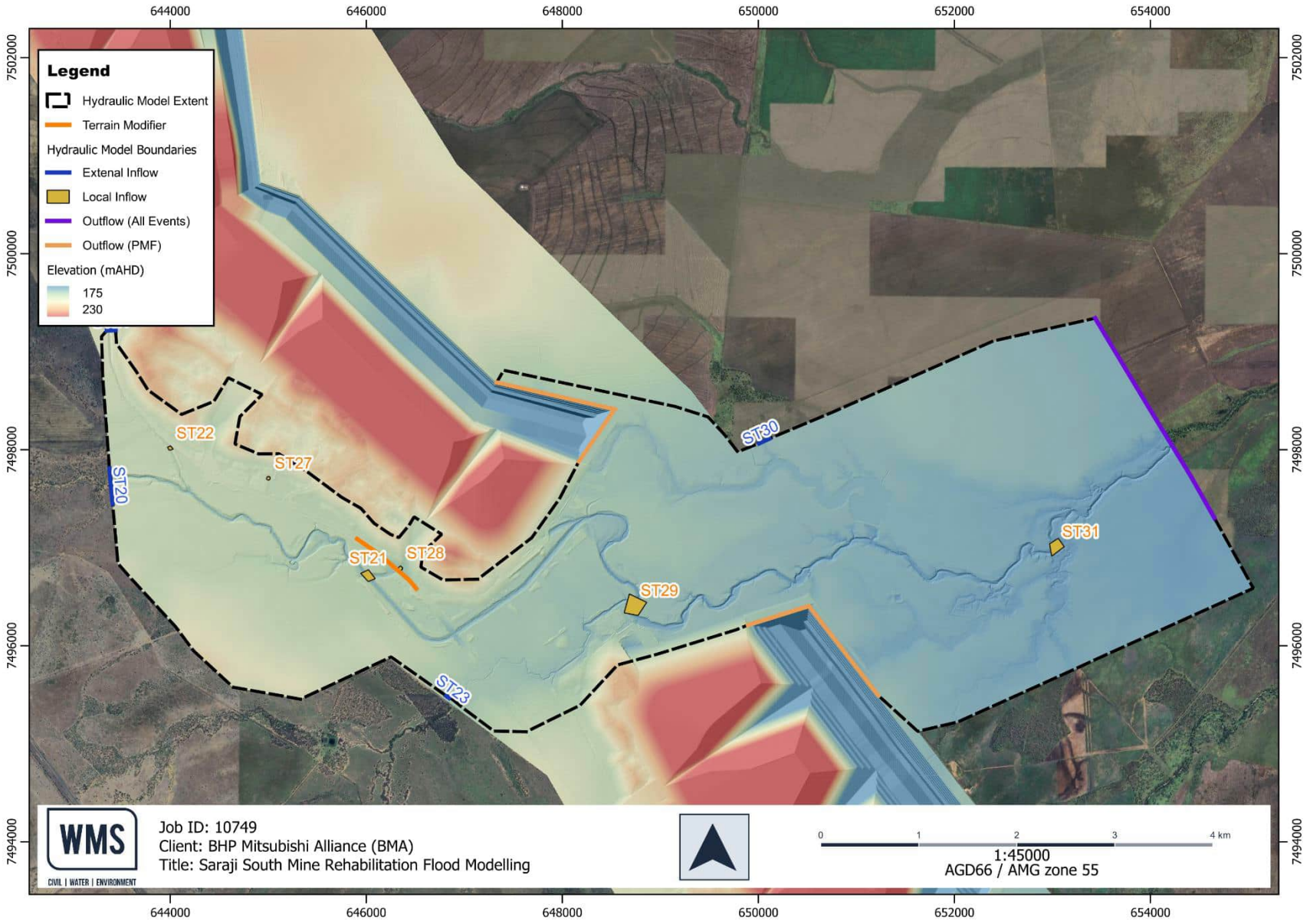

Figure 4-1 Stephens Creek PRC TUFLOW Model Layout

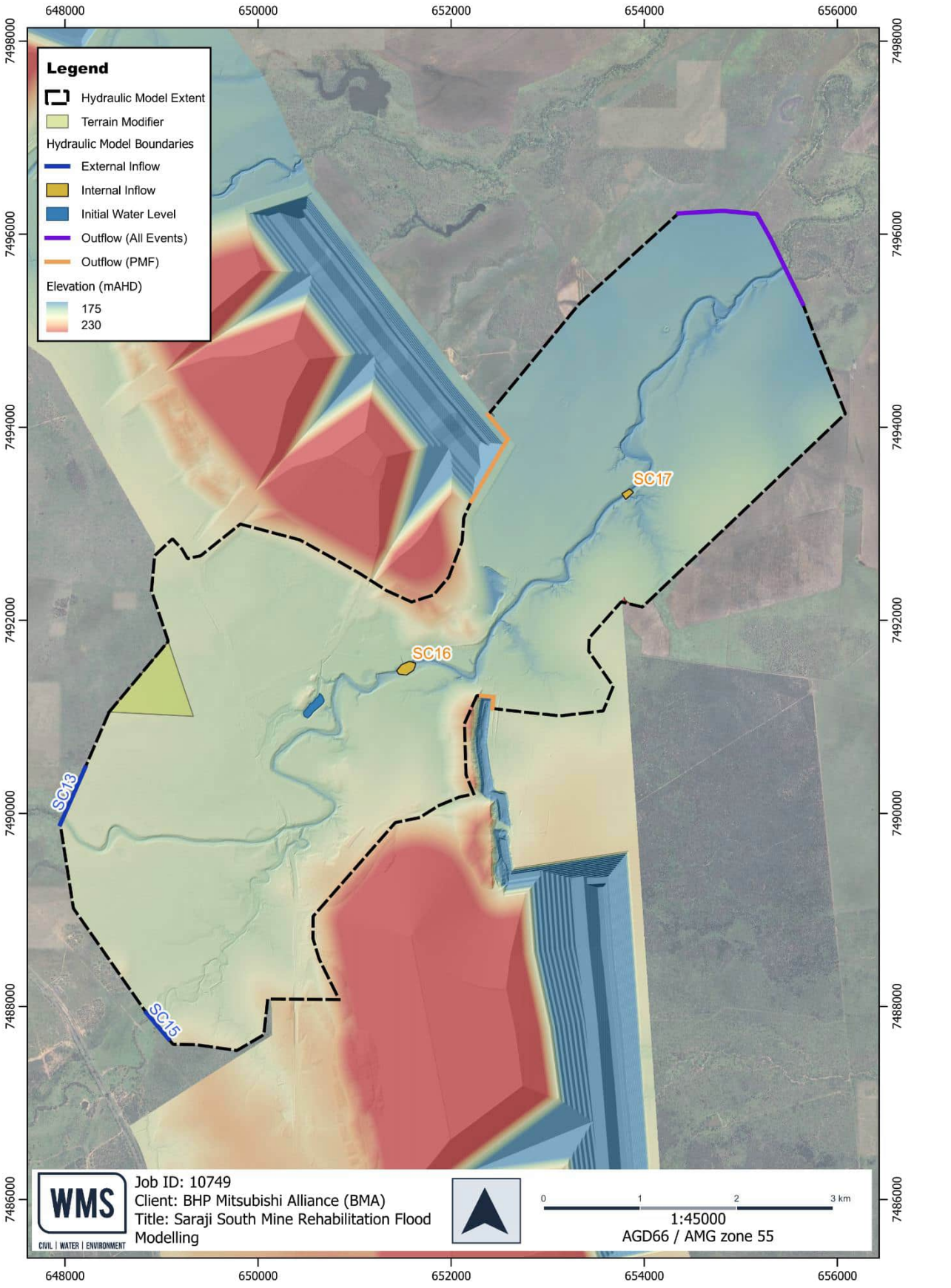

Figure 4-2 Scotts Creek PRC TUFLOW Model Layout

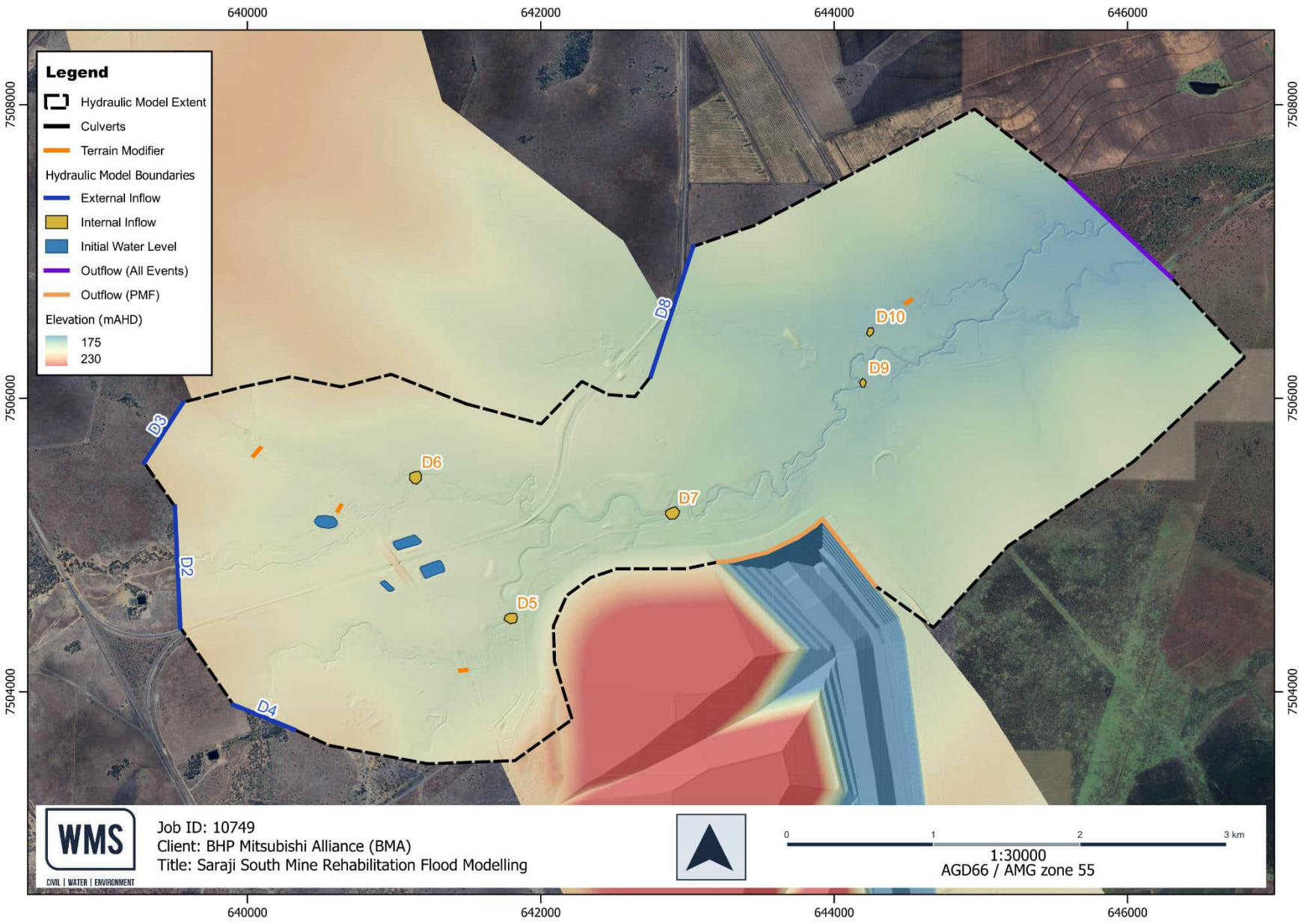

Figure 4-3 Downs Creek PRC TUFLOW Model Layout

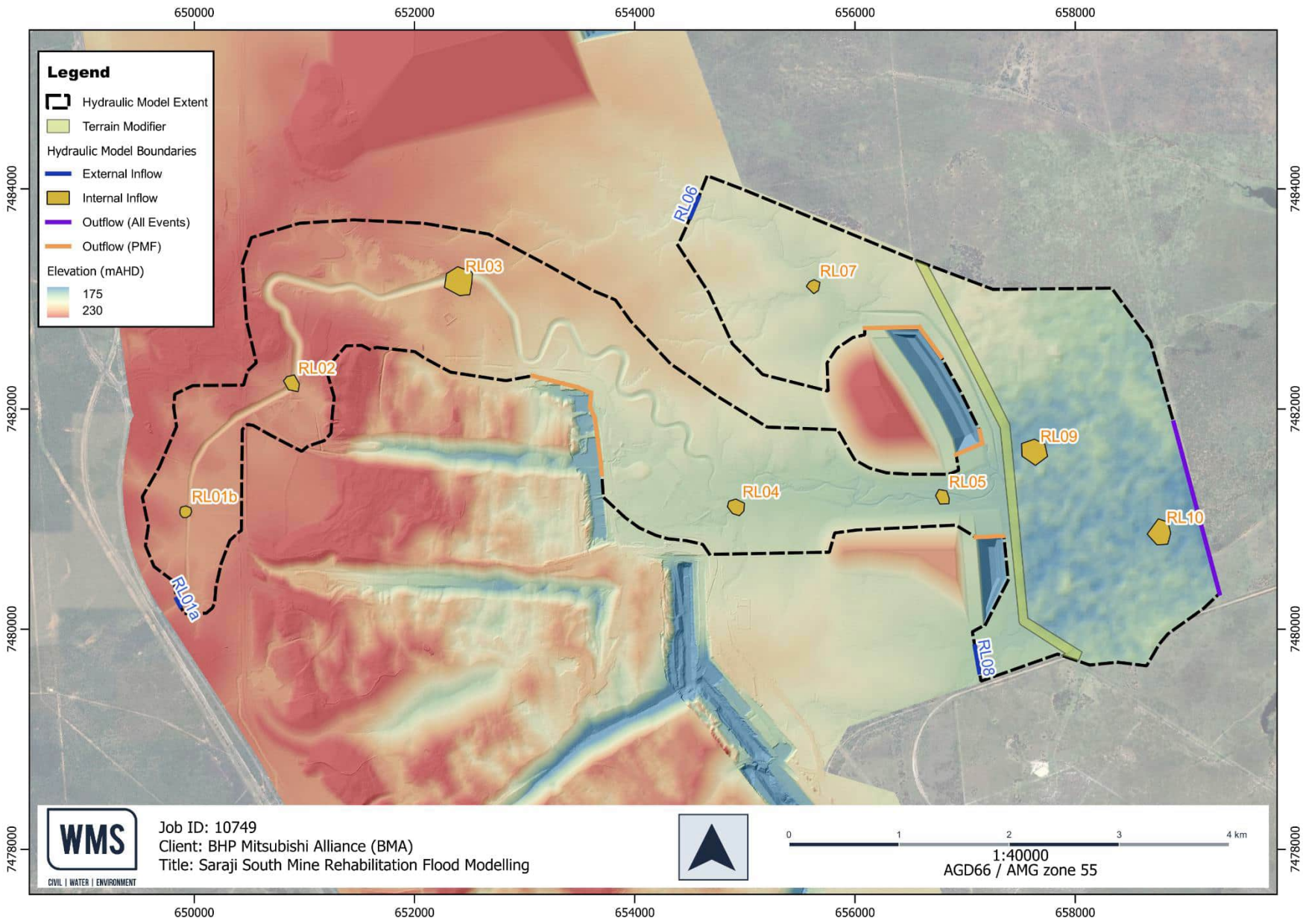

Figure 4-4 Rolf Creek PRC TUFLOW Model Layout

4.4 SENSITIVITY TESTING

4.4.1 Downstream Outflow Boundary Sensitivity

The Downs Creek Model was used to test the sensitivity to the downstream outflow boundary slope. This model was selected because its downstream boundary is placed closest to the mine voids in comparison to the other models, and therefore was more likely to be susceptible to boundary changes.

The boundary slope was decreased by half to simulate a higher tailwater level and the 0.1% AEP climate change (RCP 4.5 P90) event was simulated to assess any changes. Inspection of the resulting water surface outputs indicated no change to the water levels in the main watercourse between the void locations. Water level increases were contained within approximately 400 m upstream of the boundary, and ranged between 10 mm to 300 mm. The flood model results can therefore be considered insensitive to the selected boundary assumptions. This insensitivity is likely due to the placement of downstream boundaries at least 1 km from the areas of interest.

4.4.2 Manning's Sensitivity

Sensitivity testing on the 2D manning's n roughness values was performed for all models. The global manning's roughness values were increased and decreased by 20% and the 0.1% AEP climate change RCP 4.5 P90 event was simulated for each scenario. A summary of sensitivity testing results is provided in Table 4-3. Reported water level increases are the maximums throughout the model areas. Water level increases near any of the pit locations did not exceed approximately 0.3 m. These potential increases are not expected to pose material risk to the landform flood immunity as a freeboard of 1.0 m or higher has been provided around all pits.

Table 4-3 Manning's Sensitivity Testing Summary

Model	20% Decrease in Global Manning's		20% Increase in Global Manning's	
	Maximum Decrease in Water Level (m)	Maximum Increase in Water Level (m)	Maximum Decrease in Water Level (m)	Maximum Increase in Water Level (m)
Stephens Creek	0.5	0.0	0.0	0.5
Scotts Creek	0.5	0.0	0.0	0.5
Downs Creek	0.4	0.05	0.05	0.2
Rolf Creek	0.4	0.002	0.09	0.4

4.5 PRE-MINING CONDITIONS MODELLING

To assess how flood characteristics and flow paths have changed as a result of mining operations, a pre-mining conditions (PMC) scenario was developed within the models as a comparison to the PRC model results. TUFLOW scenario switches were used to read in the additional model files. This section outlines the model build approach for the PMC scenario. Where parameters or methods are not stated, they remain unchanged from the PRC model.

Layouts and key features of each hydraulic model for the PMC scenario are presented in Figure 4-5, Figure 4-6, Figure 4-7 and Figure 4-8.

4.5.1 PMC Extent and Topography

The basis of the PMC model scenario was the Saraji South Mine Pre-Mining DEM developed by SLR as part of the voids in floodplain assessment. The digital surface was provided by BMA and is derived from 2 m interval topographic contours. Due to the age and format of the source data the digital surface was very coarse but represents the best information available. The PMC scenario should not be relied upon for anything more than a general check against the PRC model results. Limitations of the underlying data should be considered when interpreting the results.

The PMC model code was delineated based on the Pre-Mining DEM to accommodate the changed watercourses and floodplain. Terrain modifiers were read into the model to define the watercourse main channel in some locations where the features were not discernible in the topography. Topography modifiers were also used to add additional surfaces on the periphery of the model where the Pre-Mining DEM had no coverage.

4.5.2 PMC Inflows and Boundaries

For the modelling of the pre-mining scenario, the catchment delineation developed for the PRC scenario was modified to reflect the pre-mining sub-catchment arrangement. Updated local sub-catchment hydrographs were derived by scaling flows in TUFLOW based on the relative areas of appropriate PRC donor catchments. These flows were read into the TUFLOW model with updated '2d_sa' polygons. This was considered an appropriate method as the modified local sub-catchments only represented a small portion of the total flow traversing the mine site areas.

Total inflow hydrographs at the upstream model extents remained unchanged, although the "2d_bc" inflow lines were adjusted in some instances to accommodate the modified code and watercourse location.

The downstream boundary lines were adjusted to accommodate the revised floodplain topography and no pit outflows were required for the PMC scenario.

4.5.3 PMC Hydraulic Roughness

Aerial imagery from pre-mining years was limited for the study so PMC ground features and watercourse vegetation remain uncertain. Manning's 'n' values were therefore delineated using a broad approach. It is likely that the pre-mining landscape was predominantly pasture and forest. Manning's n values were applied using the values in Table 4-2. The PMC scenario's active channel area was delineated from the topography where inconsistent with modern satellite imagery. Areas of the existing mine or uncertain cover were assumed to be light vegetation under pre-mining conditions.

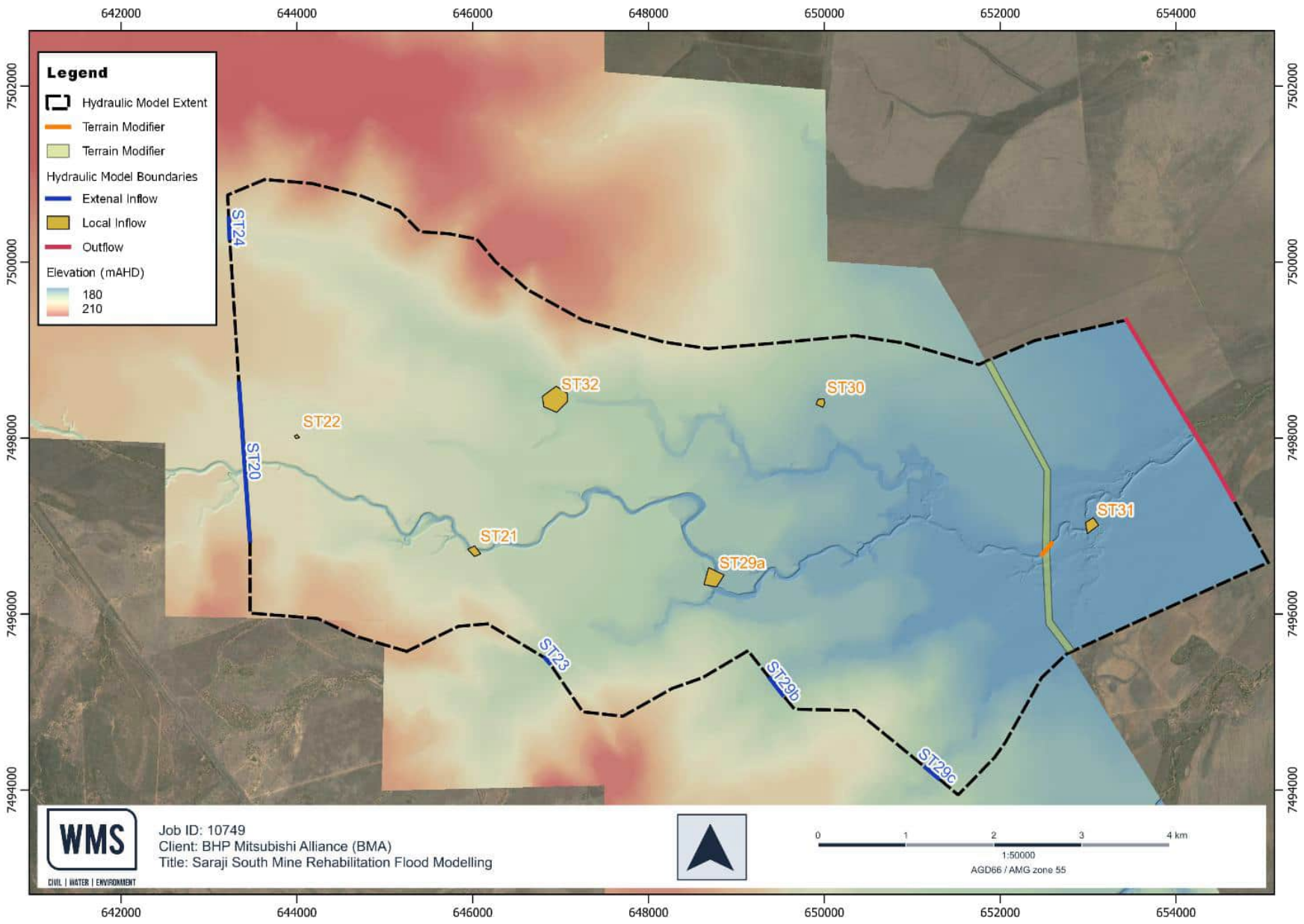

Figure 4-5 Stephens Creek PMC TUFLOW Model Layout

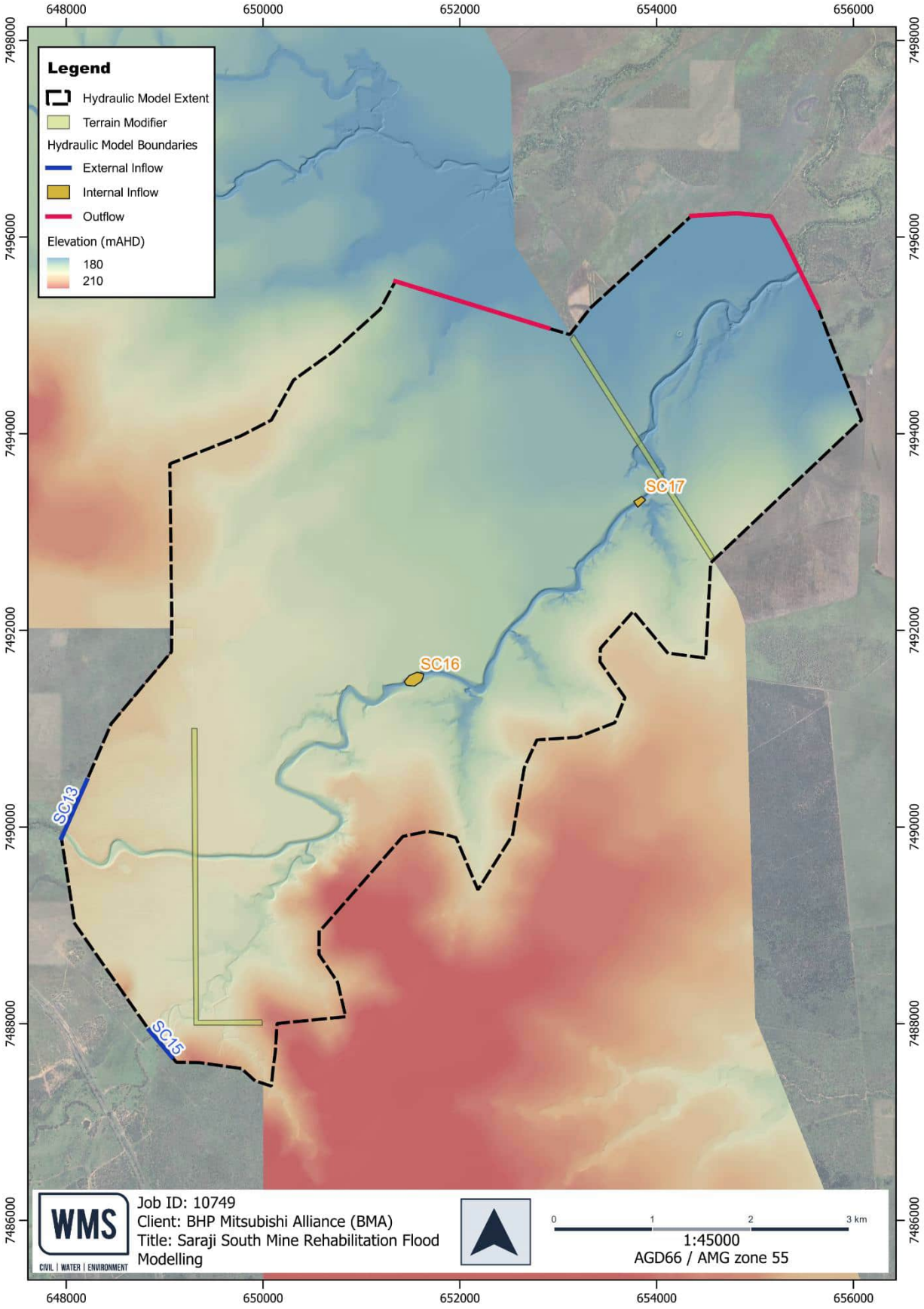

Figure 4-6 Scotts Creek PMC TUFLOW Model Layout

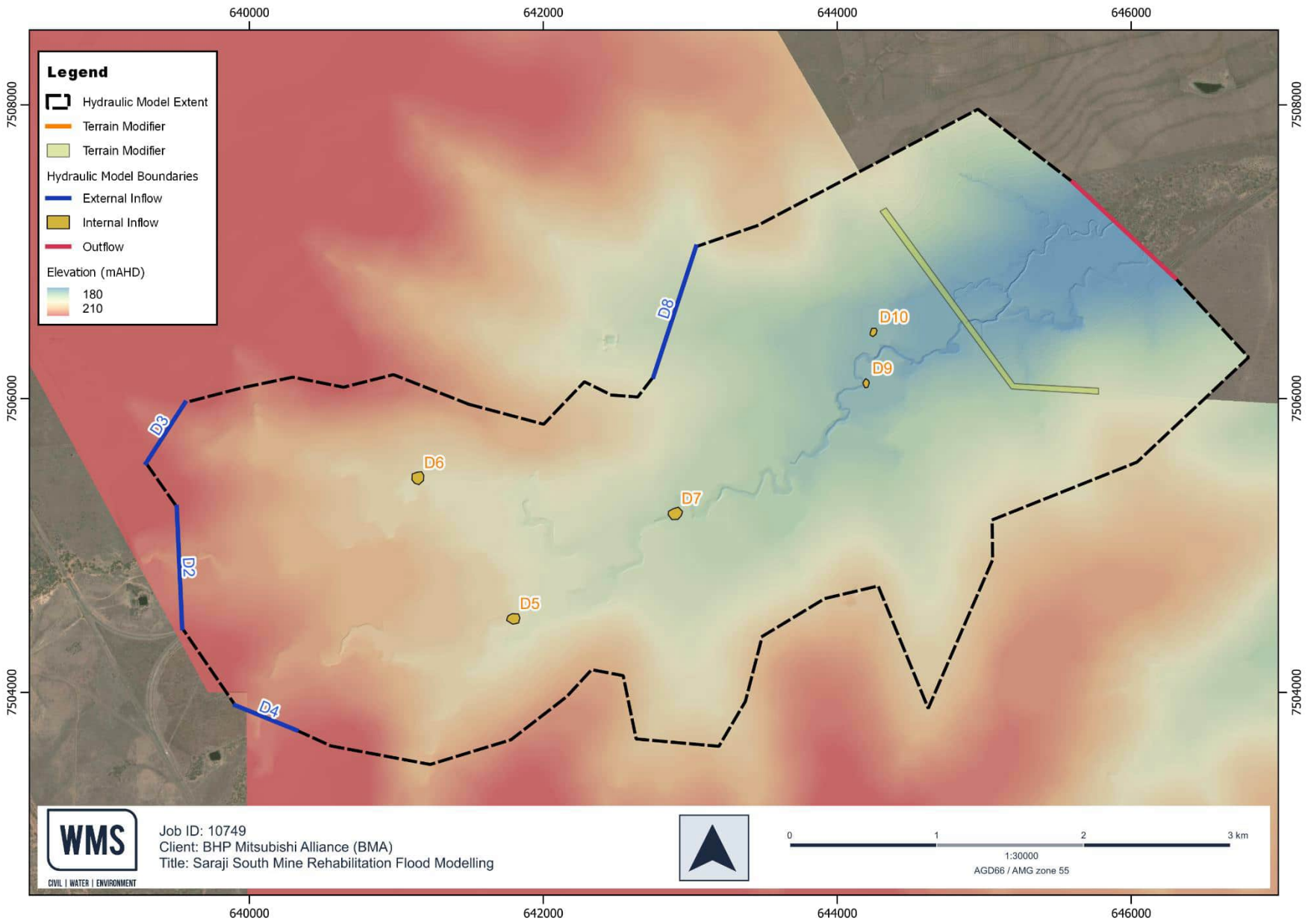

Figure 4-7 Downs Creek PMC TUFLOW Model Layout

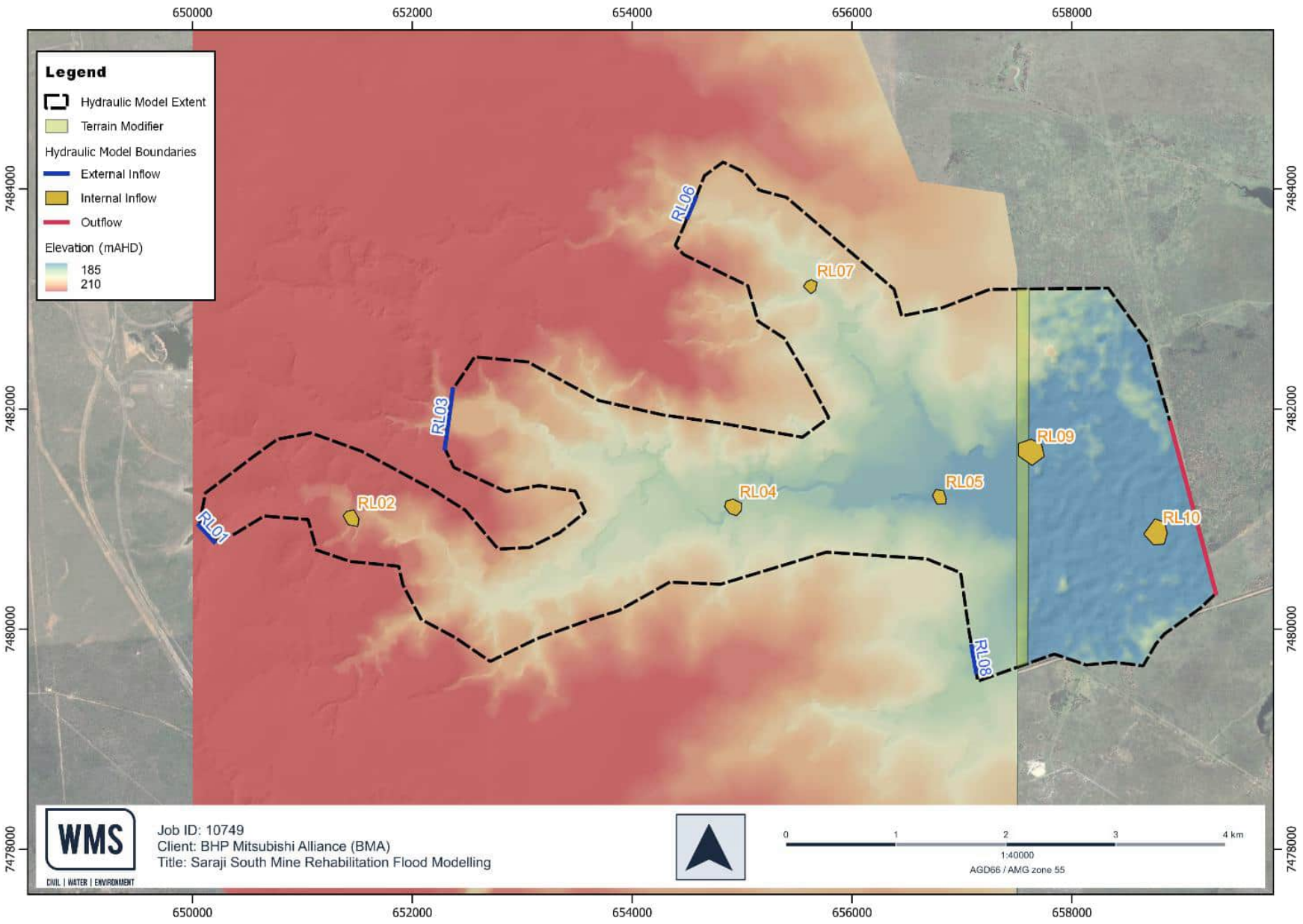

Figure 4-8 Rolf Creek PMC TUFLOW Model Layout

5 RESULTS AND DISCUSSION

Mapped model results for each of the study watercourses are presented in the appendices as follows:

- Appendix A – Stephens Creek
    - Maps 1 – 15: PRC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 16 – 21: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
    - Maps 22 – 36: PMC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 37 – 42: PMC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
- Appendix B – Scotts Creek
    - Maps 1 – 15: PRC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 16 – 21: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
    - Maps 22 – 36: PMC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 37 – 42: PMC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
- Appendix C – Downs Creek
    - Maps 1 – 15: PRC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 16 – 21: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
    - Maps 22 – 36: PMC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 37 – 42: PMC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
- Appendix D – Rolf Creek
    - Maps 1 – 15: PRC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 16 – 21: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).
    - Maps 22 – 36: PMC peak depth and water level contours, peak velocities and peak stream power for 39% AEP, 2% AEP, 1% AEP, 0.1% AEP and PMF events.
    - Maps 37 – 42: PMC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 2.6 (P50) and RCP 4.5 (P50 P90).

5.1 FLOOD INGRESS TO VOIDS

It is the intention of BMA that prior to mine closure all voids be immune from flood ingress up to and including the 0.1% AEP climate change RCP 4.5 P90 event. The model results indicate that for the current landform all voids are immune to floodwater ingress in the 0.1% AEP climate change RCP 4.5 P90 event and more frequent events, with ingress only occurring in the PMF.

The floodwater ingress to voids is summarised in Table 5-1. PMF ingress volumes have been provided for reference purposes only, as the design target of ingress immunity in the 0.1% AEP climate change RCP 4.5 P90 event has been achieved.

Table 5-1 Flood Ingress to Voids Summary

Void	Watercourse	PMF Ingress Volume (ML)
Lotus/Campbell Pit	Downs Creek	2
	Stephens Creek	2788
Gilbert Pit	Stephens Creek	789
	Scotts Creek	319
Price Pit	Scotts Creek	2613
Leichhardt Pit	–	–
Roper Pit	Rolf Creek	120
East Pit	Rolf Creek	573

In addition to preventing floodwater ingress in the 0.1% AEP climate change RCP 4.5 P90 event, the PRC landform has generally been designed to ensure an adequate level of freeboard is available around the voids. A summary of the proposed landform levels and respective water levels and available freeboard is provided in Table 5-2. All voids have freeboard of 1.0 m or greater.

Table 5-2 Water Levels Summary – 0.1% AEP CC RCP 4.5 P90

Void	Watercourse	Landform Level (mAHD)	Water Level Against Landform (mAHD)	Available Freeboard (m)
Lotus/Campbell Pit	Downs Creek	189.6 – 192.0	188.0 – 190.6	1.4 – 1.6
	Stephens Creek	186.4 – 187.2	185.3 – 185.4	1.1 – 1.8
Gilbert Pit	Stephens Creek	182.1 – 185.7	180.9 – 184.7	1.0 – 1.2
	Scotts Creek	185.4 – 187.7	184.0 – 186.4	1.3 – 1.4
Price Pit	Scotts Creek	192.7 – 192.8	191.5 – 191.7	1.1 – 1.2
Leichhardt Pit	–	–	–	–
Roper Pit	Rolf Creek	199.0 – 206.0	196.0 – 204.0	2.0 – 3.0
East Pit	Rolf Creek (centre)	187.0 – 187.6	185.5 – 186.5	1.1 – 1.5
	Rolf Creek (north)	197.0	195.9	1.1

5.2 INTERACTIONS WITH THE LANDFORM

The PRC results have been inspected to identify locations where floodwaters interact with the landform design. As recommended by BMA, particular attention was paid to areas where floodwaters are ponding against the landform, or where particularly high stream power or velocities occur.

There are several locations across the study area where floodwaters spill out of the main watercourse channel and make contact with the landform. As these locations are at the edge of the floodplain, the velocities and stream power are generally low, however some locations where values are higher than the surroundings do occur. The key locations of interaction with the landform are highlighted in Figure 5-1 through to Figure 5-4.

Where floodwaters have the potential to interact with constructed landforms and impact on landform stability, geotechnical and other, rehabilitation design considerations should be incorporated into the final landform engineering plans at the time of construction, where appropriate.

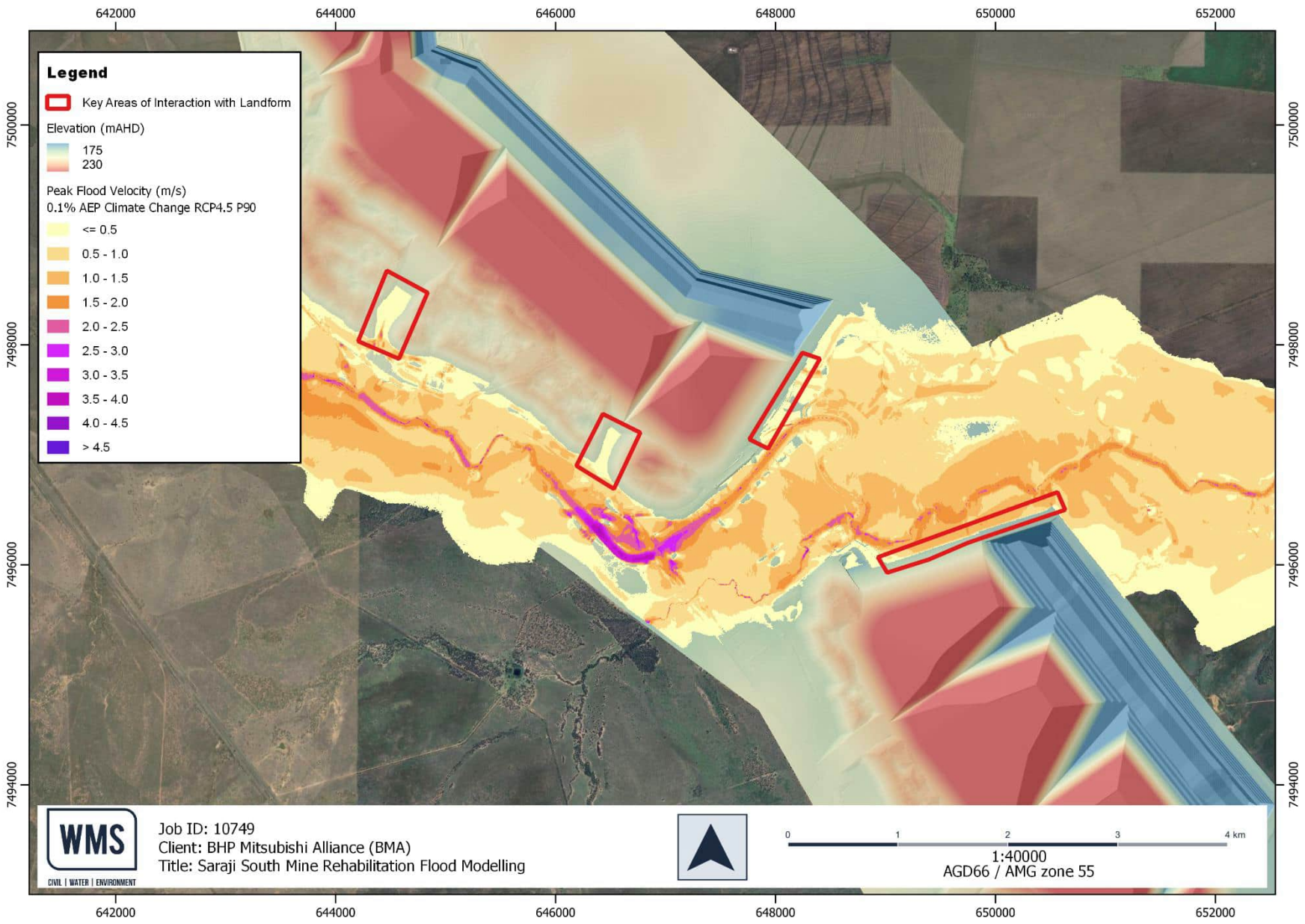

Figure 5-1 Stephens Creek Key Locations of Interaction with the Landform

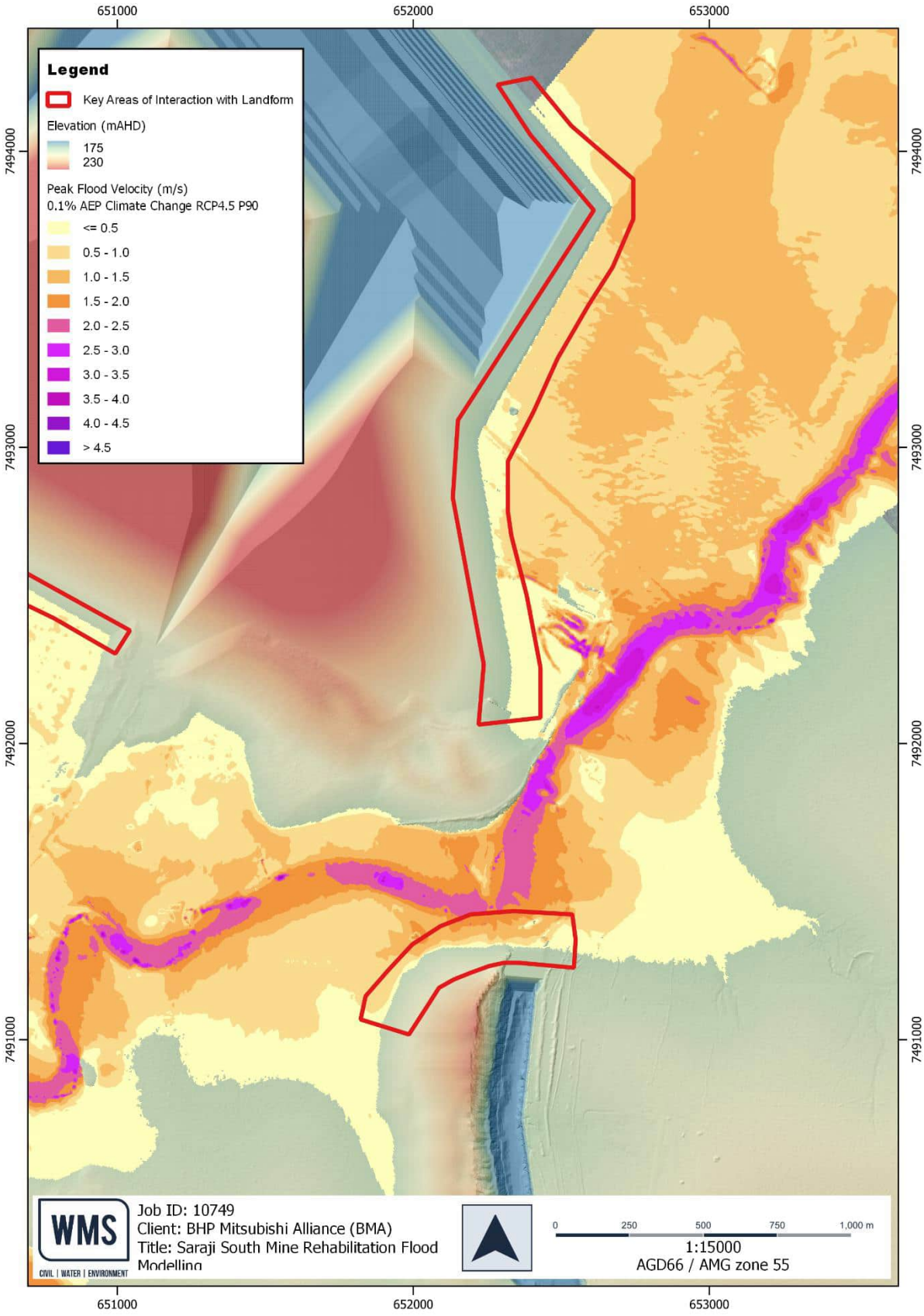

Figure 5-2 Scotts Creek Key Locations of Interaction with the Landform

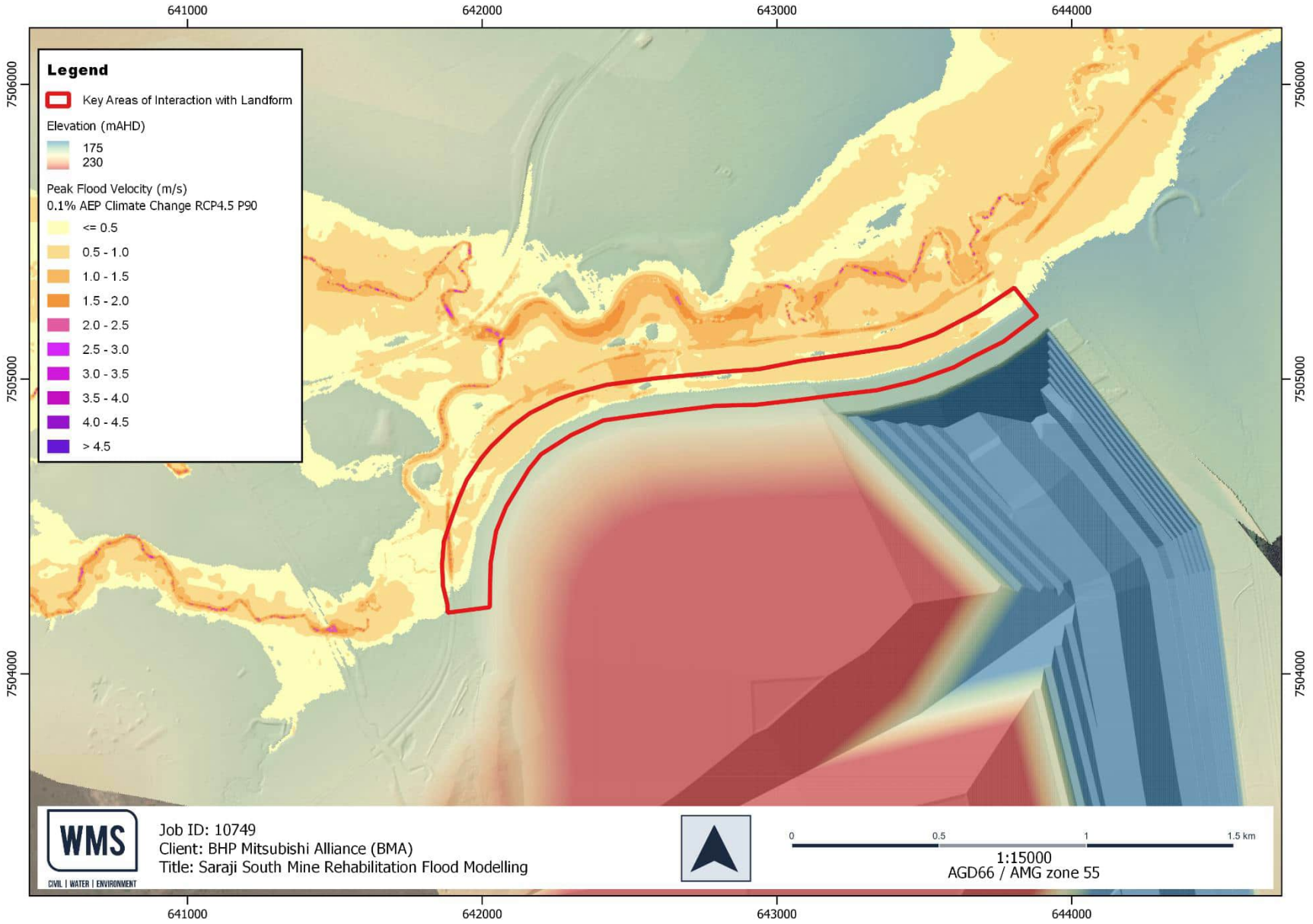

Figure 5-3 Downs Creek Key Locations of Interaction with the Landform

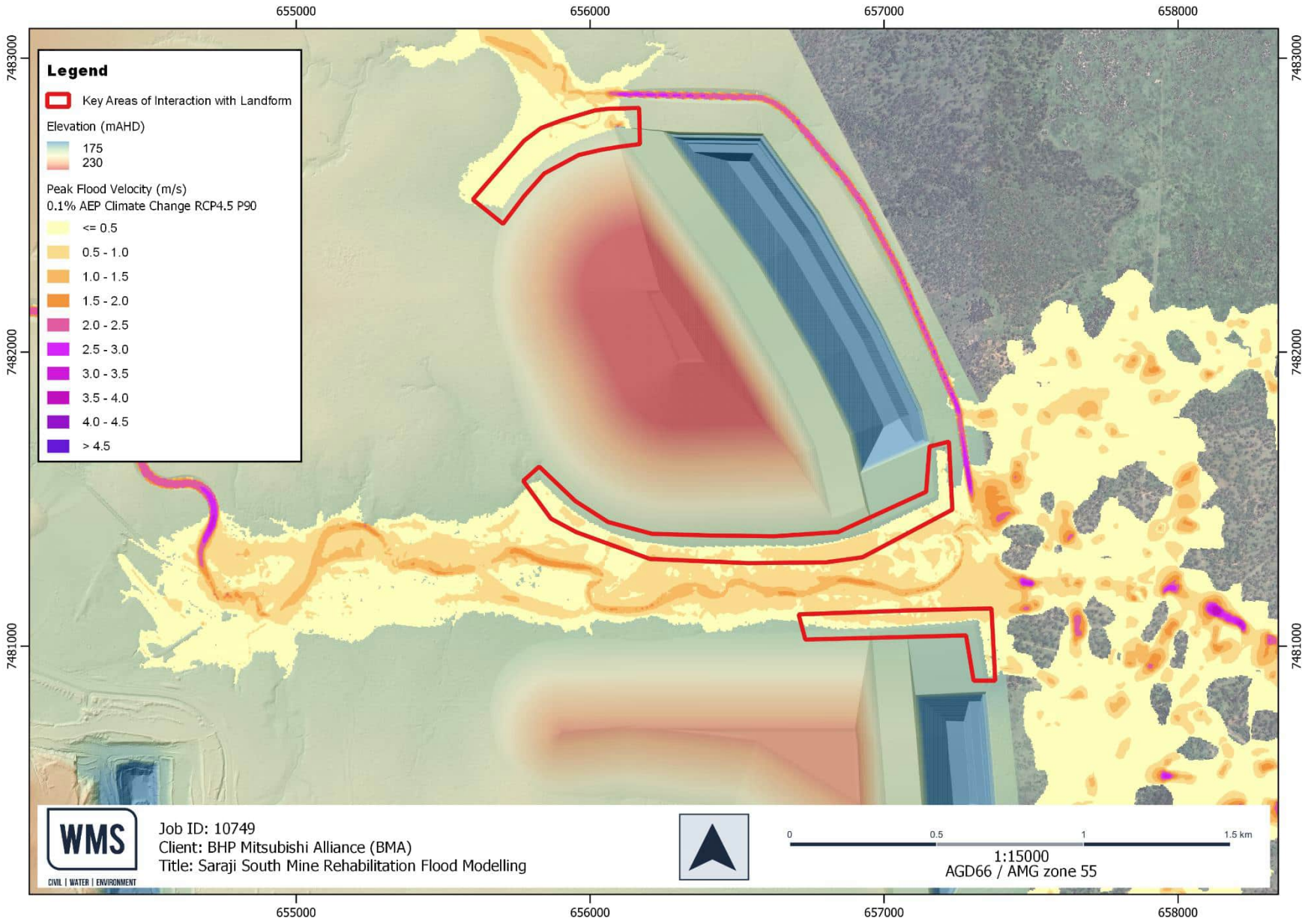

Figure 5-4 Rolf Creek Key Locations of Interaction with the Landform

5.3 CONSIDERATION OF ALTERATION OF FLOWS

As part of the PRCP guidelines consideration should be given to the alteration of flows upstream and downstream of the mine site. For Stephens Creek, Scotts Creek and Downs Creek, flows upstream of the mine site can be considered unaltered as the upstream catchments are unaffected by mining operations. For Rolf Creek, the upstream catchment is located wholly within the mine and therefore there is no upstream catchment.

For the assessment of flow alteration downstream of the mine site, flows and volumes from the PRC and PMC scenarios have been extracted from a downstream location in each of the hydraulic models. Peak flows and volumes through the selected downstream locations are shown in Table 5-3 for a range of events.

For Rolf Creek, three separate locations were selected, as illustrated in Figure 5-5, and the flows and volume from each location were added to determine the approximate values downstream of the mine. This is due to the low resolution of the terrain downstream of the mine where the Rolf Creek streams converge, which limits the accuracy of the model results at this location.

In addition to assessing the flows and volumes immediately downstream of the mine site, an assessment of flows and volumes at a location immediately upstream of the confluence with the Isaac River was undertaken. This assessment provides a better understanding of the potential impact of the mine site in the context of the Isaac River tributaries. The flows and volumes were calculated by scaling the modelled flows based on the ratio between catchment areas at the mine site and at the Isaac River confluence. The results are provided in Table 5-4.

In acknowledging the long operational life of SSM and the ongoing landform modifications over this period, some alteration to the watercourse flow regime is to be expected. Key points to note from Table 5-3 and Table 5-4 are:

- Virtually no change is observed for Stephens Creek and Scotts Creek flows and volume at both assessment locations. This is expected as the size of the unchanged catchments upstream of the mine is what drives the flows downstream, rather than the catchments internal to the mine. As such, the relatively minor changes to the internal catchments produced limited effect on the downstream flows.
- Immediately downstream of the mine, a small volume decrease of generally less than 7% is observed for Downs Creek. This decrease is likely due to the approximately 8% decrease in PRC versus PMC catchment areas (54 km^2 versus 58 km^2, respectively).
- Near the confluence with the Isaac River, small volume decreases of less than 3% are observed for Downs Creek.
- For Rolf Creek immediately downstream of the mine, there is a decrease of up to approximately 28% in flows and volume. This decrease can likely be attributed to the approximately 29% decrease in PRC versus PMC catchment areas (31 km^2 versus 44 km^2, respectively). This also highlights that the location of the mine site in relation to the catchment can significantly influence the observed percentage change in flows and volume. The further downstream, the more likely flows are to incur minimal change, as the flows will be driven by the large catchment upstream – as is the case with Stephens Creek and Scotts Creek. As the Rolf Creek catchment starts within SSM, it is to be expected that changes in the landform would result in more significant changes to the flow and volumes immediately downstream of the mine.
- Near the confluence with the Isaac River, the percentage changes in flow and volumes observed for Rolf Creek are significantly smaller and do not exceed 10%. This was expected given the relatively small size of the Rolf Creek catchment within SSM compared to the total catchment draining to the confluence with the Isaac River.

Table 5-3 Peak Flow Comparison Immediately Downstream of the Mine – PRC vs PMC

Model	Event	Peak Flow			Total Volume		
		PRC Peak Flow (10^2 m³/s)	PMC Peak Flow (10^2 m³/s)	Percentage Change	PRC Total Volume (GL)	PMC Total Volume (GL)	Percentage Change
Stephens Creek	39% AEP	3	3	0%	160	161	-1%
	2% AEP	13	13	0%	577	583	-1%
	1% AEP	18	18	0%	858	869	-1%
	0.1% AEP	29	29	0%	1284	1302	-1%
	0.1% AEP CC RCP4.5 P90	35	35	0%	1566	1587	-1%
Scotts Creek	39% AEP	3	3	0%	119	118	1%
	2% AEP	12	12	0%	464	460	1%
	1% AEP	17	17	0%	651	652	0%
	0.1% AEP	27	27	0%	1038	1041	0%
	0.1% AEP CC RCP4.5 P90	34	34	0%	1263	1265	0%
Downs Creek	39% AEP	1	1	0%	16	17	-6%
	2% AEP	2	2	0%	35	37	-5%
	1% AEP	3	3	0%	63	67	-6%
	0.1% AEP	5	6	-17%	77	83	-7%
	0.1% AEP CC RCP4.5 P90	7	8	-13%	95	102	-7%
Rolf Creek	39% AEP	0.2	0.2	0%	6.0	8.0	-25%
	2% AEP	1.2	1.5	-20%	22.0	30.0	-27%
	1% AEP	1.8	2.5	-28%	38.0	52.0	-27%
	0.1% AEP	3.6	4.6	-22%	48.0	66.0	-27%
	0.1% AEP CC RCP4.5 P90	4.5	6.0	-25%	60.0	83.0	-28%

Table 5-4 Peak Flow Comparison Immediately Upstream of Confluence with the Isaac River – PRC vs PMC

Model	Event	Peak Flow			Total Volume		
		PRC Peak Flow (10^2 m³/s)	PMC Peak Flow (10^2 m³/s)	Percentage Change	PRC Total Volume (GL)	PMC Total Volume (GL)	Percentage Change
Stephens Creek	39% AEP	7	7	0%	350	351	0%
	2% AEP	28	28	0%	1265	1271	0%
	1% AEP	39	39	0%	1884	1895	-1%
	0.1% AEP	63	63	0%	2821	2839	-1%
	0.1% AEP CC RCP4.5 P90	76	76	0%	3440	3461	-1%
Scotts Creek	39% AEP	9	9	0%	337	336	0%
	2% AEP	34	34	0%	1314	1310	0%
	1% AEP	48	48	0%	1856	1857	0%
	0.1% AEP	77	77	0%	2962	2965	0%
	0.1% AEP CC RCP4.5 P90	97	97	0%	3601	3603	0%
Downs Creek	39% AEP	3	3	0%	47	48	-2%
	2% AEP	6	6	0%	103	105	-2%
	1% AEP	9	9	0%	187	191	-2%
	0.1% AEP	16	17	-6%	230	236	-3%
	0.1% AEP CC RCP4.5 P90	22	23	-4%	284	291	-2%
Rolf Creek	39% AEP	0.6	0.6	0%	21	23	-9%
	2% AEP	4.0	4.3	-7%	77	85	-9%
	1% AEP	6.4	7.1	-10%	134	148	-9%
	0.1% AEP	12.1	13.1	-8%	170	188	-10%
	0.1% AEP CC RCP4.5 P90	15.6	17.1	-9%	213	236	-10%

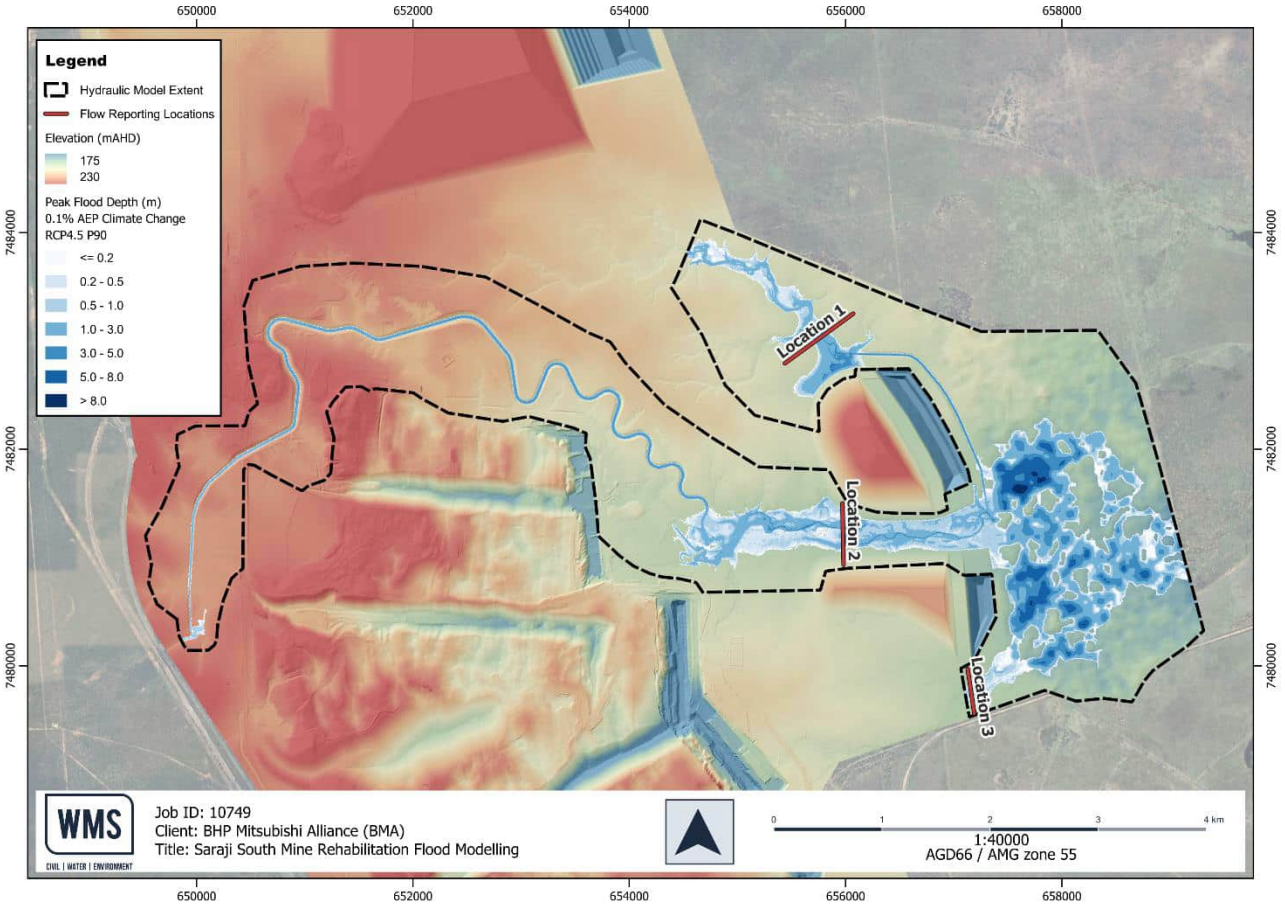

Figure 5-5 Rolf Creek Peak Flow and Total Volume Comparison Locations

6 FLOODING RISK PROFILE

A Flood Risk Profile (FRP) was developed by WMS based on BHP's *"Risk Management Our Requirements"* document and review of the *"Risk Assessment Approach"* provided by BMA. The FRP has been developed for the PRC scenario and uses the model results to inform potential future flood risks. The identified risks have been discussed in Section 5 but the FRP goes further to quantify, classify, and suggest mitigation for the risks. The process can be outlined as follows:

1. Risk identification based on model results.
2. Quantify risk in terms of Maximum Foreseeable Loss (MFL) as defined in the Severity and Likelihood table in Appendix A of BHP's Risk Management Document.
3. If the MFL is rated 4 or above identify control measures, type, and purpose.
4. Assess the residual severity to determine the Residual Risk Rating (RRR) following implementation of the control measures.
5. Determine the emerging risks likelihood factor following implementation of control measures.
6. Use the RRR heat map provided in BHP's Risk Management Document to determine if the risk appetite is exceeded for each risk. RRR < 90 denotes an acceptable risk.

Details of the FRP are provided in Appendix E and a summary is provided below:

- The key risks identified relate to:
  - Floodwater ingress into pits in the PMF event for all watercourses;
  - Alterations of flow downstream of the mine compared to pre-mining conditions for Rolf Creek;
  - Floodwater contact with landform for all watercourses.

All risks have been attributed an MFL of less than 4 and therefore no control measures are required.

7 SUMMARY AND RECOMMENDATIONS

WMS was engaged by BMA to undertake Rehabilitation Flood Modelling for SSM to provide supporting technical information for the SSM PRC plans.

Hydrologic and hydraulic modelling has been undertaken for four watercourses within the study area that interact with the mine site. These watercourses include: Stephens Creek, Scotts Creek, Downs Creek and Rolf Creek. The modelling was based on a PRC landform design which was provided to WMS as a digital surface for inclusion in the models (file name: *prcp_npm_lf1_1_modelled_dem_agd66z55_20230825.asc*). To assess how flood characteristics and flow paths have changed as a result of mining operations, a pre-mining conditions (PMC) scenario was also developed within the models as a comparison to the PRC model results. As requested in the project brief, the models were run for the 39%, 2%, 1%, 0.1% AEP and PMF events, as well as three climate change scenarios for the 1% and 0.1% AEP events. Mapping of peak depth and water level contours, velocities and stream power has been provided as appendices to this report.

The flood modelling results have been interrogated to identify potential issues in the interaction of floodwaters with the landform design. The key findings of this assessment were:

- All voids have achieved immunity from floodwater ingress up to and including the 0.1% AEP climate change RCP 4.5 P90 event, and the only event where flood ingress to void is observed is the PMF.
- Ponding of floodwater against the landform occurs for all watercourses, to varying degrees. This occurs in events as frequent as the 39% AEP in some models. Figures illustrating key locations of interaction in the 0.1% AEP climate change RCP 4.5 P90 have been provided for BMA's consideration. Where floodwaters have the potential to interact with constructed landforms and impact on landform stability, geotechnical and other, rehabilitation design considerations should be incorporated into the final landform engineering plans at the time of construction, where appropriate.

The modelling results have also been interrogated to assess the alteration of flows upstream and downstream of the mine site, by comparing peak flows from the PRC and PMC scenarios. The key conclusions from this assessment were:

- Flows and volumes upstream of the mine site can be considered unaltered as the upstream catchments are unaffected by mining operations.
- Virtually no change in flows and volumes downstream of the mine site was observed for Stephens Creek and Scotts Creek flows and volume. This is expected as the size of the unchanged catchments upstream of the mine is what drives the flows downstream, rather than the catchments internal to the mine. As such, the relatively minor changes to the internal catchments produced limited effect on the downstream flows.
- For Downs Creek, a small volume decrease of 7% or less was observed immediately downstream of the mine due to decreases in local catchment area. This has been estimated to result in a 3% decrease or less in volume at the confluence with the Isaac River.
- Rolf Creek experienced the highest percentage changes in flows and volumes (up to 28% decrease) immediately downstream of the mine site. This can be attributed to the mine being located at the upper reaches of the Rolf Creek catchment, and therefore the lack of upstream catchment to drive the flows through the mine. When the flows and volumes near the confluence with the Isaac River are assessed, the percentage change decreases to a maximum of 10% decrease.

8 REFERENCES

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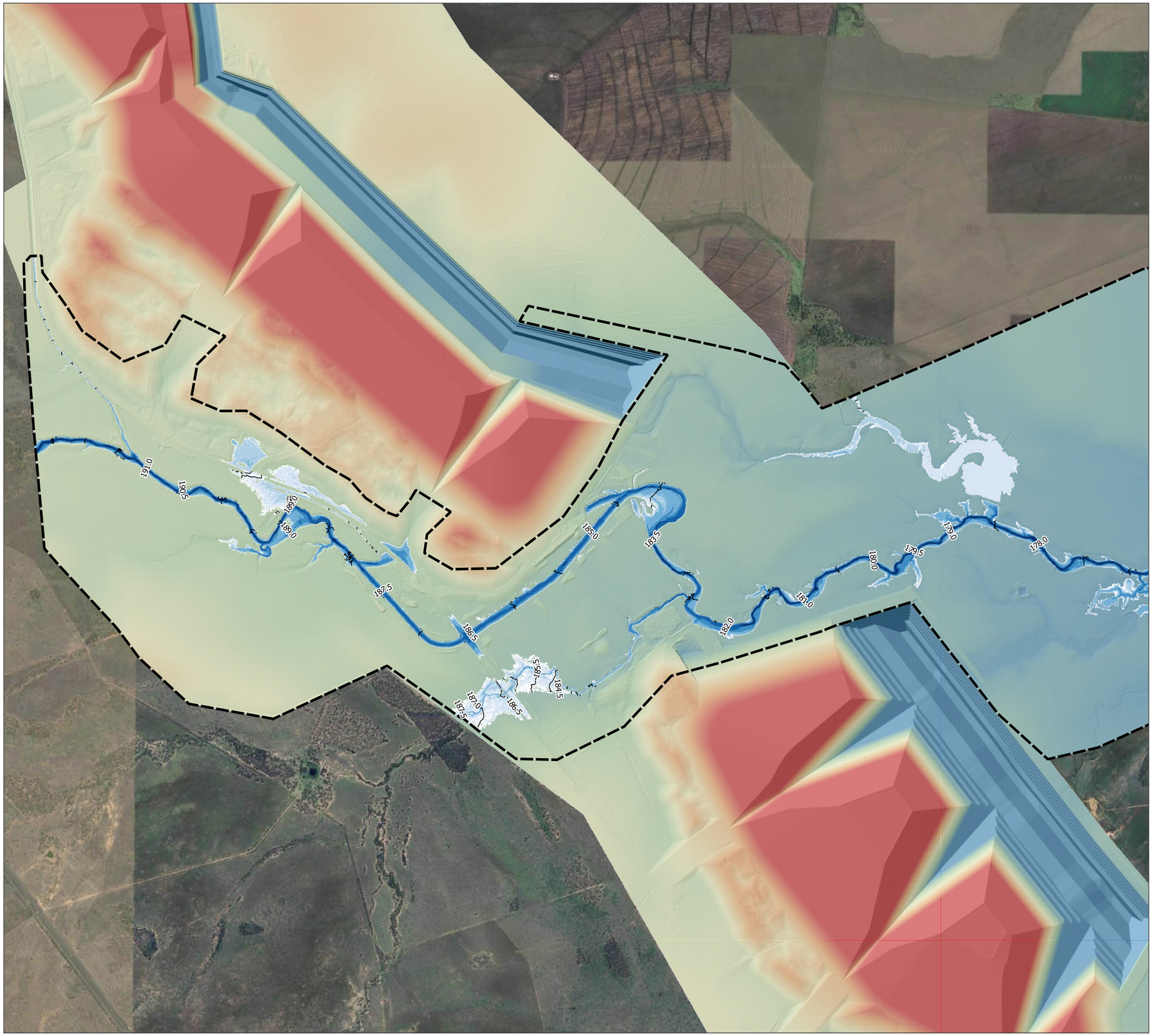
APPENDIX A

STEPHENS CREEK



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CIVIL | WATER | ENVIRONMENT

Appendix A-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

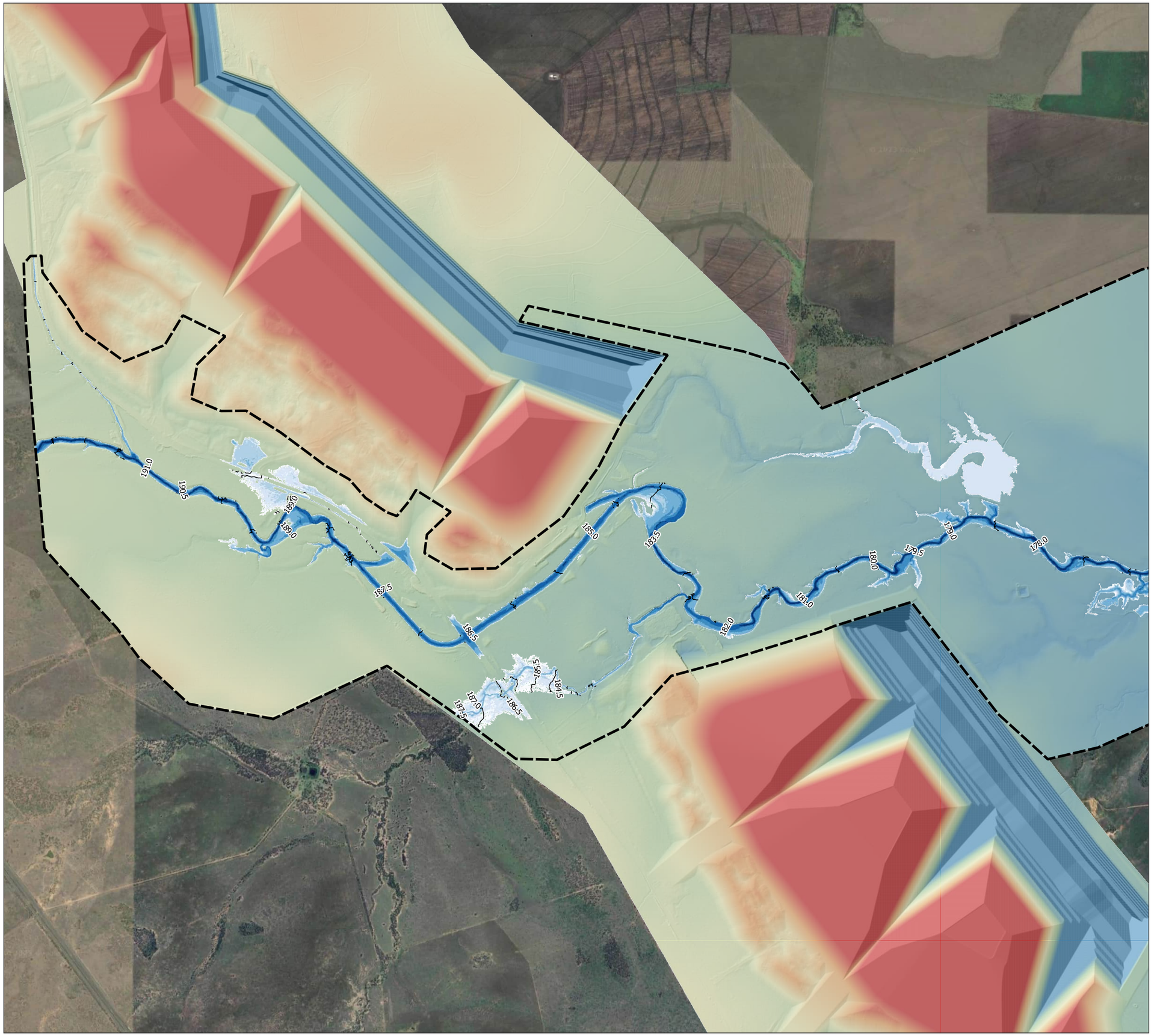
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



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Appendix A-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-2

PRC Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

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Appendix A-3

PRC Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

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Appendix A-4

PRC Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-5

PRC Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-6

PRC Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

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Appendix A-7

PRC Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

175
230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

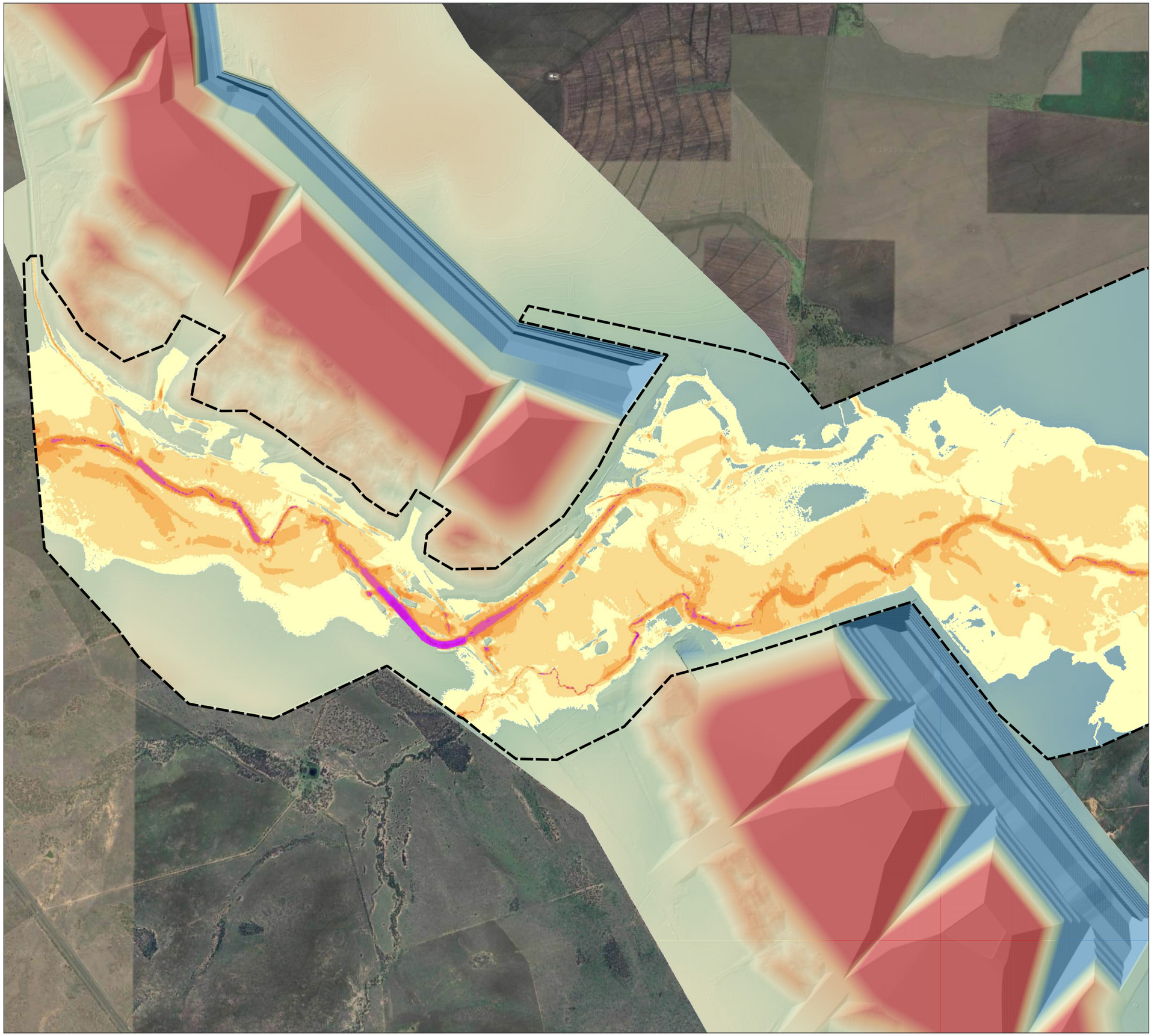
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



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CIVIL | WATER | ENVIRONMENT

Appendix A-8

PRC Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-9

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

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CIVIL | WATER | ENVIRONMENT

Appendix A-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

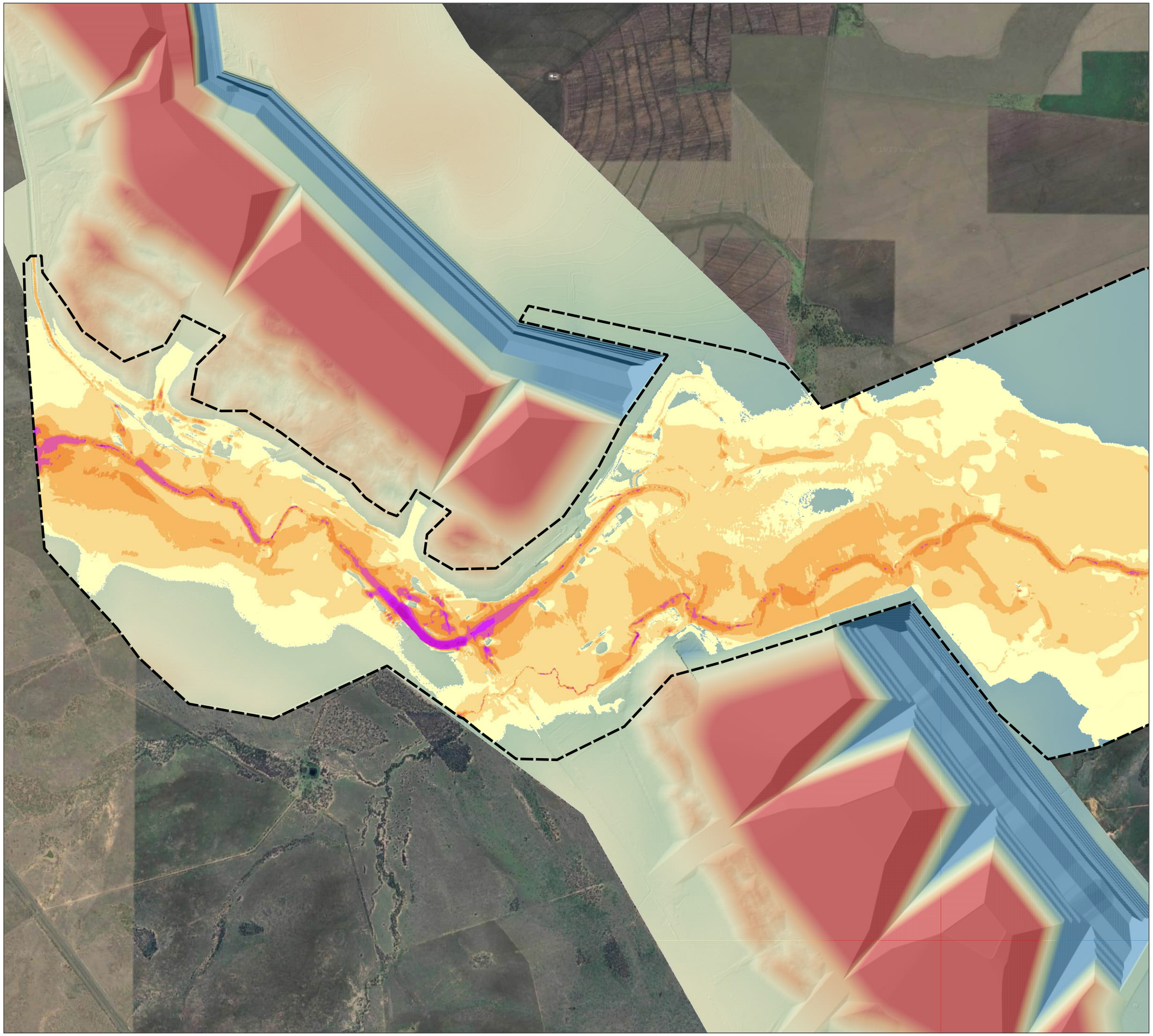
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



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CIVIL | WATER | ENVIRONMENT

Appendix A-11

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

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Appendix A-12

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

CIVIL | WATER | ENVIRONMENT

Appendix A-13

PRC Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-14

PRC Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-15

PRC Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-16

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-17

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

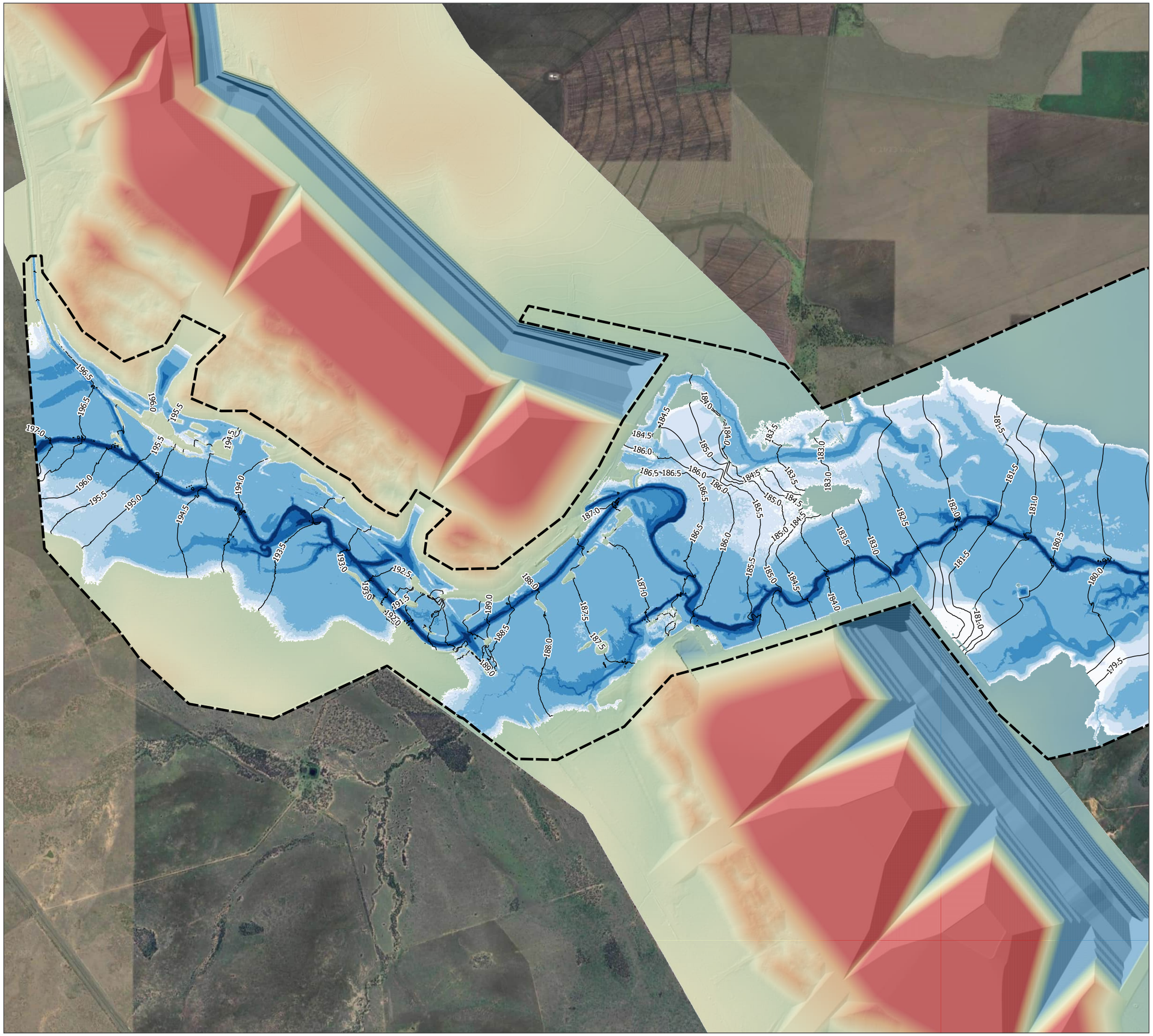
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-18

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-19

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

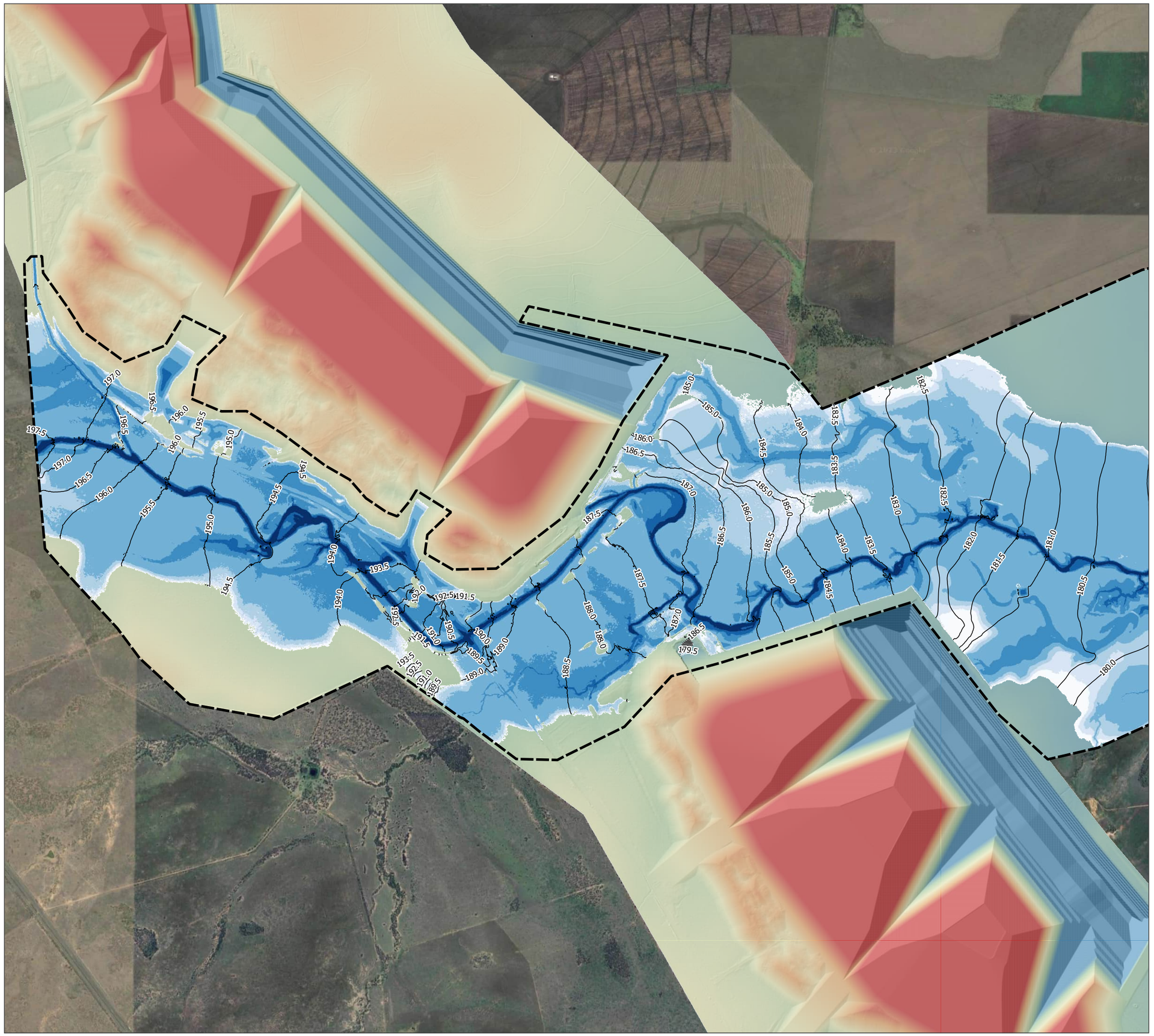
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-20

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

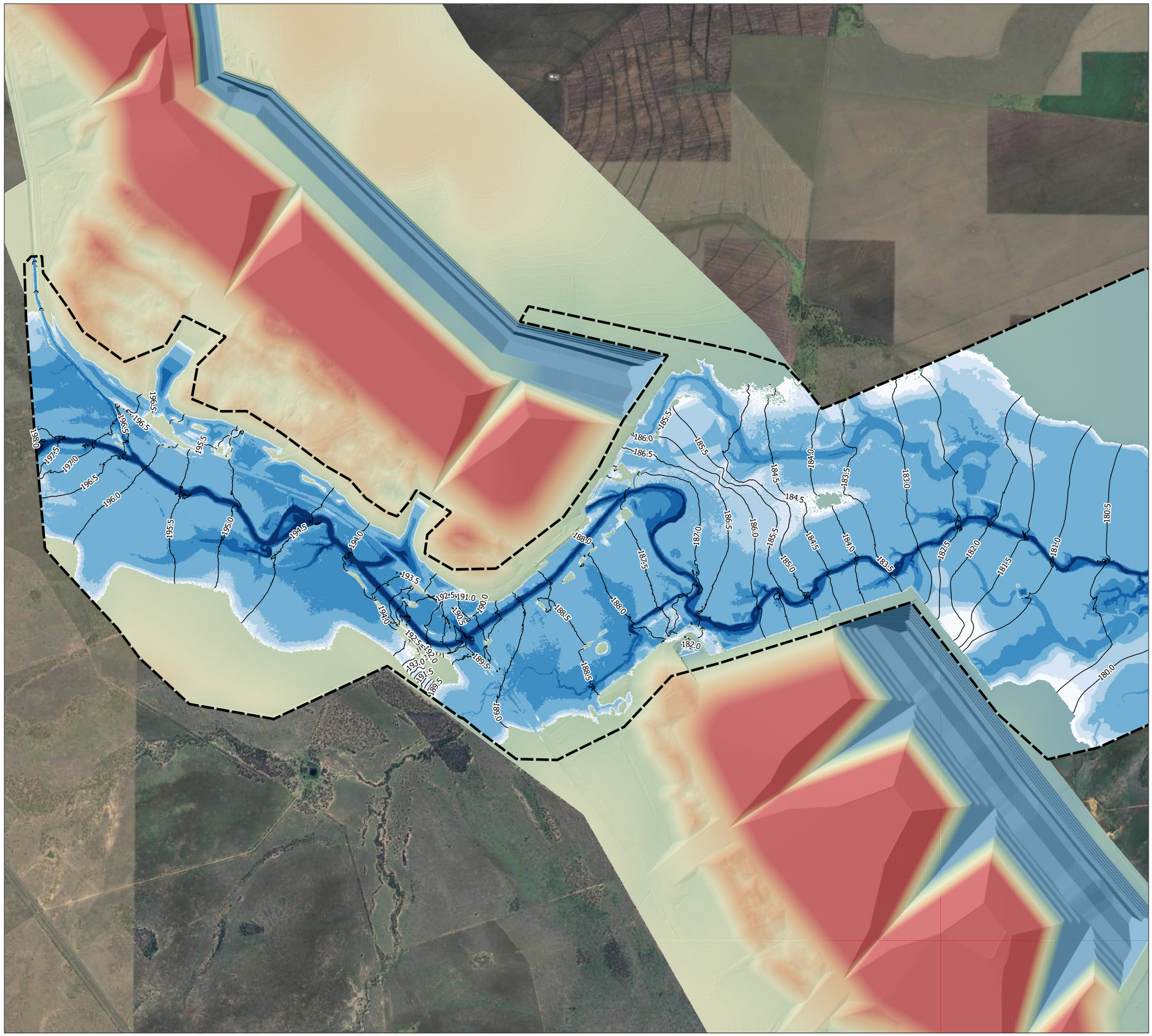
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-21

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

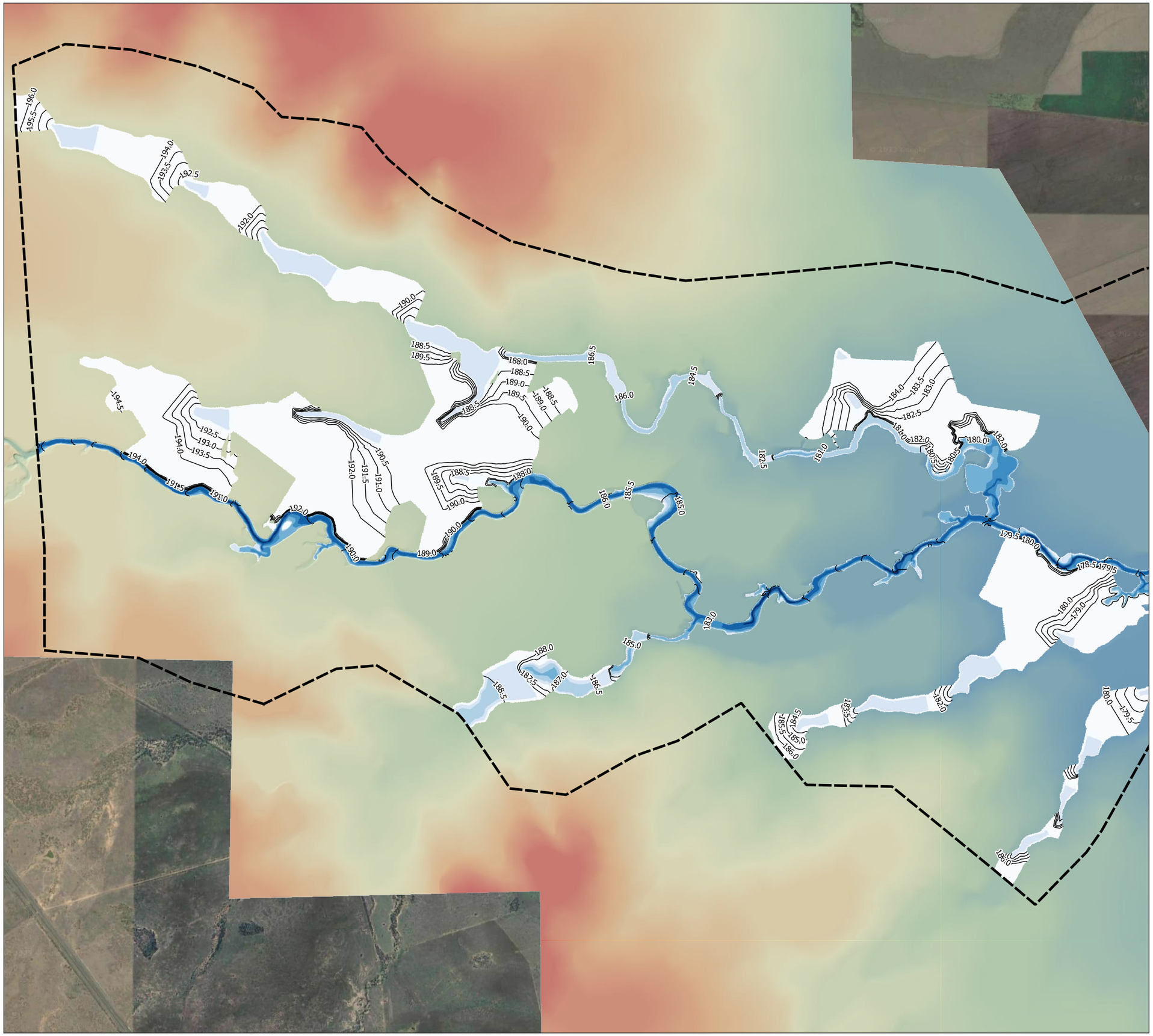
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-22

Pre-mining Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

Hydraulic Model Extent

Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-23

Pre-mining Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

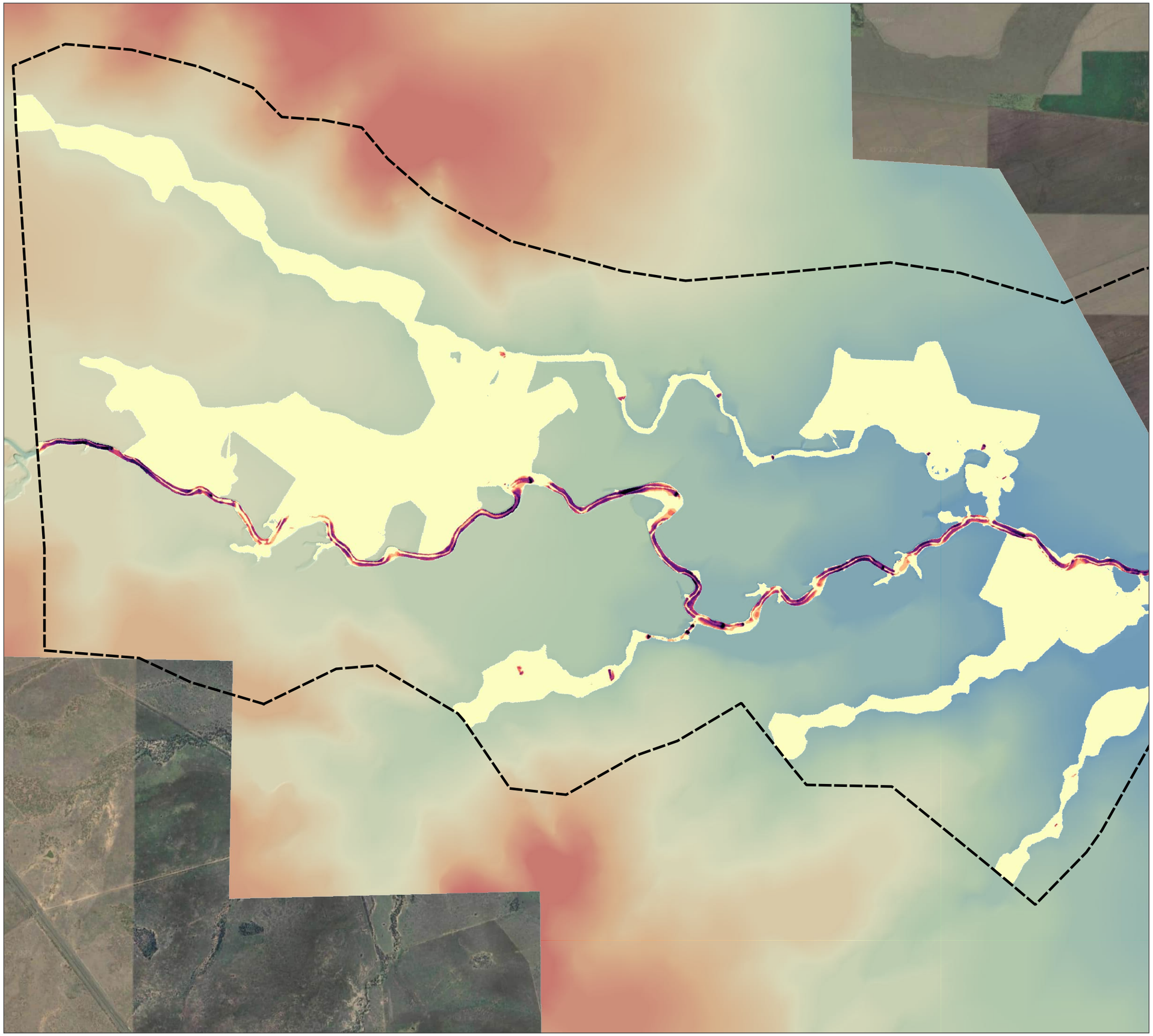
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-24

Pre-mining Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

CIVIL | WATER | ENVIRONMENT

Appendix A-25

Pre-mining Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-26

Pre-mining Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-27

Pre-mining Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-28

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

Hydraulic Model Extent

Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-29

Pre-mining Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-30

Pre-mining Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

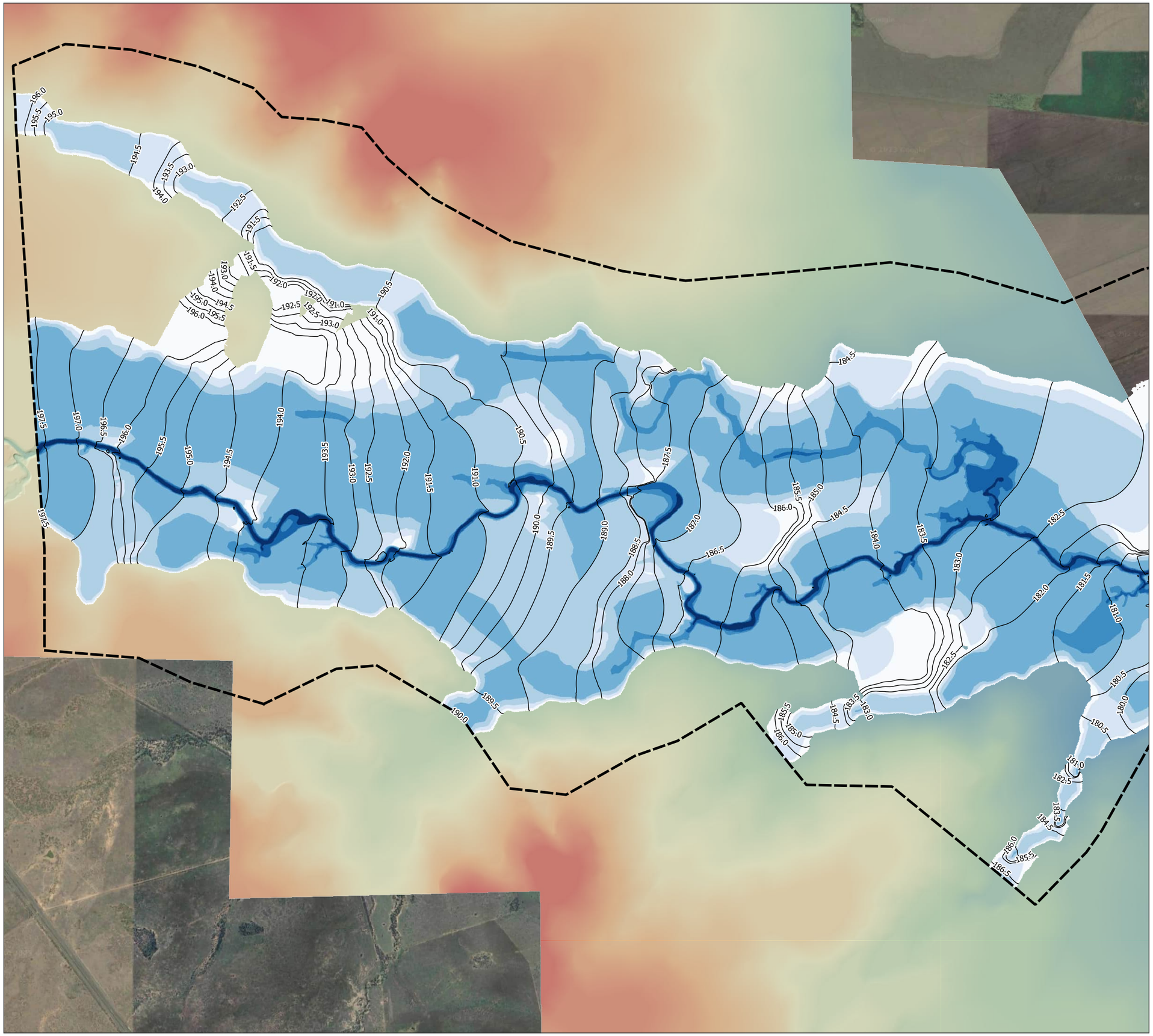
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-31

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

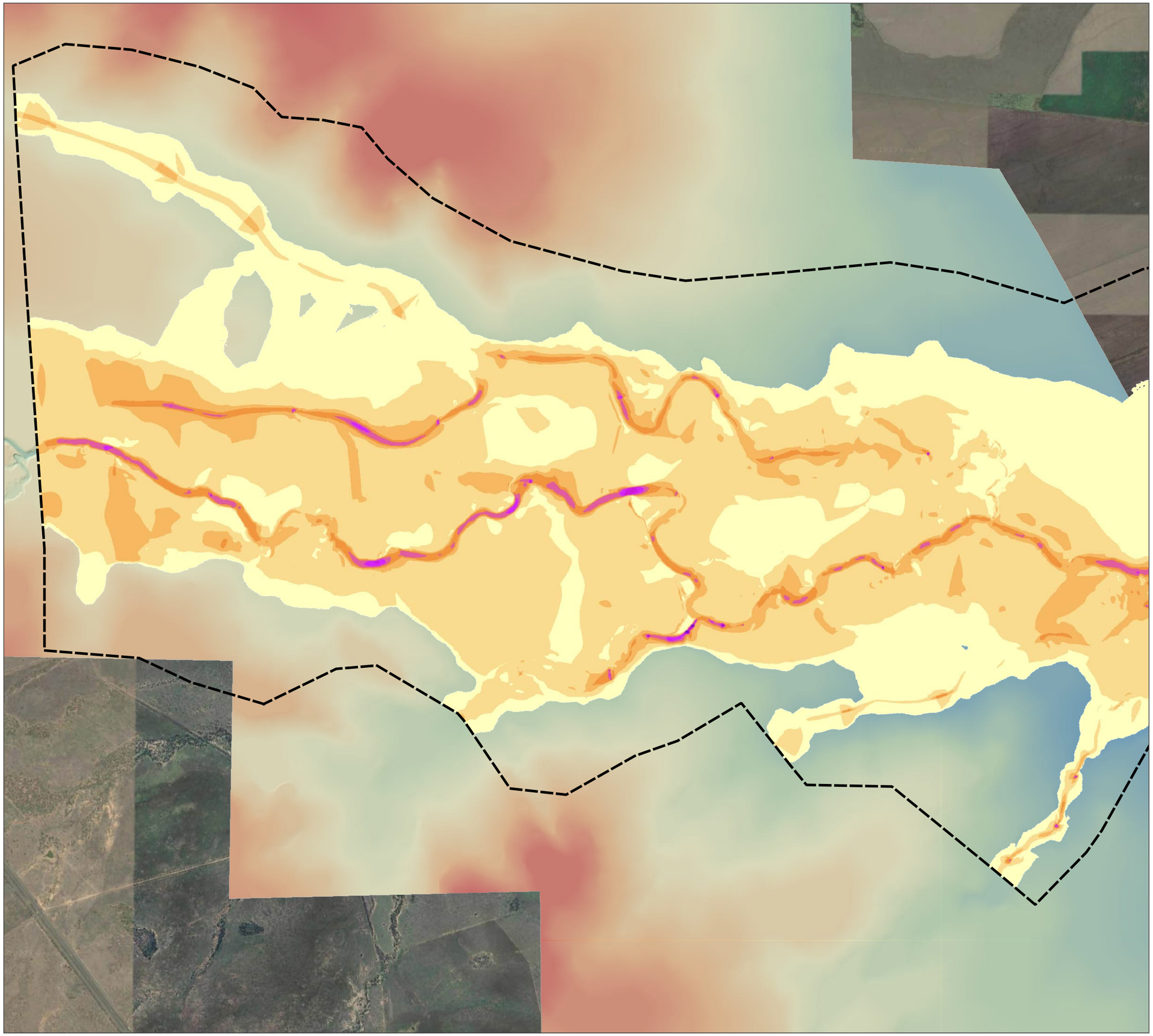
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-32

Pre-mining Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-33

Pre-mining Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

CIVIL | WATER | ENVIRONMENT

Appendix A-34

Pre-mining Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

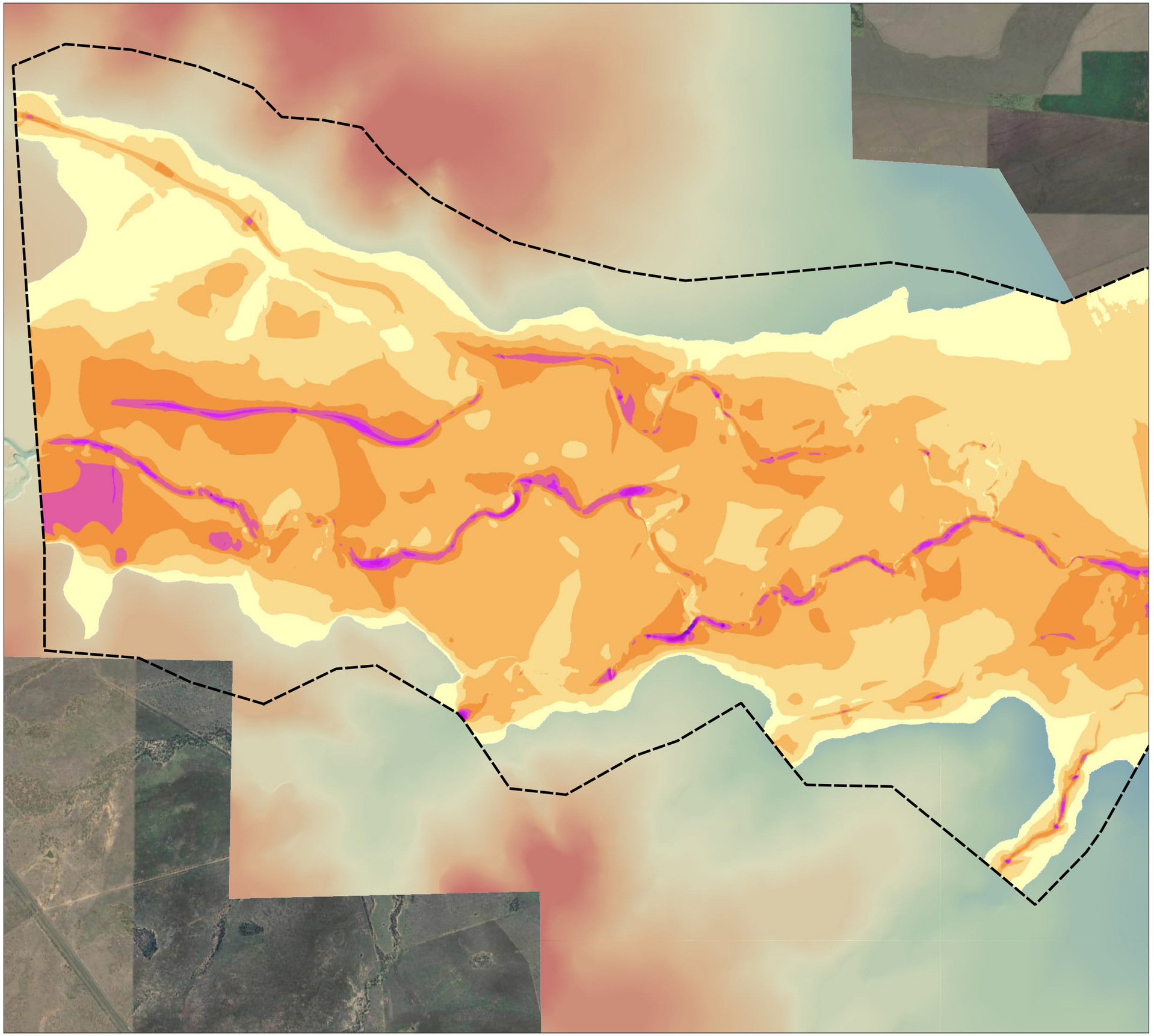
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-35

Pre-mining Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

- 180
- 210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-36

Pre-mining Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

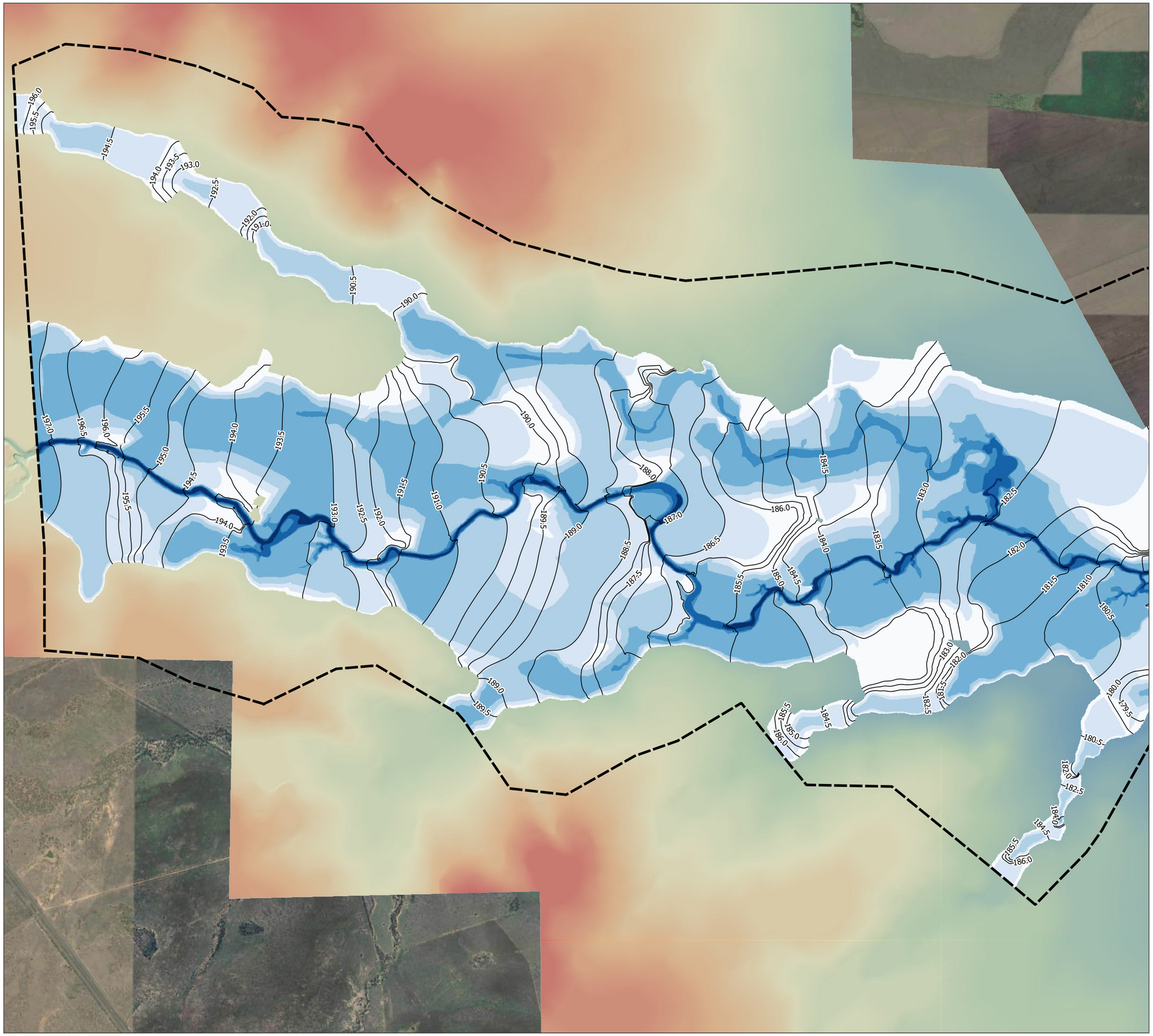
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-37

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-38

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

Hydraulic Model Extent

Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

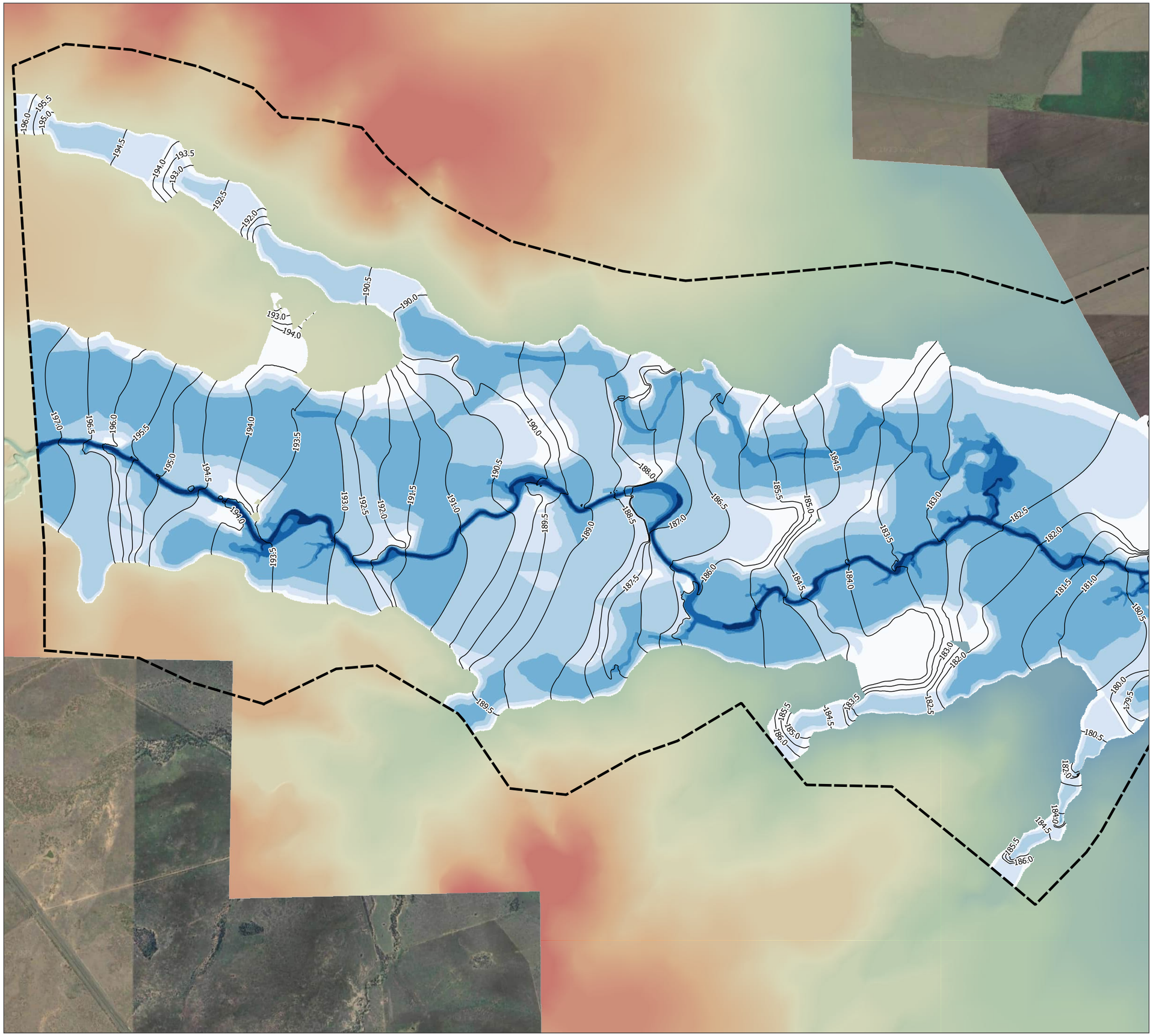
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-39

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-40

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

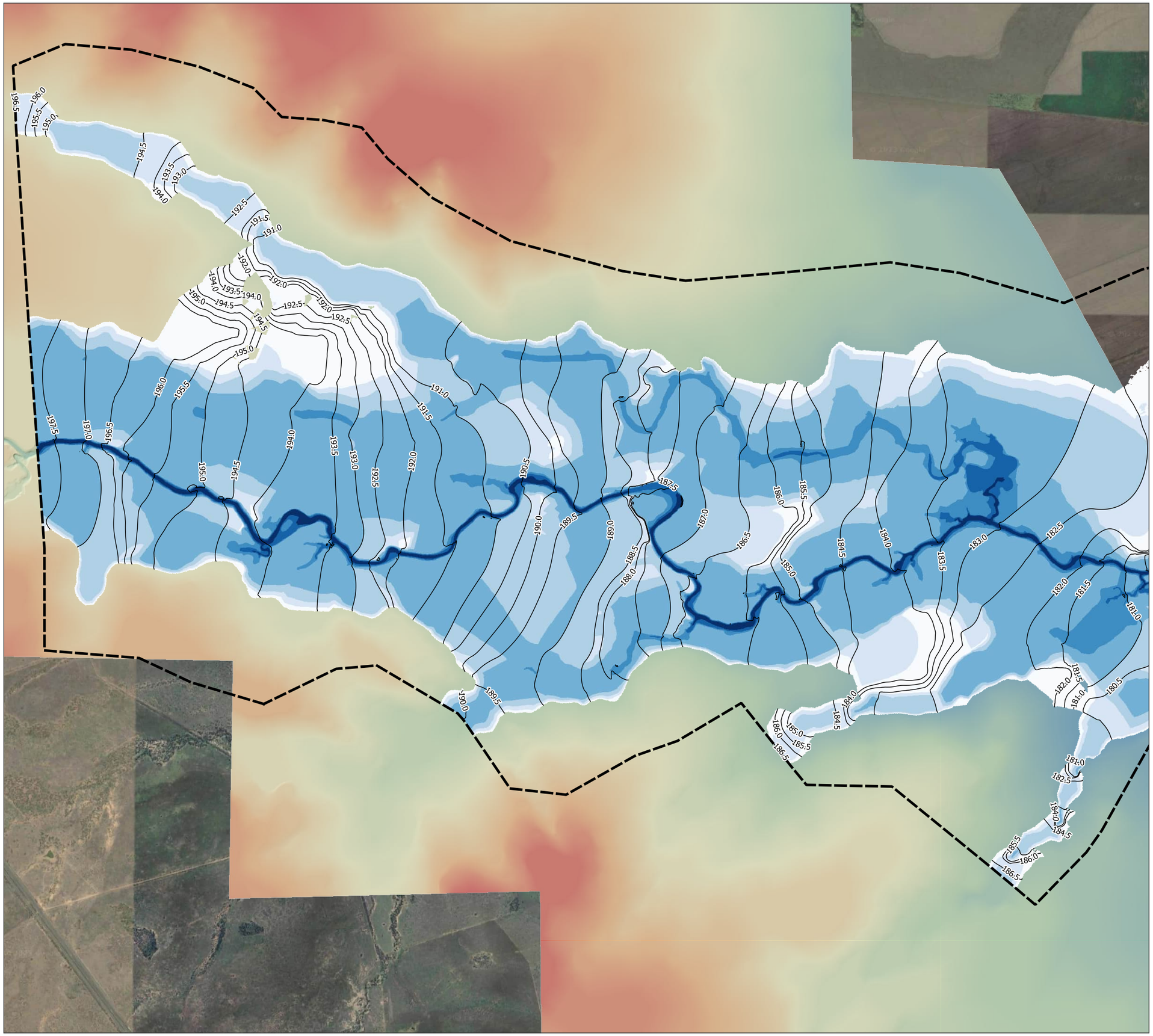
Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-41

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-42

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

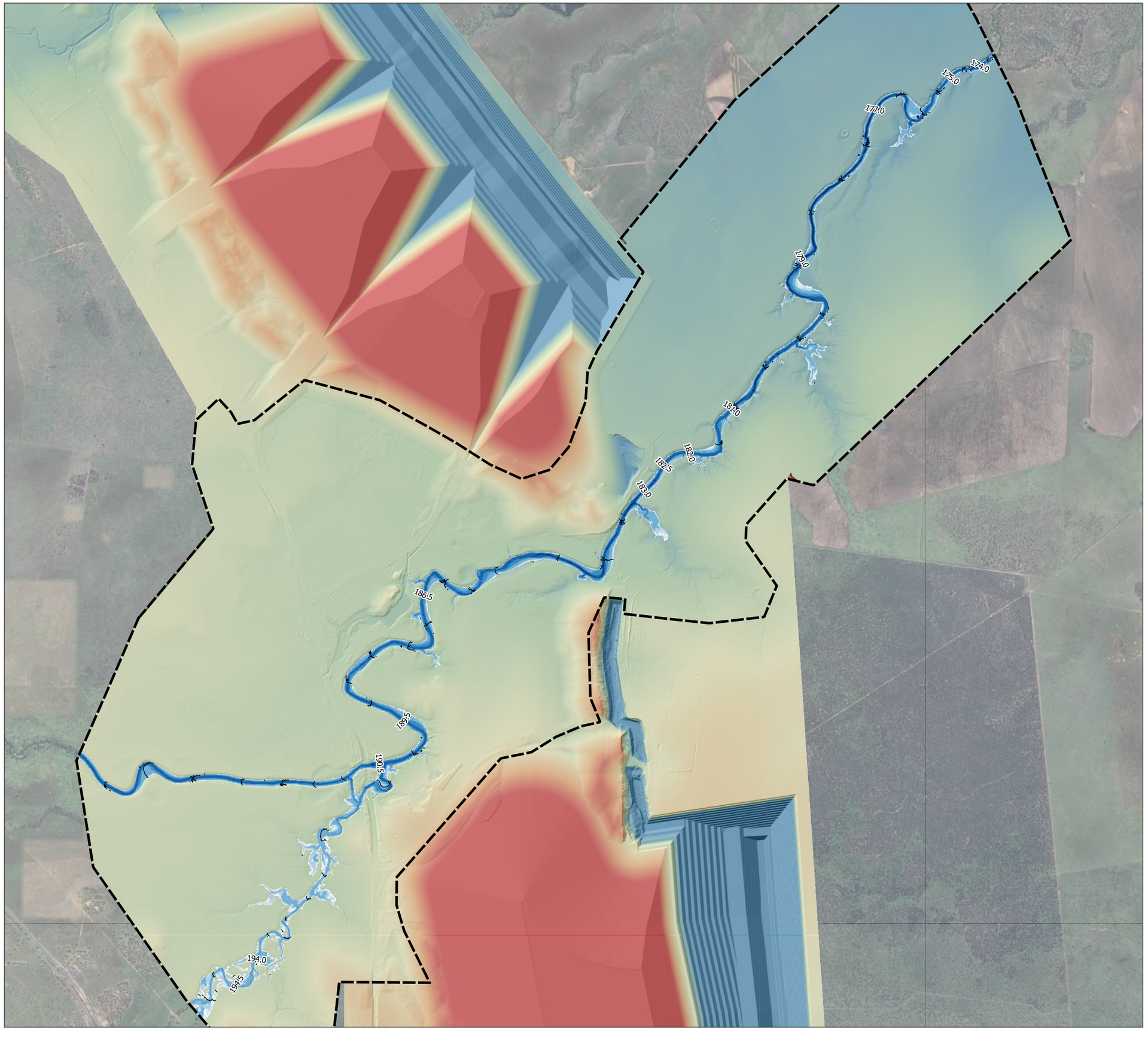
A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

APPENDIX B

SCOTTS CREEK



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-2

PRC Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-3

PRC Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-4

PRC Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

175
230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

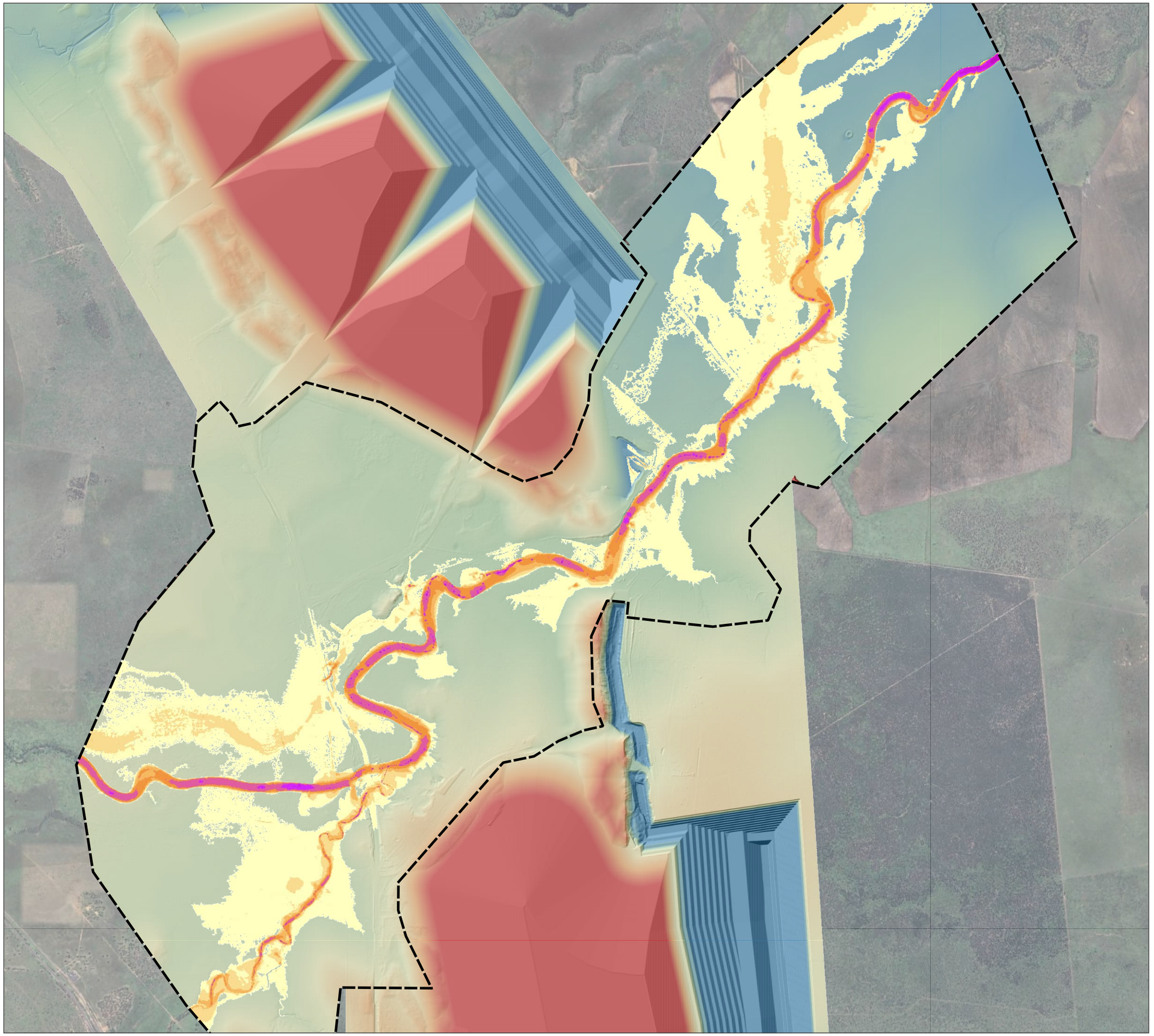
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-5

PRC Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-6

PRC Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

CIVIL | WATER | ENVIRONMENT

Appendix B-7

PRC Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-8

PRC Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-9

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-11

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-12

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-13

PRC Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-14

PRC Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-15

PRC Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

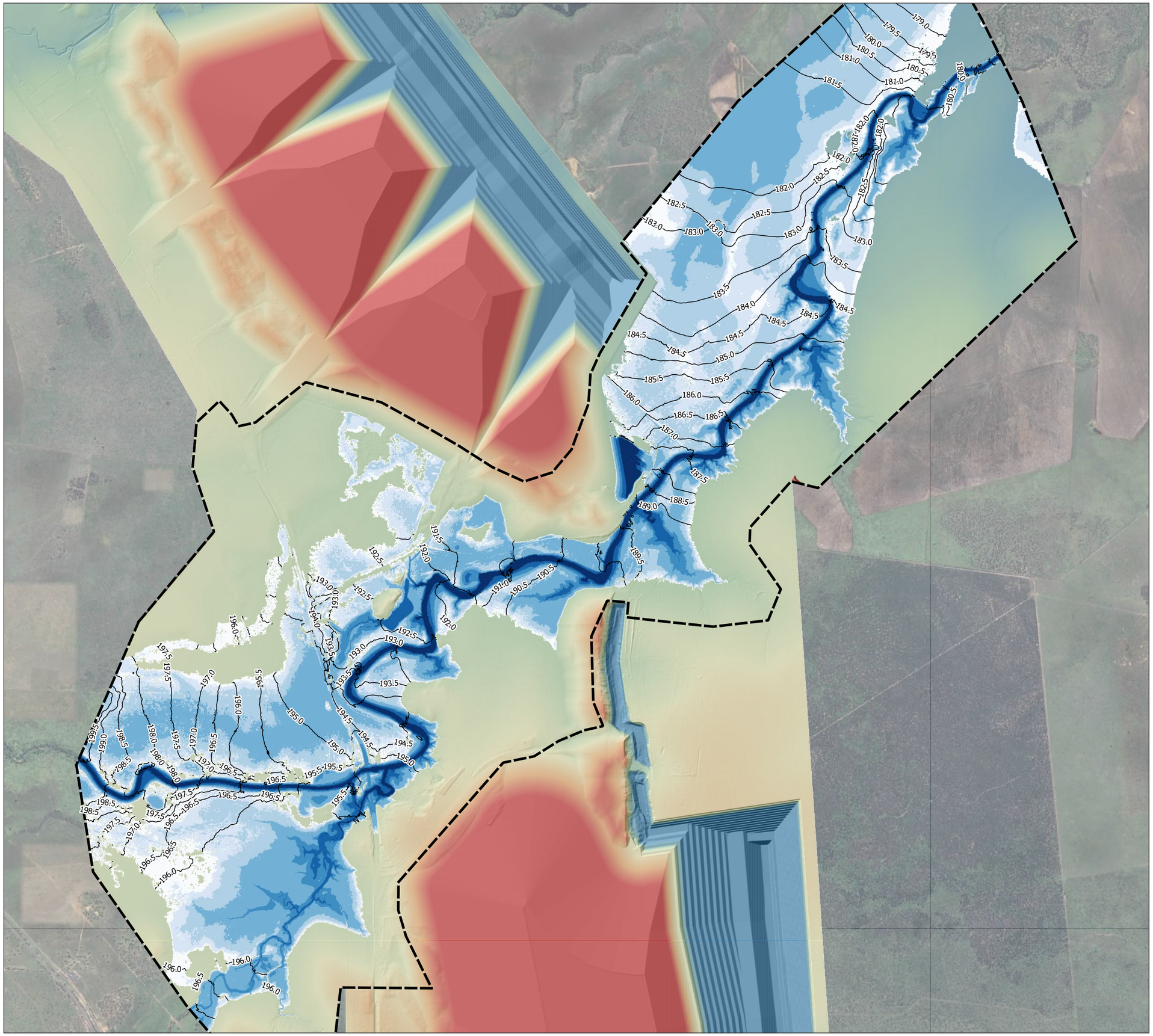
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-16

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

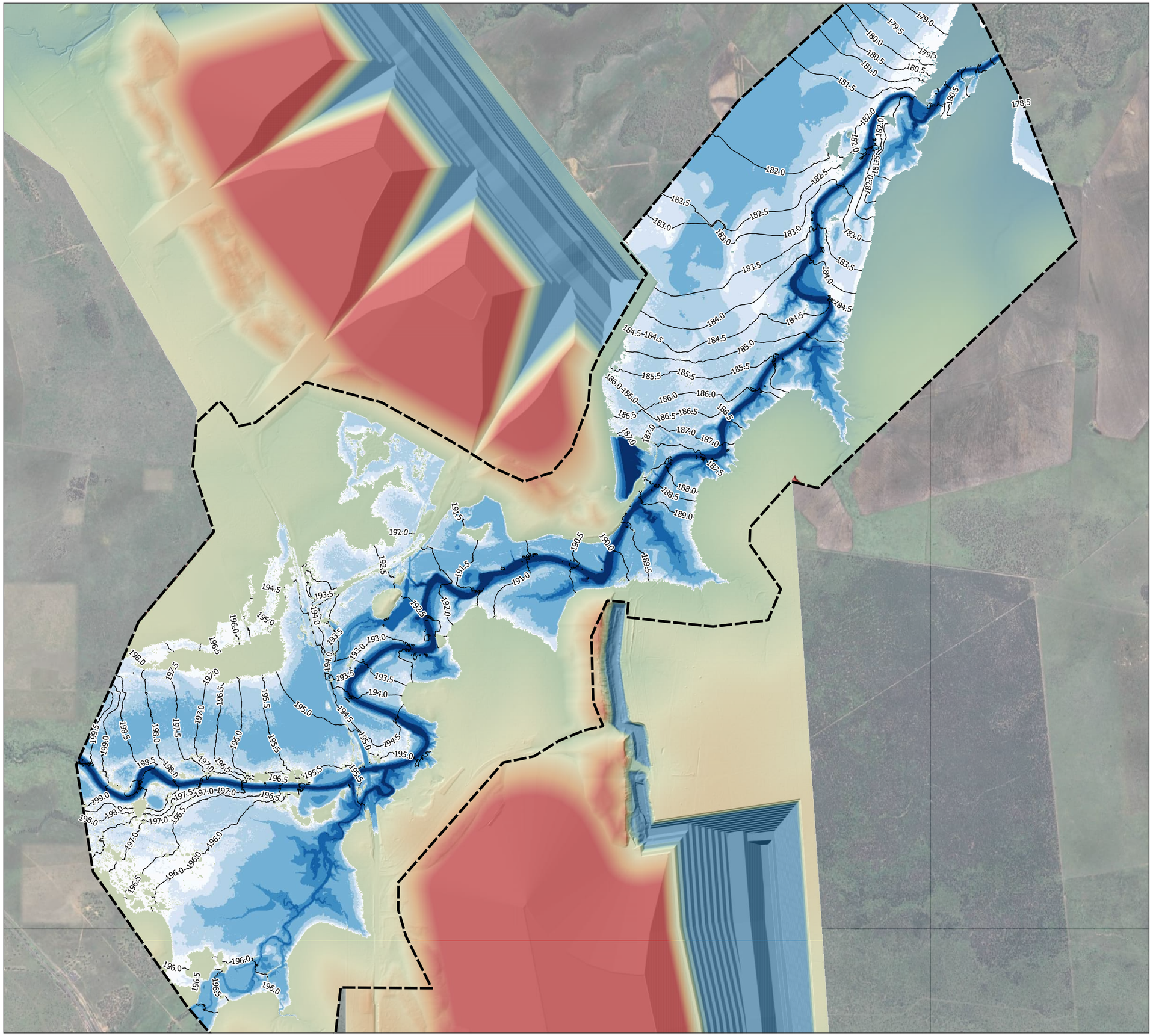
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-17

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

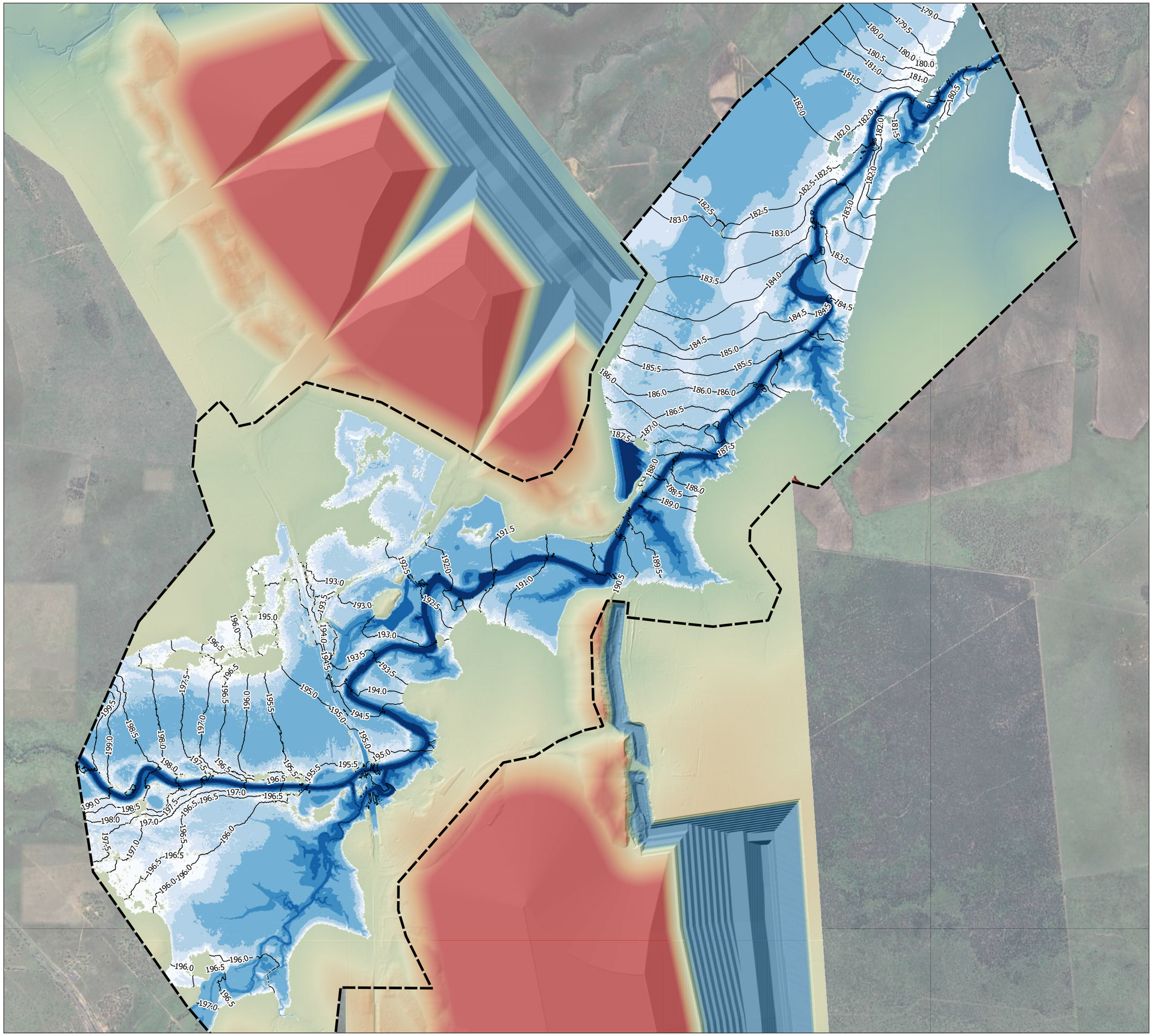
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-18

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

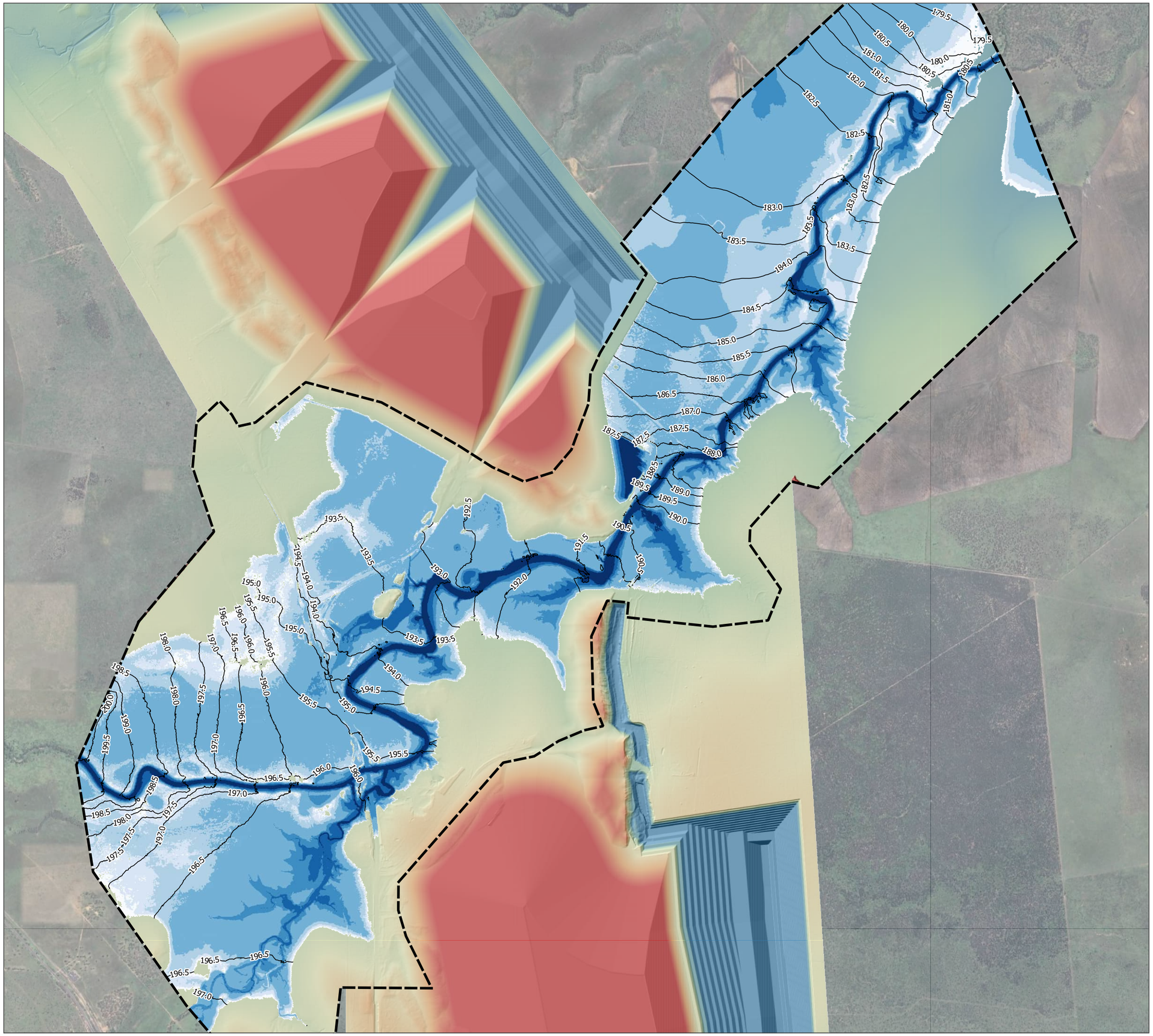
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-19

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

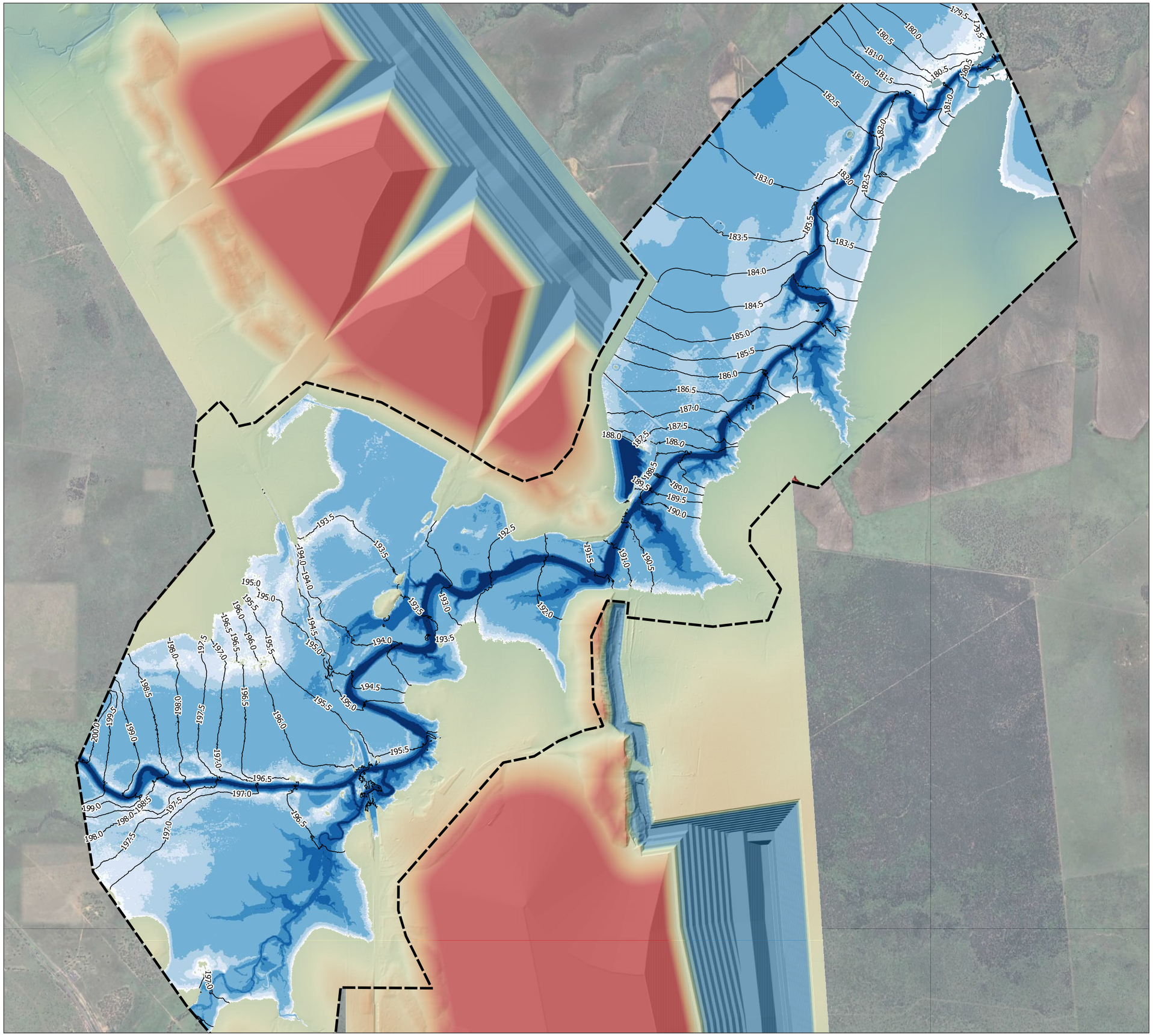
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-20

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

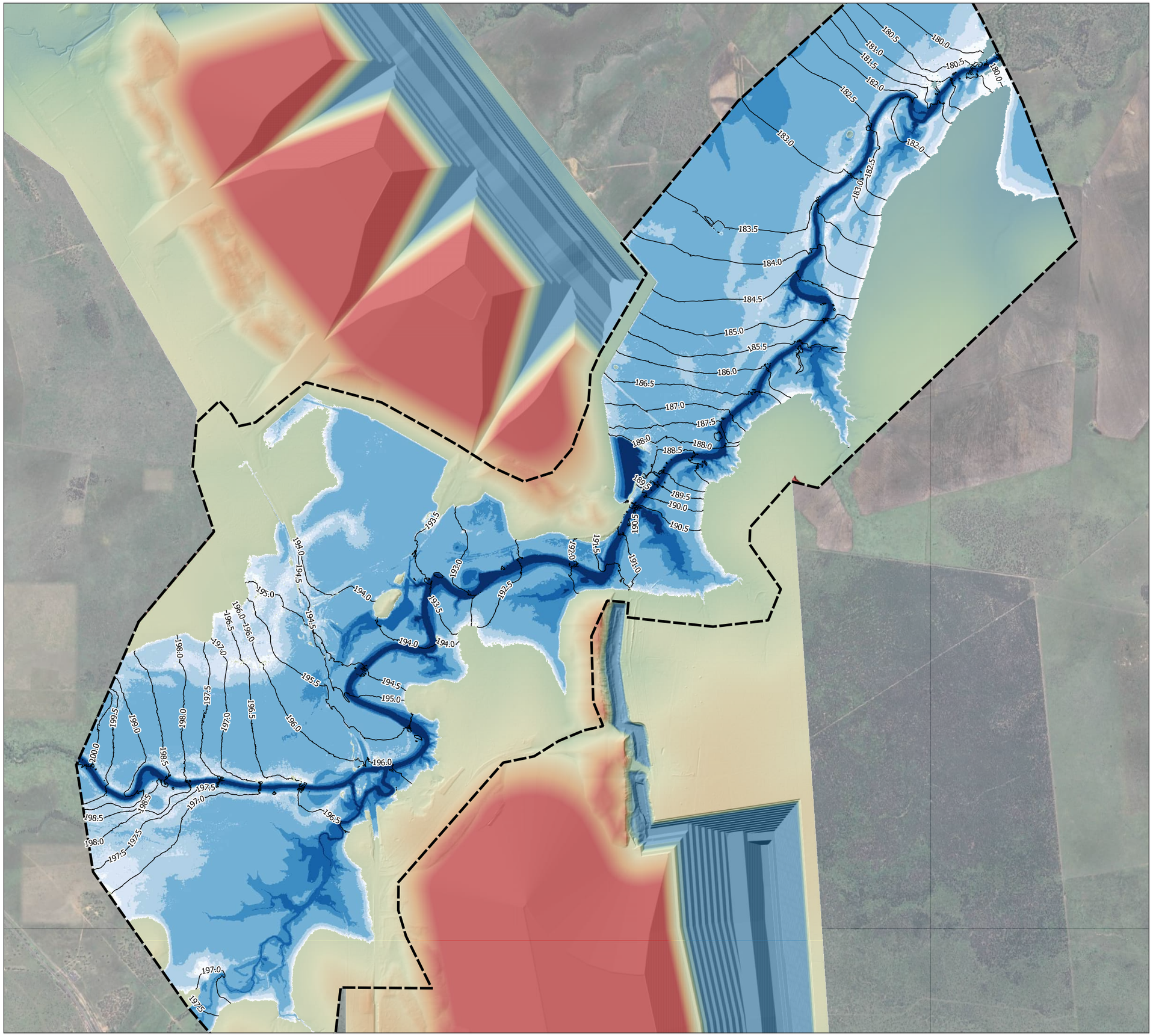
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-21

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

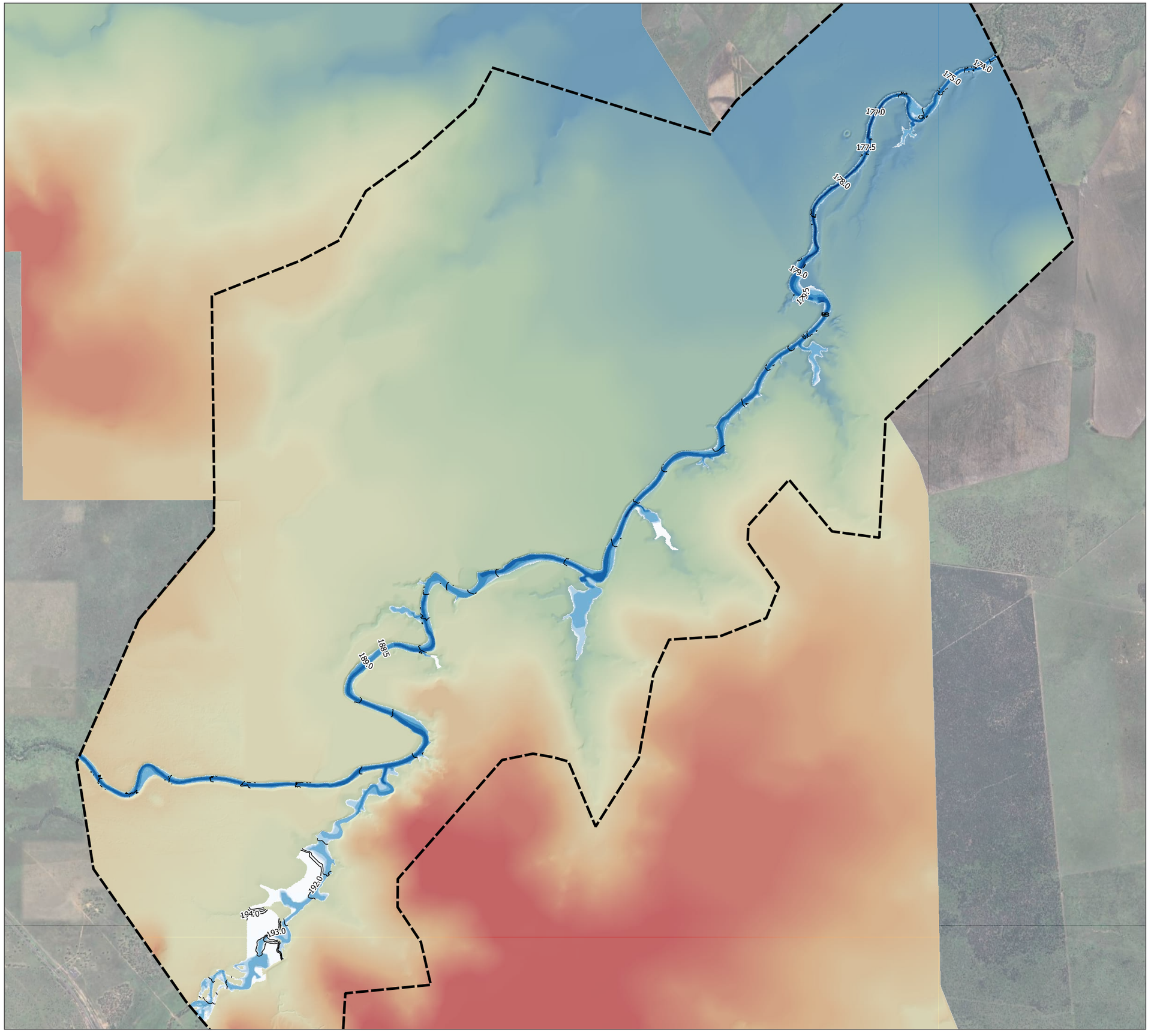
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-22

Pre-mining Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

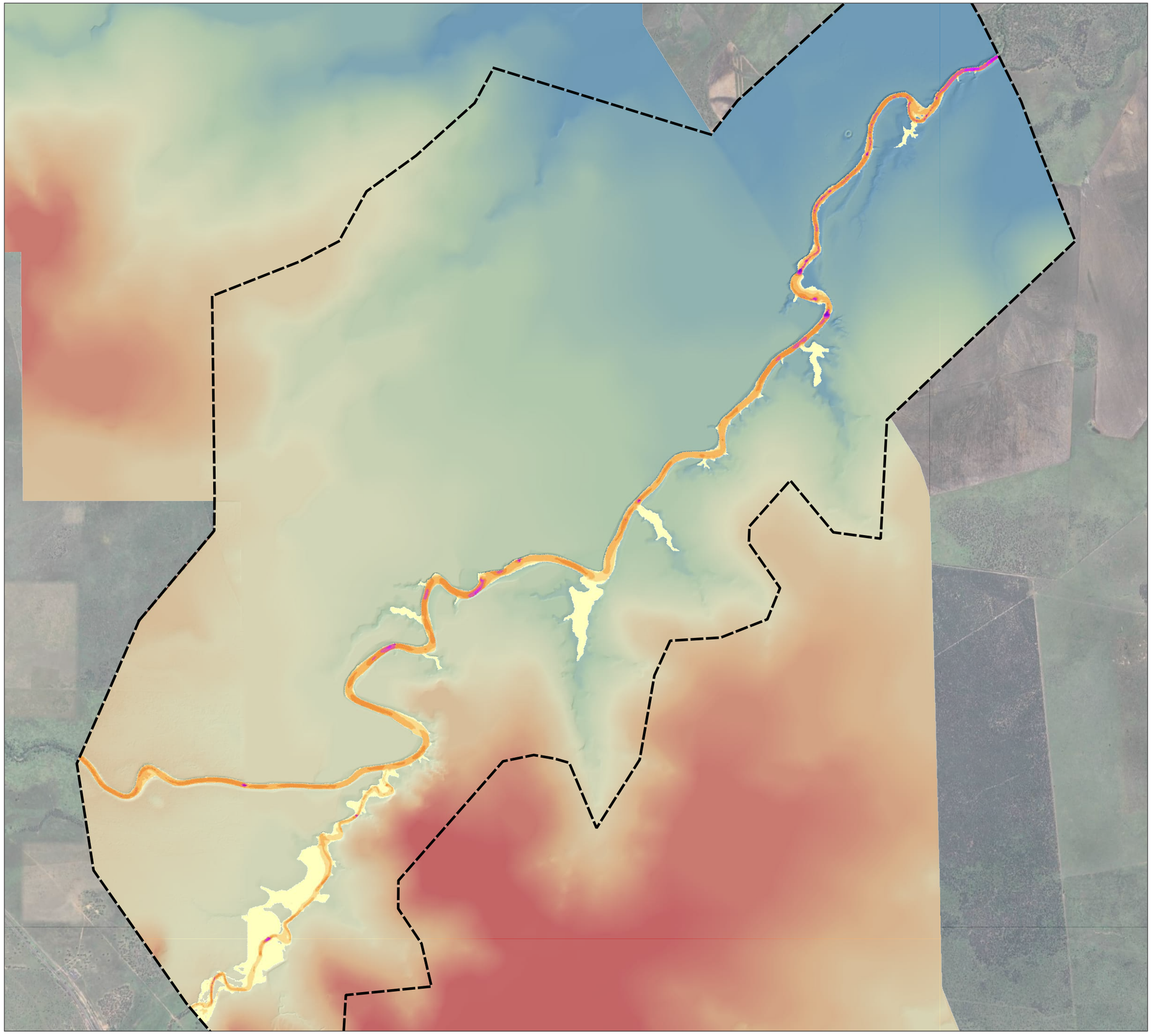
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



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Appendix B-23

Pre-mining Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-24

Pre-mining Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-25

Pre-mining Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-26

Pre-mining Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

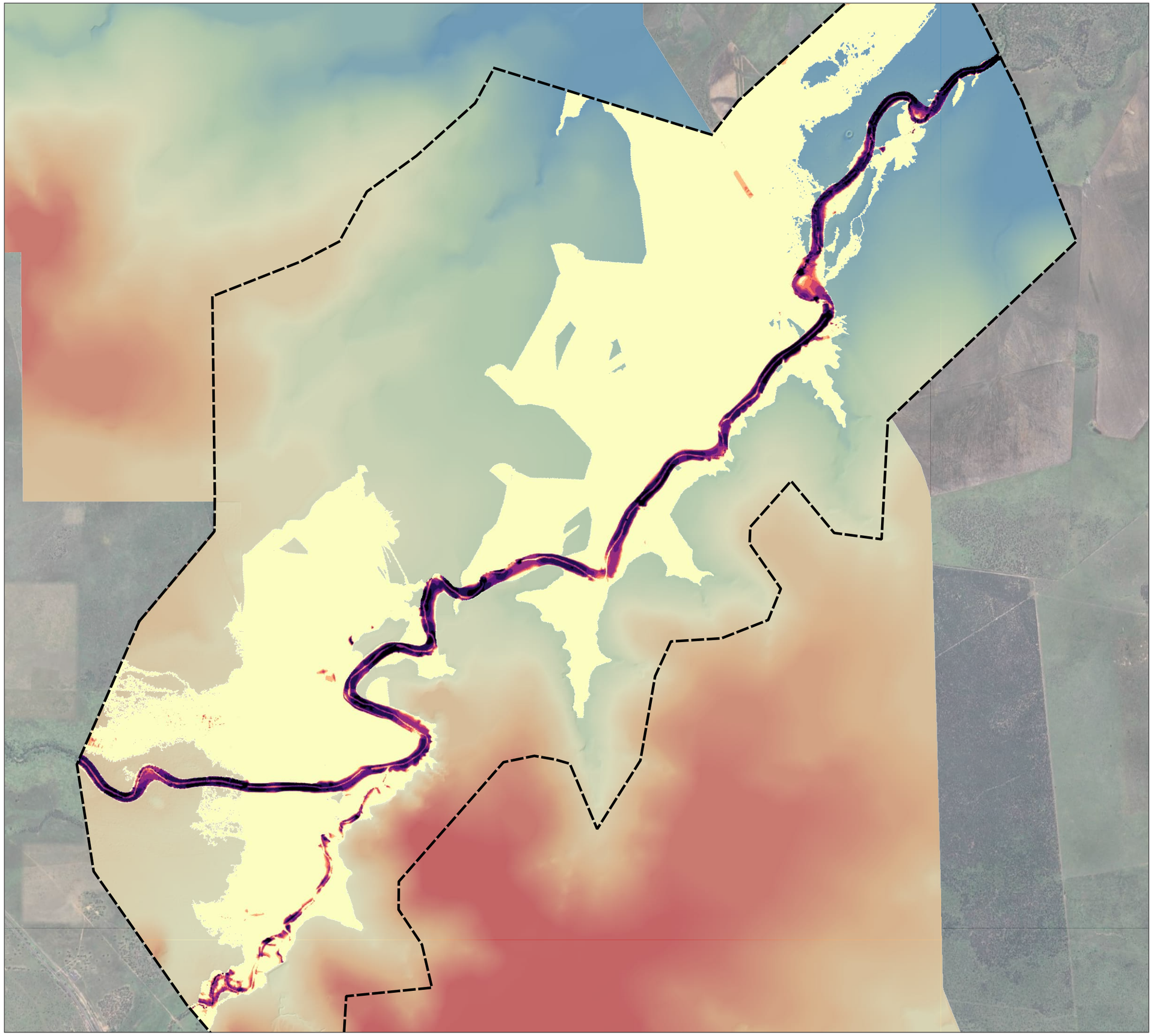
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



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Appendix B-27

Pre-mining Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-28

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-29

Pre-mining Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

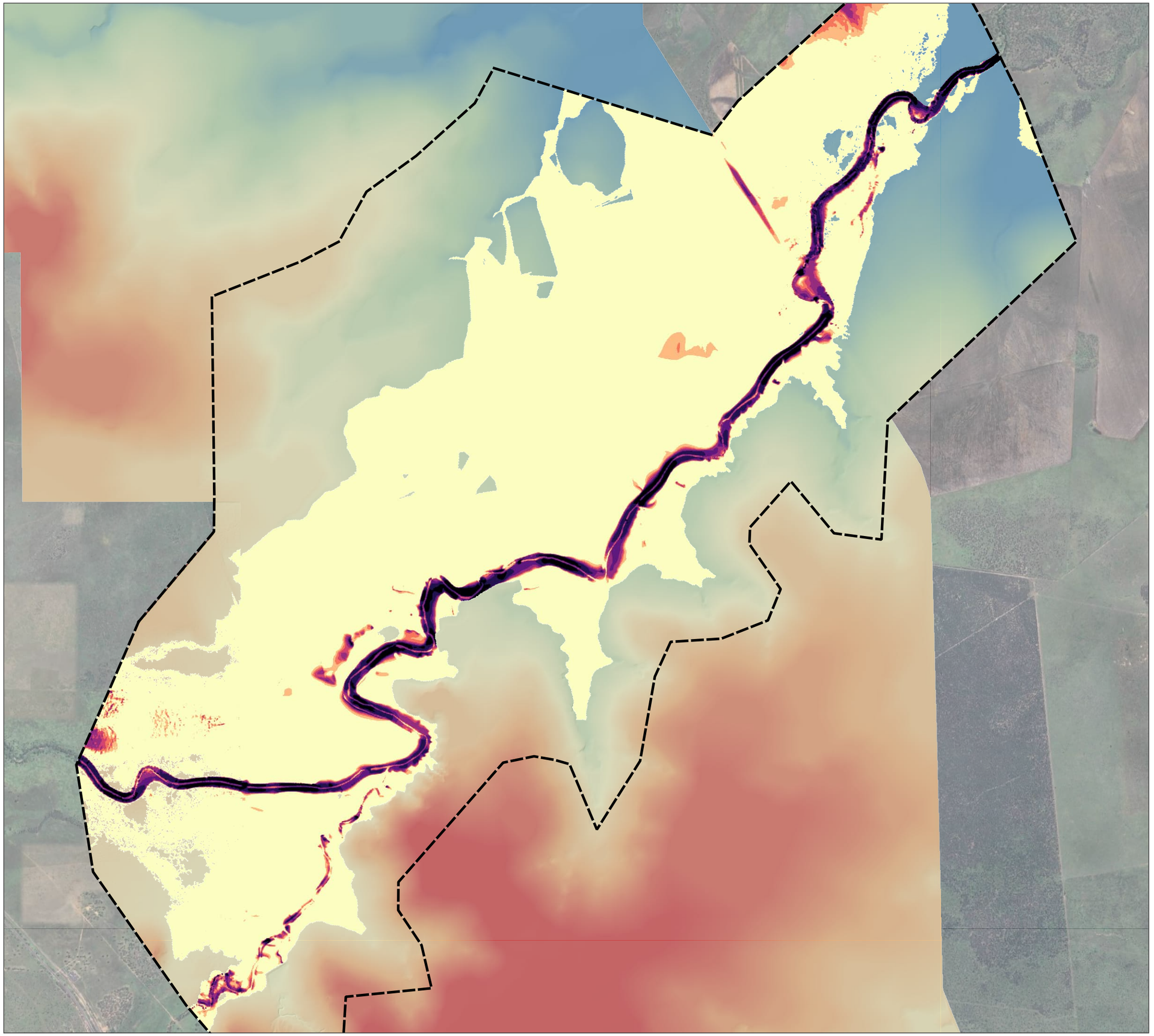
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



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Appendix B-30

Pre-mining Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-31

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

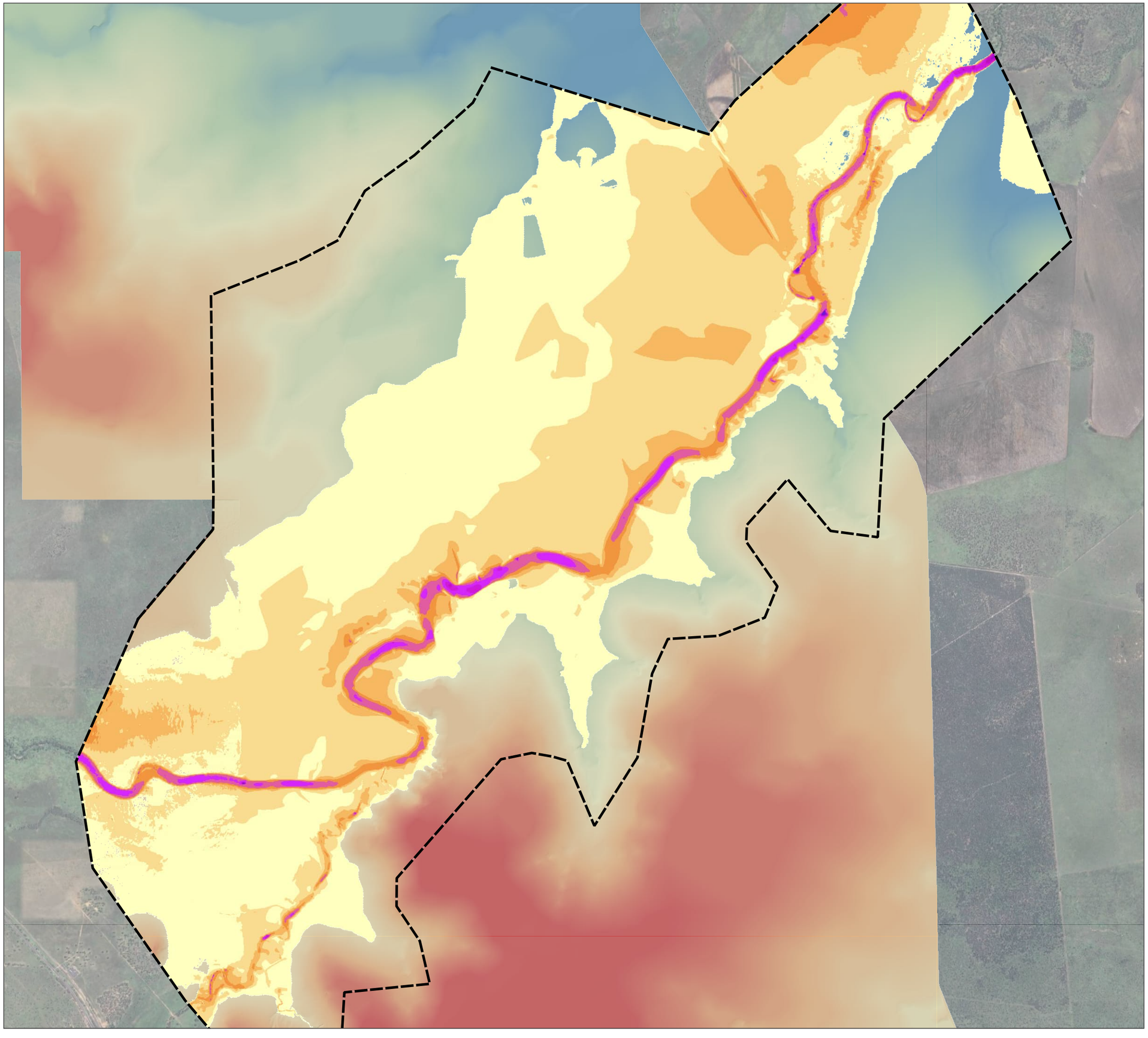
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



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CIVIL | WATER | ENVIRONMENT

Appendix B-32

Pre-mining Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

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Appendix B-33

Pre-mining Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

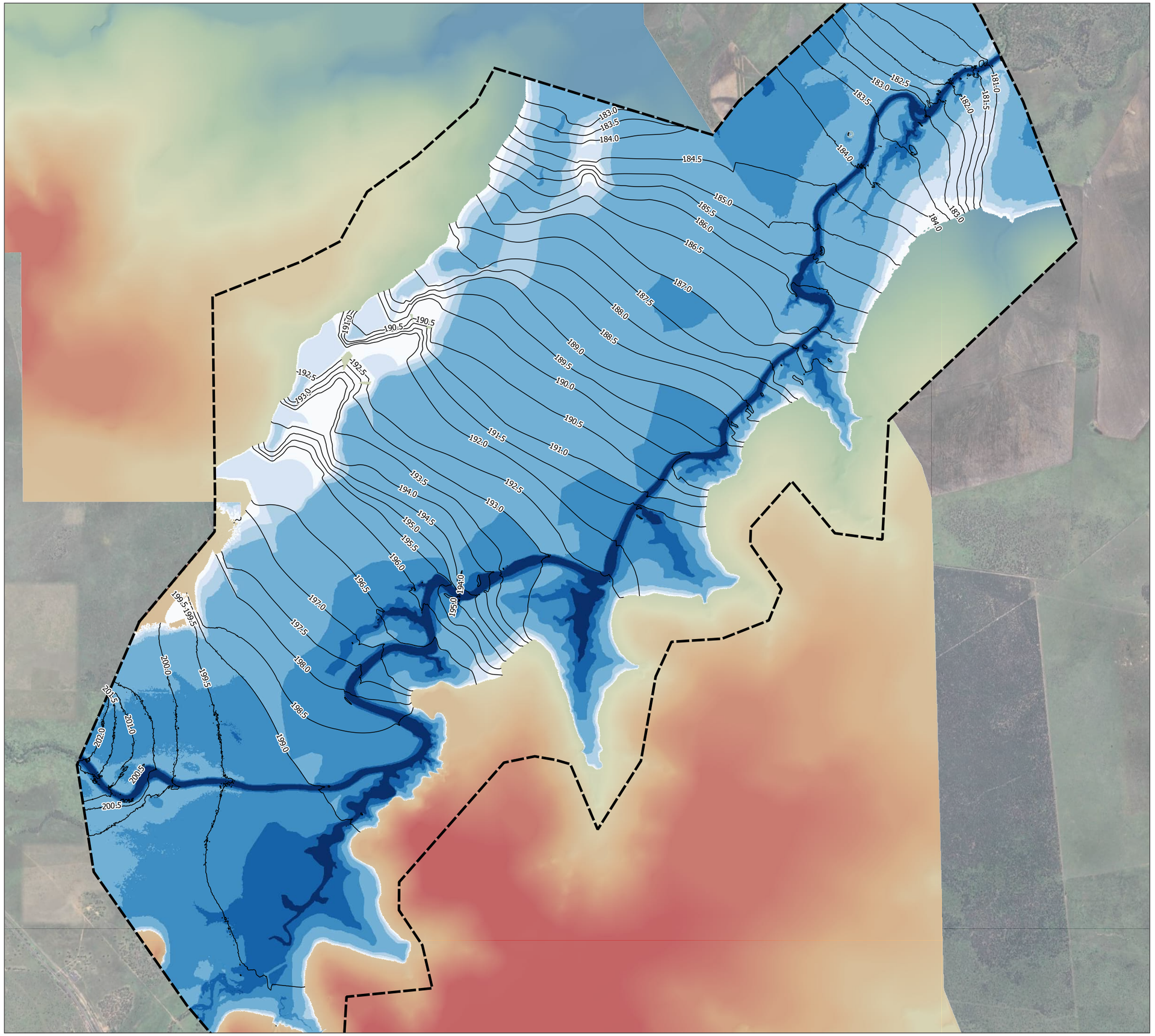
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-34

Pre-mining Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

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Appendix B-35

Pre-mining Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

<= 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
> 4.5

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-36

Pre-mining Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-37

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-38

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-39

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-40

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-41

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

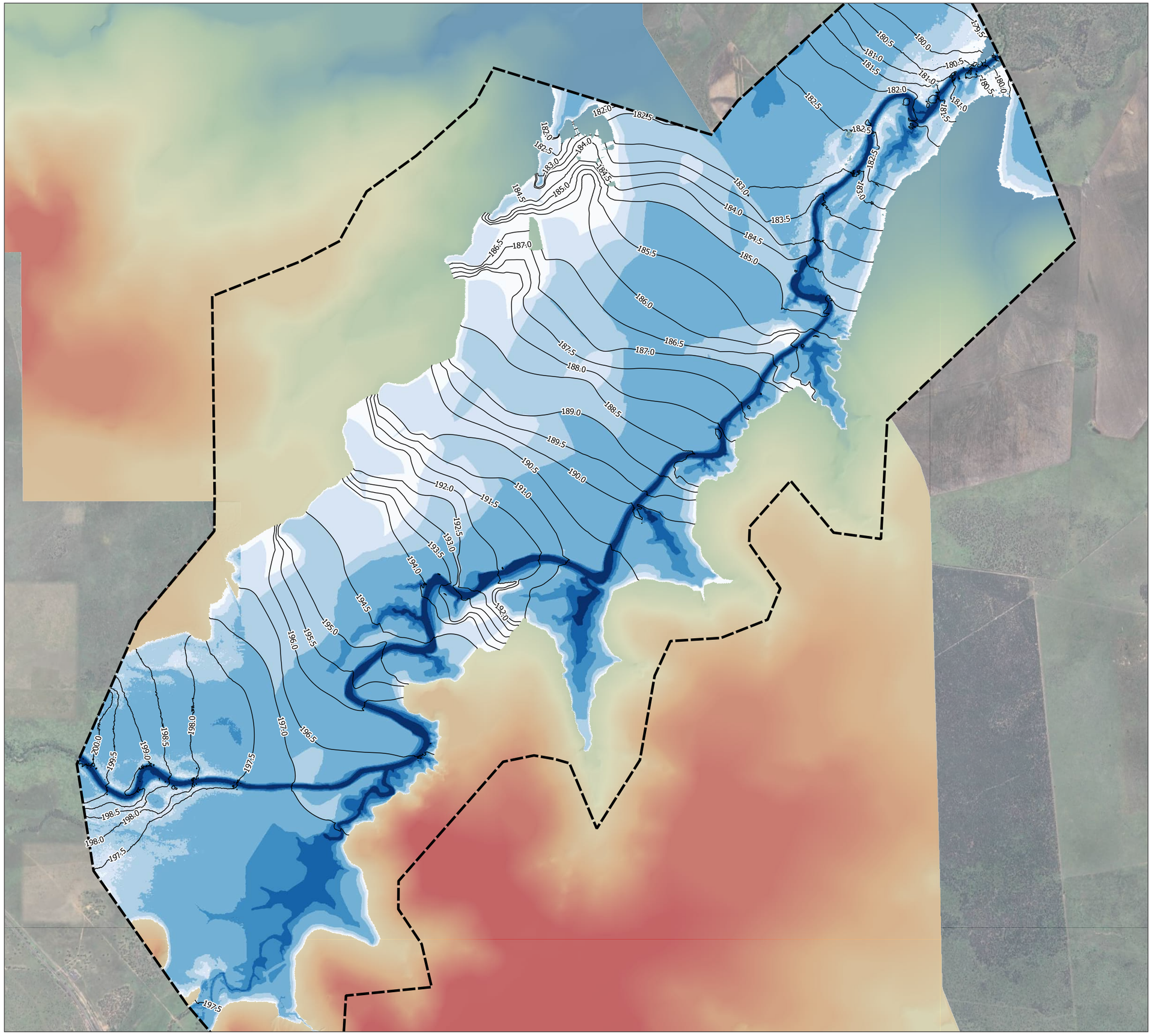
Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023



WMS

CIVIL | WATER | ENVIRONMENT

Appendix B-42

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

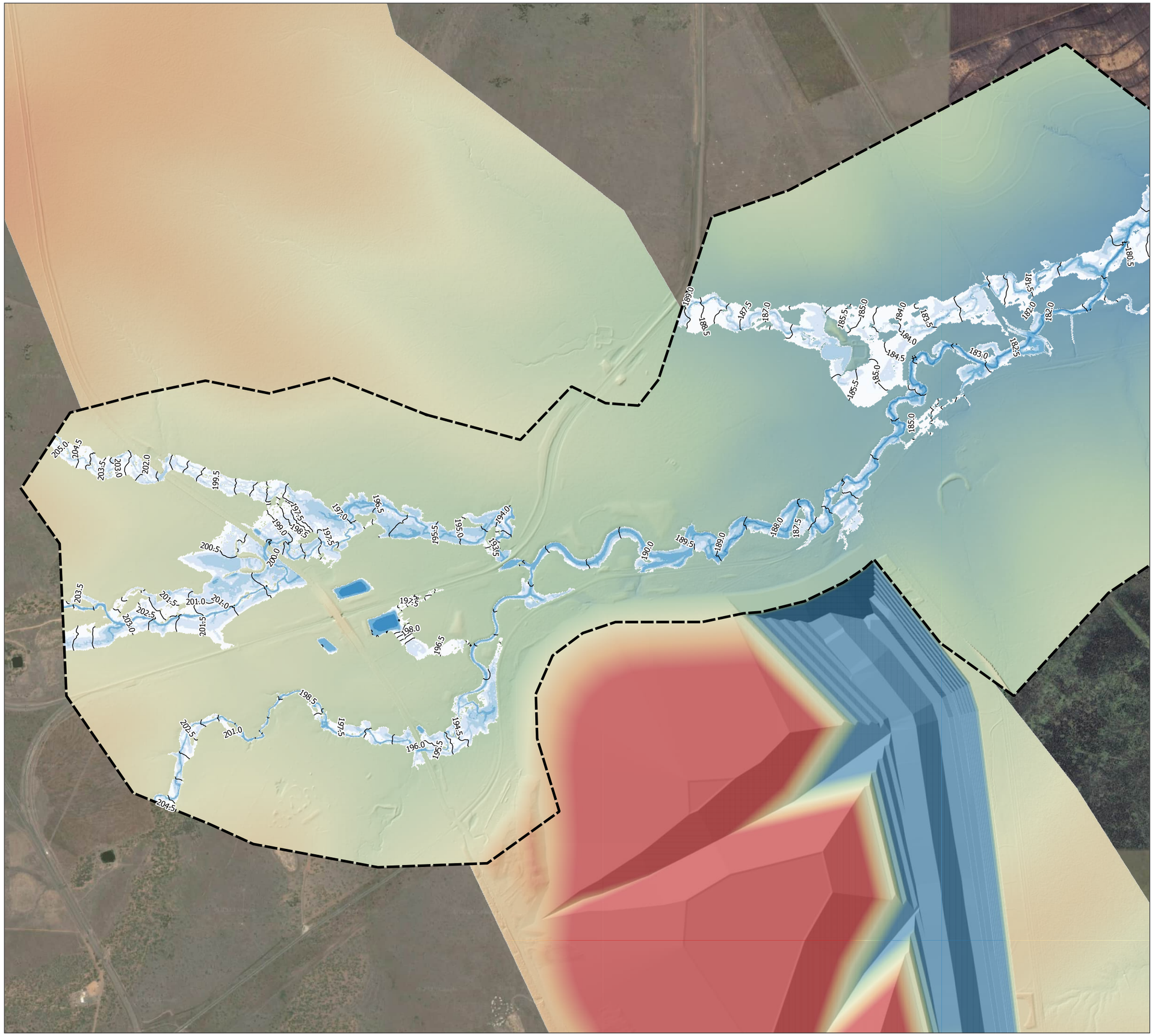
A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

APPENDIX C

DOWNS CREEK



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

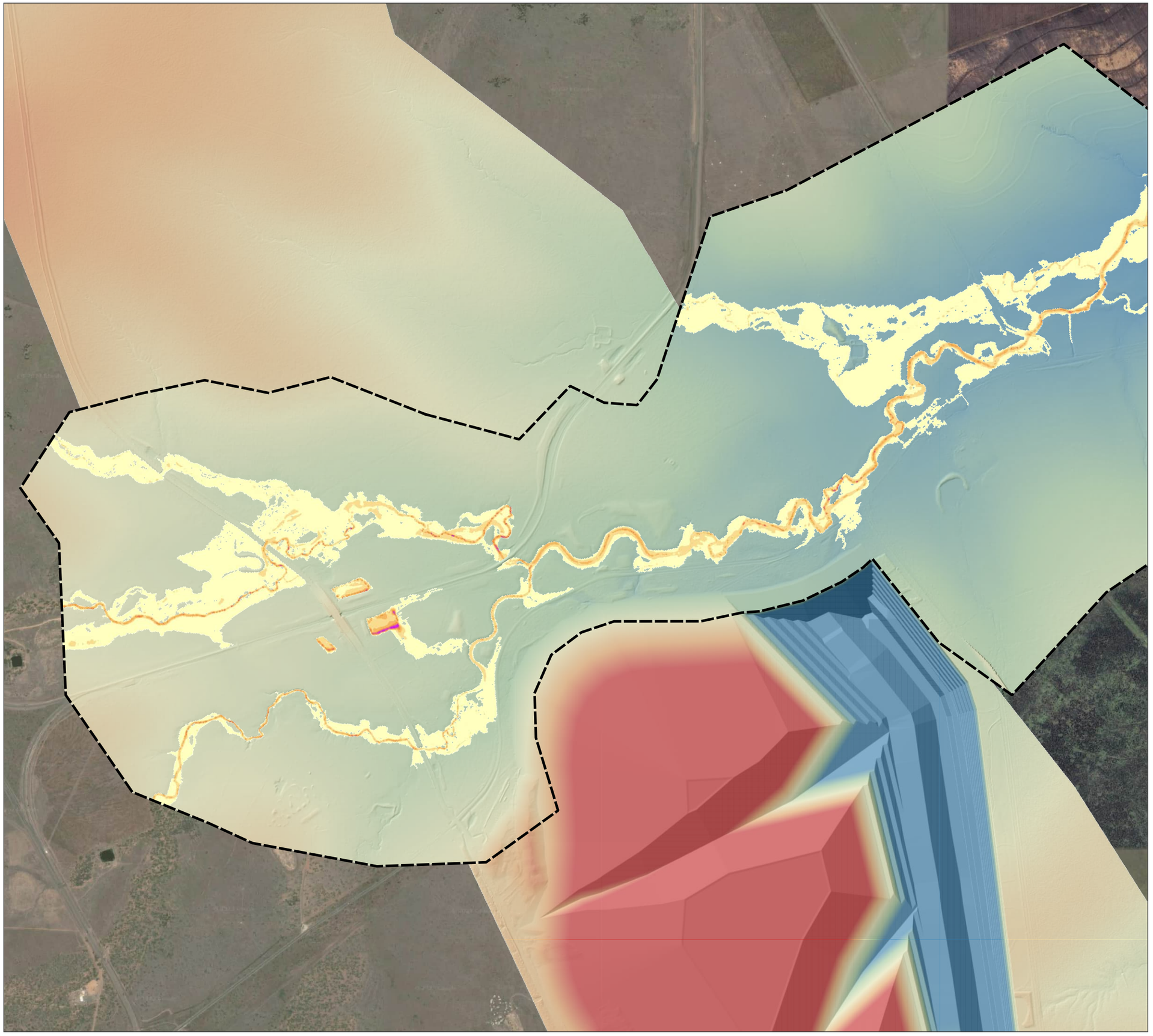
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-2

PRC Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Peak Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-3

PRC Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-4

PRC Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-5

PRC Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Peak Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

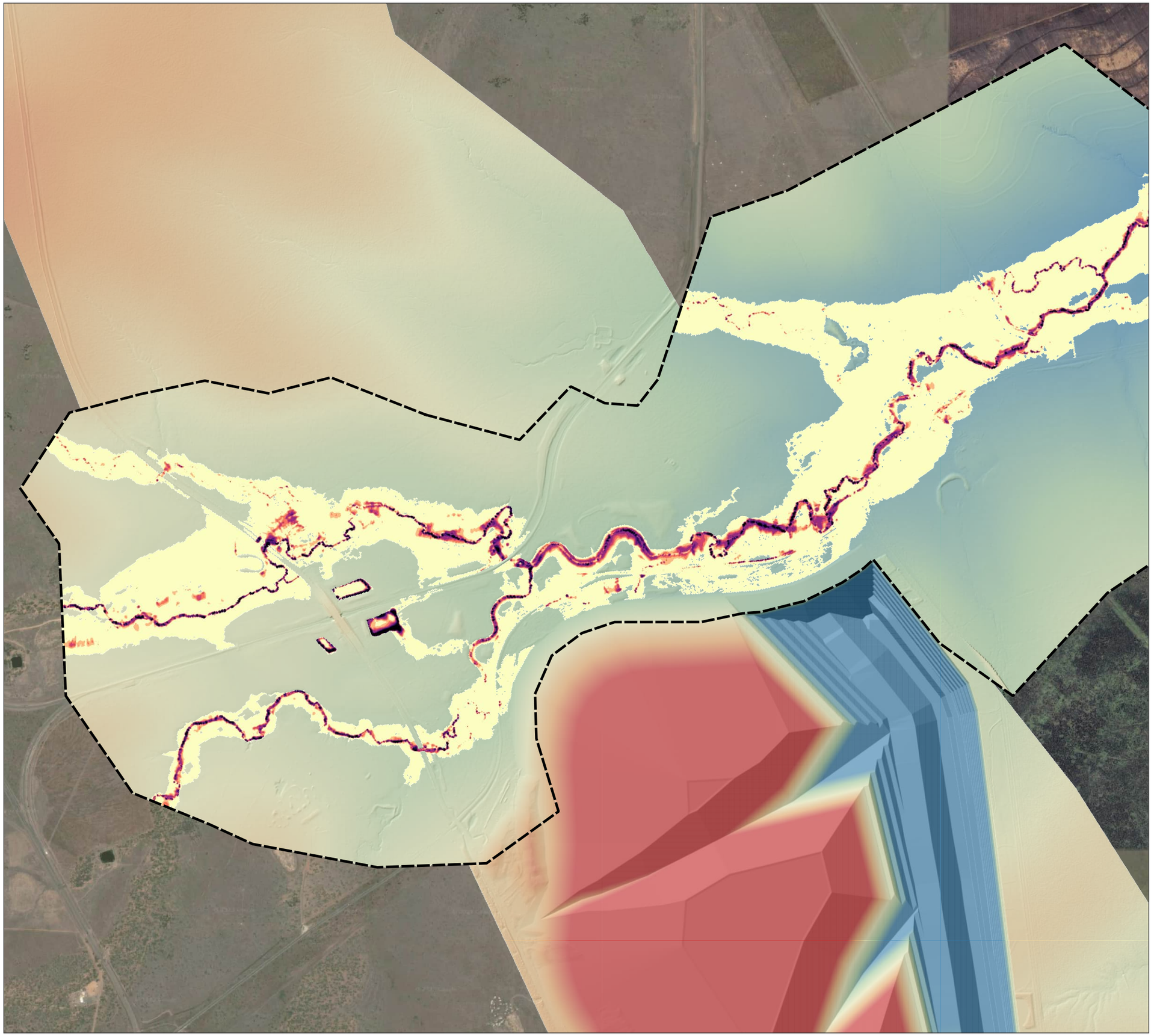
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

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Appendix C-6

PRC Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-7

PRC Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
230

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

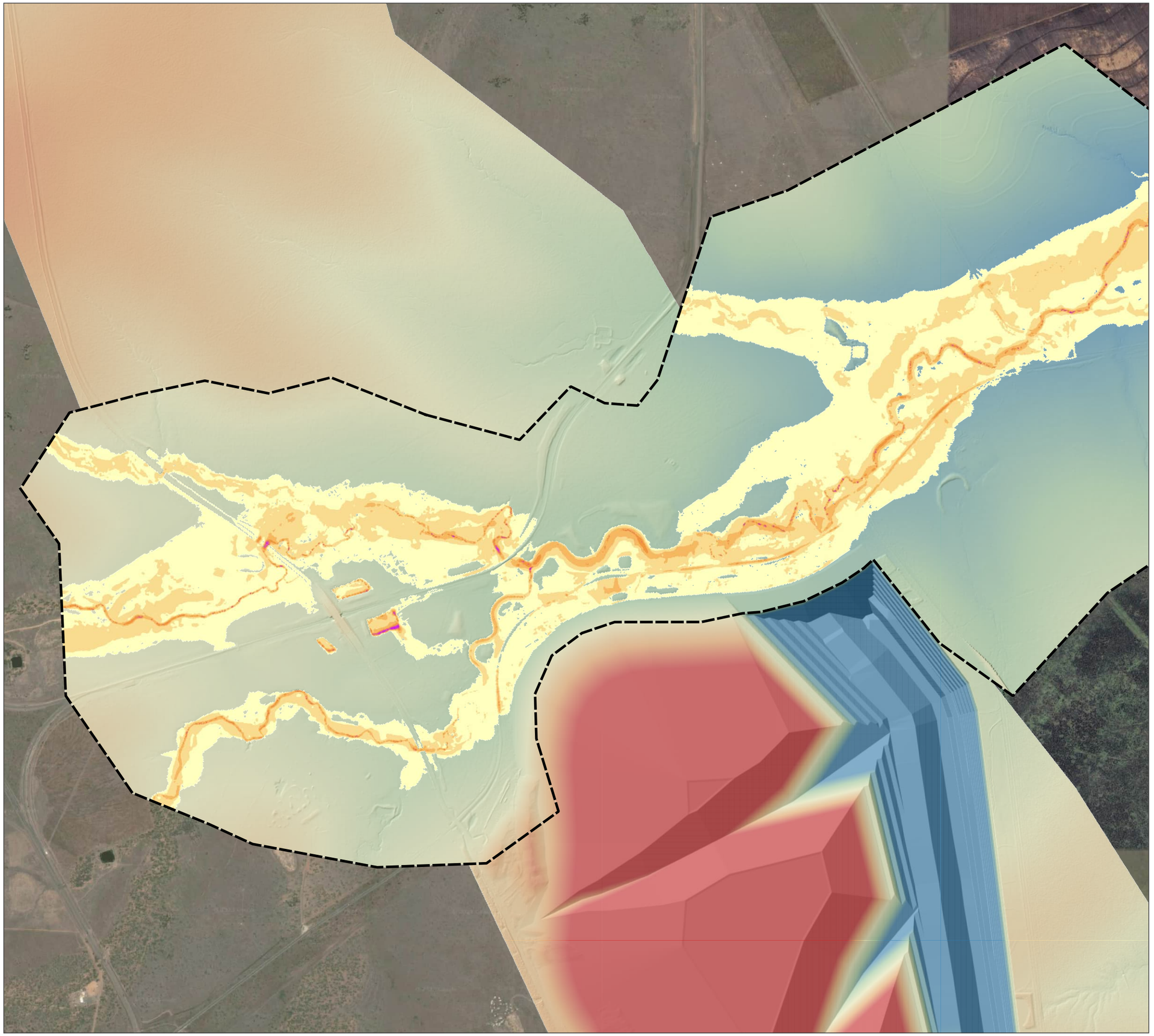
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-8

PRC Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Peak Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-9

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

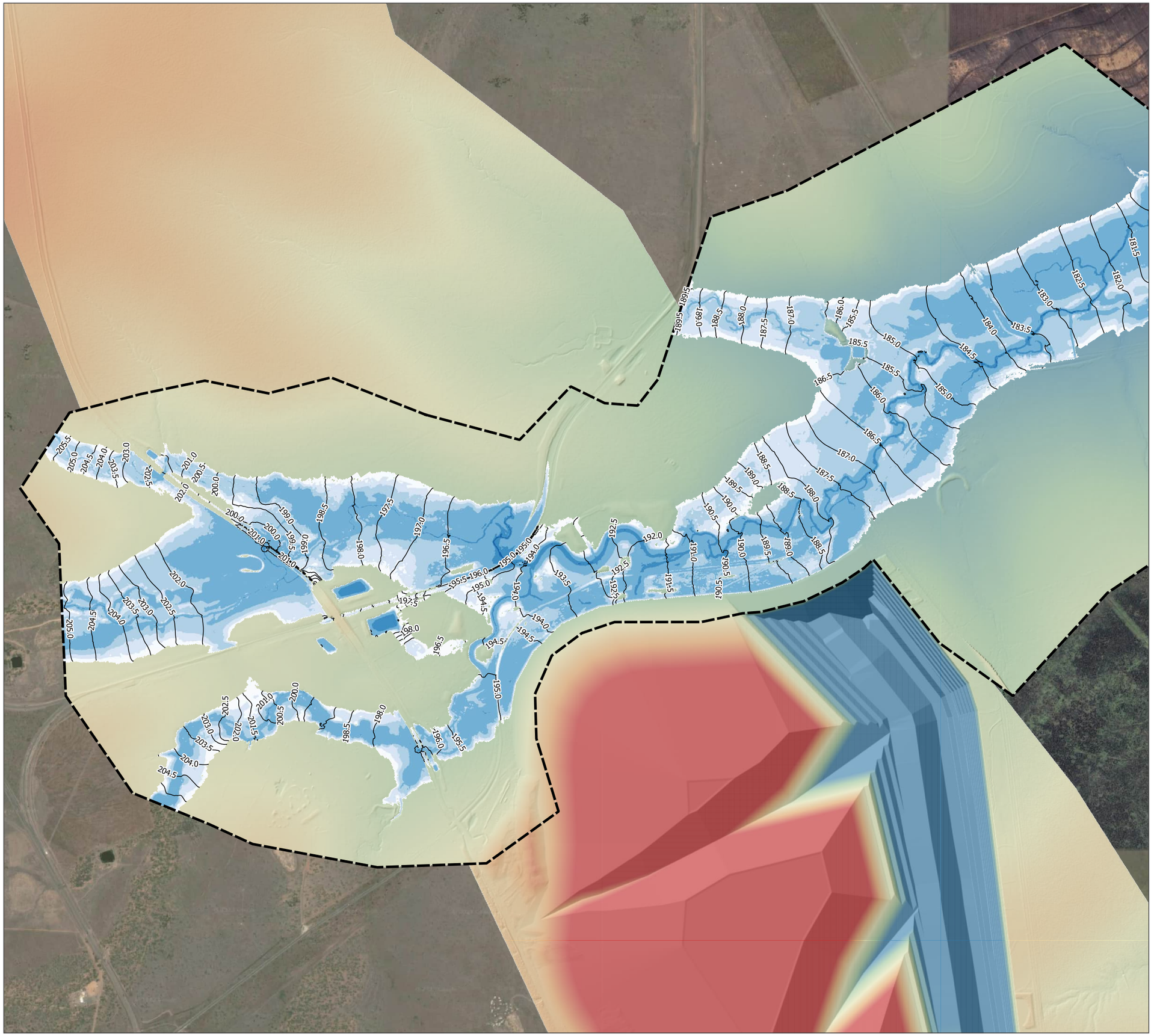
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-11

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Peak Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-12

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-13

PRC Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

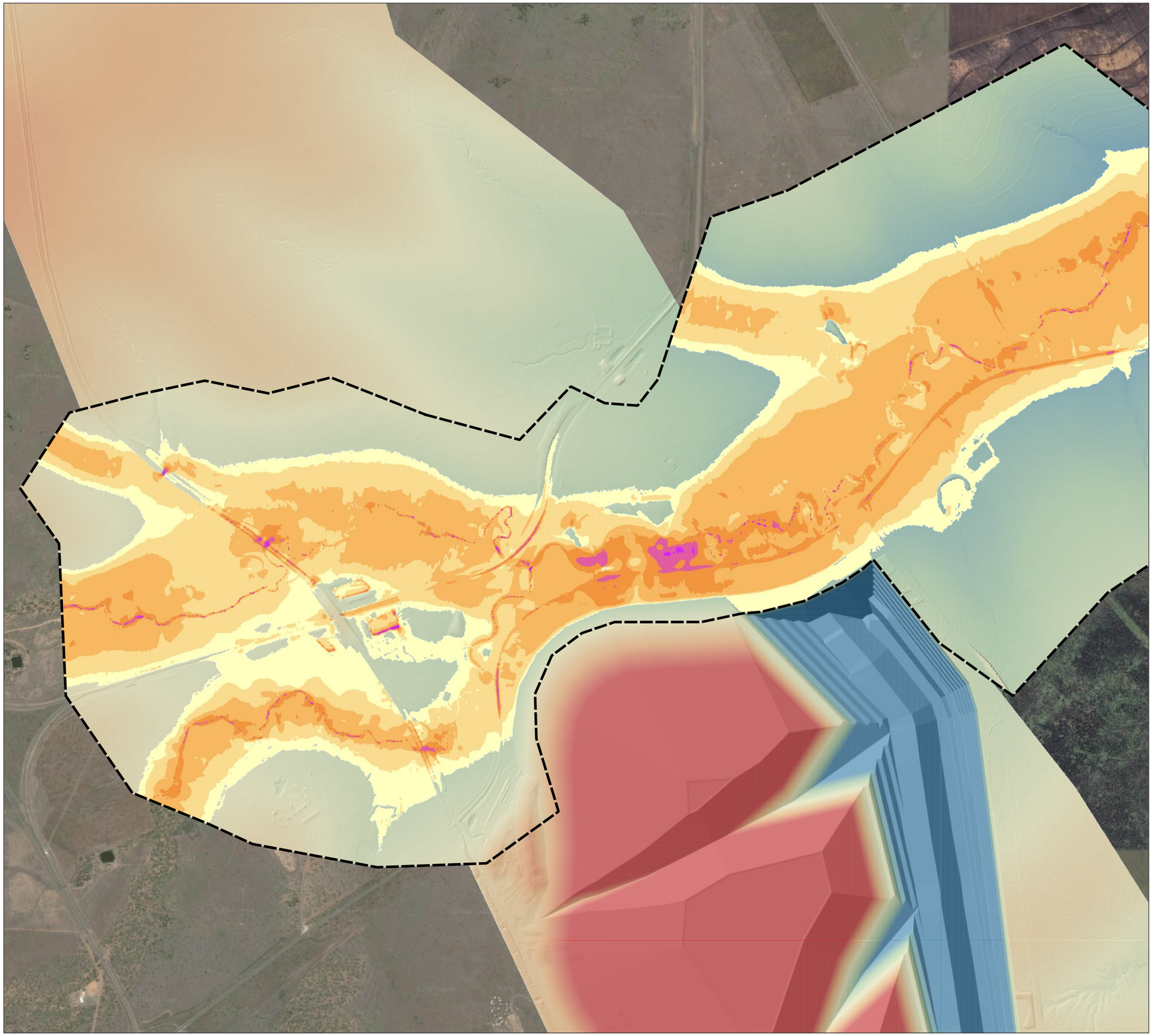
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

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Appendix C-14

PRC Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Peak Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

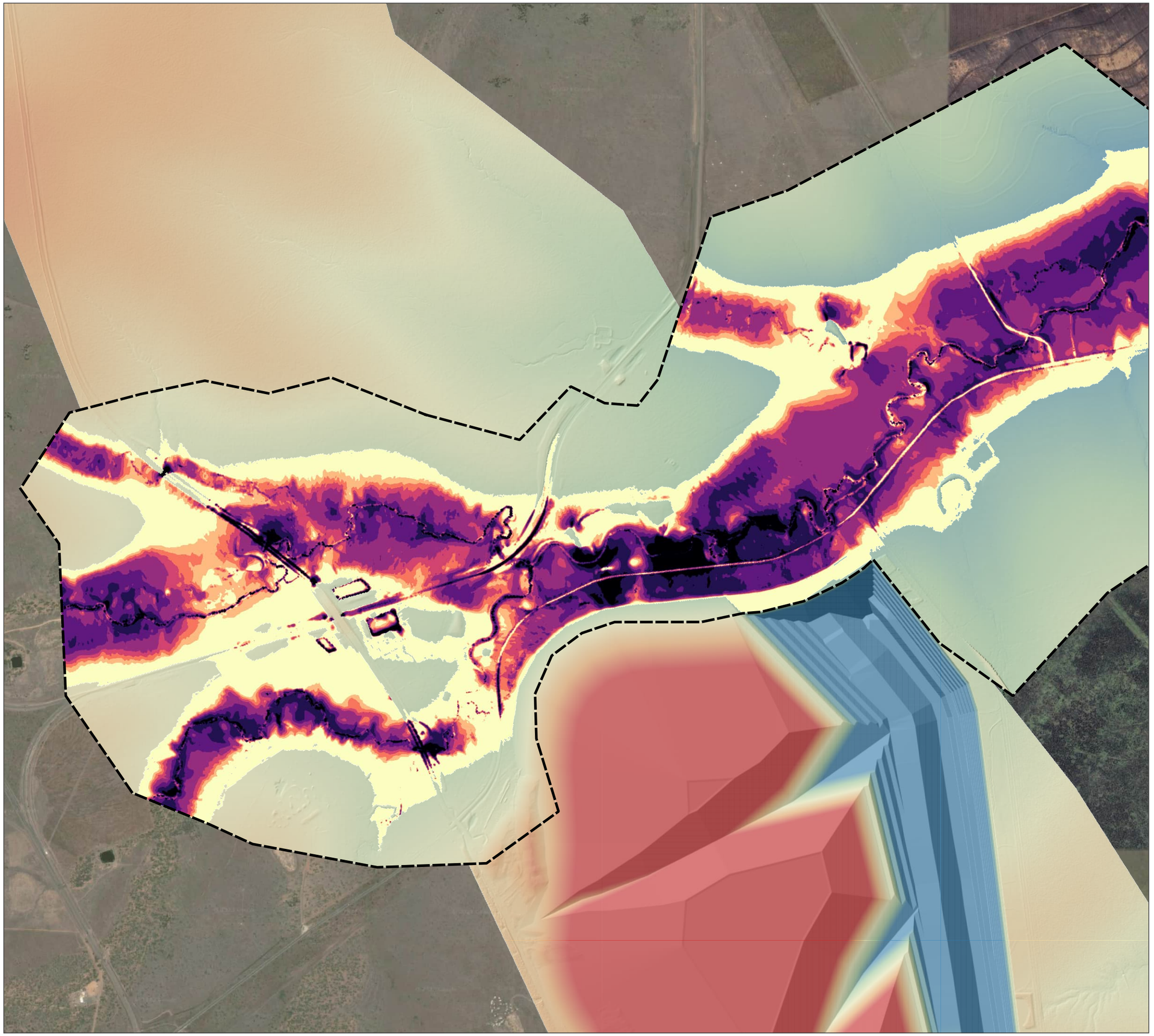
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

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Appendix C-15

PRC Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

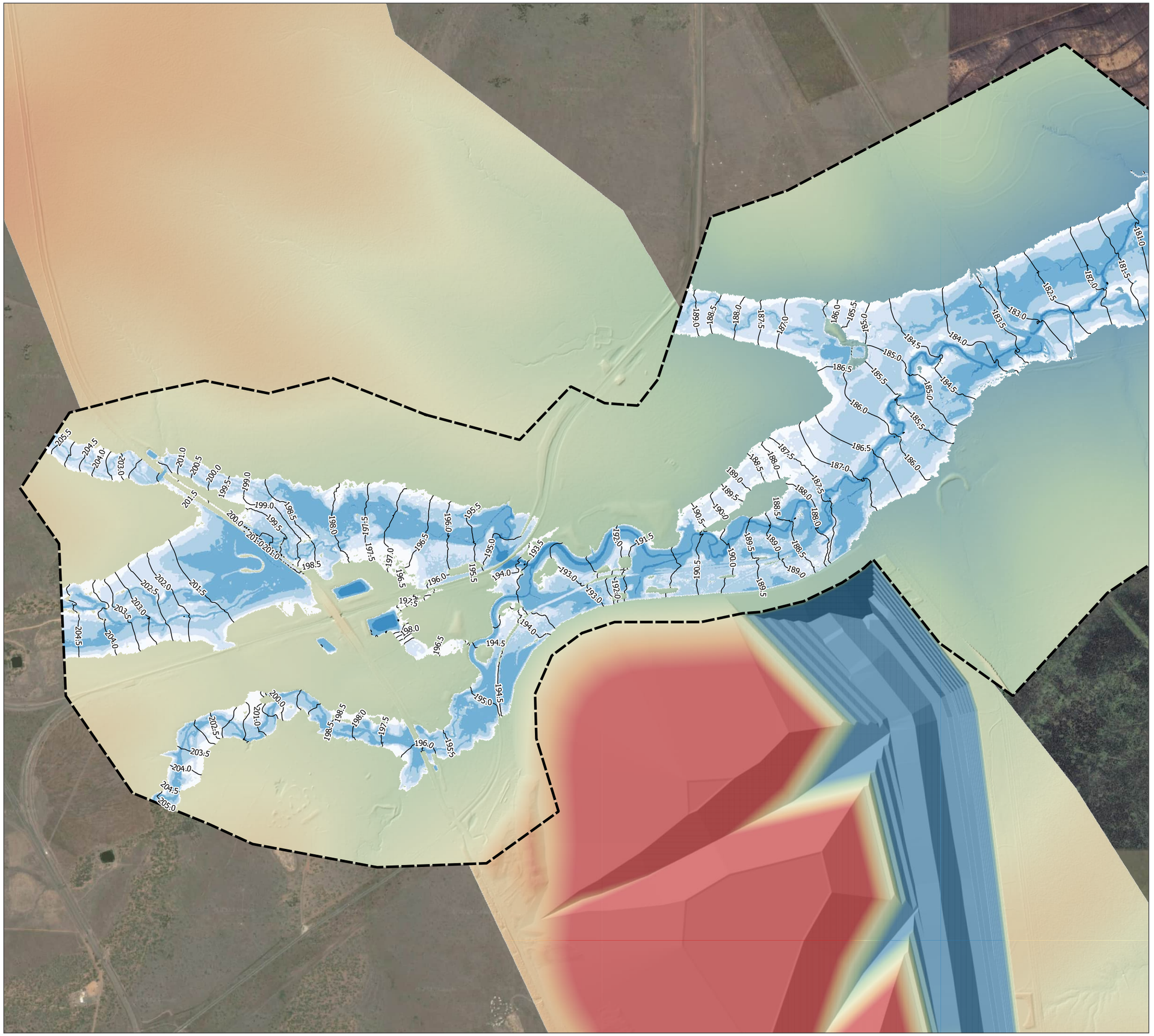
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-16

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-17

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

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Appendix C-18

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-19

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
230

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

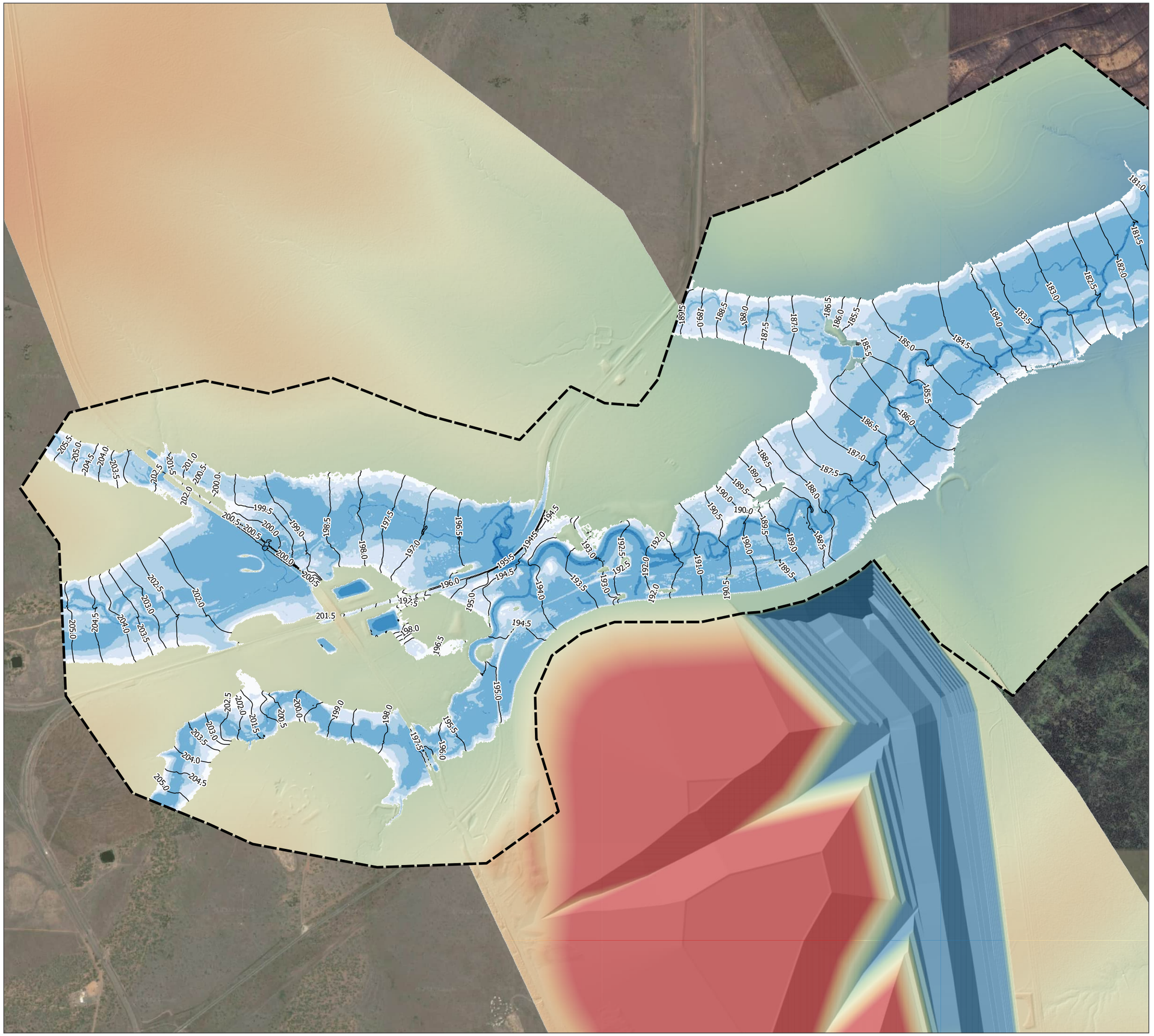
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-20

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-21

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:20000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-22

Pre-mining Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS
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Appendix C-23

Pre-mining Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

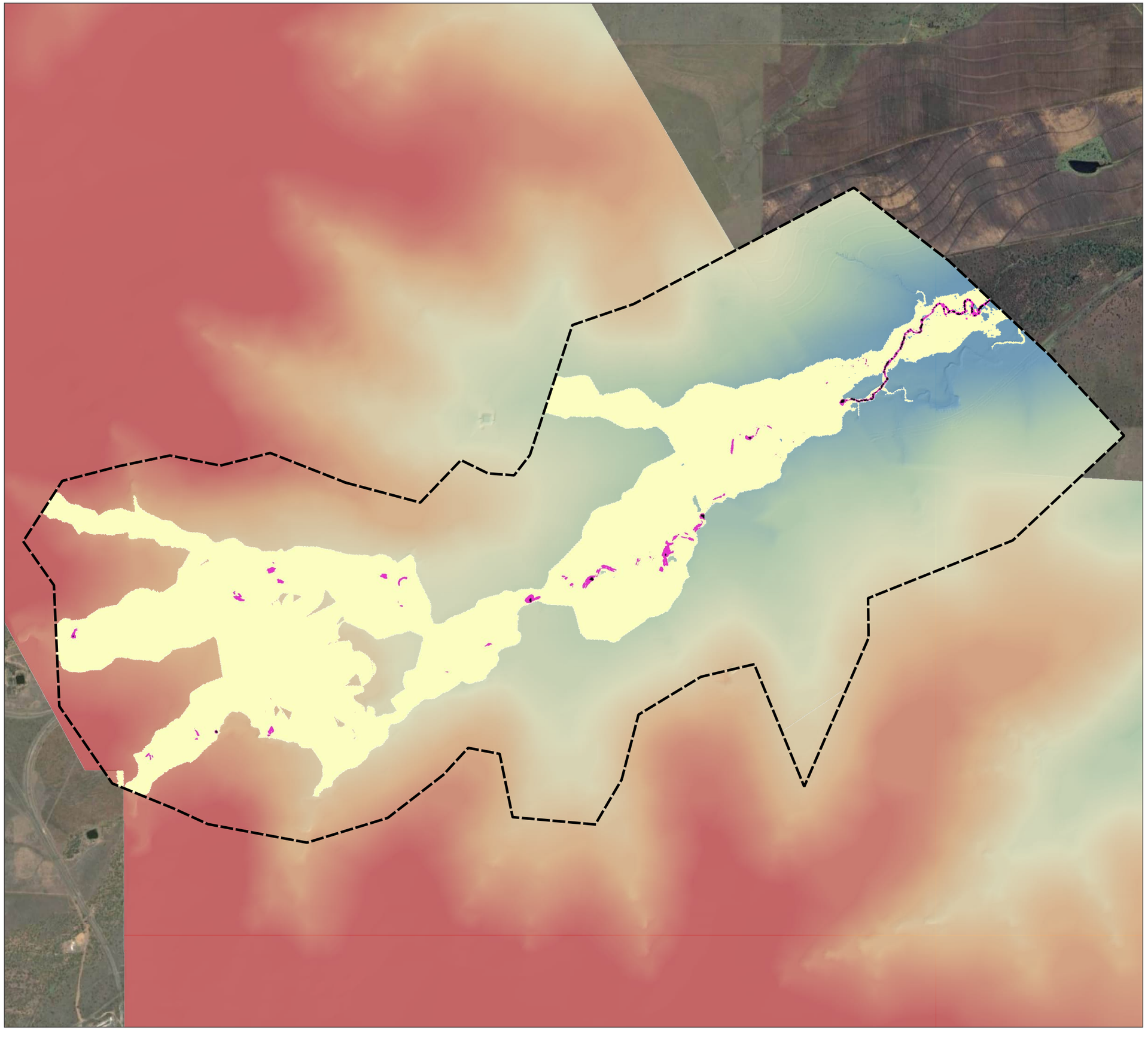
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-24

Pre-mining Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

Band 1

<= 35.0000

35.0000 - 150.0000

> 150.0000

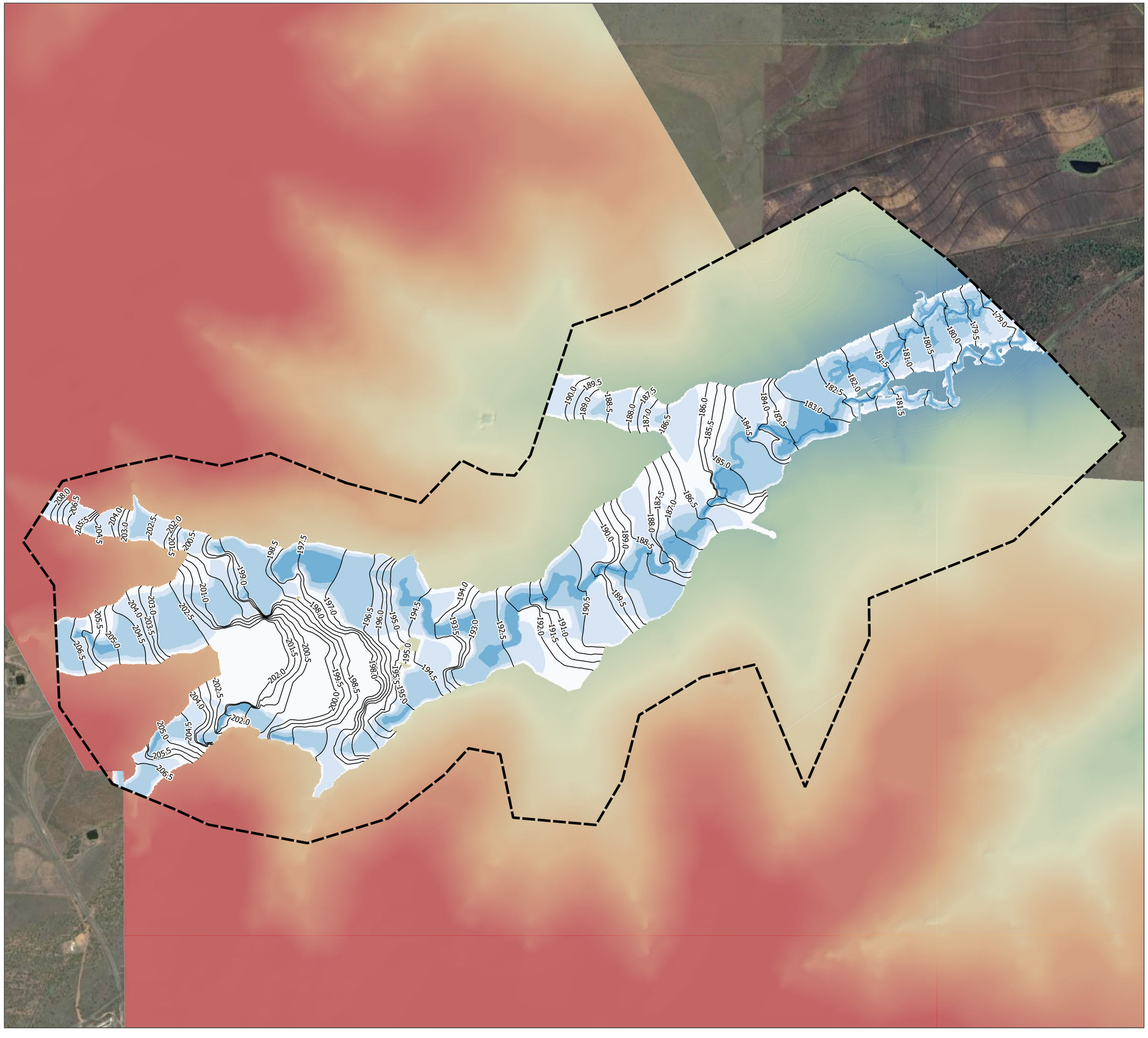
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



Appendix C-25

Pre-mining Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

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Appendix C-26

Pre-mining Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

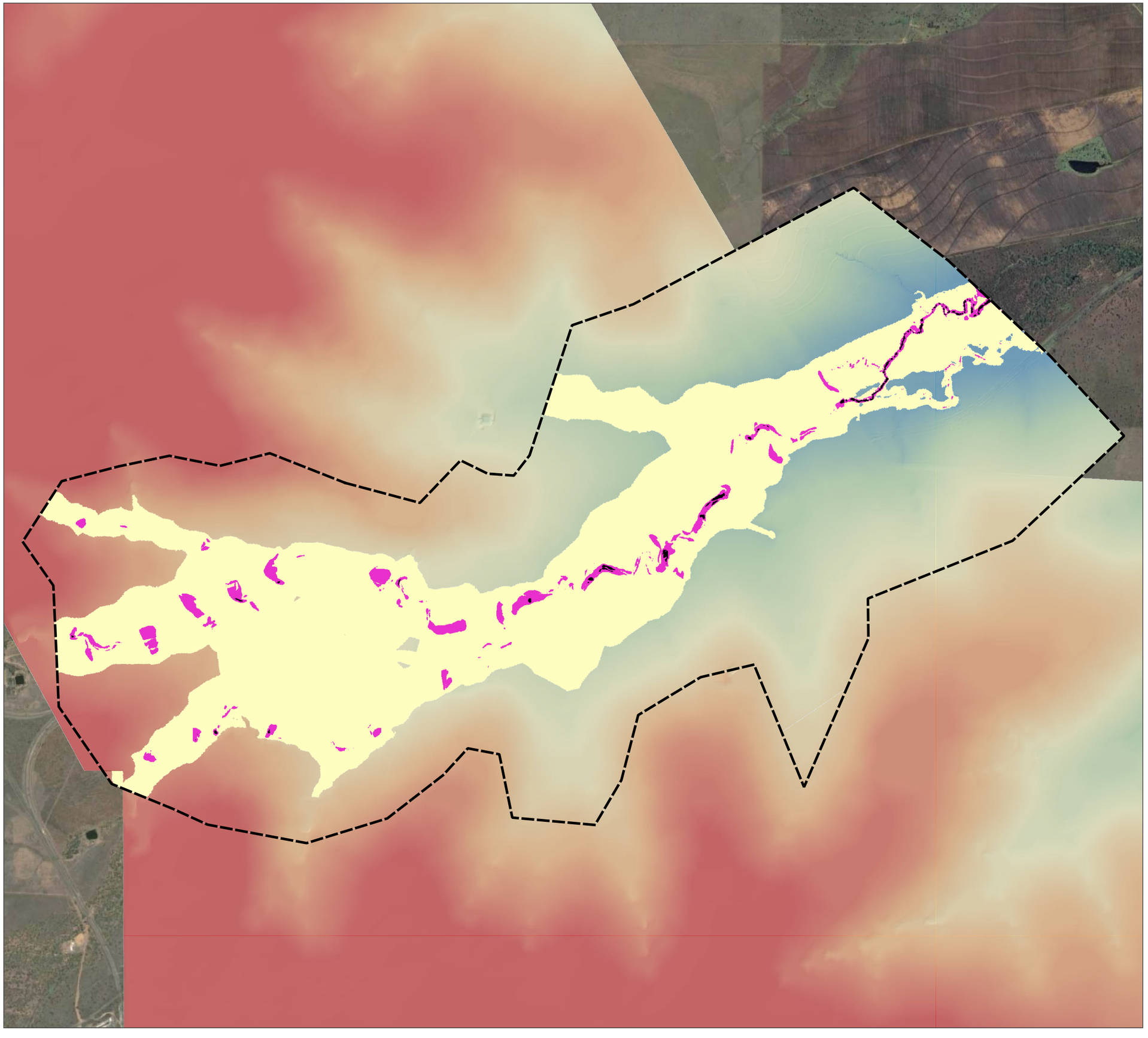
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-27

Pre-mining Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

Band 1

<= 35.0000

35.0000 - 150.0000

> 150.0000

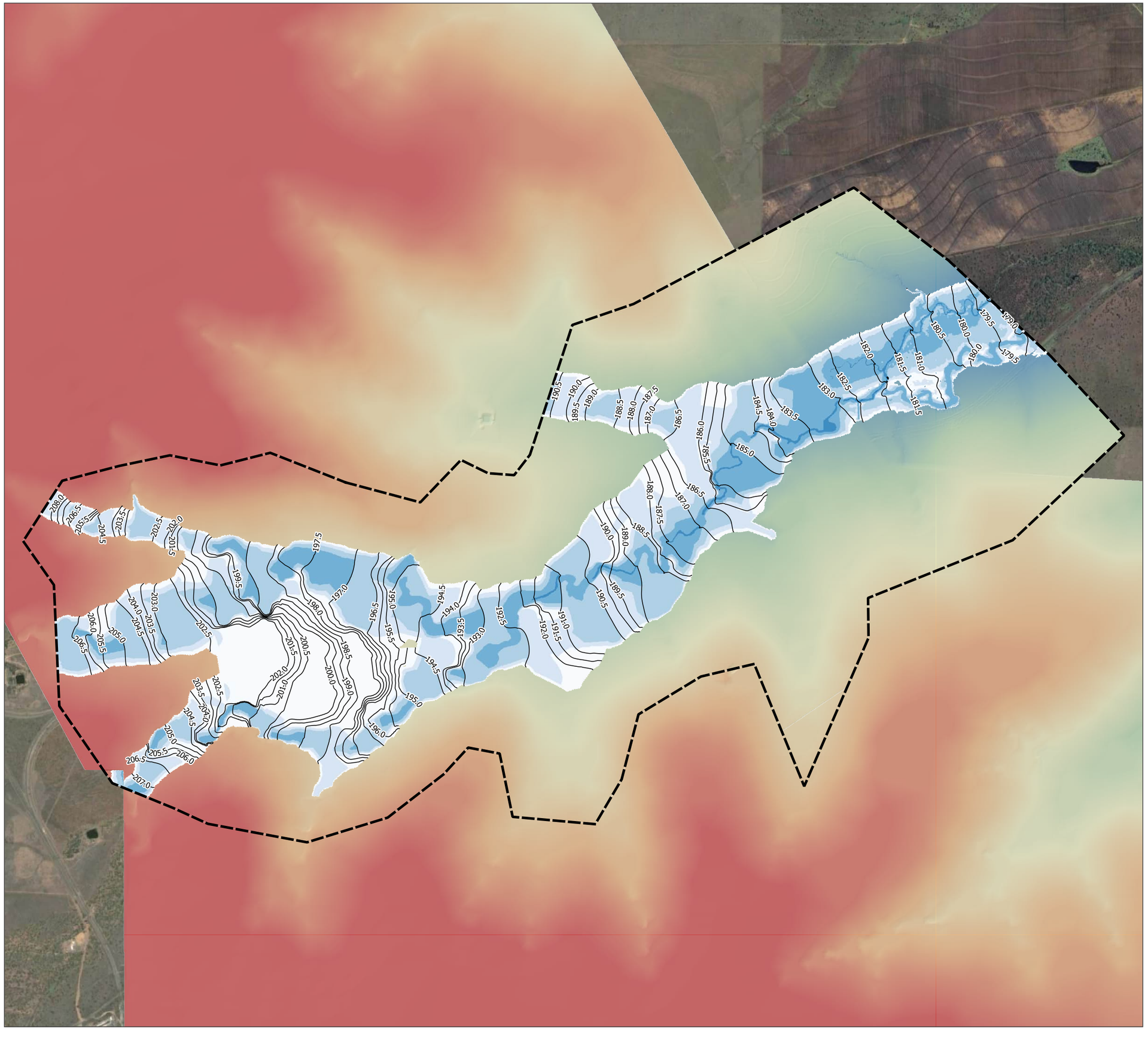
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-28

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

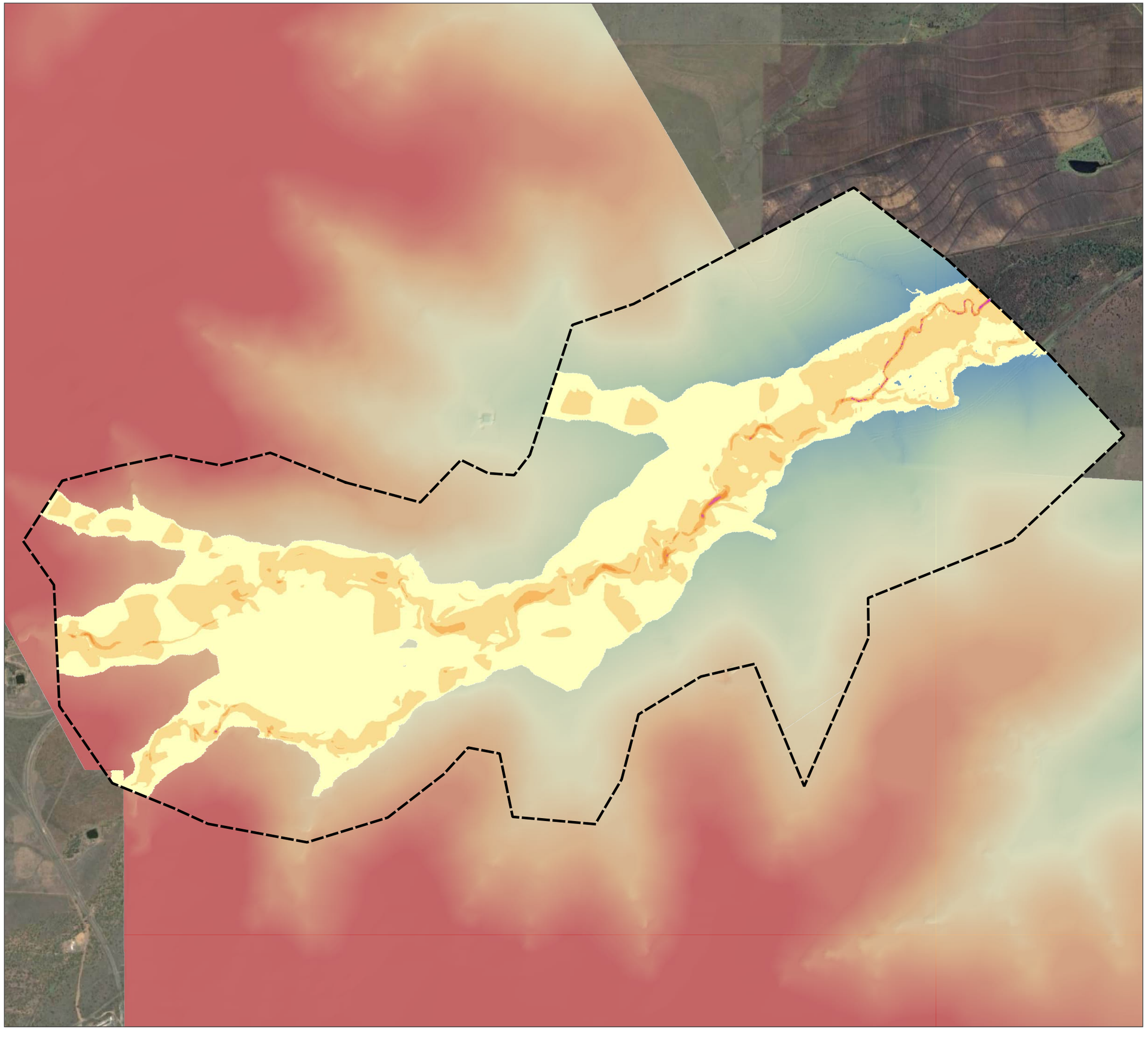
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-29

Pre-mining Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-30

Pre-mining Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

Band 1

<= 35.0000

35.0000 - 150.0000

> 150.0000

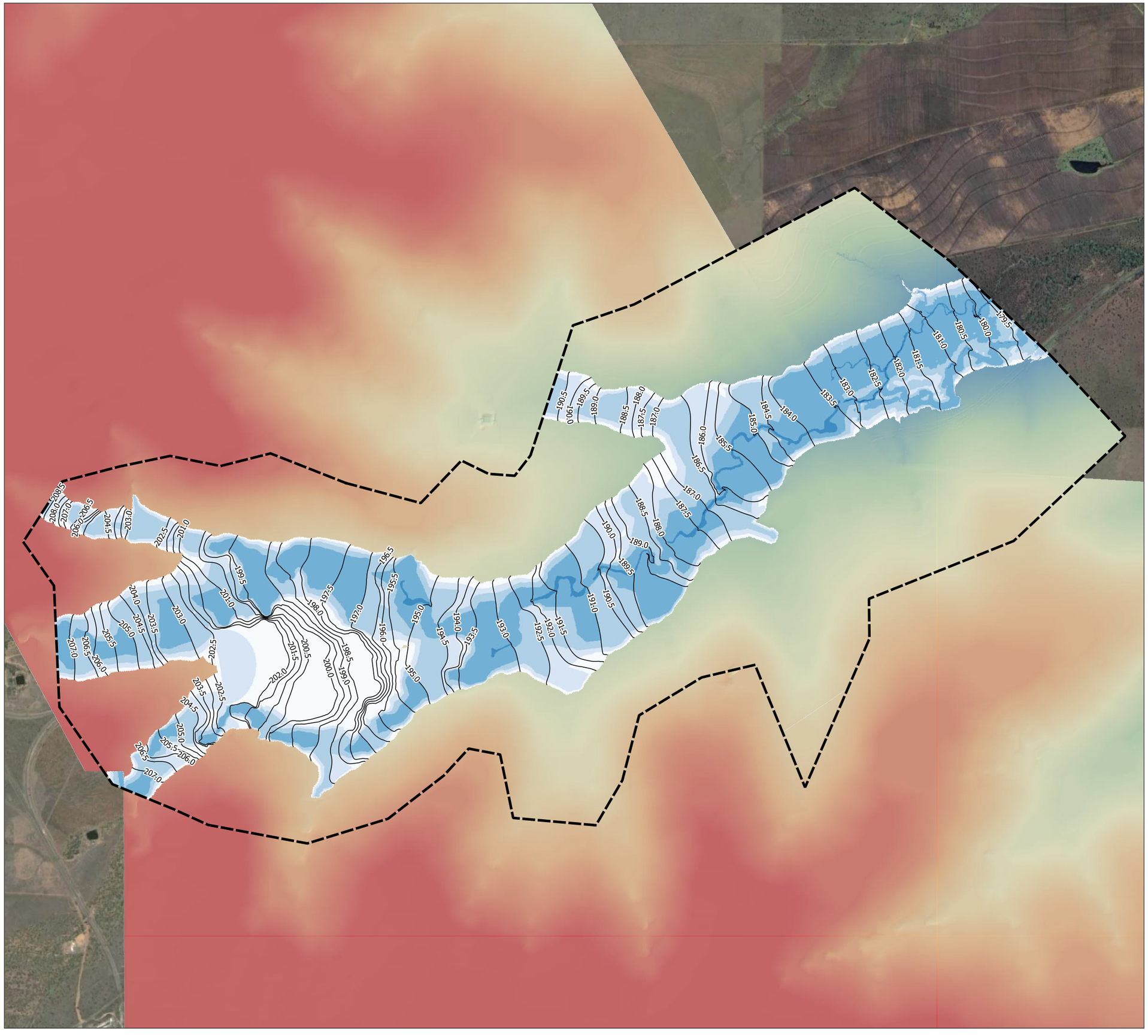
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-31

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-32

Pre-mining Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-33

Pre-mining Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

Band 1

<= 35.0000

35.0000 - 150.0000

> 150.0000

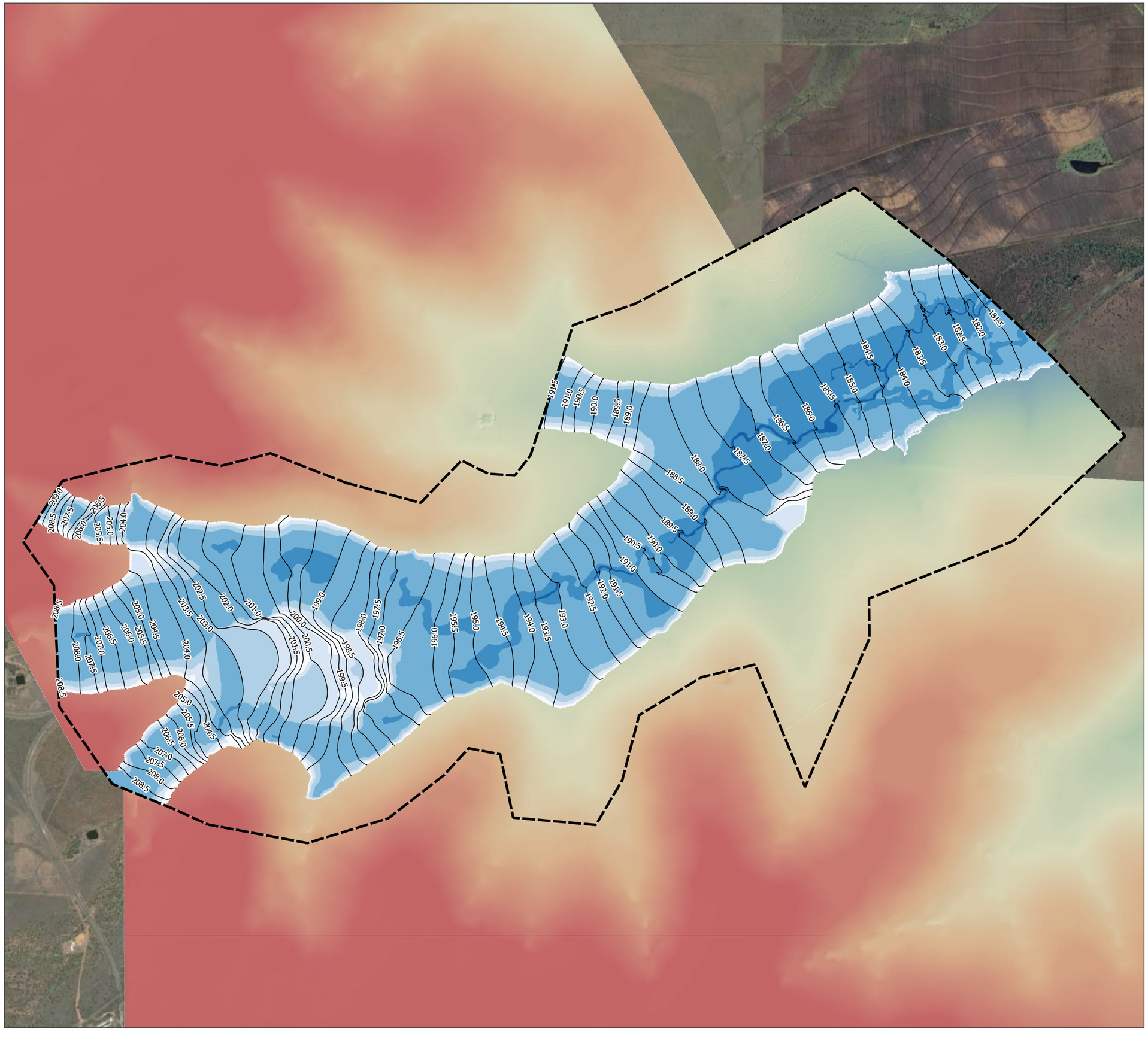
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-34

Pre-mining Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-35

Pre-mining Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

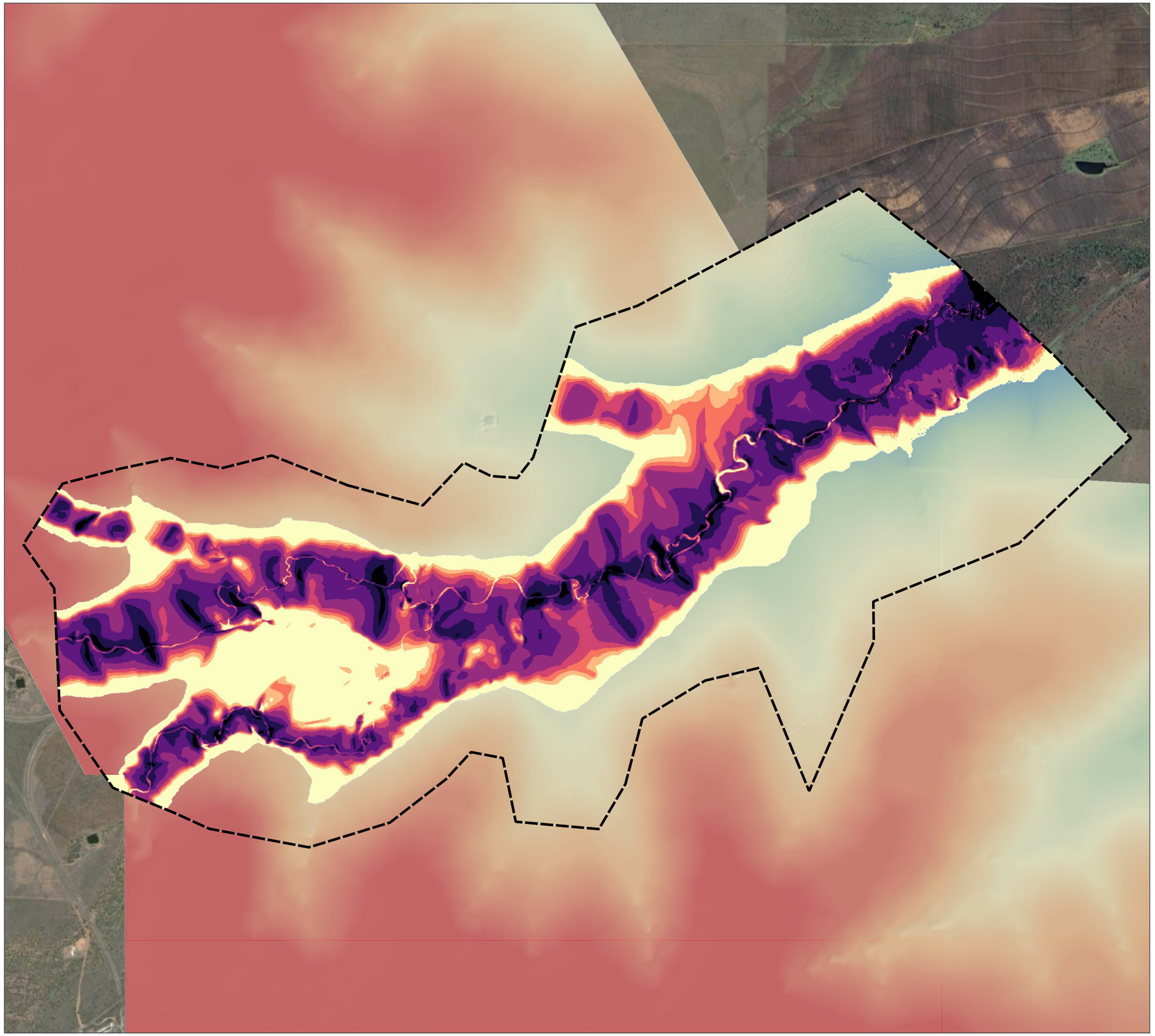
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-36

Pre-mining Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

180
210

Stream Power (W/m²)

Band 1

<= 35.0000

35.0000 - 150.0000

> 150.0000

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-37

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

180
210

Flood Depth (m)

<= 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 8.0
> 8.0

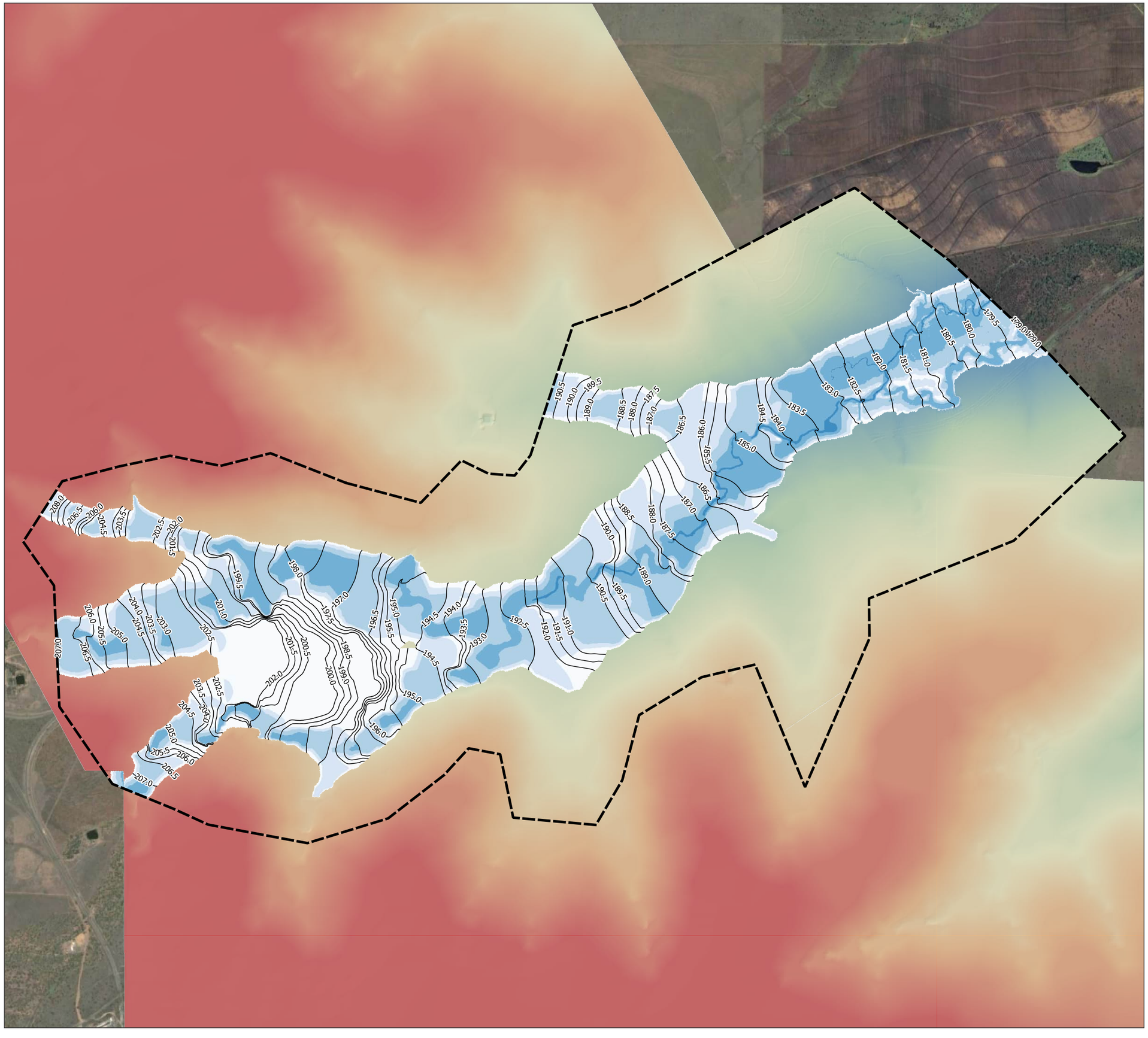
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-38

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

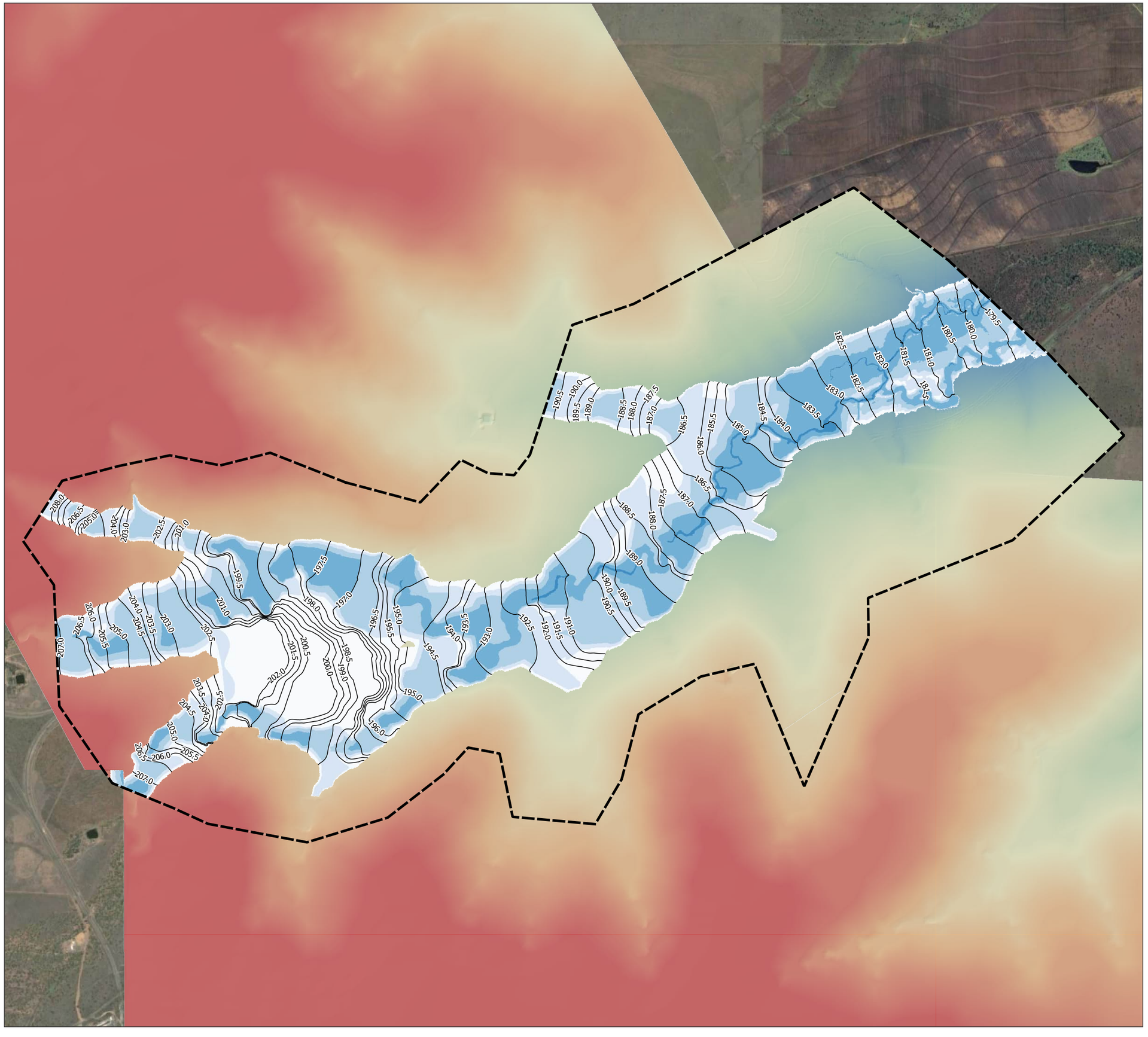
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-39

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-40

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

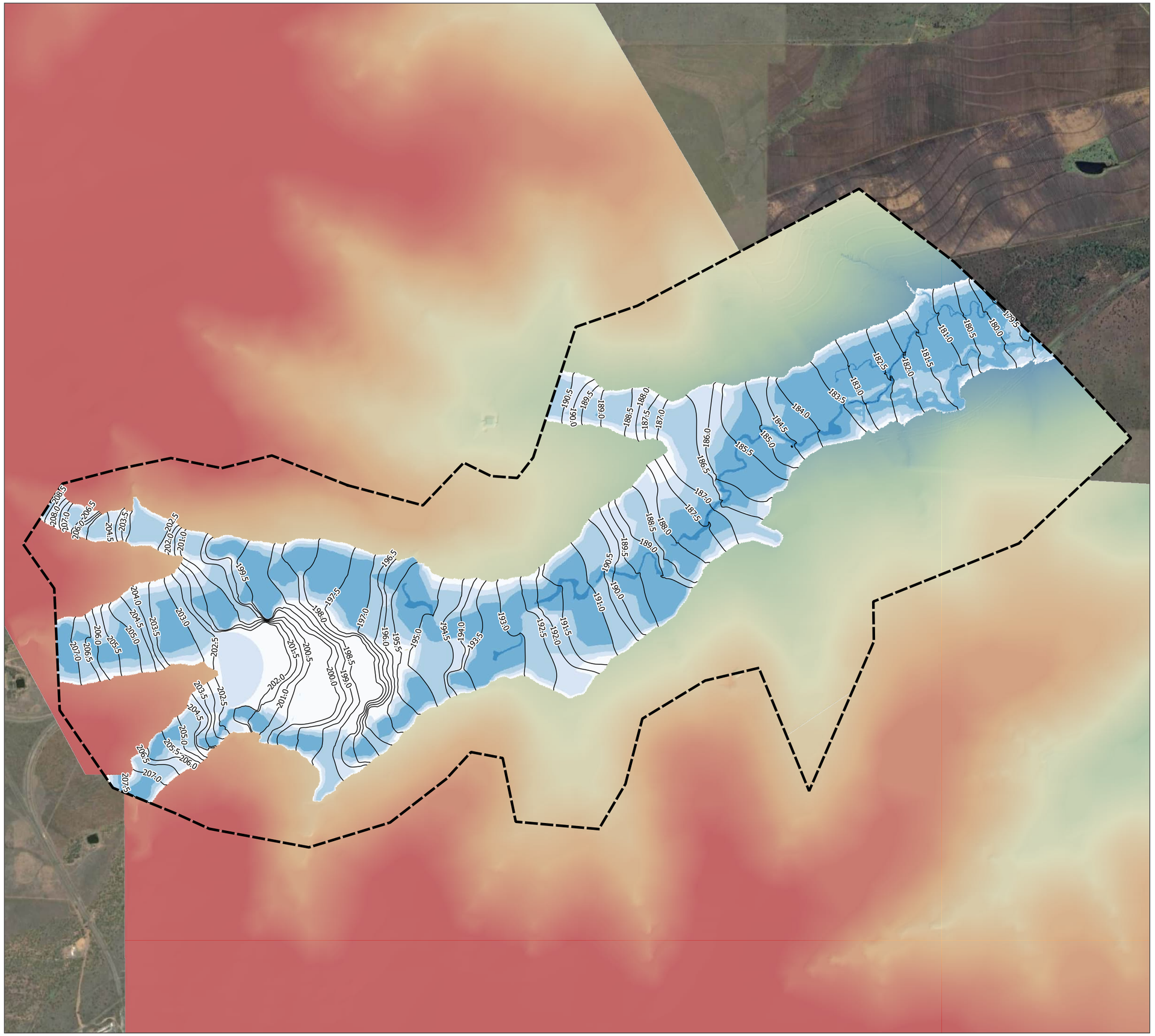
Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-41

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix C-42

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 180
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Downs Creek

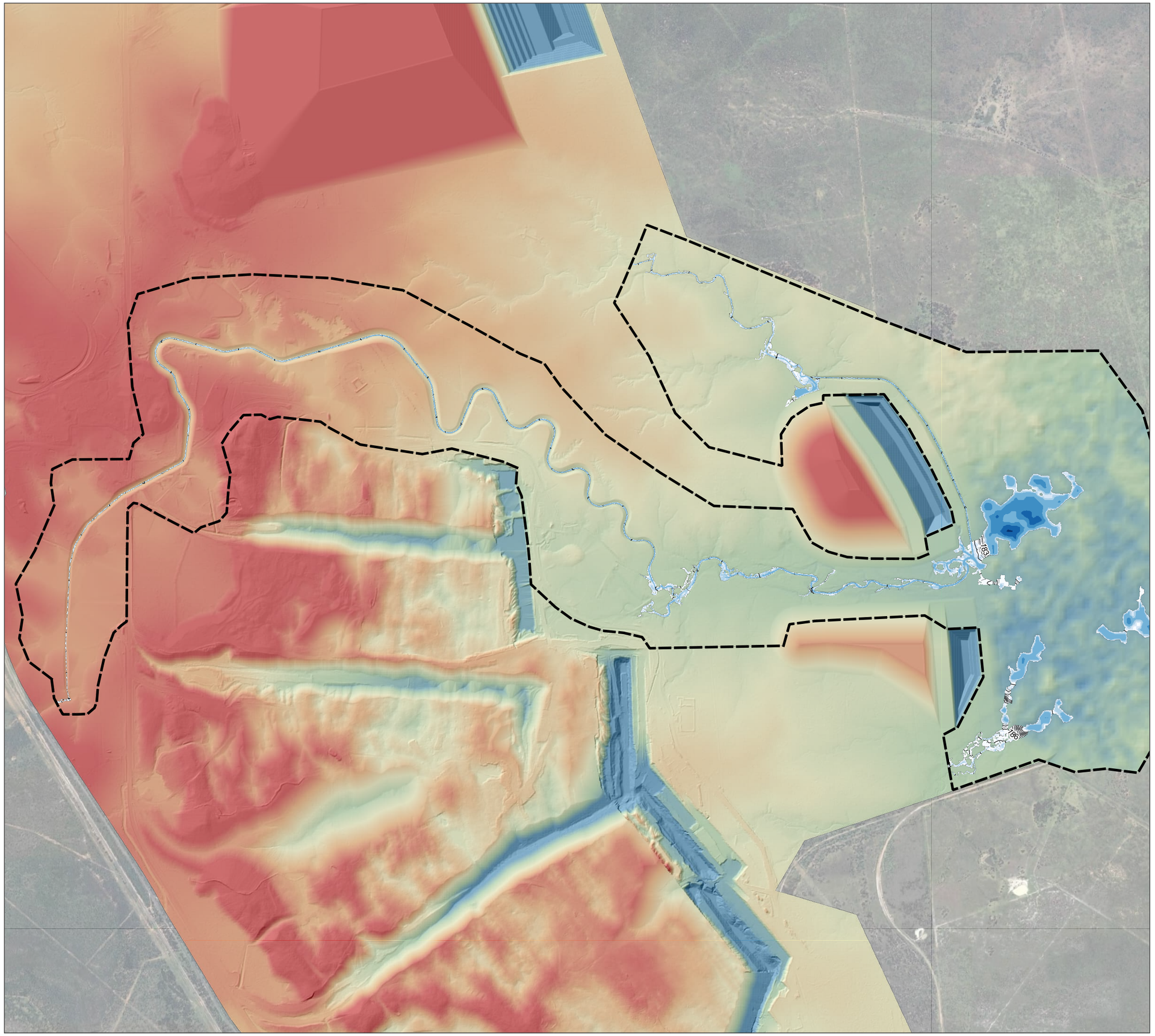
A3 Scale: 1:25000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 km

APPENDIX D

ROLF CREEK



WMS
CIVIL | WATER | ENVIRONMENT

Appendix D-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

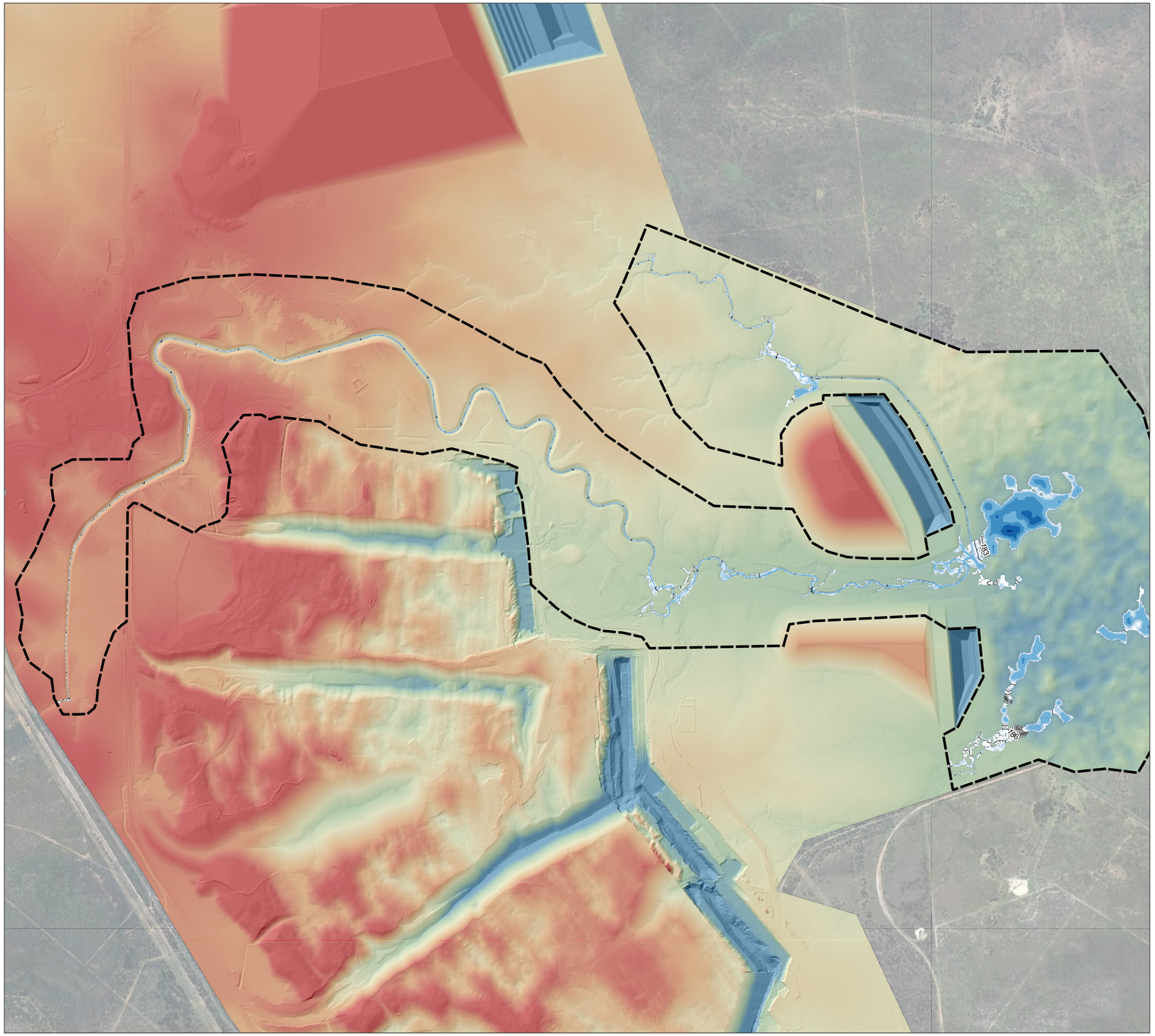
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS
CIVIL | WATER | ENVIRONMENT

Appendix D-1

PRC Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

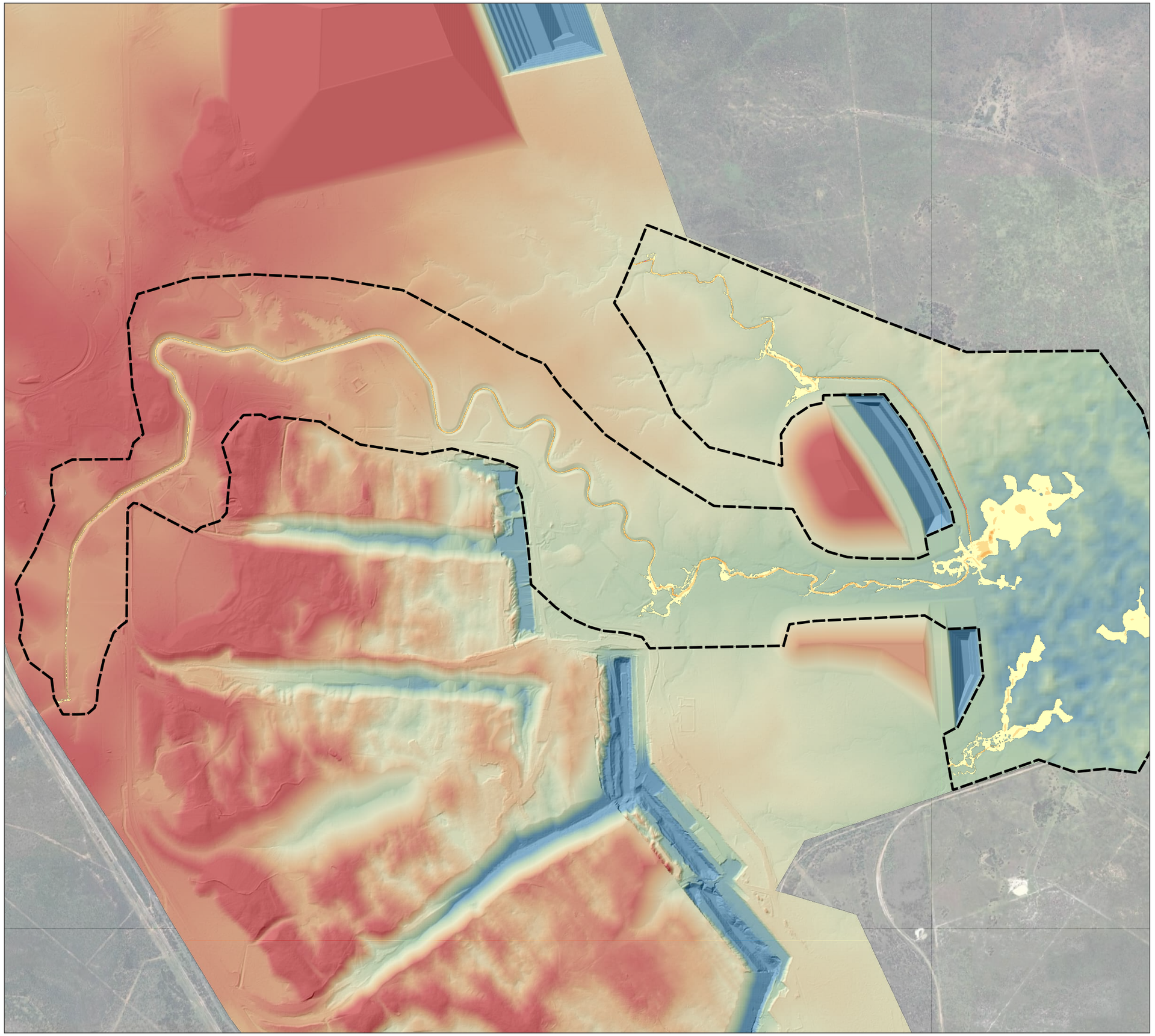
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-2

PRC Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

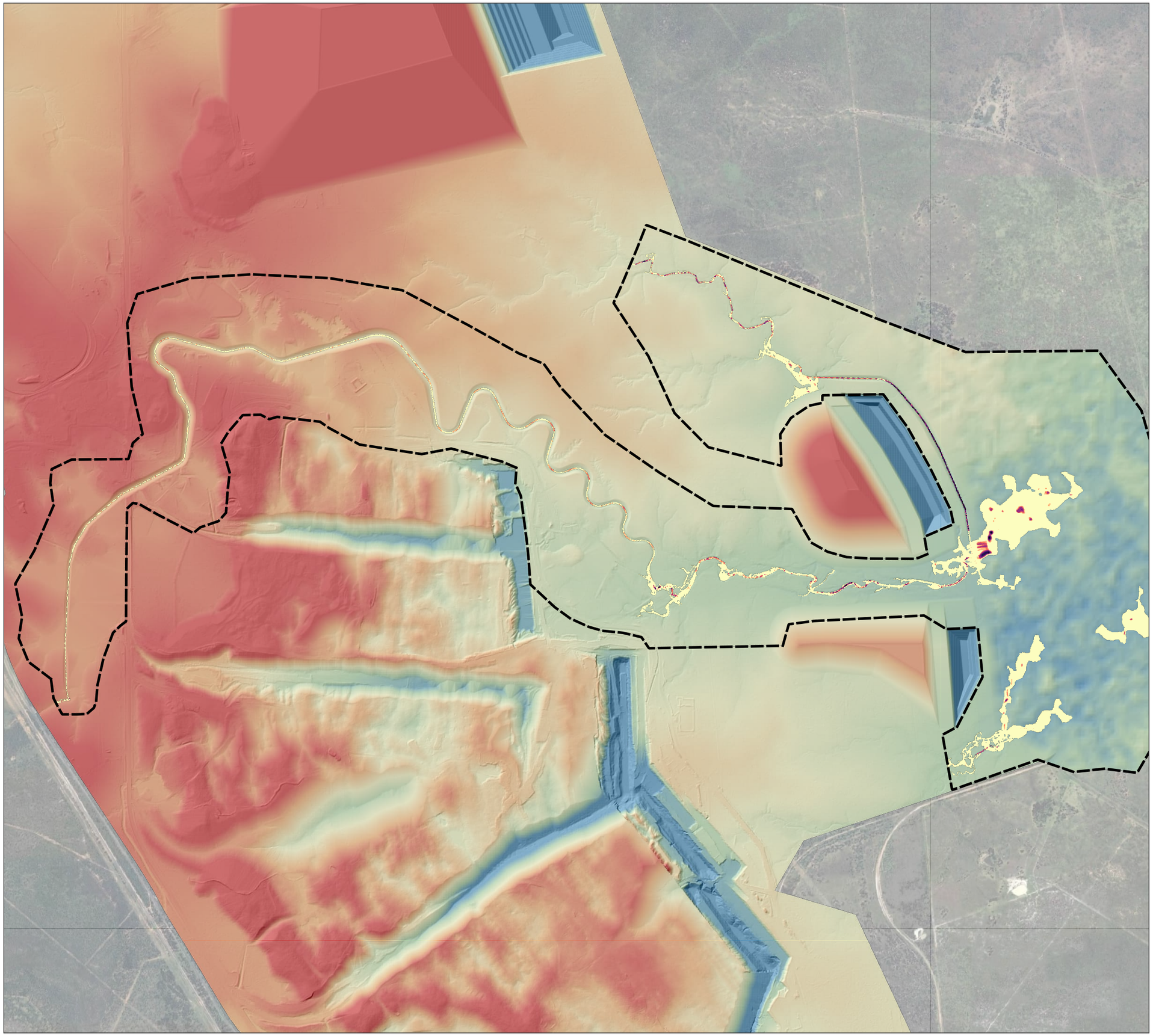
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-3

PRC Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

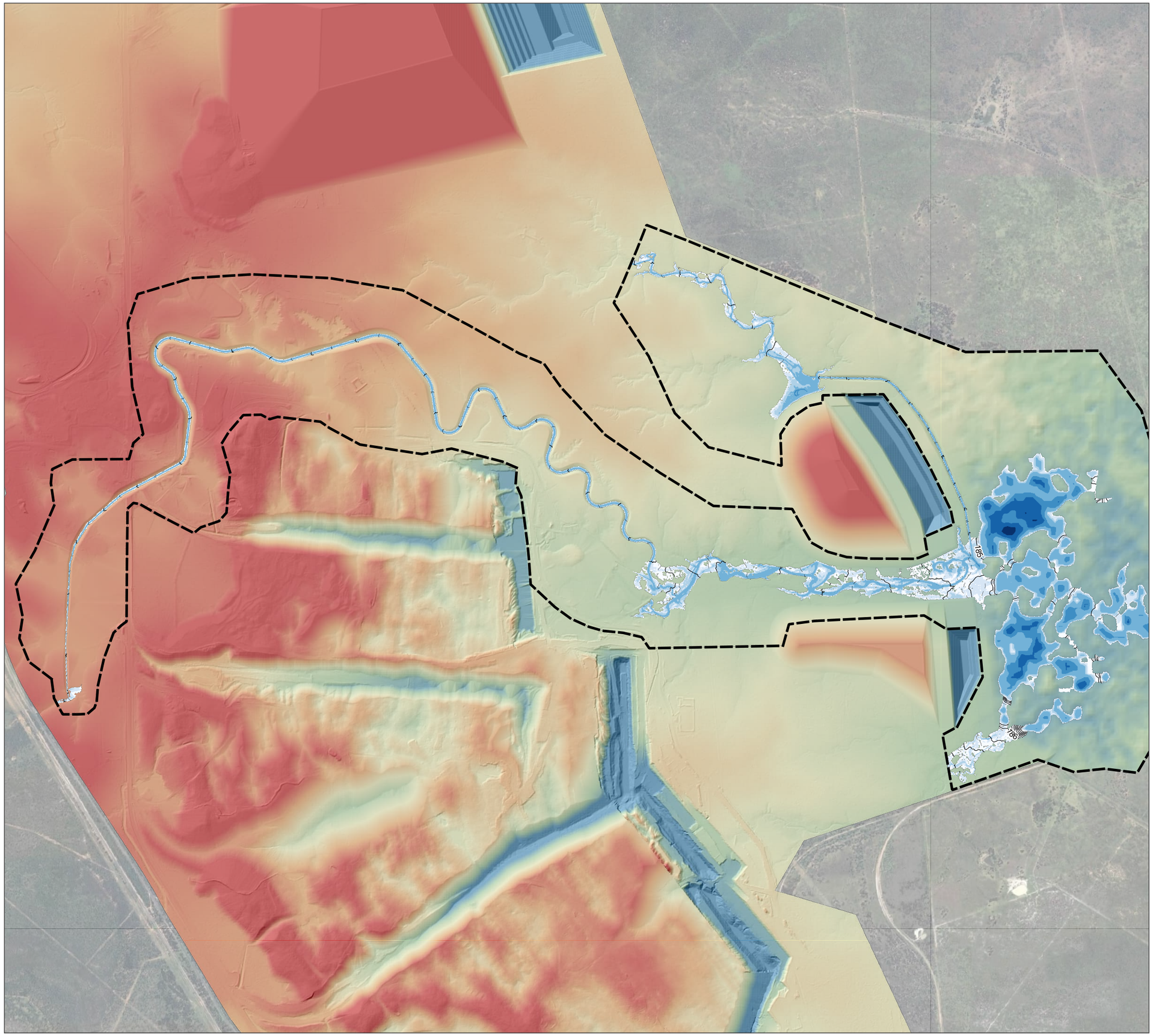
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS
CIVIL | WATER | ENVIRONMENT

Appendix D-4

PRC Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-5

PRC Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-6

PRC Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

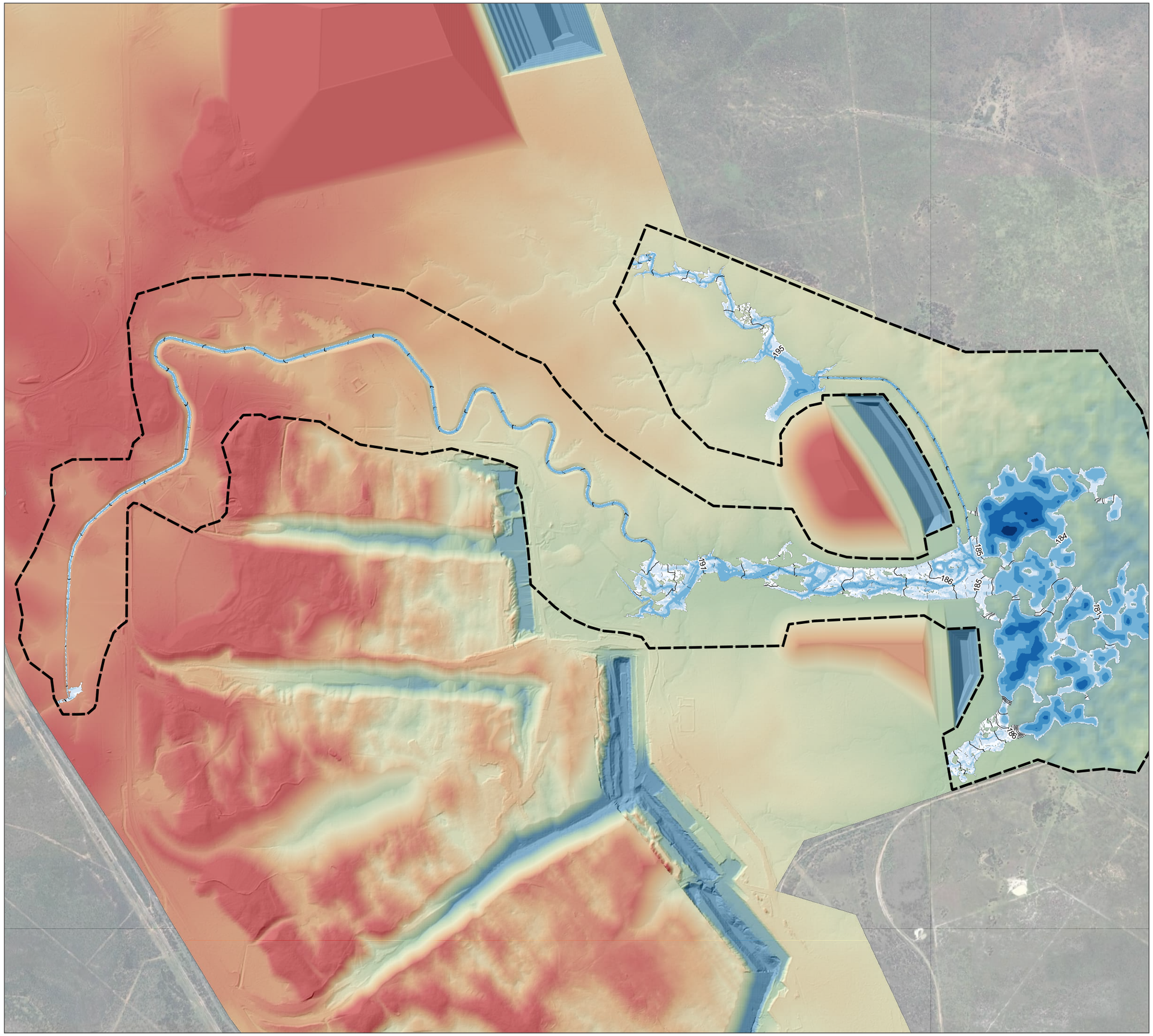
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-7

PRC Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-8

PRC Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-9

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-11

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-12

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-13

PRC Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-14

PRC Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-15

PRC Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

175
230

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-16

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

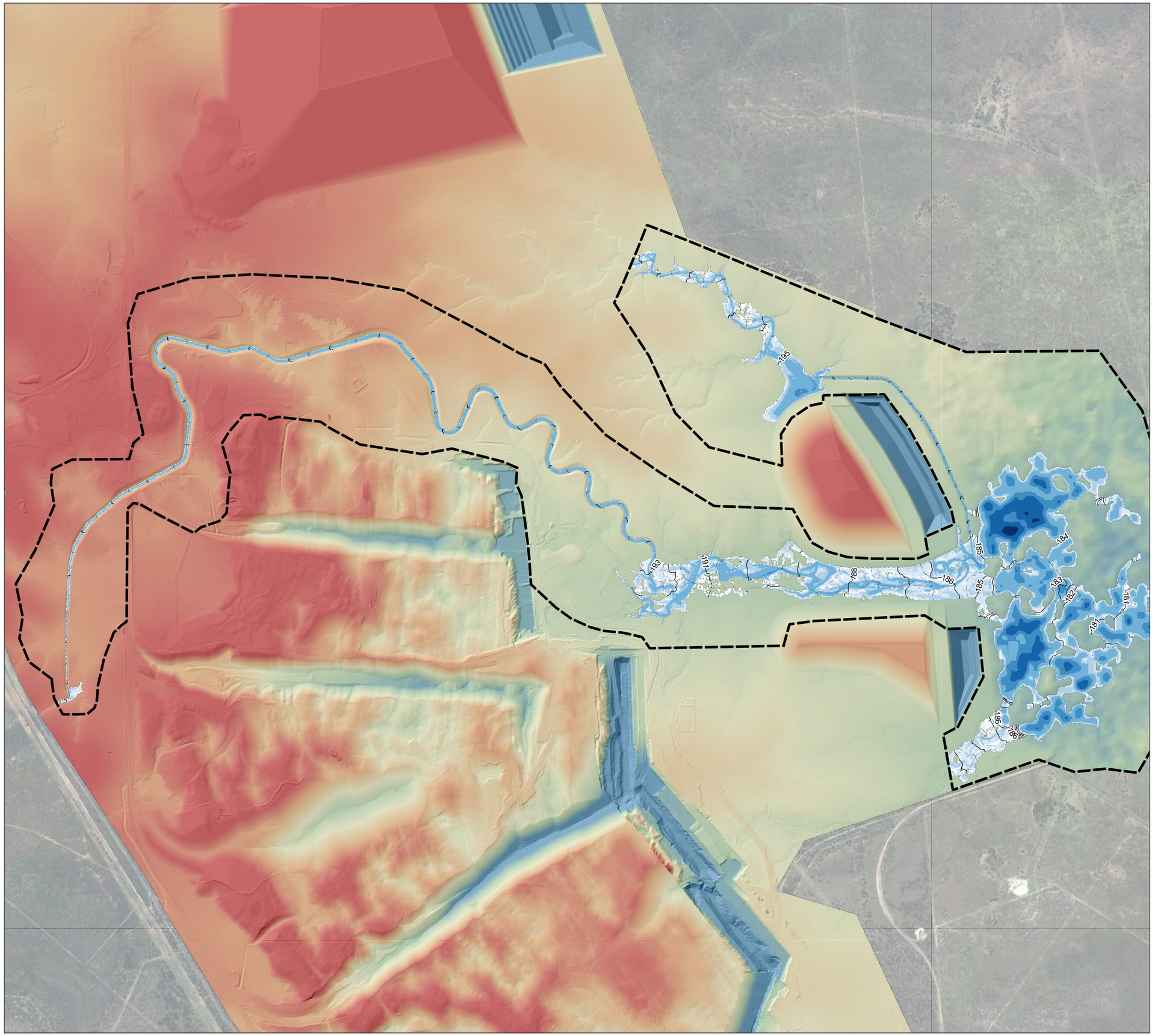
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-17

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

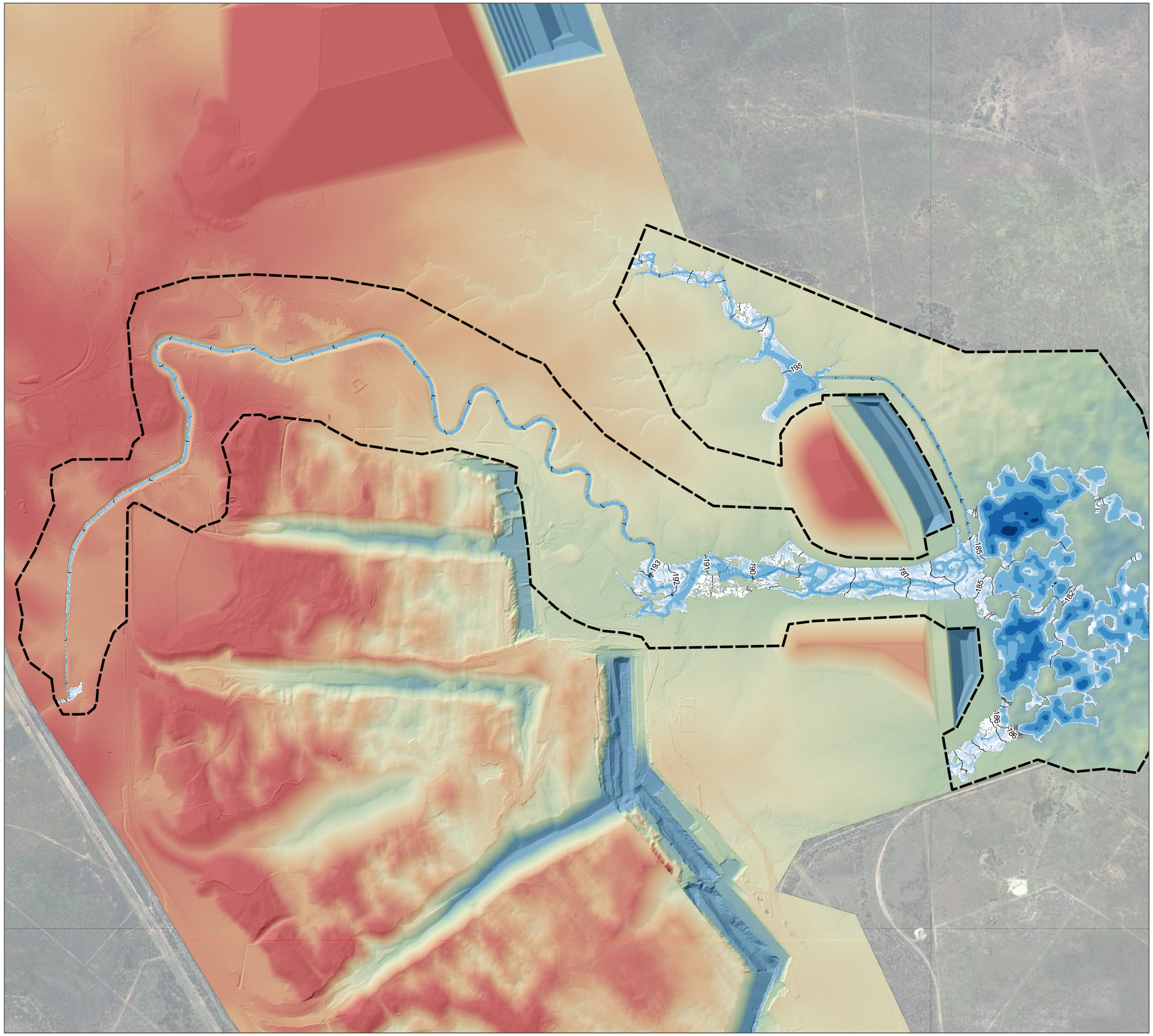
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-18

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-19

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

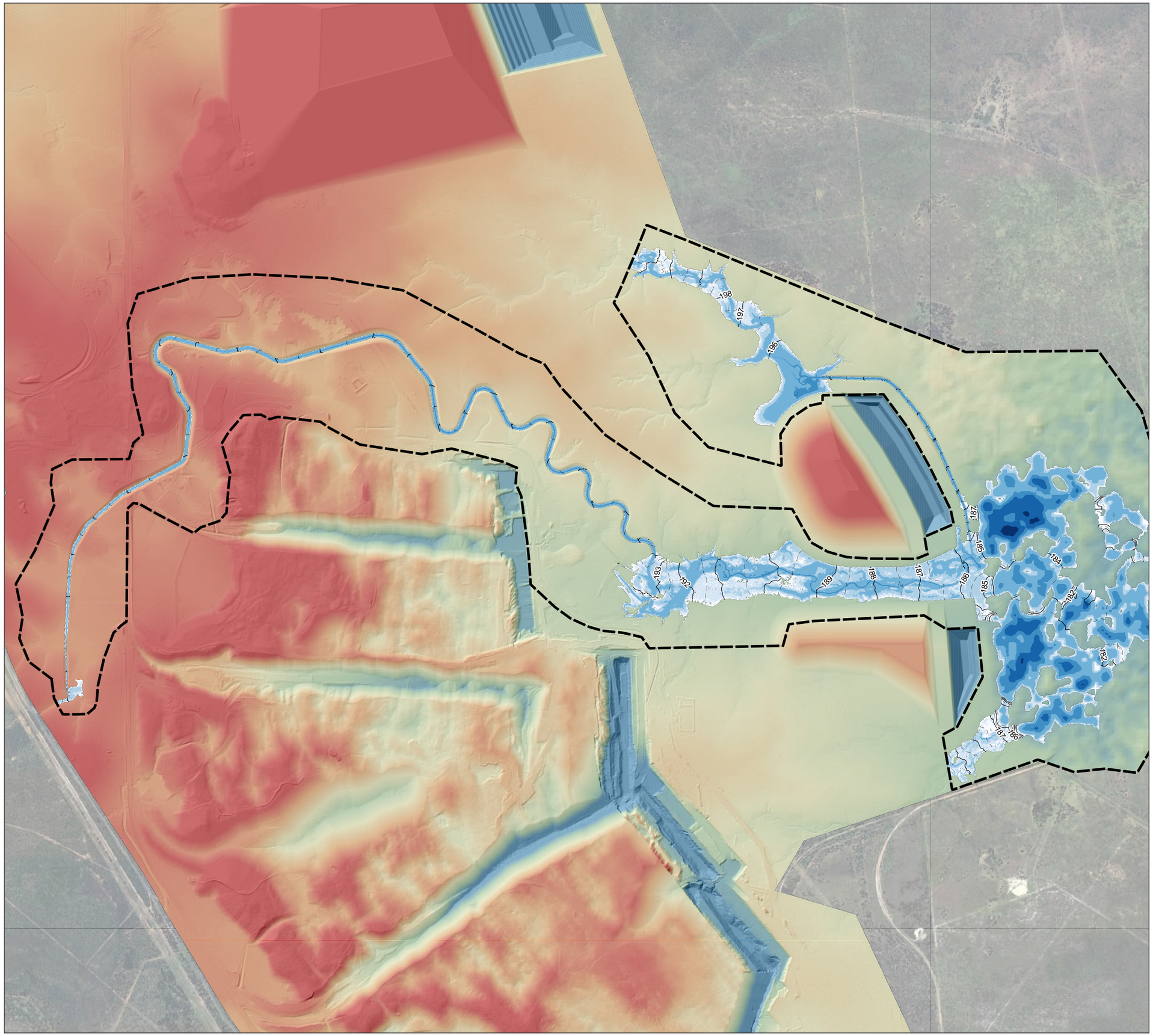
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-20

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)
- 175
- 230

Flood Depth (m)
- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

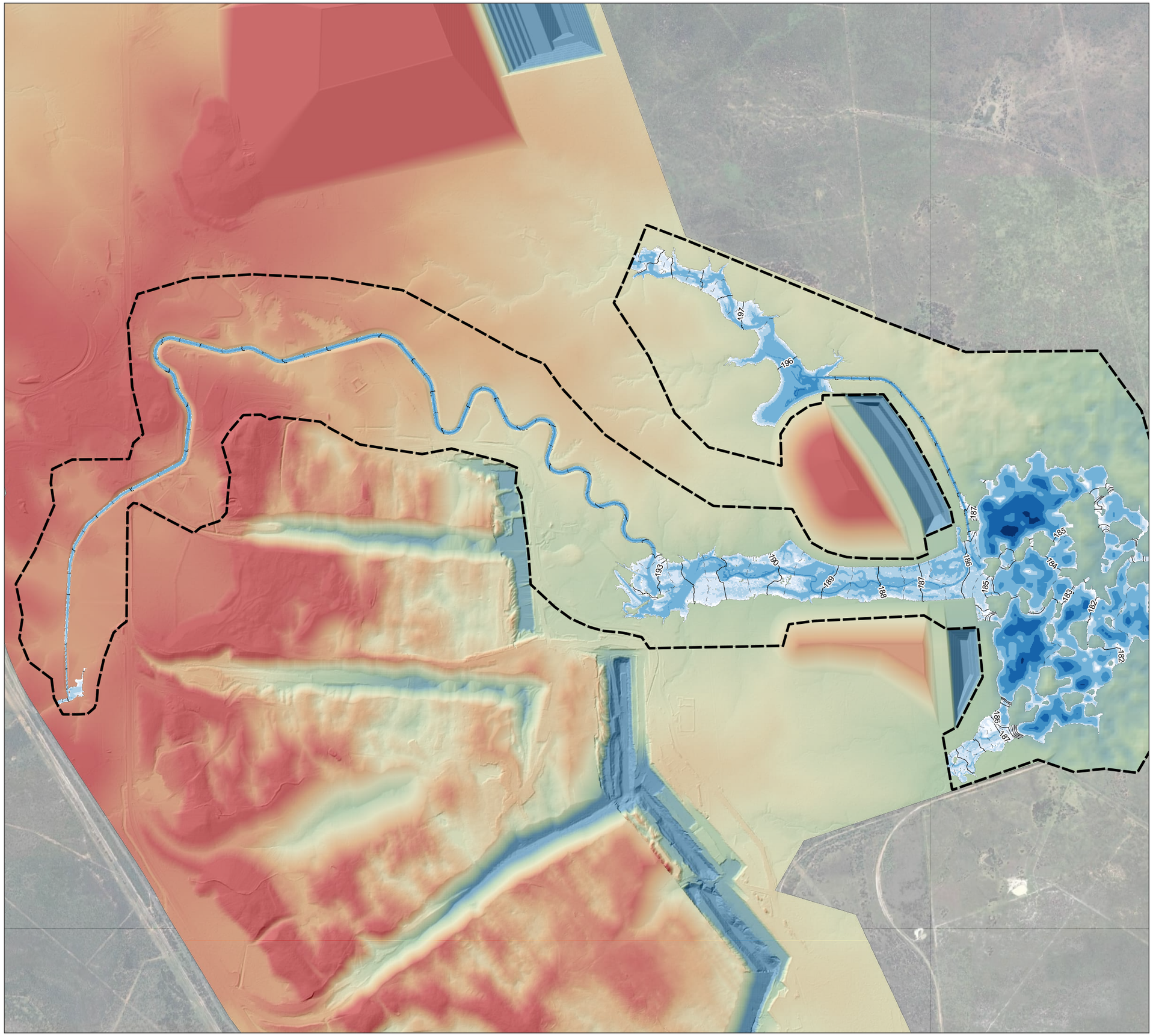
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-21

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-22

Pre-mining Conditions
Peak Depth & Water Level Contours
39% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

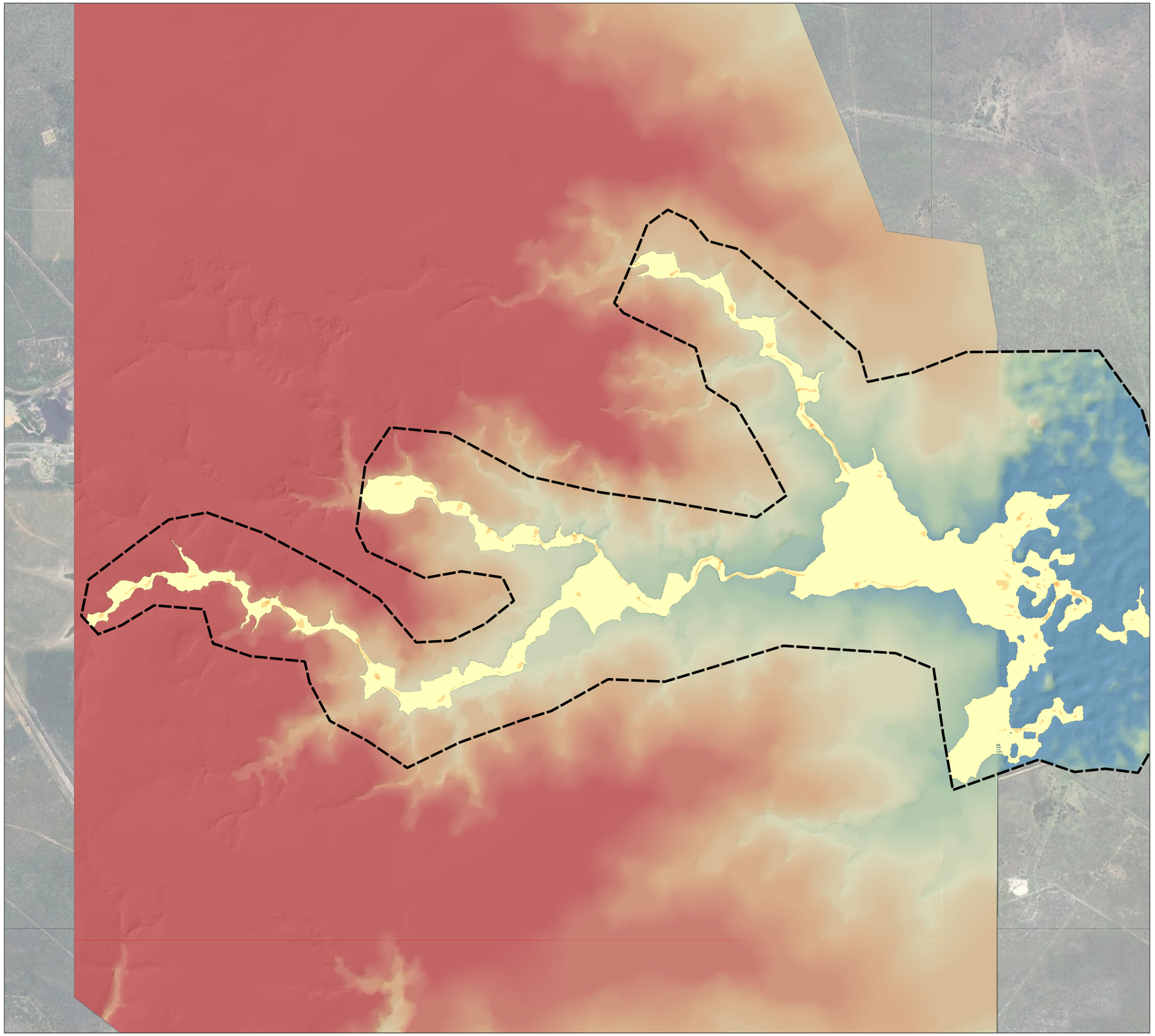
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-23

Pre-mining Conditions
Peak Velocity
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-24

Pre-mining Conditions
Peak Stream Power
39% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

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Appendix D-25

Pre-mining Conditions
Peak Depth & Water Level Contours
2% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

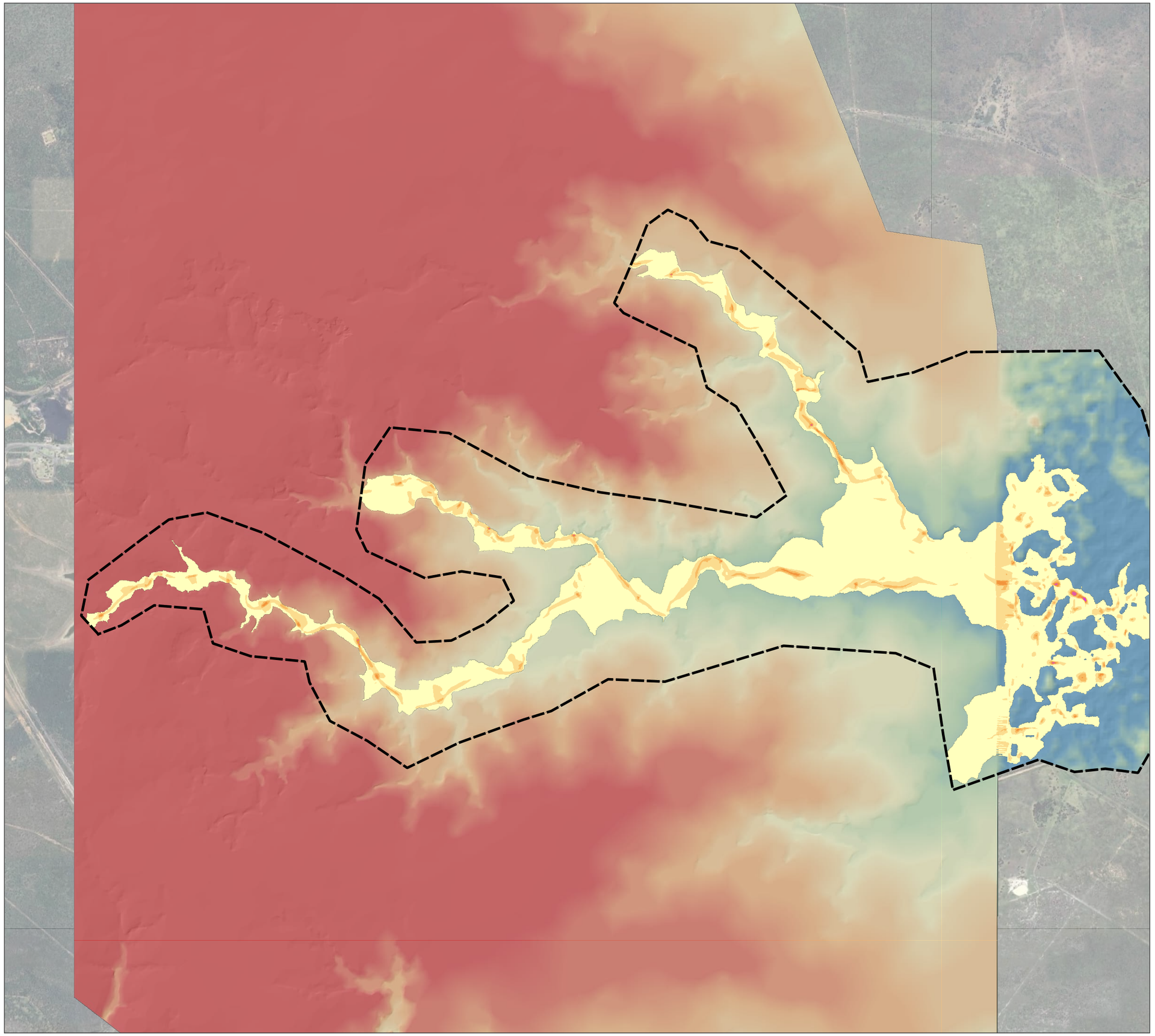
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-26

Pre-mining Conditions
Peak Velocity
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

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Appendix D-27

Pre-mining Conditions
Peak Stream Power
2% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

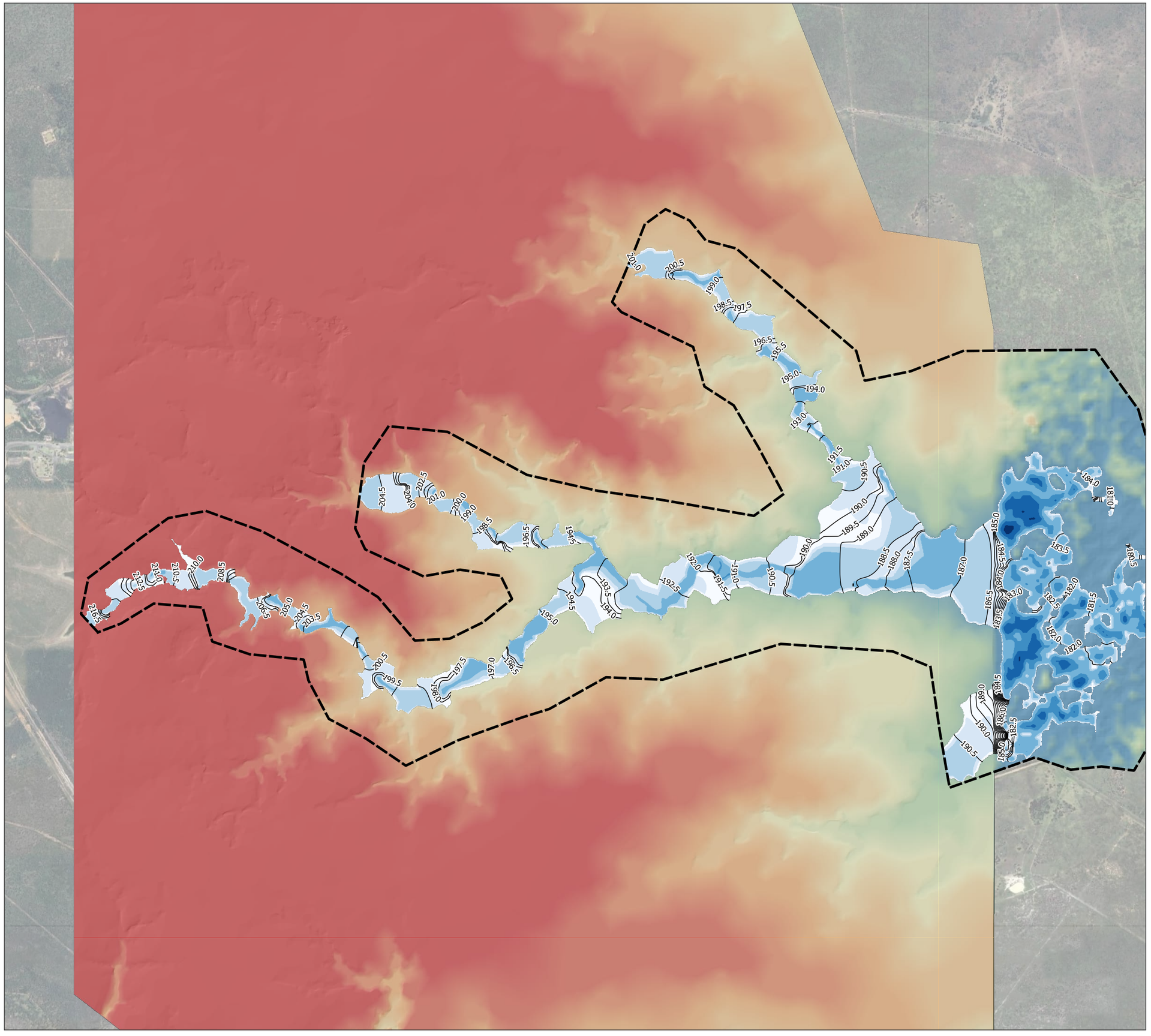
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-28

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

Hydraulic Model Extent

Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

185

210

Flood Depth (m)

<= 0.2

0.2 - 0.5

0.5 - 1.0

1.0 - 3.0

3.0 - 5.0

5.0 - 8.0

> 8.0

Saraji South Mine Rehabilitation Flood Modelling

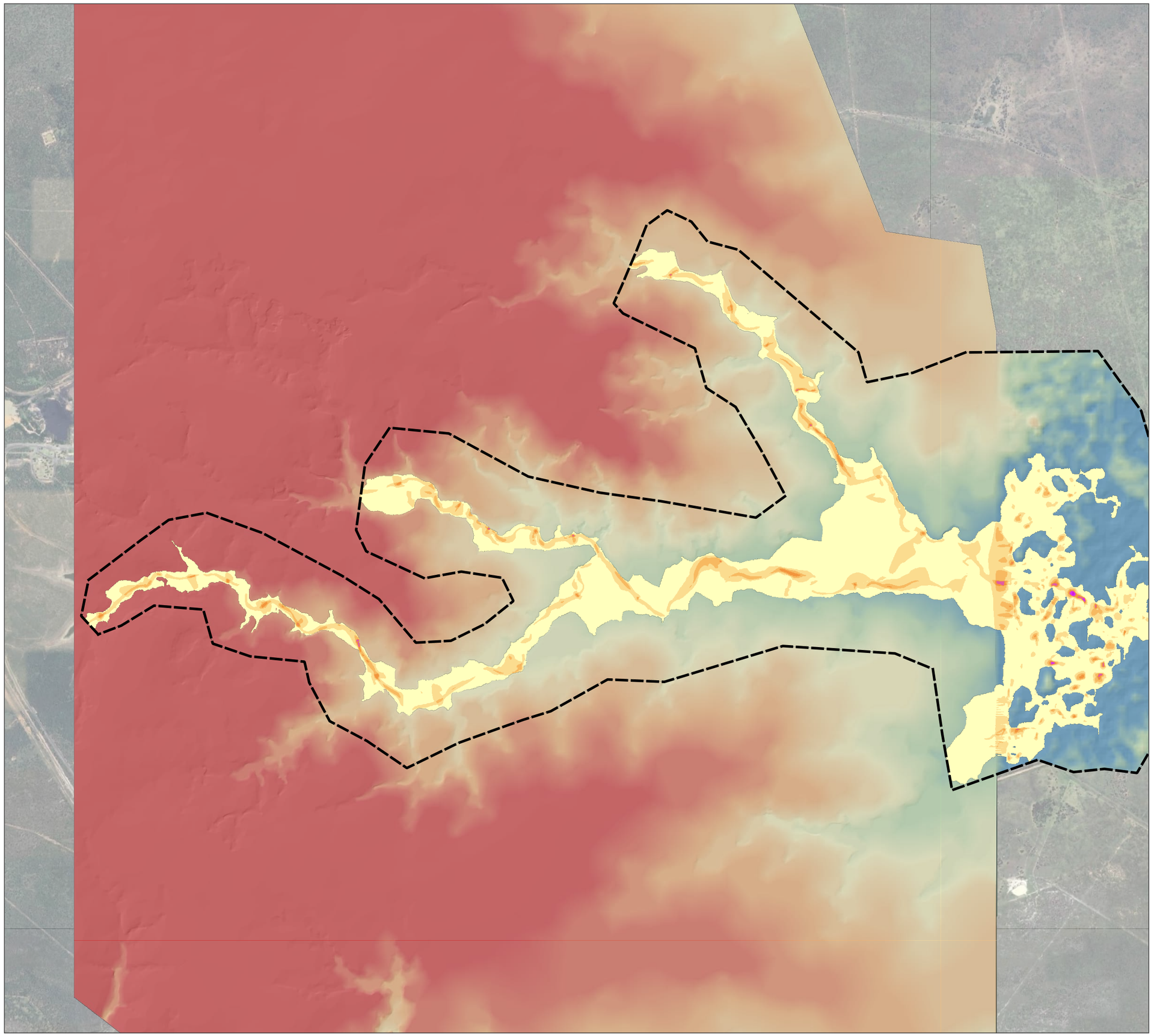
Rolf Creek

A3 Scale: 1:30000

Job No: 10749

Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-29

Pre-mining Conditions
Peak Velocity
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

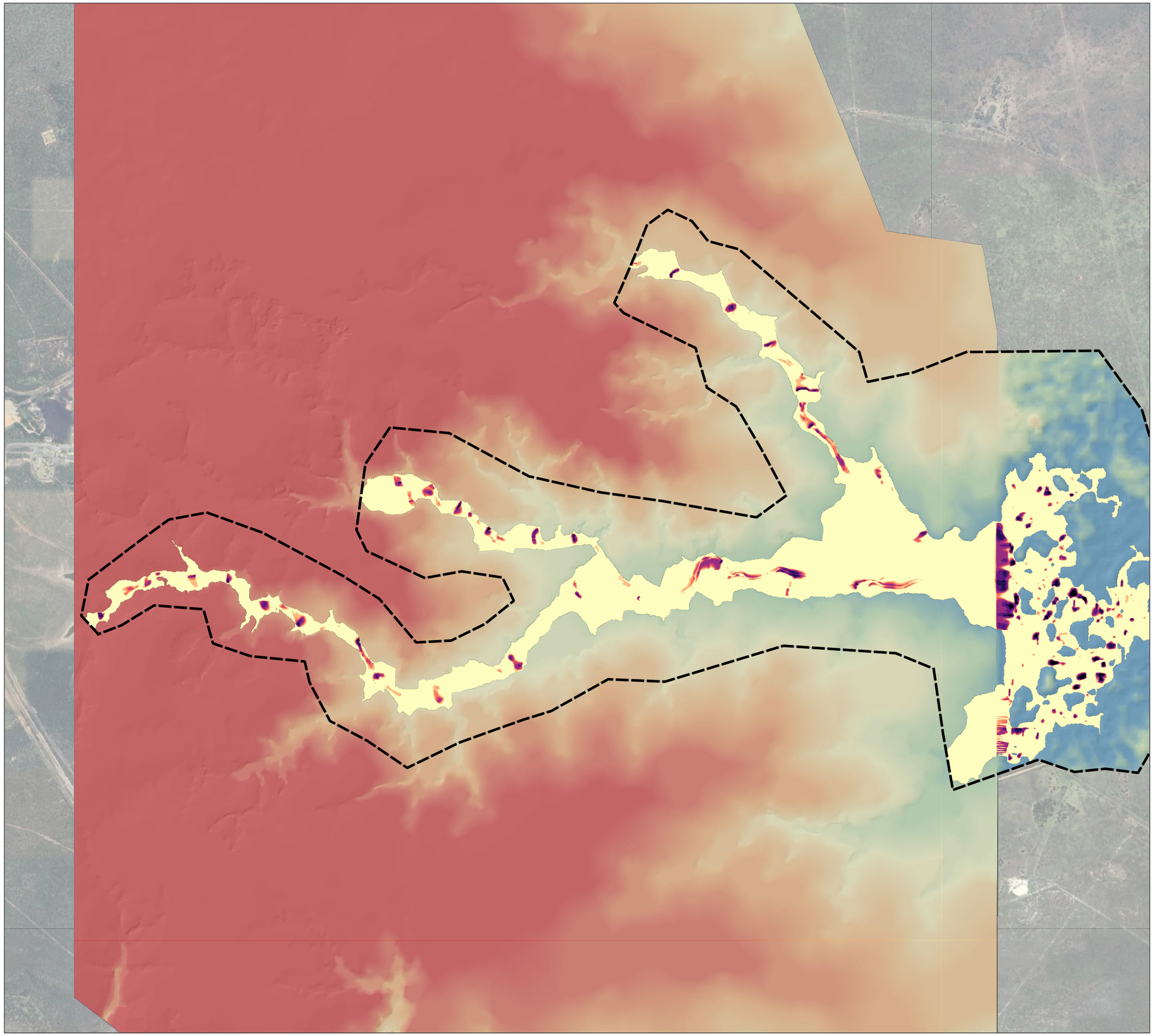
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-30

Pre-mining Conditions
Peak Stream Power
1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

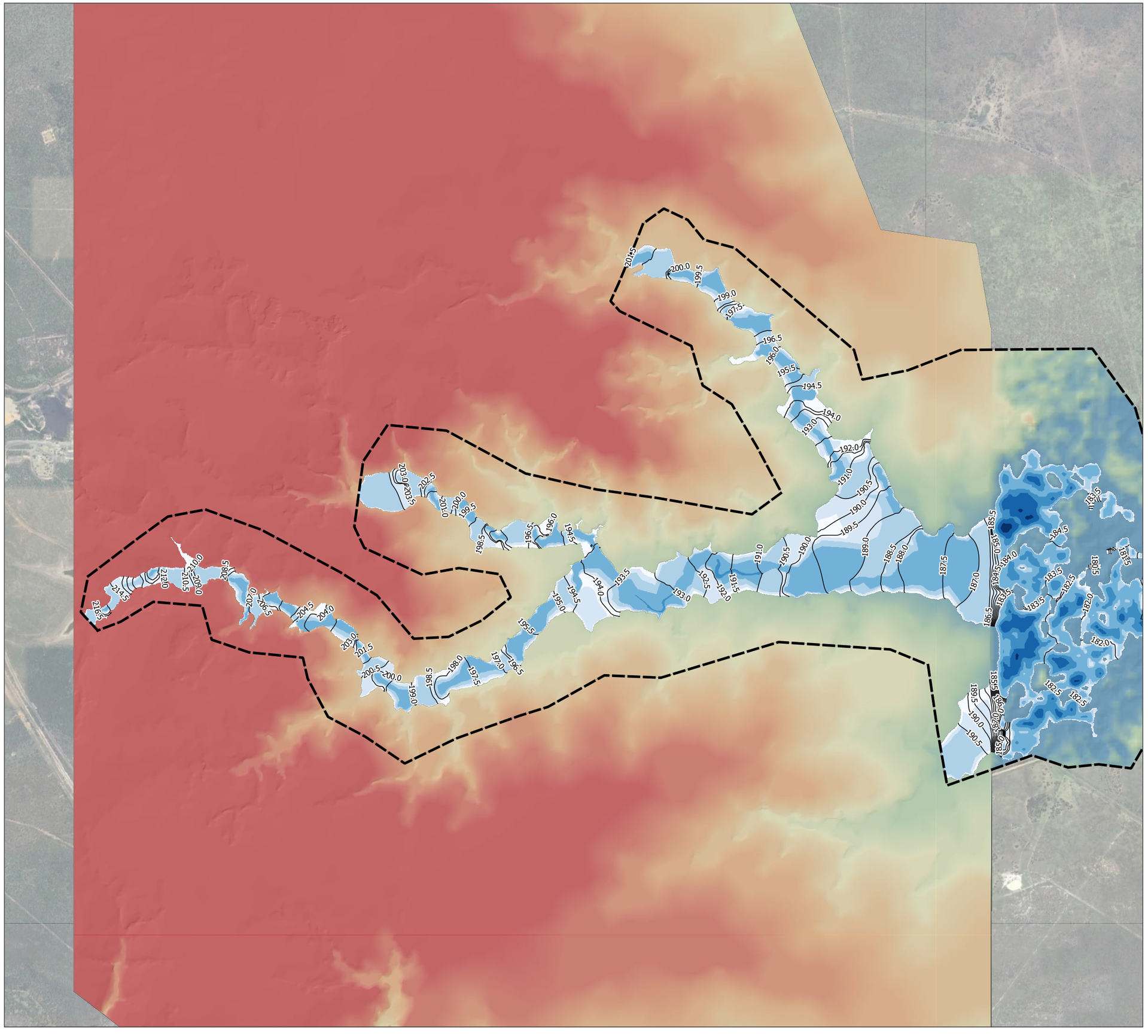
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-31

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-32

Pre-mining Conditions
Peak Velocity
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

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Appendix D-33

Pre-mining Conditions
Peak Stream Power
0.1% AEP

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-34

Pre-mining Conditions
Peak Depth & Water Level Contours
PMF

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

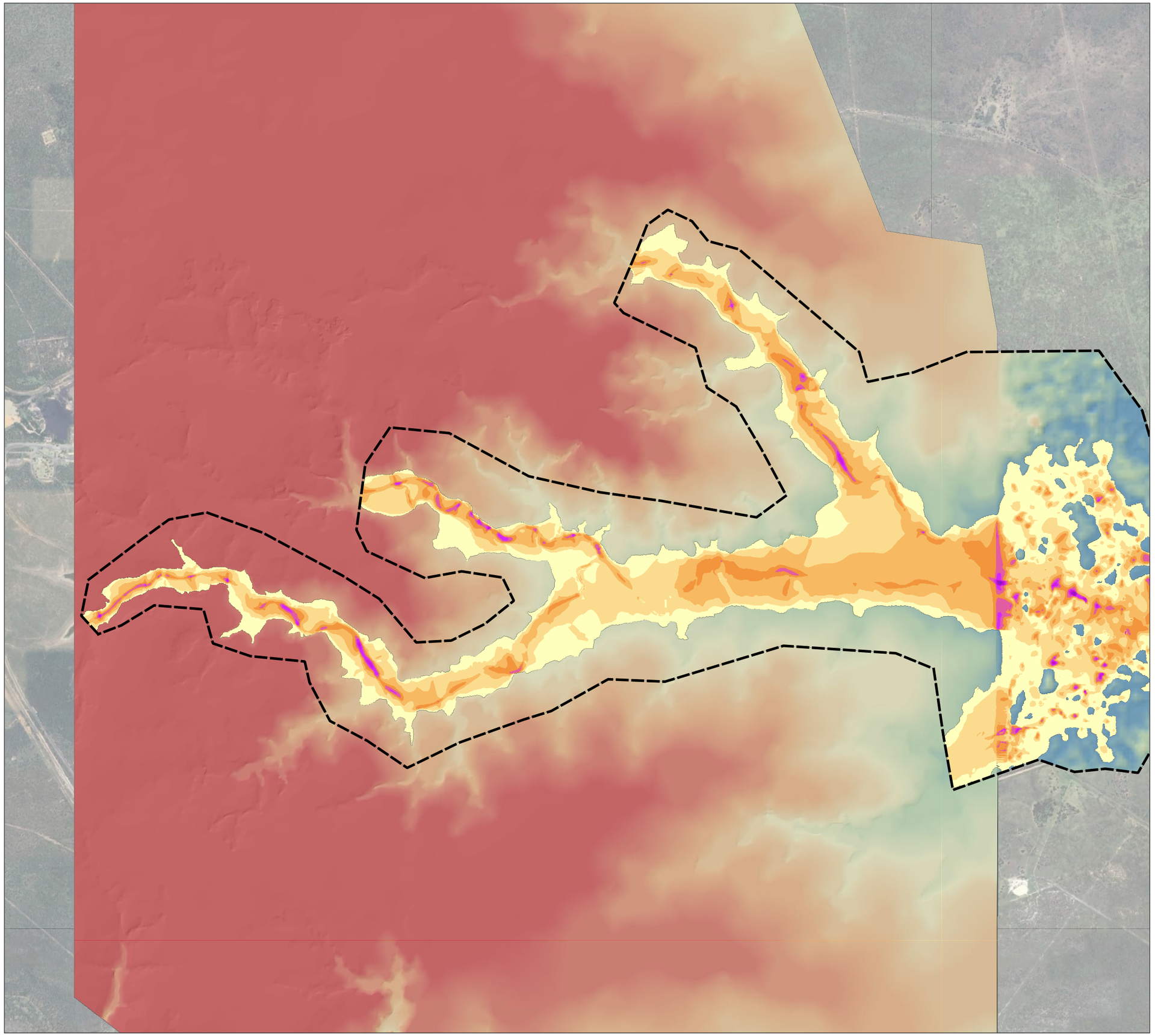
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-35

Pre-mining Conditions
Peak Velocity
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Flood Velocity (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

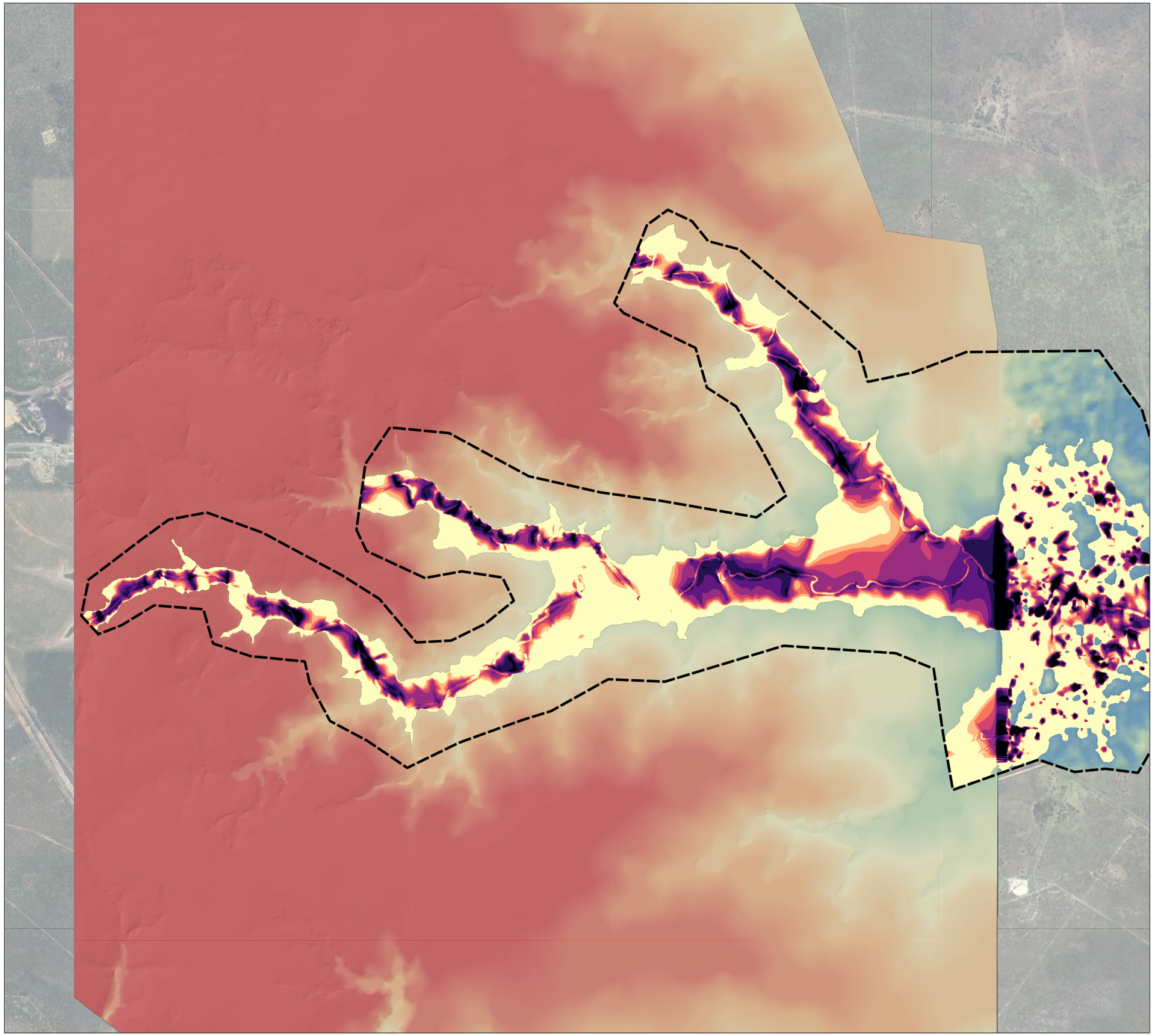
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-36

Pre-mining Conditions
Peak Stream Power
PMF

LEGEND

Hydraulic Model Extent

Elevation (mAHD)

185
210

Stream Power (W/m²)

<= 25
25 - 35
35 - 45
45 - 60
60 - 100
100 - 150
150 - 250
> 250

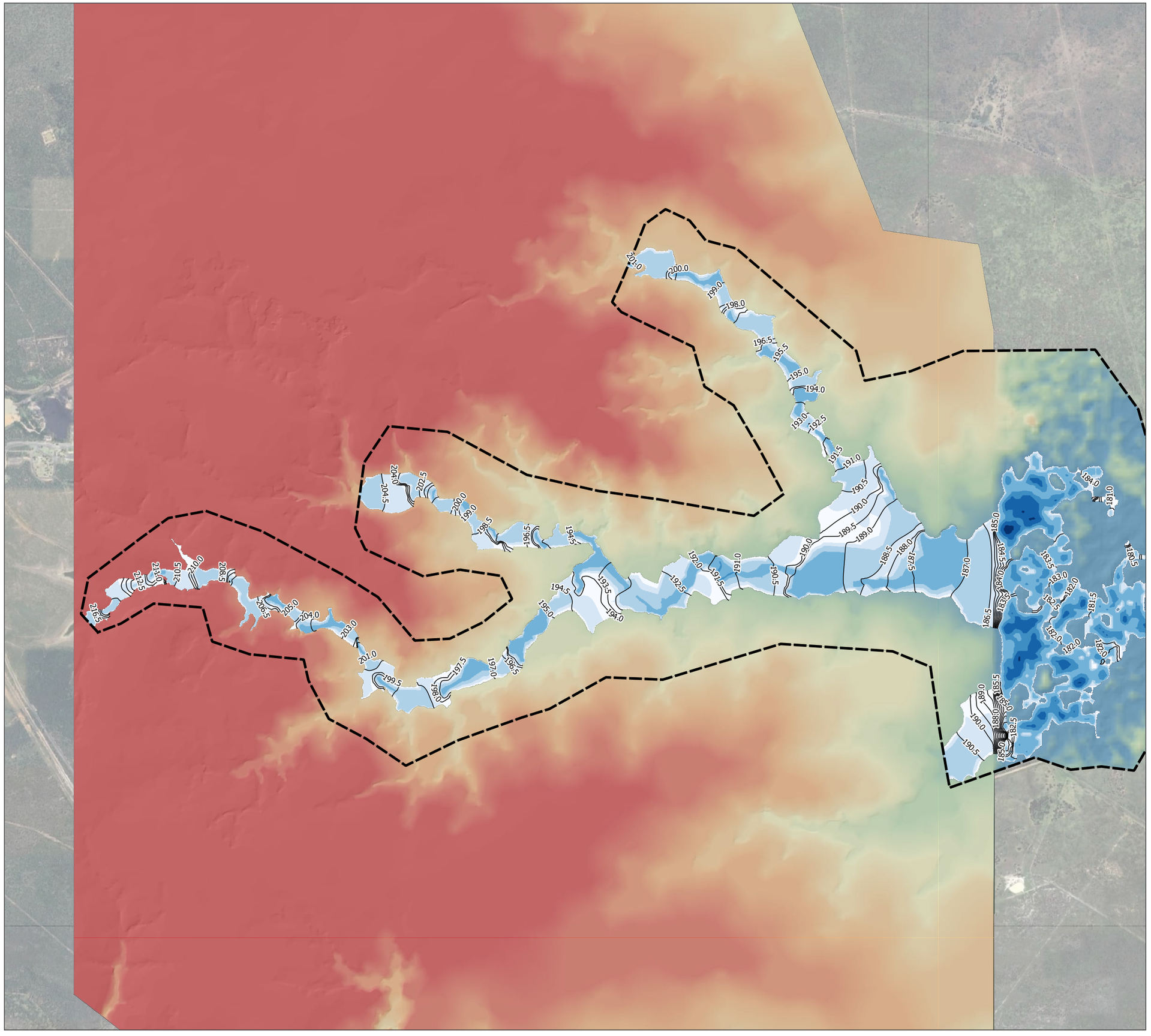
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-37

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP2.6 P50
(6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

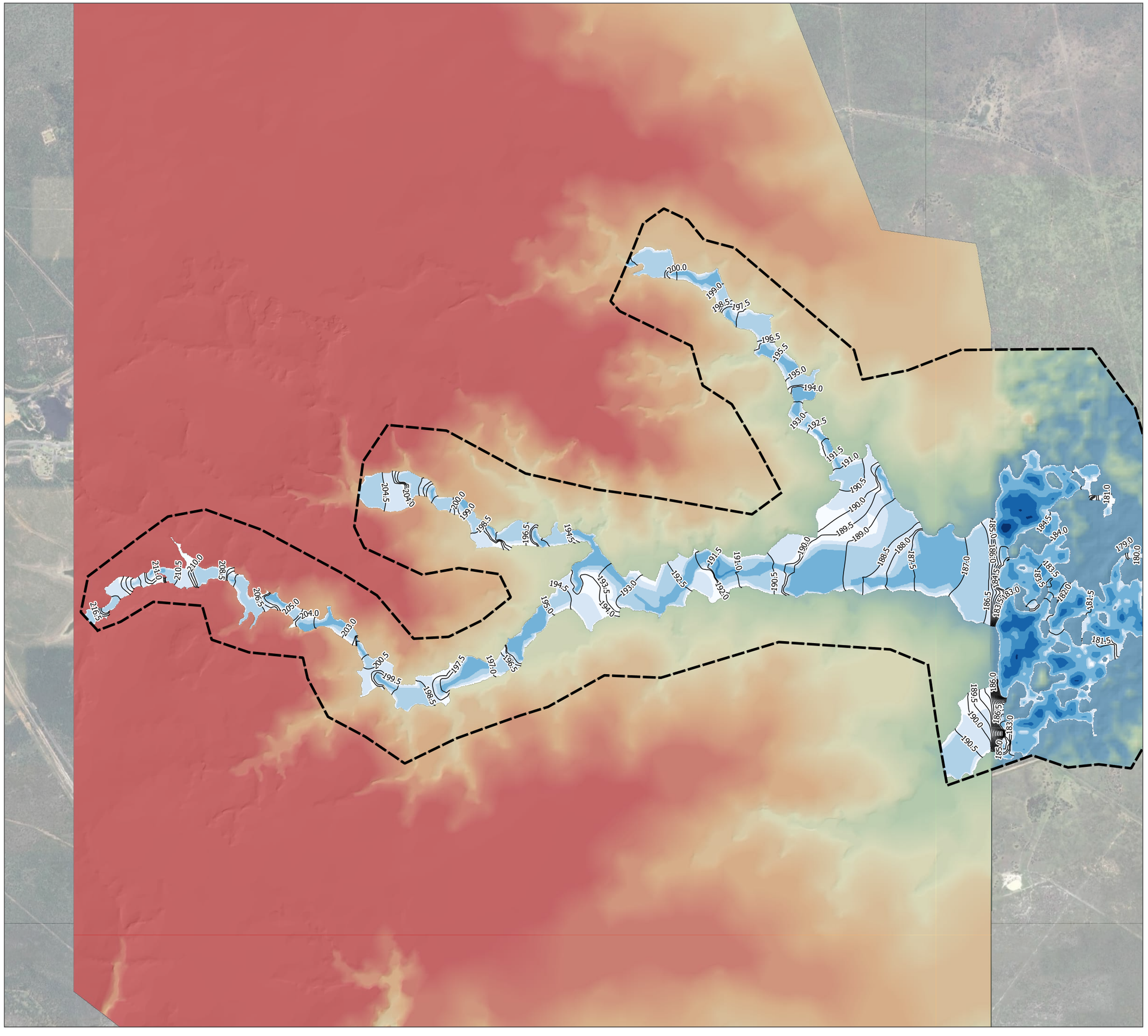
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



Appendix D-38

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

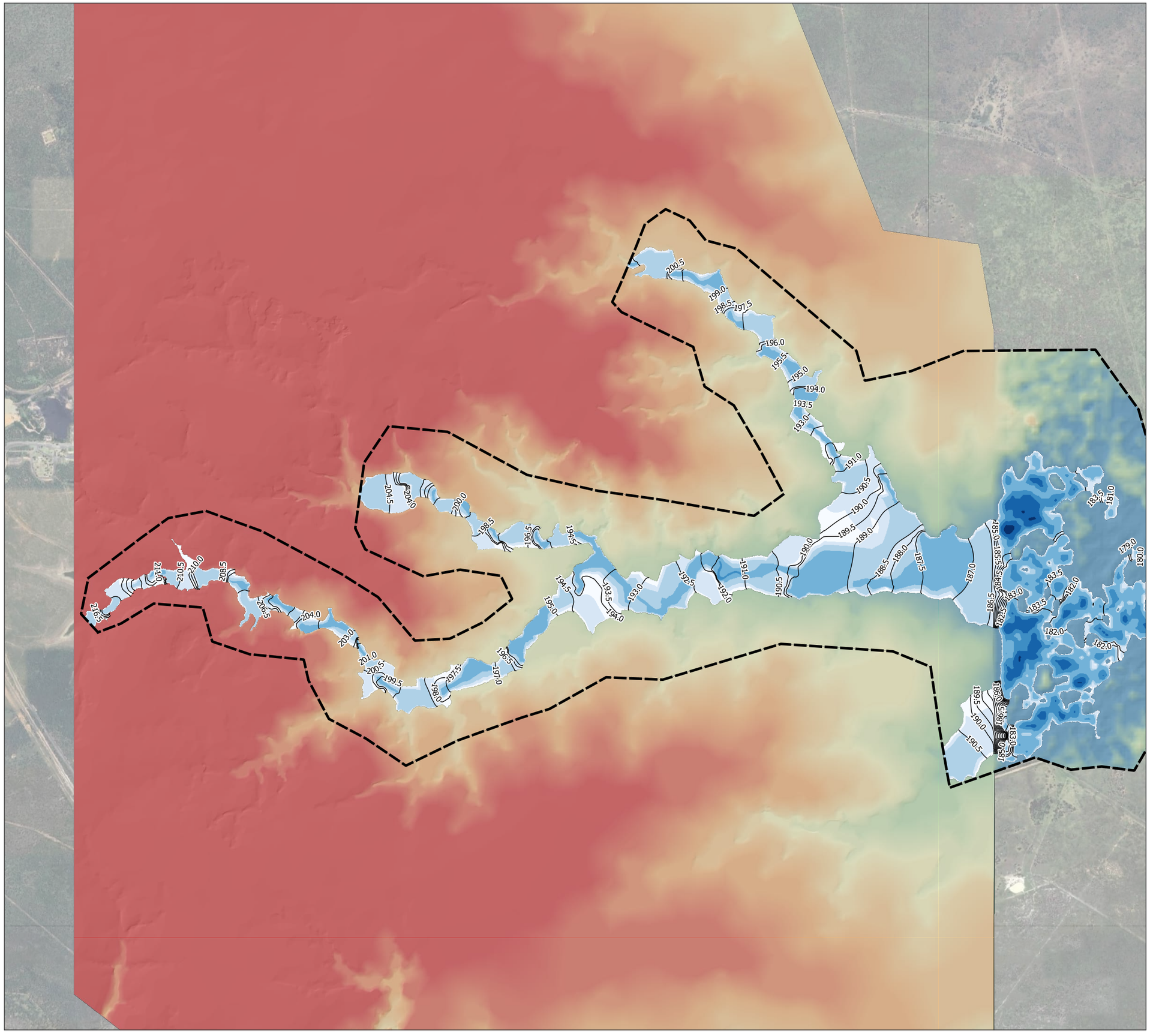
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-39

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-40

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP2.6
P50 (6% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

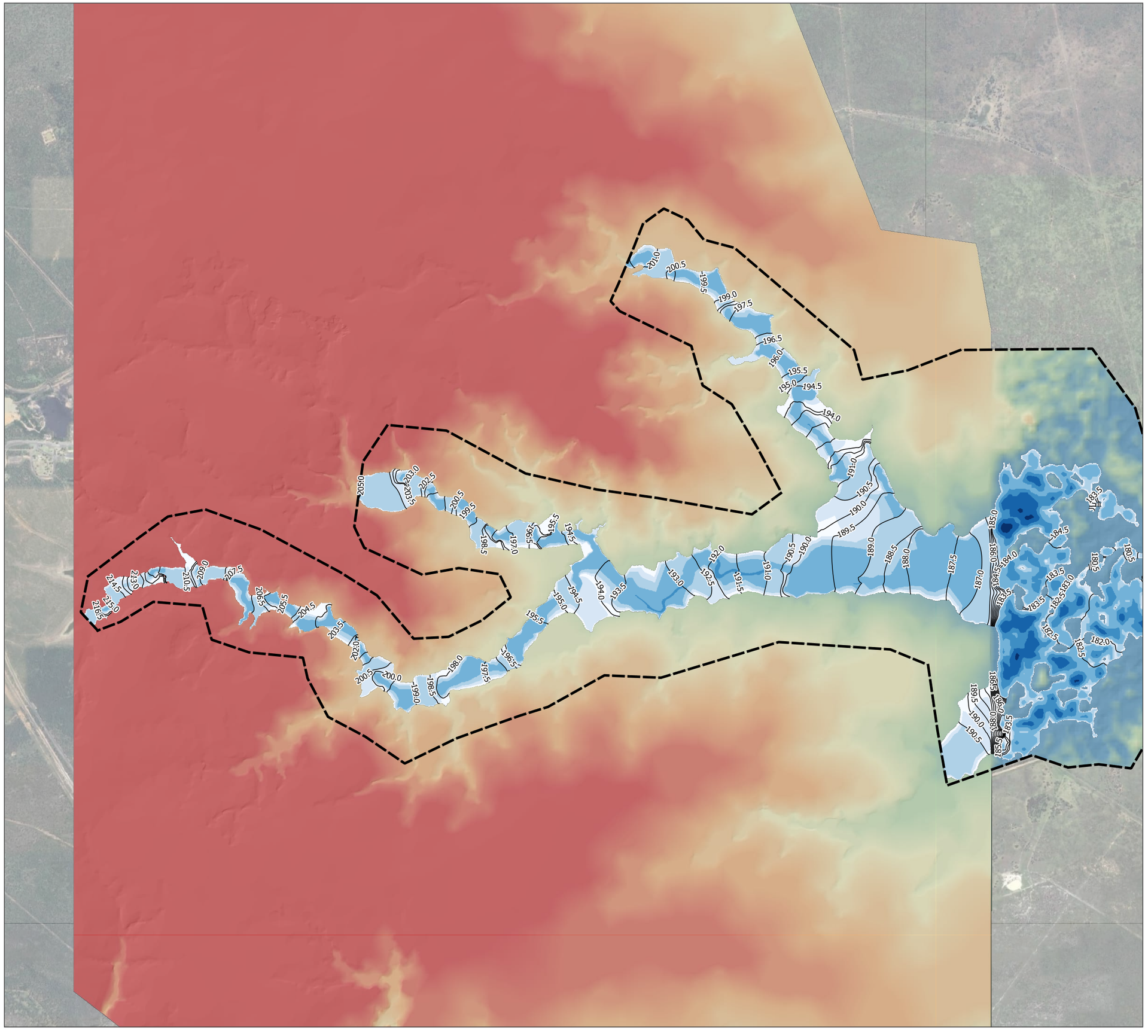
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-41

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

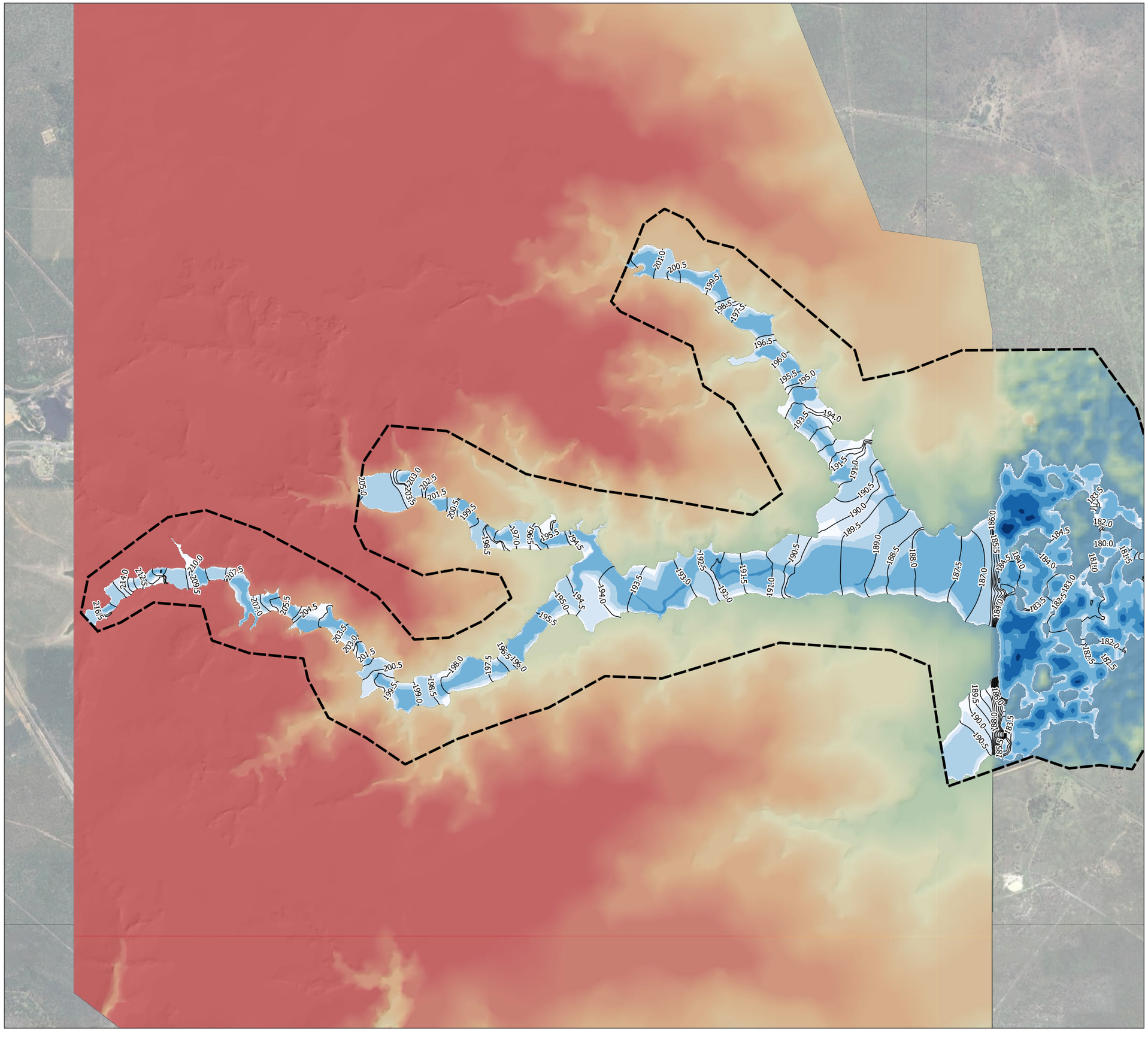
Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km



WMS

CIVIL | WATER | ENVIRONMENT

Appendix D-42

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 185
- 210

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

APPENDIX E

FLOODING RISK PROFILE

Risk Title	MFL Impacts					MFL	Control	Control Description	Control Owner	Control Purpose	Likelihood	Residual Severity					Severity Factor	RRR	Actions	Accountability
	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				
Stephens Creek																				
Lotus/Campbell Pit and Gilbert Pit floodwater ingress from Stephens Creek in the PMF.	1	3	3	3	1	3	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Contact with landform at several locations.	1	2	1	2	1	2	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Scotts Creek																				
Gilbert and Price Pit floodwater ingress from Scotts Creek in the PMF.	1	3	3	3	1	3	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Contact with landform at several locations.	1	2	1	2	1	2	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Downs Creek																				
Lotus/Campbell Pit floodwater ingress from Downs Creek in the PMF.	1	3	3	3	1	3	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Contact with landform at several locations.	1	2	1	2	1	2	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Decrease of flows downstream of the site compared to pre-mining conditions.	1	2	2	2	2	2	MFL less than 4 so no controls required	N/A	N/A	N/A	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Rolf Creek																				
East Pit floodwater ingress from Rolf Creek in the PMF.	1	3	3	3	1	3	Reconfiguration of Landform Design to prevent ingress	Design Adjustment	BMA	preventative control	0.03	1	1	1	1	1	10	0.3		
Roper Pit floodwater ingress from Rolf Creek in the PMF.	1	3	3	3	1	3	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Contact with landform at several locations.	1	2	1	2	1	2	MFL less than 4 so no controls required	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Decrease of flows downstream of the site compared to pre-mining conditions.	1	2	2	2	2	2	MFL less than 4 so no controls required	N/A	N/A	N/A	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A		

All risks considered "emerging risk: as associated with future development, therefore no critical controls are required.

BHP

Saraji South Mine

Previously known as Norwich Park Mine

Progressive Rehabilitation and Closure Plan

Environmental Geochemical Characterisation and Risk Assessment of Mineral Waste

23 May 2024

Final Rev 0.

Authors

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EXECUTIVE SUMMARY

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials associated with Saraji South Mine (SSM)[1], as supporting information for the progressive rehabilitation and closure plan (PRCP) for SSM.

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at SSM 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.

SSM administration area is located approximately 22 kilometres (km) south of Dysart township. The northernmost part of the mine is located approximately 2.5 km east of Dysart; and the mine extends approximately 31 km south. The northernmost pit at SSM (Lotus Pit) is located approximately 6.5 km south of Saraji Mine, which is operated by BHP Mitsubishi Alliance Pty Ltd (BMA). SSM is flanked on the east and west by pastoral leases, and by Dysart township to the northwest of the mine. SSM commenced operations in approximately 1979. Between 2012 and 2021 the site was inactive.

SSM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facility (TSF), stockpiles, raw water dams, surface water drains and administration areas. The coal handling and preparation plant (CHPP) has been decommissioned and, since 2021 (when SSM re-commenced mining), all run-of-mine (ROM) coal processing is now undertaken at Saraji Mine. Tailings and rejects from the Saraji Mine CHPP are disposed at Saraji Mine – and rehabilitation of these rejects and tailings are addressed under the Saraji Mine PRCP.

The southern area of the site comprising Roper pits, Old Tailings Dam (OTD) TSF, rejects disposal areas, Murphy's Dam and Little Murphy's Dam – and low-wall spoil dumps located in the vicinity of Roper pits – has been excluded from this Waste Characterisation report as directed by BMA, pending further technical investigation of this area. Due to the reasonable uncertainty around the final landforms and final voids within this area (herein called the Roper Study Area), the relevant waste characterisation assessment of the Roper Study Area has not been undertaken in this report. Upon completion of the required additional technical studies within the Roper Study Area, finalisation of the waste characterisation assessment will occur in line with proposed rehabilitation and closure milestones.

Current activities of relevance to this waste characterisation report comprise:

- Current and historic disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Short-term storage of ROM coal on pads near the ramp heads;
- The operation of raw water dams and sediment control structures as stipulated in the EA.

The mine domains of direct relevance to mineral waste characterisation and management at SSM at closure are:

- Pits (grouped as per the five residual voids):
  - Lotus-Campbell pit;
  - Gilbert pit;
  - Price-Leichhardt pit;
  - East North pit; and
  - East South pit.

  East North and East South pits are proposed (approved) pits that have not commenced mining/operation.

1 SSM was previously known as Norwich Park Mine (NPM).

- Spoil dumps (grouped as per the five residual voids and associated spoil landforms):
  - Lotus-Campbell dump;
  - Gilbert dump;
  - Price-Leichhardt dump;
  - East North dump; and
  - East South dump.

  East North and East South pits are proposed (approved) pits that have not commenced mining/operation – hence East North and East South dumps currently don't exist.
- Coal stockpiles: ROM coal pads and stockpiles.

Excluding tailings and rejects disposed in the Roper Study Area, SSM has one predominant type of mineral waste (spoil), and the geochemical characteristics and potential hazards associated with spoil is discussed.

Spoil (overburden and interburden) includes weathered waste (Tertiary and Permian-age – in approximately equal proportions) and fresh (unweathered) waste (all Permian-age). Based on highwall drilling data at each pit, weathered/oxidised materials comprise a significant proportion of spoil – ranging from approximately 15% to over 50% of spoil – and the proportion of weathered to fresh varies from pit to pit.

A very small quantity of rejects (conservatively estimated at up to 20,000 m^3 [0.02 Mm^3]) have been used to create two 'ramp head' ROM pads at the northern end of the site. These ROM pads are located within the Lotus-Campbell spoil landform and, prior to or during closure, will be covered by spoil. Although comprising a negligible proportion of the Lotus-Campbell landform (conservatively estimated to comprise less than 0.01% of the landform), rejects are discussed in this assessment to provide context.

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 dump, and remnant coal exposed on pit highwalls (such as in residual voids).

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 Mineral Waste and Coal Material Types

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 sedimentary materials in the Bowen Basin.

Based on the results, non-carbonaceous spoil has a generally low potential to generate AMD as either AD and/or NMD and/or SD. A small proportion of non-carbonaceous spoil does have a higher potential to generate AMD (as AD, NMD and/or SD), however when mixed and distributed amongst the broader spoil material the overall potential for non-carbonaceous spoil to generate AMD is assessed to be low.

The total sulphur (S) concentration of non-carbonaceous spoil is low, with a 90th percentile total S concentration of 0.26%. As such, and combined with moderate to high acid neutralising capacity (ANC) values (median 25 kg H_2SO_4/t), approximately 91% of non-carbonaceous spoil samples tested were classified as non-acid forming (NAF), with a further 2% of samples classified as UC(NAF) [uncertain, but expected to be NAF] or NAF-S [NAF, but with total S greater than 1%].

Eight per cent 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 or PAF-LC]. Most of the non-carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-70% available under field conditions, with iron-dolomite being the main carbonate mineral 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 101 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. However, almost half of the samples tested were moderately to significantly enriched in selenium (Se) and a smaller number in arsenic (As). There was no clear correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment, however most of the samples with higher levels of enrichment generally had moderate to high(er) total S and, in most cases, were classified as 'PAF' of some type. 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 105 non-carbonaceous samples) indicate that leachate from this material is expected to contain low concentrations of soluble metals and metalloids. Four samples (out of 105 samples) all classified as PAF – produced moderate to high soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of aluminium (Al), barium (Ba), cobalt (Co), iron (Fe), manganese (Mn), nickel (Ni) and/or zinc (Zn). Peroxide leaching undertaken on 13 non-carbonaceous spoil samples showed that 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 SSM 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.

Based on the results, most carbonaceous spoil has a generally low to moderate potential to generate AD and/or NMD and/or SD. Some carbonaceous spoil – mostly 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-moderate, with a 90th percentile total S concentration of 0.83% (from 202 samples). Thirteen samples had high total S concentrations (S>1.5%) and of these 13 samples, 12 were classified as PAF. The remaining sample was classified as UC(NAF).

Approximately 78% of carbonaceous spoil samples were classified as NAF, which includes 6% of samples classified as UC(NAF). The remaining samples were classified as PAF, PAF-LC or UC(PAF). All carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC in these samples is expected to be about 30-60% available under field conditions, with iron-dolomite being 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 35 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. However, most carbonaceous spoil samples were moderately to significantly enriched in Se and a small number in As. Similar to non-carbonaceous spoil, there was no clear correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment. In summary, carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 35 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 35 samples, 33 had low soluble metal and metalloid concentrations and two samples had moderate soluble metal and metalloid concentrations. Peroxide leaching undertaken on seven fresh carbonaceous spoil samples classified as PAF shows that these 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 Aged Rejects

Aged rejects is expected to generate near-neutral contact water (run-off and seepage).

Based on the results, most aged rejects have a low-moderate potential to generate AMD. A minority of the samples tested have a moderate to high potential to generate AMD as either AD and/or NMD and/or SD. Outside of the Roper Study Area, rejects are only found in the Lotus-Campbell spoil landform and will comprise less than 0.01% of the final landform.

Aged rejects generally have low to low-moderate total S and ANC values, resulting in 53% of aged rejects samples (24 out of 45 samples) being classified as NAF or UC(NAF). Twenty (out of 45 rejects) samples were classified as UC(PAF) and one sample was classified as PAF-LC.

There is a level of uncertainty surrounding the AMD classification of 28 rejects samples (about 62% of rejects samples) and, as such, most of these 'uncertain' samples were tentatively classified as UC(PAF) [and the remaining classified as UC(NAF)] based on our geochemical understanding of a much larger dataset of coal rejects samples from ROM coal from these same seams at Saraji Mine. Despite this potential shortcoming, the classification of the rejects samples is conservative and classifying approximately 47% of rejects samples as PAF (to some degree) is almost certainly an upper limit. The generally low sulphur concentrations in rejects samples indicate that the sulphate loads from sulphide oxidation would likely be low.

The test-work undertaken has demonstrated that the ANC in rejects samples is expected to be about 40-60% available under field conditions – similar to carbonaceous spoil. Iron-dolomite is expected to be the main carbonate mineral contributing to the acid buffering potential of rejects. Overall, rejects samples have modest acid neutralising capacity.

The total metal and metalloid concentrations from nine aged rejects samples are generally low compared to average element abundance in soil in the earth's crust. All nine samples had significant enrichment with regard to Se and three samples had significant enrichment with respect to As. Two samples had significant enrichment with respect to S, which was consistent with the geochemical data. There was no correlation found between AMD classifications of the rejects samples compared to elemental enrichment. In summary, rejects has generally low enrichment in total metals and metalloids compared to unmineralised rocks – similar to carbonaceous spoil.

Solubility data indicates that leachate from rejects under freshwater (deionised water) is expected to contain low to moderate concentrations of soluble metals and metalloids. Peroxide leaching undertaken on two UC(PAF) and one PAF-LC rejects samples showed that rejects samples produced moderately to weakly acidic leachate with high soluble metals and metalloid concentrations. The results indicate that PAF rejects, when oxidised, have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

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 7% of all lithological material at SSM (i.e. about 7% 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. 1-2% at the most). ROM coal is processed at Saraji Mine and rejects and tailings generated from SSM ROM coal is disposed at Saraji Mine.

Based on the results, and as a bulk material, ROM coal is assessed as having a moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal would have a moderate to 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).

The total S concentration of coal is generally low-moderate and approximately 35% (median value) of the total S is present as sulphide. Coal samples have a wide range of ANC values, however the median ANC is low. As such, 51% of coal samples were classified as NAF, NAF-S or UC(NAF) and the remaining 49% of samples classified as PAF, PAF-LC or UC(PAF). Coal samples classified as PAF, PAF-LC or UC(PAF) were from all seam groups,

however the Harrow Creek (upper and lower) and Dysart (upper and lower) seam groups currently and historically comprise all of the coal mined at SSM.

Assay data for 23 coal samples show that the total metal and metalloid concentrations are generally low compared to average element abundance in soil in the earth's crust. Some samples were significantly enriched in one or more of As, mercury (Hg) and/or Se and two samples had significant enrichment with respect to S, which was consistent with the geochemical data.

Soluble multi-element results from 25 coal samples tested indicate that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids.

Salinity, Sodicity and Dispersion Potential of Potential Spoil, Rejects and Coal

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has median and 90th percentile $EC_{1:5}$ values (from 1256 samples) of 310 and 802 microSiemens per centimetre (µS/cm), 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).

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 15% of the samples displayed some degree of dispersion, with the remaining bulk of the samples classified as non-dispersive.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has median and 90th percentile $EC_{1:5}$ values (from 241 samples) of 271 and 575 µS/cm, and has very 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 modest CEC values and generally high ESP values comparable to non-carbonaceous spoil, resulting in most samples being 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. All samples underwent Emerson aggregate class testing to directly measure dispersion, which found that all samples were non-dispersive – indicating that despite being sodic (to some degree) sodic, carbonaceous spoil is not expected to be highly dispersive.

Salinity Potential of Aged Rejects

Aged rejects has median and 90th percentile $EC_{1:5}$ values of 1850 and 2420, respectively. On this basis, contact water (run-off and seepage) from most rejects is expected to be moderately saline to saline (>900 µS/cm). Most rejects have low-moderate total S concentrations, therefore the potential for SD (from sulphide oxidation) is low to low-moderate.

Salinity Potential of Coal

Coal has median and 90th percentile $EC_{1:5}$ values of 131 and 569 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, 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 (ability/likelihood; based on the proportion of NAF

vs PAF samples), the AMD capacity (severity; conservatively based on the 75th percentile total S value for the PAF, PAF-LC, UC(PAF) and NAF-S samples) and the quantity (volume) 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 = **Low-Moderate**
- Rejects: AMD source hazard score = **Low-Moderate**
- Coal: AMD source hazard score = **Moderate**

When combined, and taking into account the proportion of 'PAF' material of each type relative to the total proportion of all materials in a final landform and the residual voids, the AMD hazard score for the landforms, void highwalls and void floors at closure has been determined.

Spoil landforms

There are five spoil landforms at SSM that will remain at closure:

- Lotus-Campbell;
- Gilbert;
- Price-Leichhardt;
- East North; and
- East South.

Each landform has 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. East North and East South landforms are very small – only about 10% of the size of each of the other three landforms.

A very small quantity of rejects are currently located at the head of Ramps 54 and 55 within Lotus-Campbell landform and serve as temporary ROM pads. At closure, these rejects will be buried by spoil as part of landform reshaping – and will comprise less than 0.01% of the final Lotus-Campbell spoil landform. No rejects or tailings are disposed within any other landform outside of the Roper Study Area.

Taking into account material quantities (proportions), all spoil landforms pose a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.

Residual voids

There are five open pits at SSM that will remain at closure as residual voids [void dimensions shown are indicative]:

- Lotus-Campbell: approximately 9.2 km long and 110 m deep (at closure);
- Gilbert: approximately 3.7 km long and 100 m deep (at closure);
- Price-Leichhardt: approximately 6.1 km long and 200 m deep (at closure);
- East North: approximately 1.5 km long and 85 m deep (at closure); and
- East South: approximately 1.0 km long and 50 m deep (at closure).

At closure, the floor of Lotus-Campbell and Gilbert residual voids will be the Dysart Lower (DL) seam group, which is currently the floor of each of these pits. The floor of the middle and southern sections of Price-Leichhardt residual void (i.e. the Leichhardt pit) will also be DL seam group (DL seam is the current floor). The floor of northern end of Price-Leichhardt residual void (i.e. Price pit) will be the Harrow Creek (HC) Lower seam group (currently the floor of this pit; noting also that no further mining is proposed for Price pit). The floor of East (North and South) residual voids will be the HC Upper seam group – noting that East pits have not begun mining (i.e. the pits currently don't exist, however these two small pits are approved under the EA and, therefore, are part of the PRCP).

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD risk associated with residual void highwalls and floors.

The residual void highwall assessment found that approximately 8% to 12% of the void highwall in all voids is estimated to be PAF, which includes material classified as UC(PAF) and PAF-LC. As such, the assessment has found that AMD generation from the void highwalls is **Unlikely**.

The residual void floor assessment found that approximately 9% of the floor of the Lotus-Campbell, Gilbert and the 'Leichhardt pit' end of the Price-Leichardt void, is estimated to be PAF [which includes material classified as UC(PAF) and PAF-LC]; approximately 35% of the floor of the 'Price pit' end of the Price-Leichardt void is estimated to be 'PAF'; and approximately 38% of the floor of the East voids (combined) is estimated to be 'PAF'. As such, the void floor assessment has found that AMD generation from the floor of all voids is **Probable/Likely** until such time that the floor becomes submerged by groundwater (post-closure).

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 the final spoil landforms and the residual voids with respect to plausible surface water and groundwater receptors.

Conceptual site model

A post-mining conceptual site model (CSM), which applies generically to the spoil landforms and their respective residual voids at SSM, and the relationship that spoil landforms and residual voids have with surface water and groundwater in the district, has been produced by SLR (2024).

The CSM assists with the SPR assessment with regard to potential environmental geochemical impacts from mineral waste facilities.

Plausible pathways and receptors

Note: the assessment of shallow groundwater at SSM – 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. Thus, with regard to the five 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 creeks (various creeks, depending on the proximity of creeks to the landform);
- Seepage from the spoil landforms via shallow permeable strata into creeks (various creeks, depending on the proximity of creeks to the landform);
- Seepage from the spoil landforms into the residual voids; and
- Surface water run-off and seepage from void highwalls 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* from 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 and/or local surface water features.

SPR risk rating of final 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**.

SPR risk rating of residual voids

The final 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 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**.

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2024) shows that seepage from the void lake (of each void) into groundwater, if any, would be limited.

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 mineral wastes 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). 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:
    - Lotus-Campbell void;
    - Gilbert void;
    - Price-Leichhardt void;
    - East North void; and
    - East South void.
- Spoil dumps: will be reshaped into five final spoil landforms (corresponding to the five residual voids listed above) and seeded.
- Ramp head ROM pads (comprising rejects) are located within the Lotus-Campbell spoil landform footprint. These pads will be covered by spoil and become part of the Lotus-Campbell spoil landform.
- Main ROM pad: Remove remnant coal from the ROM Pad and dispose within spoil. The former ROM Pad will be reshaped, covered with soil, ripped and seeded.
- Coal stockpile: Remove remnant coal from the coal stockpile pad 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.
CFM	Conceptual facility model.
CHPP	Coal handling and preparation plant. The CHPP at SSM was decommissioned in 2012 and has since been dismantled. All ROM coal from SSM is trucked to Saraji Mine for processing at the Saraji Mine CHPP.
Co-Disposal	The practice of disposing different waste types together. For example, disposing coarse reject amongst spoil.
CSM	Conceptual site model.
EC	Electrical conductivity, expressed as µS/cm.
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.
NPM	Norwich Park Mine. The previous name of the site subject to this PRCP. Now called SSM.
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.
OxCon	Oxygen consumption test. A type of kinetic (dynamic) test for estimating the sulphide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological materials.
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 a 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. SSM ceased producing rejects in 2012. Rejects historically produced at SSM are primarily disposed within disused ramps in the Roper Study Area. A small proportion of rejects have been used in construction activities, such as TSF embankments and used for capping/construction of pads.
ROM	Run-of-Mine. The term given to mined coal before being processed at a CHPP.
ROM pad	Location where ROM coal is temporarily stored pending processing at a 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 dump	In-pit or out-of-pit landform containing mineral waste.
SPR	Source-pathway-receptor.
SRM	Saraji Mine. A coal mine operated by BMA and located north of SSM.
SSM	Saraji South Mine. The name of the site subject to this PRCP.
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. SSM ceased producing tailings in 2012. Historic tailings produced at SSM are disposed within Tailings Storage Facilities (TSFs – also called tailings dams).
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 SSM, tailings are located in OTD TSF and Ramp 67 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.
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 associated with Saraji South Mine (SSM) [previously known as Norwich Park Mine (NPM)]. The management of mineral waste at SSM is defined under the current Environmental Authority (EA) EPML00865013, held by BHP Mitsubishi Alliance (BMA). In this report the term 'mineral waste' refers to all geologic material generated by or associated with SSM during the course of mining, handling and processing coal.

It is a requirement of a Progressive Rehabilitation and Closure Plan (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 SSM 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 SSM 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

SSM is located within the Bowen Basin in Central Queensland. The mine administration area is located approximately 22 kilometres (km) south of Dysart township. The northernmost part of the mine is located approximately 2.5 km east of Dysart; and the mine extends approximately 31 km south. The northernmost pit at SSM (Lotus Pit) is located approximately 6.5 km south of Saraji Mine, which is operated by BHP Mitsubishi Alliance Pty Ltd (BMA). SSM is flanked on the east and west by pastoral leases, and by Dysart township to the northwest of the mine. SSM commenced operations in approximately 1979.

SSM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facility (TSF), stockpiles, raw water dams, surface water drains and administration areas. The site used to have a coal handling and preparation plant (CHPP), but this has been decommissioned and all run-of-mine (ROM) coal processing is now undertaken at Saraji Mine [and tailings and rejects from the Saraji Mine CHPP remain at Saraji Mine]. The key facilities and natural features at SSM 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:

- Current and historical disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Short-term storage of ROM coal on pads near the ramp heads.

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.

2.1.1 PRCP Roper Study Area

The southern area of the site comprising Roper pits, Old Tailings Dam (OTD) TSF, rejects disposal areas, Murphy's Dam and Little Murphy's Dam – and low-wall spoil dumps located in the vicinity of Roper pits – has been excluded from this Waste Characterisation report, pending further technical investigation of this area. As these investigations cannot be completed by BMA within the PRCP notice period, BMA has implemented a Roper Study Area (**Figure 1)**. Refer to the main volume of the PRCP for detailed information. Due to the reasonable uncertainty around the final landforms and final voids within the Roper Study Area, the relevant waste characterisation assessment of the Roper Study Area has not been undertaken in this report. Upon completion of the required additional technical studies within the Roper Study Area, finalisation of the waste characterisation assessment will occur in line with proposed rehabilitation and closure milestones.

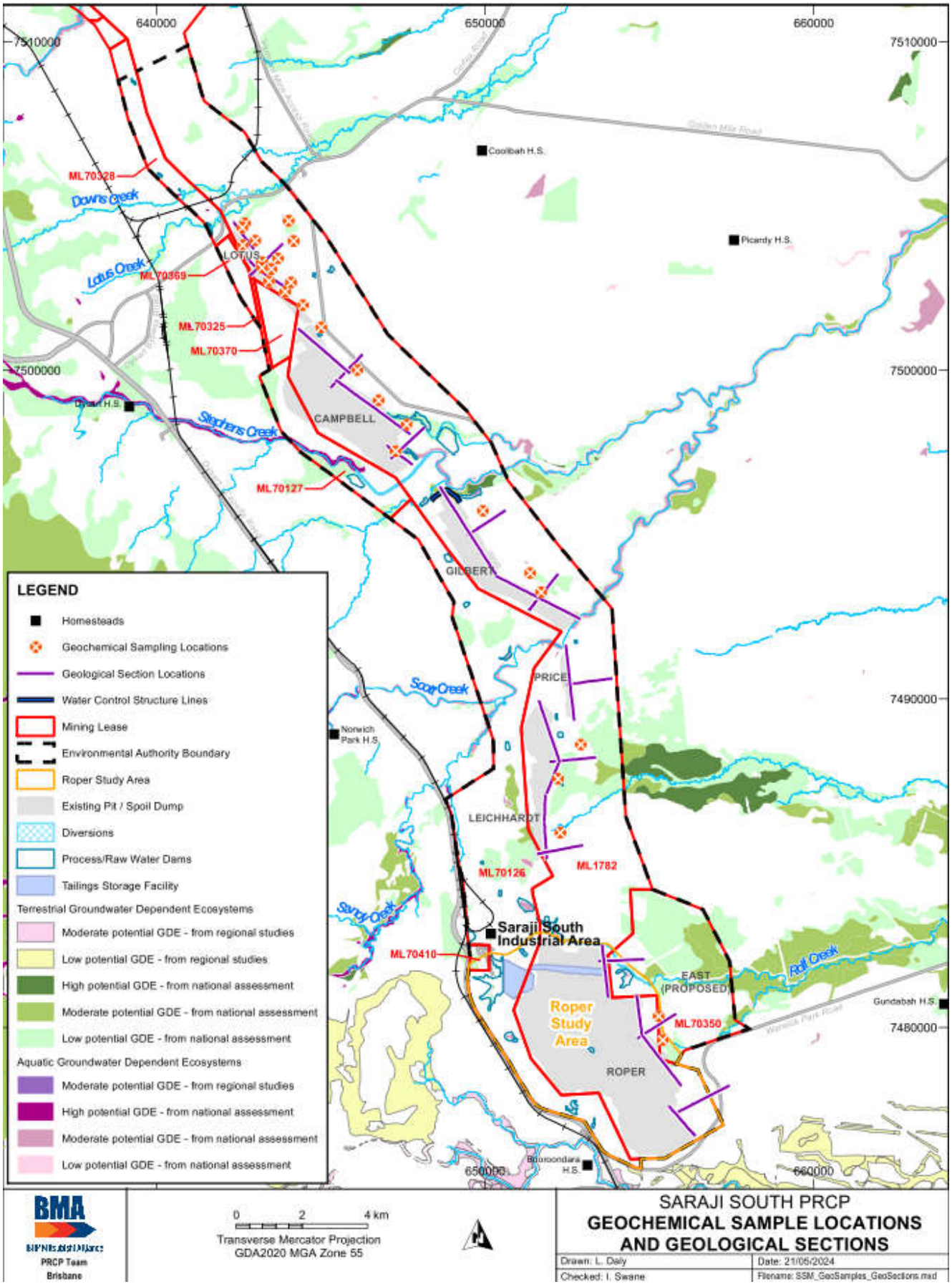


Figure 1. Project layout, geochemical sample locations and locations of geological sections

2.2 Mine Domains

The mine domains of direct relevance to mineral waste characterisation and management at SSM (excluding those areas within the Roper Study Area) are:

- Residual voids (pits remaining at end of mine life):
    - Lotus-Campbell residual void;
    - Gilbert residual void;
    - Price-Leichhardt residual void;
    - East North residual void;
    - East South residual void.

  East North and East South pits do not currently exist – they are proposed pits (future mining areas) under the current EA.

  The rehabilitation and closure of Roper Pit is currently excluded from the PRCP (and this waste characterisation report), as explained in **Section 2.1**.

- Spoil landforms:
    - Lotus-Campbell spoil landform;
    - Gilbert spoil landform;
    - Price-Leichhardt spoil landform;
    - East North spoil landform;
    - East South spoil landform.

  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.

  The rehabilitation and closure of Roper spoil dumps are currently excluded from the PRCP (and this waste characterisation report), as explained in **Section 2.1.1**.

- Coal stockpiles: ROM coal pads and stockpiles. ROM coal is temporarily stockpiled at ramp heads pending transfer to Saraji Mine for processing.

2.2.1 Material Types and Quantities

Excluding tailings and rejects disposed in the Roper Study Area, SSM has one predominant type of mineral waste (spoil), and the geochemical characteristics and potential hazards associated with spoil is discussed.

Spoil (overburden and interburden) includes weathered waste (Tertiary and Permian-age – in approximately equal proportions) and fresh (unweathered) waste (all Permian-age). Based on highwall drilling data at each pit, weathered/oxidised materials comprise a significant proportion of spoil – ranging from approximately 15% to over 50% of spoil – and the proportion of weathered to fresh varies from pit to pit. Therefore, weathered/oxidised materials comprise a significant proportion of spoil.

A very small quantity of rejects (conservatively estimated at up to 20,000 m^3 [0.02 Mm^3]) have been used to create two 'ramp head' ROM pads at the northern end of the site. These ROM pads are located within the Lotus-Campbell spoil landform and, prior to or during closure, will be covered by spoil. Although comprising a negligible proportion of the Lotus-Campbell landform (conservatively estimated to comprise less than 0.01% of the landform), rejects are discussed in this assessment to provide context.

Coal is also included in the assessment; however, it is understood that coal is generally not considered mineral waste. Coal is primarily representative of ROM coal, however is also representative of potential waste coal from sub-economic seams and remnant coal exposed on pit highwalls (such as in final voids).

Excluding the very small quantity of rejects in the Lotus-Campbell area, rejects and tailings generated by historical ROM coal processing at SSM (from the old CHPP) are essentially all disposed within the Roper Study Area and, as such, are excluded from this waste characterisation report.

2.3 Baseline Information

2.3.1 Topography

The regional topography of the Bowen Basin is dominated by flat to gently sloping landforms and low rolling hills. Topography at SSM is relatively subdued, with an average elevation of approximately 200 m Australian Height Datum (AHD). The eastern flanks of the Harrow Range west of the site rise to approximately 450 m elevation. At the Isaac River, approximately 20 km northeast of SSM, the elevation is approximately 190 mAHD. The slopes associated with the Harrow Range contrast with the extensive flat areas along the base of the valley where SSM is located.

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 SSM.

SSM 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). The nearest Bureau of meteorology weather stations are located at Dysart township (data from 1988 to 2006) and Booroondarra, located at the southern extent of SSM (data from 1929 to present).

Median maximum temperatures range from approximately 24°C in June/July to approximately 34°C in December/January, with minimum temperatures ranging from approximately 9°C in July to approximately 22°C in January. The average annual rainfall and 'actual evapotranspiration' are approximately 2380 and 1030 mm per year, respectively (the 'potential evapotranspiration' is estimated at 2385 mm/year). The average potential monthly evapotranspiration exceeds the average monthly rainfall over the entire year, often by more than double. 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

SSM is located on the western limb of the northern Bowen Basin, and is characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation. The lithology at SSM is characterised by typical basin-fill sediments, comprising mudstone, claystone, siltstone, sandstone (typically fine- to medium-grained), carbonaceous sediments and coal seams. Igneous intrusions are present as dykes and sills throughout the site. The depth to base of weathering ranges from about 15 to 25 m below natural surface in the northern half of the site (north of Leichhardt Pit) to about 25 to 50 m below natural surface in the southern half of the site (Leichhardt Pit and further south).

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 SSM are the late Permian-age German Creek Formation (GCF) and contemporaneous equivalent Moranbah Coal Measures (MCM), with the facies change between the GCF and MCM located approximately at Lotus/Campbell Pit area. As such, most of SSM is within the GCF. The site comprises the following seam groups in stratigraphic order, from youngest to oldest:

- P seam group [minor upper seams; mostly in the weathered zone; potentially only encountered in late-stage mining below base of weathering in Gilbert, Price and Leichhardt pits];
- Harrow Creek Upper (HCU) seam group [also called Aquila and Tieri seams];
- Harrow Creek Lower (HCL) seam group;
- Dysart seam group, comprising Dysart Upper (DU) and Dysart Lower (DL) seams.

Seam splitting is prevalent along the length (north-south) of all pits. Non-mined seams below the main Dysart seam group include the DLL group.

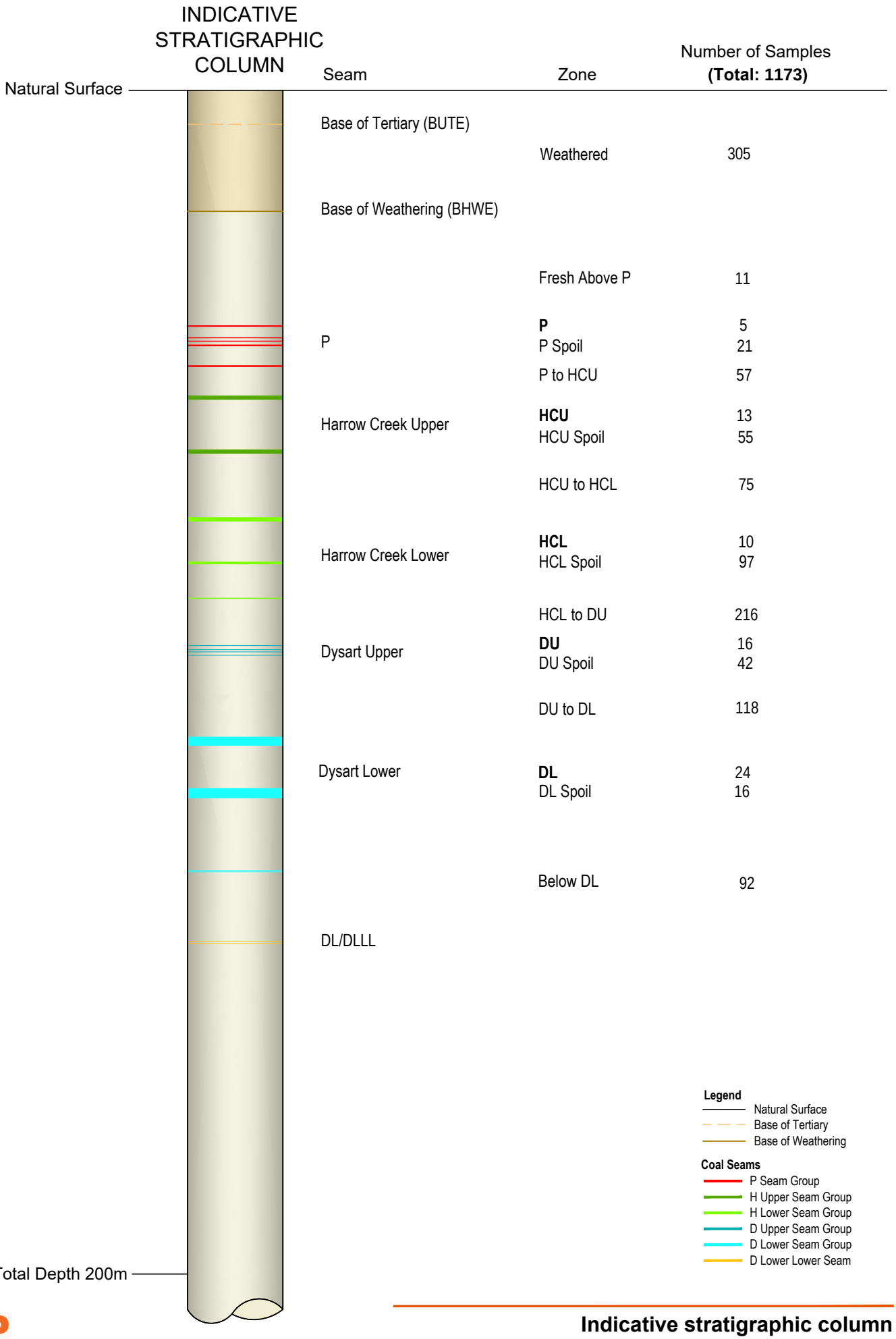
Overlying the GCF/MCM at SSM is the late Permian-age Macmillan Formation – a transgressive marine unit within the weathered zone at SSM, and comprised of fine-grained weathered mudstone/siltstone sediments. The late Permian-age Fort Cooper Coal Measures also overly the MCM and sub-crop east of SSM (i.e. not present at SSM).

To date, all of the coal mined at SSM has been from the HCL and Dysart seam groups. As mining progresses eastwards (down-dip) the HCU seam group will become more prevalent. The P seam group is currently well within the weathered zone and may only be mined from fresh rock towards the latter years of mining.

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) along the current highwall of the pits are provided at **Attachment A – Figures A1 to A5**. Geological cross-sections (indicatively west-east) through the pits (including current topography) are provided at **Attachment A – Figures A6 to A9**. Refer to **Figure 1** for section locations. The seam groups are shown in the geological sections. Although the Roper Study Area is excluded from this assessment, geological sections are provided for Roper pit to provide context for the proposed East pits/voids, since the East pits are directly down dip of Roper pit and will be mining the same overburden and seams as Roper pit down to the base of the HC Upper seam group.

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 long- and cross-sections in **Attachment A**.



BHP

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Indicative stratigraphic column

Figure **2**

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 at SSM.

The catchment for the SSM watercourses begins in the Harrow Range west of SSM and flows downstream to meet the Isaac River (part of Fitzroy basin) approximately 20 km northeast of SSM, with an overall easterly to north-easterly gradient of less than 1%.

All watercourses and tributaries within and in the vicinity of SSM are highly ephemeral and only flow briefly after rainfall. The creeks at SSM, which transverse the site from generally west to east (excluding Back Creek), are shown on **Figure 1** and include:

- Lotus/Downs Creek transverses the site at the northern edge of Lotus landform and pit;
- Stephens Creek transverses the site between Campbell landform/pit and Gilbert landform/pit;
- Scott Creek transverses the site between Gilbert landform/pit and Leichhardt landform/pit. Scott Creek flows into Stephens Creek approximately 7.5 km east of the ML boundary;
- Back Creek commences in the highwall area of Leichhardt void and flows east for about 14 km before flowing into Rolf Creek;
- Rolf Creek flows from the site between Leichhardt landform/pit and Roper pit and from the highwall area of Roper pit, between East Pit North and East Pit South; and
- Roper Creek, which skirts the site at the southern ML boundary (south of Roper pit area).

Immediately to the west of the site some minor tributaries flow into these creeks. Sandy Creek flows into Scott Creek at approximately the western ML boundary. Yarraman Creek flows into Roper Creek just west of the ML boundary. Various un-named minor tributaries also flow into the main creeks west of the ML boundary.

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 at SSM.

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 basalt formations, 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 SSM 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 and basalt 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 SSM.

The coal seams within the Moranbah Coal Measures are the primary aquifer at SSM. The coal seams can be characterised as confined aquifers, with the Harrow Creek (HC) seam groups and Dysart (D) seam groups forming the main aquifer units locally. The overburden and interburden within the Moranbah Coal Measures act as aquitards and are typically dry or very low yielding.

The hydrogeological units at SSM comprise:

- Quaternary alluvium – unconfined aquifer (sporadically water-bearing strata of permeable unconsolidated sand or gravel) localised to major ephemeral drainage line channels at SSM along Downs Creek, Scott Creek and Rolf Creek;

- Quaternary to Tertiary non-alluvial sediments and weathered units (collectively termed 'regolith') – unconfined unit with limited saturation at SSM and nearby.
- Permian coal measures interburden and overburden units – low permeability sedimentary rock with aquitard properties; and
- Permian coal seams – exhibiting water bearing properties associated with secondary porosity through cracks and fissures.

Groundwater quality

The physico-chemical results from groundwater sampling at SSM indicate the water chemistry is typically pH-neutral for all geological formations. Groundwater associated with the Tertiary formation(s) have variable salinity levels (measured as electrical conductivity), ranging from relatively fresh to saline, but typically brackish – with salinity generally higher where groundwater is shallower (close to the surface around creek lines) and is influenced by low recharge coupled with long-term evapoconcentration. Groundwater within the deeper Permian formation (primarily coal seams) is typically brackish to saline.

Groundwater exhibits a wide chemical profile, though considered collectively (both Tertiary and Permian aquifers) it is not a suitable groundwater resource for drinking water or aquatic ecosystem protection – exceeding the water quality guidelines for freshwater ecosystems (ANZG, 2018; QWQG 2006) for many parameters.

The water quality from the monitoring wells located at and close to SSM indicates that, generally, the water is unsuitable for human consumption as assessed against the Australian Drinking Water Guidelines (HMRC-NRMMC 2011). Where groundwater is used (several kilometres from SSM) it is used primarily for livestock purposes owing to the variable salinity levels and generally low yields.

2.3.6 Potential Environmental and Human Health Receptors

A conceptual environmental geochemical model (source-pathway-receptor (SPR) model) for SSM 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 approximately 20 km northeast and downstream of SSM.

- The northern area of the site (Lotus-Campbell landform) drains to tributaries of Downs and Stephens creeks.
- In the central area, Gilbert landform drains to tributaries of Stephens and Scott creeks and Price-Leichhardt landform primarily drains to tributaries of Scott Creek. The southern side of the Price-Leichhardt landform drains to a tributary of Rolf Creek.
- East (South and North) landforms drain to Rolf Creek.
- [The Roper Study Area drains to Rolf Creek].

All of these creeks eventually drain into the Isaac River. SSM shares the Isaac River Catchment with several other coal mines upstream and downstream.

Potential groundwater receptors

Aquatic and terrestrial groundwater dependent ecosystems (from national assessment) are shown in **Figure 1**.

Potential domestic (human) receptors

The nearest homestead to SSM is Booroondara, located approximately 750m southwest of the southwestern corner of the ML boundary. The next closest homesteads are Dysart and Norwich Park homesteads, located on the western side of SSM about 4.5 km west of the ML boundary. These homesteads are all located upstream (via surface water) and upgradient (via groundwater) from SSM.

There are no homesteads located east of SSM within a 5 km distance of the ML boundary. The nearest infrastructure east of the ML boundary (apart from livestock dams) are Coolibah homestead (approximately 5.5 km east of Lotus Pit), Picardy homestead (~9.5 km east of Campbell Pit) and Gundabah homestead (~6.5 km east of East pits.

2.3.7 Acid and Metalliferous Drainage

Environmental geochemical information with regard to AMD from mineral waste materials at SSM 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 SSM 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 SSM.

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[2]; DIIS, 2016[3]). 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.

2 INAP, 2009. Global Acid Rock Drainage Guide.

3 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 and rejects (mineral wastes) and coal at SSM.

All tailings (and almost all rejects) at SSM are located in the Roper Exclusion Area and are excluded from this current assessment (refer to **Section 2.1.1**).

4.1 Information Review

Sampling and laboratory test-work has been undertaken by BHP and consultants throughout the development and operation of SSM. 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 have been collected from 34 drill-holes located throughout SSM (shown in **Figure 1**). Geochemical data is available from two drilling/sampling/analysis programs: a program in 2006 (508 samples) in the vicinity of Lotus pit, and a program in 2023 (1084 samples) throughout the entire site.

The drillholes are distributed along strike (approximately north-south) and, as such, intersect all mined geological units along the entire site – thus covering both the GCF and MCM units. At most drill-hole locations, sampling has been 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 SSM. No geochemical data is available specifically for East pit, however the geology at East pit (based on a review of exploration drill-holes) is consistent with the geology of the SSM at Roper pit and Leichhardt pit.

The SSM coal resource model provides an estimate of coal resources from current pit highwall through to the eastern extent of each pit. The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of the residual voids is consistent with the current proportions on the pit highwalls. The model also shows that the proportion of each seam group is expected to be similar to current seam group proportions on the highwall of the current pits. As such, the mineral waste types assessed, and their relative proportions, are representative of the mineral waste types and proportions expected to be present at closure.

Geochemical data comprising, at minimum, total S and ANC results, is available for 1173 drill-hole samples collected from 25 drill-holes. An additional 419 samples collected from the same 25 drillholes plus nine additional drillholes (i.e. 34 drill-holes) have pH and electrical conductivity (EC) results only. Geochemical samples (n=1173) collected and tested were sourced from the following key mineral waste domains:

- Weathered, non-carbonaceous spoil. 291 samples.
- Weathered, carbonaceous spoil, including weathered coal. 14 samples.
- Fresh, non-carbonaceous spoil. 612 samples.
- Fresh, carbonaceous spoil. 188 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. 68 samples.

All samples (n=1173) from the 2023 program were collected from core-drilling. The 508 samples from the 2006 program (of which, 419 samples had pH and EC data only) were a mix of drill-chip and drill-core. Drill-chip samples were typically collected at set intervals (e.g. every 1 or 2 m) or within targeted sampling zones. Drill-core 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.

Approximately half of the spoil samples were sampled close to seams – typically interburden or parting between plys of the same seam group or spoil samples collected within approximately 1.5m above or below seams. 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).

Rejects Samples – representing mid- to very coarse coal process waste

The ROM pads at the heads of Ramp 54 and Ramp 55 are the only rejects disposal areas within the scope of this assessment (i.e. outside of the Roper Study Area), and are constructed from 'aged' rejects sourced from site.

Geochemical data is available (within the geochemical database) for 45 'aged' rejects samples collected from test pits at the Ramp 68 (located within the Roper Study Area). These samples were logged as 'dry' to 'moist' at the time of collection. These rejects samples from Ramp 68 are deemed to be representative of 'aged' rejects that may be found at rejects disposal areas awaiting burial/rehabilitation across the site – such as rejects located at Ramp 54 and Ramp 55.

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 SSM, 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 pulped samples);
- 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].
    - 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).

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 in order 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 and peroxide (NAG) leaching methods. The deionised water leaches assess the initial solubility under fresh water conditions, whereas the peroxide leach assesses the solubility after the samples have been oxidised.

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 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.

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.

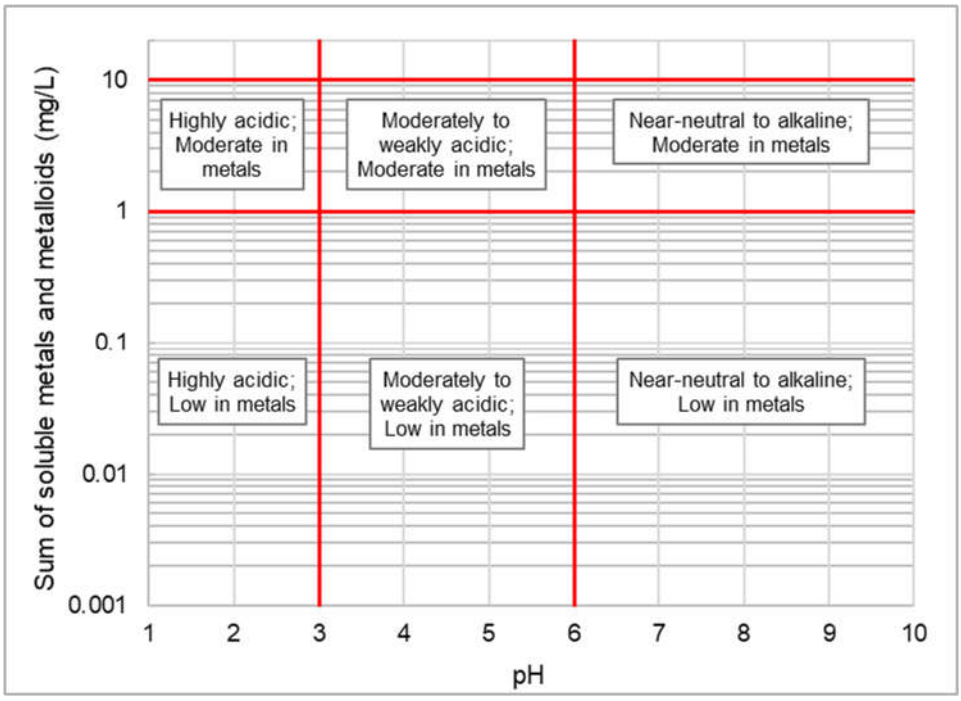

Figure 3. Classification of soluble metals and metalloids as a function of pH

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 HC Upper, HC Lower, 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 SSM and nearby Saraji Mine suggests that jarosite is an insignificant mineral within the Moranbah Coal Measures.

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 HC Upper 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 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.

The method described below was used for estimating the proportion of key material domains on the highwalls in each pit.

Exploration drill-holes in proximity to the current/recent highwall/s were selected by BHP Coal Geology Planners for each pit. The holes extended to depths approximating future pit floor depths. Lotus-Campbell pit group used data from 66 drillholes; Gilbert pit used data from 31 drillholes; Price-Leichhardt pit group used data from 83 drillholes; and East pits (North and South, combined) used data from three drillholes (noting that East pit is planned pit that currently doesn't exist).

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 (Tertiary);
- Weathered, non-carbonaceous (Permian);
- Weathered, carbonaceous [includes weathered coal];
- Fresh, non-carbonaceous;
- Fresh, carbonaceous;
- Fresh, coal.

Coal plys were grouped into their respective seam groups, such as HC Upper, HC Lower, etc.

For each pit group highwall, a statistical assessment was conducted on each drill-hole sub-set (as applicable to each pit group) 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.

The pit highwall AMD hazard assessment is based on data being representative of current and near-future mining (indicatively now to 10 years). The SSM coal resource model was used to estimate coal resources and overburden/interburden proportion from current pit highwall through to the currently approved extent of each pit.

The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of the residual voids is consistent with the current proportions on the pit highwalls. The model shows that the proportion of each seam group at closure is consistent with the current pit wall exposure estimates.

Therefore, the overall AMD hazard posed by the pit highwall and floor of the residual voids at end of mining is expected to be similar to that shown in the current highwalls and pits.

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 SSM, the seam groups forming the floor of each final void are as follows:

- HC Upper – East pits/voids (north and south);
- HC Lower – Price pit/void (i.e. the northern end of Price-Leichhardt void);
- DY Lower – all other pits/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.

4.4.4 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 scores 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 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 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 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 is rated as MODERATE for AMD capacity
	5	Moderate	Greater than 5% of material reporting to a landform is rated as LOW-MODERATE or MODERATE for AMD capacity
	7	Moderate-High	Less than 5% of material reporting to a landform is rated as MODERATE-HIGH or HIGH for AMD capacity
	10	High	Greater than 5% of material reporting to a landform is 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. 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 1173 samples at SSM that underwent geochemical characterisation, only three samples were classified as NAF-S (all three were coal samples).

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.

4.4.5 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, SSM has five residual voids and their associated five spoil landforms, as listed in **Section 2.2**.

- **Spoil 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. Note that three samples (out of 1173 samples in total) were classified as NAF-S. As such,

the proportion of NAF-S samples in spoil dumps is insignificant relative to other NAF samples [NAF and UC(NAF)] and PAF samples.

- **Residual voids**: the landform AMD hazard score 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.

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

For landforms (including pits) with AMD hazard scores greater than 10, a conservative likelihood of 'Likely' should initially be assigned if no 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.

5 Results

Environmental geochemical data is available for 1105 overburden/interburden (spoil) samples, 68 coal samples and 45 '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. 291 drill-hole samples;
- Weathered Carbonaceous: Weathered carb. overburden [includes weathered coal]. 14 drill-hole samples;
- Fresh, Non-carbonaceous: Fresh non-carbonaceous overburden/interburden. 612 drill-hole samples;
- Fresh, Carbonaceous: Fresh carbonaceous overburden/interburden. 188 drill-hole samples.

Coal

- Fresh Coal: Fresh coal, broadly representative of ROM coal. 68 drill-hole samples.

Rejects

- Aged rejects: Rejects sampled from test pits at Ramp 68 and representative of rejects that have been on site for many years. 45 samples.

5.1 Mineralogy

Mineralogical analysis by Quantitative X-Ray Diffraction (QXRD) is available for 51 spoil samples and one coal sample. The results are summarised in **Figure 4** for non-carbonaceous spoil samples and **Figure 5** for carbonaceous spoil samples plus the single coal sample.

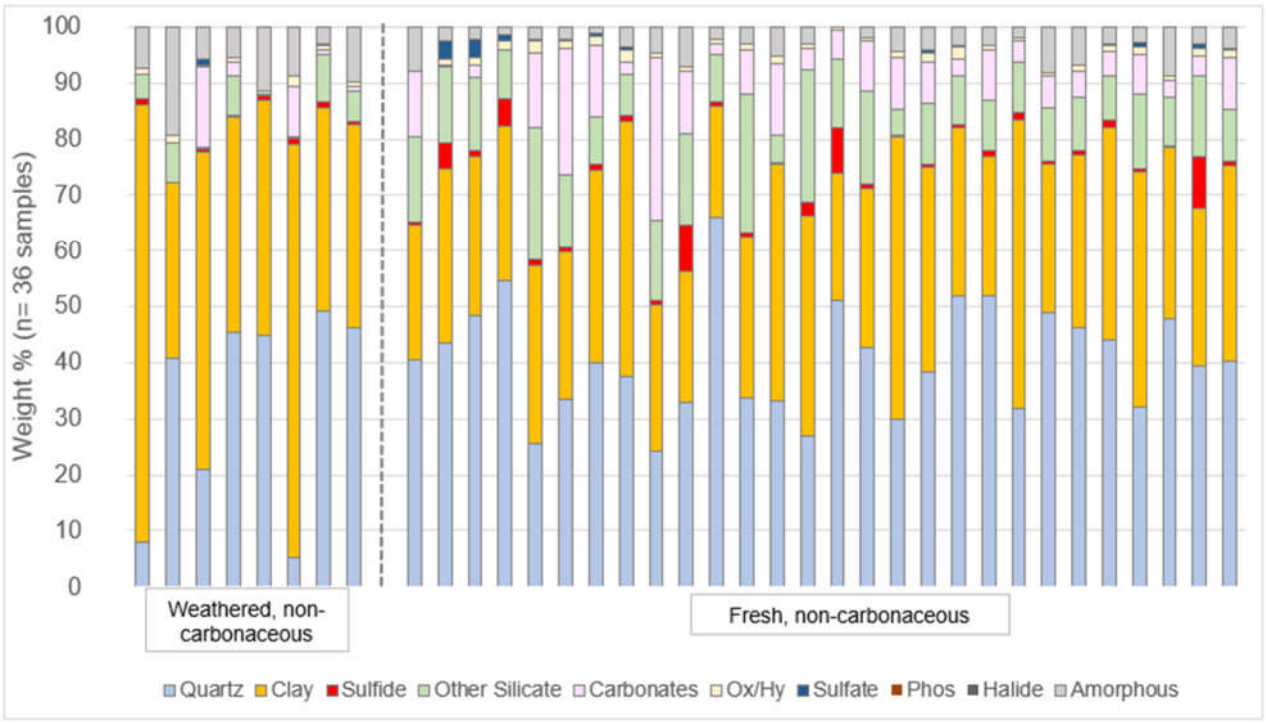

Figure 4. Mineral distribution within non-carbonaceous spoil samples

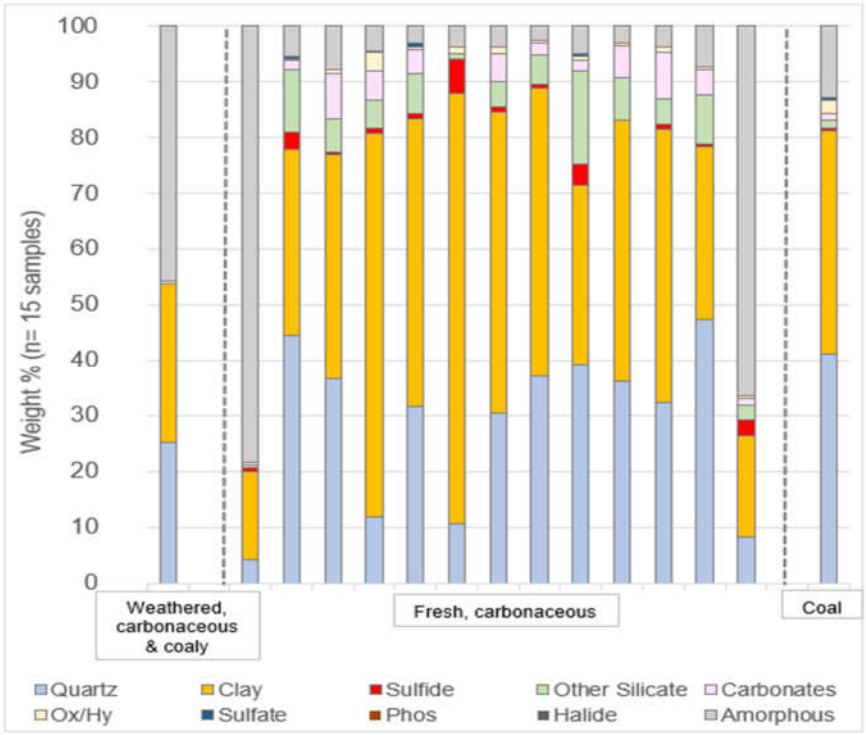

Figure 5. Mineral distribution within carbonaceous spoil samples and one coal sample

Most samples are dominated by clay and quartz minerals (silicate group minerals) and non-crystalline (amorphous) material with variable contributions of carbonate and other silicate minerals. The key acid generating minerals are pyrite and marcasite, and the key acid neutralising minerals are calcite and iron-dolomite/dolomite. Siderite is also detected, but although a carbonate, it does not provide acid neutralising capacity.

Most spoil samples have low sulphide mineral proportions as expected (median = 0.8%, 75th percentile = 1.1%). Sulphide, where present, is present as pyrite and/or marcasite. Sulphate was detected in approximately half of the samples (fresh and weathered) and most have low sulphate concentrations typically less than 1%, which is present as alunite, gypsum and/or jarosite. Seven spoil samples (five non-carbonaceous and two carbonaceous) reported high sulphide (pyrite) concentrations (3.7% to 9.2%). Most of these seven samples were close to or within coal seams and may be mined as part of ROM coal and, therefore, may represent 'potential' reject more so than spoil.

Across all material types, carbonate group minerals predominantly comprised calcite, ankerite (Fe-dolomite) and siderite in variable proportions.

Amorphous (non-crystalline) material was detected in all samples, but generally present in greater proportions in the coal sample (13%). The non-carbonaceous and carbonaceous spoil samples had a similar range of amorphous material, with median values of 3.5% and 4.7%, respectively. Most of the carbonaceous spoil sample had amorphous contents broadly similar to non-carbonaceous spoil, however three of the 14 carbonaceous samples that underwent mineralogical analysis had very high amorphous contents (48%, 67% and 78%). The nature of the non-crystalline material is largely unknown, although for coal and highly carbonaceous waste it may be associated with organic carbon.

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** (coal and aged rejects) and **Table 13** (spoil) and discussed in the following sections. Results can be provided on request.

Table 12. ABA results statistics for coal and aged rejects samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Coal Fresh	Count (*n*)	*68*	*54 (54)*	*68*	*68*	*68*	*68*	*50*
	Maximum	9.26	6.42 (9.26)	82	283	265	30.4	8.5
	95th percentile	3.67	3.22 (3.93)	36	112	104	2.2	7.5
	75th percentile	0.95	0.47 (0.96)	16	29	20	0.8	6.2
	Median	**0.53**	**0.18 (0.54)**	**10**	**16**	**7.6**	**0.5**	**5.5**
	25th percentile	0.45	0.08 (0.45)	6.2	14	2.5	0.2	3.3
	5th percentile	0.27	0.02 (0.34)	<0.5	8.2	-11	0.0	2.2
	Minimum	0.04	0.01 (0.15)	<0.5	1.3	-45	0.0	2.0
Rejects Aged	Count (*n*)	*45*	*45*	*45*	*45*	*45*	*45*	*45*
	Maximum	1.05	0.70	37	32	20	3.4	8.4
	95th percentile	0.95	0.41	27	29	11	1.7	7.9
	75th percentile	0.66	0.22	22	20	5.9	1.2	5.4
	Median	**0.55**	**0.14**	**17**	**17**	**1.2**	**0.9**	**4.0**
	25th percentile	0.49	0.08	12	15	-2.9	0.7	3.4
	5th percentile	0.33	0.04	5.6	10	-11	0.3	2.7
	Minimum	0.11	0.02	0.3	3.4	-26	0.1	2.6

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr was measured on all rejects samples and generally on potential spoil and coal 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.

Table 13. 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*)	*291*	*5 (5)*	*302*	*291*	*291*	*291*	*4*
	Maximum	1.43	0.24 (0.28)	923	43.8	29	2588	7.9
	95th percentile	0.05	0.23 (0.27)	379	1.5	-3.6	945	7.4
	75th percentile	0.02	0.19 (0.25)	120	0.6	-9.3	262	5.4
	Median	**0.02**	**0.17 (0.21)**	**26**	**0.6**	**-25**	**51**	**4.2**
	25th percentile	0.01	0.13 (0.15)	10.3	0.3	-119	16	3.7
	5th percentile	<0.01	0.03 (0.12)	5.0	0.2	-378	3.6	3.2
	Minimum	<0.01	0.01 (0.11)	<0.5	0.1	-922	0.3	3.1
Spoil Weath., carb.	Count (*n*)	*14*	*5 (5)*	*14*	*14*	*14*	*14*	*5*
	Maximum	3.75	0.09 (0.37)	53	115	100	57	7.3
	95th percentile	2.14	0.08 (0.36)	30	65	54	31	7.2
	75th percentile	0.36	0.01 (0.34)	12	11	8.4	5.4	6.6
	Median	**0.17**	**0.01 (0.19)**	**9.2**	**5.2**	**-1.1**	**1.3**	**5.0**
	25th percentile	0.07	0.01 (0.15)	5.6	2.0	-8.7	0.4	2.5
	5th percentile	0.03	0.01 (0.12)	1.4	0.8	-29	0.1	2.3
	Minimum	0.02	0.01 (0.11)	1.1	0.6	-52	0.1	2.3
Spoil Fresh, non-carb.	Count (*n*)	*612*	*184 (184)*	*617*	*612*	*612*	*612*	*134*
	Maximum	11.9	8.38 (11.9)	575	364	364	877	8.7
	95th percentile	0.76	1.73 (2.21)	137	23	10.3	134	8.6
	75th percentile	0.15	0.32 (0.37)	51	4.6	-9.1	29	8.4
	Median	**0.08**	**0.16 (0.19)**	**25**	**2.5**	**-21**	**9.9**	**5.6**
	25th percentile	0.05	0.01 (0.13)	14	1.5	-48	3.5	3.2
	5th percentile	0.03	0.08 (0.10)	5.7	0.9	-136	0.4	2.2
	Minimum	0.01	0.04 (0.04)	<0.5	0.2	-571	<0.1	1.9
Spoil Fresh, Carb.	Count (*n*)	*188*	*78 (78)*	*188*	*188*	*188*	*188*	*73*
	Maximum	5.67	4.57 (5.67)	153	174	158	1294	8.7
	95th percentile	1.78	2.71 (3.04)	59	54	48	30	8.5
	75th percentile	0.41	0.71 (0.79)	22	123	-1.7	9.1	7.8
	Median	**0.18**	**0.59 (0.76)**	**17**	**5.5**	**-11**	**3.2**	**4.7**
	25th percentile	0.06	0.09 (0.17)	11	1.9	-19	1.1	2.8
	5th percentile	0.03	0.04 (0.10)	5.6	0.9	-57	0.2	2.2
	Minimum	<0.01	0.01 (0.10)	<0.5	<0.1	-151	<0.1	1.8
Spoil ALL	Count (*n*)	*1105*	*272 (272)*	*1121*	*1105*	*1105*	*1105*	*216*
	Maximum	11.9	8.38 (11.9)	923	364	364	2588	8.7
	95th percentile	0.78	2.20 (2.59)	218	24	12	406	8.6
	75th percentile	0.15	0.42 (0.50)	53	4.6	-7.8	42	8.3
	Median	**0.06**	**0.16 (0.22)**	**21**	**1.8**	**-19**	**12**	**4.9**
	25th percentile	0.03	0.10 (0.14)	12	0.9	-51	3.6	3.0
	5th percentile	0.01	0.05 (0.10)	5.3	0.3	-216	0.4	2.2
	Minimum	<0.01	0.01 (0.04)	<0.5	<0.1	-922	<0.1	1.8

[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 and coal 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.

Sulphur and Sulphide

The total sulphur (total S) distribution for all samples is presented in **Figure 6**. The total S concentration of spoil samples was generally very low to low with;

- A very low median value of 0.06% and;
- A low-moderate 95th percentile value of 0.78%.

Carbonaceous spoil samples had higher total S values compared to non-carbonaceous spoil. Of the 1105 spoil samples, 29 samples (less than 3% of all spoil samples) had high total S values (greater than 1.5%) and of these 29 samples, 12 samples were closely associated with seams (i.e. parting or thicker interburden between plys).

Total S concentration of most rejects samples was similar to coal samples and generally higher than most spoil samples. The total S concentration of most rejects was low-moderate with a median value of 0.55%.

Coal samples from drill core had generally low-moderate total S values, with median and 75th percentile values of 0.54% and 0.96%, respectively. This sample subset has a total S distribution statistically equivalent to that of the larger BHP coal quality database. In particular, the 2943 coal samples from the SSM coal quality database have median and 75th percentile total S values of 0.61% and 0.69%, respectively. Thus, the total S distribution in coal from the smaller geochemical dataset (n=70) is broadly comparable to the total S distribution in coal from the much larger coal quality dataset (n=2943).

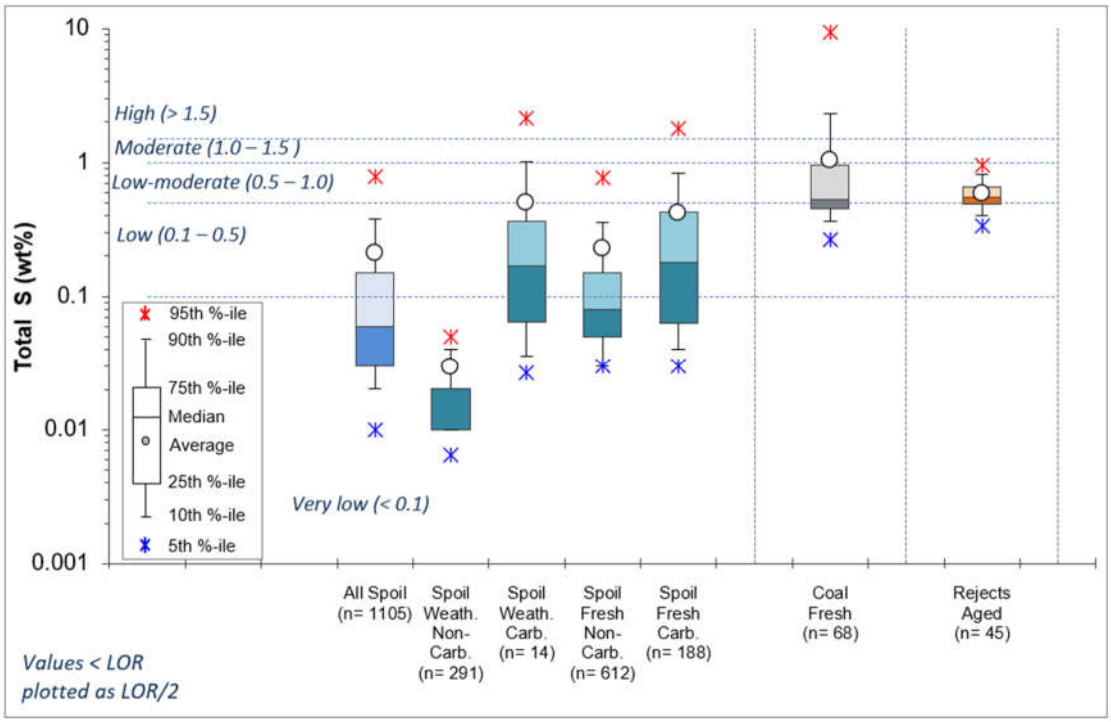

Figure 6. Sulphur (S) distribution

Chromium reducible sulphur (Scr) data is available for 272 spoil samples, 45 aged rejects samples and 54 coal samples. Scr was measured on all aged rejects samples. For spoil and coal samples, Scr was measured on samples with total S values greater than 0.1%. Where sulphide was measured in weathered samples, this was generally only in those samples described as being 'slightly' weathered. The total S and Scr distribution for spoil and coal samples is shown at **Figure 7** and for aged rejects samples at **Figure 8**. Only total S values are shown for the same samples that underwent Scr tests.

As evident in **Figure 7** all spoil samples except for weathered carbonaceous spoil had Scr distributions only marginally lower than the total S distributions from the same group of samples. Five weathered carbonaceous spoil samples had negligible Scr values compared to the total S values from the same samples. The Scr values for coal and rejects samples was generally lower compared to the total S values from the same samples. Sulphate (SO_4)

data is available for 24 aged rejects samples underwent SO_4 analysis, which by difference from total S, allowed the proportion of S as sulphate, sulphide and organic S to be determined. Based on median values, these rejects were comprised of approximately 23% S as SO_4 and 26% S as organic S – with the remainder being present as sulphide.

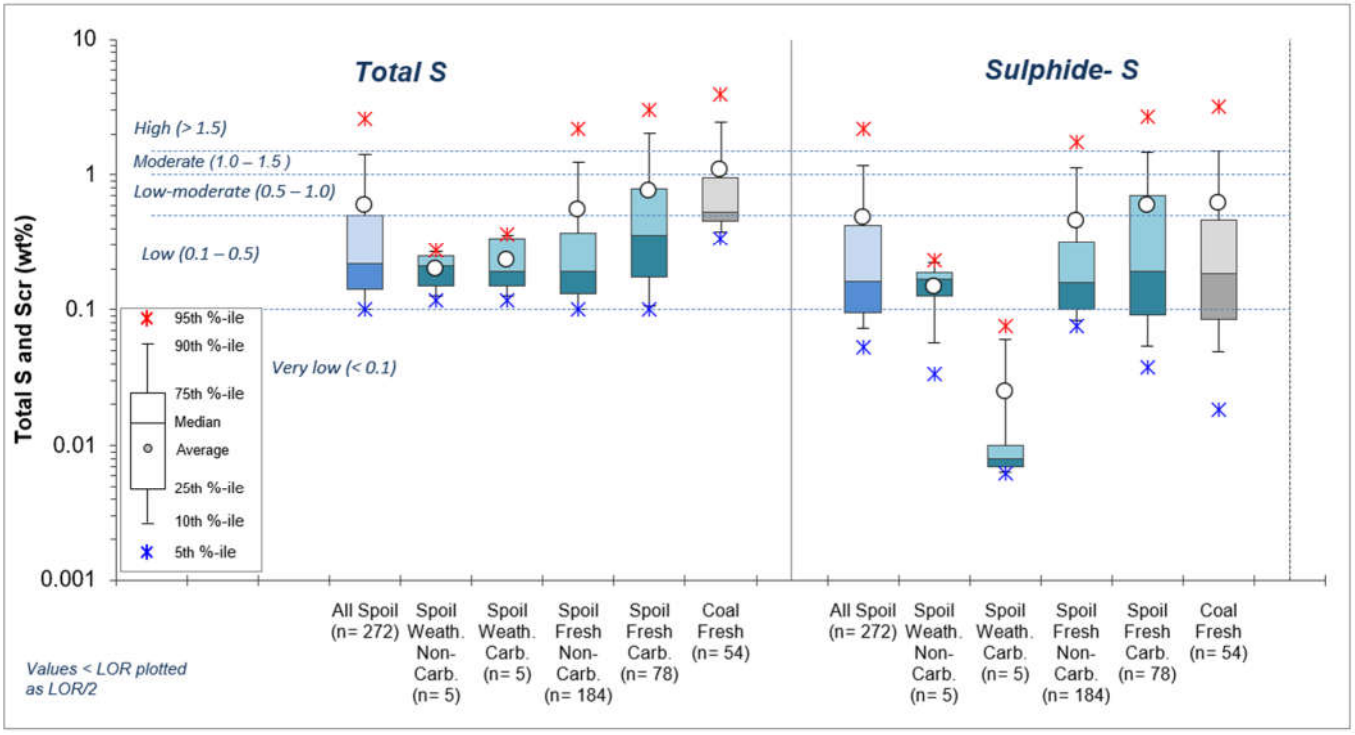

Figure 7. Sulphur (S) and sulphide (Scr) distribution of spoil and coal samples

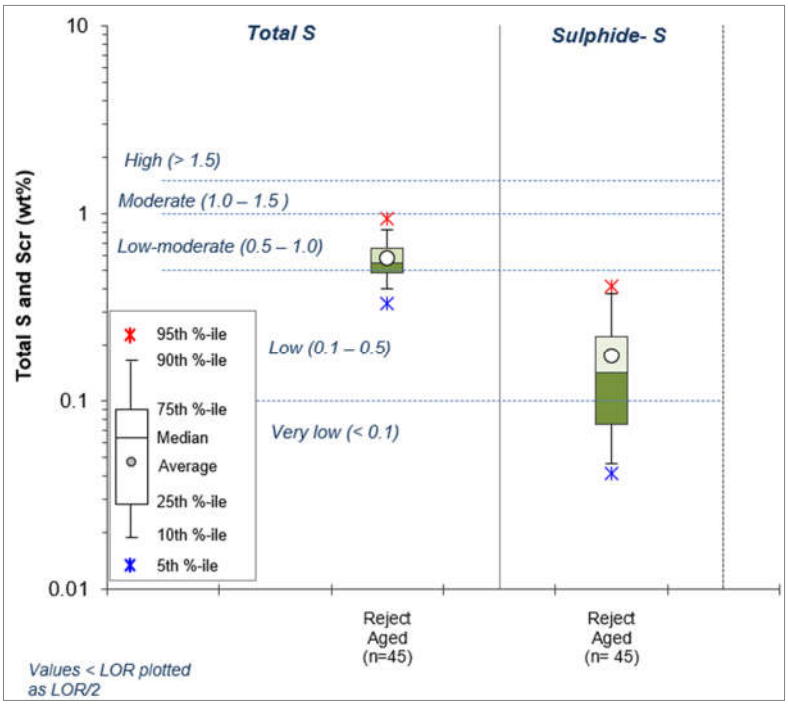

Figure 8. Sulphur (S) and sulphide (Scr) distribution of aged rejects samples

The relationship between Scr versus total S for spoil and coal samples where Scr data is available is shown in **Figure 9**. As a proportion of total S, Scr accounts for 73% (median value) of total S in spoil samples and 34% in coal samples. As a proportion of total S, Scr accounts for:

- Spoil samples: 73% (median value) of total S. Scr accounts for approximately 80% (median value) of total S in weathered and fresh non-carbonaceous spoil, 4% in weathered carbonaceous spoil and 77% of total S in fresh carbonaceous spoil. This means that the proportion of acid generating sulphur is generally lowest in the weathered carbonaceous spoil.

- Coal samples: 34% (median value) of total S. The lower proportion of Scr (compared to spoil) is likely due to 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.

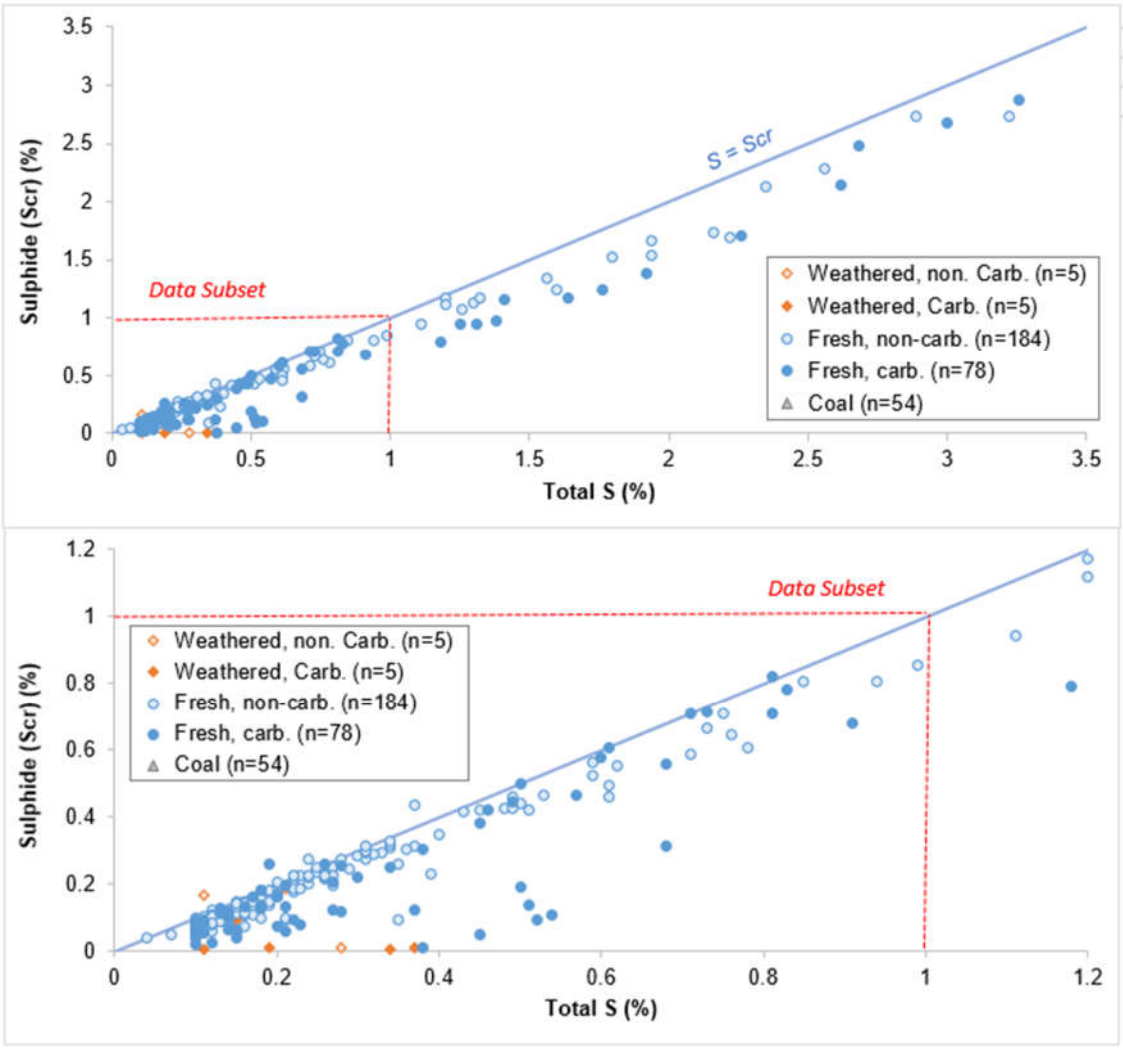

Figure 9. Sulphide (Scr) versus sulphur (S) for spoil and coal samples

The relationship between Scr versus total S for all aged rejects samples is shown in **Figure 10**, which shows that as a proportion of total S, Scr accounts for 25% (median value) of total S in aged rejects samples. These results indicate that using total S as an indication of AMD hazard for the rejects samples will result in a conservative outcome, since it is reasonable to assume that at least some of the sulphide that may have been originally present in these rejects when they were fresh may have oxidised to sulphate.

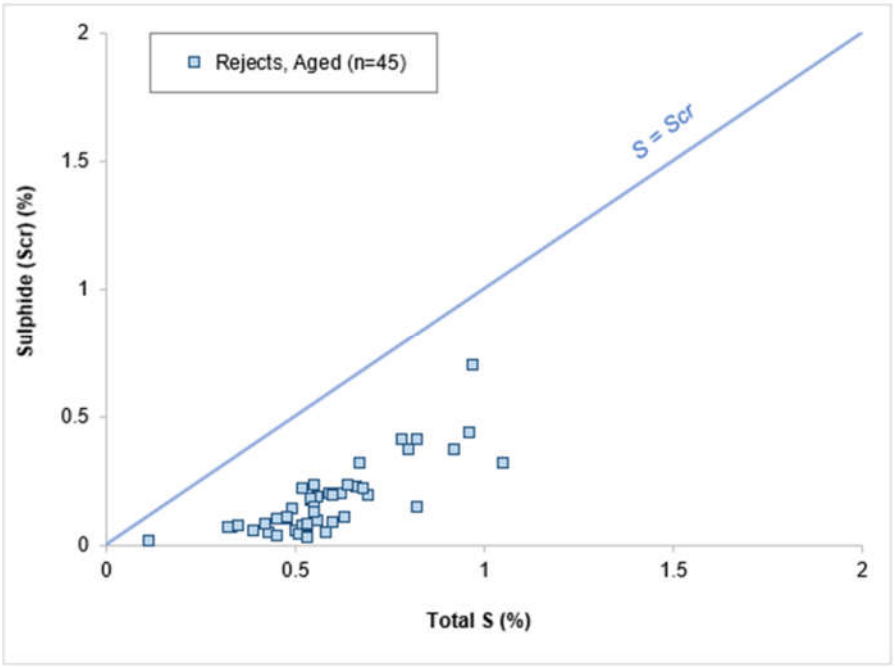

Figure 10. Sulphide (Scr) versus sulphur (S) for aged rejects samples

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 6**). Due to the generally low to low-moderate total S (and Scr) values for spoil samples the MPA was correspondingly low-moderate, with a 75th and 95th percentile MPA values of 4.6 and 24 kg H_2SO_4/t, respectively (n=1105 samples). As such, spoil represented by these samples is expected to have low potential to generate acid/acidity and low 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=68) produced MPA values generally higher than spoil – as expected by the higher total S values of coal samples. Coal samples had 75th and 95th percentile MPA values of 29 and 112 kg H_2SO_4/t, respectively. As discussed above, the proportion of total S associated with sulphide minerals in coal samples is low (34% of total S as Scr), with most sulphur likely associated with organic sulphur. Therefore, MPA values calculated from total S for coal samples is very conservative. For comparison, the 75th percentile MPA value for coal samples calculated from Scr (n=54) is 14 kg H_2SO_4/t – i.e. about half of the 75th percentile MPA value calculated from total S.

The range of total S values for rejects samples was low to moderate and therefore resulted in low to moderate MPA values. For example, the 75th percentile MPA value for rejects samples calculated from Scr (n=45) is 7 kg H_2SO_4/t – i.e. about one third of the 75th percentile MPA value (20 kg H_2SO_4/t) calculated from total S.

Acid Neutralising Capacity

The ANC distribution for all samples is presented in **Figure 11**. The ANC values of spoil samples are typically well in excess of the MPA values and span a very large range, from less than 0.3 to 923 kg H_2SO_4/t, with a moderate median ANC value of 21 kg H_2SO_4/t. Over 90% of spoil samples have an ANC greater than 7.4 kg H_2SO_4/t which, if all ANC was readily available, would neutralise the acidity generated by material containing 0.25 wt% S. Only 93 out of 1105 spoil samples had total S values greater than 0.25%.

Coal samples generally had low ANC values with 10th percentile and median ANC values of less than 1 and 9 kg H_2SO_4/t, respectively. The ANC for aged rejects samples was generally low to moderate, with 10th percentile and median ANC values of 7 and 17 kg H_2SO_4/t, respectively.

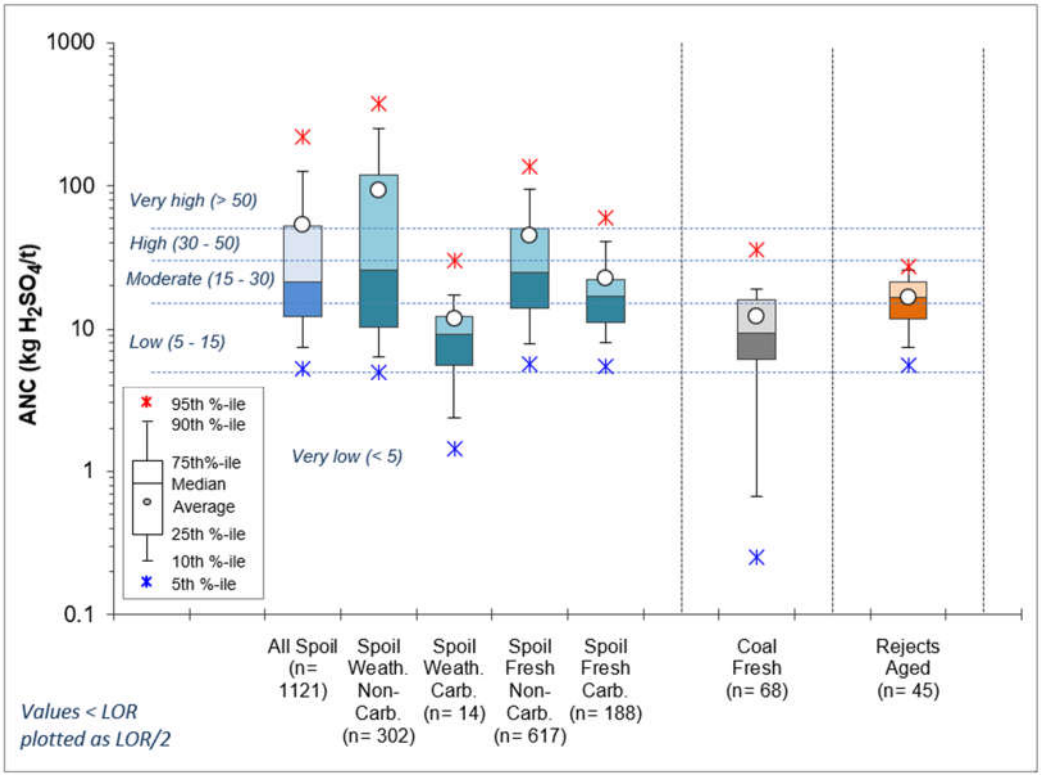

Figure 11. Acid neutralising capacity (ANC) distribution

Available Acid Neutralising Capacity

Acid buffering characterisation curve (ABCC) tests were undertaken on 47 spoil samples and six aged rejects 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 12** for spoil samples and **Figure 13** for rejects samples.

For the 47 spoil samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 10% to nominally 100% of the ANC, with a median of approximately 47%[4].

For the six aged rejects samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 32% to 64% of the ANC, with a median of approximately 49%.

4 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.

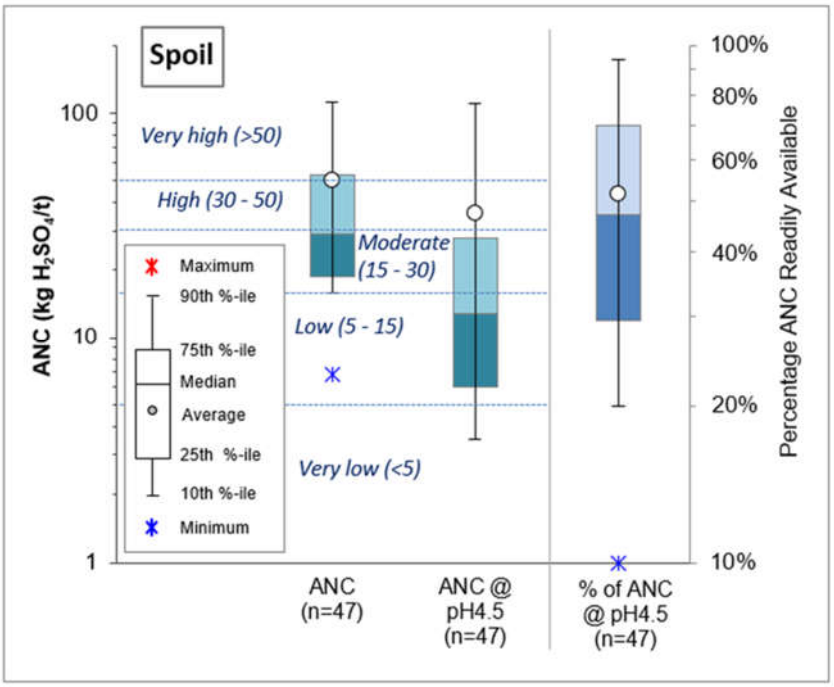

Figure 12. Distribution of acid neutralising capacity (ANC) [total], ANC at pH4.5 and proportion (%) of ANC expected to be readily available for spoil samples

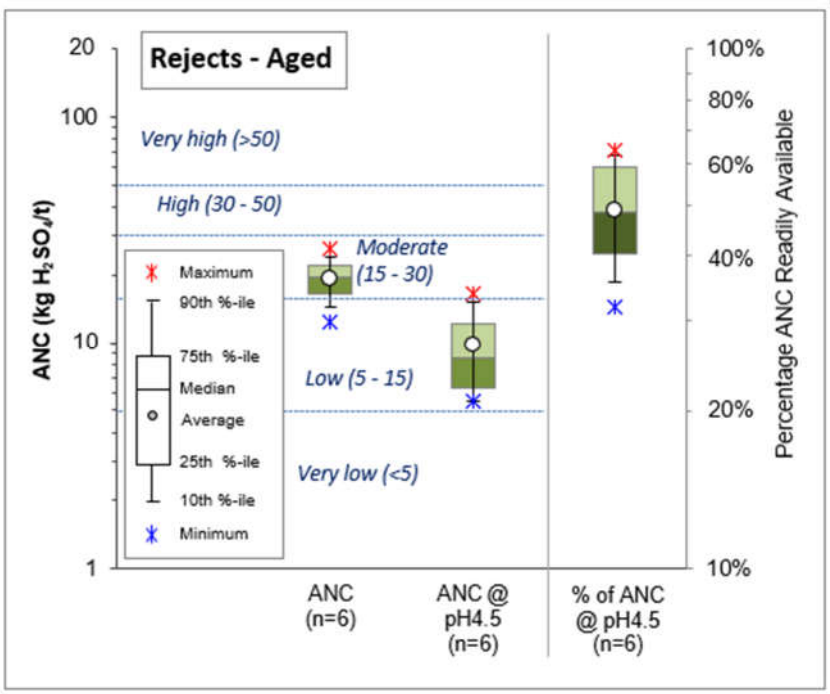

Figure 13. Distribution of acid neutralising capacity (ANC) [total], ANC at pH4.5 and proportion (%) of ANC expected to be readily available for aged rejects samples

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 14**.

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. ABCC reaction rate curves can be

provided on request. For both spoil and rejects samples, iron dolomite (Fe-dolomite) appears to be the dominant carbonate mineral (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. Several samples appear to have trace amounts of dolomite.

Based on the above, and supported by the QXRD data (**Section 5.1**) for spoil samples, the carbonate mineral in bulk spoil and rejects is likely to be Fe-dolomite +/- siderite with varying influence from calcite.

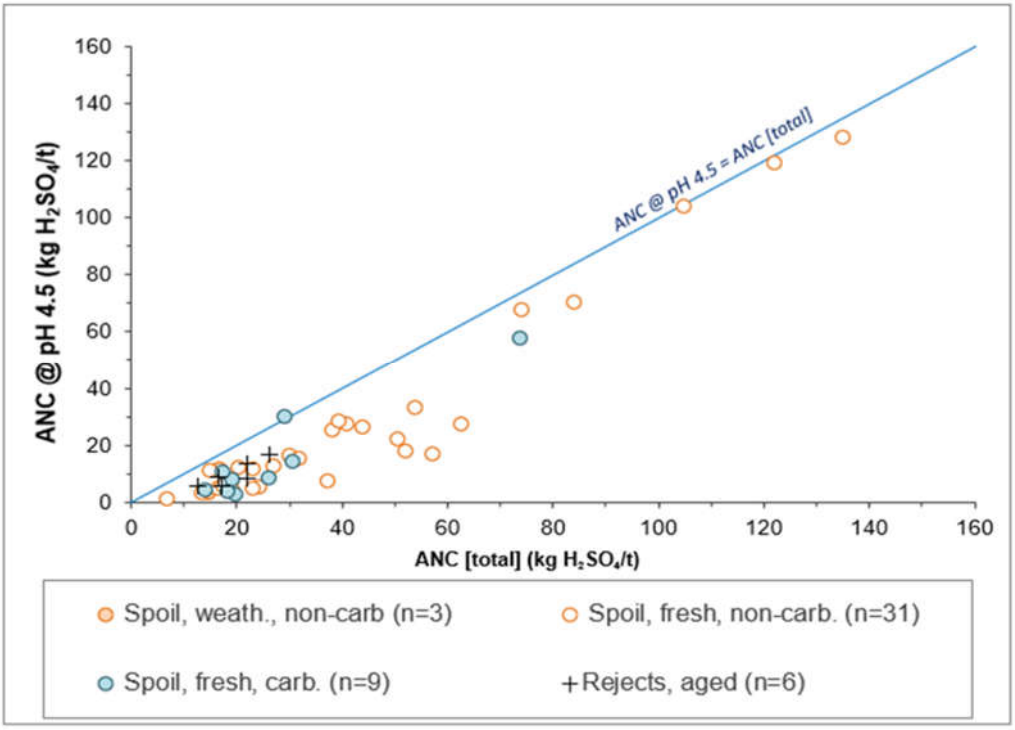

Figure 14. ABCC ANC [ANC @ pH 4.5] versus ANC

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[5]), 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 15**, show that 915 of the 1105 spoil samples (83% of spoil samples) have an ANC/MPA ratio greater than two – noting that 56% of all spoil samples are fresh, non-carbonaceous. Approximately 63% of fresh carbonaceous spoil samples (118 out of 188 samples) have an ANC/MPA ratio greater than two. Five out of 68 coal samples and one out of 45 rejects samples have an ANC/MPA ratio greater than two.

5 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.

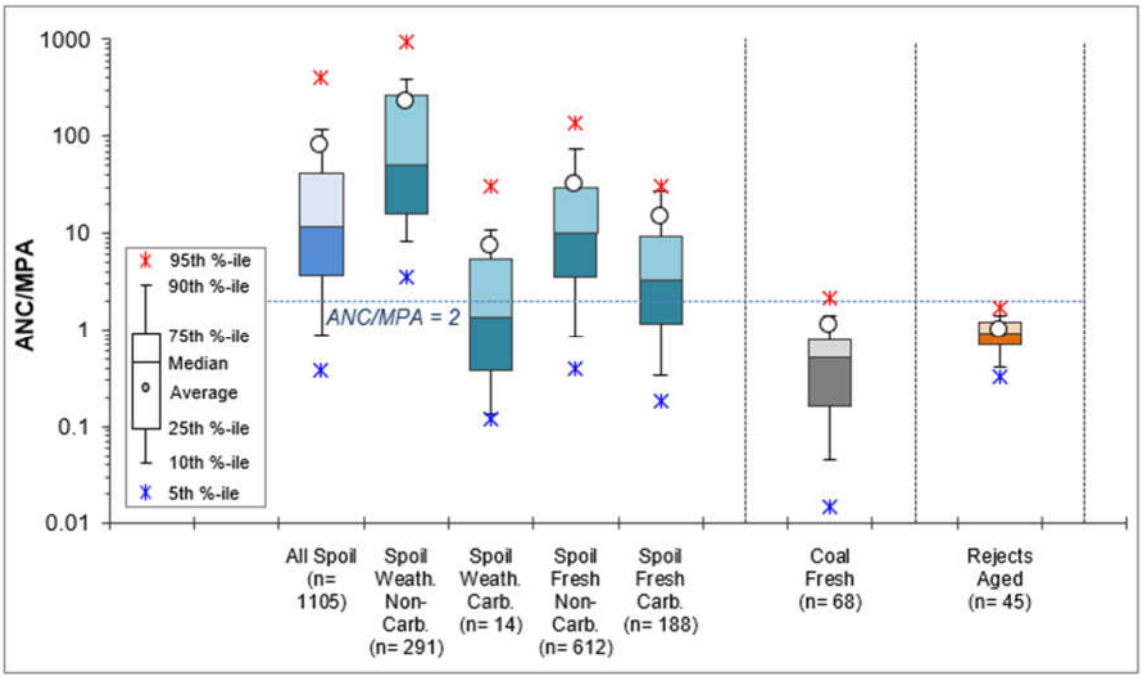

Figure 15. Distribution of the ratio of acid neutralising capacity (ANC) to maximum potential acidity (MPA) [ANC/MPA ratio]

Net Acid Producing Potential

The NAPP distribution for all samples is presented in **Figure 16**. Based on the generally low MPA and higher ANC values (relative to the MPA), the calculated NAPP values are negative for the large majority of spoil samples. The results indicate that, overall, there is significantly excess neutralising capacity (ANC) compared to potential acidity (MPA) for bulk spoil material. All aged rejects samples have a mix of low negative and low positive NAPP values; and most of the coal samples reported positive NAPP values.

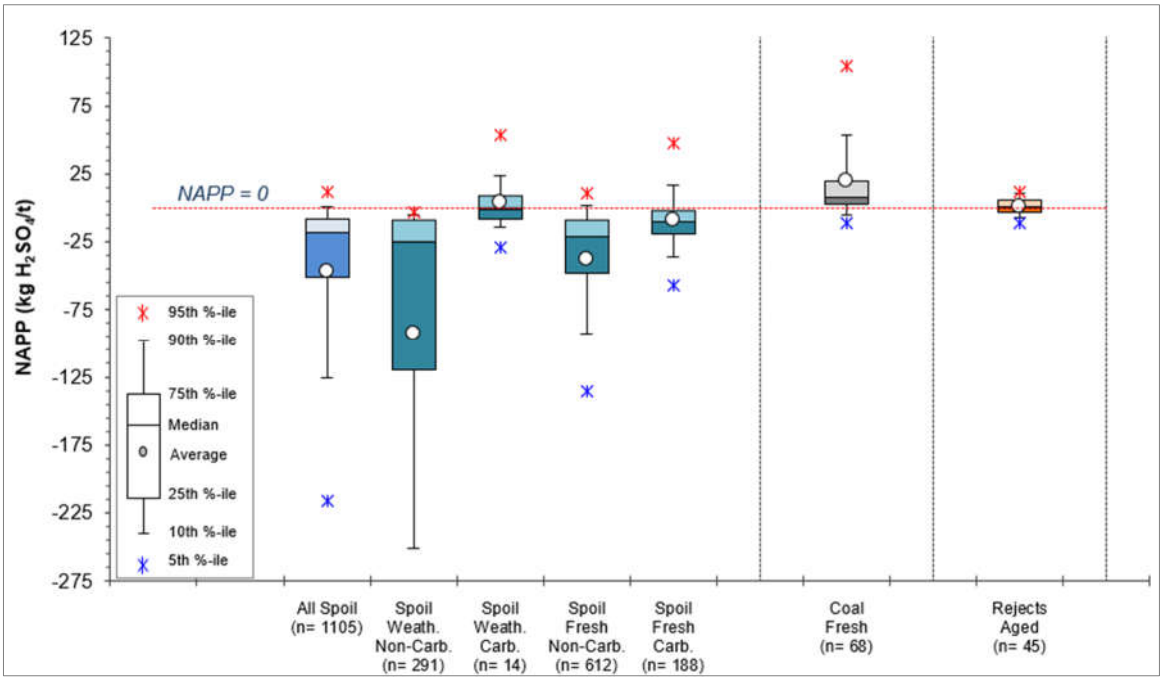

Figure 16. Distribution of net acid producing potential (NAPP)
Non-carbonaceous weathered spoil had a 5th percentile value of -378 kg H_2SO_4/t and is not shown in the plot

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 216 spoil samples, 50 coal samples and 45 aged rejects samples – with the NAGpH distribution for these samples shown in **Figure 17**. Of the samples tested; 55% of spoil (118 of 216 samples), 58% of coal (29 of 50 samples) and 36% of rejects (16 of 45 samples) tested had NAGpH values greater than pH4.5.

As per general practice, especially with some of the 'historic' data, NAG tests tend to be undertaken on samples with higher total S values and/or those samples potentially considered to have a greater potential to generate AMD, such as samples closely associated with coal seams. As such, the proportion of samples with NAGpH values less than pH4.5 is not representing the actual proportion of material in the field that can generate acid conditions, but is indicative of the type of material (based on total S and ANC concentrations) that may generate AD under field conditions.

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, 55 samples underwent an Extended Boil NAG method (NAG Extended), comprising six coaly/carbonaceous spoil samples and 49 coal samples.

Twenty-nine (29) of these 55 samples (or 53% of samples) returned Extended NAGpH values greater than pH4.5, suggesting that for approximately half of the coal 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.

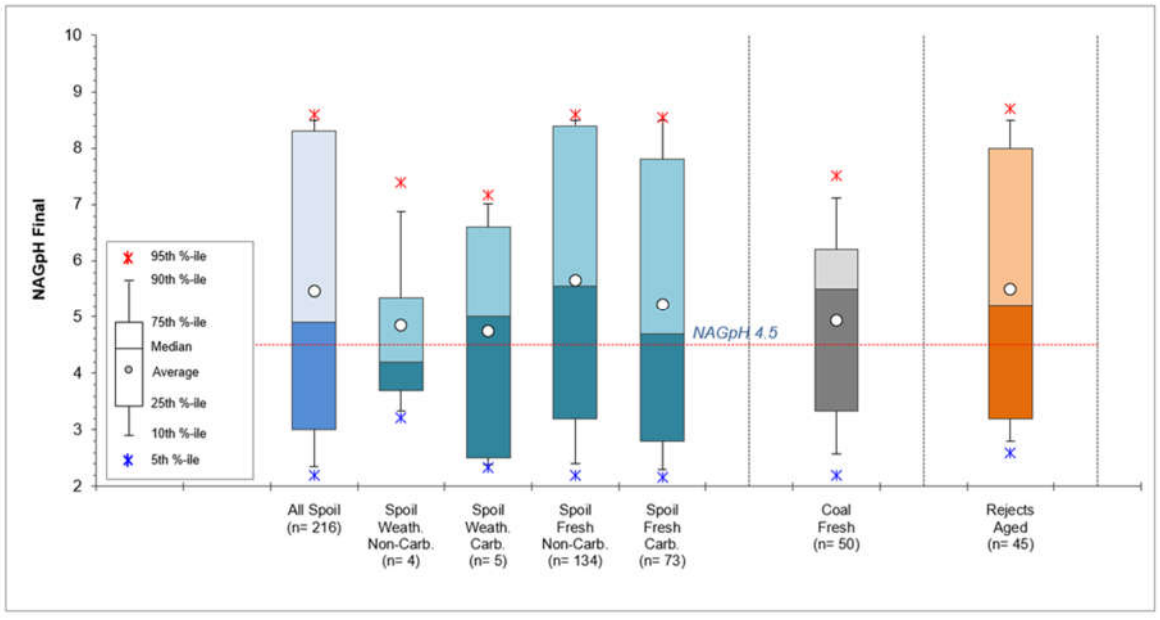

Figure 17. Distribution of net acid generation pH
NAGpH values includes the outcome of NAG single or NAG Extended Boil or Stage 1 NAG Sequential

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 14**.

Table 14. 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=291)	282 (98%)	2 (<1%)	0	2 (<1%)	2 (<1%)	1 (<1%)
Spoil, weathered carbonaceous (n=14)	8 (57%)	1 (7%)	0	2 (14%)	0	3 (21%)
Spoil, fresh non-carbonaceous (n=612)	537 (87%)	12 (2%)	0	11 (2%)	22 (4%)	32 (5%)
Spoil, fresh carbonaceous (n=186)	135 (73%)	11 (5%)	0	10 (5%)	11 (6%)	21 (11%)
Spoil [all] (n=1105)	962 (87%)	26 (2.5%)	0	25 (2.5%)	35 (3%)	57 (5%)
	988 (89%)		*0*	*117 (11%)*		
Coal (n=68)	31 (46%)	1 (~1%)	3 (4%)	0	15 (22%)	18 (26%)
	32 (47%)		*3 (4%)*	*34 (49%)*		
Rejects, aged (n=45)	16(36%)	8 (18%)	0	20 (44%)	1 (2%)	0
	24 (53%)		*0*	*21 (47%)*		

Spoil

The classifications in **Table 14** show that 89% 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. Eleven percent (11%) of spoil samples (117 out of 1105 samples) were classified as PAF, PAF-LC or UC(PAF). No spoil samples were classified as NAF-S.

Data shows 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. PAF spoil is mostly associated with seams, as seam roof, parting or floor, which may largely report to the CHPP as ROM coal and leave the CHPP as rejects. PAF spoil is also likely to be associated with thicker interburden zones between seam plys of the same seam group. That is, PAF spoil is rarely encountered well away from seams.

Coal

Coal samples had marginally higher total S values and marginally lower ANC compared to spoil, which resulted in 49% of coal samples being classified as PAF, PAF-LC or UC(PAF) and a further 4% of samples classified as NAF-S. The proportion of PAF, PAF-LC, UC(PAF) and NAF-S samples is comparable across all coal seam groups being mined at SSM. It is worth noting that at least half of the coal samples classified as some form of ‘PAF’ showed limited or uncertain capacity to generate acidity, suggesting that ‘PAF’ coal is unlikely to generate significant acid(ity). Furthermore, the Scr content of coal samples was generally low, suggesting that the ‘PAF’ (including PAF sub-groups) classification is conservative for most coal samples. On the other side of the acid-base account, it is recognised that ANC is likely an overestimate, however the AMD classification already takes this into account by assuming ANC is only 50% available (i.e. the classification uses an ANC/MPA ratio of 2).

Approximately 47% of coal samples tested (32 out of 68 samples) were classified as NAF or UC(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 either stored on a ROM pad, located within pit walls or un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would likely be bulk NAF. A small proportion of coal (from all seam groups) poses a greater, but relatively low AMD source hazard. As mentioned earlier, the Harrow Creek and Dysart seams comprise all coal mined at SSM. Future mining is expected to uncover similar proportions of Harrow Creek and Dysart seams as currently mined, with the addition of minor P seam in some pit areas near the end of mine life.

Aged rejects

The results show that 53% of aged rejects samples (24 out of 45 samples) were classified as NAF or UC(NAF). Approximately 47% of samples had some type of broader 'PAF' classification – mostly UC(PAF) with limited or 'uncertain' capacity to generate acid(ity). No rejects samples were classified as NAF-S. These results suggest that from an acid generating perspective approximately 47% of aged rejects have been conservatively assessed as posing a potential source hazard with respect to AMD – albeit a low-moderate AMD hazard.

5.3 Total Metals and Metalloids

Multi-element (metal and metalloid) data is available for 168 samples, comprising 136 spoil samples [30 weathered non-carbonaceous, 2 weathered carbonaceous, 71 fresh non-carbonaceous and 33 fresh carbonaceous], 23 coal samples and 9 aged rejects samples. The degree of enrichment with respect to elements potentially of environmental interest for the spoil, coal and reject materials is shown in **Figure 18**.

The GAI values show that 48 (out of 136) spoil samples were significantly enriched [GAI ≥3] with regard to arsenic (As) and/or selenium (Se) and/or tellurium (Te), and a much smaller number of these same samples were significantly enriched with regard to bismuth (Bi) and/or mercury (Hg) and/or sulphur (S). The large majority of these spoil samples displaying significant element enrichment were coaly and carbonaceous samples and samples closely associated with coal seams. The level of S enrichment in these samples is consistent with the ABA data for these same samples.

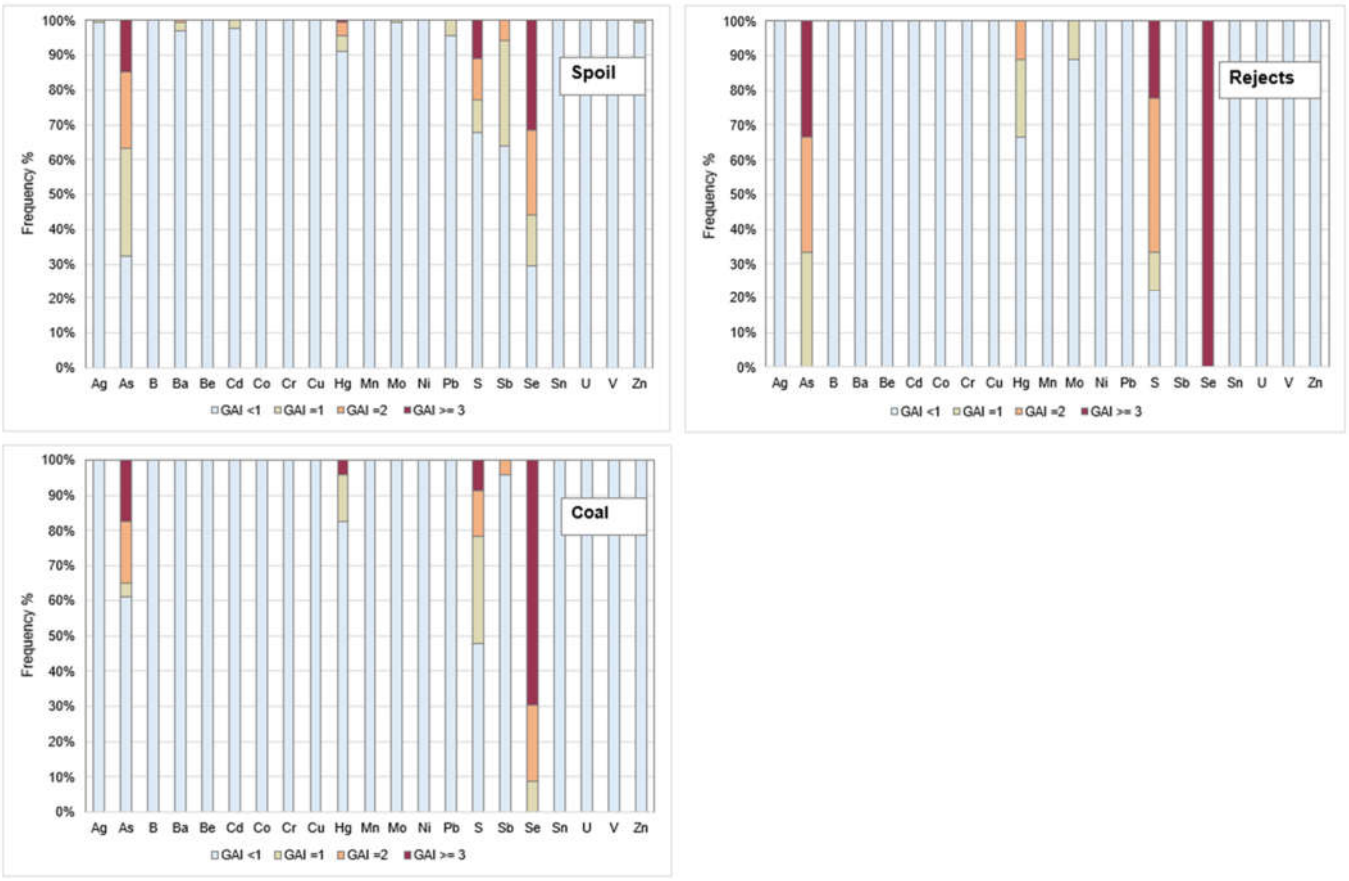

Figure 18. Frequency distribution of geochemical abundance indices (GAI) of selected elements

Assay data available for 23 coal samples found that almost all coal samples have minor or significant enrichment with regard to Se and Te, and four of these samples have significant enrichment with regard to As and/or Hg and/or S. That is, the degree of enrichment in coal samples is consistent with the degree of enrichment in (primarily) coaly and carbonaceous spoil samples.

Three (out of nine) aged rejects samples were significantly enriched [GAI ≥3] with regard to one or more of As and/or S, and all nine rejects samples were significantly enriched with regard to Se – again, similar to what we see with coal samples and coaly/carbonaceous spoil samples.

Overall, the results suggest that bulk spoil (dominated by non-carbonaceous spoil) has generally low levels of metal and metalloid enrichment, which is consistent with Permian-age coal measures throughout eastern Australia. A small proportion of samples that are primarily associated with coaly and carbonaceous material and located near coal seams have a higher degree of enrichment in some metals and metalloids.

5.4 Initial Solubility in Deionised Water

Water extract test results for pH and EC are available for 1637 samples, comprising: 1495 spoil samples, 97 coal samples and 45 aged rejects samples. Test results for major ions and soluble metals/metalloids are available for 174 samples which comprise of 140 spoil samples, 25 coal samples and 9 aged rejects samples. This data were used to evaluate the initial solubility of multi-elements in these 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 SSM. Water extract tests provide a preliminary indication of the elements that may be readily mobilised from any given material type.

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 Queensland. 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 1637 samples at 1:5 w:v on pulp (**Figure 19**).

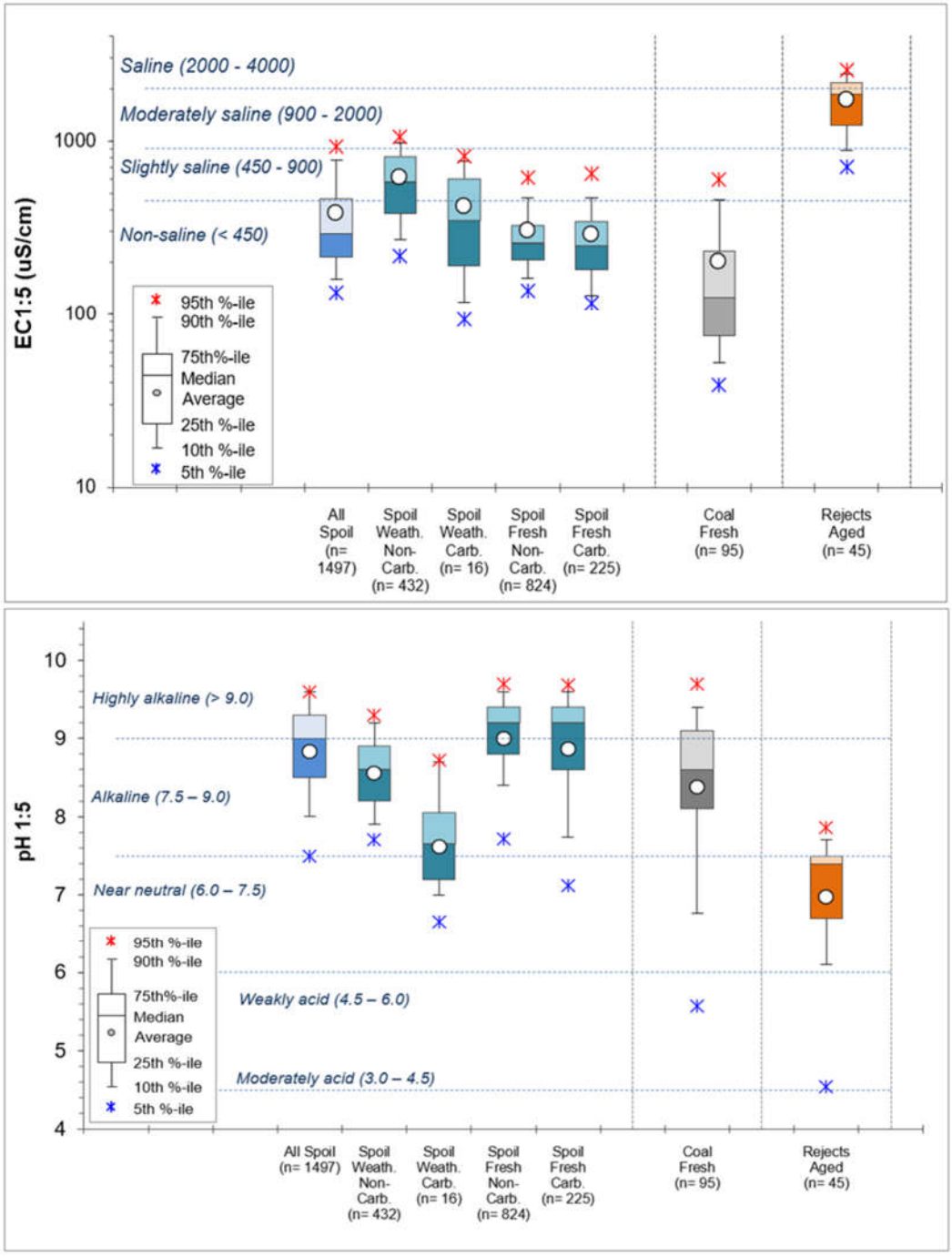

Figure 19. Electrical conductivity (EC) and pH distribution

The $EC_{1:5}$ of 1495 spoil samples spanned a large range from less than 100 to 3780 µS/cm, with median and 75th percentile $EC_{1:5}$ values of 291 and 466 µS/cm, respectively. The weathered spoil samples have generally higher $EC_{1:5}$ values compared to the fresh (unweathered) samples - especially the weathered non-carbonaceous samples compared to the fresh non-carbonaceous samples. However, as a bulk material, spoil is non-saline to slightly saline. These $EC_{1:5}$ results are common (if not typical) for Bowen Basin Permian and Tertiary material in the region.

Coal samples (n=95) are also non-saline to slightly saline. Aged rejects samples (n=45) are generally moderately saline to saline, with median and 75th percentile $EC_{1:5}$ values of 1850 and 2160 µS/cm, respectively.

The pH distribution by material type shows bulk spoil to be alkaline to highly alkaline, with the weathered spoil samples having slightly lower overall $pH_{1:5}$ values compared to the fresh spoil samples. Coal samples had a similar but slightly larger range of $pH_{1:5}$ values to spoil. Rejects samples generally had $pH_{1:5}$ values placing them in the 'near-neutral' pH range. These pH results are common – if not typical – for Bowen Basin Permian and Tertiary material in the region.

Of the 1637 samples, 32 samples (2% of samples) had $pH_{1:5}$ values less than pH 6.0; comprising 21 spoil samples, seven coal samples and four rejects samples. Of the 32 samples with $pH_{1:5}$ values less than pH 6.0, approximately half were weakly acid with $pH_{1:5}$ values between 4.5 and 6.0 and the remaining fraction were moderately acid with $pH_{1:5}$ values between 3.0 and 4.5. For the 21 spoil samples with acidic pH, approximately half were closely associated with seams.

Soluble Metals and Metalloids

Deionised water extract (leaching) data for major ions and a broad suite of metals/metalloids is available for 140 spoil samples, 25 coal samples and nine aged rejects samples. All samples underwent a 1:5 w:v (solid:water) water extract procedure on pulps. All samples were analysed under ICP-MS method.

The sum of 16 environmentally important elements are plotted as a function of pH in **Figure 20**, in a modified Ficklin plot (after Ficklin *et al*., 1992). The 16 selected metals/metalloids comprise: aluminium [Al], antimony [Sb], arsenic [As], cadmium [Cd], cobalt [Co], chromium [Cr], copper [Cu], lead [Pb], mercury [Hg], manganese [Mn], molybdenum [Mo], nickel [Ni], selenium [Se], uranium [U], vanadium [V] and zinc [Zn].

As evident in **Figure 20**, 128 of 140 (91% of) spoil samples have low soluble metals concentrations and have near-neutral to alkaline pH. A further nine spoil samples (of which three were classified as PAF and the remaining as NAF) have moderate concentrations of soluble metals and have near-neutral to alkaline pH. The remaining three spoil samples have moderate to high soluble metals concentrations associated with weakly to moderately acidic pH. These three samples were located within, 0.5 m of coal seams and had high total S (>1.5% S).

The coal samples generally have near-neutral to alkaline pH and have low soluble metals concentration. All aged rejects samples have near-neutral to alkaline pH. Of the 9 aged rejects samples, six have low soluble metals concentration and 3 samples that were classified as PAF of some type have moderate soluble metals concentrations.

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.

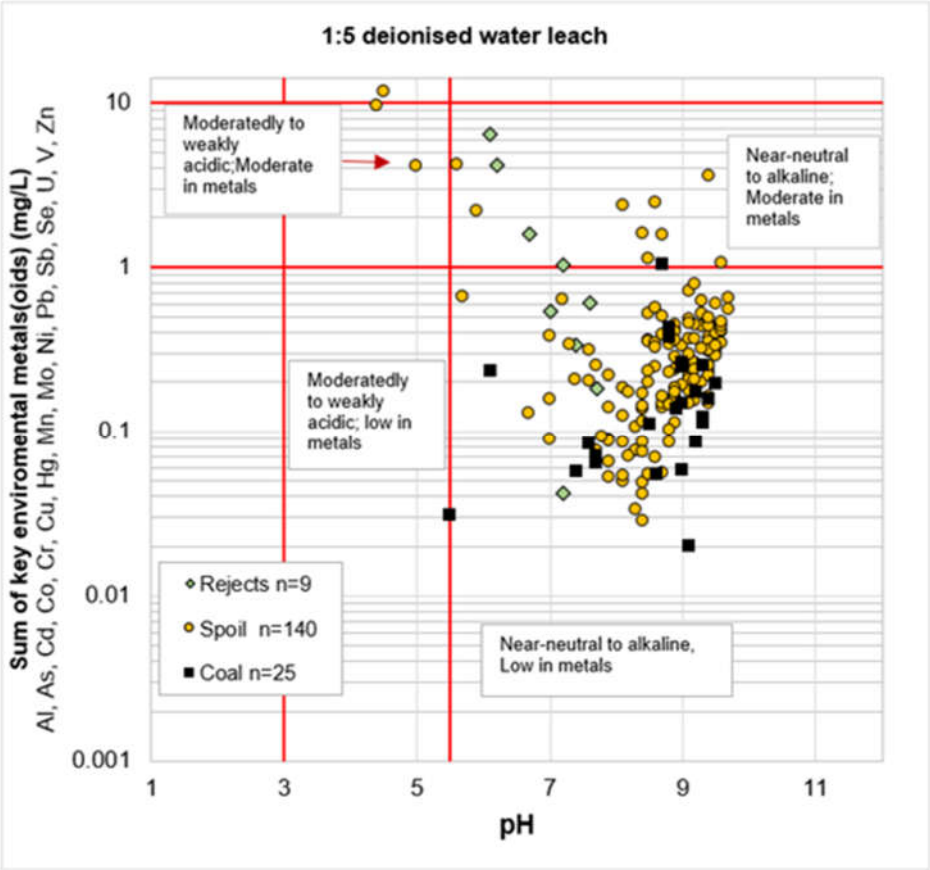

Figure 20. Sum of key environmental metals versus pH in deionised water extracts

The median concentrations of major ions and environmentally important metals/metalloids in deionised water extracts are shown in **Table 15** for spoil, coal and rejects.

Table 15. Median concentrations of major ions and selected elements in deionised water extracts

Median concentration mg/L	**Spoil** (n=140)	**Coal** (n=25)	**Rejects** (n=9)
≤ 0.0001	Cd, Hg	Cd, Hg	Cd, Hg
≤ 0.001	Ag, Be, Bi, Co, Cr, Cu, Mn, Ni, Pb, Sn, U, W	Ag, As, Be, Bi, Sb, Cr, Co, Cu, Pb, Mn, Ni, Sn, U, W	Ag, As, Sb, Be, Bi, Cr, Co, Cu, Pb, Mo, Sn, U, W
≤ 0.01	As, Ba, Sb, Se, Ti, V, Zn	Ba, Mo, Se, Ti, V, Zn	Al, Ni, Se, Ti, V, Zn
≤ 0.1	B, Fe, Mo	Al, B, Fe	B, Ba, Fe,
≤ 1.0	Al, P, F, Ca, Mg	F, P, K	Mn, P, F
≤ 10	Cl, K	Ca, Cl, Mg	Cl, K
≤ 100	Na, SO_4	Na, SO_4	Na, Mg
≤ 1000	-	-	Ca, SO_4

5.5 Peroxide Leachate Solutions

Peroxide leachate (NAG leach) data is available for:

- 13 fresh non-carbonaceous spoil samples: eight samples classified as PAF, two samples classified as PAF-LC, two samples classified as PAF-LC, two samples classified as UC(PAF) and one sample classified as NAF;
- 8 fresh carbonaceous spoil samples: four samples classified as PAF, three samples classified as PAF-LC and one sample classified as NAF; and
- 3 aged rejects samples: two samples classified as UC(PAF) and one sample classified as PAF-LC.

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 21**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach.

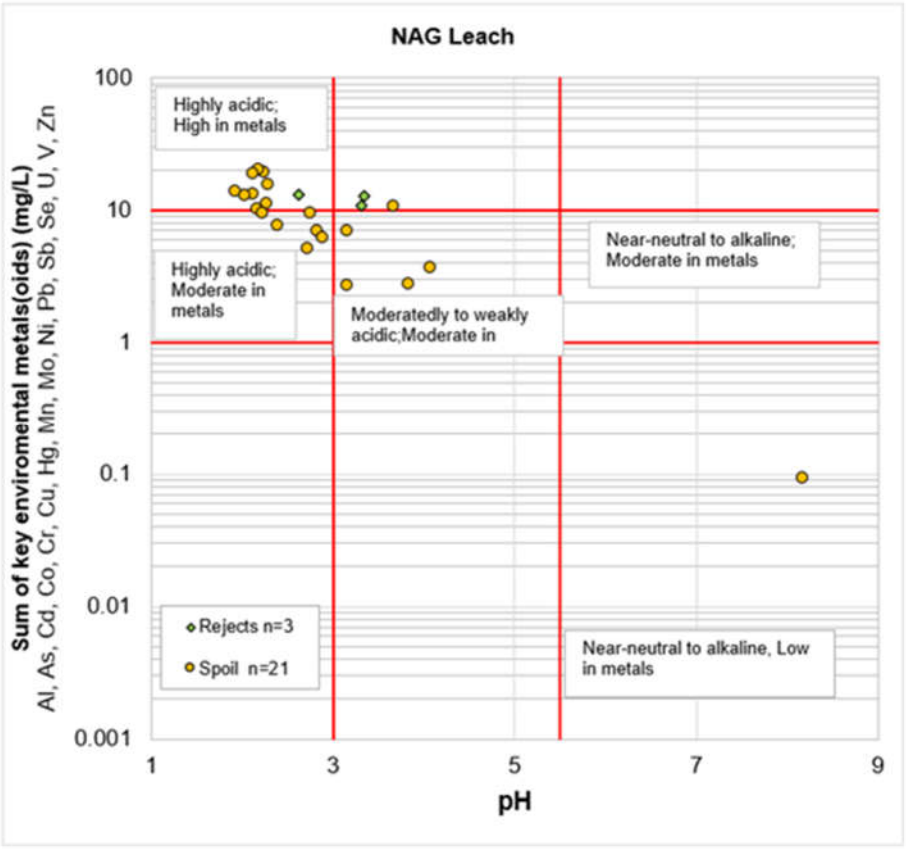

Figure 21. Sum of key environmental metals versus pH in peroxide (NAG) leachate solution

After undergoing a peroxide (NAG) leach most samples have weakly to highly acidic pH and moderate to high soluble metals concentrations – primarily due to the low pH enhancing solubility. One non-carbonaceous spoil sample that was classified as NAF had low metals and near-neutral to alkaline pH. Five spoil samples that are weakly to moderately acidic were classified as UC(PAF) or PAF-LC. Spoil samples that were classified as PAF (of some type) were all closely associated with coal seams as intraseam spoil or situated close to seam roof/floor. All three rejects samples have high soluble metals concentrations.

The median concentrations of major ions and environmentally important metals/metalloids in peroxide leachate solution from spoil and reject samples are shown in **Table 16**.

Compared to the 1:5 deionised water extract solutions, the median concentration of several metals and metalloids in the peroxide leach is higher, as expected, notably Cu, Ni, Mn and SO_4 in the spoil samples. For rejects samples, Ca concentrations were notably higher in 1:5 deionised water extract solution compared to NAG extract solution.

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 to buffer acidity, material similar to that tested might mobilise metals and metalloids at elevated concentrations, over time.

Table 16. Median concentrations of major ions and selected elements in peroxide (NAG) leachate solution

Median concentration mg/L	**Spoil** (n=21)	**Rejects** (n=3)
≤ 0.0001	Hg	-
≤ 0.001	Ag, As, Sb, Bi, Mo Sn, W	Cd, Hg
≤ 0.01	Be, Cd, Se, Ti, U, V	Ag, As, Sb, Be, Bi, Mo, Sn, W, U
≤ 0.1	B, Ba, Cr, Co, Pb, F	Cr, Co, Cu, Ni, Se, Ti, V
≤ 1.0	Cu, Ni, Zn, Cl	B, F, Pb
≤ 10	Al, K, Mn	Al, Ba, Cl, K, Mn, Zn
≤ 100	Ca, Fe, Mg, Na	Ca, Fe, Mg, Na
≤ 1000	SO_4	SO_4

5.6 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 114 spoil samples. The results are summarised in **Figure 22**.

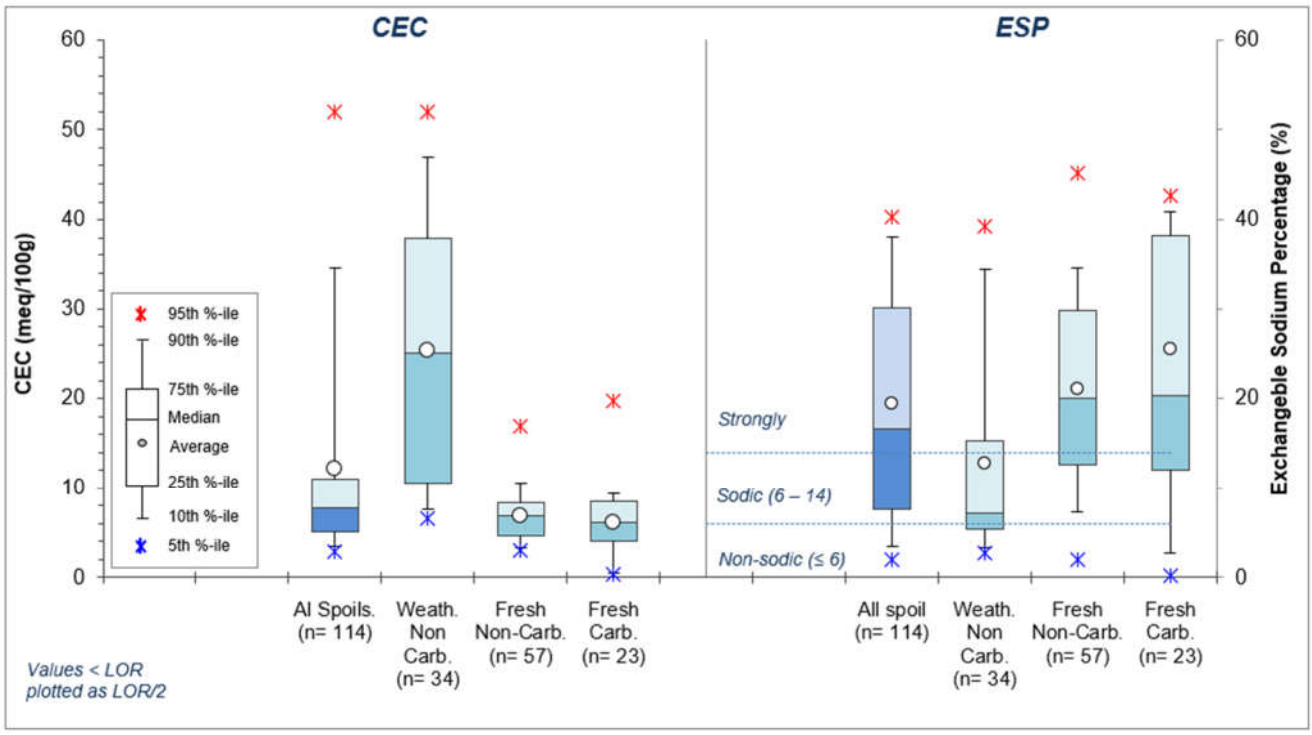

Figure 22. Cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) of spoil

The CEC spans a large range from less than 1 milliequivalents per 100 grams (meq/100g) to 52 meq/100g, with a relatively low median CEC value of 8 meq/100g. There was generally little difference between the CEC of the different spoil types.

The ESP results generally ranged from less than 1% to 45%, with a median ESP of 16%. One sample had an ESP value of 100% due to essentially no exchangeable Ca, Mg or K. Approximately 56% of samples had ESP values greater than 14% and a further 25% of samples had ESP values between 6% and 14%. Therefore, based on the ESP values alone, approximately 80% of the spoil samples are regarded as being 'sodic' to 'strongly sodic' and, as such, a significant proportion of mine spoil at SSM can be expected to have potential for dispersion.

A subset of 105 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 the majority of the samples (72% or 76 out of 105) had Emerson Class 7, meaning they are non-slaking (not dispersive) but swelling, while 16% of the samples (17 out of 105 samples) were classed as non-dispersive with calcite or gypsum present (Emerson Class 4). A minority of the samples (11%) showed potential for dispersion, with variable degrees of 'severity'. In particular, they were classed as completely dispersive (Class 1, two samples), somewhat dispersive (Class 2, three samples) or dispersive (Class 4).

In summary, the Emerson Class testing suggests only a small proportion of the samples (about 12% of samples) may be prone to dispersion. Refer to **Section 4.4** for class descriptions. These results are generally inconsistent with the dispersion predictions from the CEC and ESP results, which suggested that most spoil would be dispersive – whereas the Emerson Class results suggest that most spoil is non-dispersive. Therefore, relying only on CEC and ESP results to assess the potential for dispersion may lead to a very conservative prediction.

Based on the CEC, ESP and Emerson aggregate class test results, a significant proportion of spoil at SSM is expected to be strongly sodic, however the dispersivity of spoil may vary – and the variance is likely to be associated with a minority of the spoil material.

These exchangeable cation (and Emerson aggregate class) results are common for Bowen Basin Permian and Tertiary material in the region – and highlight that spoil is likely to have mixed sodicity and dispersion potential.

6 Summary of Geochemical Characteristics

The geochemical characteristics of overburden/interburden (potential spoil) and coarse reject from SSM 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 the mineral waste at SSM. Rejects – located within the Lotus-Campbell spoil landform footprint – comprise less than 0.003% of mineral waste at SSM (outside of the Roper Study Area). 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 Spoil, Rejects 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 sedimentary materials in the Bowen Basin.

Based on the results, non-carbonaceous spoil has a generally low potential to generate AMD as either AD and/or NMD and/or SD. A small proportion of non-carbonaceous spoil does have a higher potential to generate AMD (as AD, NMD and/or SD), however when mixed and distributed amongst the broader spoil material the overall potential for non-carbonaceous spoil to generate AMD is assessed to be low.

The total S concentration of non-carbonaceous spoil is low, with a 90th percentile total S concentration of 0.26%. As such, and combined with moderate to high ANC values (median 25 kg H_2SO_4/t), which is significantly higher than the MPA (median 1.5 kg H_2SO_4/t), approximately 91% of non-carbonaceous spoil samples tested were classified as NAF, with a further 2% of samples classified as UC(NAF). Eight per cent of non-carbonaceous spoil samples were classified as PAF, PAF-LC or UC(PAF). Most of the non-carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-70% available under field conditions, with iron-dolomite being the main carbonate mineral 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 101 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. However, almost half of the samples tested were moderately to significantly enriched in Se and a smaller number in As. There was no clear correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment, however most of the samples with higher levels of enrichment generally had moderate to high(er) total S and, in most cases, were classified as 'PAF' of some type. 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 105 non-carbonaceous samples) indicate that leachate from this material is expected to contain low concentrations of soluble metals and metalloids. Four samples (out of 105 samples) all classified as PAF – produced moderate to high soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of Al, Ba, Co, Fe, Mn, Ni and/or Zn. Peroxide leaching undertaken on 13 non-carbonaceous spoil samples showed that 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 SSM 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.

Based on the results, most carbonaceous spoil has a generally low to moderate potential to generate AD and/or NMD and/or SD. Some carbonaceous spoil – mostly 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-moderate, with a 90th percentile total S concentration of 0.83% (from 202 samples). Thirteen samples had high total S concentrations (S>1.5%) and of these 13 samples, 12 were classified as PAF. The remaining sample was classified as UC(NAF).

Approximately 78% of carbonaceous spoil samples were classified as NAF, which includes 6% of samples classified as UC(NAF). The remaining samples were classified as PAF, PAF-LC or UC(PAF). All carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC in these samples is expected to be about 30-60% available under field conditions, with iron-dolomite being 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 35 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. However, most carbonaceous spoil samples were moderately to significantly enriched in Se and a small number in As. Similar to non-carbonaceous spoil, there was no clear correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment. In summary, carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 35 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 35 samples, 33 had low soluble metal and metalloid concentrations and two samples had moderate soluble metal and metalloid concentrations. Peroxide leaching undertaken on seven fresh carbonaceous spoil samples classified as PAF shows that these 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 Aged Rejects

Aged rejects (sampled from Ramp 68 – and considered to be broadly representative of aged rejects on site) is expected to generate near-neutral contact water (run-off and seepage).

Based on the results, most aged rejects have a low-moderate potential to generate AMD. A minority of the samples tested have a moderate to high potential to generate AMD as either AD and/or NMD and/or SD. Outside of the Roper Study Area, rejects are only found in the Lotus-Campbell spoil landform and will comprise less than 0.01% of the final landform.

Aged rejects generally have low to low-moderate total S and ANC values, resulting in 53% of aged rejects samples (24 out of 45 samples) being classified as NAF or UC(NAF). Twenty (out of 45 rejects) samples were classified as UC(PAF) and one sample was classified as PAF-LC.

There is a level of uncertainty surrounding the AMD classification of 28 rejects samples (about 62% of rejects samples) and, as such, most of these 'uncertain' samples were tentatively classified as UC(PAF) [and the remaining classified as UC(NAF)] based on our geochemical understanding of a much larger dataset of coal rejects samples from ROM coal from these same seams at Saraji Mine. Despite this potential shortcoming, the classification of the rejects samples is conservative and classifying approximately 47% of rejects samples as PAF (to some degree) is almost certainly an upper limit. The generally low sulphur concentrations in rejects samples indicate that the sulphate loads from sulphide oxidation would likely be low.

The test-work undertaken has demonstrated that the ANC in rejects samples is expected to be about 40-60% available under field conditions – similar to carbonaceous spoil. Iron-dolomite is expected to be the main carbonate mineral contributing to the acid buffering potential of rejects. Overall, rejects samples have modest acid neutralising capacity.

The total metal and metalloid concentrations from nine aged rejects samples are generally low compared to average element abundance in soil in the earth's crust. All nine samples had significant enrichment with regard to

Se and three samples had significant enrichment with respect to As. Two samples had significant enrichment with respect to S, which was consistent with the geochemical data. There was no correlation found between AMD classifications of the rejects samples compared to elemental enrichment. In summary, rejects has generally low enrichment in total metals and metalloids compared to unmineralised rocks – similar to carbonaceous spoil.

Solubility data indicates that leachate from rejects under freshwater (deionised water) is expected to contain low to moderate concentrations of soluble metals and metalloids. Peroxide leaching undertaken on two UC(PAF) and one PAF-LC rejects samples showed that rejects samples produced moderately to weakly acidic leachate with high soluble metals and metalloid concentrations. The results indicate that PAF rejects, when oxidised, have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

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 7% of all lithological material at SSM (i.e. about 7% of the highwall meterage; refer to **Section 7.1.2**) 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. 1-2% at the most). ROM coal is processed at Saraji Mine and rejects and tailings generated from SSM ROM coal is disposed at Saraji Mine.

Based on the results, and as a bulk material, ROM coal is assessed as having a moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal would have a moderate to 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).

The total S concentration of coal is generally low-moderate and approximately 35% (median value) of the total S is present as sulphide (Scr). Coal samples have a wide range of ANC values, however the median ANC is low. As such, 51% of coal samples were classified as NAF, NAF-S or UC(NAF) and the remaining 49% of samples classified as PAF, PAF-LC or UC(PAF). Coal samples classified as PAF, PAF-LC or UC(PAF) were from all seam groups, however the Harrow Creek (upper and lower) and Dysart (upper and lower) seam groups currently and historically comprise all of the coal mined at SSM.

Assay data for 23 coal samples show that the total metal and metalloid concentrations are generally low compared to average element abundance in soil in the earth's crust. Some samples were significantly enriched in one or more of As, Hg and/or Se and two samples had significant enrichment with respect to S, which was consistent with the geochemical data.

Soluble multi-element results from 25 coal samples tested indicate that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids.

6.2 Salinity, Sodicity and Dispersion Potential of Spoil, Rejects and Coal

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has median and 90th percentile $EC_{1:5}$ values (from 1256 samples) of 310 and 802 µS/cm, 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).

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 15% of the samples displayed some degree of dispersion, with the remaining bulk of the samples classified as non-dispersive.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has median and 90th percentile $EC_{1:5}$ values (from 241 samples) of 271 and 575 µS/cm, and has very 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 modest CEC values and generally high ESP values comparable to non-carbonaceous spoil, resulting in most samples being 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. All samples underwent Emerson aggregate class testing to directly measure dispersion, which found that all samples were non-dispersive – indicating that despite being sodic (to some degree) sodic, carbonaceous spoil is not expected to be highly dispersive.

Salinity Potential of Aged Rejects

Aged rejects has median and 90th percentile $EC_{1:5}$ values of 1850 and 2420, respectively. On this basis, contact water (run-off and seepage) from most rejects is expected to be moderately saline to saline (>900 µS/cm). Most rejects have low-moderate total S concentrations, therefore the potential for SD (from sulphide oxidation) is low to low-moderate.

Salinity Potential of Coal

Coal has median and 90th percentile $EC_{1:5}$ values of 131 and 569 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 AMD Hazard Assessment of Spoil, Rejects and Coal

7.1.1 Spoil Landforms

Excluding Roper spoil landform(s) (refer to **Section 2.1.1**), there are five spoil landforms at SSM that will remain at closure:

- Lotus-Campbell;
- Gilbert;
- Price-Leichhardt;
- East (North); and
- East (South).

Each landform has essentially the same construction, comprising mined overburden and interburden disposed behind the active mining face to form a low-wall spoil dump. A very small quantity of rejects are currently located at the head of Ramps 54 and 55 within Lotus-Campbell landform and serve as temporary ROM pads. At closure, these rejects will be buried by spoil as part of landform reshaping – and will comprise less than 0.01% of the final Lotus-Campbell spoil landform. No rejects or tailings are disposed within any other landform outside of the Roper Study Area.

The general layout of the spoil landforms (and residual voids) at closure is shown in **Figure 23**. At closure, the current spoil dumps will be reshaped and seeded (refer to the PRC Plan for spoil dump rehabilitation details).

The source materials within the spoil dumps comprise weathered and fresh spoil, in broadly similar proportions. The proportion of fresh spoil to weathered spoil is not expected to increase substantially as mining progresses and the pits become slightly deeper. 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 spoil, as appropriate. Furthermore, assuming all spoil is ‘fresh’ adds a degree of conservatism to the assessment, since fresh carbonaceous material poses a greater AMD hazard compared to weathered carbonaceous material.

The source hazard assessment methodology outlined in **Section 4.4.4** (AMD hazard scoring) and **Section 4.4.5** (landform AMD likelihood scoring) has been applied to the spoil materials (and the small quantity of rejects as applicable for Lotus-Campbell final landform). Stratigraphic information from the coal geology database for SSM 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 6% to 8% (average 7%) of all 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 6% of the stratigraphy at SSM, therefore if a very small amount of coal was to report as ‘waste’ the increase to the proportion of carbonaceous spoil would be minimal.

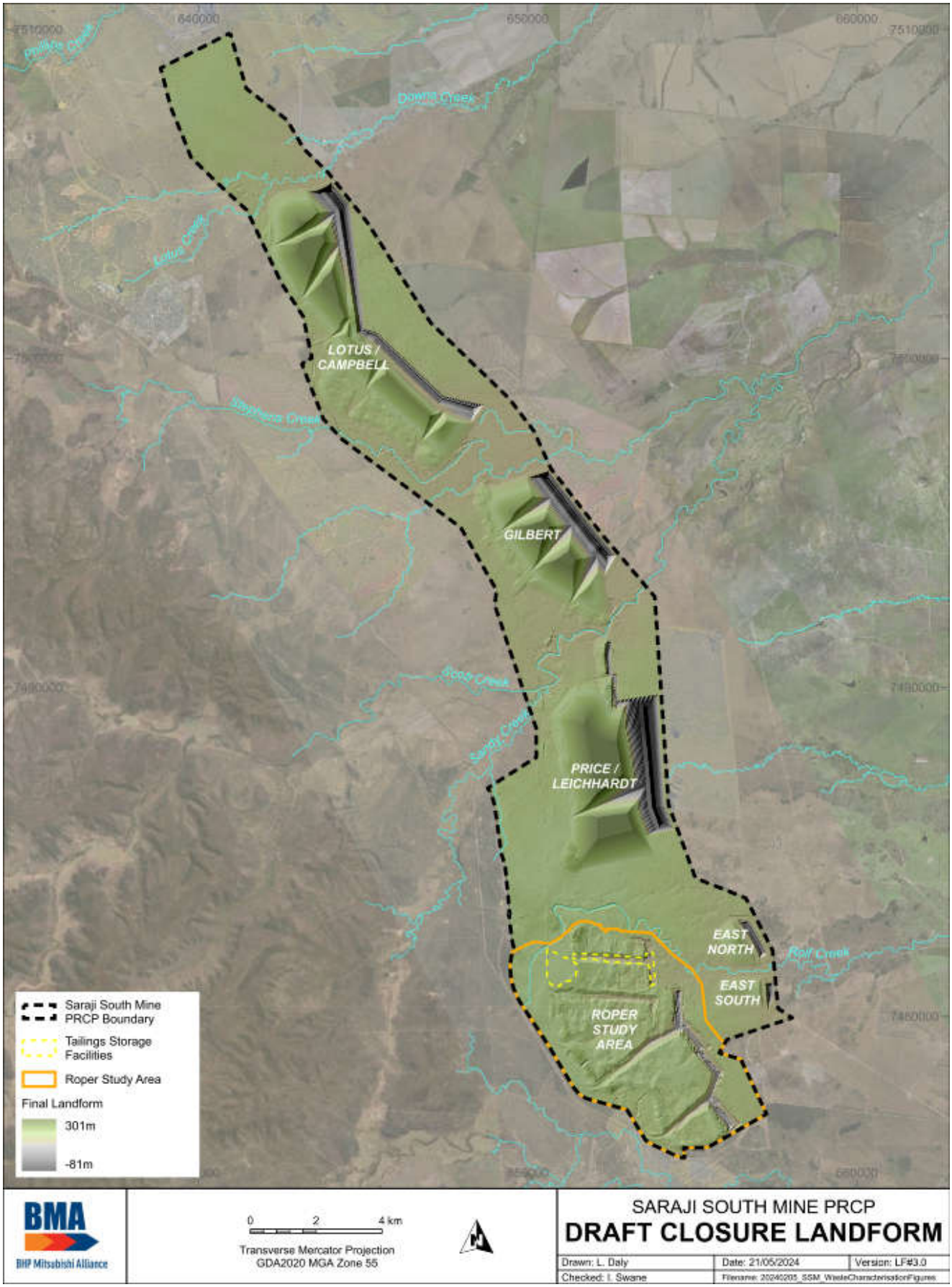

Figure 23. Conceptual closure landform

The source materials, and their approximate proportions within each spoil landform, based on geological, mining and coal processing information, comprise:

Lotus-Campbell

- Overburden/interburden – non-carbonaceous (94%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (6%);
- Rejects (<0.01%);
- Tailings (0%).

Gilbert

- Overburden/interburden – non-carbonaceous (92%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (8%);
- Rejects (0%);
- Tailings (0%).

Price-Leichhardt

- Overburden/interburden – non-carbonaceous (94%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (6%);
- Rejects (0%);
- Tailings (0%).

East (North and South landforms combined)

- Overburden/interburden – non-carbonaceous (92%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (8%);
- Rejects (0%);
- Tailings (0%).

The AMD hazard scoring tables for spoil landforms are provided in **Attachment B – Tables B1 to B4**.

The source hazard assessment, which describes the AMD hazard of individual material domains within each landform (i.e. also takes into account material quantity), has found that both non-carbonaceous and carbonaceous spoil (i.e. all spoil) pose a Low-Moderate AMD source hazard – 11% of spoil samples have been classified as PAF of some type (**Table 14**). Notably, over 75% 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 a significant proportion of 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.

Rejects have also been assessed to pose a Low-Moderate AMD source hazard. However, it is worth noting that the assessment of rejects has conservatively applied a UC(PAF) classification to nearly half of all rejects samples and thus, in reality, the actual AMD hazard posed by rejects is likely to be lower than indicated.

On this basis, and taking into account material quantities (proportions) and expected proportion of PAF and NAF-S materials reporting to each individual landform, the AMD hazard score and AMD likelihood for each landform is as follows:

- Lotus-Campbell spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. Rejects also have a Low-Moderate AMD source hazard, however the quantity of rejects within this landform is negligibly small (comprising less than 0.01% of the final landform). As such, the AMD hazard and likelihood of

AMD generation from this landform is based almost entirely on the AMD source hazard posed by spoil (as it is for all other final landforms discussed herein that have no rejects within their landform).

- Gilbert spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.
- Price-Leichhardt spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.
- East (North and South, combined) spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.

7.1.2 Residual Voids – Exposed Walls and Floor

Excluding Roper pits (refer to **Section 2.1.1**), there are five pits at SSM that will remain at closure as residual voids [void dimensions shown below are indicative]:

- Lotus-Campbell void; approximately 9.2 km long and 110 m deep (at closure);
- Gilbert void; approximately 3.7 km long and 100 m deep (at closure);
- Price-Leichhardt void; approximately 6.1 km long and 200 m deep (at closure);
- East (North) void; approximately 1.5 km long and 85 m deep (at closure); and
- East (South) void; approximately 1.0 km long and 50 m deep (at closure).

At closure, the floor of the residual voids will comprise the following:

- Lotus-Campbell void: DY Lower seam group;
- Gilbert void: DY Lower seam group;
- Price-Leichhardt void: DY Lower seam group in the middle and southern sections of the void (i.e. Leichhardt pit) and HC Lower seam group in the northern section of the void (i.e. Price pit) – noting that no further mining is proposed for Price pit.
- East voids (North and South); HC Upper seam group – noting that East pits have not begun mining (i.e. the pits currently don't exist, however these two small pits are approved under the EA and, therefore, are part of the PRCP).

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 source materials within the highwall and floor of each residual void comprise weathered and fresh materials, with weathered materials comprising about 54% to 58% of the highwalls for all except East pits – at East pits the weathered zone comprises about 23% of the highwall. The depth of weathering is generally consistent across the site. As mining progresses the pits become only marginally deeper. Therefore, the proportion of fresh material to weathered material at closure will remain broadly similar to current proportions.

The statistical distribution of residual void highwall materials and the proportion of exposed coal seam (groups) is shown in **Figure 24** for current Lotus-Campbell pit, **Figure 25** for current Gilbert pit, **Figure 26** for current Price-Leichhardt pit and **Figure 27** for future East pit (North and South pits combined).

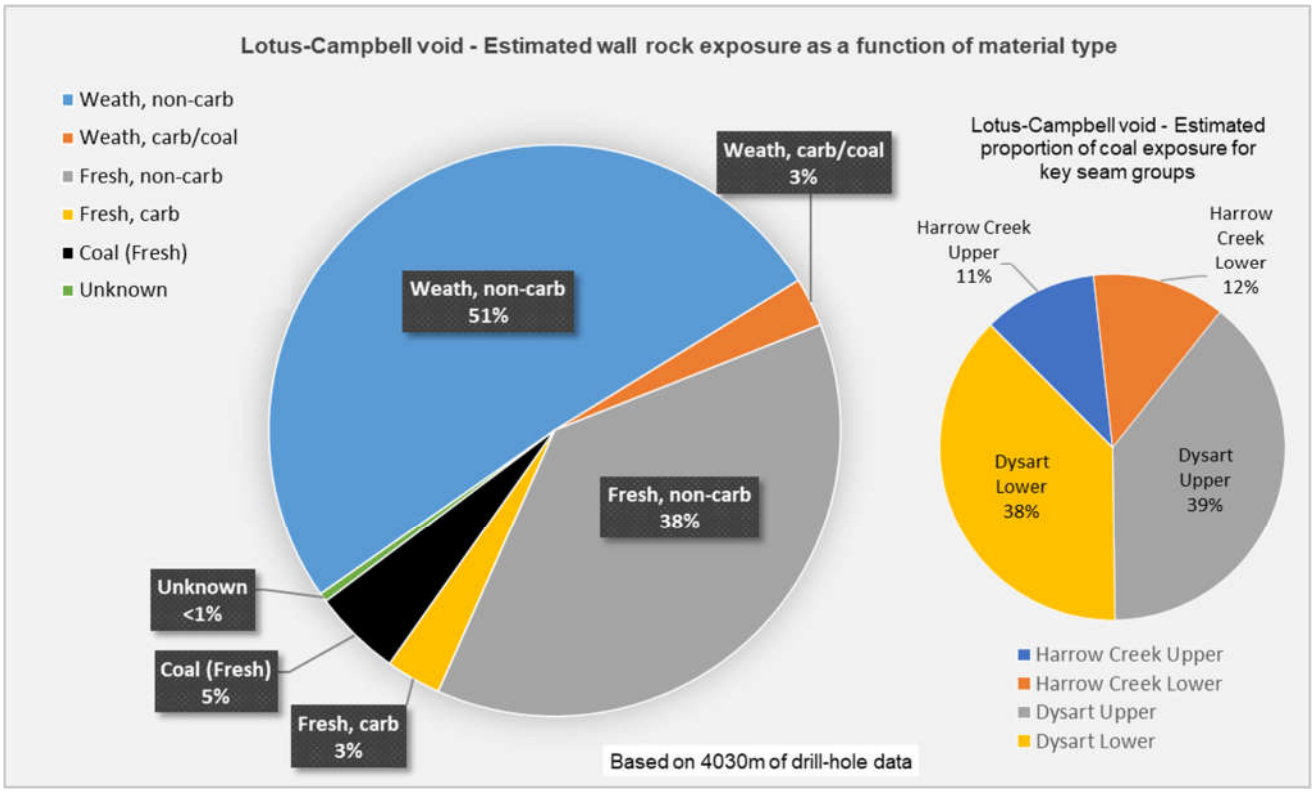

Figure 24. Estimated Lotus-Campbell residual void highwall exposure by material type and proportion of coal exposure

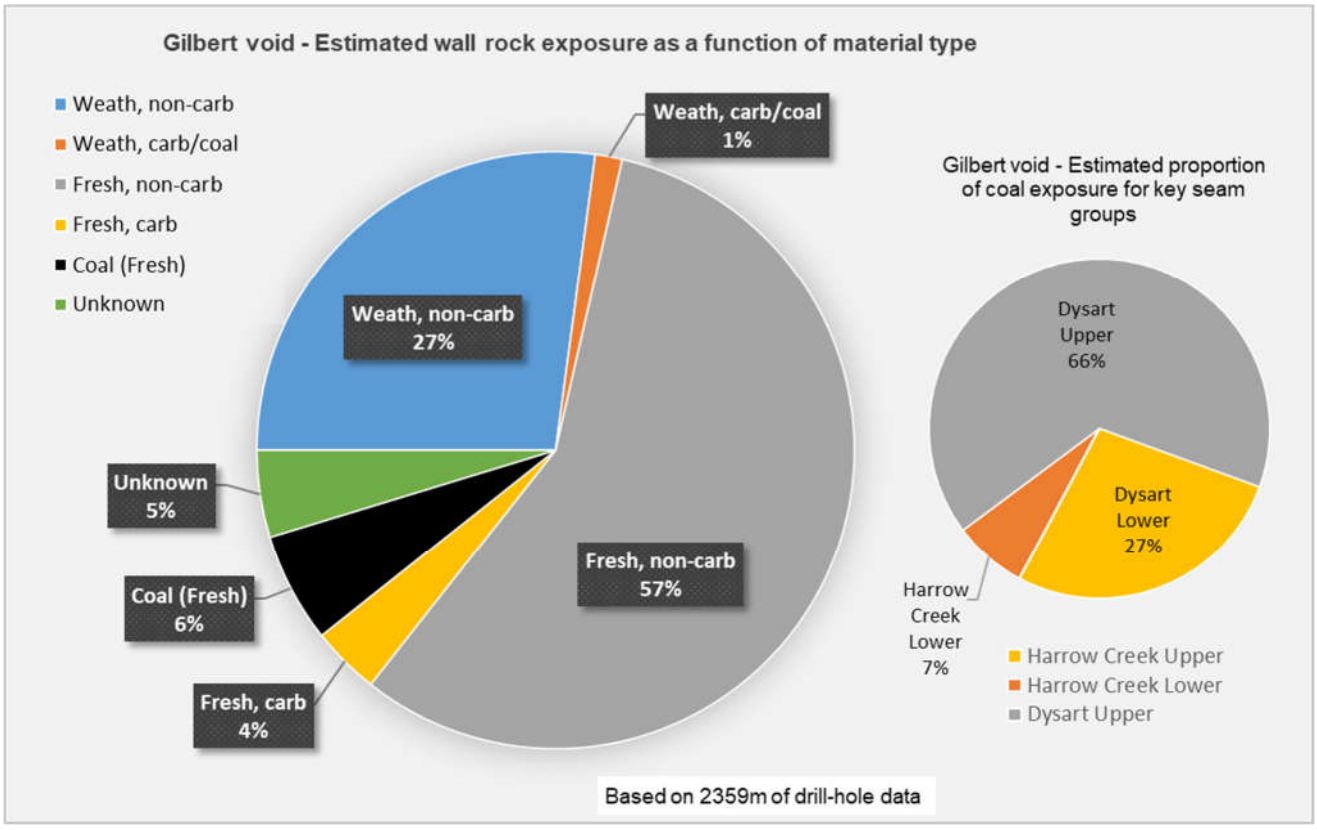

Figure 25. Estimated Gilbert residual void highwall exposure by material type and proportion of coal exposure

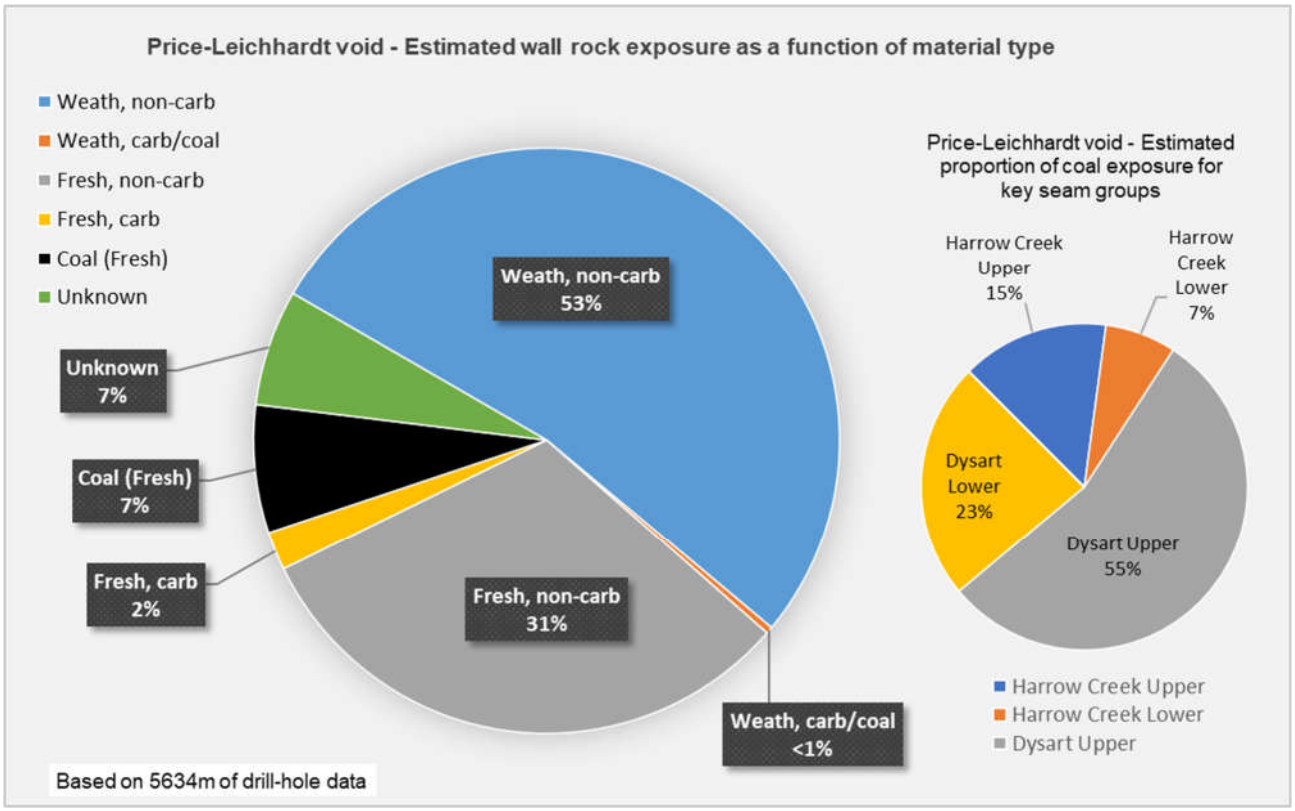

Figure 26. Estimated Price-Leichhardt residual void highwall exposure by material type and proportion of coal exposure

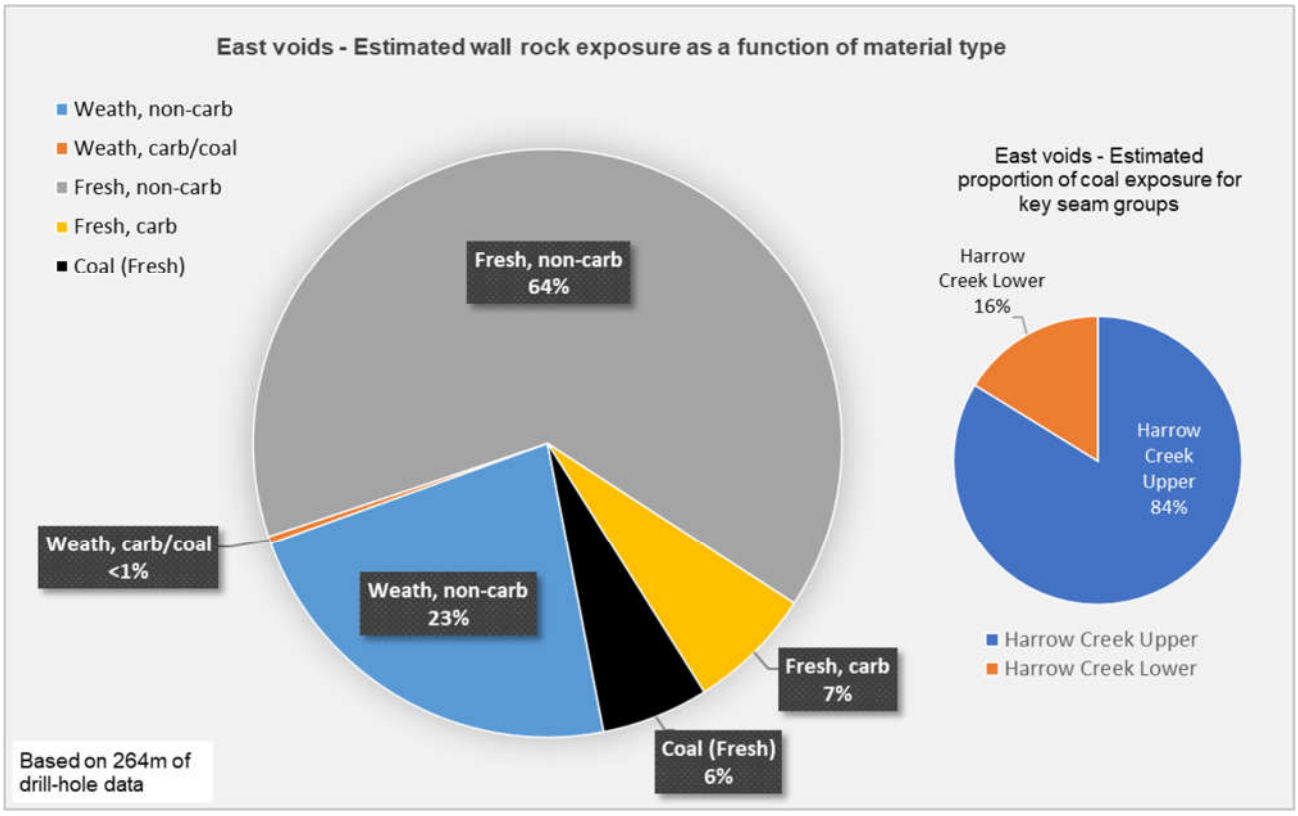

Figure 27. Estimated East (North and South, combined) residual void highwall exposure by material type and proportion of coal exposure

The residual void highwall AMD hazard assessment is based on data being representative of current and near-future mining (indicatively now to 10 years). The SSM coal resource model is used to estimate coal resources from current pit highwall through to the eastern extent of the mine. The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of all voids is consistent with the current proportions on the pit highwalls. The model also shows that the proportion of each seam group is expected to be similar to current seam group proportions on the highwall of all voids. As such, the proportions of the various mineral waste types on the residual void highwall and floor (of all voids) is not expected to change significantly from those shown in the current pits. Therefore, the overall AMD hazard posed by the highwall and floor (of all residual voids) at end of mining is expected to be similar to that shown for the current pits.

Based on drill-hole data from the coal geology database, all current (and future predicted) pit highwalls are dominated by weathered and fresh non-carbonaceous materials [noting that there is no current highwall for east pit]. The composition (proportions) of the seam groups exposed on the highwalls in the pits (including East pit – based on drill-hole data) are shown as the small 'inset' pie chart in each of **Figures 24 to 27**.

The Dysart seam group (upper and lower) represents the dominant coal seam group exposed on the highwalls of the Lotus-Campbell, Gilbert and Price-Leichhardt (Leichhardt section) pits. The Harrow Creek seam is expected to be exposed on the East pits and on the 'Price' section of the Price-Leichhardt pit. At closure, a small amount of P seam is expected to be exposed in the highwalls of Gilbert void and the 'Leichhardt' section of Price-Leichhardt void. Overall, remnant coal (seams) are expected to comprise about 6% of the highwalls in the residual voids.

Note that the source hazard assessment methodology outlined in **Sections 4.4.1** to **4.4.5** has been applied to the materials expected to be exposed on the pit highwalls and floor at closure (i.e. on the highwalls and floors of the residual voids).

The highwall AMD hazard assessment has found that approximately 8% to 12% of the void highwall in all voids is estimated to be PAF, which includes material classified as UC(PAF), PAF-LC and NAF-S. As such, the assessment has found that the likelihood of AMD generation from the void highwalls is **Unlikely**.

The void floor AMD hazard assessment has found that approximately 9% of the floor of the Lotus-Campbell, Gilbert and the 'Leichhardt' section of the Price-Leichardt void, is estimated to be PAF, which includes material classified as UC(PAF), PAF-LC and NAF-S. For Price void (i.e. the 'Price' section of the Price-Leichhardt void), approximately 35% of the floor is estimated to be 'PAF'/NAF-S; and for East voids (combined), approximately 38% of the floor is estimated to be 'PAF'/NAF-S.

The assessment has found that the likelihood of AMD generation from the floor of all voids subject to this PRCP is **Probable/Likely** until such time that the floor becomes submerged by groundwater (post-closure). Price pit currently contains water and the floor is already submerged.

The AMD hazard scoring tables for the residual voids are provided in **Attachment B – Tables B5 to B9**.

7.2 Geochemical Source-Pathway-Risk Assessment

7.2.1 Conceptual Site Model and Conceptual Facility Models

A post-mining 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 SLR (2024) (**Figure 28)**. 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, rejects), plausible receptors (e.g. creeks, groundwater) and the pathways between the two (e.g. seepage, drainage).

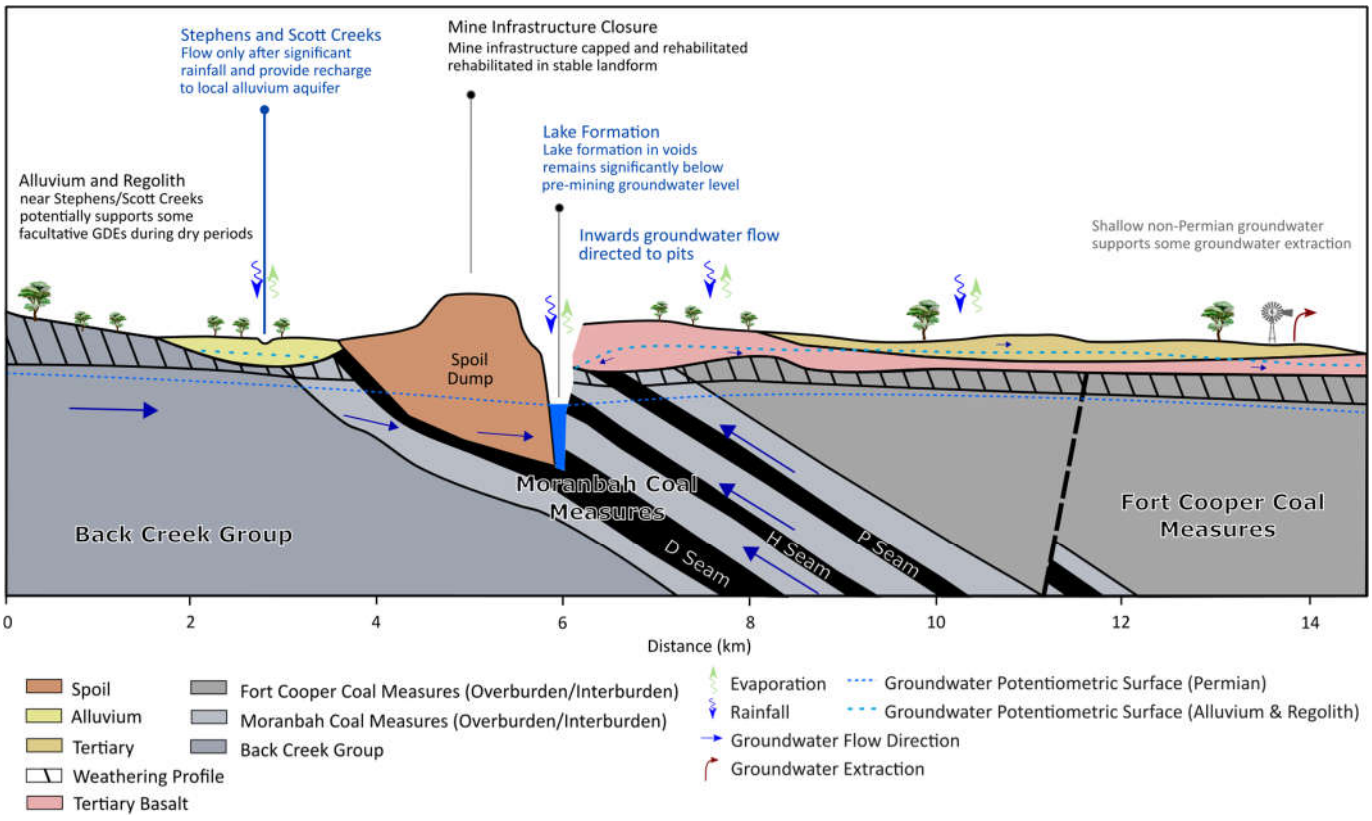

Figure 28. Source-Pathway-Receptor (SPR) conceptual site model (CSM) post-mining
(SLR, 2024)

Permian groundwater flow at SSM 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 SLR (2024) shows the residual voids will ultimately be groundwater 'sinks' – that is, the residual voids will be receptors of run-off and seepage from the final landforms, run-off from void highwalls, and groundwater will flow towards the voids, as illustrated in the CSM (**Figure 28**). The residual voids are classified as non-use management areas (NUMAs). The spoil landforms are located behind (west of) the residual voids and will drain into the voids. Seepage from the spoil landforms and the highwalls of the residual voids reports to the residual void. As such, the floor of residual voids (i.e. pit floors) are not likely AMD sources for groundwater or surface water receptors due to the fact they will be submerged by inflowing groundwater and run-off/seepage.

The hydrogeological assessment undertaken for the PRCP (SLR, 2024) indicates that the nearest 'true' alluvial aquifer of any significant spatial extent is along the Isaac River floodplain, over 15 km east of SSM. The assessment indicates there may be shallow permeable strata present sporadically along (and/or near to) several

creeks at SSM 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 SSM is unlikely. Furthermore, modelling undertaken by SLR for the PRCP 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 eventually report to the mine pits. The general downward migration of shallow groundwater (and seepage) into deeper groundwater and towards the mine pits (residual voids) is logical, given the very large drawdown (sink) of the pits.

The assessment of shallow groundwater at SSM – 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 spoil landforms and seepage from residual voids due to physical distance (over 20 km) and/or lack of a connecting pathway.

With regard to the post-closure mineral waste facilities (spoil landforms and residual voids), the plausible mechanisms for AMD affected water and/or non-oxidative salinity to report to receptors are identified in **Table 17**.

The geochemical source hazard assessment (**Section 7.1**) found that the spoil landforms, which are comprised of approximately 94% non-carbonaceous spoil (average across all landforms), posed a **Low-Moderate** AMD hazard, with AMD generation from the spoil landforms rated as **Unlikely**.

Table 17. Sources, potential receptors and potential pathways between the source and receptor (post-closure)

Sources	Potential Pathways from Source	Potential Receptors from Source
Spoil landforms		
Lotus-Campbell	Surface water [run-off]	• Lotus/Downs Creek[1] (northern toe) / Stephens Creek[2] (southwestern and southern toe) • Lotus-Campbell residual void
	Seepage [shallow permeable strata]	• Lotus/Downs Creek[1] (northern toe) / Stephens Creek[2] (southwestern and southern toe)
	Seepage [groundwater]	• Lotus-Campbell residual void
Gilbert	Surface water [run-off]	• Stephens Creek[2] (northern toe) / Scott Creek[3] (southern toe) • Gilbert residual void
	Seepage [shallow permeable strata]	• Stephens Creek[2] (northern toe) / Scott Creek[3] (southern toe)
	Seepage [groundwater]	• Gilbert residual void
Price-Leichhardt	Surface water [run-off]	• Scott Creek[3] (northern toe) / Sandy Creek[4] (western toe) / un-named creek[5] (southern toe) • Price-Leichhardt residual void
	Seepage [shallow permeable strata]	• Scott Creek[3] (northern toe) / Sandy Creek[4] (western toe) / un-named creek[5] (southern toe)
	Seepage [groundwater]	• Price-Leichhardt residual void

East landform on next page.

Table notes:

1. Downs Creek flows east around the northern toe of Lotus-Campbell landform/void.
2. Stephens Creek flows east between Campbell and Gilbert pits.
3. Scott Creek flows east between Gilbert and Price pits.
4. Sandy Creek – a tributary of Scott Creek – has several un-named tributaries draining from the western side of the ML at Price-Leichhardt landform.
5. Un-named creek on the southern side of Leichhardt pit (Price-Leichhardt landform) is a northern tributary of Rolf Creek.

Table 17 continued…

Sources	Potential Pathways	Potential Receptors
Spoil landforms (continued)		
East North	Surface water [run-off]	• Un-named tributary of Rolf Creek[6] (northern toe) / Rolf Creek[7] (southern toe) • East North residual void
	Seepage [shallow permeable strata]	• Un-named tributary of Rolf Creek[6] (northern toe) / Rolf Creek[7] (southern toe)
	Seepage [groundwater]	• East North residual void
East South	Surface water [run-off]	• Rolf Creek[7] (northern toe) / Un-named tributary of Rolf Creek[8] (southern side of landform) • East South residual void
	Seepage [shallow permeable strata]	• Rolf Creek[7] (northern toe)
	Seepage [groundwater]	• East South residual void
Void highwalls		
Lotus-Campbell	Surface water [run-off]	Lotus-Campbell residual void
Gilbert	Surface water [run-off]	Gilbert residual void
Price-Leichhardt	Surface water [run-off]	Price-Leichhardt residual void
East North	Surface water [run-off]	East North residual void
East South	Surface water [run-off]	East South residual void

Table notes:

6. Un-named creek on the northern side of East North landform is a northern tributary of Rolf Creek. Currently flows through the proposed East North landform and pit area, but will be diverted around (northeast of) East North pit once mining at East North pit commences and, as such, is expected to re-connect with Rolf Creek approximately at the eastern ML boundary.
7. Rolf Creek flows from the northern end of Roper landform in an easterly direction between East North and East South landforms/voids.
8. Un-named creek about 400m south of East South landform is a southern tributary of Rolf Creek and joins Rolf Creek about 2 km east of East South void.

The BHP residual risk rating heat map (**Table 18**) has been adopted to assess the risks associated with SPR from the spoil 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 18. 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 rating for the spoil landforms with respect to plausible surface water receptors is shown in **Attachment C – Tables C1 to C4** and discussed in **Section 7.2.2**. The risk rating for the spoil landforms with respect to residual void receptors is shown in **Attachment C – Table C5** and also discussed in **Section 7.2.2**. The risk rating for the residual voids with respect to the void receptor is shown in **Attachment C – Table C6** and discussed in **Section7.2.3**. The potential impact of seepage, if any, from the residual voids into the Permian groundwater aquifer is discussed in the void closure plan (WSP, 2024).

The SPR assessment showed that the risk rating for AMD to impact receptors is **Low**. The risk rating for non-oxidative salinity to impact receptors is also rated as **Low**, based on a 75th percentile EC value applied to the source.

The assessment shows that all receptors are generally at **Low** risk of direct environmental impact from mineral waste with respect to AMD (including acid/acidity, NMD and SD) and also with respect to non-oxidative salinity. The risk ratings were assigned with consideration for the key aspects for each key facility/domain.

7.2.2 Final spoil landforms

Source materials hazard

The spoil landforms are comprised of approximately 92 to 94% non-carbonaceous overburden/interburden with coaly and carbonaceous material (predominantly in the form of carbonaceous spoil) comprising the remaining 6 to 8% of the final landforms. Spoil has been conservatively assessed as posing a Low-Moderate AMD source hazard – consistent with spoil from Tertiary- and Permian-age material throughout the Bowen Basin. Aged rejects located within Lotus-Campbell spoil landform comprise less than 0.01% of this landform and have been conservatively assessed as posing a Low-Moderate AMD source hazard. During landform reshaping, currently exposed reject areas at Lotus-Campbell area will be covered by spoil. Refer to **Section 8** for rejects management measures.

Source materials generally have low EC values and are expected to produce generally non-saline to slightly saline run-off and seepage, with release of (non-oxidative) salinity rated as a low hazard.

The overall low total S and generally excess ANC of the combined mineral waste – for all landforms – results in an ‘Unlikely’ hazard score for AMD generation. With respect to non-oxidative salinity, all spoil landforms have a conservative hazard score of ‘Unlikely’.

Pathways

Surface water

Surface water receptors (ephemeral creeks) are located adjacent to each spoil landform – ranging from less than 100m to approximately 750m from landform edges. It is plausible for surface water run-off from final rehabilitated landforms to reach most of these creeks. Refer to **Figure 1**, **Figure 23** and **Attachment C – Tables C1 to C4** for surface water receptors associated with each spoil landform. The small quantity of rejects located at Lotus-Campbell landform will be buried by several metres of spoil, therefore all run-off will be from general spoil (overburden/interburden) material and no rejects will be exposed to (or at risk of) surface water run-off. Furthermore, the rejects at Lotus-Campbell landform are located over 3 km from the nearest creek.

Seepage / Groundwater

The water table is expected to intersect the deeper zones of each in-pit final landform within the Permian coal measures (SLR, 2024). However, groundwater is captured by the residual void (as a 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 report to the residual void – not to the broader aquifer.

As discussed in **Section 7.2.1**, it is plausible for seepage from the near-surface and unsaturated zone of the in-pit final landforms to migrate downwards into the water table. It is also plausible (however likely) 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 SSM, 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 SSM is downwards and towards (into) the residual voids [excluding Roper Study Area]. Therefore, it is reasonably assumed that the likelihood of seepage from final 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 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 each spoil landform and **Attachment C – Table C5** for groundwater pathways to the residual voids.

Receptors

Plausible receptors identified in this qualitative assessment include ephemeral creeks and the residual voids. Refer to **Attachment C – Tables C1 to C4** for surface water receptors associated with each spoil landform and **Attachment C – Table C5** for residual void receptors. Due to the geochemical nature of the final 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. Excluding a homestead located about 750 m southwest of the Roper Study Area (located upstream [via surface water] and upgradient [via groundwater]), the nearest homesteads to SSM are all located over four kilometres west and east of the ML boundary and, as such, 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**.

7.2.3 Residual voids

Source materials hazard

The surfaces of residual void highwalls are comprised of approximately 87% to 89% non-carbonaceous overburden/ interburden, 6% to 8% carbonaceous overburden/interburden (incl. sub-economic seams reporting to waste; some of which potentially represent seam roof, parting and floor) and about 5% to 7% coal (seams). Approximately 23% to 53% of the current pit highwalls are weathered material. Fresh and weathered non-carbonaceous overburden/interburden material in the Bowen Basin is widely recognised as posing a low AMD risk. Coal seams at SSM pose a low to moderate AMD risk.

Generally, highwall materials have low EC values, with release of (non-oxidative) salinity rated as a low hazard.

For each void highwall the AMD source hazard of each material type on the highwall has been assessed, taking into account the proportion of each material type exposed on the highwall. The results show that, overall, the void highwall AMD hazard is low-moderate and the likelihood for AMD generation from all residual void highwalls is 'Unlikely'.

The floor of Lotus-Campbell, Gilbert and Leichhardt (middle and southern sections of Price-Leichhardt) residual voids is expected to be comprised of DY Lower seam and is conservatively estimated to contain approximately 9% PAF coal – assuming 100% of the floor is coal and not some other material. The Price pit floor (northern section of Price-Leichhardt void) is comprised of HC Lower seam and is estimated to contain approximately 35% PAF coal. The floor of East void (North and South) will be comprised of HC Upper seam and is estimated to contain approximately 38% PAF coal. The void floors, as described, pose a moderate AMD hazard – which does not take into account likely mitigating factors, such as void floor flooding. After flooding, the floor of each void would be expected to pose a low AMD hazard.

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

The residual voids subject to this PRCP assessment will act as groundwater sinks and the water table will intersect the deeper zones of these residual voids, resulting in the formation of a relatively small void lake in each void (SLR, 2024; and **Figure 28**). The void lake 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.

Receptors

Modelling undertaken by SLR (2024) shows the residual voids to be 'sinks' – receiving surface water run-off and seepage from spoil landforms and surface water run-off from void highwalls. 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 will be discussed in the void closure plan (WSP, 2024).

Due to the geochemical nature of the materials exposed in the highwall of each void, the likelihood of undiluted salinity or AMD (if any) to impact on residual void water quality has been rated unlikely.

The floor of each residual void will be covered post-closure by water as rainfall and groundwater reporting to or interacting with 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.

Consideration was also made to people living in the homesteads near the project area. Excluding a homestead located about 750 m southwest of the Roper Study Area (and upgradient of Roper Study Area via groundwater),

the nearest homesteads to SSM are all located over four kilometres west and east of the ML boundary. As such, the potential for these homesteads to be impacted by AMD from the residual voids is implausible.

SPR risk rating of residual voids

The final 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 (SLR, 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**.

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2024) shows that seepage from the void lake (of each void) into groundwater, if any, would be limited.

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 mineral wastes 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). 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:
    - Lotus-Campbell void;
    - Gilbert void;
    - Price-Leichhardt void;
    - East North void; and
    - East South void.
- Spoil dumps: will be reshaped into five final spoil landforms (corresponding to the five residual voids listed above) and seeded.
- Ramp head ROM pads (comprising rejects) are located within the Lotus-Campbell spoil landform footprint. These pads will be covered by spoil and become part of the Lotus-Campbell spoil landform.
- Main ROM pad: Remove remnant coal from the ROM Pad and dispose within spoil. The former ROM Pad will be reshaped, covered with soil, ripped and seeded.
- Coal stockpile: Remove remnant coal from the coal stockpile pad 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 (outside of the Roper Study Area – refer to **Section 2.1.1**). However, BHP will continue to undertake sampling of likely mineral waste materials (and subsequent characterisation and assessment of those samples) from SSM 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 SSM and between shallow groundwater and surface water systems at SSM.

The Roper Study Area will undergo detailed assessment under a separate scope of works to address rehabilitation and closure planning requirements. Refer to the main volume of the PRCP for detailed information.

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Attachment A – Geological Sections

Pit highwall long-sections

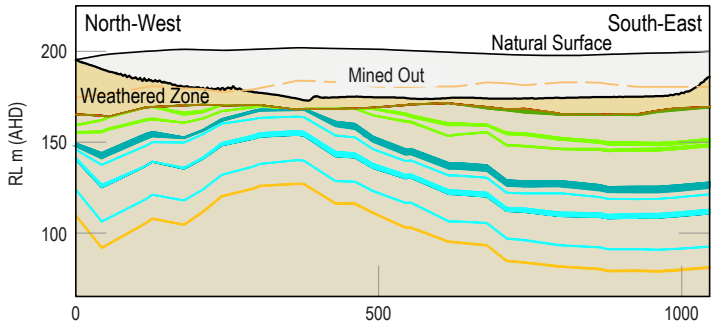
- Figure A1 Lotus pit
- Figure A2 Campbell pit
- Figure A3 Gilbert pit
- Figure A4 Price pit and Leichhardt pit
- Figure A5 Roper pit

Pit highwall cross-sections

- Figure A6 Lotus pit and Campbell pit
- Figure A7 Gilbert pit and Price pit
- Figure A8 Leichhardt pit
- Figure A9 Roper pit

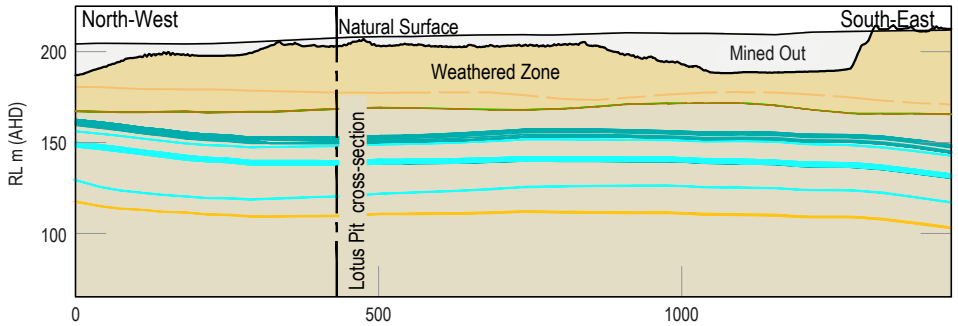
LONG-SECTION | Lotus Pit (north)

Viewed Looking North-East (Vertical Exaggeration x3.0)



LONG-SECTION | Lotus Pit (south)

Viewed Looking North (Vertical Exaggeration x3.0)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

Vertical Scale

0 — 100m

Horizontal Scale

0 — 300m

(V/H = 3.0:1)

BHP

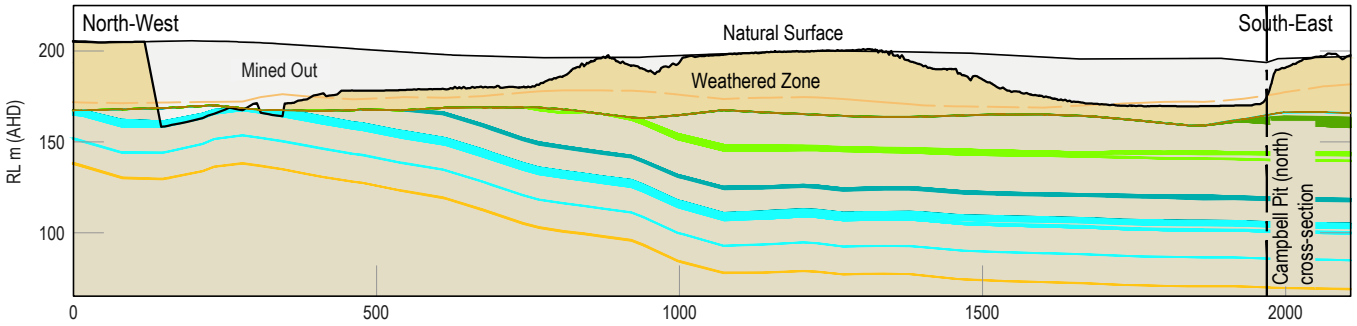
Minserve CAD File: Bhpb008m09.dwg

Pit highwall long-sections

Figure **A1**

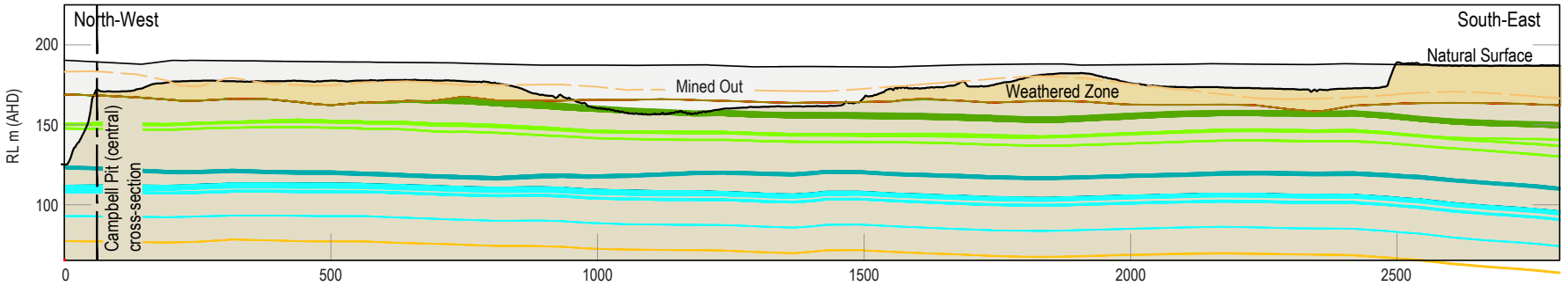
LONG-SECTION | Campbell Pit (north)

Viewed Looking North (Vertical Exaggeration x3.0)



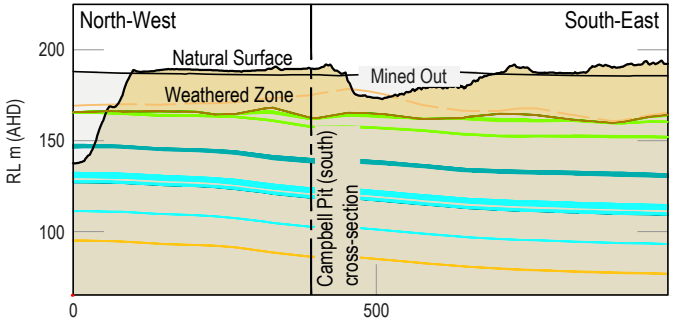
LONG-SECTION | Campbell Pit (central)

Viewed Looking North-East (Vertical Exaggeration x3.0)



LONG-SECTION | Campbell Pit (south)

Viewed Looking North (Vertical Exaggeration x3.0)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

0 100m

Horizontal Scale

0 300m

(V/H = 3.0:1)

BHP

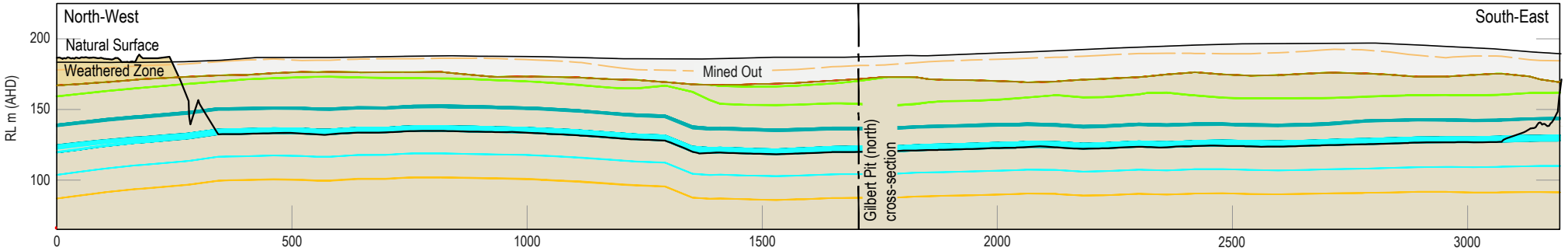
Minserve CAD File: Bhpb008m09.dwg

Pit highwall long-sections

Figure **A2**

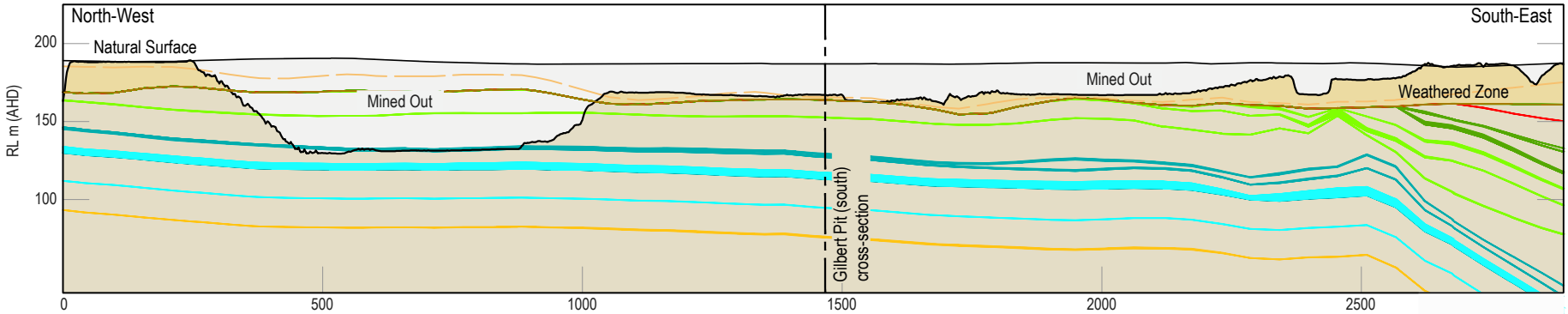
LONG-SECTION | Gilbert Pit (north)

Viewed Looking North (Vertical Exaggeration x3.0)



LONG-SECTION | Gilbert Pit (south)

Viewed Looking North-East (Vertical Exaggeration x3.0)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

Vertical Scale

0 — 100m

Horizontal Scale

0 — 300m

(V/H = 3.0:1)

BHP

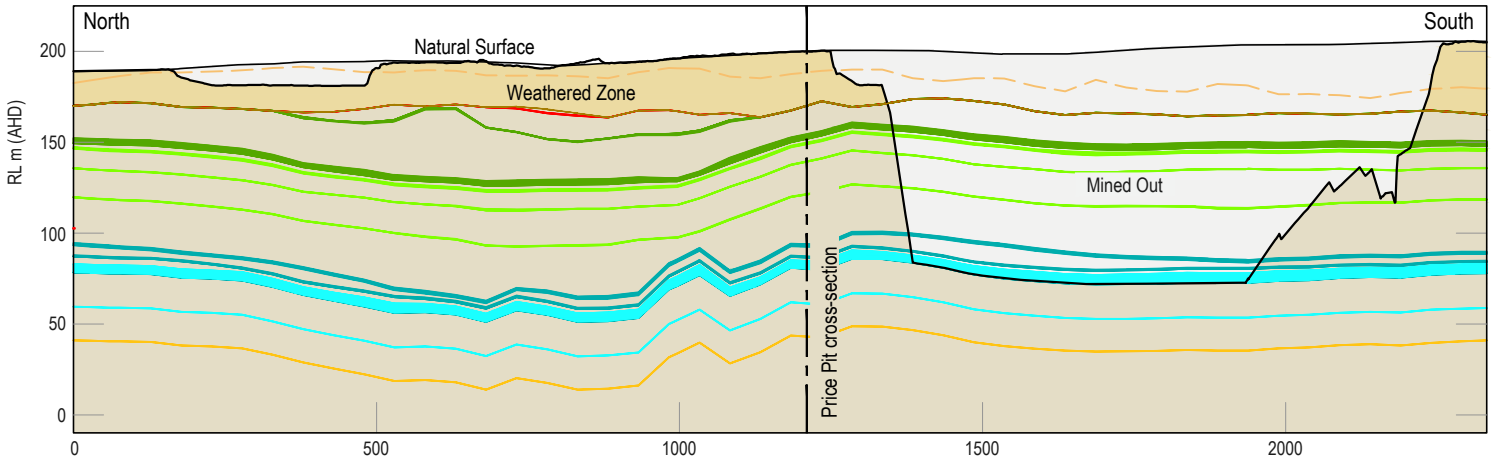
Minserve CAD File: Bhpb008m09.dwg

Pit highwall long-sections

Figure **A3**

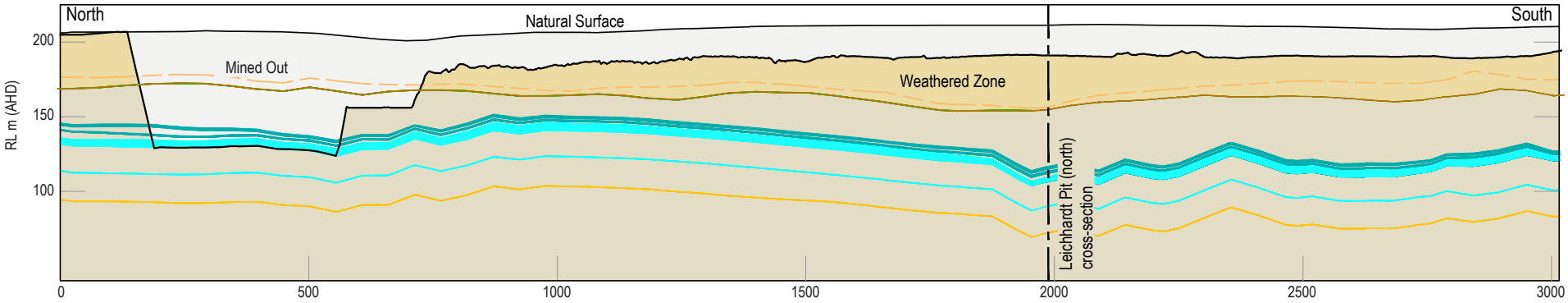
LONG-SECTION | Price Pit

Viewed Looking East (Vertical Exaggeration x3.0)



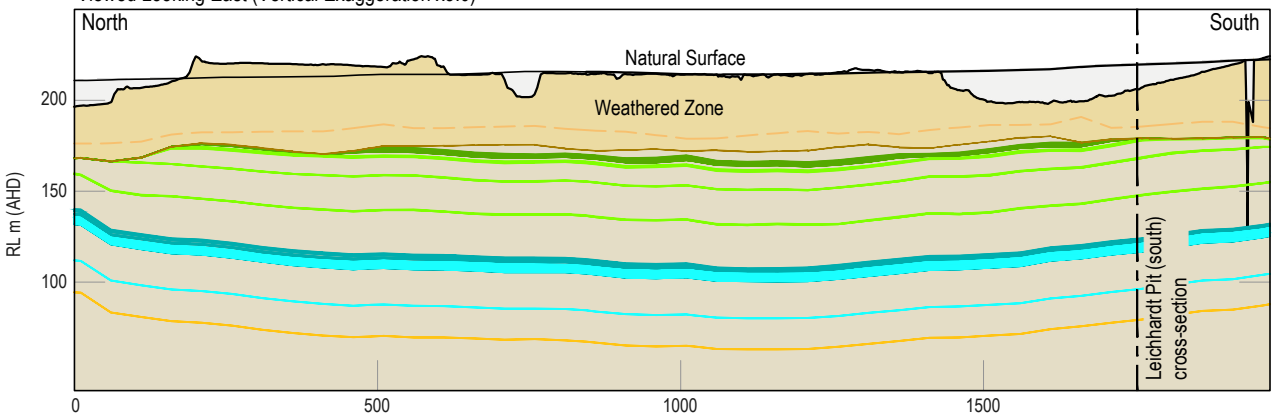
LONG-SECTION | Leichhardt Pit (north)

Viewed Looking East (Vertical Exaggeration x3.0)



LONG-SECTION | Leichhardt Pit (south)

Viewed Looking East (Vertical Exaggeration x3.0)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

Vertical Scale

0 — 100m

Horizontal Scale

0 — 300m

(V/H = 3.0:1)

BHP

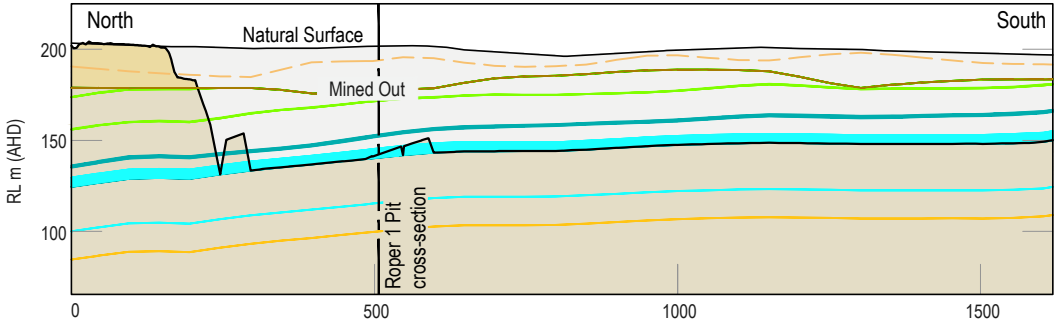
Minserve CAD File: Bhpb008m09.dwg

Pit highwall long-sections

Figure **A4**

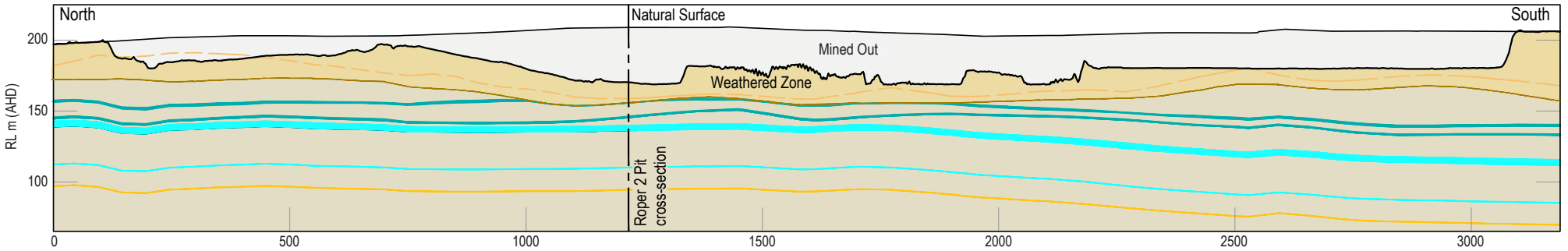
LONG-SECTION | Roper 1 Pit

Viewed Looking East (Vertical Exaggeration x3.0)



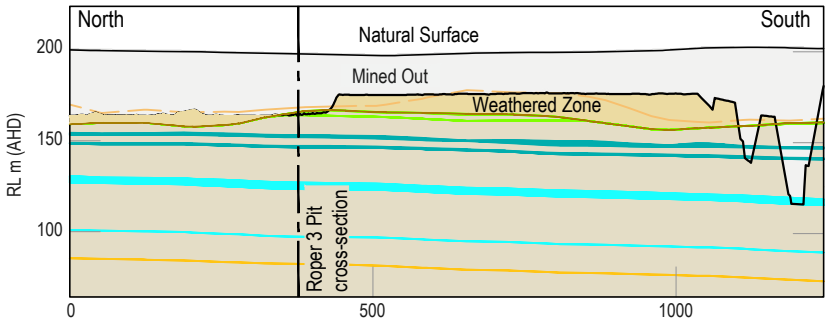
LONG-SECTION | Roper 2 Pit

Viewed Looking East (Vertical Exaggeration x3.0)



LONG-SECTION | Roper 3 Pit

Viewed Looking East (Vertical Exaggeration x3.0)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

Vertical Scale

0 — 80m

Horizontal Scale

0 — 200m

(V/H = 2.5:1)

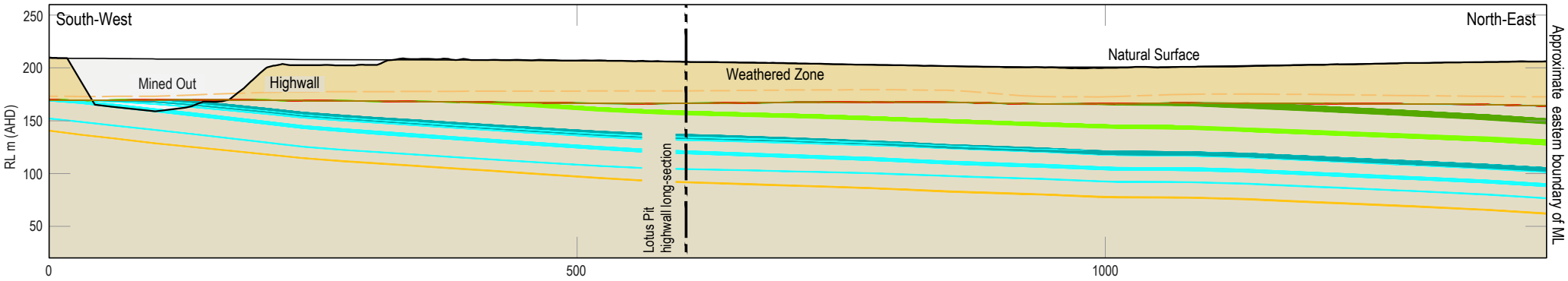
BHP

Minserve CAD File: Bhpb008m09.dwg

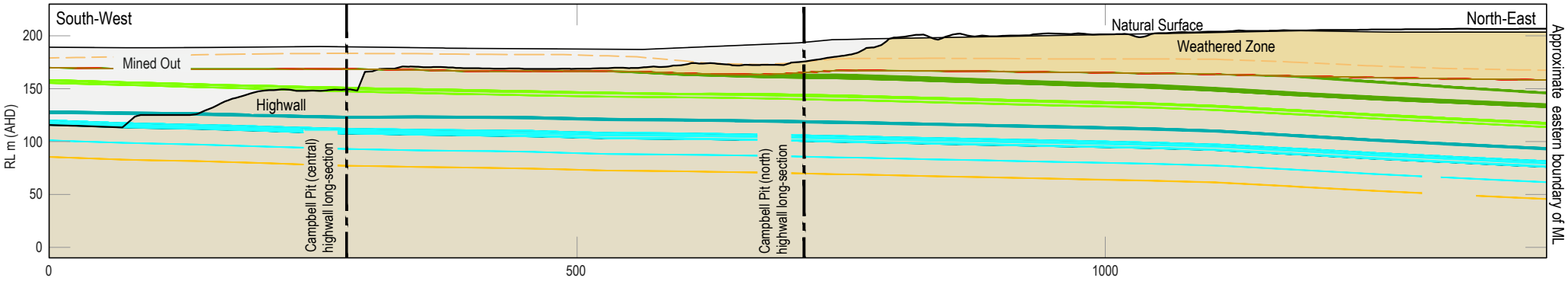
Pit highwall long-sections

Figure **A5**

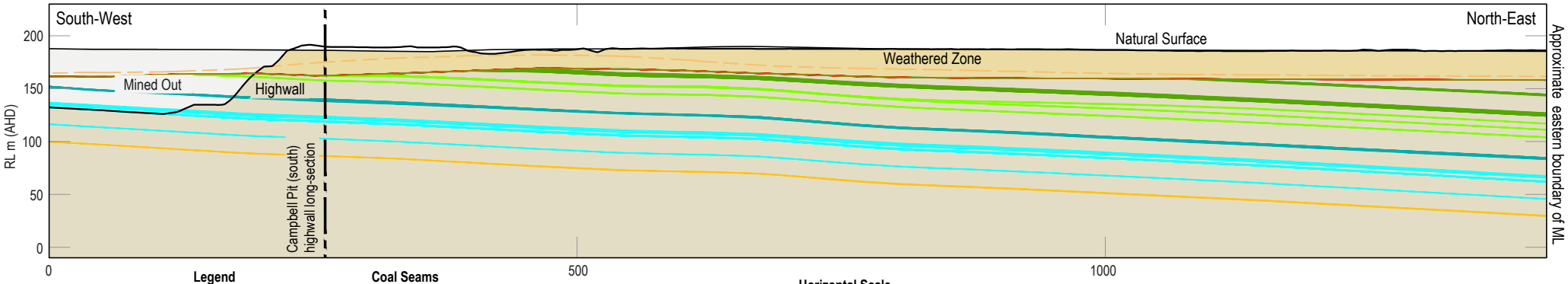
CROSS-SECTION | Lotus Pit
Viewed Looking North-West



CROSS-SECTION | Campbell Pit (north)
Viewed Looking North-West



CROSS-SECTION | Campbell Pit (south)
Viewed Looking North-West



Legend
- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams
- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- DLL Seam Group

Horizontal Scale
(V/H = 1)
0 75 150

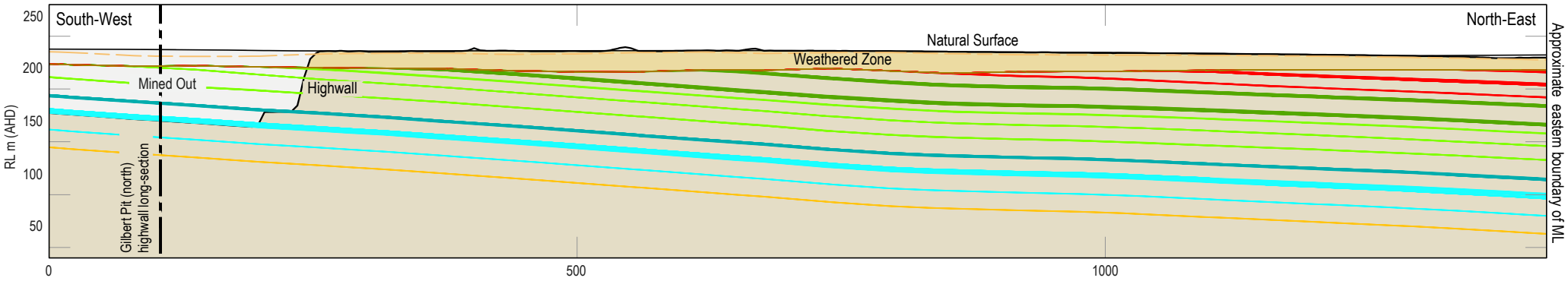
BHP

Minserve CAD File: Bhpb008m09.dwg

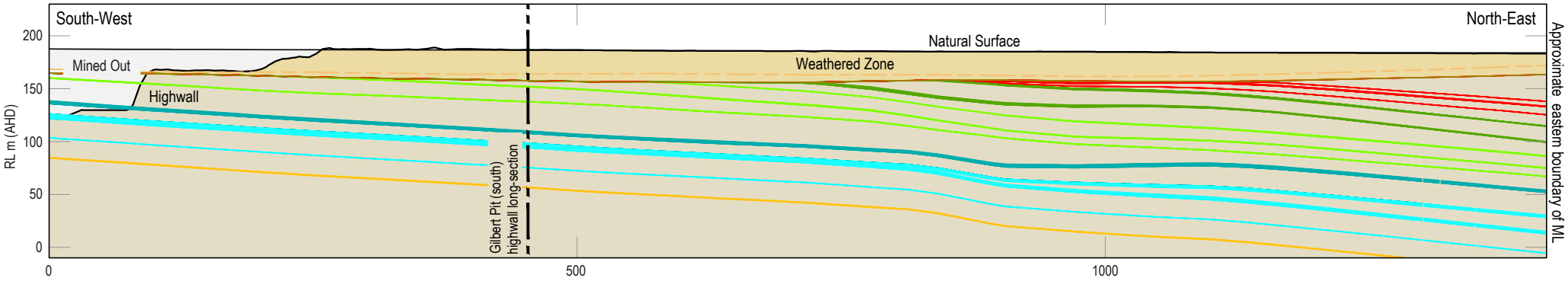
Pit cross-sections

Figure **A6**

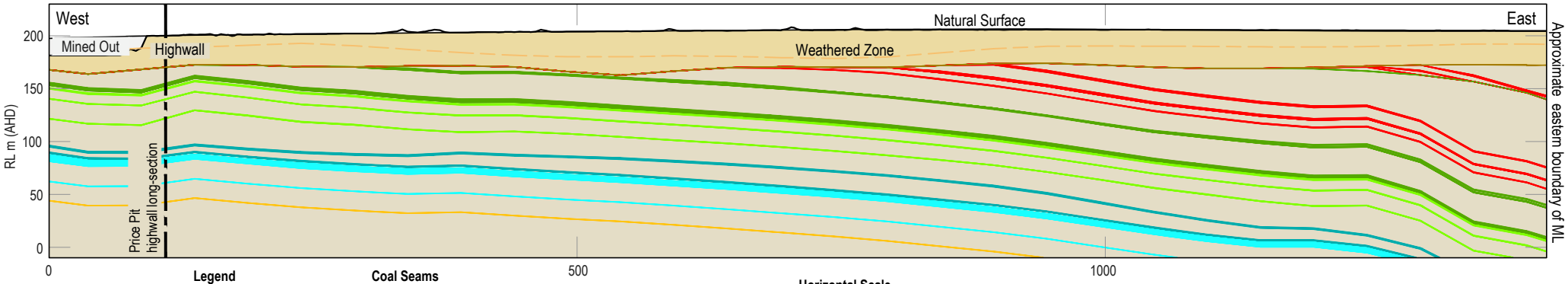
CROSS-SECTION | Gilbert Pit (north)
Viewed Looking North-West



CROSS-SECTION | Gilbert Pit (south)
Viewed Looking North-West



CROSS-SECTION | Price Pit
Viewed Looking North



Legend
- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams
- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- DLL Seam Group

Horizontal Scale
(V/H = 1)
0 75 150

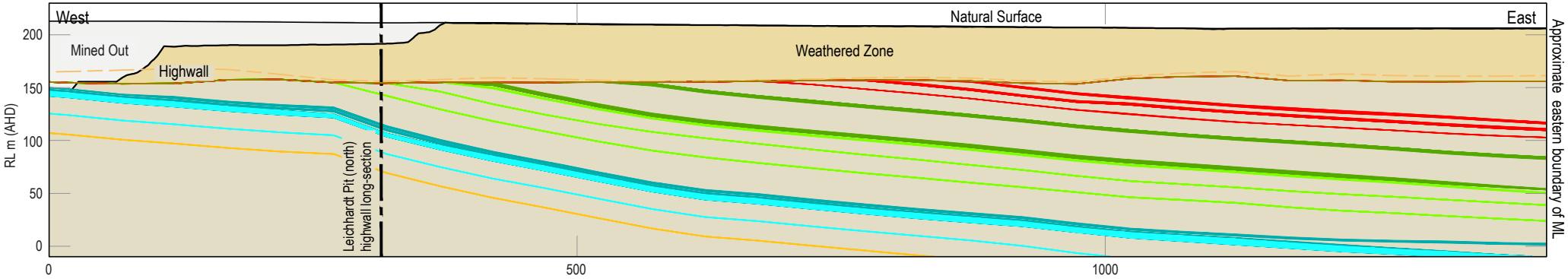
BHP

Minserve CAD File: Bhpb008m09.dwg

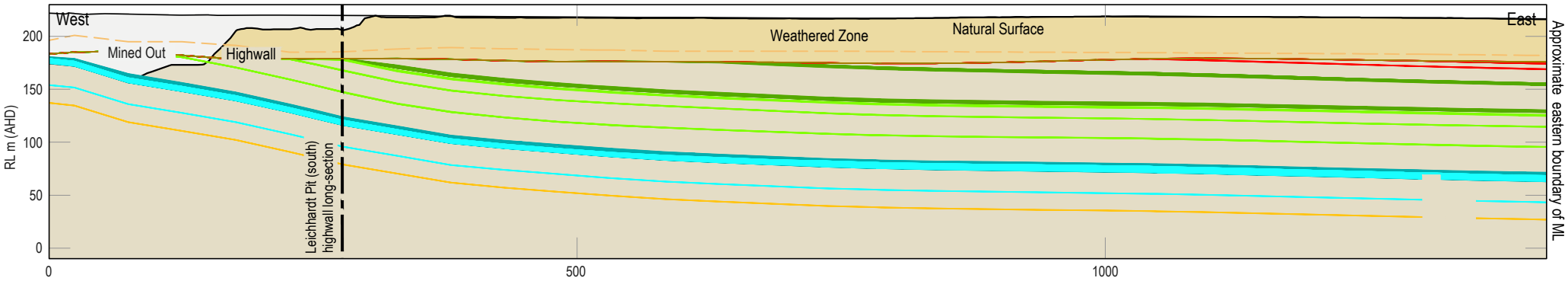
Pit cross-sections

Figure **A7**

CROSS-SECTION | Leichhardt Pit (north)
Viewed Looking North



CROSS-SECTION | Leichhardt Pit (south)
Viewed Looking North



Legend
- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams
- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- DLL Seam Group

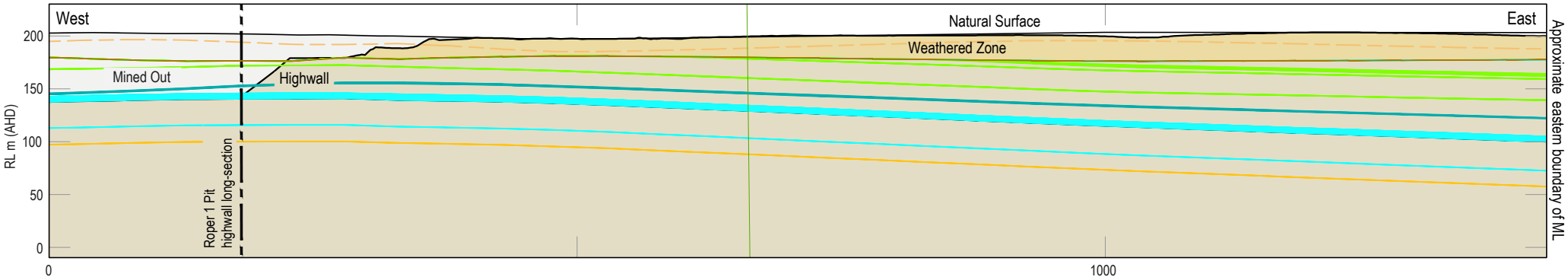
Horizontal Scale
(V/H = 1)
0 75 150

BHP
Minserve CAD File: Bhpb008m09.dwg

Pit cross-sections
Figure **A8**

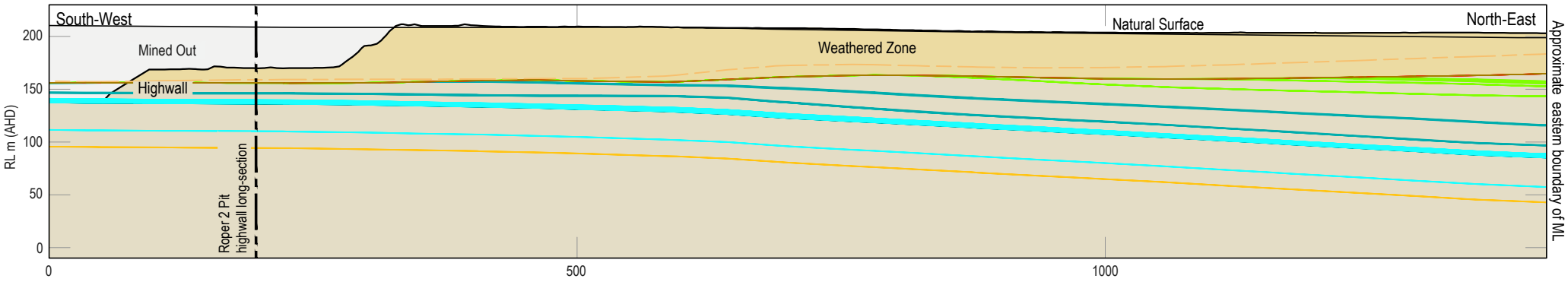
CROSS-SECTION | Roper 1 Pit

Viewed Looking North



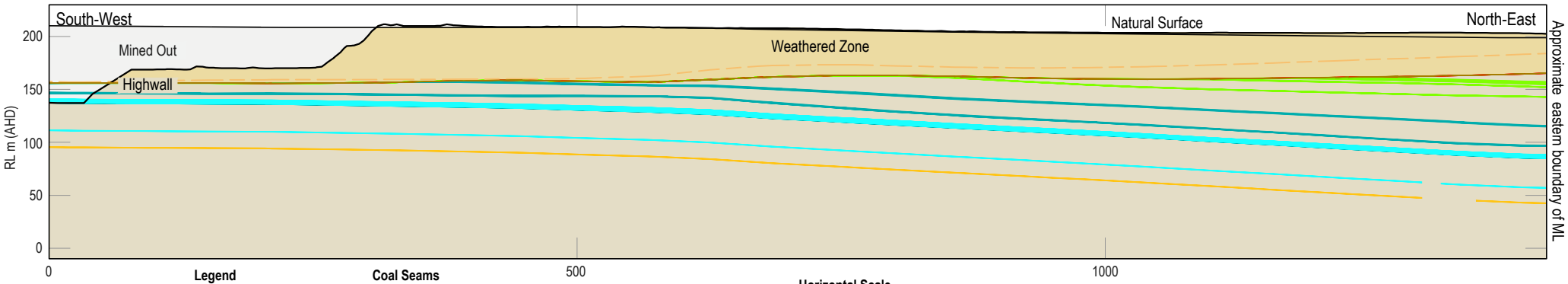
CROSS-SECTION | Roper 2 Pit

Viewed Looking North-West



CROSS-SECTION | Roper 3 Pit

Viewed Looking North-West



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- P Seam Group
- H Upper Seam Group
- H Lower Seam Group
- D Upper Seam Group
- D Lower Seam Group
- D Lower Lower Seam

Horizontal Scale

(V/H = 1)

0 75 150

BHP

Minserve CAD File: Bhpb008m09.dwg

Pit cross-sections

Figure **A9**

Attachment B – AMD Hazard Scoring Tables

AMD hazard and likelihood of AMD generation from post-closure landforms

- Table B1 Lotus-Campbell spoil landform
- Table B2 Gilbert spoil landform
- Table B3 Price-Leichhardt spoil landform
- Table B4 East (North and South) spoil landforms

AMD hazard and likelihood of AMD generation from residual voids

- Table B5 Lotus-Campbell residual void walls and floor
- Table B6 Gilbert spoil residual void walls and floor
- Table B7 Price-Leichhardt residual void walls
- Table B8 Price-Leichhardt residual void floor
- Table B9 East (North and South) residual voids walls and floor

Table B1. AMD hazard scoring for source materials and likelihood for AMD generation from Lotus-Campbell final landform

Lotus-Campbell: 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 Lotus-Campbell spoil landform
Non-carbonaceous spoil Distributed throughout	94%	8%	7.3%	Total S is low (75th percentile = 0.10%). NAF samples have a 75th percentile total S value of 0.08%. PAF samples have a 75th percentile total S value of 1.40% (and AMD capacity is based on this number). Up to 8% of non-carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). 75th percentile EC of non-carbonaceous spoil = 488 µS/cm. Over half of the PAF material is associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 94% of mineral waste in the landform. ANC is largely available under field conditions. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**3** Low-Moderate	**10** Low-Moderate	**8.0** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Over three quarters of PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, 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. Rejects located at Ramp 54 and Ramp 55 ROM pads comprise a negligible proportion of the landform (<0.01%), however, nearly half of the rejects at these locations have been conservatively classified as UC(PAF) and are assessed as posing a low-moderate AMD source hazard. Overall, about 9% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and most of this is associated with non-carbonaceous spoil. Non-carbonaceous and carbonaceous spoil are both assigned a low-moderate AMD capacity rating based on the 75th percentile total S value for PAF samples, however PAF spoil comprises only a small proportion of the landform. Rejects are regarded as posing a low-moderate AMD source hazard and are present in negligible quantities (<0.01% of the landform). Rejects will be buried by overwhemingly NAF spoil. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 482 µS/cm. The hazard for AMD generation from Lotus-Campbell spoil landform at SSM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the final Lotus-Campbell spoil landform at SSM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	6%	23%	1.4%	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). NAF samples have a 75th percentile total S value of 0.21%. PAF samples have a 75th percentile total S value of 1.39% (and AMD capacity is based on this number). 75th percentile EC of carbonaceous spoil = 381 µS/cm. Carbonaceous spoil is estimated to comprise approximately 6% of mineral waste in the landform, and assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**1** Low	**9** Low-Moderate		
Rejects A very small quantity of rejects have been used to create ROM pads at Ramps 54 and 55, and comprise less than 0.01% of the estimated final volume of the landform.	0.008%	47%	0.004%	Up to 47% of rejects at SSM have been conservatively classified as UC(PAF) [including 1 sample classified as PAF-LC]. ANC is largely available under field conditions. AMD capacity is based on a 75th percentile S value of 0.69%. NAF samples have a 75th percentile S value of 0.63%, whereas 'PAF' samples have a 75th percentile S value of 0.69%. 75th percentile EC of rejects = 2160 µS/cm. Rejects will comprise a negligibly small proportion of mineral waste in the landform - less than 0.01%. That is, the final spoil landform will essentially be comprised of spoil only. AMD quantity conservatively assumes proportion of PAF rejects samples approximates the proportion of rejects that is PAF.	**7** Expected	**5** Moderate	**1** Low	**10** Low-Moderate		

Table B2. AMD hazard scoring for source materials and likelihood for AMD generation from Gilbert final landform

Gilbert: 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 Gilbert spoil landform
Non-carbonaceous spoil Distributed throughout	92%	8%	7.1%	Total S is low (75th percentile = 0.10%). NAF samples have a 75th percentile total S value of 0.08%. PAF samples have a 75th percentile total S value of 1.40% (and AMD capacity is based on this number). Up to 8% of non-carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). 75th percentile EC of non-carbonaceous spoil = 488 µS/cm. Over half of the PAF material is 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. ANC is largely available under field conditions. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**3** Low-Moderate	**10** Low-Moderate	**7.5** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Over three quarters of PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, 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. Gilbert landform contains no rejects or tailings. Overall, about 9% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and most of this is associated with non-carbonaceous spoil. Non-carbonaceous and carbonaceous spoil are both assigned a low-moderate AMD capacity rating based on the 75th percentile total S value for PAF samples, however PAF spoil comprises only a small proportion of the landform. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 479 µS/cm. The hazard for AMD generation from Gilbert spoil landform at SSM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the final Gilbert spoil landform at SSM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	8%	23%	1.8%	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). NAF samples have a 75th percentile total S value of 0.21%. PAF samples have a 75th percentile total S value of 1.39% (and AMD capacity is based on this number). 75th percentile EC of carbonaceous spoil = 381 µS/cm. Carbonaceous spoil is estimated to comprise approximately 8% of mineral waste in the landform, and assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**1** Low	**9** Low-Moderate		
Rejects No rejects disposed into Gilbert landform	0.0%	0%	0.0%	No rejects located within Gilbert landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B3. AMD hazard scoring for source materials and likelihood for AMD generation from Price-Leichhardt final landform

Price-Leichhardt: 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 Price-Leichhardt spoil landform
Non-carbonaceous spoil Distributed throughout	94%	8%	7.3%	Total S is low (75th percentile = 0.10%). NAF samples have a 75th percentile total S value of 0.08%. PAF samples have a 75th percentile total S value of 1.40% (and AMD capacity is based on this number). Up to 8% of non-carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). 75th percentile EC of non-carbonaceous spoil = 488 µS/cm. Over half of the PAF material is associated with seams - as parting or within 1.5m above and below seams. Non-carbonaceous spoil is estimated to comprise approximately 94% of mineral waste in the landform. ANC is largely available under field conditions. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**3** Low-Moderate	**10** Low-Moderate	**8.0** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Over three quarters of PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, 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. Price-Leichhardt landform contains no rejects or tailings. Overall, about 9% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and most of this is associated with non-carbonaceous spoil. Non-carbonaceous and carbonaceous spoil are both assigned a low-moderate AMD capacity rating based on the 75th percentile total S value for PAF samples, however PAF spoil comprises only a small proportion of the landform. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 482 µS/cm. The hazard for AMD generation from Price-Leichhardt spoil landform at SSM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the final Price-Leichhardt spoil landform at SSM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	6%	23%	1.4%	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). NAF samples have a 75th percentile total S value of 0.21%. PAF samples have a 75th percentile total S value of 1.39% (and AMD capacity is based on this number). 75th percentile EC of carbonaceous spoil = 381 µS/cm. Carbonaceous spoil is estimated to comprise approximately 6% of mineral waste in the landform, and assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**1** Low	**9** Low-Moderate		
Rejects No rejects disposed into landform	0.0%	47%	0.0%	No rejects located within Price-Leichhardt landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B4. AMD hazard scoring for source materials and likelihood for AMD generation from East (North and South) final landforms

East (North and South): 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 East (North and South) spoil landforms
Non-carbonaceous spoil Distributed throughout	*92%*	8%	7.1%	Total S is low (75th percentile = 0.10%). NAF samples have a 75th percentile total S value of 0.08%. PAF samples have a 75th percentile total S value of 1.40% (and AMD capacity is based on this number). Up to 8% of non-carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). 75th percentile EC of non-carbonaceous spoil = 488 µS/cm. Over half of the PAF material is 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. ANC is largely available under field conditions. AMD quantity conservatively assumes proportion of PAF non-carbonaceous spoil samples approximates the proportion of non-carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**3** Low-Moderate	**10** Low-Moderate	**7.5** Low-Moderate	East Pit is divided (north and south) by Rolf Creek and, correspondingly, the relatively small spoil landforms associated with East pit are also split into two (north and south). East-North and East-South landforms, although separated by Rolf Creek, are assessed here as a single landform. General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Over three quarters of PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, 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. The East landforms contain no rejects or tailings. Overall, about 9% of the East landforms (North and South, combined) are conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and most of this is associated with non-carbonaceous spoil. Non-carbonaceous and carbonaceous spoil are both assigned a low-moderate AMD capacity rating based on the 75th percentile total S value for PAF samples, however PAF spoil comprises only a small proportion of the landform. The 75th percentile EC of the East landforms (based on the EC of the source materials proportionally represented) is estimated at 479 µS/cm. The hazard for AMD generation from the East spoil landforms at SSM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the East spoil landforms at SSM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	*8%*	23%	1.8%	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). NAF samples have a 75th percentile total S value of 0.21%. PAF samples have a 75th percentile total S value of 1.39% (and AMD capacity is based on this number). 75th percentile EC of carbonaceous spoil = 381 µS/cm. Carbonaceous spoil is estimated to comprise approximately 8% of mineral waste in the landform, and assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF.	**5** Plausible	**7** Moderate-High	**1** Low	**9** Low-Moderate		
Rejects No rejects disposed into landform	*0.0%*	47%	0.0%	No rejects located within East North or East South landform.	**n/a**	**n/a**	**n/a**	**n/a**		

Table B5. AMD hazard scoring for source materials and likelihood for AMD generation from Lotus-Campbell residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	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 Lotus-Campbell void highwall
Lotus-Campbell Void Highwall	Weathered, non-carbonaceous	51%	92% (where known)	8% (where known)	0%	1.4%	Less than 2% of weathered non-carbonaceous samples (4 samples out of 288) were UC(PAF) or PAF-LC [no "PAF" samples] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.7%	This material is expected to comprise approximately 51% of the void wall material by meterage. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Very small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.02%. AMD capacity based on PAF samples 75th percentile total S of 0.28%.	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, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 9% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Void wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Lotus-Campbell void highwall = **LOW-MODERATE**. The likelihood for AMD generation from Lotus-Campbell void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	2.8%	71% (where known)	29% (where known)	0%	36%	Five out of 14 weathered carbonaceous or coaly samples were UC(PAF) and 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. About 70% of this material lies above the water table.	1.0%	This material is expected to comprise approximately 3% of the void wall material by meterage. Five (out of 14) samples were PAF, and do not contain significant sulphide minerals. Being weathered, PAF materials are likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.36%. AMD capacity based on PAF samples 75th percentile total S of 1.27%.	5	7	1	9	
	Fresh, non-carbonaceous	37%	47% (where known)	53% (where known)	37%	11%	Approximately 11% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [66 out of 615 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 47% of this material is currently above the water table and would be potentially subject to oxidation.	4.0%	This material is estimated to comprise approximately 37% of the void wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 11% of samples were PAF (of some type), and over half were closely associated with coal seams (as roof, parting or floor), with the remaining half predominantly located within Harrow Creek interburden. This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.15%. AMD capacity based on PAF samples 75th percentile total S of 1.53%.	5	10	1	11	
	Fresh, carbonaceous	3.1%	54% (where known)	46% (where known)	3.1%	22%	41 out of 186 samples (22% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 54% of this material is currently above the water table and would be potentially subject to oxidation.	0.7%	Generation of AMD from fresh carbonaceous units cannot be excluded as 22% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 3% of the void wall material. Some carbonaceous overburden has excess ANC. The 75th percentile total S value for this material is 0.41%. AMD capacity based on PAF samples 75th percentile total S of 1.41%.	5	7	1	9	
	Coal (fresh)	5.0%	45% (where known)	55% (where known)	5.0%	49%	Approximately half of the 70 coal samples were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 45% of this material is currently above the water table and would be potentially subject to oxidation.	2.4%	Fresh coal is expected to comprise about 5% of the void wall material by meterage. Geochemical data is available for 70 coal samples sourced from across SSM seams. Of these, 19 samples were PAF and 16 were PAF-LC [i.e. 49% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is 0.96%. AMD capacity based on PAF samples 75th percentile total S of 1.69%. With regard to the coal quality database (n=2943 samples), the 75th percentile total S value is 0.69% - lower, but generally consistent with the smaller geochemical database. The seams/plys exposed on the highwall are predominantly the DY Upper and Lower seam groups, with lesser exposure of HC Upper and Lower seam groups.	7	10	1	13	
	Unknown	0.5%	79%	21%	0.3%	0%	Lithology unknown. Approximately 55% of this material is below base of weathering (ie. fresh)	0%	Negligible proportion; approximately 45% of this material is within weathered zone. Assume negligible PAF. Assume 'High' AMD capacity rating.	1	10	1	7	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							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 Lotus-Campbell void floor
Lotus-Campbell Void Floor	Coal: DY Lower seam	100%	0%	100%	100%	9%	PAF proportion estimated by applying a total S 'cut-off' of 0.69% to the coal quality data for DY Lower seam samples (1198 samples). The S cut-off was based on the median total S value for PAF coal and PAF reject samples (combined) from the geochemical database. 113 out of 1198 DY Lower samples had total S ≥0.69%. Based on the geochemical database, 49% of 70 coal samples were conservatively classifed as PAF. Whereas, based on the much larger coal quality database (1198 samples), 9% of the void floor is estimated to be PAF. All void floor is below the water table and would become submerged shortly after mining ceases.	9%	The floor of Lotus-Campbell void is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 1198 DY Lower samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 1.69% for PAF coal samples from the geochemical database. Approximately 9% of DY Lower seam coal samples from SSM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a moderate proportion of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	10	3	12	Approximately 9% 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 Lotus-Campbell void floor = **PROBABLE/LIKELY**

Table B6. AMD hazard scoring for source materials and likelihood for AMD generation from Gilbert residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	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 Gilbert void highwall
Gilbert Void Highwall	Weathered, non-carbonaceous	27%	79% (where known)	21% (where known)	0%	1.4%	Less than 2% of weathered non-carbonaceous samples (4 samples out of 288) were UC(PAF) or PAF-LC [no "PAF" samples] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.4%	This material is expected to comprise approximately 27% of the void wall material by meterage. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Very small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.02%. AMD capacity based on PAF samples 75th percentile total S of 0.28%.	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, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 11% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Void wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Gilbert void highwall = **LOW-MODERATE**. The likelihood for AMD generation from Gilbert void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	1.5%	28% (where known)	72% (where known)	0%	36%	Five out of 14 weathered carbonaceous or coaly samples were UC(PAF) and 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. About 28% of this material lies above the water table.	0.5%	This material is expected to comprise less than 2% of the void wall material by meterage. Five (out of 14) samples were PAF, and do not contain significant sulphide minerals. Being weathered, PAF materials are likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.36%. AMD capacity based on PAF samples 75th percentile total S of 1.27%.	5	7	1	9	
	Fresh, non-carbonaceous	57%	58% (where known)	42% (where known)	57%	11%	Approximately 11% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [66 out of 615 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 58% of this material is currently above the water table and would be potentially subject to oxidation.	6.1%	This material is estimated to comprise approximately 57% of the void wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 11% of samples were PAF (of some type), and over half were closely associated with coal seams (as roof, parting or floor), with the remaining half predominantly located within Harrow Creek interburden. This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.15%. AMD capacity based on PAF samples 75th percentile total S of 1.53%.	5	10	1	11	
	Fresh, carbonaceous	3.7%	38% (where known)	62% (where known)	3.7%	22%	41 out of 186 samples (22% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 38% of this material is currently above the water table and would be potentially subject to oxidation.	0.8%	Generation of AMD from fresh carbonaceous units cannot be excluded as 22% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 4% of the void wall material. Some carbonaceous overburden has excess ANC. The 75th percentile total S value for this material is 0.41%. AMD capacity based on PAF samples 75th percentile total S of 1.41%.	5	7	1	9	
	Coal (fresh)	6.0%	41% (where known)	59% (where known)	6.0%	49%	Approximately half of the 70 coal samples were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 41% of this material is currently above the water table and would be potentially subject to oxidation.	2.9%	Fresh coal is expected to comprise about 6% of the void wall material by meterage. Geochemical data is available for 70 coal samples sourced from across SSM seams. Of these, 19 samples were PAF and 16 were PAF-LC [i.e. 49% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is 0.96%. AMD capacity based on PAF samples 75th percentile total S of 1.69%. With regard to the much larger coal quality database (n=2943 samples), the 75th percentile total S value is 0.69% - lower, but generally consistent with the smaller geochemical database. The seams/plys exposed on the highwall are predominantly the DY Upper and Lower seam groups, with lesser exposure of HC Upper and Lower seam groups. Minor P seam will be exposed at end of mine life.	7	10	1	13	
	Unknown	4.7%	79%	21%	0.3%	0%	Lithology unknown. Approximately 54% of this material is below base of weathering (ie. fresh)	0%	Negligible proportion; approximately 46% of this material is within weathered zone. Assume negligible PAF. Assume 'High' AMD capacity rating.	1	10	1	7	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							11%						

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 Gilbert void floor	
Gilbert Void Floor	Coal: DY Lower seam	100%	0%	100%	100%	9%	PAF proportion estimated by applying a total S 'cut-off' of 0.69% to the coal quality data for DY Lower seam samples (1198 samples). The S cut-off was based on the median total S value for PAF coal and PAF reject samples (combined) from the geochemical database. 113 out of 1198 DY Lower samples had total S $\geq$0.69%. Based on the geochemical database, 49% of 70 coal samples were conservatively classifed as PAF. Whereas, based on the much larger coal quality database (1198 samples), 9% of the void floor is estimated to be PAF. All void floor is below the water table and would become submerged shortly after mining ceases.	9%	The floor of Gilbert void is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 1198 DY Lower samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 1.69% for PAF coal samples from the geochemical database. Approximately 9% of DY Lower seam coal samples from SSM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a moderate proportion of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	10	3	12	Approximately 9% 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 Gilbert void floor = **PROBABLE/LIKELY**

Table B7. AMD hazard scoring for source materials and likelihood for AMD generation from Price-Leichhardt residual void walls

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	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 Price-Leichhardt void highwall
Price-Leichhardt Void Highwall	Weathered, non-carbonaceous	53%	100% (where known)	0% (where known)	0%	1.4%	Less than 2% of weathered non-carbonaceous samples (4 samples out of 288) were UC(PAF) or PAF-LC [no "PAF" samples] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.7%	This material is expected to comprise approximately 53% of the void wall material by meterage. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Very small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.02%. AMD capacity based on PAF samples 75th percentile total S of 0.28%.	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, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 8% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Void wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Price-Leichhardt void highwall = **LOW-MODERATE**. The likelihood for AMD generation from Price-Leichhardt void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	0.4%	100% (where known)	0% (where known)	0%	36%	Five out of 14 weathered carbonaceous or coaly samples were UC(PAF) and 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. Essentially all of this material lies above the water table.	0.1%	This material is expected to comprise less than 1% of the void wall material by meterage. Five (out of 14) samples were PAF, and do not contain significant sulphide minerals. Being weathered, PAF materials are likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.36%. AMD capacity based on PAF samples 75th percentile total S of 1.27%.	5	7	1	9	
	Fresh, non-carbonaceous	31%	70% (where known)	30% (where known)	31%	11%	Approximately 11% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [66 out of 615 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 70% of this material is currently above the water table and would be potentially subject to oxidation.	3.3%	This material is estimated to comprise approximately 31% of the void wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 11% of samples were PAF (of some type), and over half were closely associated with coal seams (as roof, parting or floor), with the remaining half predominantly located within Harrow Creek interburden. This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.15%. AMD capacity based on PAF samples 75th percentile total S of 1.53%.	5	10	1	11	
	Fresh, carbonaceous	2.1%	51% (where known)	49% (where known)	2.1%	22%	41 out of 186 samples (22% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 51% of this material is currently above the water table and would be potentially subject to oxidation.	0.5%	Generation of AMD from fresh carbonaceous units cannot be excluded as 22% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 2% of the void wall material. Some carbonaceous overburden has excess ANC. The 75th percentile total S value for this material is 0.41%. AMD capacity based on PAF samples 75th percentile total S of 1.41%.	5	7	1	9	
	Coal (fresh)	7.1%	61% (where known)	39% (where known)	7.1%	49%	Approximately half of the 70 coal samples were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 61% of this material is currently above the water table and would be potentially subject to oxidation.	3.4%	Fresh coal is expected to comprise about 7% of the void wall material by meterage. Geochemical data is available for 70 coal samples sourced from across SSM seams - 49% of coal samples were PAF of some type. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is 0.96%. AMD capacity based on PAF samples 75th percentile total S of 1.69%. With regard to the much larger coal quality database (n=2943 samples), the 75th percentile total S value is 0.69% - lower, but generally consistent with the smaller geochemical database. The seams/plys exposed on the Price pit highwall are HC Upper and Lower seam groups. Seam groups exposed on the Leichhardt pit highwall are predominantly the DY Upper and Lower seam groups, with lesser exposure of HC Upper and Lower seam groups. Minor P seam will be exposed on Leichhardt highwall at end of mine life.	7	10	1	13	
	Unknown	6.4%	100%	0%	0.3%	0%	Lithology unknown. Approximately 80% of this material is below base of weathering (ie. fresh)	0%	Negligible proportion; approximately 20% of this material is within weathered zone. Assume negligible PAF. Assume 'High' AMD capacity rating.	1	10	1	7	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							8%						

Table B8. AMD hazard scoring for source materials and likelihood for AMD generation from Price-Leichhardt residual void floor

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 Price void floor	
Void Floor (Price pit) Northern end of Price-Leichhardt void	Coal: HC Lower seam	100%	0%	100%	100%	35%	PAF proportion estimated by applying a total S 'cut-off' of 0.69% to the coal quality data for HC Lower seam samples (254 samples). The S cut-off was based on the median total S value for PAF coal and PAF reject samples (combined) from the geochemical database. 88 out of 254 HC Lower samples had total S ≥0.69%. Based on the geochemical database, 49% of 70 coal samples were conservatively classifed as PAF. Whereas, based on the larger coal quality database (254 samples), 35% of the Price end of the Price-Leichhardt void floor is estimated to be PAF. All void floor is below the water table and would become submerged shortly after mining ceases.	35%	The floor of Price void (ie. the Price end of the Price-Leichhardt void) is likely to be HC Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.84% (based on 254 HC Lower samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 1.69% for PAF coal samples from the geochemical database. Approximately 35% of HC Lower seam coal samples from SSM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	10	7	14	Approximately 35% 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 Price void floor = **PROBABLE/LIKELY**

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 Leichhardt void floor	
Void Floor (Leichhardt pit) Middle and southern end of Price-Leichhardt void	Coal: DY Lower seam	100%	0%	100%	100%	9%	PAF proportion estimated by applying a total S 'cut-off' of 0.69% to the coal quality data for DY Lower seam samples (1198 samples). The S cut-off was based on the median total S value for PAF coal and PAF reject samples (combined) from the geochemical database. 113 out of 1198 DY Lower samples had total S ≥0.69%. Based on the geochemical database, 49% of 70 coal samples were conservatively classifed as PAF. Whereas, based on the much larger coal quality database (1198 samples), 9% of the Leichhardt end of the Price-Leichhardt void floor is estimated to be PAF. All void floor is below the water table and would become submerged shortly after mining ceases.	9%	The floor of Leichhardt void (ie. the Leichhardt end of the Price-Leichhardt void) is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 1198 DY Lower samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 1.69% for PAF coal samples from the geochemical database. Approximately 9% of DY Lower seam coal samples from SSM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a moderate proportion of the void floor cannot be excluded - assuming the entire void floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	10	3	12	Approximately 9% 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 Leichhardt void floor = **PROBABLE/LIKELY**

Table B9. AMD hazard scoring for source materials and likelihood for AMD generation from East (North and South) residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	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 highwall of East Void
East Void Highwall - (North and South voids combined)	Weathered, non-carbonaceous	23%	100% (where known)	0% (where known)	0%	1.4%	Less than 2% of weathered non-carbonaceous samples (4 samples out of 288) were UC(PAF) or PAF-LC [no "PAF" samples] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.3%	This material is expected to comprise approximately 23% of the void wall material by meterage. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Very small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.02%. AMD capacity based on PAF samples 75th percentile total S of 0.28%.	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, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 12% (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. Void wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from East voids highwalls = **LOW-MODERATE**. The likelihood for AMD generation from East voids highwalls = **UNLIKELY**
	Weathered, carbonaceous & coaly	0.4%	100% (where known)	0% (where known)	0%	36%	Five out of 14 weathered carbonaceous or coaly samples were UC(PAF) and 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. Essentially all of this material lies above the water table.	0.1%	This material is expected to comprise less than 1% of the void wall material by meterage. Five (out of 14) samples were PAF, and do not contain significant sulphide minerals. Being weathered, PAF materials are likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.36%. AMD capacity based on PAF samples 75th percentile total S of 1.27%.	5	7	1	9	
	Fresh, non-carbonaceous	64%	14% (where known)	86% (where known)	64%	11%	Approximately 11% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [66 out of 615 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 14% of this material is currently above the water table and would be potentially subject to oxidation.	6.9%	This material is estimated to comprise approximately 64% of the void wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 11% of samples were PAF (of some type), and over half were closely associated with coal seams (as roof, parting or floor), with the remaining half predominantly located within Harrow Creek interburden. This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.15%. AMD capacity based on PAF samples 75th percentile total S of 1.53%.	5	10	1	11	
	Fresh, carbonaceous	6.9%	0% (where known)	100% (where known)	6.9%	22%	41 out of 186 samples (22% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, none of this material is currently above the water table and, as such, this material is unlikely to be subject to oxidation.	1.5%	Generation of AMD from fresh carbonaceous units cannot be excluded as 22% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 7% of the void wall material. Some carbonaceous overburden has excess ANC. The 75th percentile total S value for this material is 0.41%. AMD capacity based on PAF samples 75th percentile total S of 1.41%.	5	7	1	9	
	Coal (fresh)	5.9%	12% (where known)	88% (where known)	5.9%	49%	Approximately half of the 70 coal samples were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 12% of this material is currently above the water table and would be potentially subject to oxidation.	2.9%	Fresh coal is expected to comprise about 6% of the void wall material by meterage. Geochemical data is available for 70 coal samples sourced from across SSM seams. Of these, 19 samples were PAF and 16 were PAF-LC [i.e. 49% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is 0.96%. AMD capacity based on PAF samples 75th percentile total S of 1.69%. With regard to the much larger coal quality database (n=2943 samples), the 75th percentile total S value is 0.69% - lower, but generally consistent with the smaller geochemical database. The seams/plys exposed on the highwall are the HC Upper and Lower seam groups.	7	10	1	13	
	Unknown	0.0%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	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							12%						

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 East Void void floor	
East Void Floor (North and South voids combined)	Coal: HC Upper seam	100%	0%	100%	100%	38%	PAF proportion estimated by applying a total S 'cut-off' of 0.69% to the coal quality data for HC Upper seam samples (356 samples). The S cut-off was based on the median total S value for PAF coal and PAF reject samples (combined) from the geochemical database. 137 out of 356 HC Upper samples had total S ≥0.69%. Based on the geochemical database, 49% of 70 coal samples were conservatively classifed as PAF. Whereas, based on the larger coal quality database (356 samples), 38% of the pit floor is estimated to be PAF. All pit floor is below the water table and would become submerged shortly after mining ceases.	38%	The floor of the East voids are likely to be HC Upper seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.83% (based on 356 HC Upper samples in the coal quality database). AMD capacity is based on 75th percentile total S value of 1.69% for PAF coal samples from the geochemical database. Approximately 38% of HC Upper seam coal samples from SSM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	10	7	14	Approximately 38% 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 East voids floor = **PROBABLE/LIKELY**

Attachment C – SPR Assessment Tables

SPR assessment of post-closure spoil landform (source) to surface water (receptor)

- Table C1 Lotus-Campbell final landform
- Table C2 Gilbert final landform
- Table C3 Price-Leichhardt final landform
- Table C4 East (North and South) final landforms

SPR assessment of post-closure spoil landform (source) to residual void (receptor)

- Table C5 All spoil landforms

SPR assessment of residual void highwall and floor (source) to residual void (receptor)

- Table C6 All residual voids

Table C1. Source-Pathway-Receptor (SPR) assessment of Lotus-Campbell 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
Lotus-Campbell spoil landform (post-closure) Comprised of approximately 94% non-carbonaceous spoil; approximately 6% carbonaceous spoil; and less than 0.01% rejects *AMD source hazard of landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of landform: **Low***	From Lotus-Campbell spoil landform via surface water run-off into ephemeral Lotus Creek / Downs Creek. Distance ~200m 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: **Probable***	Ephemeral creek (via surface water run-off): Lotus Creek / Downs Creek @ northern side of Lotus-Campbell landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Lotus/Downs Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Lotus/Downs Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Lotus/Downs Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Lotus/Downs Creek [via run-off]	Unlikely	S2	Low
	From Lotus-Campbell landform via seepage into shallow permeable strata then into ephemeral Lotus Creek / Downs Creek. Distance ~200m to receptor (north). Ramp 54/55 ROM pads (rejects locations) are located >3 km from creeks (i.e. implausible pathway). *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: Lotus Creek / Downs Creek @ northern side of Lotus-Campbell landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Lotus/Downs Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Lotus/Downs Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Lotus/Downs Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Lotus/Downs Creek [via seepage]	Unlikely	S2	Low
	From Lotus-Campbell spoil landform via surface water run-off into ephemeral Stephens Creek (and tributaries). Distance ~200-400m to receptor (southwest and 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: **Probable***	Ephemeral creek (via surface water run-off): Stephens Creek and tributaries @ southwestern and southern side of Lotus-Campbell landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Stephens Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Stephens Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Stephens Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Stephens Creek [via run-off]	Unlikely	S2	Low
	From Lotus-Campbell spoil landform via seepage into shallow permeable strata then into ephemeral Stephens Creek (and tributaries). Distance ~200-400m to receptor (southwest and 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): Stephens Creek and tributaries @ southwestern and southern side of Lotus-Campbell landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Stephens Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Stephens Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Stephens Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Stephens Creek [via seepage]	Unlikely	S2	Low

Table C2. Source-Pathway-Receptor (SPR) assessment of Gilbert 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
Gilbert spoil landform (post-closure) Comprised of approximately 92% non-carbonaceous spoil; approximately 8% carbonaceous spoil *AMD source hazard of landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of landform: **Low***	From Gilbert spoil landform via surface water run-off into ephemeral Stephens Creek. Distance <200m 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: **Probable***	Ephemeral creek (via surface water run-off): Stephens Creek @ northern side of Gilbert landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Stephens Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Stephens Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Stephens Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Stephens Creek [via run-off]	Unlikely	S2	**Low**
	From Gilbert landform via seepage into shallow permeable strata then into ephemeral Stephens Creek. Distance <200m to receptor (north). *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: Stephens Creek @ northern side of Gilbert landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Stephens Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Stephens Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Stephens Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Stephens Creek [via seepage]	Unlikely	S2	**Low**
	From Gilbert spoil landform via surface water run-off into ephemeral Scott Creek. Distance ~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: **Probable***	Ephemeral creek (via surface water run-off): Scott Creek @ southern side of Gilbert landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Scott Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Scott Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Scott Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Scott Creek [via run-off]	Unlikely	S2	**Low**
	From Gilbert spoil landform via seepage into shallow permeable strata then into ephemeral Scott Creek. Distance ~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): Scott Creek @ southern side of Gilbert landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Scott Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Scott Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Scott Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Scott Creek [via seepage]	Unlikely	S2	**Low**

Table C3. Source-Pathway-Receptor (SPR) assessment of Price-Leichhardt 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
Price-Leichhardt spoil landform (post-closure) Comprised of approximately 94% non-carbonaceous spoil; approximately 6% carbonaceous spoil. *AMD source hazard of landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of landform: **Low***	From Price-Leichhardt spoil landform via surface water run-off into ephemeral Scott Creek. Distance <100m 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: **Probable***	Ephemeral creek (via surface water run-off): Scott Creek @ northern side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Scott Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Scott Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Scott Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Scott Creek [via run-off]	Unlikely	S2	Low
	From Price-Leichhardt landform via seepage into shallow permeable strata then into ephemeral Scott Creek. Distance <100m to receptor (north). *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: Scott Creek @ northern side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Scott Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Scott Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Scott Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Scott Creek [via seepage]	Unlikely	S2	Low
	From Price-Leichhardt spoil landform via surface water run-off into ephemeral Sandy Creek (and tributaries). Distance ~400m to receptor (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: **Probable***	Ephemeral creek (via surface water run-off): Sandy Creek and tributaries @ western side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Sandy Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Sandy Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Sandy Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Sandy Creek [via run-off]	Unlikely	S2	Low
	From Price-Leichhardt spoil landform via seepage into shallow permeable strata then into ephemeral Sandy Creek (and tributaries). Distance ~400m to receptor (west). *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): Sandy Creek and tributaries @ western side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Sandy Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Sandy Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Sandy Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Sandy Creek [via seepage]	Unlikely	S2	Low
	From Price-Leichhardt spoil landform via surface water run-off into ephemeral Rolf Creek north tributary. Distance ~750m 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: **Probable***	Ephemeral creek (via surface water run-off): Rolf Creek north tributary @ southern side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
	From Price-Leichhardt spoil landform via seepage into shallow permeable strata then into ephemeral Rolf Creek north tributary. Distance ~750m 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): Rolf Creek north tributary @ southern side of Price-Leichhardt landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek north tributary [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek north tributary [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Ck north tributary [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek north tributary [via seepage]	Highly Unlikely	S2	Low

Table C4. Source-Pathway-Receptor (SPR) assessment of East (North and South) post-closure spoil landforms: 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
East North and East South spoil landforms (post-closure) Combined, these two landforms are comprised of approximately 92% non-carbonaceous spoil; approximately 8% carbonaceous spoil. *AMD source hazard of landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of landform: **Low***	From East North spoil landform via surface water run-off into ephemeral Rolf Creek north tributary. Distance <100m 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: **Probable***	Ephemeral creek (via surface water run-off): Rolf Creek north tributary @ northern side of East North landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek north tributary [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek north tributary [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek north tributary [via run-off]	Unlikely	S2	Low
	From East North spoil landform via seepage into shallow permeable strata then into ephemeral Rolf Creek north tributary. Distance <100m to receptor (north). *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: Rolf Creek north tributary @ northern side of East North landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek north tributary [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek north tributary [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek north tributary [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek north tributary [via seepage]	Unlikely	S2	Low
	From East spoil landforms (combined) via surface water run-off into ephemeral Rolf Creek. Distance ~150m to receptor (creek runs between the two spoil landforms). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Rolf Creek between East North and East South landforms. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek [via run-off]	Unlikely	S2	Low
	From East spoil landforms via seepage into shallow permeable strata then into ephemeral Rolf Creek. Distance ~150m to receptor (creek runs between the two spoil landforms). *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): Rolf Creek between East North and East South landforms. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek [via seepage]	Unlikely	S2	Low
	From East South spoil landform via surface water run-off into ephemeral Rolf Creek tributary. Distance ~400m 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: **Probable***	Ephemeral creek (via surface water run-off): Rolf Creek tributary @ southern side of East South landform. *Potential for AMD to reach Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek south tributary [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek south tributary [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Rolf Creek south tributary [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek south tributary [via run-off]	Unlikely	S2	Low
	From East South spoil landform via seepage into shallow permeable strata then into ephemeral Rolf Creek tributary. Distance ~400m 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): Rolf Creek tributary @ southern side of East South landform. *Potential for AMD to reach Creek: **Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Creek: **Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Rolf Creek south tributary [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Rolf Creek south tributary [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxdn.): Salt (sulphate) impacting Rolf Creek south tributary [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Rolf Creek south tributary [via seepage]	Unlikely	S2	Low

Table C5. Source-Pathway-Receptor (SPR) assessment of post-closure spoil landforms: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Lotus-Campbell spoil landform (post-closure) Approximate composition: 94% non-carb. spoil; 6% carb. spoil; <0.01% rejects. Rejects are concentrated in one area. No tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Low***	Seepage / percolation into groundwater, which flows into Lotus-Cambell residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	Lotus-Campbell residual void (NUMA) *Potential for AMD to reach residual void:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Lotus-Campbell residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Lotus-Campbell residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Lotus-Campbell residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Lotus-Campbell residual void water quality	Unlikely	S2	**Low**
Gilbert spoil landform (post-closure) Approximate composition: 92% non-carb. spoil; 8% carb. spoil. No rejects or tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Low***	Seepage / percolation into groundwater, which flows into Gilbert residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	Gilbert residual void (NUMA) *Potential for AMD to reach residual void:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Gilbert residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Gilbert residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Gilbert residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Gilbert residual void water quality	Unlikely	S2	**Low**
Price-Leichhardt spoil landform (post-closure) Approximate composition: 94% non-carb. spoil; 6% carb. spoil. No rejects or tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Low***	Seepage / percolation into groundwater, which flows into Price-Leichhardt residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	Price-Leichhardt residual void (NUMA) *Potential for AMD to reach residual void:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Price-Leichhardt residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Price-Leichhardt residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Price-Leichhardt residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Price-Leichhardt residual void water quality	Unlikely	S2	**Low**
East North and East South spoil landforms (post-closure) Approximate combined composition: 92% non-carb. spoil; 8% carb. spoil. No rejects or tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Low***	Seepage / percolation into groundwater, which flows into East North and East South residual voids. Residual voids are expected to intersect the water table. Residual voids are groundwater 'sinks', drawing all groundwater within landform catchment towards the residual voids. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	East North and East South residual voids (NUMAs) *Potential for AMD to reach residual voids:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual voids:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting East (North / South) residual voids water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting East (North / South) residual voids water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting East (North / South) residual voids water quality	Highly Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting East (North / South) residual voids water quality	Unlikely	S2	**Low**

Table C6. Source-Pathway-Receptor (SPR) assessment of residual void highwall and floor: residual void receptors for Lotus-Campbell, Gilbert, Price-Leichhardt and East (North and South) voids

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Highwall and floor of Lotus-Cambell, Gilbert, Price-Leichhardt and East residual voids (post-closure) Highwalls of these residual voids are comprised of approximately: • 87 to 89% non-carbonaceous overburden/interburden; • 6 to 8% carbonaceous overburden/interburden; • 5 to 7% coal (residual coal seams). PAF exposure on highwalls conservatively estimated at approximately 8 to 12% (vertical meterage). A proportion of this will be in lower seams, which will be submerged. PAF exposure on pit floors conservatively estimated at approximately 9% for Lotus-Campbell, Gilbert and Leichhardt pit floors; 35% for Price pit floor; and 38% for East pit floor – however pit floors will be submerged. *AMD source hazard from exposed highwalls and submerged pit floors is **Low-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. All voids are groundwater 'sinks'. *Potential for AMD to enter surface water run-off from highwall: **Unlikely*** *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: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual voids: **Unlikely***	**Acid/acidic drainage** Low pH water impacting residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage Metals impacting residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting residual void water quality	Unlikely	S1	**Low**
			Saline drainage Salt impacting residual void water quality	Unlikely	S1	**Low**

BHP

Landloch

EROSION AND LANDFORM EVOLUTION SIMULATIONS TO SUPPORT WASTE LANDFORM DESIGN: SARAJI SOUTH MINE

September 2024

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Project Number: 1447.21a6

Report Title: Erosion and landform evolution simulations to support waste landform design: Saraji South Mine

Client: BM Alliance Coal Operations Pty Ltd (BMA)

Review History

Version Number	Prepared by:	Reviewed by:	Date
Rev 0 (draft)	E. Howard	A. Hooper (BHP)	31/10/2023
Rev 1 (final)	E. Howard	I. Kelder	29/11/2023
Rev 2 (revised final)	E. Howard		16/09/2024

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1 SUMMARY

For waste landforms at Saraji South Mine (SSM), 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.

WEPP simulations were carried out for:

- Batter slopes 500m long, at 30% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.
- Batter slopes 1,000m long, at 15% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.
- Batter slopes 1,000m long, at 10% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.

Erodibility data for materials considered in WEPP simulations were sourced from previous Saraji mine studies and from direct measurement of materials from SSM, and included:

- Clay soil from Saraji Mine (S01); and
- Permian sandstone waste (NPM6) from SSM.

In deriving and applying SIBERIA parameters, it was assumed that the:

- Clay soil will be used for outward-facing batters and support a vegetation groundcover level of 70%
- Permian sandstone waste will be used for inward-facing (low wall) batters and support a vegetation groundcover level of 50%.

It is considered that these simulations address all options being considered for SSM. SIBERIA model output showed batter slopes erode at rates below target levels, except in some locations at the interface between existing rehabilitation and dump areas and the vegetated clay-covered surfaces. Where this occurs, the result is an artefact of the elevations within 3-D design files supplied and in reality the final landform will be smoothed in these areas and they are not likely to erode at rates that would increase the risk of rill or gully erosion.

The SIBERIA outputs indicate that the proposed landforms at SSM are not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

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 Saraji South Mine (SSM).

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[1] 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 wastes types present at SSM were sourced from Landloch's SSM material characterisation study report (Landloch 2023a) and soils and land suitability assessment (Landloch 2023b). Soil and waste erodibility parameters for the WEPP runoff/erosion model were taken from samples collected from SSM and from similar studies for the neighbouring Saraji Mine (Landloch 2018).

[1] Water Erosion Prediction Project

3.2 Topsoils

The SSM material characterisation study report (Landloch 2023a) and soils and land suitability assessment (Landloch 2023b) indicate that soils at SSM are dominated by clay soils, with 95% of the currently stockpiled soils and 89% of the undisturbed soils that may become available for use in rehabilitation in the future being clays (vertosols). The remaining soils are sands and loams.

WEPP runoff/erosion model parameters for a similar clay soil to those at SSM exists for a sample tested at the neighbouring Saraji Mine (Landloch 2018). The properties of this topsoil (sample S01) is given in Table 1, along with the typical properties of clay soils at SSM.

Both the Saraji Mine topsoil and the SSM clay soils have alkaline pH_w values, low salinity ($EC_{1:5}$), low abundance of rock, medium/heavy clay textures (consistent with a vertosol), and are non-sodic. The Saraji Mine soil (sample S01) was therefore suitable to model the erosion potential of the clay soils at SSM.

Table 1: Properties of clay soils at SSM and a clay sample from Saraji for which erodibility parameters exist.

Analysis	Saraji Topsoil (S01)	SSM Clay Soils
pH_w (pH Units)	8.0	7.9–8.8
$EC_{1:5}$ (dS/m)	0.1	0.11–0.39
ECEC (meg/100g)	16.0	23–66
Exchangeable sodium percentage (ESP) (%)	5.0	1.4–10.6
Clay content (%)	50.6	>30
Rock content (%)	0.2	<10

3.3 Wastes

3.3.1 Broad waste information

Waste materials at SSM include tertiary/weathered and fresh Permian materials. Landloch (2023a) summarised a number of waste characterisation studies for SSM. Generally, spoil materials at SSM were found to be:

- Non-acid forming, with acid neutralising capacity (ANC). Some potentially acid forming (PAF) materials occur in the stratigraphic unit, but the excess ANC means acid and metalliferous drainage (AMD) is not considered a significant issue in the mixed spoil material;
- Slightly acidic (tertiary waste) to strongly alkaline (Permian waste);
- Sodic to strongly sodic and dispersive;
- Moderately to highly saline; and
- Low fertility, but significant responses to nitrogen and phosphorus fertilisers.

3.3.2 Waste sampling

Permian wastes are targeted for use near the surface of rehabilitated landforms. Two waste samples were sourced from SSM and assessed for erodibility. These samples were identified as NPM5 and NPM6. Images of these materials are given in Figures 1 to 3 and their properties are given in Table 2.

Visually, NPM5 appears to contain a mixture of tertiary and Permian materials, whereas NPM6 contains a higher proportion of Permian wastes.

Both NPM5 and NPM6 have alkaline pH_w values. NPM6 is saline, whereas NPM5 has low salinity. Both materials have similar ECEC and ESP values.

NPM5 has a much finer particle size distribution than NPM6. NPM5 has a rock content of 15% compared to 35% for NPM6. In addition, the fine fraction (<2mm) of NPM is dominated by fine sand and clay, whereas NPM6 has a greater proportion of coarse sand and a lower proportion of silt and clay.

Figure 1: Images of *in situ* sample NPM5 (left) and NPM6 (right).

Figure 2: Images of rainfall simulator plots of sample NPM5 (left) and NPM6 (right).

Figure 3: Images of overland flow flumes of sample NPM5 (left) and NPM6 (right).

Table 2: Properties of NPM5 and NPM6 wastes from SSM.

Analysis	NPM5	NPM6
pH_w (pH Units)	8.5	9.4
$EC_{1:5}$ (dS/m)	1.3	0.15
ECEC (meg/100g)	12.3	7.0
ESP (%)	5.3	4.1
Coarse Sand (%)	9.6	36.6
Fine Sand (%)	42.6	35.2
Silt (%)	17.1	8.6
Clay (%)	30.8	19.6
Rock content (%)	15	35

3.4 WEPP simulations

3.4.1 Parameters used

In the case of both the clay soil and Permian waste, erodibility parameters for WEPP runoff/erosion simulations have been determined experimentally, and include:

- Effective hydraulic conductivity;
- Interrill erodibility;
- Rill erodibility; and
- Critical flow shear stress for initiation of rilling.

3.4.2 Slope, materials, and vegetation groundcover options

WEPP simulations were carried out for:

- Batter slopes 500m long, at 30% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.
- Batter slopes 1,000m long, at 15% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.
- Batter slopes 1,000m long, at 10% gradient, surfaced with:
  - Clay soil (SO1) with vegetation groundcover levels of 0–90%
  - Permian waste (NPM6) with vegetation groundcover levels of 0–50%.

3.4.3 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).

As a conservative approach, vegetation groundcover levels ranging from 0–50% for materials of relatively low fertility (wastes) and 0–70% for more fertile materials (clay soils) have been applied 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.

It is recommended that further sampling, modelling, and monitoring be completed to determine specific minimum vegetation groundcover levels for the site.

3.4.4 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.

3.4.5 Climate

All simulations used a synthetic 100-year climate file prepared to match all relevant characteristics of Moranbah climate.

3.4.6 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.

3.4.7 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 greater than 50m, and situations where – due to either or both rainfall limitations or soil fertility concerns – vegetation growth is unlikely to rapidly colonise and stabilise any rills that form.

As the landforms at SSM 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 greatly 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.

3.5 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 soil) was a maximum of 5t/ha/y at any point on the batter slope. The target erosion rate for modelling inward-facing batters (low walls, Permian waste) was a maximum of 10t/ha/y at any point on the batter slope.

4.1 Outward-facing slopes surfaced with vegetated clay soil

For the clay soil modelled, simulations indicate that gradients of 30% would require very high vegetation groundcover levels (90%) (Figure 5). Slopes that are 1,000m long are predicted to be stable for a vegetation groundcover level of 70% for a 15% gradient slope (Figure 6) and 50% for a 10% gradient slope (Figure 7).

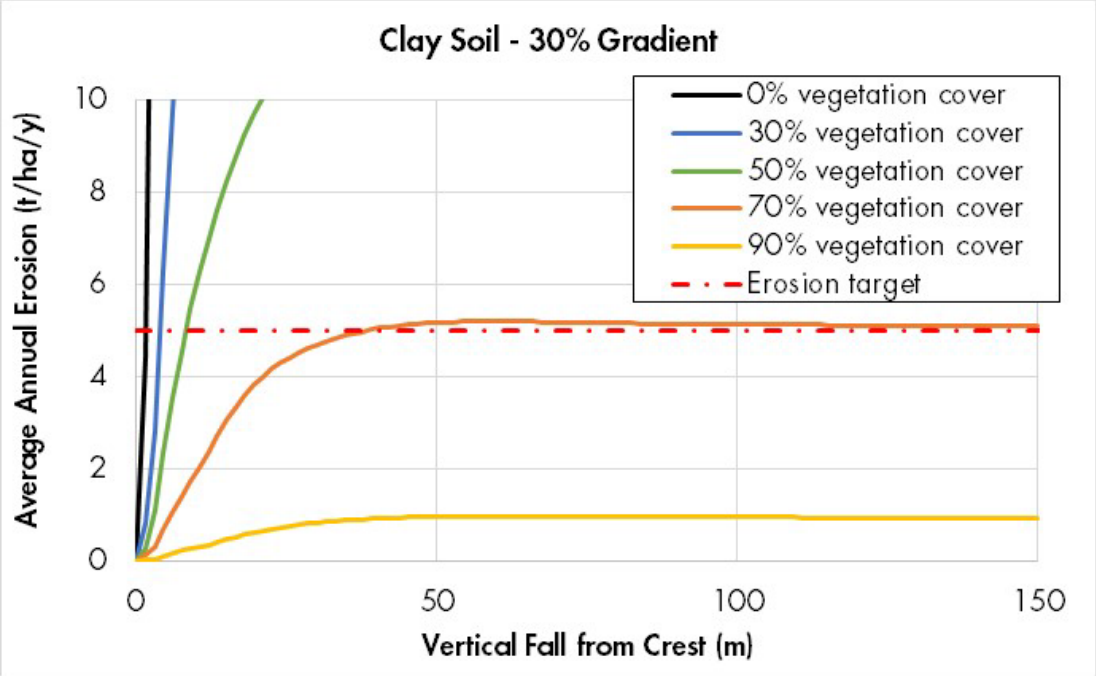

Figure 5: Predicted erosion rates on 30% gradient outward-facing slope sheeted with clay soil.

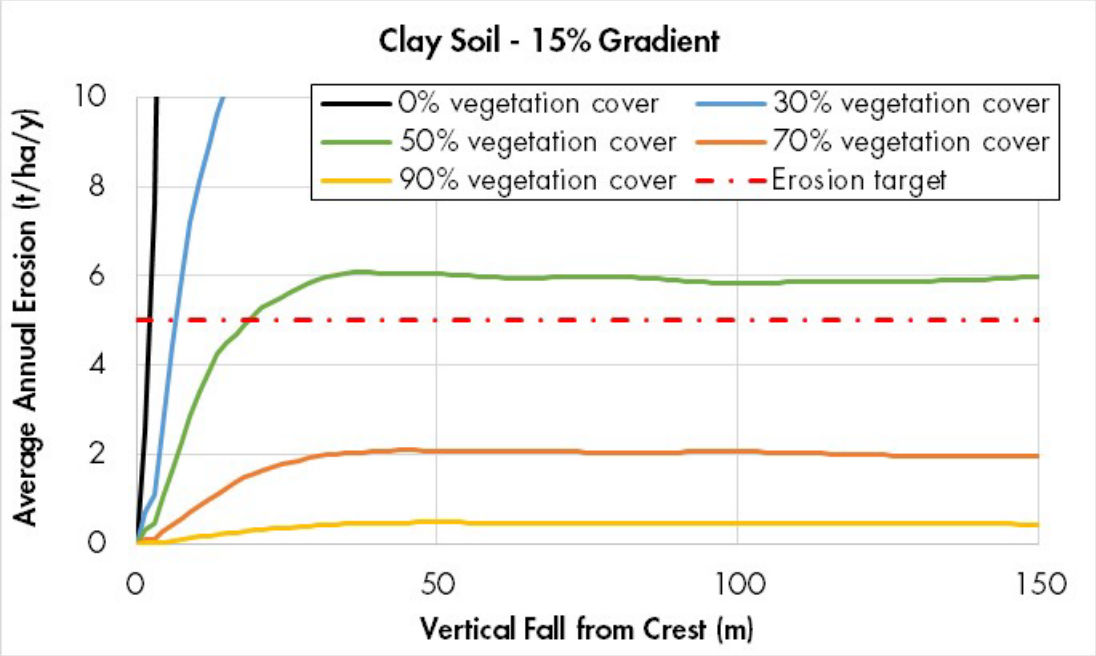

Figure 6: Predicted erosion rates on a 15% gradient outward-facing slope sheeted with clay soil.

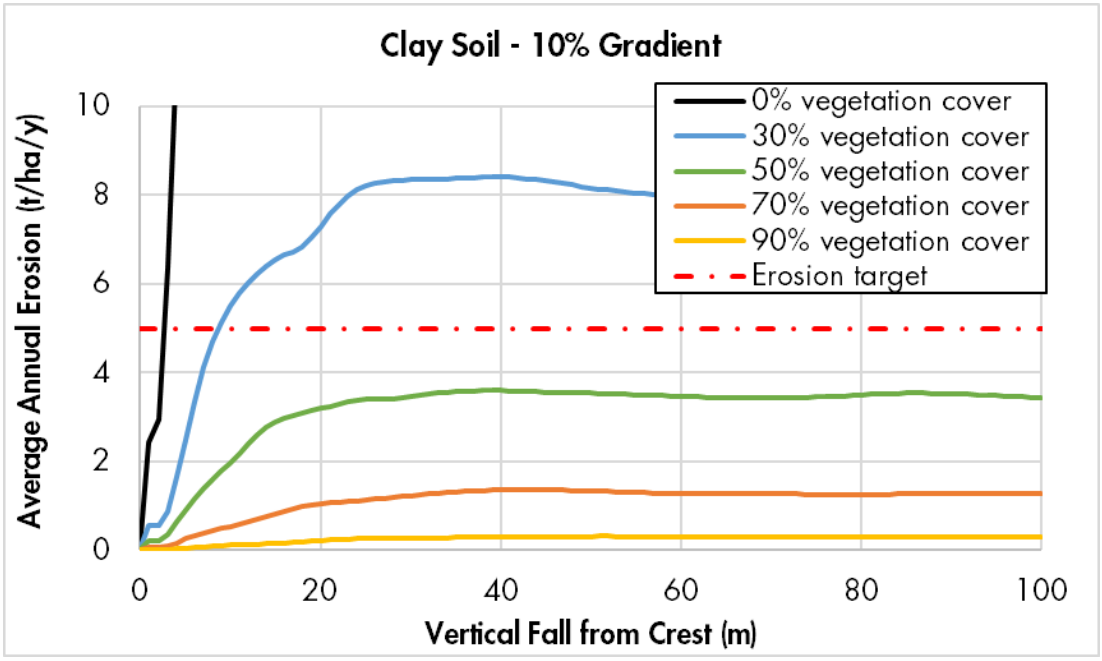

Figure 7: Predicted erosion rates on a 10% gradient outward-facing slope sheeted with clay soil.

4.2 Inward-facing low walls sheeted with Permian waste

For the Permian waste modelled, simulations indicate that 500m long slopes on gradients of 30% would require vegetation groundcover levels of 50% (Figure 8). Slopes with gradients of either 15% or 10% are predicted to be stable for a vegetation groundcover level of 30% or greater (Figures 9 and 10).

It is concluded that inward-facing slopes with a gradient of 30% will require at least 50% vegetation groundcover levels. Gradients of less than 30% could be considered to improve erosional performance if required. The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would reduce the vegetation groundcover compared to clay soil alone for 15% slopes (Section 4.1).

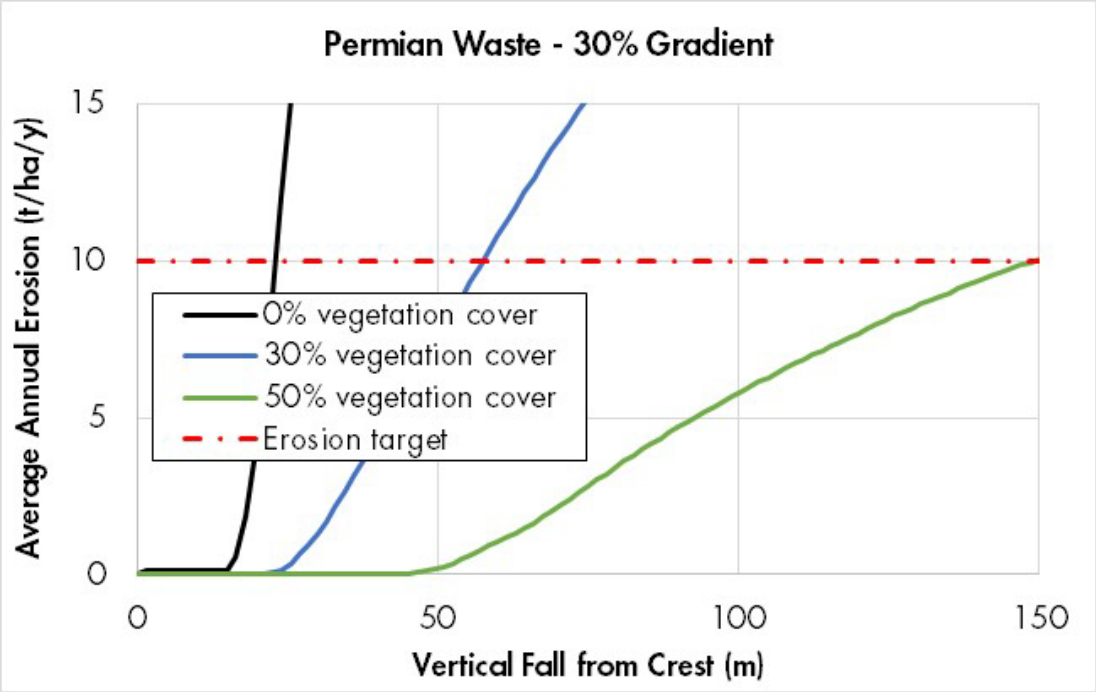

Figure 8: Predicted erosion rates on a 30% gradient inward-facing slope sheeted with Permian waste.

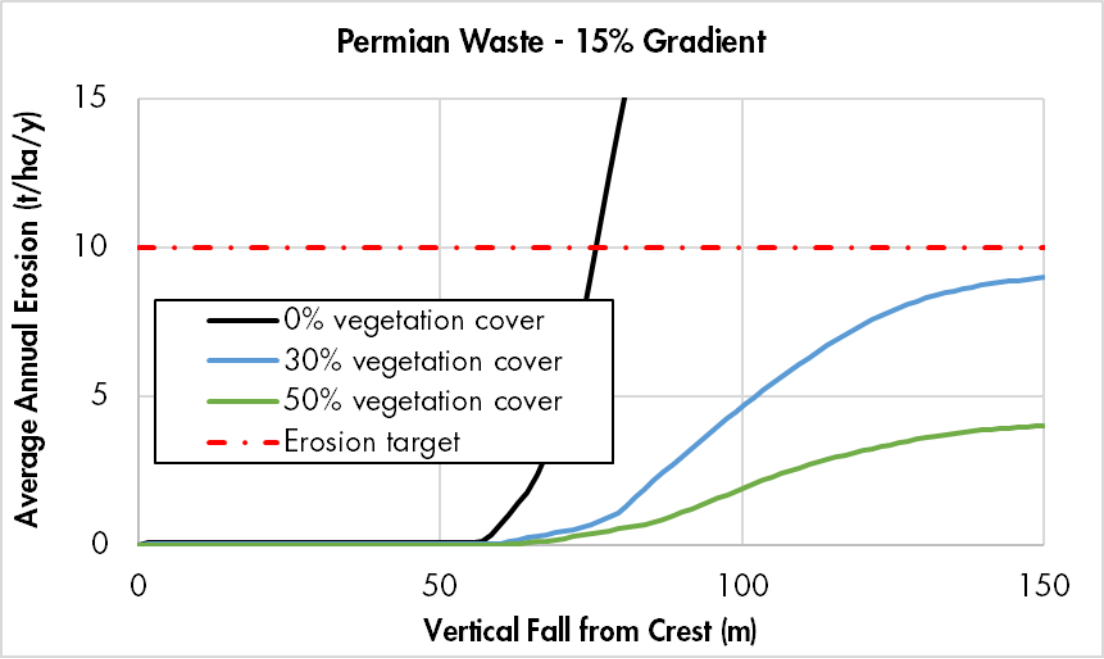

Figure 9: Predicted erosion rates on a 15% gradient inward-facing slope sheeted with Permian waste.

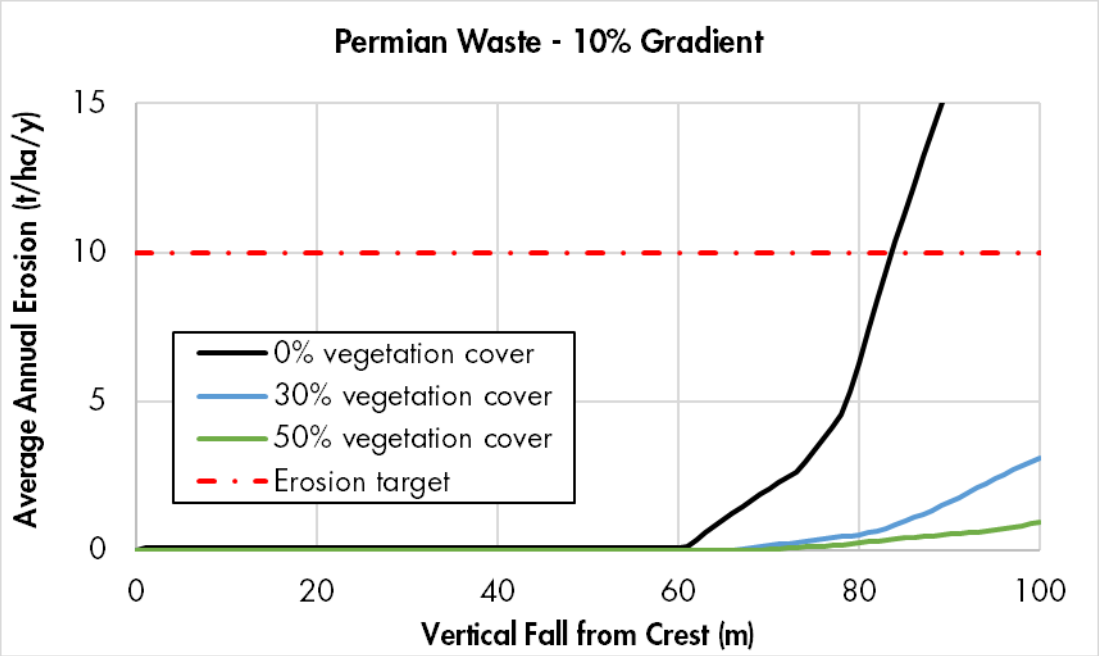

Figure 10: Predicted erosion rates on a 10% gradient inward-facing slope sheeted with Permian waste.

5 SIBERIA MODEL SETUP

5.1 Elevation models

Proposed 3-D final landform design files for SSM were provided by BMA. The landforms modelled included:

- East North Pit;
- East South Pit;
- Gilbert Pit;
- Lotus Campbell Pit; and
- Price Leichhardt Pit.

These landforms were designed on the basis of WEPP model runoff/erosion results for potential surface materials to be applied (Figures 11–15). These figures also show the regions in which different surface materials and vegetation groundcover levels were applied.

All landforms included areas of level dump top that will not discharge onto the adjoining batter slopes. Inclusion of that design feature greatly reduces the risk of high rates of erosion on the adjoining batters and is, therefore, strongly recommended.

Key assumptions in the landform evolution modelling based on WEPP results were:

- Clay soil (S01) will be used for rehabilitation works associated with outward-facing slopes.
- Permian waste (NPM6) will be used for rehabilitation works associated with the low walls.

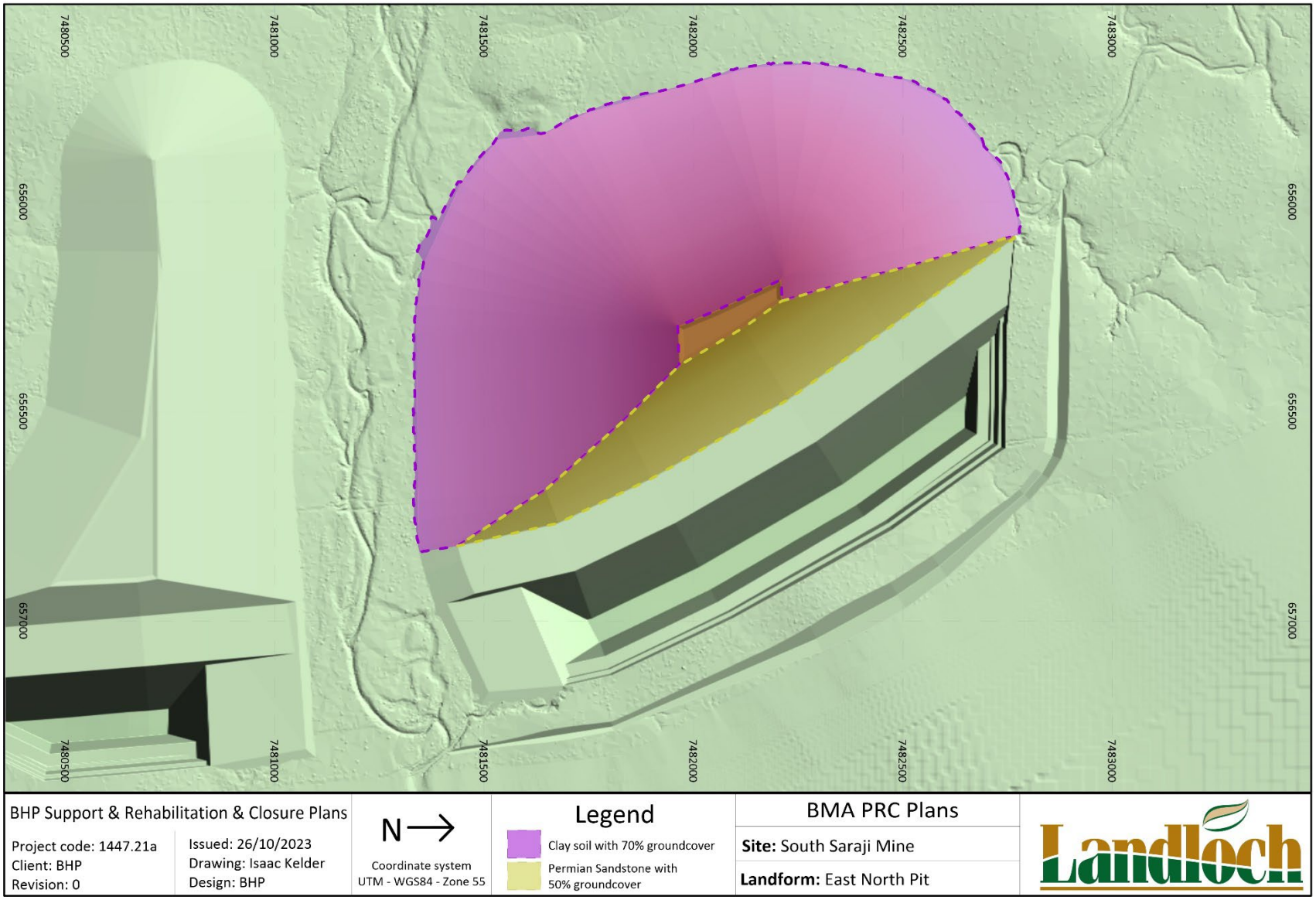

Figure 11: East North Pit rehabilitation landform.

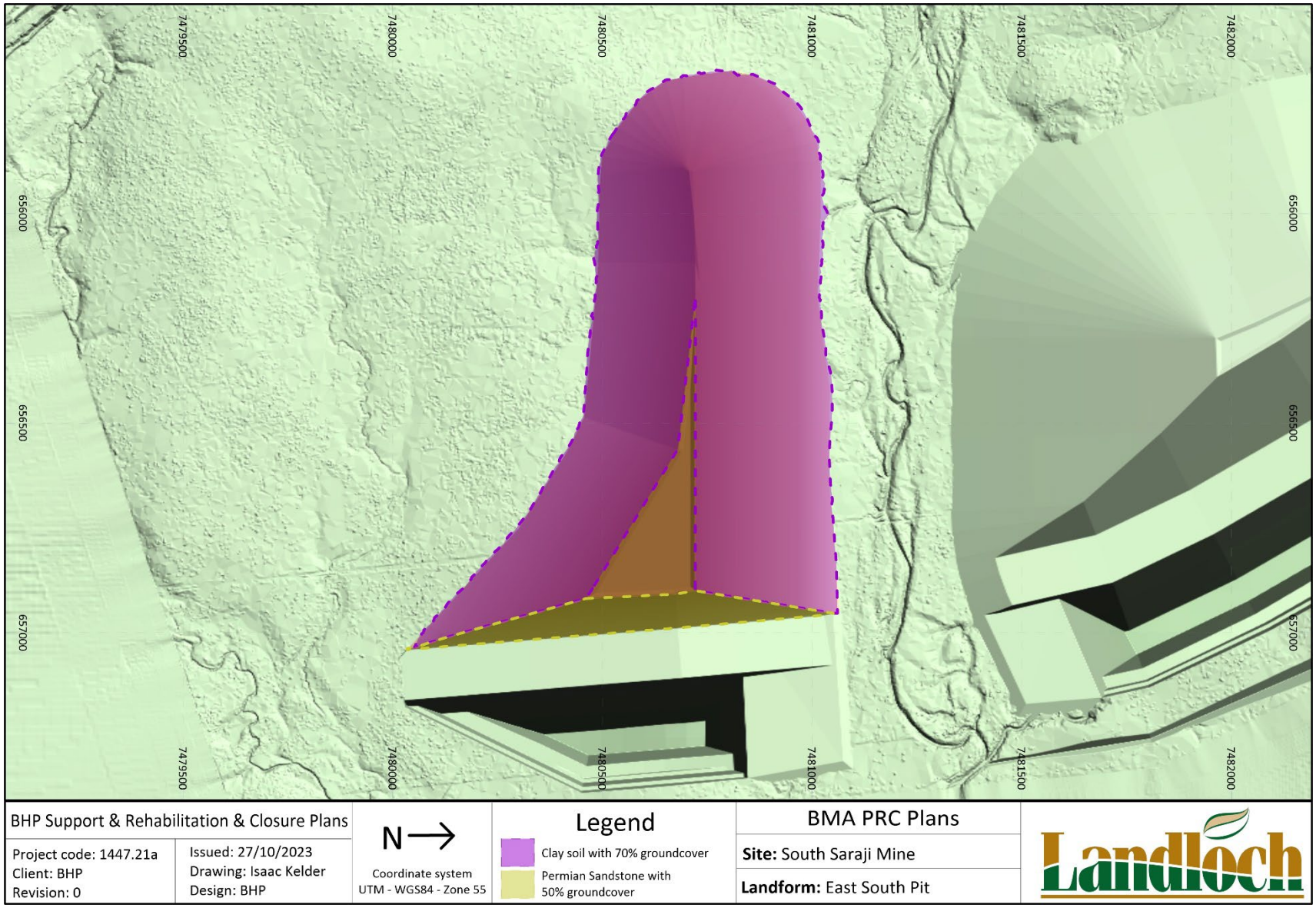

Figure 12: East South Pit rehabilitation landform.

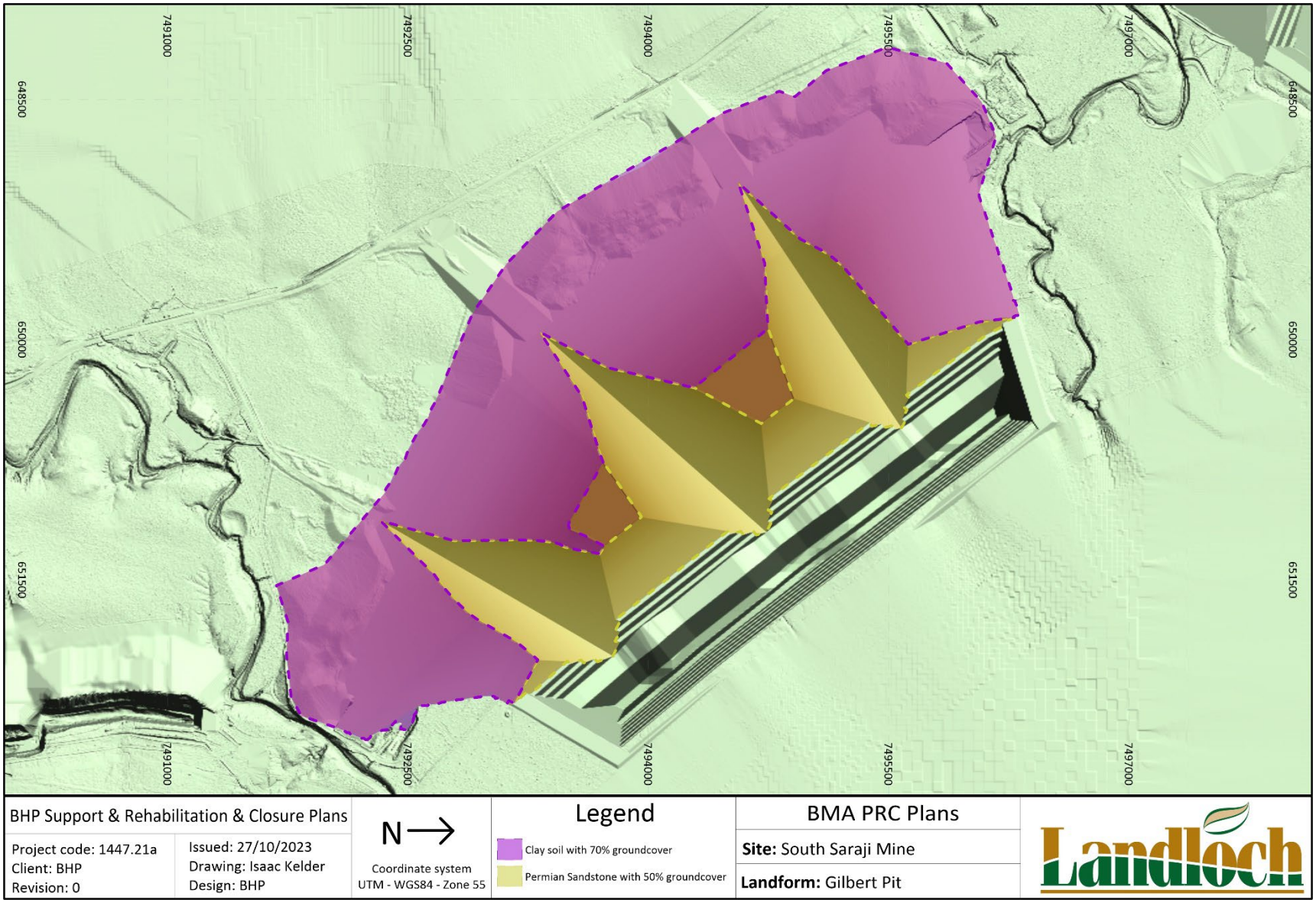

Figure 13: Gilbert Pit rehabilitation landform.

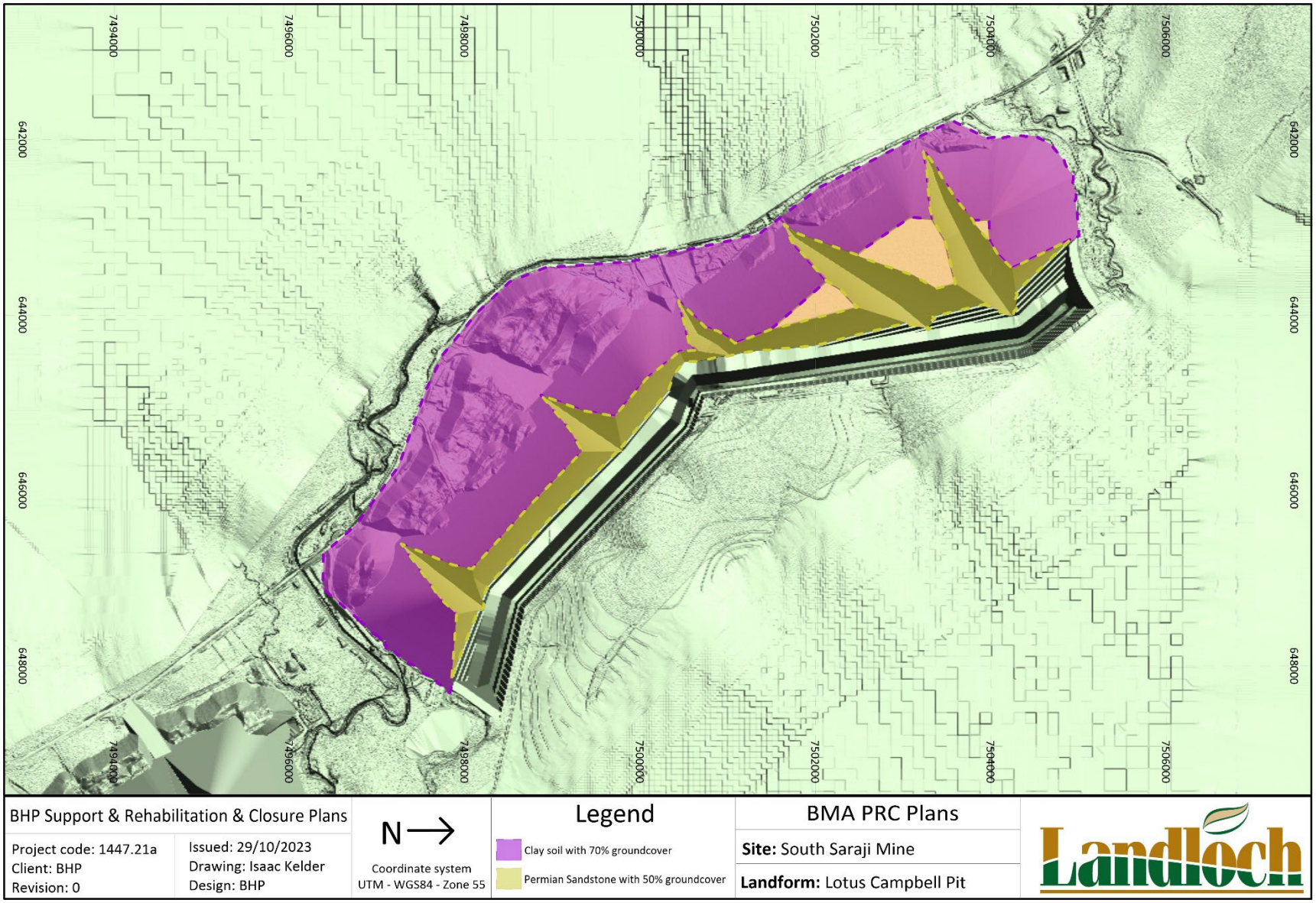

Figure 14: Lotus Campbell Pit rehabilitation landform.

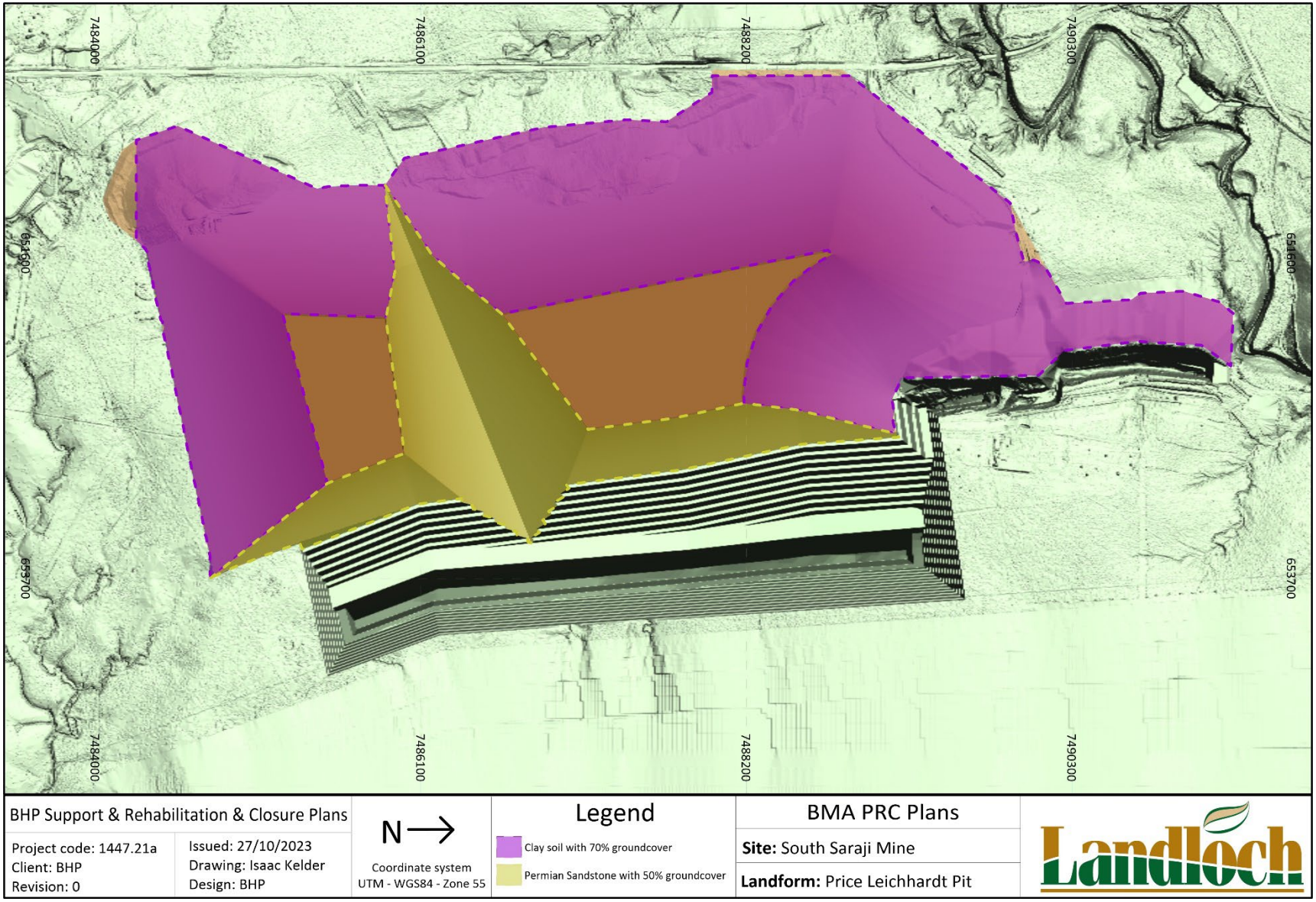

Figure 15: Price Leichhardt Pit rehabilitation landform.

5.2 Parameter development

SIBERIA model parameters derived from WEPP simulations are shown in Table 3. As noted previously (section 3.4.3), 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 soil	70	1.0483	0.01143	1.5
Permian sandstone waste	50	1.1732	0.00057	1.5

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 0.3 m are highlighted in the visualisations.

Visualisations for are 300 years are shown below. However, all visualisations (50, 100, 200, and 300 years) are provided in Appendix A.

6.1 East North Pit landform

Rehabilitation of the East North Pit landform is planned to use vegetated clay soils on the outward-facing slopes, and vegetated Permian waste on the inward-facing (low wall) slopes (Figure 11). SIBERIA modelling has assumed a vegetation groundcover of 70% for the outward-facing clay soils surfaces and 50% for the inward-facing Permian waste surfaces.

Predicted erosion rates shown in Table 4 indicate that at a vegetation groundcover level of 70%, predicted erosion rates of the outward-facing batter slopes are below the target level of 5t/ha/y. Similarly, if vegetation groundcover of the inward-facing batter is 50%, then batter slope erosion rates are well below the soil loss target. This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to clay soil alone.

Table 4: Predicted erosion rates and gully depths for the East North Pit landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay with 70% vegetation groundcover			
50	-	4.6	15
100	-	4.6	30
200	-	4.6	61
300	-	4.6	91
Permian Sandstone with 50% vegetation groundcover			
50	-	2.7	9
100	-	2.6	18
200	-	2.5	35
300	-	2.5	51

Figure 16 shows SIBERIA output after 300 years of simulation. The combined line colouring of the interface between the clay-covered area and the Permian waste-covered area in the north of the landform appears red, but the erosion depths in this location are <0.3m and hence not indicating an area of increased erosion potential. The SIBERIA outputs indicate that the East North Pit landform is not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

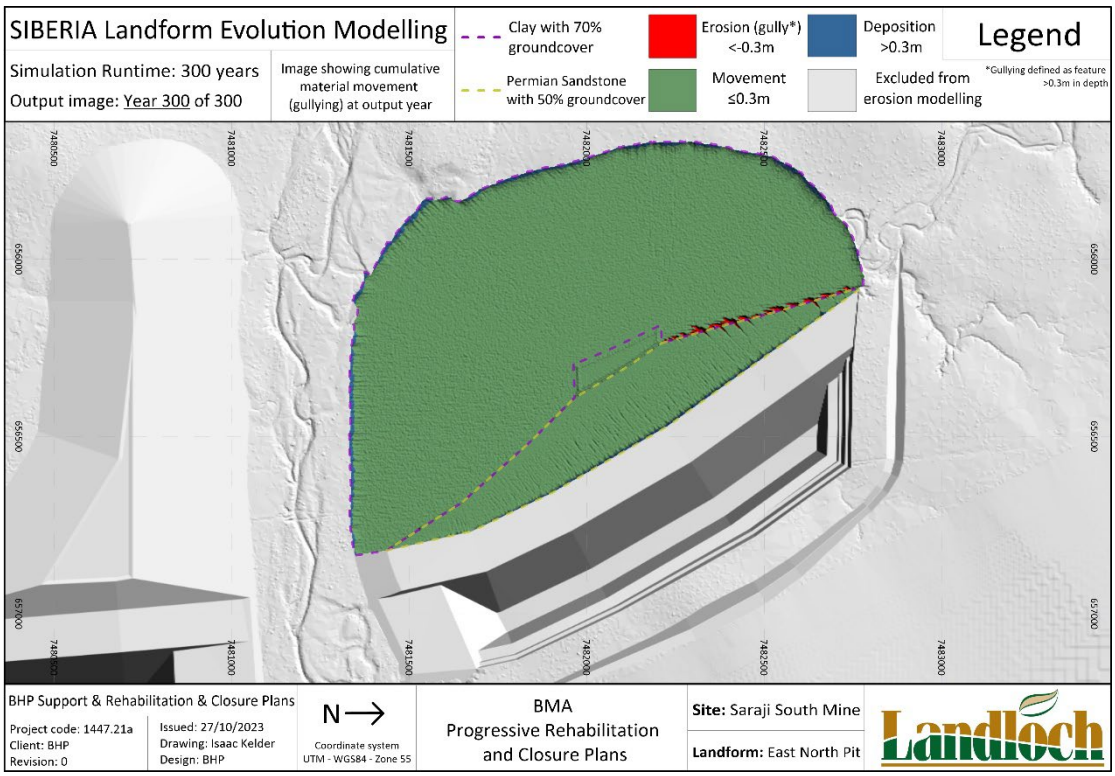

Figure 16: Predicted erosion and deposition depths of the East North Pit rehabilitation landform after 300 years.

6.2 East South Pit landform

Rehabilitation of the East South Pit landform is planned to use vegetated clay soils on the outward-facing slopes, and vegetated Permian waste on the inward-facing (low wall) slopes (Figure 12). SIBERIA modelling has assumed a vegetation groundcover of 70% for the outward-facing clay soils surfaces and 50% for the inward-facing Permian waste surfaces.

Predicted erosion rates shown in Table 5 indicate that at a vegetation groundcover level of 70%, predicted erosion rates of the outward-facing batter slopes are below the target level of 5t/ha/y. Similarly, if vegetation groundcover of the inward-facing batters is 50%, then batter slope erosion rates are well below the soil loss target. This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to clay soil alone.

Figure 17 shows SIBERIA output after 300 years of simulation. Predicted erosion depths do not exceed 0.3m at any point of the surface for all simulations years considered, up to and including 300 years.

The SIBERIA outputs indicate that the East South Pit landform is not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

Table 5: Predicted erosion rates and gully depths for the East South Pit landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay with 70% vegetation groundcover			
50	-	4.5	15
100	-	4.6	30
200	-	4.6	61
300	-	4.6	91
Permian Sandstone with 50% vegetation groundcover			
50	-	2.4	8
100	-	2.3	16
200	-	2.3	31
300	-	2.2	46

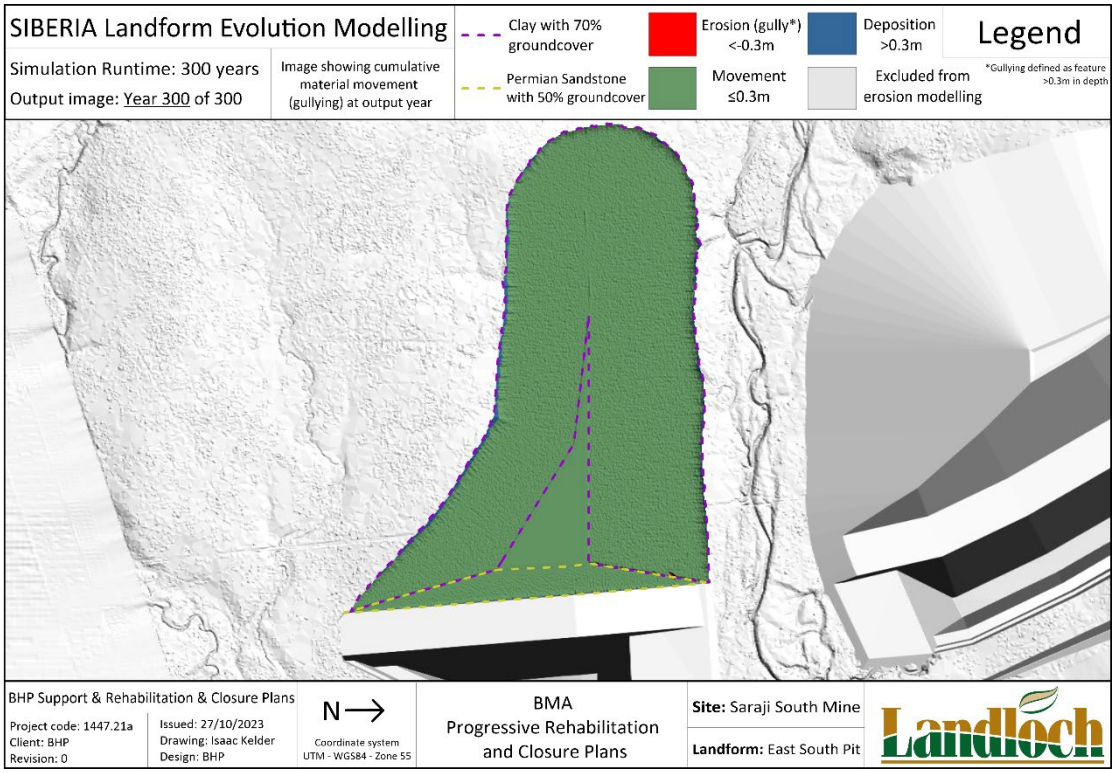

Figure 17: Predicted erosion and deposition depths of the East South Pit rehabilitation landform after 300 years.

6.3 Gilbert Pit landforms

Rehabilitation of the Gilbert Pit landform is planned to use vegetated clay soils on the outward-facing slopes, and vegetated Permian waste on the inward-facing (low wall) slopes (Figure 13). SIBERIA modelling has assumed a vegetation groundcover of 70% for the outward-facing clay soils surfaces and 50% for the inward-facing Permian waste surfaces. Areas of existing rehabilitation were assigned the parameters for the vegetated clay soil material.

Predicted erosion rates shown in Table 6 indicate that at a vegetation groundcover level of 70%, predicted erosion rates of the outward-facing batter slopes are below the target level of 5t/ha/y. Similarly, if vegetation groundcover of the inward-facing batters is 50%, then batter slope erosion rates are well below the soil loss target. This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to clay soil alone.

Figure 18 shows SIBERIA output after 300 years of simulation. Predicted erosion depths do not exceed 0.3m at any point of the Permian-covered surface for all simulations years considered, up to and including 300 years. Erosion depths of the vegetated clay surfaces do exceed 0.3m in a small section of the northern end of the landform at 300 years. This result occurred at the interface between an existing dump area and the new dump area that will be covered in vegetated clay soil. 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.

The SIBERIA outputs indicate that the Gilbert Pit landform is not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

Table 6: Predicted erosion rates and gully depths for the Gilbert Pit landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay with 70% vegetation groundcover			
50	-	4.7	16
100	-	4.7	32
200	-	4.7	63
300	0.3	4.7	95
Permian Sandstone with 50% vegetation groundcover			
50	-	2.9	10
100	-	2.8	19
200	-	2.7	37
300	-	2.6	54
Existing dump area			
50	-	3.2	11
100	-	3.2	22
200	-	3.3	43
300	0.3	3.3	65

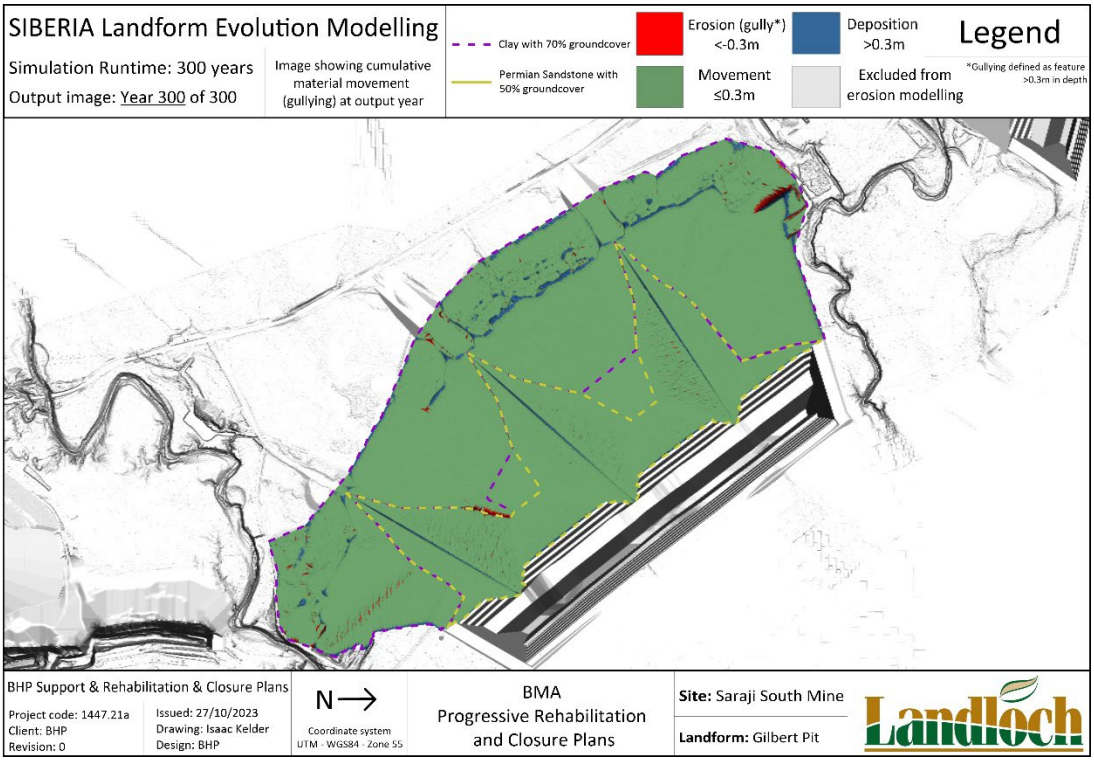

Figure 18: Predicted erosion and deposition depths of the Gilbert Pit rehabilitation landform after 300 years.

6.4 Lotus Campbell Pit landform

Rehabilitation of the Lotus Campbell Pit landform is planned to use vegetated clay soils on the outward-facing slopes, and vegetated Permian waste on the inward-facing (low wall) slopes (Figure 14). SIBERIA modelling has assumed a vegetation groundcover of 70% for the outward-facing clay soils surfaces and 50% for the inward-facing Permian waste surfaces. Areas of existing rehabilitation were assigned the parameters for the vegetated clay soil material.

Predicted erosion rates shown in Table 7 indicate that at a vegetation groundcover level of 70%, predicted erosion rates of the outward-facing batter slopes are at or below the target level of 5t/ha/y. Similarly, if vegetation groundcover of the inward-facing batters is 50%, then batter slope erosion rates are well below the soil loss target. This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to clay soil alone.

Figure 19 shows SIBERIA output after 300 years of simulation. Predicted erosion depths do not exceed 0.3m at any point of the Permian-covered surface for all simulations years considered, up to and including 300 years. Erosion depths of the vegetated clay surfaces do exceed 0.3m in small sections at 200 years. This occurred at the interface between the existing dump area and the new dump area that will be covered in vegetated clay soil. The result is an artefact of the elevations within 3-D design file supplied; in reality these transition areas will be smoother than modelled and these areas are not likely to erode at rates that would increase the risk of rill or gully erosion.

The SIBERIA outputs indicate that the Lotus Campbell Pit landform is not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

Table 7: Predicted erosion rates and gully depths for the Lotus Campbell landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay with 70% vegetation groundcover			
50	-	5.0	17
100	-	5.0	33
200	-	4.9	66
300	-	4.9	99
Permian Sandstone with 50% vegetation groundcover			
50	-	2.8	9
100	-	2.8	19
200	-	2.7	37
300	-	2.7	55
Existing dump areas			
50	-	3.2	11
100	-	3.0	21
200	0.3	2.8	39
300	0.4	2.7	57

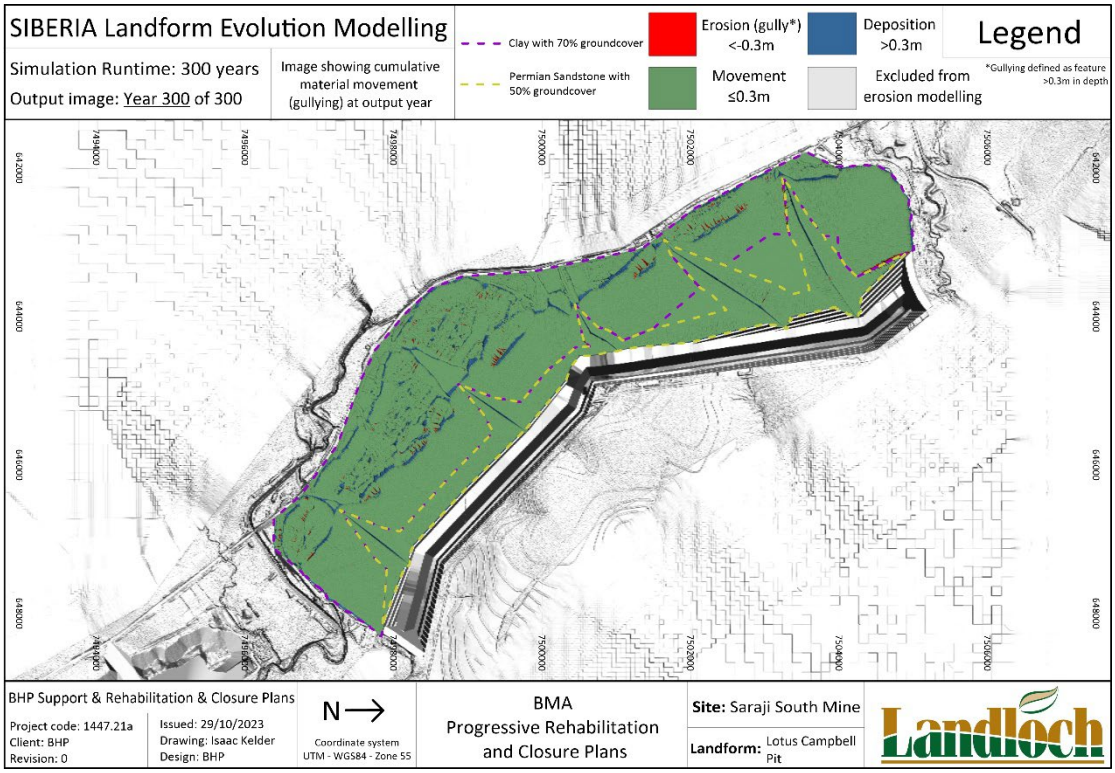

Figure 19: Predicted erosion and deposition depths of the Lotus Campbell Pit rehabilitation landform after 300 years.

6.5 Price Leichhardt Pit landform

Rehabilitation of the Price Leichhardt Pit landform is planned to use vegetated clay soils on the outward-facing slopes, and vegetated Permian waste on the inward-facing (low wall) slopes (Figure 15). SIBERIA modelling has assumed a vegetation groundcover of 70% for the outward-facing clay soils surfaces and 50% for the inward-facing Permian waste surfaces. Areas of existing rehabilitation were assigned the parameters for the vegetated clay soil material.

Predicted erosion rates (Table 8) indicate that at a vegetation groundcover level of 70%, predicted erosion rates of the outward-facing batter slopes are below the target level of 5t/ha/y. Similarly, if vegetation groundcover of the inward-facing batters is 50%, then batter slope erosion rates are well below the soil loss target. This indicates lower vegetation groundcover levels can meet the target erosion rate.

The results also indicate that incorporating Permian waste into the surface of the outward-facing slopes would improve erosional performance and reduce the vegetation groundcover required compared to clay soil alone.

Figure 20 shows SIBERIA output after 300 years of simulation. Predicted erosion depths do not exceed 0.3m at any point of the Permian-covered or clay covered surfaces for all simulations years considered, up to and including 300 years. Erosion depths of the existing rehabilitation surfaces do exceed 0.3m in small sections at 200 years. This occurred at the interface between the existing dump area and the new dump area that will be covered in vegetated clay soil. It also occurred at the interface of the landform at the high wall. The result is an artefact of the elevations within 3-D design file supplied;

in reality these transition areas will be smoother than modelled and these areas are not likely to erode at rates that would increase the risk of rill or gully erosion. The SIBERIA outputs indicate that the Price Leichhardt Pit landform is not prone to significant levels of rill or gully erosion if the surface conditions (material type and vegetation groundcover levels) are achieved.

Table 8: Predicted erosion rates and gully depths for the Price Leichardt Pit landform.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative erosion (mm)
Clay with 70% vegetation groundcover			
50	-	4.7	16
100	-	4.7	32
200	-	4.8	63
300	-	4.8	95
Permian Sandstone with 50% vegetation groundcover			
50	-	3.1	10
100	-	3.1	20
200	-	3.0	41
300	-	3.0	61
Existing dump area			
50	-	2.1	7
100	-	2.3	15
200	0.5	2.4	31
300	0.8	2.5	48

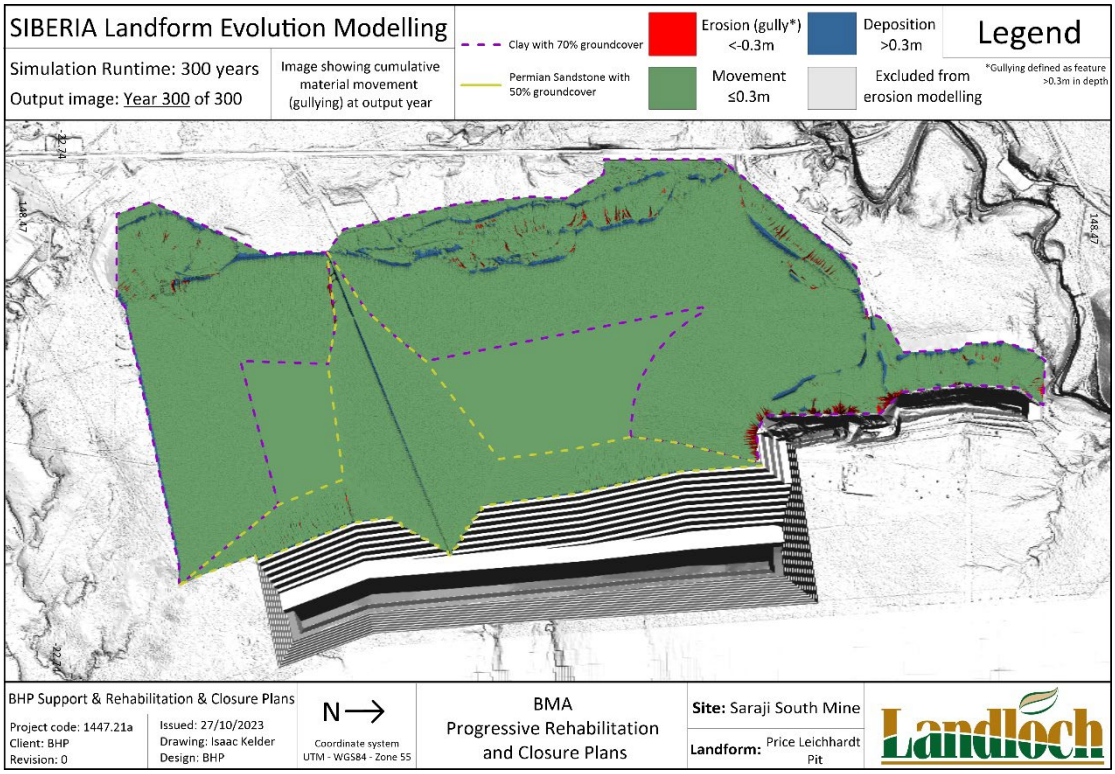

Figure 20: Predicted erosion and deposition depths of the Price Leichhardt Pit rehabilitation landform after 300 years.

7 WATER MANAGEMENT

Water management recommendations for waste landforms at SSM 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 SSM 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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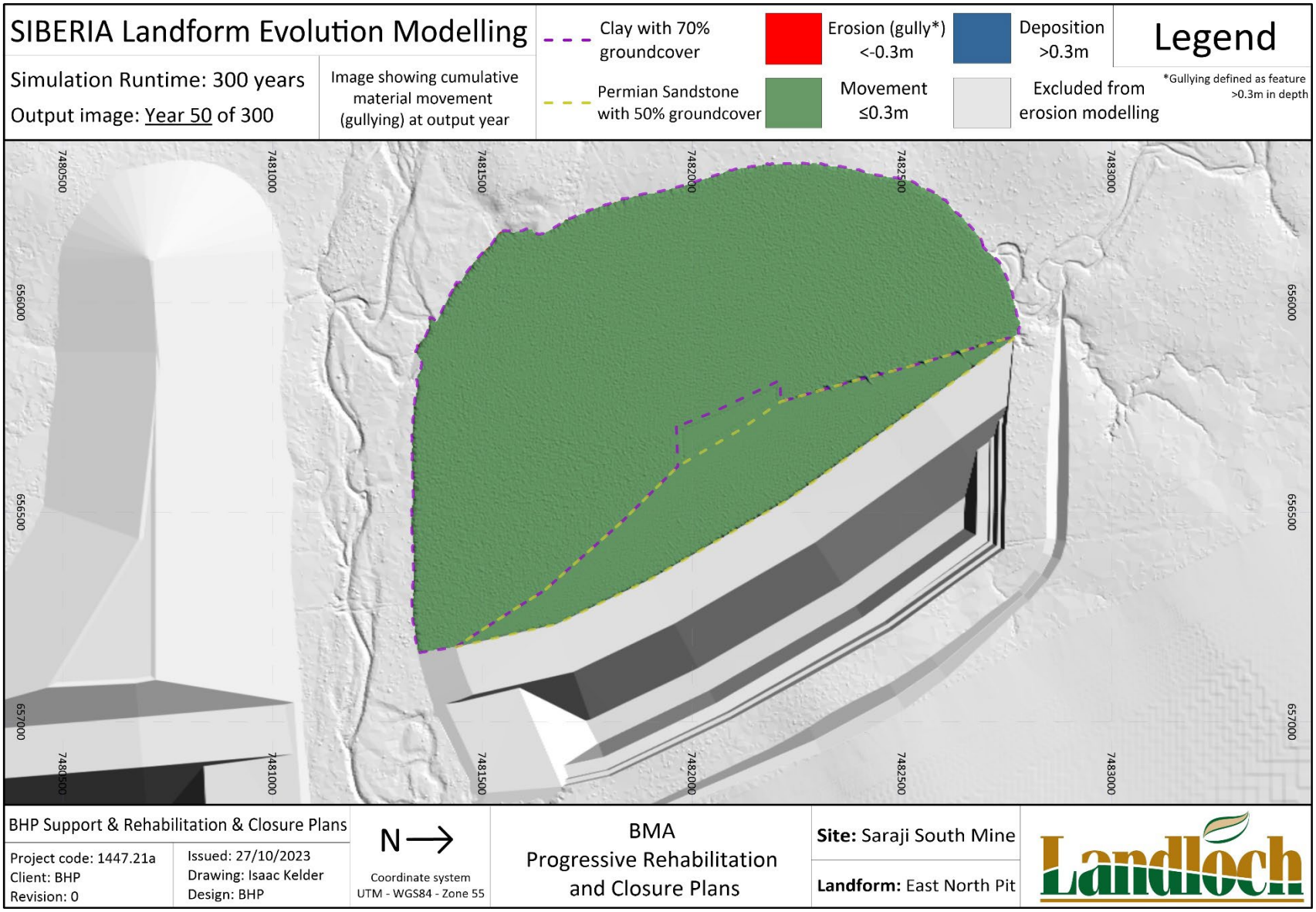
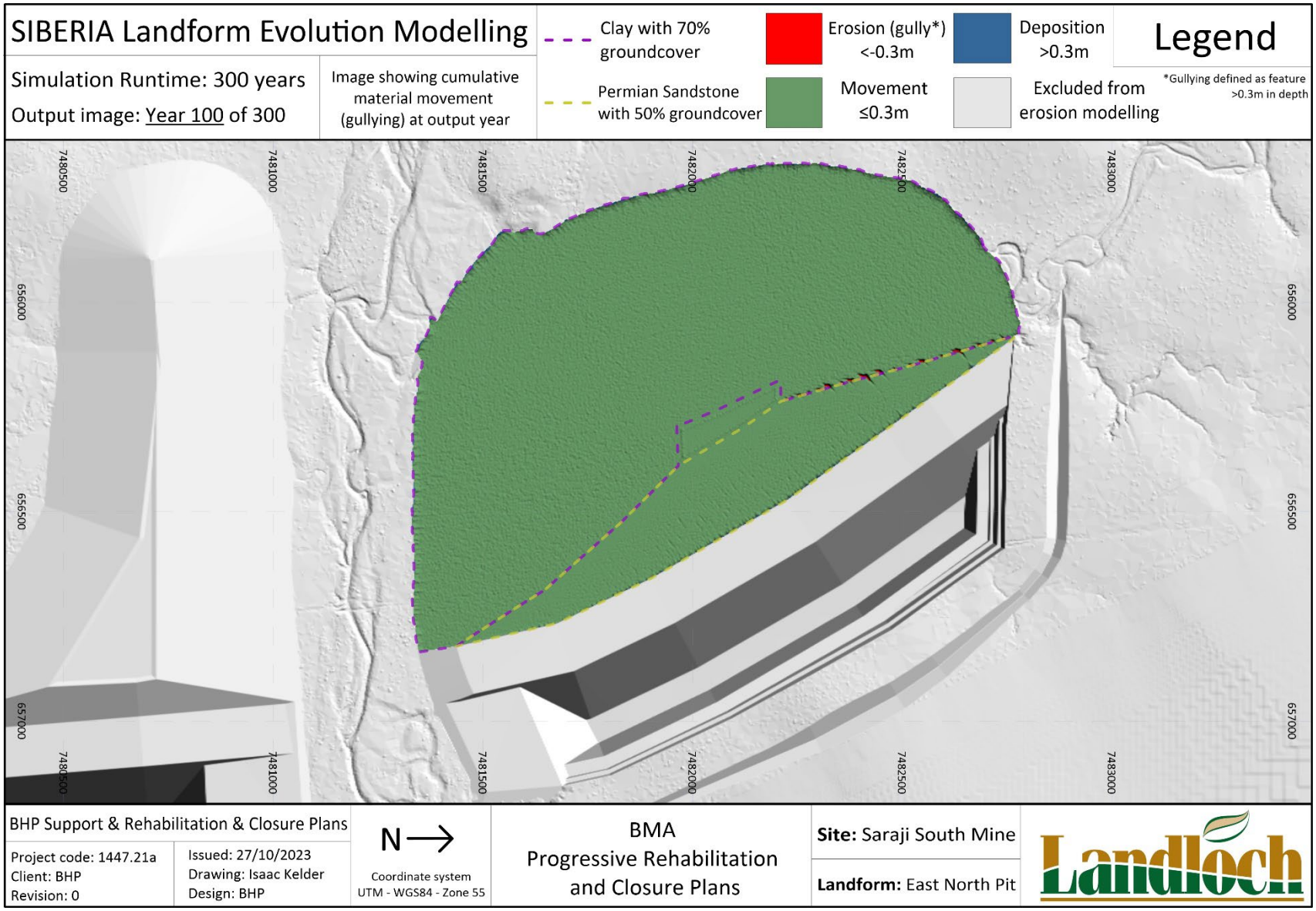


Figure A-1: Predicted erosion and deposition depths of the East North Pit rehabilitation landform after 50 years.



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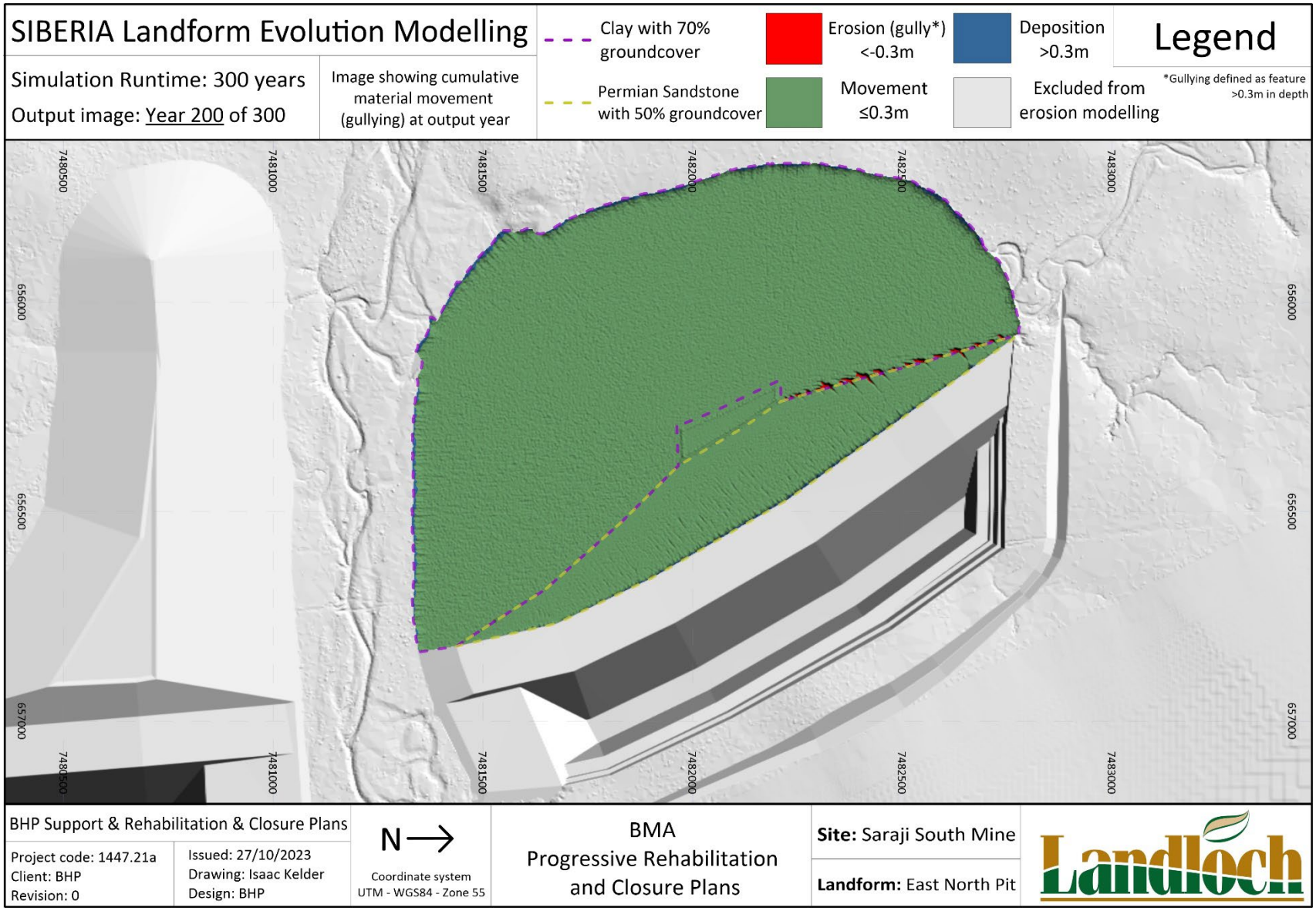

Figure A-3: Predicted erosion and deposition depths of the East North Pit rehabilitation landform after 200 years.

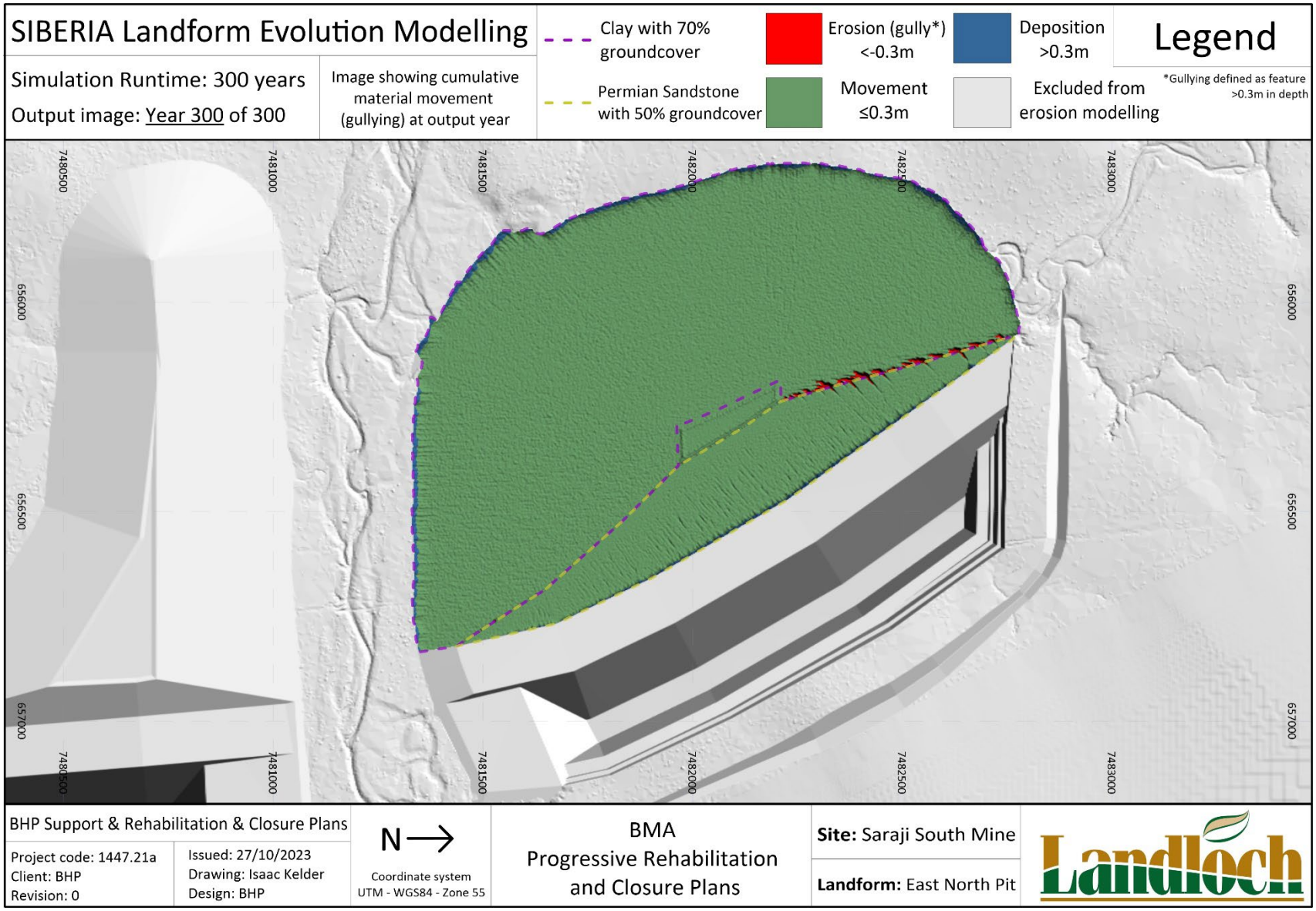

Figure A-4: Predicted erosion and deposition depths of the East North Pit rehabilitation landform after 300 years.

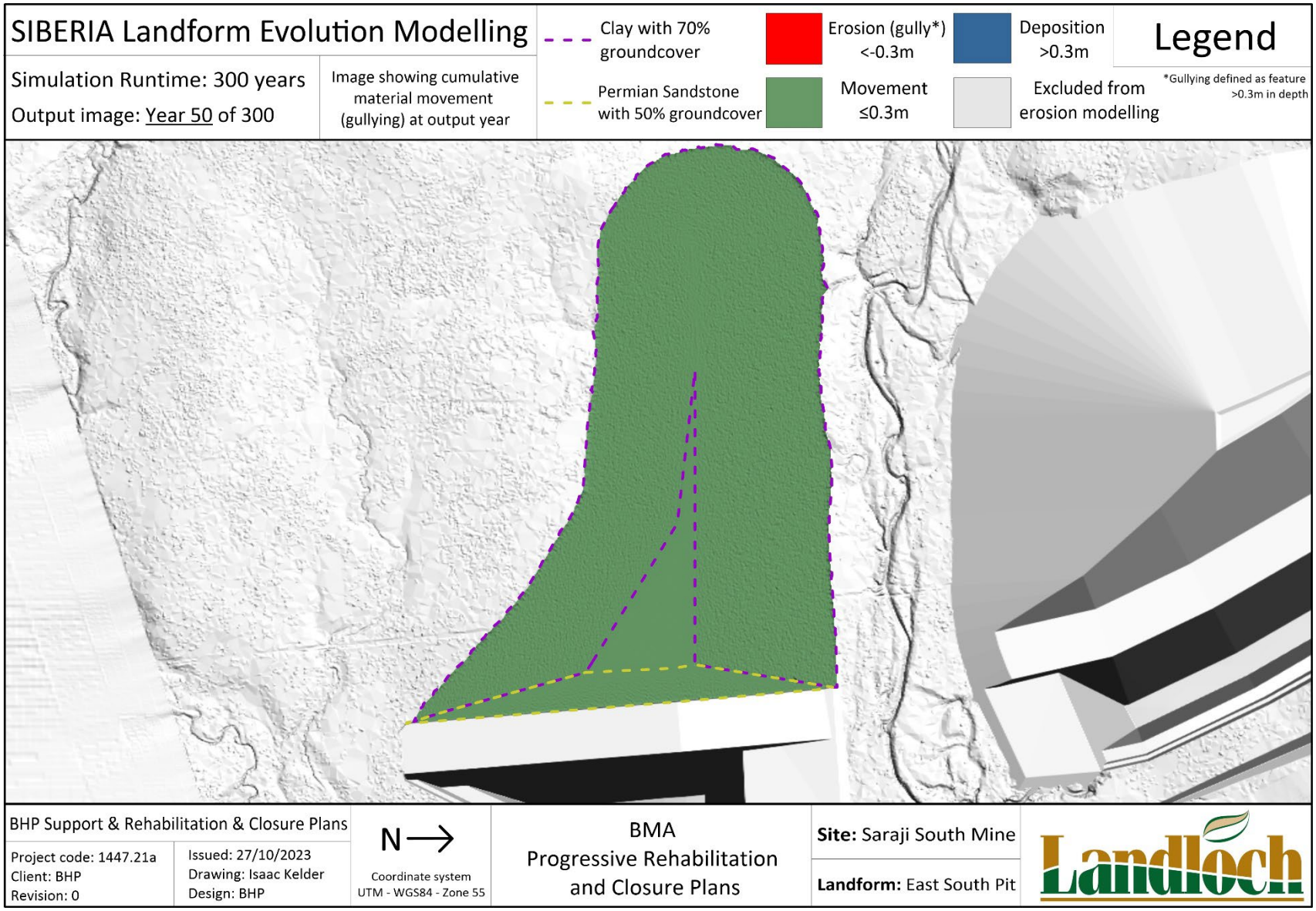

Figure A-5: Predicted erosion and deposition depths of the East South Pit rehabilitation landform after 50 years.

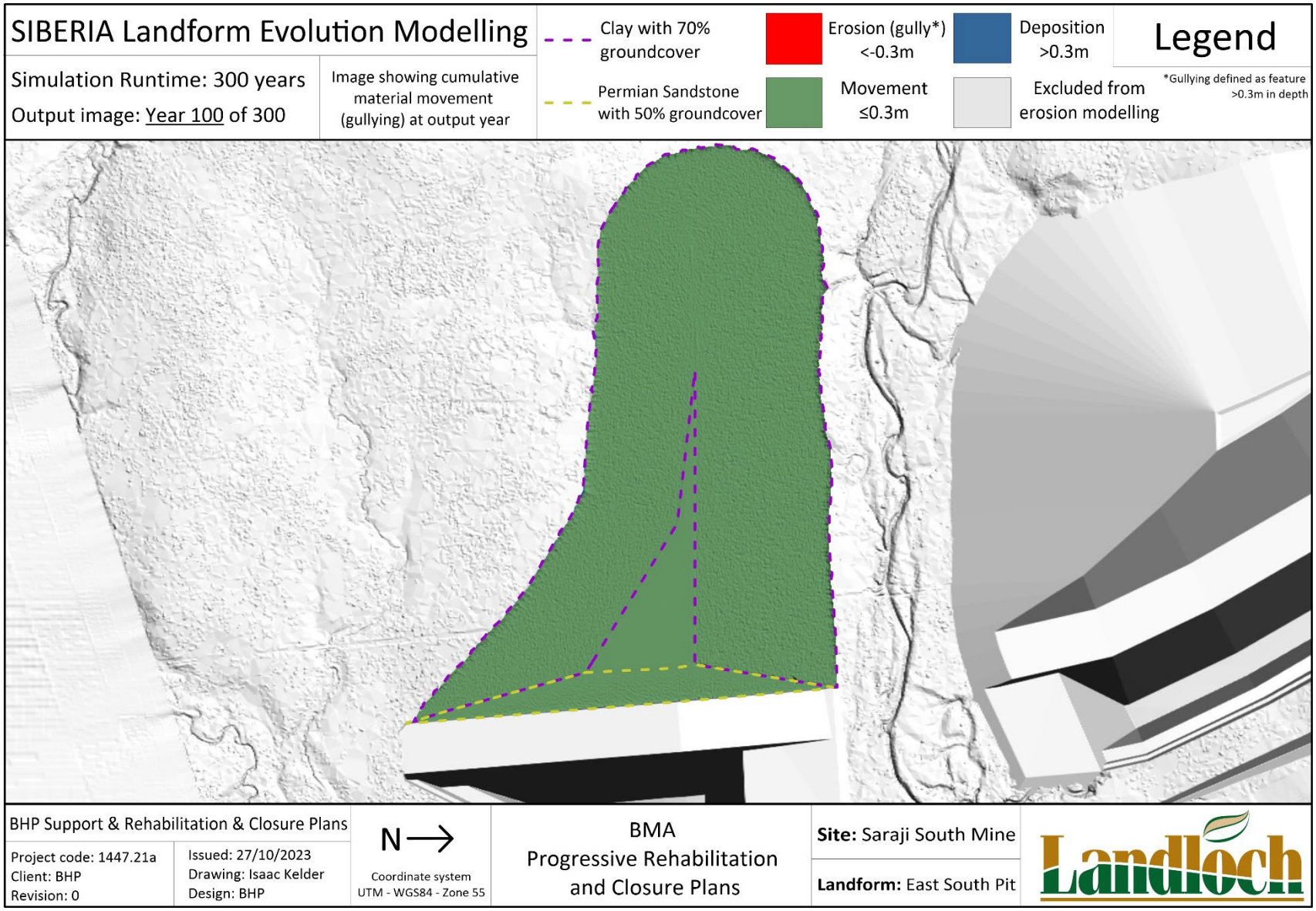

Figure A-6: Predicted erosion and deposition depths of the East South Pit rehabilitation landform after 100 years.

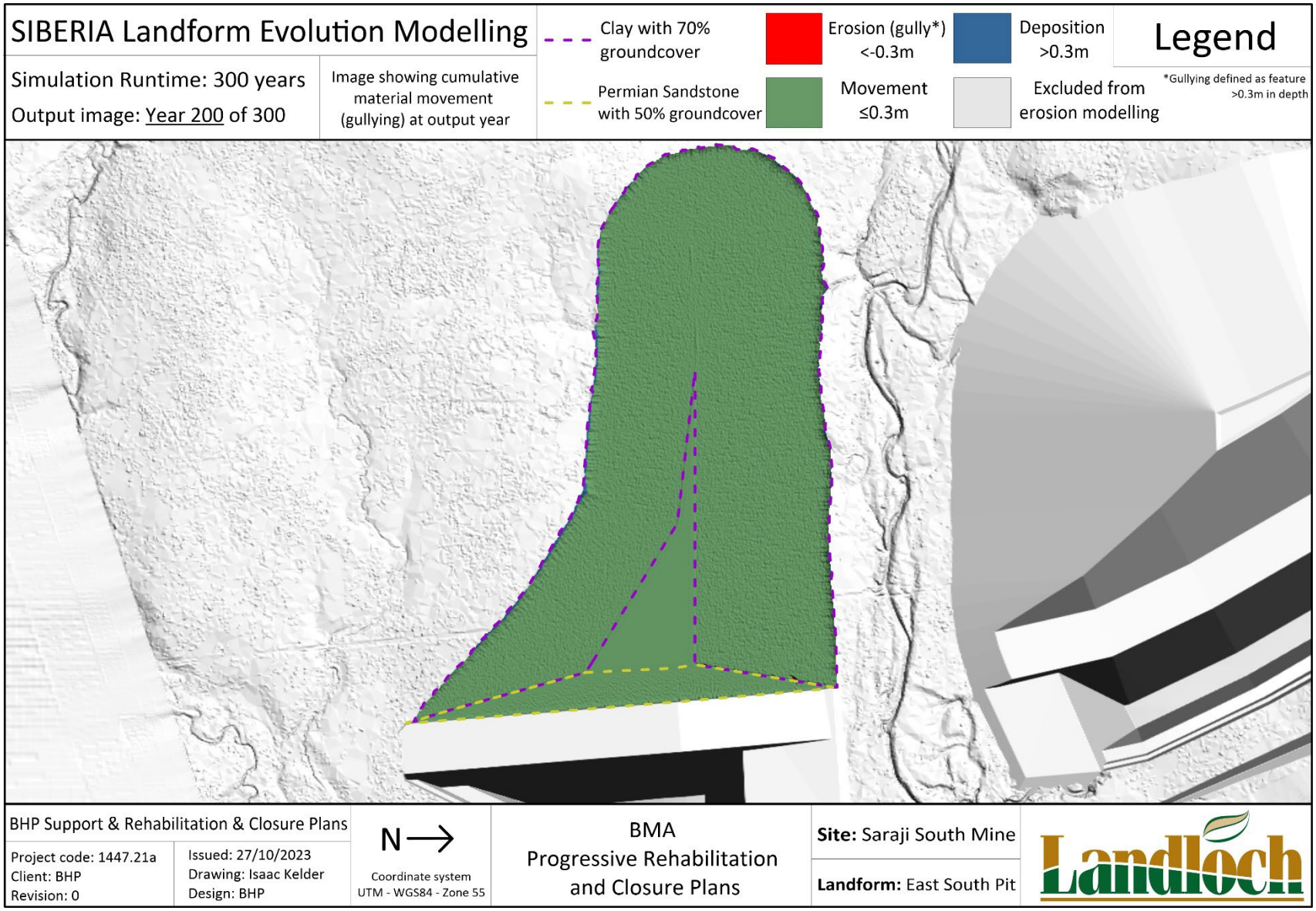

Figure A-7: Predicted erosion and deposition depths of the East South Pit rehabilitation landform after 200 years.

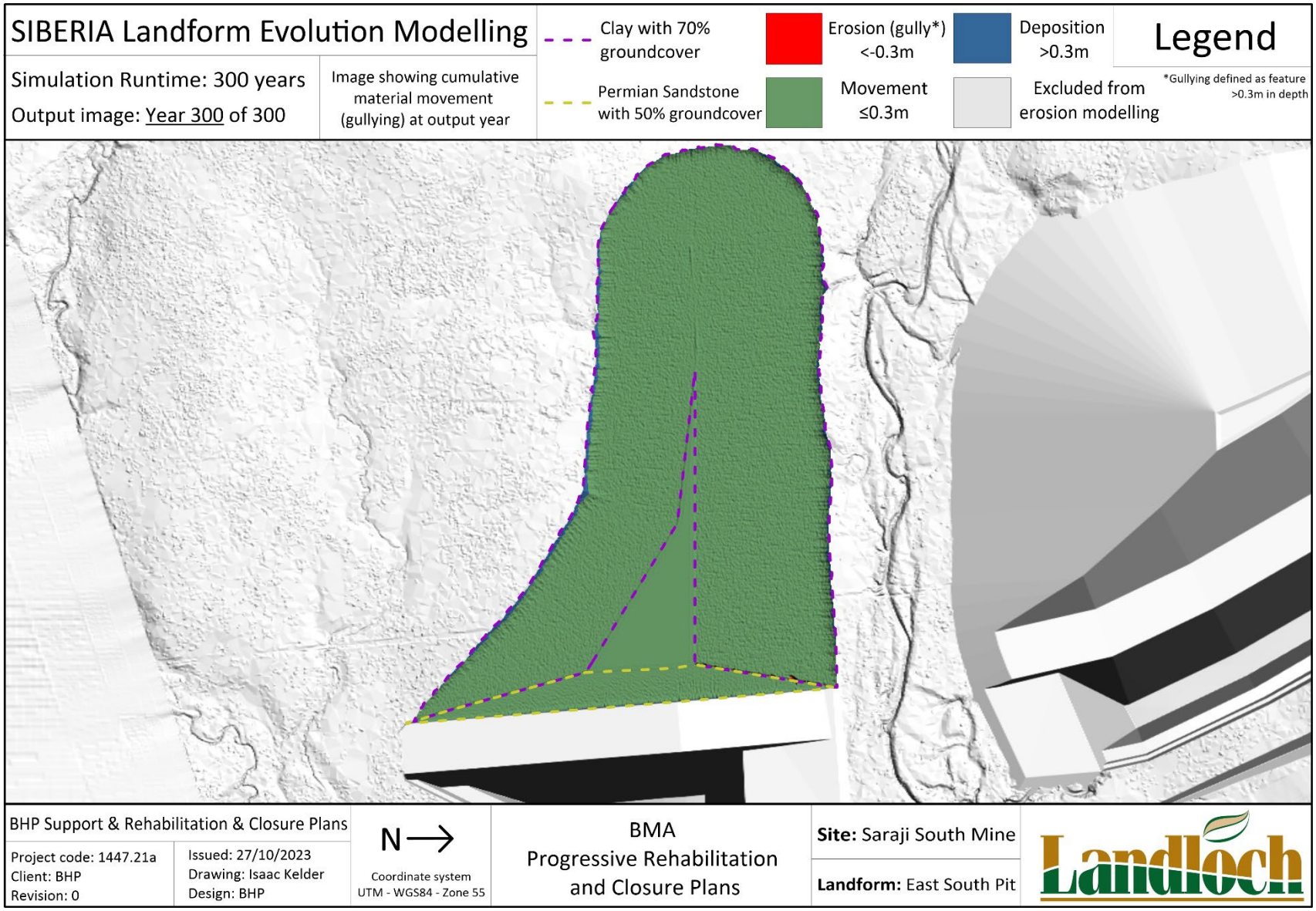

Figure A-8: Predicted erosion and deposition depths of the East South Pit rehabilitation landform after 300 years.

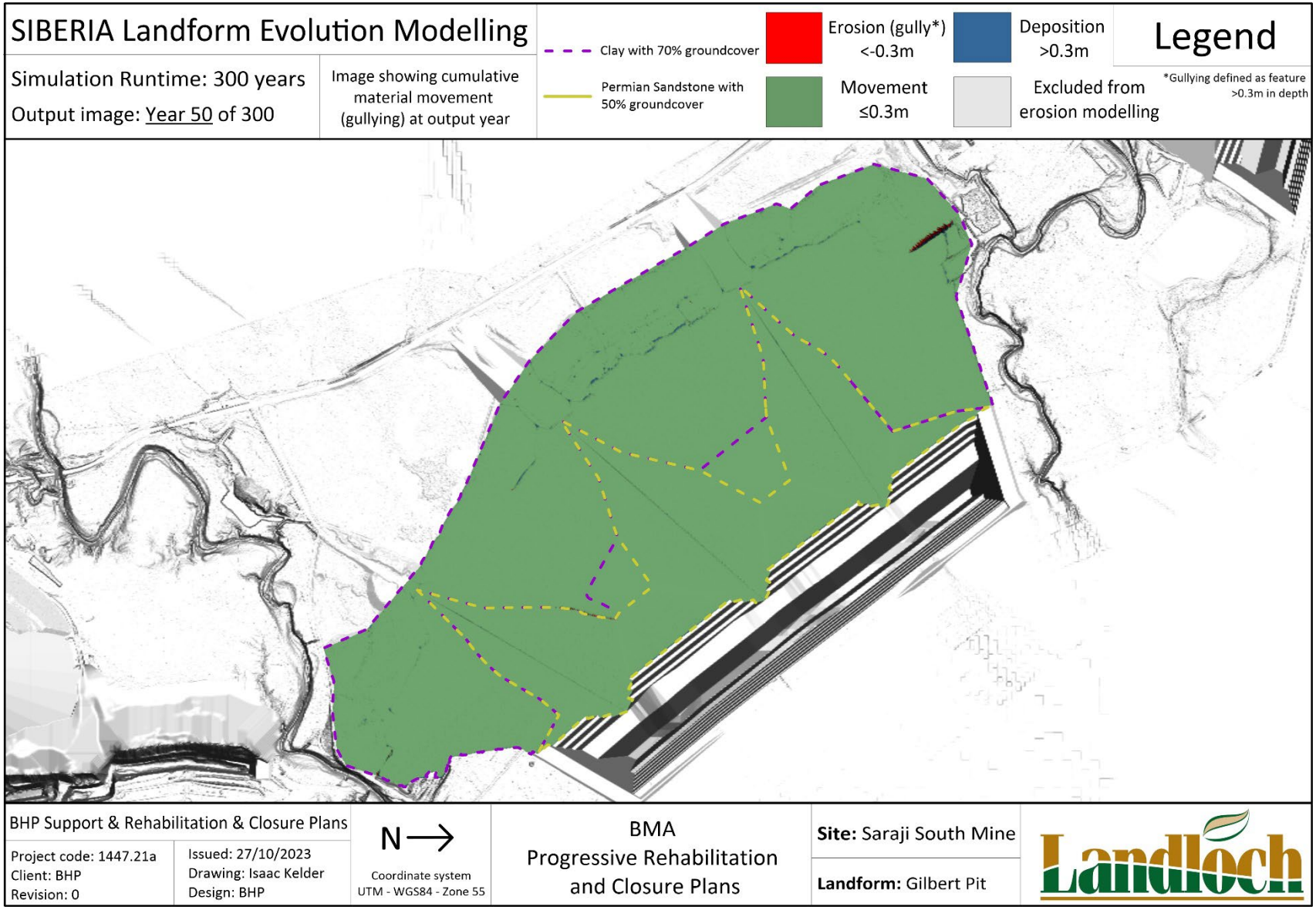

Figure A-9: Predicted erosion and deposition depths of the Gilbert Pit rehabilitation landform after 50 years.

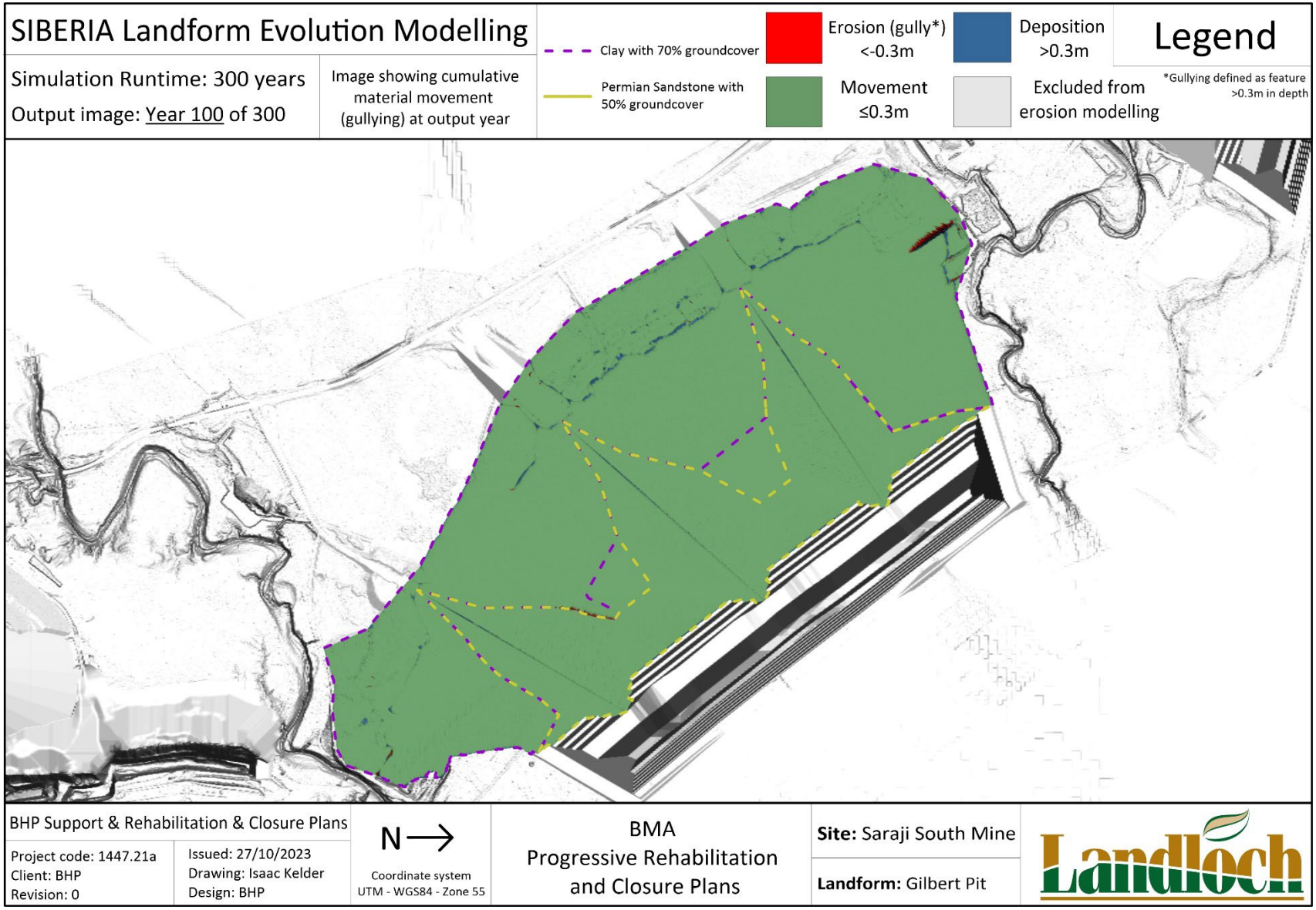

Figure A-10: Predicted erosion and deposition depths of the Gilbert Pit rehabilitation landform after 100 years.

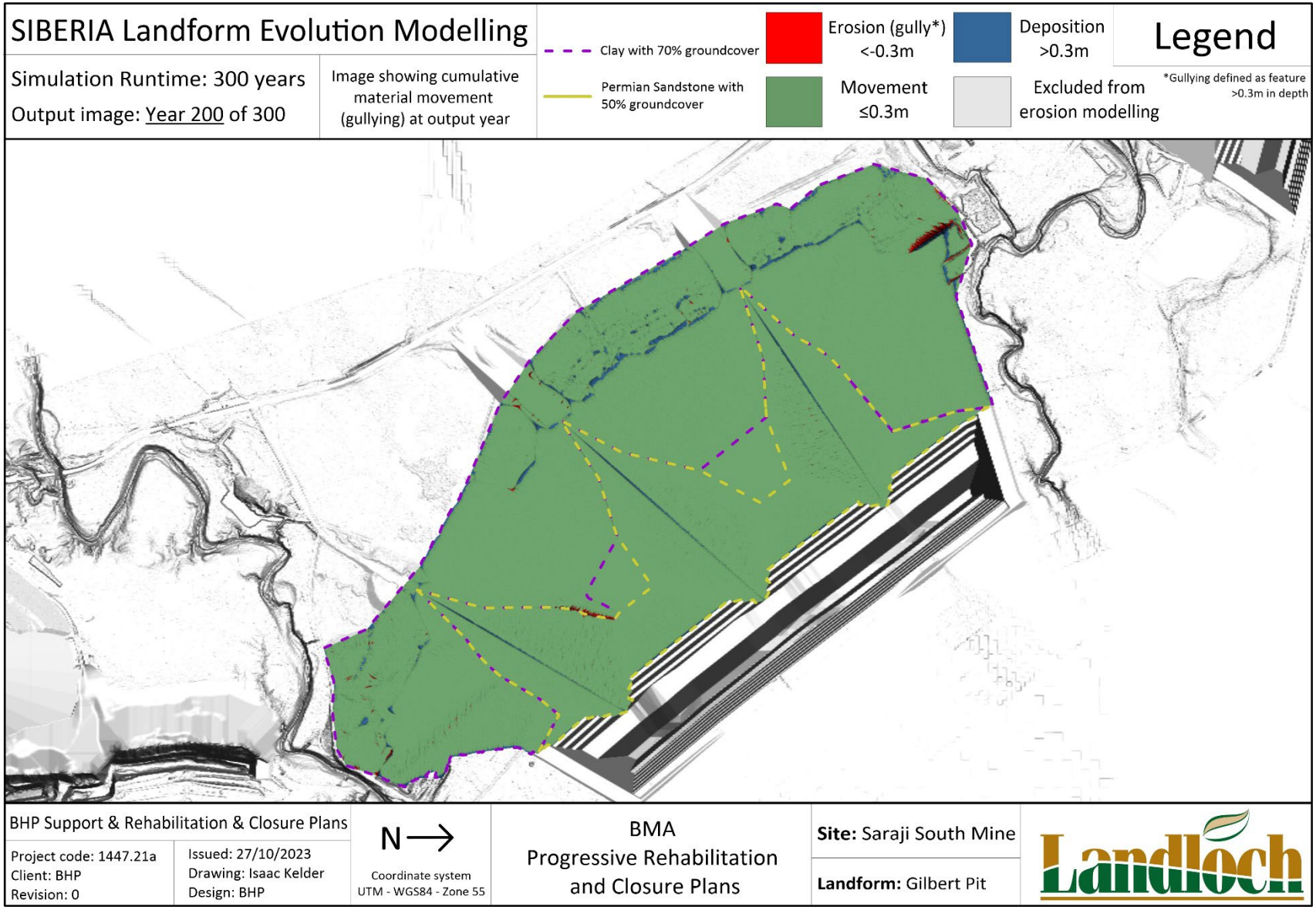

Figure A-11: Predicted erosion and deposition depths of the Gilbert Pit rehabilitation landform after 200 years.

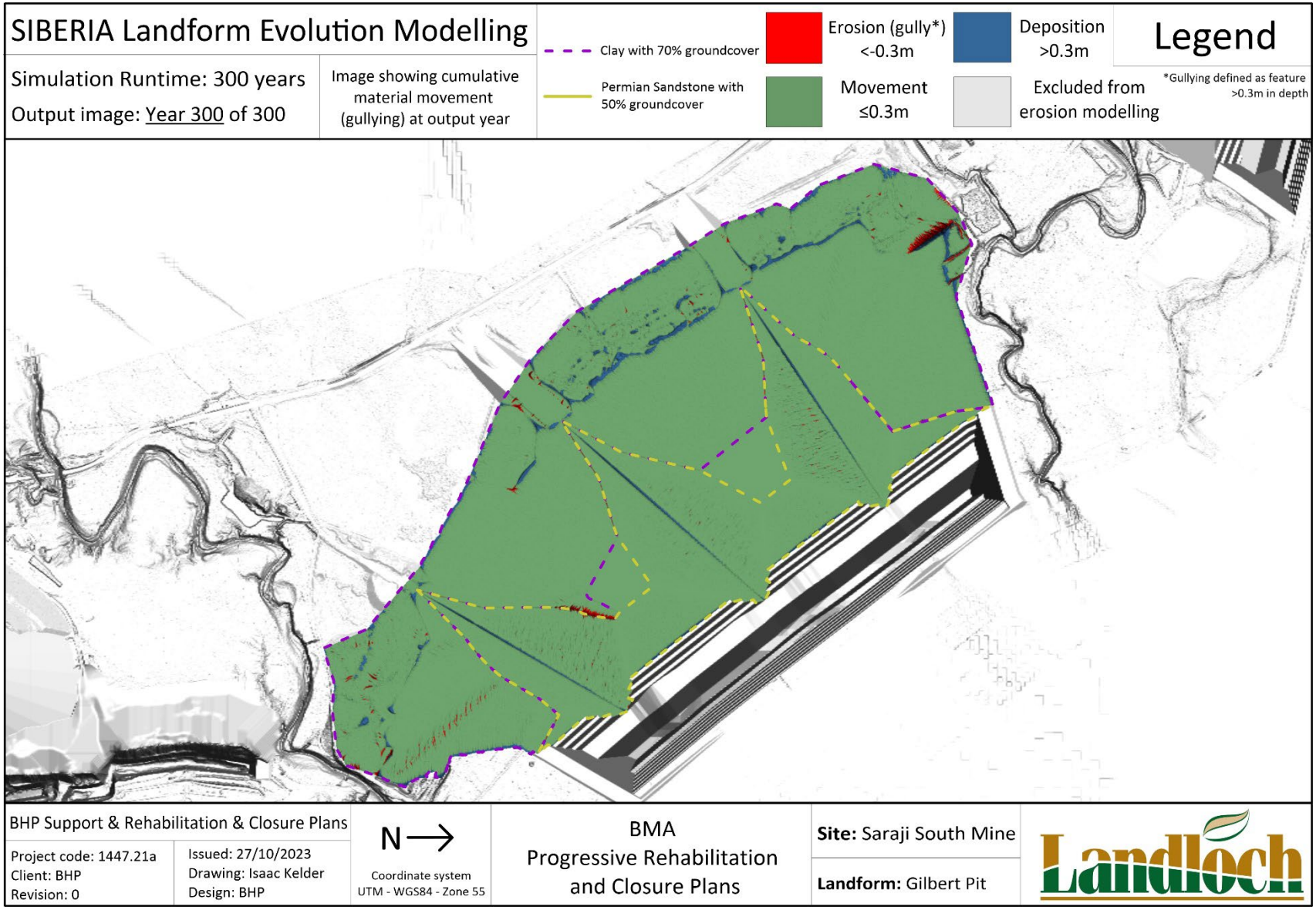

Figure A-12: Predicted erosion and deposition depths of the Gilbert Pit rehabilitation landform after 300 years.

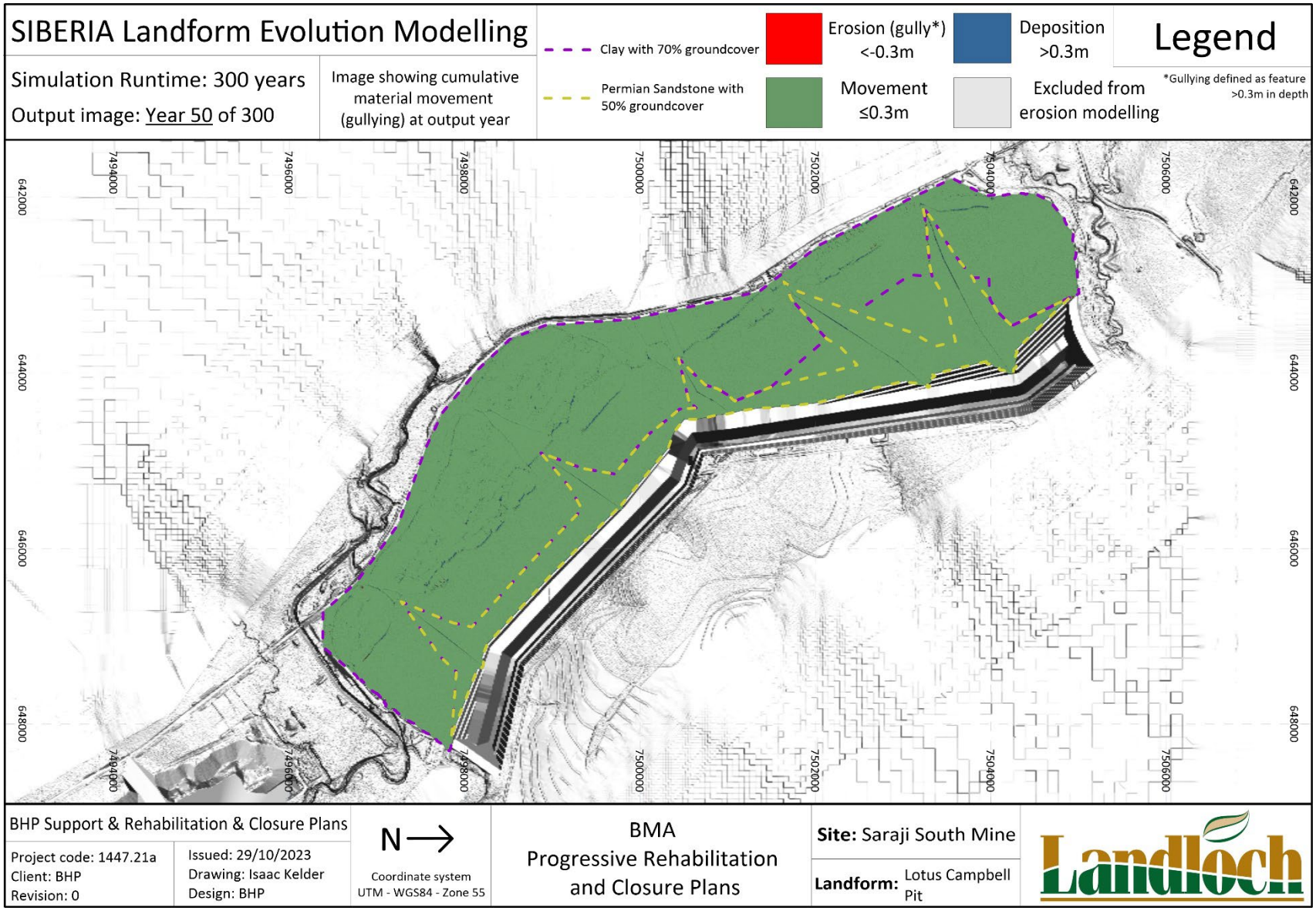

Figure A-13: Predicted erosion and deposition depths of the Lotus Campbell Pit rehabilitation landform after 50 years.

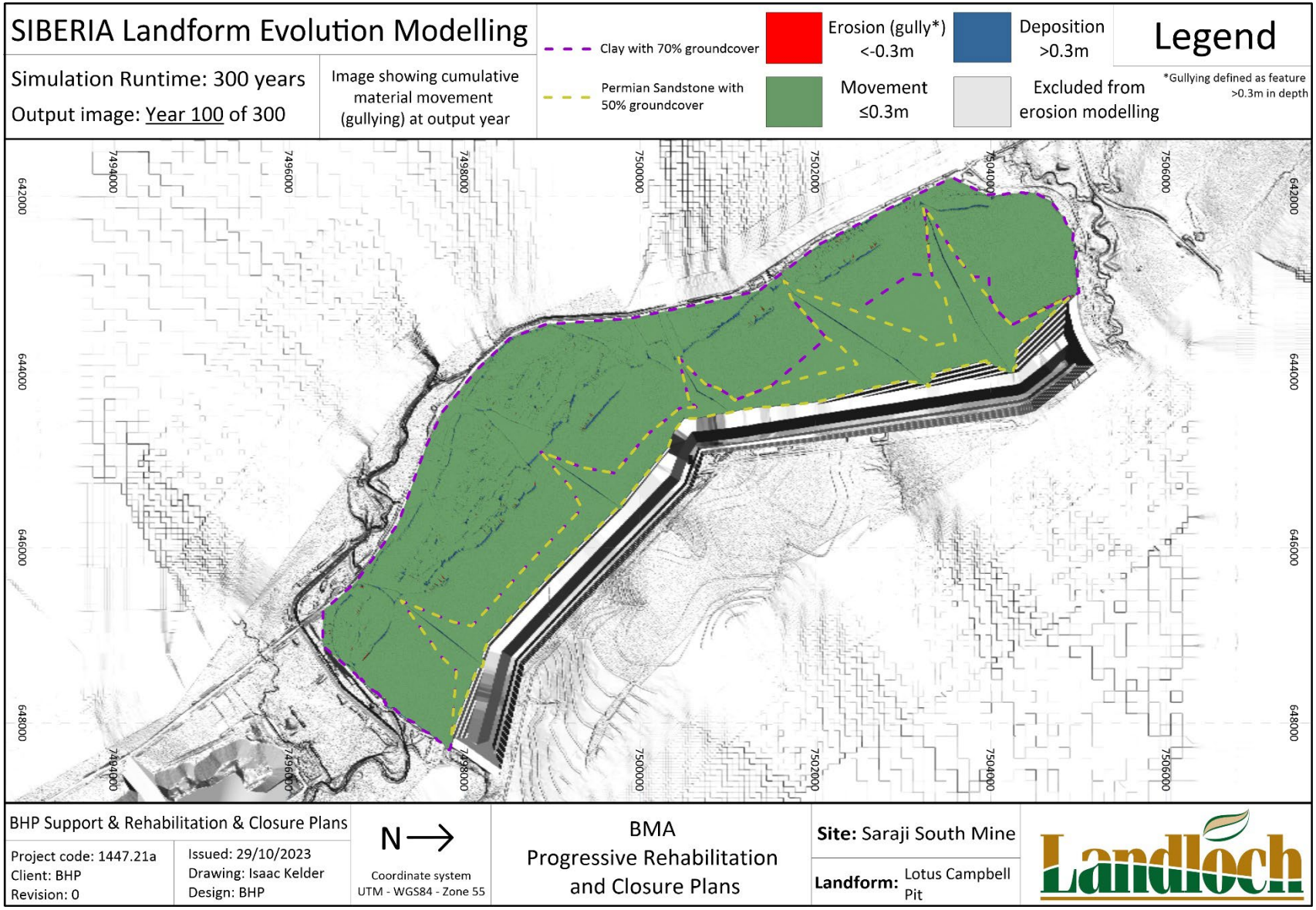

Figure A-14: Predicted erosion and deposition depths of the Lotus Campbell Pit rehabilitation landform after 100 years.

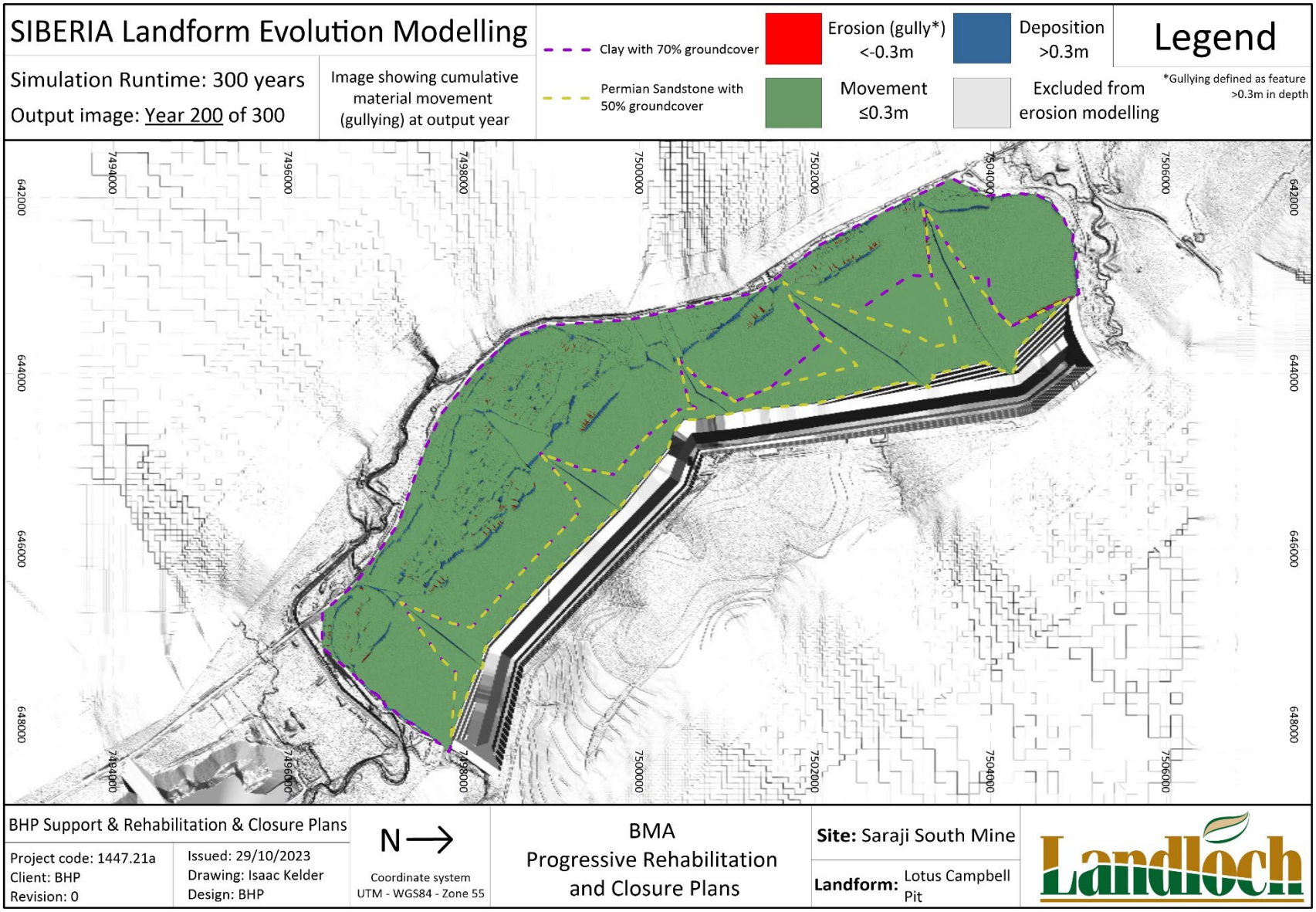

Figure A-15: Predicted erosion and deposition depths of the Lotus Campbell Pit rehabilitation landform after 200 years.

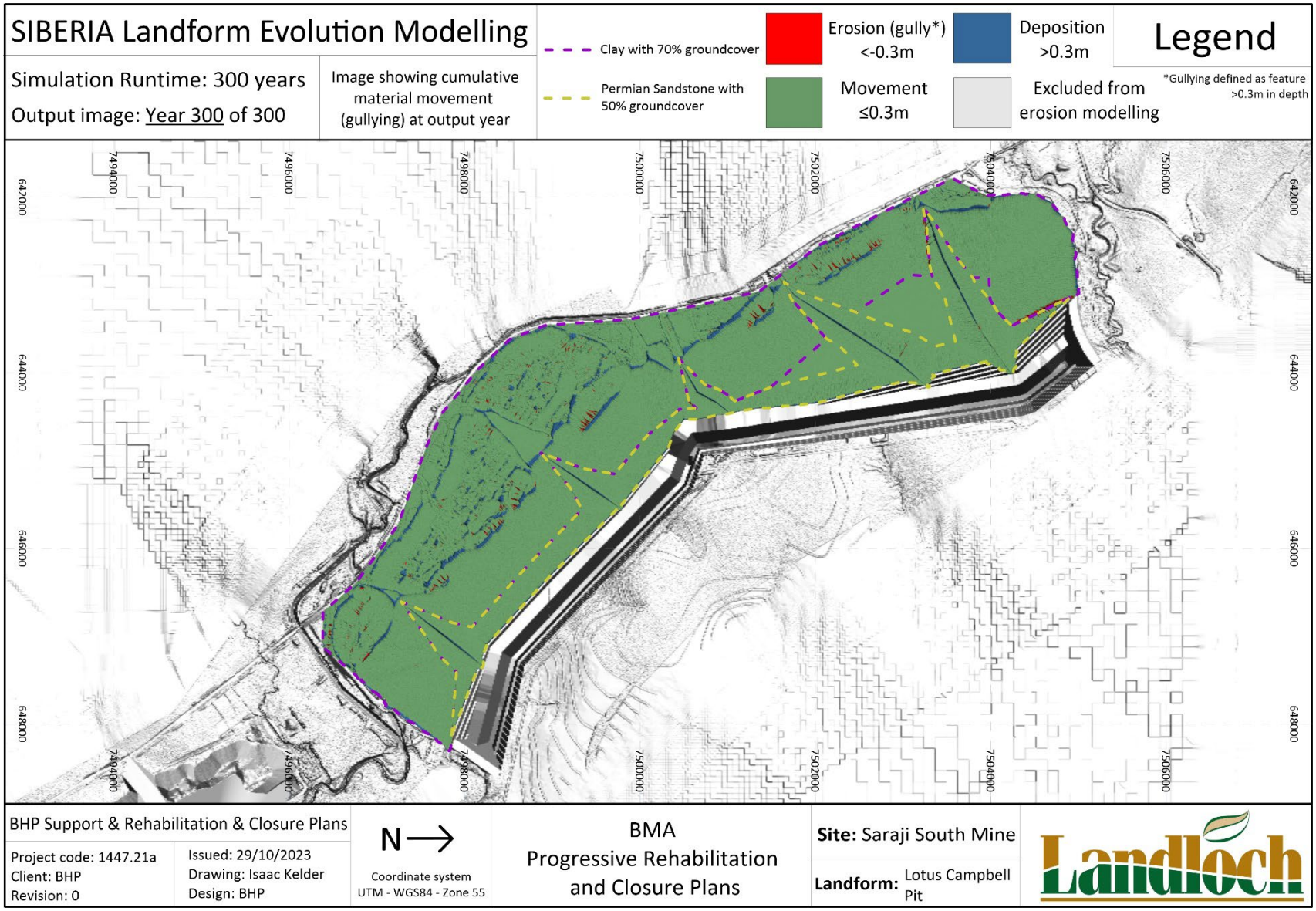

Figure A-16: Predicted erosion and deposition depths of the Lotus Campbell Pit rehabilitation landform after 300 years.

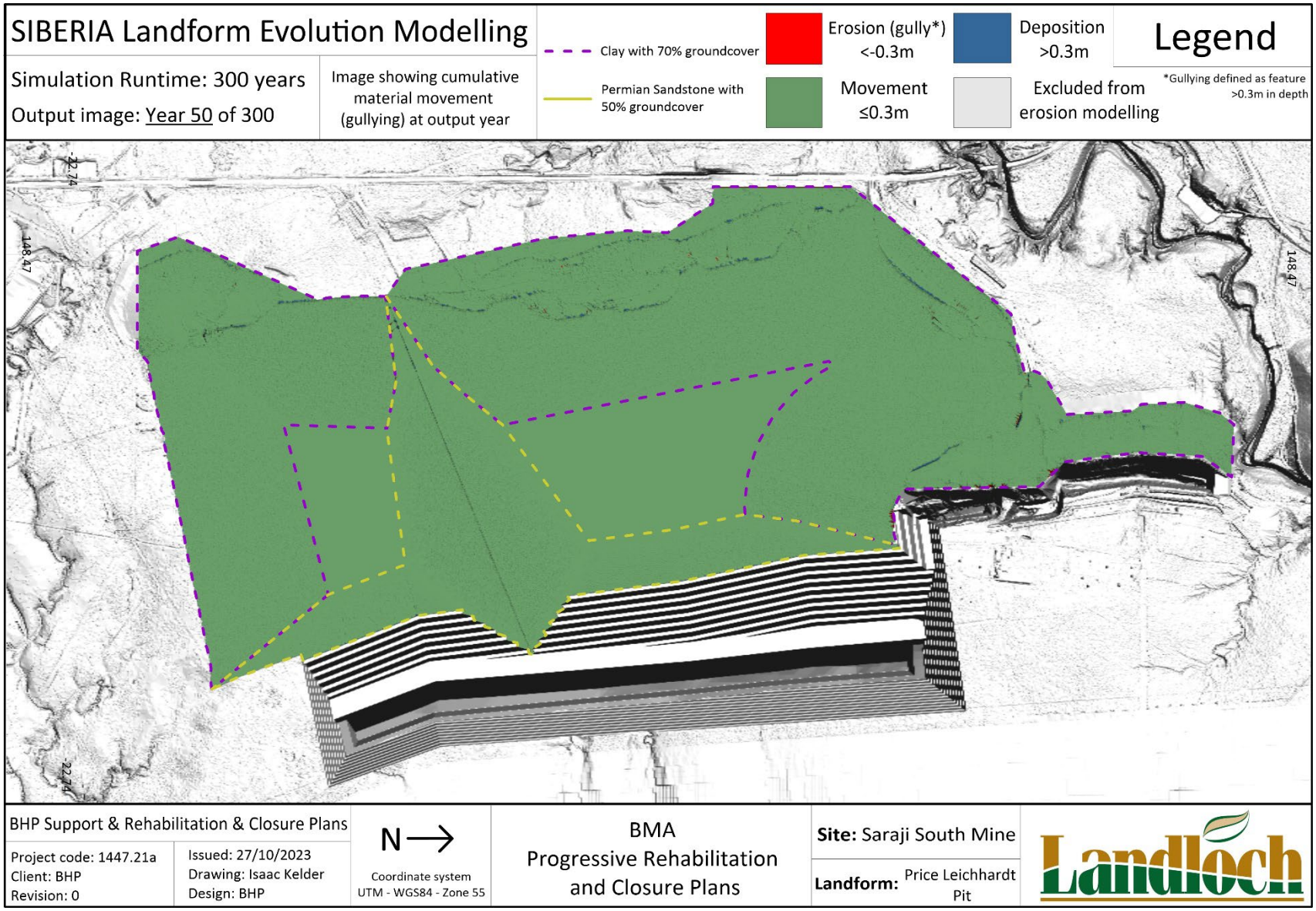

Figure A-17: Predicted erosion and deposition depths of the Price Leichhardt Pit rehabilitation landform after 50 years.

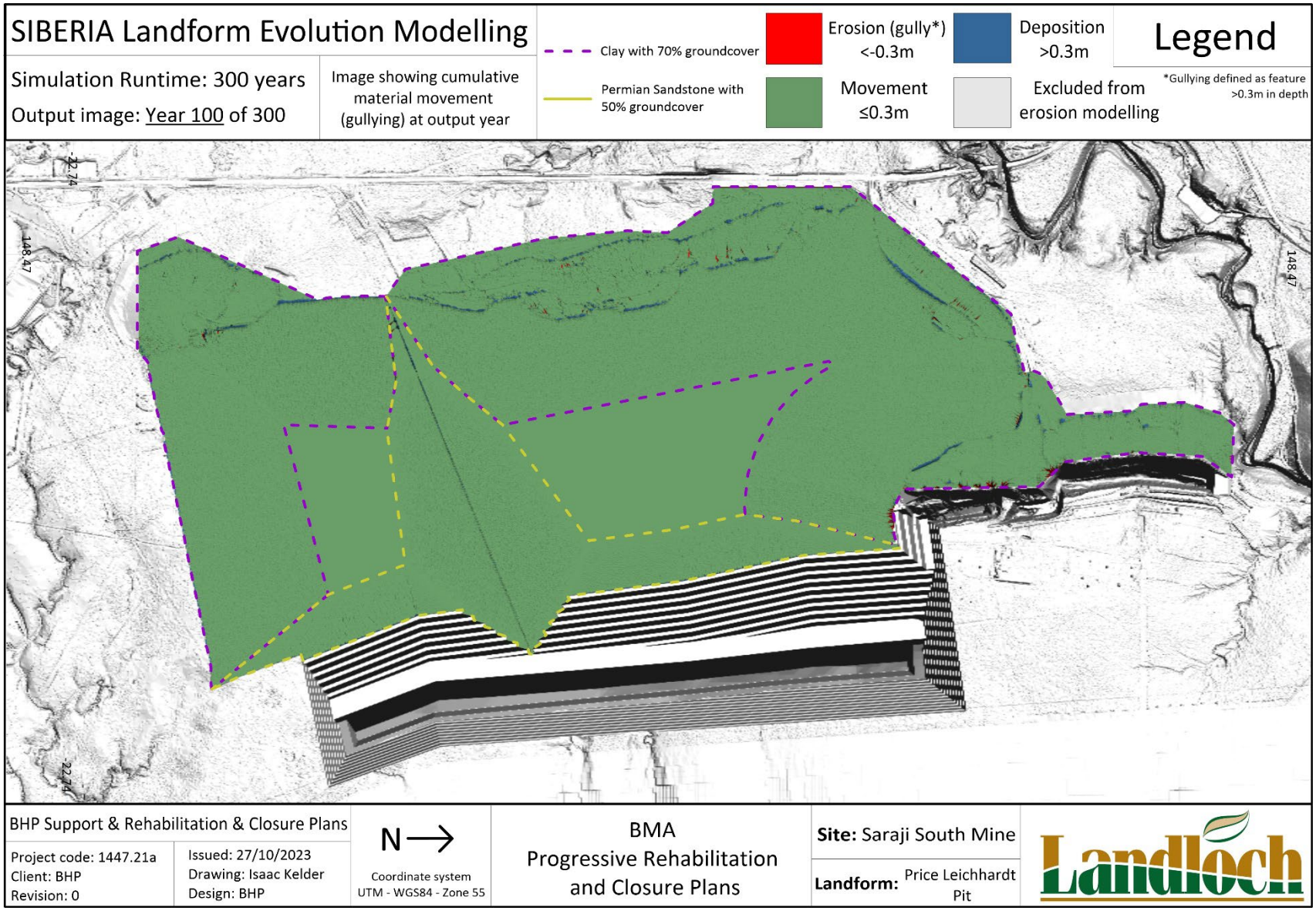

Figure A-18: Predicted erosion and deposition depths of the Price Leichhardt Pit rehabilitation landform after 100 years.

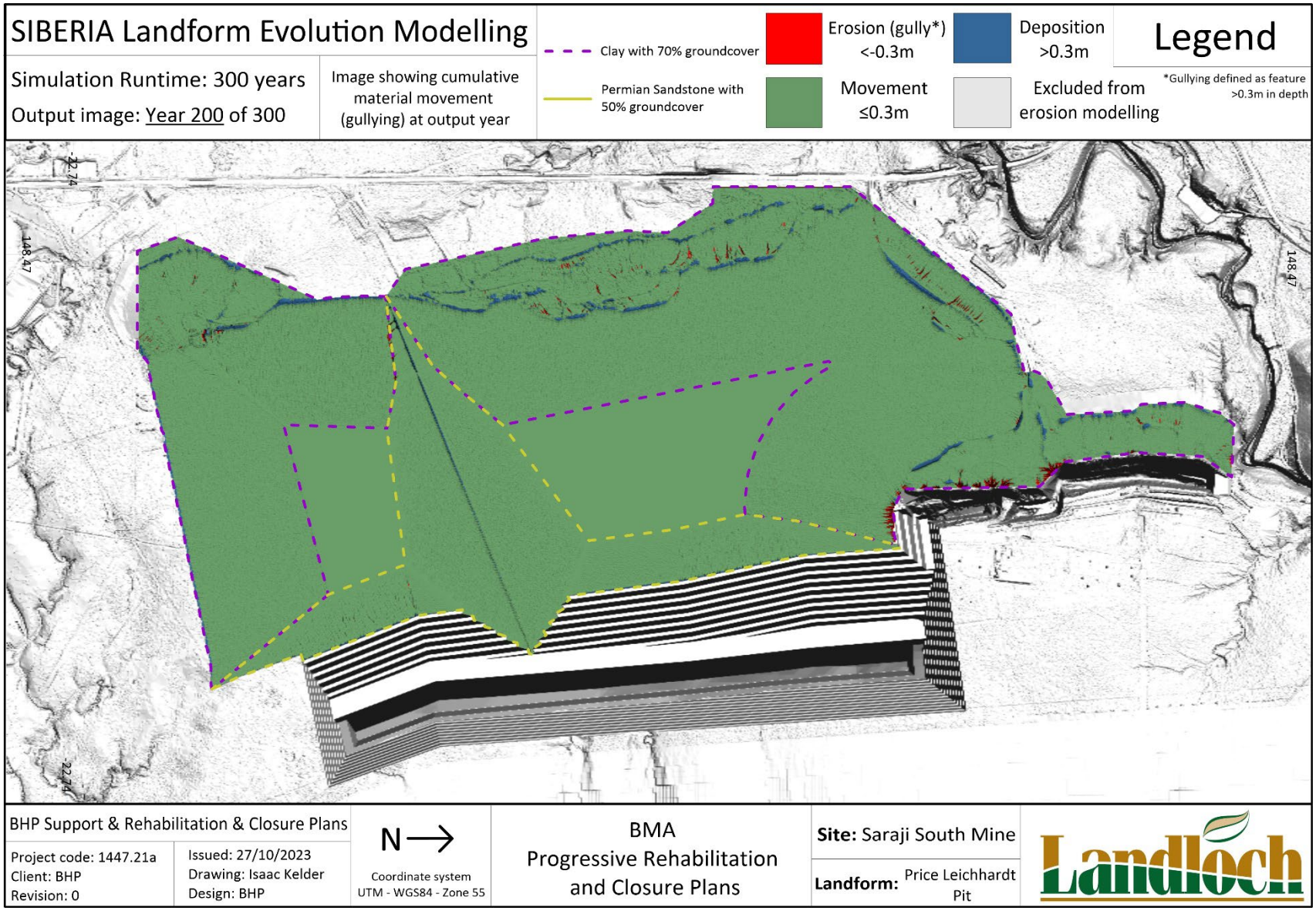

Figure A-19: Predicted erosion and deposition depths of the Price Leichhardt Pit rehabilitation landform after 200 years.

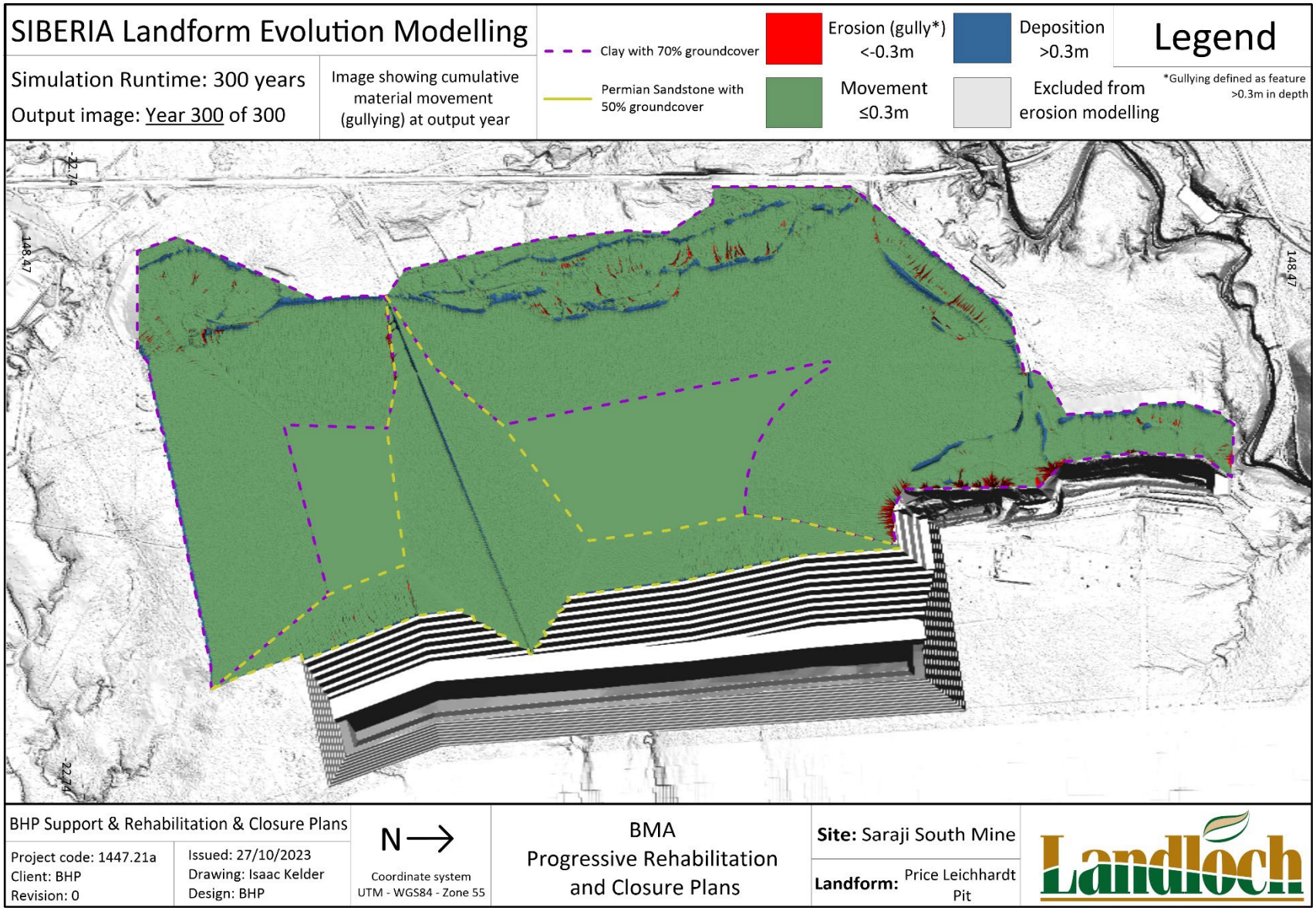

Figure A-20: Predicted erosion and deposition depths of the Price Leichhardt Pit rehabilitation landform after 300 years.

ENGENY

BMA

PRCP Concept Design Report

Rolf Creek East

QC1000_049-REP-001-1

4 JANUARY 2024

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the relinquishment of the Rolf Creek Diversion of Rolf Creek. The diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Norwich Park Mine (NPM)[1].

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 NPM 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 Assessment.
- 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 chapter and schedule.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP chapter and schedule.

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.

[1] It is noted that NPM is referred to as Saraji South Mine (SSM) for internal BMA planning purposes. However, as the Site's EA is under NPM, this Concept Design Report and supporting reports will consistently reference NPM.

2. OVERVIEW

2.1 Location

Rolf Creek is an ephemeral tributary located in the Isaac River sub-basin within the larger Fitzroy River Basin. The upper catchment within the NPM lease is not clearly defined, and it eventually flows into Browns Dam, which is part of the mine's affected water management system, situated east of the mine processing area. Although some parts of the upstream catchment contribute to Rolf Creek, the main portion of runoff from the mine operations area enters the diversion via Browns Dam.

The Rolf Creek diversion was constructed in the mid-1990s. It begins at the overflow of Browns Dam and extends approximately 700 meters east before being plugged. The plug diverts the flows from the original diversion alignment through a drain, culvert under the haul road, and into the Ramp 5 pit. A minor tributary, potentially unaffected by mine activities, joins the diversion in this sub-reach. Currently, all in-channel flows in this sub-reach eventually end up in the Ramp 5 pit, except for flows exceeding the creeks capacity, which would continue downstream. Refer to Figure 2.1 for the location of the Rolf Creek diversion.

650,000 651,000 652,000 653,000 654,000 655,000 656,000 657,000

7,484,000 7,483,000 7,482,000 7,481,000 7,480,000

ML 70126
ML 70410
ML 1782
ML 70350
Rolf Creek
Downstream Reach

LEGEND
- Existing Diverison Reach
- Downstream Reach
- Watercourses
- ML Boundary

R	DETAILS	DATE
1	Final Issue	24-08-2023

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DRAWN	SS	CHECKED	BK
APPROVED	RK	DATE	24-08-2023

NOTES:

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DISCLAIMER
Engeny has endeavoured to ensure accuracy and completeness of the data. Engeny assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

DATA SOURCE
QLD Government Open Data Source

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BHP

Figure 2.1

BHP Coal
Norwich Park Mine
Location of Rolf Creek Diversion

Drg Ref.

M:\Projects\M11000_BHP Billiton\M11000_528 BHP PRCP NPM Diversions\05 Design\QGIS\Workspaces\M110000_528-WOR-001-A_Rolf Ck Flood Modelling_SJS.qgz

2.2 Pre-Mining Condition

Due to the construction of the diversion in the early to mid 1990's, there is limited information relating to the pre-mining condition. The Rolf Creek baseline monitoring report completed by Alluvium in 2011 is the first documented conditions of the diversion that was available (Alluvium, 2011). The pre-mining natural upstream, downstream and diversion reaches have been described as follows:

- **Upstream reach –** Based on historical imagery, it appears that there were two tributaries that flowed east to form Rolf Creek.
- **Downstream reach –** The downstream reach's condition is impacted primarily by cattle grazing, however the first monitoring report indicated that the downstream reach was in good condition with further improvement for riparian vegetation establishment.
- **Diversion reach (pre-mining)** – Utilising historical imagery, the diversion reach was made of two drainage lines that conveyed both Murphys Dam and Little Murphys dam catchments to a downstream confluence. The soil and weathered sediment rock horizons the diversion has been constructed through are highly dispersive as evidenced by extensive erosion on the banks.

2.3 Current Conditions

Monitoring of Rolf Creek diversion has been undertaken since 2011 and the last major monitoring was completed following the 2019/ 2020 wet season by Engeny. As part of the major monitoring, the latest condition of the Rolf Creek diversion has been described as follows (Engeny, 2020):

- The diversion is not developing features similar to those in the local landscape due to ongoing geomorphic instability, dispersive soils and poor riparian vegetation condition. In addition, the hydrological impacts of Browns Dam and diversion of flows into Ramp 5 pit 700m downstream of Browns Dam spillway will continue to impede the ability for the diversion to develop features that are representative of the local landscape.
- The diversion does not currently maintain a sediment transport regime due primarily to the presence of Browns Dam and the diversion plug within the system. In addition, exposed dispersive soils within the diversion channel will continue to generate excess sediment and adversely impact the sediment regime.
- The diversion in its current form does not maintain a state of dynamic equilibrium. Significant engineering works would be required to result in the diversion maintaining equilibrium.

Due to this current condition, it is considered unlikely the existing diversion will achieve a state of dynamic equilibrium and be suitable for relinquishment following closure of the NPM. The upstream, downstream and diversion reaches of the Rolf Creek diversion at NPM 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.

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 Rolf 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 Rolf 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 three 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.

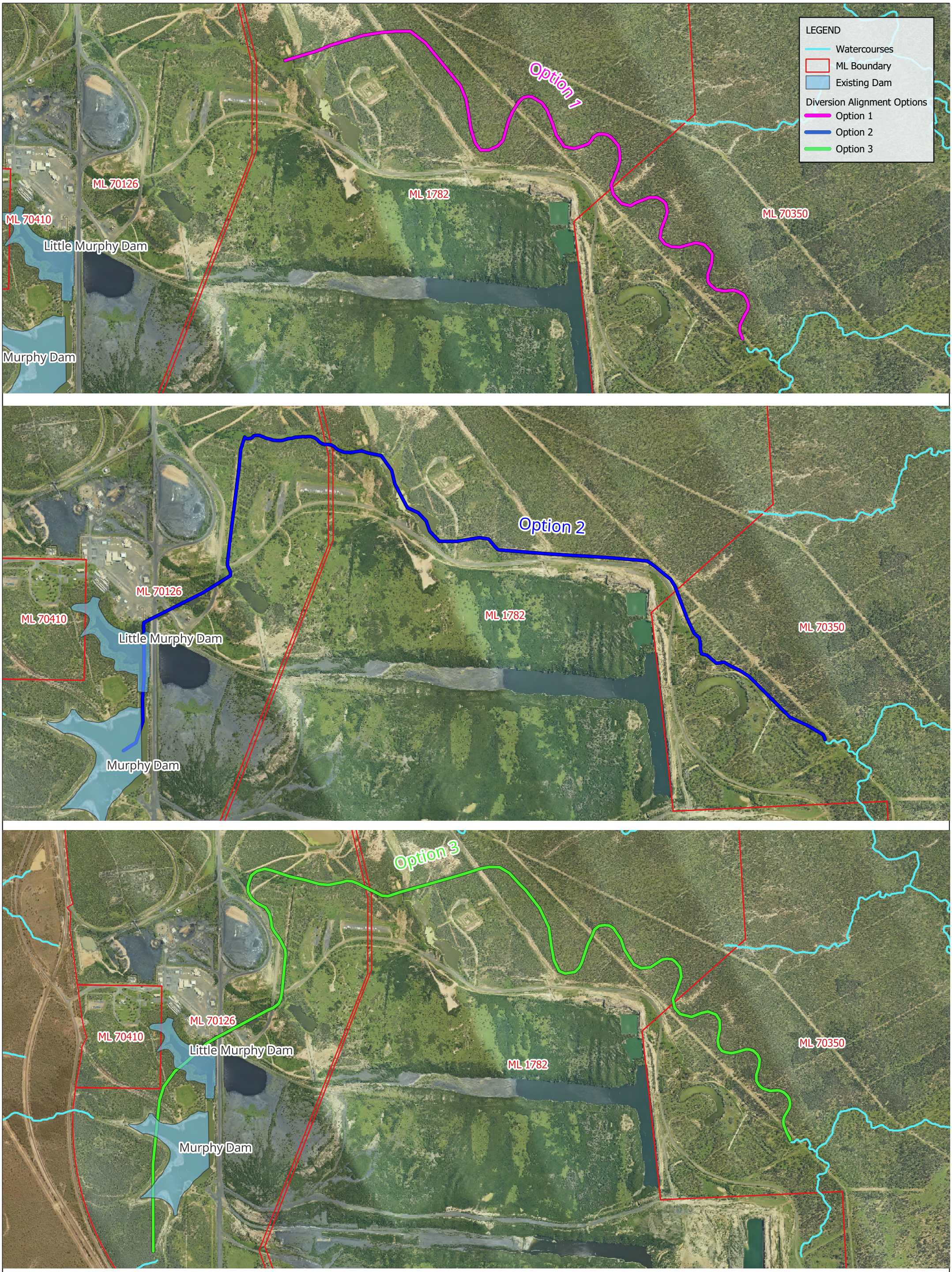
The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

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	Option 3
Description	Keep Murphy's dam and Little Murphy's dam. Construct Engeny (2021) design alignment.	Manage Murphy's dam catchment to tie into the current diversion alignment. Regrading of the current diversion will be required, in addition to the removal of Brown's dam.	Manage Murphy's dam catchment by filling Murphy's and Little Murphy's dam, and draining to a new diversion alignment similar to the original Engeny Design. Rehabilitation of the diversion reach required.
Likelihood that diversion will achieve state of dynamic equilibrium	Low – Similar grade and length to the existing creek alignment. Ponding of the murphy's dam catchment will limit downstream streamflow to below pre-mining levels and likely cause salt imbalances.	Moderate - similar grade and catchment to the existing creek alignment. Previously, this alignment has resulted in instabilities. Back fill of Brown's dam may be required.	High – similar grade, catchment area and length to the pre-mining alignment.
Diversion constructed through spoil	No	No	Yes (the fill of Murphy's dam)
Order of magnitude cost estimate*	$16.5 M	$35.7 M	$32.3 M
Ability to isolate diversion from flows during establishment period	Yes	Yes	Yes (with the exception of Murphy's dam segment)

* Costs estimated based on average $10/m^3.



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1	Final Issue	31-08-2023
2	Final Issue	03-01-2024

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BHP

Figure 4.1

BHP Coal
Norwich Park Mine
Rolf Creek Diversion Realignment Options

Drg Ref.

\\online.com\files\Management\Projects\M11000_BHP Billiton\M11000_528 BHP PRCP NPM Diversions\05 Design\QGIS\Workspaces\M110000_528-WOR-001-A_Rolf Ck Flood Modelling_SJS.qgz

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	40%
Diversion constructed through spoil	30%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

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 all three options without a fatal flaw 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	0.5	1
Relative Risk	Neutral Risk	Low Risk	Lowest Risk
Fatal Flaw	Yes	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 ACART 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] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*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 Diversion Alignment

Option 3 was identified to be the preferred option alignment using the MCA. The option was further refined to optimise the estimated capital costs and quantify the works associated with rehabilitation of the existing channel. The full concept drawing package for the permanent Rolf Ck Creek diversion is included in Appendix C and the interaction of the design with the PRCP landform in Appendix D.

6.3 Channel Geometry and Grade

The typical downstream 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. The location of the reference cross sections is shown in Figure 6.1.

Table 6.2 summarises the selected typical channel cross section selected for the concept design. The concept design drawings in Appendix D 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	5 m	
Channel Depth	2.5 m	Consistent depth of low flow channel at 1.5 m
Batter Slope	1V:3H	For both the low flow channel and high flow channel batters. The batters will ~~then~~ be covered with topsoil, hydromulch and hydroseed (Appendix C) to ensure stability and prompt revegetation of the channel batters.

650,000 651,000 652,000 653,000 654,000 655,000 656,000 657,000

7,484,000 7,483,000 7,482,000 7,481,000 7,480,000

ML 70126

ML 70410

ML 1782

ML 70350

Downstream Reach

LEGEND

- Reference Cross-section Locations
- Downstream Reach
- Diversion Reach
- Watercourses
- ML Boundary

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1	Final Issue	09-08-2023

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SCALE @ A3 - 1:18,865
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Figure 6.1

BHP Coal
Norwich Park Mine
Locations of Reference Cross-Sectional Areas

Drg Ref.

M:\Projects\M11000_BHP Billiton\M11000_528 BHP PRCP NPM Diversions\05 Design\QGIS\Workspaces\M110000_528-WOR-001-A_Rolf Ck Flood Modelling_SJS.qgz

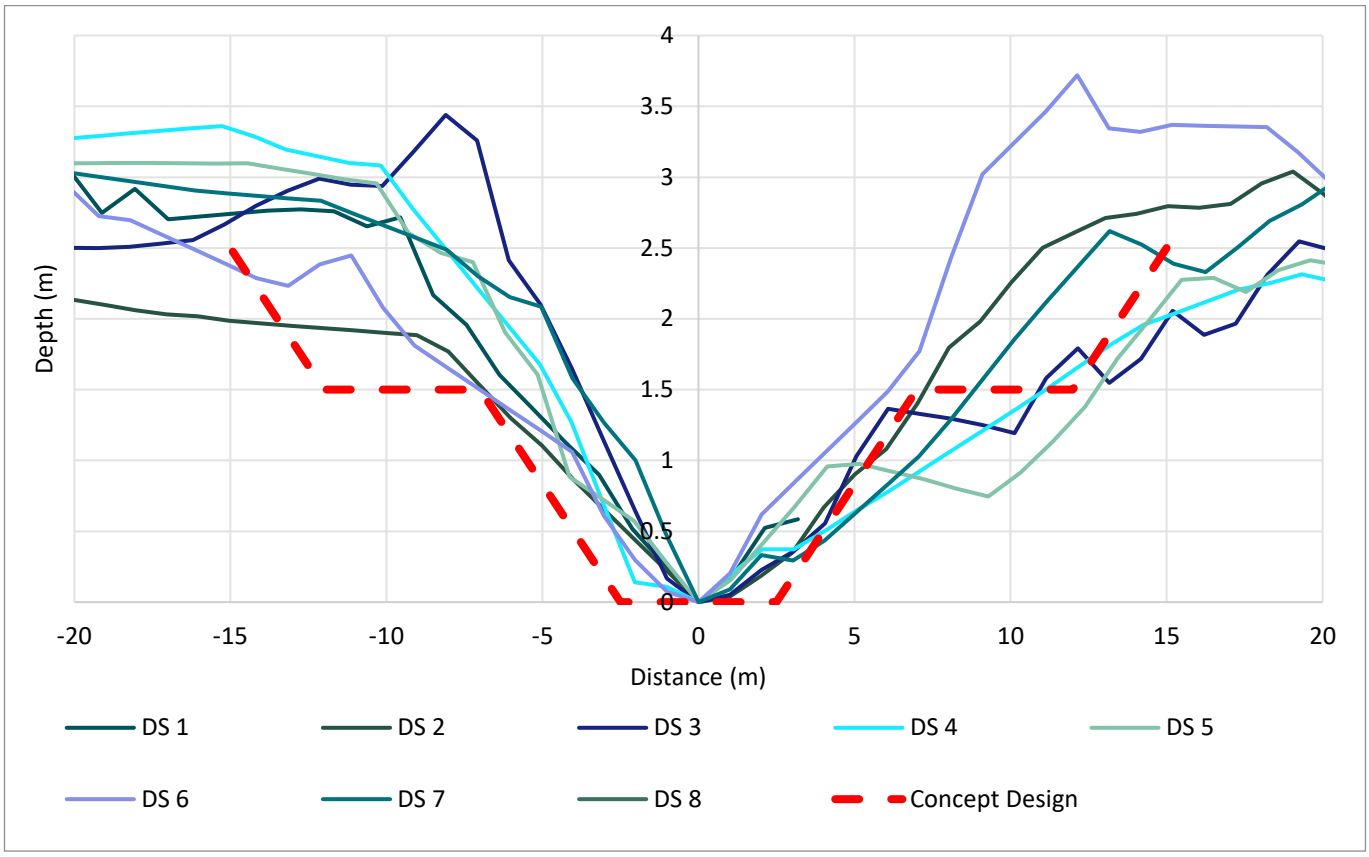

Figure 6.2: Typical Downstream Channel Cross Section of Rolf Creek

The concept design does not seek to change the vertical grade. The natural sinuosity of the current diversion is retained further downstream of the proposed design. However, the first 2 km of the concept design diversion is adopted as a straight channel to achieve the natural grade of the upstream catchments.

The natural longitudinal gradient downstream of the confluence was estimated to be approximately 0.3%. Based on a channel length of 9.6km for the diversion design, a grade of 0.31% was able to be achieved. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix D.

6.4 Hydrology

A hydrologic model of Rolf Creek (concept design) was ~~originally~~ developed using XP-RAFTS software. The model was used to estimate flows for the 1 in 2-year, 1 in 50-year and 1 in 1000-year flood events. The Rolf Creek catchment is presented in Figure 6.3.

649,000 650,000 651,000 652,000 653,000 654,000 655,000 656,000

7,484,000 7,483,000 7,482,000 7,481,000 7,480,000

RF_01 RF_02 RF_03 RF_04 RF_05 RF_06 RF_07 RF_08 RF_09 RF_10 RF_11 RF_12 RF_13 RF_14 RF_15 RF_16 RF_17 RF_18 RF_19 RF_20 RF_21 RF_22

LEGEND

Rolf Creek Subcatchments

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Figure 6.3

BHP Coal
Norwich Park Mine
Map of Catchments

Drg Ref.

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6.4.1 Frequent Events

Peak flows for frequent events (39% AEP and 2% AEP) for the Rolf Creek diversion (concept design) were estimated using the ACARP (2002) methods and are presented in Table 6.4. 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. However, the calculated flood magnitudes for the 39% and 2% AEP events were estimated to be lower when compared to XP-RAFTS peak flows. Therefore, the XP-RAFTS peak flows were 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 Rolf Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters. The critical duration and associated peak inflows for the simulated events have been summarised in Table 6.3.

TABLE 6.3: XP-RAFTS PEAK FLOW AND CRITICAL DURATION RESULTS

Rainfall Event	Peak Flow (m^3/s)	Critical Duration (hrs)
1,000-year ARI	181.13	1.5hr (temporal pattern 3)
50-year ARI	81.74	2hr (temporal pattern 8)
2-year ARI	27.68	2hr (temporal pattern 8)

TABLE 6.4: ROLF CREEK DIVERSION ACARP DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m3/s
2% AEP (50-year ARI)	68.51
39% AEP (2-year ARI)	20.87

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP landform 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, and potential impacts to downstream infrastructure.

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 2yr and 50yr ARI events.

Note: Impacts to the flooding regime in the 1,000-year ARI event and risk to pit flood inundation have been assessed through the Rehabilitation Flood modelling assessment including climate change (WMS, 2023).

Details of the model build, and assumptions are included in Appendix B.

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 6.5). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 6.5: 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)	29.06	<60	65.64	<150
Stream Velocity (m/s)	0.95	<1.5	1.28	<2.5
Shear Stress (N/m^2)	26.61	<40	43.17	<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 6.5 that all diversion hydraulic results are (on average) below design parameters. 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 B.

6.6 Risks and Mitigation Measures

Table 6.6 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 6.6: 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.	Probable	2	9	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.	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). 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.	Highly Unlikely	1	0.3
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
Difficulty in topsoiling and revegetating channel banks with existing rock armouring	Highly Unlikely	2	0.9	Adopt an increased soil depth and detailed revegetation methodology to ensure all air voids filled	Highly Unlikely	2	0.9
Downstream natural channel within mining lease degraded by grazing and land clearing – no rehabilitation proposed with concept design	Unlikely	2	3	Potential to extend design further east to shape batters and promote revegetation.	Unlikely	2	3

6.7 Additional Design and Construction Considerations

6.7.1 Flood Ingress into Final Void and 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 creek by a sufficient distance limit seepage into the voids. The PRCP landform will need to be executed to provide flood protection for the Ramp 5 Tailings Dam Pit, ensuring the 0.1% AEP flood event does not contribute to additional external inflows into the void (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 Backfilling of Existing Dams

The concept design and flow assessments are based on the nearby dams (Horseshoe Dam, Browns Dam, Murphy Dam and Little Murphy Dam) being de-commissioned. Sediment deposits created by the Murphy Dam and Little Murphy Dam will need to be removed and the natural channel alignment and cross section re-instated to achieve a free draining landform into the diversion. The individual channel cross sections need to be comparable to and representative of upstream tributaries.

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 develop an appropriate growth media for the diversion banks with recommendation of ameliorants and 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 all 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 function design for Rolf 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 Norwich Park 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 carrying 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 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 NPM.

Three options for rehabilitation of the Diversion were identified and assessed using the BMA Multi-Criteria Analysis outlined in Section 5. The option selected to proceed to concept design was Option 3 which includes the construction of a new diversion alignment by backfilling the Murphy's and Little Murphy's dam to meet the DNRME design criteria. The final concept design, typical cross sections and longitudinal section are presented in Appendix C.

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 meet the DNRME design criteria for stability if the channel remains unvegetated. This risk can be mitigated by construction timing and development of a revegetation plan. The PRCP landform will also need to ensure the flood protection of final voids located south-west of the concept design, including sufficient buffer between the concept diversion design 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.

(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.

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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.

9. REFERENCES

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APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Rolf Creek Diversion

Project: PRCP NPM Diversions
Workshop Date: NA

-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.	40%	-1	1	2	Option 1: Has an alignment with a length and grade similar to the pre-mining alignment. The ponding of the murphy's dam catchment will limit downstream streamflow to below pre-mining levels and likely cause salt imbalances. Potential issues with TSF seepage. Option 2: Ties into the existing diversion, which has know stability issues. Option 2 will also require the division to be cut deep into to terrain. Option 3: Has an alignment with a length, grade, and catchment similar to the pre-mining alignment.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	30%	2	2	1	Option 1 and Option 2: Won't require construction through spoil. Option 2 potential movement of contaminants (TSF seepage) through deep cuts. Option 3: Will require partial construction through spoil, once Murphy's dam and Little Murphy's dam has been filled.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	20%	0	-2	-1	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.	10%	2	-1	1	Option 1: Can be constructed and established in isolation from the existing diversion Option 2: Will be constructed on the existing diversion alignment and through Murphy's and Little Murphy's dams. Option 3: The majority of the diversion can be constructed offline from the existing diversion. Only the Murphy's dam segment can't be constructed offline
	Overall Weighted Score		0.4	0.5	1.0	

Is there a Fatal Flaw?	**No**	**No**	**No**
Relative Risk	**Neutral Risk**	**Low Risk**	**Lowest Risk**

APPENDIX B: HYDRAULIC PARAMETER MODELLING RESULT

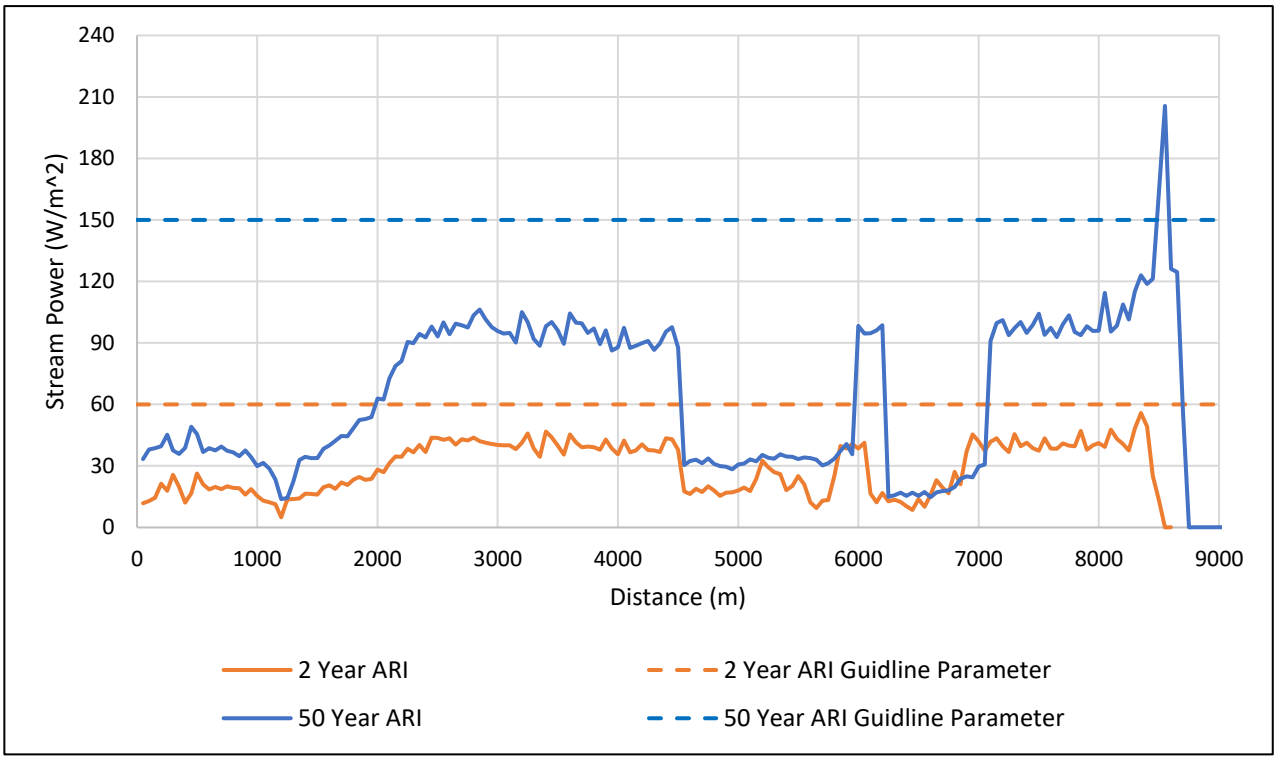


FIGURE B.1: STREAM POWER TUFLOW MODEL RESULTS

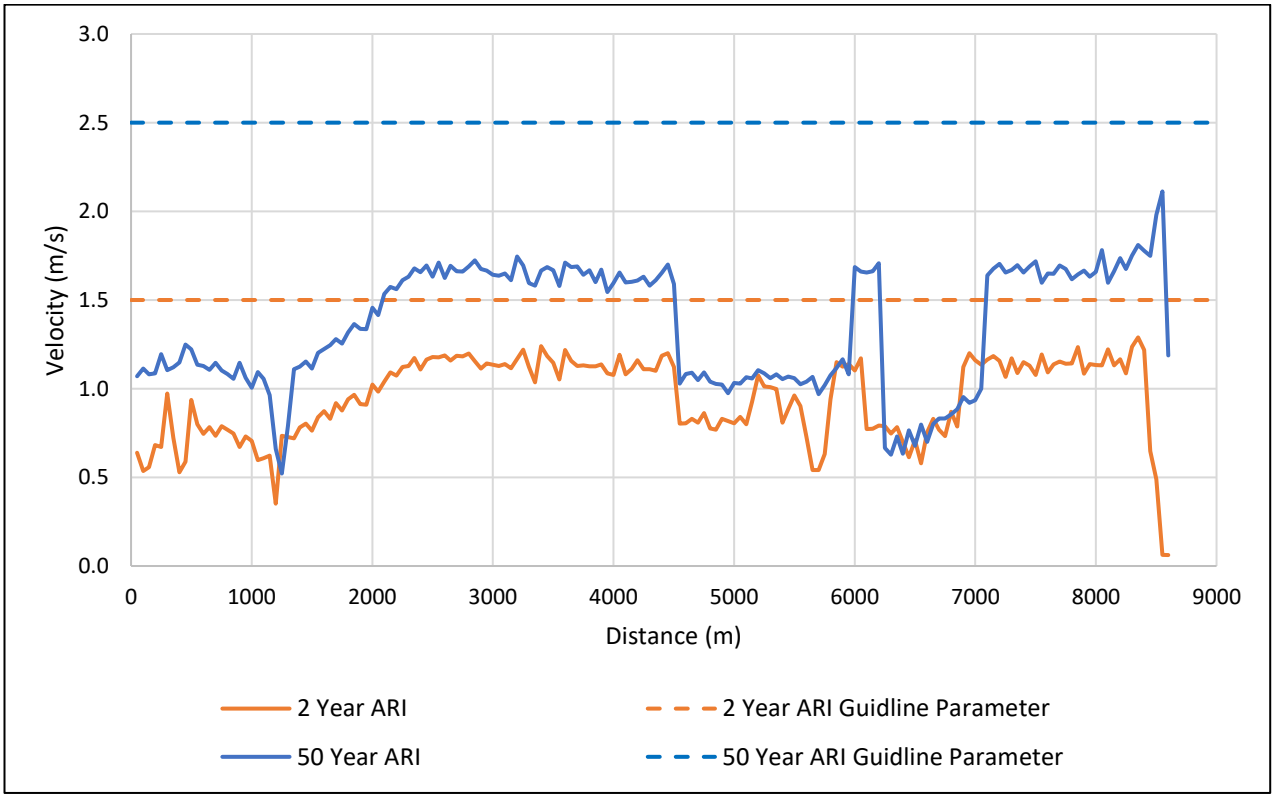


FIGURE B.2: VELOCITY TUFLOW MODEL RESULTS

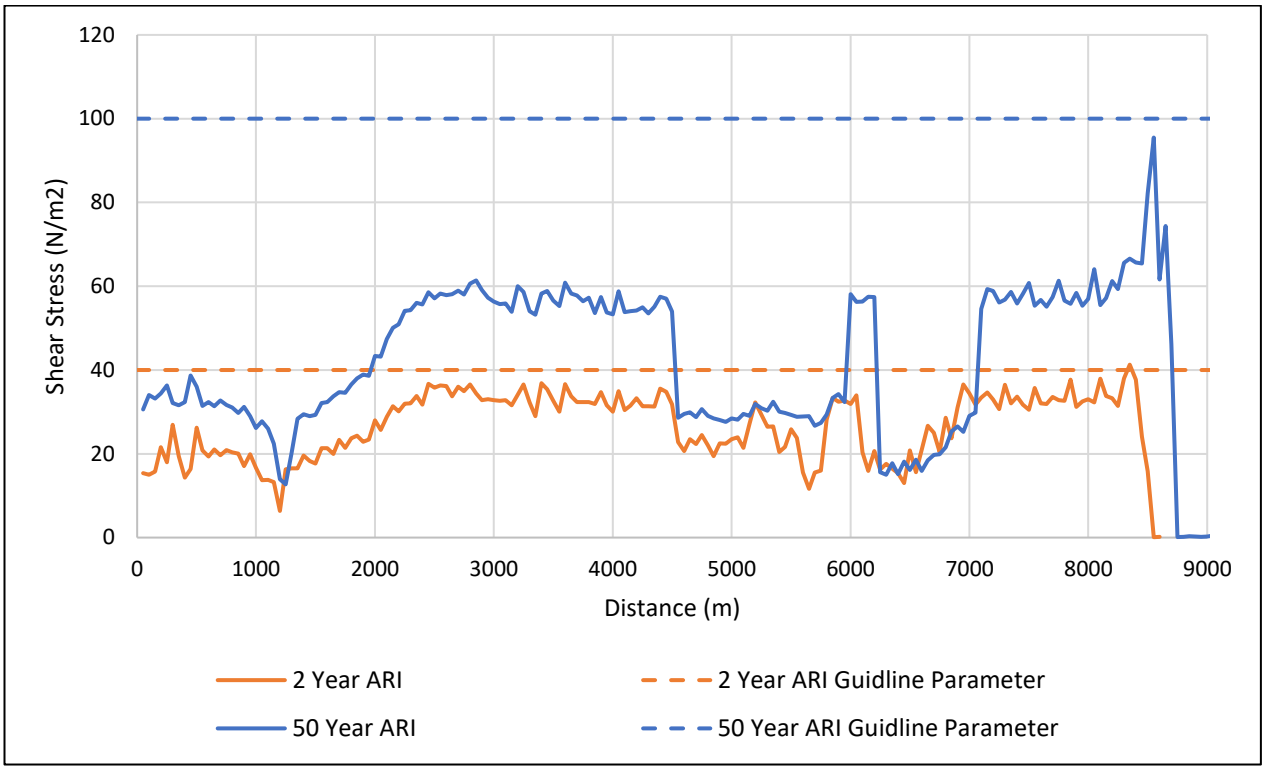
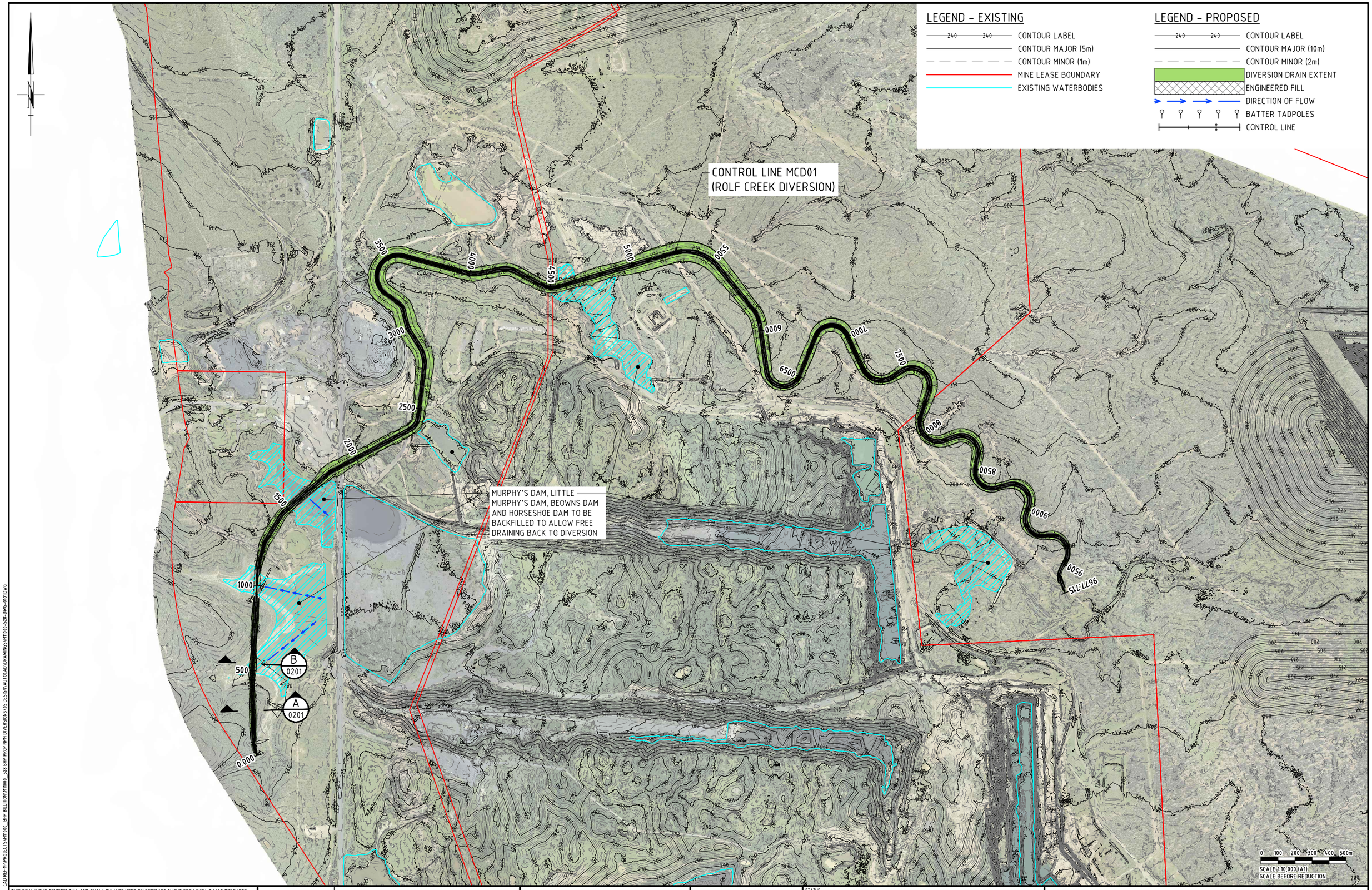


FIGURE B.3: SHEAR STRESS TUFLOW MODEL RESULTS

APPENDIX C: PREFERRED OPTION CONCEPT DESIGN DRAWINGS



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REV	BY	DATE	REVISION DESCRIPTION	PM APPD.
B	SSA	04.01.24	CONCEPT DESIGN - NOTE CHANGES	-
A	SSA	28.08.23	CONCEPT DESIGN	-

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

BMA BHP Mitsubishi Alliance

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CPENG	-	CPENG No.	-

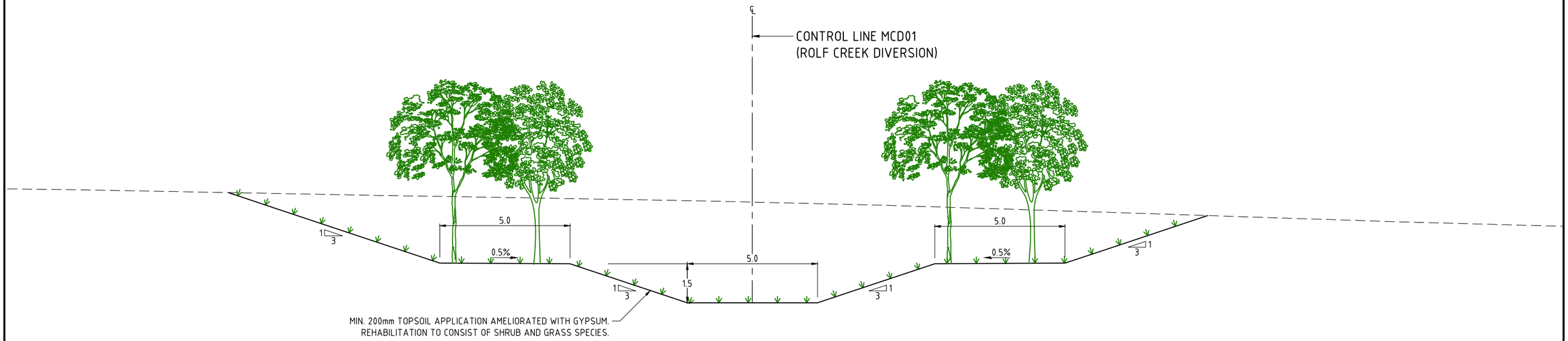
NORWICH PARK MINE

PRCP ROLF CREEK DIVERSION
GENERAL ARRANGEMENT PLAN

ORIGINAL SIZE A1

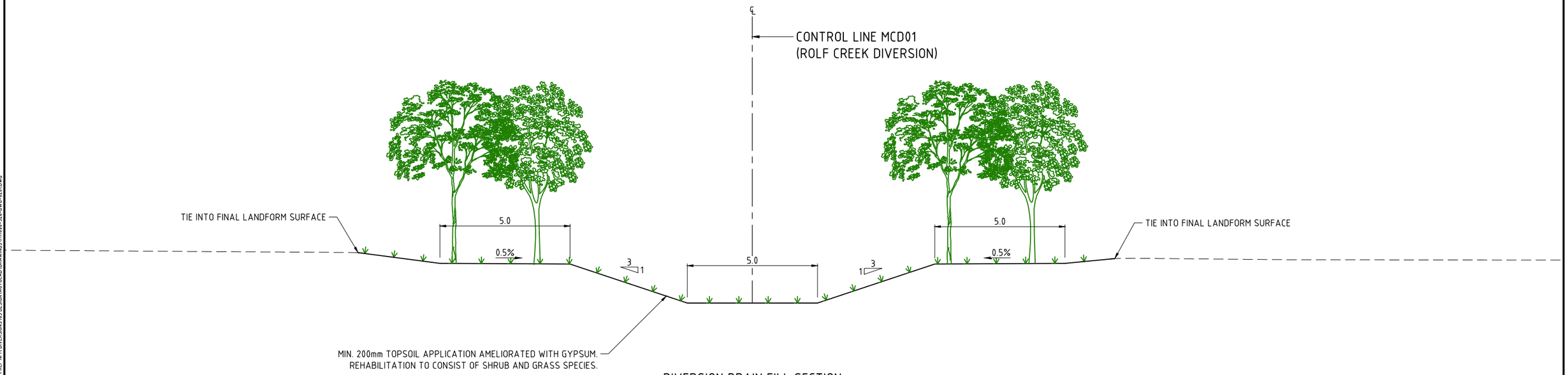
DWG NO. M11000-528-DWG-0101

REV. B



DIVERSION DRAIN CUT SECTION

SECTION A 0101
SCALE 1:75



DIVERSION DRAIN FILL SECTION

SECTION B 0101
SCALE 1:75

LEGEND

EXISTING SURFACE

DESIGN SURFACE

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SCALE 1:75 (A1)
SCALE BEFORE REDUCTION

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CPENG	-	CPENG No.	-

NORWICH PARK MINE

PRCP ROLF CREEK DIVERSION
TYPICAL SECTIONS AND DETAILS

ORIGINAL SIZE A1
DWG NO. M11000-528-DWG-0201
REV. A

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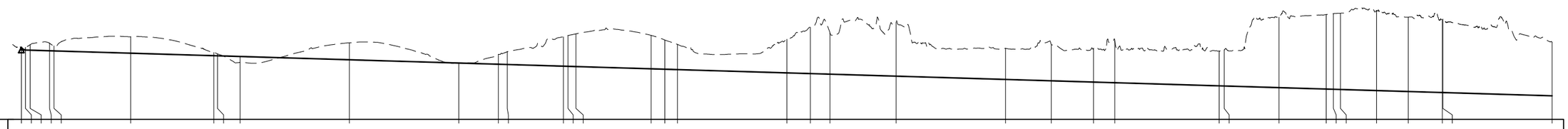

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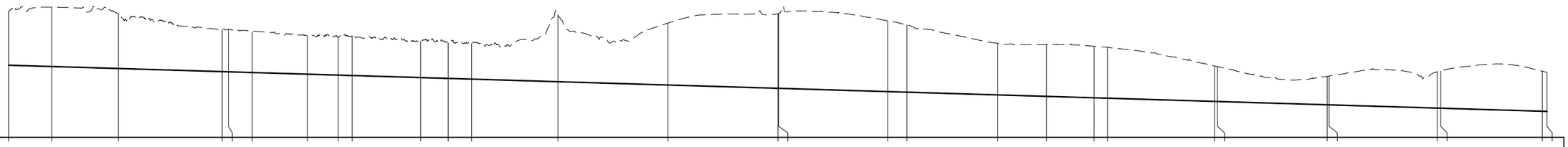
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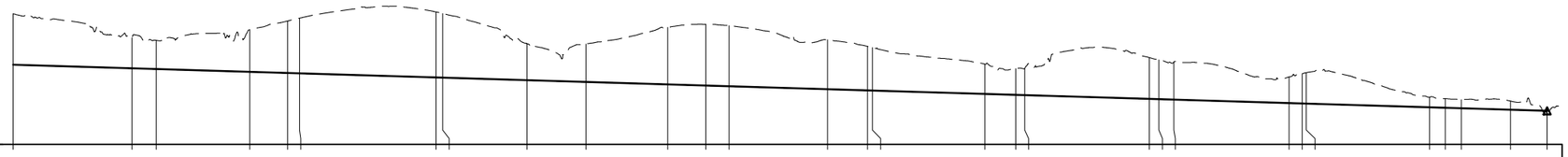
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APPENDIX D: CONCEPT DESIGN WITH PRCP LANDFORM INTERACTION

650,000 651,000 652,000 653,000 654,000 655,000

7,483,000 7,482,000 7,481,000 7,480,000

Rolf Creek

LEGEND

Rolf Creek Proposed Design

Rolf Creek Existing Diverison

PRCP Final Landform (mAHD)

Band 1 (Gray)

236.631817

187.229815

R	DETAILS	DATE
1	Final Issue	09-08-2023

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APPROVED	RK	DATE	09-08-2023

NOTES:

N

0 0.3 0.6 km

SCALE @ A3 - 1:15,000

AGD66 / AMG zone 55

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DATA SOURCE
QLD Government Open Data Source

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BHP

Figure D.1

BHP Coal
Norwich Park Mine
Rolf Creek Concept Design with PRCP Landform

Drg Ref.

M:\Projects\M11000_BHP Billiton\M11000_528 BHP PRCP NPM Diversions\05 Design\QGIS\Workspaces\M110000_528-WOR-001-A_Rolf Ck Flood Modelling_SJS.qgz

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Norwich Park Mine
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Rev	Date	Details
Rev A	17/07/2024	Draft for client comment
Rev 0	30/09/2024	Final for submission

	Name	Date	Signature
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Reviewed/Approved by:	Gareth Simpson	30/09/2024	

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 Heigh Datum
AWBM	Australian Water Balance Model
BMA	BHP Mitsubishi Alliance
CHPP	Coal Handling and Processing Plant
DESI	Department of Environment, Science and Innovation
EA	Environmental Authority
FoS	Factor of Safety
GDE	Groundwater Dependent Ecosystems
LOD	Land Outcome Document
LOR	Limit of Reporting
PCM	Permian Coal Measures
MCM	Moranbah Coal Measures
MIA	Mine Infrastructure Area
ML/year	Megalitres per year
ML	Mining Lease
NPM	Norwich Park Mine – also referred to as Saraji South Mine
NUMA	Non-use Management Area
PMF	Probable Maximum Flood
PMLU	Post-Mining Land Use
PRC plan	Progressive Rehabilitation and Closure Plan
QC	Quality Control
RCP	Representative Concentration Pathway
SRM	Saraji Mine
SSM	Saraji South Mine (formerly known as Norwich Park Mine)
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
WBM	Water Balance Model

1 Introduction

Norwich Park Mine (NPM) is an open-cut coal mine which forms part of BHP Mitsubishi Alliance's (BMA) central region mine complex. NPM is now operationally referred to as Saraji South Mine (SSM), however, as the Environmental Authority (EA) refers to Norwich Park Mine, this plan refers to the site as NPM. NPM is located approximately 25 kilometres (km) south of Dysart in the Bowen Basin, Central Queensland. The site is operated on various Mining Leases (MLs): ML1782, ML70126, ML70127, ML70325, ML70328, ML70350, ML70369, ML70370, ML70410.

Operations at NPM are authorised under EA (EPML00865013), which 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[1] (DESI) for NPM, requiring a PRC plan to be submitted to the administering authority by 1 October 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 NPM – specifically the residual voids associated with Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, East 2 and Roper 1 - 4 pits. This void closure plan is an appendix to the NPM PRC plan and is required by the DES *Progressive rehabilitation and closure plan (PRC plans) Guideline (version 3.0)*, hereafter referred to as the 'PRC Plan Guideline', dated 4 April 2023.

Technical studies, including hydrogeology and rehabilitation flood modelling, have been undertaken through an iterative approach to 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 NPM final residual voids.

1.1 Scope and objectives

The following NPM mining pits are currently in various operational stages – Lotus, Campbell, Gilbert, Price, Leichhardt, Roper, East 1 and East 2 pits. Post-closure, these pits are pre-approved as non-use management areas (NUMAs). They will be combined in a final closure landform design as nine residual voids – Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, East 2, and Roper 1 – 4 (herein referred to as the NPM 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 NUMA extents
- Minimise active management of the residual voids post-closure
- Avoid unmitigated access to the NUMA by humans and livestock.

[1] Previously referred to as Department of Environment and Science (DES)

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

Where technical assessments are presented for all NPM residual voids in this void closure plan, the outcomes of the technical studies for Roper 1, 2, 3 and 4 residual voids are discussed as point-in-time assessments only as further understanding of the key, relevant risks and potential design criteria limitations associated with these residual voids in the closure landform is required.

A targeted study that encompasses these voids - referred to as the Roper Study Area, has been included as a milestone for the PRCP schedule to undertake additional technical studies to develop a detailed closure plan. Outcomes from this study will be used to improve understanding of void interconnectivity within the Roper voids and the East 1 and 2 voids and identify modifications that may be required to further manage and/or control areas of potential environmental harm resulting from the Roper residual voids in the closure landform. The PRC plan provides more detailed information on the Roper Study Area, with related rehabilitation milestones defined in the PRCP Schedule.

1.2 Applicable legislation and guidelines

The following applicable legislation and guidelines have informed the development of this void closure plan:

- *Environmental Protection Act 1994* (QLD)
- EA (EPML00865013) dated 29 June 2023
- *PRC Plan Guideline* (version 3.0) dated 4 April 2023.

2 Site overview

NPM is a conventional open-cut strip mine targeting hard-coking coal resources to produce metallurgical coal. It is located approximately 25 km south of Dysart, Queensland. Saraji Mine (SRM) is located directly to the north of NPM. Coal mining activities have been carried out across most of the mining leases with the current mining pits in various operational stages.

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 truck and shovel fleets (and historical use of draglines). 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 the BMA owned SRM coal handling and preparation plant (CHPP). Tailings and rejects from the CHPP are disposed of at SRM. Product coal is transported by rail to the Hay Point Coal Terminal for export.

Operations at NPM began in 1980 and entered a period of care-and-maintenance between 2012 and 2021; operations recommenced thereafter.

The planned closure dates for the individual residual voids vary, based on the current projected mine plan, as follows:

— 2098: Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 voids
— 2023: Roper voids.

An overview of the existing environmental site context within and surrounding NPM is provided in the PRC plan, and therefore not repeated in this void closure plan.

3 Proposed residual voids

Residual voids are identified and authorised under Schedule E (Condition E6 and E7) of the EA (which is NPM's Land Outcome Document (LOD)). The nine proposed NPM residual voids are being transitioned as pre-approved NUMAs in the NPM PRC plan.

The pits will be progressively backfilled with spoil as mining advances, with partial backfill of the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 final voids planned to assist with flood protection so 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 NPM residual voids, including the void lakes, is presented in Figure 3.1.

Table 3.1 Indicative NPM residual void dimensions

Residual void	Indicative maximum width (m)	Indicative maximum length (m)	Indicative maximum depth (m)
Lotus/Campbell	440	9,000	168
Gilbert	645	3,500	164
Price/Leichhardt	980	6,390	273
East 1	275	1,260	90
East 2	255	800	75
Roper 1	230	1,430	18
Roper 2	250	2,330	25
Roper 3	290	1,280	14
Roper 4	350	4,960	67

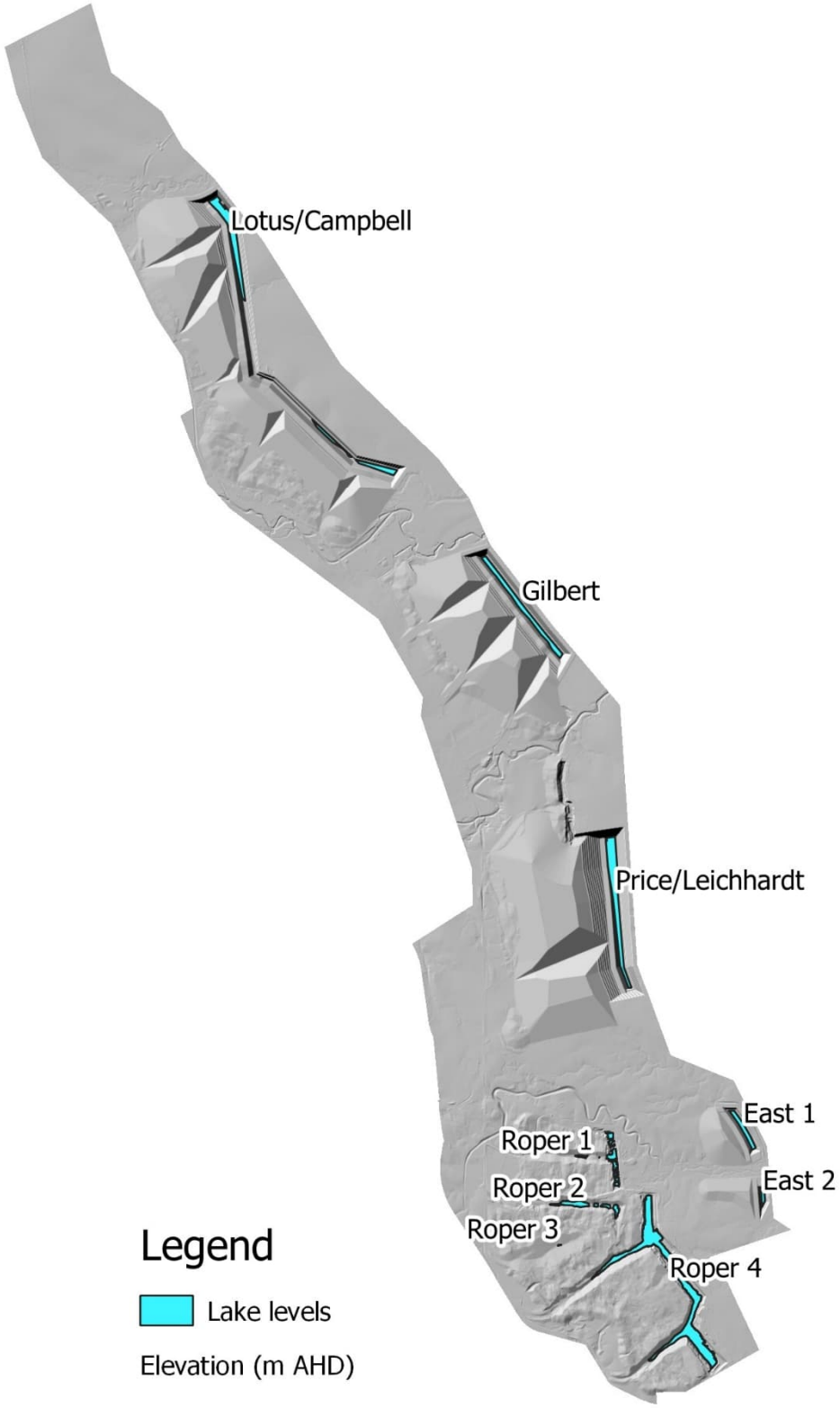

Figure 3.1 3D void design plan: an overview of NPM residual voids and void lakes at the end of the water balance model simulation

4 Groundwater

The hydrogeological assessment completed includes conceptual and numerical modelling to determine groundwater interactions with and the potential for contaminant transport from NPM residual voids (SLR, 2024b). The complete hydrogeological assessment, including details of the model set-up, calibration, and discussion of the results, is provided as an attachment to the PRC plan and, therefore, is not repeated in this void closure plan. This section summarises the hydrogeological assessment of the NPM 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.

Calibrated numerical modelling was undertaken (SLR, 2024b) to evaluate the potential impacts of the final closure state landforms for the NPM residual voids on the groundwater regime. The objectives of the predictive modelling were to assess the:

- Associated groundwater fluxes to/from voids as the void water levels recover.
- Post-mining equilibrium groundwater levels in all relevant hydrogeologic units, and associated impacts on current and potential future receptors (drawdown, water quality and groundwater flow direction).
- Impacts to alluvial and Tertiary hosted groundwater and any identified potential receptors.

The final closure state landform was replicated in the model, including the nine NPM residual voids and the spoil emplacements within the mined-out pits. The closure model timeframe was developed to commence at the end of mining and cover a period of 578 years over 32 model stress periods. The predicted end-of-mining groundwater level was used as the starting heads (SLR, 2024b).

Three climate scenarios (wetter-R1, mid-R3, and drier-R6) from the water balance model (WBM) (refer to Section 6) were adopted to generate three sets of groundwater model predictions to account for climate sensitivity. Groundwater level predictions and the associated discussion herein focus primarily on the mid-climate scenario (R3) with the drier (R6) and wetter (R1) scenarios modelled as sensitivities. The predicted equilibrium (long-term steady state) of the water table elevation adjacent to the final voids is shown in Figure 4.1 for the mid-climate scenario.

The groundwater levels in the water table proximal to the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 residual voids are predicted to remain below the post-closure recovered groundwater levels in the long-term. This suppression of the groundwater levels is driven by ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves (Figure 4.1). Long-term inwards groundwater flow gradients in these residual voids are maintained post-mining.

Definitive hydraulic gradients centred on the Lotus/Campbell, Gilbert and Price/Leichhardt residual voids are predicted to develop post-closure (Figure 4.1). Relatively steep water table gradients also occur within the spoil emplacements west of these residual voids. Flatter hydraulic gradients are modelled to occur centred on the East 1 and 2 residual voids (SLR, 2024b).

Assessment of the iterative model alignment between the groundwater model and the water balance model indicates that the northern three NPM residual voids (Lotus/Campbell, Gilbert, Price/Leichhardt) are well aligned. However, despite reasonable efforts to align the models for Roper voids and East 1 and 2 residual voids, the models remain poorly aligned with reasonable variance between the model runs. Efforts to align the groundwater model and the water balance model included the development of an auto-iterator and several model iterations for the area containing the Roper voids and East 1 and 2 residual voids.

Therefore, as previously discussed (Section 1.1), the targeted Roper Study Area has been initiated to further reduce uncertainty in the modelling and develop a detailed closure plan for the Roper residual voids. On-going works and assessment of additional groundwater data are required to further reduce the uncertainty within the numerical model and improve the understanding of groundwater characteristics, particularly within the area of the Roper residual voids.

The area of the Roper residual voids contains landforms that are likely to be hydrogeologically interconnected including: in-pit tailings storage; out of pit tailings dams; ramp reject disposal areas; mine affected water dams; ramp voids; and

multiple residual voids. The complex hydrogeology of the area containing the Roper residual voids will require additional assessment and detailed technical studies to enable further development of the numerical groundwater model, which is required to understand any potential for contaminant plume migration and inform an appropriate closure strategy for the area.

Although the Roper residual voids have been included within the underlying groundwater model build ((SLR, 2024b), upon completion of further detailed assessment, the groundwater model in the proximity of the Roper residual voids will need to be updated. Therefore, results in this section are presented for the area of NPM residual voids, outside of the Roper Study Area only.

Furthermore, the East 1 and 2 residual voids are located down dip from the Roper Study Area, and changes to the Roper residual voids will impact the hydrogeology and void lakes within the East 1 and 2 residual voids. This potential interconnectivity between the Roper and the East 1 and 2 voids and possible modifications that may be required to further manage the Roper residual voids in the final closure landform will be addressed as part of the detailed studies of the Roper Study Area.

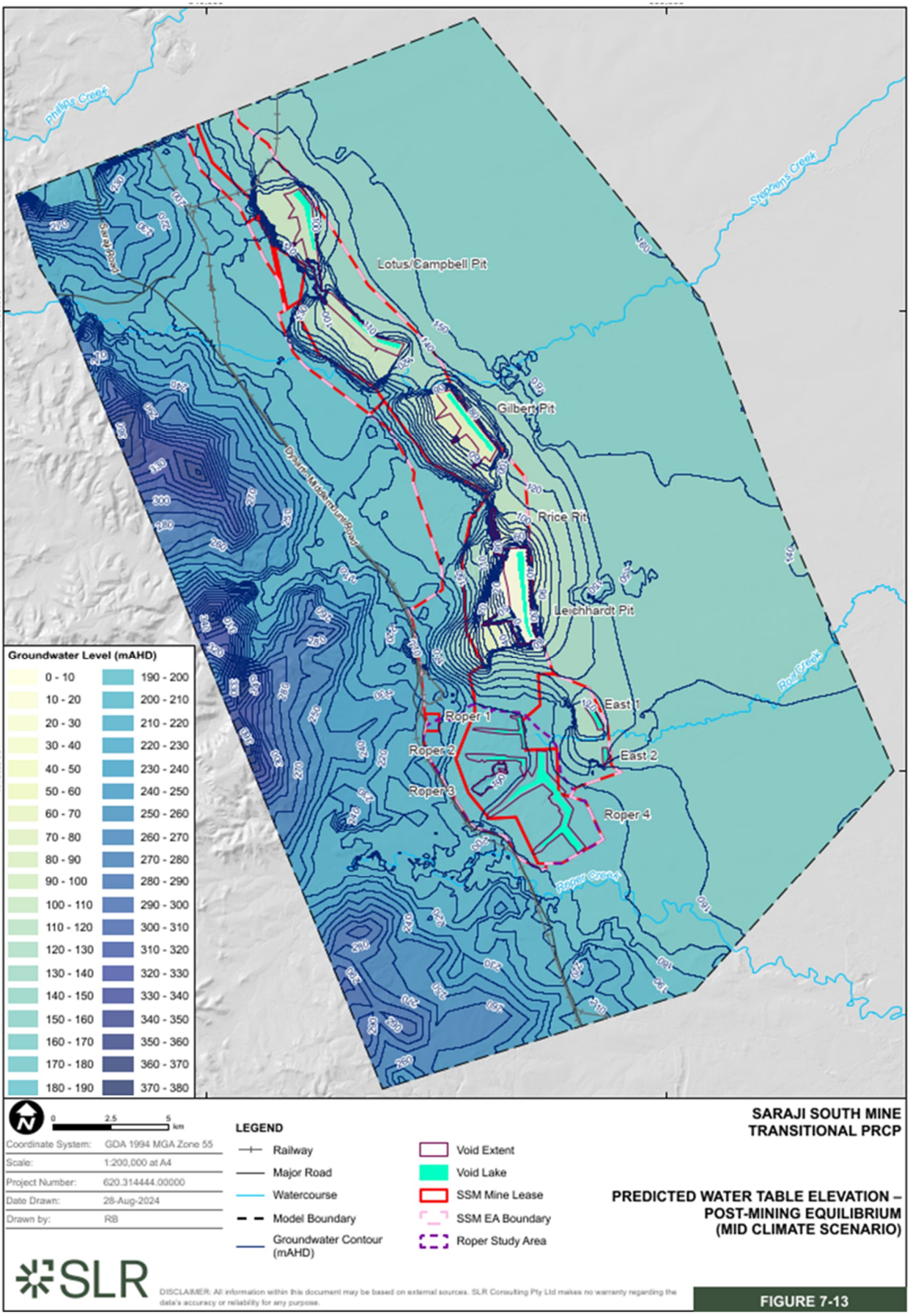

Figure 4.1 Predicted water table elevation at NPM – post-mining equilibrium (mid-climate scenario) (SLR, 2024b)

There are periods of variability in inflows and outflows of groundwater predicted by the groundwater model for the Lotus/Campbell, Gilbert, East 1 and East 2 residual voids over approximately the first 13 to 39 years post-mining. Price/Leichhardt is predicted to maintain inflows to the void for the entire simulation period. These fluxes in groundwater inflows and outflows from these NPM residual voids are predicted to occur over the following approximate time periods (SLR, 2024b):

- Lotus/Campbell residual void: up to 39 years post-mining.
- Gilbert residual void: up to 13 years post-mining.
- East 1 residual void: up to 14 years post-mining.
- East 2 residual void: up to 39 years post-mining.

During this initial 13 - 39 year period, groundwater levels in the spoil and natural geological formations are recovering from mine dewatering activities and remain below the residual void lake levels, as predicted by the WBM (see Section 6). Over this time, modelled groundwater fluxes to these residual voids are largely controlled by the difference between the modelled residual void lake levels and predicted groundwater levels in the spoil. The void lake levels rise and fall periodically according to the climatic simulation applied to the WBM, as well as how the daily timestep water balance results are translated to the comparatively simplified stress periods set up in the groundwater model.

Model results indicate that over these initial periods:

- Outflows derived from rainfall captured in the Lotus/Campbell and Gilbert residual voids periodically flow to the in-pit spoil (typically the low-walls) surrounding these residual void lakes.
- Outflows occur from East 1 and 2 residual voids to the natural geological formations surrounding these residual void lakes in the initial 15 years post-mining.

These fluxes occur as the groundwater levels in the surrounding in-pit spoil landform and natural geological formations slowly recover from mining activities to levels above these residual void lake levels. However, as the groundwater levels in the surrounding in-pit spoil landform and natural geology recover to elevations above some of the void lakes and lake levels stabilise, the direction of flow out of the void lakes to the in-pit spoil is reversed and long-term groundwater inflow to the lakes is established. After the initial periods of outflows for the Lotus/Campbell, Gilbert, , East 1 and East 2 residual voids, inflow only conditions prevail with most groundwater inflows to the residual voids occurring via in-pit spoil. Price/Leichhardt residual void does not show periods of variable groundwater inflow and outflow, maintaining a net groundwater inflow flux throughout the simulation (SLR, 2024b).

Predicted groundwater inflows for the mid-climate scenario for NPM residual voids are shown on Figure 4.2 to Figure 4.6.

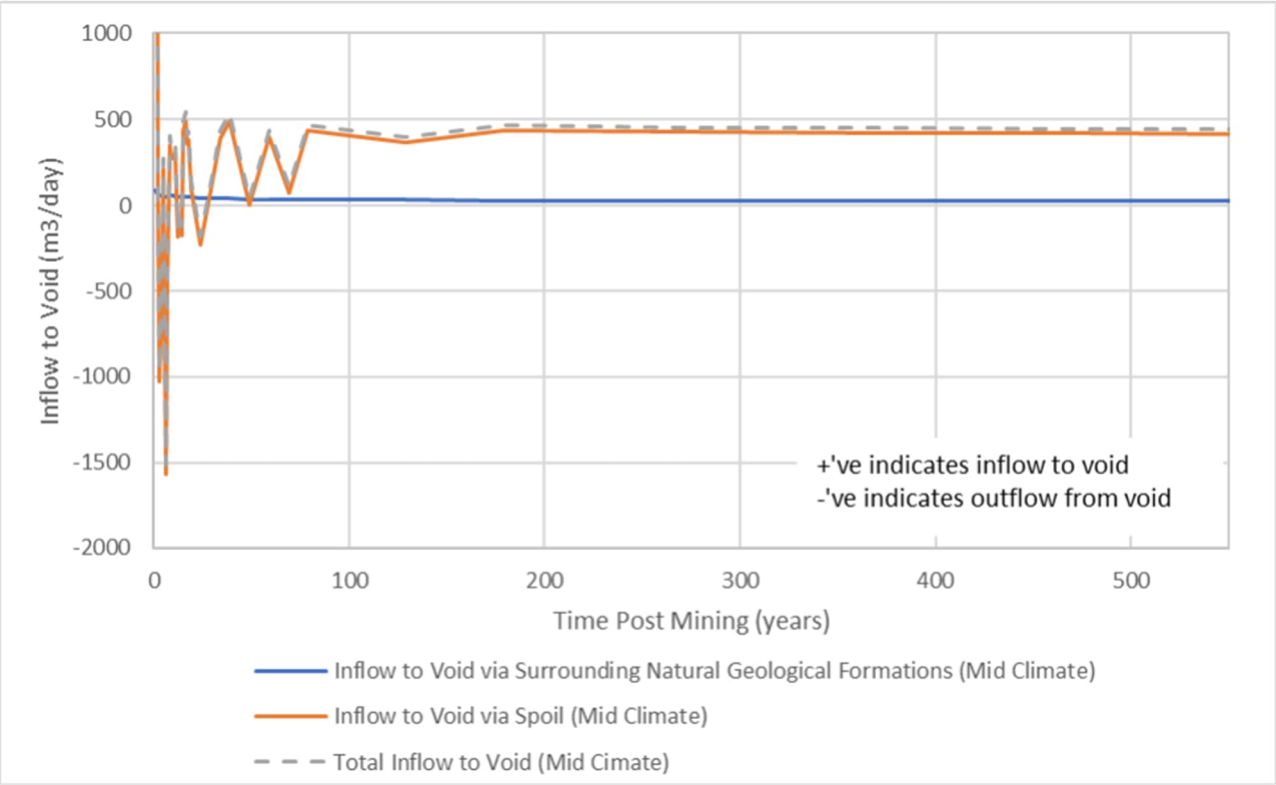

Figure 4.2 Predicted groundwater inflows to the Lotus/Campbell residual void (SLR, 2024b)

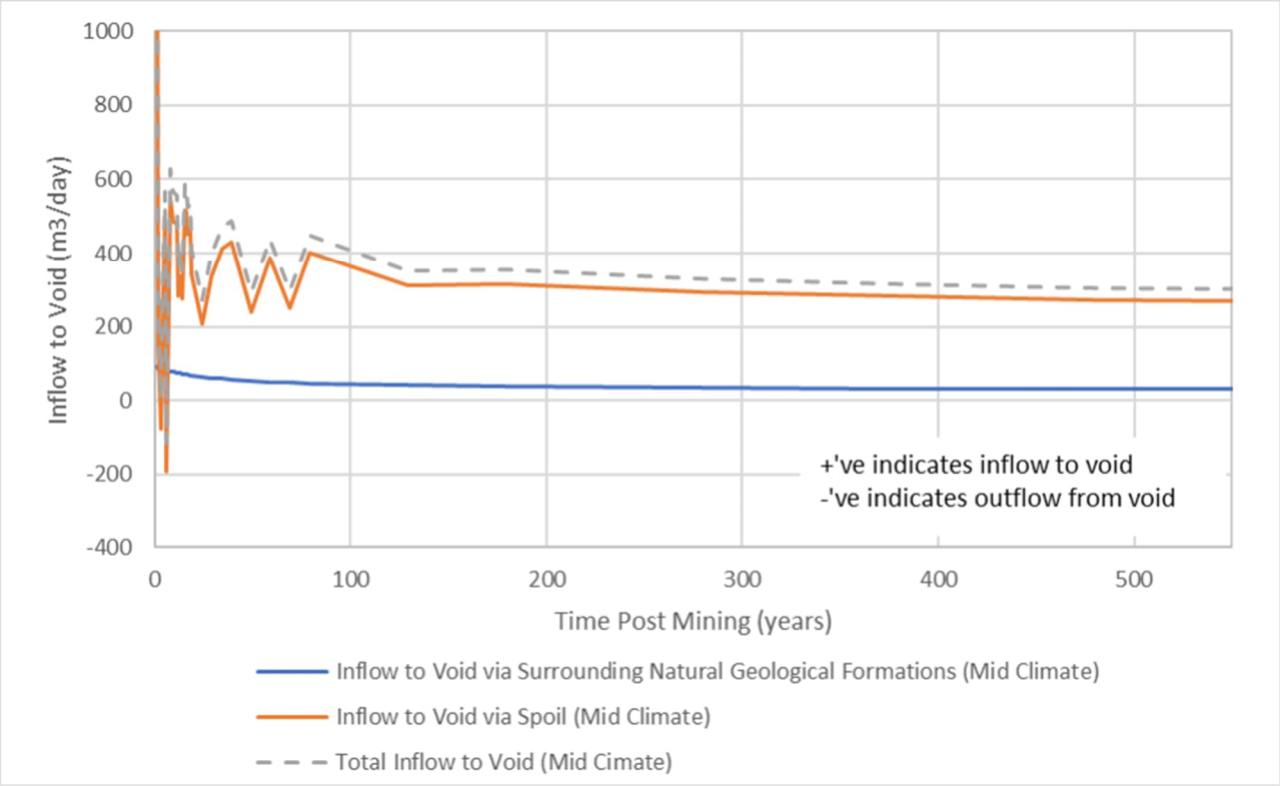

Figure 4.3 Predicted groundwater inflows to the Gilbert residual void (SLR, 2024b)

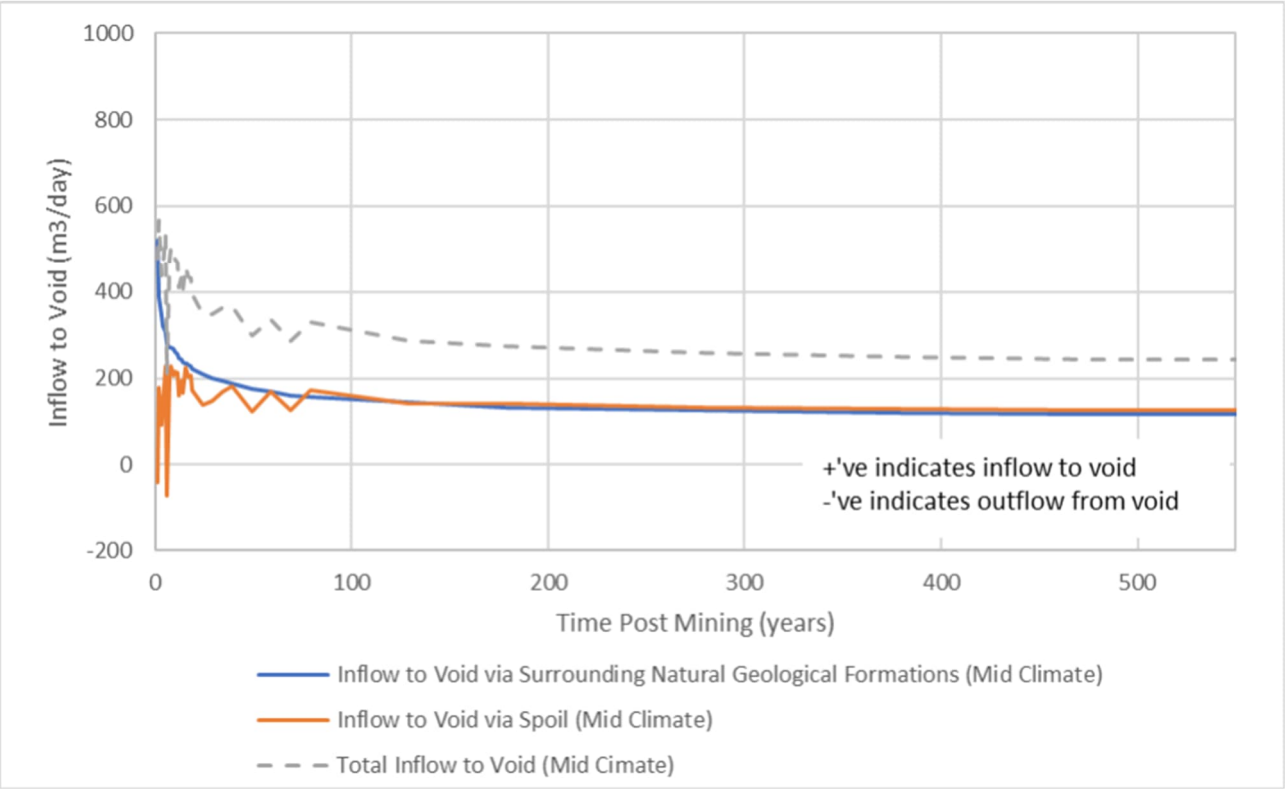

Figure 4.4 Predicted groundwater inflows to the Price/Leichhardt residual void (SLR, 2024b)

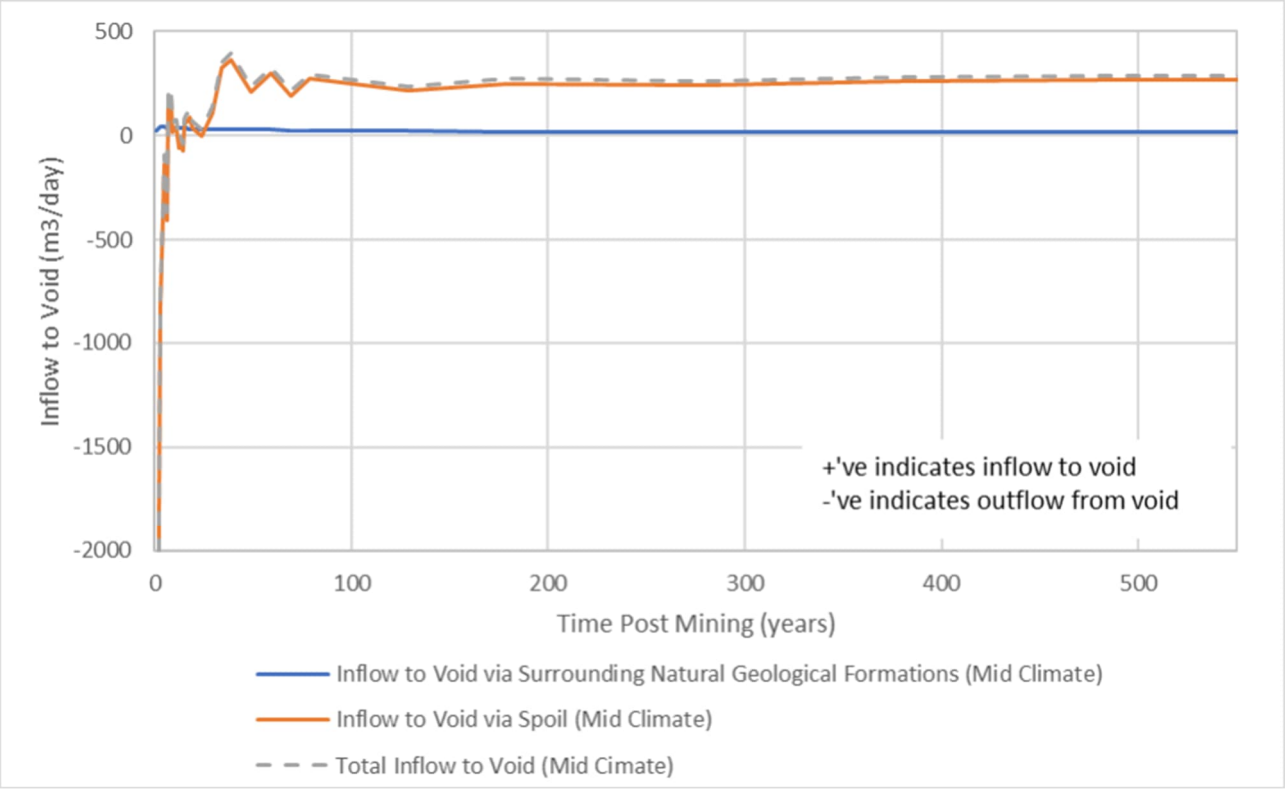

Figure 4.5 Predicted groundwater inflows to the East 1 residual void (SLR, 2024b)

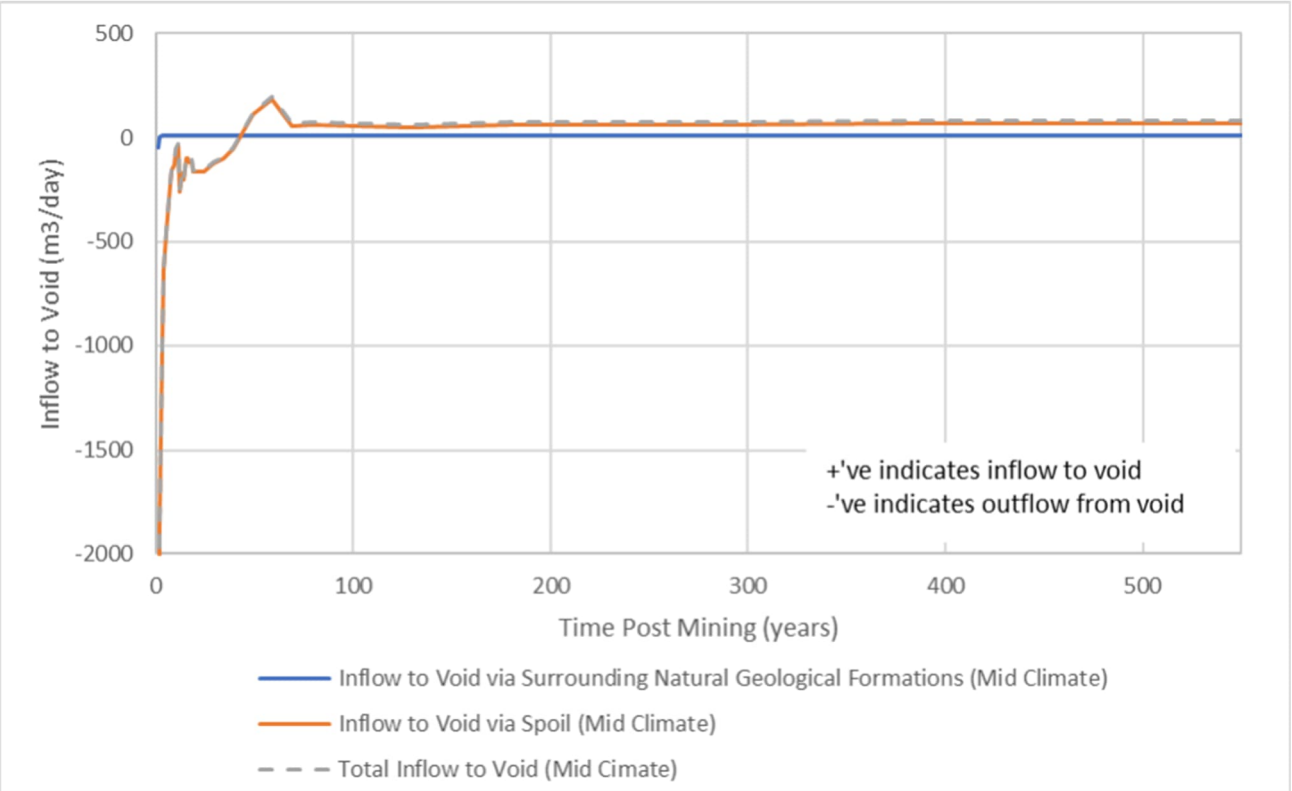

Figure 4.6 Predicted groundwater inflows to the East 2 residual void (SLR, 2024b)

Most groundwater levels in the Permian Coal Measures (PCM) are predicted to remain suppressed in the long-term; however, the majority of the post-mining drawdown is not expected to be greater than that predicted during the operational mining period. Predictive hydrographs for the PCM seams in areas adjacent to the residual voids show the change in groundwater levels over time. Figure 4.7 to Figure 4.9 depict the predictive hydrographs for a selection of the NPM residual voids. Refer to the hydrogeological assessment attached to the PRC plan for the complete set of predictive hydrographs.

The hydrographs demonstrate that the vast majority of groundwater level drawdown in the PCM occurs as a result of operational mining activities with recovery of groundwater levels in the deeper coal seams adjacent to the NPM residual voids occurring post-closure (SLR, 2024b). The hydrographs (Figure 4.7 to Figure 4.11) demonstrate very little effect on groundwater levels from the residual void inflow flux variability.

Predicted residual void lake levels remain below the predicted groundwater levels for the duration of the modelled period for the NPM residual voids. This indicates a very low potential for outwards movement of void water to the PCM seams outside these residual voids.

The hydrographs demonstrate very little effect on groundwater levels from the variability in inflows and outflows derived from rainfall captured in the residual voids in the early post-closure period. These fluxes are predicted to periodically flow into the in-pit spoil over approximately the first 13 to 39 years post-mining for the Lotus/Campbell, Gilbert, East 1 and East 2 residual voids as groundwater levels recover (SLR, 2024b).

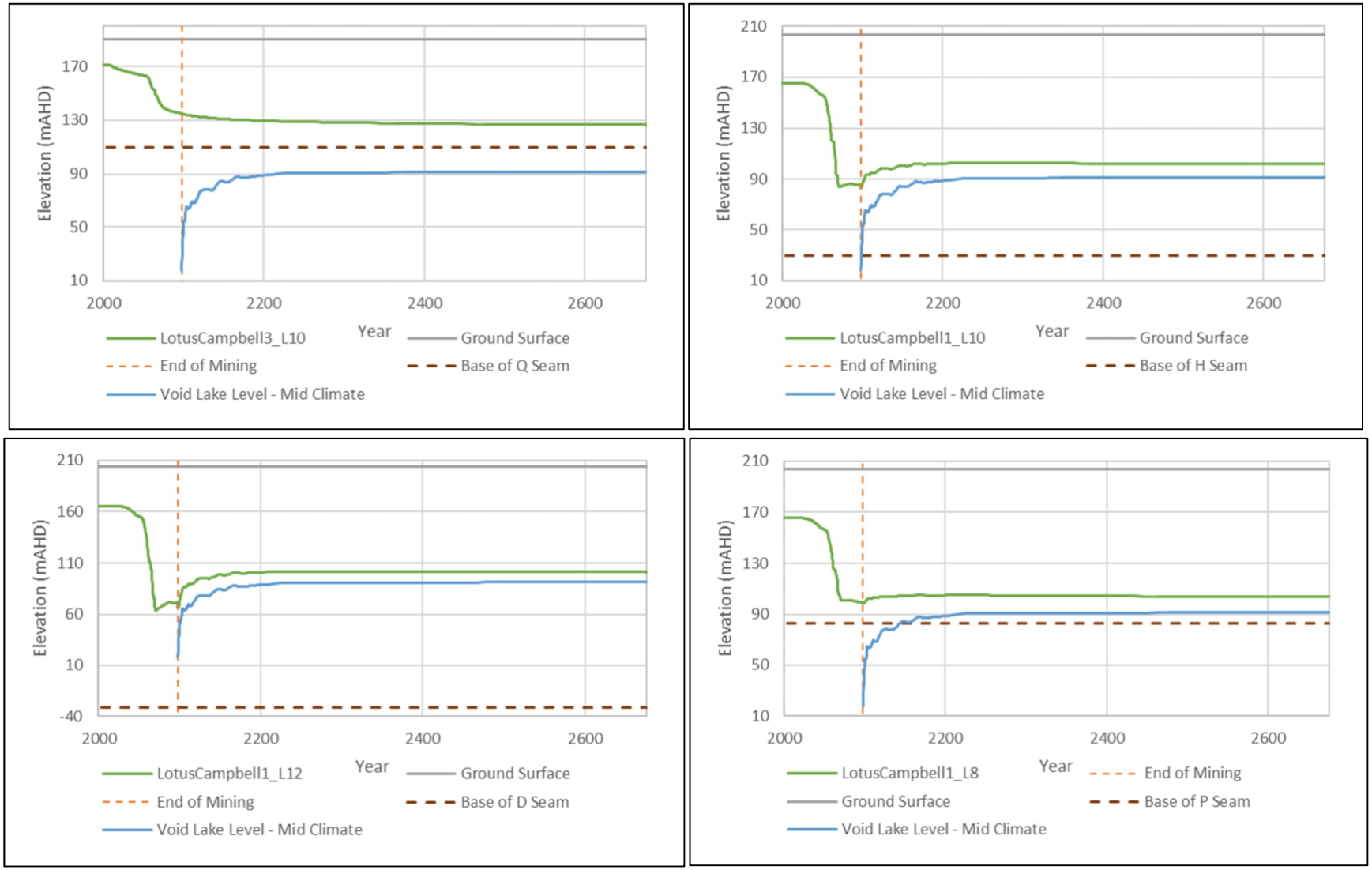

Figure 4.7 Predictive hydrographs at four locations showing groundwater recovery in the PCM seams (green line) adjacent to Lotus/Campbell residual void (SLR, 2024b)

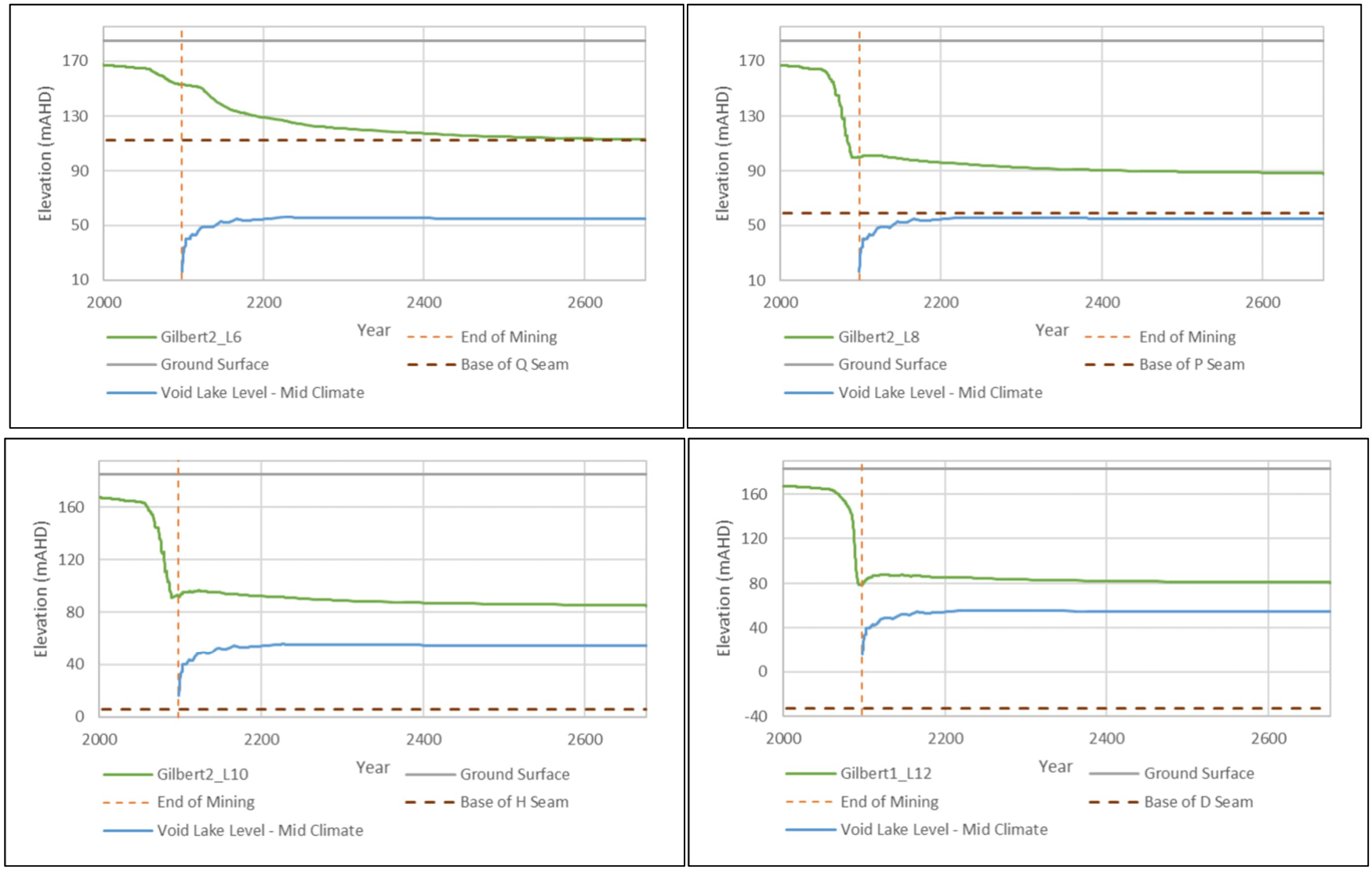

Figure 4.8 Predictive hydrographs at four locations showing groundwater recovery in the PCM seams (green line) adjacent to Gilbert residual void (SLR, 2024b)

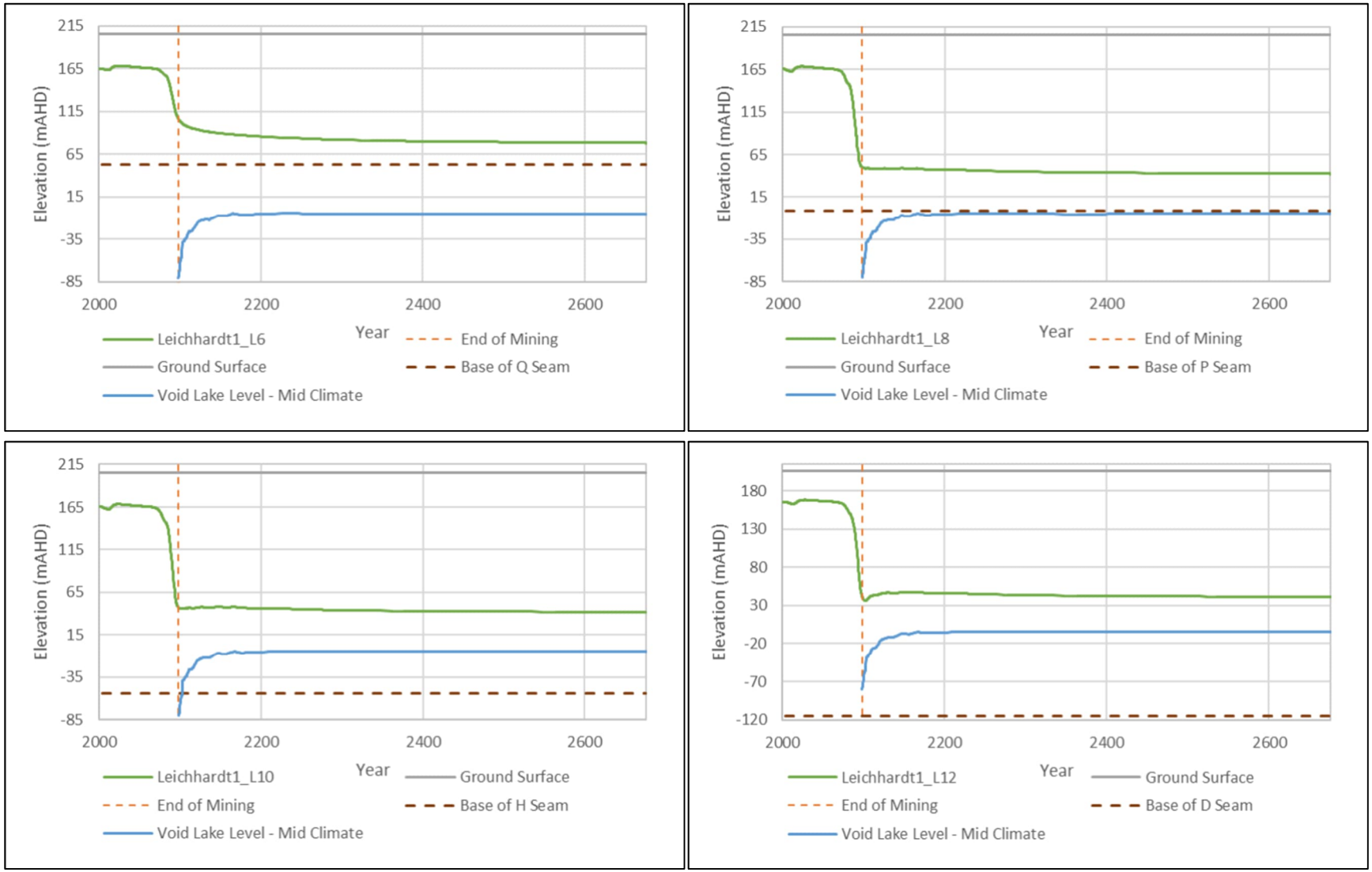

Figure 4.9 Predictive hydrographs at four locations showing groundwater recovery in the PCM seams (green line) adjacent Price/Leichhardt residual void (SLR, 2024b)

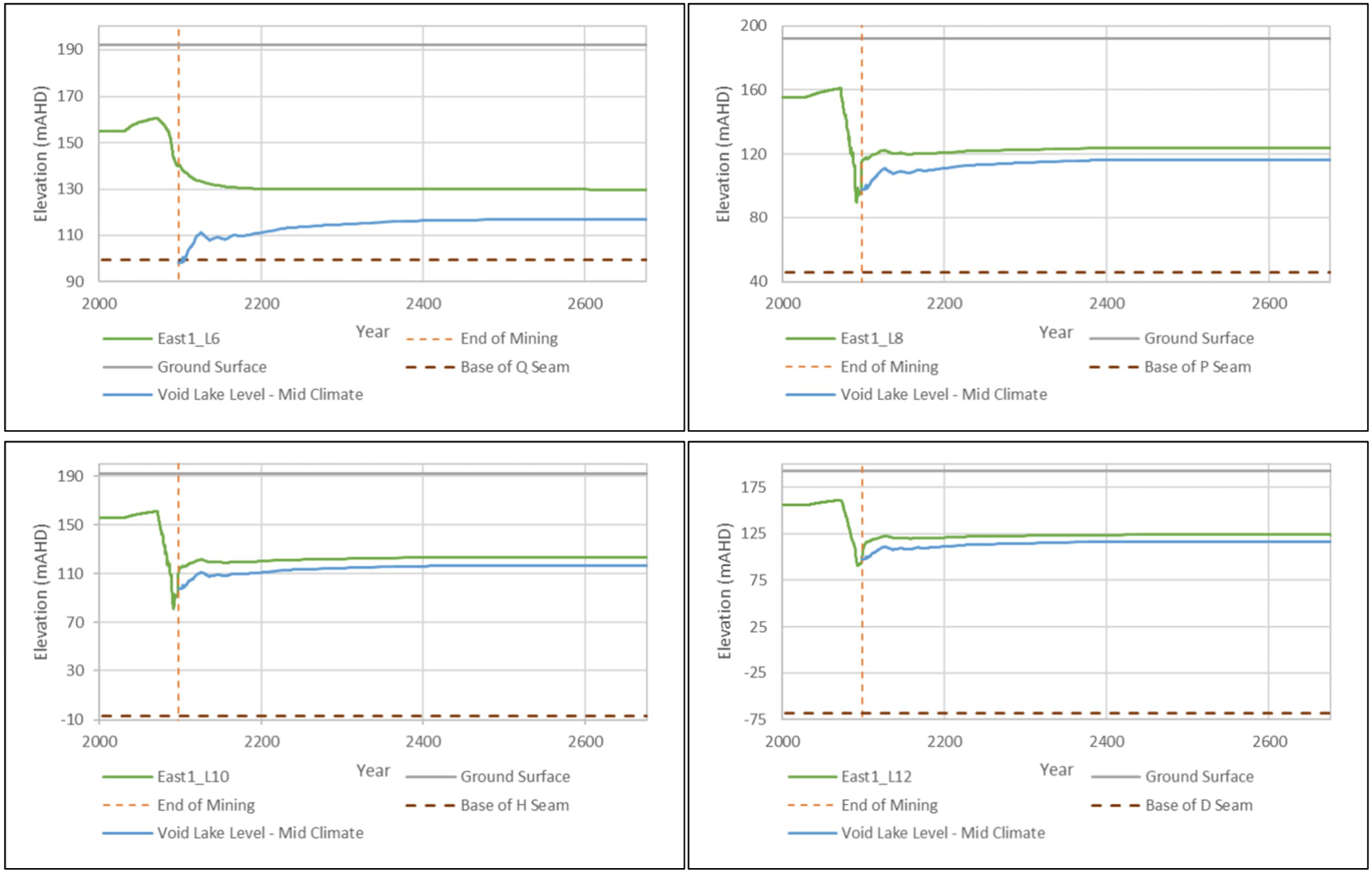

Figure 4.10 Predictive hydrographs at four locations showing groundwater recovery in the PCM seams (green line) adjacent East 1 residual void (SLR, 2024b)

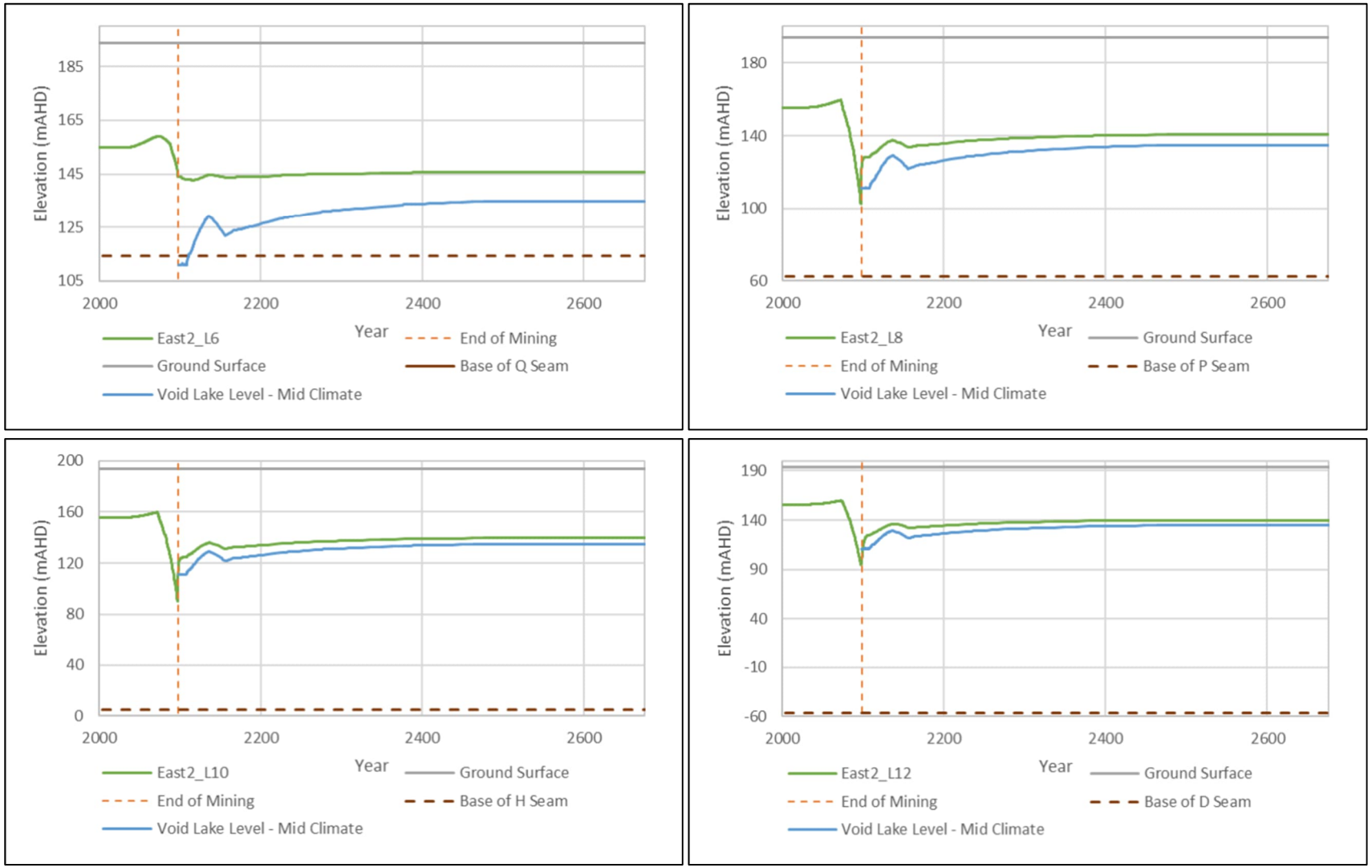

Figure 4.11 Predictive hydrographs at four locations showing groundwater recovery in the PCM seams (green line) adjacent East 2 residual void (SLR, 2024b)

Using the numerical groundwater model and the 'mod-PATH3DU' code, an analysis of 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 (SLR, 2024b).

The particle movement simulation for particles placed within the residual voids (Figure 4.12) indicated that groundwater at NPM will mostly remain within the final closure state landform (i.e., rehabilitated in-pit spoil and residual voids) in the long-term (SLR, 2024b). This included the modelled initial fluxes of water from the residual voids to the in-pit spoil of the final closure state landform. The simulation also predicted that the Lotus/Campbell, Gilbert and Price/Leichhardt, East 1 and East 2 residual voids would remain groundwater sinks and the particles would not flow from the residual voids off-site to the receiving environment (SLR, 2024b).

Note: The particle path lines generally follow predicted head gradients; however, at times, they appear to be contrary to the head contours shown in the figure. The particle path lines are simulated from the start of the recovery simulation, yet the contours shown in the figure represent the head levels at the end of the recovery simulation period when groundwater levels have reached equilibrium. Hence, Figure 4.12 shows the path the particles follow during the transient head changes that are occurring throughout the recovery simulation period as void lake levels stabilise and the groundwater system partially recovers post-mining.

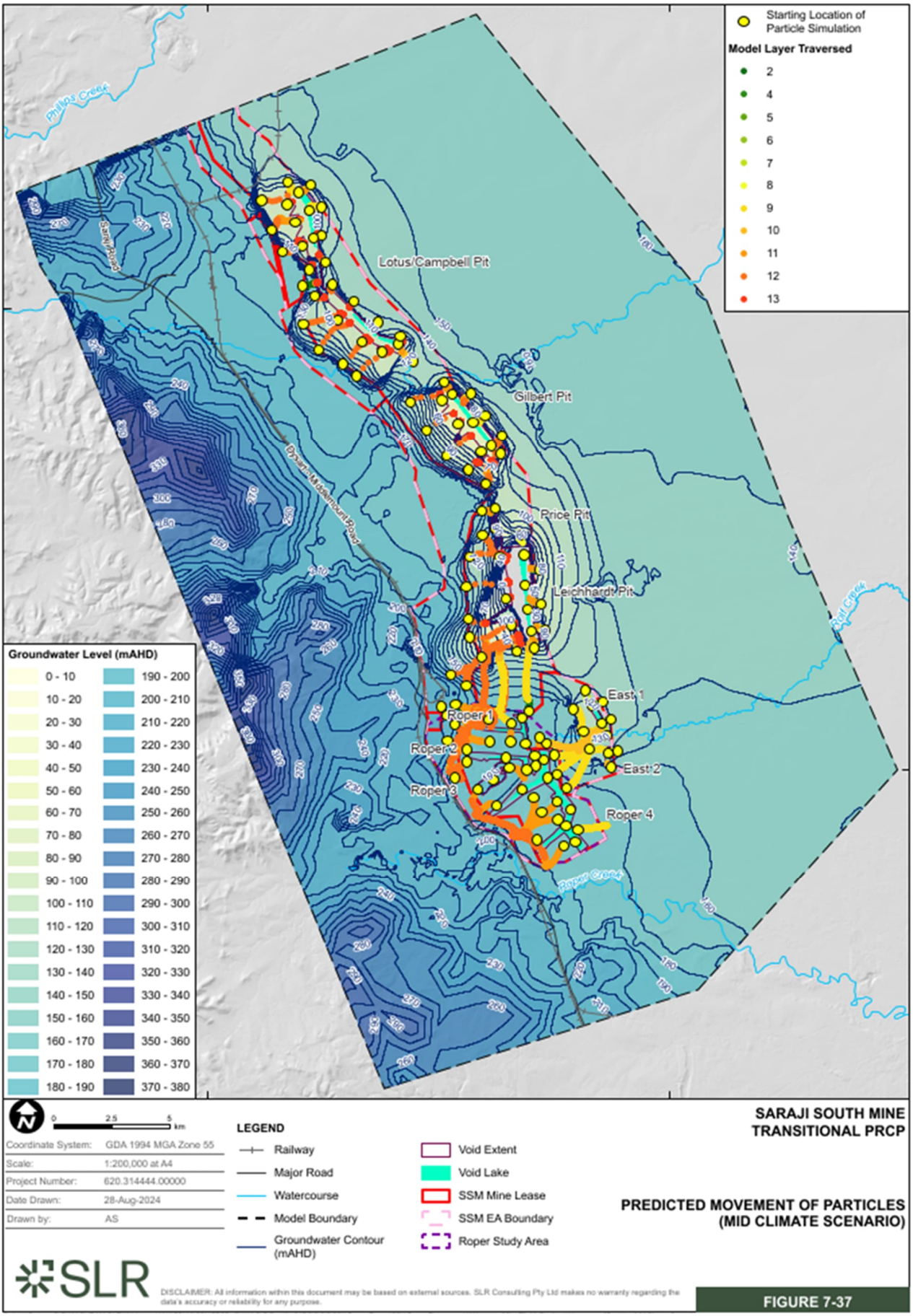

Figure 4.12 Predicted movement of particles from particle tracking simulation – mid-climate scenario (SLR, 2024b)

Although initial fluxes of rainfall-derived water captured in the residual voids to the in-pit spoil, is predicted to occur for Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 residual voids, no environmental harm is expected to result beyond that of the voids themselves from these minor fluctuations. This is due to the initial outflows to the in-pit spoil areas returning to the residual voids once groundwater levels and lake levels stabilise and net inward hydraulic gradients are predicted to prevail in the long-term. Additionally, the water quality model (see Section 8) indicates that the water quality within the voids is unlikely to establish acidic conditions and the total dissolved solids have not have evapo-concentrated beyond the lower EA groundwater trigger values during the period of potential outflows. This absence of environmental harm is supported by the groundwater modelling, particle tracking simulation, and the absence of third-party bores and GDEs within the spoil areas of the residual voids.

Predictive hydrographs were derived from the groundwater model at the potential GDE sites identified within and adjacent to the NPM mining leases (

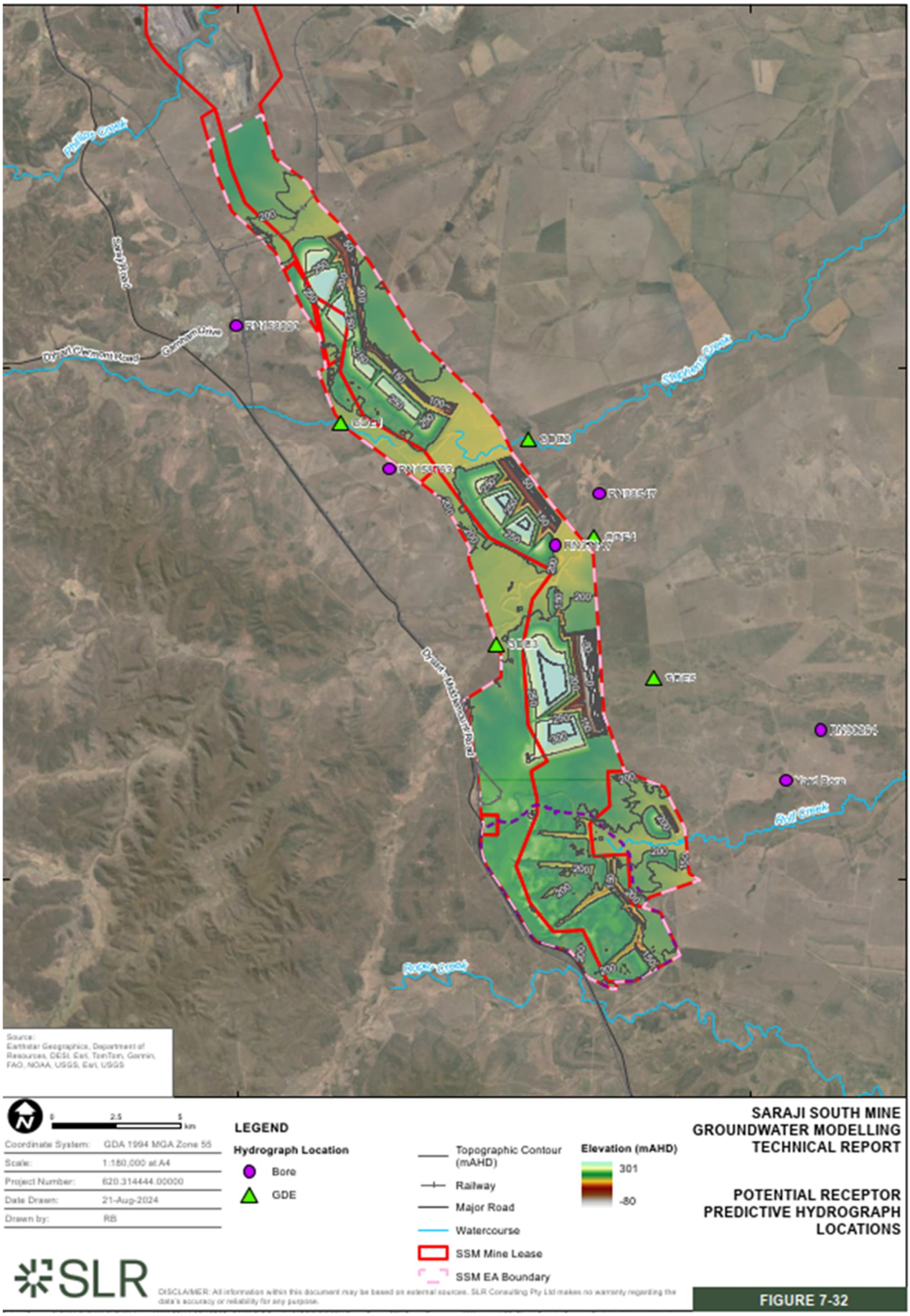
Source:
Earthstar Geographics, Department of Resources, DEGI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
0 2.5 5 km
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:180,000 at A4
Project Number: 620.314444.00000
Date Drawn: 21-Aug-2024
Drawn by: RB
LEGEND
Hydrograph Location
Bore
GDE
Topographic Contour (mAHD)
Railway
Major Road
Watercourse
SSM Mine Lease
SSM EA Boundary
Elevation (mAHD)
301
-80
SARAJI SOUTH MINE GROUNDWATER MODELLING TECHNICAL REPORT
POTENTIAL RECEPTOR PREDICTIVE HYDROGRAPH LOCATIONS
SLR
DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.
FIGURE 7-32

Figure 4.13). Noting that the hydrograph locations are not likely to contain GDEs due to the predicted depth to the groundwater in excess of 10 m, . The hydrographs (Figure 4.14) indicate that most water table drawdown in the vicinity of the potential GDEs is predicted to occur prior to the end of mining (i.e., associated with approved NPM mining operations). Any additional drawdown occurring over the post-mining period is predicted to be a result of continuing operational drawdown trends (i.e., a time lag from active mining), rather than new impacts caused by the final closure state landform design (SLR, 2024b). Note, there was no difference in the hydrographs for the drier or wetter climate scenarios.

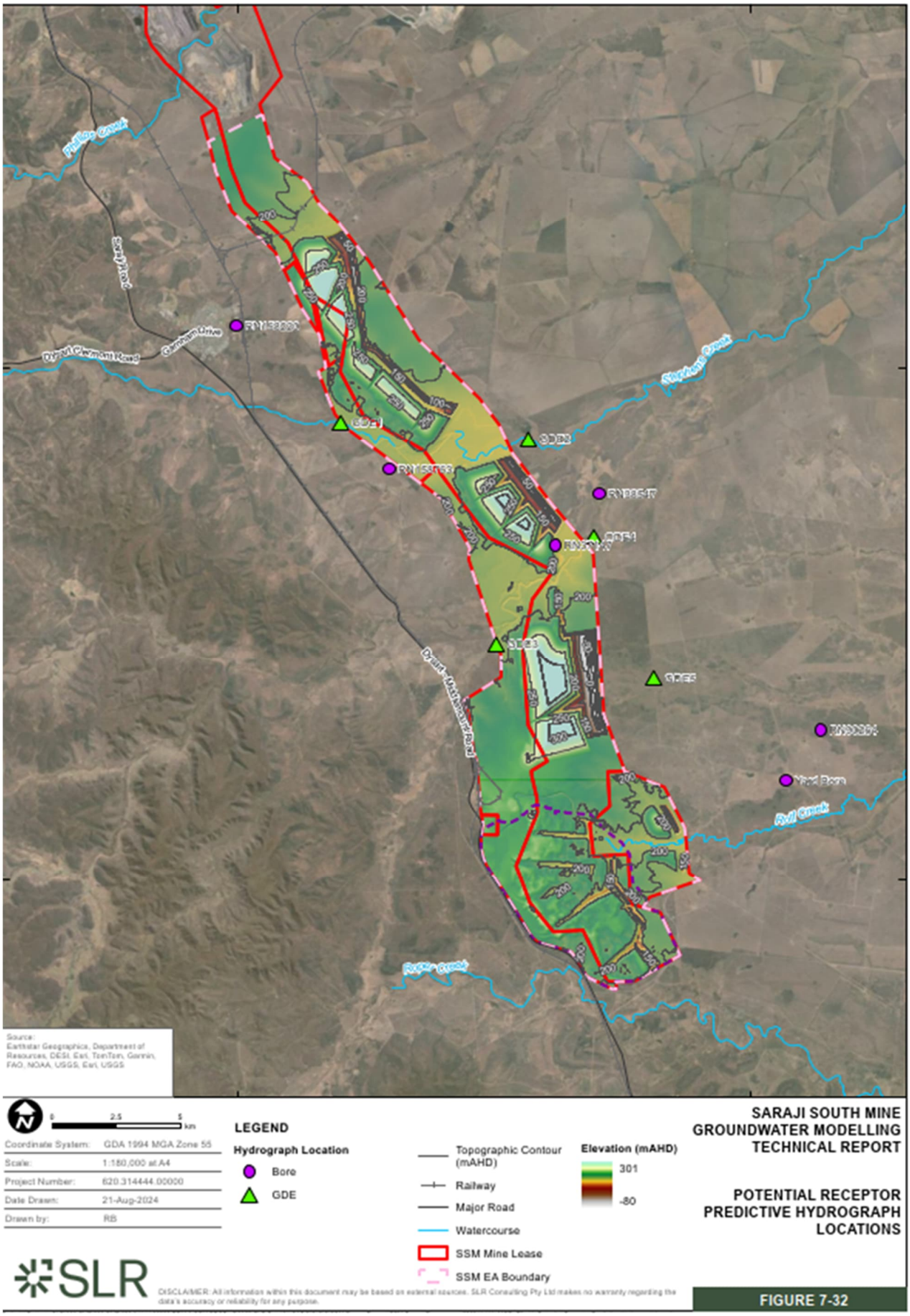

Figure 4.13 Predictive hydrograph locations of potential NPM receptors (SLR, 2024b)

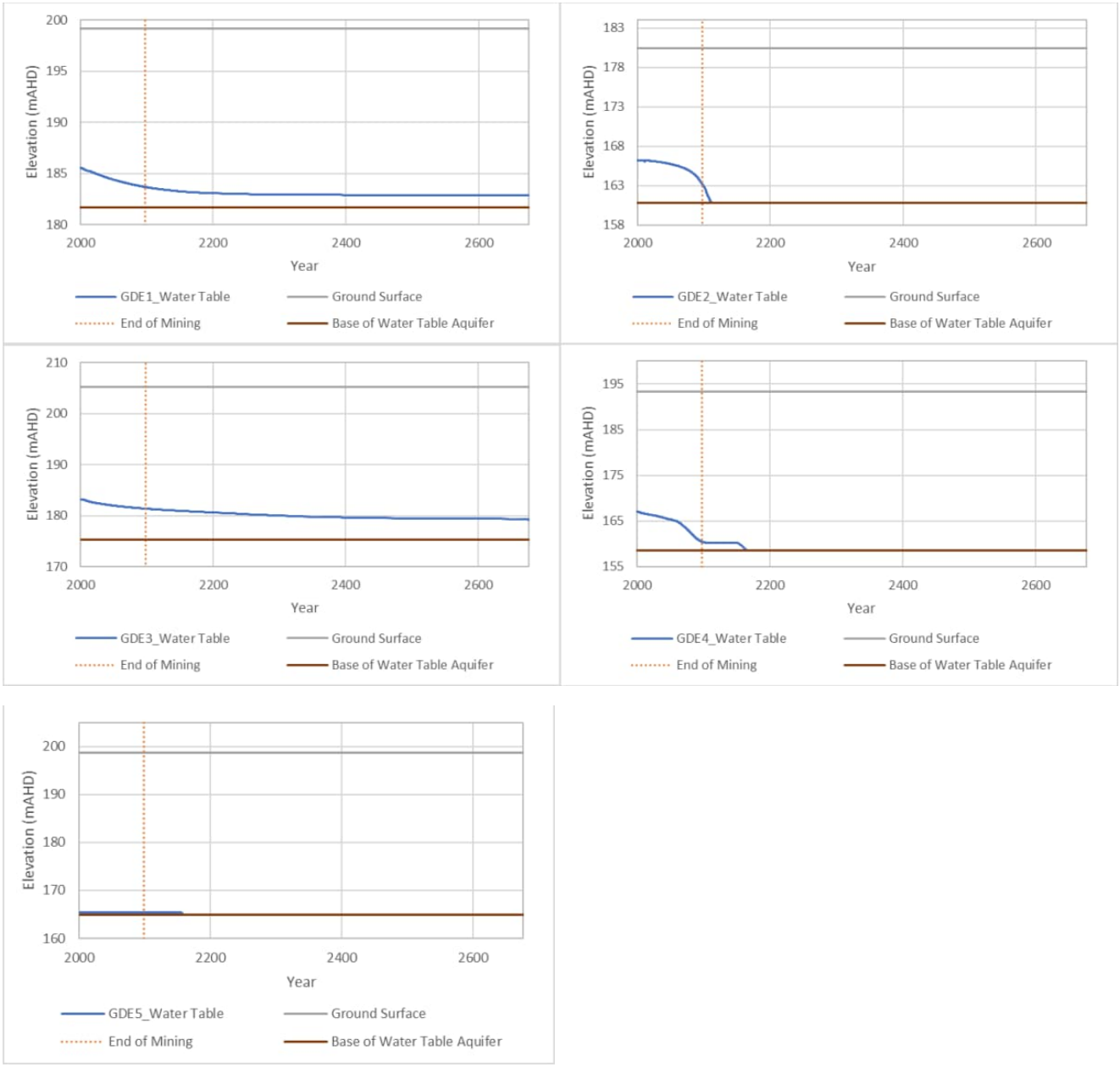

Figure 4.14 Predictive hydrographs for potential GDE sites (SLR, 2024b)

Predictive hydrographs were derived from the groundwater model for the twelve identified third-party water supply bores with sufficient information to attribute a source aquifer. A selected subset of hydrographs (

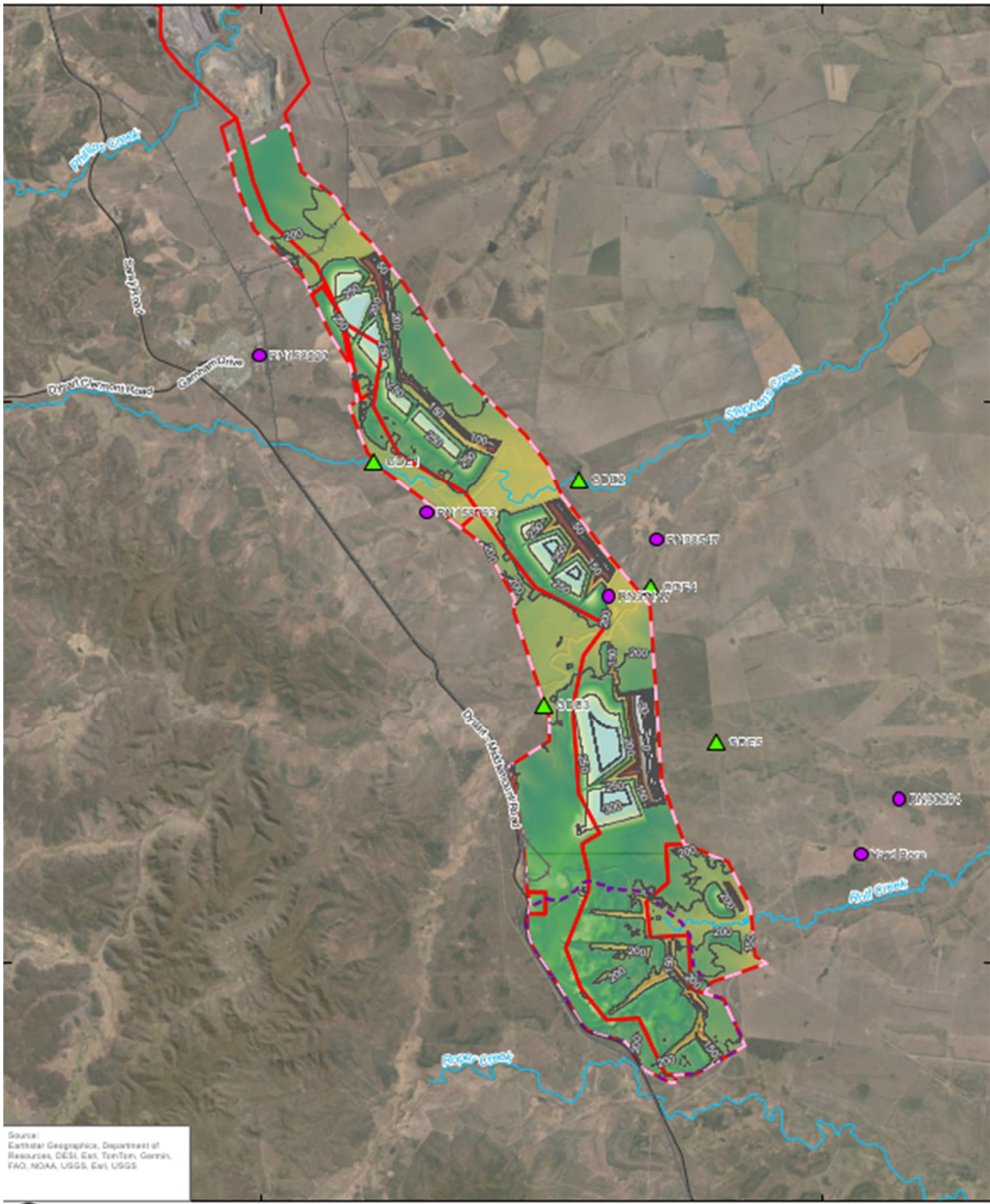
Source: Esri/Intermap Geographics, Department of Resources, DESI, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS
0 2.5 5 km
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:180,000 at A4
Project Number: 620.314444.00000
Date Drawn: 21-Aug-2024
Drawn by: RB
LEGEND
Hydrograph Location
Bore
GDE
Topographic Contour (mAHD)
Railway
Major Road
Watercourse
SSM Mine Lease
SSM EA Boundary
Elevation (mAHD)
301
-80
SARAJI SOUTH MINE GROUNDWATER MODELLING TECHNICAL REPORT
POTENTIAL RECEPTOR PREDICTIVE HYDROGRAPH LOCATIONS
SLR
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FIGURE 7-32

Figure 4.13) represent the greatest drawdown (RN38547, RN43061, RN89469, RN89470, and RN90014) with relatively significant (predicted) ongoing post-mining drawdown (> 5 m). Noting the maximum drawdown occurs over hundreds of years and is mostly related to:

- Continuing operational drawdown trends (i.e., a time lag from active mining).
- Regional-scale influences represented in the model (such as other third-party mining activities) - given these bores access groundwater from the Fort Cooper Coal Measures, a geological unit not present across the majority of the NPM area.

The hydrograph for the other third-party water supply bores (RN37861, RN43060, RN43794, RN90017, RN158220, RN158763, and RN90264) located in the Fort Cooper Coal Measures approx. 1 to 3 km to the east of the Gilbert, Price/Leichhardt and Lotus Campbell voids show some predicted long-term post-mining groundwater drawdown (< 5 m).

Note, that there was no difference in the hydrographs for the drier or wetter climate scenarios (SLR, 2024b).

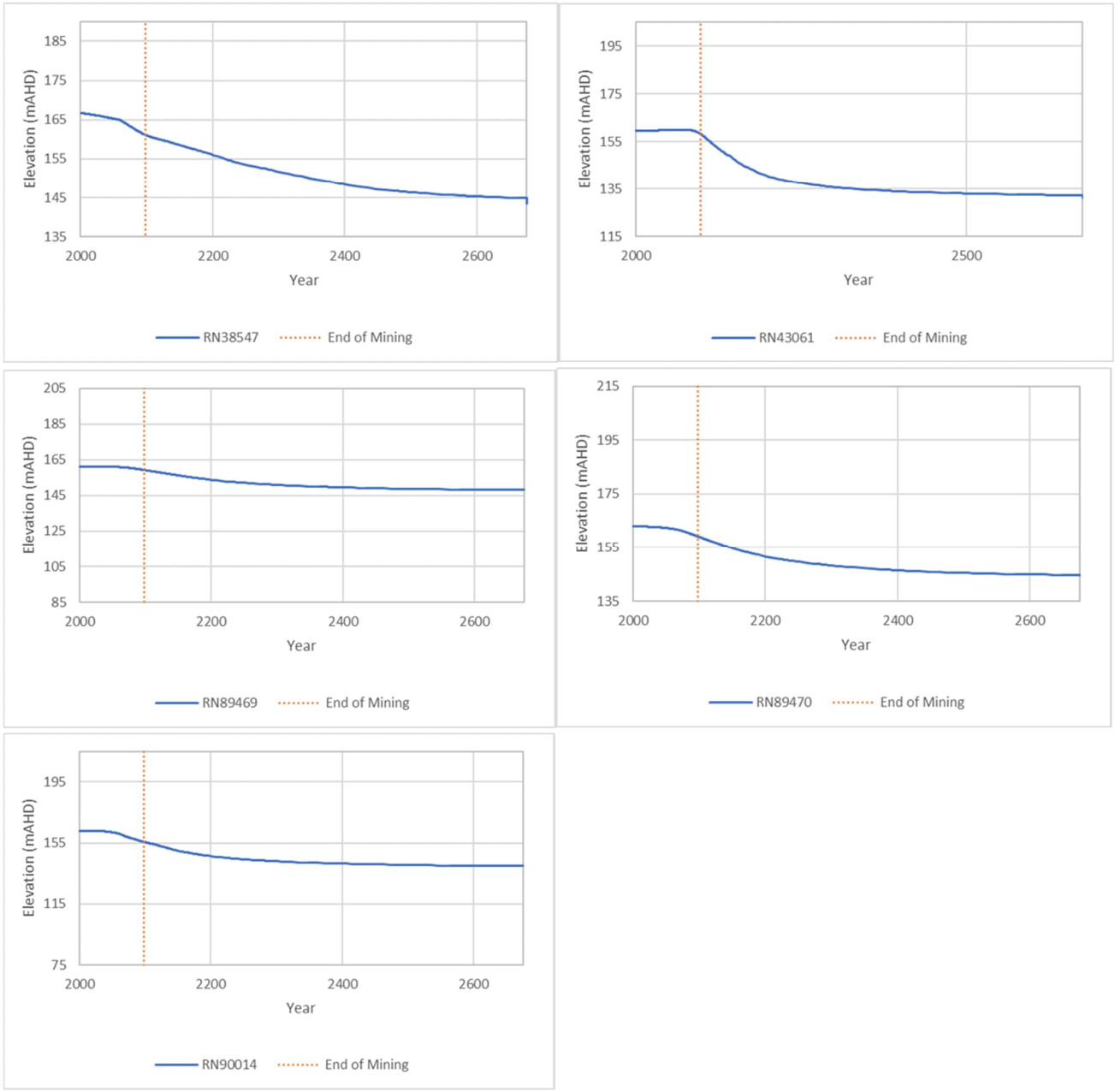

Figure 4.15 Predictive hydrographs for five selected third-party water supply bores identified near NPM (SLR, 2024b)

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 Lotus/Campbell, Gilbert, Price/Leichhardt, East 1, East 2 and Roper residual voids. This section summarises the assessment findings as relevant to void closure at NPM. Refer to the main volume of the PRC plan for the complete voids in floodplain and closure-related rehabilitation flooding assessments.

5.1 Voids in floodplains

The specific locations of the pre-approved NUMAs are not identified in the LOD (EA EPML00562013), and therefore, in accordance with the DES *PRC Plan Guideline* transitional provisions, an assessment of voids in flood plains was undertaken (SLR, 2024c). 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 inflood plains information sheet (DES, 2020).

The voids in flood plain assessment of the *pre-mining landform* identified that the final voids extents associated with the Lotus/Campbell and Gilbert residual voids would be located within the pre-mining landform flood plain of Stephens Creek and Scott Creek respectively. The remaining voids are located outside the flood plain in the 0.1% annual exceedance probability (AEP) event. For the final closure state landform, the residual void extents located within the rehabilitation area flood plain extents of Stephens Creek and Scott Creek have been reduced and refined 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 AEPs, including 0.1%, Probable Maximum Flood (PMF), and smaller events in accordance with the DES *PRC Plan Guideline* to predict the flood event inundation extent and depths for post-mining conditions (WMS Engineering, 2024).

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 Stephens Creek, Scott Creek, Downs Creek and Rolf Creek. To incorporate the final closure state landform, the hydrological model catchment configuration, reach lengths and storm definitions were updated.

Four hydraulic models were developed, covering the four watercourses, to determine flood behaviour around the final closure state landforms associated with the residual voids.

Effects of climate change through the increase in rainfall intensity were considered in the hydrological analysis. The upper climate change Representative Concentration Pathway (RCP) 4.5 at or above the 90th percentile scenario (RCP 4.5 P90) was modelled as the upper rainfall for a 20% rainfall intensity increase (WMS Engineering, 2024). RCPs are projections of greenhouse gas and aerosol concentrations (pathways) and, together with land use change, are consistent with a set of broad climate outcomes adopted by the Intergovernmental Panel on Climate Change and used by the climate modelling community.

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 climate change RCP 4.5 P90 scenario. The results of the hydraulic model showed the proposed NPM residual voids are not subject to inundation from floodwaters up to and including the 0.1% AEP under the climate change RCP 4.5 P90 scenario (WMS Engineering, 2024).

Figure 5.1 to Figure 5.4 show modelled peak flow depths for Stephens Creek, Scott Creek, Downs Creek and Rolf Creek for the 0.1% AEP under the climate change RCP 4.5 P90 scenario.

WMS

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Appendix A-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Stephens Creek

A3 Scale: 1:30000

Job No: 10749
Date: 16/10/2023

0 0.5 1 1.5 2 km

Figure 5.1 Modelled peak flood depths for Stephens Creek (0.1% AEP climate change RCP 4.5 P90 scenario) (WMS Engineering, 2024)

WMS

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Appendix B-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contour - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Scotts Creek

A3 Scale: 1:30000

0 0.25 0.5 0.75 1 km

Job No: 10749
Date: 17/10/2023

Figure 5.2 Modelled peak flood depths for Scott Creek (0.1% AEP climate change RCP 4.5 P90 scenario) (WMS Engineering, 2024)

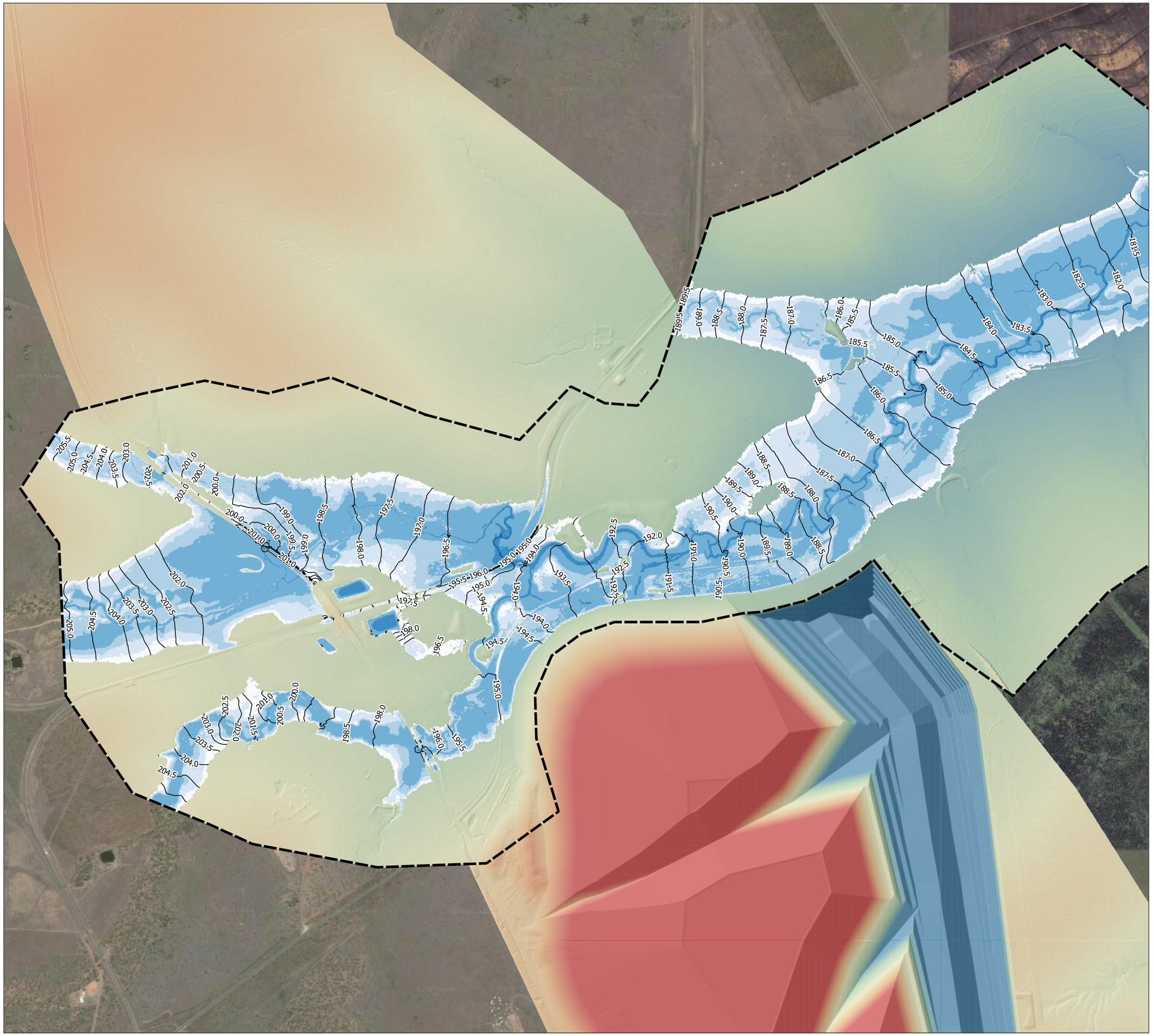

Figure 5.3 Modelled peak flood depths for Downs Creek (0.1% AEP climate change RCP 4.5 P90 scenario) (WMS Engineering, 2024)

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Appendix D-10

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Water Level Contours - 0.5 m Interval (mAHD)

Elevation (mAHD)

- 175
- 230

Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Saraji South Mine Rehabilitation Flood Modelling

Rolf Creek

A3 Scale: 1:30000

Job No: 10749
Date: 19/03/2024

0 0.5 1 1.5 2 km

Figure 5.4 Modelled peak flood depths for Rolf Creek (0.1% AEP climate change RCP 4.5 P90 scenario) (WMS Engineering, 2024)

6 Void water balance

A void water balance assessment was completed to determine the behaviour of the NPM residual voids in their closure state. The assessment also sought to understand the inherent hydrological closure risks and to inform separate assessments relating to the 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 NPM, are presented below.

6.1 Water balance model

A WBM was developed using the software program GoldSim to estimate the changes in the volume of water in the final closure state landforms 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 NPM residual voids incorporated direct rainfall, surface water runoff, groundwater interactions, and evaporation.

A model period of 377 years – from the year 2023 to 2399, 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 for the NPM 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. This slope map recognises zones with ‘flat’ slopes and zones with downward slopes. This information was then used to delimitate the void catchment areas into three 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.

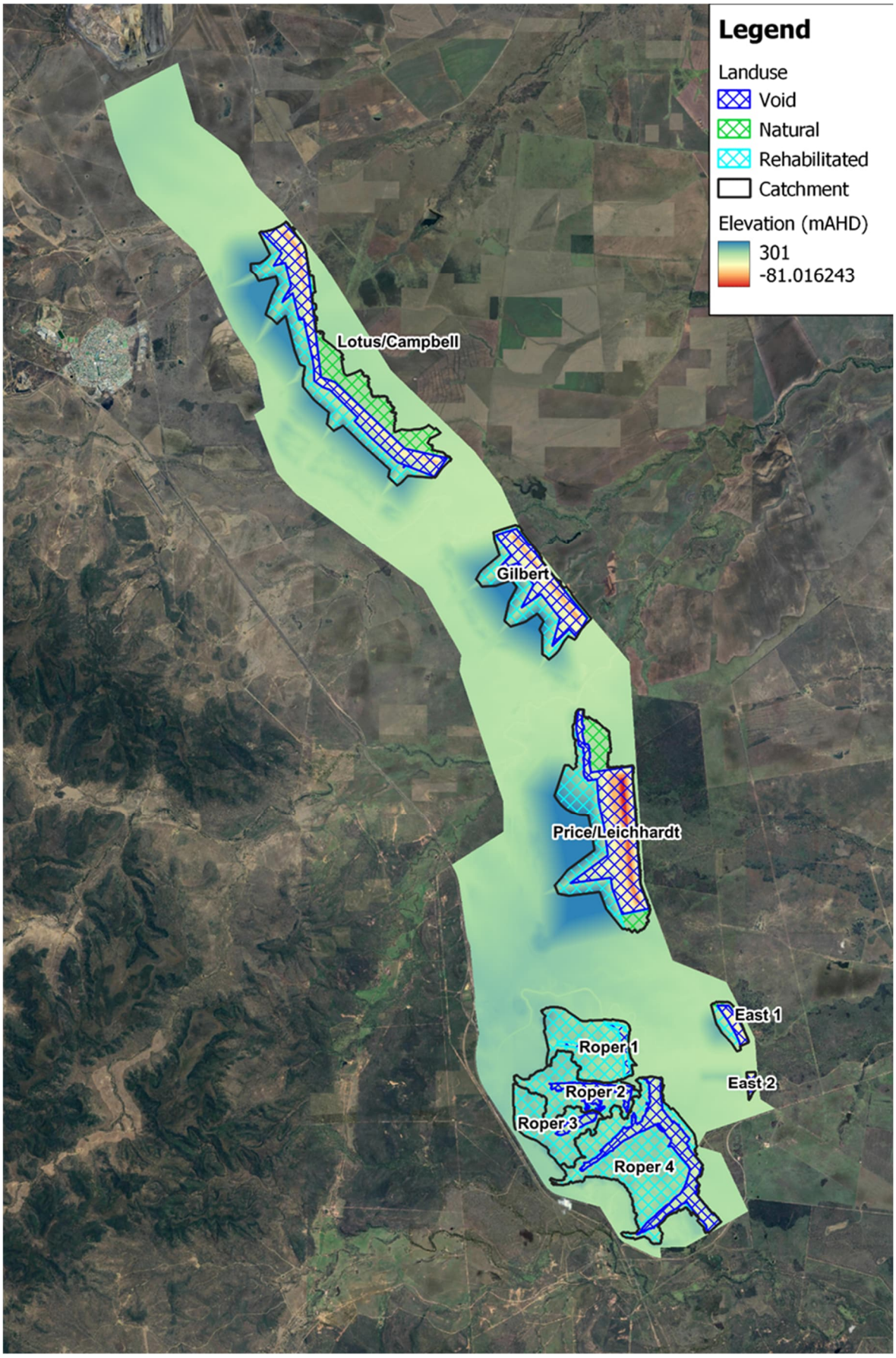

Figure 6.1 Catchment delimitation for each catchment area zone land use applied to the WBM for the NPM residual voids

Table 6.1 Catchment areas for each zone land use applied to the WBM for the NPM residual voids

Surface catchment	Lotus/ Campbell (ha)	Gilbert (ha)	Price/ Leichhardt (ha)	East 1 (ha)	East 2 (ha)	Roper 1 (ha)	Roper 2 (ha)	Roper 3 (ha)	Roper 4 (ha)
Rehabilitated	404	262	342	38	0	319	267	255	712
Natural	275	17	129	11	0	0	0	0	0
Void	386	241	449	33	15	60	75	28	277
Total	1,065	520	920	82	15	379	342	283	989

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 NPM residual voids

Void	Lotus/ Campbell	Gilbert	Price/ Leichhardt	East 1	East 2	Roper 1	Roper 2	Roper 3	Roper 4
Spill elevation (m AHD)	186	180	193	188	186	197	204	204	198

Stage-storage relationships were derived from the closure state landform to obtain the relationship between lake elevation and volume/surface of the lake, as shown in Figure 6.2 and Figure 6.3. These relationships were used in the WBM to estimate the lake surface area and elevation based on the lake volume for each modelled time-step.

The residual voids (except Roper 4) were initially assumed to begin at a zero level, implying that they were considered empty at the cessation of mining and, hence, the start of the WBM simulations. Roper 4 commenced the simulation with an initial water level of 170 m AHD, based on the 2023 survey of lake water levels. For the Roper voids, the WBM simulation commenced in 2023 based on the date of the most recent lake-level survey available (at the commencement of the WBM simulations).

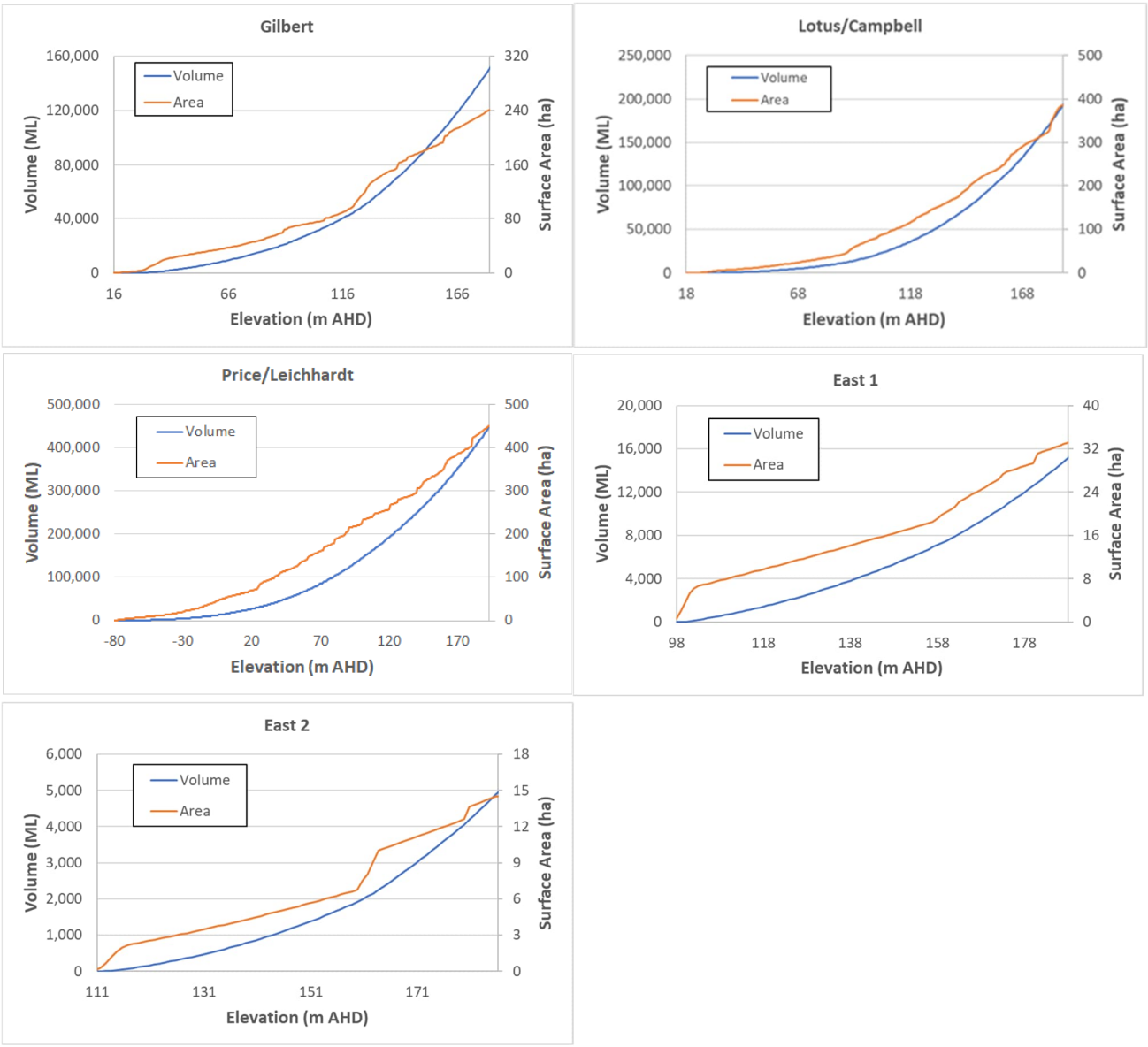

Figure 6.2 Lotus/Campbell Gilbert Price/Leichhardt East 1 and East 2 residual voids stage-storage relationship

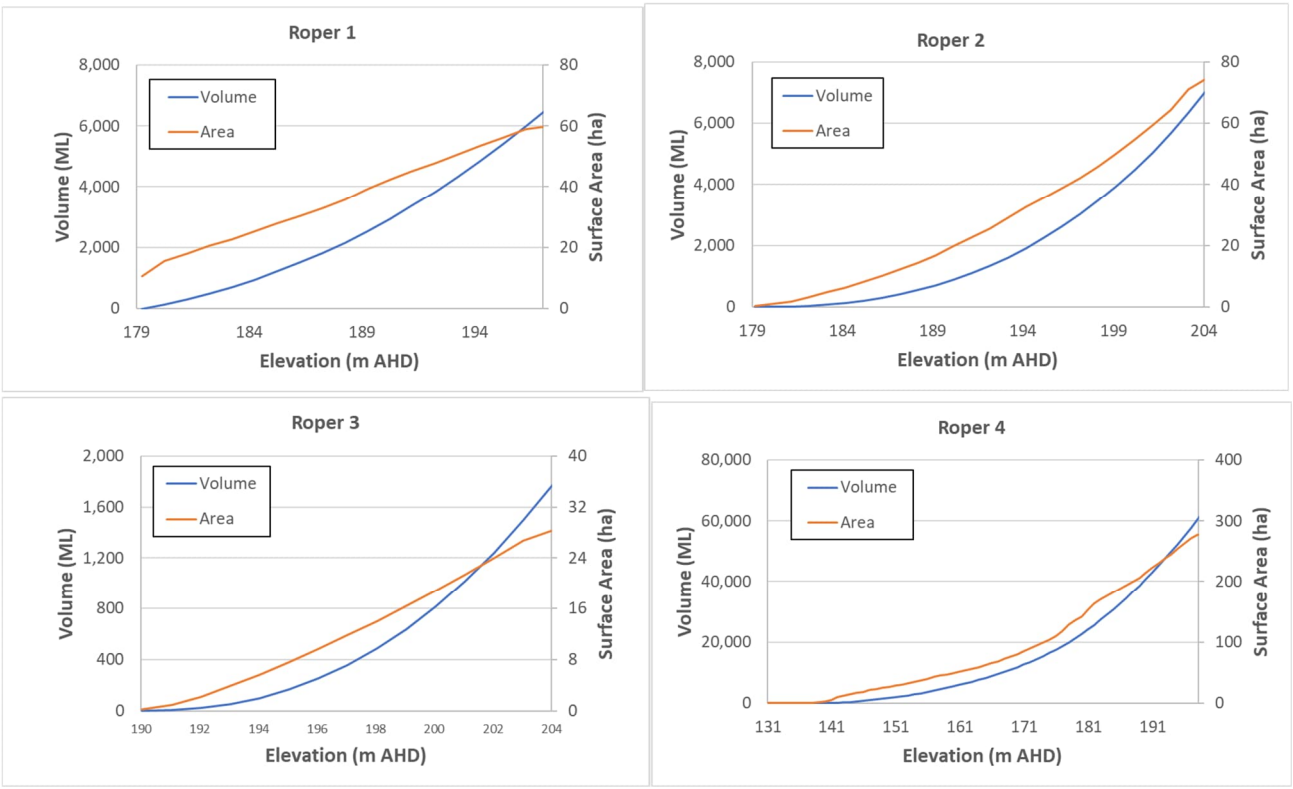

Figure 6.3 Roper 1 – 4 residual voids stage-storage relationship

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, 2022b) 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, as shown in Figure 6.4 and presented in Table 6.3. Each capacity is added together with fractional areas for weights, which are summarised in Table 6.4.

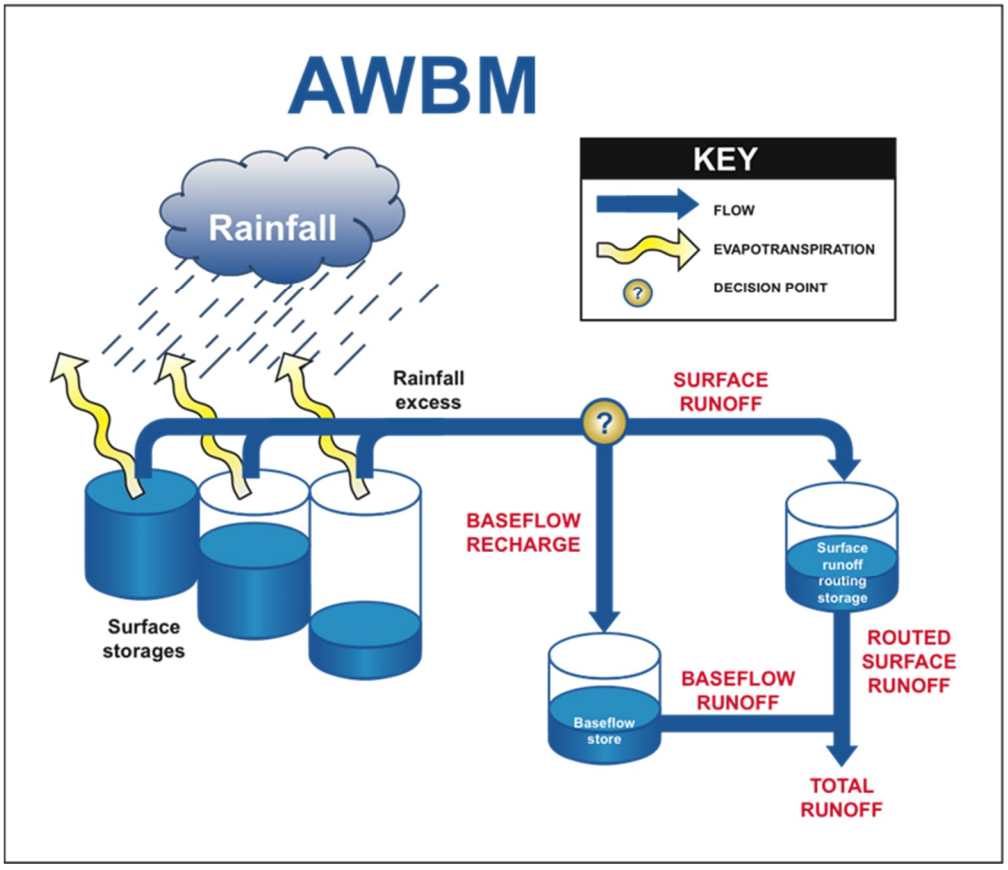

Figure 6.4 Structure of AWBM rainfall-runoff model including small, medium, and large surface storages

Table 6.3 Surface storage capacities (BMA, 2022b) applied to the water balance model for NPM

Land use	Small (mm)	Medium (mm)	Large (mm)
Natural	5	120	140
Void	5	20	35
Rehabilitated	5	120	140

Table 6.4 Surface storage proportions (BMA, 2022b) applied to the water balance model for NPM

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 do not include effects of high intensity and short duration events.

Table 6.5 Baseflow and channel parameters applied to the water balance model for NPM (BMA, 2022b)

Area	Baseflow index	Channel coefficient (1/day)	Baseflow coefficient (1/day)
Natural	0.35	0.1	0.7
Void	0.1	0.1	0.7
Rehabilitated	0.35	0.1	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 different climate models (Access 1-0Q and MPI-ESM-LRQ). The climate model Access 1-0Q was evaluated under RCP 4.5 while MPI-ESM-LRQ was evaluated under two RCP's (4.5 and 8.5).

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 (R6), middle (R3) and the drier (R1) climate ranges. . 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 NPM WBM

Realisation	Climate model	RCP
R1	ACCESS1-0Q	4.5
R3	MPI-ESM-LRQ	4.5
R6	MPI-ESM-LRQ	8.5

To cover the WBM simulation period of 377 years, the climate projections were applied from 2023 until 31 December 2399. 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. This methodology is summarised in Table 6.7.

The annual rainfall for each year in a pivotal year period was calculated from daily rainfall projections from each of the climate change scenarios. For each pivotal year period, the annual rainfall was averaged over this period. A pivotal year period represents the future average climate of a decade centred on the pivotal year: for example, the pivotal year of 2070 projects the climate from 2060 to 2079 (CSIRO, 2022). The pivotal years relevant to the WBM simulation period are 2030 (projections from 2023 to 2040), 2050 (projections from 2041 to 2060), 2070 (projections from 2061 to 2080) and 2090 (projections from 2081 to 2099). As the data does not extend past 2099, the projections from the pivotal year 2090 were applied for the period beyond 2100. The annual mean rainfall calculated for each climate realisation applied to the WBM for each simulated period via this methodology is summarised in Table 6.7

Table 6.7 Annual mean rainfall calculated for each climate realisation applied to the NPM residual voids WBM for each simulated period

Simulation period	Mean annual precipitation (mm)		
	R1	R3	R6
01-01-2024 to 31-12-2039	528	586	486
01-01-2040 to 31-12-2059	526	488	474
01-01-2060 to 31-12-2079	589	522	473
01-01-2080 to 31-12-2099	565	488	506
01-01-2100 to 31-12-2399	565	488	506

The future increase in evaporation was estimated considering:

- Reference period between 1986 to 2005.
- Projected period between 2024 and 2099

The result is a value showing the annual increase in evaporation for each climate change scenario. This factor was applied to the monthly values for evaporation. These factors are presented in Table 6.8.

Table 6.8 Percentage increase of evaporation considered for each realisation from 2024 to 2099

Aspect	R1	R3	R6
1986-2005			
Mean evaporation (mm/year)	1,594	1,610	1,616
2024-2039			
Mean evaporation (mm/year)	1,725	1,608	1,711
Increase in average evaporation (%)	8.2	-0.1	5.9
2040-2059			
Mean evaporation (mm/year)	1,779	1,794	1,850
Increase in average evaporation (%)	11.4	11.4	14.5
2060-2079			
Mean evaporation (mm/year)	1,787	1,843	1,979
Increase in average evaporation (%)	12.1	14.5	22.5
2080-2099			
Mean evaporation (mm/year)	1,818	1,785	2,087
Increase in average evaporation (%)	14.0	10.9	29.2

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 (SLR, 2024a). The modelled groundwater inflow rates used as inputs to the WBM are presented in Figure 6.5 to Figure 6.7. Groundwater inflows to the residual voids, as discussed in Section 4, are predicted to equate to between 10 and 20% of the total volumetric inflow (SLR, 2024b). Surface water fluxes act as the dominant driver on final void water levels.

Iterative model outputs between the numerical groundwater model and the WBM indicates an appropriate level of convergence was achieved for the Lotus/Campbell, Gilbert, Price/Leichhardt residual voids. Despite reasonable efforts including multiple model iterations, the WBM for the Roper and East 1 and 2 residual voids did not achieve the same

level of convergence with the numerical groundwater model. Water levels and groundwater inflows/outflows continue to fluctuate between iterations, particularly in the early stages of the simulations. Initial outcomes from the WBM indicate that outflows to groundwater may occur from all Roper voids by the end of the simulation. Further collection of data and understanding of the drivers and interactions between surface water and groundwater associated with these voids is required. This data and understanding are required to inform if any modifications to the landform are required that is expected to enable an improved level of convergence to be achieved between lake levels and groundwater. This will be addressed as part of the detailed studies for the Roper Study Area.

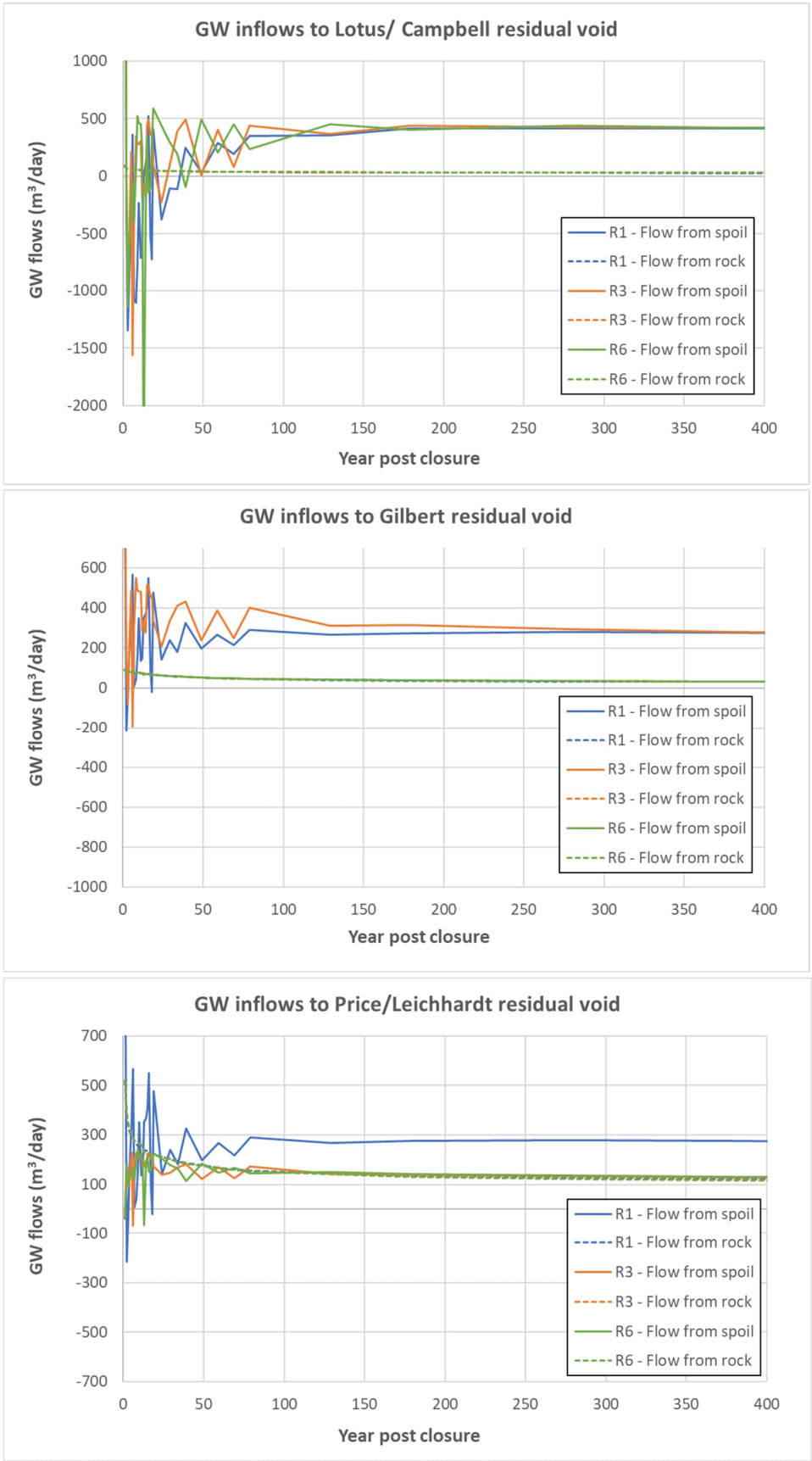

Figure 6.5 Groundwater inflows to Lotus/Campbell Gilbert and Price/Leichhardt residual voids – generated from (SLR, 2024a)

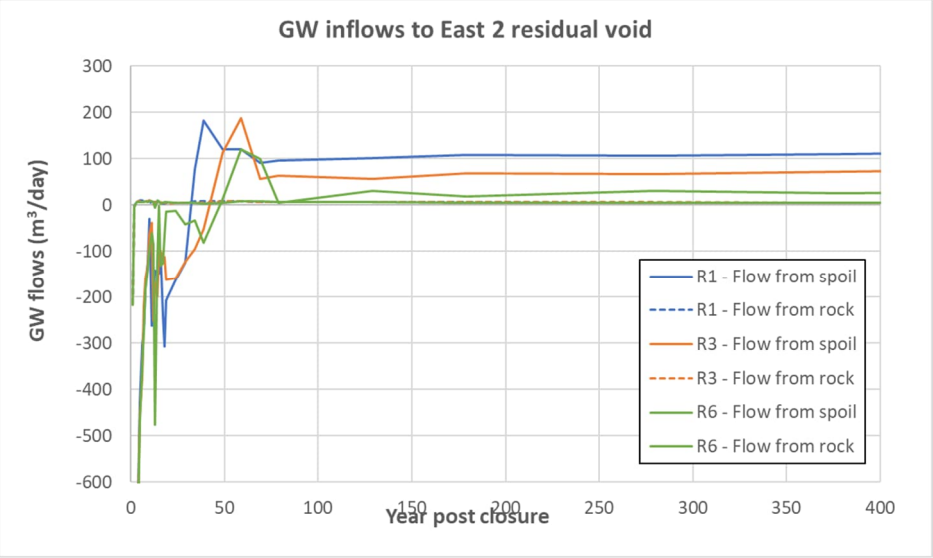

Figure 6.6 Groundwater inflows to East 1 and East 2 residual voids – generated from (SLR, 2024a)

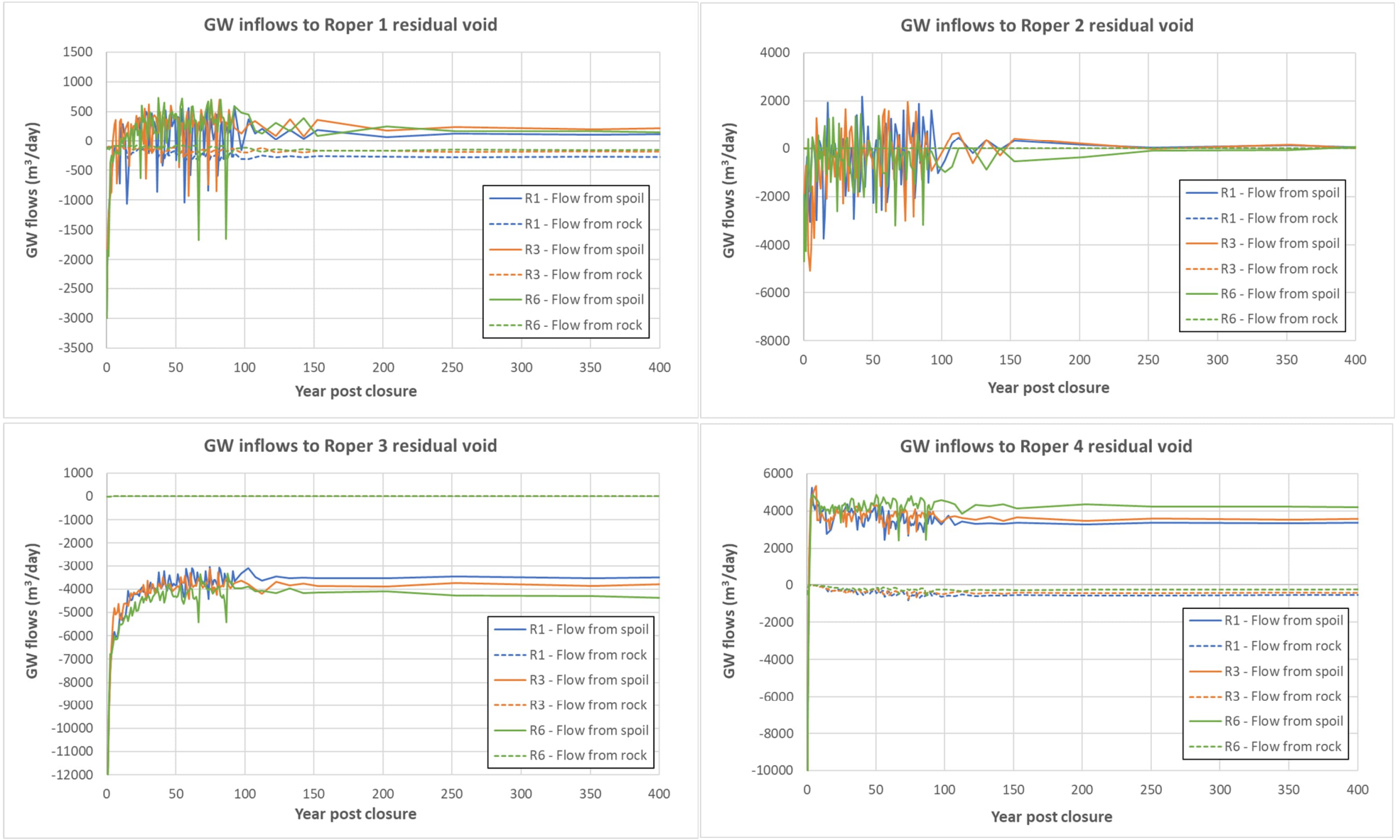

Figure 6.7 Groundwater inflows to Roper 1 – 4 residual voids – generated from (SLR, 2024a)

6.2 Residual void water balance outcomes

6.2.1 Lotus/Campbell residual void

By 2399, 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 2380 to 2399 and are presented in Figure 6.8. The mean (total) annual inflow to Lotus/Campbell residual void is 1,048 megalitres per year (ML/year) for the simulation period of 2380 to 2399, equal to the mean annual outflow for the same period. This indicates that the mean water balance for Lotus/Campbell residual void can be considered to have reached equilibrium.

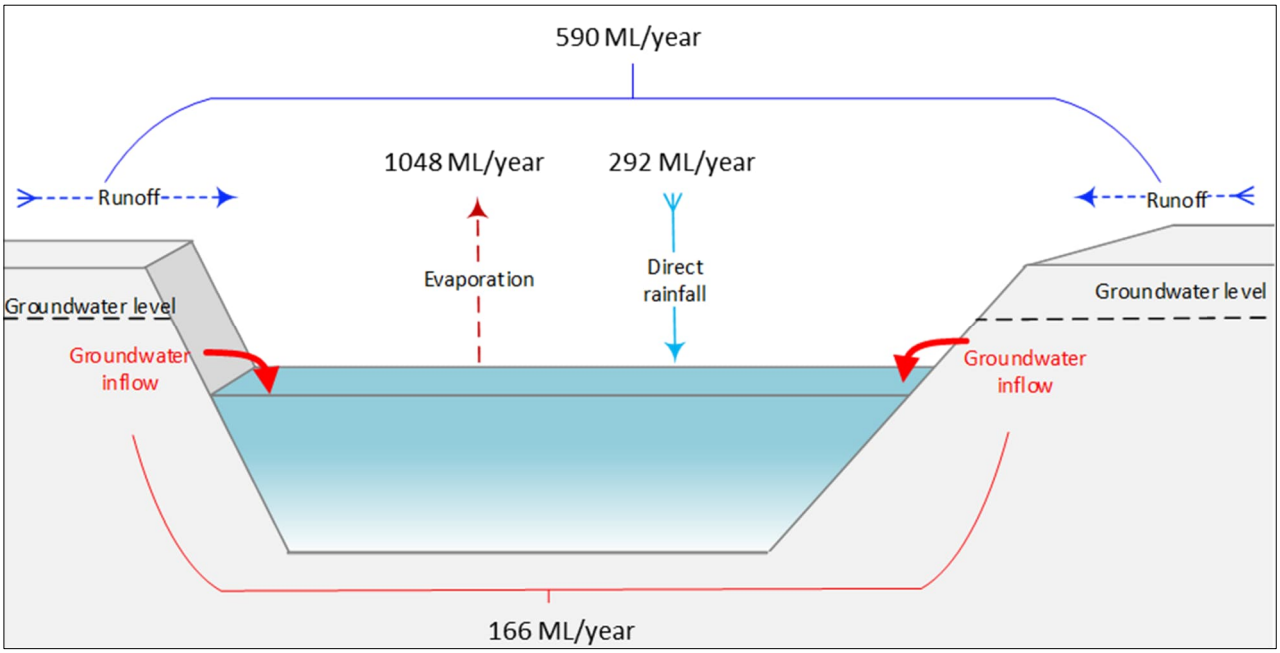

Figure 6.8 Schematic representation of average inflows/outflows simulated for the period from 2380 to 2399 – Lotus/Campbell residual void (realisations 1, 3, and 6)

The results from the WBM for Lotus/Campbell residual void indicate that, after an initial increase in void water level and volumes observed from the beginning of the simulation until the year 2210, the mean void water levels start to stabilise. The mean void water elevation reaches 92 m AHD (Figure 6.9) and the mean void water volume reaches 13,900 megalitres (Figure 6.10) by the end of the simulation across all realisations.

For the duration of the simulation, the residual void water levels remain a minimum of approximately 10 m below the predicted post-mining equilibrium groundwater level of the deepest aquifer (D Seam) for the R3 climate scenario (SLR, 2024b). The residual void lake levels also remain below the lowest elevation of the base of the shallow geologic formations (weathered regolith) (around 155.3 m AHD) (SLR, 2024b) (Figure 6.9) and consequently, water levels remain below the void spill point (186 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

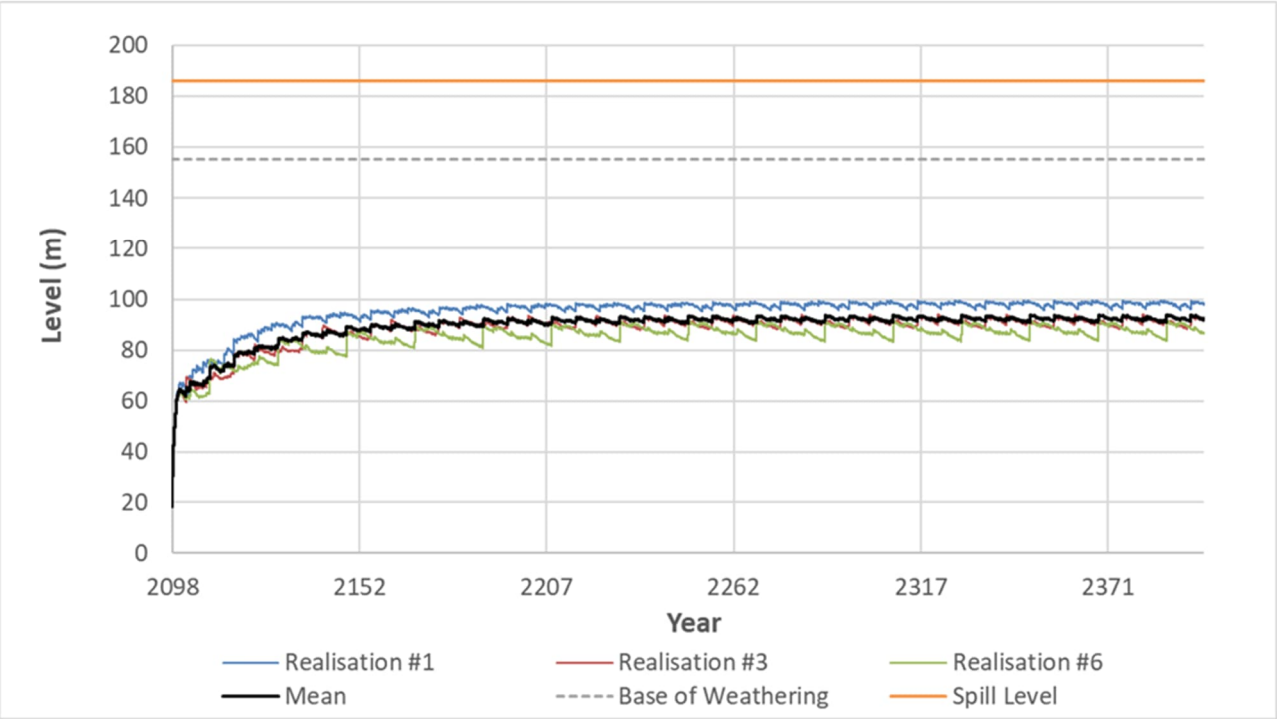

Figure 6.9 Modelled water levels in Lotus/Campbell residual void compared to spill level and the base elevation of shallow geologic formation (realisations 1, 3, and 6)

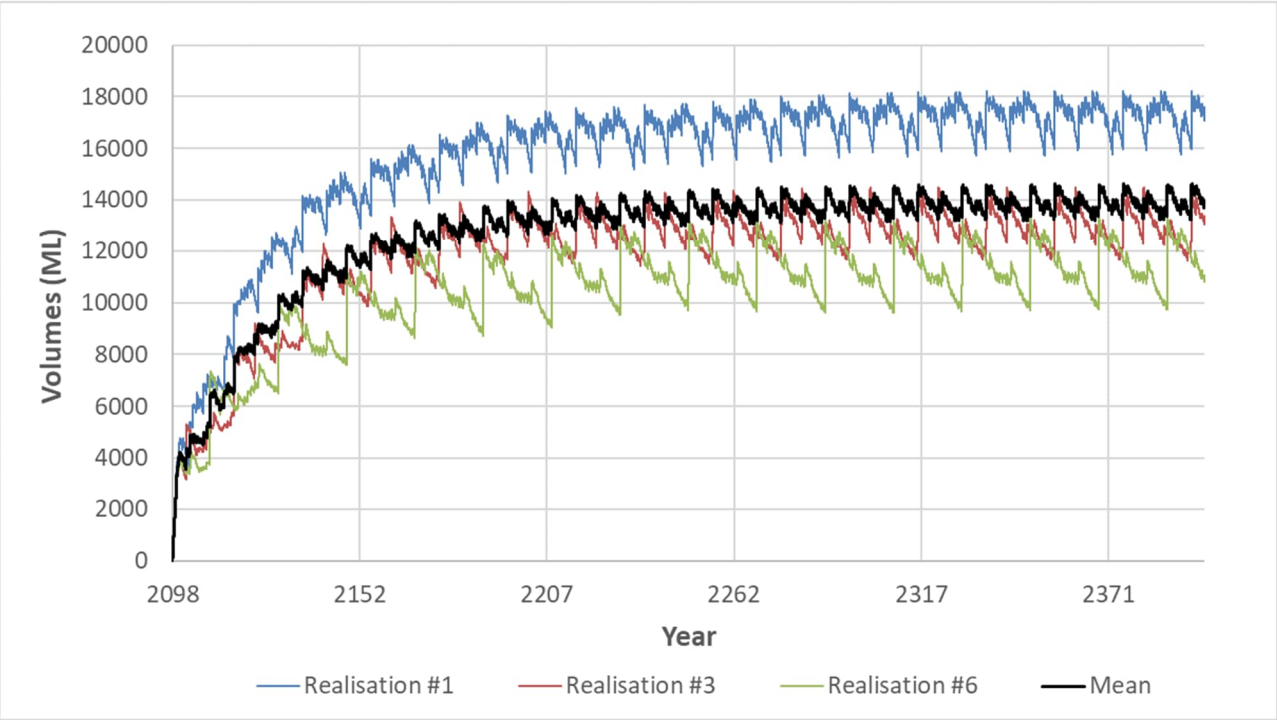

Figure 6.10 Modelled water volumes in Lotus/Campbell residual void (realisations 1, 3, and 6)

6.2.2 Gilbert residual void

By 2399, 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 2380 to 2399 and are presented in Figure 6.11. The mean (total) annual inflow to Gilbert residual void is 604 ML/year for the final 20-year period. The mean annual outflow for the same period is 605 ML/year. This indicates that the mean water balance for Gibert residual void can be considered to have reached equilibrium.

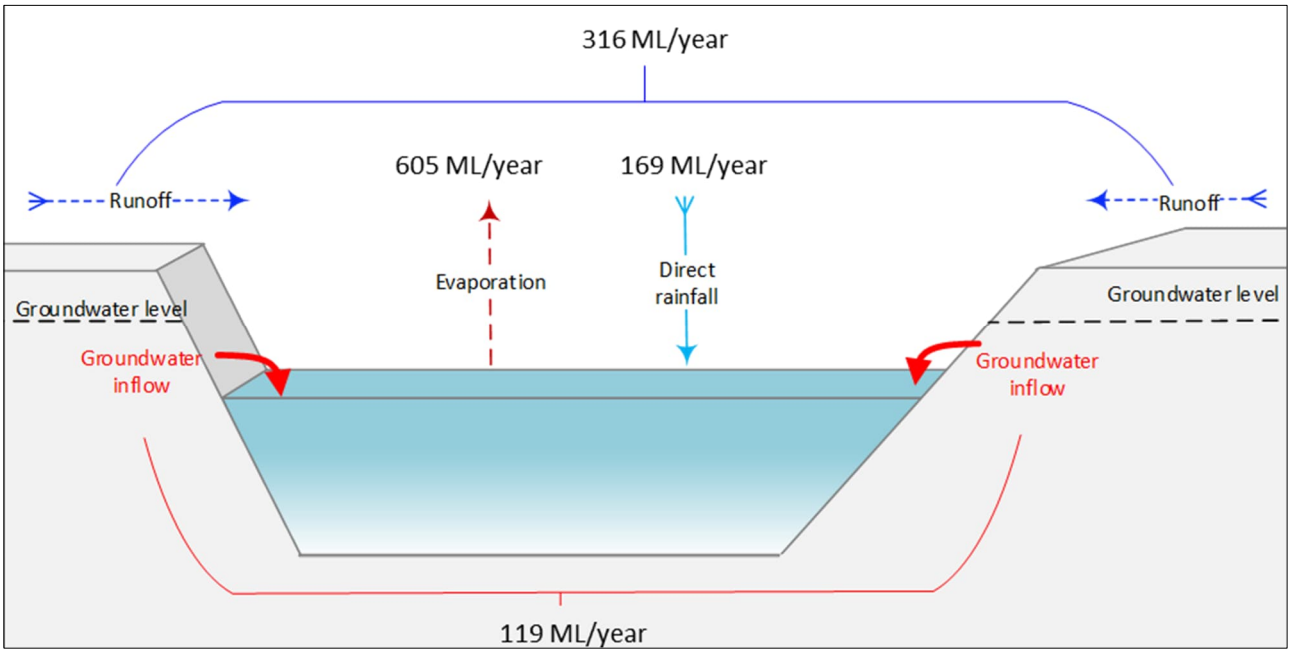

Figure 6.11 Schematic representation of average inflows/outflows simulated for period from 2380 to 2399 – Gilbert residual void (realisations 1, 3, and 6)

The results from the WBM for Gilbert residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2220, the mean void water levels start to stabilise. The mean void water elevation reaches 57 m AHD (Figure 6.12) and the mean void water volume of 6,549 megalitres (Figure 6.13) by the end of the simulation across all realisations.

For the duration of the simulation, the residual void water levels remain a minimum of approximately 26 m below the predicted post-mining equilibrium groundwater level of the deepest aquifer (D Seam) for the R3 climate scenario (SLR, 2024b). The residual void lake levels also remain below the lowest elevation of the base of the shallow geologic formations (weathered regolith) (around 150.6 m AHD) (SLR, 2024b) (Figure 6.12). Consequently, water levels also remain below the void spill point (180 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

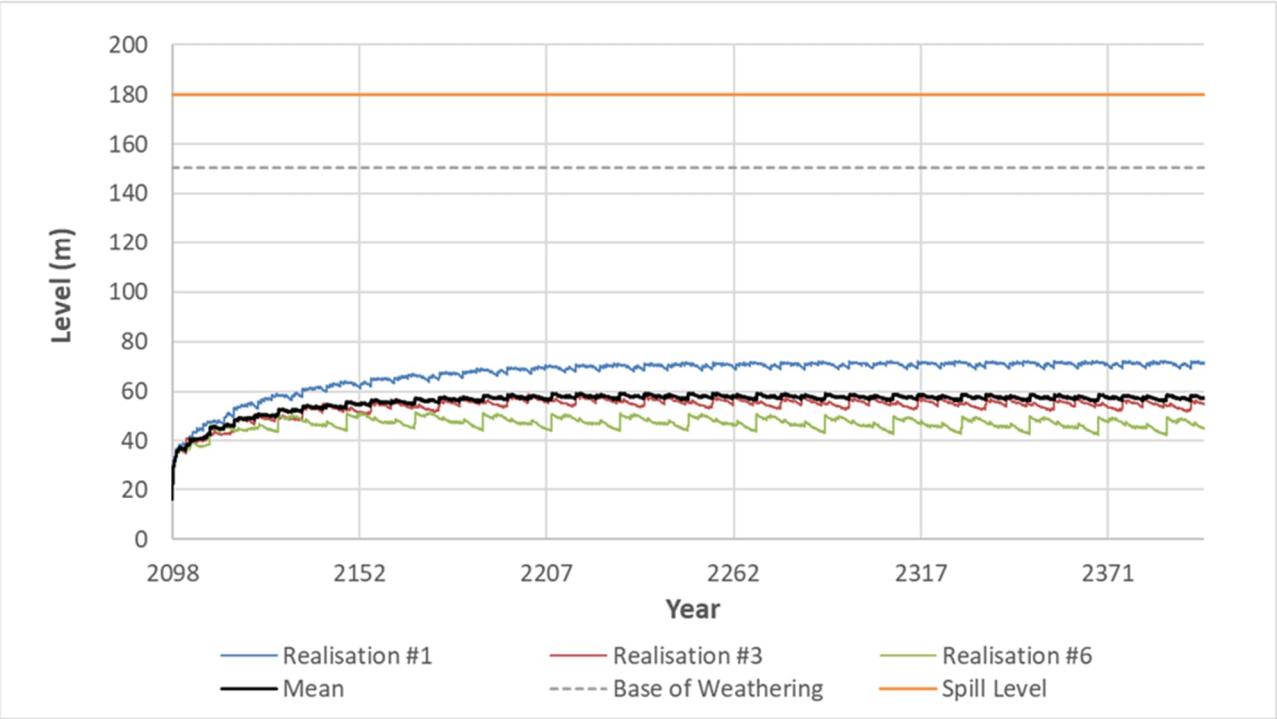

Figure 6.12 Modelled water levels in Gilbert residual void compared to spill level and the base elevation of shallow geologic formation (realisations 1, 3, and 6)

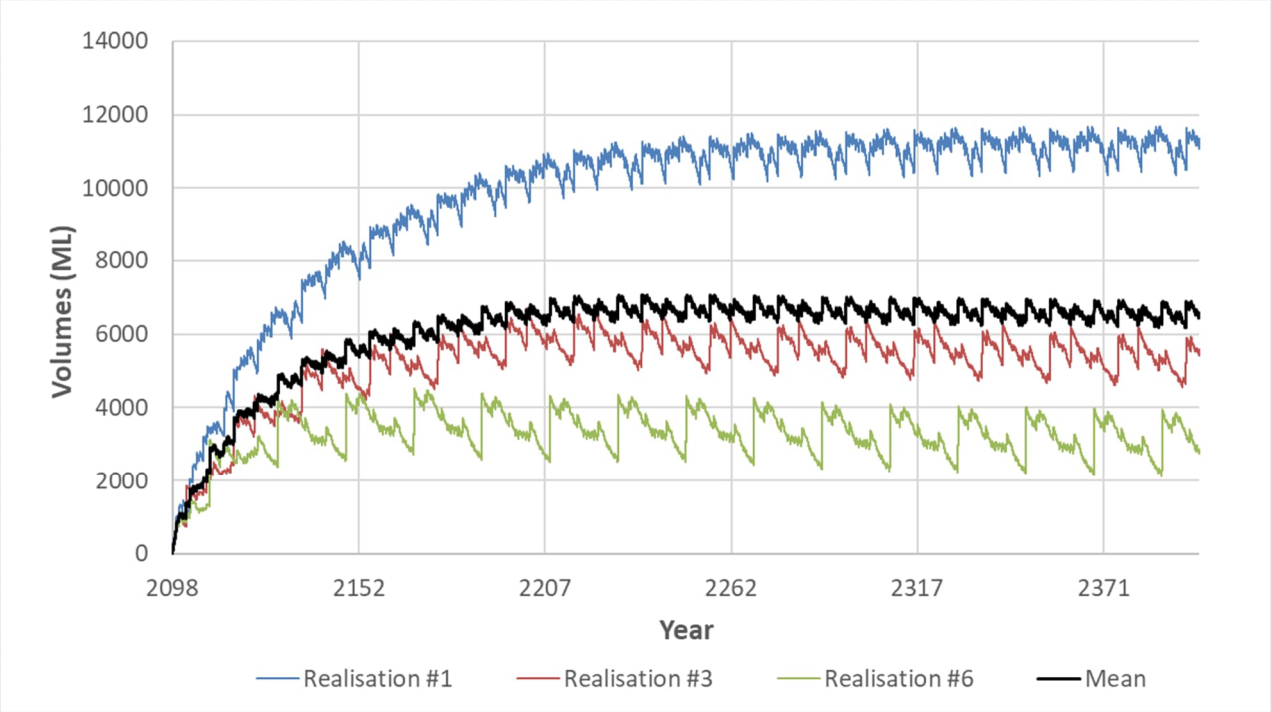

Figure 6.13 Modelled water volumes in Gilbert residual void (realisations 1, 3, and 6)

6.2.3 Price/Leichhardt residual void

By 2399, 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 2380 to 2399 and are presented in Figure 6.14. The mean (total) annual inflow to Price/Leichhardt residual void is 936 ML/year for the final 20-year period, equal to the mean annual outflow for the same

period. This indicates that the mean water balance for Price/Leichhardt residual void can be considered to have reached equilibrium.

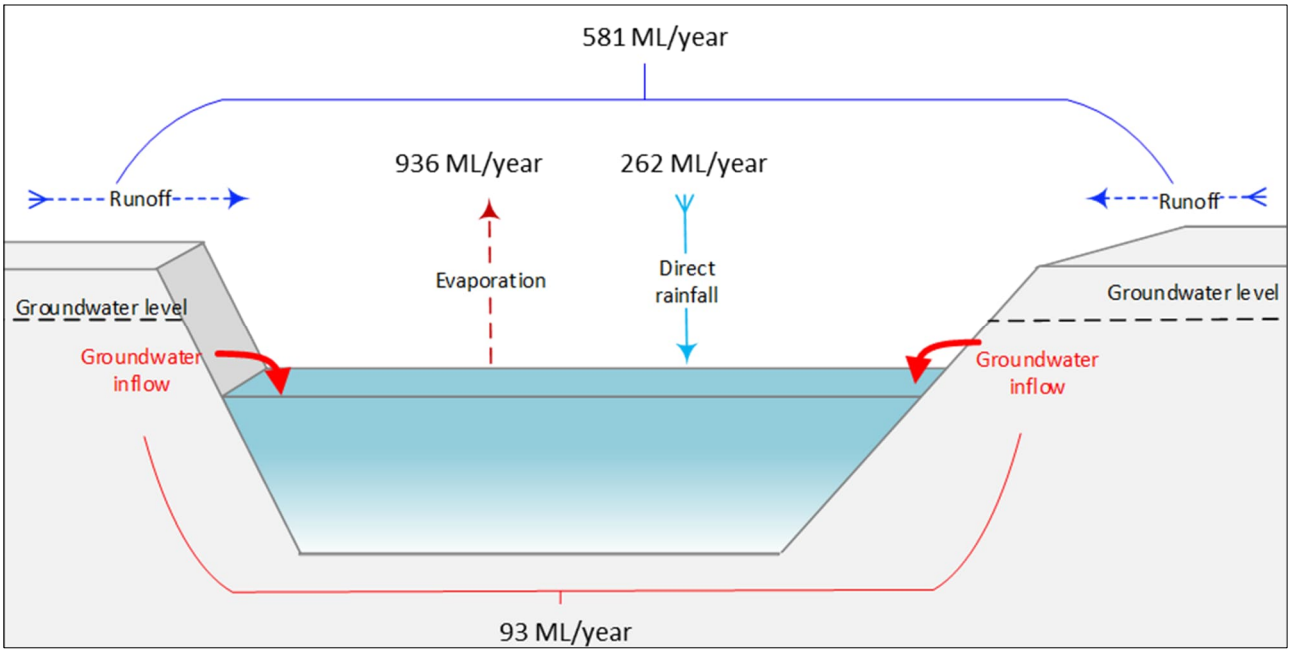

Figure 6.14 Schematic representation of average inflows/outflows simulated for period from 2380 to 2399 – Price/Leichhardt residual void (realisations 1, 3, and 6)

The results from the WBM for Price/Leichhardt residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2220, the mean void water levels start to stabilise. The mean void water elevation reaches 0 m AHD (Figure 6.15) and the mean void water volume of 15,741 megalitres (Figure 6.16) by the end of the simulation across all realisations.

For the duration of the simulation, the residual void water levels remain a minimum of approximately 46 m below the predicted post-mining equilibrium groundwater level of the deepest aquifer (D Seam) for the R3 climate scenario (SLR, 2024b). The residual void lake water levels also remain below the lowest elevation of the base of the shallow geologic formations (weathered regolith) (around 163.2 m AHD) (Figure 6.15). Consequently, water levels also remain below the void spill point (193 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

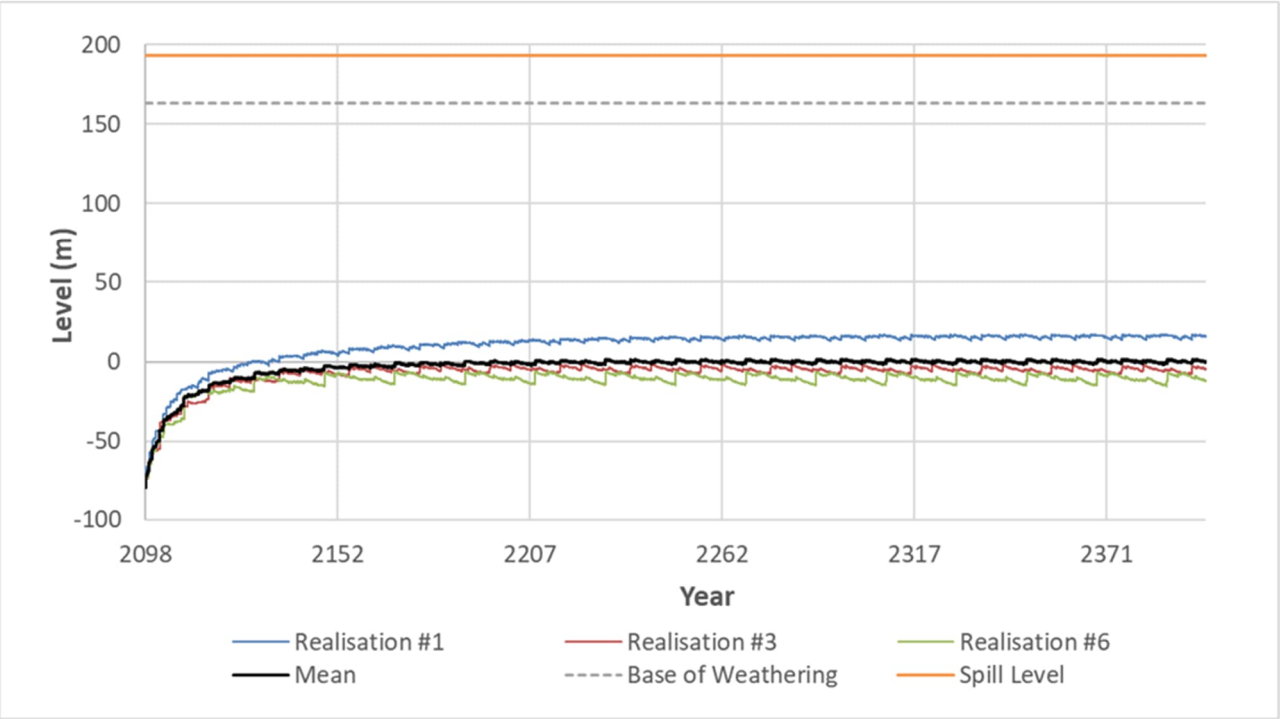

Figure 6.15 Modelled water levels in Price/Leichhardt residual void compared to spill level and the base elevation of shallow geologic formation (realisations 1, 3, and 6)

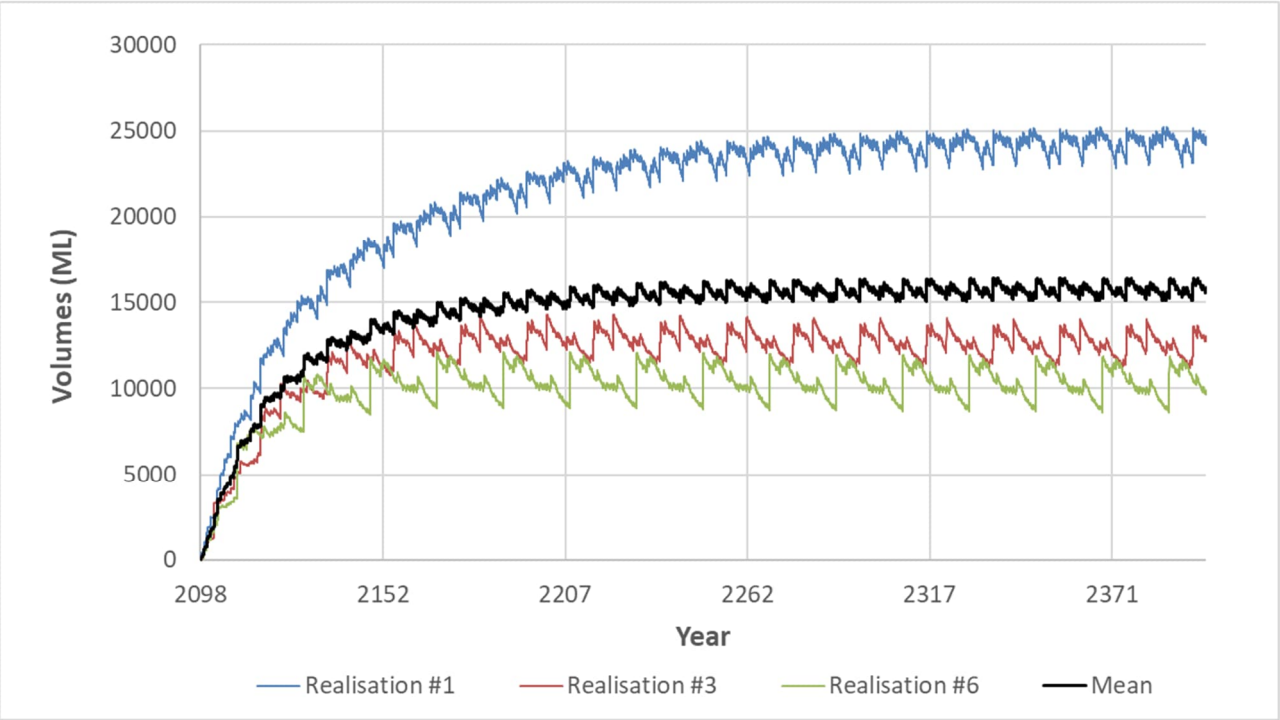

Figure 6.16 Modelled water volumes in Price/Leichhardt residual void (realisations 1, 3, and 6)

6.2.4 East 1 residual void

By 2399, 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 2380 to 2399 and are presented in Figure 6.17. The mean (total) annual inflow to East 1 residual void is 201 ML/year for the final 20-year period. The mean annual outflow for the same period is 200 ML/year. This indicates that the mean water balance for the East 1 residual void can be considered to have reached equilibrium.

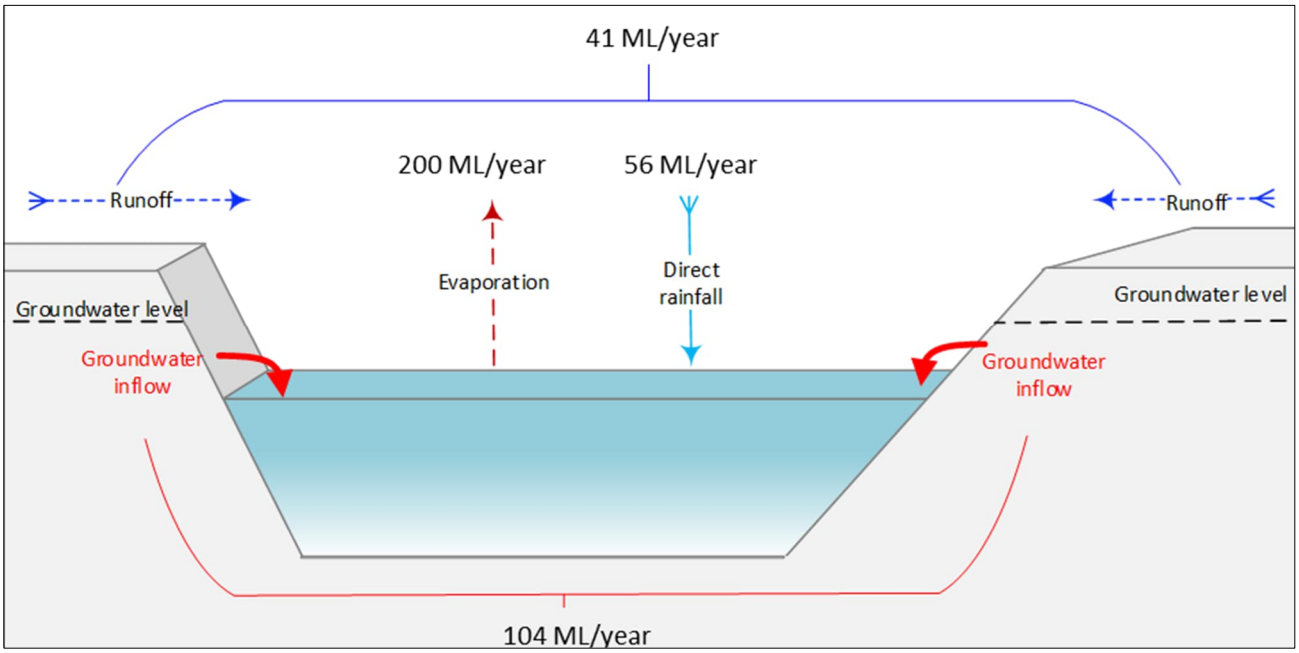

Figure 6.17 Schematic representation of average inflows/outflows simulated for period from 2380 to 2399 – East 1 residual void (realisations 1, 3, and 6)

The results from the WBM for East 1 residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2370, the mean void water levels start to stabilise. The mean void water elevation reaches 122 m AHD (Figure 6.18) and the mean void water volume of 1,937 megalitres (Figure 6.19) by the end of the simulation across all realisations.

For the duration of the simulation, the residual void water levels remain a minimum of approximately 7 m below the predicted post-mining equilibrium groundwater level of the deepest aquifer (D Seam) for the R3 climate scenario (SLR, 2024b). The residual void lake water levels also remain below the lowest elevation of the base of the shallow geologic formations (weathered regolith) (around 152 m AHD) (SLR, 2024b) (Figure 6.18). Consequently, water levels also remain below the void spill point (188 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

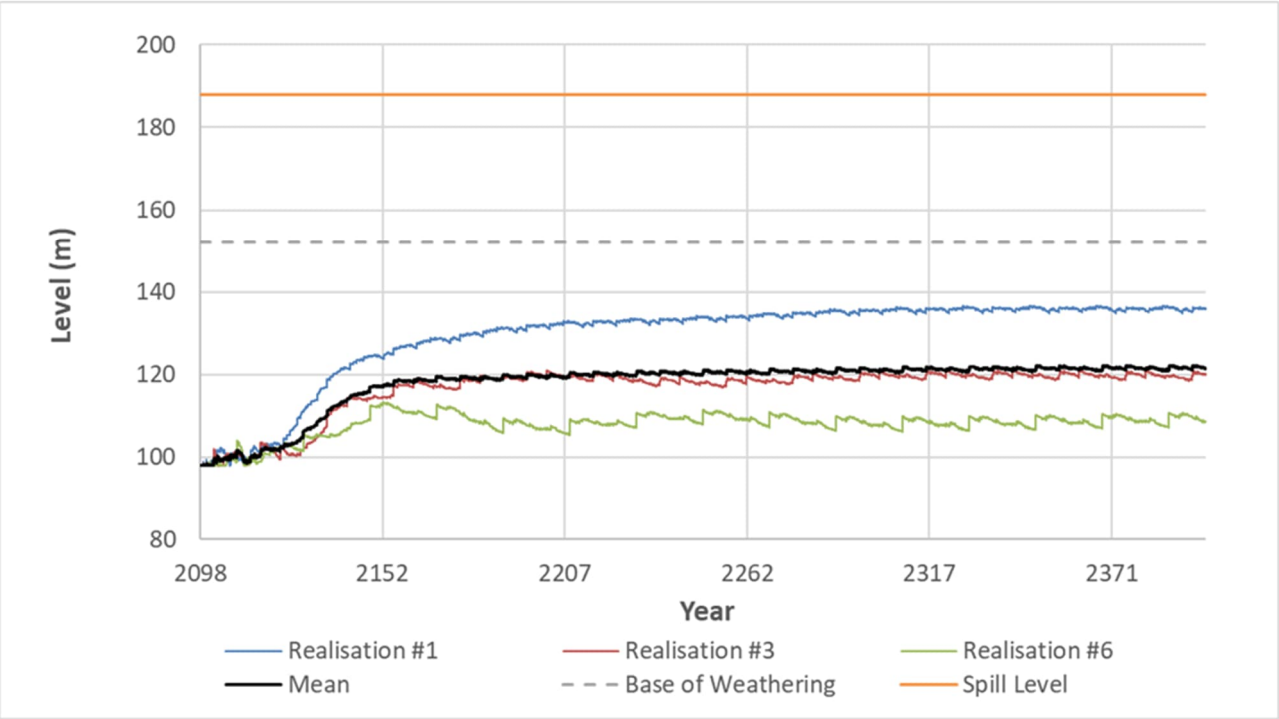

Figure 6.18 Modelled water levels in East 1 residual void compared to spill level and the base elevation of shallow geologic formation (realisations 1, 3, and 6)

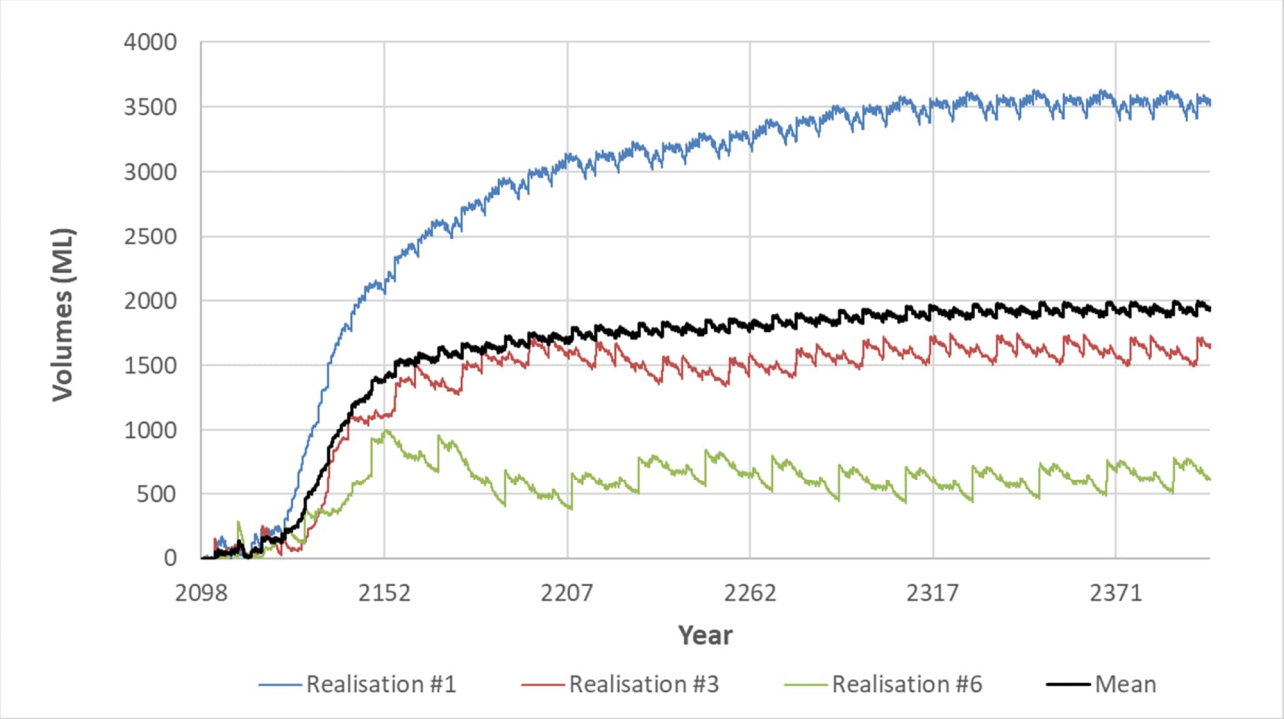

Figure 6.19 Modelled water volumes in East 1 residual void (realisations 1, 3, and 6)

6.2.5 *East 2 residual void*

By 2399, 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 2380 to 2399 and are presented in Figure 6.17. The mean (total) annual inflow to East 2 is

55 ML/year for the final 20-year period, equal to the mean annual outflow for the same period. This indicates that the mean water balance for the East 2 residual void can be considered to have reached equilibrium.

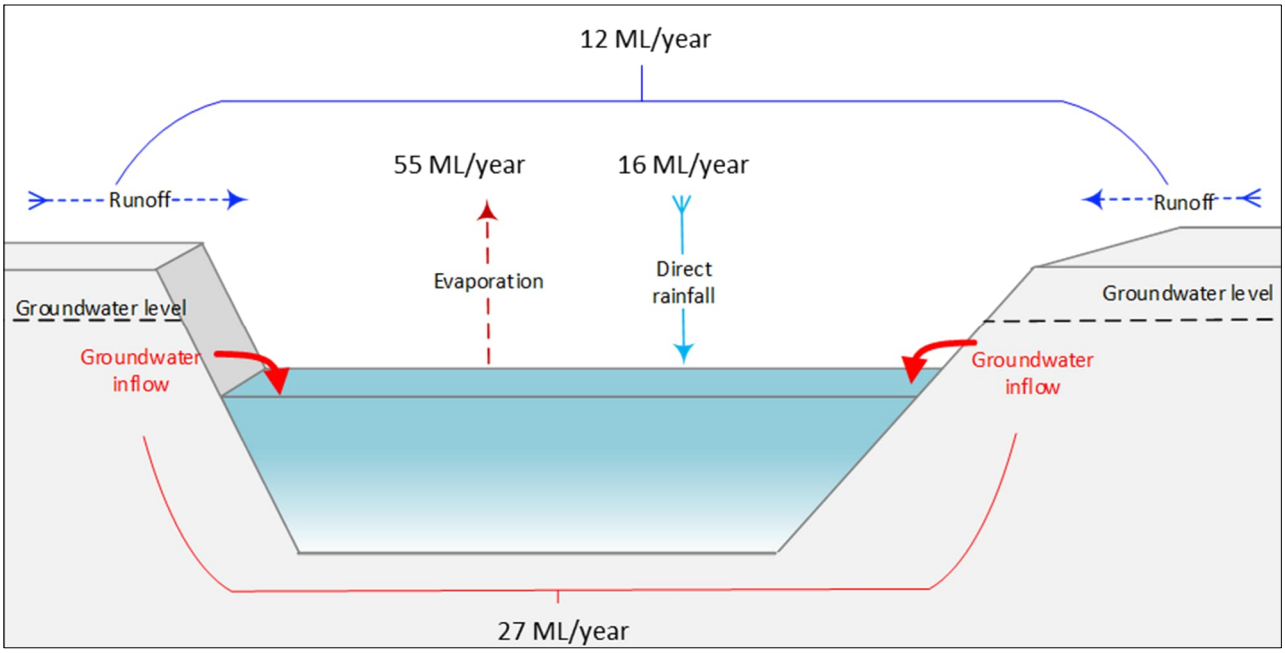

Figure 6.20 Schematic representation of average inflows/outflows simulated for period from 2380 to 2399 – East 2 residual void (realisations 1, 3, and 6)

The results from the WBM for East 2 residual void indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation until the year 2310, the mean void water levels start to stabilise. The mean void water elevation reaches 126 m AHD (Figure 6.18) and the mean void water volume reaches 365 megalitres (Figure 6.19) by the end of the simulation across all realisations.

For the duration of the simulation, the residual void water levels remain a minimum of approximately 5 m below the predicted post-mining equilibrium groundwater level of the deepest aquifer (D Seam) for the R3 climate scenario (SLR, 2024b). The residual void lake water levels also remain below the lowest elevation of the base of the shallow geologic formations (weathered regolith) (around 155.1 m AHD) (SLR, 2024b) (Figure 6.18). Consequently, water levels also remain below the void spill point (186 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

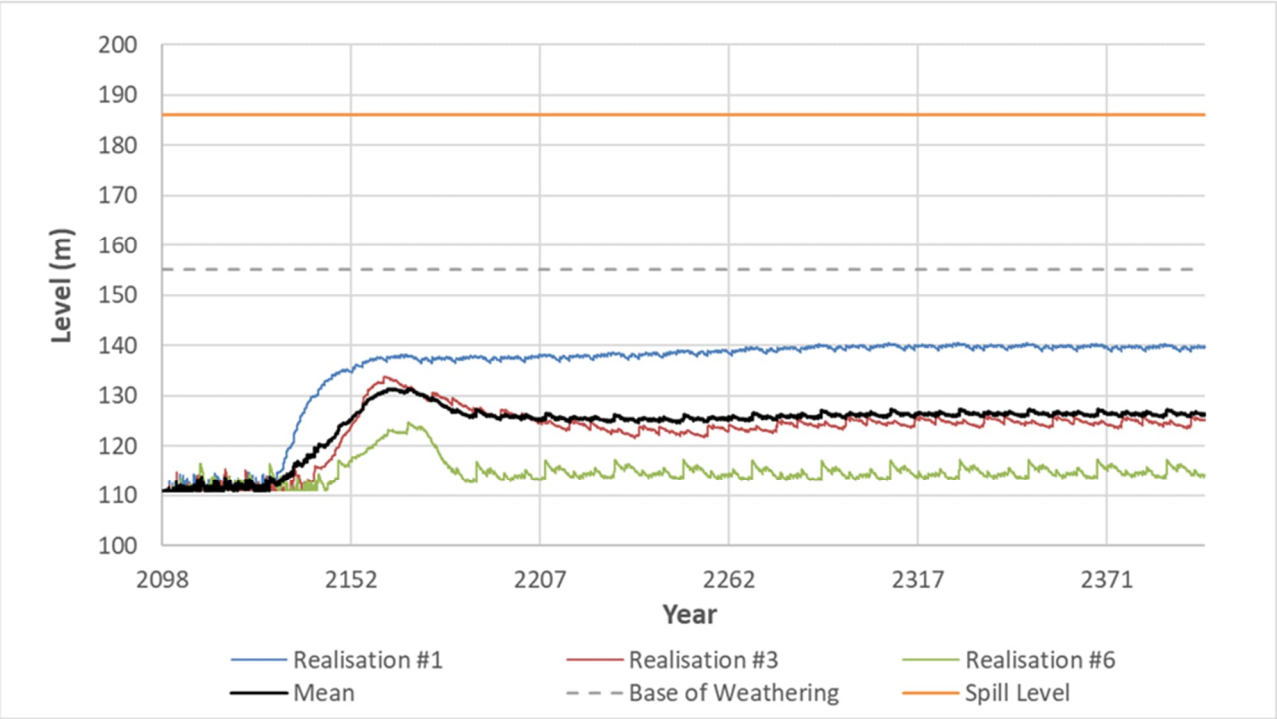

Figure 6.21 Modelled water levels in East 2 residual void compared to spill level and the base elevation of shallow geologic formation (realisations 1, 3, and 6)

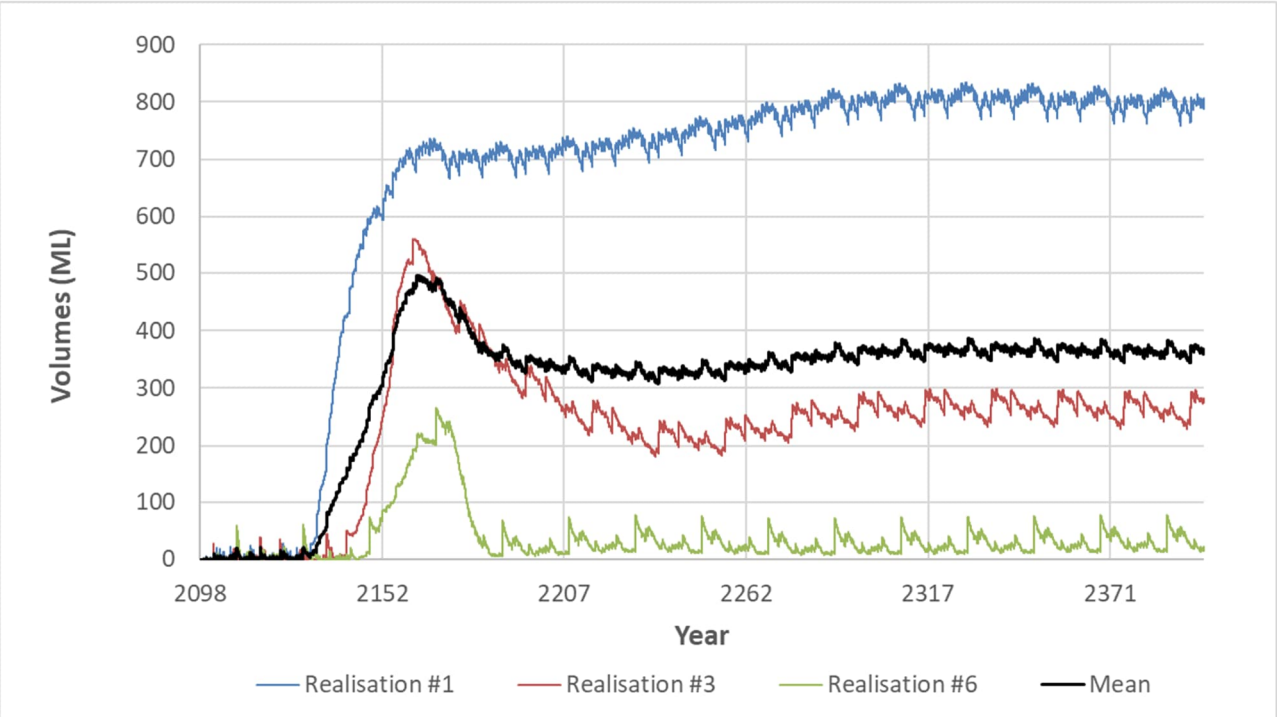

Figure 6.22 Modelled water volumes in East 2 residual void (realisations 1, 3, and 6)

6.2.6 *Roper residual voids*

The WBM outcomes for Roper 1, 2, 3 and 4 residual voids are point-in-time assessments and further understanding of the key relevant risks and potential design limitations associated with these residual voids in the closure landform is required. The Roper Study Area has been included as a milestone for the PRCP schedule to undertake additional technical studies to develop a detailed closure plan for these residual voids. Outcomes from this study will be used to improve understanding of void interconnectivity within these voids and the East 1 and 2 voids; and identify modifications which

may be required to further manage and/or control areas of potential environmental harm within the Roper Study Area in the closure landform. The following section provides a summary of the initial outcomes of the WBM.

Despite reasonable efforts, the WBM and numerical groundwater model did not achieve the same level of convergence for the Roper voids as the northern voids. Until the drivers and interactions between surface water and groundwater associated with these voids is understood, the following sections provide the interim outcomes of the WBM simulations for the projected climate scenarios albeit without model convergence.

By 2399, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance for each of the Roper residual voids can be considered to have reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2380 to 2399 and are presented in Table 6.9 for all Roper residual voids. The mean (total) annual inflow for the final 20-year period was either equal to or very similar to the mean annual outflow for the same period.

Table 6.9 Average annual inflows and outflows calculated for the Roper residual voids

Residual void	Mean annual inflow (ML/year)	Mean annual outflow (ML/year)
Roper 1	246	246
Roper 2	265	267
Roper 3	128	128
Roper 4	2,255	2,254

Roper 1 and 3 residual voids intermittently fill and dry out; therefore, a stabilised lake level does not establish in these voids . For the duration of the simulation, the residual void water levels of:

- Roper 1 remains below the void spill point (197 m AHD) and therefore there is a low risk of this void overtopping for all the scenarios considered.
- Roper 3 remains below the void spill point (204 m AHD) and therefore there is a low risk of this void overtopping for all the scenarios considered

The results from the WBM for Roper 2 and 4 residual voids indicate that, after an initial increase in void volumes and water level observed from the beginning of the simulation, the mean void water levels start to stabilise (Table 6.10). The mean void water elevation reaches 188 m AHD for Roper 2 and 177 m AHD for Roper 4. Roper 2 and 4 residual voids reach mean void water volumes of 560 and 18,593 megalitres respectively by the end of the simulation across all realisations.

Table 6.10 Mean water levels and volumes for Roper 2 and 4 residual voids at NPM

Residual void	Mean void water level (m AHD)	Spill elevation (m AHD)	Mean void water volume (megalitres)
Roper 2	188	204	560
Roper 4	177	198	18,593

For the duration of the simulation, the residual void water levels of:

- Roper 2 remains below the void spill point (204 m AHD) and therefore there is a low risk of this void overtopping for all the scenarios considered.
- Roper 4 remains below the void spill point (198 m AHD) and therefore there is a low risk of this void overtopping for all the scenarios considered.

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 NPM residual voids. This section presents the assessment findings relevant to void closure at NPM.

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 NPM 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 particular materials. However, the method is generally accepted by industry as a practical industry method and has therefore been adopted for the PRC plan at NPM.

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, a FoS less than 1 indicates instability, and a value greater than 1 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.

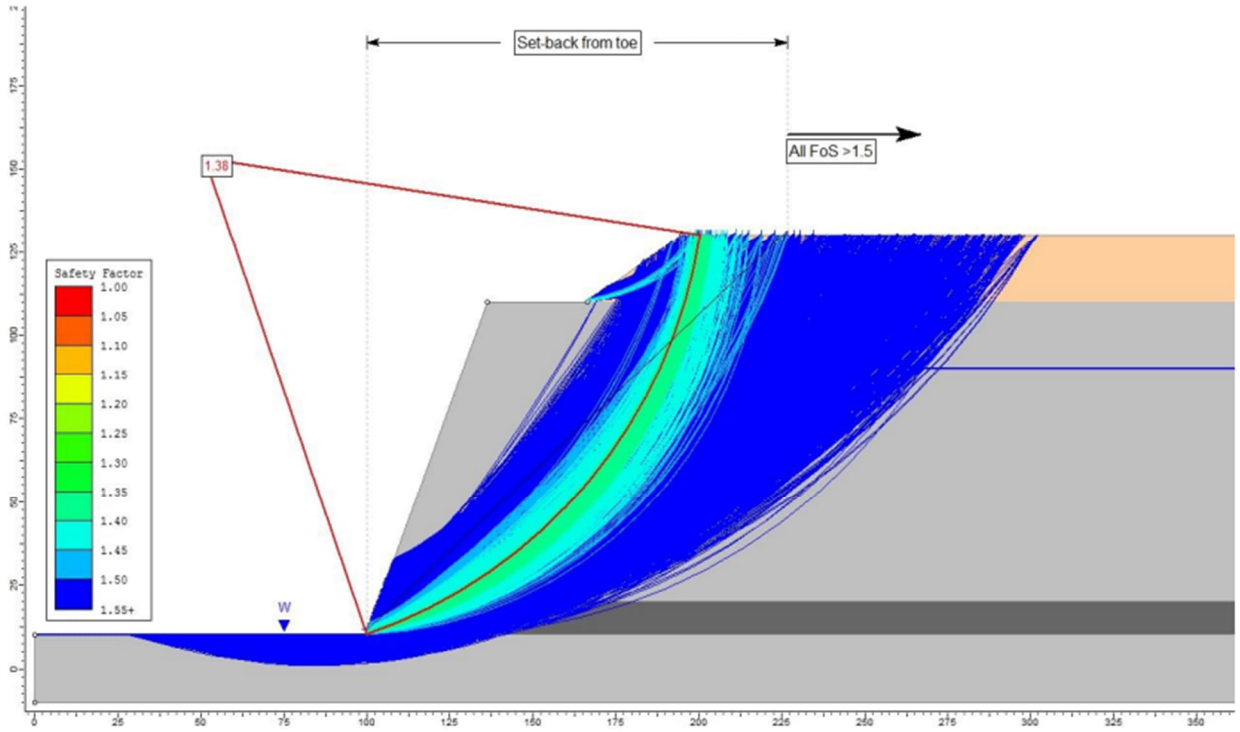

Figure 7.1 Example illustration of set-back to FoS of ≥1.5

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

Aspect	Value range
Bench width at base of Tertiary overburden	30 m (constant)
Average wall angle in Permian overburden	40° to 70°
Depth of Permian overburden incl. 10 m coal	50 m to 400 m

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 NPM 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.

7.1.1.4 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 NPM predicts average and long-term void water levels many metres below the base of weathering.

Unweathered (fresh) coal measure rocks generally do not show significant strength loss on wetting. Particular claystones and mudstones may be more sensitive to moisture, but these tend to start slaking soon after exposure to humid air, and so are apparent during mining when wall designs can be amended to mitigate any impact on wall stability. Residual void water is only expected to contact fresh rock and so will not affect geotechnical stability of 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 RCP 4.5 P90 event.

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.

7.1.2 Inputs to assessment – local

Long sections extracted from the current NPM geological model provided void wall profile data as summarised in Table 7.3.

Table 7.3 Geotechnical profiles for the residual void walls at NPM

Geotechnical profile parameters		Lotus/ Campbell North[1]	Lotus/ Campbell South[1]	Gilbert	Price/ Leichhardt North[1]	Price/ Leichhardt South[1]	East 1 and 2	Roper 1	Roper 4
Depth of tertiary overburden (m)	Average Range	34 19 - 44	18 7 - 29	9 1 - 17	13 4 - 28	35 28 - 45	9 4 - 13	5	31 9 - 52
Depth of tertiary/ weathered overburden (m)	Average Range	40 29 - 47	30 16 - 42	19 11 - 22	30 22 - 39	40 31 - 49	23 18 - 28	13	39 14 – 53
Thickness of base coal seam (m)	Average Range	2 2 - 4	3 2 - 3	3 1 - 4	1 0 - 4	2 0 - 5	2 2 - 3	0	<1 0 - 1
Depth of fresh overburden (m)	Average Range	80 15 - 145	77 57 - 107	131 120 - 141	18 0 - 29	155 15 - 234	59 44 - 72	4	17 0 - 33
Total wall depth (m)	Average Range	120 51 - 177	107 98 - 133	150 141 - 163	47 29 - 60	195 58 - 272	83 72 - 95	18	56 14 - 74

[1] Values provided separately for these voids in geotechnical assessment (Price and Leichardt) although they have been combined in the final closure state landform.

The depth ranges for Tertiary/weathered and fresh Permian overburdens for the Lotus/Campbell, Gilbert, Price/Leichhardt South and East 1 and 2 voids are within the application limits for the design tool. Computations were made with an assumed wall angle of 60°. The computed set-back from the wall toe is not very 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 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) 0
- 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 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 Price/Leichhardt North, Roper 1 and Roper 4 void sections contain features that were outside of the design tool parameters and therefore a bespoke stability analysis was undertaken. The same general approach and material properties as the design tool were applied with the addition of specific geotechnical profiles for the tailings, Tertiary overburden and weathered Permian overburden. The strength properties for these tailings and spoil materials are presented in Table 7.4. Some projection of the typical pit high-wall and floor slope angles was required to provide interfaces between intact material and spoil or tailings.

Due to the final closure state landform for Roper 2 and 3 residual voids not containing steep sections of in-situ high-wall, these residual voids were not assessed.

At the time of the geotechnical high-wall and end-wall assessment, detailed residual void water balance modelling was not available. For the purpose of the high-wall geotechnical assessment, long-term residual void water levels were estimated based on the water surface area at which average annual inflow from catchment runoff and direct rainfall balance average annual evaporation.

Table 7.4 Additional strength properties applied to the stability analyses for Price/Leichhardt, Roper 1 and Roper 4 residual voids (BHP, 2020)[a]

	Cohesion (kPa)	Friction angle (°)	Unit weight (kN/m^3)
Saturated Tertiary	15	30	20
Unsaturated weathered Permian	75	30	24
Saturated weathered Permian[1]	30	30	24
Saturated Spoil (Cat 2)	15	23	20
Unsaturated Spoil (Cat 2)	30	28	18

	Cohesion (kPa)	Friction angle (°)	Unit weight (kN/m^3)
Tailings[2]	20	0	18

[a] Exceptions:

[1] cohesion assumed 40% value for unsaturated.

[2] typical for normally consolidated saturated coal tailings.

As with the analysis completed with the design tool, the bespoke stability analysis is used for initial planning only. As mining approaches the final pit extents and additional geological and geotechnical data becomes available, individual assessment of each high-wall and end-wall will be undertaken as part of the detailed closure design stage for each final residual void.

7.1.3 High-wall and end-wall stability assessment results

The results for the NPM high-walls are summarised in Table 7.5 and Table 7.6. 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 7.5 Set-backs for long-term high-wall stability at NPM – design tool analysis

Geotechnical profile parameters		Lotus/ Campbell North[1]	Lotus/ Campbell South[1]	Gilbert	Price/ Leichhardt South	East 1 and 2
S_1 (m)	Average	128	144	132	179	98
	Range	85 - 158	130 - 163	122 – 143	117 – 223	91 – 106
	90% less than	154	151	139	219	104
FoS_p	Average	1.71	1.81	1.43	1.41	2.04
	Range	1.34 – 2.17	1.55 – 2.05	1.38 – 1.48	1.12 – 2.17	1.85 – 2.30
	90% less than	1.41	1.61	1.40	1.14	1.86
S_p (m)	Average	142	117	157	263	98
	Range	88 - 209	105 - 129	140 – 181	117 – 414	91 – 106
	90% less than	187	124	171	393	104
Set-back from toe of wall (m)	Average	139	122	157	263	98
	Range	85 - 209	105 - 144	140 – 181	117 – 414	91 – 106
	90% less than	186	135	171	393	104

[1] Results provided separately for these voids in geotechnical assessment (Price and Leichardt) that are combined in the final closure state landform.

The bespoke analysis for Price/Leichhardt North residual void had minimum FoS of <1.5 at the void crest. Set-backs required to achieve a FoS≥1.5 were measured from the wall crest rather than the toe due to the void already existing and the atypical geometry of the void. The Roper 1 and 4 analysed cross sections all achieved a minimum FoS of ≥1.5 (Table 7.6).

Table 7.6 Set-backs for long-term high-wall stability at NPM – bespoke analysis

	Price/Leichhardt North	Roper 1	Roper 4
FoS at crest	0.94 – 1.39	≥4.19	≥1.70
Set-back from crest (m) to achieve FoS ≥1.5	16 - 42	0	0

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 and assumptions
- Plan for partial backfill of the residual void. In simple terms, this would reduce the (exposed) wall depth and depth of fresh Permian overburden, which would in turn reduce the required set-back.

For NPM, the conceptual voids have been designed with the toes or crest (where relevant) of each void wall at least the set-back 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.

7.2 Low-wall stability assessment

The geotechnical stability of low-walls has been assessed for the NPM 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 NPM residual voids was undertaken using the 2-dimensional (2D) limit equilibrium analysis software Slide2 (version 9.010). Seven 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. Roper 2 and 3 residual voids were not assessed as the spoil height and floor dip were not considered to present critical low-wall instability conditions in these residual voids (i.e. low-wall slopes steeper than approximately 10 degrees). The section locations for the analyses are presented in Figure 7.2 and the corresponding sections are identified as:

- Section 1 and 2 (Lotus/Campbell residual void)
- Section 3 (Gilbert residual void)
- Section 4 and 5 (Price/Leichhardt residual void)
- Section 6 (East 1 residual void)
- Section 7 (East 2 residual void)
- Section 8 (Roper 1 residual void)
- Section 9 (Roper 4 residual void).

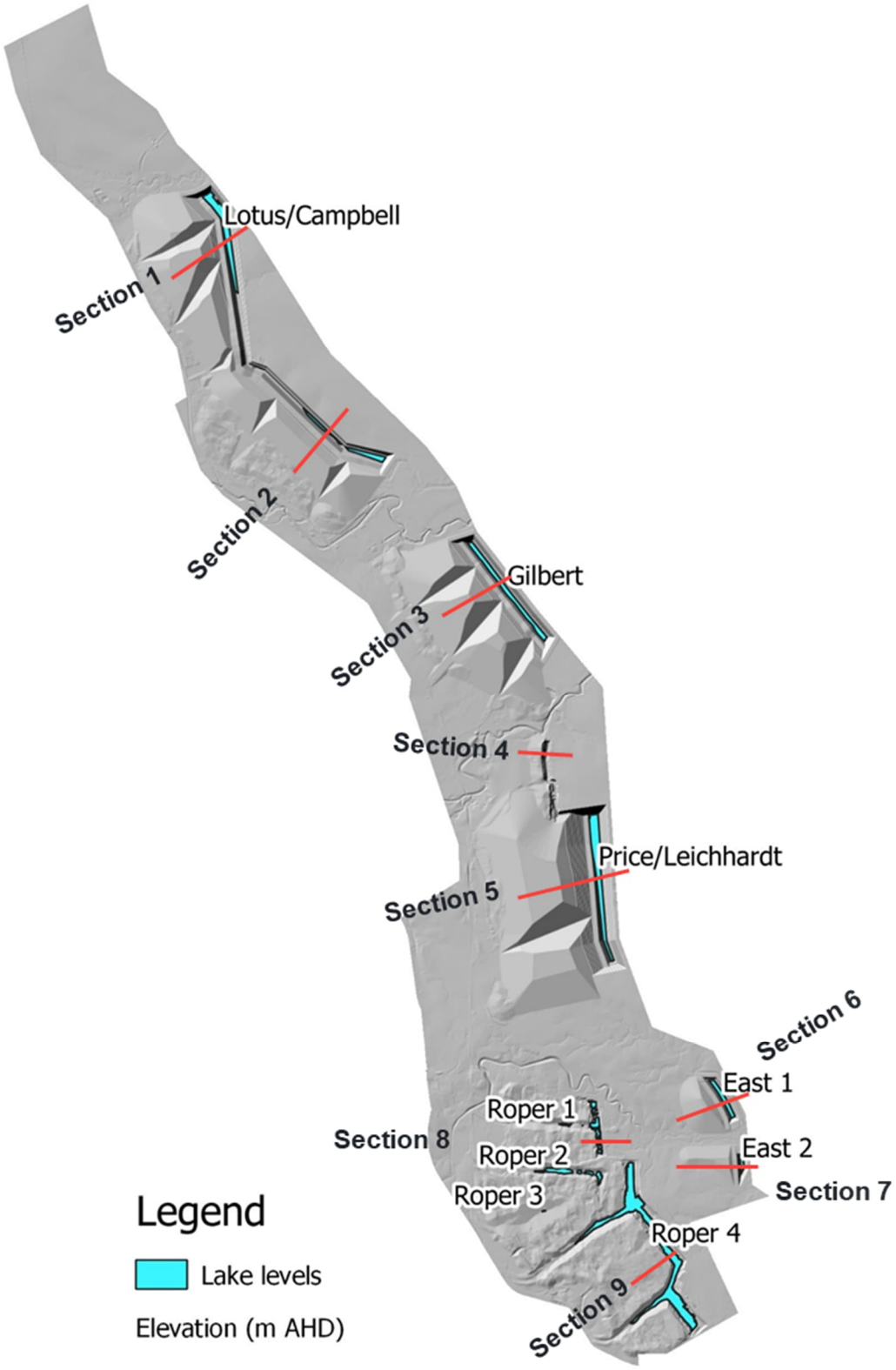

Figure 7.2 Cross-section locations for the NPM residual voids low-wall stability analyses

For each of the nine 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 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 NPM residual voids that returned the lowest FoS are presented in Sections 7.2.1 to 7.2.7.

7.2.1 Lotus/Campbell residual void

The geotechnical stability assessment for Lotus/Campbell residual void (cross-section 1 and 2) 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 7.3 to Figure 7.6.

Table 7.7 Summary of low-wall geotechnical stability analysis results for Lotus/Campbell residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety [a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
1	237	1.9	2.2
2	201	2.0	2.4

[a] Morgenstern-Price, non-circular

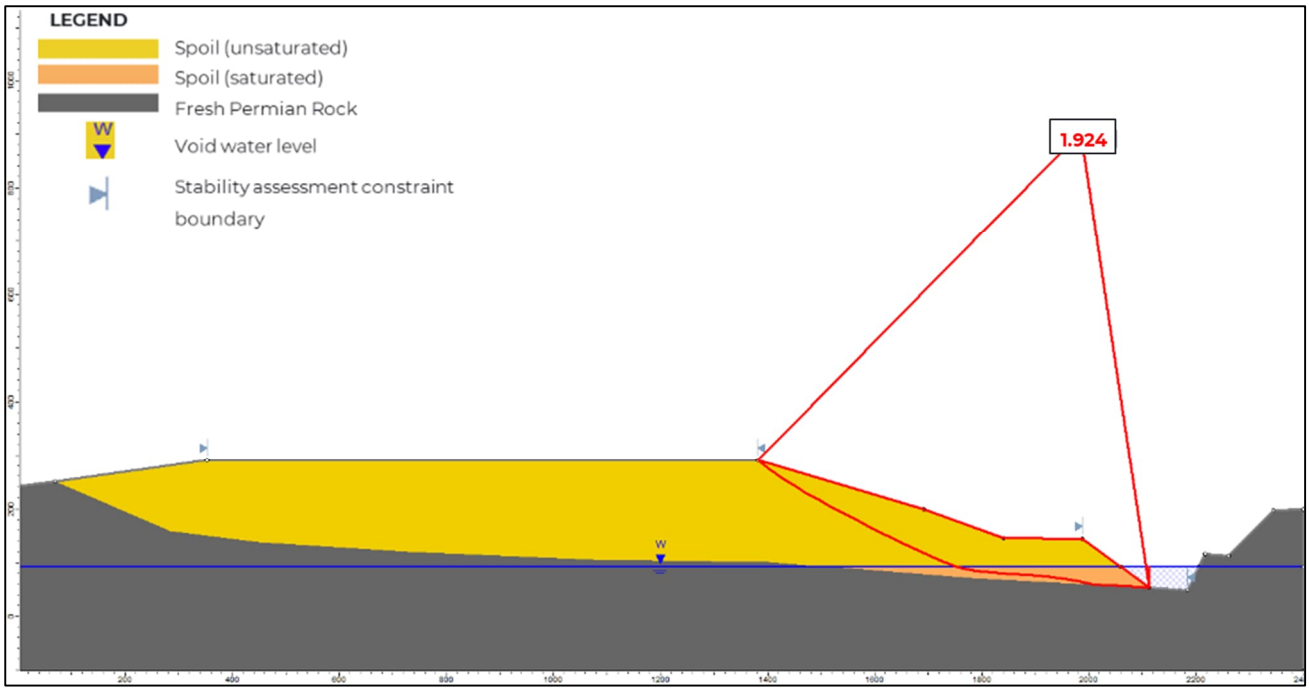

Figure 7.3 Lotus/Campbell residual void (cross-section 1) – global stability (Morgenstern-Price, non-circular)

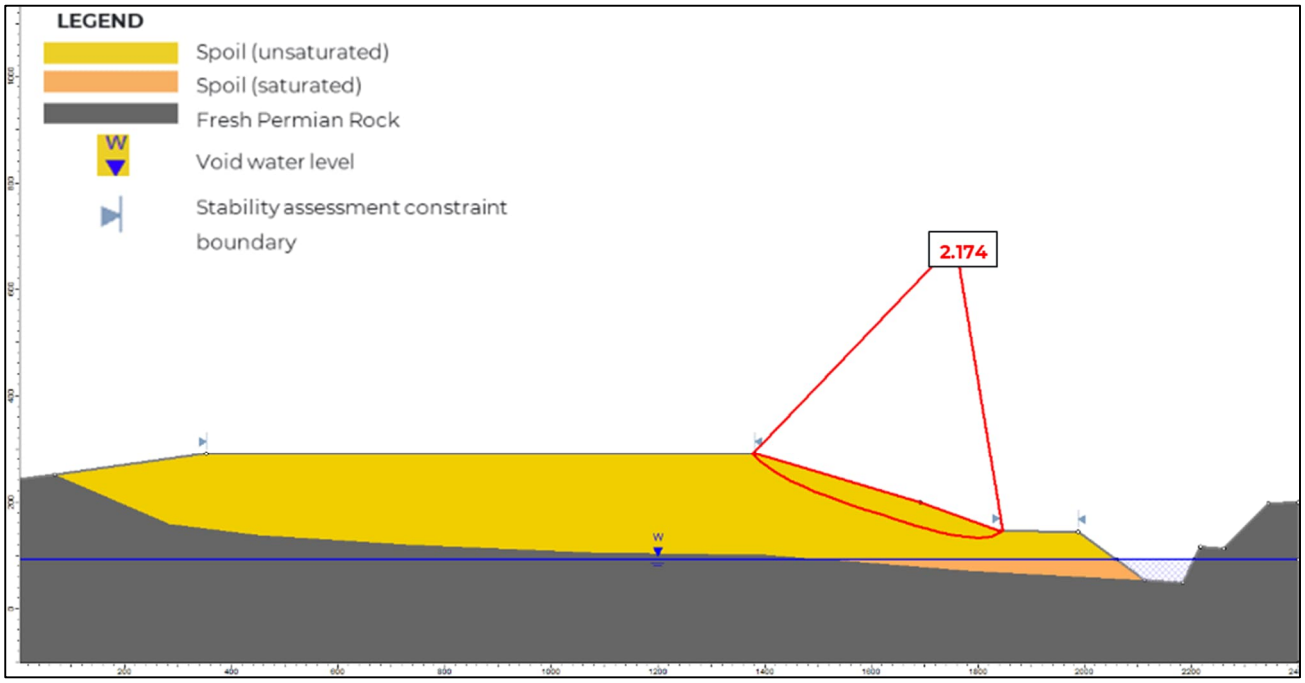

Figure 7.4 Lotus/Campbell residual void (cross-section 1) – local stability (Morgenstern-Price, non-circular)

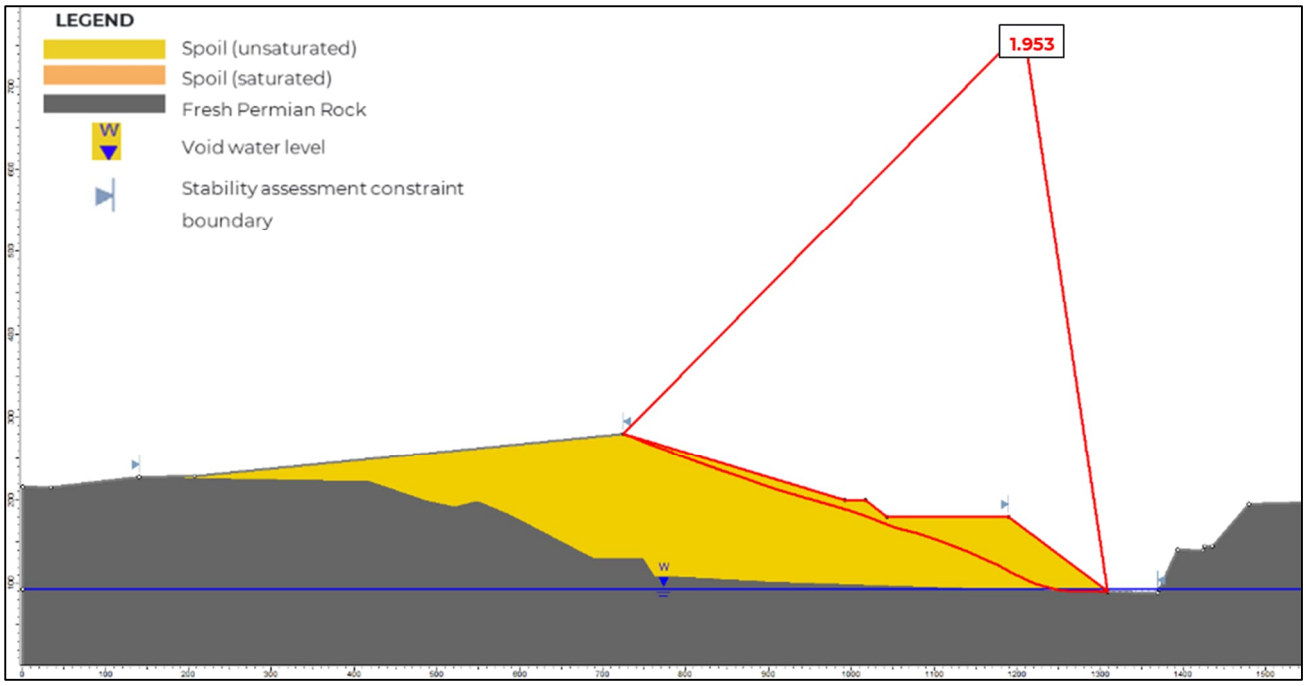

Figure 7.5 Lotus/Campbell residual void (cross-section 2) – global stability (Morgenstern-Price, non-circular)

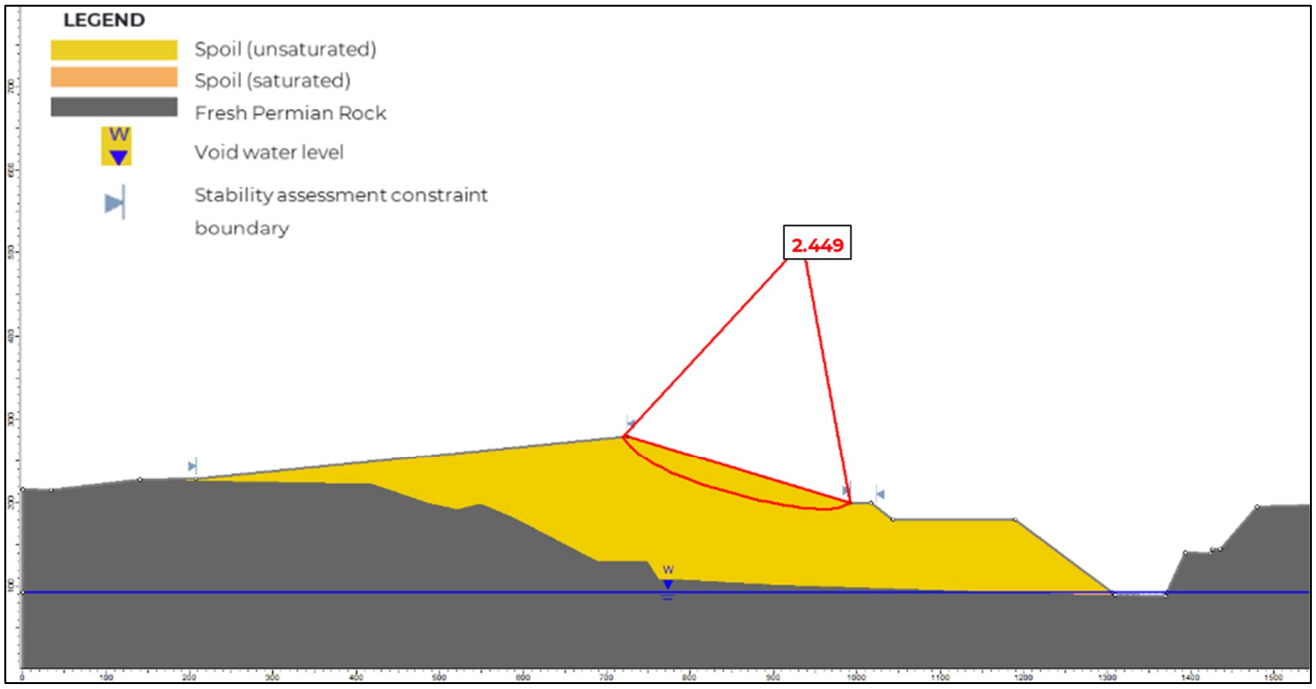

Figure 7.6 Lotus/Campbell residual void (cross-section 2) – local stability (Morgenstern-Price, non-circular)

7.2.2 Gilbert residual void

The geotechnical stability assessment for Gilbert residual void (cross-section 3) 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 7.8, and depicted in Figure 7.7 and Figure 7.8.

Table 7.8 Summary of low-wall stability analysis results for Gilbert residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety [a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
3	265	2.8	3.1

[a] Morgenstern-Price, non-circular

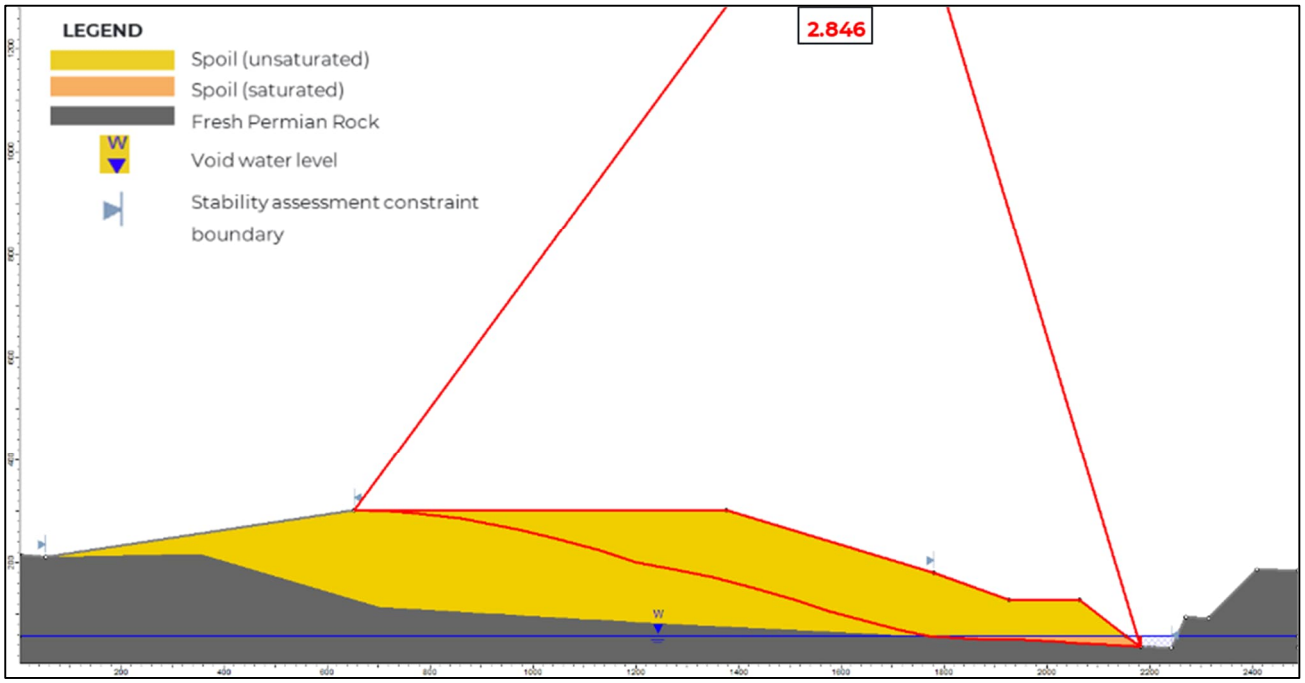

Figure 7.7 Gilbert residual void (cross-section 3) – global stability (Morgenstern-Price, non-circular)

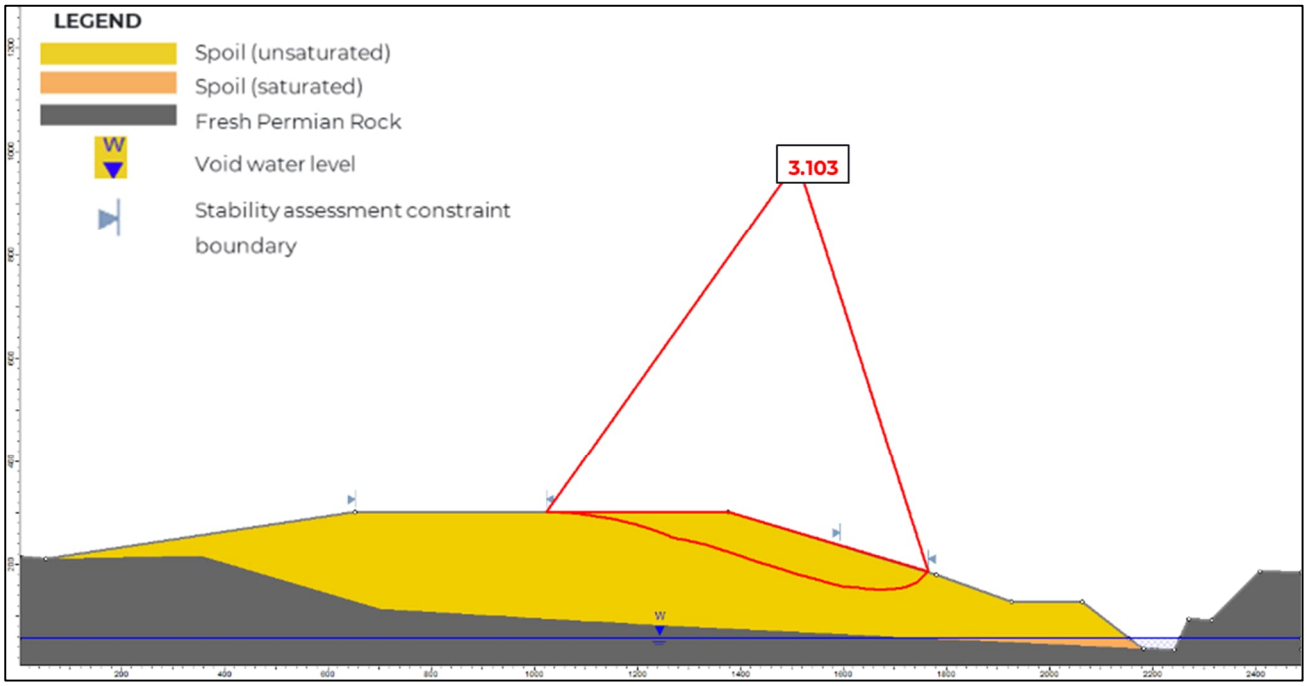

Figure 7.8 Gilbert residual void (cross-section 3) – local stability (Morgenstern-Price, non-circular)

7.2.3 Price/Leichhardt residual void

The geotechnical stability assessment for the Price/Leichhardt residual void (cross-section 4 and 5) 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 for cross-section 5. For cross-section 4, inclusion of management measures such as benching of the slope or buttressing at the low-wall toe met the minimum FoS of 1.5. Increasing the set-back distance will also meet the minimum FoS of 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 are provided in Table 7.9, and depicted in Figure 7.9 to Figure 7.14.

Table 7.9 Summary of low-wall stability analysis results for Price/Leichhardt residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)[a]
4	72	1.3[a]	1.9
4 (inc. buttress)		1.5[a]	1.9
4 (inc. bench)		1.8[a]	1.9
5	338	1.7[b]	2.4

[a] Morgenstern-Price, non-circular

[b] Sarma, non-vertical slices

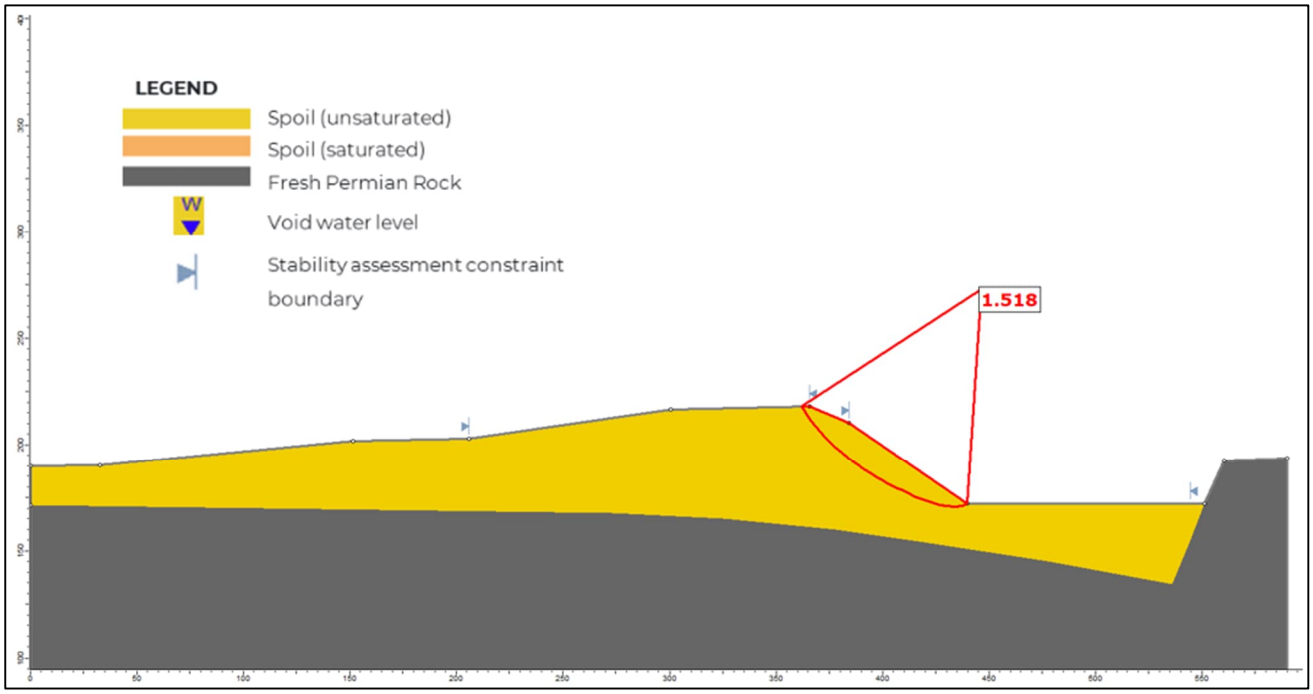

Figure 7.9 Price/Leichhardt residual void (cross-section 4: with buttress option) – global stability (Morgenstern-Price, non-circular)

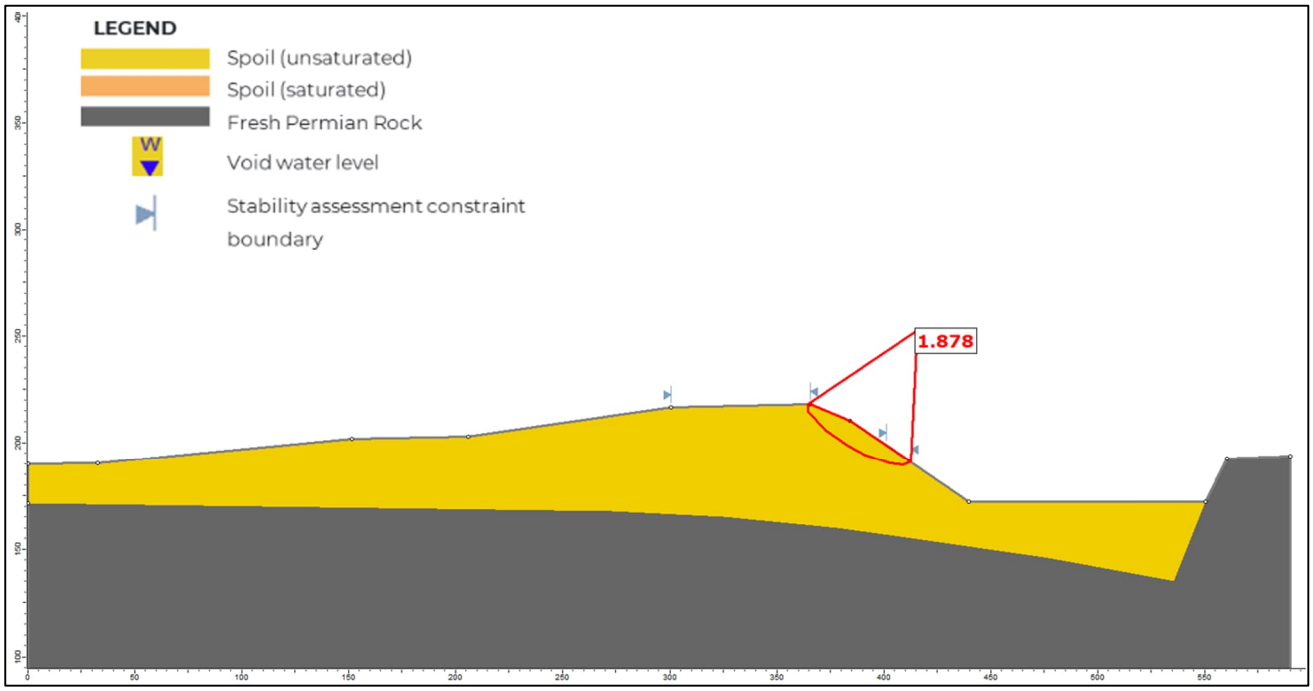

Figure 7.10 Price/Leichhardt residual void (cross-section 4: with buttress option) – local stability (Morgenstern-Price, non-circular)

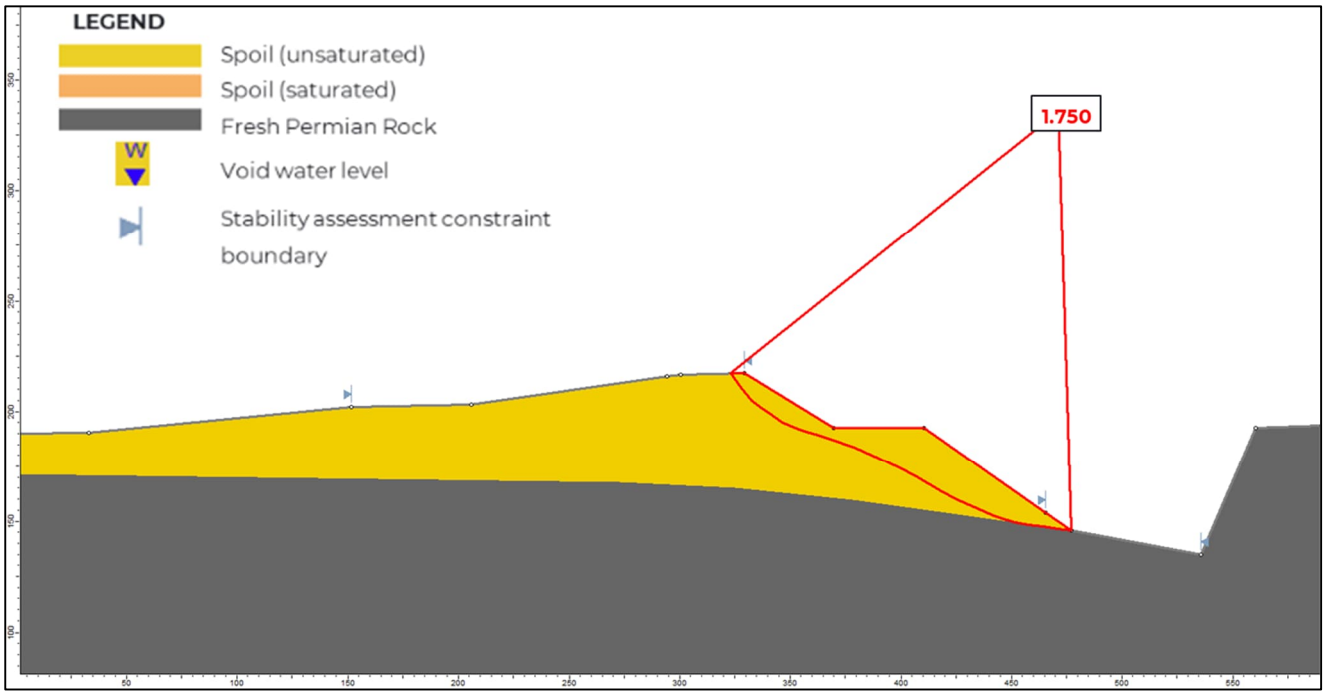

Figure 7.11 Price/Leichhardt residual void (cross-section 4: with bench option) – global stability (Morgenstern-Price, non-circular)

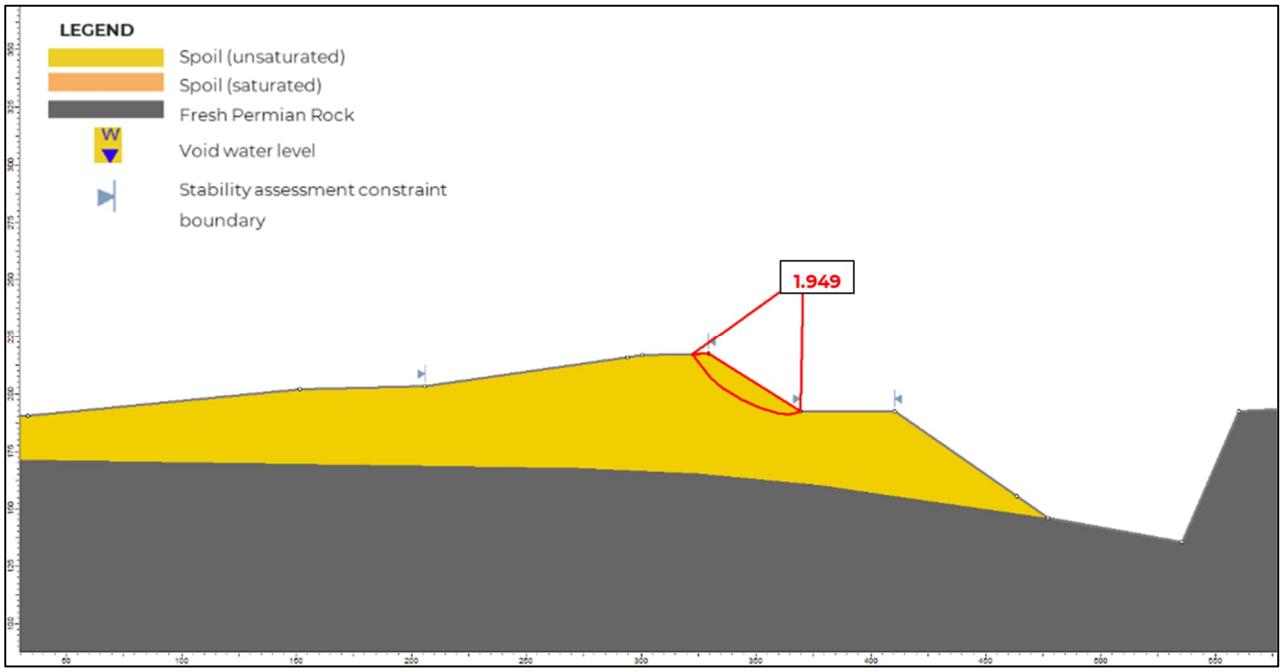

Figure 7.12 Price/Leichhardt residual void (cross-section 4: with bench option) – local stability (Morgenstern-Price, non-circular)

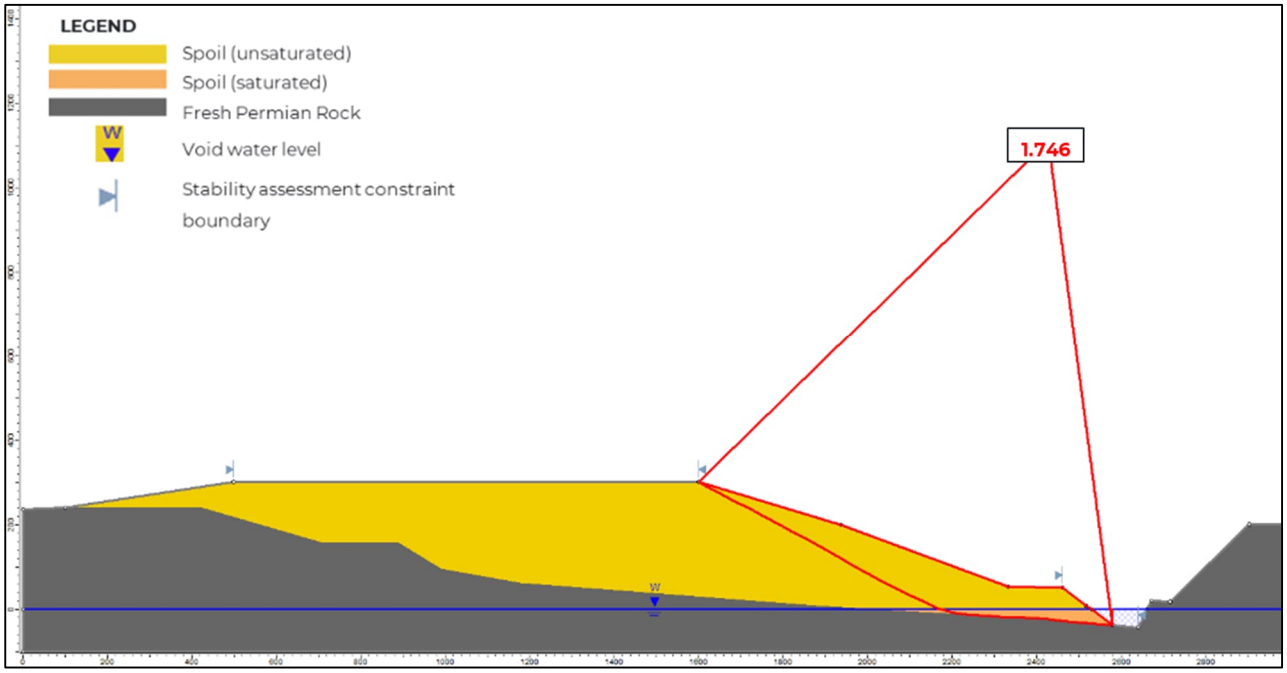

Figure 7.13 Price/Leichhardt residual void (cross-section 5) – global stability (Sarma, non-vertical slices)

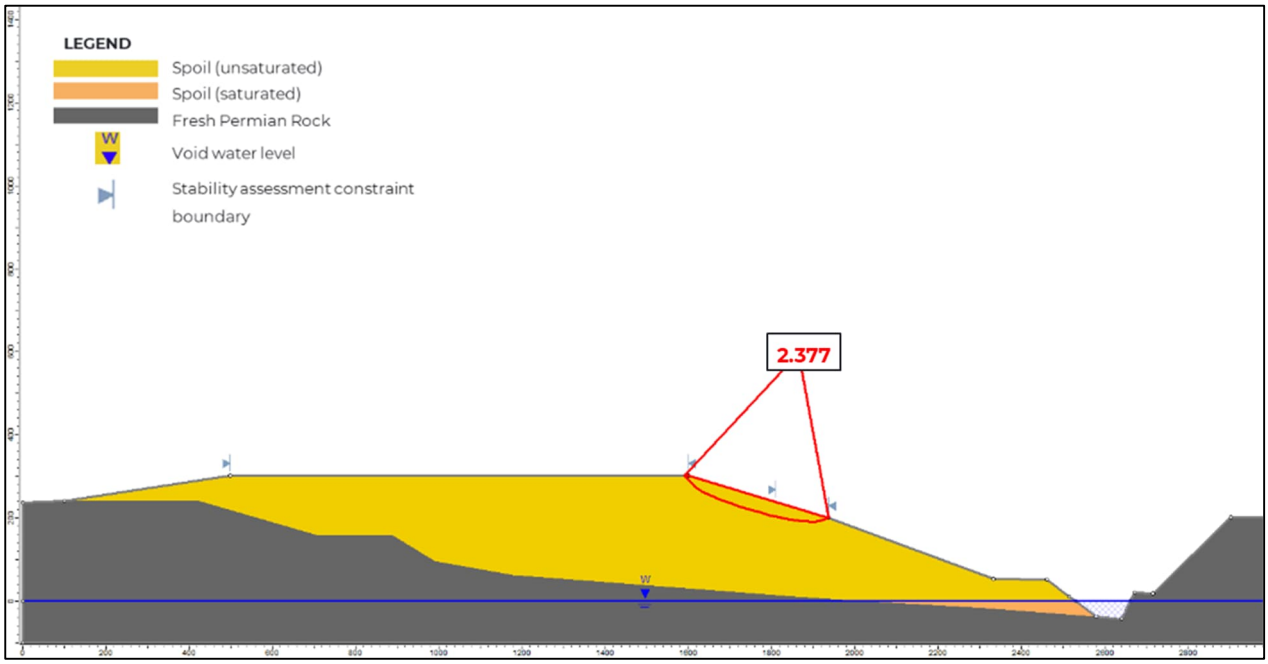

Figure 7.14 Price/Leichhardt residual void (cross-section 5) – local stability (Morgenstern-Price, non-circular)

7.2.4 East 1 residual void

The geotechnical stability assessment for the East 1 residual void (cross-section 6) 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 7.15 and Figure 7.16.

Table 7.10 Summary of low-wall stability analysis results for East 1 residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety [a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
6	170	1.8	2.4

[a] Morgenstern-Price, non-circular

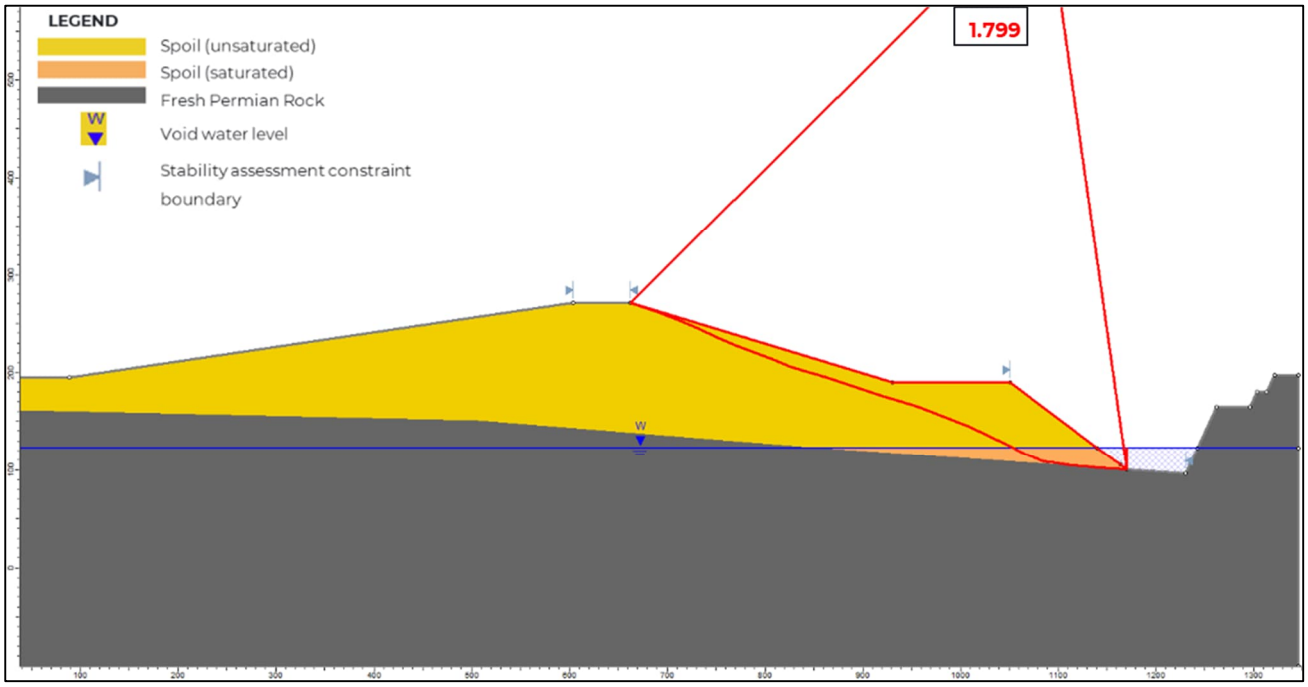

Figure 7.15 East 1 residual void (cross-section 4) – global stability (Morgenstern-Price, non-circular)

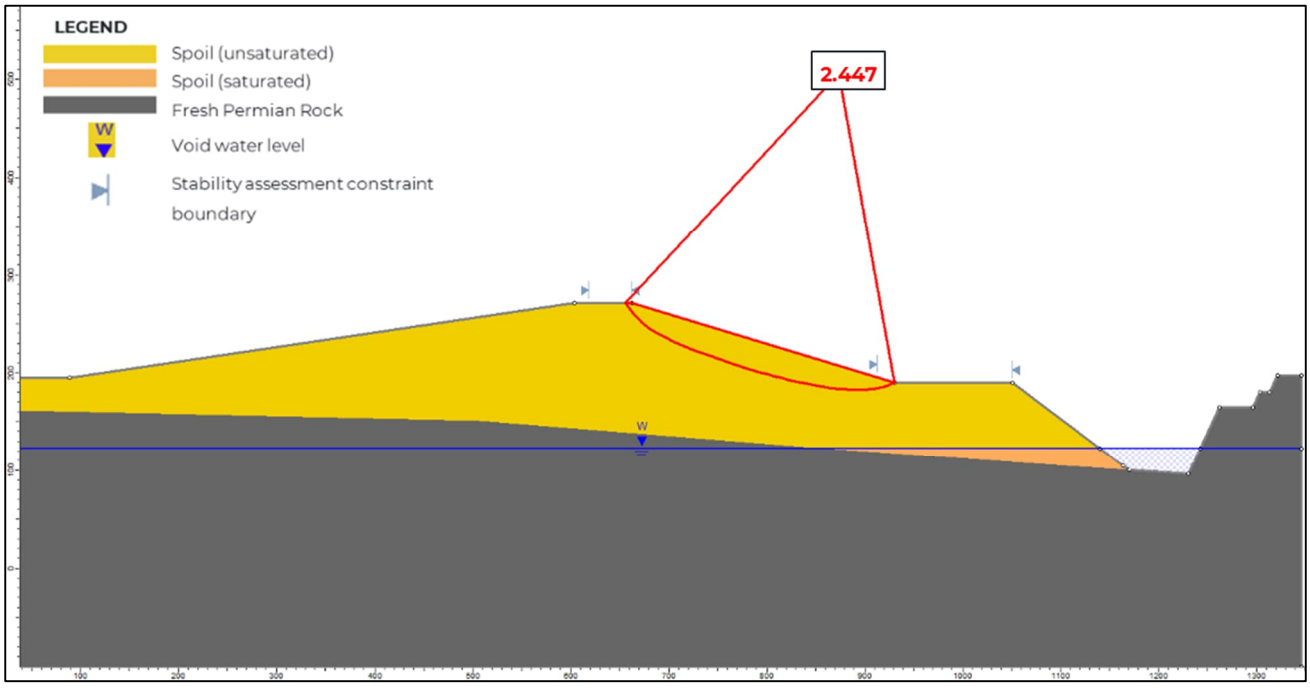

Figure 7.16 East 1 residual void (cross-section 4) – local stability (Morgenstern-Price, non-circular)

7.2.5 East 2 residual void

The geotechnical stability assessment for East 2 residual void (section 7) 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 7.11, and depicted in Figure 7.17 and Figure 7.18.

Table 7.11 Summary of low-wall stability analysis results for East 2 residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety [a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
7	114	1.8	2.9

[a] Morgenstern-Price, non-circular

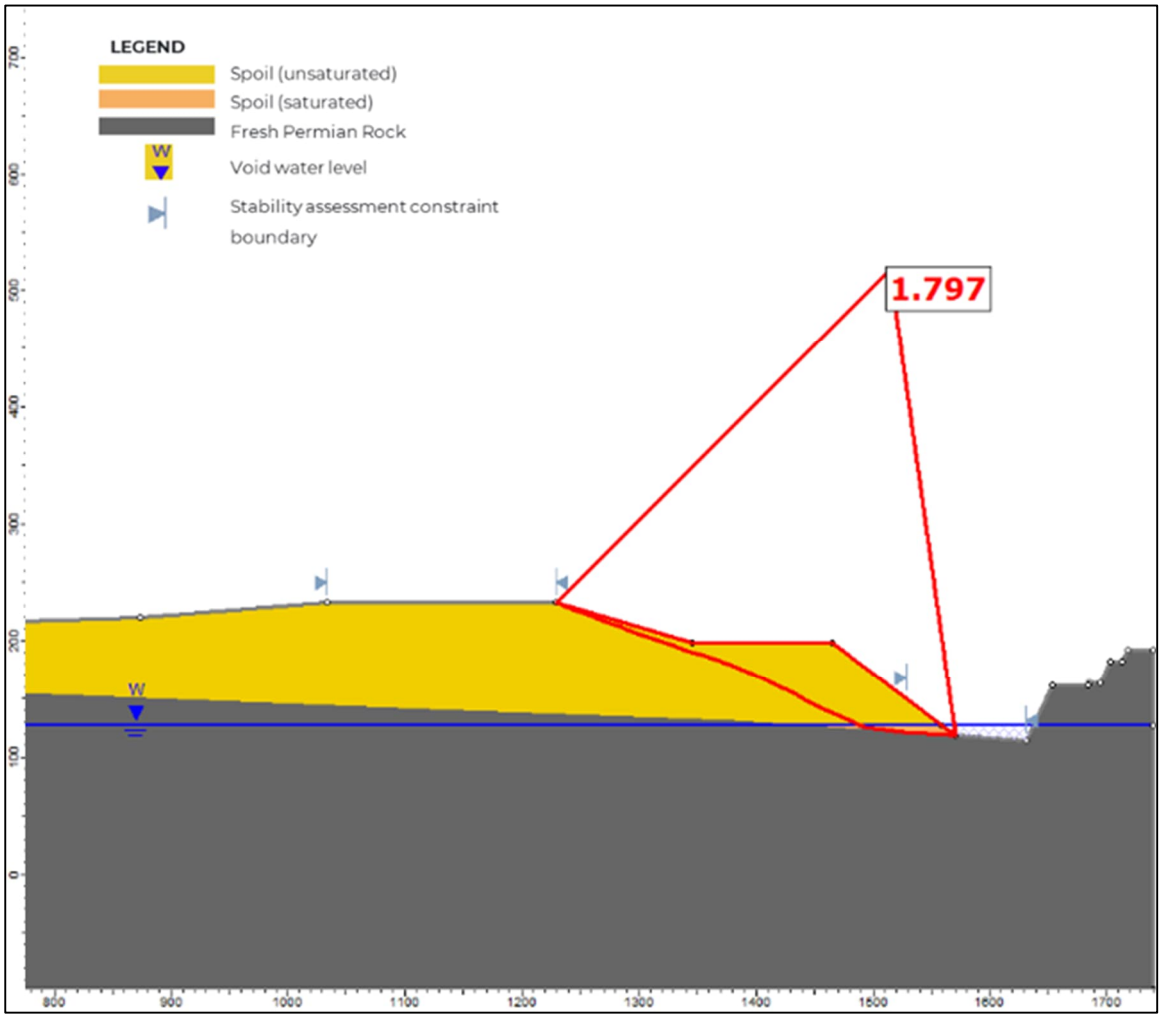

Figure 7.17 East 2 residual void (cross-section 7) – global stability (Morgenstern-Price, non-circular)

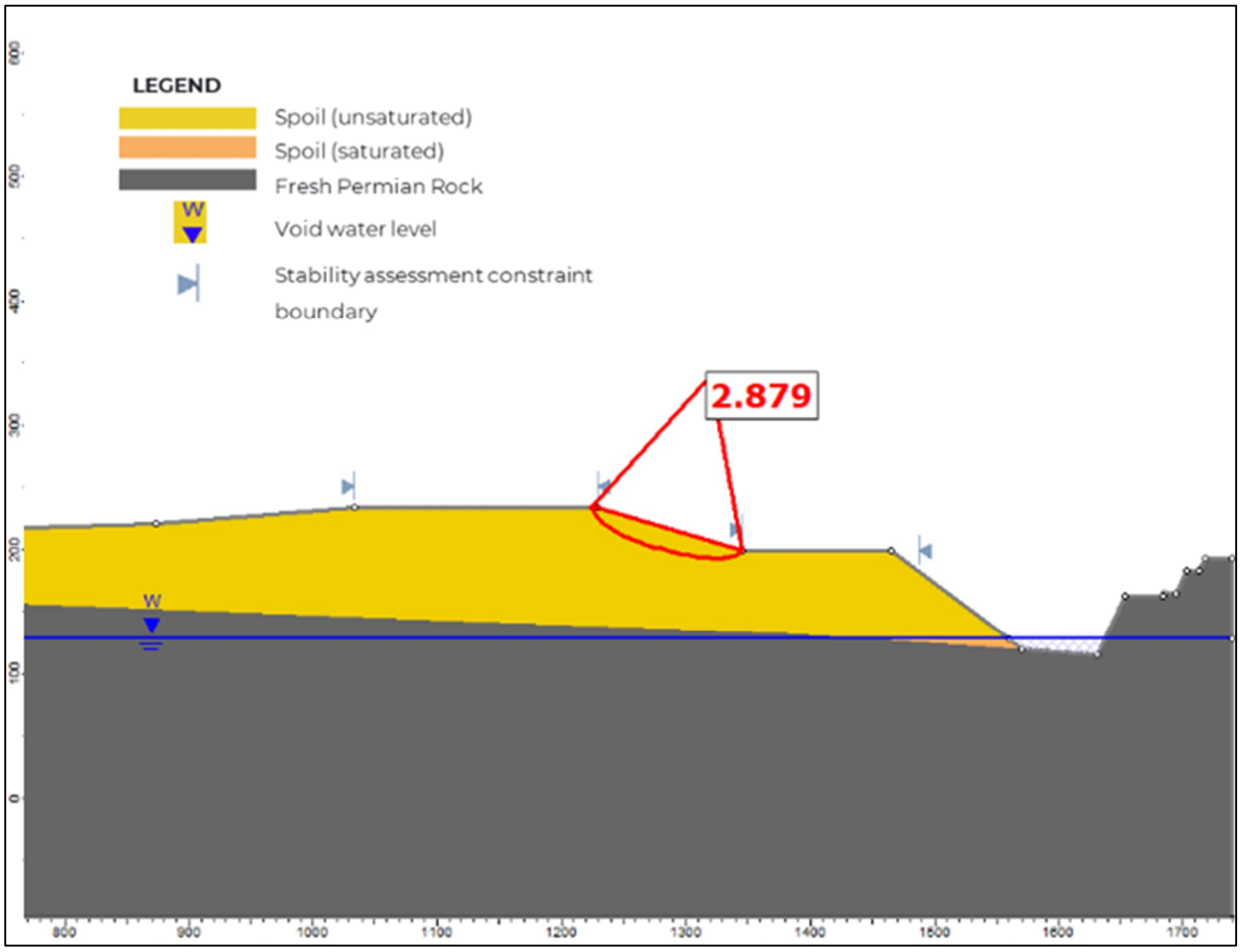

Figure 7.18 East 2 residual void (cross-section 7) – local stability (Morgenstern-Price, non-circular)

7.2.6 *Roper 1 residual void*

Although the Roper voids are the subject of additional studies, the initial geotechnical stability assessment for Roper 1 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 7.12, and depicted in Figure 7.21 and Figure 7.22.

Table 7.12 Summary of low-wall stability analysis results for Roper 1 residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety [a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
8	63	1.5	3.2

[a] Morgenstern-Price, non-circular

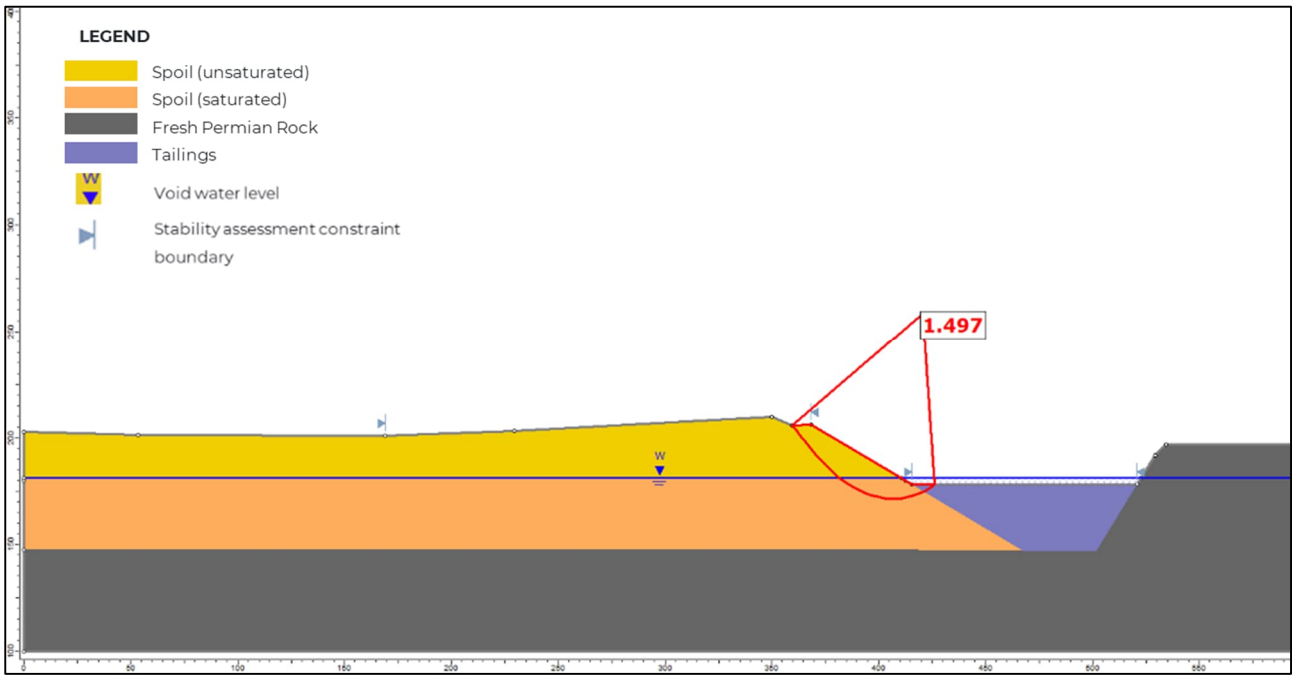

Figure 7.19 Roper 1 residual void (cross-section 8) – global stability (Sarma non-vertical slices)

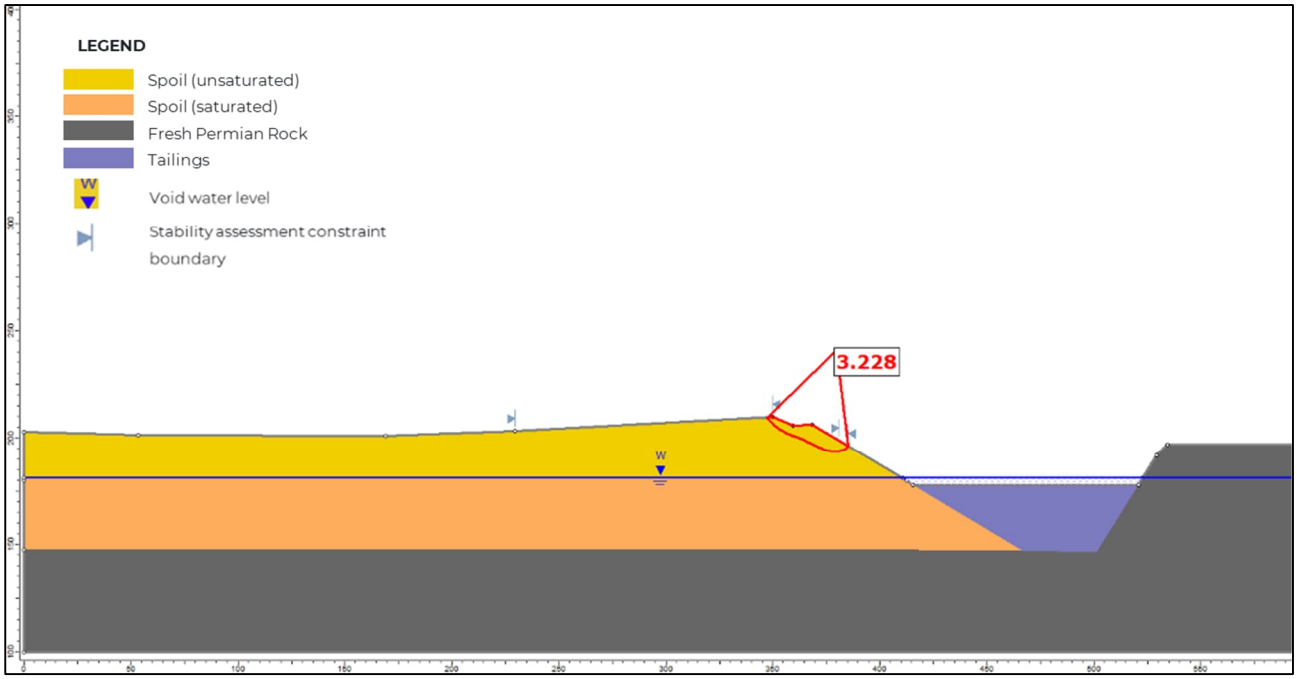

Figure 7.20 Roper 1 residual void (cross-section 8) – local stability (Sarma non-vertical slices)

7.2.7 Roper 4 residual void

Although the Roper voids are the subject of additional studies, the initial geotechnical stability assessment for Roper 4 residual void (section 9) 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 with inclusion of management measures such as increasing the set-back distance or buttressing at the low-wall toe.
- 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 are provided in Table 7.12, and depicted in Figure 7.21 and Figure 7.22.

Table 7.13 Summary of low-wall stability analysis results for Roper 4 residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety[a]	
		Overall slope (global stability)	Slope outside NUMA (local stability)
8	84	1.1	14.9
8 (inc. increased set-back)	84	1.5	14.9

[a] Sarma, non-vertical slices

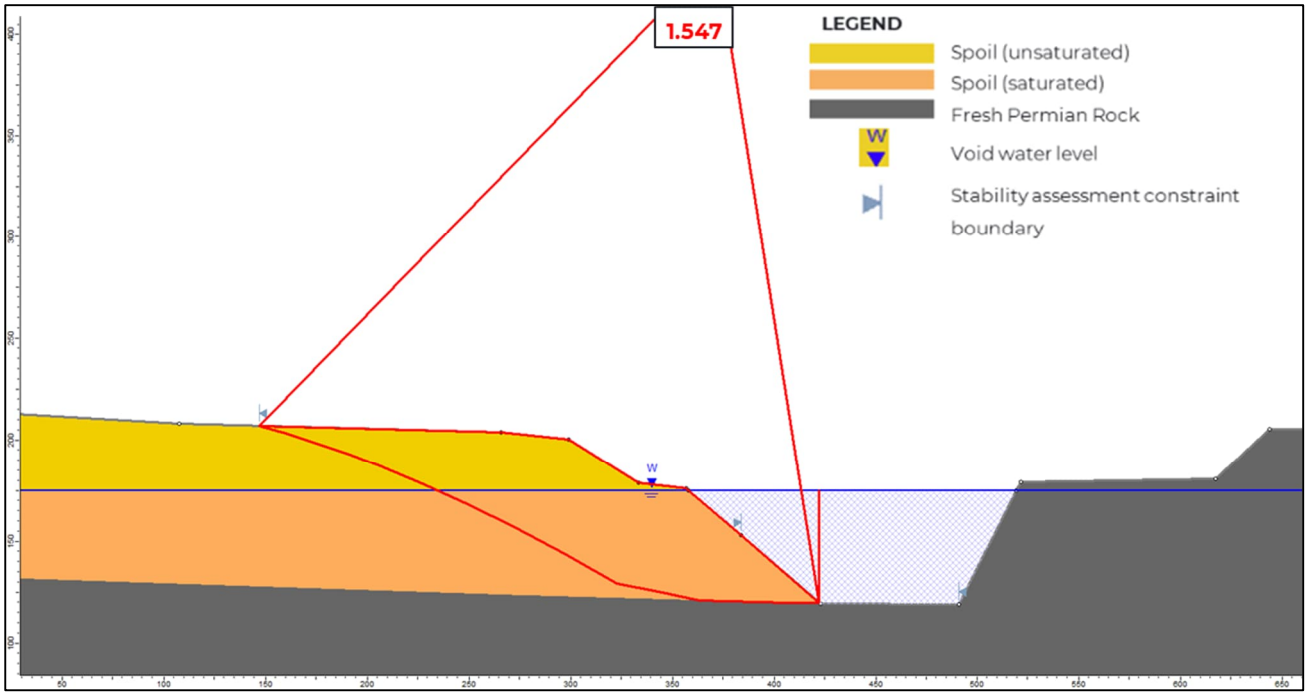

Figure 7.21 Roper 4 residual void (cross-section 8: increased set-back distance) – global stability (Sarma non-vertical slices)

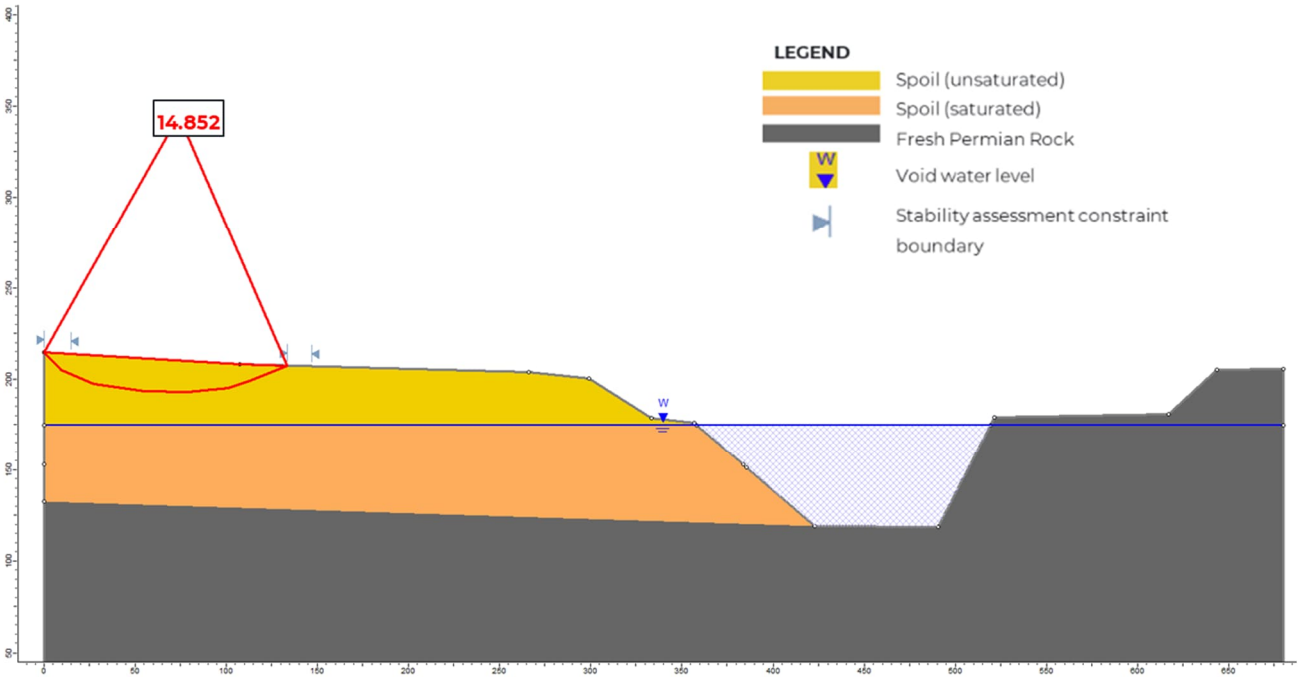

Figure 7.22 Roper 4 residual void (cross-section 8: increased set-back distance) – local stability (Sarma non-vertical slices)

7.2.8 Assumptions

The following assumptions were made and used to inform the low-wall geotechnical stability assessments:

- The current assessment of stability of the low-wall final closure state landform at NPM is preliminary in nature. It has been based on inputs and assumptions that will be reviewed and verified as mining approaches the final void limits and more geological and geotechnical data becomes available.
- This assessment has not considered any 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 was assigned a FoS equal to 1.5 (in accordance with EA condition E3 and 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 7.14.

Table 7.14 Adopted material parameters for the NPM low-wall geotechnical assessment (BHP, 2020)

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 landforms for the NPM residual voids.

The objectives of the geochemical assessment were to:

- Predict the changes in water quality of NPM residual voids in a long-term closure scenario.
- Determine, at a conceptual level (by comparison to EA groundwater trigger values), 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 NPM residual voids (see Section 6) and covers the same timeframe: a period of 302 years post-closure (2098 through 2399) for all residual voids except those within the Roper Study Area. Within these timeframes, the water level in the void lakes reach an equilibrium.

As previously mentioned, the Roper residual voids 1 to 4 are subject to additional investigations as part of the Roper Study Area. This includes additional waste characterisation required to inform geochemical void lake water quality modelling. Hence, this geochemical assessment has not included the Roper 1 – 4 residual voids. On completion of the required additional technical studies, geochemical void lake water quality modelling will be undertaken for the Roper Study Area (see PRC Plan for more detail).

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).
- Non-carbonaceous interburden used for covering the outside of the landform interacting with rainfall/runoff.
- 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 NPM 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 high-walls were derived from the stratigraphic distribution (meterage) of each material within selected drill holes. Material that had no lithological classification (classified as unknown) was reallocated to carbonaceous and non-carbonaceous domains using the carbonaceous percentage in Table 8.1.

Table 8.1 Proportions of lithologies in the excavated NPM void walls (high-wall database)

Lithology grouping	Excavated high-wall exposure (%)			
	Lotus/Campbell	Gilbert	Price/ Leichhardt	East (1 and 2)
Weathered, non-carbonaceous	51	27	53	23
Weathered, carbonaceous/coal	3	1	<1	<1
Fresh, non-carbonaceous	38	57 (62)	31 (38)	64
Fresh, carbonaceous	3	4 (4.2)	2 (2.2)	7
Coal	5	6	7	6
Unknown	<1	5	7	-
Total	100	100	100	100
Carbonaceous %	-	8.1	7.5	-

Note: Carbonaceous % used to redistribute 'unknown' to carbonaceous and non-carbonaceous. Rescaled results are indicated in brackets.

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 undertaken on drill core material collected at NPP and source-terms were derived only for analytes that were common to all datasets.

For the derivation of the groundwater source term, groundwater data from 2004 to 2024 was used that included monitoring information from 51 monitoring bores. 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 NPM residual voids

Source term (water balance)	Comment	n	Source
Natural catchment runoff	Median of leach test results from weathered non-carbonaceous drill core samples.	417	NPM Drill core database
Rehabilitated catchment runoff (in pit spoil runoff)	Median of leach test results from fresh non-carbonaceous drill core samples (Permian interburden specified as cover material for final landform)	782	NPM Drill core database
High-wall runoff	BMA's drill core databases for NPM were used to derive source terms for each lithological domain. The median of all leach test results for each domain was combined for each pit in the proportions of their high-wall exposure.	1,525	NPM Drill core database
Groundwater inflow	Median water quality from NPM groundwater database; assumed pe = 4.0	381	NPM Groundwater database
Rainfall	Pure water equilibrated with atmospheric CO_2	-	-

Notes: '-' indicates not available; n= number of samples; pe = electron activity expressed in factors of 10: pE = -log(e-)

Table 8.3 Summary of geochemical source terms (median results) derived from NPM's data sources

Parameter	Unit	NPM drill core leach test data					Groundwater	Rainfall
		Coal	Carbonaceous	Fresh non-carbonaceous	Weathered carbonaceous	Weathered non-carbonaceous		
pH	pH units	8.6	9.2	9.2	7.65	8.6	7.52	5.5
Log of electron activity (pe) [1]		8.0	8.0	8.0	8.0	8.0	4.0	8.0
Alkalinity	mg $CaCO_3$/L	22	42	61	9	82	448	-
Calcium (Ca)	mg/L	2	0.5	0.5	1	4	101	-
Magnesium (Mg)	mg/L	0.5	0.5	0.5	1	4	212	-
Sodium (Na) [3]	mg/L	25	40.5	45	51	69	1,000	-
Potassium (K)	mg/L	0.5	2	8	2	2	5	-
Chloride (Cl) [3]	mg/L	5.5	6.5	8	35	54	1,400	-
Fluoride (F)	mg/L	0.1	0.3	0.4	0.1	0.4	0.2	-
Sulphate (SO_4)	mg/L	28.5	30.5	23	50	27	305	-
Nitrate (NO_3)	mg/L	0.005	0.005	0.005	0.03	0.025	0.005	-
Aluminium (Al)	mg/L	0.09	0.15	0.15	0.34	0.08	0.005	-
Silver (Ag)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	-
Arsenic (As)	mg/L	0.0005	0.009	0.019	0.0005	0.001	0.001	-
Boron (B)	mg/L	0.05	0.05	0.05	0.05	0.05	0.5	-
Barium (Ba)	mg/L	0.006	0.006	0.007	0.013	0.0185	0.062	-
Beryllium (Be)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	-
Cadmium (Cd)	mg/L	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	-
Cobalt (Co)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.03	-
Copper (Cu)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.003	-
Chromium (Cr)	mg/L	*0.0005*	*0.0005*	*0.0005*	*0.0005*	0.002	0.003	-
Iron (Fe)	mg/L	0.025	0.025	0.025	0.16	0.025	0.335	-
Mercury (Hg)	mg/L	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	-

Parameter	Unit	NPM drill core leach test data					Groundwater	Rainfall
		Coal	Carbonaceous	Fresh non-carbonaceous	Weathered carbonaceous	Weathered non-carbonaceous		
Manganese (Mn)	mg/L	0.001	0.0005	0.0005	0.004	0.002	0.098	-
Molybdenum (Mo)	mg/L	0.007	0.0295	0.031	0.002	0.002	0.0005	-
Nickel (Ni)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0405	-
Phosphorous (P)	mg/L	0.5	0.5	0.5	0.5	0.5	0.055	-
Lead (Pb)	mg/L	*0.0005*	*0.0005*	*0.0005*	*0.0005*	*0.0005*	*0.0005*	-
Antimony (Sb)	mg/L	0.0005	0.002	0.003	0.0005	0.0005	0.0005	-
Selenium (Se)	mg/L	0.005	0.01	0.005	0.01	0.005	0.005	-
Silicon (Si)	mg/L	-	-	-	-	-	10.8	-
Strontium (Sr)	mg/L	0.051	0.0315	0.018	0.03	0.0835	2.385	-
Thorium (Th)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	-
Titanium (Ti)	mg/L	0.005	0.005	0.005	0.02	0.005	0.005	-
Thallium (Tl)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	-
Uranium (U)	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.003	-
Vanadium (V)	mg/L	0.005	0.005	0.01	0.005	0.01	0.005	-
Zinc (Zn)	mg/L	*0.0025*	*0.0025*	*0.0025*	*0.0025*	*0.0025*	0.048	-
No. of samples		32 to 417	3 to 16	72 to 782	30 to 214	25 to 96	18 to 381	-
Charge % error		-0.02%	-0.02%	+0.03%	+0.02%	+0.004%	+1.14%	-
Used to represent:		**High-wall runoff**	**High-wall runoff**	**High-wall, rehabilitation area and spoil runoff**	**High-wall runoff**	**High-wall and natural catchment runoff**	**Groundwater inflow**	**Direct rainfall**

Notes:

'-' indicates not measured; treated as a concentration of zero.

italics indicate a median result that is equal to or less than the limit of reporting (LOR), following substitution of LOR with 0.5 LOR.

8.1.3 Geochemical model approach and development

The geochemical model was run for major cations, anions, and selected metal(loid)s per the availability of data.

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 (US EPA, 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 being 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 geochemical model:

- At all times, the void lake is fully mixed, geochemical reactions occur within the modelled timestep and are not kinetically controlled. Mineral precipitates are retained within the void lake.
- Solute release from high-wall rock and spoil does not occur below the 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.
- There is no outflow from the void to the groundwater system as the voids act as groundwater sinks (noting Roper 1 – 4 are not included in this geochemical assessment).
- 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 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 geochemical controls 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 requirements 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 EA EC values specified in Table I2 of the EA applying a 0.67 factor (considered acceptable for freshwater). It should be noted that Table I2 relates to trigger values for groundwater (Table 8.5). The WBM and groundwater model outcomes indicate that the NPM residual voids modelled for water quality will behave as post-closure groundwater sinks. Therefore, the comparison of the water quality model outcomes against the EC and pH range of values from Table I2 of the EA are for interpretive purposes only, as no modelled groundwater outflows from the modelled residual void lakes are expected.

Table 8.5 Trigger value ranges from Table I2 of the EA considered for comparison of the NPM water quality modelling results

Parameter	Groundwater trigger value range
TDS* (mg/L)	4,992 – 10,599
pH (pH units)	6.5 – 8.5

*TDS calculated from EC assuming a conversion factor of 0.67

The results of the geochemical modelling for the modelled residual void lakes at NPM for EC 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 void water quality in the modelled NPM 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. TDS concentrations retain a 20-year cyclicity from the WBM with minor seasonal variation. Brackish to mildly saline conditions develop in Lotus/Campbell, Gilbert and Price/Leichhardt residual voids. Brackish to hyper-saline conditions develop in the East 1 and East 2 residual voids.

TDS concentrations for Price/Leichhardt residual void remain below the upper trigger value range (10,599 mg/L) for the modelled period regardless of whether geochemical controls are applied or not. Lotus/Campell residual void's TDS concentrations also remain below the upper range for much of the modelled period regardless of whether geochemical controls are applied or not. Gilbert residual void remains below the upper range for approximately the initial 150 years post-closure. East 1 and 2 residual void TDS concentrations are elevated above the upper range for TDS early in the modelling simulation period (Figure 8.1).

The TDS concentrations are all modelled to increase throughout the simulation; however, the rate of TDS increase is largest within the East 1 and East 2 residual voids. None of the residual voids achieve an equilibrium TDS water quality composition.

TDS concentrations are lower in simulations with geochemical controls due to the removal of calcium, magnesium and dissolved inorganic carbon through magnesite and calcite precipitation. Geochemical controls do not lead to an 'equilibrium' state for water quality (i.e., constant TDS). Other mineral phases predicted to precipitate do not significantly affect TDS.

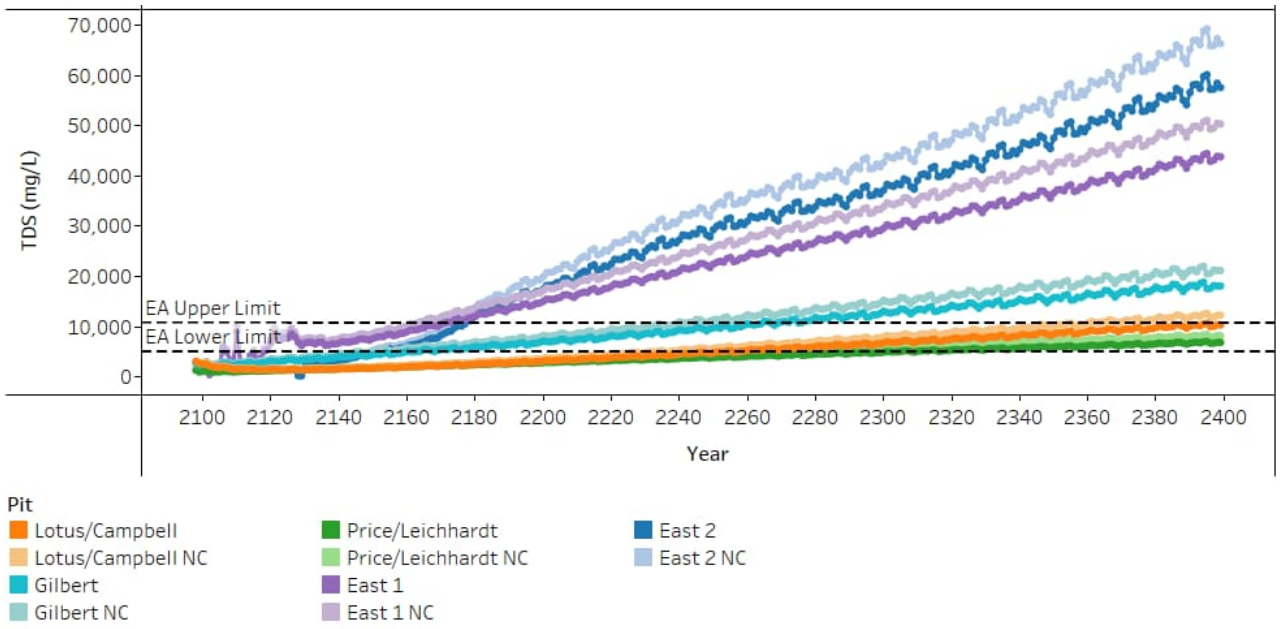

Figure 8.1 Summary of predicted TDS conditions in the NPM residual voids (NC = no geochemical controls)

pH:

Acidic conditions are unlikely to form within any of the modelled NPM residual voids. The modelled pH remains within the pH trigger value range (6.5 – 8.5) for the duration of the simulation for the majority of the NPM residual voids, regardless of whether geochemical controls are applied or not. The pH within Lotus/Campbell and Price/Leichhardt residual voids is slightly elevated above the upper range early in the simulation period where geochemical controls are applied (Figure 8.2).

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 CO_2 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.

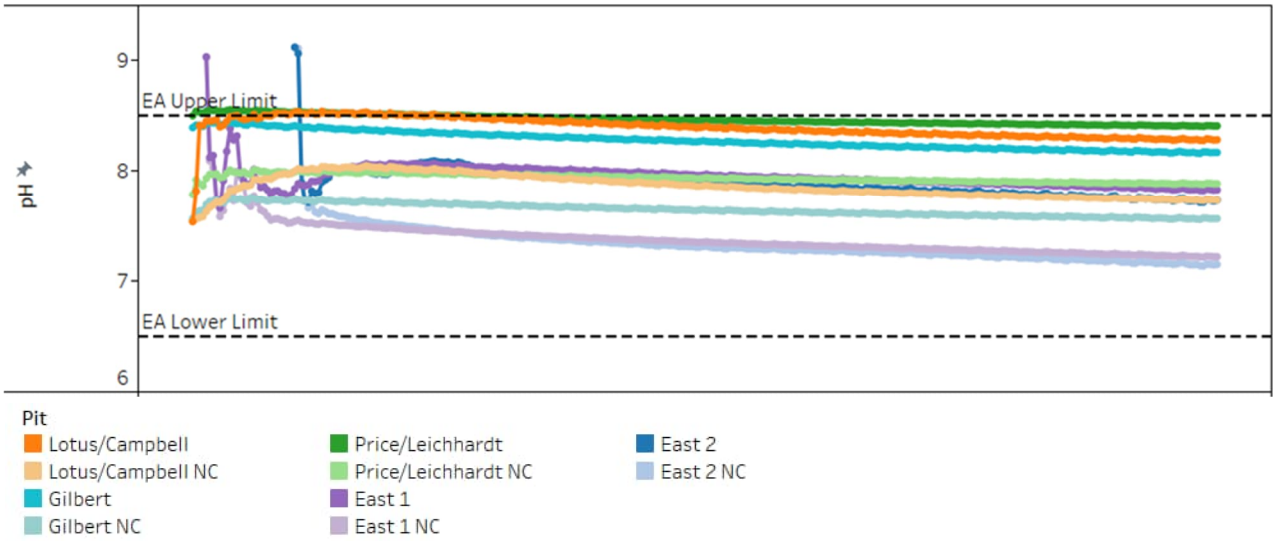

Figure 8.2 Summary of predicted pH conditions in the NPM residual voids (NC = no geochemical controls)

Stratification:

The steep sides of the voids and the maximum water depth (ranging from approx. 16 to 82 m) present favourable conditions for stratification in all voids except Price/Leichhardt. Water of higher density (cooler or more saline) may potentially 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, in relation to the TDS and pH modelling, for the NPM residual voids:

- Available data at the time of modelling was used to represent relevant geochemical interactions. Availability of additional data in future may result in different model outputs.
- Water movements are based on complementary studies (groundwater and water balance). These studies constrain the model duration and the water sources. Most notably, it is currently not possible to quantify in-pit seepage through spoil.
- Screening was performed against EA criteria for groundwater contaminant trigger values. The criteria for TDS were derived from the EA EC value using a 0.67 factor that is considered acceptable for freshwater.
- The Roper Study Area has been excluded from this geochemical void lake water quality modelling due to lack of geochemical data available in the area..

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 the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 residual voids. These void lake levels are modelled to equilibrate below both the base of shallow geologic formations and recovered groundwater levels in the deeper geology for these residual voids.
- Continued evaporation from the void lakes following stabilisation of lake levels and groundwater will result in ongoing groundwater inflow to the Lotus/Campbell, Gilbert, Price/Leichhardt, East 1 and East 2 residual voids (i.e., the listed residual voids will act as terminal sinks). Groundwater outflows are not predicted in the long-term (i.e., >39 years post-mining). The residual voids continue to capture infiltration of rainfall through the in-pit spoil dumps.
- Iterative model outputs between the numerical groundwater model and the WBM indicate an appropriate level of convergence was achieved for the Lotus/Campbell, Gilbert, Price/Leichhardt residual voids. Despite reasonable efforts, the WBM and numerical groundwater model for the Roper and East 1 and 2 residual voids did not achieve the same level of convergence. A refined understanding of the drivers and interactions between surface water and groundwater associated with these voids is required to determine any management strategies that may be needed to manage the potential risks associated with the Roper residual voids in the final closure landform. This will be addressed as part of the detailed studies for the Roper Study Area and outlined in the PRC Plan Schedule.
- No additional impact beyond the mining-related groundwater drawdown at the end of mining is expected on surficial aquifers, including the shallow geological formation, and minimal impact on environmental or anthropogenic receptors (e.g. water extraction bores) is expected.
- WBM results predict that residual voids at NPM are at low risk of overtopping for the modelled scenarios. Roper 1 and 3 residual voids intermittently fill and dry out; however, the maximum modelled void water level is well below the spill elevations for these voids. The remaining NPM 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 NPM residual voids

Residual void	Mean void water elevation (m AHD)	Mean void water volume (megalitres)
Lotus/Campbell	92	13,900
Gilbert	57	6,549
Price/Leichhardt	0	15,741
East 1	122	1,937
East 2	126	365
Roper 2	188	560
Roper4	177	18,593

- The final closure state landforms have been designed such that the geotechnical stability for the low-walls of the Lotus/Campbell, Gilbert, East 1, East 2 and Roper 1 residual voids achieved a FoS ≥1.5. Therefore, the low-walls of the final closure state landforms can be considered stable for these residual voids.

- Price/Leichhardt and Roper 4 residual voids require the inclusion of management measures during final closure state landform design to achieve a FoS ≥1.5. Therefore, the low-walls for these residual voids can be considered stable following the inclusion of management measures to the final closure state landforms.
- 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 NPM 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 NPM are not subject to inundation from floodwaters up to and including the 0.1% AEP under the upper climate change rainfall intensity event.
- Monitoring and maintenance of the residual voids in accordance with the relevant section of the PRC plan is expected to be restricted to the following:
    - Monitoring and maintenance of exclusion fences/bunds to ensure these remain effective.
    - Groundwater and residual void lake level monitoring to confirm the voids are progressing towards acting as sinks.
- All nine NPM 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.
- A targeted study of the Roper Study Area has been incorporated into the milestone criteria of the PRCP Schedule. Outcomes from this study will improve the understanding of void interconnectivity within the Roper voids and the groundwater. The study will identify any further management strategies (if required) to manage potential risks and minimise the potential of environmental harm from the Roper residual voids in the final closure landform.

Table 9.2 NPM 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 – all residual voids	✓	-	— 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. — Set-backs are included within the NUMA extent to ensure stability and that no assets (BMA, third-party, or areas of significant environmental value) are retained within this boundary at closure.	— As mining approaches the final limits, re-assess the geotechnical wall designs and 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 of 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).

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
Void hydrology (excluding Roper Study Area)	✓	✓	— All NPM final residual voids in the final closure state landform are not modelled to be 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 modelled water levels remain below the shallow geologic formations for all NPM residual voids (and well below the voids' spill points), the voids are not predicted to overtop and environmental harm beyond that of the void itself is not expected. Therefore, no management activities required. — The modelled long-term mean void lake levels for the NPM residual voids remain below modelled recovered groundwater levels. This provides an available storage capacity for these voids to keep acting as long-term sinks (based on average gradients). <u>For Lotus/Campbell residual void:</u> — After 2210 mean water levels start to stabilise, with simulated mean inflows of 1,048 ML/year being equal to the mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For Gilbert residual void:</u> — After 2220 mean water levels start to stabilise, with simulated mean inflows of 604 ML/year being very similar to the mean outflows of 605 ML/year. This indicates that the mean water balance has reached an equilibrium.	— Residual void catchments are minimised as far as practicable and predominantly include only the low-wall areas. — At cessation of mining activities, review and update the void water balance modelling, incorporating identified changes to the final closure state landforms and spill point elevations, 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		
			<u>For Price/Leichhardt residual void:</u> — After 2220 mean water levels start to stabilise, with simulated mean inflows of 936 ML/year being equal to the mean outflows. This indicates that the mean water balance has reached an equilibrium. <u>For East 1 residual void:</u> — After 2370 mean water levels start to stabilise, with simulated mean inflows of 201 ML/year being very similar to the mean outflows of 200 ML/year. This indicates that the mean water balance has reached an equilibrium. <u>For East 2 residual void:</u> — After 2310 mean water levels start to stabilise, with simulated mean inflows of 55 ML/year equal to the mean outflows. This indicates that the mean water balance has reached an equilibrium.	
Void hydrology (Roper Study Area)	✓	✓	— All NPM final residual voids in the Roper Study Area 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. — The Roper residual voids will not overtop for the scenarios modelled. The Roper 1 and 3 residual voids maximum void water levels are well below the respective spill elevations. The Roper 2 and 4 residual voids mean void water levels are well below the spill elevations for the respective voids.	— Review the drivers and interactions between surface water and groundwater associated with the voids. — On completion of the additional studies focussed on the Roper Study Area: — Review and update the void water balance modelling, incorporating any identified changes to the final closure state landforms and spill point elevations, rainfall and evaporation, surface water runoff and groundwater inflows, and climate projections. — Review and update the numerical groundwater modelling.

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
			<u>For Roper 1 residual void:</u> — Although the mean water balance has reached an equilibrium with inflows equalling outflows at 246 ML/year, the void is modelled to intermittently fill and dry out. <u>For Roper 2 residual void:</u> — After 2350 mean water levels start to stabilise, with simulated mean inflows of 265 ML/year very similar to the mean outflows of 267 ML/year. This indicates that the mean water balance has reached an equilibrium. <u>For Roper 3 residual void:</u> — Although the mean water balance has reached an equilibrium with inflows equalling outflows at 128 ML/year, the void is modelled to intermittently fill and dry out. <u>For Roper 4 residual void:</u> — After 2150 mean water levels start to stabilise, with simulated mean inflows of 2,255 ML/year very similar to the mean outflows of 2,254 ML/year. This indicates that the mean water balance has reached an equilibrium.	— If modifications to the landform are required, minimise the residual void catchments and exclude catchment as far as practicable. — If future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, implement management strategies (to be defined as part of the Roper Study Area studies). — Obtain certification from an appropriately qualified person that the residual voids will not cause environmental harm beyond the tenure boundary.

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
Void hydrogeology (excluding Roper Study Area)	-	✓	— Mining-related dewatering activities have lowered groundwater levels that will result in suppression of the water table centred on the NPM 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. — Void water levels are modelled to remain below the recovered groundwater levels for the NPM residual voids will act as groundwater sinks post-closure. — Modelling, including particle tracking, indicates that infiltration of rainfall from the spoil 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 hydrogeology (Roper Study Area)	-	✓	— Void lakes are predicted to form in the Roper 2 and 4 residual voids while Roper 1 and 3 residual voids intermittently retain water and dry out. Based on initial study outcomes, the hydraulic gradients of the Roper residual voids indicate they may develop as sources or flow through systems to groundwater.
			— Modelling, including particle tracking, indicates that most of the outward flows to groundwater from the Roper residual voids will migrate towards and be captured within the East 1 and 2 residual voids or remain within the tenure boundary, minimising the risk of environmental harm due to the proposed final closure state landform.
				— Review the drivers and interactions between surface water and groundwater associated with the voids including any potential interconnectivity within the Roper voids and the East 1 and 2 voids.
				— On completion of the additional studies focussed on the Roper Study Area and following any modifications that may be required to further manage the Roper residual voids in the final closure landform:
				  — Review and update the void water balance modelling, incorporating any identified changes to the final closure state landforms and spill point elevations, rainfall and evaporation, surface water runoff and groundwater inflows, and climate projections.
				  — Review and update the numerical groundwater modelling, incorporating updates to the WBM.
				  — Review and update the management considerations for the residual voids in the Roper Study Area.
				— 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 (excluding Roper Study Area)	-	✓	— There are no significant sources of acid generation associated with NPM's closure-related surface water hydrology, and acidic conditions are unlikely to develop in the voids. — TDS in all NPM residual voids will continue to increase over time. — Preliminary, high-level screening base on predicted TDS levels suggest that all NPM residual voids, except Price/Leichhardt may become chemically stratified. — All NPM residual voids do not present an unacceptable risk of environmental harm beyond that of the void itself as they stabilise as groundwater sinks over time.	— 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 water quality (Roper Study Area)			— Following completion of other detailed studies associated with the Roper Study Area, the Roper residual voids will be subject to additional investigations including additional waste characterisation required to inform geochemical void lake water quality modelling.	— On completion of the required additional waste characterisation of the Roper Study Area, undertake geochemical void lake water quality modelling for the Roper residual voids (if residual void lakes are evident in final closure state landform).
Void access control - all residual voids	✓	-	— 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.

Residual void closure aspect	Closure objective		Residual void closure context	Management consideration
	Safety	Env. harm		
				— Obtain certification from an appropriately qualified person that the residual void is safe to humans and livestock.

Monitoring of the residual voids will be undertaken as part of monitoring of the NUMA extents (see Monitoring Section in the PRC plan). This monitoring will aim to demonstrate achievement of sufficient improvement (final NUMA management milestone) that enables certification from an appropriately qualified person that all residual voids:

- Will not present an unacceptable risk of environmental harm outside of the tenure boundary.
- Are safe to humans and livestock.

10 Conclusion

This void closure plan provides outcomes of technical studies completed to support closure planning and achievement of sufficient improvement to the residual voids at NPM such that they are safe and not cause environmental harm – specifically the residual voids associated with Lotus/Campbell Pit, Gilber Pit, Price/Leichhardt Pit, East 1 Pit, East 2 Pit and Roper 1-4 Pit. This void closure plan is an appendix to the NPM PRC plan and has been compiled 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.

Additional studies focussed on the Roper Study Area are required to further understand the key risks and potential design limitations associated with these residual voids in the final closure landform. Outcomes from this study will be used to identify management strategies that may be required to further manage and/or control areas of potential environmental harm from the Roper residual voids in the final closure landform.

This plan (and associated supporting technical studies) may be required to be updated if amendments to the site's PRC plan are required.

11 References

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Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Severity	Preventative Controls	Likelihood Basis *(chance of the impact at the severity, taking into account the effectiveness of the preventative controls)*	Likelihood	Likelihood	RRR
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 8. Not achieving design 9. Selection of inappropriate PMLU	- Erosion - Growth media loss - Failure of vegetation - Slumping and settlement - Mass movement of landform	4	- Monitoring of landform stability and rehabilitation success to be undertaken post rehabiltiation - 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 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 tailings - Growth media assessment by AQP to determine	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 (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 of groundwater due to void lakes acting as a sink driven by evaporation from the lakes.	- Groundwater chemistry altered rendering it not suitable for extraction and/or to support the PMLU - 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	3	- All imported hazardous materials are to be stored and used in in accordance with relevant standards and removed from site on completion of mining - At the completion of operations, all stored hazardous materials and infrastructure within the MIA and CHPP, that have the potential to release contaminants to groundwater, will be removed from site - 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 conditions - 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 - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Landforms constructed to minimise the potential for flooding of the residual voids	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

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Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 creek 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. Creeks and drainage lines not attaining successful rehabilitated state	- 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 carried by surface waters, including erodability and	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	2	- All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Mine affected water dams to be decommissioned and areas rehabilitated - Surface water monitoring to be undertaken in accordance with EA conditions - Monitoring of surrounding ecosystems will be undertaken in accordance with EA conditions - A contaminated land investigation will be undertaken at the completion of operations and remediation works undertaken as appropriate - Rehabilitation of disturbed areas will be undertaken as soon as practical after land becomes available - Rehabilitation and monitoring of disturbed reaches of creeks undertaken - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Landforms constructed to minimise the potential for flooding of the residual voids	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	3
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU4	Creek 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 2. Geomorphic instability (bank erosion) 3. Seepage to/from residual voids impacting on stability 4. Sediment transport regime is not in equilibrium with and/or representative of the natural reaches 5. Poor riparian vegetation diversity and cover 6. High percentage of weeds/ invasive species 7. Poor water quality from runoff from surrounding landforms and rehabilitated areas 8. Failure of landforms impacting the performance of the diversion	- Sediment regime impacts within diversion 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 within diversion embankments and surrounding the diversion causing landform instability, damage to rehabilitation areas and alteration of diversion hydraulics - Changes to environmental flows and flood regimes impacting on surrounding land users and environmental receptors	4	- Surface water and creek 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	2	- Creek diversion monitoring to relevant IDC standard and maintenance during the operational phase - Diversion remediation designs in accordance with the DNRME 2019 hydraulic design criteria for permanent diversions - Growth media and spoil assessment by AQP to determine ameliorant and fertiliser requirements - Revegetation species aligned to growth media, landforms and PMLU - Mine infrastructure that interacts with the creek diversions 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 creek diversion to meet closure objectives is unlikely	Unlikely	0.1	3

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Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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.	- 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	5	- 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	- Cleaning up of spills upon identification - Remediation or management of residual risk - Contaminated land investigation to be undertaken at 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 PMLU - Management of operational activities to limit any potenital contamination - Create landforms that include strong groundwater sinks to manage migration of contaminants off site	The contaminated land investigation and remediation/management works will 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 capped and contained, any landfill materials capped and managed, the likelihood of contaminated land impacts preventing attainment of closure criteria is unlikely. SSM: Areas of primary concern: MIA/CHPP/TSF/MAW storages and drains. Particular focus on Roper residual voids dut to the potential for voids acting as a source to groundwater. Due to the age, duration and nature of the heavy industrial site use, remediation/management are anticipated to be required to render the site suitable for the intended PMLUs and reduce the potential for environmental harm post-mining.	Probably	0.3	30
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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	- 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	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	1	- 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	Flood modelling indicates limited flood water interaction with rehabilitated landforms and velocities outside of the creeks and diversions is unlikely to impact rehabilitated landforms. Preventative controls include decommissioning of dams and culverts that could contribute to, or impact flood conditions.	Unlikely	0.1	1
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 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	3	- 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 receeded, landform design and alteration could be undertaken to reduce possible future events.	1	- Removal of infrastructure that would adversely interfere with stream hydraulics (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 be free draining where practical	With preventative controls implemented, identified impacts associated with alteration of flood hydrology are unlikely	Unlikely	0.1	1

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Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 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	- 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 by AQP to determine ameliorant and fertiliser requirements - Amelioration and fertiliser applied as per assessment - Selective handling of materials for placement - Compliance to plan	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
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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 (ie 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 6. Generation and release of AD/SD/NMD and salinity from coal during operation accumulating in groundwater, surface water, soils	- Release of contaminates to surface and groundwater from rehabilitated landforms. - Vegetation failure - Water cannot be used by end user	5	- Monitoring of rehabilitation success to confirm stability and identify requirements for rectification works. - Maintenance and rectification works undertaken - NUMAs are acting as sinks for groundwater therefore capturing potential AMD / salinity impacted seepage from TSF/spoil piles/reject stockpiles - Spoil materials have excess buffering capacity (ie. acid neutralising capacity in excess of acid generating capacity)	1	- Material characterisation (outcomes stored into Geological database) in line with BHP Materials Management Standard (5 pillars) - Remove and / or cover undesirable materials - Ongoing sampling of tailings and rejects from processing plant - Ongoing sampling of overburden / Interburden - Appropriate material placement and selective handling during operations - 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	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 (reference PDM EA Table E1 - cattle grazing, woodland habitat and watercourse) 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 (ie 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	- Release of contaminates to surface and groundwater from rehabilitated landforms. - Vegetation failure - Erosion	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 (outcomes stored into Geological database) in line with BHP Materials Management Standard (5 pillars) - Physical and chemical characterisation of materials to be used in the construction of the cover - Installation of cover conducted in accordance with cover design - Documented compliance to plan - Cover appropriate for managing identified geochemical / physical risk - Appropriate material selected for cover - Modelling of cover performance	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 (reference PMLU table E1 - cattle grazing, woodland habitat, water course) 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. Significant exisiting rehabilitation	- 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. - Significant volume of established leucaena resulting in poor growth of preferred species	4	- Monitoring of rehabilitation success to confirm stability and identify requirements for rectification works - Rectification works undertaken e.g. repair erosion areas, retest materials, review seed mix and revegetate	1	- Growth media assessment by AQP to determine ameliorant and fertiliser requirements - Management of seed selection, provenance and quality - Plant at optimal time of year - Revegetation species aligned to growth media, landforms and PMLU	With all controls in place, including revegetating with species aligned to growth media, landforms and PMLUs, as well as ongoing monitoring and maintenance, inadequate or inappropriate revegetation is unlikely	Unlikely	0.1	1

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Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU12	Deterioration of built infrastructure conditions	1. Potential soil contamination around mine industrial areas	- Reduced soil fertility to support PMLU land capability - Potential contamination of surface water runoff affecting integrity of local catchments.	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	1	- Clean up and remediate contamination during operational period. - Undertake contaminated land assessment and remediation/management where required post mining	With all controls in place, including ongoing monitoring and maintenance, deterioration of built infrastructure is unlikely	Unlikely	0.1	1
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 - Identify requirements for rectification works.	1	- Geotechnical assessment and final void wall design to be completed by AQP - 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 equlivent landform, fencing and signage placed at FoS limit	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 by an AQP to determine FoS limit - Compliance to plan	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	- Uncontrolled capture of flood waters - Altered/changed alignment of creeks 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 completed by AQP - Flood mitigation designed to correct flood event - 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	Highly Unlikely	0.03	0.9
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	- Reduction in surface and/or groundwater quality down gradient of the site - Degradation of ecosystems interacting with impacted water - Changes to the chemistry of shallow groundwater units - Groundwater extraction/use off site impacted	5	- Groundwater monitoring - Water quality monitoring	3	- Modelling completed by AQP - Flood mitigation designed to correct flood event - Flood mitigation (partial backfill and/or landforms) installed - Landform design to enable establishment of collective groundwater sink within tenure boundary - 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