BARALABA COAL MINE

TRANSITIONAL PROGRESSIVE REHABILITATION AND CLOSURE PLAN

PREPARED FOR
Baralaba Coal Pty Ltd and Wonbindi Coal Pty Ltd

5 June 2026

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List of Abbreviations

AEP	Annual exceedance probability
AHD	Australian Height Datum
AQP	Appropriately Qualified Person
BNCOP	Baralaba North Continued Operations Project
DES	Department of Environment and Science
EA	Environmental Authority
EC	Electrical Conductivity
EIS	Environmental Impact Assessment
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
EP Act	*Environmental Protection Act 1994*
ESC	Erosion and Sediment Control
ESP	Exchangeable Sodium Percentage
EV	Environmental Value
GNP	Gaangalu Nation People
IA	Improvement areas
LGA	Local Government Area
LOD	Land outcome document
LOR	Limit of Reporting
MIA	Mine infrastructure area
ML / MLs	Mining Lease / Mining Leases
NAF	Non-acid forming
NAPP	Net acid producing potential
NC	*Nature Conservation Act 1992*
NUMA	Non-use management area
PAF	Potentially acid forming
PMF	Probable maximum flood
PMLU	Post-mining land use
PRCP	Progressive Rehabilitation and Closure Plan
RA	Rehabilitation areas
RE	Regional Ecosystem
REMP	Receiving environment monitoring program
RM	Rehabilitation milestones
ROM	Run of Mine
SCL	Strategic cropping land
SPP	State Planning Policy
SEP	Stakeholder Engagement Plan
TDS	Total dissolved solids
WEPP	Watershed Erosion Prediction project
WQO	Water Quality Objective

1 Introduction

AARC Environmental Solutions Pty Ltd (AARC) has been commissioned by Baralaba Coal Company Pty Ltd to develop a Progressive Rehabilitation and Closure Plan (PRCP) for Baralaba Coal Mine in accordance with the requirements of the *Environmental Protection Act 1994* (EP Act).

A PRCP transition notice was issued under section 754 of the EP Act by the Department of Environment and Science (DES) to the holders of Environmental Authority (EA) EPML00223213 for the Baralaba Coal Mine on 18 August 2021.

This transitional PRCP has been developed in accordance with sections 126C and 126D of the EP Act and with the requirements of the Progressive Rehabilitation and Closure Plan Guideline (DES 2021a) (PRCP Guideline).

Section 750 of the EP Act defines land outcome documents. The PRCP Guideline states that the land outcome document list is hierarchical and if there are inconsistencies between these documents on either the final outcomes or details of the outcome, then the document appearing first in the list will prevail to the extent of the inconsistency. For the Baralaba Coal Mine, the following are considered to be land outcome documents:

- EA (EPML00223213); and
- The Environmental Impact Statement (EIS) Assessment Report for the Baralaba North Continued Operations Project (BNCOP) dated November 2014.

1.1 Scope and objective

The purpose of this PRCP is to describe how progressive rehabilitation will be carried out at Baralaba Coal Mine. This PRCP has been developed in accordance with the requirements of the PRCP Guideline, which states that the PRCP must include the following parts:

Rehabilitation Planning part:

The purpose of the rehabilitation planning part of the PRCP is to support and justify the development of the proposed PRCP schedule. This part must detail how progressive rehabilitation, and closure will be carried out over the entire Baralaba Coal Mine site and on both a rehabilitation area and improvement area basis. The key components of the rehabilitation planning part for Baralaba Coal Mine are:

- community consultation information (refer to Section 4).
- post-mining land use (PMLU) and/or non-use management area (NUMA) determination (refer to Section 5 and 6);
- rehabilitation and management methodology (refer to Section 7)
- risk assessment (refer to Section 8); and
- a monitoring and maintenance program (refer to Section 9).

Rehabilitation Schedule part:

The rehabilitation schedule is a required element of a PRCP. Once approved, the schedule becomes a legally binding and enforceable instrument that Baralaba Coal Mine must comply with. The schedule must include:

- nomination of either a PMLU or NUMA for all land within the relevant resource tenures, including land uses for undisturbed land.
- identification of when land becomes available for rehabilitation or improvement.
- rehabilitation or management milestones to achieve the PMLU or NUMA outcomes.
- milestone criteria that demonstrate when each milestone has been completed.
- completion dates for each milestone to be achieved; and
- any conditions considered necessary or desirable.

2 Project overview

2.1 Location

The Baralaba Coal Mine is an open-cut coal mine approved for a run of mine (ROM) coal production of up to 4.1 million tonnes per annum (Mtpa). The Baralaba Coal Mine is located in the Bowen basin of central Queensland, approximately 3 km from the township of Baralaba. It is located approximately 150 km southwest of Rockhampton and 210 km west of the Port of Gladstone (Figure 1).

2.2 History

Evidence of underground mining dating between 1915 and 1969 is present around the Baralaba underground mining leases ML 5580, ML 5581, and ML 5590. These leases were granted between November 1953 and August 1975.

Cockatoo Coal Limited acquired the majority share of the entities holding the Baralaba leases from Peabody Pacific Pty Ltd on 12 December 2008, thereby taking control of the Baralaba Coal Mine, which operated on ML 5605. Subsequently, in April 2010, ML 80157 was granted, leading to the expansion of the Baralaba Coal Mine to include this additional lease. Following this, in August 2013, ML 80169 was granted, followed by ML 80170 in September 2013. For non-mining purposes (i.e., an anabranch crossing), ML 80200 was granted in February 2014, and in June 2016, ML 80201 was also granted. In July 2017, ML 700004 was granted for the purposes of 'road/access/right of way.' Figure 2 provides an overview of the various mining leases across the Baralaba Coal Mine. Cockatoo Coal Ltd underwent a name change to Baralaba Coal Company Limited in November 2016; however, the company faced financial difficulties and entered administration in July 2017.

In February 2018, in conjunction with the existing administration, the company was split up and both Baralaba Coal Company Limited and its subsidiaries came under new ownership. Baralaba Coal Company Limited was sold to one party and certain subsidiaries of Baralaba Coal Company Limited, including Wonbindi Coal Pty Limited and Baralaba Coal Pty Ltd, were sold to another. Cockatiel Coal Pty Ltd, the head entity of the group of the subsidiaries was renamed to Baralaba Coal Company Pty Ltd as part of this process.

After a period of care and maintenance, the Baralaba Coal Mine recommenced operations on 14 March 2018 under new ownership and management. The mine was then bought by the current owners in December 2021.

2.3 Mining tenure and underlying landholders

Baralaba Coal Mine currently operates across seven active MLs, at various stages of development (Figure 2 and Table 1). The Baralaba Coal Mine MLs are held by either Baralaba Coal Pty Ltd or Wonbindi Coal Pty Limited who are jointly the EA holders for EPML00223213. These companies are subsidiaries of, and wholly owned by Baralaba Coal Company Pty Ltd. Landholders of the area underlying Baralaba Coal Mine are outlined in Table 3.

Table 1: Baralaba Mining Leases

Mining Lease	Hectares	Site Reference
ML 5605	258.68	Baralaba Central
ML 80157	151.19	Baralaba Central
ML 80169	121.80	Baralaba North
ML 80170	888.58	Baralaba North
ML 80200	7.78	Baralaba Central
ML 80201	1486.76	Baralaba North
ML 700004	13.43	Baralaba Central

Baralaba Coal Mine falls across two local government areas (LGAs), the Central Highlands Regional Council and the Banana Shire Council. The MLs north of the Dawson River Anabranch are located within the Central Highlands LGA and the southern leases are within the Banana Shire Council LGA Figure 2.

The tenements, which are listed in the EA, but are outside the boundaries of authorised mining, are shown in Table 2 and Figure 2, Figure *3*.

Table 2: Additional tenements

Tenement	Status	Granted	Expiry	Area (ha)	
				Total	Surface
ML 5580	Granted	01/12/62	30/11/28	258.63	18.97
ML 5581	Granted	01/11/53	30/11/28	25.62	0.98
ML 5590	Granted	07/08/75	31/08/29	72.43	0.0

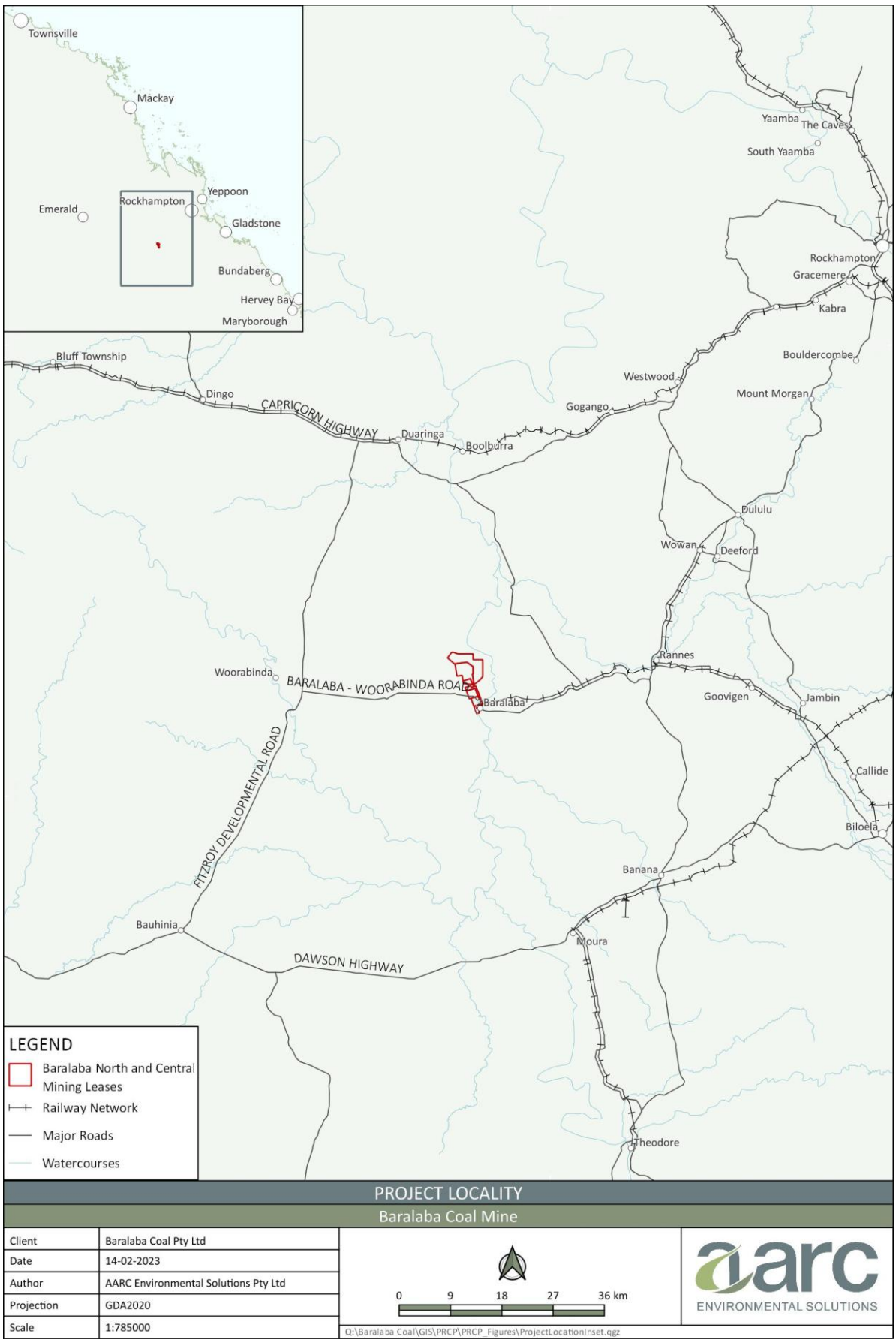

Figure 1: Project Locality

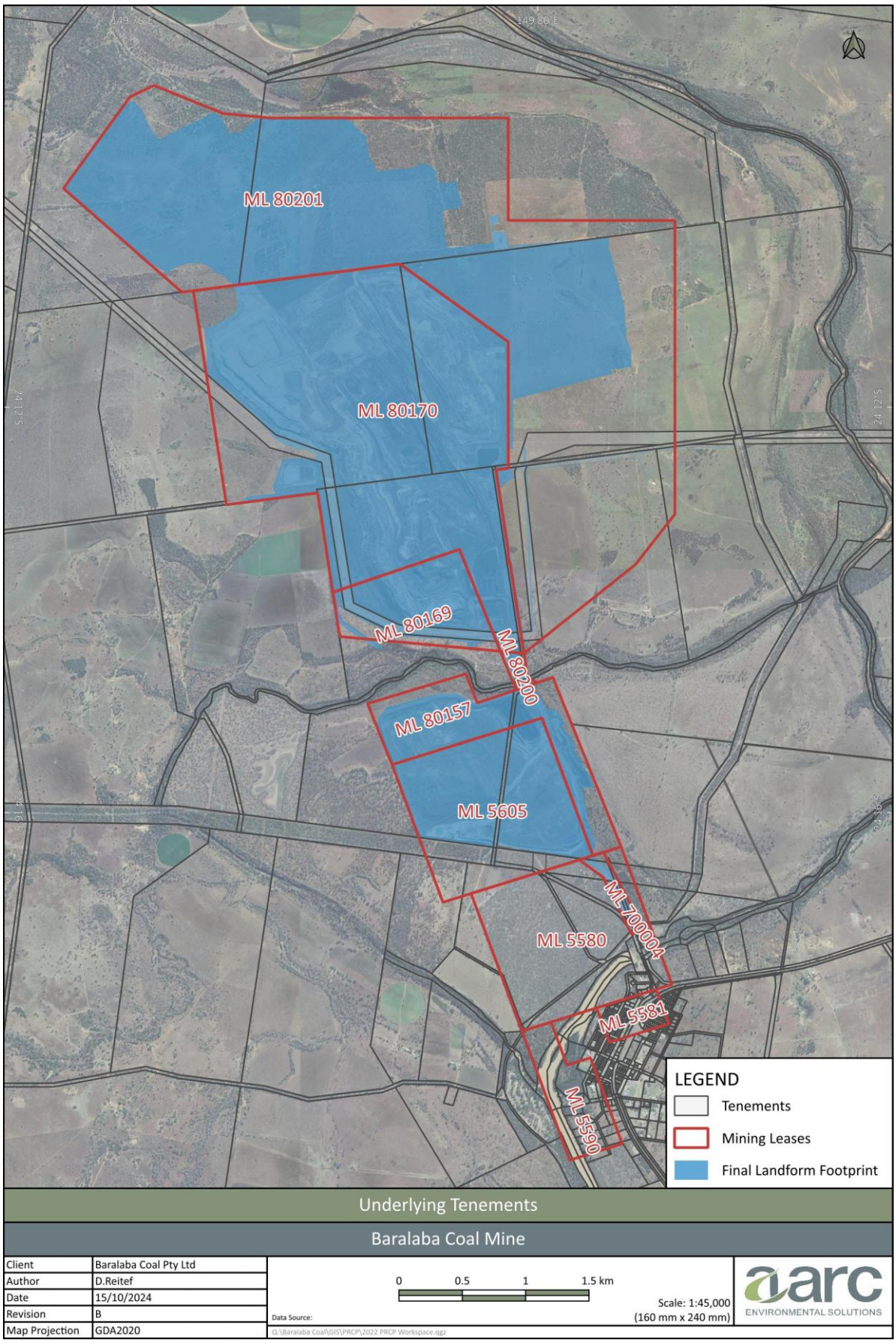

Figure 2: Baralaba mining leases and underlying property descriptions

Table 3: Property descriptions and tenure

Lot	Plan	Tenure	Local Government	Underlying Landholder	Purposes	Tenement
1	RP618842	Freehold	Central Highlands Regional	Baralaba Coal Pty Ltd	Mining Other minimal use	ML 5605
1	SP235019	Freehold	Central Highlands Regional	Baralaba Coal Pty Ltd	Mining Other minimal use	ML 80157 ML 5605 ML 700004
2	RP618842	Freehold	Central Highlands Regional	Baralaba Coal Pty Ltd	Mining Cropping Other minimal use	ML 80157
8	SP256221	Freehold	Central Highlands Regional	Baralaba Coal Pty Ltd	Mining Other minimal use	ML 80170 ML 80169 ML 80200
12	SP256221	Freehold	Central Highlands Regional	Baralaba Coal Pty Ltd	Mining Grazing	ML 80170
54	KM75	Freehold	Central Highlands Regional	Gregory David Barsby and Deanne Leigh Roberts	Grazing native vegetation	ML 5605
28	KM64	Reserve	Central Highlands Regional	Reserve for Racecourse	Services	ML 5605
1	AP5432	Unallocated State Land	Banana Shire Council	State of Queensland (Represented by the Department of Natural Resources and Water)	Grazing native vegetation	ML 700004
2	AP5432	Unallocated State Land	Banana Shire Council	State of Queensland (Represented by the Department of Natural Resources and Water)	Grazing native vegetation	ML 700004
2	SP235019	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Mining	ML 80200
6	KM44	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Grazing native vegetation	ML 80201
7	KM44	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Grazing native vegetation	ML 80201
11	KM46	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Grazing native vegetation	ML 80170 ML 80201
13	KM182	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Grazing native vegetation	ML 80201

Lot	Plan	Tenure	Local Government	Underlying Landholder	Purposes	Tenement
14	KM183	Freehold	Central Highlands Regional	WONBINDI COAL PTY LTD	Grazing native vegetation	ML 80201
	Anabranch Dawson River	River Reserve	Central Highlands Regional		Road	ML 80200
	Baralaba Woorabinda Road	Road Reserve	Central Highlands Regional		Road	ML 5605
	Baralaba Woorabinda Road	Road Reserve	Banana Shire Council		Road	ML 700004
	Hoadleys Road	Road Reserve	Central Highlands Regional		Road	ML 80170
	Hoadleys Road	Road Reserve	Central Highlands Regional		Road	ML 80200
	Hoadleys Road	Road Reserve	Central Highlands Regional		Road	ML 80201
	Hoadleys Road – Temporarily Closed	Road Reserve	Central Highlands Regional		Road	ML 80157
	River Road	Road Reserve	Banana Shire Council		Road	ML 700004
	River Road/Baralaba Woorabinda Road	Road Reserve	Banana Shire Council		Road	ML 700004
	Road	Road Reserve	Central Highlands Regional		Road	ML 80170
	Unnamed Road	Road Reserve	Banana Shire Council		Road	ML 700004
	Unnamed Road	Road Reserve	Central Highlands Regional		Road	ML 80201

2.4 Primary mine features/infrastructure

The extent of disturbance is regulated under EA (EPML00223213) condition A2. This condition states that:

> *In carrying out the mining activity authorised by this environmental authority, disturbance of land:*
>
> *a) may occur in the areas marked 'A'.*
>
> *b) must not occur in the areas marked 'B'.*
>
> *c) must not occur in the areas marked 'C' without consultation first occurring with the administering authority, and*
>
> *d) must not occur in the areas marked 'D' which is mapped as per the definition in the Vegetation Management Act 1999.*
>
> *e) may only occur in areas marked 'E' for the purposes of rehabilitation activities.*
>
> *The authorised areas of disturbance stated in (a) to (d) of this condition is presented in Figure 1a – Land Disturbance at Baralaba North Operations and Figure 1b – Land Disturbance at Baralaba Central Mine, attached to this environmental authority as Appendix 2.*

Figure 3 shows the extent of EA Disturbance categories A, B and C permitted at Baralaba Coal Mine, as per condition A2.

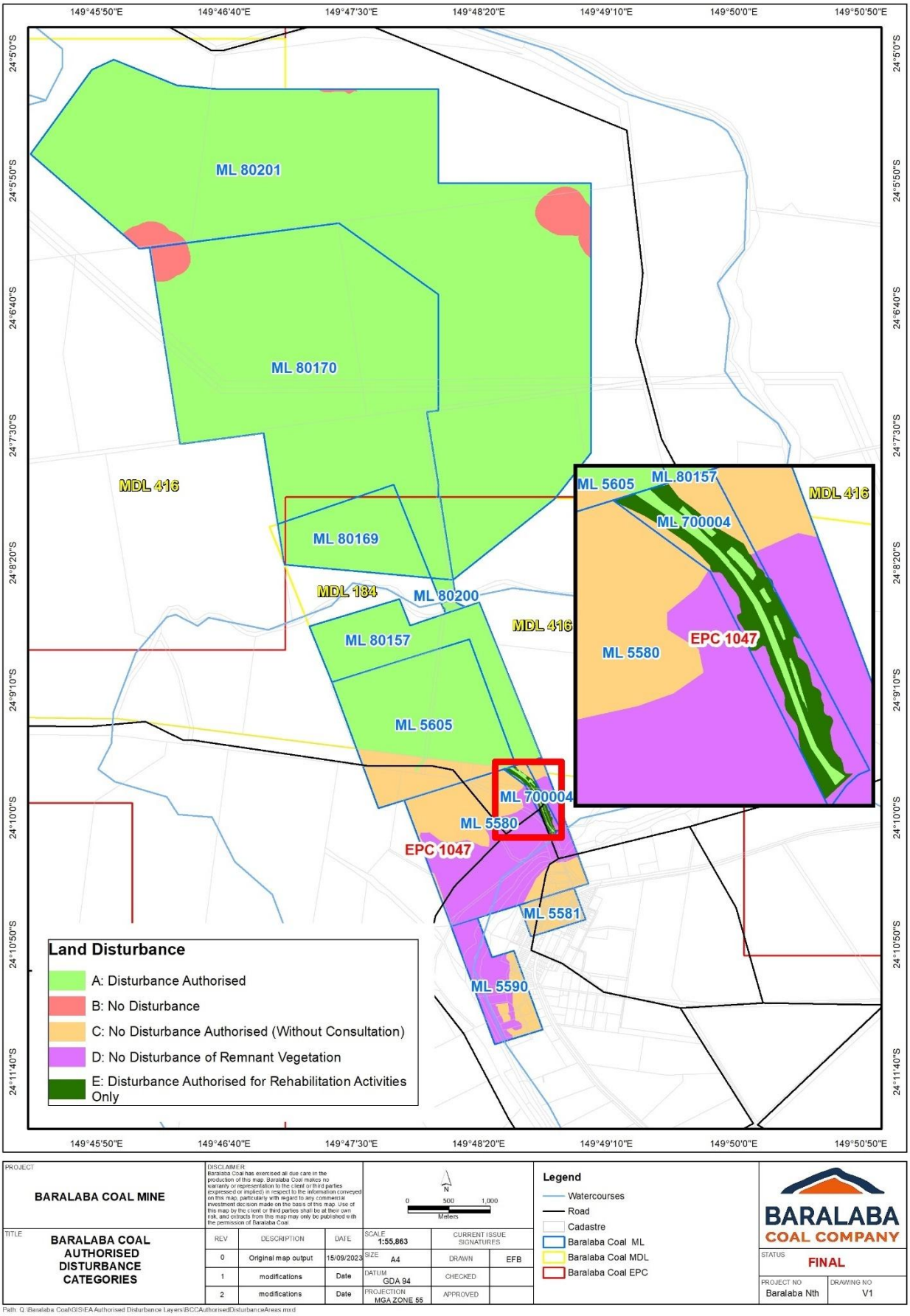

Figure 3: Land disturbance at Baralaba North

As depicted in Figure 3, Baralaba Coal Mine is generally split into two operational areas, Baralaba North and Baralaba Central (Figure 5 - Figure *6*). Built infrastructure at Baralaba North includes workshops, hydrocarbon storages, stores, explosive storages, administration facilities, ablution blocks, slabs, footings, walkways, services, potable, and wastewater storage tanks. These infrastructure areas are depicted in Figure 4 and included in Rehabilitation Area 5, outlined in Section 7.2.

All current and future extraction activities are undertaken within the Baralaba North operational area. This area therefore contains the main mining features of the mine, including a void, levee, overburden dumps, water storages, roads, etc. These main features of the Baralaba North operational area are depicted in Figure *6*. Mining operations are planned to continue until 2036.

The proposed rehabilitation timing of the Baralaba North operational area is detailed further in the PRCP schedule and stage plans provided in Appendix C.

Figure 4: Baralaba North Infrastructure Areas

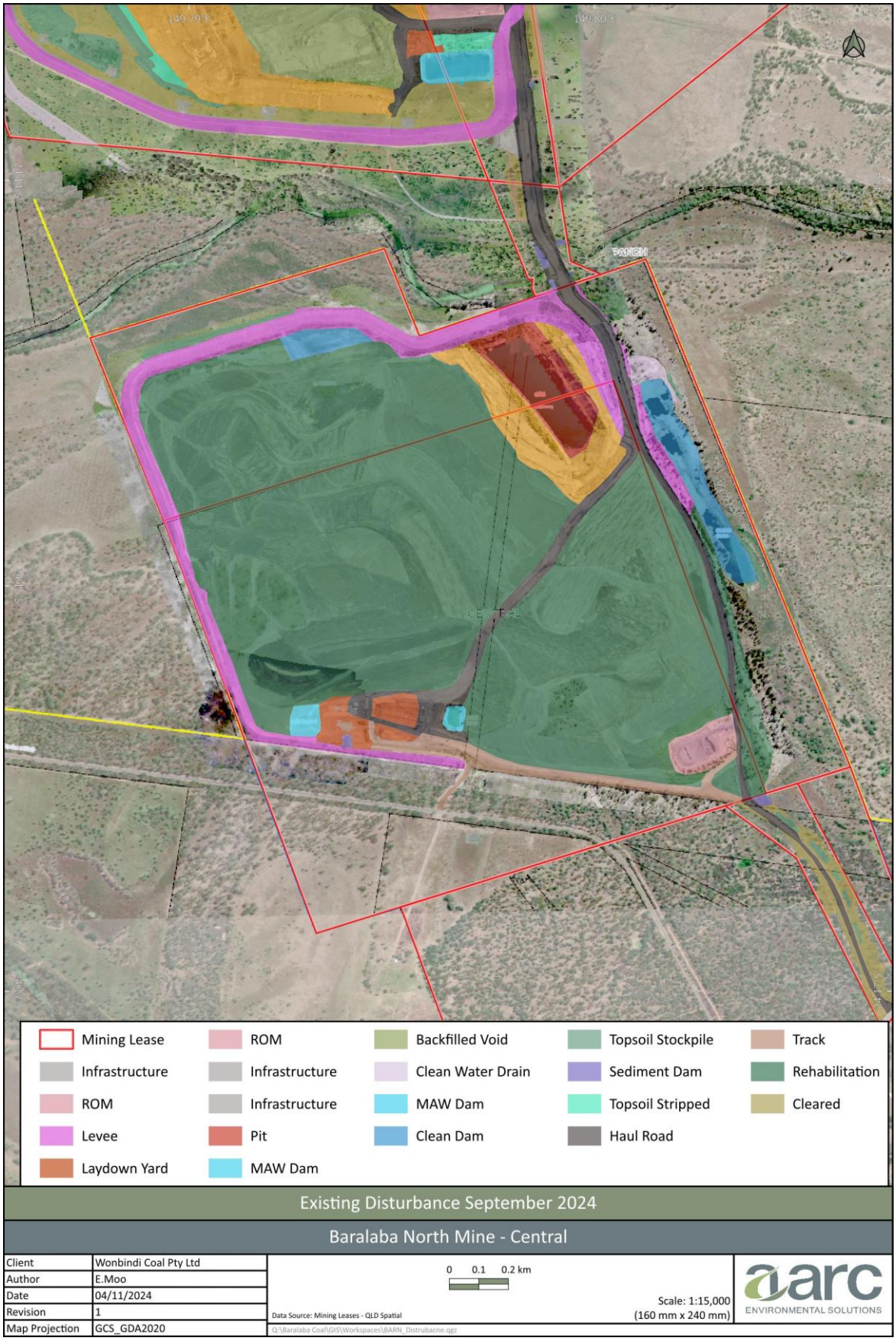

Figure 5: Existing disturbance – Baralaba Central.

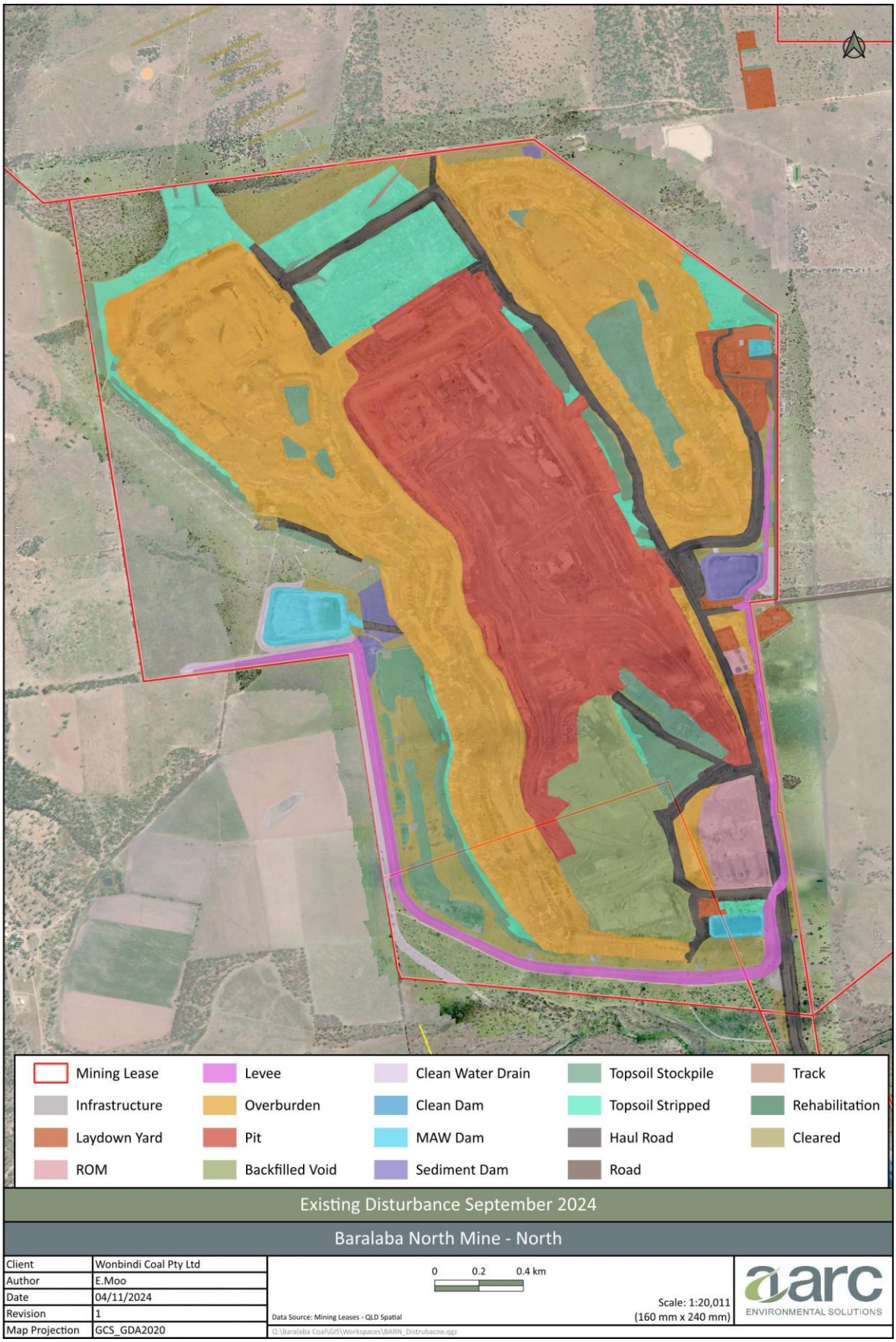

Figure 6: Existing Disturbance – Baralaba North

2.5 Mining methods

Mining activities at Baralaba Coal Mine include:

- Ongoing coal resource definition (exploration activities).
- Vegetation clearing.
- Topsoil removal and stockpiling (or direct placement, where possible).
- Progressive backfilling of the mine void with waste rock behind the advancing open cut mining operations at the Baralaba North Pit and/or within the Baralaba Central void;
- Continued and expanded placement of waste rock in spoil dumps adjacent to the pit extents;
- Progressive development of new haul roads and internal roads.
- Progressive development of sediment dams and storage dams, pumps, pipelines and other water management equipment and structures (including levees).
- Continued development of topsoil stockpiles, laydown areas and borrow areas.
- Use of administration and maintenance facilities at the Baralaba Central and Baralaba North mining areas.
- Other associated minor infrastructure, plant, equipment, and activities, including minor modifications and alterations to existing infrastructure as required to accommodate the increased throughput.
- Continued road transport of product coal using AB triple and AAB quad trucks along the existing product coal road transport route (56 km south of Baralaba Coal Mine using a network of public and private roads including Theodore-Baralaba Road) to the existing Moura Train Load Out facility, located about 5 km east of Moura; and
- Use of product coal stockpiles and loading of product coal for transport.

2.6 Existing rehabilitation

Progressive rehabilitation at Baralaba Coal Mine has been undertaken as areas become available. Most recently, substantial works were completed in 2023 to backfill and rehabilitate the Central void and associated waste dump.

Under historical ownership, approximately 10.7 ha of rehabilitation completed between 2008 and 2010 was classified as temporary, as the area was earmarked for reworking during the Central void and spoil dump reshaping. Consequently, ongoing annual monitoring of this rehabilitation was not conducted. However, a field inspection by Aurecon in June 2012 recorded dense grass cover with scattered woody vegetation.

Following a critical review of historical rehabilitation designs for Central, in 2022, this area was identified as being able to be retained and, as such has been incorporated into the PRCP Schedule as RA8 – Existing Rehabilitation.

As of 2023, a total of 216 ha of completed rehabilitation has been established within the Central operational area. This area is comprised of MAW Dams, Infrastructure (Roads, Hard stands), Waste Dumps and the Central backfilled void

This rehabilitation area is designated for grazing (refer to Figure 7) and followed the methodologies outlined in Section 7.

In 2022, all infrastructure within the rehabilitation area was decommissioned, including Mine Dam 1 (a mine-affected water dam) and the site's explosive magazine. In line with the design strategy and Section 7.13 methodology, a 0.5 m sediment layer was removed from the dam and disposed of in-pit before the area was backfilled to match surrounding land levels and ensure free drainage.

The magazine was decommissioned, with all infrastructure and materials relocated to the Baralaba North magazine. Any potentially contaminated soil, including the 0.5 cm stemming base, was removed and disposed of in-pit.

Following decommissioning, rehabilitation works were implemented in accordance with the following methodology:

- Major dozer push was undertaken to establish slope profiles of 0–15% on waste rock dumps, and 0–5% on infrastructure areas, in accordance with the final landform design outline in section 7.7.
- Placement of 200 mm topsoil across all surfaces following bulk earthworks;
- Ripping and rock-raking along contours to prepare the surface for seeding;
- Seeding with a grazing-appropriate PMLU mix and fertilisation prior to the wet season; and
- Topsoil was further ameliorated as required.

Annual monitoring of the 2023 rehabilitation has reported a ground cover of approximately 98%, dominated by Rhodes Grass (*Chloris gayana*), which comprises around 90% of the cover. The remaining 10% includes Buffel Grass (*Cenchrus ciliaris*), Green Panic (*Megathyrsus maximus*), Mozambique Grass (*Urochloa mosambicensis*), Red Natal (*Melinis repens*), and Ruby Saltbush (*Enchylaena tomentosa*).

Scattered woody vegetation is present, predominantly Sally Wattle (*Acacia salicina*), juvenile eucalypt species, Mimosa Bush (*Acacia farnesiana*), and Leucaena (*Leucaena leucocephala*), ranging in height from 1.5 to 3.5 metres.

Field inspections and imagery analysis confirm that the landform is largely stable, with minimal evidence of soil erosion due to the dense grass cover. Some small patches (less than 2 m^2) of bare ground were observed halfway down some slopes, where topsoil had been lost, exposing underlying rock. Minor gully erosion is beginning to develop in these isolated areas.

Figure 7: Existing Rehabilitation

3 Baseline information

3.1 Climate

The climate of the region is sub-tropical, with a wet season dominated by rainfall and mild, dry winter months. Rainfall is highly seasonal and is typically associated with thunderstorms and cyclone weather patterns. A summary of long-term average rainfall, temperature and humidity for the region is provided in Figure 8.

The average annual rainfall for Baralaba is 600 mm with an average evaporation rate of 2035 mm. The average temperature range is between 15.2–29.5°C.

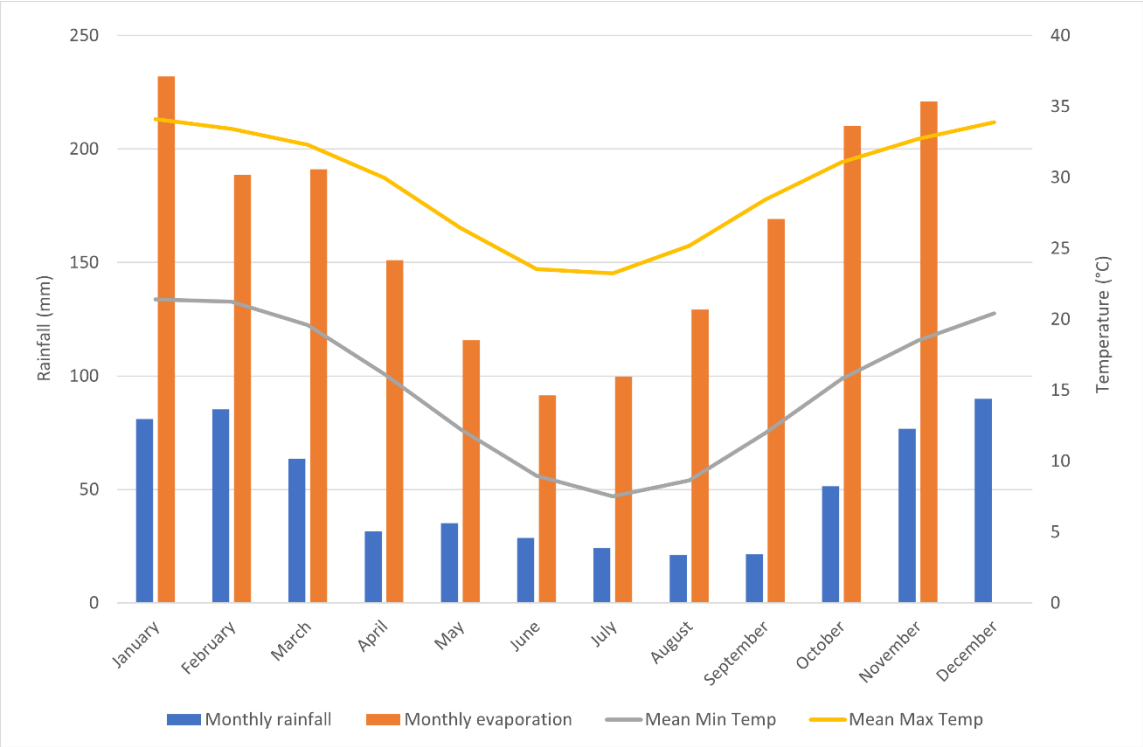

Figure 8: Rainfall, evaporation, and temperature records from SILO 1957-2022 (latitude -24.15, longitude 149.8)

3.2 Geological

The bowen basin is divided into broad morphotectonic zones, which represent areas of maximum sediment accumulation and adjacent shelf areas. Subdivision of these areas is broadly north-northwest to south-southeast in the northern part of the basin and, is typically, bounded by major faults. Baralaba Coal Mine lies within the Permo-Triassic aged southern bowen basin in a structurally complex zone, on the eastern limb of the Mimosa Syncline. The Mimosa Syncline is characterised by a complex pattern of northerly trending folds and thrust (reverse) faults.

The economic coal seams lie in the Permian Baralaba Coal Measures and correlate to the Rangal Coal Measures of the Blackwater Group, which are overlain by the Rewan formation. The Baralaba Coal Measures generally strike in a north-north-westerly direction (Figure 9). The coal bearing section of the Baralaba Coal Measures is variable in thickness across Baralaba Coal Mine but is up to 400 m thick in some areas. The Baralaba Coal Measures are almost entirely overlain by Quaternary sediments, with outcrops at the surface only observed along creeks and riverbanks.

Immediately underlying the Baralaba Coal Measures is the Gyranda Formation (Kaloola Member). The Kaloola Member is known to contain minor coal horizons. The Kaloola Member strata are comprised of fine sandstones and siltstones, with subordinate carbonaceous shale, tuffs and banded coal having some coking and thermal properties.

Surficial geology within the Baralaba MLs is mapped predominantly as:

- Recent alluvium associated with the Dawson River and associated tributaries, including the Dawson River Anabranch;
- Older unconsolidated undifferentiated Tertiary-Quaternary sediments that sit 3-5 m higher in the landscape than the alluvium; and
- Unnamed/undifferentiated Tertiary sandstone.

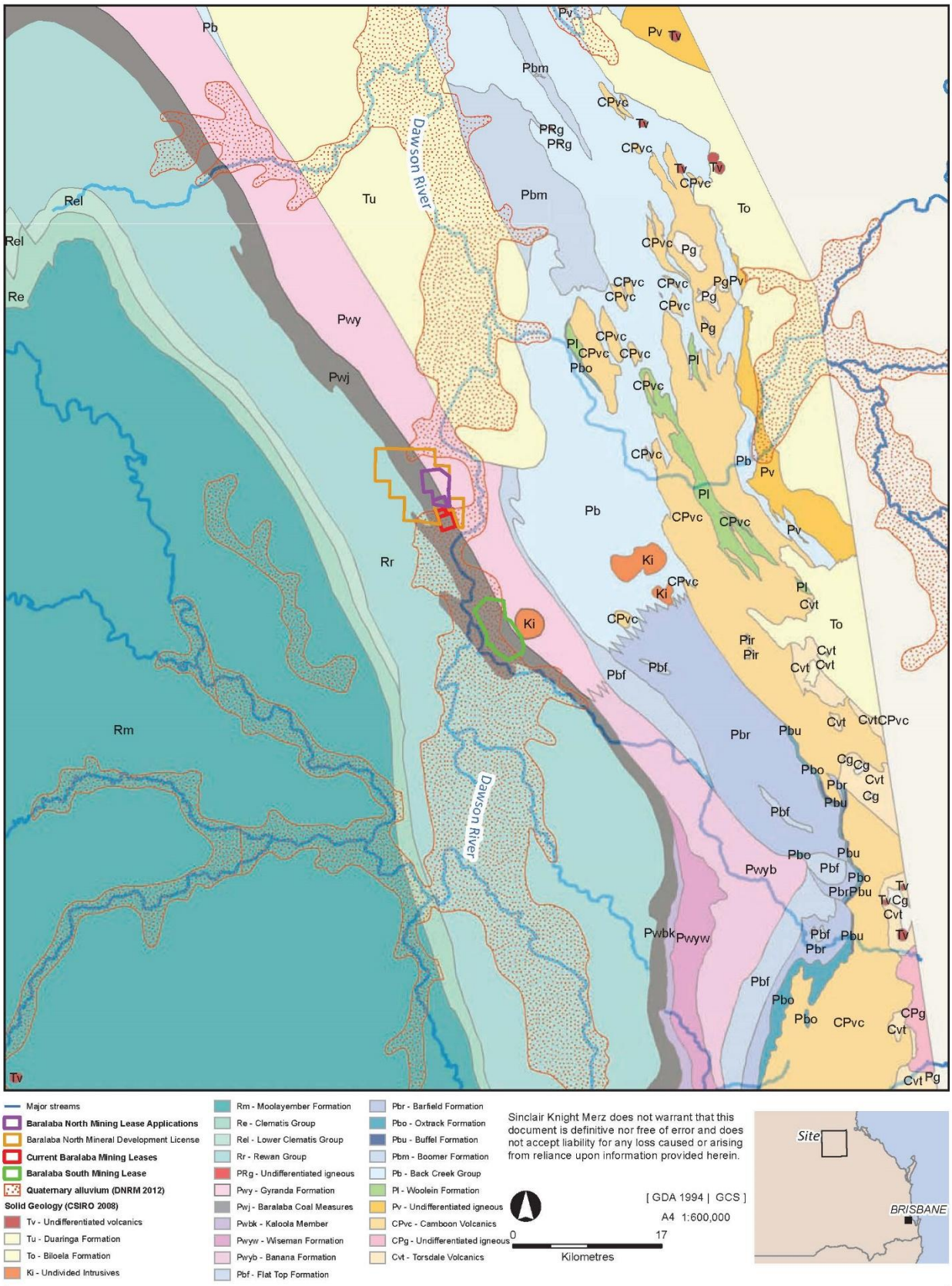

Figure 8 Basin Geology

Figure 9: Basin Geology (SKM, 2014)

3.3 Surface topography and hydrology

Baralaba Coal Mine is located in the Lower Dawson Sub-catchment Area of the Fitzroy Basin under the Water Resource (Fitzroy Basin) Plan 2011 (Qld) (Figure *10*).

The topography of the Baralaba area is dominated by the Dawson River floodplain. The area is relatively flat with only slight undulation. Ground elevations range between 75 and 105 m Australian Height Datum (AHD). The Baralaba township is situated adjacent to the Dawson River on relatively high ground, at approximately 93 m AHD. At 433 m AHD, Mount Ramsay is a key topographic feature in the region, located approximately 15 km south of Baralaba.

The major drainage features include the Dawson River and its tributaries the Dawson River Anabranch and Saline Creek (Figure 11). The Dawson River adjacent to Baralaba Coal Mine is classified as an 8th order stream and the Anabranch is classified as a 7th order stream. Saline Creek is classified as a 3rd and 4th order. At its confluence with the Dawson River, Saline Creek is a 5th order stream.

The Dawson River Anabranch flows in an easterly direction, between the Central and North mining areas. Saline Creek flows northeast past the northern boundary of ML80170 to the north of ML80201 before joining the northerly flowing Dawson River. Flows in the Dawson River are regulated by the Neville Hewitt Weir at the town of Baralaba, an 8.5 m tall dam with 11,300 ML storage capacity. The Neville Hewitt Weir also regulates the Dawson River stage above what would otherwise be the natural levels upstream of the weir (SKM 2014).

The *'Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (Qld) Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment' (DES, 2019) lists the environmental values for all waters that are within the Baralaba Coal Mine catchment area, for the Dawson River Sub-basin, these values include:

- protection of aquatic ecosystem values;
- suitability for drinking water supplies;
- suitability for primary contact recreation;
- suitability for secondary contact recreation;
- suitability for visual recreation;
- suitability for human consumers of wild or stocked fish, shellfish, or crustaceans;
- protection of cultural and spiritual values;
- suitability for crop irrigation;
- suitability for aquaculture (e.g., red claw crayfish, barramundi);
- suitability for stock watering; and
- suitability for industrial use.

Environmental values relevant to Baralaba Coal Mine's defined receiving environment are the protection of aquatic ecosystem values and suitability for stock watering. There are currently no identified EVs for Baralaba Coal Mine relating to industrial, recreational, and cultural/spiritual values for surface water.

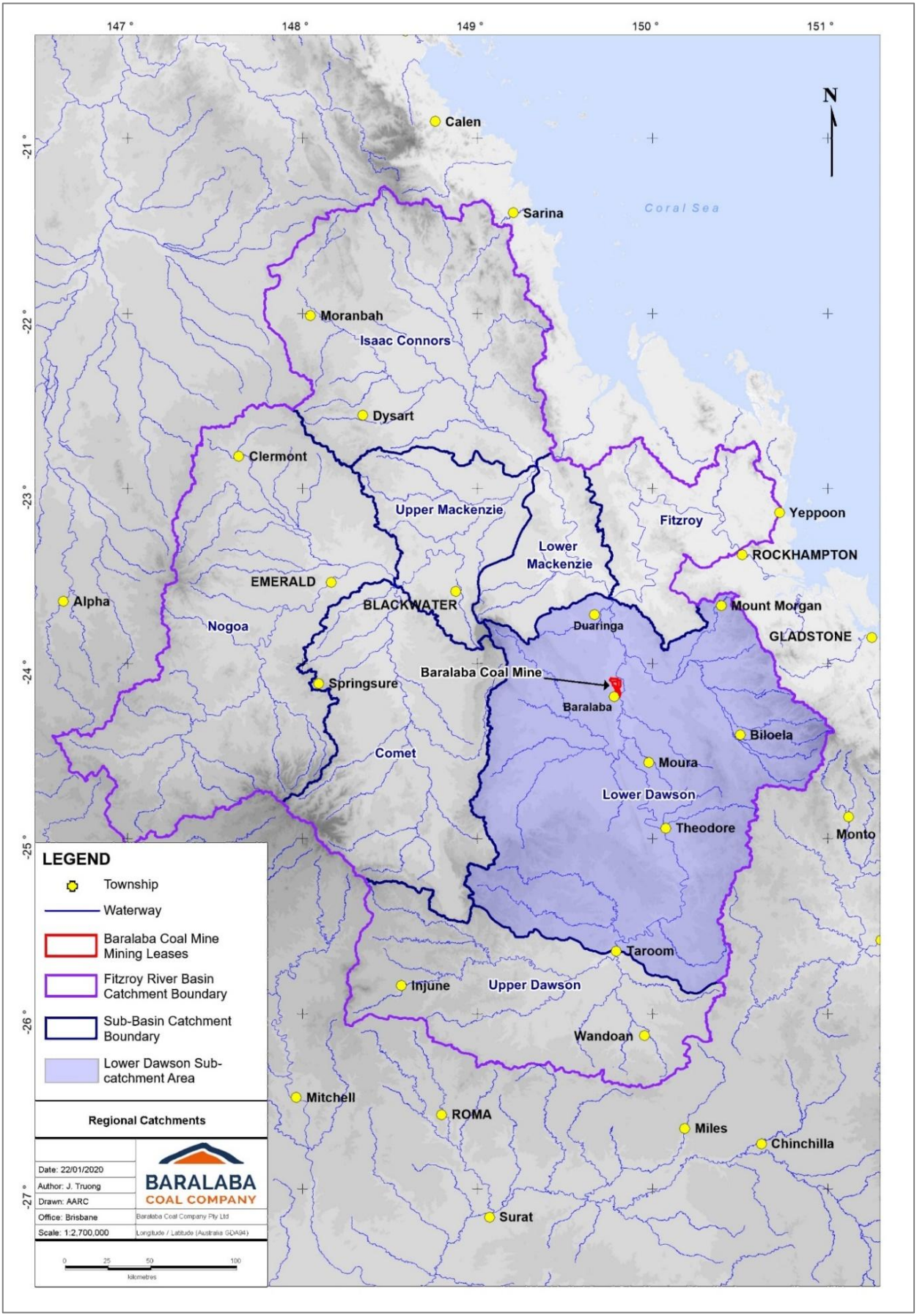

Figure 10: Regional catchments

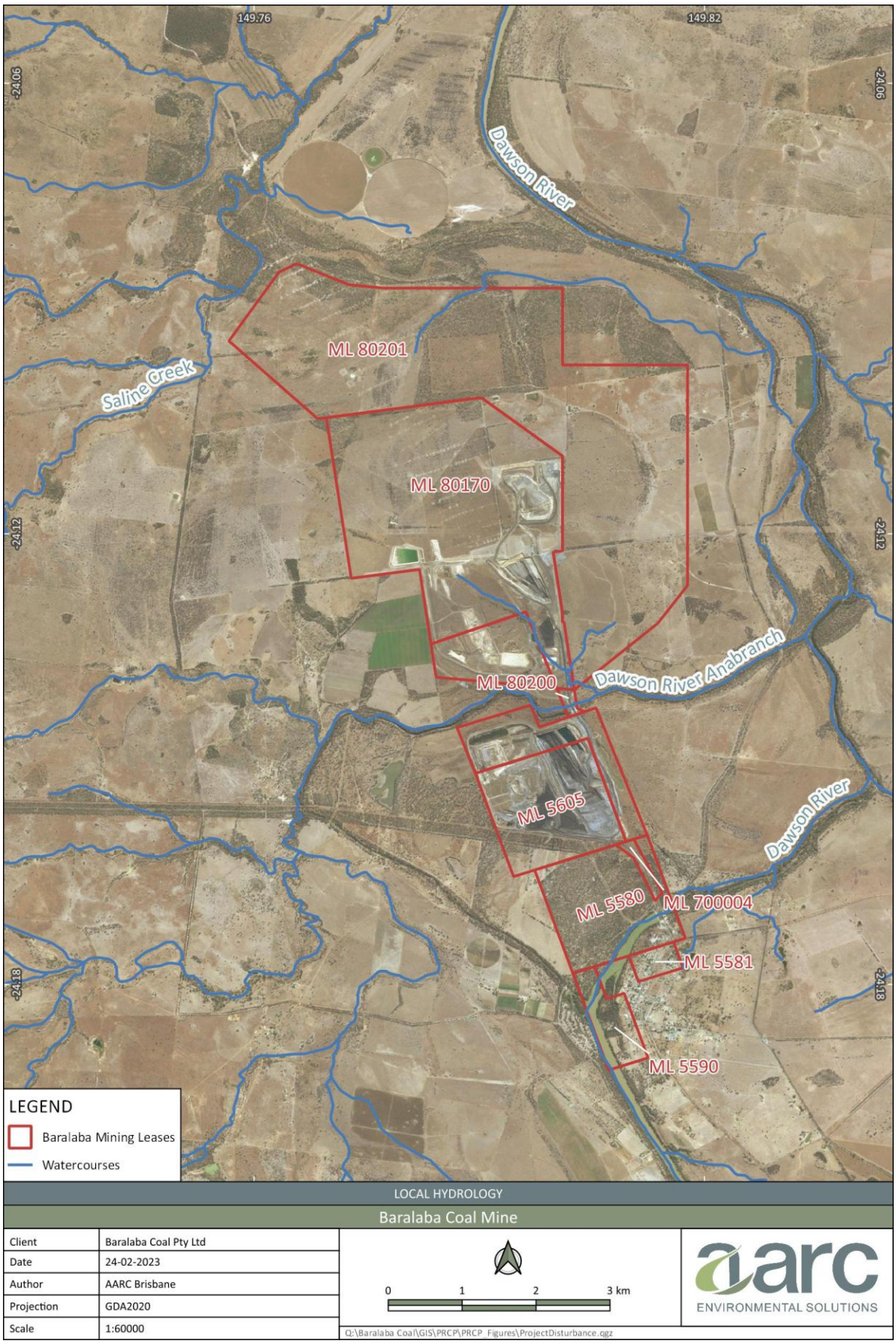

Figure 11: Local hydrology network

3.4 Groundwater

Numerous groundwater studies have been undertaken over the Baralaba Coal Mine MLs including but not limited to:

- AGE, 2005. Baralaba Coal Mine: Groundwater Regime and Monitoring Program. Proj G1326. December 2005.
- AGE, 2012. Baralaba North – Mine Extension Groundwater Management Plan. Proj G1565. January 2012.
- SKM, 2013. Baralaba North Mine Water Management Support: Groundwater Field Installation Draft Report. QE99082.300. February 2013.
- GES, 2014. Monitoring Bore Installation and Hydraulic Testing at the Baralaba Coal Project. February 2014.
- SKM, 2014. Baralaba North Continued Operations EIS Groundwater Studies: Preliminary Conceptual Groundwater Model. Report QE06728.200, July 2013.
- HydroSimulations, 2014. Baralaba Coal Continued Operations Project Groundwater Modelling and Assessment. HC2014/002, April 2014 (HydroSimulations 2014)
- JBT Consulting, 2021. Review of Conceptual Groundwater Model and Groundwater Monitoring Bore Network. JBT-083-001, May 2021 (JBT, 2021)

The conceptual model developed by JBT Consulting (JBT 2021) builds on the outcomes of these previous assessments and considers the most recent data collected. The outcome of this assessment is provided below and included in Appendix A.

3.4.1 Level

- Groundwater levels in alluvial monitoring bores have been relatively stable over the period of monitoring.
- Permian groundwater monitoring bores to the west of the mining area (SKM_PM01, SKM_PM05, which are both screened within overburden above coal seams) have recorded stable water level trends.
- Permian groundwater monitoring bores to the south of Baralaba North/ north of Baralaba Central (SKM_PM03, PZ13) are recording a downward water level trend that is interpreted to be related to mining.
- Permian bore PZ14D, which is located to the north of the advancing Baralaba North Pit, has recorded a water level drawdown since mid-2020 that is interpreted to be related to mining.

The data is interpreted to indicate that groundwater drawdown within the Permian coal measures occurs mainly in the direction that is along the strike of the coal seams (i.e., generally in the north northwest/ south-southeast direction) and has not been developed to the west of the mining operation (within the overburden/interburden).

This result is unsurprising as the coal seams, although of generally low permeability, tend to be the conduits for groundwater flow, with the interburden/overburden units tending to be of a significantly lower permeability than the coal seams. This observation is supported by site data, with minor rates of groundwater inflow to the Baralaba North pit reported from the base of coal seams (often as an indication of a wet-soaked area), with no inflow reported from the interburden units (JBT Consulting 2021).

3.4.2 Quality

Baralaba lies within Zone 34 of the Dawson River sub-basin, for which water quality objectives (WQOs) have been set (DEHP 2011). This zone is described as "*Saline*: [high] Na, Cl" on map 6 accompanying the WQOs (DEHP 2011).

The alluvial salinities are fairly consistent across the Baralaba North Operational Area. The median salinities are approximately 500 mg/L in alluvium, 2,000 mg/L for northern Permian sediments and 4,000 mg/L for combined southern and northern Permian sediments. The corresponding 75th percentiles are about 600 mg/L, 9,000 mg/L and 13,000 mg/L respectively.

The pH values are confined to a narrow range for both alluvial groundwater and Permian groundwater. Both groundwaters are close to neutral at their median values (6.9 for alluvium; and 7.2 for Permian). Overall, the Permian groundwater is slightly more alkaline.

In conclusion, existing pre-mine groundwater has been assessed as relatively poor quality (Hydro Simulations 2013).

3.5 Soil landscape

Baseline soil mapping and characterisation were done as part of the BNCOP EIS to determine topsoil resources for salvage and assess land pre-mining land suitability, Agricultural Land Class status, Strategic Cropping Land (SCL) status and inherent erosion potential within the Baralaba Coal Mine disturbance footprint. This assessment has been provided in Appendix B of this PRCP.

Twenty two soil types were recognised and mapped within mining lease areas (Figure 12). A summary of the identified soil types is provided in Table 4.

Each of these soil types has been assessed for its inherent erosion potential (following in-situ disturbance). Soils 8c and 8d have low inherent erosion potential, Soils 2b, 3a, 7c, 8a, 8b, and 9a are considered moderate, while Soils 4c, 4d, 5 and 9b are inherently predisposed to high erosion potential following disturbance. The remaining group of soils, namely Soils 3b, 7a, 7b and 7d, are characterised by strongly sodic and extremely dispersive, shallow subsoils, and have very high inherent erosion potential.

Table 4: Soil types of the Baralaba Coal Mine

Soil Unit	Soil landscape description	Regional soil name
1	Firm to hard setting, silty surfaced, black cracking clay on low-lying channel benches and banks.	Isaac (Is)
2b	Moderately self-mulching, often silty, black cracking clay on level backplains within the lower floodplain.	Bluchers (Bc), Lindsay (Ld)
3a	Hardsetting to coarsely self-mulching, (poached), black cracking clay in narrow terrace drainage lines of the upper floodplain.	Bluchers (Bc), Lindsay (Ld)
3b	Hardsetting, clay loamy surfaced (0.2-0.4m), bleached, brown sodic texture contrast soil on level alluvial plains of Saline Creek and associated tributaries.	Roper (Rp)
3c	Deep brown uniform sand grading to a very thick, soft sandy surfaced (1.0->1.5m), brown non-sodic texture contrast soil on active terrace flats, levees and scroll plains of Saline Ck and other tributaries.	German (Gm), Parrot (Pr)
4a	Hardsetting to firm, silty, black cracking clay on upper floodplain levees and terrace sideslopes.	Stephens (St)
4b	Moderately to strongly self-mulching (coarse), black cracking clay to 1.2m (over brown or grey clay) on elevated level backplains.	Lindsay (Ld)
4c	Moderately to strongly self-mulching, black cracking clay on elevated level backplains.	Langley (Lg)

Soil Unit	Soil landscape description	Regional soil name
4d	Weakly to moderately self-mulching, grey cracking clay with weak to moderate melon hole gilgai (VI <0.3-0.6m, HI 10-25m) on level backplains of the Dawson River	Langley (Lg), Tralee (Tl)
4e	Hardsetting, sandy to clay loamy surfaced (0.2-0.5m), grey or brown texture contrast soil on level backplains of the Dawson River.	Honeycomb (Hy)
5	Firm pedal or weakly to moderately self-mulching, black cracking clay on gently undulating sideslopes/plains that mark the transition from recent alluvium to older elevated plains.	Affinities with Tralee (Tl)
6b	Hardsetting, loamy to clay loamy surfaced (0.25m), sporadically bleached, brown, or red texture contrast soil on elevated terrace/levee remnants.	Affinities with Roper (Rp)
6c	Thick, soft sandy surfaced (1.0-1.5m), mottled, brown or grey texture contrast soil on high levees.	Parrot (Pr)
7a	Hardsetting or firm pedal to weakly self-mulching, grey cracking clay with strongly developed melonhole gilgai (VI 0.3-0.8m, HI 12-20m) on older clay sheets; saline, sodic and acidic at depth.	Turon (Tr)/Greycliffe melonhole phase (GcMp)
7b	Hardsetting, thin clay loamy surfaced (<0.05-0.2m), bleached, grey or brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occasional weak gilgai (VI 0.1m, HI 10m) on older unconsolidated sediments and clay sheets.	Foxleigh clay loamy phase (FxLp) grading to Warwick (Ww)/Greycliffe (Gc)
7c	Hardsetting, thick sandy surfaced (0.4-0.7m), bleached, often mottled, brown non-sodic to weakly sodic texture contrast soil on elevated relict alluvial deposits.	Collawmar (Cm)
7d	Hardsetting, clay loamy surfaced (0.10-0.2m), bleached, black sodic texture contrast soil on older unconsolidated sediments and clay sheets.	Racetrack (Rt)/Kokotungo (Kk)
swp 7a swap	Hardsetting, silty surfaced, mottled, grey non-cracking/cracking clay ± weak gilgai (VI <0.1-0.3m, HI 8-12m) etched within the Cainozoic clay sheets and subject to localized alluvial deposition.	Thirteenmile (Tt)
8a	Hardsetting, massive, gradational loamy red earth overlying weathered Tertiary sandstone (>1.5m).	Bills Hut (Bh)/Spear (Sp)
8b	Soft to loose, thick sandy surfaced (0.3-1.0m), bleached, strongly mottled, grey non-sodic texture contrast soil overlying insitu Tertiary sandstone from 0.8->1.5m.	Wyndham (Wm), affinities with Emoh (Em)
8c	Loose, massive, bleached, grey coarse sand on steeper colluvial footslopes.	Wyndham (Wm), affinities - Cherwell (Cw)
8d	Loose, massive red or brown earthy sand grading to a very thick sandy surfaced (1.0->1.5m), red or brown non-sodic texture contrast soil on gentle colluvial pediments and outwash deposits.	Wyndham (Wm), Bills Hut sandy variant (BhSv)
9a	Hardsetting, loamy to clay loamy surfaced (0.2-0.3m), brown non-sodic texture contrast soil grading to a structured, brown non-cracking clay overlying calcareous sediments from 0.7m->1.5m.	Mayfair (Mf), Kirkcaldy (Kc)
9b	Hardsetting to moderately self-mulching, black cracking clay with weak normal gilgai (VI <0.1-0.2m, HI 8-15m) overlying calcareous sediments from >1.2m.	Kirkcaldy (Kc), Affinities with Carfax (Cx)

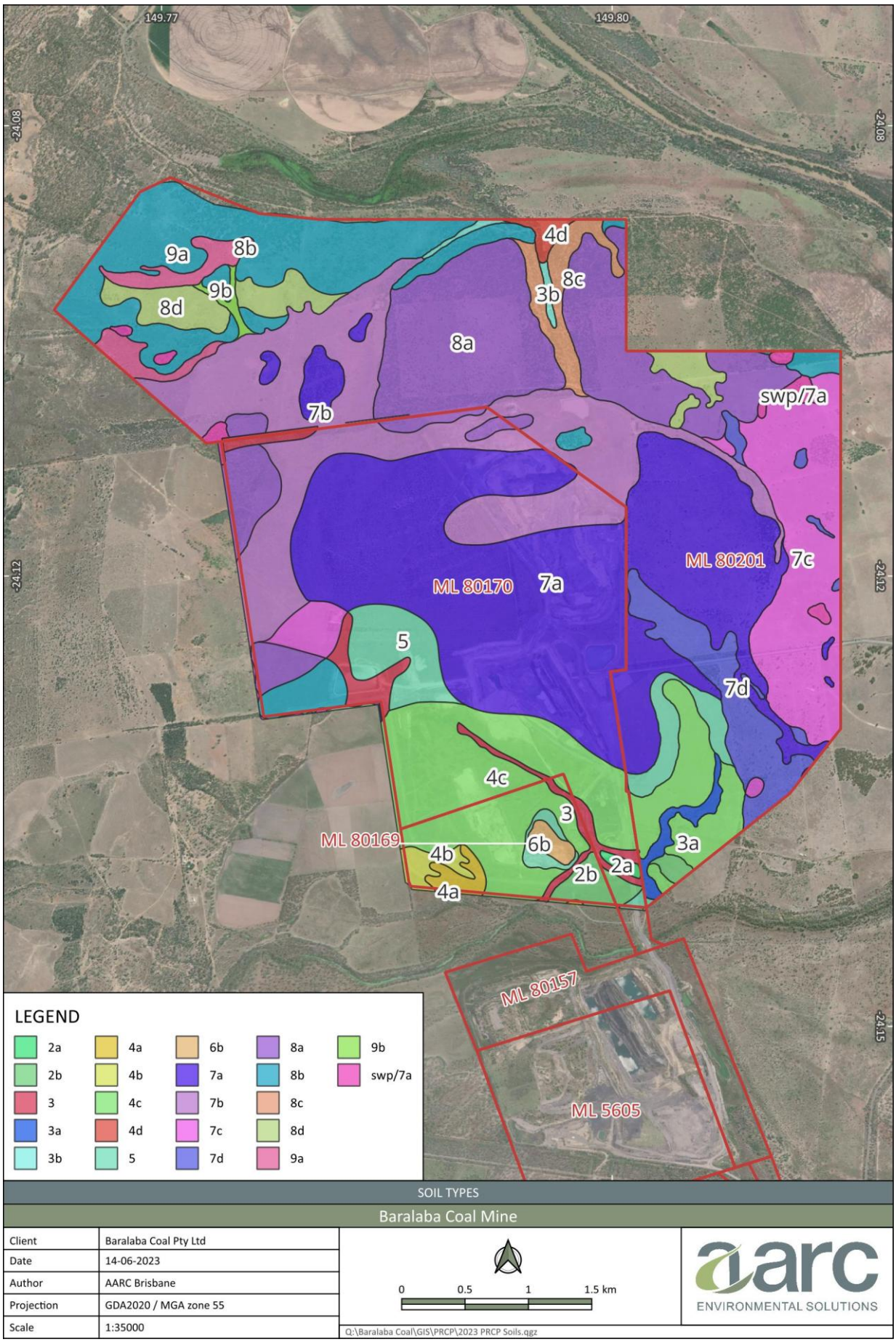

Figure 12: Baralaba Coal Mine soil survey outcomes

3.6 Land suitability assessment

The pre-mining land use for the Baralaba Coal Mine was beef cattle grazing, with land suitability class 2 (suitable land with minor limitations).

Land uses surrounding the Baralaba Coal Mine include rural activities such as beef cattle grazing, and limited crop cultivation. Crops are generally restricted to forage for cattle, with Leucaena sp. well established within the area. Crops such as wheat (Triticum aestivum) and cotton (Gossypium sp.) are produced on an opportunistic basis (Burgess 2014).

The 2014 baseline soil mapping and land suitability assessment identified that 45.5% of the land underlying the Baralaba Coal Mine (675 ha) was suitable for improved pasture development. Soils 2b, 3a, 4c, 4d, 5, and 7a (365ha or 24.5%) are capable of reliably fattening cattle in most seasons (Classes 1-2), while a further 310ha or 21% (Soils 3b, 7b, 7d, 9b, swp/7a) is better suited to 'growing out' younger cattle (Class 3). Of the remaining area, 713 ha or 48% is lower fertility country (Soils 7c, 8a, 8b, 9a) that is marginal for improved pasture development (and associated fattening/growing activities) but is suited to year round breeding herd utilisation (Class 4). A small area in the north (98ha or 6.5%) comprises very sandy, infertile soils (Soils 8c, 8d) that have limited grazing potential and are best suited to wet season breeding use only (Class 5 – requiring dry season destocking when grazed in isolation) (Burgess 2014).

Pre-mining soil attributes and associated suitability classes have been provided within Table 5 and Table 6.

Table 5 Grazing suitability soil attributes in the Baralaba Mine disturbance footprint (QDME 1995)

Limitation	Attribute	2b		3a		3b		4c		4d		5		7a		7b		7c	
Water availability (M)	PAWC (0.6m)	70-75mm	2	70-75mm	2	45-55m	3	70-75mm	2	70-75mm	2	70-75mm	2	50-70mm	2	30-60mm	3	30-35mm	4
Nutrient deficiency (Nd)	Fertility (P)	P - 73ppm N - high	2	P -83ppm N - high	2	P -28ppm N - high	2	P - 56ppm N - very high	1	P - 36ppm N - very high	1	P - 32ppm N - high	1	P - 20ppm N - high	1	P - 6-8ppm N - moderate	3	p - <11ppm N - moderate	3
Soil physical factors (Ps)	Surface cond.	mod. SM 2-5mm	2	HS - mod. SM 5-10mm	2	HS FS/z >60%	2	mod-str. SM 2-5mm	2	weak-mod. SM 2-5 mm	2	firm-mod. SM 2-5mm	2	HS-weak SM 2-5mm	2	very HS FS/z >60%	2	HS FS/z >60%	2
Root zone salinity (Sa)	Mean EC (dS/m)	0.08	1	0.13	1	0.05	1	0.19	2	0.18	2	0.27	2	0.31	2	0.15-0.27	2	0.04	1
Rockiness (R)	Abund.& size	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1
Microrelief (Tm)	Size & % land	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI <0.6m 30-70%	2	non-gilgaied	1	VI 0.3-0.8m >70%	2	VI <0.1m 30-70%	1	non-gilgaied	1
Wetness (W)	Soil/landscape	low lying	2	low lying	2	level - sodic TC	2	elevated	1	level plain	2	undulating	1	level plain	2	level plain	2	undulating	1
Water erosion (E)	Slope & disp.	<1% cracking clay	1	<1% cracking clay	1	<1% cracking clay	1	<1% cracking clay	1	<1% cracking clay	1	1-3% cracking clay	1	<1% cracking clay	1	<1% sodic TC/Ncc	1	0.5-2% non-sodic rigid	1

Limitation	Attribute	2b		3a		3b		4c		4d		5		7a		7b		7c	
Flooding (F)	Occurrence	reg. flooding	2	reg. flooding	2	occ. flooding	2	occ. flooding	2	occ. flooding	2	occ. flooding	2	flood free	1	flood free	1	flood free	1
Vegetation (V)	Veg. type	coolibah	2	coolibah	2	poplar box	2	brigalow	1	brigalow gilgal	2	brigalow	1	brigalow gilgai	2	shrubby box	2	Euc - softwood	2
Surface pH (pH)	pH (0-0.1m)	7.5	2	6.7-7.7	2	5.9	1	7.4-8.7	2	7.8-8.5	2	7.8-8.7	2	7.0-8.0	2	6.4-7.4	2	6.0-6.7	1
Surface ESP (ESP)	ESP (0-0.1m)	ESP 1	1	ESP 1	1	ESP 2	1	ESP 3	1	ESP 1	1	ESP 4	1	ESP 4	1	ESP 4-7	2	ESP 1	1
Final suitability Class			**2**		**2**		**3**		**2**		**2**		**2**		**2**		**3**		**4**

Table 6: Grazing suitability soil attributes in the Baralaba Mine disturbance footprint cont. (QDME 1995)

Limitation	Attribute	7d		SWP/7a		8a		8b		8c		8d		9a		9b	
Water availability (M)	PAWC (0.6m)	50mm	3	50-70mm	2	35-45mm	4	30-35mm	4	25mm	5	25 mm	5	50-60mm	3	70mm	2
Nutrient deficiency (Nd)	Fertility (P)	P - 28ppm N - high	1	P - 20ppm N- high	2	P - 1ppm N - moderate	4	P - 2ppm N - low-mod.	4	P - 1-2ppm N - low-mod.	4	P - 1-2ppm N - low-mod.	4	P - 4ppm N - mod-high	4	P - <10ppm N -high	3
Soil physical factors (Ps)	Surface cond.	Hs FS/z >50%	2	HS-weak SM 2-5mm	2	HS FS/z >60%	2	loose-soft sandy	1	loose sandy	1	loose sandy	1	HS FS/z >60%	2	HS - mod. SM 2-5mm	2

Limitation	Attribute	7d		SWP/7a		8a		8b		8c		8d		9a		9b	
Root zone salinity (Sa)	Mean EC (dS/m)	0.13	1	0.16	2	0.04	1	0.04	1	<0.03	1	0.03	1	0.08	1	0.19	2
Rockiness (R)	Abund. & size	no rock	1	no rock	1	no rock	1	<2% outcrop	1	no rock	1	no rock	1	no rock	1	no rock	1
Microrelief (Tm)	Size & % land	non-gilgailed	1	VI < 0.3m 30-70%	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI 0.1-0.2m 30-70%	1
Wetness (W)	Soil/landscape	level - sodic TC	2	seasonal swp.	3	elevated plain	1	undulating	1	undulating	1	undulating	1	undulating	1	level plain	2
Water erosion (E)	Slope & disp.	<1-2% sodic rigid TC	2	<1% crackin clay	1	<1-5% non-sodic rigid	1 2	<1-12% non-sodic rigid	1 2	1-5% non-sodic rigid	1 2	<1-3% non-sodic rigid	1	<1-3% non-sodic rigid	1	<1% cracking clay	1
Flooding (F)	Occurrence	flood free	1	reg. inundation	2	flood free	1	flood free	1	flood free	1	flood free	1	flood free	1	flood free	1
Vegetation (V)	veg. type	brigaiow - euc	1	forest red gum	1	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	open grassland	1
Surface pH (pH)	pH (0-0.1m)	6.0-7.2	1	5.5-6.9	1	5.5-6.3	1	5.2-6.4	1	5.5-6.5	1	5.5-6.5	1	5.9-6.4	1	7.1	2
Surface ESP (ESP)	ESP (0-0.1m)	ESP 3	1	ESP <4	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 3	1
Final suitability Class			**3**		**3**		**4**		**4**		**5**		**5**		**4**		**3**

3.7 Vegetation communities

Baralaba Coal Mine is located within the north-east portion of the Brigalow Belt South Bioregion. The Brigalow Belt South Bioregion is extensively cleared with 41.6% of the original vegetation remaining (Accad et al. 2013). Within the MLs, native vegetation grows in patches, often along watercourses, in seasonally damp areas, as windbreaks between cultivated paddocks or as stock shelter.

A flora survey was carried out in 2014 within the ML boundary of ML 80201 and surrounding lands. The survey identified 16 native vegetation communities within the boundaries of ML80201, which correspond to nine regional ecosystems (REs). These REs represent (in order of dominance): Riparian Woodland, Eucalypt Open Forest, Brigalow Palustrine Wetlands, Brigalow Woodlands, and Ephemeral Wetlands (Figure 13). The Riparian Woodland occurs along watercourses and is relatively continuous compared to other vegetation types which are highly fragmented and degraded (to various degrees) by weeds (including declared plants), declared animals and edge effects.

The identified REs correspond with the following:

- RE 11.3.1: Acacia harpophylla and/or Casuarina cristata open forest on alluvial plains
- RE 11.4.8: Eucalyptus cambageana woodland to open forest with A. harpophylla or Acacia argyrodendron on Cainozoic clay plains
- RE 11.3.3: Eucalyptus coolabah woodland on alluvial plains
- RE: 11.4.8a Brigalow (A. harpophylla) Palustrine Wetland
- RE 11.3.4: Eucalyptus tereticornis and/or Eucalyptus spp. woodland on alluvial plains
- RE 11.5.5: Eucalyptus melanophloia, Callitris glaucophylla woodland on Cainozoic sand plains and/or remnant surfaces. Deep red sands
- RE 11.3.2: Eucalyptus populnea woodland on alluvial plains
- RE 11.5.9: Eucalyptus crebra and other Eucalyptus spp. and Corymbia spp. woodland on Cainozoic sand plains and/or remnant surfaces
- Re 11.3.27: Freshwater wetlands

The identified REs are listed under the *Vegetation Management Act 1999* and Biodiversity status is as follows:

- Endangered: 11.3.1, 11.4.8, 11.4.8a
- Of Concern: 11.3.3, 11.3.4, 11.3.2
- Least Concern: 11.5.5, 11.5.9, 11.3.27

No conservation significant flora species, listed under the *Nature Conservation Act 1992* (NC Act) and/or EPBC Act, have been located in or near the BNCOP area.

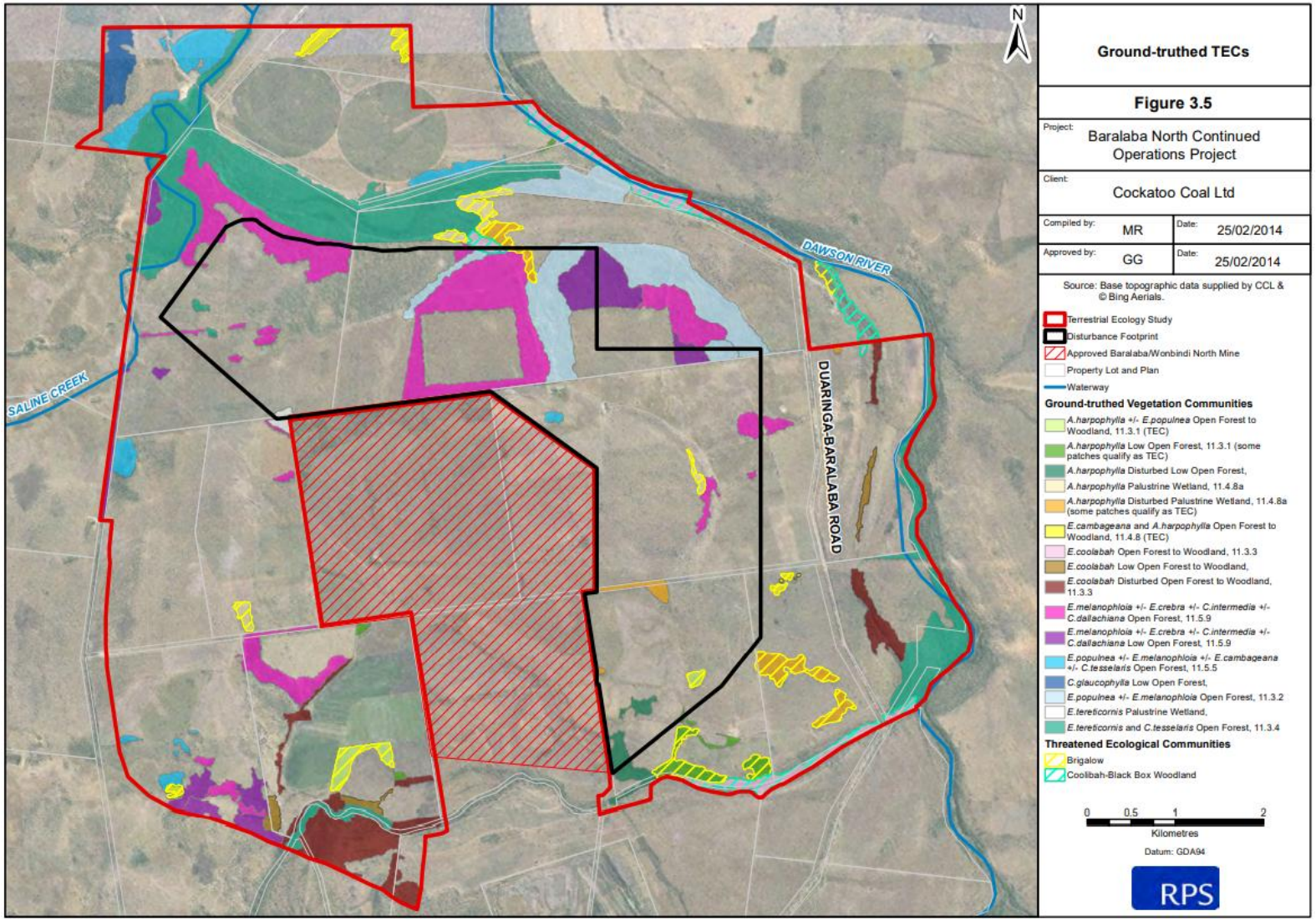

Figure 13: Baralaba North ground-truthed threatened ecological communities (RPS 2014)

3.8 Fauna presence

A range of fauna species have been recorded during surveys covering the boundaries of ML80201 and its surrounds. The highest number of amphibian species (13 species), reptile species (21 species) and mammal species (15 species) were recorded in the Riparian Woodland Habitat Type in the wider area. The highest number of bird species was recorded in the Eucalypt Open Forest Habitat Type (62 species).

One threatened fauna species listed under the NC Act and EPBC Act (as Vulnerable in both Acts) has been confirmed within the boundaries of ML8021, the Squatter Pigeon (southern) (*Geophaps scripta scripta*).

A second species listed under the NC Act and EPBC Act (as Vulnerable in both Acts) was recorded in the locality of the Baralaba Coal Mine, the Large-eared Pied Bat (*Chalinolobus dwyeri*).

A third threatened fauna species listed under the NC Act and/or EPBC Act (as Vulnerable) has been recorded outside of the Baralaba MLs, namely, the Ornamental Snake (*Denisonia maculata*). This species has more specific habitat requirements than the Squatter Pigeon (southern) and South-eastern Long-eared Pied Bat. The Ornamental Snake is most likely to occur in Brigalow-dominated ecosystems supporting gilgai formations.

The South-eastern Long-eared Bat (*Nyctophilus corbeni*) (listed as Vulnerable in both acts) may have been recorded but the Anabat call recordings are not definitive for this species.

4 Community consultation

Section 126C(1)(c) of the EP Act includes the following requirements regarding community consultation in relation to the PRCP:

> *iii) requires that the PRC Plan – Rehabilitation Planning Part include details of any community consultation undertaken in the development of the PRCP Plan; and*
>
> *iv) requires that the PRC Plan – Rehabilitation Planning Part include details as to how ongoing community consultation will be undertaken regarding rehabilitation.*

The DETSI information sheet *Community Consultation for Progressive Rehabilitation and Closure Plan* (DES, 2019) (the Community Consultation Guideline) provides additional detail on identifying relevant parties and the nature of their interest.

The Community Consultation Guideline refers to engagement with stakeholders, where a relevant party is identified as having a genuine interest in:

- the land where the activity will occur;
- the land adjacent to where the activity will occur;
- the land/amenities surrounding where the activity will occur that were likely to be impacted by the activities.

Throughout the life of Baralaba Coal Mine ongoing engagement with stakeholders who hold a genuine interest in the land has been undertaken through the development of compensation, make good, leasing, and agistment agreements. A summary of these discussions undertaken under the current ownership structure is provided in Table 7.

Table 7: Community consultation register

Date	Stakeholder and community member(s)	Consultation Type	Information Provided	Issues raised by the community	How issues were considered	Decisions/Outcomes	Commitments
February 2021	Gaangalu Nation People (GNP)	Cultural Heritage Coordinating Committee Meeting	A presentation regarding ongoing mining activities and closure post mining land uses (PMLUs).	Nil issues, applicable to rehabilitation activities onsite were raised. Positive commentary was provided on the progressive rehabilitation of Central Pit.	N/A	N/A	Continued commitment to rehabilitate Central Pit in accordance with existing rehabilitation commitments. Continue to engage with GNP on rehabilitation opportunities.
April 2021	Department of Environment and Science	Presentation and inspection of existing rehabilitation works and mining activities.	A presentation of existing rehabilitation and mining activities.	Baralaba Coal Company Pty Ltd and DETSI discussed the most beneficial post mining land use for the rehabilitated areas as grazing, as the likely post mining landholder would be a grazier. It was discussed that maximising the proposed grazing areas on the final landform will increase the site's productive land and provide greater long term stability. In addition, grazing will provide a higher ranking land outcome based on: - providing a productive land use, - aligns with regional planning tools,	Baralaba Coal Company Pty Ltd agreed with the outcomes discussed and decided to progress an EA amendment to change the elevated landform PMLU to grazing.	An EA amendment was submitted to the DETSI to amend the approved PMLUs for elevated landforms from nature conservation areas to grazing.	Elevated landforms will be rehabilitated to a PMLU of grazing.

Date	Stakeholder and community member(s)	Consultation Type	Information Provided	Issues raised by the community	How issues were considered	Decisions/Outcomes	Commitments
				- aligns with stakeholder interests, and - reflects surrounding land uses.			
November 2021	Neighbouring landholder	Meeting with Baralaba Coal Chief Financial Officer	Discussions of ongoing agistment agreements and EA amendment on proposed changes to the PMLUs.	Nil issues, applicable to rehabilitation activities onsite were raised. The neighbouring landholder showed interest and agreement in the change of the elevated landform PMLUs to grazing.	The engagement resulted in continued commitment to the change of the elevated landform PMLUs to grazing.	An EA amendment was submitted to the DES to amend the approved PMLUs for elevated landforms from nature conservation areas to grazing.	Elevated landforms will be rehabilitated to a PMLU of grazing. Remain in contact and discuss future opportunities for grazing.
February 2022	Baralaba Community Members and Groups	Baralaba Coal Mine Open Day	Discussions regarding the change in ownership, ongoing life of the mine, and existing rehabilitation activities at Baralaba Central.	Nil issues, applicable to rehabilitation activities onsite were raised. Affirmation was received on the site's commitment to the rehabilitation of Baralaba Central.	N/A	N/A	Continued commitment to rehabilitate Central Pit in accordance with existing rehabilitation commitments. Continue to engage with the Baralaba Community on rehabilitation opportunities.

Date	Stakeholder and community member(s)	Consultation Type	Information Provided	Issues raised by the community	How issues were considered	Decisions/Outcomes	Commitments
April 2022	Affected Landholders (neighbouring landholders)	Joint meeting with Baralaba Coal Mine General Manager	Discussions regarding ongoing mining activities, existing rehabilitation activities at Baralaba Central and final landform drainage pathways.	Landholder raised concerns about the removal of a drain between the Baralaba North Levee and their property boundary.	Baralaba Coal reviewed the final landform and flooding assessment to ensure (1) the drain remained within the final landform and (2) the final landform did not cause flooding impacts on the neighbouring property.	Drain to remain within the final landform.	Drain to remain within the final landform.
May 2022	Department of Environment and Science	Presentation and meeting with Baralaba Coal General Manager and Senior Environment and Community Advisor.	Presentation of conditional amendments proposed in EA amendment and supporting documentation.	Both parties reviewed and discussed the proposed PMLU amendments and amendments to the rehabilitation objectives within the EA.	Guidance provided by DETSI on grazing and nature conservation rehabilitation objectives were accepted and implemented within the EA.	The EA was amended in accordance with the outcomes of the discussions held with DES.	Continue to engage with DETSI on rehabilitation opportunities and progression.
June 2022	Neighbouring landholders	Joint meeting with Baralaba Coal Mine General Manager	Informal discussion in person regarding ongoing site operations.	Nil issues, applicable to rehabilitation activities onsite were raised.	N/A	N/A	Continue to engage with landholders on rehabilitation opportunities.

Date	Stakeholder and community member(s)	Consultation Type	Information Provided	Issues raised by the community	How issues were considered	Decisions/Outcomes	Commitments
October 2022	Gaangalu Nation People	Presentation and Bus Tour	A presentation regarding ongoing mining activities and current rehabilitation activities.	Nil issues, applicable to rehabilitation activities onsite were raised. Positive commentary was provided on the progressive rehabilitation of Central Pit.	N/A	N/A	Continued commitment to rehabilitate Central Pit in accordance with existing rehabilitation commitments. Continue to engage with GNP on rehabilitation opportunities.
8 March 2023	Community Consultative Committee Meeting	Formal meeting	A presentation regarding ongoing mining activities and current rehabilitation activities.	Nil issues, applicable to rehabilitation activities onsite were raised.	N/A	N/A	Continue to engage with the Community Consultative Committee on rehabilitation opportunities.
7 June 2023	Community Consultative Committee Meeting	Formal meeting	A presentation regarding ongoing mining activities and current rehabilitation activities.	Nil issues, applicable to rehabilitation activities onsite were raised.	N/A	N/A	Continue to engage with the Community Consultative Committee on rehabilitation opportunities.

Date	Stakeholder and community member(s)	Consultation Type	Information Provided	Issues raised by the community	How issues were considered	Decisions/Outcomes	Commitments
26 July 2023	Save the Dawson Member	Formal meeting and site visit.	A presentation regarding ongoing mining activities, current rehabilitation activities and EIS works currently underway on the Baralaba South Project.	Nil issues, applicable to rehabilitation activities onsite were raised.	N/A	N/A	Ongoing consultation.
12 September 2023	Community Consultative Committee Meeting	Formal Meeting	A presentation regarding ongoing mining activities and current rehabilitation activities.	Nil issues, applicable to rehabilitation activities onsite were raised.	N/A	N/A	Continue to engage with the Community Consultative Committee on rehabilitation opportunities.

The outcomes of all stakeholder consultation are recorded in the Baralaba Coal Mine Community Complaints and Engagement Register (register). This document is considered a stand-alone register. Should the PRCP schedule change in a way that may affect any interested stakeholders, consultation shall be undertaken, in accordance with the Section 4.1, regarding proposed changes with the outcomes detailed in this register.

This register will be updated as required, independent of this PRCP and will be considered prior to any future amendments to this PRCP.

4.1 Community and Stakeholder Engagement Plan

To meet the requirement of section 126C(1)(iv) of the EP Act, and the PRCP guidelines, Baralaba Coal Mine has developed a community consultation and stakeholder engagement plan (SEP) that outlines how ongoing consultation will be undertaken with stakeholders who hold a genuine interest in relation to the rehabilitation to be carried out under this PRCP (Table 8).

The SEP is intended as a framework to facilitate engagement, consultation, and collaboration with stakeholders on, among other things, matters relating to rehabilitation and closure.

The key objective of the plan is to achieve the following:

- provide information about the timing and extent of planned rehabilitation and closure-related activities.
- provide information about the progress in implementing rehabilitation.
- receive community feedback on matters concerning rehabilitation, and
- provide timely responses to community feedback and enquiries relating to matters concerning rehabilitation.

This SEP will be continually reviewed and revised, where appropriate to allow for continual refinement.

Table 8: Community Consultation and Stakeholder Engagement Plan

Stakeholder	Engagement Type	Area of interest	Frequency
Neighbouring and underlying landholders, and agistees.	• One on one meetings • Newsletters • Town office open door policy.	• Future access to and ownership of lands. • Water access, site drainage, and flooding. • Environmental management /stewardship • Post-mining land use and landform/landscape • Progress of rehabilitation activities.	As required. Quarterly meetings with landholders in accordance with existing make good agreements. Site tours
Gaangalu Nation People Gaangalu Nation People Endorsed Parties.	• Coordinating committee meeting • Site tours	• Cultural Heritage and Native Title • Potential impacts to the cultural landscape or connections to Country.	As required
Baralaba Community Members and Interested Local Groups	• Community Open Days • Community Consultative Committee Meetings • Site Tours • Newsletters	• Post-mining land use and landform/landscape • Rehabilitation schedule • Future access to and ownership of lands • Economic and community sustainability post-mining	As required. Site tours

Stakeholder	Engagement Type	Area of interest	Frequency
	• Town office open door policy.		
Baralaba Coal Employees and Contractors	• Pre-start and Crew Meetings	• Job opportunities • Loss of jobs with closure • Working conditions	Monthly
Central Highlands Regional Council Banana Shire Council	• One on one meetings	• Economic and community sustainability post-mining • Effects of on Council services and infrastructure • Mine rehabilitation and progress of rehabilitation of council lands. • Management of closure impacts on employment and businesses	As required. Site tours
Elected representatives and Government agencies	• One on one meetings	• Post-mining land use and landform/land scape • Rehabilitation schedule	As required

Should any proposed changes to the PRCP or schedule be required, stakeholders listed in Table 9 will be engaged as part of the amendment process. Table 9 provides an overview of the key engagement objectives, consultation methods, frequency, the information that will be released and how feedback will be considered during consultation for proposed changes to the PRCP or schedule.

Table 9: Consultation plan for PRCP or schedule changes

Stakeholder	Consultation Method	Frequency	Information released for consultation	How feedback will be considered.
Neighbouring and underlying landholders, and agistees.	One on one meeting to discuss proposed changes to PRCP or schedule and gather feedback.	One or more meetings as required.	A summary document providing an outline of the proposed PRCP, or schedule changes and any additional information requested by the stakeholders.	Feedback will be considered in the context of the proposed changes and other relevant feedback and if technically viable and reasonably possible it will be incorporated in the final version of the PRCP amendment application.
Gaangalu Nation People				
Gaangalu Nation People Endorsed Parties.				
Baralaba Coal Employees and Contractors				
Central Highlands Regional Council				
Baralaba Community Members and Interested Local Groups	Meeting with community consultative committee, community open days, site tours, aimed at discussing the proposed changes to PRCP or	One or more meetings as required prior to lodgement of amendment to PRCP, or schedule proposed changes.	A summary document providing an outline of the proposed PRCP, or schedule changes and any additional information	Feedback will be considered in the context of the proposed changes and other relevant feedback and if technically viable and reasonably possible it will be

Stakeholder	Consultation Method	Frequency	Information released for consultation	How feedback will be considered.
	schedule, and gather feedback.		requested by the stakeholders.	incorporated in the final version of the PRCP amendment application.

5 Post-mining land use

The EA is the primary land outcome document for Baralaba Coal Mine. PMLUs for the Baralaba Coal Mine are outlined in Table H2 (a) and (b) within the EA, along with projected disturbance areas, post-mine land descriptions, land suitability classifications and various landform criteria for each disturbance type. Table H2 (a) and (b) have been reproduced here as Table 10 and Table 11.

With the exception of the residual void, and infrastructure on ML700004, Table H2 (a) and (b) of EA nominates a post mining land use description of 'grazing' for all areas with a Class 4 land suitability. The selection of this PMLU has been informed by the pre-mining and historical land uses within and surrounding the Baralaba Coal Mine.

Table H2(a) defines the PMLU for Infrastructure on ML700004 as self-sustaining natural vegetation or habitat which is further described as '*Establish a stable landform and revegetate with native and/or pasture grass species to control erosion. Allow the establishment of native trees and shrubs*. The native ecosystem rehabilitation options decision support flowchart was used (Spain et al 2023) to further define this PMLU. Given the highly fragmented and disturbed pre-mining landscape in this area and pre-mining vegetation, a native vegetation PMLU is proposed, where a mix of species found in local REs including RE 11.3.1, RE 11.3.2, RE 11.3.3 and RE 11.3.4 along with dominant species recorded in baseline surveys will be established within the rehabilitated landform. The intent of the native vegetation PMLU is to deliver the 'Beneficial Environmental Outcome' of providing habitat connectivity to the surrounding REs, which is consistent with the intention of the LOD description for the PMLU. Although committed to transitioning this area to a native vegetation PMLU, an existing compensation agreement is held between Banana Shire Council and Wonbindi Coal Pty Ltd (dated 18 April 2017) for the Local Government Roads known as River Road, Baralaba-Woorabinda Road, and Unnamed roads within this mining lease. This agreement leaves the decision for retention of the existing infrastructure within ML700004 to the landholder (Banana Shire Council), to be determined at the end of the term of the agreement.

The PMLUs are underpinned by rehabilitation objectives that focus on achieving a safe, stable, sustainable, and non-polluting landform.

The approved PMLUs within the EA for Baralaba Coal Mine are presented in Figure 14. The achievement of these PMLUs is in line with the consultation completed to date (Section 4).

Table 10: Post-mining land use (from the resource activity EA Table H2 (a)

	Elevated landform – Upper Surface	**Elevated landform – Upper Surface**	**Infrastructure**	**Infrastructure**
Tenure ID	ML5605, ML80157	ML5605, ML80157	ML5605, ML80157	ML700004
Projective surface area (ha)	100	128	102	13.35
Pre-mine land use	Grazing	Grazing	Grazing	Grazing and Natural Vegetation
Post mine land use	Grazing	Grazing	Grazing	Self-sustaining natural vegetation or habitat
Post mine land use description	Establish a stable landform and revegetate with pasture species which may support cattle grazing and will be compatible with the	Establish a stable landform and revegetate with grass species to control erosion and encourage limited grazing.	Establish a stable landform and revegetate with pasture species which may support cattle grazing and will be compatible with the surrounding "new" landform.	Establish a stable landform and revegetate with native and/or pasture grass species to control erosion. Allow the establishment of

	Elevated landform – Upper Surface	Elevated landform – Upper Surface	Infrastructure	Infrastructure
	surrounding landform.			native trees and shrubs.
Post mine land suitability classification (Note)	Class 4 land suitability	Class 4 land suitability	Class 4 land suitability	Class 4 land suitability
Projective cover range (%)	Approximately 70%	Approximately 70%	Approximately 70%	Approximately 70%

Table 11: Post-mining land use (from the resource activity EA Table H2 (b)

	Residual Void	Elevated landform – Upper Surface	In-pit spoil and Elevated Landform – Slopes	Infrastructure
Tenure ID	ML80170, ML80201	ML80169, ML80170, ML80201	ML80169, ML80170, ML80201	ML80169, ML80170, ML80201, ML80200
Projective surface area (ha)	144	385	1096	282.8
Pre-mine land use	Grazing	Grazing	Grazing	Grazing
Post mine land use	Non-use management area (NUMA)	Cattle Grazing	Cattle Grazing	Cattle Grazing
Post mine land use description	Non-use management area (NUMA)	Establish a stable landform and revegetate with pasture species which may support cattle grazing and will be compatible with the surrounding landform.	Establish a stable landform and revegetate with grass species to control erosion and encourage limited grazing.	Establish a stable landform and revegetate with pasture species which may support cattle grazing and will be compatible with the surrounding "new" landform.
Post mine land suitability classification (Note)	Not applicable	Class 4 land suitability	Class 4 land suitability	Class 4 land suitability
Projective cover range (%)	Not Applicable	Approximately 70%	Approximately 70%	Approximately 70%

Note: DSITI & DNRM (2015). Guidelines for agricultural land evaluation in Queensland (2nd edn). Queensland Government (Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines), Brisbane, Queensland.

An existing *Transmission Network Assets Relocation Agreement for the Baralaba North Expansion Project Affecting Feeders 7113 and 7114/1* (dated 17 December 2019) between Queensland Electricity Transmission Corporation Ltd (trading as "Powerlink Queensland") and Wonbindi Coal Pty Limited, transfers the ownership and liability of the infrastructure and land associated with the high voltage powerline that traverses the west, east and southern boundary of the Baralaba North Pit, to Powerlink. A statutory declaration on the applicable content of this agreement has been included in Appendix D.

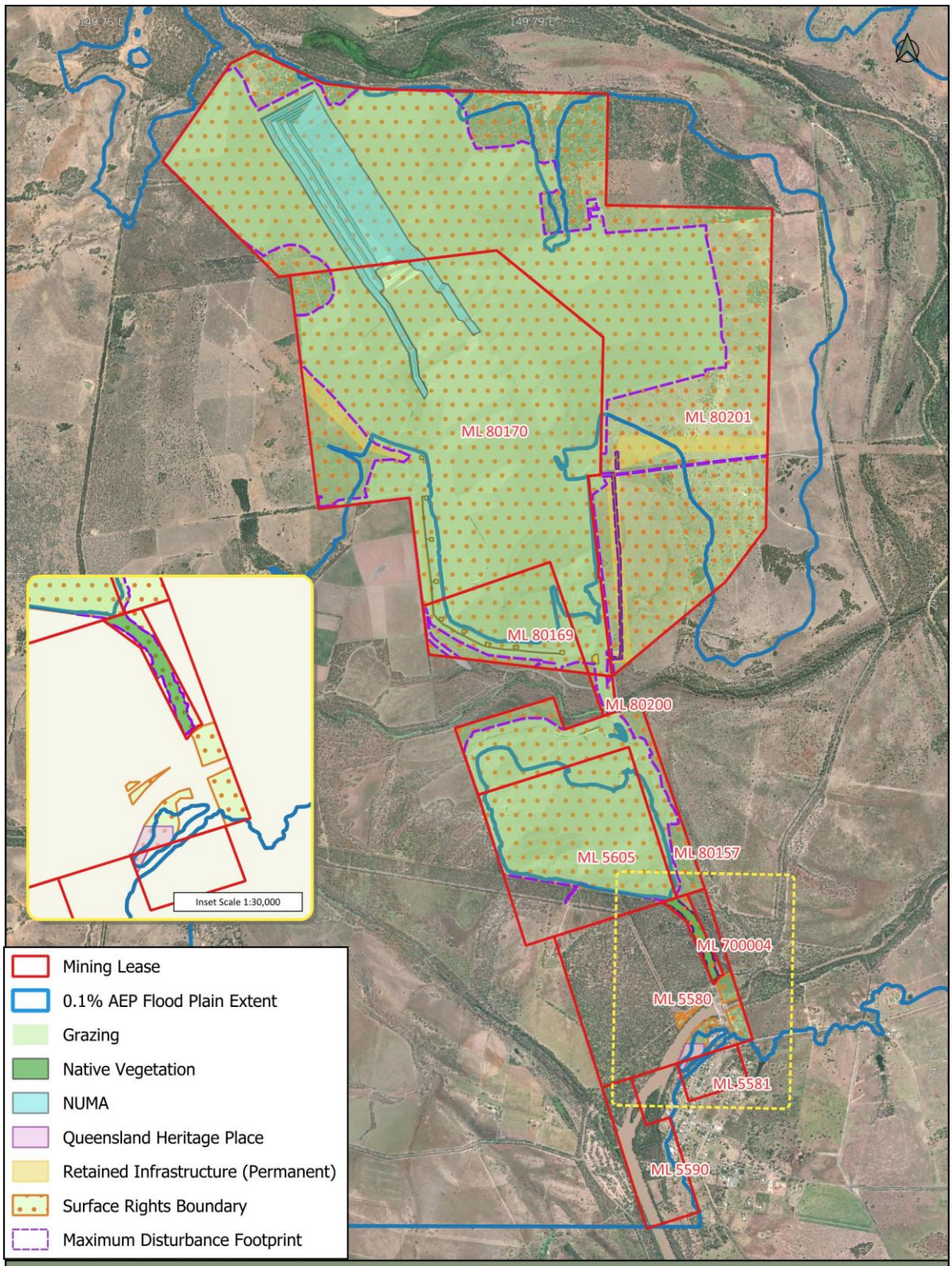

Figure 1: Conceptual Final Landform

Baralaba Coal Mine

Client	Baralaba Coal Pty Ltd
Author	C.An
Date	19/09/2025
Revision	5
Map Projection	GDA2020 / MGA zone 55

0 500 1,000 m

Scale: 1:60,000 (160 mm x 240 mm)

Data Source:

Q:\Baralaba Coal\GIS\Workspaces\250219_PRCP_RFI.qgz

Figure 14: Conceptual final landform

5.1 Regional planning integration

Baralaba Coal Mine is located in the "rural zone" under the Central Highlands Regional Council Planning Scheme (CHRC 2016). The rural zone is intended to:

- provide rural uses including cropping, intensive horticulture, intensive animal industries, animal husbandry, animal keeping and other primary production activities.
- provide opportunities for non-rural uses that are compatible with agriculture, the environmental features, and landscape character of the rural area where the uses do not compromise the long-term use of the land for rural purposes; and
- protect or manage significant natural resources and processes to maintain capacity for primary production.

Whilst also mimicking the existing neighbouring land uses of grazing, the nominated PMLUs for Baralaba Coal Mine are consistent with the intention of this rural zone as outlined in this planning schedule.

The PMLUs also align with the regional outcomes under the Central Queensland Regional Plan 2013, which is intended to allow agriculture, within Central Queensland, to expand collectively with the resource industries.

5.2 Completion criteria

The completion criteria for the PMLUs are defined in Appendix 3 – Rehabilitation Requirements of the EA and have been reproduced in Table 12.

Table 12: PMLU completion criteria

Post Mining Land Use	Rehabilitation Goal	Closure Criteria
Grazing	Site is safe for humans and wildlife	Evidence of low risk of land contamination via a contaminated land assessment report
		Landform deemed safe by an appropriately qualifiedand experienced person for PMLU activities
		Landform design does not exceed the Baralaba Coal Mine surface areas as outlined in. Table H2 (a) – Final Land use and rehabilitation approval schedule – Baralaba Central Mine. Table H2 (b) – Final Land use and rehabilitation approval schedule – Baralaba North Operations.
		The hazard in the grazing areas must have no significant difference to hazards in local grazing lands in surrounding unminded landscapes, as identified through reference site monitoring
	Non-polluting	pH: 6.5 – 8.5 (median) EC: 500 µS/cm (median) or less Sulphate: 250 mg/L (median) or less
	Stable	An appropriately qualified person certifies the long-term geotechnical stability of the landform and evidence of this is documented in a rehabilitation report
		Spoil settlement analysis of in-pit spoil completed by a suitably qualified and experienced person certifies that the long term landform is stable and functioning as per design intent.

Post Mining Land Use	Rehabilitation Goal	Closure Criteria
		A flood assessment by a suitably qualified and experienced person certifies that a 0.1% AEP flood event will not impede on the stability of the final landform.
		Align with criteria described in Table H3: Landform Design Criteria
		Rehabilitation monitoring reports do not identify erosion classifications higher than 'minor' and no active erosion present, as demonstrated by no increase in erosion over time.
		>70% established and persistent groundcover (such as vegetation, rock, mulch, or other surface protection) for all rehabilitated areas.
	Sustainable post-mining land use.	Grazing land to meet a minimum of less than orequal to Class 4 land suitability for grazing.
Native vegetation	Safe to humans and wildlife	Evidence of low risk of land contamination via acontaminated land assessment report
		Landform deemed safe for PMLU activities
		Landform design does not exceed Baralaba Coal Mine surface areas as outlined in. Table H2 (a) – Final Land use and rehabilitation approval schedule – Baralaba Central Mine. Table H2 (b) – Final Land use and rehabilitation approval schedule – Baralaba North Operations.
		The hazard in the native vegetation must have no significant difference to hazards in local regional ecosystems in surrounding unminded landscapes, as identified through reference site monitoring.
	Non-polluting	pH: 6.5 – 8.5 (median) EC: 500 µS/cm or less (median) Sulphate: 250 mg/L or less (median)
	Stable	An appropriately qualified person certifies the long-term geotechnical stability of the landform and evidence of this is documented in a rehabilitation report.
		As described in Table H3: Landform Design Criteria –Baralaba Coal Mine.
		Rehabilitation monitoring reports do not identify erosion classifications higher than 'minor' and noactive erosion present, as demonstrated by no increase in erosion over time.
		>70% established and persistent groundcover (such as vegetation, rock, mulch, or other surface protection) for all rehabilitated areas.
	Sustainable post-mining land use	A. Native plant species richness: Trees ≥3 count. Shrubs ≥2 count Groundcover species ≥5 count. B. Cover: - Tree canopy cover is at least 28%

6 Non-use management areas

The Baralaba North Pit is identified in Table H2 (b) of the EA (Table 11) as a non-use management area (NUMA). Table H2(b) outlines the NUMA projective surface area of 144 Ha, while Table H3 defines the approved slope ranges of:

- 0 – 9° to the base of tertiary; and
- 9 – 70° below the base of tertiary.

Under the relevant transitional provisions, as this Baralaba North Pit is a pre-approved NUMA described within a land outcome document, the Baralaba Coal Company is not required to:

- justify the proposed NUMA;
- provide evidence to support the justification of the NUMA;
- go through the Public Interest Evaluation process; and
- comply with the prohibition of voids located within a flood plain having to be rehabilitated to a stable condition.

However, all NUMAs, regardless of whether they have been identified in a land outcome document, are required to be managed in a way that achieves best practice management and minimises risks to the environment. Excerpts from the BNCOP EIS technical assessments are provided below and described further in section 7.4. These sections demonstrate how the Baralaba North Residual Void will be managed to achieve best practice management and minimise any risk to the environment.

As the NUMA proposed in this PRCP is consistent with the approved NUMAs described in the EA, it can be inferred that the NUMAs remain consistent with the outcomes of past consultation processes (undertaken as part of the EA and ML approvals).

6.1 Completion criteria

The completion criteria for the NUMA are defined in Appendix 3 – Rehabilitation Requirements of EA (EPML00223213) and have been reproduced in Table 13.

Table 13: Completion criteria for the NUMA

Land Outcome	Rehabilitation goals	Completion criteria
Non-use Management Area	Safe to humans and wildlife	The hazards in the NUMA must have no offsite impacts
		Exclusion fencing and suitable signage at a distance from slope crest to the 'zone of void influence', has been established around the highwall, low wall, and end walls.
	Stable	NUMA Area does not exceed 144 Ha.
		Certification by an appropriately qualified person that the residual void is outside of the 1:1000 annual exceedance probability (AEP) floodplain.
		Factor of Safety ≥ 1.2
		Align with criteria described in • Table H3: Landform Design Criteria

Land Outcome	Rehabilitation goals	Completion criteria
		Long term groundwater modelling confirms the final void will remain as a sink in perpetuity.
	Non-polluting	NUMA area contains 100% of runoff generated.
		Certification by an appropriately qualified person in the Rehabilitation Report that the residual void has an adequate protection system to prevent inundation from a probable maximum flood (PMF) event.

6.2 Community Consultation

Since taking ownership in late 2021, consistent community consultation has taken place. Relevant stakeholders, including but not limited to, the Gaangalu Nation People, neighbouring landholders and the general Baralaba community have had regular consultations. Matters of PMLUs and rehabilitation objectives have been regularly discussed and no queries or issues with the NUMA have been raised by relevant stakeholders to date. Section 4 further details the community consultation to date as well as the SEP, which addresses the requirement of section 126C(1)(iv) of the EP Act and the PRCP guidelines.

6.3 Relevant Legislation, Plans and Strategies

Relevant local, state and national Strategies, Plans and Legislation applicable to NUMAs at the Baralaba Coal Mine are outlined in Table 14.

Table 14: Relevant Legislation, Strategies or Plans for Local, State and National Governments

Legislation, Strategy or Plan	Overview	NUMA Consistency
Local/Regional		
Central Highlands Regional Council Planning Scheme	The planning scheme has been developed in accordance with the Planning Act 2016. The scheme is a framework that regulates land use, buildings, and development to ensure appropriate growth in designated areas. It facilitates infrastructure planning to support regional growth.	The scheme acknowledges mining as a key industry sustaining the region's economy. As NUMAs are common in open-cut mining operations, this shows consistency with the plan.
Banana Shire Planning Scheme 2021	The planning scheme outlines future development in a local government area, ensuring sufficient land is allocated for housing, industry, and community needs. It helps protect resources, prevent land use conflicts, and promote efficient infrastructure development.	The scheme acknowledges mining as a key industry sustaining the region's economy. As NUMAs are common in open-cut mining operations, this shows consistency with the plan.
State		
Environmental Protection Act 1994		
Central Queensland Regional Plan	The statutory plan offers strategic guidance and policies to achieve	The plan acknowledges mining as a key industry sustaining the region's

Legislation, Strategy or Plan	Overview	NUMA Consistency
2013	regional outcomes that align with the state's planning and development priorities.	economy. As NUMAs are common in open-cut mining operations, this shows consistency with the plan.
Mined Land Rehabilitation Policy 2017	The policy presents the Queensland Government's position on mine rehabilitation. The policy states that the NUMA can be proposed if: • the proposed treatment of the land meets current best practise management; • rehabilitation poses a greater environmental risk than not rehabilitating the area; and • the environmental risks from the area are localised and the cost of rehabilitation would be so excessive as to be not in the public interest.	The NUMA area meets the requirements for proposing a NUMA, as set forth by the policy.
State Planning Policy (SPP) (*Department of Infrastructure, Local* *Government and Planning, 2017*)	The State Planning Policy (SPP) outlines the state's priorities in land use planning and development. A state interest, as defined by the Planning Act, is any matter that the Planning Minister deems to impact the economic or environmental interests of the state or its regions, or that influences the achievement of the Act's objectives. Local governments are required by the Planning Act to incorporate relevant state interests into their planning schemes	The inclusion of a NUMA does not affect the SPP layers that are applicable to the Baralaba Coal Mine, including: • Agricultural land classification – class A and B • Flood hazard area – Level 1 & local government flood mapping
State Infrastructure Strategy 2022	This strategy aims to promote sustainable and essential infrastructure development for the state, while highlighting the substantial economic contribution of the mining industry.	The strategy acknowledges mining as a key industry sustaining the state's economy. As NUMAs are common in open-cut mining operations, this shows consistency with the plan.
Central and Western Queensland Infrastructure Plan 2023	The plan aims to continue supporting major regional development by establishing regional priorities. It recognizes the vital role the resource sector plays in sustaining economic growth.	The plan acknowledges mining as a key industry sustaining the region's economy. As NUMAs are common in open-cut mining operations, this shows consistency with the plan.
National		
No national strategies or plans were identified as applicable.		

6.4 Voids in a floodplain

Section 126D(3) of the EP Act stipulates that *'if the land subject to a proposed PRCP schedule will contain a void situated wholly or partly in a floodplain, the PRCP schedule must provide for rehabilitation of the land to a stable condition*'. The PRCP Guideline notes that Section 126D(3) of the EP Act does not apply where a NUMA has already been identified in a LOD and is transitioned into the PRCP schedule consistent with the LOD (DES 2021a). As the Baralaba North residual void has been previously identified and detailed in the LODs for Baralaba Coal Mine, evidence, and justification for the location of the residual void are not required to be provided in the PRCP.

Notwithstanding section 126D(3), the Baralaba North Residual Void is located outside the 0.1% AEP modelled flood extent and therefore does not represent a threat to the stability of the residual voids.

7 Rehabilitation and management methodology

7.1 Rehabilitation objectives

In Queensland, mine rehabilitation is required under the EP Act. Amendments to the EP Act in late 2018 implemented key elements of the State Government's Mined Land Rehabilitation Policy (Queensland Government 2018) which intends to ensure that, for land disturbed by mining activities:

- 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 post-mining land use (section 111A of the EP Act).

These three objectives are the general rehabilitation goals for all areas disturbed by mining in Queensland.

7.2 Rehabilitation areas and improvement areas

To allow the development of a PRCP schedule that satisfies the requirements of the PRCP Guideline, discrete rehabilitation areas (RAs) and improvement areas (IAs) have been defined for the Baralaba Coal Mine. An RA is defined in the *Environmental Protection Regulation 2019* (EP Regulations) as an area of land in the PMLU to which a rehabilitation milestone for the post-mining use relates. An IA is defined in the EP Regulation as, for a NUMA, an area of land in the NUMA to which a management milestone for the NUMA relates. Either RAs or IAs have been nominated for areas of disturbance within the Baralaba Coal Mine and are shown in Table 15 and Figure 15.

Table 15: Nominated rehabilitation and improvement areas.

Rehabilitation Area Reference	Description
RA1 – Elevated Landforms Upper Surfaces	Flatter areas of in-pit and out-of-pit spoil that will be rehabilitated to achieve a PMLU of grazing
RA2 - Elevated Landforms Slopes	Steeper areas of in-pit and out-of-pit spoil that will be rehabilitated to achieve a PMLU of grazing
RA3 – Mine Affected Water Dams	Dams that will be recontoured and rehabilitated to achieve a grazing PMLU.
RA4 – Clean Water Dams	Dams that will be recontoured and rehabilitated to achieve a grazing PMLU.
RA5 – Infrastructure areas – Grazing	infrastructure areas including areas within backfilled voids, roads and hard stand areas rehabilitated to achieve a PMLU of grazing.
RA6 – Infrastructure Area – Native Vegetation	infrastructure areas including roads to be rehabilitated to achieve a PMLU of Native Vegetation.
RA7 - Permanent Infrastructure	Powerline infrastructure.
RA8 – Existing Rehabilitation	Waste dumps, backfilled voids and infrastructure including (MAW dams, roads, hard stands) rehabilitated to achieve a PMLU of grazing.
Improvement Areas	**Description**
IA – Final Void	Residual void area including the water containment (lake) and the surrounding walls and in situ materials.

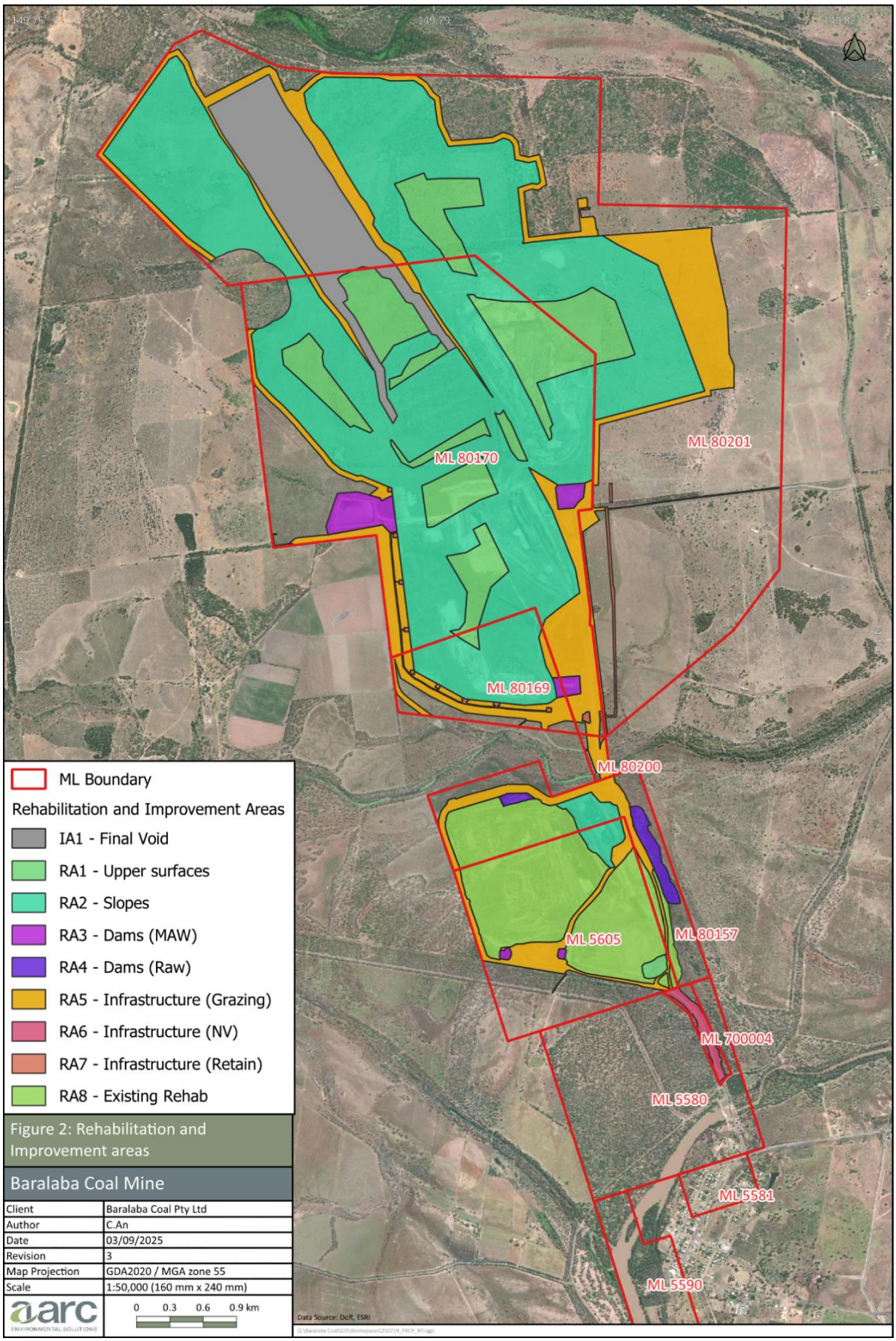

Figure 15: Baralaba Coal Mine rehabilitation and improvement areas

7.2.1 Rehabilitation milestones and timeframes

The rehabilitation milestones for Baralaba Coal Mine are outlined in Appendix C. Not all rehabilitation milestones are applicable to all RAs. The applicability of rehabilitation milestones to the various RAs is also shown in Table 16. Rehabilitation milestones have been informed by the pre-approved completion criteria in the EA, reproduced here as Table 12. Rehabilitation milestones have been developed with consideration of site characteristics and best practices to ensure that the final landform can demonstrate that it is safe, stable, can sustain the proposed PMLU and does not cause environmental harm.

Rehabilitation is required to be commenced as soon as practicable after land becomes available for rehabilitation. Land is considered to be available for rehabilitation at the completion of mining, unless –

1) the land is being used for operating infrastructure or machinery for mining, including, for example, a dam or water storage facility; or

2) contains a probable or proved ore reserve that is to be mined within 10 years after the land would otherwise have become available for rehabilitation; or

    a) the land is required for the mining of a probable or proved ore reserve mentioned in paragraph (2); or

3) the land contains permanent infrastructure identified in the proposed PRCP schedule as remaining on the land for a post-mining land use.

Rehabilitation milestone timeframes and scheduling have been developed with consideration of:

- the size of the rehabilitation area;
- the availability of equipment;
- the activities applicable to the milestone; and
- interim rehabilitation activities that are scheduled to occur or anticipated to be required prior to the area becoming available for rehabilitation.

These considerations ensure that the rehabilitation progresses as soon as practical after the land becomes available, reflecting the genuine intent to rehabilitate progressively during the mine's life, as required by the PRCP objective.

Based on the current capacity of the Baralaba Coal Mine mining fleet, during operation, rehabilitation activities are limited to a maximum of 60 hectares per year, for applicable milestones. On completion of mining in 2036, this rate increases to 100 ha/yr. Any attempt to exceed this would significantly impact the mine's economic viability (for example, by reducing the coal mining rate) or increase health and safety risks at the mine site (if additional equipment was mobilised). Therefore, applying a rehabilitation rate greater than that depicted within the PRC Schedule (Appendix C), would not be feasible for Baralaba Coal Mine and would conflict with the requirements of Section 126D(4) of the Act.

As site specific rehabilitation monitoring data relating to the timeframes required to achieve rehabilitation milestones is limited, a conservative timeframe of 15 years for grazing areas, and 20 years for native vegetation, has been proposed to achieve surface requirements. This timeframe takes into consideration unfavourable growing seasons and unforeseen extreme events such as droughts or storms that could negatively impact vegetation establishment.

Table 16: Rehabilitation milestone timeframes justification

Rehabilitation Milestones (RM)	Applicable RAs	Summary completion criteria	Nominated time frame (years)	Justification for assigned timeframe
RM1: Infrastructure decommissioning and removal	RA1 RA2 RA3 RA4 RA5 RA6	• Infrastructure decommissioning and disposal	1	Some mine infrastructure (e.g. haul roads and tracks) will be required to facilitate rehabilitation activities and will therefore not become available for rehabilitation for several years post-closure. The timeframe assigned is 1 year.
RM2: Identification, remediation and removal of contaminated land	RA1 RA2 RA3 RA4 RA5 RA6	• Remediation or removal of contaminated material (where applicable) • Determination of contaminated land status by appropriately qualified person	1	A contaminated land assessment will be undertaken by an appropriately qualified person. If contaminated land is identified, remediation works will be undertaken promptly. The timeframe assigned is 1 year.
RM3: Landform development and reshaping	RA1 RA2 RA3 RA4 RA5 RA6	• Installation of drainage features • Bulk earthworks re-shaping • Final re-profiling • Geotechnical assessment of stability	1	As land becomes available, all bulk earthworks and installation of drainage features will be completed to design specifications and assessed as geotechnically stable by a suitability qualified person. The timeframe assigned is 1 year to a maximum area extent of 60 Ha
RM4: Surface preparation	RA1 RA2 RA3 RA4 RA5 RA6	• Surface preparation (e.g. topsoiling, contour ripping, soil amelioration activities as required)	1	Subsoil and topsoil amelioration and prompt vegetation establishment are key processes to minimise the identified risks. The timeframe assigned is 1 year to a maximum area extent of 60 ha, applicable to all RA.
RM5: Revegetation (grazing)	RA1 RA2 RA3 RA4 RA5	• Revegetation with seed consistent with the PMLU • no moderate or severe erosion	1	The seeding and / or planting of suitable target species is classified as 'Low' risk. The assigned timeframe of 1 year allows time for revegetation. The timeframe assigned is 1 year to a maximum area extent of 60 ha, applicable to all RA.

Rehabilitation Milestones (RM)	Applicable RAs	Summary completion criteria	Nominated time frame (years)	Justification for assigned timeframe
RM6: Revegetation (native vegetation)	RA6	• Revegetation with seed and consistent with the PMLU • no moderate or severe erosion	1	The seeding and / or planting of suitable target species is classified as 'Low' risk. The assigned timeframe of 1 year allows time for revegetation. The timeframe assigned is 1 year to a maximum area extent of 60 ha, applicable to all RA.
RM7: Achievement of surface requirements (grazing)	RA1 RA2 RA3 RA4 RA5 RA8	• groundcover to be >70% • no moderate or severe erosion • weed presence is a maximum of 10% of total vegetative cover	5	Achievement of a target PMLU requires it to be stable, safe, non-polluting and sustainable. The five years assigned for this timeframe considers the time necessary for establishment of mature, self- sustaining vegetation. Allowance is also given for natural hazard events such as fires or severe storms that may drive additional maintenance works or even revegetation.
RM8: Achievement of surface requirements (nature vegetation)	RA6	• groundcover to be >70%, • no moderate or severe erosion • Yr 5 modified BioCondition score reached • weed presence is a maximum of 10% of total vegetative cover • achievement of runoff water quality objectives	5	
RM9: Achievement of post mining land use to stable condition (grazing)	RA1 RA2 RA3 RA4 RA5 RA9	• groundcover to be >70%, • no moderate or severe erosion • weed presence is a maximum of 10% of total vegetative cover • land suitability Class 4 or better for grazing • completion of a hazard assessment • Groundwater and surface water monitoring.	10	Achievement of target revegetation criteria is dependent on good climatic conditions and soil preparation. Allowance is made for poor growing seasons and extreme events such as droughts or storms that will negatively impact vegetation establishment, and consequent maintenance actions that may be required. Consideration has also been applied to the timing needed to achieve the surface water quality objectives. Given these factors, the timeframe assigned is 10 years.

Rehabilitation Milestones (RM)	Applicable RAs	Summary completion criteria	Nominated time frame (years)	Justification for assigned timeframe
RM10: Achievement of post mining land use to stable condition (Native vegetation)	RA6	• groundcover to be >70%, • Yr 10 - 15 modified BioCondition score reached[1]. • no moderate or severe erosion • weed presence is a maximum of 10% of total vegetative cover • completion of a hazard assessment • Groundwater and surface water monitoring.	15	Achievement of target revegetation criteria is dependent on good climatic conditions and soil preparation. Allowance is made for poor growing seasons and extreme events such as droughts or storms that will negatively impact vegetation establishment, and consequent maintenance actions that may be required. Consideration has also been applied to the timing needed to achieve the surface water quality objectives. Given these factors, the timeframe assigned is 15 years
RM11: Achievement of post-mining land use (permanent Infrastructure)	RA7	• Permeant infrastructure (not related to grazing) is suitable for transfer to the landholder	1	Assess and ensure infrastructure is safe, stable and non-polluting in accordance with a landholder agreement.

See section 8 for risk determination.

1. Biocondition Benchmark criteria in Table 17.

7.2.2 Management milestones

The nominated management milestones and timeframes for the NUMA in the final landform are outlined in Table 17. As there is only one IA at Baralaba Coal Mine, all the management milestones are applicable to it.

Table 17: Management milestones

Reference	Management Milestone	Description	Nominated time frame (years)	Justification for assigned timeframe
MM1	Achievement of Final Landform	a) Highwalls batters shaped to achieve the nominated slope. b) Highwalls batters achieve the nominated stable slope - 0-9° to the base of tertiary, and 9 - 70° below the base of tertiary. c) Predictive modelling undertaken by an appropriately qualified person, confirming that the voids will remain as a groundwater sink and that there is no risk of contamination post mining.	1	The process for creating the stable final void landform will require alignment with geotechnical specifications regarding safe highwall design as well as other mitigation strategies such as the establishment of catch benches and buttressing. It is estimated that it will take 2 years to reach MM1 and MM2.
MM2	Achievement of surface and safety requirements	a) Safety bund setback distance is in accordance with calculated geotechnical factor of safety. b) Safety bund constructed of competent rock and to a geometry that prevents traversing by vehicles. c) Perimeter fencing and signage erected to prevent access to humans, cattle, and wildlife.	1	
MM3	Achievement of sufficient improvement	a) Voids assessed to be geotechnically stable by an appropriately qualified person, modelled to achieve a factor of safety of ≥ 1.2. b) Groundwater monitoring locations and frequency complies with Table D1, in the current EA (EPML00223213). c) Groundwater complies with the Table D2 and D3 – Groundwater Contaminant Trigger Levels in the current EA (EPML00223213).	1	A further year has been assigned to the achievement of MM3 to allow sufficient time to monitor water quality, water level and slope stability to comply with final landform design.

7.3 General rehabilitation practice

The rehabilitation practices used at any mining site inevitably evolve as a result of increasing knowledge gained from experience in the following areas:

- early rehabilitation successes and failures.
- weather, subsoils, soils, local flora and fauna and revegetation species; and
- site preparation, seeding practices, the maintenance and repair of previously rehabilitated areas and/or local agricultural practices.

For this reason, the rehabilitation practices outlined in the following subsections should not be interpreted as the precise method that will be used from this point on, but rather as a record of the current rehabilitation knowledge and intent at the time of writing; and with the expectation that rehabilitation practices will further evolve and develop from this point on. A record of the existing rehabilitation efforts at the site is detailed further below.

While rehabilitation completion criteria for Baralaba Coal Mine are detailed in sections 5.2 and 6.1, from the perspective of operational rehabilitation planning and practice, the following overarching principles are considered key:

- Ensuring that reshaped areas proposed for rehabilitation meet the required landform design principles, that prepared areas meet the rehabilitation design specification for the area, and that local site drainage has been considered and surrounding areas graded to mitigate any rainfall run-off from adjacent areas to run-on to prepared rehabilitation areas.
- Topdressing materials, final surface preparation methods and soil amelioration activities have the objective of supporting vegetative growth.
- Revegetation species selection, seeding and/or planting methods, and fertiliser applications target rapid vegetative ground cover effective at mitigating soil erosion, during the period of initial revegetation when areas are most at risk.
- Ongoing monitoring and maintenance are used both to assess rehabilitated area performance against completion criteria as well as to feedback, and update rehabilitation practices; and to identify maintenance or modification requirements such that rehabilitation areas are proceeding along a trajectory towards the designated PMLU.

There will be circumstances when rehabilitation practices outside of those discussed within this PRCP are utilised. For example, discrete areas of steeper slopes, rehabilitation failures or other scenarios that may necessitate more intensive rehabilitation practices. These circumstances will be identified and assessed and rehabilitation activities planned for as required.

7.4 Hydrogeology

The existing and pre-mining hydrogeological regime surrounding the Baralaba Coal Mine is detailed in Section 3.4. To understand any potential impacts from the cessation of mining and the final landform, Hydrosimulations undertook a predictive model assessment to review the post mining recovery rate for the groundwater regime through to 2500.

The recovery of the system is illustrated with predicted hydrographs in the Baralaba Central and Baralaba North mine pits in Figure 16, as well as in the mapping presented in Figure 17 (regional water table only). Figure 16 indicates that:

- There is predicted to be complete water level recovery at Baralaba Central, with half the recovery occurring within about 25 years.
- Almost complete recovery at the southern end of the Baralaba North with water levels predicted to rise to within around 20 m of their pre-mine standing water level. In the deeper layers, 50% of the recovery takes about 60 years, while shallower layers, particularly of spoil, recover more quickly due to the enhanced recharge rates (within a decade); and
- In the BNCOP final void, lake water levels would rise about 70 m above the pit floor over the first 100 years after mining ceases, with final water levels recovering to about 40-50 m below pre-mining standing water levels.

Figure 17 shows regional water table levels that have stabilised into a remnant cone of depression 450 years after mining ceases. The final void lake that will remain at the northern end of the Baralaba North Pit acts as a long-term hydraulic sink (also depicted in the third chart in Figure 16). The remnant cone of depression at this time extends under Saline Creek and extends towards but not beneath the Dawson River and the Anabranch.

As Baralaba Coal Mine is predicted to continue as a groundwater sink and waste rock produced is considered unlikely to generate poor quality runoff or leachate (Section 7.6), no impacts to the groundwater environmental values from the final landform are predicted.

Through the Baralaba South EIS development process, HydroSimulations (2021) has developed a numerical groundwater model using MODFLOW-USG which, by comparison to MODFLOW-SURFACT used for the previous BNCOP numerical groundwater model in 2014, is a later (newer) version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the United States Geological Survey (USGS). The validation process ran the model with the calibrated parameters from the BNCOP 2014 model, including additional validation points and measurements. The statistics for the match between simulated and measured groundwater levels were then regenerated using this updated data set.

The validation covered a period of between 2005 to 2018 which was extended by 5 years compared to the BNCOP (2014) model. The groundwater level measurements were increased from 365 in the BNCOP (2014) model to 1106 in the validation process and the number of the observation sites increased from 61 in the BNCOP (2014) model to 95 in the validation. This validation process determined that the MODFLOW-USG model continues to display an overall reasonably good fit between the computed groundwater heads and past water level observations, albeit at a distance from the BSP datasets. HydroSimulation (2021) determined that the match between observed and computed groundwater levels and trends remains good for the numerical groundwater model.

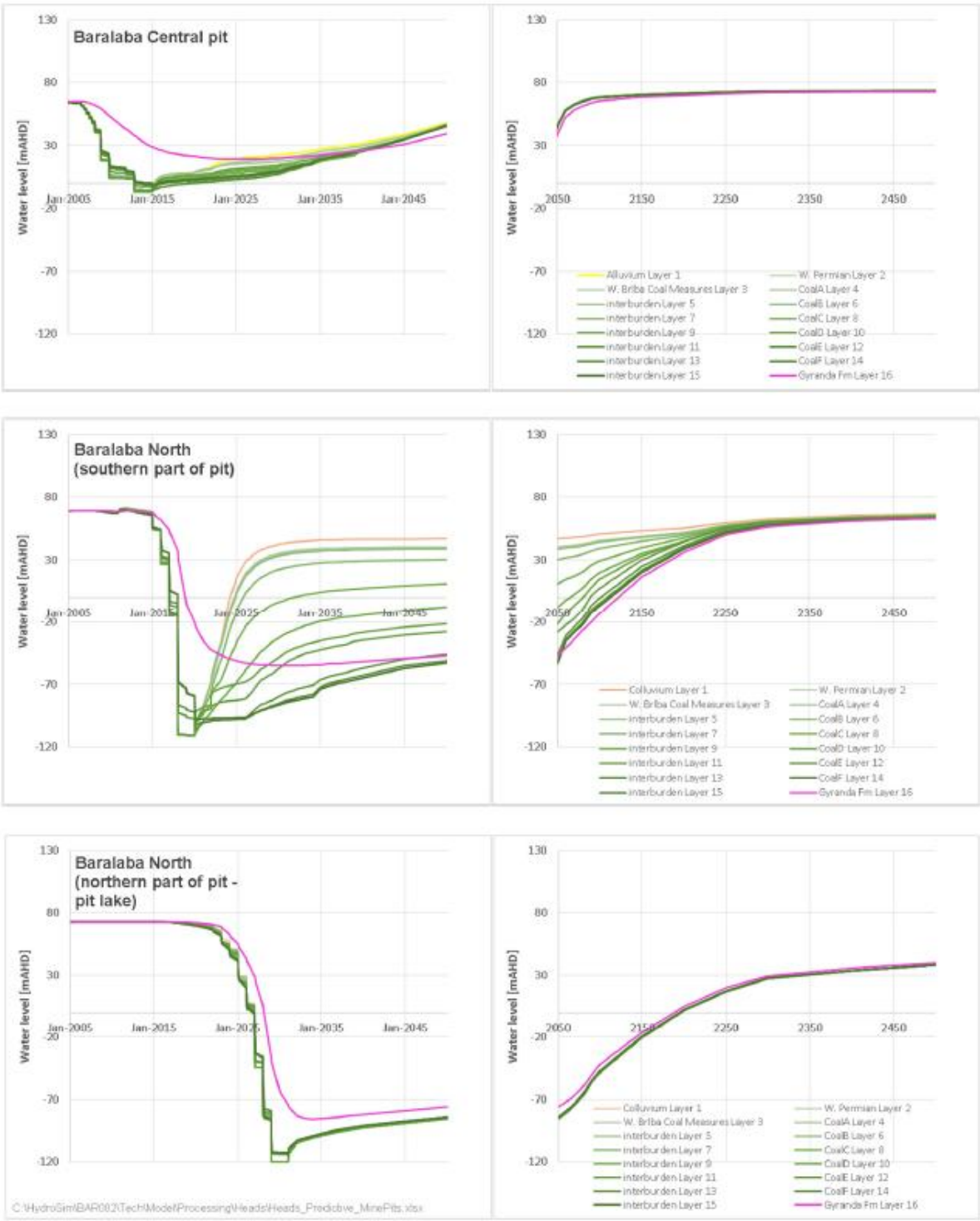

Figure 16: Predicted heads in the Baralaba Coal Mine pits (Hydrosimulations 2014)

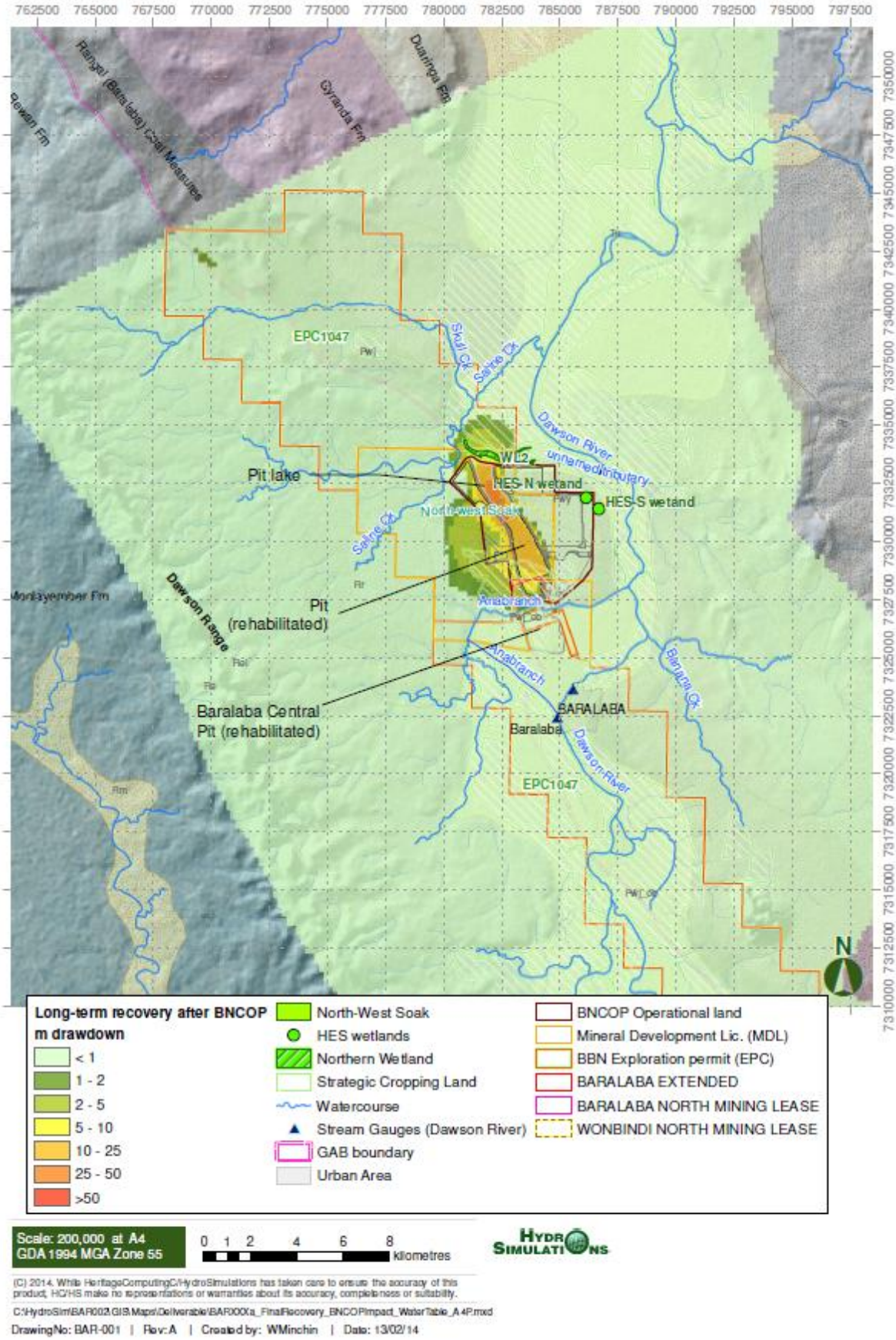

Figure 17: Predicted long-term drawdown in the water table 450 years after BNCOP mining (Hydrosimulations 2014)

7.5 Flooding

As noted in Section 3.3, Baralaba Coal Mine is situated in the Dawson River catchment, part of the Fitzroy Basin. The catchment area of the Dawson River upstream of the site is 40,500 km^2. The southern extent of the Baralaba Coal Mine is located within the Dawson River floodplain, adjacent to the Dawson River anabranch. As existing operations are located within the Dawson River floodplain, numerous flooding assessments have been undertaken on the existing and end of life landform. The most relevant being the Baralaba North Continued Operation Flood Study Project (Water Solution 2014). A summary of what is presented within this study is provided here for context and reference purposes only.

The assessment developed a Watershed Bounded Network Model covering the catchment of the Dawson River to gauging station 130322A Dawson River at Beckers, and the small catchment of Saline Creek, which joins the Dawson River just downstream of the Beckers gauging station. This study modelled five design events, the AEP 1 in 20, 1 in 50, AEP 1 in 100 and AEP 1 in 1000 events and the Probable Maximum Flood (PMF) for all operational cases including the final landform presented in Figure 14.With the modelling confirming the AEP 1 in 1000 event was more than 1 m below the lowest edge of the final void, providing a factor of safety for this event (Figure 19) (Water Solutions 2014).

The model highlighted that flood velocities surrounding the final landform case up to the AEP 1 in 1000 were moderate. With some small sections of higher velocities approaching 1.5m/s on some of the corners of the final landform features on Baralaba Central (Figure 18).

The study concluded that the areas of high velocity in the AEP 1 in 1000 event were small, with areas downstream, in the natural section of the stream, with higher velocities. It highlighted that some minor erosion may occur on the corner of the final landform features. However, ensuring good vegetation is established on these features it would likely provide sufficient protection against erosion (Water Solutions 2014). Since the completion of this study, Baralaba Coal has restricted the mine plan, enabling a reduction in the out of pit landforms required and updated the final landform to ensure Probable Maximum Flood (PMF) immunity. Baralaba Coal commissioned Engeny to review these amendments to the final landform to verify the current final landform remained consistent with the outcomes of the Water Solutions Flood Study. To infer flooding interactions and behaviour for the final landform, Engeny overlayed the updated final landform and recent aerial surveys on the flood results from the WaterSolutions flood study. The interpreted design flood elevation contours were assessed for flooding interactions and extent. The WaterSolutions Flood Study velocity results were then reviewed against the final landform features with potential flooding interactions to assess landform flood risk and susceptibility to erosion and stability. A summary of the Engeny assessment outcomes is provided below, with the full report available in Appendix E for reference:

- The final landform is located in a floodplain storage area of the Dawson River and anabranch with low conveyance and velocity.
- Very rare flooding against the final landform is expected to have generally low flow velocities of less than 1.0 m/s, with isolated locations of 1.5 m/s indicating a low risk of erosion to the rehabilitated landforms.
- The PMF is expected to result in flow velocities (generally below 1.5 m/s) against the final landform.
- Two isolated locations are expected to have PMF flow velocities up to 2.5 m/s:
    - The Dawson River anabranch channel and areas north of the Neville Hewitt Weir are predicted to reach isolated velocities of 2.5m/s. This may result in minor localised erosion on the landforms boarding the anabranch channel, however, is expected to be mitigated with well-established vegetation.
    - The final landform will partially obstruct a flow path along a ridgeline to the north of the Dawson River anabranch, where it re-enters the Dawson River downstream of the Becker Gauging Station north of the mine. These flood waters will flow against the eastern extent of the final landform before re-entering the Dawson River via a natural depression in the topography. Flow velocities are expected to remain below 1 m/s against most of the landform with an isolated location of 2 m/s against the eastern extent of the landform, this may result in minor localised erosion. However, long term well-established vegetation will significantly reduce the risk of erosion.

- The rehabilitated landforms surrounding the final void provide PMF immunity. The final landform design has a minimum overtopping level of 96 m AHD at the southern end of the final void and 89m AHD at the northern end of the final void. This provides the final void with 2 m and 1.5 m freeboard above the PMF at the southern and northern ends of the void respectively.

Long-term well established vegetation coupled with the very low likelihood of a PMF event, the assessment concludes that the flood influence on the final landform are considered low.

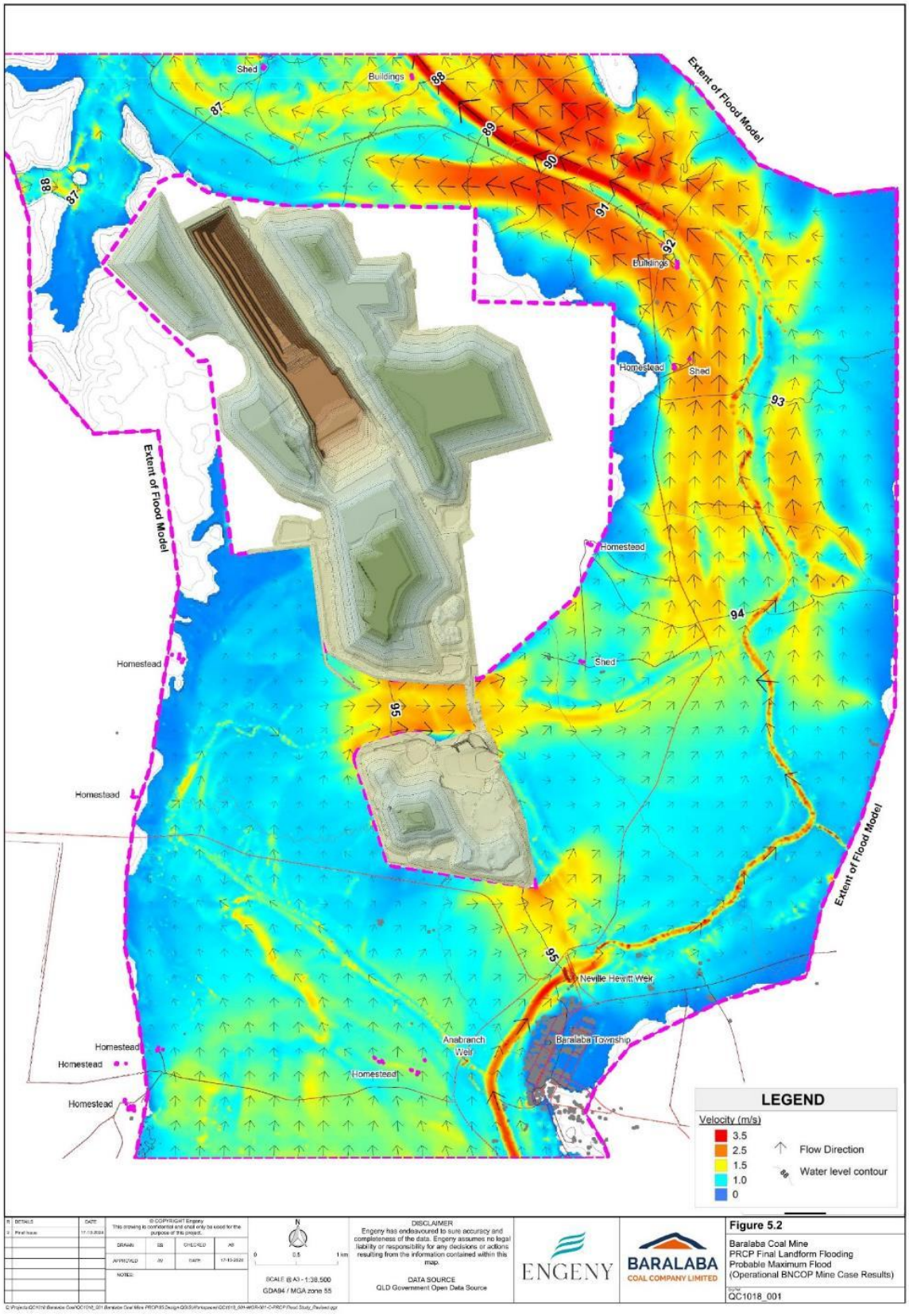

Figure 18: Post-mine case: Probable Maximum Flood (Engeny 2024)

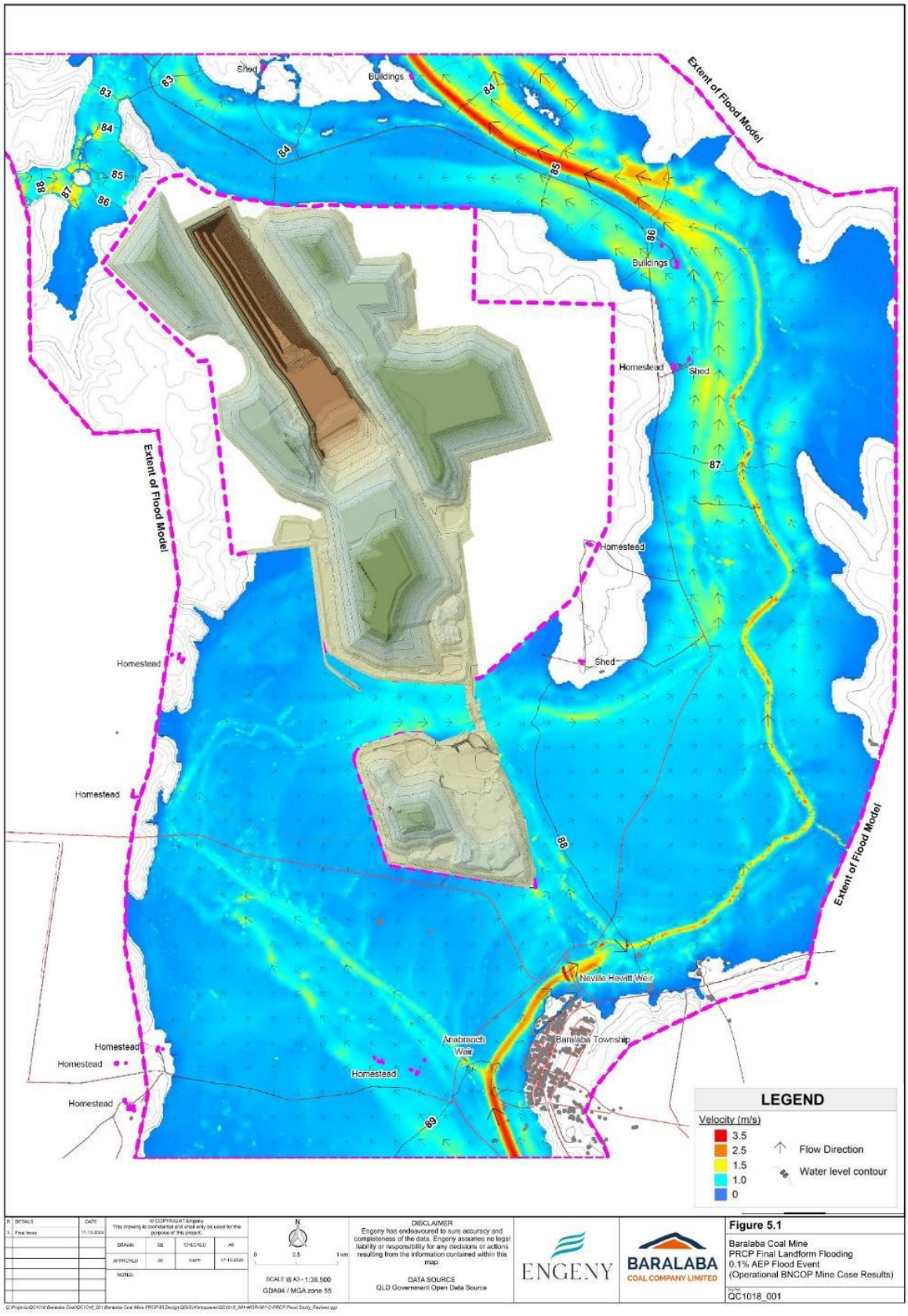

Figure 19: Post-mine case: 0.1% AEP Flood Event (Engeny 2024)

7.6 Waste characterisation

Although the BNCOP EIS considered the requirements for a coal handling and processing facility at Baralaba Coal Mine, continued mine exploration and coal quality sampling surrounding the operations have resulted in the elimination of this requirement for the life of the mine.

Baralaba Coal Mine produce a high quality low volatile PCI and thermal product. ROM coal is only required to be screened and analysed for ash to be considered product coal and hauled to the TLO facility. This process does not produce tailings or reject materials. Therefore, waste rock to be disposed of within elevated landforms or backfilled in the final void will consist entirely of spoil. The geochemical and dispersive characteristics of the spoil material are discussed in sections 7.6.1 and 7.6.2.

7.6.1 Geochemistry

A geochemistry assessment of all available geochemical data collected from exploration drill-core and cutting samples across Baralaba Coal Mine has been completed by Terrenus-RGS (2012). The following is a summary of the Terrenus-RGS 2012 and 2014 assessments. The Terrenus -RGS (2014) Geochemical Assessment, completed in support of the BNCOP is provided in Appendix F.

Spoil, as a bulk material, is not expected to vary significantly in quality across the two pits. It is expected to generate alkaline pH and low-salinity surface run-off and seepage following surface exposure (Figure 20 and Figure 21). With weathered spoil is expected to have similar geochemical characteristics to unweathered spoil (Terrenus -RGS 2014).

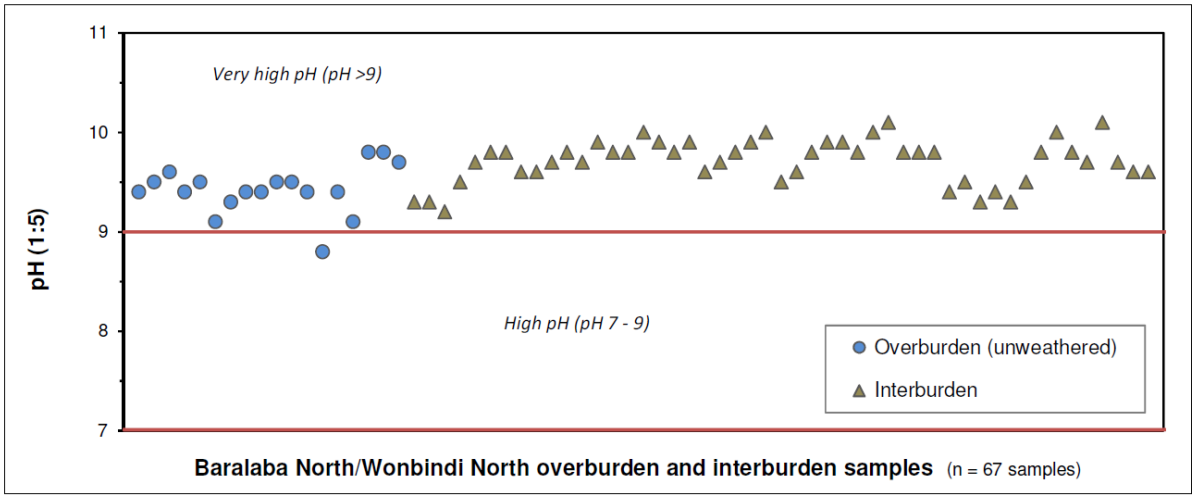

Figure 20: Baralaba North Pit Spoil pH results (Terrenus 2014)

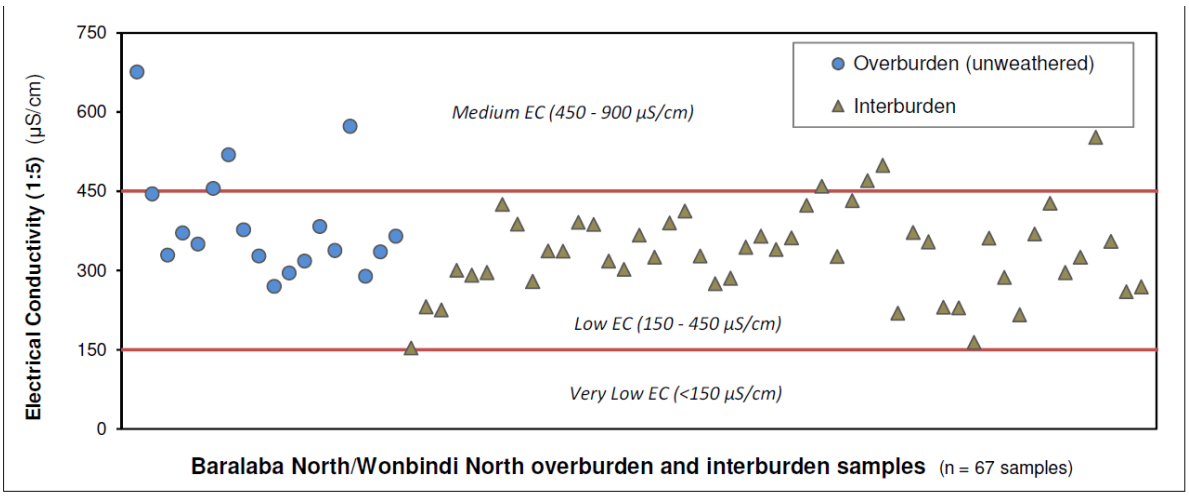

Figure 21: Baralaba North pit spoil electrical conductivity results (Terrenus 2014)

The total sulphur concentration of spoil samples were very low, with a median value of 0.03% and values ranging from <0.01% to 0.37% (Figure 22). Only four of the 67 spoil samples had total sulphur values above 0.10% (thereby classifying 94% of the soil samples as non-acid forming (NAF-barren) (Terrenus -RGS 2014).

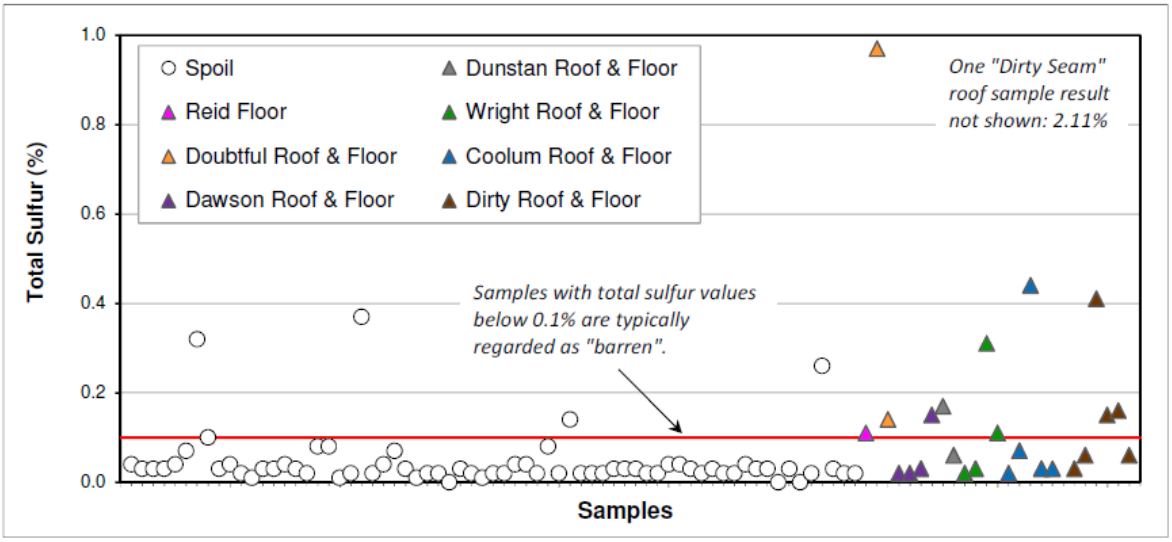

Figure 22: Total sulphur (%) for all samples (Terrenus-RGS 2012)

Table 18 shows that almost all spoil samples tested (98.5 %) fall in the NAF-Barren or NAF categories. Spoil materials represented by these samples have very low sulphur values, excess acid neutralising capacity, and have little to no capacity to generate acidity or be potentially acid forming (PAF). With only one sample was classified as uncertain due to a low oxidisable sulphur (Scr) content and low net acid producing potential (NAPP) value (Terrenus -RGS 2012).

Table 18: Baralaba North NAF and PAF (Terrenus-RGS 2012).

Geochemical Classification	Total Sulfur (%)	Scr (%)	NAPP (kg H_2SO_4/t)	ANC/MPA Ratio	No. of Spoil Samples (n=67)	% of Spoil Samples
NAF - Barren	≤ 0.1				63	94
NAF	S ≤ 0.2 or	Scr ≤ 0.1%		> 2	3	4.5
			≤ -10	> 3		
Uncertain	> 0.2		< 0	< 2	1	1.5
		< 0.2	> 0 and < 10	< 2		
PAF – Low Capacity	S > 0.2 or	Scr > 0.2%	> 0 and < 10	< 2	0	0
PAF			> 10	< 2	0	0

The multi-element (solid) results, presented in Appendix F, shows that total metal and metalloid concentrations in spoil samples are low. All samples reported total metals and metalloid concentrations below the applied National Environmental Protection Council (NEPC) (1999a) health-based investigation levels (HILs) (E) for soils. However, the multi-element results indicate that spoil materials may produce leachate containing slightly elevated soluble molybdenum (and potentially selenium) concentrations, which is common for spoil materials at coal mines in the Bowen Basin.

The effective cation exchange capacity (eCEC) was determined on spoil samples, and the results are presented in Appendix F, and indicate that the eCEC of spoil samples ranges from 11 to 33 meq/100g (median 23 meq/100g). The exchangeable sodium percentage (ESP) results presented in Appendix F indicate that the sodicity is generally high in most tested spoil materials, ranging from 5 to 44% (median 19%).

In addition to potential dispersion problems, sodic soils often have unbalanced nutrient ratios that can lead to macro-nutrient deficiencies (Hazelton and Murphy 2007). The proportions of each exchangeable cation relative to eCEC are shown in Table 19. The 'desirable' proportions of each major cation are also shown (Abbott 1989, in Hazelton and Murphy 2007).

Table 19: Exchangeable cation samples (Terrenus-RGS 2012).

Exchangeable Cation	Desirable ranges (% CEC)	Spoil samples (% CEC)
Calcium (Ca)	65 - 80	36 – 86 (median 61)
Magnesium (Mg)	10 - 15	2 – 36 (median 18)
Potassium (K)	1 - 5	1 – 5 (median 3)
Sodium (Na)	0 - 1	5 – 44 (median 19)

When compared to the desirable ranges for major exchangeable cations in soil (Table 19), exchangeable Ca, Mg and K proportions in spoil are generally acceptable (based on median values). Some samples have low exchangeable Ca and both low and high exchangeable Mg proportions, but generally, as a bulk material, the ratios of Ca:Mg:K of spoil are reasonably balanced. Comparatively, exchangeable Na proportions are very high, as discussed above.

The results show that although the samples are generally sodic and therefore 'potentially prone' to dispersion, the physical characteristics show that the materials have a much lower propensity to disperse than what the sodicity results infer.

7.6.2 Stability analysis

As outlined in Section 7.6.1, the waste material at Baralaba Coal Mine is overwhelmingly NAF with relatively low concentrations of metals/metalloids and has a negligible risk of developing acid, saline, or metalliferous drainage. Some weathered spoil may have an increased potential for dispersion, however most unweathered spoil, is expected to have low sodicity and be non-dispersive.

At Baralaba Coal Mine, overburden dumps are designed to ensure potentially dispersive spoil is placed inside waste dumps or into pit voids and is covered by non- dispersive spoil. Therefore, dispersive spoil should not report to final surfaces to any significant extent and would not pose a significant management risk for overburden dump stability. Spoil used for final landform outer slopes will primarily comprise of unweathered Permian material, which has a low salinity, generally low sodicity and low potential for dispersion. All constructed infrastructure is proposed to be either removed in its entirety or reshaped to the extent that ongoing geotechnical stability assessments are not required.

7.7 Landform Design

The final landform at Baralaba Coal Mine has been designed to be consistent with the requirements for Class 4 suitability grazing land, and the surrounding topography of the land. A stable landform will be achieved by ensuring the final landform achieves the desired slope length, angle presented within Table H3 of the EA (Table 20), suitable materials are selected and establishment of groundcover to reduce the erosion risk. Operational landforms (slope, height, size/footprint etc) for waste rock dumps are designed considering the size/footprint, height, and operational slopes at the completion of the dump. In this way the waste rock dump at cessation of operation is as close as possible to the approved final landform design, reducing the bulk earthwork requirements to achieve the desired final landform.

Table 20: EA (EPML00223213) Landform Design Criteria

Disturbance Type	Slope Range (° degrees and %)
Elevated Landforms – Upper Surfaces	0 – 9° (0-15%)
Elevated Landform - slopes	5.75 – 9° (10-15%)
Infrastructure	3° (<5%)

The Baralaba Coal Mine final landform has been developed in accordance with:

- Design and completion criteria outlined in the EA (Section 5.2);
- The mapped wetlands neighbouring the mining operations; and
- The Dawson River Anabranch and its associated drainage lines.

Figure 23 shows the designed final landform for Baralaba Coal Mine.

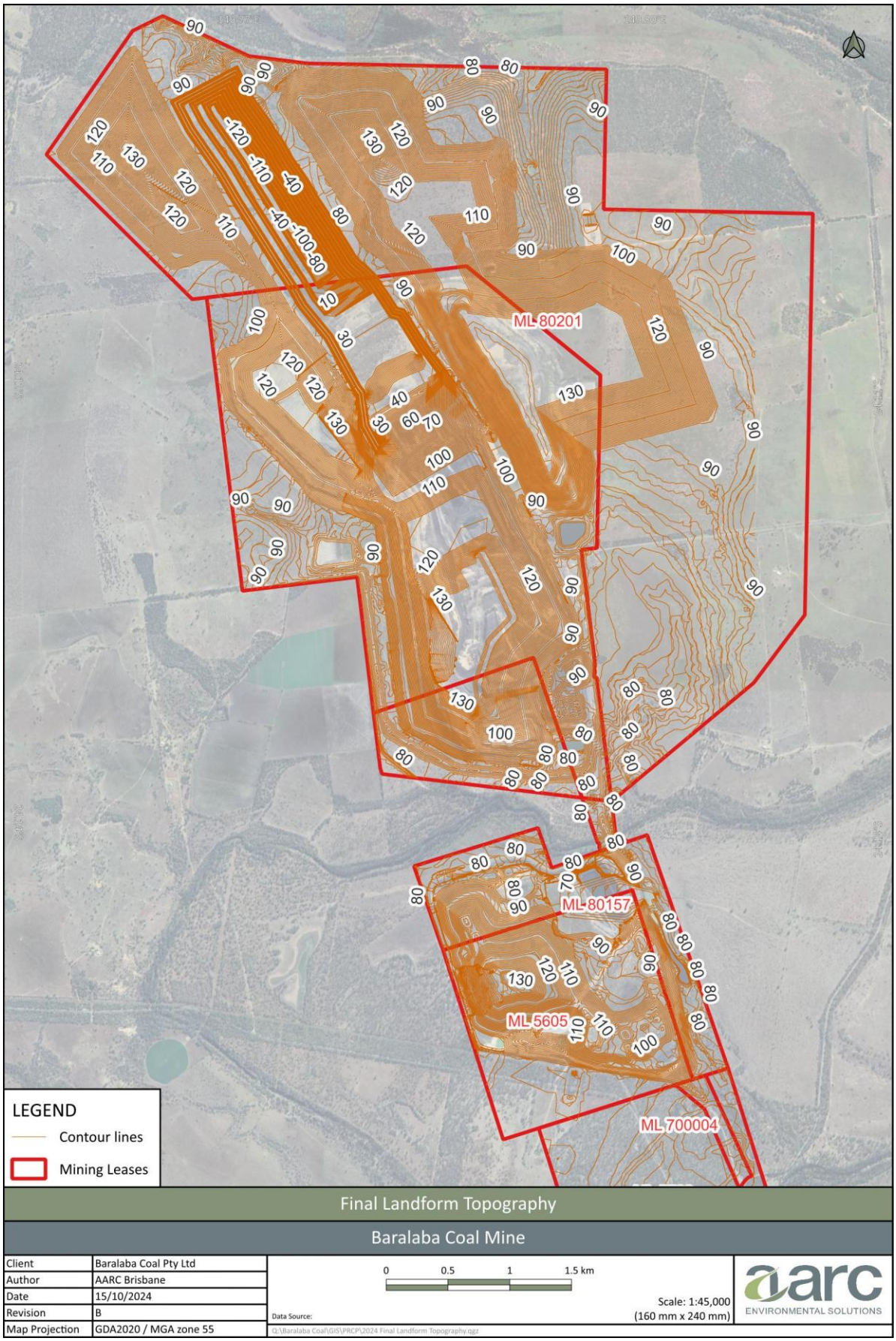

Figure 23: Contours of Baralaba Coal Mine Conceptual Final Landform

7.7.1 Final landform stability

Erosion modelling through the Watershed Erosion Prediction Project (WEPP) was conducted to assess the long-term stability and land suitability of the proposed final landform. WEPP modelling considers four key data points: climate information, soil profile, land use management and slope design. Climate parameters were modelled from the area using CLIGEN 5.3, with input data sourced from SILO (daily rainfall, maximum and minimum temperature, solar radiation, and maximum relative humidity) and an on-site weather station (rainfall intensity). Sixteen soil samples were included for modelling, covering all relevant soil units (as described in Table 4). The model considered site specific inputs of these soil units including sand, clay and rock content (%), organic matter (%) and cation exchange capacity (meq/100g), as determined within Appendix B and shown below in Table 21 Wang *et al.* (2022) concludes that satisfactory predictions of runoff and soil loss can be made without laboratory testing. As such it is reasonable to conclude that site-specific data can be used to accurately provide baseline erodibility parameters for the site. These baseline parameters can then be considered sufficient for predicting runoff and soil loss.

In creating the land use management parameters for WEPP modelling, cover classes were established at 5% intervals ranging from 0% to 100%. Vegetation cover was fixed at these percentages throughout the WEPP simulations, such that consistent cover was maintained across the 100-year simulation period without growth or decay. Slope design specifications were sourced from the proposed final landform design, with the selected slope sampled from the proposed WRD final landform design, as shown in Figure 25. The slope in Figure 25 was selected as it represents the maximum slope design present on the site. The top of the slope is approximately 133 m RL (AHD), with the bottom of the slope approximately 86 m RL, giving a slope height of 47 m. The slope is a continuous decline over 396 m, resulting in an approximate slope grade of 1:8. A cross-section of the slope described can be found in Figure 24.

Table 21: WEPP site specific inputs

Soil Type	Sand (%)	Clay (%)	Organic Matter (%)	CEC (meq/100g)	Rock (%)
2b	11	66	3	38	0
3a	19	61	3	30	0
3b	53	21	3	9	0
4c	16	60	3	37	0
4d	48	39	3	28	0
5	26	59	3	33	0
7a	36	45	3	21	0
7b	57	29	3	11	0
7c	84	10	3	4	0
7d	60	27	3	10	0
8a	80	15	3	4	0
8b	89	9	3	4	2
8c	85	9	3	3	0
8d	85	9	3	3	0
9a	68	23	3	12	0
9b	42	38	3	23	0

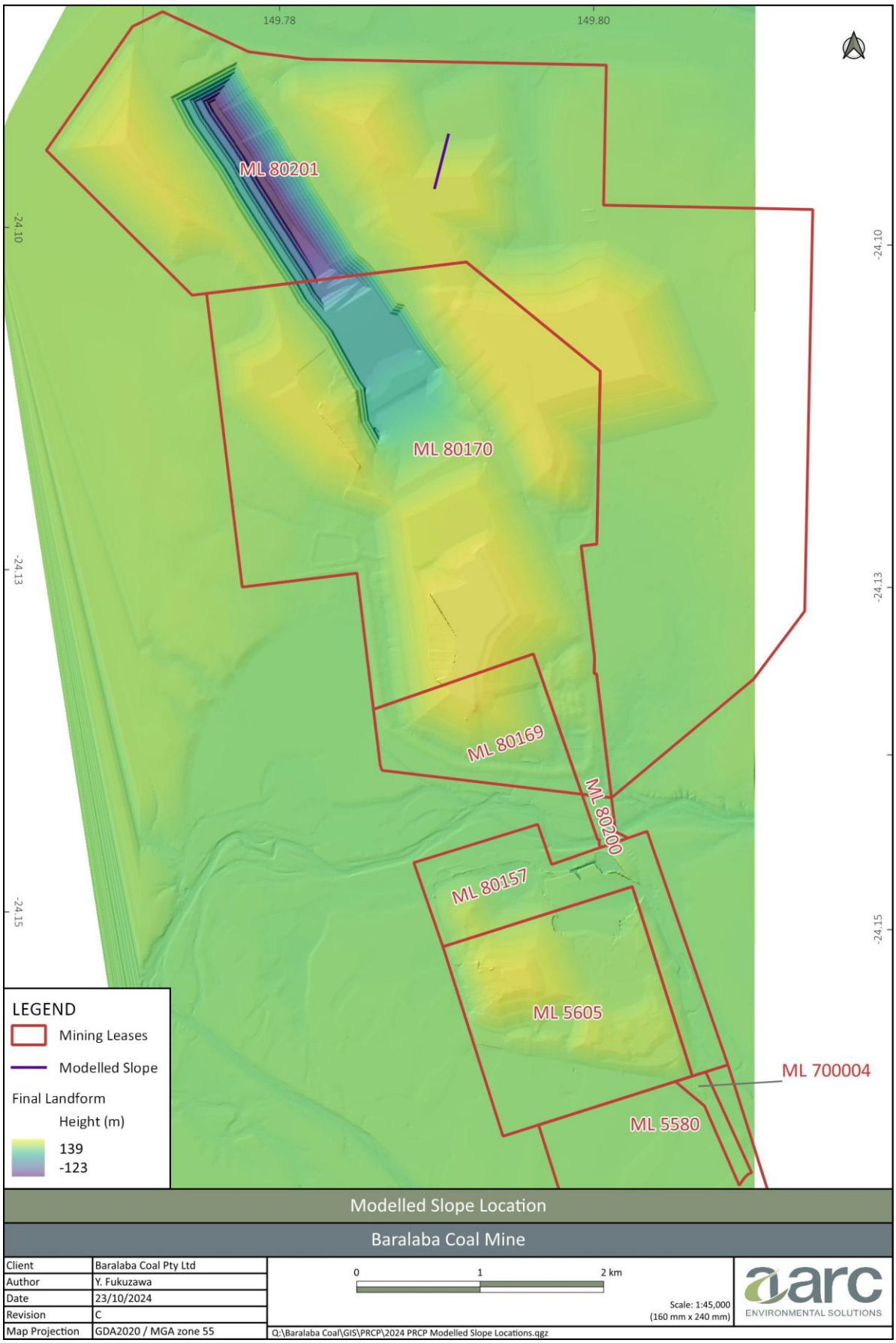

Figure 24: Modelled slope location.

336 100-year WEPP iterations were run, covering the range of soil samples and land use management profiles identified above. To determine the maximum potential erosivity of the slope, the average annual soil loss, expressed in tonnes per hectare per year (t/ha/yr), for each iteration was calculated and assessed against a target and maximum erosion rate. A target erosion rate of 5 t/ha was adopted for assessing land suitability and erosivity risk (Landloch 2013; Howard and Loch 2019). Additionally, a maximum tolerable erosion rate of 10 t/ha was adopted, as the rate was considered acceptable for mining rehabilitation purposes (Lu 2001). The results of this analysis can be found in Figure 25.

The average base erosion modelled for the slope is 53.34 t/h/yr, with a maximum base erosion rate of 120 t/ha/yr (2b). At 45% vegetation cover, erosion on the slope is modelled to be within the maximum erosion threshold of 10 t/ha/yr for all soil samples. 65% vegetation cover is required for all soil samples to meet the target erosion rate of 5 t/ha. Given these results, the slopes of the proposed WRD should remain stable and non-erosive irrespective of topsoil properties, where 65% vegetation cover is maintained based on the target erosion rate. However, vegetation cover can decrease to 40% while maintaining structural integrity on the slope when considering a maximum tolerable erosion rate of 10 t/ha. Therefore, it is expected that all proposed final landforms should remain erosionally stable irrespective of topsoil properties.

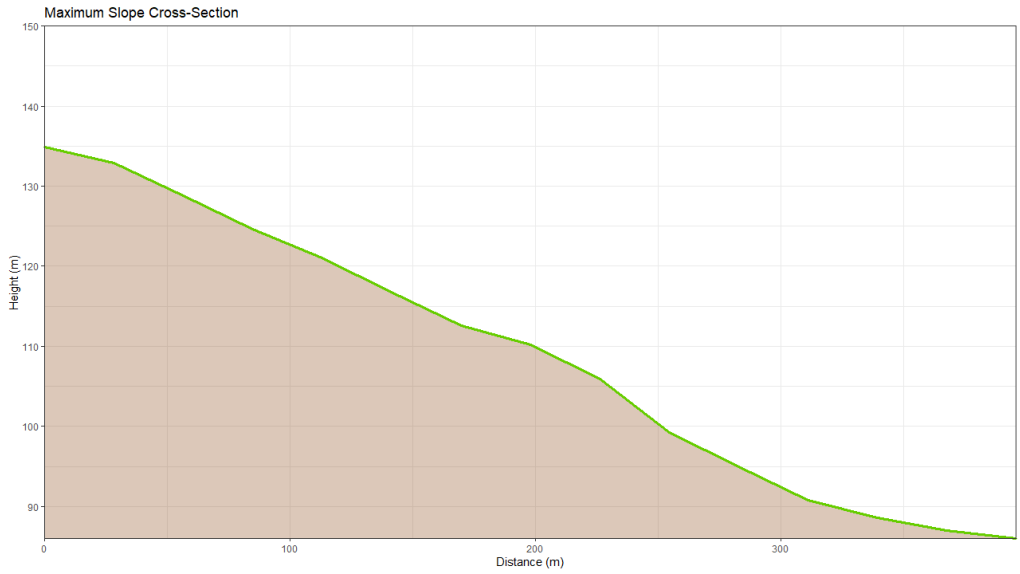

Figure 25: Slope cross-section incorporated into WEPP modelling.

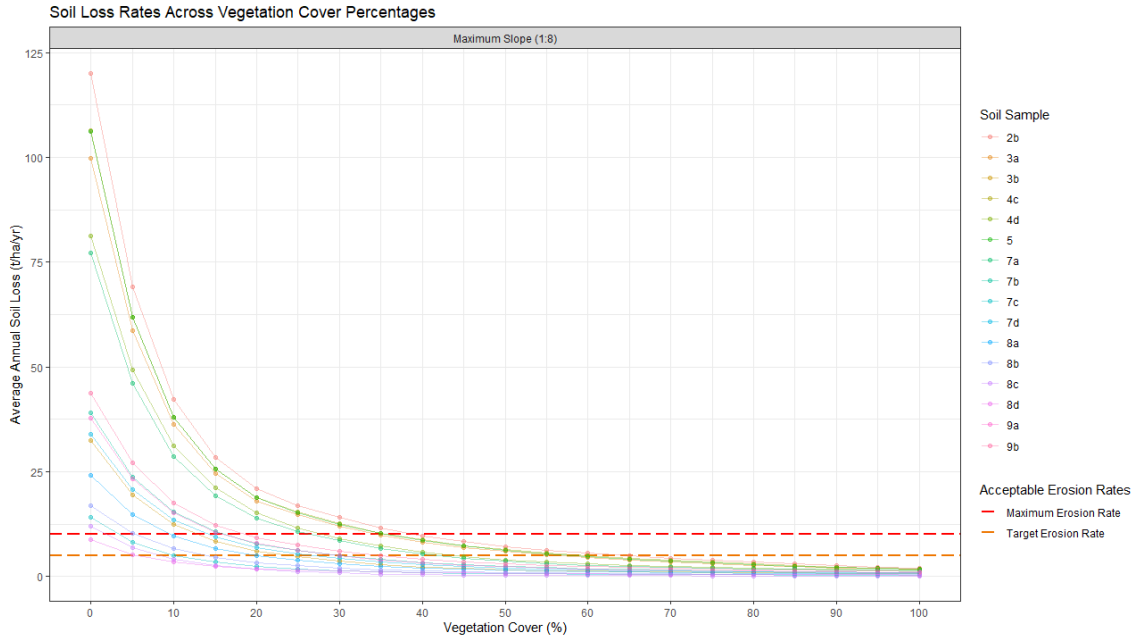

Figure 26: Average annual soil loss rates (t/ha/year) as vegetation cover increases.

7.8 Soil and capping material assessment

As previously detailed in Section 7.6, the mineral waste generated at Baralaba Coal Mine is considered benign, with some potential to produce leachate containing slightly elevated soluble Mo (and potentially Se) concentrations, which is common for spoil materials at coal mines in the bowen basin. Accordingly, capping of waste dumps is not required on rehabilitated landforms, and therefore has not been proposed in this PRCP. The placement of cover material at Baralaba Coal Mine will be restricted to previously salvaged topsoil to a minimum depth of 200 mm.

The BAR-ENV-PL-002 Baralaba Topsoil Management Plan details the requirements for the management of topsoil resources at Baralaba Coal Mine. As noted in Section 3.5, topsoil at Baralaba Coal Mine is generally suitable for use as seed surface material or root zone material, although some topsoil was identified as having alkaline pH likely requiring fertiliser. For soils identified with a moderate-high erosion potential, the application of gypsum at a rate of 500 Kg/ha (Engeny 2022; Green Acres Group QLD 2022) is recommended to improve the stability of topsoils.

Stripped topsoil will either be directly placed on rehabilitation areas (where practicable) or stockpiled. Where possible, stripped topsoil will be stockpiled to prevent mixing of different SMUs, and stockpiles will have a maximum average height of 3 m to allow oxygen to diffuse through the stockpile; maintaining the viability of seed and micro-organisms.

Stripping depth for each soil type was determined from the chemical analysis of soils, with recommended stripping depth for suitability in rehabilitation activities as the target objective. Based on recommended soil stripping depths, the maximum volume of topsoil able to be reclaimed for use in rehabilitation activities is approximately 5,818,910 m^3. Allowing for working tolerances of earthmoving equipment and a 10% handling loss, it is estimated that approximately 5,237,019 m^3 of topsoil resource will be recoverable and available for use in rehabilitation activities.

Based on a minimum recommended topsoil respreading depth of 0.20 m required to establish a growth medium conducive to plant growth, a topsoil volume of up to approximately 4,607,200 m^3 will be required for rehabilitation efforts over the life of Baralaba Coal Mine. The soil balance assessment indicates that sufficient topsoil material will be available for rehabilitation efforts. Rehabilitation success improves when the respread topsoil is greater than 0.2 m. Due to thin stripping depths, diligence will be required in managing topsoil resources to ensure no wastage or deterioration.

Table 22 outlines the expected disturbance for each of the soil landscapes and the approximate topsoil and subsoil salvage volumes to be available for rehabilitation.

Table 22: Growth media materials balance

Soil Type	Spatial area (ha)	Topsoil stripping depth (m)	Subsoil stripping depth (m)	Topsoil volume (m^3)	Subsoil volume (m^3)	
2a	0.43	0.3	0.8	1,290	3,440	
2b	2.23	0.3	0.7	6,690	15,610	**Surface soil/upper subsoil material** to 0.8m has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by very high clay content (65-72%), active clay behaviour (CEC/Clay ratio 0.58-0.60), low sodicity (ESP <5), low dispersion (R1 <0.45), Ca dominant cation chemistry and low salinity (<0.2dS/m). **Subsoil material** between 0.8-1.2m has similar physical characteristics, but with increasing sodicity (ESP 9) and dispersive behaviour (R 0.58).
3a	3.1	0.3	0.7	9,300	21,700	**Surface soil/upper subsoil material** to 0.7m has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by high clay content (52-61%), active clay behaviour (CEC/Clay ratio 0.49-0.56), low sodicity (ESP <6), low dispersion (R1 <0.45), Ca dominant cation chemistry and low salinity (<0.3dS/m). **Subsoil material** between 0.7-1.0m has similar physical characteristics, but with moderate levels of salinity (EC 0.3-0.5dS/m), and increasing sodicity (ESP 6-13), and dispersive behaviour (R 0.72).
3b	1.82	0.35	nil	6,370	0	**Surface soil material** to 0.3-0.4m has high fertility, massive to very weak structure, moderately low clay content (21%), elevated levels of fine sand/silt (70-75% combined), low salinity (EC <0.1dS/m) and low sodicity (ESP<6) characteristics. **Subsoil material** below 0.3-0.4m has unfavourable physical attributes. It is characterised by coarse, dense structure and a strongly sodic (ESP 18-19), dispersive (R1 0.92-0.99), un-reactive clay fraction.
4a	0.59	0.1	0.4	590	2,360	Hardsetting to firm, silty black cracking clay. Soil type not analysed in the Soil and Land Assessment (Burgess, 2014).

Soil Type	Spatial area (ha)	Topsoil stripping depth (m)	Subsoil stripping depth (m)	Topsoil volume (m^3)	Subsoil volume (m^3)	
4b	1.08	0.2	0.6	2,160	6,480	Moderately to strongly self-mulching (coarse) black cracking clay. Soil type not analysed in the Soil and Land Assessment (Burgess, 2014).
4c	1.58	0.3	0.5	4,740	7,900	**Surface soil/upper subsoil material** to 0.4m has very high fertility and is strongly aggregated, finely structured and non-sodic to very weakly sodic (ESP 3-8). It is further characterised by high clay content (60-63%), active clay behaviour (CEC/Clay ratio 0.62-0.63), low dispersion (R1 0.39-0.47), Ca dominant cation chemistry and low salinity (<0.3dS/m). **Subsoil material** between 0.4-0.8m has similar physical characteristics, but with low to moderate levels of salinity (EC 0.3-0.6dS/m) and sodicity (ESP 8-13) and increasing dispersive behaviour (R 0.47-0.68).
4d	0	0.4	0	0	0	**Surface soil/upper subsoil** material to 0.4m (on mounds and shelves) has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by high clay content (39-49%), active clay behaviour (CEC/Clay ratio 0.53-0.72), low sodicity (ESP <6), low dispersion (R1 0.3-0.5), Ca dominant cation chemistry and low salinity (<0.3dS/m). **Lower subsoil material** below 0.4m (on mounds and shelves) has undesirable physical and chemical attributes, characterised by moderate to very high levels of salinity and significant sodicity and dispersive behaviour.
5	3.69	0.2	0.2	7,380	7,380	**Surface soil/upper subsoil material** to about 0.2m has high fertility and is strongly aggregated and finely structured. It is characterised by high clay content (59%), active clay behaviour (CEC/Clay ratio 0.56), low sodicity (ESP 4), low dispersion (R1 0.32), Ca dominant cation chemistry and low salinity (<0.3dS/m). **Subsoil material** between 0.2-0.4m has similar characteristics but is moderately sodic (ESP 4-14) and dispersive (R1 0.65).

Soil Type	Spatial area (ha)	Topsoil stripping depth (m)	Subsoil stripping depth (m)	Topsoil volume (m^3)	Subsoil volume (m^3)	
6b	0	0.2	0.4	0	0	Hardsetting, loamy to clay loamy surfaced, brown/red texture contrast soil. Soil type not analysed in the Soil and Land Assessment (Burgess, 2014).
7a	126.73	0.1	0.3-0.4	126,730	380,190	**Surface soil material** to 0.1m (on mounds) has high fertility, moderate to strong structure, and is characterised by moderately high clay content (45%), low salinity (<0.3 dS/m), low sodicity (ESP 4), only moderate reactivity and elevated levels of fine sand/silt (45%). **Subsoil material** between 0.1-0.4m (on mounds) has similar physical characteristics, but with moderate levels of salinity (EC 0.3-0.6dS/m) and sodicity (ESP 4-14) and increasing dispersive behaviour (R 0.60).
7b	215.28	0.15	nil	322,920	0	**Surface soil material** to 0.1-0.2m has moderate fertility and is characterised by low salinity (<0.3 dS/m), relatively low sodicity (ESP 4-7), hardsetting behaviour, weak to moderate structure, moderate clay content (20-35%), very limited reactivity and elevated levels of levels of fine sand/silt (62-69%). **Subsoil material** below about 0.2m is considered undesirable and is not recommended for salvage. It is characterised by moderate to very high levels of salinity and extremely sodic/dispersive behaviour.
7c	18.12	0.5	0.7	90,600	126,840	**Surface soil material** to 0.4-0.7m has moderate fertility and is characterised by massive to very weak structure, low clay content (<11%), very low salinity (<0.1dS/m) and very low sodicity (ESP 1); but with elevated dispersion (R0.64-0.88) and high levels of fine sand/silt (58-63% combined). **Clayey subsoil material** below 0.4-0.7m has relatively benign physical and chemical characteristics and represents a useful source of additional root zone media. It is characterised by a moderately structured, largely non-sodic (ESP 6-7) but un-reactive clay fraction that lacks noticeable shrink swell characteristics and is moderated by significant sand content (42-53%).

Soil Type	Spatial area (ha)	Topsoil stripping depth (m)	Subsoil stripping depth (m)	Topsoil volume (m^3)	Subsoil volume (m^3)	
7d	6.28	0.2	nil	12,560	0	**Surface soil material** to 0.1-0.2m has high fertility and is characterised by massive to weak structure, moderately low clay content (27%), low salinity (EC <0.3dS/m), low sodicity (ESP 3) and elevated levels of fine sand/silt (53% combined). **Subsoil material** below 0.1-0.2m has unfavourable physical attributes. It is characterised by coarse, dense structure and a moderately to extremely sodic (ESP 12-36%) and dispersive (R 0.66-0.99), un-reactive clay fraction.
8a	179.61	0.3	0.9	538,830	1,616,490	**Sandy to loamy surface soil material** to 0.5m has very low to moderate fertility and is characterised by the massive structure, low clay content (15-20%), very low salinity (EC <0.1dS/m), very low sodicity (ESP 1), moderate dispersion (R1 0.51-0.74) and elevated levels of fine sand (57-62%). **Loamy/clayey subsoil material** below 0.5m has similar very low salinity and sodicity attributes, as well as a non-dispersive (R1 0.17-0.24), sesquioxide rich, kaolinitic clay fraction.
8b	168.78	0.3	0.5	506,340	843,900	**Coarse sandy surface soil material** varies significantly in thickness (0.3-1.1m), has very low fertility, massive structure, very low clay content (<10%), very low salinity (EC <0.1dS/m), low sodicity (ESP 1-2) and a significant coarse sand fraction (60-65%). **Clayey Subsoil material** below 0.3-1.1m has benign physical and chemical characteristics and represents a useful source of additional root zone media. It is characterised by a moderately structured, non-sodic (ESP 4-5), un-reactive clay fraction (without shrink swell characteristics) that is moderated by significant sand content (47%).
8c	6.76	0.3	0.9	20,280	60,840	**Sandy surface soil and subsurface material** to about 1.2m (or depth to weathered rock where shallower) have very low fertility, massive/single grain structure, very low clay content (<13%), very low

Soil Type	Spatial area (ha)	Topsoil stripping depth (m)	Subsoil stripping depth (m)	Topsoil volume (m^3)	Subsoil volume (m^3)	
						salinity EC <0.1dS/m), very low sodicity (ESP 1) and a significant coarse sand fraction (37-43%).
8d	52.04	0.3	1.2	156,120	624480	**Sandy soil material** varies significantly in thickness (0.9->1.5m), has very low fertility, massive/single grain structure, very low clay content (9-13%), very low salinity (EC <0.1dS/m), very low sodicity (ESP 1) and a significant coarse sand fraction (37-43%). **Clayey subsoil material** below 0.9->1.5m (where present) has benign physical/chemical characteristics and represents a useful source of additional root zone media. It is massive (to weakly structured) and non-sodic (ESP 2), with an unreactive clay fraction that is moderated by significant sand content (54%).
9a	32.95	0.3	0.5	98,850	164,750	**Loamy/clayey surface soil material** to 0.3m has low fertility and is non-sodic (ESP 1), relatively non-dispersive (R1 0.42- 0.58), weakly to moderately structured, hardsetting and characterised by high levels of fine sand/silt (50-62% combined). **Subsoil material** between 0.3-0.8m is also benign and is characterised by a moderately structured, non-sodic (ESP<3), relatively un-reactive clay fraction (lacking shrink swell characteristics) that is moderated by significant fine sand and silt (45-50% combined).
9b	4.96	0.2	0.3	9,920	4,880	**Surface soil/upper subsoil material** to 0.2m has moderate fertility and is strongly aggregated and finely structured. It is characterised by moderately high clay content (38-39%), active clay behaviour (CEC/Clay ratio 0.61-0.72), low salinity (<0.3dS/m), low sodicity (ESP <3), low dispersion (R1 0.47-0.52) and Ca dominant cation chemistry. **Upper subsoil material** between 0.2-0.5m is characterised by increasing clay content and shrink-swell capacity, weak to moderate sodicity (ESP 7-<15) and increasing dispersive behaviour (R1 0.52-0.66).
Total	**826.03**			**1,921,670**	**3,897,240**	

7.8.1 General Waste disposal

General waste (excluding putrescibles) is permitted to be disposed of within the southern portion of the existing pit. This disposal facility is unlined and bounded by spoil backfill to the south, east and west. As the void is a perpetual sink, any contamination by leachates will be contained by the drainage properties of the void.

Rehabilitation of this waste disposal area will include encapsulated such that there is no release of general waste materials, leachate, landfill gas or other contaminants that will cause environmental harm from the landfill activities.. This spoil cap to be installed will comply with the Queensland Landfill Guideline – Landfill siting, design operation and rehabilitation (DES 2021b). The cap will be used to cover the disposed waste to minimise erosion and prevent the uncovering of waste materials. Topsoil will be placed on the cap surface at a depth of 200mm and revegetation of the final surface will be undertaken.

7.9 Water management

Water management at Baralaba Coal Mine is undertaken in accordance with Baralaba Coal Mine Water Management Plan (Appendix G). This plan is updated annually with the progression of mining.

All newly rehabilitated areas are required to drain to erosion and sediment control (ESC) devices. With the following aspects were considered in the selection, installation, and management of the ESC devices on newly rehabilitated landforms:

- Sediment dams are to be designed in accordance with IECA guidelines.
- Drains are to be installed around the base of rehabilitation areas to collect and direct stormwater runoff into sediment dams.
- Additional erosion controls should be considered at inlet points and outlet spillways, to the sediment structures and rock checks may be required in diversion drains conveying flows from the rehabilitated area to the sediment dam(s).
- Very small rehabilitation areas may be able to be sufficiently controlled with temporary sumps, coir matting, or other erosion and sediment control methods.
- All erosion and sediment control structures should be inspected following significant storm events (>50mm of rain) to ensure their operation integrity is maintained.
- Sediment dams may require desilting to maintain their design operational capacity; and
- Erosion and sediment control structures are to be retained until rehabilitation areas have been stabilised and run-off water quality meets water quality objectives.

Progressive rehabilitation at Baralaba Coal Mine will be undertaken via terraced profiles with slope grades of ~10%. Interim berms will be placed on the highest level of the newly rehabilitated landform, limiting the catchment area. Only once a suitable groundcover is achieved will the berms be removed, and the catchment area expanded. This methodology will reduce the requirement for graded banks and engineered drains, requiring ongoing maintenance within the final landform. However, prior to the achievement of rehabilitation milestone 7, sediment and erosion control devices and other temporary erosion and sediment control structures will be removed from the rehabilitated landform.

7.10 Surface preparation

The final landform will be reshaped and profiled according to the final landform design and specifications outlined in section 7.7. The approach to surface preparation will involve:

- Identification of the topsoil resource to be utilised for a given rehabilitation area, and the carrying out of composite soil sampling and agronomic laboratory analyses.
- Determination and procurement of type and quantity of ameliorants that would be beneficial for the topsoil resource (if needed).
- Topsoil should be placed by scraper or truck at the top of the profiled slope and pushed by a dozer or grader to achieve desired thickness of 200 mm (+/- 10 mm).
- Following fine spreading of topsoil, the dump surface should be ripped (dozer or grader) to a depth of 200 mm with a distance between rips of approximately 1 m, to encourage infiltration of water for plant growth.
- Seeding of topsoil to occur as soon as possible to encourage plant growth and prevent soil loss erosion.

7.11 Revegetation

As outlined in section 5, the approved PMLUs for Baralaba Coal Mine include grazing and a native vegetation. Therefore, revegetation activities are focused on.

- Establishing a suitable vegetation cover to ensure a stable and productive landform within areas identified with a grazing PMLU; or
- Reproducing the pre-existing community composition within areas identified with a native vegetation PMLUs.

Vegetation will be established either via a viable seedbank within previously stripped topsoil or by direct seeding.

When undertaking direct seeding, agricultural equipment is used to seed and fertilise within the effective root zone (200 mm – 300mm). A seed mix has been identified for both the grazing and the native vegetation PMLU (Table 23 and Table 24), which is intended to maximise the chances of successful rehabilitation. The preferred species mix depends on the PMLU and soil characteristics, therefore seed mixes may vary slightly to the mixes presented below.

Sowing rates will begin with a minimum of 14kg/ha but may be adjusted by an AQP (Appropriately Qualified Person), based on recommendations from the Department of Agriculture and Fisheries (2017), relevant guidelines (DAFF 2013; Australian Government 2017), and Future Beef (2022). Ideally, sowing will take place within one week of topsoil placement and ripping. Newly seeded areas will be fenced appropriately to exclude stock from grazing and allow the highest chance of germination and survival.

Native Vegetation PMLU seed mixes have been developed from species recorded during baseline surveys, dominant species known from surrounding REs, species used successfully on other mine sites and species that have naturally self-seeded on-site.

The Grazing PMLU seed mix has been developed from grazing species recorded during BNCOP EIS baseline vegetation surveys, species used successfully in mines locally and species that have naturally self-seeded within rehabilitation areas. Actual species planted will be determined based on seed availability at the time of rehabilitation, however, the overall target seeding rate will be achieved.

Seeding, where required, will be ideally undertaken immediately prior to the onset of the wet season, giving the seed the best chance of striking, as soil moisture will be at its highest in the late wet season.

Table 23: Grazing PMLU seed mix

Species	Common name
Bothriochloa bladhii	Forest Bluegrass
Bothriochloa decipiens	Pitted Bluegrass
Bothriochloa ewartiana	Desert Bluegrass
Capillipedium parviflorum	Scented-top Grass
Chrysopogon fallax	Golden Beard Grass
Desmanthus spp	Desmanthus
Dichanthium sericeum	Silky/Queensland Bluegrass
Digitaria spp.	Digitaria
Eucalyptus coolabah	Coolabah
Eucalyptus populnea	Bimble Box
Eucalyptus tereticornis	Forest Red Gum
Heteropogon contortus	Black Speargrass
Macroptilium bracteatum	Burgundy Bean
Megathyrsus maximus	Guinea Grass
Panicum spp. (Native)	Panics
Stylosanthes spp (Native)	-
Themeda triandra	Kangaroo Grass
Chloris gayana	Rhodes Grass
Megathyrsus maximus	Gatton Panic
Digitaria spp.	Digitaria
Bothriochloa insculpta	Bisset Creeping Bluegrass
Stylosanthes scabra	Seca Stylo
Echinochloa esculenta	Japanese Millet
Cynodon dactylon	Couch Grass
Lomandra multiflora	Many-flowered Mat-rush
Lomandra longifolia	Spiny-headed Mat-rush

Species	Common name
Lomandra confertifolia	Lomandra Mist
Chrysopogon fallax	Golden Beard Grass
Neptunia gracilis	Native Sensitive Plant

Table 24: Native vegetation PMLU Seed Mix

Regional ecosystem	Trees	Shrubs	Grasses	Forbs
11.3.2	*Acacia conferta* *Acacia excelsa* *Acacia fasciculifera* *Acacia harpophylla* *Acacia salicina* *Amyema indet.* *Amyema pendula subsp. longifolia* *Brachychiton populneus* *Atalaya hemiglauca* *Callitris glaucophylla* *Cassia brewsteri* *Casuarina cristata* *Citrus glauca* *Corymbia clarksoniana* *Cymbidium canaliculatum* *Eremophila mitchellii* *Eucalyptus camaldulensis* *Eucalyptus crebra* *Eucalyptus melanophloia* *Eucalyptus populnea* *Eucalyptus tereticornis* *Geijera parviflora* *Grevillea striata* *Lysiphyllum carronii*	*Acacia conferta* *Acacia crassa* *Acacia decora* *Acacia excelsa* *Acacia harpophylla* *Acacia oswaldii* *Acacia salicina* *Alectryon diversifolius* *Alectryon oleifolius* *Atalaya hemiglauca* *Capparis lasiantha* *Corymbia clarksoniana* *Dodonaea viscosa* *Eremophila deserti* *Eremophila glabra subsp. glabra* *Eremophila mitchellii* *Erythroxylum australe* *Eucalyptus populnea* *Ficus opposita* *Geijera parviflora* *Grevillea striata* *Grewia retusifolia* *Hakea chordophylla*	*Aristida calycina* *Aristida indet.* *Aristida personata* *Aristida ramosa* *Austrostipa verticillata* *Bothriochloa bladhii* *Bothriochloa decipiens var. decipiens* *Chloris divaricata* *Chloris truncata* *Chloris ventricosa* *Chrysopogon fallax* *Cymbopogon refractus* *Cyperus fulvus* *Cyperus gracilis* *Dichanthium sericeum subsp. sericeum* *Digitaria brownii* *Digitaria hystrichoides* *Dinebra decipiens* *Enneapogon gracilis* *Enneapogon indet.* *Enneapogon intermedius* *Enneapogon lindleyanus* *Enneapogon polyphyllus*	*Abutilon oxycarpum* *Achyranthes aspera* *Alternanthera nana* *Boerhavia dominii* *Breynia oblongifolia* *Brunoniella australis* *Calotis cuneata* *Calotis lappulacea* *Capparis lasiantha* *Carissa ovata* *Chrysocephalum apiculatum* *Clematicissus opaca* *Cyanthillium cinereum* *Desmodium rhytidophyllum* *Desmodium varians* *Einadia hastata* *Einadia nutans subsp. linifolia* *Enchylaena tomentosa* *Eremophila debilis* *Euphorbia dallachyana* *Euphorbia drummondii* *Evolvulus alsinoides* *Galactia tenuiflora*

Regional ecosystem	Trees	Shrubs	Grasses	Forbs
	Psydrax oleifolia	*Indigofera indet*	*Enneapogon virens*	*Glossocardia bidens*
	Ventilago viminalis	*Lysiphyllum carronii*	*Enteropogon acicularis*	*Glycine tabacina*
		Owenia acidula	*Enteropogon ramosus*	*Grewia latifolia*
		Owenia venosa	*Eragrostis brownii*	*Hibiscus sturtii*
		Pimelea neoanglica	*Eragrostis elongata*	*Indigofera indet.*
		Psydrax oleifolia	*Eragrostis lacunaria*	*Jasminum didymum*
		Salsola australis	*Eragrostis leptostachya*	*Maireana microphylla*
		Sida hackettiana	*Eragrostis sororia*	*Marsdenia viridiflora*
		Tephrosia indet.	*Eremochloa bimaculata*	*Melhania oblongifolia*
		Terminalia oblongata subsp. oblongata *Ventilago viminalis*	*Eriochloa crebra*	*Murdannia graminea*
		Zieria smithii	*Eriochloa pseudoacrotricha*	*Neptunia gracilis*
			Eulalia aurea	*Nyssanthes diffusa*
			Fimbristylis dichotoma	*Nyssanthes erecta*
			Heteropogon contortus	*Parsonsia lanceolata*
			Leptochloa digitata	*Peripleura hispidula*
			Panicum decompositum	*Phyllanthus virgatus*
			Panicum effusum	*Pseuderanthemum variabile*
			Panicum simile	*Psydrax oleifolia*
			Paspalidium caespitosum	*Pterocaulon redolens*
			Paspalidium gracile	*Rhagodia spinescens*
			Sporobolus caroli	*Rhynchosia minima*
			Sporobolus creber	*Rostellularia adscendens*
			Sporobolus elongatus	*Salsola australis*
			Themeda triandra	*Sclerolaena birchii*
			Tragus australianus	*Sclerolaena muricata*

Regional ecosystem	Trees	Shrubs	Grasses	Forbs
			Urochloa foliosa	*Sida hackettiana* *Sida indet.* *Sida pleiantha* *Sida rohlenae* *Sida sp. (Musselbrook M.B.Thomas+ MRS437)* *Sida trichopoda* *Stackhousia muricata* *Tribulus terrestris* *Tricoryne elatior* *Verbena indet.* *Vittadinia pustulata* *Vittadinia sulcata* *Wahlenbergia gracilis*
11.3.3	*Acacia cambagei* *Acacia harpophylla* *Acacia pendula* *Acacia salicina* *Alectryon oleifolius subsp. elongatus* *Amyema congener* *Amyema quandang* *Apophyllum anomalum* *Casuarina cristata* *Casuarina cunninghamiana* *Corymbia tessellaris*	*Acacia excelsa* *Acacia harpophylla* *Acacia oswaldii* *Acacia pendula* *Acacia salicina* *Acacia stenophylla* *Alectryon diversifolius* *Alectryon oleifolius subsp. elongatus* *Atalaya hemiglauca* *Avicennia marina* *Bursaria spinosa subsp. spinosa*	*Aristida leptopoda* *Bothriochloa bladhii subsp. bladhii* *Bothriochloa decipiens* *Bothriochloa ewartiana* *Cenchrus ciliaris* *Chloris divaricata* *Chloris ventricosa* *Chrysopogon fallax* *Cymbopogon refractus* *Cyperus exaltatus* *Cyperus gracilis*	*Abutilon fraseri* *Abutilon oxycarpum* *Achyranthes aspera* *Alectryon diversifolius* *Alternanthera denticulata* *Alternanthera nodiflora* *Atriplex muelleri* *Basilicum polystachyon* *Boerhavia dominii* *Boerhavia indet.* *Brunoniella australis*

Regional ecosystem	Trees	Shrubs	Grasses	Forbs
	Cymbidium canaliculatum	*Capparis lasiantha*	*Cyperus indet.*	*Calotis cuneata*
	Dodonaea viscosa	*Carissa ovata*	*Cyperus javanicus*	*Camptacra barbata*
	Eremophila mitchellii	*Cassia brewsteri*	*Dichanthium sericeum subsp. sericeum*	*Capparis lasiantha*
	Eucalyptus camaldulensis	*Casuarina cristata*	*Digitaria brownii*	*Citrus glauca*
	Eucalyptus coolabah	*Citrus glauca*	*Dinebra decipiens*	*Crotalaria indet.*
	Eucalyptus melanophloia	*Clematicissus opaca*	*Eleocharis acuta*	*Cyanthillium cinereum*
	Eucalyptus populnea	*Denhamia indet.*	*Eleocharis pallens*	*Cymbidium canaliculatum Eclipta prostrata**
	Eucalyptus tereticornis	*Diospyros humilis*	*Enteropogon acicularis*	*Duma florulenta*
	Exocarpos aphyllus	*Dodonaea lanceolata*	*Enteropogon ramosus*	*Einadia nutans subsp. linifolia*
	Geijera parviflora	*Duma florulenta*	*Eragrostis lacunaria*	*Enchylaena tomentosa*
	Lysiphyllum hookeri	*Ehretia membranifolia*	*Eriochloa crebra*	*Eremophila debilis*
	Melaleuca bracteata	*Eremophila bignoniiflora*	*Eriochloa procera*	*Euphorbia dallachyana*
	Myoporum acuminatum	*Eremophila deserti*	*Eriochloa pseudoacrotricha*	*Euphorbia drummondii*
	Owenia acidula	*Eremophila mitchellii*	*Eulalia aurea*	*Euphorbia indet.*
	Psydrax oleifolia	*Eucalyptus coolabah*	*Heteropogon contortus*	*Euphorbia psammogeton*
	Terminalia oblongata subsp. oblongata	*Eucalyptus tereticornis*	*Leptochloa digitata*	*Eustrephus latifolius*
	Ventilago viminalis	*Enchylaena tomentosa*	*Panicum decompositum*	*Glycine tabacina*
		Excoecaria agallocha	*Panicum laevinode*	*Haloragis aspera*
		Ficus opposita	*Paspalidium caespitosum*	*Jasminum didymum subsp. racemosum*
		Geijera parviflora	*Paspalidium distans*	*Jasminum didymum subsp.didymum*
		Grewia latifolia	*Paspalidium gracile*	*Lomandra longifolia*
		Lysiphyllum carronii	*Paspalidium indet.*	*Maireana microphylla*
		Lysiphyllum hookeri	*Paspalidium jubiflorum*	*Marsilea drummondii*
		Melaleuca bracteata	*Sporobolus caroli*	*Marsilea hirsuta*
		Myoporum acuminatum	*Sporobolus creber*	

Regional ecosystem	Trees	Shrubs	Grasses	Forbs
		Notelaea microcarpa	*Sporobolus mitchellii*	*Melhania oblongifolia*
		Pittosporum angustifolium	*Thellungia advena*	*Neptunia gracilis*
		Psydrax forsteri	*Themeda avenacea*	*Oxalis perennans*
		Psydrax johnsonii		*Phyllanthus maderaspatensis*
		Psydrax oleifolia		*Rhagodia spinescens*
		Santalum lanceolatum		*Rhynchosia minima*
		Senna barclayana		*Rostellularia adscendens*
		Sesbania cannabina var. cannabina		*Salsola australis*
		Terminalia oblongata subsp. oblongata		*Sclerolaena muricata*
		Ventilago viminalis		*Sclerolaena tetracuspis*
				Senna barclayana
				Sida hackettiana
				Sida indet.
				Sida trichopoda
				Tetragonia tetragonoides
				Verbena indet.
				Wahlenbergia gracilis
				Zaleya galericulata subsp. Galericulata

7.12 Residual void

During the development of the BNCOP EIS, a Site Water Balance and Surface Water Assessment (WRM, 2014) was completed (Appendix H). This assessment simulated the recovery of the void lake water levels and quality. The outcomes of this assessment are summarised below for reference.

As noted in Section 7.4, Baralaba South EIS development process, developed a numerical groundwater model using MODFLOW-USG. The validation process ran the model with the calibrated parameters from the BNCOP 2014 model, including additional validation points and measurements. This validation process determined that the MODFLOW-USG model continues to display an overall reasonably good fit between the computed groundwater heads and past water level observations, albeit at a distance from the BSP datasets. HydroSimulations (2021) determined that the match between observed and computed groundwater levels and trends remains good for the numerical groundwater model.

7.12.1 Residual void lake

Once mining operations cease, the north void will gradually begin to fill with water. Inflows into the final void will comprise of incident rainfall, runoff within the final void catchment area (Figure 28) and groundwater (including spoil dump infiltration). The catchment area of the final void would be defined by the surrounding landform including safety bunds and/or diversion channels. The final void catchment area is estimated to be approximately 286 ha (Figure 28) (WRM 2014).

A residual void inflow assessment was completed by HydroSimulations (2014) using MODFLOW Drain cells. This assessment determined that groundwater inflows from the surrounding unmined geological units decline as the lake level increases (Figure 27). However, inflow from the in-pit spoil dump (i.e. the area to the south of the final void) increases as the lake level increases. Hydrosimulations hypothesised that this increase is not due to a change in hydraulic gradient between the lake and spoil dump (the gradient remains fairly constant) but rather an increase in the saturated cross-sectional area through which water can be transmitted (i.e., while the lake level is increasing, the head in the spoil dump are also increasing) (WRM,2014).

Based on the outcomes of the HydroSimulations (2014) inflow assessment, WRM (2014) concluded that the combined flow rate from the surrounding unmined geological units and from the in-pit spoil dump to the south decreased from 1.5ML/d at the base of the void to around 1.1ML/d when the water level reaches about -40mAHD. Above this void lake level, the groundwater inflow rate remains relatively constant at 1.1ML/day.

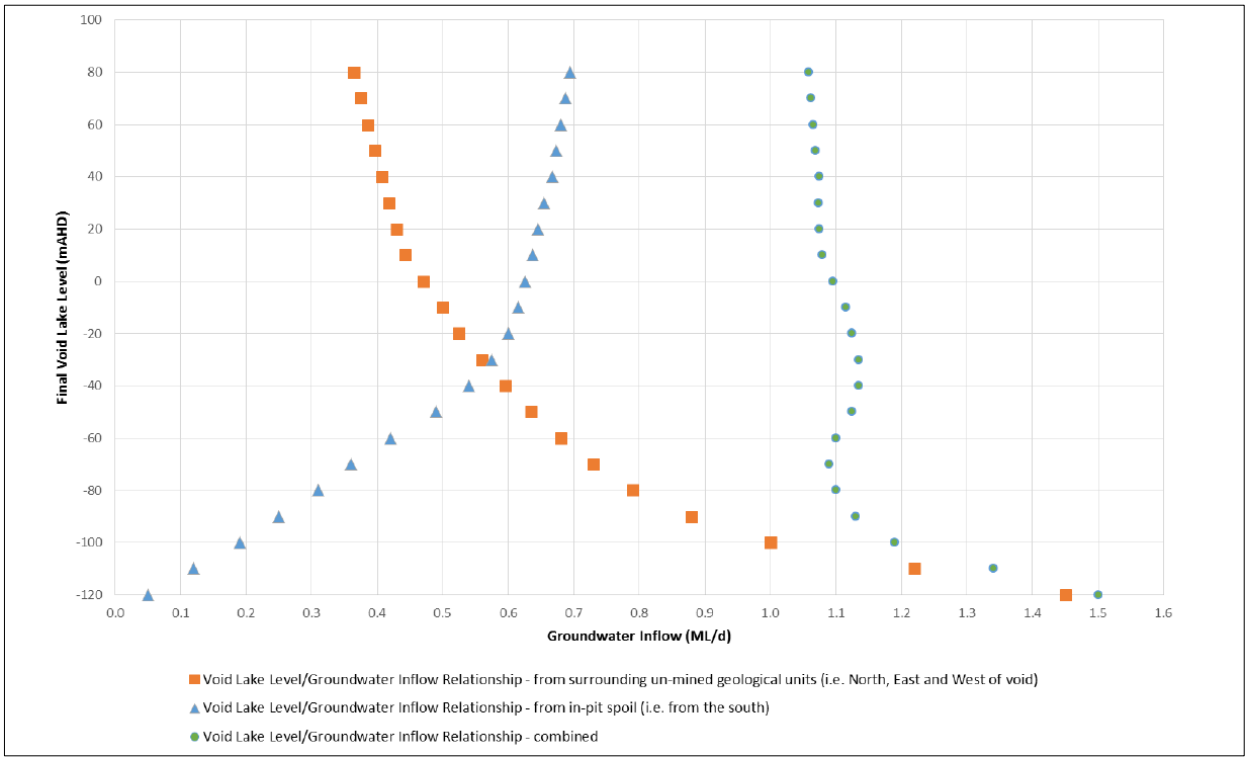

Figure 27: Adopted long term groundwater and seepage inflows and outflows to the final voids (WRM 2014)

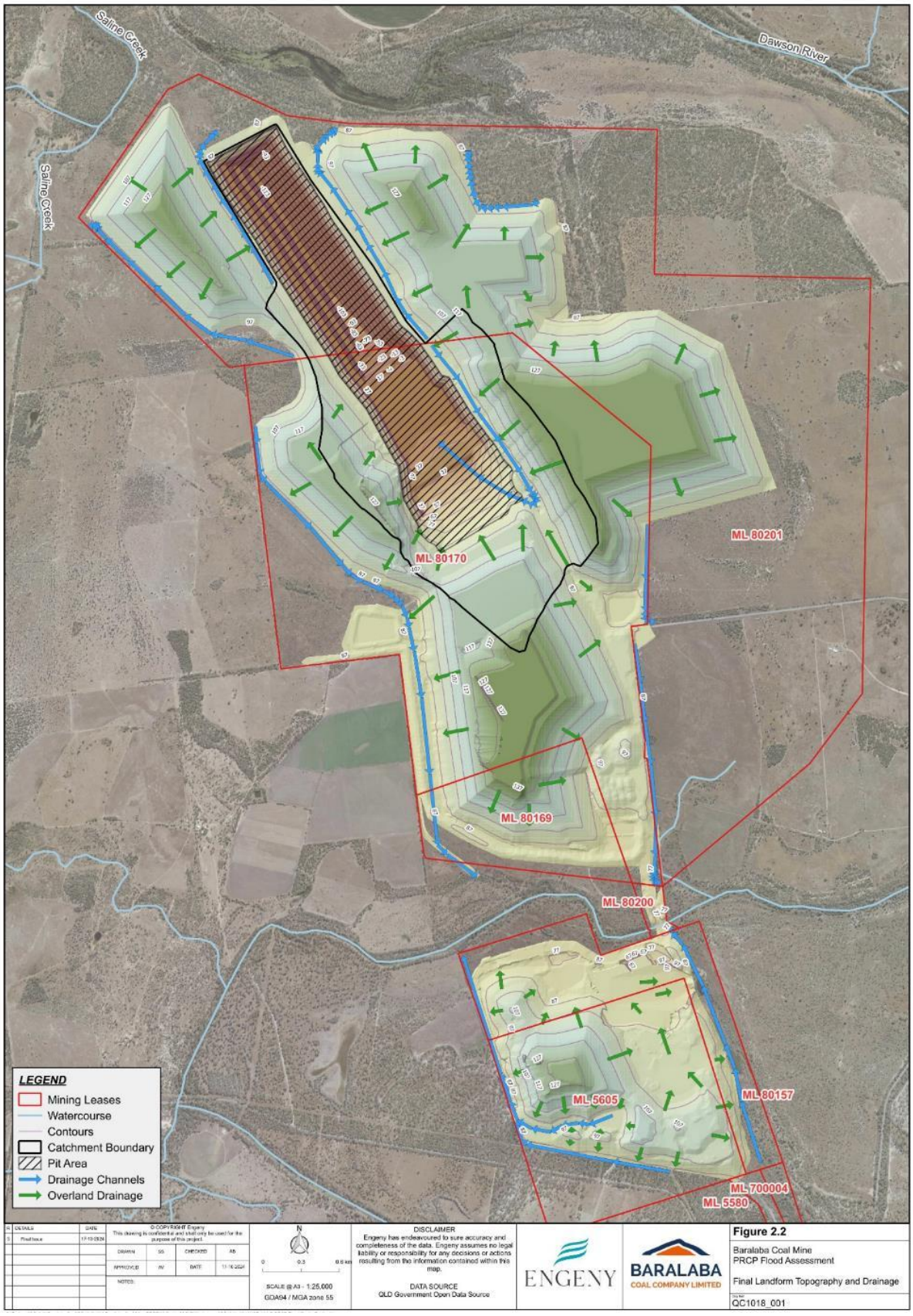

Figure 28: Conceptual Landform drainage and topography (Engeny 2024)

7.12.2 Residual void water and salt balance

Hydrosimulations (2014) describe the baseline groundwater elevation as approximately 70.1-75m AHD in the vicinity of the Baralaba North void. Which indicates that the open pit void acts as a sink to groundwater flow, and gradually fills over time. The water balance and final equilibrium water level of the final void is dependent on the rainfall and runoff entering the void, evaporation loss, and the inflow of groundwater. To estimate the long-term accumulation of water and salts in the final void WRM Water and Environment Pty Ltd (WRM) was commissioned to simulate a water balance model, as part of the BNCOP EIS.

The WRM (2014) predicted void lake level and salt concentration, represented as total dissolved solids (TDS), in the final void is shown in Figure 29 and Figure 30 respectively. The simulation results of the WRM (2014) assessment are:

- The final void water levels would rise about 70 m above the pit floor over the first 100 years after mining ceases, with the final void reaching an equilibrium water level of approximately 20 mAHD (i.e., 140m above the void base) after about 400 years.
- The freeboard between the final water level surface and the void spill height is approximately 50 m. Hence, the final void is unlikely to be filled (nor spill), as a rainfall event causing enough catchment runoff to fill the void is unlikely.
- The salinity in the final void would gradually increase due to the salinity of groundwater inflows, with TDS concentrations reaching 30,000 mg/L towards the end of the simulation period (500 years). TDS concentrations would likely continue to increase over time as water evaporates and salt mass increases.
- The final lake level is expected to be below the baseline groundwater level; hence the void would remain as a groundwater sink. The results of this analysis would be affected by the dynamic interactions between lake level, groundwater inflow and evaporation. However, groundwater inflow would effectively cease once the lake level reached the regional groundwater level which is below the overflow level.

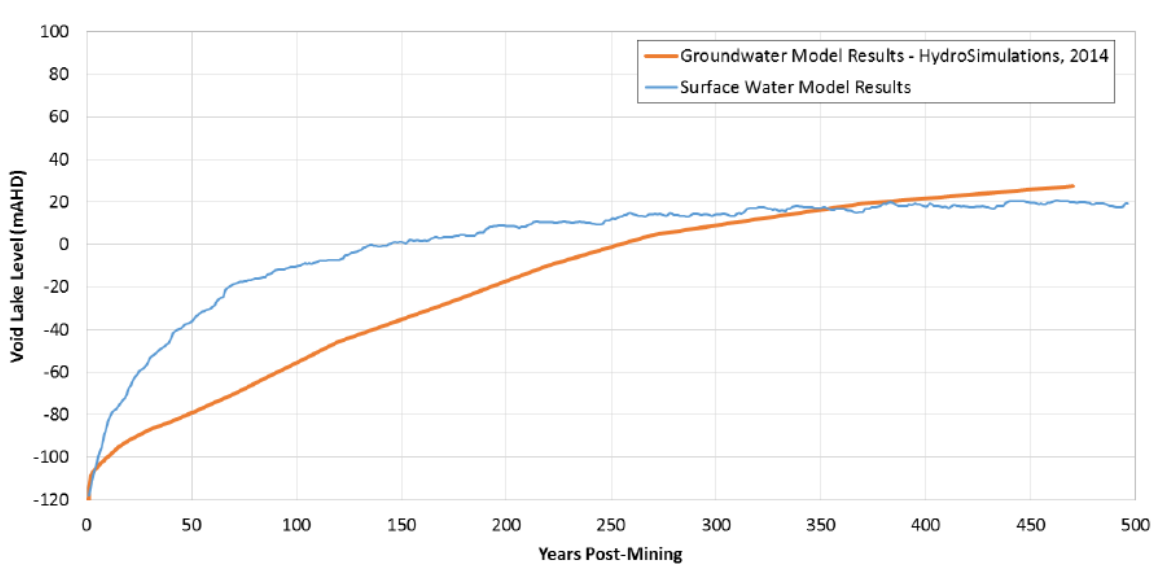

Figure 29: Final void lake level (WRM 2014)

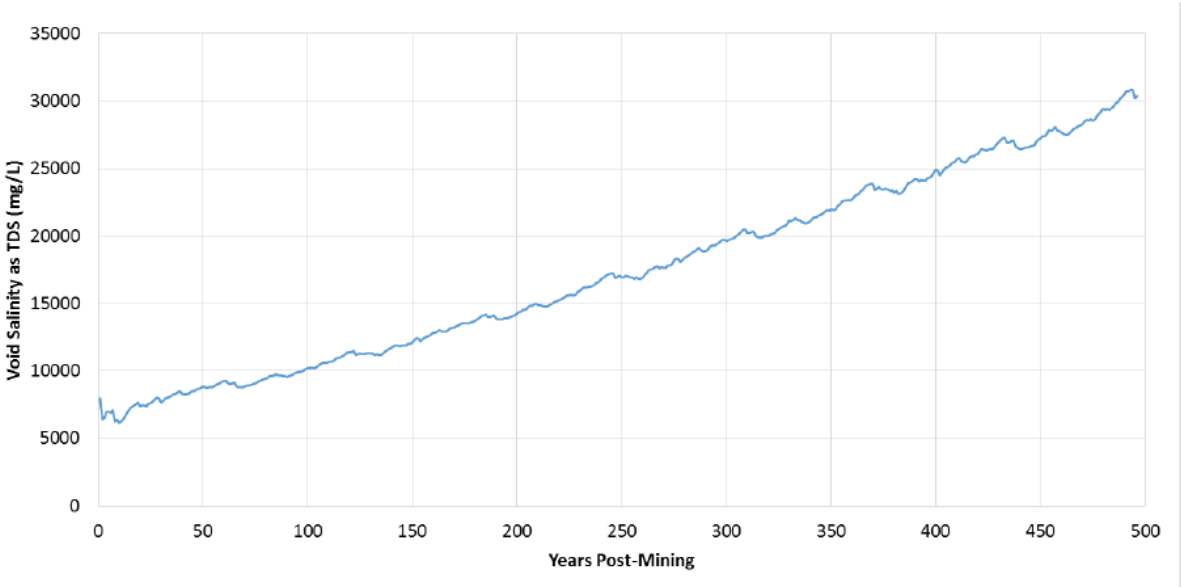

Figure 30: Final void total dissolved solids concentration (WRM 2014)

7.12.3 Residual void stability

In July 2021, Sherwood Geotechnical and Research Services undertook a review of the Baralaba Coal Mine Geotechnical Design Recommendations (Appendix I). This report provided design parameters, which created ground conditions where the consequences of instability or excessive ground movement are understood, therefore reducing the likelihood of instability to an acceptable level of risk. The review considered prior mining performance together with a geotechnical analysis of stability, safety and potential ground movement and concluded that the slope ranges provided in Table H3 of the EA (EPML00332313) would achieve a factor of safety greater than 1.2 (Simmons 2021).

7.13 Built infrastructure

RA5 consists of all major infrastructure at Baralaba Coal Mine and covers a total area of 350 ha. Majority of surface infrastructure is required up until the end of mine life, with decommissioning of this major built infrastructure scheduled to commence in 2033.

Baralaba Coal will decommission and remove all infrastructure from the site unless otherwise agreed with post-mining landholder(s) and DETSI. Hydrocarbons (petrol, diesel, oils, greases, degreasers, and kerosene), explosives, chemicals and liquid and non-liquid wastes unused at the completion of mining will be returned to the supplier in accordance with relevant safety and handling procedures. Hydrocarbon and chemical storages are designed, operated, and maintained at Baralaba Coal in accordance with relevant Australian Standards and are therefore considered to have minimal potential for impact requiring significant remediation. Where remediation, identified during a contaminated land assessment, is required, these works will be completed in accordance with the recommendation of an appropriately qualified person and may include in situ remediation. In-situ remediation will likely involve the removal of the affected soil, which is then buried in the pit. Underlying soil is tested to ensure all contaminated soil has been removed. With the location of contaminated soil and remediation activities recorded internally.

Where infrastructure is not required by the post mining landholder, it will be decommissioned in line with the following processes:

- Disconnect and isolate all services (power/communications).
- Remove all surface services/infrastructure (e.g., power/communications lines and pipelines).
- All concrete slabs/footings will also be removed.

- Removal of contaminated material/other actions as determined by the contaminated land assessment;
- Removal of sediment from the base of all water storages. Excavated materials will be placed in the void.
- Removal of constructed walls and backfilling of all storages, where the finished surface will be at the approximate natural ground level, with no ability to retain water. The final surface will be topsoil and seeded.
- Roads covered in 200 mm of gravel/crushed rock will have the gravel removed before being graded and seeded with pasture.
- Salinity testing will be completed on the haul roads, to ensure no residual contamination from haul road dust suppression. The area will then be ripped, shaped and seeded with pasture seeds.
- Earthen laydown yards will be ripped, topsoiled to a depth of 200 mm, and seeded to pasture or native vegetation, depending on its location.
- Any identified contaminated material incompatible with the proposed PMLU will be either treated in situ on-site and confined by burial, or removed, transported to an approved landfill for disposal or alternatively risk assessed and listed on the environmental management register to the extent necessary.

Fences required to manage livestock across rehabilitated areas will be progressively installed on an 'as needed' basis in response to planned grazing activities. Where stock fences are required to be constructed, the location and type of fence will be finalised with the relevant stakeholders.

Existing infrastructure required to benefit and improve the use of the land for a grazing PMLU, includes access roads, laydown areas and dams. This existing infrastructure will be handed over during relinquishment and will be maintained until such time.

All infrastructure which is currently planned to be retained post-closure includes:

- All above ground pipelines;
- All access tracks, roads and haul roads, which do not intersect the realignment of the Hoadley's Road Easement.
- The 2nd North Mine Infrastructure Area (MIA) Temporary Workshop and Central Heavy Vehicle Workshop;
- North Sediment Dam, MIA North Dam, Lagoon Dam, Farm Dam, Central Sediment Dam, Central ROM Dam, Mine Dam 4a, clean water drains, minor sediment dams and retention basins.
- Build Pad, North Mine Infrastructure Areas, North HV Park Up, North Mag and Reload, Central Mine Infrastructure Area; Central run of mine (ROM) Pad; and North ROM and Laydown Yard; and
- All existing fencing and security installations

This infrastructure has been selected to be maintained by the landholder for the purposes of supporting the implementation of industry best practice grazing management. The dams are distributed across the landform to provide suitable access to watering points for cellular or rotational grazing practices. Pipelines provide the ability to the grazier to move water across the property as necessary. Access tracks and haul roads provide safe access to paddocks for animal and property management. Laydown areas and workshops provide suitable areas for farm equipment, maintenance and storage.

ML700004 Haul Road is located on Banana Shire Council held land. The retention of this infrastructure at the completion of mine-life is at the Council's discretion. The Banana Shire Council decision will be reflected in a signed agreement prior to the schedule completion date for RM1 for RA6 in 2041.

The signed landholder agreement relating to this infrastructure can be found as Appendix K. This agreement dictates that infrastructure included within the agreement must be safe, stable and not cause environmental harm before being surrendered to the landholder.

8 Risk assessment

8.1 Risk assessment requirements

Section 126C(1)(f) of the EP Act requires the PRCP to identify the risks, for each PMLU, of a stable condition not being achieved and how the applicant intends to manage or minimise the risk.

A risk assessment has been carried out in accordance with the following standards:

- AS/NZS ISO 31000:2018 Risk management - Guidelines; and
- HB203:2012 Managing environment-related risk.

This risk assessment has informed the scope of the planning part of this PRCP, as well as the development of comprehensive rehabilitation success criteria. Where higher risks were identified for Baralaba Coal Mine, the scope of the PRCP was expanded to provide confidence in the rehabilitation methods to achieve the objectives and milestones proposed.

8.1.1 Risk assessment process

Any risk assessment needs to be undertaken with consideration of the scope, context, and criteria relevant to the assessment. For this risk assessment, the following scope and purpose was discussed and agreed to:

"The purpose of this risk analysis is to identify the risks of rehabilitation objectives not being achieved for the agreed PMLUs and NUMAs nominated and the approach to be taken by Baralaba Coal Mine to manage and minimise the risks identified".

For this risk assessment, risk scenarios (or 'threats') were identified and considered for each rehabilitation area and non-use management area associated with Baralaba Coal Mine. The causes attributable to each risk scenario were documented as well as the potential impacts. Existing controls were noted, defined as those reasonably expected to be in place for a Project of this nature and having appropriate and contemporary management systems. Each risk scenario was then assessed with respect to health, safety, the environment, and compliance against the risk assessment schema outlined in section 8.1.2.

8.1.2 Risk assessment schema

Risks specific to the rehabilitation of the Baralaba Coal Mine were classified using the risk classification schema which is described below. The risk assessment schema used is comparable to those used widely within the mining industry and comprises the following components:

- a likelihood classification descriptors table (Table 25); and
- a consequence classification descriptors table (Table 26) intended to guide a consistent assessment of consequences.

Following a consensus determination of likelihood and consequence, the risk level was determined using the matrix shown in Table 27. For any risks classified as 'high' or above, mitigation and management measures were identified and documented. Mitigation and management measures were also documented for some lower-level risks.

Table 25: Likelihood of exposure to the hazard

Level of Risk Probability	Descriptive Guidance	Probability	Frequency
Highly Probable	The event is expected to occur in most circumstances	Higher than 80%	The event and consequence are expected to occur at least once per year
Probable	The event will probably occur in most circumstances	From 33% up to 80%	The event and consequence is expected to occur at least once in 1 to 3 years
Possible	The event could occur at some time	From 5% up to 33%	The event and consequence is expected to occur at least once in 3 to 20 years
Improbable	Not expected but the event may occur at some time in the future	From 1% up to 5%	The event and consequence is expected to occur at least once in 20 to 100 years
Highly Improbable	The event may occur only in exceptional circumstances	Less than 1%	The event and consequence are expected to occur less than once in every 100 years

Table 26: Consequence classification descriptors

Category	Consequence Scale				
	1. Very Minor	2. Minor	3. Moderate	4. Major	5. Catastrophic
Safety	First Aid (FAI) Very minor injury or illness deemed report only. Return to work following first aid treatment.	First Aid (FAI) Minor Injury or Illness. Return to work following first aid treatment.	Lost Time Injury (LTI), Restricted Work Injury (RWI), Medical Treatment Injury (MTI), High Potential Incident (HPI). Serious Injury Involving Medical Treatment or Restricted Duties. Unable to return to work for one or more shifts.	Single fatality, permanent total incapacity, or disability. Serious accident as defined by legislation. Significant irreversible health effects. Unable to return to work.	Multiple fatalities. Multiple significant irreversible health effects/cases. Multiple permanent incapacity injuries.
Environmental	Small contaminant release or land disturbance localised on-site area affected. Routine short-term clean-up/ remediation. Non-reportable incident resulting in an on-site impact	Moderate contaminant release or land disturbance localised on-site. Routine short-term clean-up/ remediation. Non-reportable incident resulting in an on-site impact.	Large contaminant release or land disturbance localised off-site. Short-term clean-up/remediation. Reportable incident resulting in an off-site impact.	Large contaminant release or land disturbance localised off-site. Long-term clean-up/ remediation, potentially irreversible. Incident resulting in a fine by statutory regulations.	Very large contaminant release, extensive off-site area affected. Complex long-term clean-up/ remediation, irreversible. Incident resulting in suspension of operations.

Table 27: Risk level classification matrix

Likelihood	Consequence				
	Catastrophic	**Major**	**Moderate**	**Minor**	**Very Minor**
Highly Probable	Extreme	Extreme	Extreme	Extreme	High
Probable	Extreme	Extreme	Extreme	High	High
Possible	Extreme	High	High	Moderate	Moderate
Improbable	High	High	Moderate	Low	Low
Highly Improbable	High	Moderate	Low	Low	Low

8.1.3 Risk assessment outcomes and management

Detailed risk assessment outcomes are provided in Appendix J. For Baralaba Coal Mine, a total of 32 individual risk scenarios were identified resulting in 26 assessed risks including three classified as 'high', five classified as 'moderate' and the remainder 13 classified as 'low'. A summary of risk outcomes is shown in Table 28.

Table 28: Risk assessment outcomes by rehabilitation area/improvement area

Rehabilitation area	Risk level				
	Low	**Moderate**	**High**	**Extreme**	**Total**
Elevated Landforms	2	2	2	0	**6**
Infrastructure (Grazing)	5	1	0	0	**6**
Native Conservation Area	4	1	0	0	**5**
Final void	2	1	1	0	**9**
Total	13	5	3	0	**26**

One of the Elevated Landform scenarios classified as 'high' relates to the risk of erosion gullies. This consequence considered the design of the final landform, the erosivity of the soil, and the potential failure of surface preparation activities, and as such could not be mitigated below a significant risk class in this assessment. However, monitoring efforts will ensure that any failed surface preparations will be detected and repaired.

The second Elevated Landform scenario classified as 'high' relates to the risk of highly saline or sediment-laden run-off from rehabilitated areas. This consequence considered the design of the final landform, the erosivity of the soil, and the potential failure of vegetation establishment, and as such could not be mitigated below a significant risk class in this assessment. Rehabilitation actions will be sequenced up slope so that

new rehabilitation drains into established areas. This will assist with drainage system impacts but will not reduce risk further. If downstream impacts are detected in regular monitoring efforts, an investigation will be undertaken to determine the cause and mitigate.

The scenario classified as 'high' relates to the safety of the final void area, which potentially could be accessible to people and fauna if the exclusion fencing were to fail. This consequence considered the potential for a fatality and as such could not be mitigated below a significant risk class in this assessment. However, considering the difficulty to gain access to the mining lease, this outcome is considered conservative. As such, no further management is deemed necessary.

9 Monitoring and maintenance

9.1 Monitoring and maintenance program

To develop the PRCP schedule, eleven rehabilitation milestones have been proposed as being applicable for the Baralaba Coal Mine. The PRCP Guideline (DES 2021a) requires consideration of measures to be undertaken to demonstrate that milestones and milestone criteria have been achieved.

With respect to determining the achievement of rehabilitation milestones, a clear definition of milestone criteria have been developed for each rehabilitation milestone (Section 7.2.1). Assessment of rehabilitation areas against milestone criteria will be incorporated into the ongoing environmental management for the Baralaba Coal Mine. Assessment of rehabilitation areas against the milestone criteria that pertain to vegetation and achievement of post mining land uses will be undertaken as part of the annual rehabilitation monitoring program that exists for the Baralaba Coal Mine. Monitoring of rehabilitation will commence following the completion of activities of the first rehabilitation milestone applicable to the relevant rehabilitation area.

The completion criteria for each PMLU has been transitioned into the milestone criteria for the final milestone in the schedule, which shows the achievement of the PMLU to a stable condition at surrender. When the final rehabilitation milestone applicable to the rehabilitation area is deemed to be satisfied, a final rehabilitation assessment will be undertaken before an application for progressive certification or ML surrender is made. Table 29 provides a summary of the measures to be undertaken to determine the achievement of each rehabilitation milestone. Determination of the boundary of an area reaching a given rehabilitation milestone at a given point in time will utilise standard survey techniques, including land-based survey and airborne survey at an appropriate frequency – nominally annually – to achieve satisfactory geolocation of areas.

Table 29: Rehabilitation milestone monitoring and management measures

Rehabilitation milestone	Description of RM criteria is detailed further in section 7.2.1	Proposed monitoring and management measure(s)
RM1: Infrastructure decommissioning and removal	Applicable to all infrastructure identified to be decommissioned/ removed from site. Considered to be met when the only remaining infrastructure forms part of a landholder agreement.	Infrastructure decommissioned/removed at closure will be subject to relevant environment and safety planning requirements including completion inspections. A visual inspection(s) will be conducted to determine that no infrastructure remains that does not form part of a Landholder Agreement.
RM2: Identification, remediation and removal of contaminated land	Applicable to mine infrastructure areas (i.e., where notifiable activities have been carried out), and inpit spoil used as a landfill, and, at a minimum, involves the completion of a Phase 1 contaminated land investigation undertaken by an appropriately qualified person. Considered to be met when contaminated material has been placed in the void, removed from site, or remediated *in situ*, a validation report has been completed, and, if required, a site suitability statement has been prepared.	A completed Phase 1 contaminated land investigation report, as well as any consequent reports, where required. Submission of waste tracking records. Visual inspection of potential sites or sources of contaminated material will be conducted, and samples collected as required. The contaminated land investigation will determine the presence of any contaminants. Remediation activities will be undertaken if required following consultation on appropriate remediation activities. A validation report will detail the remediation of contaminated land and, if required, a site suitability statement

Rehabilitation milestone	Description of RM criteria is detailed further in section 7.2.1	Proposed monitoring and management measure(s)
		prepared by an appropriately qualified person that states that the land is suitable for use according to the nominated PMLU.
RM3: Landform development and reshaping	Applicable to all areas where bulk earthworks and other grading are required to achieve the target landform. Considered to be met when surface preparation activities have been completed, and slope requirements from the completion criteria (section 5.2) including batter angles and geotechnical stability are met.	Land based and/or remote sensing survey techniques will be employed to confirm that graded slopes meet design specifications. Survey to be to an accuracy of +/-0.2m. AQP to confirm erosion and sediment control systems have been properly installed as per the construction design. Additionally, visual inspections will be done to determine if landform surface drainage has been designed and installed, and if any future maintenance/repair action is required. A geotechnical assessment will be conducted by an appropriately qualified person to confirm that long-term stability has been achieved for all relevant landforms. Records of inpit spoil placement over waste to be kept, and spot checks undertaken regularly to ensure the achievement of 1000mm cover depth.
RM4: Surface preparation	Areas undergoing surface preparation for seeding. Considered to be met when soil health and suitability has been assessed to be suitable for target establishment and when topsoil has met the detailed suitability targets.	A soil health assessment will be conducted by an appropriately qualified person prior to use in the rehabilitation process to determine topsoil and effective root zone health and suitability, and recommendations made for ameliorants where required. Qualitative assessment of contour ripping, including depth, spacing and machinery used. Records of topsoil placement and spot checks confirming achievement of a target depth of ≥ 0.2 m. Records to include any ameliorants applied, including types, rates, and timing of applications. Topsoil to undergo soil testing for pH, available phosphorus, electrical conductivity and ESP prior to application.
RM5: Revegetation (grazing)	Applicable to all areas requiring revegetation to a PMLU of grazing. Includes final profiling and application of topsoil materials, soil testing, soil amelioration, and seeding. Considered to be met when soil condition is conducive to plant germination and growth, and when records demonstrate that seeding	Records of seed mix and/or planted species consistent with the species listed in Appendix C Yearly monitoring of erosion. Visual assessments undertaken every 6 months of stock exclusion fencing. Firebreaks will be inspected and maintained on a quarterly basis by an

Rehabilitation milestone	Description of RM criteria is detailed further in section 7.2.1	Proposed monitoring and management measure(s)
	and/or planting of target species has been completed, with the understanding that remedial works such as reseeding or infill planting may be necessary to meet target vegetation completion criteria.	appropriately qualified person until rehabilitation is completed.
RM6: Revegetation (native vegetation)	Applicable to all areas requiring revegetation to a PMLU of native vegetation. Includes final profiling and application of topsoil materials, soil testing, soil amelioration, and seeding. Considered to be met when soil conditions are conducive to plant germination and growth, runoff water meets the criteria outlined in Section 9.2.6 and when records demonstrate that seeding and/or planting of target species has been completed, with the understanding that remedial works such as reseeding or infill planting may be necessary to meet target vegetation completion criteria.	Records of seed mix and/or planted species consistent with the species listed in Appendix C. Yearly monitoring of erosion. Visual assessments undertaken every 6 months of stock exclusion fencing. Firebreaks will be inspected and maintained on a quarterly basis by an appropriately qualified person until rehabilitation is completed.
RM7: Achievement of surface requirements (grazing)	Applicable to all areas targeting a PMLU of grazing. Involves monitoring activities and remediation works if monitoring identifies risks to the rehabilitation milestone being achieved. Considered to be met when monitoring data collected over three consecutive years demonstrates that vegetative groundcover and erosion meets the rehabilitation milestone criteria (RM7).	Rehabilitation monitoring undertaken annually using the methodology described in Section 9.2.1. Monitoring targets vegetation groundcover, weed presence and erosion.
RM8: Achievement of surface requirements (native ecosystem)	Applicable to all areas targeting a PMLU of native ecosystem. Involves monitoring activities and remediation works if monitoring identifies risks to the rehabilitation milestone being achieved. Considered to be met when monitoring data collected over three consecutive years demonstrates that vegetative groundcover and erosion meets the rehabilitation milestone criteria (RM8).	Rehabilitation monitoring undertaken annually using the methodology described in Section 9.2.1. Monitoring targets vegetation groundcover, weed presence and erosion.
RM9 Achievement of post mining land use to stable condition (Grazing):	Applicable to all areas that have been revegetated for a PMLU of grazing. This involves monitoring activities and implementing remediation works if monitoring identifies risks to the achievement of the rehabilitation milestone. The criteria are considered to be met when monitoring data collected over	Land class suitability assessment performed by an AQP. Annual vegetation monitoring of the following: • groundcover; • weed presence; and • erosion.

Rehabilitation milestone	Description of RM criteria is detailed further in section 7.2.1	Proposed monitoring and management measure(s)
	three consecutive years demonstrates that pasture productivity and erosion meet the PMLU completion criteria and the rehabilitation milestone criteria. Additionally, water quality in the receiving environment must be comparable to upstream levels.	Records of slopes for RA1, RA2, RA3 and RA4 of ≤ 15%. Records of slopes for RA5 and RA7 of ≤5%. Visual inspections, LiDAR imagery of the landform Monitoring for any evidence of salt rise or salt deposition on the landform surface. A BioCondition assessment completed by an AQP A hazard assessment by an AQP compared to local grazing in surrounding lands. Surface water quality recorded within 24 hours of flow and not exceeding limits as specified in Appendix C for a minimum of 5 consecutive years. Surface water monitoring results of downstream locations equal to or less than upstream locations, over 5 consecutive years. Groundwater quality monitored and in accordance with limits specified within Appendix C, annually for 5 years, then every 5 years after, not exceeding specified limits for 3 consecutive years.
RM10: Achievement of post mining land use to stable condition (Native vegetation)	The criteria are considered to be met when monitoring data collected over three consecutive years demonstrates that pasture productivity and erosion meet the PMLU completion criteria and the rehabilitation milestone criteria. Additionally, water quality in the receiving environment must be comparable to upstream levels.	Annual vegetation monitoring of the following: • groundcover. • weed presence; and • erosion. Records of slopes for RA1, RA2, RA3 and RA4 of ≤ 15%. Records of slopes for RA5 and RA7 of ≤5%. Visual inspections, LiDAR imagery of the landform to ensure that it is free draining. A BioCondition assessment completed by an AQP. Monitoring for any evidence of salt rise or salt deposition on the landform surface. A hazard assessment by an AQP compared to local grazing in surrounding lands. Surface water quality recorded within 24 hours of flow and not exceeding limits as specified in Table 33 for a minimum of 5 consecutive years. Surface water monitoring results of downstream locations equal to or less

Rehabilitation milestone	Description of RM criteria is detailed further in section 7.2.1	Proposed monitoring and management measure(s)
		than upstream locations, over 5 consecutive years. Groundwater quality monitored and in accordance with limits specified within Table 35, annually for 5 years, then every 5 years after, not exceeding specified limits for 3 consecutive years.
RM11: Achievement of postmining land use (permanent infrastructure)	Applicable to all areas of retained infrastructure that are to be retained for purposes other than grazing. The criteria are considered to be met when the only remaining infrastructure forms part of a landholder agreement. Monitoring data collected demonstrates that erosion meets the rehabilitation milestone criteria	A visual inspection(s) will be conducted to determine that no infrastructure remains that does not form part of a Landholder Agreement, and that land is at a quality required under the landholder agreement.

9.2 Monitoring program

9.2.1 Annual rehabilitation monitoring

Rehabilitation will be monitored on an annual basis, with the survey period occurring post wet season, as monitoring at this time allows for more accurate identification of the species present and a clearer understanding of species richness on-site. Where sufficient data is acquired that demonstrates that rehabilitation is clearly on a trajectory to achieve milestone criteria, the frequency of monitoring may be reviewed and reduced as recommended by an appropriately qualified person.

The rehabilitation monitoring program aims to achieve data collection at sufficient spatial and temporal resolution to ensure statistically valid results. The following methods are employed at each monitoring site and described in detail in the following sections:

- permanent vegetation monitoring transects (ground cover monitoring and species richness).
- photographic monitoring.
- erosion monitoring; and
- topsoil characterisation (every 2–3 years).

In conjunction with walking between transects, rehabilitation areas will be visually assessed to identify signs of fauna utilisation, noticeable issues such as erosion, vegetation cover deficiencies, or weed and/or pest infestations. Satellite imagery technology may also be employed. These observations are incorporated with the results of each rehabilitation progress report.

9.2.2 Analogue sites and PMLU monitoring

Due to the lack of availability of suitable reference sites that are reflective of the rehabilitation conditions at Baralaba Coal Mine, monitoring of analogue or reference sites has not been included in the Baralaba Coal Mine rehabilitation monitoring program and within this PRCP, and requirements for such are proposed to be removed from the EA.

Monitoring of grazing will be assessed against:

- The milestone criteria for RM7 and RM9 (Appendix C), which is based on standard methods for assessing pasture condition consistent with industry guidelines; and
- The land suitability assessment criteria for RM6, which was formed from baseline soil and land suitability assessments (Section 3.6).

Monitoring for native vegetation will be assessed against the BioCondition Benchmarks of RE 11.3.2 and RE 11.3.3 (REs local to the Baralaba Coal Mine). Milestone criteria have been developed to align with these benchmarks, this criteria is described in Table 30.

Table 30: BioCondition benchmark criteria

BioCondition Assessable Attributes	BioCondition Assessable Attribute Weighting	Hybrid Regional Ecosystem RE 11.3.2 / 11.3.3 Rehabilitated Eucalyptus populnea / *Eucalyptus conica* woodland on alluvial plains		
		Average benchmark	Indicative benchmark	
			RM8	RM10
Recruitment	5	100%	0	20% (=3 out of 5 weighting)
Non-native plant cover	10	0%	<25% (=5 out of 10 weighting)	<25% (=5 out of 10 weighting)
Native tree species richness	5	3	≥1 (=2.5 out of 5 weighting)	≥3 (=5 out of 5 weighting)
Native shrub species richness	5	4	≥1 (=2.5 out of 5 weighting)	≥4 (=5 out of 5 weighting)
Native grass species richness	5	11	≥3 (=2.5 out of 5 weighting)	≥3 (=2.5 out of 5 weighting)
Native forb / other native species richness	5	15	≥4 (=2.5 out of 5 weighting)	≥4 (=2.5 out of 5 weighting)
Tree canopy height	5	18m	0	≥4.5m (=3 out of 5 weighting)
Tree canopy cover	5	32.5%	≥3.25% (=2 out of 5 weighting)	≥16.25% (=5 out of 5 weighting)
Shrub canopy cover	5	4%	≥0.4% (=3 out of 5 weighting)	≥0.4% (=3 out of 5 weighting)
Native perennial grass	5	35.5%	≥17.75% (=3 out of 5 weighting)	≥17.75% (=3 out of 5 weighting)
Organic litter ground cover	5	32.5%	0	≥3.25% (=3 out of 5 weighting)
Total BioCondition Assessable attribute weighting score	**60**		**Overall BioCondition score required >20**	**Overall BioCondition score required >40**

9.2.3 Permanent vegetation monitoring transects.

Monitoring across permanent vegetation transects involves the collection of quantitative data on ground cover composition, species richness, woody stem density, and canopy cover, where the rehabilitation milestone requires the collection of this data. Monitoring sites will be placed at random within newly established rehabilitation polygons, at a density of approximately one site per 10 hectares. At each monitoring site, a 50 m tape will be run out to establish a transect and observations/measurements taken every five metres on either side of the transect, thereby representing a plot size of 50 m x 10 m. A star picket is installed at each end point of the transect, to identify consistently and precisely the permanent transect location. Photographic records and GPS locations for all monitoring sites and observed issues will be kept up to date in an appropriate database. To monitor revegetation progress, the data for each vegetation scenario will be averaged across monitoring sites established in similar timeframes and compared to the corresponding milestone and completion criteria.

Across each transect groundcover, species richness, woody stem and canopy cover will be monitored. The survey methodologies outlined below have been adapted from the Queensland Herbarium survey technique (*Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Version 5.0)) (Neldner et al. 2019) and the *Method for the Establishment and Survey of Reference Sites for BioCondition* (Eyre et al. 2017).

9.2.3.1 Ground cover monitoring

Percentage ground cover for each species is recorded within ten 1 m by 1 m quadrats placed on alternating sides every 5 m along the 50 m transect, commencing at 0 m on the left and the final quadrat at 45 m (see Figure 31). In each quadrat, the percentage cover of rock, bare ground, organic litter, and live plant species present is recorded. Live plant species are classified into one of the following six groups for reporting purposes:

- native pasture grasses.
- exotic pasture grasses.
- non-pasture grasses.
- forb and other non-grass species.
- shrubs; and
- restricted invasive plants as listed in the Biosecurity Act 2014 (QLD)

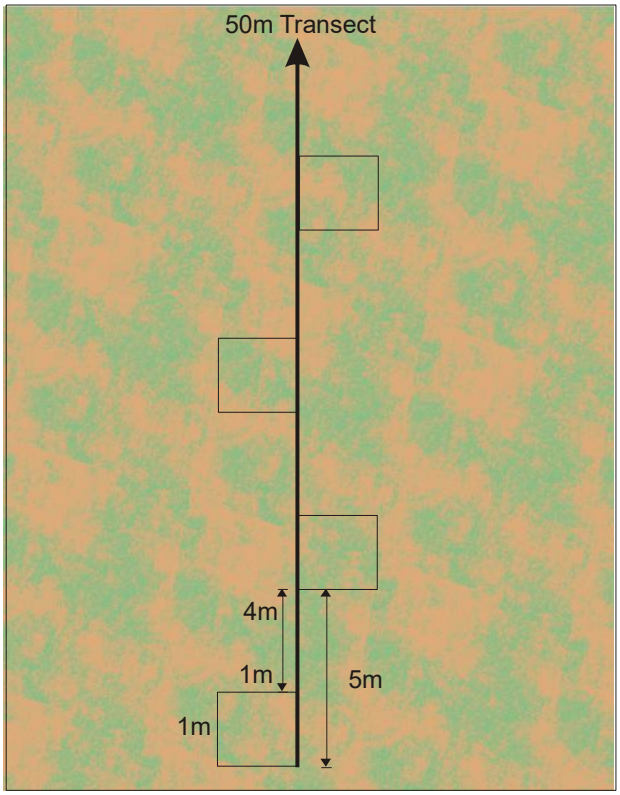

Figure 31: Ground cover percentage sampling

9.2.3.2 Species richness

Species richness is assessed using the method outlined in Eyre et al. (2017), where all vascular plants occurring within a 10 m x 50 m plot are recorded. The surveyor walks along each side of the 50 m transect centreline and records all trees, shrubs, forbs/other species, and grasses occurring within 5 m on either side of the centreline.

9.2.3.3 Woody stem density

Woody stem density is calculated using methodology adapted from *the Method for the Establishment and Survey of Reference Sites for BioCondition* (Eyre et al. 2017). All woody stems for each tree and shrub species are counted within the 10 m x 50 m plot area (i.e., 5 m on either side of each 50 m transect). From this data, both total woody stem density, as well as the density of each individual tree or shrub species can be calculated. The density of species and growth forms on the monitoring sites is then calculated using the following equation:

Density per hectare (ha) = Number of stems recorded within the transect x 20.

9.2.3.4 Canopy cover

Tree canopy cover can be used to characterise stand productivity and the distribution and abundance of biomass (Eyre et al. 2017). It refers to the estimation of the percentage canopy cover of the living, native tree layer along a 50 m transect, using the line intercept method (Greig-Smith et al. 1964). For this attribute, the vertical projection of tree canopy cover of the species making up the tree canopy cover was assessed. The vertical projection of the tree canopy over the 50 m transect was recorded as illustrated in Figure 32. The total length of the Baralaba Coal Mine canopy of each layer is then divided by the total length of the tape to give an estimate of the percentage of canopy cover on the site.

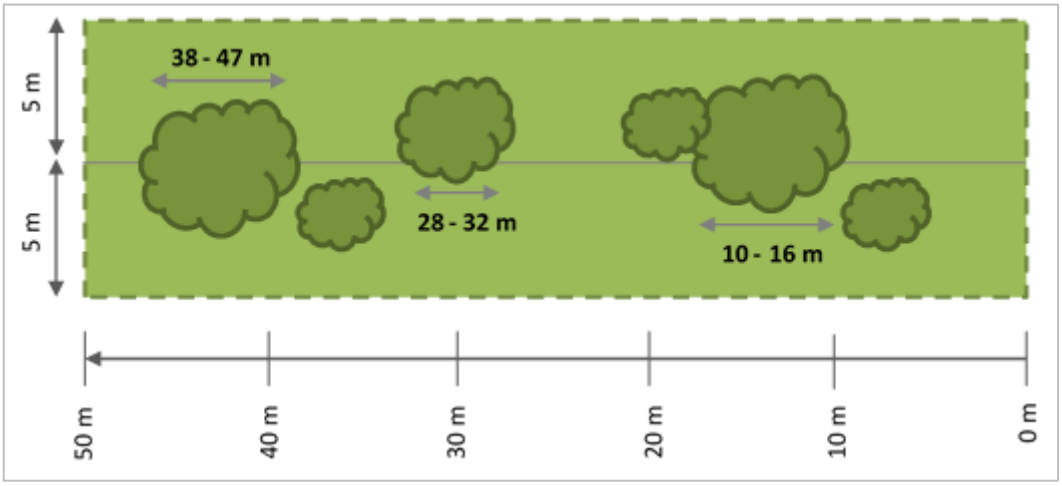

Figure 32: Guide to monitoring canopy cover (Eyre et al. 2017)

9.2.3.5 Recruitment

Recruitment is assessed within the 10 m x 50 m transect (5 m either side of each 50 m transect). Within this plot, the proportion of dominant species found to be regenerating are counted. A regenerating individual is identified as a woody stem species at breast height, with a diameter of < 5 cm.

9.2.4 Photographic monitoring

Photographic monitoring at monitoring sites shows a visual comparison over time of the vegetation, ground cover, erosion, and general appearance of each monitoring site. The process consisted of taking one photograph from the start of the transect (0 m) facing towards the end of the transect, and another from the end of the transect (50 m) facing towards the beginning.

9.2.5 Erosion monitoring

An erosion monitoring methodology has been developed by experienced AARC ecologists with consideration to relevant guidelines and research (Neldner *et al*. 2019, Eyre *et al*. 2017 and DSITI 2015). Erosion at the survey sites is monitored through visual assessment over time. Assessment is undertaken by traversing the 50 metres (m) transect on foot and recording the number and average depth of any erosion features, rill lines or gullies. However, the placement of the permanent transects does not adequately capture the level of erosion across the entire rehabilitation landforms, and observations during the surveys have also been considered for the preparation of each monitoring report.

Classification of observations will be undertaken using the criteria outlined in Table 31. The overall classification of the erosion on each transect is determined by the higher classification attributed to either the number of rills/gullies or the average depth. This is to recognise that while a transect may present only one or two rills if such rills are recorded as being 25 centimetres (cm) deep, it will lead to a classification of 'Moderate' erosion. Tunnel erosion and mass movement will be noted to be absent or present. Sheet erosion will be monitored using the descriptions within Table 31.

Table 31: Erosion classification framework

Erosion classification	Minor	Moderate	Severe
Sheet erosion	Shallow soil deposits downslope.	Partial exposure of roots; moderate soil deposits downslope.	Loss of surface horizon; subsoil exposure; root exposure; substantial soil deposits downslope.
Rill	<15 rills per transect*	15–30 rills per transect*	>30 rills per transect*

Gully erosion	Absent	Absent	Present
Tunnel erosion	Absent	Absent	Present
Mass movement	Absent	Absent	Present

Source: NCST (2024) *Australian Soil and Land Survey Field Handbook, 4th edition*. The National Committee on Soil and Terrain. CSIRO Publishing, Collingwood, Australia.
*Transect 100 m across the contour (Source: Tongway, D. J. and Hindley, N. L. 2005. Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes. CSIRO Publishing, Canberra, Australia.

In addition, high-resolution satellite imagery may be used to monitor and identify changes in erosion features over time.

9.2.6 Surface water quality monitoring

The purpose of the surface water monitoring is to identify long-term trends and to provide evidence that rehabilitation has occurred to a condition that does not significantly impact downstream surface water EVs.

Post mine closure, surface water monitoring will occur at locations associated with the release of mine-affected water and receiving environment monitoring program (REMP) monitoring points, as specified in the Baralaba EA. These locations were identified in accordance with the Receiving Environment Monitoring Program Guideline (DESI, 2014), to ensure controlled and uncontrolled releases from the site were suitably captured and monitored.

Whilst the water quality objectives (WQO) or limits presented within Table 33 were sourced from the 'Environmental Protection (Water) Policy 2009 Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment' (EHP 2011).

The location and WQO were developed to support and protect the different environmental values identified for waters within the Dawson River Sub-basin, as such the implementation of these objectives within the PRC planning part and schedule are considered suitable.

Surface water quality monitoring will be undertaken within 24 hrs of a rainfall event which produced runoff from the corresponding rehabilitated landform into a flowing receiving environment at, but not limited to, downstream location identified in Table 32 and at least annually. surface water quality data will be assessed against the trigger levels specified in Table 33.

All sampling will be undertaken in accordance with the Queensland Monitoring and Sampling Manual (DES 2018) methodology and the Australian Standard (AS) AS5667 Water Quality Sampling. Field readings of pH, dissolved oxygen, electrical conductivity (EC) and temperature will be recorded. In situ measurements will be collected using a multi-parameter water quality meter that is laboratory calibrated to the manufacturers' specifications

Grab samples will be collected at a depth of 10 to 20 cm where sufficient water is available. Two water metals samples, one total (unfiltered) and one dissolved (field filtered) will be collected at each site. Samples will be collected in the laboratory-provided sample collection bottles with preservative added where required. All water samples will be kept on ice or refrigerated during storage and transport to a NATA accredited laboratory for analysis.

Table 32: REMP monitoring locations

Monitoring Locations	Receiving water's location description	Latitude (decimal degree, GDA2020)	Longitude (decimal degree, GDA2020)
Upstream monitoring locations			
A1	Dawson River, between the two confluences with the Dawson River Anabranch and downstream of the Neville Hewitt Weir	-24.170934	149.814274
D2	Dawson River Anabranch located near the boundary of the mining lease on the Anabranch, upstream of the mine	-24.145636	149.786631

DR1	Dawson River upstream	-24.185062	149.806264
Downstream monitoring locations			
D1	Downstream of the mine along Dawson River Anabranch.	-24.135547	149.830368
DR3	Dawson River downstream of Beckers gauging station	-24.081964	149.810034
DR4	Dawson River within 8 km downstream of the confluence with the Dawson River Anabranch.	-24.133027	149.833979
D3	Downstream of the mine along Dawson River Anabranch.	-24.141387	149.809407
W1	Located at the palustrine wetland in between the Dawson River and Saline Creek, downstream of the mine	-24.085191	149.777049

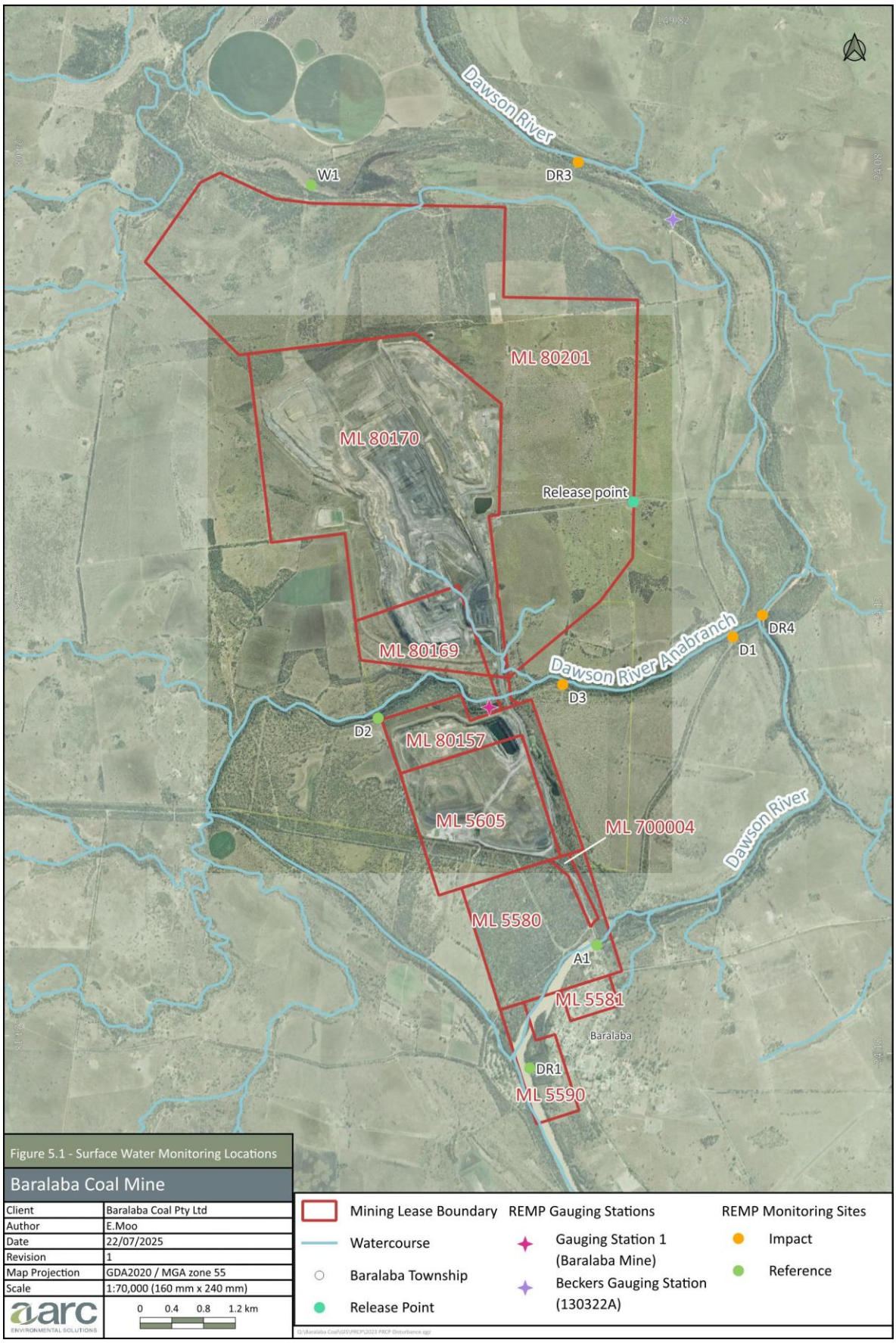

Figure 33: REMP monitoring locations

Table 33: Surface water quality limits

Quality characteristics (units) [(1)(2)(3)]	**Limit** [(2)(3)]	**Comment on limit**
pH	6.5–8.5	Lower Dawson River Sub-basin fresh waters WQO
Electrical Conductivity (µS/cm)	340	Lower Dawson River Sub-basin fresh waters WQO. Baseflow
Suspended Solids (mg/L)	10	Lower Dawson River Sub-basin fresh waters WQO.
Sulfate (mg/L)	25	Lower Dawson River Sub-basin fresh waters WQO
Aluminium - dissolved (µg/L)	55	ANZG 2018
Antimony – dissolved (µg/L)	9	ANZG 2018
Arsenic - dissolved (µg/L)	13	ANZG 2018
Manganese - dissolved (µg/L)	1,900	ANZG 2018
Molybdenum - dissolved (µg/L)	34	ANZG 2018
Selenium - dissolved (µg/L)	5	ANZG 2018
Uranium - dissolved (µg/L)	0.5	ANZG 2018
Zinc - dissolved (µg/L)	8	ANZG 2018
Ammonia (µg/L)	900	ANZG 2018
Nitrate (µg/L)	1,100	For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for Total Nitrate
Total recoverable hydrocarbons (C6-C9) (µg/L) [(6)]	20	For aquatic ecosystem protection, based on LOR for GCMS [(4)(5)]
Total recoverable hydrocarbons (C10-C36) (µg/L) [(6)]	100	For aquatic ecosystem protection, based on LOR for GCMS [(4)(5)]
Major ions (mg/L) Calcium, chloride, potassium, magnesium, sodium, bicarbonate, carbonate	For interpretation purposes	-

Notes:
1. All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample) and total (unfiltered).
2. Limits for metals and metalloids apply to dissolved results.
3. ANZG (2018) Aquatic ecosystem protection for moderately disturbed system (95% protection)
4. LOR (limit of reporting) – typical reporting for method stated.
5. GCMS – analytical method required to achieve LOR
6. Silica Gel Cleanup, SW-846 Method 3630C, December 1996, US EPA

9.2.7 Groundwater quality monitoring

The purpose of the groundwater monitoring is to identify long-term trends and to provide evidence that rehabilitation has occurred to a condition that does not significantly impact groundwater. The existing groundwater monitoring program is considered appropriate to monitor groundwater parameters during rehabilitation until the final milestone is achieved. Groundwater monitoring will be undertaken by a competent person and will be in accordance with the latest edition of the administering authorities water quality sampling manual (DES 2018a).

The trigger thresholds presented in the PRCP are designed to monitor the natural response of groundwater aquifers to mining activities and therefore have been transitioned into the post closure groundwater monitoring program.

Parameters and levels for the monitoring of groundwater are specified below in Table 35 and Table 36. Monitoring will continue at the locations specified in Table 34 and Figure 34. The frequency of groundwater parameter monitoring will be quarterly until sufficient data is gathered to demonstrate achievement of the associated milestone.

The groundwater bores contaminant levels have been derived through the process described by DETSI (2021) *Using monitoring data to assess groundwater quality and potential environmental impacts.* The methodology used is as follows:

- bore specific values were derived from the 95th percentile of a suitable data set;
- if there are insufficient samples or exceedances when compared to historical data a trigger is then derived from the 95th percentile of the wider aquifer group; and
- where bore site-specific values were not able to be derived a single contaminant trigger based on a combination of ecosystem protection WQOs was adopted;
- where the limit of reporting is greater than the WQO, then the limit of reporting is adopted.

Table 34: Groundwater monitoring locations

Site	Latitude (GDA94)	Longitude (GDA94)	Geologic Unit	Monitoring Purpose		Frequency
				Water Level	Water Quality	
BN0744A	-24.08124	149.76338	Alluvium	1	1	Quarterly
BN0748A	-24.08693	149.78298	Alluvium	2	1	Quarterly
PZ_20A	-24.162861	149.810683	Alluvium	2	1	Quarterly
PZ_21A	-24.145238	149.804817	Alluvium	2	1	Quarterly
PZ_25A	-24.106175	149.812200	Alluvium	2	1	Quarterly
PZ_26A	-24.10480422	149.76588386	Alluvium	1	1	Quarterly
PZ_28A	-24.1629163	149.7933958	Alluvium	3	3	Quarterly
PZ14S[A]	-24.10359	149.78213	Alluvium	1	1	Quarterly
SKMAM04	-24.14363	149.78775	Alluvium	1	1	Quarterly
PZ_24A	-24.14804	149.787564	Alluvium	1	1	Quarterly
PZ13R	-24.1409891	149.7946627	Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone	1	2	Quarterly
PZ_25P	-24.106182	149.81225	Permian (Gyranda Formation)	1	1	Quarterly
PZ_26P	-24.104924	149.765911	Baralaba Coal Measures – Coal Seam Interburden	1	1	Quarterly
PZ_27P	-24.097118	149.776907	Baralaba Coal Measures – Coal seam (Sub Dirty Seam)	1	1	Quarterly
SKMPM01	-24.10989	149.77088	Baralaba Coal Measures – Interburden	1	2	Quarterly
SKMPM02[A]	-24.10236	149.79014	Permian (Gyranda Formation)	2	1	Quarterly
SKMPM03R	-24.1423084	149.7979088	Baralaba Coal Measures – Interburden	1	1	Quarterly
SKMPM04R	-24.143826	149.7869114	Baralaba Coal Measures – Interburden	1	1	Quarterly
SKMPM05R	-24.123947	149.772979	Baralaba Coal Measures – Interburden	1	1	Quarterly
SKMPM06R	-24.116973	149.800797	Permian (Gyranda Formation)	1	1	Quarterly

[1] Monitored as per the frequency listed in the frequency column.

[2] Monitored as per the frequency listed in the frequency column for interpretation only.

[A] To be monitored as per frequency listed until destroyed by mining

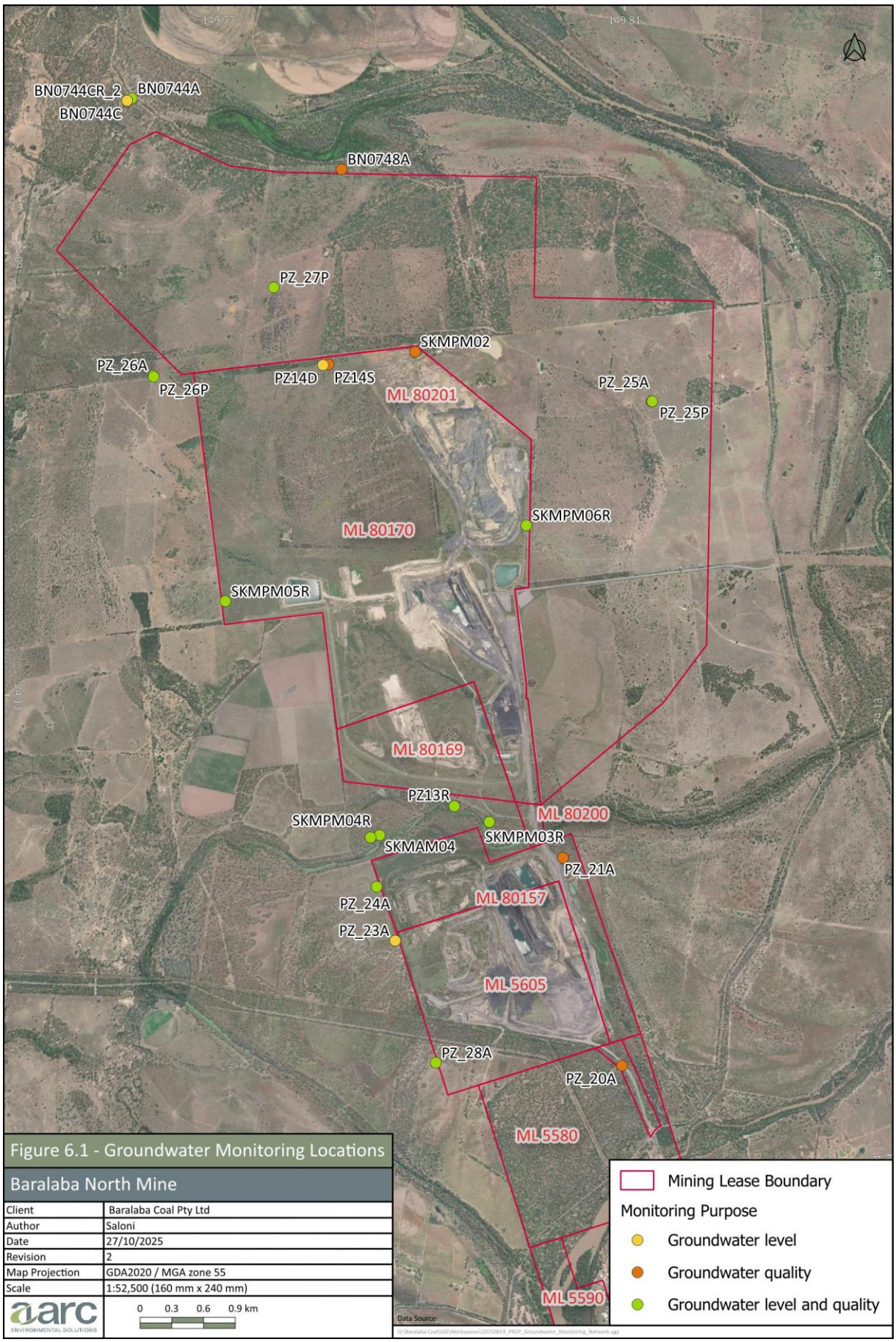

Figure 34: Groundwater monitoring locations

Table 35: Groundwater quality triggers levels

Geologic Unit	Quality Characteristic	pH (field)	Electrical Conductivity (Lab)	Aluminium(dissolved)	Antimony (dissolved)	Arsenic (dissolve d)	Manganese (dissolved)	Molybdenum (dissolved)	Selenium (dissolve d)	Uranium (dissolved)	Zinc (dissolved)	Sulfate (dissolved)	TRH C10 - C16 Fraction [K]	TRHC16 -C34 Fraction [K]	TRHC34 -C40 Fraction [K]	Bicarbonate, sodium, carbonate,calcium, chloride, potassium,
	Trigger level type	**Range**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Maximum**	**Interpretation Only**
	Location	**pH units**	**µS/cm**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/ L**	**mg/L**	**µg/L**	**µg/ L**	**µg/L**	**mg/L**
Alluvium	BN0744A	6.4 – 6.7[A]	731[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	150[A]	4.5[A]	50[C]	100[C]	100[C]	N/A
Alluvium	BN0748A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_20A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_21A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_24A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	145[M]	62[B]	50[C]	100[c]	100[c]	N/A
Alluvium	PZ_25A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_26A	6.5-8.5	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	3.5[AL]	154[A]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_28A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5[A]	25[A]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ14S	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	SKMAM04	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone	PZ13R[3]	7.4 - 8.6[B]	20000[A]	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	72[A]	6.0[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	PZ_25P	6.6 - 7.1[A]	6200[A]	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5.0[A]	140[A]	51[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal Seam Interburden	PZ_26P	6.5-8.5	2,880A	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	2[A]	20[AL]	113[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal seam (Sub Dirty Seam)	PZ_27P	7.4 - 8.6[B]	1355[A]	50[B]	9[D]	85[A]	1,900[D]	34[D]	11[D]	0.5[DN]	13[AL]	13[A]	50[C]	100[C]	100[C]	N/A

Geologic Unit	Quality Characteristic	pH (field)	Electrical Conductivity (Lab)	Aluminium(dissolved)	Antimony (dissolved)	Arsenic (dissolve d)	Manganese (dissolved)	Molybdenum (dissolved)	Selenium (dissolve d)	Uranium (dissolved)	Zinc (dissolved)	Sulfate (dissolved)	TRH C10 - C16 Fraction [K]	TRHC16 -C34 Fraction [K]	TRHC34 -C40 Fraction [K]	Bicarbonate, sodium, carbonate,calcium, chloride, potassium,
	Trigger level type	Range	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Maximum	Interpretation Only
	Location	pH units	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/ L	mg/L	µg/L	µg/ L	µg/L	mg/L
Baralaba Coal Measures – Interburden	SKMPM01	10-12	4268[A]	178[A]	9[D]	13[D]	1,900[D]	47[A]	11[D]	0.5[D]	14[A]	18[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	SKMPM02	7.3 - 8.5[B]	3,542[I]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	6[O]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM03R	7.3 - 8.5[B]	2112[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	27[A]	132[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM04R	7.3 - 8.5[B]	19470[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	130[A]	63[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM05R	7.3 - 8.5[B]	3421[I]	55[D]	9[D]	18[A]	1,900[D]	62[A]	11[D]	0.5[D]	85[ALN]	6[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	SKMPM06R	6.6 – 7.1[A]	20750[H]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5[A]	76[A]	179[A]	50[C]	100[C]	100[C]	N/A

Note:
A 95th percentile of site-specific value
B 95th percentile of aquifer group specific value (Alluvium, Permian Coal Seam, Permian Interburden)
C Limit of reporting available for TPH fractions for ALS laboratories
D ANZG (2018) 95% Protection aquatic species (fresh water)
E Fitzroy Plan WQ1310 groundwater water quality objectives (aquatic ecosystem) Zone 34 (shallow) 80th percentile - Dawson River Sub-basin Environmental Values and Water Quality Objectives
F Fitzroy Plan WQ1310 groundwater water quality objectives (aquatic ecosystem) Zone 34 (deep) 80th percentile - Dawson River Sub-basin Environmental Values and Water Quality Objectives
G 95th percentile of BN0744C and BN0744CR_2
H 95th percentile of SKMPM04 and SKMPM06R
I 95th percentile of SKMPM02 and SKMPM05R
J 95th percentile of SKMPM01, SKMPM04, SKMPM05, SKMPM05R, SKMPM06R
K. Silica Gel Cleanup, SW-846 Method 3630C, December 1996, US EPA
L Site specific data trigger has been set on a small number of data points, outside the QWQG recommended minimum dataset. Once sufficient data is available this trigger should be reconsidered.
M 95th percentile of BN0744A and PZ_24A

N Due to insufficient data, this limit is interim until a sufficient data set has been collected and a site specific or grouped specific trigger can be applied.

O Due to insufficient data this interim trigger has been calculated based on data collected from SKMPM05R

Table 36: Groundwater level threshold

Site	Unit	Starting water level for purpose of trigger level assessment		Maximum modelled drawdown (m)	Maximum permissible impacted water level	
		(mTOC)	(mAHD)		(mTOC)	mAHD
BN0744A	Alluvium	12.5	68.96	1	13.5	67.96
PZ_23A	Alluvium	12.51	70.294	0	12.51	70.294
PZ_24A [A]	Alluvium	10.84	71.56	0	10.84	71.56
PZ_26A	Alluvium	22.91	74.34	0	22.91	74.34
PZ_28A A	Alluvium	Dry	Dry	0	n/a - Dry	n/a - Dry
SKMAM04	Alluvium	Dry	Dry	0	n/a - Dry	n/a - Dry
BN0744C	Baralaba Coal Measures – Coal Seam (Reid Seam)	14.65	*	7.13	21.78	*
BN0744CR_2	Baralaba Coal Measures – Coal Seam (Reid Seam)	17.41	64.09	7.13	24.54	56.96
PZ_25P	Permian (Gyranda Formation)	19.79	73.61	0	19.79	73.61
PZ_26P	Baralaba Coal Measures – Coal Seam Interburden	22.29	74.96	2.82	25.11	72.14
PZ_27P	Baralaba Coal Measures – Coal seam (Sub Dirty Seam)	24.12	70.88	53.35	77.47	17.53
PZ13R	Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone	12.77	69	24.63	37.4	44.37
PZ14D	Baralaba Coal Measures - Coal Seam (Coolum Seam)	23.86	67.6	50.94	74.8	16.66
SKMPM01	Permian Interburden	30.6	65.34	4.12	34.72	61.22

Site	Unit	Starting water level for purpose of trigger level assessment		Maximum modelled drawdown (m)	Maximum permissible impacted water level	
		(mTOC)	(mAHD)		(mTOC)	mAHD
SKMPM03R	Permian Interburden	13.35	66.27	20.28	33.63	45.99
SKMPM04R	Permian Interburden	TBD	TBD	TBD	TBD	TBD
SKMPM05R	Permian Interburden	28.38	64.82	5.15	33.53	59.67
SKMPM06R	Permian Interburden	25.1	63.5	0.09	25.19	63.41

[A] Monitoring bores to be updated in accordance with the requirements of Conditions D11 to D16 of environmental authority EPML00223213, dated 6 June 2025* Relative water level (mAHD) must be reviewed, prior to November 2025, on collection of a validated collar height RL by an AQP surveyor

9.2.8 Soil sampling

Soil monitoring involves the collection of topsoil samples from a maximum depth of 10 cm to obtain quantitative data on the chemical and physical properties of soil. Soil sampling methodology has been adapted from the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018). Soil sampling is conducted by collecting approximately 200 g samples with a clean non-metallic shovel and bucket every 10 m along the 50 m permanent vegetation monitoring transects outlined in Section 9.2.3. The first sample is collected at 0 m. The five samples are then mixed in the bucket. The final 200 g soil sample is taken from the mix and placed into plastic sample bag. Samples are sent to a NATA certified laboratory for full suite analysis of topsoil indicators of soil nutrition and chemistry. Chemical and physical parameters that should be measured are outlined in Table 37.

Data acquired from soil monitoring will be analysed by an appropriately qualified person and rehabilitation milestone criteria. This information will be used to establish initial characteristics of the rehabilitated soil profile to allow for trend analysis of these fixed points over time.

Table 37: Chemical and physical parameters for topsoil testing

Analytes	
Physical Parameters	Moisture Content
	Organic Matter (Organic Carbon)
	Soil Particle Density (Gravel/Clay/Silt/Coarse Sand/Fine Sand)
	Aggregate stability (Emmerson aggregate testing)
General Soil Characteristics	pH Value
	Electrical Conductivity @ 25°C
	Chloride
	Available Phosphorus
Exchangeable Cations	Exchangeable Calcium
	Exchangeable Magnesium
	Exchangeable Potassium
	Exchangeable Sodium
	Cation Exchange Capacity
	Exchangeable Sodium Percent (ESP)
	Calcium/Magnesium Ratio
Exchangeable N_2, P	Nitrite + Nitrate as N (Sol.)
	Bicarbonate Ext. P (Colwell)
	Bicarbonate Ext. K (Colwell)

Soil moisture content is measured for interpretive purposes only and will not be assessed in determining rehabilitation performance.

9.2.9 NUMA milestone monitoring

Table 38: Management milestone monitoring and management measures

Management milestone	Description of MM criteria is detailed further in Table 17.	Proposed monitoring and management measure(s)
MM1: Achievement of Final Landform.	Applicable to the NUMA and surrounding area. Considered to be met when void and surface preparation activities have been completed, and slope requirements from the completion criteria (Section 6.1) including highwall batter angles and geotechnical stability are met.	The final void hydrological design will be assessed by an AQP to determine whether the relevant milestone criteria in Table 17 have been met. Upon the completion of earthworks at the final void, a geotechnical assessment will be conducted by an AQP to assess whether the relevant milestone criteria in Table 17 have been met.
MM2: Achievement of surface and safety requirements.	Applicable to areas surrounding the NUMA. Considered to be met once the appropriate safety infrastructure and geotechnical and risk mitigation measures have been completed.	Following the installation of safety infrastructure, an AQP will assess whether they are constructed to the specification outlined in Table 17.
MM3: Achievement of sufficient improvement.	Applicable to the NUMA and surrounding area. Considered to be met once an AQP has assessed whether groundwater and lake void monitoring have confirmed that the final void is acting as a sink and that all hazards have been assessed to have no offsite impacts.	Groundwater quality and levels will be assessed by an AQP (see Section 9.2.7). Assessments will take place annually until completion criteria are met (see Section 6.1). Once groundwater quality and levels have met completion criteria, a geotechnical and hazards assessment of the final void will be undertaken to ensure it meets the criteria specified in Table 17.

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Appendix A. Baralaba North Review of Conceptual Groundwater Model

Baralaba Coal Pty Ltd

BARALABA NORTH PROJECT

REVIEW OF CONCEPTUAL GROUNDWATER MODEL and GROUNDWATER MONITORING BORE NETWORK

May 2021

JBT01-087-001

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1.0 INTRODUCTION

Baralaba Coal Company Pty Ltd (BCCL) operates the Baralaba North Mine, located approximately 3 km north of the township of Baralaba and 45 km west-south-west of Rockhampton. The project area is shown below in Figure 1-1.

The mine targets the Baralaba Coal Measures, which in the project area dip steeply to the west at an angle of between 25 and 55º. Due to the steeply dipping strata the seams are mined to a maximum economic depth (approximately 200 m) and then progressed along strike (i.e. along a north-east to south-west orientation).

JBT Consulting Pty Ltd (JBT) has been commissioned by BCCL to:

- Undertake a review of available groundwater data to provide an updated conceptual groundwater model for the site. The conceptual that is presented in this report draws upon information compiled for the initial conceptual groundwater model (e.g. as presented in EIS groundwater reports including SKM (2014) and Hydrosimulations (2014a), as well as groundwater monitoring information (water level and water quality) obtained from the commencement of operations to present;
- Review the current groundwater monitoring network and:
  - Recommend any changes necessary to the existing bore network (e.g. replacement of existing bores); and,
  - Recommend drilling locations and target monitoring intervals/depths for an expanded groundwater monitoring network.

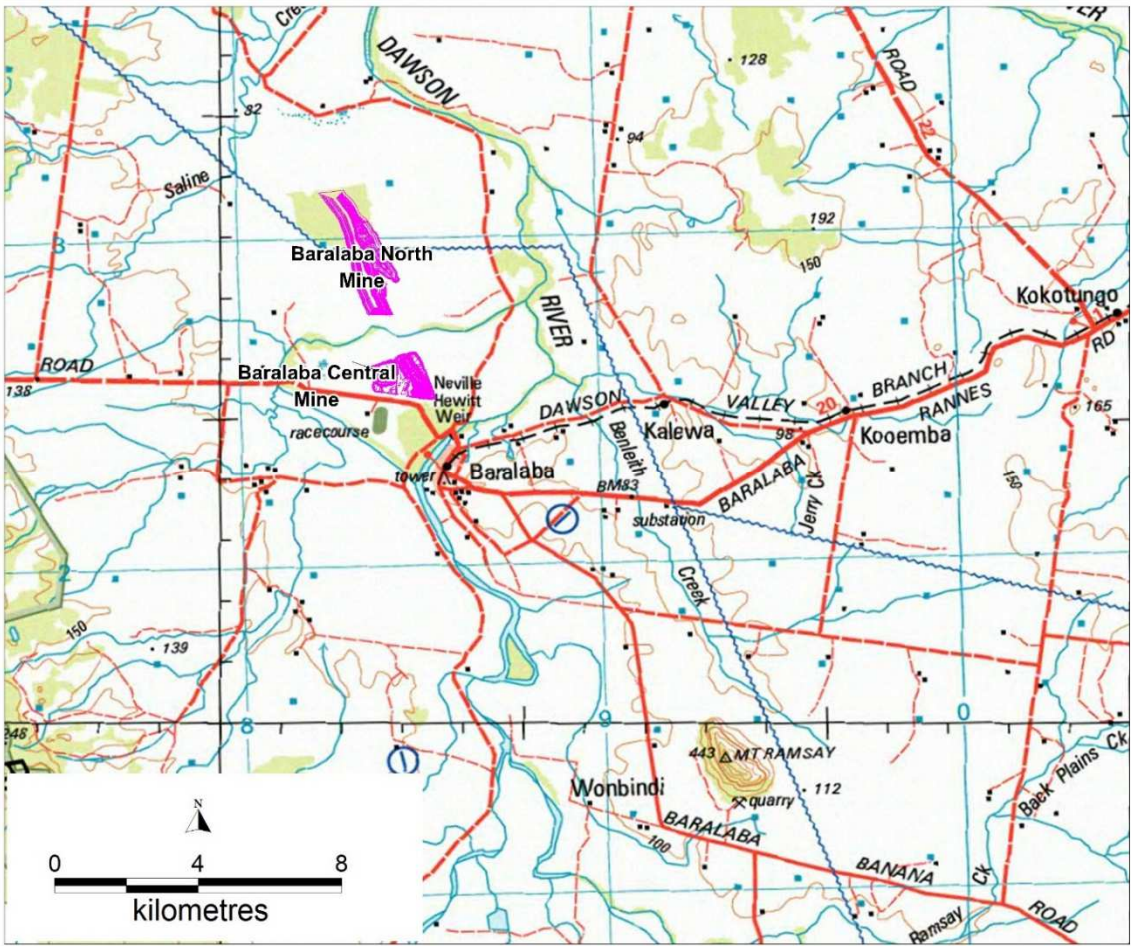

Figure 1-1: Project Location

2.0 AVAILABLE DATA

Available data that has been reviewed for this study includes:

- AARC (2021) GWMMP Review. Report prepared for Baralaba Coal Company by AACC Environmental Solutions, February 2021;
- AGE (2005) Baralaba Coal Mine – Groundwater Regime and Monitoring Program. Report prepared for Baralaba Coal Pty Ltd by Australasian Groundwater & Environmental Consultants Pty Ltd. Project No. G1326, December 2005;
- AGE (2012) Baralaba North Mine Extension – Groundwater Management Plan. Report prepared for Cockatoo Coal Limited by Australasian Groundwater & Environmental Consultants Pty Ltd. Project No. G1565, January 2012;
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- Hydrosimulations (2014b) - Baralaba Coal Mine, Baralaba North/ Wonbindi North / Baralaba Central Groundwater Monitoring and Management Plan. Report prepared for Cockatoo Coal Limited by Hydrosimulations. Document No. BAR-ENV-PL0019-A, 19 September 2014;
- SKM (2014) Baralaba North Continued Operations EIS Groundwater Studies – Preliminary Conceptual Groundwater Model. Report prepared for Cockatoo Coal Limited by Sinclair Knight Merz. Report No QE06728.200, February 2014.
- Excel spreadsheets containing available groundwater level data for site groundwater monitoring bores constructed within the alluvium and coal measures;
- Excel spreadsheets containing available groundwater quality data from site groundwater monitoring bores.
- Geological Sections from the site geological model, prepared by Cockatoo Coal Limited prior to mining of the Baralaba North Pit. A number of the sections have been utilised to provide conceptual sections that are discussed in Section 6.0.

3.0 GEOLOGY AND HYDROGEOLOGY

3.1 Site Stratigraphy

The stratigraphy at Baralaba North broadly comprises (from surface downwards):

- Unconsolidated alluvial deposits of Tertiary and Quaternary age, which are pervasive across the project area. The Tertiary sediments occur as isolated pockets across the project area, with the majority of alluvium of Quaternary age, which range in thickness from 13 m to 20 m (AGE 2012). Along the flood plains of the Dawson River and anabranch the Quaternary sediments comprise a 2-10 m thick upper clayey layer and a 1-16 m thick lower layer of sands and gravels; and,
- Permian Coal Measures, comprising Kaloola Coal Measures overlain by late Permian Baralaba Coal Measures. The Baralaba Coal Measures contain the target coal seams within the project area, which are folded and faulted, but generally dip steeply to the west at angles of between 25° and 55° (SKM 2014). There are a total of 12 major coal seams, which range in thickness from 0.5 to 4.4 m, with an average interburden thickness of 25 m (AGE 2012). The average thickness of the coal measures within the project area are shown below in Table 3-1. The relationship between the strata at the project site is shown below in Figure 3-1 (note: BA = base of alluvium, BW = base of weathering)

Table 3-1: Baralaba Coal Measures – Average Thickness of Coal Seams (source: AGE 2012)

Seam	Average Thickness (m)
Moody	0.8
Boyd	2.5
Cameron	2.3
Reid	2.5
Doubtful Upper	1.5
Doubtful Lower	1.2
Dawson	2.7
Dunstan	3.4
Sub-Dunstan	0.9
Wright	2.7
Double	0.4
Coolum	4.4
Dirty	2.5
Sub-Dirty	0.5

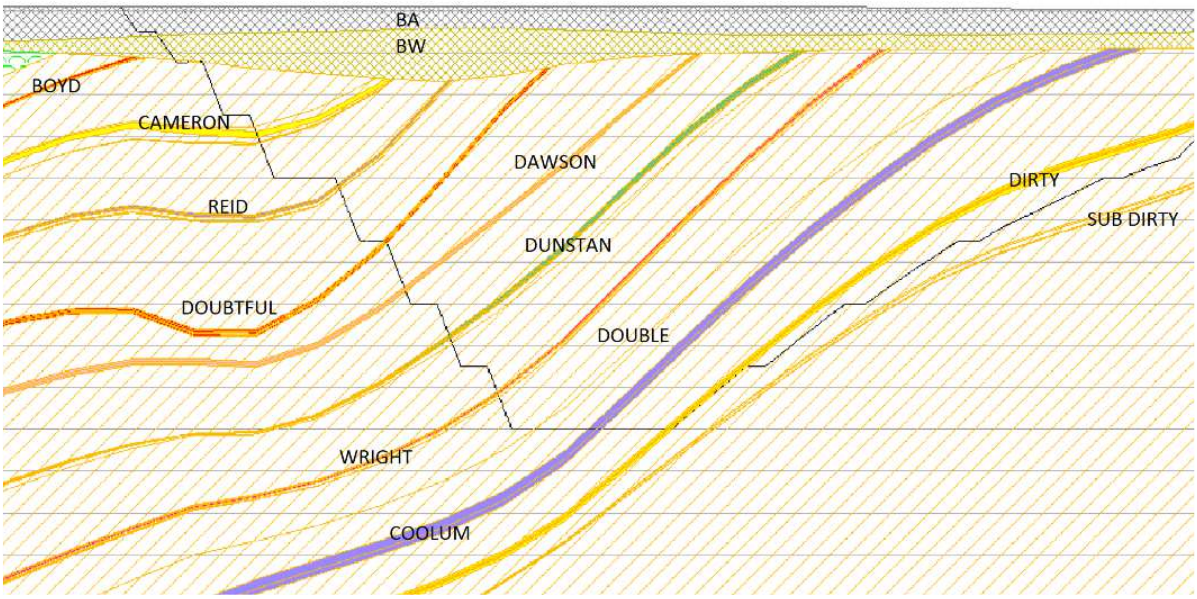


Figure 3-1: Stratigraphic Relationship at Baralaba North

Figure 3-2 shows the solid geology for the site, based on published data from Sliwa et al. (2008). The solid geology map is prepared by removing the Cainozoic cover rocks (i.e. unconsolidated Quaternary and Tertiary sediments), revealing the relationships between older rocks (Permian and Triassic) in the project area. As described above, the coal seams dip steeply to the west, with mining occurring at the eastern extent of the Baralaba Coal Measures where the coal seams occur at shallow depth that is accessible for open cut mining. As noted in Figure 3-2, site geological data indicates that the Baralaba Coal Measures extend further to the east than is shown in the published data; this has implications for siting of additional groundwater monitoring bores, as discussed further in Section 7.2. Figure 3-2 also shows the locations of geological cross sections, which are presented and discussed in Section 5.0 as a means of demonstrating the geology of the site and assisting with the interpretation of site groundwater level and groundwater quality data.

It is noted that there is no published 1:100,000 scale geological map for the Baralaba area, therefore the extent of Tertiary/Quaternary deposits cannot be shown on a figure. However, as noted above, the Tertiary/Quaternary units are pervasive across the site.

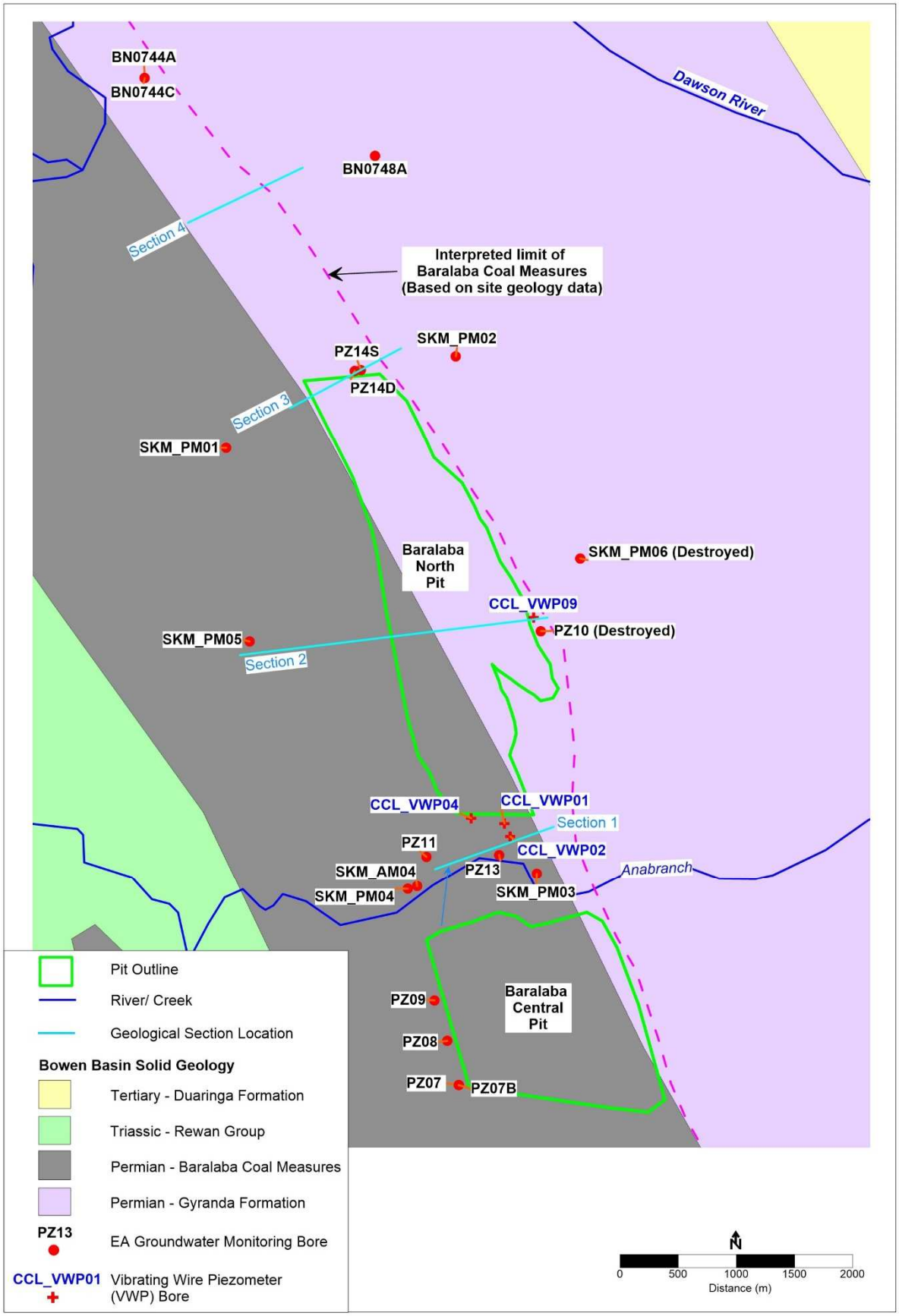


Figure 3-2: Bowen Basin Solid Geology and Bore Locations

3.2 Structures

The Permian sequences within the Project area lie on the eastern limb of a tightly folded and faulted syncline, which strikes in a north to north-westerly direction and dips to the west in the area where mining occurs at angles of between 25º and 55º.

Local-scale faulting occurs within the Permian strata in the mining area, with these tending to be thrust faults that strike to the north-west and are interpreted to dip steeply to the south-west at angles of 60º to 80º (SKM (2014).

4.0 RAINFALL AND EVAPORATION

Rainfall and evaporation data has been obtained from the SILO Datadrill for a location in the centre of the Baralaba North lease and is summarised as:

- Average annual rainfall is 663.3,
- Average annual evaporation of 2035.9 mm.

Monthly rainfall data and the residual rainfall mass curve for the Baralaba site (based on SILO data) is shown below in Figure 4-1. The data indicates that the rainfall residual mass curve has been in decline due to below-average rainfall conditions since ~2013, indicating a potential for groundwater level decline over that period due to below-average groundwater recharge conditions.

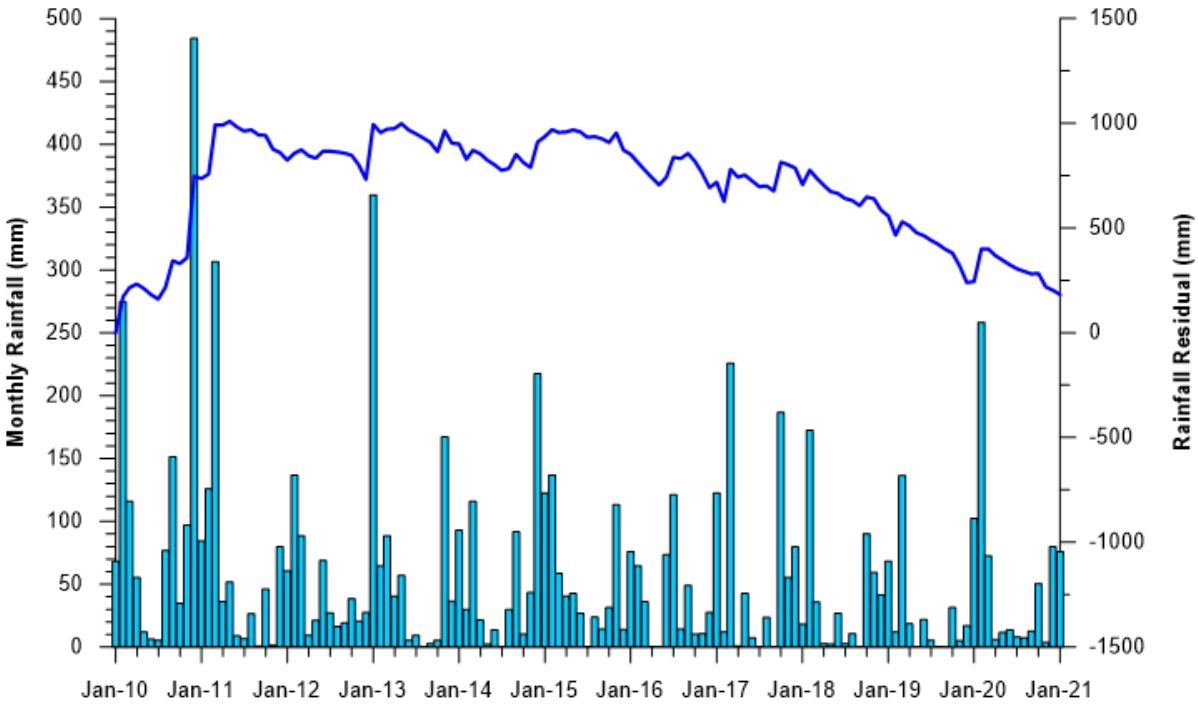


Figure 4-1: Monthly Rainfall Data and Rainfall Residual Mass Curve

5.0 GROUNDWATER MONITORING DATA

5.1 Water Level Data

Water level data is available from a number of groundwater monitoring bores at site (refer Figure 5-1 for bore locations). Bores are screened either within alluvial sediments or the underlying coal measures. A number of bores are constructed as vibrating wire piezometer (VWP) installations that target multiple units within the coal measures. Groundwater level data from EA compliance groundwater monitoring bores is shown in Figure 5-2. The following observations are made with respect to site water levels data:

- Groundwater levels in alluvial monitoring bores have been relatively stable over the period of monitoring;
- Permian groundwater monitoring bores to the west of the mining area (SKM_PM01, SKM_PM05, which are both screened within overburden above coal seams) have recorded stable water level trends;
- Permian groundwater monitoring bores to the south of Baralaba North/ north of Baralaba Central (SKM_PM03, PZ13) are recording a downward water level trend that is interpreted to be related to mining;
- Permian bore PZ14D, which is located to the north of the advancing Baralaba North Pit, has recorded a water level drawdown since mid-2020 that is interpreted to be related to mining; and,

The data is interpreted to indicate that groundwater drawdown within the Permian coal measures occurs mainly in the direction that is along the strike of the coal seams (i.e. generally in the north-northwest/ south-southeast direction) and has not been developed to the west of the mining operation (within the overburden/interburden). This result is unsurprising as the coal seams, although of generally low permeability, tend to be the conduits for groundwater flow, with the interburden/overburden units tending to be of a significantly lower permeability than the coal seams. This observation is supported by site data, with minor rates of groundwater inflow to the Baralaba North pit reported from the base of coal seams (often as an indication of a wet-soaked area), with no inflow reported from the interburden units.

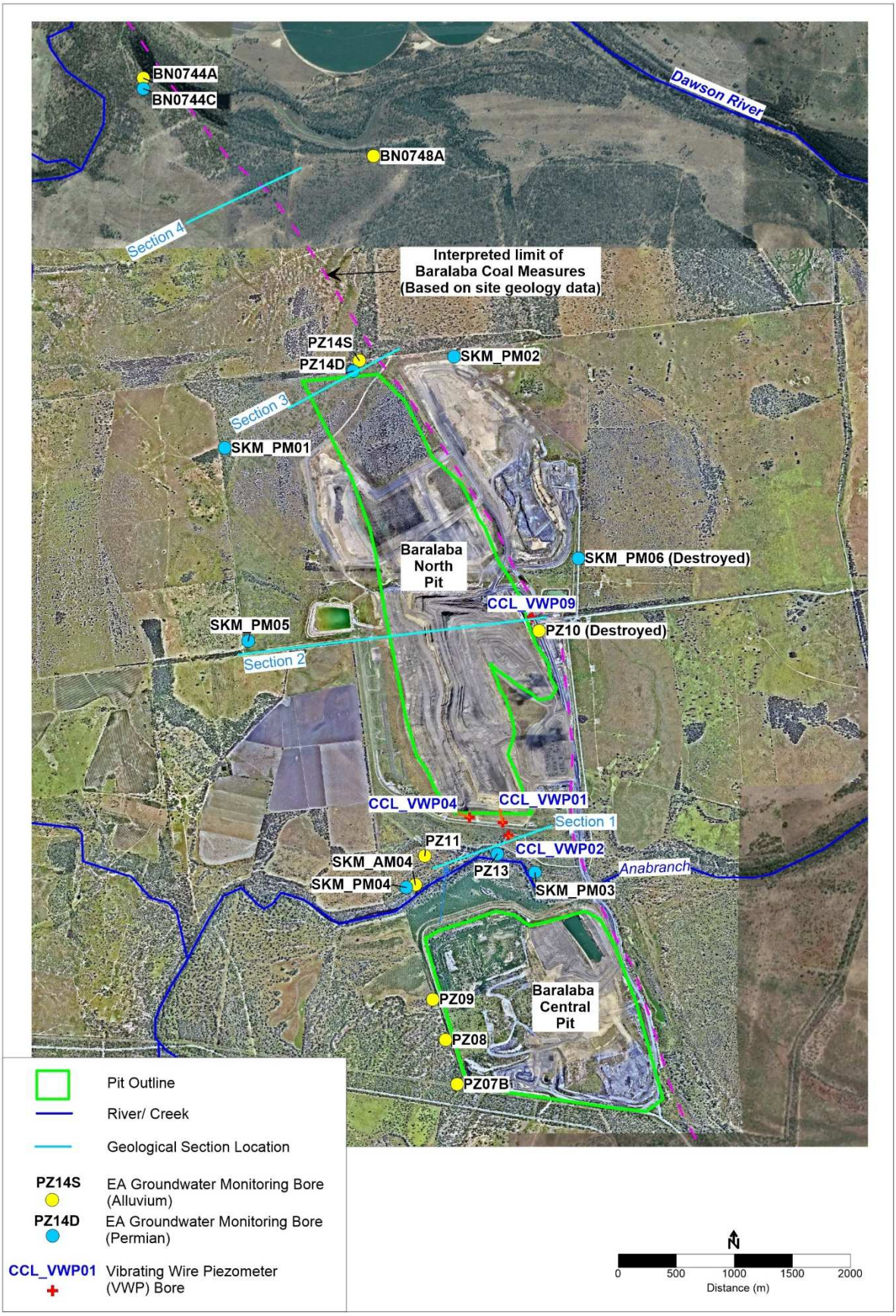
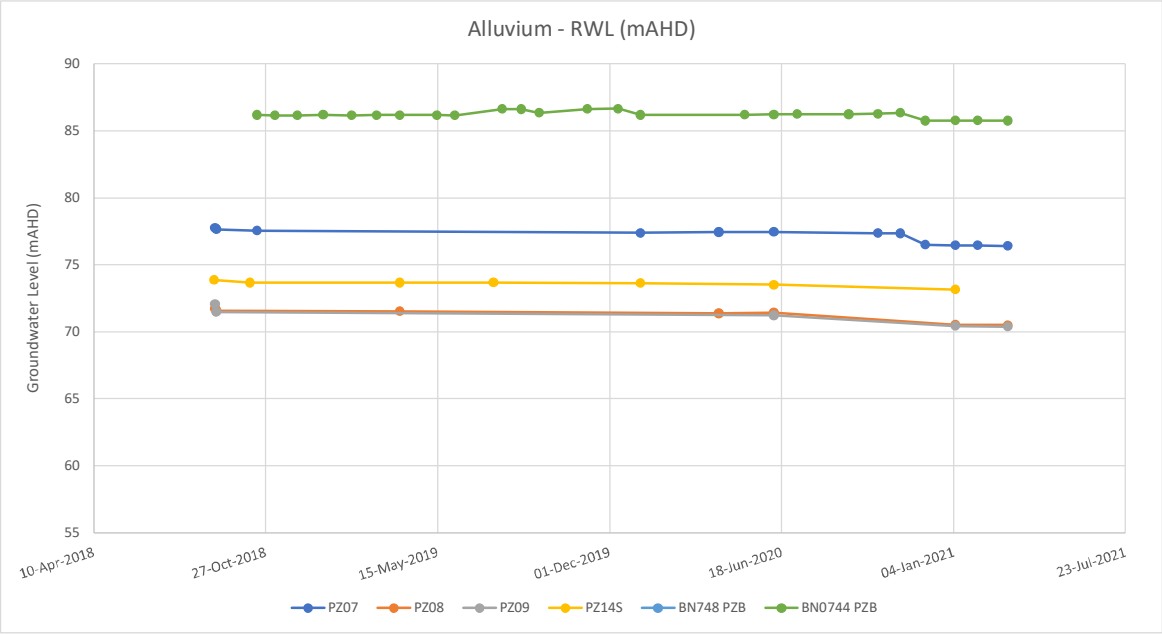
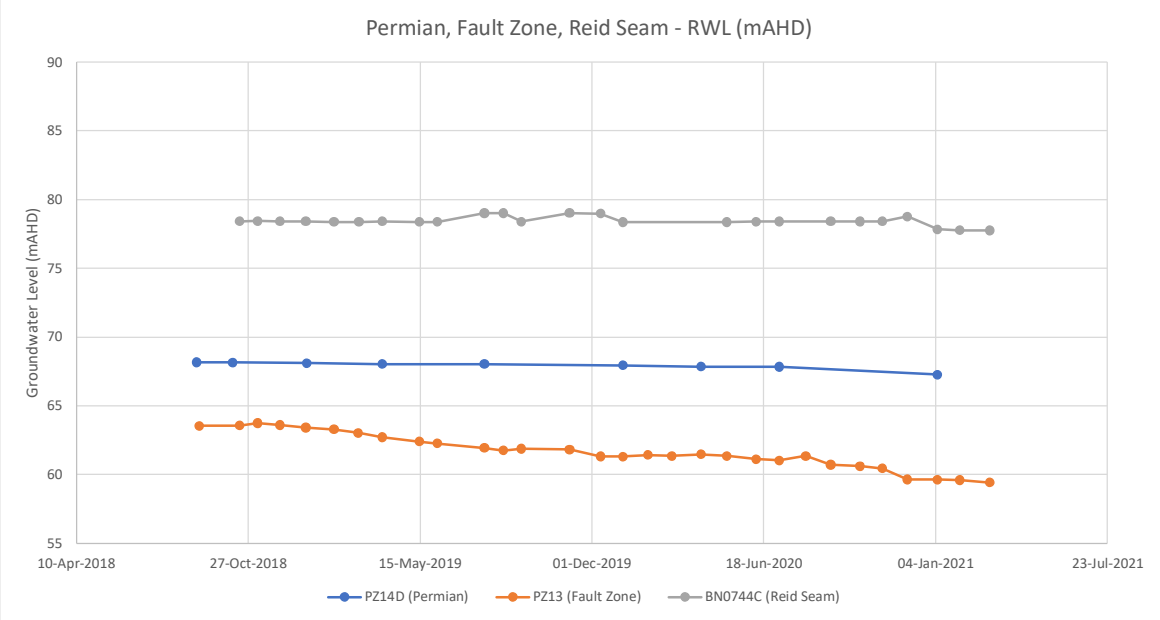


Figure 5-1: Locations of Groundwater Monitoring Bores





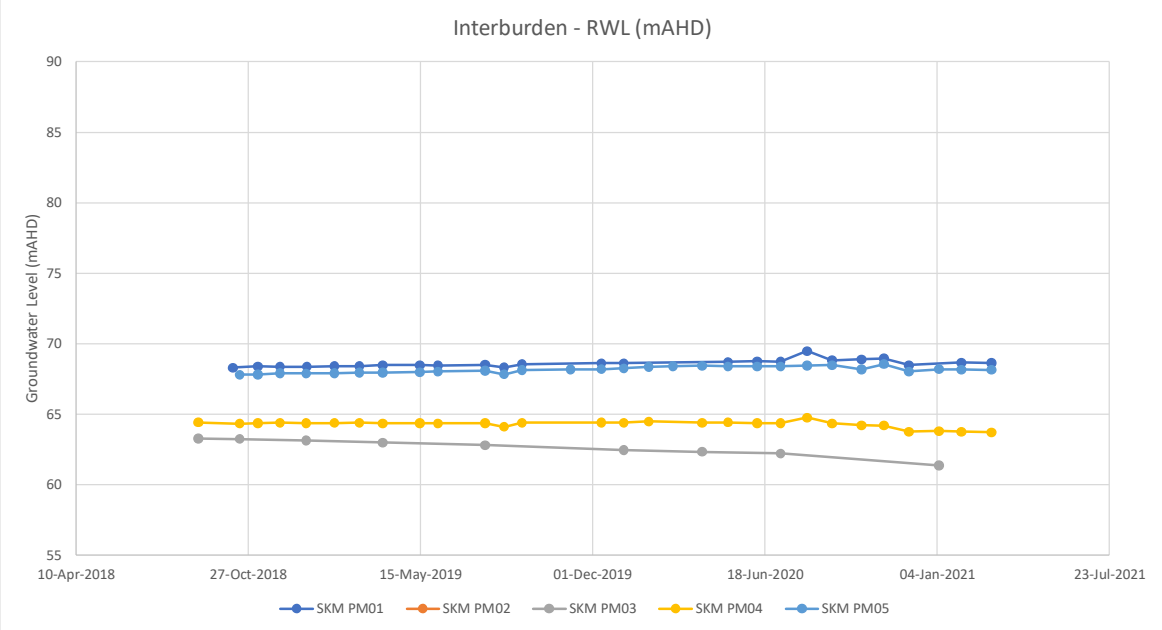


Figure 5-2: Groundwater Level Data – EA Bores

5.2 Groundwater Quality Data

5.2.1 Available Data

Available data includes major ion and dissolved/total metal/metalloid data at generally quarterly intervals between October 2013 and present. This report does not present a full interpretation of groundwater chemistry data; rather, the intent is to present aspects of the data that assist with the conceptualisation of the groundwater system. The groundwater chemistry that assists most with the interpretation of the groundwater system is the major ion chemistry; this is discussed below with reference to Piper trilinear diagrams and box and whisker plots of selected parameters.

5.2.2 Box and Whisker Plots

Box and whisker plots are presented for selected parameters as a means to visually highlight the variability in data. Information relevant each box and whisker plot includes:

- Each box and whisker plot shows:
  - The upper and lower limits of the data (upper and lower bounds of "whiskers");
  - The 20th and 80th percentile of the data (lower and upper limits of box);
  - The data median; and,
  - The number of data points.
- The selected parameters and observations include:
  - pH data - The pH range is generally within the range of 6.5 to 8.5. However, two bores (SKM_PM01 and SKM_PM05) record pH values that are generally >10. From review of available chemistry data for these bores it is noted that both sites record elevated levels of hydroxide alkalinity (therefore the alkalinity data and pH data are consistent). This is interpreted to indicate that these bores have persistent construction issues, i.e. that the grout has not fully cured in these bores and continues to release alkalinity. This makes these bores unsuitable for the recording of major ion chemistry and it is recommended (Section 7.1) that these bores are replaced.
  - EC data – the box and whisker plot provides an indication of the variability of EC data across the site and within individual bores, with a distinct grouping of bores that record and EC <~3,000 µS/cm) and bores that record >10,000 µS/cm. Data for bore BN044C is included in this assessment even though the bore has been reported as being potentially damaged, to highlight the variability in recorded EC at this site.
  - Sulphate data - the sulphate concentration is generally low at site (<1,000 mg/L. Two bores (PZ07 and PZ08) record relatively high sulphate concentration (as well as high EC data, as evident from the EC box and whisker plot). It is recommended that this issue be investigated further to determine the origin of the high sulphate/EC data and to develop mitigation measures if/as required.

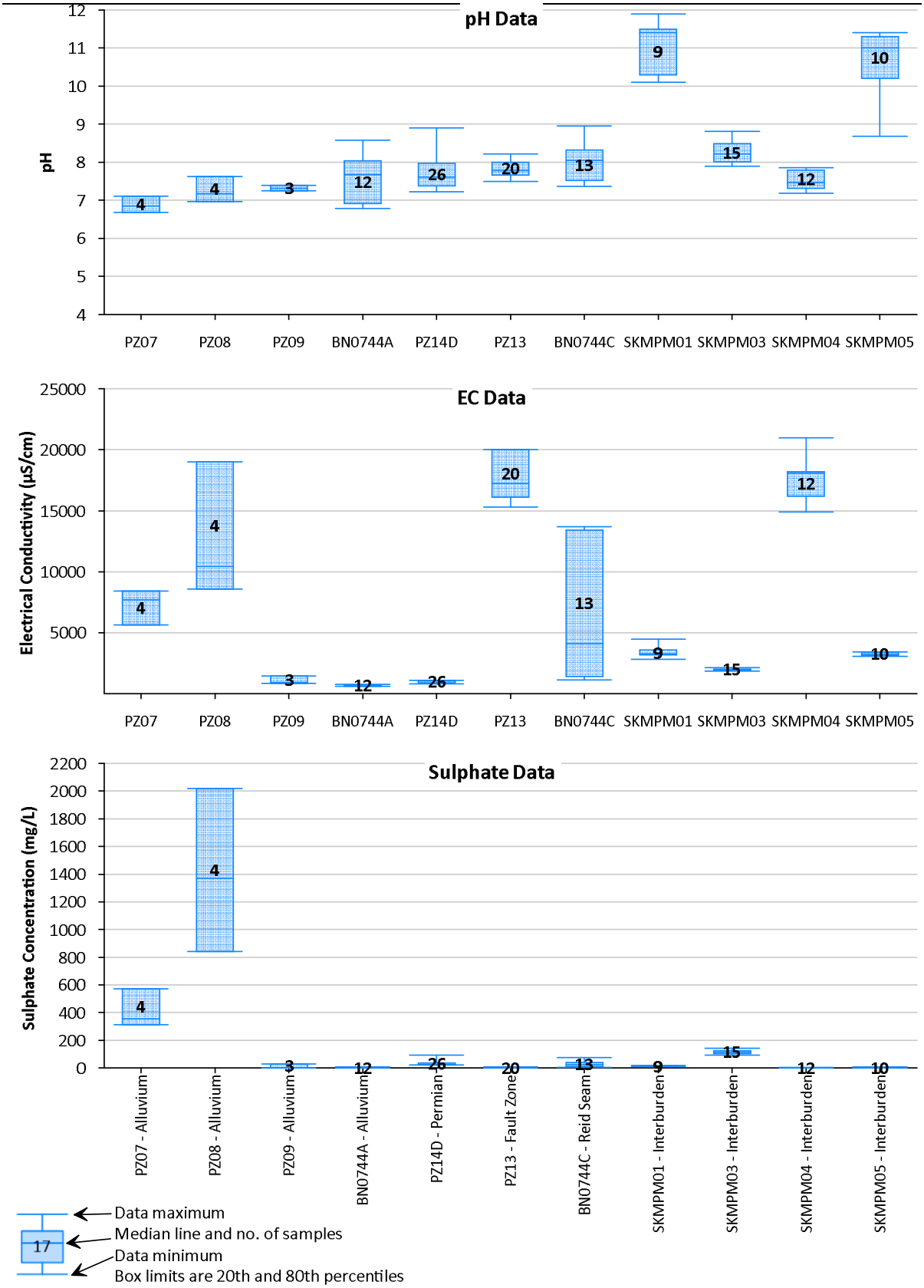


Figure 5-3: Box and Whisker Plots – pH, EC and Sulphate Data

5.2.3 Piper Diagram

Figure 5-4 shows a piper ternary diagram that is based on the mean major ion data for each site monitoring bore. The data on which the piper diagram is based, as well as an assessment of water type for each monitoring bore, is also included in Table 5-1. Observations from review of the data are as follows:

- Groundwater that is interpreted to be located at distance along a groundwater flow line (i.e. groundwater that is distant from the recharge area) tends towards being strongly sodium-chloride (Na-Cl) type water and therefore plots in the bottom right-hand area of the cation/anion plots. This is observed at bores such as PZ13 (fault zone), where the mean EC is <17,000 µS/cm. This site is discussed further in Section 6.0.
- Groundwater that is interpreted to be located close to recharge areas tends to be of sodium-bicarbonate (Na-HCO3) or Sodium-Calcium-Bicarbonate (Na-Ca-HCO3) water type. This data tends to plot towards the central-basal area of the anion plot and the central area of the cation plot, based on elevated milliequivalent concentration of bicarbonate relative to chloride, and calcium/magnesium relative to sodium.
- As groundwater moves further along the groundwater flow line (and with increasing residence time) the trend is for the data to move along a line from the areas described above towards the lower right-hand area of the cation/anion plots in the area that is dominated by Na-Cl water type.

Table 5-1: Mean Milliequivalent Data and Water Type Analysis

Groundwater Unit/ Site	PERCENTAGE meq/L OF TOTAL CATION/ANION						Water Type
	Ca	Mg	Na + K	Cl	CO_3 + HCO_3	SO_4	
PZ07 - Alluvium	32.68	22.33	44.98	82.75	5.84	11.41	Na-Ca-Cl
PZ08 - Alluvium	22.77	19.81	57.42	67.63	11.11	21.27	Na-Cl
PZ09 - Alluvium	19.52	11.17	69.31	49.40	48.46	2.14	Na-Cl-HCO3
BN0744A - Alluvium	17.91	30.06	52.03	44.40	54.73	0.87	Na-HCO3
PZ14D - Permian	15.29	8.14	76.57	18.80	75.31	5.90	Na-HCO3
PZ13 - Fault Zone	5.48	2.92	91.60	94.60	5.37	0.03	Na-Cl
SKMPM01 - Interburden	11.65	0.28	88.07	74.02	24.81	1.17	Na-Cl
SKMPM03 - Interburden	6.37	7.99	85.65	33.81	54.95	11.25	Na-HCO3
SKMPM04 - Interburden	19.21	18.54	62.25	98.46	1.52	0.02	Na-Cl
SKMPM05 - Interburden	1.04	0.60	98.36	57.49	42.29	0.22	Na-Cl

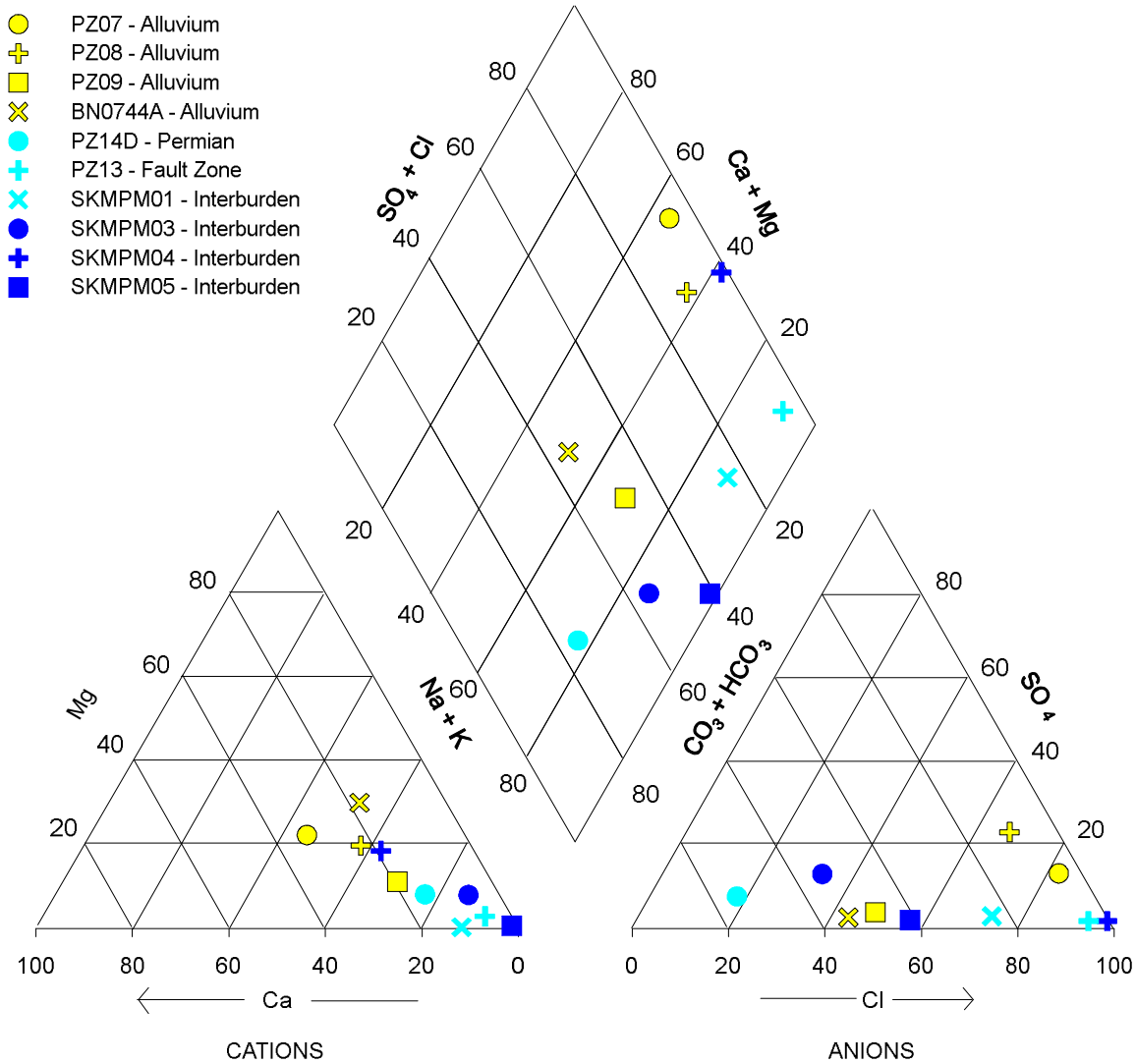


Figure 5-4: Piper Diagram – Site Groundwater Data

5.3 Assessment of Groundwater Recharge via the CBM Method

Groundwater data from Baralaba North groundwater monitoring bores has been used to provide an estimate of groundwater recharge based on the chloride mass balance (CMB) method, which utilises the concentration of chloride in rainfall and the concentration of chloride in groundwater to provide an estimate of the net recharge rate to groundwater. The CMB equation is given as:

$$R = \frac{PCp}{Cg}$$

Where: R = Recharge (mm/year).

P = *Rainfall* (mm/year).

Cp = Chloride concentration in rainfall (mg/L).

Cg = Chloride concentration in groundwater (mg/L).

Utilising the above formula, the recharge rates for each groundwater unit were calculated using the following input data:

- Average annual rainfall at the Baralaba site of 663.3 mm/year (SILO data).

- Average chloride concentration in rainfall for the Baralaba North Mine site of 4.0 mg/L, based on the following inputs and calculations:
  - An average chloride deposition rate for the Baralaba North Mine site of 26.6 kg/ha/year (CSIRO 2014);
  - An average annual rainfall at the Baralaba site of 663.3 mm/year; and,
  - 26.6 kg/ha/year = 2,660 mg/m^2/year divided by 663.3 mm/year rainfall = chloride in rainfall of 4.0 mg/L.
- The average chloride concentration of groundwater as shown for each site in Table 5-2.

The calculated recharge rates to groundwater are shown below in Table 5-2. The recharge rates should be regarded as being indicative of the relative recharge rate at each site rather than absolute rates of recharge, but the data supports the overall conclusions presented above, based on a review of major ion and EC data at each site.

Table 5-2: Groundwater Recharge Calculated by Chloride Mass Balance Method

Statistic	Alluvium				Permian Coal Measures					
	PZ07	PZ08	PZ09	BN0744A	PZ14D	PZ13	SKMPM01	SKMPM03	SKMPM04	SKMPM05
mg/L chloride in groundwater (mean value)	2138	3288	188	103	76	5847	606	253	6351	632
mg/L chloride in rainfall (mean value)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Annual average rainfall (mm)	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3
Annual average recharge (mm)	1.24	0.81	14.17	25.72	35.11	0.45	4.39	10.52	0.42	4.21
Recharge as % of average annual rainfall	0.19	0.12	2.14	3.88	5.29	0.07	0.66	1.59	0.06	0.63

6.0 CONCEPTUAL GROUNDWATER MODEL

The initial groundwater conceptual model has been discussed in detail in SKM (2014) and only elements that are regarded as being significant to the siting of the groundwater monitoring bore network are discussed in further detail in this report.

Data that has been discussed above (water level, water quality and groundwater recharge data) has been interpreted in conjunction with geological cross sections (refer Figure 5-1 for section locations), with observations as follows:

- The geological cross sections that are presented as Figure 6-1 to Figure 6-1 are presented from the south to the north of the Baralaba North site and are located as close as possible to the locations of existing groundwater monitoring bores;
- The sections show:
  - the locations and extent of folding and faulting along the section line;
  - the locations of groundwater monitoring bores that are located along each section;
  - The most recent water level data available for each monitoring location;
  - For bores where water quality data exists, the mean EC of groundwater at that site (based on all available monitoring data)
- Figure 6-1 shows a cross section at the southern end of the Baralaba North Pit, in the area of the Dawson River Anabranch. Observations include:
  - The section is located in the area of a shear zone that is monitored by bore PZ13. The faults that area shown in the section can be seen to completely disrupt the continuity of the coal seams, which has the potential to impact on groundwater flow. Based on data from bore PZ13, which is screened within one of the fault zones, the faults are interpreted to be acting as barriers to groundwater flow. This is evident from the high EC at this site (mean EC of 17,675 µS/cm and correspondingly low calculated recharge rage of 0.07% of average annual rainfall);
  - An overall downward flow (i.e. recharge) potential in this area is evident from the VWP bore (CCL_VWP02) at this site. However, as evident from the data from bores PZ13 and SKM_PM04 it is interpreted that the faults are acting as barriers to groundwater flow in this area, leading to long residence times for groundwater and correspondingly high EC;
  - Bore SKM_PM03 records a mean EC of 1,967 µS/cm. In addition, the major ion data from this site plots to the left of the anion plot on the Piper diagram (Figure 5-4) and is of Na-HCO3 water type (Table 5-1), indicating that groundwater recharge is occurring in this area. The bore is screened in Permian sandstone at relatively shallow depth (~38-42 m) below sand/gravel (to 16 mbgl).
- Figure 6-2 shows a cross section in the location of the current northern mining area at Baralaba North. Observations include:
  - The section highlights the degree of folding that occurs at locations across the site
  - The approximate extent and depth of mining is shown on the section. This highlights the distance of bore SKM_PM05 from mining. The lack of drawdown at SKM_PM05 (discussed in Section 5.1) is interpreted to be due not only to the distance of the bore from mining, but also because any drawdown would need to propagate though low-permeability interburden and, due to the dip of the unit, the propagation of drawdown would be through a component of the low vertical permeability direction of the strata. This is one reason that drawdown could be expected to propagate preferentially along the strike of the coal seams (i.e. in a roughly

north-northwest/ south-southeast direction) rather than across strike/ down-dip. It is also noted that the coal seams do not extend to the east of the coal seams shown in this section (i.e. this represents the eastern extent of the Baralaba Coal Measures; therefore, propagation of drawdown to the east is judged to be of low risk potential due to the lack of coal seams (which act as the primary conduits for groundwater flow) and the low overall permeability of the Gyranda Formation sediments (which is interpreted to have a similar permeability to the interburden units of the Baralaba Coal Measures).

- Figure 6-3 shows a cross section in the location of bore PZ14S and PZ14D. Observations include:
  - The overall dip of the coal seams is very steep at this location;
  - PZ14D (Coolum Seam) records a low mean EC (949 µS/cm); in addition, the bore plots to the left of the anion plot in the Piper diagram (Figure 5-4), is of Na-HCO3 water type (Table 5-1) and is assessed to be within a groundwater recharge area based on CMB recharge analysis (Table 5-2). From Figure 6-3 it is evident that PZ14D is screened in the Coolum Seam in an area where the seam subcrops beneath alluvial sediments and is therefore in an area where the coal seam could be expected to be directly recharged. As discussed above, it is interpreted that, with increasing distance along the groundwater flow line, the groundwater quality would naturally become increasing saline and trend towards the high EC/ Na-Cl water that is evident at other locations.
- Figure 6-4 shows a cross section in the north of the lease area, adjacent to bore BN0748A. Observations include:
  - The section highlights the constrained nature of the resource (i.e. a lesser west-east extent of mineable coal resource relative to the southern area of the deposit);
  - BN0748A is located to the east of the limit of Baralaba Coal Measures and within alluvium overlying the Gyranda Formation. Mining in this area may impact locally on groundwater levels within the alluvium (via lateral drainage), though the low potential for drawdown within the Permian unit (Gyranda Formation) means that there is a low potential for impacts on the alluvium that would be related to any downward flow that would be induced by a falling water level in the Permian units.

In summary:

- It is interpreted that groundwater recharge is related to:
  - Direct rainfall recharge of alluvial units;
  - Downward infiltration to the Permian coal measures in areas that are underlain by alluvium, especially in areas where the coal seams subcrop directly below the alluvium (e.g. at the location of PZ14D)
- SKM (2014) interpreted an overall groundwater flow direction in the Permian units that honoured topography and generally resulted in a groundwater flow direction in the Baralaba North area from north to south, towards the Dawson River Anabranch. While this general groundwater flow direction is supported by a review of data undertaken for this assessment, it is evident that groundwater flow patterns are locally impacted by the mining operation, as the pits are acting as sinks for groundwater flow. The localised drawdown in groundwater level is most evident for bores that are screened within the coal seams and along strike (i.e. directly to the north or south) of mining operations. Groundwater level drawdown is not yet evident in bores to the east/west of the mining area, supporting an interpretation that groundwater level drawdown due to mining is likely to be preferentially along strike and within the zone where the coal seams are mined, with limited

potential for drawdown across strike/down-dip of the mining area, or to the east of the boundary between the Baralaba Coal Measures and the Gyranda Formation.

- At Baralaba Central Mine it is understood that the water level in the pit voids is currently managed to be at a level that is always below the Tertiary/Quaternary sediments, which limits the potential for discharge via the shallow groundwater system. However, groundwater monitoring adjacent to the pit area is still recommended as the water level may rise in the voids under high rainfall conditions, and flow from site dams (that are located above the void water level) may still occur, as discussed in Section 5.2.2).

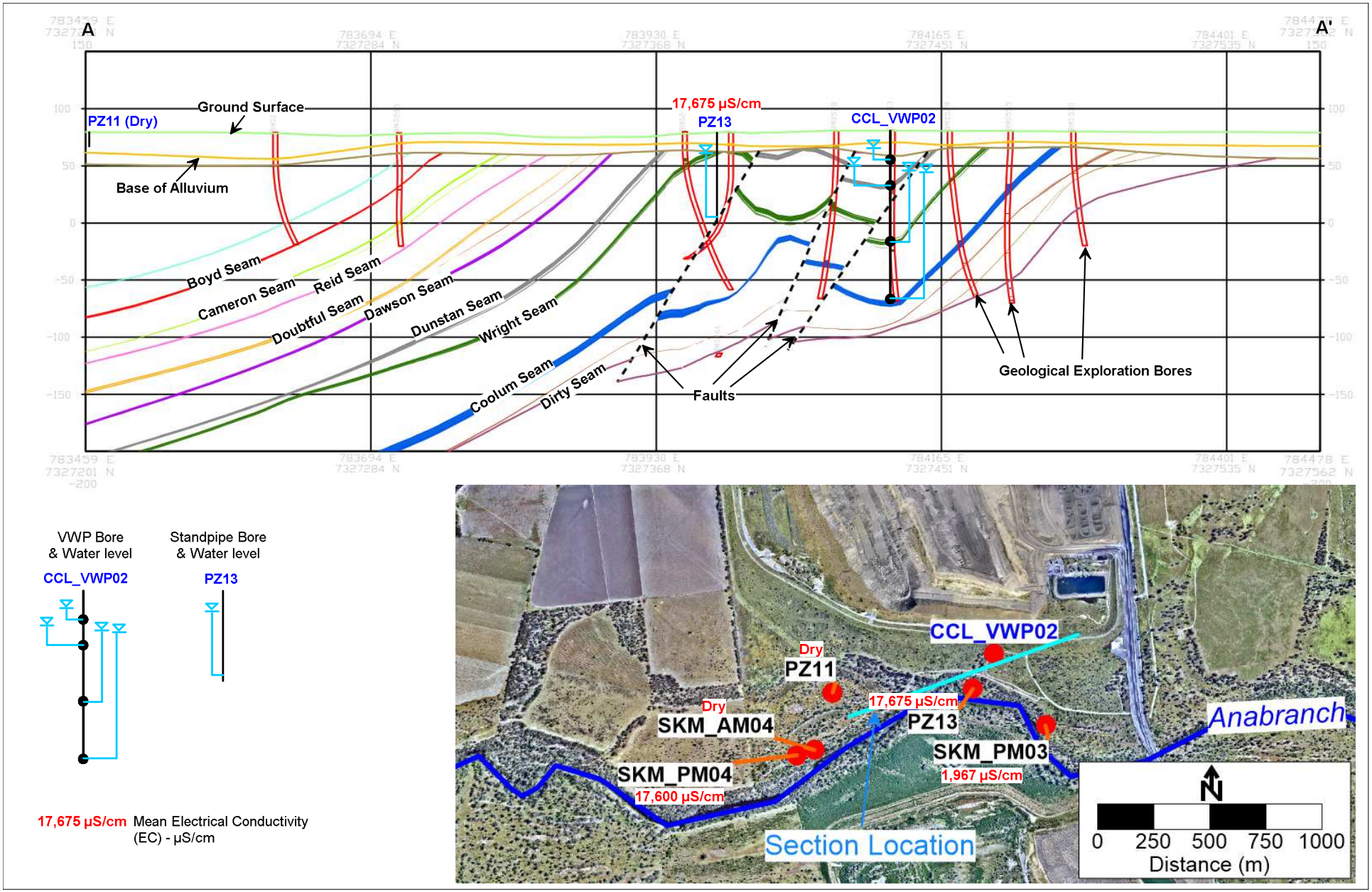


Figure 6-1: Geological Section 1

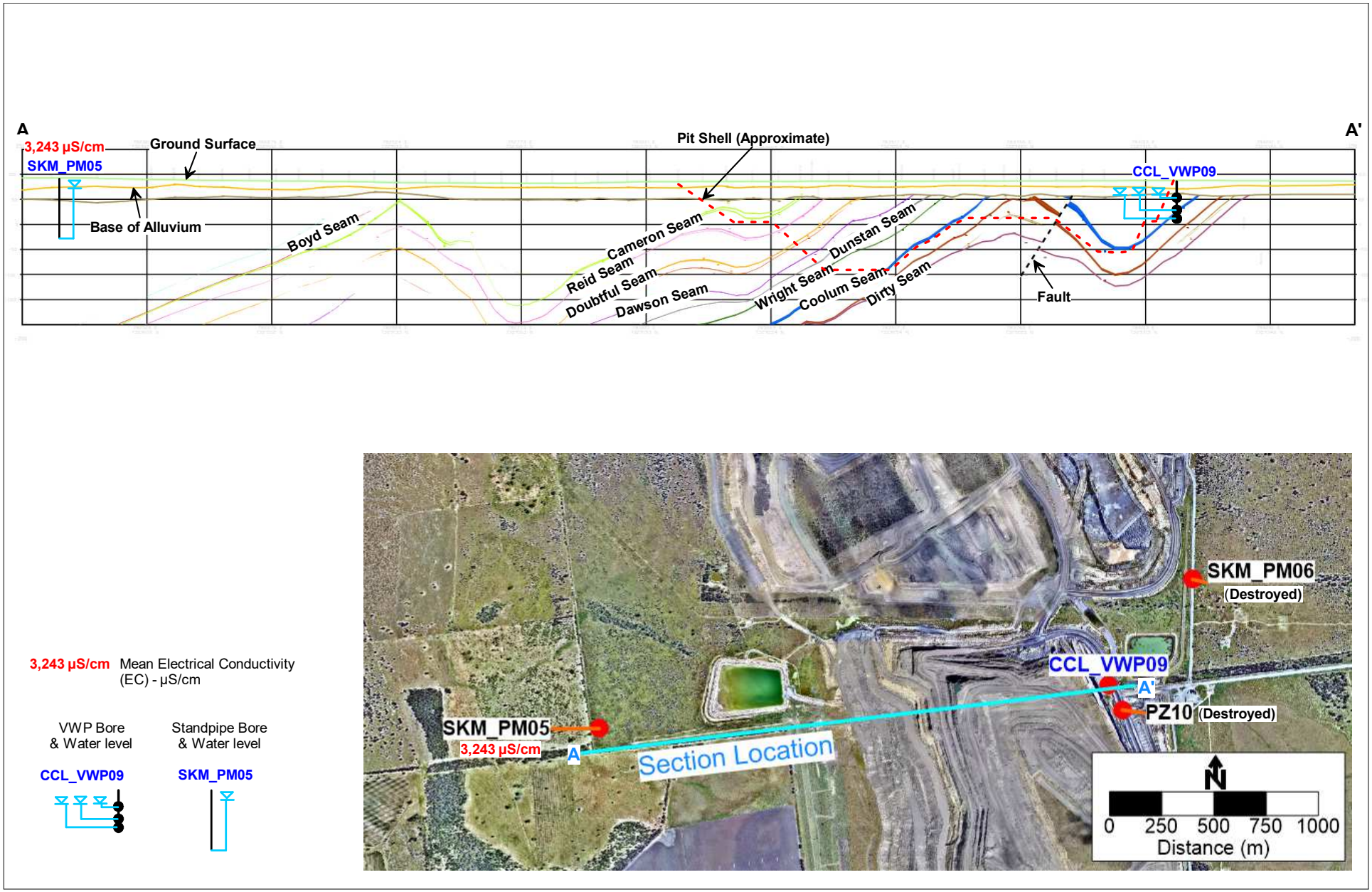


Figure 6-2: Geological Section 2

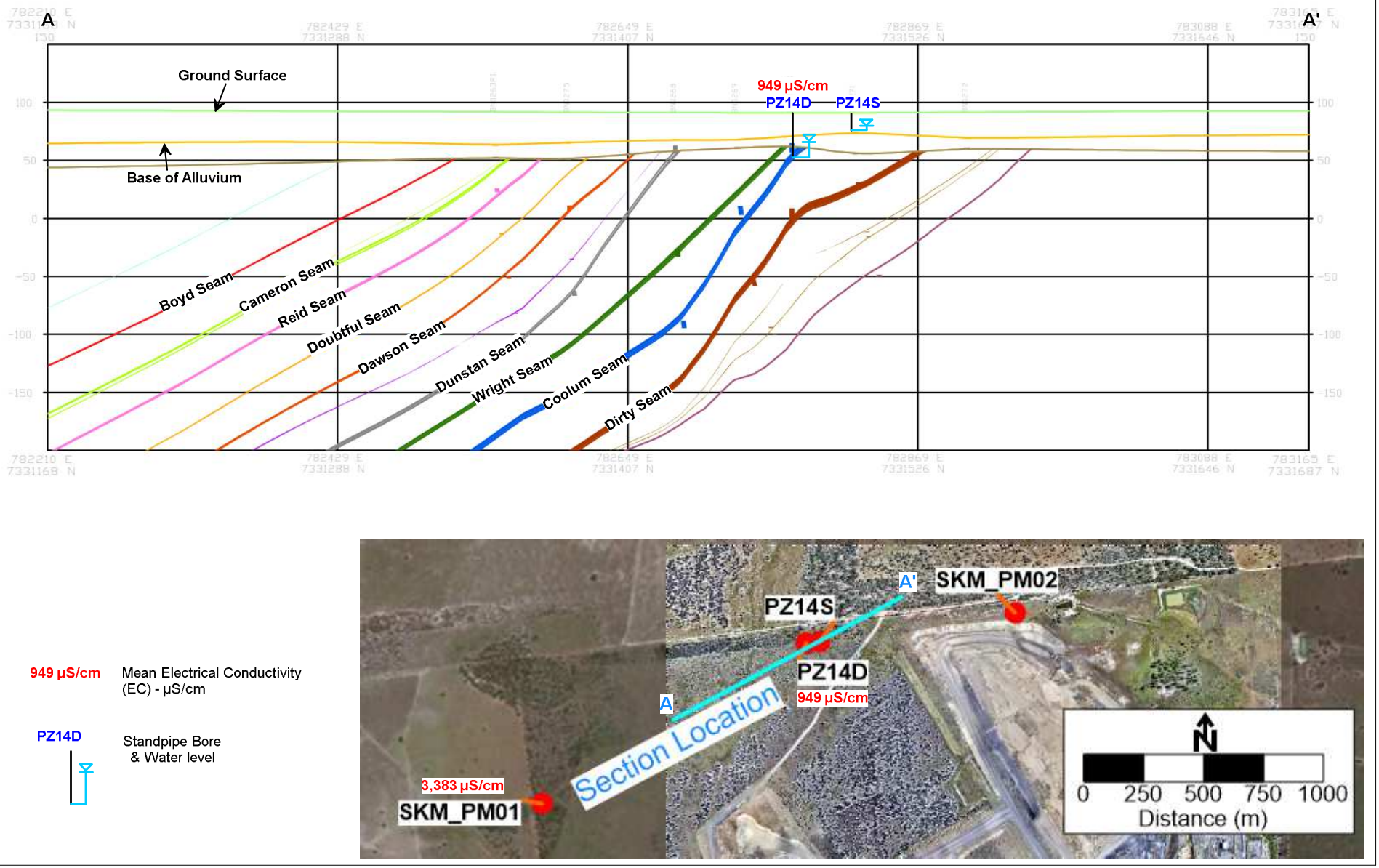


Figure 6-3: Geological Section 3

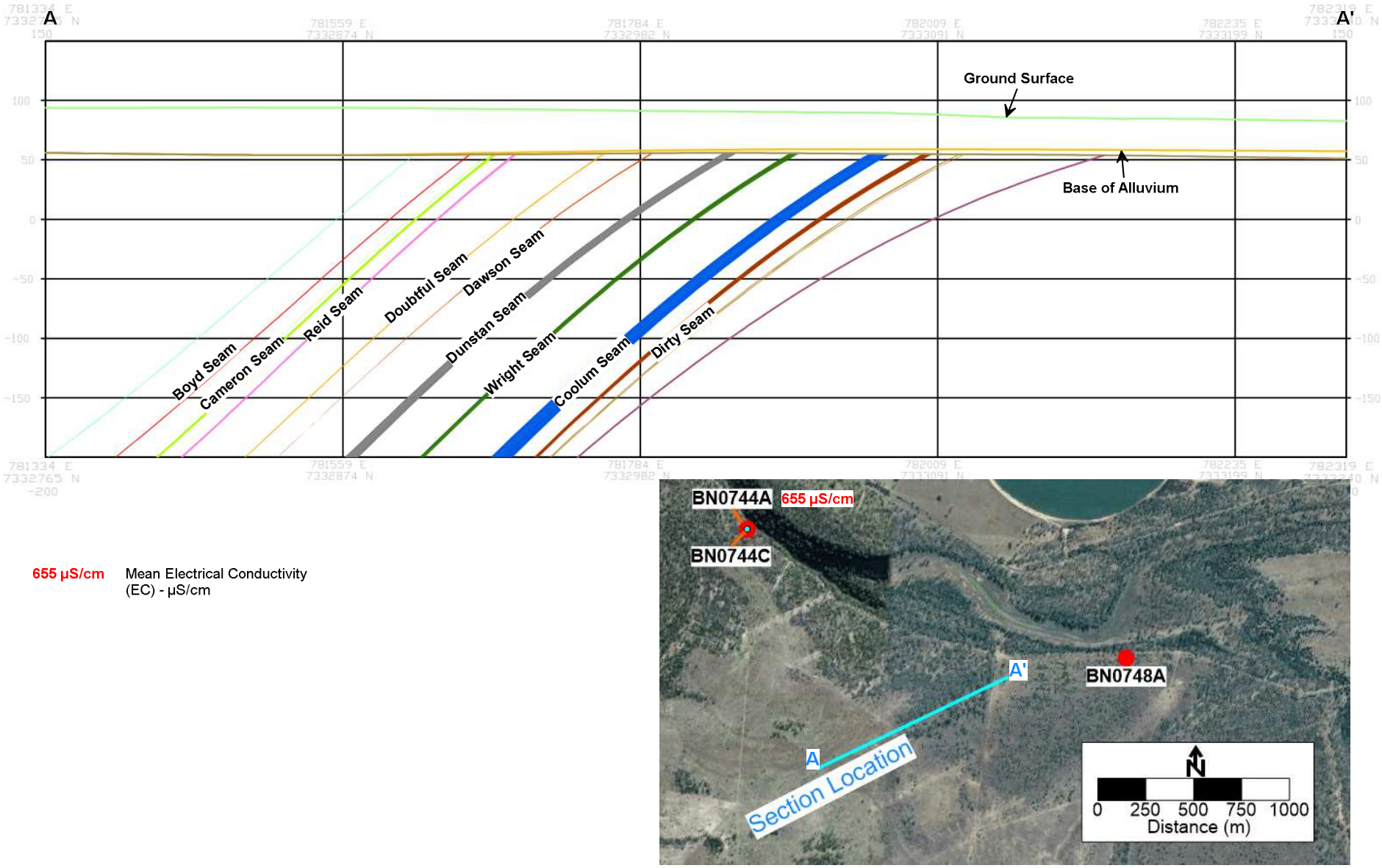


Figure 6-4: Geological Section 4

7.0 GROUNDWATER MONITORING BORE NETWORK

7.1 Recommendations for Existing Bore Network

The existing groundwater monitoring bores are shown in Figure 7-1. The existing EA groundwater monitoring network has been assessed for functionality (for both water level and water quality monitoring. Observations and recommendations are shown in Table 7-1.

Table 7-1: Existing EA Groundwater Monitoring Bores and Status/Recommendations

Monitoring Point	Groundwater Unit	Comment/ Recommendations
Established monitoring network		
Quaternary and Tertiary Alluvial Aquifers		
PZ07	Alluvium	20 mm conduit not suitable for water quality sampling **Recommend that bore is decommissioned.**
PZ07B	Alluvium	20 mm conduit not suitable for water quality sampling – It is understood that this bore is located adjacent to PZ07. Only one alluvial monitoring bore is required at this site. **Recommended the bore is decommissioned**
PZ08	Alluvium	20 mm conduit not suitable for water quality sampling **Recommend that bore is redrilled with a bore adjacent (Site 3 on Figure 7-2)**
PZ09	Alluvium	20 mm conduit not suitable for water quality sampling **Recommend that bore is redrilled with a bore adjacent (Site 4 on Figure 7-2).**
PZ10	Tertiary alluvium	The bore has been destroyed by mining activities. The bore is 9.5 m deep and recorded a water level of 9.01 m (i.e. just above base of bore) when the bore was first drilled in 2011. It is concluded that the alluvium at this site, being adjacent to the open cut, would now be dry and that there would be no justification for re-drilling a bore at this site. **It is assessed that no replacement bore is required at the site of PZ10 and it is recommended that a request be made with the regulator to remove the bore from the EA.**
PZ11	Alluvium	50 mm diameter bore – currently dry but functional
PZ14S	Quaternary alluvium	50 mm diameter bore – functional
Permian Coal Seam Aquifers		
PZ14D	Coolum seam	50 mm diameter bore – functional
Fault Zone		
PZ13	Sandstone – Fault zone	50 mm diameter bore – functional
Additional Monitoring Network		
BN0744A	Alluvium	50 mm diameter bore – functional Bore construction log has not yet been found; however, it is also noted that the bore depth is known and that the bore is screened within the upper aquifer (alluvium), therefore sealing between aquifer units is not an issue at this site. **It is recommended that this bore continue to be monitored**
BN0744C	Reid Seam	Bore potentially damaged (based on review of water chemistry, as discussed previously with the regulator). **Recommend that bore is redrilled**
BN0748A	Alluvium	50 mm diameter bore – functional Bore construction log has not yet been found; however, it is also noted that the bore depth is known and that the bore is screened within the upper aquifer (alluvium), therefore sealing between aquifer units is not an issue at this site. **It is recommended that this bore continue to be monitored**
SKM AM04	Alluvium	50 mm diameter bore – currently dry but functional
SKM PM01	Interburden	50 mm diameter bore

Monitoring Point	Groundwater Unit	Comment/ Recommendations
		Potential construction issues interpreted, based on water chemistry (high pH and elevated hydroxide alkalinity), suggestive of uncured grout seal **It is recommended that this bore be decommissioned, and replaced with a shall/deep nested site at Site 7 (Figure 7-2)**
SKM PM02	Interburden	50 mm diameter bore – functional
SKM PM03	Interburden	50 mm diameter bore – functional
SKM PM04	Interburden	50 mm diameter bore – functional
SKM PM05	Interburden	50 mm diameter bore Potential construction issues interpreted, based on water chemistry (high pH and elevated hydroxide alkalinity), suggestive of uncured grout seal **It is recommended that this bore be re-drilled**
SKM PM06	Interburden	The bore has been destroyed by mining activities. The bore is located within the Gyranda Formation, and it is assessed that groundwater level drawdown at this site due to mining presents an extremely low risk. However, it is noted that the bore is located between the mining area and the high-value wetland that is to be monitored by Site 6 (Figure 7-2) **It is therefore recommended that this bore be re-drilled at a location that is between the mining operation and Site 6 (assuming that the existing site is inaccessible)**

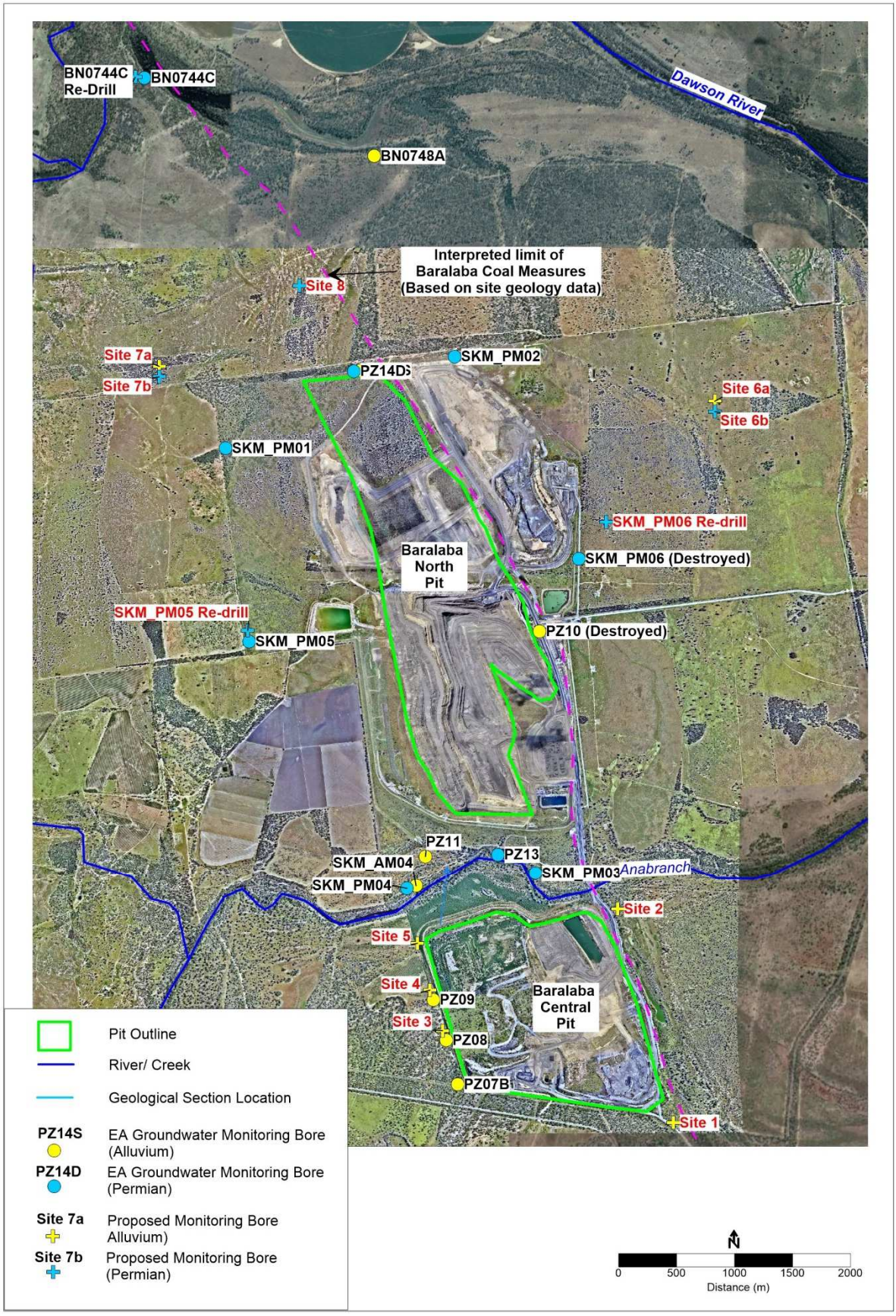


Figure 7-1: Locations of Existing and Recommended Groundwater Monitoring Bores

7.2 Recommendations for Extended Bore Network

Recommendations for additional groundwater monitoring bores are presented below in Table 7-2, with bore locations shown in Figure 7-1.

Table 7-2: Recommended Additional Monitoring Bore Sites

Site	Easing (GDA94)*	Northing (GDA94)*	Comment
Site 1	785522	7325005	Alluvial bore proposed for the south-west corner of the Baralaba Central Pit
Site 2	785041	7326849	Alluvial bore proposed for the north-west corner of the Baralaba Central Pit
Site 3	783533	7325800	Alluvial bore to replace PZ08
Site 4	783425	7326150	Alluvial bore to replace PZ09
Site 5	783317	7326554	Alluvial bore to monitor groundwater conditions between the Baralaba Central pit area and the anabranch
Site 6a	785879	7331235	Alluvial bore located adjacent to high value wetland
Site 6b	785879	7331240	Permian bore located adjacent to high value wetland. The intent at this site is to monitor the regional water table within the Permian sediments
Site 7a	781091	7331440	Alluvial bore located adjacent to high value wetland. This site is to replace bore SKM_PM01, which has been assessed (based on water chemistry) to have construction issues.
Site 7b	781091	7331445	Permian bore located adjacent to high value wetland. The intent at this site is to monitor the regional water table within the Permian sediments
Site 8	782300	7332226	Permian bore to monitor groundwater level drawdown to the north of the pit. The bore may be removed by mining in the future, but the intent is to monitor for drawdown impacts in advance of mining, with a new bore to be drilled to the north (i.e. closer to BN0744A/C) if drawdown impacts are detected at this site

* Coordinates are approximate and may require adjustment in the field to take into account site access issues etc.

8.0 REFERENCES

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Appendix B. Soil and Land Suitability Assessment

Baralaba North Continued Operations Project

Environmental Impact Statement

APPENDIX J

SOIL AND LAND SUITABILITY ASSESSMENT

Baralaba North Continued Operations Project

Cockatoo Coal Limited

Soil and Land Suitability Assessment

Soil mapping, characterization, topsoil stripping, pre-mining land suitability, Strategic Cropping Land and erosion potential

Jon Burgess
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0448 451 402

April 2014

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1. Introduction

This report presents findings from a baseline soil mapping and soil characterization investigation within the Baralaba North Continued Operations Project (BNCOP) area, situated north of the township of Baralaba. The purpose of the investigation was firstly to define and quantify soil landscapes within the defined BNCOP Soil Investigation survey area (see Figures 1 and 2); and secondly to determine topsoil resources for salvage and to assess pre-mining land suitability, Agricultural Land Class status, Strategic Cropping Land (SCL) status and inherent erosion potential more specifically within the BNCOP Disturbance Footprint. Soil Mapping and Monitoring Pty Ltd (in association with B.R. Emmerton Pty Ltd) were commissioned by Cockatoo Coal Pty Ltd to undertake the investigation.

The aims of the investigation were threefold. Initial field and laboratory studies aimed to map, describe and fully characterise the soil landscapes present within the defined BNCOP soil investigation survey area (see Figures 1 and 2). Subsequent analysis of the data from this process has enabled clear identification of the distribution, abundance and nature of suitable topsoil and root zone (subsoil) resources for stripping and salvage. In addition, soil attributes contributing to pre-mining land suitability (dryland cropping and grazing), SCL status and inherent erodibility have been investigated, analysed and reported on.

Specific objectives and milestones completed during the study include:

- **preliminary photo interpretation and digital elevation model (DEM) analysis** to investigate differences in soil distribution associated with lithology, landscape position/weathering status and vegetation;
- **detailed soil characterization and field mapping** at a suitable scale (1:25000);
- **field logging of undisturbed soil cores** to characterize the morphology of surface soil and subsoil materials (e.g. texture, colour, structure, behavioural properties in the field);
- **representative sampling and laboratory analyses** to quantify physical and chemical characteristics of topsoil and subsoil materials;
- identification of the nature and depth of suitable **topsoil materials** available for salvage;
- identification of the presence of **benign root zone materials** that are potentially useful as additional rehabilitation media;
- assessment of **pre-mining land suitability for dryland cropping and grazing**;
- assessment of **Agricultural Land Class (ALC)** status
- assessment of **Strategic Cropping Land (SCL)** status;
- assessment of **inherent erosion potential**;
- presentation of **detailed mapping** showing the distribution and spatial extent of soil resources, pre-mining land suitability, ALC status, SCL status and inherent erosion potential within the investigation area; and
- **documentation** of all methodology, soil data, interpreted soil characteristics, stripping recommendations and land suitability/ALC/SCL/erosion assessment findings.

Twenty three soil types are recognized within the 2013 BNCOP Soil Investigation survey area. Field site locations were based initially on a combination of air photo interpretation (1:25000 1952 B&W photography) and DEM analysis and were designed to investigate differences in soil distribution associated with changes in lithology, landscape position, weathering status and pre-clearing vegetation patterns.

Field logging and sampling (from 75mm undisturbed soil cores) were undertaken at 113 field sites. Comprehensive field data was collected at each site to fully describe and characterize the soil resource present. All sites were fully sampled and strategic laboratory analysis was undertaken at a select number of representative sites.

Each of the soils delineated during mapping varies significantly in terms of origins and spatial extent, and this is reflected in the depth, thickness and quality of topsoil and subsoil horizons that have developed. Differences in soil attributes have been carefully mapped, analysed and documented during the investigation. **Topsoil stripping and management recommendations**, assessment of **pre-mining land suitability** for dryland cropping and grazing land uses, **Agricultural Land Class (ALC)** determinations, **Strategic Cropping Land (SCL)** status and assessment of **inherent erosion potential** are discussed for each soil in the sections that follow.

In addition, detailed description and characterisation data for each soil type, including stripping recommendations and pre-mining suitability findings are summarized for quick reference in the **Soil Characterisation Section** of this report. All relevant data is presented both in the text (where appropriate) and also in the Appendices attached to this report.

2. Study area

The 2013 BNCOP Soil Investigation survey area collectively covers 2970ha, and extends mapping coverage eastwards, westwards and northwards from previous soil mapping undertaken within ML80169 and ML80170 (Soil Mapping and Monitoring (SMM) 2010b; North Queensland Soil Assessment (NQSA) 2011a, 2011b). Study area boundaries and naming conventions are presented in **Figures 1 and 2**.

The completed 2013 BNCOP Soil Investigation survey area encompasses the following entities:

- buffer areas external to the BNCOP EIS Operational Area;
- the proposed BNCOP Disturbance Footprint (external to ML80169 and ML80170) that occupies the eastern and northern parts of the BNCOP EIS Operational Area; and the
- existing Baralaba/Wonbindi North Mine Lease (ML80169/ML80170) that occupies the western section of the BNCOP EIS Operational Area.

The BNCOP EIS Operational Area is wholly contained within the 2013 survey boundary and comprises two existing leases, namely ML80169 and ML80170, as well as the proposed BNCOP Disturbance Footprint that lies adjacent. Whilst soils information across the entire 2013 Soil Investigation survey area (2970ha) is presented, only new information relating directly to the BNCOP Disturbance Footprint, plus previously assessed findings within ML80169 and ML80170, are relevant to the BNCOP Operational Area Environmental Impact Statement (EIS).

Pre-existing soil mapping covering areas within ML80169 and ML80170 (NQSA 2011a, 2011b), is presented to demonstrate continuity between assessment stages and complete soils coverage within the BNCOP, but is not discussed as part of this report. Detailed technical assessments, findings and discussion for soils in the pre-existing leases is available from the relevant reports and documentation submitted during approval of ML80169 and ML80170 (NQSA 2011a, 2011b).

The detailed technical assessments, findings and discussion presented in this report specifically target the proposed BNCOP Disturbance Footprint which covers an area of 1486ha and lies immediately north-east and external to ML80169 and ML80170. New work has not been undertaken within ML80169 and ML80170.

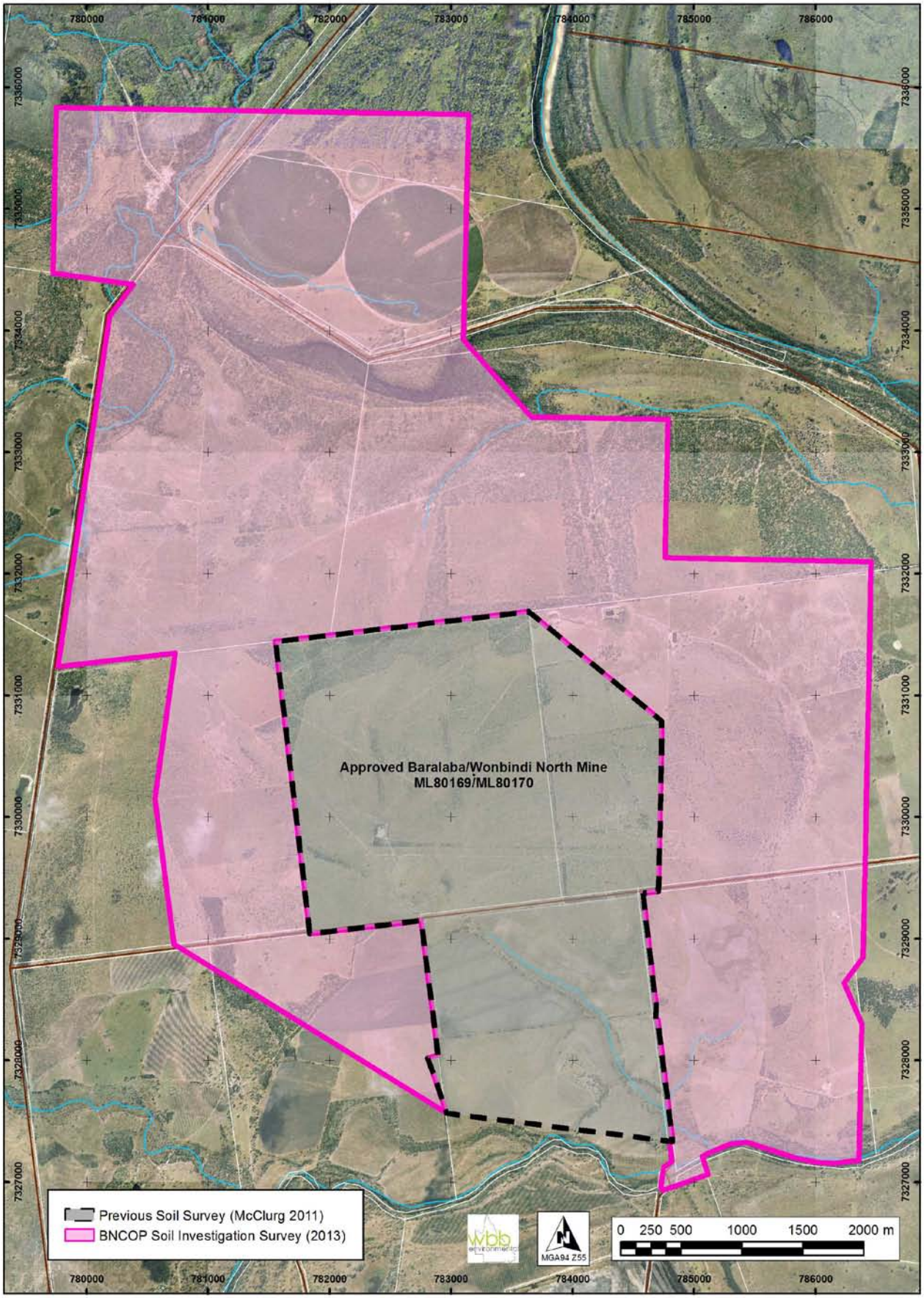


Figure 1. Baralaba North location showing the extent of the 2013 BNCOP Soil Investigation survey area (pink) in relation to the approved Baralaba/Wonbindi North Mine Lease - ML80169 and ML80170 (grey).

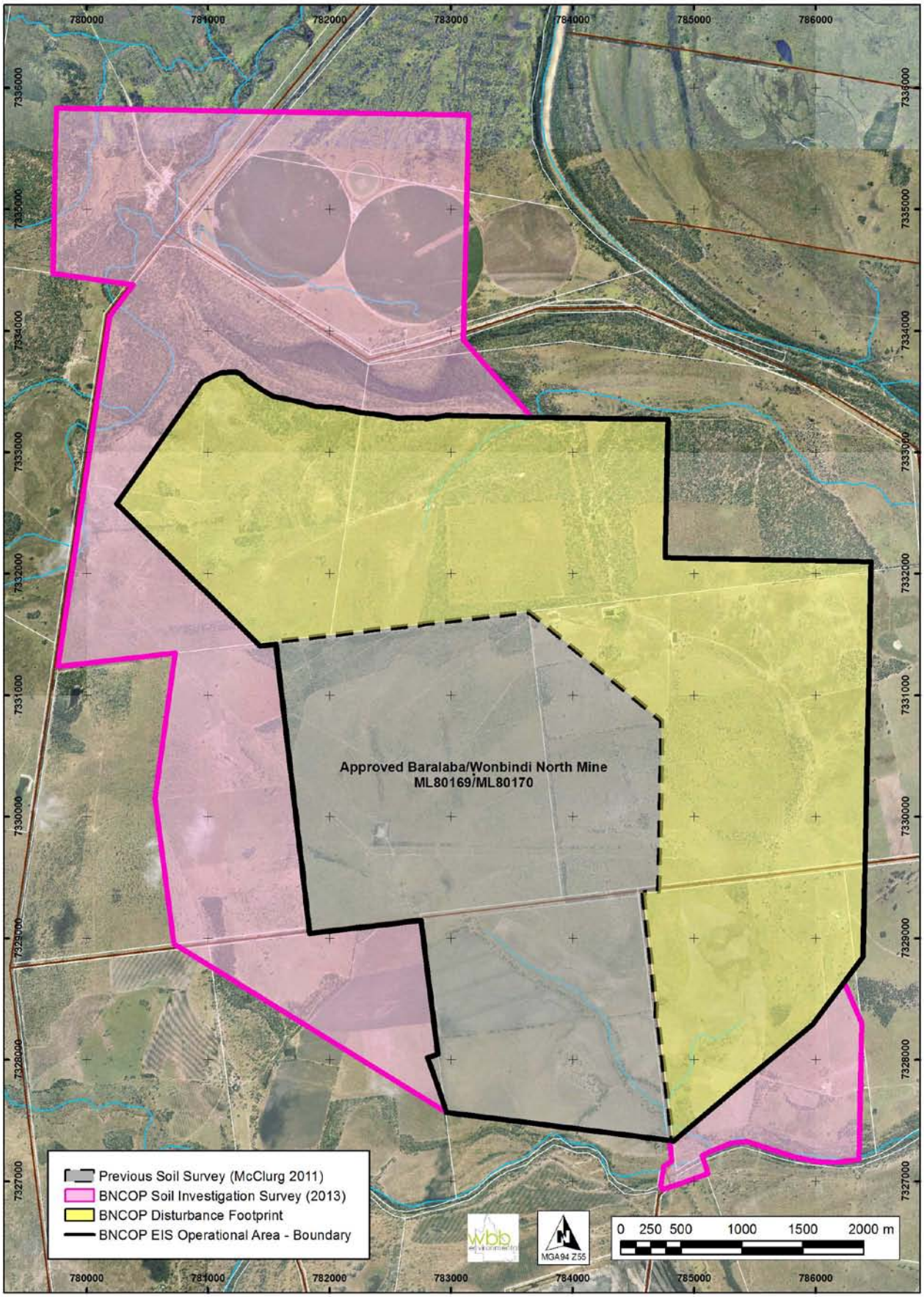


Figure 2. Location and extent of the BNCOP Disturbance Footprint (yellow), ML80169 and ML80170 (grey) and the BNCOP EIS Operational Area (yellow + grey) nested within the 2013 BNCOP Soil Investigation survey area (pink).

3. Previous land resource studies

Previous broadscale geologic and/or land resource studies that are either spatially relevant or provide a descriptive soil-landscape framework relevant to the current BNCOP investigation include:

- Balfe *et al* (1988). *Bowen Basin Solid Geology 1:500 000 Map series*, Queensland Department of Mines, Brisbane.
- Olgers *et al* (1963). *1:250 000 Geological Map Series - Baralaba Sheet SG 55-4*. Bureau of Mineral Resources, Geology and Geophysics, Canberra in conjunction with Geological Survey Queensland , Brisbane.
- Perry *et al* (1968). *Land Systems of the Dawson Fitzroy area.* CSIRO Land Research Series Number 21. Canberra. (1:500 000 land system mapping).
- Burgess JW (2003a). *Land Resource Assessment of the Windeyers Hill Area, Isaac – Connors and Mackenzie River Catchments, Central Queensland, Volume 1*, Department of Natural Resources and Mines, Land Resources Bulletin Series QNRM02189, Brisbane.
- Burgess JW (2003b). *Land Resource Assessment of the Windeyers Hill Area, Isaac – Connors and Mackenzie River Catchments, Central Queensland, Volume 2 - Appendices*, Department of Natural Resources and Mines, Land Resources Bulletin Series QNRM02189, Brisbane.
- Muller PG (2008). *Soils of the Banana Area, Central Queensland*. Department of Natural Resources and Water, Land Resources Bulletin Series, Brisbane.

The broadscale land system mapping of Perry *et al* (1968) indicates alluvial landscapes within the investigation area comprise either Coolibah (C), Dakenba (D) or Juandah (J) land systems, while more elevated landscapes are mapped as Thomby (T), Eurombah (E), and Peach (P) land systems. Thomby (T) land system is developed on unconsolidated Tertiary-Quaternary sediments (Cz, TQr) and sits above any recent alluvial influences. Eurombah (E) is associated mainly with relatively intact areas of weathered Tertiary substrate, while Peach (P) is developed on little weathered, moderately dissected, medium to coarse grained siliceous Tertiary sandstones.

More recent detailed soil studies associated with previous EIS investigations for the Baralaba Mine, that lie adjacent to or overlap the current investigation (and are at similar scales and survey intensities to the current study), include:

- Soil Mapping and Monitoring (SMM) (2010a). *Soil mapping, stripping recommendations and pre-mining suitability for Stage 1 of the Baralaba Coal Mine Lease Extension*, Consultancy Report, Soil Mapping and Monitoring Pty Ltd, Qld.
- Soil Mapping and Monitoring (SMM) (2010b). *Soil mapping, stripping recommendations and pre-mining suitability for Stage 2 of the Baralaba Coal Mine Lease Extension*, Consultancy Report, Soil Mapping and Monitoring Pty Ltd, Qld.
- North Queensland Soil Assessment (NQSA) (2011a). *Pre-mining Agricultural Land Suitability and Soil Reuse Recommendations - Wonbindi North area, Baralaba, Queensland.* Consultancy Report, North Queensland Soil Assessment Pty Ltd, Qld.
- North Queensland Soil Assessment (NQSA) (2011b). *Strategic Cropping Land Report - Baralaba Coal, Queensland*. Consultancy Report, North Queensland Soil Assessment Pty Ltd, Qld.

Of these, SMM (20010a, 2010b) completed detailed soil mapping and associated land suitability assessments for initial expansion at Baralaba Mine, while more recently NQSA (2011a, 2011b) completed additional detailed soil studies, including assessment of Strategic Cropping Land (SCL)

status, within the approved Baralaba/Wonbindi North Mine Lease (ML80169 and ML80170). All of the previous detailed soils studies are directly relevant to the current investigation, either because of close proximity, or through continuity of landscapes between adjacent expansion stages.

A number of soils mapped in the previous studies have been encountered during current investigations, and correlation between studies has been undertaken to ensure consistency between project stages. Of the 23 soils mapped within the 2013 BNCOP Soil Investigation survey area, 8 have been previously described by SMM (2010a, 2010b) and a further 5 by NQSA (2011a). Soils presented in the current report that have been similarly mapped within previous studies include Soils 1, 2b, 3a, 4a, 4b, 4c, 5, 6b, 7a, 7b, 7c, 8a and 8b. Further description and characterization of these soils within the current study builds on the understanding and knowledge already available.

4. Methodology

Field survey methodologies used during the study have followed recognized standard procedures detailed in the *Australian Soil and Land Survey Handbook Series* (Isbell 1996; McKenzie *et al* 2002; McKenzie *et al* 2008; National Committee on Soil and Terrain (NCST) 2009; Rayment and Lyons 2011), the *Technical Guidelines for Environmental Management of Exploration and Mining in Queensland* (QDME 1995) and the *Guidelines for Applying the Proposed Strategic Cropping Land Criteria* (DNRM 2011d), as specified in the BNCOP Operational Area EIS terms of reference.

Industry standards and guidelines used in the investigation

Technical assessments undertaken during the investigation are in accordance with the following standards, guidelines and texts:

Soil and landscape field assessment

National Committee on Soil and Terrain (2009). *Australian Soil and Land Survey Field Handbook, Third Edition.* Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Soil survey specifications

McKenzie NJ, Grundy MJ, Webster R and Ringrose-Voase (2008). *Guidelines for Surveying Soil and Land Resources.* Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Soil classification

Isbell RF (1996). *The Australian Soil Classification*. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Field vegetation assessment

Hnatiuk RJ, Thackway R and Walker J (2009). Vegetation. In *Australian Soil and Land Survey Field Handbook, Third Edition.* Australian Soil and Land Survey Handbook Series. National Committee on Soil and Terrain, CSIRO Publishing, Melbourne

Soil chemistry/analysis methodology

Rayment GE and Lyons D (2011). *Soil Chemical Methods – Australasia*. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Soil physics

Mckenzie NJ, Coughlan KJ and Cresswell HP (2002). *Soil Physical Measurement and Interpretation for Land Evaluation.* Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Topsoil stripping assessment and management

QDME (1995). *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Mines and Energy, Brisbane, Queensland.

Pre-mining land suitability

DNRM/DSITIA (2013a). *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane, Queensland.

DNRM/DSITIA (2013b). *Regional Land Suitability Frameworks for Queensland*, *Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area*, Queensland Government, Brisbane, Queensland.

QDME (1995). *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Mines and Energy, Brisbane, Queensland.

Agricultural Land Class (ALC) assessment and land use conflict

DNRM/DSITIA (2013a). *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane, Queensland.

Queensland Government (1992). *State Planning Policy 1/92: Development and the Conservation of Agricultural Land.* Queensland Government, Brisbane, Queensland.

DPI/DHLGP (1993). *Planning Guidelines: The identification of Good Quality Agricultural Land*. Department of Primary Industries and Department of Housing and Local Government and Planning, Brisbane, Queensland.

Strategic Cropping Land (SCL) assessment

DNRM (2011a). *Protecting Queensland's Strategic Cropping Land – Statewide Strategic Cropping Land Trigger Mapping 2011 – Map Sheet C2/C5.* Department of Natural Resources and Mines, Brisbane, Queensland.

DNRM (2011b). *Protecting Queensland's Strategic Cropping Land – Proposed Criteria for Identifying Strategic Cropping Land, April 2011.* Department of Natural Resources and Mines, Brisbane, Queensland.

DNRM (2011c). *Strategic Cropping Land – Strategic Cropping Protection Areas and Strategic Cropping Management Areas, DNRM Fact Sheet July 2011.* Department of Natural Resources and Mines, Brisbane, Queensland.

DNRM (2011d). *Protecting Queensland's Strategic Cropping Land – Guidelines for Applying the Proposed Strategic Cropping Land Criteria, September 2011.* Department of Natural Resources and Mines, Brisbane, Queensland.

DNRM (2012). *Protecting Queensland's Strategic Cropping Land – Cropping History Assessment Guidelines.* Department of Natural Resources and Mines, Brisbane, Queensland.

Queensland Government (2011). *Strategic Cropping Land Act 2011 – Act No. 47 of 2011, December 2011*. Queensland Government, Brisbane, Queensland.

All methodologies employed during the study are in accordance with the recognized industry standards listed above, and have been aligned with the requirements and recommendations specified by the regulator (DNRM and DEHP) in the Terms of Reference for the BNCOP Operational Area. This has ensured all information and outcomes from the project satisfy expected requirements for contemporary resource industry EIS assessment in Queensland.

Mapping methodology

Preliminary photo interpretation incorporating geological mapping, DEM analysis, landscape features and pre-clearing soil–vegetation photo patterns (1952) was used to delineate potential soil type changes within the investigation area. Proposed field sampling locations were selected during this process. Preliminary linework boundaries were verified and/or adjusted during fieldwork and final linework was scanned and digitized in GIS following completion of fieldwork. Based on available time and resources, the degree of landscape complexity and the outcomes required from the project a final published mapping scale of 1:25000 was considered appropriate to meet the technical requirements specified in the BNCOP EIS Terms of Reference. Fieldwork site intensities reflect the investigation density required to validate mapping at this scale. Maps included with the report have been reduced to a scale of 1:40000 for presentation purposes only.

Mapping at 1:25000 scale requires a minimum recommended ground observation density of 1 site/12.5 ha. This equates to approximately 235 field observations across the 2013 BNCOP Soil Investigation survey area (2970ha). At large mapping scales such as 1:25000, McKenzie *et al* (2008) recommend data collection include both detailed soil profile descriptions (about 35% of observations) and representative sampling sites for laboratory analysis (about 5% of observations), but with an emphasis on map boundary observations (about 60% of observations) to accurately delineate soil changes on the ground. As such, predicted data requirements within the BNCOP Soil Investigation survey area (2970ha) necessitated a minimum of at least 83 detailed soil profile descriptions, 12 fully analysed representative sample sites and up to 143 map boundary observations (captured by GPS and recorded as brief field description notes for direct incorporation into final linework) to meet minimum recommended site densities.

Completed survey statistics from the field investigation are presented in the tables below and confirm completed ground observation densities surpass the minimum mapping requirements of McKenzie *et al* (2008) for detailed soil mapping at a scale of 1:25000. Fieldwork was targeted during the survey program to ensure the relative representation of detailed and analysed representative sites within the BNCOP Disturbance Footprint and associated SCL trigger area was sufficient to guarantee the quality, reliability and robustness of soil data in areas earmarked for ground disturbance and/or SCL validation. Australian map grid co-ordinates (GDA94) for all detailed field site locations (Sites 1-113) are presented in **Appendix 1**.

Recommended and actual survey statistics for the 2013 BNCOP Soil Investigation survey area

Minimum recommended observations McKenzie *et al* (2008)	Detailed sites (35%)	Rep. sample sites (5%)	Mapping obs. (60%)	Total (100%)
2013 BNCOP survey area (2970ha)	83	12	143	238
BNCOP Disturbance Footprint (1486ha)	42	6	71	119
SCL trigger area (118ha)	3	1	6	10

Actual ground observations completed	Detailed sites (35%)	Rep. sample sites (5%)	Mapping obs. (60%)	Total (100%)
2013 BNCOP survey area (2970ha)	97 (32%)	16 (6%)	188 (62%)	301 (100%)
BNCOP Disturbance Footprint (1486ha)	44 (32%)	14 (10%)	81 (58%)	139 (100%)
SCL trigger area (118ha)	6 (40%)	5 (33%)	4 (27%)	15 (100%)

While gross soil distribution was relatively predictable across much of the investigation area, localised soil complexity associated with subtle lithological or weathering variations, depth of colluvial cover and localised drainage characteristics required greater ground observation densities in some areas than predicted. This was particularly the case with relict alluvium in landscape 7 and the sedimentary rocks of landscapes 8 and 9. During fieldwork, map boundary observations were recorded either as brief field notes or as annotations on field maps. Where landscapes or soil distributions were complex (and time and resources allowed), detailed field descriptions and representative sampling in excess of the minimum requirements were undertaken.

Experience with similar unconsolidated and insitu sedimentary landscapes elsewhere in the Bowen Basin (Burgess 2003a, 2003b; SMM 2010a, 2010b) mean completed site intensities are considered adequate to fully understand and investigate the soil catenary relationships occurring within the investigation area. The presence of remnant vegetation in some areas, distinct landform/lithological changes and clearly recognizable soil - vegetation relationships from pre-clearing aerial photography greatly increased the efficiency and reliability of field mapping.

Field descriptions

All field descriptions were collected in accordance with standards outlined by the National Committee on Soil and Terrain (2009), Hnatiuk *et al* (2009) and Isbell (1996). Field observations recorded included geology/parent material, landform (pattern and element), slope, relief/modal slope class, substrate lithology, site disturbance, erosion, microrelief, surface rock, surface condition, dominant vegetation (tallest, mid and lower strata where important) detailed soil profile morphology, site drainage and permeability characteristics. Field assessment of soil profile morphology included description of soil horizons, boundaries, texture, colour, mottling, bleaching, structure, consistence, gravel, segregations and substrate material (where present); as well as field assessment of sodicity, dispersive behaviour and pH.

Soil profiles were examined and described from 75mm intact (or augered soil cores where access was limited) to a depth of 1.5m; or to depth of hard rock or impenetrable gravel where shallower. Soil cores were described in detail and sampled in the field. Representative sites for subsequent laboratory analysis to determine physical and chemical characteristics were selected post fieldwork. Where gilgai were present, mounds were preferentially described and sampled because of their potentially larger relative contribution to final stripping volumes and typically shallower depth to saline/sodic subsoil materials. Previous work in Central Queensland has shown conclusively that subsoil constraints such as inherent salinity, elevated sodicity and undesirable dispersive behaviour are far more limiting and at shallower depths in mound profiles (Burgess 2003a, 2003b). Investigation of mound characteristics is critical therefore to successfully determine potential stripping reserves.

Sampling program

Sampling of surface soil and subsoil materials at standard depth intervals (0-0.1m, 0.25-0.35m, 0.55-0.65m, 0.85-0.95m and 1.15-1.25m, plus selected intermediate depths where required) was undertaken during the course of field investigations at all detailed field sites. Following the completion of fieldwork and finalization of mapping units, at least one representative site from all spatially dominant soil landscapes was selected for laboratory analysis. In all, 85 sample depths from 17 representative field sites were submitted for analysis (BNCOP field sites – 27, 29, 30, 36, 38, 40, 43, 65, 66, 69, 71, 74, 87, 88, 90, 99 and 110). All sites were sampled at 0.1m increments to a maximum depth of 1.25m (or depth to hard rock or other impenetrable layer where shallower). Sample depths selected for analysis at each representative site were chosen to characterize the range of materials present within the profile. Sampling intervals were correlated with soil profile

descriptions and altered where necessary to allow for thin surface horizons (if important) and to ensure sampling depths did not compromise major subsoil horizon boundaries (Baker and Eldershaw 1993).

Laboratory analyses

In any soil investigation, laboratory analyses are required to reliably quantify the quality of topsoil and subsoil materials for salvage, establish the depth and nature of unsalvageable materials and to calculate soil parameters/attribute values required for pre-mining land suitability, SCL and erosion potential assessments. As such, a range of physical and chemical laboratory analyses were undertaken on surface and subsoil samples from each representative site. Analytical data collected at selected depths within each profile included pH, electrical conductivity (EC), soluble chloride (Cl), cation exchange capacity (CEC), exchangeable cations (Ca, Mg, Na, K), exchangeable sodium percentage (ESP), dispersive behaviour (R1), particle size analysis (clay, silt and sand fractions), clay mineralogy/clay activity and fine sand/silt fractions (%). In addition, surface soil fertility (Total Nitrogen (%), Available Phosphorous (ppm), Exchangeable Calcium (meq/100g) and Exchangeable Potassium (meq/100g)) was measured from bulk 0-0.1m samples at each representative site. A brief explanation of the analyses undertaken and the use and interpretation of the data is presented in **Table 1**.

Prior to sample submission for representative characterization and specific SCL analyses, laboratory pH $_{1:5}$ and EC $_{1:5}$ measurements were undertaken on samples at standard depth intervals (0.1m, 0.3m, 0.6m, 0.9m and 1.2m plus selected intermediate depths where required) from all 113 field sites to provide a low cost, comprehensive set of screening data with a spatial distribution spanning the entire 2013 BNCOP Soil Investigation survey area. Salt profiles generated from $EC_{1:5}$ measurements provide valuable information about leaching characteristics and subsoil salt loads across the landscape, and are particularly useful when determining effective rooting depth (ERD) or formulating practical stripping depths that are spatially relevant. $pH_{1:5}$ and EC $_{1:5}$ results for all sites and depths are presented in **Appendix 2**. Effective rooting depth (ERD) and plant available water capacity (PAWC) estimates are presented for soils mapped within the BNCOP Disturbance Footprint in **Appendix 3.** These estimates use a combination of salinity screening data and morphological field data (horizon depths and field texture ranges) in their calculation (DNRM 2011d, Queensland Government 2011).

Using pH and EC screening data to guide sample selection, a total of 17 representative sites (27, 29, 30, 36, 38, 40, 43, 65, 66, 69, 71, 74, 87, 88, 90, 99 and 110) were selected for full laboratory characterization and samples from depth ranges corresponding to surface soil (0-0.1m), upper subsoil (0.25-0.35m and 0.55-0.65m) and lower subsoil/substrate where present (0.85-0.95m ± 1.15-1.25m) were submitted for analysis. Standard depths were sampled to enable direct comparison of analytical results between sites. All samples were air dried at 40^0 C and ground and sieved to <2mm prior to analysis. All analytical results are expressed on an air dry basis unless otherwise indicated.

All laboratory analyses (ph, EC, Cl, CEC/cations, ESP, PSA, R1 dispersion, Organic C, Total N, Bicarb. P, Exch. Ca and Exch. K) performed on samples from the 17 representative sites were undertaken by the Agricultural Chemistry Pty Ltd Laboratory in Ipswich, near Brisbane. This is an ASPAC accredited laboratory with extensive experience in agricultural soil and water testing for government and industry. Methodologies used by this laboratory are outlined in **Table 1** and **Appendix 4** and follow the procedures described by Rayment and Lyons (2011) and McKenzie *et al* (2002). Detailed descriptions of the methods are available from the ACLEP laboratory handbooks *Soil Chemical Methods - Australasia* (Rayment and Lyons 2011) and *Soil Physical Measurement and Interpretation for Land Evaluation* (McKenzie *et al* 2002). Additional pH $_{1:5}$ and EC $_{1:5}$ analyses completed on samples from all 113 field sites were undertaken by B.R. Emmerton Pty Ltd and follow

the procedures described for Standard Methods 4A1 and 3A1 in Rayment and Lyons (2011). Interpreted analyses from selected depths have been correlated with recorded soil horizons at each site to quantify the characteristics, depth and thickness of surface soil and subsoil/substrate materials present in each soil. Completed analytical data for all representative sites and depths are presented in **Appendix 5**. Field data recorded at each of the 17 representative sites (particularly horizon depths and nomenclature, field texture, bolus behaviour and structure), is presented in **Appendix 6**. Assessment criteria defined by Baker and Eldershaw (1993), Bruce and Rayment (1982), Peverill *et al* (1999), Burgess (2003a, 2003b) and QDME (1995) have been used to rate the analytical data collected during the investigation.

SCL Zonal Criteria within the Western Cropping Zone (WCZ) require sampling and analysis of 0.3m and 0.6m depth intervals for **$pH_{1:5}$** and **soluble Cl (ppm)** at all detailed field sites within areas triggered for SCL assessment. Sites sampled and analysed from triggered lands within the BNCOP Disturbance Footprint include Sites 65, 66, 67, 68, 69, 70, 71, 72, 73, 74 and 75. The data is requirement of the legislation and is necessary to satisfy regulatory provisions associated with compliance for WCZ Zonal Criteria 6 and 7.

Table 1. Explanation of laboratory analyses undertaken on surface soil and subsoil samples from representative sites

Laboratory analyses	Use and interpretation of data
Cation chemistry	
Cation Exchange Capacity (CEC/ECEC meq/100g)	• CEC is a measure of a soils capacity to retain cations based on the surface area and surface charge of the clay fraction. Influences physical and chemical properties particularly in the clay subsoil
Exchangeable Calcium (meq/100g)	• Measure of the amount of Ca on the clay exchange complex
Exchangeable Magnesium (meq/100g)	• Measure of the amount of Mg on the clay exchange complex
Exchangeable Sodium (meq/100g)	• Measure of the amount of Na on the clay exchange complex
Exchangeable Potassium (meq/100g)	• Measure of the amount of K on the clay exchange complex
Ca/Mg ratio	• Measure of the relative dominance of magnesium, useful in explaining soil physical behaviour
Clay Activity Ratio (CEC/clay %)	• Used to infer clay mineralogy and reactivity of the clay fraction.
Sodicity and dispersion	
Exchangeable sodium % (ESP)	• Measure of soil sodicity, which affects the physical behaviour (permeability/density/strength) and dispersive nature of soils. ESP measures the relative abundance of Na on the exchange complex
Dispersion ratio (R1)	• Measure of soil dispersion based on the amount of dispersed silt and clay during testing compared with total silt and clay levels
pH and salinity	
pH (1:5 soil/water)	• Measure of the acidity or alkalinity of soil material
Electrical Conductivity (EC)(1:5 soil/water)	• Estimate of the concentration of total soluble salts in the soil solution
Soluble Chloride (Cl) (mg/kg)	• Measure of the level of soluble Cl in the soil solution. Provides a direct estimate of the soluble NaCl salt concentration in the soil solution.
Particle size analysis (PSA)	
% Coarse sand (0.2 - 2mm)	• Visible sand range, open pore spaces, friable, permeable
% Fine sand (0.02 – 0.2mm)	• Non-visible sand, causes packing, increased density, intractable, “bulldust”, hardsetting, erodible
% Silt (0.002 - 0.02mm)	• Causes increased packing and density, highly erosive fraction, surface sealing, intractable, dilatancy, “bulldust”, hardsetting
% Clay (< 0.002mm)	• Colloidal fraction, determines CEC, moisture holding capacity, shrink-swell characteristics, soil structure and cracking behaviour
Surface soil fertility	
Organic Carbon (%C)	• Provides an estimate of the total store of carbon (C) in the surface soil and can be used in surrogate calculations to estimate organic matter (OM%)
Total nitrogen (%N)	• Provides an estimate of the total store of nitrogen (N) in the surface soil that can potentially be mineralised
Bicarbonate extractable phosphorus (mg/kg P)	• Provides a reliable and consistent estimate of plant available phosphorus (P) in the surface soil across a range of pH conditions
Exchangeable Calcium (meq/100g Ca)	• Provides an estimate of the relative abundance of potentially available calcium (Ca/CEC %) within the fine earth fraction in the surface soil
Exchangeable Potassium (meq/100g K)	• Provides an estimate of the relative abundance of potentially available potassium (K/CEC %) within the fine earth fraction in the surface soil

Topsoil stripping assessment

Multi stage stripping and replacement is widely recognized as best management practice for the salvage and reuse of soil/rehabilitation media from areas of mining disturbance. Accordingly, stripping recommendations from the current investigation are presented on a two stage preferred basis. For the purposes of this report, surface materials to be stripped during a two stage process will be referred to as **topsoil**, while additional subsoil resources that may be suitable for salvage will be referred to as **root zone material**.

In practice, two stage stripping involves the removal and subsequent reinstatement of the most biologically active topsoil material separately from the underlying root zone material. Two stage removal and replacement is recommended because it better mimics natural soil systems, minimizes the surface presentation of detrimental or unmanageable materials, optimizes surface physical conditions and enhances the utilization of natural seed sources that may be present.

It is recognized however, that **single stage stripping,** which involves the salvage of maximum quantities of useable soil material, irrespective of its source depth, is often the preferred stripping methodology for many mines. As such, recommendations for single stage stripping outlining one off salvage depths for the retrieval of all useable materials are also presented. It is important to note, that single stage stripping by its very nature will result in greater mixing of discordant materials and a dilution of soil quality. When compared with two stage reinstatement, single stage material will be subject to slower infiltration and higher runoff rates, with plant establishment typically slower and less successful overall.

Analytical criteria and ratings used in the evaluation of stripping criteria presented below have been adapted from those reported by Burgess (2003a, 2003b) and Baker and Eldershaw (1993) for the assessment of soil data in inland Central Queensland.

1. Two stage stripping – topsoil material

The following generalized goals apply when determining the suitability of topsoil materials for salvage and subsequent surface reinstatement on reshaped spoil. Suitable **topsoil material** should ideally conform to most, if not all, of the following characteristics:

- represent that part of the natural soil profile with maximum biological activity and seed source potential (i.e. immediate surface soil);
- have a particle size distribution that is dominated either by the coarse sand fraction or alternatively an active clay fraction; preferably with limited fine sand and/or silt fractions;
- have a pH range appropriate for plant growth;
- be characterized by non-sodic/non-dispersive physical behaviour (particularly clays); and
- have very low levels of soluble salts.

Materials conforming to these general principles would typically be considered appropriate for salvage as topsoil during two stage stripping operations. In cases where materials are suitable except for elevated fine sand/silt fractions, salvage may still be possible but reinstatement will be restricted to very low slope angles because of increased runoff and erosion risk.

2. Two stage stripping – root zone material

Generalized goals for determining the suitability of subsoil materials for salvage as **root zone media** differ somewhat. During the two stage stripping process, root zone materials are specifically salvaged for the purpose of constructing a surrogate subsoil cover over reshaped spoil prior to final

topsoiling. Suitable root zone material should ideally conform to most, if not all, of the following characteristics:

- have a particle size distribution that is dominated either by the clay loam fraction or clay fraction; preferably with limited fine sand and/or silt fractions;
- have a pH range appropriate for plant growth;
- have a non-sodic (optimal) to weakly sodic (acceptable) clay fraction;
- be characterized by non-dispersive (optimal) or low to moderately dispersive (acceptable) physical behaviour, particularly where clay materials are being considered for stripping; and
- have very low (optimal) to moderate (acceptable) levels of soluble salts.

Materials conforming to these general principles would typically be considered appropriate for salvage as root zone material during two stage stripping operations. In cases where materials are suitable except for elevated fine sand/silt fractions, salvage may still be possible but reinstatement will be restricted to lower slope angles because of reduced permeability and increased erosion risk.

3. Single stage stripping – topsoil and/or subsoil material

The primary objective with single stage stripping is the one off salvage of maximum volumes of useable material, irrespective of original soil depth or origins (i.e. salvage of all suitable topsoil, subsoil and/or substrate material in one operation). Typically, surface soil and subsoil materials with differing characteristics are not kept segregated and are subject to significant mixing during stripping operations. Because any of the stripped material, whether topsoil or subsoil, can potentially be exposed as final surface cover on reshaped spoil, all materials to be salvaged should have characteristics capable of supporting this use. For these reasons, generalized goals for single stage stripping are similar in many ways to those presented above for topsoil materials under two stage stripping. Materials to be stripped during single stage operations should ideally conform to most, if not all, of the following characteristics:

- have a particle size distribution that is dominated either by the coarse sand fraction or active clay fraction; preferably with limited fine sand and/or silt fractions;
- have a pH range appropriate for plant growth;
- be characterized by non-sodic/non-dispersive physical behaviour, (particularly clays); and
- have very low levels of soluble salts.

Materials conforming to these general principles would typically be considered appropriate for salvage during single stage stripping. In cases where materials are suitable except for elevated fine sand/silt fractions, salvage may still be possible but reinstatement will be restricted to very low slope angles because of increased runoff and erosion risk.

Whilst these goals provide a useful framework for selecting soil materials for salvage, the reality in many situations is that the only available resources are inferior with behavioural characteristics that are less than optimal. In such cases, relaxation of stripping guidelines may be necessary to ensure quantities of salvaged topsoil and root zone media are sufficient to service the mines rehabilitation requirements. Careful identification of the limitations and undesirable attributes associated with inferior soil resources is essential however, to ensure only the most appropriate media are selected, and that such materials are used in accordance with their capability (i.e., capable of sustaining the end use to which they are put).

Pre-mining land suitability assessment

Pre-mining land suitability for soils within the BNCOP Disturbance Footprint has been assessed for dryland cropping and grazing (the dominant existing land uses in the local area) to establish a record of the agricultural potential of the land prior to disturbance or development. The assessment has utilised spatially accurate mapping (1:25000) and detailed soil attribute data, and follows the suitability methodology defined by the Queensland Government (DNRM/DSITIA 2013a, 2013b), in accordance with the requirements of the BNCOP Terms of Reference. All explanation, terminology and abbreviations used in the land suitability assessments presented come directly from or are consistent with QDME (1995), Isbell (1996), McKenzie *et al* (2002), Mckenzie *et al* (2008), the NCST (2009), Rayment and Lyons (2011), DNRM (2011d) and DNRM/DSITIA (2013a, 2013b).

Land suitability assessment for dryland cropping within the BNCOP Disturbance Footprint follows the framework, methodology, criteria and decision rules (without change or addition) described in the documents:

- *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition (2013a). DNRM/DSITIA, Queensland Government, Brisbane, Queensland; and
- *Regional Land Suitability Frameworks for Queensland*, *Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area* (2013b). DNRM/DSITIA, Queensland Government, Brisbane, Queensland.

Whilst the framework itself has not been reproduced as part of this report the dryland cropping suitability assessment tables presented later in this document provide a clear record of the limitations, attributes and subclass rules used in the assessment.

Land suitability assessment for grazing within the BNCOP Disturbance Footprint follows the framework, methodology, criteria and decision rules (without change or addition) described in the document:

- *Technical guidelines for Environmental Management of Exploration and Mining in Queensland* (1995). Queensland Department of Mines and Energy (QDME), Brisbane, Queensland.

The limitations, attribute values and suitability subclass rules for grazing suitability presented originally in "A*ttachment 2*" from the "*Land Suitability Assessment Techniques*" section within the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland"* (QDME 1995) are reproduced without change or addition in **Appendix 8** of this report.

Both suitability frameworks present limitations, attribute values and subclass rules appropriate for assessing the agricultural potential (either dryland cropping or grazing) of lands within inland Central Queensland. The schemes use a standard land suitability framework (DNRM/DSITIA 2013a) with a common set of attributes/limitations, but separate decision rules for each land use.

Five land suitability classes are defined for use in Queensland (DNRM/DSITIA 2013a), with land suitability decreasing progressively from Class 1 to Class 5. These classes are used to describe an area of land in terms of suitability for a particular land use which allows optimum, sustainable production with current technology, while minimising degradation to the land resource in the short, medium or long-term. Land is considered less suitable as the severity of limitations affecting a particular land use increases, reflecting either:

- reduced potential for production and/or;
- increased inputs required to achieve an acceptable level of production and/or;
- increased inputs required to prepare the land for successful production and/or;
- increased inputs required to prevent land degradation.

The five land suitability classes defined for Queensland are:

Class 1 **Suitable land with negligible limitations.** This is highly productive land requiring only simple management practices to maintain economic production.

Class 2 **Suitable land with minor limitations** which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.

Class 3 **Suitable land with moderate limitations** which either further lower production or require more than the management practices of Class 2 land to maintain economic production.

Class 4 **Marginal land, which is presently considered unsuitable due to severe limitations**. The long term significance of these limitations on the proposed land use is either unknown or currently not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.

Class 5 **Unsuitable land with extreme limitations** that preclude its use.

Classes 1, 2 and 3 are considered suitable for a specified land use, as the benefits from using the land for that use in the long term should outweigh the inputs required to initiate and maintain production. **Class 4 land is regarded as marginal (currently unsuitable)** for a specified land use, due to the severity of one or a number of limiting factors. It is probable that the inputs required to achieve and maintain production in the long-term will outweigh the benefits. Class 4 land may sometimes be upgraded to a suitable class in cases where future agronomic, soil or engineering advances make production economically viable and environmentally sustainable. Changes in climate, economic conditions, or technology may significantly alter the level of management inputs required to achieve satisfactory productivity on Class 4 lands.

Class 5 land is regarded as unsuitable for a specified land use because it has limitations that singularly or in aggregate are so severe that the benefits would not justify the inputs required to initiate and maintain sustainable production in the long term. It would require a major change in economics, technology or management expertise before Class 5 land could be considered suitable. However, some Class 5 land such as mountains, deeply incised landscapes and steep escarpments, will always remain unsuitable for agriculture.

DNRM/DSITIA (2013a) have defined a set of Queensland wide land use requirements for dryland cropping, that relate to plant growth, machinery use, land preparation, irrigation and the prevention of land degradation (where relevant); while QDME (1995) have defined a similar set for grazing. To assess the suitability of any parcel of land for a particular land use, it is necessary that each of the relevant land use requirements be considered. Attributes of land which cause the specified land to have less than optimal conditions for a particular use are known as limitations. Management is concerned with overcoming or reducing the effects of such limitations.

In inland Central Queensland, where dryland cropping and grazing are the predominant land uses, a total of 8 land use requirements and associated limitations (E, Es, M, Pm, Ps, R, Tm, W) have been identified as important for dryland cropping by the Inland Fitzroy - South Burdekin Region suitability framework (DNRM/DSITIA 2013b); while for grazing QDME (1995) recognises a total of 13 land use requirements and associated limitations (E, M, Ps, R, Tm, W, Nd, Sa, Tg, F, V, pH, ESP). A brief outline of the combined dryland cropping and grazing requirements and associated limitations relevant to inland Central Queensland are listed below.

Land use requirements		Limitations	Soil and land attributes used to assess each limitation
1.	Minimum soil loss from erosion	water erosion (E)	slope/surface soil stability group combinations
2.	Minimum soil loss from erosion	erosion hazard (Es) - subsoil erodibility	slope/subsoil stability group combinations
3.	Adequate water supply	water availability (M)	PAWC, ERD (including effects of subsoil sodicity and inherent salinity), deep drainage losses, infiltration rate, crop modelling
4.	Soil workability, suitable timing for cultivation	narrow moisture range (Pm)	surface condition, surface soil texture, surface soil drainage
3.	Ease of seedbed preparation and plant establishment	surface condition (Ps)	surface soil structure, surface condition, surface soil texture
6.	Rock-free	rockiness (R)	size and content (%) of coarse fragments, % rock outcrop
7.	Level land surface	microrelief (Tm)	size and frequency of microrelief, % land surface
8.	Adequate soil aeration	wetness (W)	field based soil drainage and permeability classes
9.	Adequate nutrient supply	nutrient deficiency (Nd)	surface soil (0.1m) levels of Bicarb P (ppm), vegetation surrogate for Total N (%)
10.	Salinity free root zone	root zone salinity (Sa)	average salinity within the root zone (ERD)
11.	Trafficable, stable land surface	topography (Tg)	size, depth and frequency of gullies
12.	Absence of damaging floods	flooding (F)	frequency of flooding based on average recurrence interval (ARI)
13.	Absence of undesirable vegetation	vegetation (V)	vegetation type, regrowth potential, potential for shrubby thickening, soil fertility
14.	Non limiting surface soil pH	surface soil pH (pH)	surface soil pH suitable for pasture growth (4.5-9.0)
15.	Absence of surface soil dispersion	surface soil dispersive potential (ESP)	surface soil ESP <15

The **suitability classification defined by DNRM/DSITIA (2013b) for dryland cropping** evaluates the potential of land to grow a range of broadacre summer and/or winter crops (predominantly sorghum, wheat and other equivalent broadacre crops) under rainfed conditions within the Inland Fitzroy and Southern Burdekin Region. It assesses soil and land based limitations that may impact on production and assigns a final suitability class based on the most limiting factor. For the purposes of the classification, dryland cropping in inland Central Queensland is defined as summer or winter cropping that is fallow dependent, subject to highly variable/unreliable seasonal rainfall (particularly for planting opportunities) and is grown almost entirely on stored moisture. Cropping systems are largely opportunistic and the actual crops planted are dependent upon the timing and variability of rainfall, as well as previous cropping history and fallow management. The limitations, associated soil and land attributes and limitation subclasses used in the assessment of dryland cropping suitability in this investigation have been implemented (without change or addition) directly from the published DNRM/DSITIA (2013b) framework for the Inland Fitzroy and Southern Burdekin Region.

The **suitability classification defined by QDME (1995) for grazing** evaluates soils in terms of the potential to graze and finish cattle on improved pastures. It assesses a range of soil or land based limitations that either affect the establishment of improved pastures or impact directly on the grazing productivity of the land (predominantly soil fertility based). Typically, grazing systems in inland Central Queensland aim to produce finished, grassfed cattle, without inputs other than pasture development. The limitations, associated soil and land attributes and limitation subclasses used in the assessment of grazing suitability in this investigation have been implemented (without change or addition) directly from the published QDME (1995) framework for Central Queensland.

It is important to note that the QDME scheme (1995) specifies a maximum ERD (in the absence of rock or salinity >800ppm Cl) of 0.6m for pasture growth in grazing situations. However, PAWC sub-class values for the assessment of moisture availability in grazing situations (described in Table 2.2 of the original QDME (1995) scheme) are presented on a per 1.0m soil basis. Sub-class cut-offs and moisture availability ranges have been re-calculated on a 0.6m basis and adjusted accordingly. As a result, PAWC cut-off values used to rate moisture availability for grazing suitability of individual soils in the current study represent only 60% of those originally presented (i.e. on a 1.0m soil depth basis in Table 2.2 of the QDME (1995) scheme).

Pre-mining Agricultural Land Class (ALC) assessment

Agricultural Land Class status (ALC) has been assessed using ALC criteria and rules relevant to Central Queensland as defined by:

- *State Planning Policy 1/92: Development and the Conservation of Agricultural Land.* (1992). Queensland Government, Brisbane, Queensland;
- *Planning Guidelines: The identification of Good Quality Agricultural Land* (1993). Department of Primary Industries and Department of Housing and Local Government and Planning, Brisbane, Queensland; and the
- *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition (2013a). DNRM/DSITIA, Queensland Government, Brisbane, Queensland.

Agricultural Land Classification (ALC) in Queensland has recently been revised (DNRM/DSITIA 2013a) and now follows a simple, consistent hierarchical scheme that is applicable across the State. Adoption of the new classification allows the standardized re-interpretation of complex and detailed land suitability data to more simply identify agricultural land that is capable of being used sustainably for a wide range of uses with a minimum of land degradation. As such, it provides a concise and meaningful statement about the status and extent of recognised Agricultural Land prior to disturbance.

Three classes of agricultural land and one class of non-agricultural land are defined for Queensland (DNRM/DSITIA 2013a):

- Class A – Crop land;
- Class B – Limited crop land;
- Class C – Pasture land; and
- Class D – Non-agricultural land.

The classes indicate a decreasing range of land use choice, an increasing level of land use limitations and an increasing land degradation hazard. The classification is hierarchical, with crop land having the greatest potential for the production of the widest array of produce through to non-agricultural land which is unsuitable for any type of agricultural pursuit. Definition of Agricultural Land Classes A, B, C and D as described by DNRM/DSITIA (2013a) are summarised below:

Agricultural Land Class (ALC)	Definition and description
Class A – Crop Land	• Land that is suitable for a wide range of current and potential crops with nil to moderate limitations to production.
Sub-class – A1	• Land that is suitable for a wide range[1] of current and potential broadacre and horticulture crops with limitations to production that range from none to moderate levels.
Sub-class – A2	• Land that is suitable for a wide range of current and potential horticultural crops only, with limitations to production that range from none to moderate levels.
Class B – Limited Crop Land	• Land that is suitable for a narrow range[2] of current and potential crops. Land that is marginal for current and potential crops due to severe limitations, but is suitable for pastures. Land may be suitable for cropping with engineering and/or agronomic improvements.
Class C – Pasture Land	• Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
Sub-class – C1	• Suitable for grazing sown pastures (with ground disturbance for establishment); or native pastures on higher fertility soils.

Agricultural Land Class (ALC)	Definition and description
Sub-class – C2	• Suitable for grazing native pastures with or without the introduction of pasture species; lower fertility soils than C1.
Sub-class – C3	• Suitable for light grazing of native pastures in accessible areas; includes steep land more suited to forestry/catchment protection.
Class D – Non-Agricultural Land	• Land not suitable for agricultural uses due to extreme limitations. Includes undisturbed land with significant conservation and/or catchment values; or land that is unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity, acidity or severe degradation; also includes stream beds, channels, water bodies and disturbed lands (e.g. urbanised, industrial, mining voids, quarries, aquaculture and feedlots).

Note 1. A wide range of crops is defined as four or more existing crops of local commercial significance. In areas where there is an infrastructure requirement to support an industry, the land need only be suitable for two or more crops, providing the crop is considered to be a regionally significant crop.
Note 2. A narrow range of crops is defined as three or less existing crops of local commercial significance, with the exception of areas where there is an infrastructure requirement to support an industry.

Class A – Crop Land (DNRM/DSITIA 2013a) is defined as any soil for which the number of suitable crops (i.e. suitability classes 1, 2 and 3) exceeds 4 or more. Further sub-division of Class A to distinguish between broadacre cropping (Class A1 – Crop Land) and horticultural cropping (Class A2 – Crop land) has not been required within the BNCOP Disturbance Footprint because horticultural production is not practised in the Baralaba area.

Soils that are suitable for 3 or less crops, or have been assessed as marginal for dryland cropping (Class 4), are classified as **Class B – Limited Crop Land** (DNRM/DSITIA 2013a); except in cases where a crop of regional significance with specific infrastructure requirements is locally important. No crops of regional significance are relevant to lands within the BNCOP Disturbance Footprint.

Class C – Pasture Land is defined in terms of grazing suitability outcomes and 3 pasture land sub-divisions are recognised that reflect differences in inherent fertility, pasture type and carrying capacity (DNRM/DSITIA 2013a); namely

- Class C1 – Pasture Land which is suitable for beef cattle fattening and/or growing out younger cattle (grazing suitability Classes 1-3);
- Class C2 – Pasture Land which is suitable for year round breeding herd utilization (grazing suitability Class 4); and
- Class C3 – Pasture Land which is restricted to seasonal grazing use, limited geographical access or capable of only very low stocking rates (grazing suitability Class 5).

Class D non-agricultural land is defined as undisturbed land with significant conservation and/or catchment values and includes land too steep, rocky, wet, flooded or degraded to be used for any agricultural purpose. Class D land has not been identified within the BNCOP Disturbance Footprint.

Assessment of ALC status within the BNCOP Disturbance Footprint has utilised the detailed land suitability findings for dryland cropping and grazing presented in this investigation. ALC assessment follows the methodology and conventions prescribed by DNRM/DSITIA (2013a), without change or addition, and provides an accurate and succinct summary as to the pre-mining agricultural potential of lands present within the project area prior to disturbance. ALC outcomes for the BNCOP Disturbance footprint are presented later in this report. Findings for the already approved Baralaba/Wonbindi North Mine Lease (ML80169 and ML80170) have been previously presented by NQSA (2011a) and are not re-presented or discussed as part of this report.

Strategic Cropping Land (SCL) assessment

Within the wider 2013 BNCOP Soil Investigation survey area only those parts intersected by both the BNCOP EIS Operational Area boundary and the state wide Strategic Cropping Land (SCL) trigger mapping (DNRM 2011a) are triggered for SCL assessment. Triggered areas that lie within the western section of the BNCOP EIS Operational Area (i.e. already approved Baralaba/Wonbindi North Mine Lease – ML80169 and ML80170) have been previously mapped and assessed by NQSA (2011a, 2011b). Findings from these studies have been the subject of previous SCL mitigation and they are not considered further or re-presented as part of this report. Only triggered land within the BNCOP Disturbance Footprint, lying to the east of (but adjacent to) the previously mitigated lands within ML80169 and ML80170, has been assessed for SCL status during the current investigation.

Strategic Cropping Land (SCL) data collection methodology

The SCL analysis presented in this report has used detailed soil profile data, representative analytical data and large scale soil mapping (1:25000 scale) collected in accordance with recognized standard land resource survey methodologies and analytical procedures (Isbell 1996; McKenzie *et al* 2002; McKenzie *et al* 2008; National Committee on Soil and Terrain 2009 and Rayment and Lyons 2011). In addition, all recorded field data, measured analytical data and calculated parameters for triggered lands have been collected in accordance with the procedures prescribed by DNRM for SCL assessment as at December 2013 (DNRM 2011b, DNRM 2011d, Queensland Government 2011) and are consistent with all necessary data requirements.

It is important to note that field site and sampling locations selected during 2013 fieldwork were carefully chosen to best represent the soil landscapes being investigated within the BNCOP Disturbance Footprint. While SCL Zonal Criteria, guidelines and legislation were taken into consideration during this process, final field site selection was based predominantly on aerial photo-interpretation, DEM characteristics, mapping scale, site intensity requirements and on-ground variability. In addition to prescribed SCL data requirements, site selection and sampling regimes focused on characterization of soil attributes that would inform stripping recommendations, land suitability evaluations and inherent erosion potential assessments (both inside and outside of the triggered land).

As such, sites did not specifically target the presence or absence of flatter landscapes ≤3% (SCL Zonal Criteria 1), localised surface rockiness (SCL Zonal Criteria 2) or gilgai microrelief (SCL Zonal Criteria 3). Site locations were selected in all cases to be as representative as possible of the soils and landscapes being mapped, while still addressing the necessary data requirements listed in the BNCOP EIS Operational Area Terms of Reference. As a result, soil data relevant to SCL assessment within the BNCOP Disturbance Footprint in some cases, comes from sites that are located nearby or adjacent to (but effectively outside) areas of mapped SCL potential. Irrespective, it is the contention of this report that the scale, robustness and integrity of the baseline soil investigation means that all data collected and presented is entirely consistent with and relevant to the prescribed requirements for SCL assessment in Queensland, and should be considered both representative and appropriate for such purposes.

All field, laboratory and assessment methodologies employed during the study were in accordance with recognized industry standards. In addition, they meet the requirements for assessment of Strategic Cropping Land (SCL) status as defined by the *Strategic Cropping Land Act 2011* (Queensland Government 2011); and also all methodology/data provisions articulated in the BNCOP Operational Area EIS Terms of Reference. Compliance with all the requisite methodologies listed has ensured collection and documentation of the information and findings used to assess SCL status within the BNCOP Disturbance Footprint are robust and in accordance with expected

outcomes for contemporary SCL assessment in Queensland. Relevant morphological and analytical soil profile data used in SCL calculations and criteria compliance assessments are presented in full in **Appendices 2-7** and summarised in the **Soil Characterization Section** of this report.

Strategic Cropping Land (SCL) zone and trigger mapping status

The BNCOP Disturbance Footprint (excluding ML80169 and ML80170) lies within the **Western Cropping Zone (WCZ)** of the **Strategic Cropping Management Area** (DNRM 2011a, DNRM 2011c). SCL trigger mapping from the DNRM website 2013 (DNRM 2011a) has been used to identify areas of 'likely' (or potential) SCL that will be triggered by the project. The ***Strategic Cropping Land Act 2011*** (Queensland Government 2011), requires any such triggered areas be assessed for relevant Cropping History (Queensland Government 2011, DNRM 2012), and also against WCZ SCL Zonal Criteria 1-8 before final SCL status can be determined.

Strategic Cropping Land (SCL) assessment process

SCL assessment for triggered land within the BNCOP Disturbance Footprint has involved the following steps:

1. Identification of SCL zone and relevant Zonal Criteria relating to the BNCOP Disturbance Footprint;
2. Identification of the spatial extent of 'likely' SCL within the BNCOP Disturbance Footprint from currently available trigger mapping (DNRM 2011a);
3. Assessment of cropping history for any triggered properties within the BNCOP Disturbance Footprint as prescribed by DNRM (2012);
4. Delineation of triggered areas complying with Zonal Criteria 1 (slope ≤3%) following DEM based spatial analysis;
5. Identification of mapped soil types within Zonal Criteria 1 compliant areas (slope ≤3%);
6. Collection of relevant representative morphological and analytical data for each soil in accordance with the requirements of the *Strategic Cropping Land Act 2011* (Queensland Government 2011);
7. Collation and analysis of relevant data against Zonal Criteria 2-7 for all mapped soils within triggered lands;
8. Determination of effective rooting depth (ERD) for all mapped soils within triggered lands, based on the soil depth and physico-chemical limitation criteria specified in Section 4.82 of the SCL Guidelines (DNRM 2011d) as at December 2013;
9. Assessment soil water status for all mapped soils within triggered lands, based on the procedure outlined in Section 4.8.3 of the SCL Guidelines (DNRM 2011d) as at December 2013;
10. Assessment of relevant data and calculated parameters for each soil against Zonal Criteria 8;
11. Spatial presentation of SCL Zonal Criteria compliance outcomes using sequential images to display eligible soil areas as each Zonal Criteria is addressed;
12. Assessment of SCL Zonal Criteria compliant land parcels against SCL minimum size requirements for the Western Cropping Zone;
13. Identification of decided SCL land parcels within the BNCOP Disturbance footprint (i.e. soil parcels that satisfy cropping history, Zonal Criteria 1-8 and minimum size requirements);
14. Identification of decided non-SCL land parcels within the BNCOP Disturbance footprint (i.e. soil parcels that do not satisfy cropping history, Zonal Criteria 1-8 or minimum size requirements).

Cropping History Assessment

The *Strategic Cropping Land Act 2011* (Queensland Government 2011) requires SCL Zonal Criteria compliant land within the Western Cropping Zone meet required cropping history criteria before SCL status can be decided. **Section 49** of the ***Strategic Cropping Land Act 2011*** (Queensland Government 2011) defines required cropping history as 3 or more cropping events having occurred on a property in the 12 year period between 1 January 1999 and 31 December 2010. Spatial examination of natural colour Landsat imagery between the years 1999 and 2010 has been used to establish the presence and frequency of cropping events within any triggered properties.

SCL WCZ Zonal Criteria Assessment

Assessment of SCL Zonal Criteria compliance (or non-compliance) for triggered land within the BNCOP Disturbance Footprint has required assessment against SCL Zonal Criteria 1-8 as defined for the **Western Cropping Zone** of the **Strategic Cropping Management Area** (DNRM 2011d, Queensland Government 2011). Representative analytical data designed to satisfy Zonal Criteria data requirements is presented in **Appendix 5** for all triggered soils within the BNCOP Disturbance Footprint. The analytical data is also summarized and further discussed in the **Soil Characterization Section** of this report. Field morphology descriptions for all detailed field sites within triggered portions of the BNCOP Disturbance Footprint are presented in **Appendix 7.**

SCL Minimum Size Requirements

The *Strategic Cropping Land Act 2011* (Queensland Government 2011) requires SCL Zonal Criteria compliant land within the Western Cropping Zone meet minimum size requirements before SCL status can be decided. Prior to any decision, the Act requires criteria compliant polygons be >100ha in extent, at least 80m wide, and where <100ha be contiguous with decided SCL or potential SCL (either internal to or external to the triggered area) to ensure a collective SCL extent >100ha (DNRM 2011d, Queensland Government 2011). As such, criteria compliant lands within triggered portions of the BNCOP Disturbance Footprint were assessed against minimum size criteria prior to final determination of the decided SCL and decided non-SCL extents.

Inherent erosion potential assessment

Inherent erosion potential (following insitu disturbance) has been assessed for soils within the BNCOP Disturbance Footprint (excluding ML80169 and ML80170), based on a range of surrogate soil characteristics thought to contribute to or influence surface erodibility (rill and gully erosion) and predisposition to tunnelling. The assessment qualitatively ranks soils in terms of inherent erosion potential and likely behaviour following insitu disturbance, and is based on the soil erodibility classes and criteria of Murphy (1984) and Charman and Murphy (2007). It considers only susceptibility to longer term post disturbance gully and tunnel erosion and does not evaluate short term sheet erosion losses that are common immediately after insitu disturbance and prior to and during rehabilitation works.

The original scheme presented by Charman and Murphy (2007) uses a range of inherent field and laboratory measured soil characteristics, particularly clay content, sand content, soil density, clay dispersion and degree of aggregation and cracking, to infer and rank relative rill, gully and/or tunnel erodibility hazard. As such, the assessment provides an estimate of insitu post disturbance erosion potential based on soil characteristics as described and sampled prior to disturbance.

The original methodology, soil data attributes, criteria and decision rules described by Charman and Murphy (2007) have been adopted in full, but modified slightly (as described below) to better

reflect soil and landscape characteristics (and associated erosive behaviour) typically experienced in Central Queensland. Three classes of inherent erosion hazard (low, moderate and high) were originally proposed by Charman and Murphy (2007), but this has been expanded to include a fourth very high category to cover soils with extremely sodic and dispersive subsoils, that are relatively common within Central Queensland (when compared with NSW). Whilst some explanation of the intent and scope of the methodology originally proposed by Charman and Murphy (2007) has been presented in this report, it is not in the scope of the current document to fully describe the rationale and reasoning behind the original scheme. The reader is directed to the source documents by Murphy (1984) and Charman and Murphy (2007) for greater detail.

The **four categories used to assess inherent erosion potential within the BNCOP Disturbance Footprint** are described below. It is important to note that assessments do not take into account external parameters such as topography, catchment area, gradient, slope length and a range of surface management factors. Spatial or temporal factors such as these directly influence erosion risk (as opposed to hazard) and mitigate erosion potential in some cases and worsen it in others. They are not inherent characteristics of the insitu soils however, and as such have not been considered.

Relevant morphological and analytical soil profile data used in the assessment of inherent erosion potential criteria are presented in **Appendices 2-7** and discussed more fully in the discussion section of this report.

Category 1 – Low erosion hazard

In general, soils in this category (Charman and Murphy 2007) have surface materials that are either:

- very organic (>3% OM); and/or
- very sandy (particularly medium to coarse fractions); or
- very strongly structured, loams/clay loams (not prone to dispersion or slaking); or
- calcium rich, fine, very strongly self-mulching clays (not prone to dispersion or slaking);

while subsoils are either:

- hard cemented layers;
- very sandy materials (particularly medium to coarse fractions); or
- very well structured, calcium dominated non dispersive clays that are stable and do not readily slake; with
- upper and lower subsoil clay fractions that are non-sodic (ESP <6) and non-dispersive (R1 <0.4) throughout.

Soils in this category have only limited potential to develop gully or tunnel erosion under natural conditions, particularly on slopes <5%. This group typically includes soils such as red Ferrosols, deep loose sandy soils, very friable non-sodic Chromosols/Dermosols and highly structured, non-sodic, calcium dominated, highly reactive cracking clays. Erosion features will only develop where significant surface flows are allowed to concentrate on long slope lengths. Where gullies do develop, repair and rehabilitation will often occur naturally either through shrink-swell movement or natural re-battering of gully sidewalls from the accumulation of strongly aggregated scree materials. Works to rehabilitate gullied areas typically only require surface flow diversion and minimal gully reshaping and revegetation for success. Tunnel erosion is not expected to be a significant issue in natural situations (but may occur in poorly compacted earthwork structures that are strongly cracked when dry, and are subject to lateral water flows from upslope water sources/storages).

Category 2 – Moderate erosion hazard

Soils in this category (Charman and Murphy 2007) have surface materials that either have:

- moderate levels of organic matter (1.5-3% OM);
- moderate levels of fine sand and/or silt (40-60% combined); or are
- strongly structured clay loam materials and self mulching clay surface soils that are prone to slaking;

while subsoils are either:

- stable/flocculated, non-dispersive loams/clay loams (often high in sesquioxides, but with variable FS/Z fractions); or
- non-dispersive to weakly dispersive (R10.4-0.6), structured clays that are prone to slaking; with
- subsoil clay fractions that are non-sodic (ESP <6) and non-dispersive (R1 <0.4) in the upper subsoil, but grade to weakly sodic (ESP 6-12) and weakly dispersive (R1 0.4-0.6) in the lower subsoil.

These **s**oils have the potential to develop moderate gully erosion on slopes greater than 3% or where significant surface flows are allowed to concentrate on long slope lengths. Typically soils in this group include red Chromosols and Kandosols with significant fine sand/silt fractions, and a range of well structured Dermosols and self mulching clay soils that are non-dispersive (to weakly dispersive at depth), but are prone to slaking. Soils in this category that lack vertic properties are effectively rigid and less able to accommodate and repair erosion damage in areas of concentrated flow, particularly when compared with the ameliorative abilities common in highly structured, non-sodic, calcium dominated, strongly cracking clays (low erosion hazard). Gully shapes are typically steeper and sidewalls more sheer and prone to collapse. Where gullies do develop, repair and rehabilitation through surface flow diversion, gully reshaping, battering and revegetation will typically be successful. Tunnel erosion is not expected to be a significant issue with these soils in natural situations, (but may occur in poorly compacted earthwork structures that are strongly cracked when dry, and are subject to lateral water flows from upslope water sources/storages).

Category 3 – High erosion hazard

Soils in this category (Charman and Murphy 2007) have surface materials with:

- low to very low levels of organic matter (<0.9-1.5% OM), particularly soils with bleached sub-surface horizons; and/or
- high to very high levels of fine sand and/or silt (>60% combined);

while subsoils are:

- sodic, dispersive clays; with
- upper subsoil clay fractions that are non-sodic to weakly sodic (ESP <6-12) and non-dispersive to weakly dispersive (R1 <0.4-0.6); and grade to
- lower subsoil clay fractions that are moderately to strongly sodic (ESP 12-20) and moderately dispersive (R1 0.6-0.8); or
- unstable, structureless/dispersive sandy loam to sandy clay materials; or
- unstable materials high in fine sand and/or silt (>60% combined), such as unconsolidated sediments and alluvial materials.

Category 4 – Very high erosion hazard

Soils in this category (Charman and Murphy 2007) have similar characteristics to those defined for Category 3 but are characterized by extreme levels of subsoil sodicity and dispersion. Typically, they have surface soils with:

- low to very low levels of organic matter (<0.9-1.5% OM), particularly soils with bleached sub-surface horizons; and/or
- high to very high levels of fine sand and/or silt (>60% combined);

while subsoils are relatively shallow :

- sodic, dispersive clays, typically high in fine sand/silt (>60% combined); with
- upper subsoil clay fractions that are strongly to extremely sodic (ESP 15->20%) and highly to extremely dispersive (R1 0.8-0.99); and
- lower subsoil clay fractions that are extremely sodic (ESP >20%) and extremely dispersive (R1 >0.95) throughout.

Soils in both the high and very high categories essentially have similar characteristics, but the magnitude and speed with which erosion features develop is likely to be far more severe and much more difficult to control and stabilise in the very high category. Soils in both categories have the potential to develop significant gully erosion on slopes greater than 1-2%, particularly where surface flows are allowed to concentrate on long slope lengths.

Soils in the high and very high categories include clays with shrink swell characteristics, as well as a range of rigid soils less able to accommodate and repair erosion damage once it has started. Irrespective of soil type, gully shapes are typically very steep and sidewalls mostly vertical and prone to severe undercutting and gully wall collapse. In addition, alluvial soils in this category (such as Soil 3b within the BNCOP Disturbance Footprint) may experience significant problems associated with disturbance around creek channels, alluvial benches and local creek flats, because of localised channel incision, steep bank slopes and concentrated surface flows.

Where gullies do develop in these materials they are normally difficult to stop or repair, and rehabilitation requires surface flow diversion and significant gully reshaping, battering, lining and revegetation to minimise future exposure of dispersive material. Diversion of surface drainage away from the gully head is essential. Surface erosion and undercutting at the gully head must be stopped and reshaping and battering of sidewalls to very low gradients (<3%) is normally required. Reinstatement of a thick cover of topsoil and successful revegetation are necessary if stabilization of the repaired gully is to occur. Where sodic clay material remains exposed in batters post rehabilitation, surface drainage down batter slopes may initiate lateral gully formation. Wherever subsequent surface erosion re-exposes dispersive subsoil material on reshaped batter walls gully erosion is likely to re-initiate.

Tunnel erosion may also be a significant issue in the sodic, texture contrast soils within the high and very high categories, particularly where infrastructure construction requires significant levelling, cut and fill works or steeply sloping batters within undulating terrain. Water sources above such structures must be removed and surface flows diverted if piping and associated gully formation are to be avoided. Rehabilitation requirements are similar to those described above for gully sidewalls.

5. Geological landscapes

Surficial geology within the 2013 BNCOP Soil Investigation survey area **(**Olgers *et al* 1963, Jell 2013**)** is mapped predominantly as:

- recent alluvium (Qa) associated with the Dawson River and associated tributaries, including the Dawson River anabranch;
- older unconsolidated undifferentiated Tertiary-Quaternary sediments (Cz, TQr) that sit 3-5 m higher in the landscape than the alluvium; and
- unnamed/undifferentiated Tertiary sandstone (Ta, Tm).

Folding in the region has resulted in the presence of a relatively shallow, Permian sedimentary rock basement immediately below the surficial sediments. Two Permian sedimentary geological units are mapped, namely the Baralaba Coal Measures (Pwj - sandstone, siltstone, mudstone, coal, conglomerate) predominantly in the western half of the study area; and the Gyranda Formation (Pwy - siltstone, shale, volcanilithic sandstone, calcareous sediments), predominantly in the eastern half of the study area (Balfe *et al* 1988, Jell 2013).

Nine distinct soil landscapes are recognised within the geologic framework described above and soil development within each landscape strongly reflects the lithological and localised depositional environment that exists in the upper part of the regolith. Soil landscapes 1, 2, 3 and 4 are all developed directly from and strongly influenced by recent alluvial deposition (Qa), and are typically still subject to flooding. Soil Landscape 5 is transitional between recent alluvium (Qa) and adjacent older, more elevated landscapes, while Soil Landscape 6 is associated with high level, relict alluvial deposits (Qa). Soil Landscape 7 is developed on unconsolidated Tertiary-Quaternary residual sediments and clay sheets (Cz, TQr), and soils in this landscape are widespread across the Bowen Basin. Soil Landscape 8 is developed on intact to dissected, residual Tertiary sediments (Ta, Tm), dominated locally by medium to coarse grained siliceous sandstones. Soil Landscape 9 is of limited occurrence and appears related to the presence of outcropping calcareous sediments (unmapped), possibly of Permian origins.

6. Soil landscapes

Soil distribution within the 2013 BNCOP Soil Investigation survey area

Twenty three soil types were recognized and mapped within the 2013 BNCOP Soil Investigation survey area (which includes additional buffer areas external to the BNCOP EIS Operational Area) and are presented in **Figure 3**. Of these, 12 have been previously mapped and described within ML80169 and ML80170 (NQSA 2011a), 10 are newly described and 1 has been described in previous stages of mine expansion (SMM 2010a, 2010b), prior to the Baralaba/Wonbindi North Mine Lease (ML80169 and ML80170).

Soils 1, 2b and 3a are young hardsetting to self-mulching alluvial clays that occupy the lowest terraces and floodplains of the Dawson River anabranch, and are associated with riverine vegetation or coolibah woodland. These soils have a spatial extent that is limited to relatively minor areas just north of the Dawson River anabranch. **Soils 3b and 3c** are also developed on recent alluvium, but have very different loamy or sandy characteristics relating to localised depositional provenance and sediment source. They are characterized by eucalypt woodland, particularly bloodwoods and poplar box, and dominate the creek flats, scroll features and local alluvial plains of the main tributaries in the area, particularly Saline Creek.

Soils 4a-4e occur exclusively on the upper terraces and floodplains of the main Dawson River system (including the southern anabranch). They are predominantly cracking clay soils with coolibah or brigalow - coolibah vegetation. Soils 4a, 4b and 4c are predominantly deep self-mulching clays with coolibah or brigalow vegetation and distribution in the current study is restricted to minor areas immediately north of the southern anabranch. Soils 4d and 4e are brigalow or brigalow - Dawson gum soils that occupy significant tracts of level floodplain north of the relict oxbow wetland. Soil 4d is a weakly melonholed alluvial grey clay, while soil 4e is a sandy to loamy surfaced texture contrast soil. While a small portion of Soil 4d occurs within the BNCOP Disturbance Footprint, these soils are more common on the floodplain further north.

Soil 5 is transitional between the young alluvial clay landscapes on the floodplains flanking the southern anabranch and the older elevated, unconsolidated Tertiary-Quaternary land surface that is extensive north of the anabranch. Its distribution is specifically associated with dissection along the margins of the older elevated Tertiary-Quaternary clay sheet, primarily as a result of ongoing incision by local tributary streams. Soil 5 is a self-mulching brigalow clay, with upper profile features that are indicative of regular flooding and clay alluviation (i.e. similar to soils in Landscape 4), but lower subsoil features that are clearly related to the older Cainozoic clay sheets to the north. As such, it represents a hybrid between the two landscapes and is characterized by attributes of both.

Soils 6b-6c are thick, sandy or loamy surfaced profiles that are characterized by eucalypt woodland, and occupy high level, elevated alluvium on relict levees and scroll plains of the main Dawson River system (including the anabranch). Soil 6b is associated with high level (almost stranded) levee/terrace alluvium along the anabranch, while Soil 6c is restricted to high relict levees adjacent to the oxbow wetland in the north of the survey area.

The remaining soils 7a-7d, 8a-8d and 9a-9b are non-alluvial and are developed either on relict, unconsolidated Tertiary-Quaternary transported sediments or from older insitu Tertiary sediments. **Soils 7a-7d** are predominantly clay soils that occupy extensive, level to gently undulating plains developed on relict, unconsolidated Tertiary-Quaternary transported clayey sediments, north of the anabranch. Soil 7a is a strongly melonholed grey clay with uniform brigalow scrub. It typically occurs in large uniform blocks but can also be mixed intimately with the hardsetting non-cracking clays and loamy surfaced texture contrast profiles of Soil 7b. Vegetation grades from pure brigalow to a very shrubby eucalypt - brigalow scrub or woodland across the 7a-7b soil boundary.

Soil 7c is associated with relatively elevated, gently undulating plains and low rises developed on unconsolidated relict alluvial deposits of indeterminate age. These sediments stratigraphically overlie the flatter Cainozoic clay sheets on which Soils 7a, 7b and 7d are developed. Soil 7c typically occurs as a hardsetting, thick sandy surfaced, bleached, mottled, brown, non-sodic to weakly sodic texture contrast soil. Vegetation ranges from a shrubby eucalypt woodland through to eucalypt-softwood scrub. Soil 7d is similar in many respects to Soil 7b, but presents only as a clay loamy surfaced, black sodic texture contrast soil and does not grade towards a non-cracking or cracking clay. Associated vegetation is also specific and is restricted to Dawson gum - brigalow scrub. Whilst the soils in Landscape 7 are spatially extensive and occupy a significant proportion of the BNCOP EIS Operational area, their distribution is largely contained between the southern anabranch and the relict oxbow wetland in the north.

In the north of the survey area, the unconsolidated Tertiary - Quaternary sheets are underlain by older outcropping insitu Tertiary sediments (predominantly sandstones) that have been significantly dissected and eroded since exposure. In addition, the landscape has been intensively weathered at some stage, although evidence of deep weathering profiles and kaolinization was not observed. Subsequent dissection has left a subtle distribution of relatively fresh and more weathered substrates exposed, without obvious landform changes to mark the differences. Soils largely reflect

grain size, mineralogy and fabric of the original sandstones ± the effects of intense weathering in more intact remnants.

Soils 8a-8d are closely related to each other and together occupy extensive areas of undulating plains and distinct low rises underlain by insitu sandstones in the north west of the survey area. Soil 8a is a deep red earth with a shrubby to open eucalypt woodland and is associated with intact remnant plateau surfaces on more weathered sandstones. Soil 8b, in contrast, is a sandy surfaced, mottled, grey texture contrast soil that occurs on dissected slopes and rises underlain by relatively fresh insitu sandstones. This soil is characterized by eucalypt woodland, but with a distinctive understory dominated by quinine bush (*Petalostigma pubescens*). Soils 8c and 8d are deep sandy colluvial variants developed on footslopes and outwash areas where localised sand accumulation has occurred.

Soils 9a-9b are of limited occurrence, and appear related to localised outcropping calcareous sediments (unmapped). Although origins are inconclusive, soil and vegetation response within the landscape is nonetheless distinctive. They are located in the vicinity of underlying folded Permian strata, in particular the Gyranda Formation (Pwy - siltstone, shale, volcanilithic sandstone, calcareous sediments), but field evidence is limited. Soil 9a grades from a loamy surfaced texture contrast soil to areas of reddish brown non-cracking clay, with a distinctive bloodwood dominated eucalypt woodland. Soil 9b is a deep, weakly gilgaied black cracking clay typically with an open grassland.

Soil distribution within the BNCOP Disturbance Footprint

A total of 20 soils are recognised within the BNCOP EIS Operational Area, but only 16 of these occur within the BNCOP Disturbance Footprint (external to ML80169 and ML80170). More specifically, 9 soils have been previously mapped and described within ML80169 and ML80170 (NQSA 2011a) but are common to both areas, while a further 7 soils are newly described and occur only within the BNCOP Disturbance Footprint. The spatial distribution of the 16 soils within the BNCOP Disturbance Footprint is presented in **Figure 4**. Soil variation associated with each of the operational or project entities described is summarized below.

Area of interest	Soils	Total
All soils - BNCOP Operational EIS Area	2a, 2b, 3/3a, 3b, 4a, 4b, 4c, 4d, 5, 6b, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d, 9a, 9b	20
All soils - ML80169 and ML80170	2a, 2b, 3/3a, 4a, 4b, 4c, 5, 6b, 7a, 7b, 7c, 8a, 8b	13
All soils - BNCOP Disturbance Footprint	2b, 3a, 3b, 4c, 4d, 5, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d, 9a, 9b	16
Soils common to ML80169/ML80170 and the BNCOP Disturbance Footprint	2b, 3a, 4c, 5, 7a, 7b, 7c, 8a, 8b	9
New soils - BNCOP Disturbance Footprint	3b, 4d, 7d, 8c, 8d, 9a, 9b	7

7. Soil characterization

Outline and explanation of terms – Soil Characterization Section

The following section provides a comprehensive summary of field descriptions, analytical data and interpreted attributes for soils within the BNCOP Disturbance Footprint (excluding ML80169 and ML80179). The **landscape framework** developed during mapping is presented in **Tables 2 and 3.** The spatial extent and distribution of individual soil units within the entire 2013 BNCOP Soil Investigation survey area is presented in **Figure 3,** while soil mapping specific to the BNCOP Disturbance Footprint is presented in **Figure 4**.

Table 2. Map legend — brief soil concepts and dominant vegetation for soil landscapes mapped within the 2013 BNCOP Soil Investigation survey area.

Soil	Landscape framework and soil concept	Dominant vegetation
Quaternary alluvium (Qa)		
Active river channels and banks		
1	Firm to hardsetting, silty surfaced black cracking clay	Coolibah
Active, channelled lower floodplain		
2b	Moderately self-mulching (often silty) black cracking clay	Coolibah ± brigalow
Active levees and alluvial plains of tributary drainage lines		
3a	Hardsetting to coarsely self mulching (poached) black cracking clay	Coolibah ± shrubs ± brigalow
3b	Hardsetting, clay loamy surfaced, brown sodic texture contrast soil	Shrubby poplar box ± brigalow
3c	Brown sand to soft, sandy surfaced, brown non-sodic texture contrast soil	Moreton Bay ash – forest red gum
Elevated, upper floodplain, terraces and backplains		
4a	Hardsetting to firm, silty black cracking clay	Coolibah ± other eucalypts
4b	Moderately to strongly self-mulching (coarse) black cracking clay	Coolibah
4c	Moderately to strongly self-mulching black cracking clay	Brigalow ± minor softwood species
4d	Weakly to moderately self-mulching grey cracking clay	Brigalow ± coolibah (emergent)
4e	Hardsetting, sandy to clay loamy surfaced, grey/brown texture contrast soil	Shrubby brigalow – Dawson gum
Gently undulating Qa –TQr transitional sideslopes		
5	Firm pedal or weakly to moderately self-mulching black cracking clay	Brigalow ± shrubby species
High level alluvial plain, levees and relict scroll plains		
6b	Hardsetting, loamy to clay loamy surfaced, brown/red texture contrast soil	Very shrubby eucalypt ± coolibah
6c	Soft, sandy surfaced, mottled, brown/grey texture contrast soil	Moreton Bay ash – forest red gum
Older unconsolidated Tertiary–Quaternary sediments (Cz/TQr)		
Level to gently undulating plains and low rises		
7a	Hardsetting to weakly self-mulching, grey cracking clay with strong melonhole	Brigalow
7b	Hardsetting, clay loamy surfaced, grey/brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occ. weak gilgai	Very shrubby poplar box
7c	Hardsetting, sandy surfaced, bleached, mottled, brown non-sodic to weakly sodic texture contrast soil	Shrubby eucalypt grading to eucalypt – softwood scrub
7d	Hardsetting, clay loamy surfaced, bleached, black sodic texture contrast soil	Brigalow ± Dawson gum
Internally drained closed depressions		
swp 7a	Hardsetting, silty, mottled, grey non-cracking/cracking clay ± weak gilgai	Forest red gum
Older insitu consolidated Tertiary sandstone (Ta/Tm)		
Level to gently undulating plains/remnant plateau surface		
8a	Hardsetting, massive, gradational loamy red earth	Eucalypt
Undulating to rolling dissected rises		
8b	Soft/loose, sandy surfaced, bleached, mottled, grey non-sodic texture contrast soil on sandstone	Eucalypt
Colluvial footslopes and pediments		
8c	Loose, massive, bleached, grey coarse sand	Eucalypt
8d	Loose, red/brown sand to sandy surfaced, red/brown texture contrast soil	Eucalypt
Older insitu calcareous sediments (Pwy)		
Gently undulating plains and low rises		
9a	Hardsetting, loamy to clay loamy surfaced, brown non-sodic texture contrast soil grading to a brown non-cracking clay	Eucalypt
9b	Hardsetting to moderately self-mulching black cracking clay ± weak gilgai	Open grassland

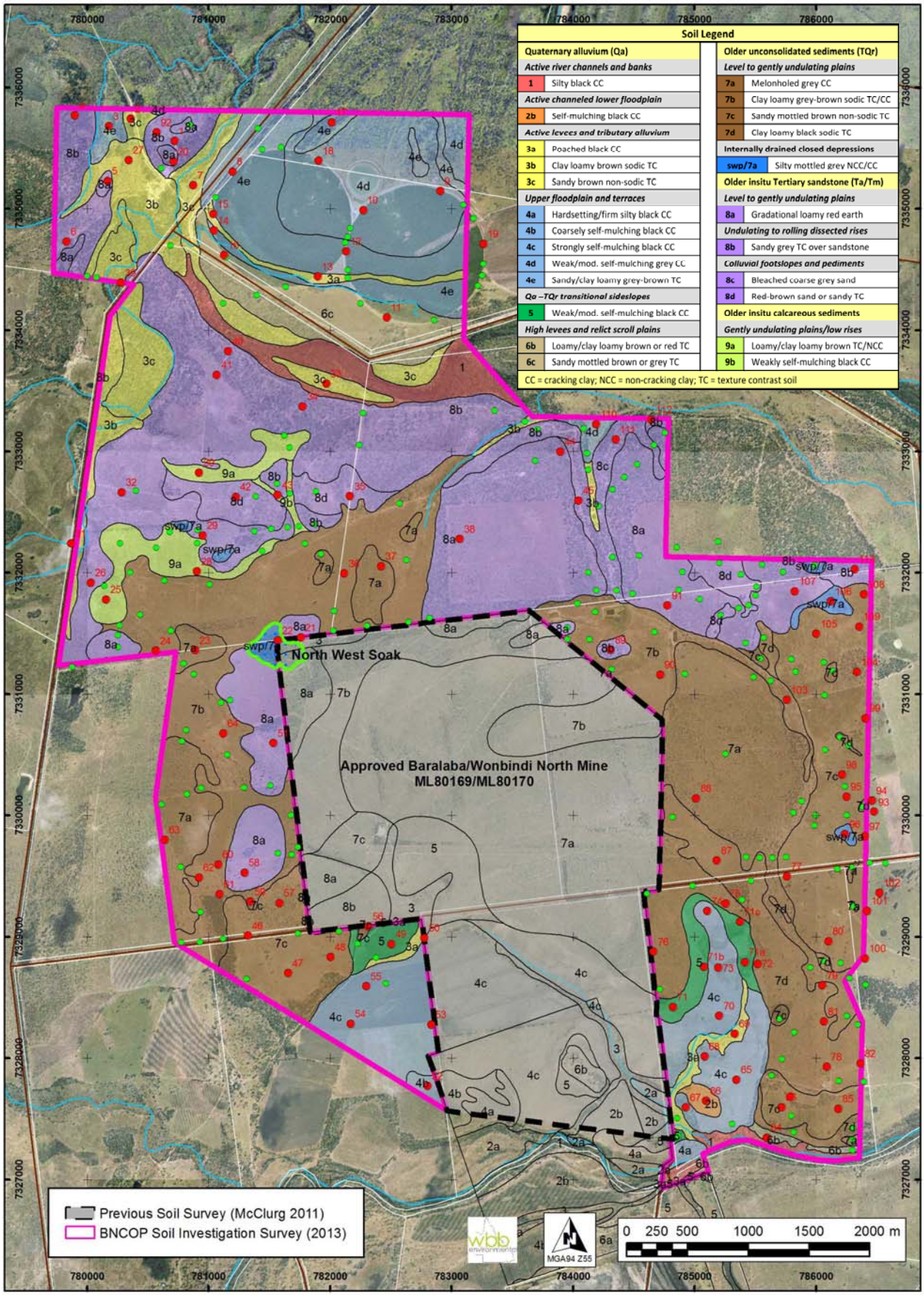


Figure 3. Soil landscapes mapped within the 2013 BNCOP Soil Investigation survey area.

Table 3. Soil landscapes within the 2013 BNCOP Soil Investigation survey area (incl. regional soil correlation, vegetation, field site summary and Land Zone).

Unit	Soil landscape description	Regional soil name[1]	Vegetation summary	Detailed field sites	LZ[1]
Soils derived from Quaternary alluvium (Qa)					
Active river channel of the Dawson River and associated anabranches; includes banks and low-lying channel benches subject to frequent flooding					
1	Firm to hardsetting, silty surfaced, black cracking clay on low-lying channel benches and banks.	Isaac (Is)	Coolibah	na	3
Active, channelled lower floodplain of the Dawson River and associated anabranches; relatively low lying, undulating unit adjacent to the main channel and subject to regular flooding					
2b	Moderately self-mulching, often silty, black cracking clay on level backplains within the lower floodplain.	Bluchers (Bc), Lindsay (Ld)	Coolibah ± brigalow	**66**	3
Active levees and alluvial plains of tributary drainage lines and floodplain drainage features within or at the margins of elevated terraces and backplains; subject to both local and wider flooding					
3a	Hardsetting to coarsely self-mulching, (poached), black cracking clay in narrow terrace drainage lines of the upper floodplain.	Bluchers (Bc), Lindsay (Ld)	Coolibah ± shrubs ± brigalow	13, 15, 50, **69**	3
3b	Hardsetting, clay loamy surfaced (0.2-0.4m), bleached, brown sodic texture contrast soil on level alluvial plains of Saline Creek and associated tributaries.	Roper (Rp)	Shrubby poplar box ± brigalow	**27**, 31	3
3c	Deep brown uniform sand grading to a very thick, soft sandy surfaced (1.0->1.5m), brown non-sodic texture contrast soil on active terrace flats, levees and scroll plains of Saline Ck and other tributaries.	German (Gm), Parrot (Pr)	Moreton Bay ash – forest red gum	2, 7, 33, 39	3
Elevated, backplains, terraces and indistinct levees of the upper floodplain of the Dawson River and associated anabranches; typically level and extensive; commonly flooded					
4a	Hardsetting to firm, silty, black cracking clay on upper floodplain levees and terrace sideslopes.	Stephens (St)	Coolibah ± other eucalypts	13 (ML80157)	3
4b	Moderately to strongly self-mulching (coarse), black cracking clay to 1.2m (over brown or grey clay) on elevated level backplains.	Lindsay (Ld)	Coolibah	52	3
4c	Moderately to strongly self-mulching, black cracking clay on elevated level backplains.	Langley (Lg)	Brigalow ± minor softwood species	53, 54, 55, **65**, 67, 68, 70, 73, 74	3
4d	Weakly to moderately self-mulching, grey cracking clay with weak to moderate melonhole gilgai (VI <0.3-0.6m, HI 10-25m) on level backplains of the Dawson River.	Langley (Lg), Tralee (Tl)	Brigalow ± coolibah (emergent)	9, 10, 18, **110**	3
4e	Hardsetting, sandy to clay loamy surfaced (0.2-0.5m), grey or brown texture contrast soil on level backplains of the Dawson River.	Honeycomb (Hy)	Shrubby brigalow – Dawson gum	3, 8, 12, 14, 17, 19	3
Gently undulating side slopes and dissected margins transitional between recent alluvium of the upper floodplain and older more elevated landscapes adjacent; rarely flooded					
5	Firm pedal or weakly to moderately self-mulching, black cracking clay on gently undulating sideslopes/plains that mark the transition from recent alluvium to older elevated plains.	Affinities with Tralee (Tl)	Brigalow ± shrubby species	49, **71**, 71a, 71b, 71c	3/4
Intact, elevated alluvial plain, high levees and relict scroll plains and prior stream channels and floodways; rarely flooded					
6b	Hardsetting, loamy to clay loamy surfaced (0.25m), sporadically bleached, brown or red texture contrast soil on elevated terrace/levee remnants.	Affinities with Roper (Rp)	Very shrubby eucalypt ± coolibah	84	3
6c	Thick, soft sandy surfaced (1.0-1.5m), mottled, brown or grey texture contrast soil on high levees.	Parrot (Pr)	Moreton Bay ash – forest red gum	11, 16	3

Unit	Soil landscape description	Regional soil name[1]	Vegetation summary	Detailed field sites	LZ[1]
Soils derived from older unconsolidated Tertiary–Quaternary sediments (Cz/TQr – elevated Cainozoic clay sheets and relict sandy alluvial deposits)					
Older, elevated, level to gently undulating plains and low rises ; not flooded					
7a	Hardsetting or firm pedal to weakly self mulching, grey cracking clay with strongly developed melon-hole gilgai (VI 0.3-0.8m, HI 12-20m) on older clay sheets; saline, sodic and acidic at depth.	Turon (Tr)/Greycliffe melonhole phase (GcMp)	Brigalow	23, 37, 63, 75, 76, **88**	4
7b	Hardsetting, thin clay loamy surfaced (<0.05-0.2m), bleached, grey or brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occasional weak gilgai (VI 0.1m, HI 10m) on older unconsolidated sediments and clay sheets.	Foxleigh clay loamy phase (FxLp) grading to Warwick (Ww)/Greycliffe (Gc)	Very shrubby poplar box	24, **36**,59, 60, 61, 62, 64, **90**, 103	4
7c	Hardsetting, thick sandy surfaced (0.4-0.7m), bleached, often mottled, brown non-sodic to weakly sodic texture contrast soil on elevated relict alluvial deposits.	Collawmar (Cm)	Shrubby eucalypt grading to eucalypt – softwood scrub	46, 47, 48, 56, 57, 77, 80, 83, 85, 86, 93, 95, 97, 98, **99**, 100, 101, 104, 105, 108, 109	5a
7d	Hardsetting, clay loamy surfaced (0.10-0.2m), bleached, black sodic texture contrast soil on older unconsolidated sediments and clay sheets.	Racetrack (Rt)/Kokotungo (Kk)	Brigalow ± Dawson gum	72, 78, 79, 81, 82, **87**, 94, 102	4
Local seasonal swamps and closed depressions – occasional landscape features sitting between elevated sandstone units (Landscape 8) and lower lying clay sheets (Landscape 7)					
swp 7a	Hardsetting, silty surfaced, mottled, grey non-cracking/cracking clay ± weak gilgai (VI <0.1-0.3m, HI 8-12m) etched within the Cainozoic clay sheets and subject to localized alluvial deposition.	Thirteenmile (Tt)	Forest red gum	22, 96, 106	3
Soils derived from older consolidated Tertiary sandstone (Ta/Tm)					
Elevated and relatively intact, level to gently undulating plateau surface					
8a	Hardsetting, massive, gradational loamy red earth overlying weathered Tertiary sandstone (>1.5m).	Bills Hut (Bh)/Spear (Sp)	Eucalypt	5, 20, 21, **38**, 44, 51, 58, 91, 107	10
Elevated and dissected, undulating to rolling remnant rises					
8b	Soft to loose, thick sandy surfaced (0.3-1.0m), bleached, strongly mottled, grey non-sodic texture contrast soil overlying insitu Tertiary sandstone from 0.8->1.5m.	Wyndham (Wm), affinities with Emoh (Em)	Eucalypt	1, 4, 6, 26, **29**, 32, 34, **40**, 41, 89, 92, 112, 113	10
Colluvial footslopes and pediments					
8c	Loose, massive, bleached, grey coarse sand on steeper colluvial footslopes.	Wyndham (Wm), affinities - Cherwell (Cw)	Eucalypt	45, 111	10
8d	Loose, massive red or brown earthy sand grading to a very thick sandy surfaced (1.0->1.5m), red or brown non-sodic texture contrast soil on gentle colluvial pediments and outwash deposits.	Wyndham (Wm), Bills Hut sandy variant (BhSv)	Eucalypt	35, 42	10
Soils derived from older calcareous sediments (possibly Pwy)					
Level to gently undulating plains and low rises					
9a	Hardsetting, loamy to clay loamy surfaced (0.2-0.3m), brown non-sodic texture contrast soil grading to a structured, brown non-cracking clay overlying calcareous sediments from 0.7m->1.5m.	Mayfair (Mf), Kirkcaldy (Kc)	Eucalypt	25, 28, **30**	4/9
9b	Hardsetting to moderately self-mulching, black cracking clay with weak normal gilgai (VI <0.1-0.2m, HI 8-15m) overlying calcareous sediments from >1.2m.	Kirkcaldy (Kc), Affinities with Carfax (Cx)	Open grassland	**43**	4/9

Note 1. Regional soil names are from Burgess (2003a, 2003b); except for Greycliffe (Gc) and Kokotungo (Kk) which come from Muller (2008); land zones (LZ) are after Sattler and Williams (1999).

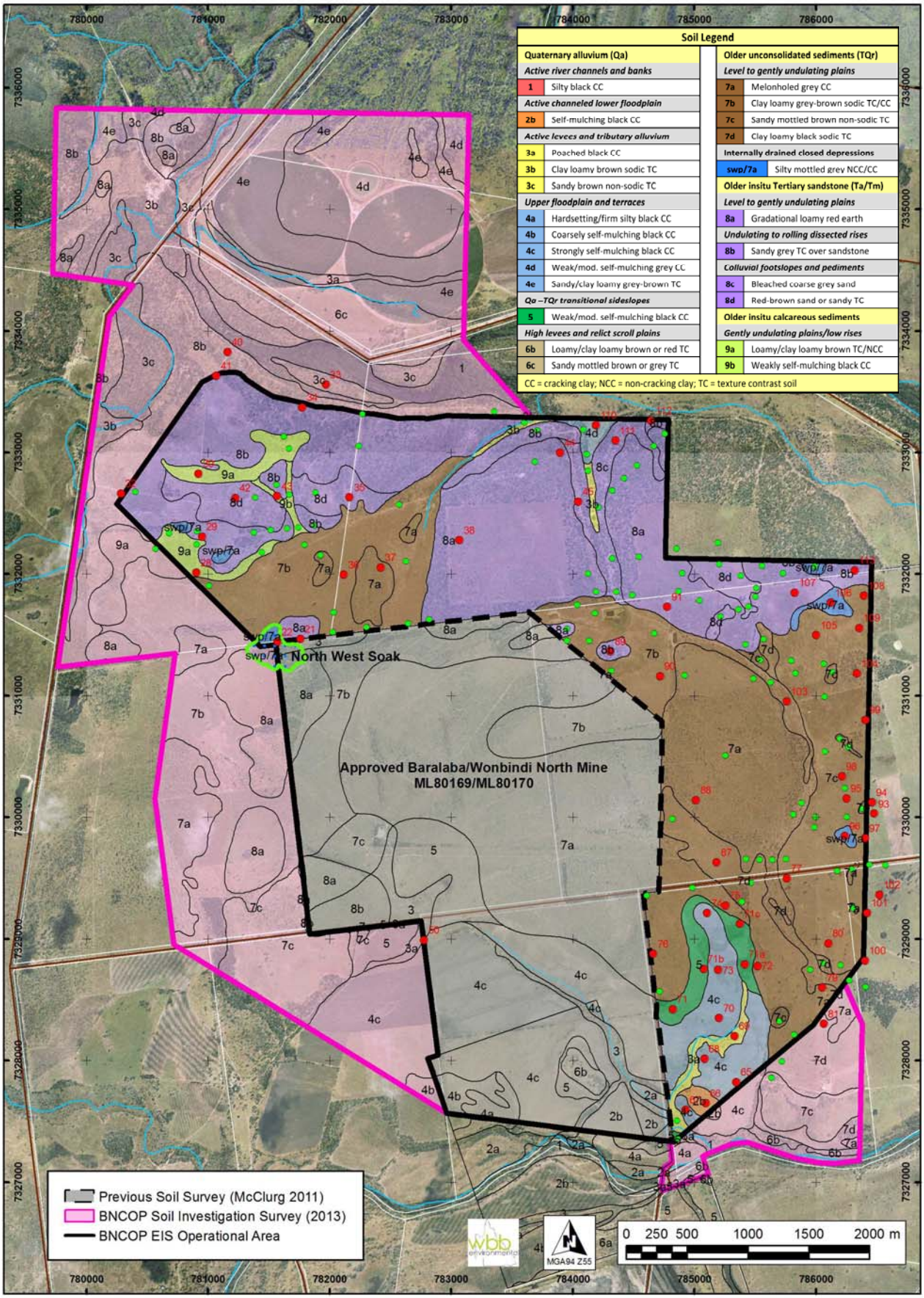


Figure 4. Soil landscapes mapped within the BNCOP Disturbance Footprint. Previous soil mapping within M80169 and ML80170 is also shown to complete coverage for the BNCOP EIS Operational Area.

Soil types within each landscape unit were split initially according to lithology/parent material, and then further sub-divided in terms of landscape age (youngest to oldest), landscape position (lowest to highest) and broad vegetation category (eucalypt, brigalow or other Acacia based scrub). **Soil mapping codes** consist of a primary number code corresponding to lithological units ordered from youngest to oldest, followed by a letter code for subdivisions based on topographical position (lowest to highest). Soils described within each landscape unit have also been assigned a Regional Soil Name according to Burgess (2003a, 2003b) and/or Muller (2008).

Information presented for each soil in the soil characterization pages that follow includes description of the overriding landscape framework (geology/lithology, landform and vegetation), detailed soil profile morphology, soil fertility data, physical soil attributes, subsoil chemistry, data interpretation, topsoil stripping recommendations, pre-mining suitability for dryland cropping and grazing and SCL status. Data interpretation uses ratings and classes defined for inland Central Queensland by Burgess (2003b). An outline of the information provided for each soil with a brief explanation of its purpose and meaning is given below.

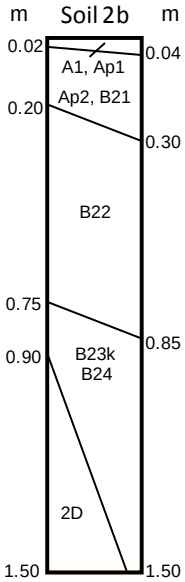
Soil/landscape attribute	Brief explanation
Regional Soil Name	• Regional soil type – Burgess (2003a, 2003b) and Muller (2008).
Soil landscape concept	• Conceptual description incorporating soil type, parent material, landscape position and vegetation.
Soil concept	• A conceptual soil description summarizing distinguishing profile features and parent material.
Soil Classification	• Australian Soil Classification – Suborder/Soil Order (Isbell 1996). • Principal Profile Form (Northcote 1979).
Geology/parent material	• Geological formation, dominant lithology of the parent material and degree of alteration.
Land zone	• Broad geological landscape as defined by the Regional Ecosystem framework (Sattler and Williams 1999).
Landform	• Dominant relief/modal slope class, landform pattern and typical slope range.
Vegetation	• Dominant vegetation and regional ecosystem (if required).
Microrelief	• Presence of microrelief including type, degree of development (weak to strong), size (vertical interval – VI (m) and horizontal interval – HI (m)) and dominance of individual components.
Runoff, permeability and drainage	• Estimates as defined by the National Committee on Soil and Terrain (2009).
Surface gravel, stone, rock outcrop	• Estimates as defined by the National Committee on Soil and Terrain (2009).
Surface condition	• Description as defined by the National Committee on Soil and Terrain (2009). • Self-mulching behaviour is further described in terms of strength of pedality, fineness of aggregates and thickness of the self-mulching layer (where applicable).
Distinguishing profile features	• Descriptions of the depth, horizon designation, dominant colour, mottling, texture, structure, segregations, gravel and field pH of the major soil horizons and underlying substrate as defined by the National Committee on Soil and Terrain (2009).
Surface soil fertility status	• Summary of the fertility status at each site including measured levels and ratings for organic carbon, total nitrogen, available phosphorus, and exchangeable potassium, and calcium.
Physical soil characteristics	• Important physical soil characteristics including clay content, sand fraction, clay mineralogy, dispersion and plant available water capacity (PAWC).
Soil chemistry	• Important soil chemistry attributes of the surface soil and subsoil including pH, electrical conductivity, soluble chloride, cation exchange capacity, exchangeable cations, cation dominance, ESP, sodicity and dispersive behaviour (R1).

Soil 2b — Moderately self-mulching black clay on lower floodplains + coolibah

Soil concept:	Moderately self-mulching, often silty, black cracking clay on level backplains within the lower floodplain.			
Regional Soil Name:	Bluchers (Bc), Lindsay (Ld)			
Aust. Soil Classification:	Black Vertosol	**Principal Profile Form:**	Ug5.17	
Landform:	Level backplains of the lower floodplain of the Dawson River anabranch; relatively low lying, active backplains characterized by flood channels/runners; subject to regular flooding. Slopes mostly <1.0%.			
Geological landscape:	Quaternary alluvium (Qa). Sand, clay and gravel.			
Land zone:	Cainozoic alluvial plains (LZ 3).			
Vegetation:	Coolibah ± brigalow.			
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.			
Surface features:	Thin, coarse (2-5mm), moderately self-mulching, silty clay surface; cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.140)	very high (73)	very high (2.5)	very high (27)
Moisture Characteristics:	**ERD:** >1.0m (no restrictions)		**PAWC:** 120mm/1.0m	
Investigation sites:	**Field sites** – 66		**Analysed sites** – 66	

Coolibah ± brigalow cropping area on the lower floodplain, north of the anabranch at Site 66.

Moderately self-mulching, silty, black cracking clay on the lower floodplain at Site 66.



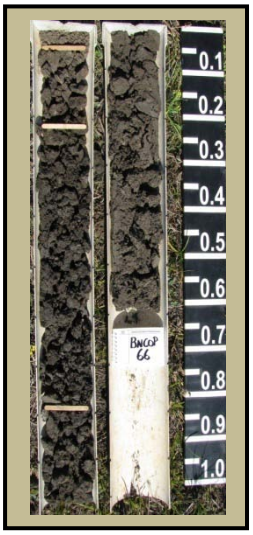
Profile description

The **surface soil** (A1, Ap1) is a black (10YR 3/1-3/2) silty light medium to silty medium clay with fine blocky structure parting to a moderate granular self-mulching surface; field pH 7.0-7.5. Clear change to

The **upper subsoil** (Ap2, B21) is a black (2.5Y, 10YR 2/1-3/1) medium heavy clay with moderate coarse blocky grading to strong lenticular structure; sometimes with minor soft or nodular carbonate; field pH 7.0-8.5. Clear or gradual change to

The **lower subsoil** (B22, B23k, B24) is a black or grey (2.5Y, 10YR 3/1, 3/2, 4/1) medium heavy to heavy clay with coarse lenticular structure; and <20% soft or nodular carbonate; field pH 8.0-9.0.

Buried layers (2D) where present are typically brown (7.5YR, 10YR 3/3-4/6) fine sandy light medium to fine sandy medium clay materials with weak to moderate blocky structure and variable levels of soft or nodular carbonate; field pH 8.0-9.0.



Subsoil Chemistry – representative data from BNCOP Site 66								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	7.2	0.346	210	38	27.0	8.4	2.50	0.47
0.25 – 0.35	8.1	0.078	<5	41	34.1	9.3	1.00	0.81
0.55 – 0.65	8.5	0.160	<5	42	32.5	12.0	0.73	1.90
0.85 – 0.95	8.7	0.180	5	43	27.7	13.9	0.67	3.74
1.15 – 1.25	8.9	0.236	15	-	-	-	-	-

pH in the surface soil is neutral, while subsoil material is alkaline. EC and Cl analyses (see Appendices 2 and 5) indicate profile salinity is consistently low (Cl <20ppm). CEC levels are very high (>38-43meq/100g) throughout, and moderately high CEC/clay ratios (0.57-0.60), obvious cracking behaviour and strong lenticular structure suggest the clay fraction is active, has significant shrink-swell characteristics and is of mixed mineralogy with a significant proportion of smectites. ESP data indicate surface and upper subsoil horizons to about 0.9m are non-sodic (ESP<6), while the lower subsoil is only moderately sodic (ESP <10). Ca/Mg ratios are very high suggesting stable structural integrity.

Physical Soil Characteristics – representative data from BNCOP Site 66										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	1	10	23	66	-	0.58	0.37	3.2	1	low
0.25 – 0.35	1	9	22	68	-	0.60	0.39	3.7	2	low
0.55 – 0.65	2	6	19	72	-	0.58	0.44	2.7	5	low
0.85 – 0.95	1	6	18	75	-	0.57	0.58	2.0	9	moderate

Clay content is uniformly very high (66-75%) throughout. Silt contents are markedly elevated in surface horizons (22-23%), and reflect regular depositional history. The surface soil/upper subsoil to about 0.5m is strongly structured, non-sodic (ESP <2), with significant shrink-swell capacity, Ca dominant cation chemistry and very low dispersion (R1 0.37-0.39). The lower subsoil to about 1.2m is similar, but with weak to moderate sodicity (ESP 5-9) and increasing dispersion (R1 0.44-0.58). Below 1.2m, sodicity, dispersion, salinity and coarse macro lenticular structure are expected to increase significantly and adverse physical behaviour and poor establishment response is likely post-disturbance.

Summary

Surface soil/upper subsoil material to 0.8m has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by very high clay content (65-72%), active clay behaviour (CEC/Clay ratio 0.58-0.60), low sodicity (ESP <5), low dispersion (R1 <0.45), Ca dominant cation chemistry and low salinity (<0.2dS/m). These attributes suggest material to 0.8m will be relatively benign and physically stable/resilient following disturbance. It is likely however, to experience shrink-swell behaviour, strong cracking and significant root zone shearing (depending on placement thickness). Salvaged topsoil materials to 0.8m are suitable for replacement on low to moderate gradients. **Subsoil material between 0.8-1.2m** has similar physical characteristics, but with increasing sodicity (ESP 9) and dispersive behaviour (R 0.58). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 1.2m** is considered increasingly undesirable with moderate levels of salinity and worsening sodicity and dispersive behaviour. It is not recommended for salvage.

Soil 2b – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional root zone media 0.3-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.8m	Strip structured surface soil/subsoil clay to 0.8m as surrogate topsoil material. Avoid increasingly undesirable grey/brown clay below 0.8m.

Soil 2b – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	2	Suitable with minor limitations	e2, es2, m2, ps2, w2	A1
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, nd2, ps2, w2, f2, v2, ph2	-

Soil 2b – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)									
Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
2b	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	**Decided SCL (slope ≤ 3%)**

Soil 3a — Flooded black clay in upper floodplain drainage lines + coolibah

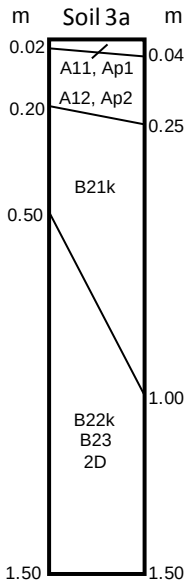
Soil concept:	Hardsetting to coarsely self-mulching, (poached), black cracking clay in narrow terrace drainage lines of the upper floodplain; subject to both local and flood inundation.
Regional Soil Name:	Bluchers (Bc), Lindsay (Ld)
Aust. Soil Classification:	Black Vertosol **Principal Profile Form:** Ug5.17
Landform:	Indistinct narrow drainage lines, runners and secondary floodways within upper floodplain terraces; subject to both local and flood inundation. Slopes <1.0% within drainage lines, 3-5% on sideslopes.
Geological landscape:	Quaternary alluvium (Qa). Sand, clay and gravel.
Land zone:	Cainozoic alluvial plains (LZ 3).
Vegetation:	Coolibah ± shrubs ± brigalow.
Runoff, perm., & drainage:	Very slow to slow runoff; slow permeability; moderately well drained.
Surface features:	Hardsetting to moderately self-mulching (very coarse 5-10mm); strong cracking; non-gilgaied; no surface gravel or stone.

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.195)	very high (83)	very high (1.33)	very high (18.1)

Moisture Characteristics:	**ERD:** 0.8->1.0m (salinity >0.8dS/m or >800ppm Cl)	**PAWC:** 95-120mm/1.0m
Investigation sites:	**Field sites** – 13, 15, 50, 69	**Analysed sites** – 69

Open coolibah ± brigalow woodland in a narrow upper floodplain drainage line at Site 69.

Hardsetting to weakly self-mulching, silty, black cracking clay in a narrow drainage line at Site 69.



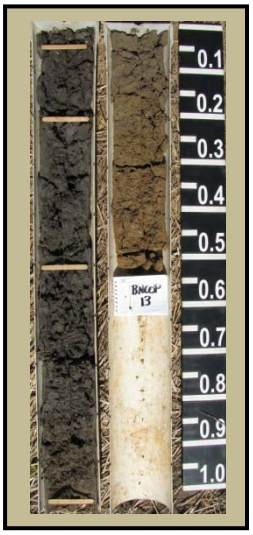
Profile description

The **surface soil** (A11, Ap1) is a black (10YR 3/1) light medium to medium clay (sometimes silty) with moderate to strong coarse granular to blocky structure ± minor <2% nodular carbonate; field pH 6.5-7.0. Clear change to

The **plough zone where cultivated** (A12, Ap2) is a black (10YR, 2.5Y 2/1-3/1) medium heavy clay with strong fine blocky or lenticular structure ± minor <2% nodular carbonate; field pH 7.0-8.5. Clear change to

The **upper subsoil** (B21k) is a black (10YR, 2.5Y 3/1) medium heavy to heavy clay with strong coarse lenticular parting to fine lenticular structure ± minor <2% nodular carbonate; field pH 7.5-9.0. Gradual/diffuse change to

The **lower subsoil** (B22k, B23, 2D) is a grey or brown (10YR, 2.5Y 4/1-4/3, 5/4) fine sandy medium to fine sandy medium heavy clay with strong very fine lenticular structure and increasing salinity; occasional sandy clay buried horizons (2D) with weak to moderate blocky structure may be present below about 1.25m; field pH 5.5-9.0.



Subsoil Chemistry – representative data from BNCOP Site 69

Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.6	0.081	30	30	18.1	9.8	1.33	0.418
0.25 – 0.35	7.5	0.057	<5	30	22.8	7.5	0.330	0.764
0.55 – 0.65	8.4	0.094	10	33	23.8	10.1	0.273	1.85
0.85 – 0.95	8.6	0.288	280	30	17.6	10.9	0.230	3.91
1.15 – 1.25	6.2	0.453	650	-	-	-	-	-

pH is neutral to alkaline throughout. EC and Cl analyses (see Appendices 2 and 5) indicate low levels of soluble salts (<0.3dS/m) to about 0.9m, but moderate to high levels below this depth. CEC levels are high (>30meq/100g) throughout. Moderately high CEC/clay ratios (0.49-0.58) and the presence of cracking and strong lenticular structure suggest the clay fraction is active, has significant shrink-swell characteristics and is of mixed mineralogy with a significant proportion of smectites. ESP data indicate surface and upper subsoil horizons to about 0.9m (0.8-1.0m = start of B22/2D) are non-sodic (ESP<6), while the lower subsoil below 1.0m is moderately sodic (ESP 13). Ca/Mg ratios are very high throughout.

Physical Soil Characteristics – representative data from BNCOP Site 69

Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	2	17	18	61	-	0.49	0.44	1.8	1	low
0.25 – 0.35	10	24	15	52	-	0.58	0.36	3.0	3	low
0.55 – 0.65	9	21	12	59	-	0.56	0.45	2.4	6	low
0.85 – 0.95	12	22	16	52	-	0.58	0.72	1.6	13	moderate

Clay content is uniformly high (52-61%) throughout. Silt contents are slightly elevated in surface horizons (15-18%), and reflect depositional history. The surface soil/upper subsoil to about 0.6-0.7m is strongly structured, non-sodic (ESP <6), with significant shrink-swell capacity, Ca dominant cation chemistry and low to very low dispersion (R1 0.36-0.45). The lower subsoil to about 1.0m is similar, but with weak to moderate sodicity (ESP 6-13) and increasing dispersion (R1 0.72). Below 1.0m, increasing sodicity, worsening dispersion and moderate to high salinity suggest adverse physical behaviour and poor establishment response is likely post-disturbance.

Summary

Surface soil/upper subsoil material to 0.7m has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by high clay content (52-61%), active clay behaviour (CEC/Clay ratio 0.49-0.56), low sodicity (ESP <6), low dispersion (R1 <0.45), Ca dominant cation chemistry and low salinity (<0.3dS/m). These attributes suggest material to 0.7m will be relatively benign and physically stable/resilient following disturbance. It is likely however, to experience shrink-swell behaviour, strong cracking and significant root zone shearing (depending on placement thickness). Salvaged topsoil materials to 0.7m are suitable for replacement on low to moderate gradients. **Subsoil material between 0.7-1.0m** has similar physical characteristics, but with moderate levels of salinity (EC 0.3-0.5dS/m), and increasing sodicity (ESP 6-13), and dispersive behaviour (R 0.72). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 1.0m** is considered increasingly undesirable, with moderate to high levels of salinity and worsening sodicity and dispersive behaviour. It is not recommended for salvage.

Soil 3a – Stripping Recommendations

Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.0m	Strip additional root zone media 0.3-1.0m for sub-surface replacement only.
Single stage	Combined	0-0.7m	Strip structured surface soil/subsoil clay to 0.7m as surrogate topsoil material. Avoid increasingly undesirable grey or brown clay below 0.7m.

Soil 3a – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)

Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	3	Suitable with moderate limitations	e2, es2, m3, ps3, w2	A1
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, nd2, ps2, w2, f2, v2, ph2	-

Soil 3a – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)

Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
3a	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	**Decided SCL (slope ≤ 3%)**

Soil 3b — Loamy brown sodic texture contrast soil on tributary alluvium + poplar box

Soil concept:	Hardsetting, clay loamy surfaced (0.2-0.4m), bleached, brown sodic texture contrast soil on level alluvial plains of Saline Creek and associated tributaries.			
Regional Soil Name:	Roper (Rp)			
Aust. Soil Classification:	Brown Sodosol	**Principal Profile Form:**	Db1.33, 1.43, Db2.33, 2.43	
Landform:	Level alluvial plains of local tributaries of the Dawson River, particularly Saline Creek; relatively narrow, ephemeral floodplains and local creek flats characterized by provenance derived fine sandy sedimentation from local upstream catchments. Slopes mostly <1.0%.			
Geological landscape:	Quaternary alluvium (Qa). Sand, clay and gravel.			
Land zone:	Cainozoic alluvial plains (LZ 3).			
Vegetation:	Shrubby poplar box ± brigalow.			
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.			
Surface features:	Hardsetting; non-cracking/rigid; non-gilgaied; no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.105)	high (28)	mod.-high (0.63)	mod.-high (5.3)
Moisture Characteristics:	**ERD:** 0.5-0.6m (rigid soil – ESP >15%)		**PAWC:** 45-55mm/1.0m	
Investigation sites:	**Field sites** – 27, 31		**Analysed sites** – 27	

Shrubby poplar box regrowth at Site 27 on the alluvial plain of Saline Creek in the north-west of the survey area.

Clay loamy surfaced, brown sodic texture contrast soil on the alluvial plain of Saline Creek at Site 27.

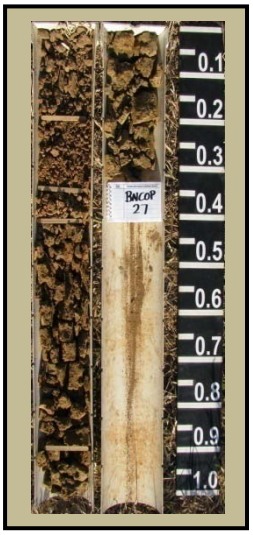
Profile description

The **surface soil** (A1) is a brown (10YR 3/3-4/3), fine sandy clay loam to clay loam fine sandy with weak subangular blocky to massive structure; field pH 5.5-6.5. Clear change to

The **sub-surface layer** (A2je) is a thin, sporadically or conspicuously bleached, brown (7.5YR, 10YR 4/4-5/4), fine sandy clay loam to clay loam fine sandy with massive structure; field pH 5.5-6.5. Abrupt change to

The **upper subsoil** (B21) is a brown (10YR 4/3-4/4), fine sandy light to light medium clay with weak prismatic to moderate blocky structure; field pH 7.0-8.0. Gradual change to

The **lower subsoil** (B22) is a grey or brown (10YR 5/2-5/4), mottled (orange), clay loam sandy to sandy light clay with weak to moderate blocky or prismatic structure; field pH 8.0-8.5.



Subsoil Chemistry – representative data from BNCOP Site 27

Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.2	0.059	40	9	5.3	2.6	0.629	0.199
0.25 – 0.35	5.6	0.021	5	4	2.2	1.5	0.132	0.242
0.55 – 0.65	6.8	0.070	35	9	3.6	4.0	0.142	1.69
0.85 – 0.95	7.9	0.096	73	9	3.6	3.8	0.13	1.67
1.15 – 1.25	8.3	0.255	265	-	-	-	-	-

pH is acidic in surface horizons and neutral to alkaline throughout the subsoil. EC and Cl analyses (see Appendices 2 and 5) indicate low salinity (EC <0.3dS/m) throughout. CEC levels are also low (4-9 meq/100g) throughout and CEC/clay ratios in the subsoil (0.31-0.38) suggest the clay fraction is largely un-reactive and of mixed mineralogy. Sodicity data indicates loamy surface soil to about 0.3-0.4m is non sodic (ESP 2-6), while subsoil clay below this depth is strongly sodic. Magnesium (Mg) levels co-dominate cation chemistry in the subsoil and are likely to enhance any dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 27

Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	8	45	29	21	-	0.43	0.65	2.0	2	low
0.25 – 0.35	9	49	25	21	-	0.19	0.75	1.5	6	low
0.55 – 0.65	14	46	13	29	-	0.31	0.99	0.9	18	high
0.85 – 0.95	19	50	10	24	-	0.38	0.92	0.9	19	high

Clay content increases sharply between surface horizons (21%) and the underlying subsoil (29%). The surface soil is massive to very weakly structured and is characterized by high levels of fine sand and silt (70-75% combined). This suggests significant slaking and pulverescent/hardsetting behaviour is likely following disturbance. PSA data indicates physical characteristics within the subsoil are co-dominated by fine sand (46-50%) and clay fractions (24-29%). Disturbed subsoil materials are likely to be un-reactive and prone to pulverescent behaviour (when dry), dense particle packing and severe compaction and crusting behaviour post disturbance. Laboratory measured dispersion is moderate (R1 0.65-0.75) in the surface soil (due to high levels of silt and fine sand), but increases to extreme levels (R1 0.92-0.99) throughout the subsoil.

Summary

Surface soil material to 0.3-0.4m has high fertility, massive to very weak structure, moderately low clay content (21%), elevated levels of fine sand/silt (70-75% combined), low salinity (EC <0.1dS/m) and low sodicity (ESP<6) characteristics. It is likely this material will be prone to pulverescent/hardsetting behaviour following disturbance and will be subject to slaking and high erosion risk. Salvaged materials are recommended only for replacement on level terrain or very low gradients. **Subsoil material below 0.3-0.4m** has unfavourable physical attributes. It is characterized by coarse, dense structure and a strongly sodic (ESP 18-19), dispersive (R1 0.92-0.99), un-reactive clay fraction. Salvaged subsoil materials would be subject to dense packing and compaction, severe slaking, dispersion, crusting and extreme erosion risk following replacement and subsequent exposure. Subsoil material is not recommended for salvage.

Soil 3b – Stripping Recommendations

Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.35m	Strip loamy surface soil to 0.35m and segregate as primary topsoil to preserve topsoil/seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	nil	Subsoil clay below 0.35m is dispersive and should be avoided.
Single stage	Combined	0-0.35m	Strip loamy surface soil to 0.35m (maximum) as topsoil/seed source material. Avoid dispersive subsoil clay below 0.35m. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.

Soil 3b – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)

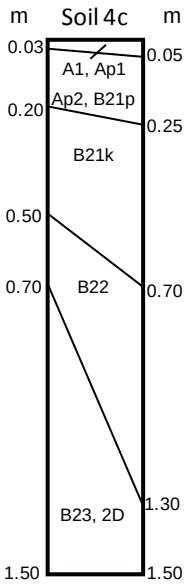
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	es3, m5, pm3, ps4, w2	-
Grazing	3	"Grower" country – suitable for improved pastures, but less productive than Classes 1 & 2	m3, nd2, ps2, w2, f2, v2	C1

Soil 4c — Strongly self-mulching black clay on upper floodplains + brigalow

Soil concept:	Moderately to strongly self-mulching, black cracking clay on elevated level backplains within the upper floodplain of the Dawson River anabranch**.**			
Regional Soil Name:	Langley (Lg)			
Aust. Soil Classification:	Black Vertosol	**Principal Profile Form:**	Ug5.15, 5.16, 5.17	
Landform:	Level backplains within elevated, upper floodplain terraces; typically level and extensive; less severely and less regularly flooded than lower floodplain areas. Slopes <1.0%.			
Geological landscape:	Quaternary alluvium (Qa). Sand, clay and gravel.			
Land zone:	Cainozoic alluvial plains (LZ 3).			
Vegetation:	Brigalow ± minor softwood species.			
Runoff, perm., & drainage:	Very slow to slow runoff; slow permeability; moderately well drained.			
Surface features:	Thick (>0.03m), moderately to strongly self-mulching surface (2-5mm) with a weak surface flake after rain; strong cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	very high (0.149)	very high (56)	very high (1.33)	very high (34.1)
Moisture Characteristics:	**ERD:** 0.75->1.0m (salinity >0.8dS/m or >800ppm Cl)		**PAWC:** 90-120mm/1.0m	
Investigation sites:	**Field sites** – 53, 54, 55, 65, 67, 68, 70, 73, 74		**Analysed sites** – 65	

Brigalow backplains within the upper floodplain developed to cropping (Soil 4c – Site 65).

Strongly self-mulching, black cracking clay typical of Soil 4c (Site 67).



Profile description

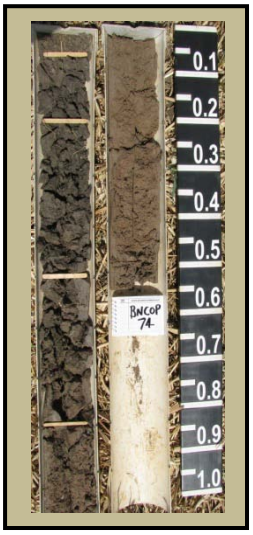
The **surface soil** (A1, Ap1) is a black (10YR, 2.5Y 3/1-3/2) medium clay with strong fine granular structure; field pH 7.0-8.5. Clear change to

The **plough zone where cultivated** (Ap2, B21p) is a black (10YR, 2.5Y 2/1-3/1) medium heavy to heavy clay with strong fine blocky or lenticular structure ± <2% nodular carbonate; field pH 8.0-8.5. Clear change to

The **upper subsoil** (B21k, B22) is a black (10YR, 2.5Y 2/1-3/1) medium heavy to heavy clay with strong fine blocky structure grading to strong fine lenticular structure with depth; and minor <2-10% soft or nodular carbonate; field pH 8.5-9.0. Gradual or diffuse change to

The **lower subsoil** (B23) is a black or grey (10YR, 2.5Y 3/1-4/2) medium to medium heavy clay with strong lenticular structure ± slickensides ± <2-10% soft or nodular carbonate; field pH 8.5 decreasing with depth to 5.0-7.0.

Buried layers (2D) where present are brown (7.5YR, 10YR 3/3-4/6) fine sandy medium to medium heavy clays with moderate blocky or strong lenticular structure; field pH 5.0-7.0.



Subsoil Chemistry – representative data from BNCOP Site 65								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	8.4	0.165	40	37	34.1	7.5	1.33	0.966
0.25 – 0.35	8.8	0.218	40	40	31.9	10.6	0.609	3.35
0.55 – 0.65	9.0	0.307	80	39	24.7	12.1	0.496	5.24
0.85 – 0.95	8.6	0.458	420	35	19.0	11.9	0.462	6.17
1.15 – 1.25	7.1	0.907	1030	-	-	-	-	-

pH is alkaline in the upper profile to about 0.7-1.2m, but becomes acidic (pH 6.5-5.0) below this. EC and chloride (Cl) data (see Appendices 2 and 5) confirm low salinity (<0.3dS/m) to about 0.6m, moderate levels (0.3-0.6dS/m) between 0.6-0.9m and increasing salinity below 0.9m. High CEC levels (35-40meq/100g), moderately high CEC/clay ratios (>0.6) and the presence of cracking and strong lenticular structure suggest the clay fraction is active, has significant shrink-swell characteristics and is of mixed mineralogy with a high proportion of smectites. ESP data indicate soil material is effectively non-sodic to 0.4m, moderately sodic (ESP 8-13) from 0.4-0.8m and strongly sodic (ESP 13-18) below about 0.8m.

Physical Soil Characteristics – representative data from BNCOP Site 65										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	2	14	23	60	-	0.62	0.39	4.5	3	low
0.25 – 0.35	2	12	21	63	-	0.63	0.47	3.0	8	low-mod.
0.55 – 0.65	3	11	22	65	-	0.60	0.68	2.0	13	mod
0.85 – 0.95	1	12	27	63	-	0.56	0.79	1.6	18	high

Clay content is very high and uniform throughout (60-65%). Silt contents are consistently elevated (21-27%) throughout and reflect depositional history. The surface soil/upper subsoil to about 0.4m is strongly structured and non-sodic to only weakly sodic (ESP 3-8), with significant shrink-swell capacity, Ca dominant cation chemistry and low dispersion (R1 0.39-0.47). The upper subsoil to about 0.8m is similar, but with moderate sodicity (ESP 8-13) and increasing dispersion (R1 0.47-0.68). Below 0.8m, increasing sodicity, worsening dispersion and moderate to very high salinity suggest adverse physical behaviour and poor establishment response is likely post-disturbance.

Summary

Surface soil/upper subsoil material to 0.4m has very high fertility and is strongly aggregated, finely structured and non-sodic to very weakly sodic (ESP 3-8). It is further characterised by high clay content (60-63%), active clay behaviour (CEC/Clay ratio 0.62-0.63), low dispersion (R1 0.39-0.47), Ca dominant cation chemistry and low salinity (<0.3dS/m). These attributes suggest material to 0.4m will be relatively benign and physically stable/resilient post disturbance. It is likely however, to experience significant shrink-swell behaviour, cracking and root zone shearing (depending on placement thickness). Salvaged topsoil materials to 0.4m are suitable for replacement on low to moderate gradients. **Subsoil material between 0.4-0.8m** has similar physical characteristics, but with low to moderate levels of salinity (EC 0.3-0.6dS/m) and sodicity (ESP 8-13), and increasing dispersive behaviour (R 0.47-0.68). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 0.8m** is considered undesirable, with high to very high levels of salinity and worsening sodicity and dispersive behaviour. It is not recommended for salvage.

Soil 4c – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-0.8m	Strip additional root zone media between 0.3-0.8m for sub-surface replacement only. Avoid grey or brown clay below about 0.7-0.9m.
Single stage	Combined	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.4m.

Soil 4c – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	3	Suitable with moderate limitations	e2, es2, m3, ps2, w2	A1
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, ps2, sa2, f2, ph2	-

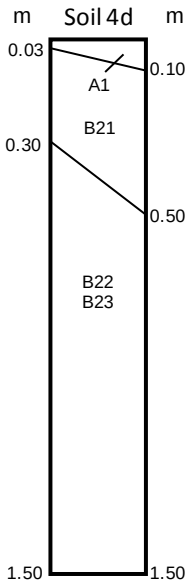
Soil 4c – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)									
Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
4c	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	**Decided SCL (slope ≤ 3%)**

Soil 4d — Weakly melonholed grey clay on upper floodplains + brigalow

Soil concept:	Weakly to moderately self-mulching, grey cracking clay with weak to moderate melonhole gilgai (VI <0.3-0.6m, HI 10-25m) on level backplains of the Dawson River.			
Regional Soil Name:	Langley (Lg), Tralee (Tl)			
Aust. Soil Classification:	Grey Vertosol	**Principal Profile Form:**	Ug5.16	
Landform:	Level backplains within the upper floodplain of the Dawson River; relatively elevated, active backplains characterized by weakly to moderately developed melonhole gilgai and a lack of obvious flood channels/runners; subject to occasional flooding. Slopes <1.0%.			
Geological landscape:	Quaternary alluvium (Qa). Sand, clay and gravel.			
Land zone:	Cainozoic alluvial plains (LZ 3).			
Vegetation:	Brigalow ± coolibah (emergent).			
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.			
Surface features:	Thin, weakly to moderately self-mulching surface (2-5mm); strong cracking; weak to moderate melonhole gilgai (VI 0.3-0.6m, HI 10-25m); no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	very high (0.255)	high (36)	very high (1.02)	very high (22.2)
Moisture Characteristics:	**ERD:** 0.7 >1.0m (salinity >0.8dS/m or >800ppm Cl)		**PAWC:** 85-120mm/1.0m	
Investigation sites:	**Field sites** – 9, 10, 18, 110		**Analysed sites** – 110	

Brigalow ± coolibah upper floodplain adjacent to the Dawson River, north of the oxbow (Site 9).

Weakly to moderately self-mulching, weakly melonholed, grey cracking clay at Site 110.

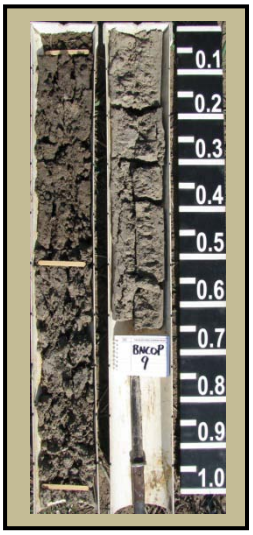


Profile description

The **surface soil** (A1, Ap where cultivated) is a black or grey (10YR 3/1-4/2) light medium to medium clay (often fine sandy) with moderate to strong granular or fine blocky structure; field pH 7.5 - 8.5. Clear change to

The **upper subsoil** (B21, B21p where cultivated) is a black or grey (10YR 3/1-5/2) medium to medium heavy clay with moderate to strong blocky or lenticular structure; and <2->20% fine, soft or nodular carbonate; field pH 8.0-9.0. Gradual or diffuse change to

The **lower subsoil** (B22, B23) is a grey or greyish brown (10YR, 2.5Y 4/2-5/3), medium to medium heavy clay with strong coarse macro lenticular parting to friable fine secondary lenticular structure; and 2-10% soft or nodular carbonate; field pH 8.5-9.0.



Subsoil Chemistry – representative data from BNCOP Site 110								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	7.4	0.128	10	28	22.2	4.9	1.02	0.089
0.25 – 0.35	9.0	0.189	18	26	17.5	11.1	0.407	1.45
0.55 – 0.65	9.0	0.829	525	28	12.2	14.7	0.37	5.06
0.85 – 0.95	8.8	1.391	1600	28	11.5	16.0	0.394	5.85
1.15 – 1.25	8.4	1.700	2250	-	-	-	-	-

pH is alkaline to strongly alkaline throughout. EC and chloride (Cl) data (see Appendices 2 and 5) indicate low salinity (<0.3dS/m) to 0.4-0.5m, moderate to high levels (0.3-0.8dS/m) to between 0.7-1.0m and increasing salinity below 0.7-1.0m. High CEC levels (26-28meq/100g), moderately high CEC/clay ratios (0.52-0.72) and the presence of cracking and strong lenticular structure suggest the clay fraction is active, has significant shrink-swell characteristics and is of mixed mineralogy with a high proportion of smectites. ESP data indicate surface and upper subsoil horizons to about 0.4m are non-sodic (ESP <6), but become strongly to extremely sodic (ESP 18-21) below 0.4m. Magnesium (Mg) dominates cation chemistry in the lower subsoil and is likely to enhance any dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 110										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	22	26	12	39	-	0.72	0.30	4.5	<1	low
0.25 – 0.35	18	21	13	49	-	0.53	0.50	1.6	6	low
0.55 – 0.65	16	20	14	54	-	0.52	0.70	0.8	18	high
0.85 – 0.95	14	21	9	53	-	0.53	0.61	0.7	21	very high

Clay content in immediate surface/upper subsoil horizons is moderately high (39-49%), with significant levels of fine sand (21-26%). The upper subsoil to about 0.4m is characterized by moderate to strong structure, strong cracking, significant reactivity and shrink-swell behaviour, Ca dominant cation chemistry, low sodicity levels (ESP <6) and low dispersion (R1 0.3-0.5). This material is likely to be relatively stable and resilient following disturbance. Below 0.4m, increasing sodicity, dispersion and salinity suggest adverse physical behaviour and poor establishment response is likely post-disturbance.

Summary

Surface soil/upper subsoil material to 0.4m (on mounds and shelves) has high to very high fertility and is strongly aggregated and finely structured. It is further characterised by high clay content (39-49%), active clay behaviour (CEC/Clay ratio 0.53-0.72), low sodicity (ESP <6), low dispersion (R1 0.3-0.5), Ca dominant cation chemistry and low salinity (<0.3dS/m). These attributes suggest material to 0.4m will be relatively benign and physically stable/resilient post disturbance. It is likely however, to experience shrink-swell behaviour, strong cracking and significant root zone shearing (depending on placement thickness). Salvaged topsoil materials to 0.4m are suitable for replacement on low to moderate gradients. **Lower subsoil material below 0.4m** (on mounds and shelves) has undesirable physical and chemical attributes, characterized by moderate to very high levels of salinity and significant sodicity and dispersive behaviour. It is not recommended for stripping, because salvaged materials are likely to be subject to detrimental salinity, dispersion, slaking and erosion risk following disturbance. Stripping recommendations are based preferentially on soil characteristics within mound profiles due to their potentially greater contribution to final stripping volumes and shallower depth to unfavourable materials (Burgess 2003a).

Soil 4d – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m and segregate as primary topsoil to preserve seed source material.
	Root zone	nil	Subsoil clay below 0.4m is undesirable and should be avoided.
Single stage	Combined	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m as primary topsoil. Avoid undesirable subsoil clay below 0.4m. Melonhole gilgai (where present) require topsoil be stripped with an excavator and batter bucket; stripping depth should follow surface contours.

Soil 4d – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	3	Suitable with moderate limitations	e2, es3, m3, ps2, tm3, w2	A1
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, ps2, sa2, tm2, w2, f2, v2, ph2	-

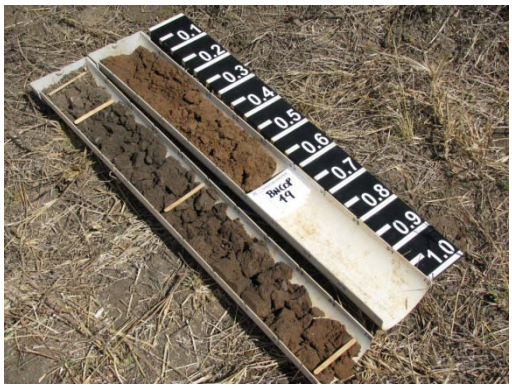
Soil 5 — Weakly to mod. self-mulching black clay on Qa – TQr sideslopes + brigalow

Soil concept:	Firm pedal or weakly to moderately self-mulching, black cracking clay on gently undulating sideslopes/plains that mark the transition from recent alluvium to older elevated plains.
Regional Soil Name:	Affinities with Tralee (Tl)
Aust. Soil Classification:	Black or Grey Vertosol **Principal Profile Form:** Ug5.15, 5.16, 5.17
Landform:	Dissected margins of the upper floodplain of the Dawson River anabranch; typically gently undulating sideslopes that are transitional between recent alluvium of the upper floodplain and older, more elevated TQr landscapes adjacent; subject to occasional flooding in large events. Slopes mostly 1-3%, up to 5% where dissected.
Geological landscape:	Quaternary alluvium (Qa) over insitu TQr clay deposits. Sand, clay and gravel.
Land zone:	Cainozoic alluvial plains (LZ 3)/transitional to Cainozoic clay deposits (LZ4).
Vegetation:	Brigalow ± shrubby species.
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.
Surface features:	Thin, firm pedal to moderately self-mulching surface (2-5mm); strong cracking; non-gilgaied; no surface gravel or stone.

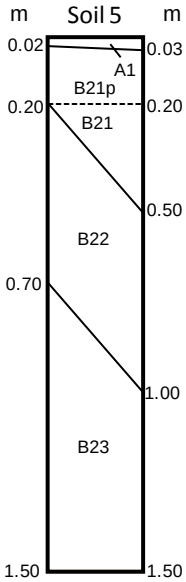
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.116)	high (32)	high (0.955)	very high (24.1)

Moisture Characteristics:	**ERD:** 0.6-0.7m (salinity >0.8dS/m or >800ppm Cl) **PAWC:** 70-85mm/1.0m
Investigation sites:	**Field sites** – 49, 71, 71a, 71b, 71c **Analysed sites** – 71

Cleared brigalow transitional side slope between the upper floodplain (cropping area) and adjacent elevated TQr landscapes (Site 49).



Weakly to moderately self-mulching, black cracking clay on transitional sideslopes at Site 49.



Profile description

The **surface soil** (A1) is a black (10YR 3/1-3/2) medium clay with moderate to strong blocky grading to fine granular structure; field pH 7.0–8.5. Clear change to

The **upper subsoil** (B21, B21p, B22) is a black (10YR 3/1-3/2) medium heavy clay with moderate to strong blocky grading to strong lenticular structure; and <2-10% soft or nodular carbonate; field pH 8.0–9.0. Clear to diffuse change to

The **lower subsoil** (B22, B23) is a brown or grey (7.5YR, 10YR 4/2-4/4), often mottled, fine sandy medium to fine sandy medium heavy clay with strong lenticular structure; field pH 5.0-7.5.

Subsoil Chemistry – representative data from BNCOP Site 71								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	8.5	0.194	95	33	24.1	9.2	0.955	1.41
0.25 – 0.35	8.9	0.370	155	32	19.2	12.7	0.343	4.35
0.55 – 0.65	8.7	0.821	790	34	15.5	14.7	0.352	6.55
0.85 – 0.95	7.7	1.180	1600	34	12.7	14.7	0.382	6.77
1.15 – 1.25	5.5	1.305	1850	-	-	-	-	-

pH is alkaline to about 1.0m, but becomes acidic or strongly acidic (pH 6.5-5.0) at depth. EC and chloride (Cl) data (see Appendices 2 and 5) indicate low salinity (<0.3dS/m) to 0.4-0.5m, moderate to high levels (0.3-0.8dS/m) to about 0.7m and increasing salinity (>0.8dS/m) below 0.7m. High CEC levels (32-34meq/100g), moderately high CEC/clay ratios (0.50-0.56) and the presence of cracking and strong lenticular structure suggest the clay fraction is active (shrink-swell behaviour) and is of mixed mineralogy with a high proportion of smectites. ESP data indicate surface and upper subsoil horizons to about 0.2m are non-sodic (ESP 4), while the upper subsoil to about 0.4-0.5m is weakly to moderately sodic (ESP 4-14). Subsoil material below this depth is subject to rapidly increasing sodicity (ESP 19-20) and dispersion (R1 >0.75). Magnesium (Mg) co-dominates cation chemistry in the lower subsoil and is likely to enhance any dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 71										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	9	17	17	59	-	0.56	0.32	2.6	4	low
0.25 – 0.35	9	15	18	60	-	0.53	0.65	1.5	14	moderate
0.55 – 0.65	7	14	15	66	-	0.52	0.75	1.1	19	high
0.85 – 0.95	6	14	14	68	-	0.50	0.78	0.9	20	high

Clay content is consistently very high throughout (59-68%), while silt levels in immediate surface horizons are only marginally elevated (17-18%) and reflect only intermittent depositional history. Surface and upper subsoil materials to about 0.2m are strongly structured, with significant reactivity (shrink swell behaviour), Ca dominant cation chemistry, low sodicity (ESP 4) and low dispersion (R1 0.32). The upper subsoil to about 0.4m is similar, but with weak to moderate sodicity (ESP 4-14) and increasing dispersion (R1 0.65). Below 0.4m, increasing sodicity, worsening dispersion and very high to extreme salinity suggest adverse physical behaviour and poor establishment response is likely post-disturbance.

Summary

Surface soil/upper subsoil material to about 0.2m has high fertility, and is strongly aggregated and finely structured. It is characterised by high clay content (59%), active clay behaviour (CEC/Clay ratio 0.56), low sodicity (ESP 4), low dispersion (R1 0.32), Ca dominant cation chemistry and low salinity (<0.3dS/m). These attributes suggest material to 0.2m will be relatively benign and physically stable/resilient post disturbance. It is however, likely to experience shrink-swell behaviour, strong cracking and significant root zone shearing (depending on placement thickness). Salvaged topsoil materials to 0.2m are suitable for replacement on low to moderate gradients. **Subsoil material between 0.2-0.4m** has similar characteristics, but is moderately sodic (ESP 4-14) and dispersive (R1 0.65). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 0.4m** is considered undesirable, with very high salinity and worsening sodicity and dispersive behaviour. It is not recommended for salvage.

Soil 5 – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.2-0.4m	Strip additional root zone media between 0.2-0.4m for sub-surface replacement only. Avoid undesirable subsoil material below 0.4m.
Single stage	Combined	0-0.2m	Strip surface soil/subsoil clay to 0.2m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.2m.

Soil 5 – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	4	Marginal due to severe limitations	e3, es4, m4, ps2, w2	B
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, ps2, sa2, f2, ph2	-

Soil 5 – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)									
Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
5	Pass	Pass	Pass	Pass	Pass	Pass	Fail	Fail	**Decided non SCL**

Soil 7a — Strongly melonholed grey clay on level TQr plains + brigalow

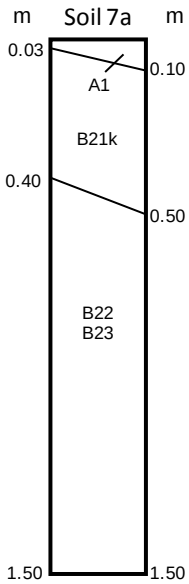
Soil concept:	Hardsetting or firm pedal to weakly self mulching, grey cracking clay with strongly developed melon-hole gilgai (VI 0.3-0.8m, HI 12-20m) on older clay sheets; saline, sodic and acidic at depth.
Regional Soil Name:	Turon (Tr), Greycliffe melonhole phase (GcMp)
Aust. Soil Classification:	Grey Vertosol **Principal Profile Form:** Ug5.24, 25, occ. Ug5.16
Landform:	Level plains associated with elevated Cainozoic clay sheets. Slopes <1%.
Geological landscape:	Unconsolidated Tertiary–Quaternary sediments (Czs, Cza, TQr). Includes insitu and reworked Tertiary clay and widespread reworked local clayey colluvium.
Land zone:	Cainozoic clay deposits (LZ 4).
Vegetation:	Brigalow.
Runoff, perm., & drainage:	Very slow runoff; slow to very slow permeability; imperfectly to mod. well drained.
Surface features:	Hardsetting, firm pedal or weakly self-mulching; cracking; well developed melonhole gilgai (VI 0.3-0.8m, HI 12-20m, proportions about equal); no surface gravel or stone.

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.140)	high (20)	moderate (0.336)	high (12.3)

Moisture Characteristics:	**ERD:** 0.4-0.6m (salinity >0.8dS/m or >800ppm Cl)	**PAWC:** 50-70mm/1.0m
Investigation sites:	**Field sites** – 23, 37, 63, 75, 76, 88	**Analysed sites** – 88

Brigalow regrowth on a moderately melonholed grey cracking clay on level TQr plains at Site 63.

Hardsetting to weakly self-mulching, moderately melonholed (VI 0.5-0.6m), grey cracking clay at Site 75.

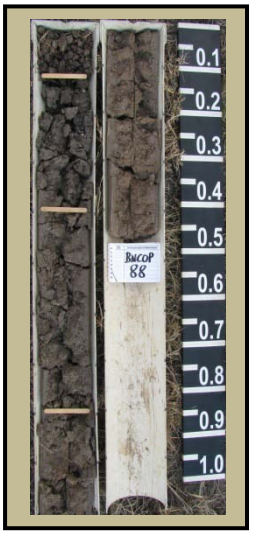


Profile description

The **surface soil** (A1) is a black or grey (10YR 3/1-4/2), fine sandy light medium to fine sandy medium clay with moderate to strong fine blocky structure; field pH 6.5-8.0. Clear change to

The **upper subsoil** (B21k) is a grey or occasionally black (10YR 3/1, 4/1-4/2), fine sandy medium to medium heavy clay with moderate to strong blocky to lenticular structure and <2–10% soft or nodular carbonate; field pH 8.0–8.5. Gradual or diffuse change to

The **lower subsoil** (B22, B23) is a grey or brown (10YR 5/2-5/3), medium clay (typically fine sandy) with weak to moderate coarse lenticular grading to polyhedral structure at depth; field pH 8.5-5.0, becoming increasingly acidic with depth.



Subsoil Chemistry – representative data from BNCOP Site 88								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.8	0.071	45	21	12.3	7.9	0.336	0.782
0.25 – 0.35	8.8	0.629	670	24	11.9	10.6	0.187	3.45
0.55 – 0.65	8.3	1.160	1440	23	9.5	11.1	0.208	4.02
0.85 – 0.95	5.3	1.004	1315	24	6.5	10.8	0.191	6.75
1.15 – 1.25	4.9	0.968	1300	-	-	-	-	-

pH is neutral in surface horizons, strongly alkaline in the upper profile and strongly acidic (pH <5.5) at depth. EC and Cl analyses (see Appendices 2 and 5) indicate low salinity (<0.3dS/m) to 0.1-0.2m, moderate levels (0.3-0.6dS/m) from 0.2-0.4m, and high to extreme salinity (>0.6dS/m) below 0.4-0.6m. CEC levels (21-24meq/100g) and CEC/clay ratios (0.46-0.49) are moderate throughout, and the presence of cracking and severe melonhole gilgai suggest the subsoil clay fraction is active, with significant shrink-swell characteristics and is of mixed mineralogy. Sodicity data indicates surface material to 0.1m is non-sodic (ESP <4), with moderate levels (ESP 4-14) by about 0.4m, and high to extreme levels (ESP 17-28) below 0.4m. Magnesium (Mg) dominates cation chemistry below 0.4m and is likely to enhance dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 88										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	9	27	18	45	-	0.47	0.41	1.6	4	low
0.25 – 0.35	11	28	16	49	-	0.49	0.60	1.1	14	moderate
0.55 – 0.65	10	27	15	50	-	0.46	0.62	0.9	17	high
0.85 – 0.95	9	24	16	52	-	0.46	0.74	0.6	28	very high

Clay content is relatively uniform throughout (45-52%). Fine sand/silt content is significant throughout (40-45% combined), and slaking and crusting behaviour are likely following disturbance. Surface soil material to about 0.1m is moderately to strongly structured, with Ca dominant cation chemistry, low sodicity (ESP 4) and low dispersion (R1 0.41). The upper subsoil to 0.4m is similar, but has weak to moderate sodicity (ESP 4-14) and increasing dispersion (R1 0.60). Below 0.4m, increasing sodicity, worsening dispersion, very high to extreme salinity and coarse macro lenticular structure suggest adverse physical behaviour and very poor establishment response is likely post-disturbance.

Summary

Surface soil material to 0.1m (on mounds) has high fertility, moderate to strong structure, and is characterised by moderately high clay content (45%), low salinity (<0.3 dS/m), low sodicity (ESP 4), only moderate reactivity and elevated levels of fine sand/silt (45%). It is likely this material will be prone to slaking and crusting behaviour following disturbance and subject to a high erosion risk as a result. Topsoil materials to 0.1m are suitable for replacement only on level terrain or low gradients. **Subsoil material between 0.1-0.4m** (on mounds) has similar physical characteristics, but with moderate levels of salinity (EC 0.3-0.6dS/m) and sodicity (ESP 4-14), and increasing dispersive behaviour (R 0.60). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 0.4m** is considered undesirable, with high to very high levels of salinity and worsening sodicity and dispersive behaviour. It is not recommended for salvage. Stripping recommendations are based on melonhole mound characteristics (Burgess 2003a).

Soil 7a – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.1m	Strip structured surface soil/subsoil clay to 0.1m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.1-0.4m	Strip additional root zone media between 0.1-0.4m for sub-surface replacement only. Avoid undesirable subsoil clay below 0.4m.
Single stage	Combined	0-0.1m	Strip surface soil/subsoil clay to 0.1m as primary topsoil. Avoid increasingly undesirable subsoil clay below 0.1m. Stripping with an excavator and batter bucket is recommended; stripping depth to follow surface contours.

Soil 7a – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e4, es3, m5, pm3, ps3, tm4, w2-4	-
Grazing	2	Fattening – suitable for improved pastures, attains max grazing productivity in most seasons	m2, ps2, sa2, tm2, w2, v2, ph2	C1

Soil 7a – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)									
Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
7a	Pass	Pass	Pass	Pass	Pass	Pass	Fail	Fail	**Decided non SCL**

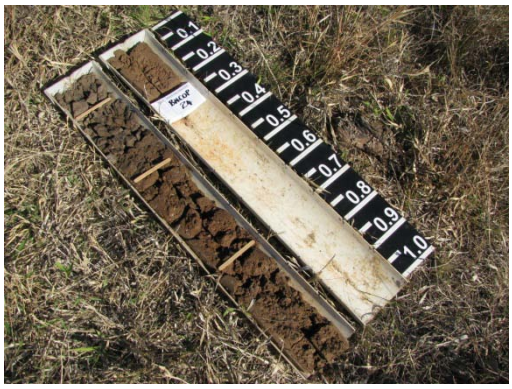
Soil 7b — Brown/grey texture contrast soil/clay on TQr plains + shrubby poplar box

Soil concept:	Hardsetting, thin clay loamy surfaced (<0.05-0.2m), bleached, grey or brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occasional weak gilgai (VI 0.1m, HI 10m) on older unconsolidated sediments and clay sheets.
Regional Soil Name:	Foxleigh clay loamy phase (FxLp) grading to Warwick (Ww)/Greycliffe (Gc)
Aust. Soil Classification:	Grey, Brown or Black Sodosol, Dermosol or Vertosol — **Principal Profile Form:** Dy2.33/43, Db/Dd1.33/43, Uf6.31/32/33, Ug5.15/16/25
Landform:	Level plains associated with elevated Cainozoic clay sheets. Slopes <1%.
Geological landscape:	Unconsolidated Tertiary–Quaternary sediments (Czs, Cza, TQr). Includes insitu and reworked Tertiary clay and widespread reworked local clayey colluvium.
Land zone:	Cainozoic clay deposits (LZ 4).
Vegetation:	Very shrubby poplar box.
Runoff, perm., & drainage:	Slow runoff; slow or very slow permeability; moderately well drained.
Surface features:	Hardsetting and poached; non-cracking to cracking; non-gilgaied to occ. very weakly gilgaied (VI 0.1m, HI 10m); no surface gravel or stone.

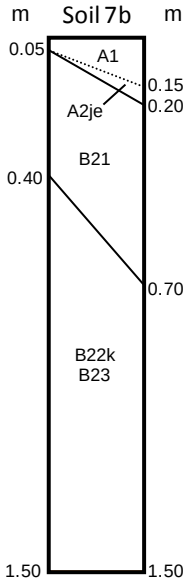
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	mod-high (0.90-0.95)	low (6-8)	low (0.2-0.3)	moderate (4.0-4.5)

Moisture Characteristics:	**ERD:** 0.3-0.5m (salinity >0.8dS/m or >800ppm Cl; and/or rigid soil – ESP >15%) — **PAWC:** 30-60mm/1.0m
Investigation sites:	**Field sites** – 24, 36, 59, 60, 61, 62, 64, 90, 103 — **Analysed sites** – 36, 90

Shrubby poplar box - brigalow ± belah regrowth on level TQr plains at Site 36.



Thin clay loamy surfaced, grey-brown sodic texture contrast soil overlying brownish unconsolidated TQr sediments at Site 24.



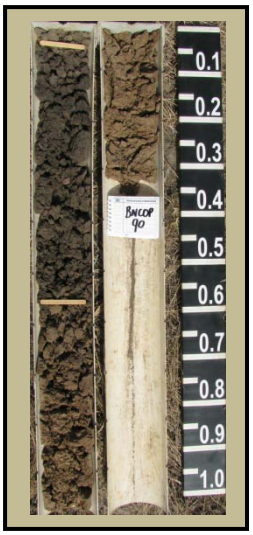
Profile description

The **surface soil** (A1) is a black, grey or brown (10YR 3/1-3/3, 4/1), fine sandy clay loam to fine sandy light clay with weak to moderate subangular blocky to blocky structure; field pH 6.0-6.5. Clear or abrupt change to

The **sub-surface layer where present** (A2je) is a thin, sporadically or conspicuously bleached, grey or brown (10YR 4/2-4/3, 5/2; 7/2 when dry), fine sandy clay loam to clay loam fine sandy with weak subangular blocky to massive structure; field pH 5.5-6.5. Abrupt change to

The **upper subsoil** (B21) is a grey, brown or occ. black (10YR 3/1, 4/1-4/3, 5/2), fine sandy medium to fine sandy medium heavy clay with moderate coarse columnar to moderate or strong blocky structure; field pH 7.0-8.5. Gradual change to

The **lower subsoil** (B22k, B23) is a brown (7.5YR, 10YR 4/3-4/6, 5/3-5/4, 6/3), fine sandy light medium to fine sandy medium clay with weak coarse lenticular to moderate blocky or polyhedral structure; and <2-10% soft or nodular carbonate (in the B22 horizon); field pH 8.0-5.0, becoming increasingly acidic with depth.



Subsoil Chemistry – representative data from BNCOP Site 90								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.4	0.051	30	11	4.3	5.3	0.204	0.75
0.25 – 0.35	8.7	0.642	780	19	7.8	10.2	0.116	3.42
0.55 – 0.65	8.2	0.732	1080	16	5.3	9.0	0.111	3.88
0.85 – 0.95	5.2	0.597	880	14	2.9	5.9	0.069	4.71
1.15 – 1.25	4.7	0.555	815	-	-	-	-	-

pH is slightly acidic in surface horizons, alkaline to strongly alkaline in the upper profile and strongly acidic (pH <5.5) at depth. EC and Cl analyses (see Appendices 2 and 5) indicate low salinity (<0.3dS/m) to 0.2m, moderate levels (0.3-0.6dS/m) from about 0.2-0.4m, and high to very high salinity (0.6->0.8dS/m) somewhere between 0.4-0.8m. Moderate CEC levels (14-19meq/100g) and CEC/clay ratios (0.38-0.49) in the subsoil and only limited cracking suggest the clay fraction is of mixed mineralogy, with limited activity and lacks significant shrink-swell characteristics. Sodicity data (Sites 36 and 90) indicate surface material to about 0.1-0.2m is mostly non-sodic (ESP 4-7), but moderate to extreme levels (ESP 13-35%) are present below this depth. Magnesium (Mg) dominates cation chemistry throughout the subsoil and is likely to enhance dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 90										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	12	45	17	29	-	0.38	0.58	0.8	7	low-mod.
0.25 – 0.35	10	36	17	39	-	0.49	0.66	0.8	18	high
0.55 – 0.65	10	39	17	37	-	0.43	0.89	0.6	24	very high
0.85 – 0.95	12	41	12	34	-	0.41	0.95	0.5	35	very high

Clay content in texture contrast profiles increases sharply between surface horizons (20%) and the underlying subsoil (34-40%), while in heavier profiles (prone to occasional cracking), clay content in thin surface horizons <0.1m is higher (29%). The surface soil to 0.1-0.2m is very hardsetting, weakly structured and is characterized by high levels of fine sand and silt (62-69% combined). This suggests significant slaking and pulverescent behaviour is likely following disturbance. Similarly, subsoil clays are only moderately structured, with limited reactivity, magnesium dominant cation chemistry, significant dispersive behaviour (R1 0.66-0.95) and elevated levels of fine sand/silt (>50-55 combined). Disturbed subsoil materials will lack shrink-swell behaviour and be subject to pulverescent behaviour (when dry), dense packing, severe compaction and significant crusting behaviour. Laboratory measured dispersion is moderate (R1 0.58-0.66) in the surface soil to about 0.2m, but increases to high or extreme levels (R1 0.85-0.95) below this depth.

Summary

Surface soil material to 0.1-0.2m has moderate fertility and is characterised by low salinity (<0.3 dS/m), relatively low sodicity (ESP 4-7), hardsetting behaviour, weak to moderate structure, moderate clay content (20-35%), very limited reactivity and elevated levels of levels of fine sand/silt (62-69%). It is likely this material will have a high erosion risk and be prone to pulverescent behaviour and severe compaction, slaking and crusting following disturbance. Topsoil materials to 0.1-0.2m are suitable for replacement only on level terrain or low gradients. **Subsoil material below about 0.2m** is considered undesirable and is not recommended for salvage. It is characterized by moderate to very high levels of salinity and extremely sodic/dispersive behaviour. Stripped material will be saline, highly dispersive and prone to compaction, slaking and crusting. It will be subject to significant erosion risk and should be avoided.

Soil 7b – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.15m	Strip surface soil/upper subsoil clay to 0.15m and segregate as primary topsoil to preserve seed source material.
	Root zone	nil	Subsoil clay below 0.15m is undesirable and should be avoided.
Single stage	Combined	0-0.15m	Strip structured surface soil/subsoil clay to 0.15m. Avoid undesirable subsoil clay below 0.15m.

Soil 7b – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e4, es3, m5, pm3-4, ps4, tm2, w2	-
Grazing	3	"Grower" country – suitable for improved pastures, but less productive than Classes 1 & 2	m3, nd3, ps2, sa2, w2, v2, ph2, esp2	C1

Soil 7c — Sandy brown texture contrast soil on relict TQr + eucalypt - softwood

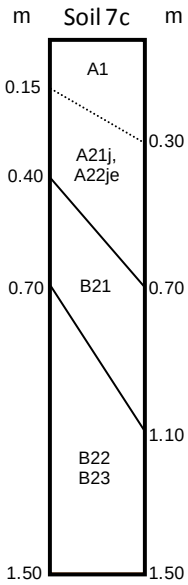
Soil concept:	Hardsetting, thick sandy surfaced (0.4-0.7m), bleached, often mottled, brown non-sodic to weakly sodic texture contrast soil on elevated relict alluvial deposits.		
Regional Soil Name:	Collawmar (Cm)		
Aust. Soil Classification:	Brown Sodosol	**Principal Profile Form:**	Db2.32/33, 2.42/43
Landform:	Level to gently undulating, relatively elevated, plains and low rises developed on unconsolidated relict alluvial deposits of indeterminate age. Slope range 0.5-2%.		
Geological landscape:	Unconsolidated Tertiary–Quaternary sediments (Czs, Cza, TQr). Includes insitu and reworked relict alluvial deposits and widespread reworked local colluvium; stratigraphically overlies adjacent Cainozoic clay sheets.		
Land zone:	Cainozoic sand deposits not underlain by a deeply weathered surface (LZ 5a).		
Vegetation:	Shrubby eucalypt grading to eucalypt - softwood scrub.		
Runoff, perm., & drainage:	Slow runoff; slow permeability; imperfectly to moderately well drained.		
Surface features:	Hardsetting; non-cracking; non-gilgaied; no surface gravel or stone.		

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	mod.-high (0.09)	moderate (11)	low (0.423)	moderate (2.4)

Moisture Characteristics:	**ERD:** >1.0m (no salinity or ESP restrictions)	**PAWC:** 70-75mm/1.0m
Investigation sites:	**Field sites** – 46, 47, 48, 56, 57, 77, 80, 83, 85, 86, 93, 95, 97, 98, 99, 100, 101, 104, 105, 108, 109	**Analysed sites** – 99

Shrubby silver-leaved ironbark - softwood scrub on sandy unconsolidated TQr sediments (Site 99).

Thick sandy surfaced, mottled, brown non-sodic texture contrast soil overlying relict alluvial TQr sediments at Site 56.



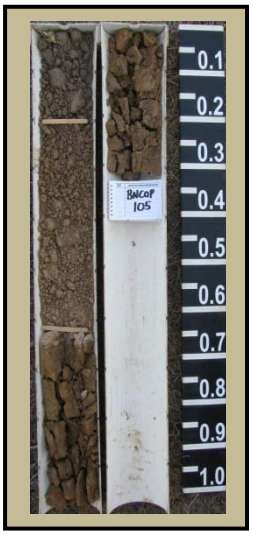
Profile description

The **surface soil** (A1) is a black or occ. brown (7.5YR, 10YR 3/2, 3/3-4/3), loamy sand to sandy loam (medium to coarse sand fraction) with weak subangular blocky to massive structure; field pH 5.5-7.5. Clear change to

The **sub-surface layer** (A21j, A22je) is a sporadically or conspicuously bleached, brown or grey (7.5YR, 10YR 4/3-4/4, 4/2-5/4) loamy sand to sandy loam (medium to coarse sand fraction) with weak subangular blocky to massive structure; field pH 5.5-7.5. Clear or abrupt change to

The **upper subsoil** (B21) is a brown (10YR 4/3, 5/3-5/6), often mottled (<2-10% faint or distinct yellow/orange), sandy light to sandy light medium clay with moderate to strong coarse prismatic/columnar parting to moderate blocky structure; field pH 6.0-8.0. Clear or gradual change to

The **lower subsoil** (B22, B23) is a brown (10YR, 2.5Y 5/3-5/6), mottled (20-50% distinct or prominent orange/grey), sandy light medium to sandy medium clay with weak to moderate blocky or prismatic structure; and occasionally <2-20% soft or nodular carbonate; field pH 6.0-8.5.



Subsoil Chemistry – representative data from BNCOP Site 99								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.3	0.042	15	4	2.4	0.97	0.423	0.041
0.25 – 0.35	6.6	0.024	5	3	2.7	0.44	0.29	0.041
0.65 – 0.75	7.2	0.026	2	10	4.8	4.2	0.202	0.564
0.85 – 0.95	7.2	0.035	8	12	5.6	5.4	0.305	0.884
1.15 – 1.25	8.1	0.073	35	-	-	-	-	-

pH is slightly acidic in surface horizons and neutral to alkaline in the subsoil. EC and chloride (Cl) analyses (see Appendices 2 and 5) confirm very low salinity (<0.1dS/m) throughout. Similarly, CEC levels are very low (3-4 meq/100g) in the sandy topsoil, and increase only marginally (10-12 meq/100g) in the clayey subsoil. CEC/clay ratios in the subsoil are low (0.23) and suggest the clay fraction is un-reactive and of mixed mineralogy (dominantly kaolinite and illite). Sodicity data indicates sandy surface soil (0.4-0.7m) is non sodic (ESP 1), while underlying subsoil clay is non-sodic to weakly sodic (ESP 6-7). Magnesium (Mg) is co-dominant in the subsoil, but is likely to have limited impact because of low ESP.

Physical Soil Characteristics – representative data from BNCOP Site 99										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	29	55	8	10	-	0.40	0.64	2.5	1	low
0.25 – 0.35	31	51	7	11	-	0.27	0.88	6.1	1	low
0.65 – 0.75	20	33	5	44	-	0.23	0.57	1.1	6	low
0.85 – 0.95	15	27	1	53	-	0.23	0.67	1.0	7	low-mod.

Clay content increases sharply between sandy surface horizons (10-11%) and the underlying clay subsoil (44-53%). The surface soil is massive to only very weakly structured and is characterized by significant fine sand ± silt (58-63% combined). Significant slaking and pulverescent/hardsetting behaviour is likely with this material following disturbance. The underlying clayey subsoil (clay fraction 44-53%) is un-reactive, non-sodic to very weakly sodic and moderated significantly by sand content (coarse sand/fine sand 42-53% combined). Salvaged subsoil material, whilst not particularly dispersive, would be subject to dense packing and significant compaction post disturbance. Laboratory measured dispersion is moderate to high (R1 0.64-0.88) in sandy surface horizons (due to high levels of unstable fine sand), but decreases to only low or moderate levels (R1 0.57-67) in the structurally more competent, non-sodic clayey subsoil.

Summary

Surface soil material to 0.4-0.7m has moderate fertility and is characterized by massive to very weak structure, low clay content (<11%), very low salinity (<0.1dS/m) and very low sodicity (ESP 1); but with elevated dispersion (R0.64-0.88) and high levels of fine sand/silt (58-63% combined). It is likely this material will be hardsetting and prone to powdery/pulverescent behaviour, slaking and high erosion risk following disturbance. Salvaged materials are recommended only for replacement on level terrain or very low gradients. **Clayey subsoil material below 0.4-0.7m** has relatively benign physical and chemical characteristics and represents a useful source of additional root zone media. It is characterized by a moderately structured, largely non-sodic (ESP 6-7) but un-reactive clay fraction that lacks noticeable shrink swell characteristics and is moderated by significant sand content (42-53%). Salvaged subsoil materials will lack structural integrity following disturbance, and be subject to dense packing, compaction and elevated erosion risk as a result (post disturbance). Clayey material below 0.4-0.7m is recommended for stripping, but only as root zone media for sub-surface replacement.

Soil 7c – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.5m	Strip sandy surface soil to 0.5m and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	0.5-1.2m	Strip additional clayey root zone media between 0.5-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy surface soil to 0.5m as primary topsoil. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.

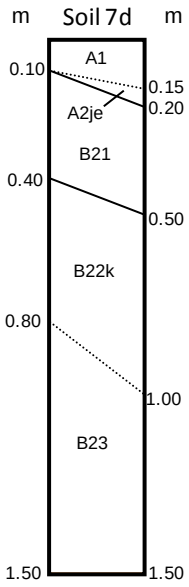
Soil 7c – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e2, es3, m5, pm3, ps4, w2-4	-
Grazing	4	Breeding country – marginal for improved pastures, suitable for grazing native pastures	m4, nd3, ps2	C2

Soil 7d — Loamy black texture contrast soil on TQr plains + brigalow-Dawson gum

Soil concept:	Hardsetting, clay loamy surfaced (0.10-0.2m), bleached, black sodic texture contrast soil on older unconsolidated sediments and clay sheets.			
Regional Soil Name:	Racetrack (Rt)/Kokotungo (Kk)			
Aust. Soil Classification:	Black Sodosol	**Principal Profile Form:**	Dd1.33/1.43	
Landform:	Level to gently undulating plains on elevated unconsolidated Cainozoic sediments and clay sheets. Slope range <1-2%.			
Geological landscape:	Unconsolidated Tertiary–Quaternary sediments (Czs, Cza, TQr). Includes insitu and reworked Tertiary clay and widespread reworked local clayey colluvium.			
Land zone:	Cainozoic clay deposits (LZ 4).			
Vegetation:	Brigalow ± Dawson gum.			
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.			
Surface features:	Hardsetting; non-cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.140)	high (28)	low (0.194)	high (6.5)
Moisture Characteristics:	**ERD:** 0.45m (rigid soil – ESP >15%)		**PAWC:** 50mm/1.0m	
Investigation sites:	**Field sites** – 72, 78, 79, 81, 82, 87, 94, 102		**Analysed sites** – 87	

Brigalow - Dawson gum regrowth on level TQr plains at Site 79.

Clay loamy surfaced, black sodic texture contrast soil overlying greyish-brown unconsolidated TQr sediments at Site 79.



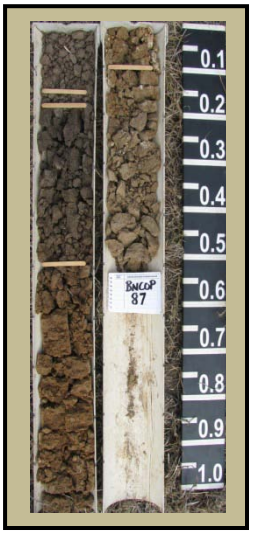
Profile description

The **surface soil** (A1) is a black (10YR 2/1-3/2), sandy clay loam to clay loam sandy (fine to medium sand fraction) with weak subangular blocky to massive structure; field pH 6.0-7.5. Clear change to

The **sub-surface layer where present** (A2je) is a thin, sporadically or conspicuously bleached, grey (10YR 4/1-5/2; 6/1-7/2 when dry), sandy clay loam to clay loam sandy (fine to medium sand fraction) with weak subangular blocky to massive structure; field pH 6.0-7.0. Abrupt change to

The **upper subsoil** (B21) is a black (10YR 3/1-3/2), sandy light medium to sandy medium clay (fine to medium sand fraction) with coarse columnar grading to moderate or strong blocky structure; field pH 8.0-9.0. Clear or gradual change to

The **lower subsoil** (B22k, B23) is a brown or grey (10YR 4/2-4/3, 5/2-5/4), occasionally mottled (<2-20% faint orange/red), sandy light to sandy light medium clay (fine to medium sand fraction) with moderate to strong blocky structure; and <2–10% soft or nodular carbonate (in B22 horizon); field pH 8.5-5.5, becoming increasingly acidic with depth. .



Subsoil Chemistry – representative data from BNCOP Site 87								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.4	0.034	5	10	6.5	3.4	0.194	0.330
0.25 – 0.35	8.5	0.087	60	15	7.4	7.3	0.130	1.83
0.55 – 0.65	9.1	0.672	730	12	3.0	6.6	0.140	3.63
0.85 – 0.95	9.2	0.976	1100	11	2.8	6.3	0.129	3.92
1.15 – 1.25	9.3	0.991	1150	-	-	-	-	-

pH is slightly acidic to neutral in surface horizons and strongly alkaline (pH >9.0) in the subsoil. EC and chloride (Cl) analyses (see Appendices 2 and 5) indicate low salinity (<0.3dS/m) to 0.4-0.5m, moderate levels (0.3-0.6dS/m) between about 0.5-0.8m, and high to very high salinity (>0.8dS/m) below 0.8->1.0m. Low to moderate CEC levels (11-15meq/100g) and CEC/clay ratios (0.36-0.39) in the subsoil and the absence of cracking suggest the clay fraction is of mixed mineralogy, with limited activity and lacks significant shrink-swell characteristics. Sodicity data indicates loamy surface material to about 0.1-0.2m is non-sodic (ESP 3), while moderate to extreme sodicity (ESP 12-36%) is present in the clay subsoil below this depth. Magnesium (Mg) dominates cation chemistry throughout the subsoil and will enhance dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 87										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	18	42	11	27	-	0.37	0.50	1.9	3	low
0.25 – 0.35	17	35	7	38	-	0.39	0.66	1.0	12	moderate
0.55 – 0.65	19	39	8	33	-	0.36	0.99	0.5	30	very high
0.85 – 0.95	18	40	11	29	-	0.38	0.99	0.4	36	very high

Clay content increases abruptly between loamy surface horizons (27%) and the underlying clayey subsoil (38%). The surface soil is massive to only weakly structured and characterized by elevated levels of fine sand/silt (53% combined). Significant slaking and pulverescent/hardsetting behaviour is likely post disturbance. Clayey subsoil material (below 0.1-0.2m) is dispersive, un-reactive and has equivalent proportions of clay (29-38%) and fine sand (35-40%). It is likely to be pulverescent (when dry) and prone to severe compaction and crusting post disturbance. Laboratory dispersion is low (R1 0.50) in the loamy surface soil to 0.1-0.2m, but increases to extreme levels in the subsoil (R1 0.66-0.99) below about 0.4m.

Summary

Surface soil material to 0.1-0.2m has high fertility and is characterized by massive to weak structure, moderately low clay content (27%), low salinity (EC <0.3dS/m), low sodicity (ESP 3) and elevated levels of fine sand/silt (53% combined). It is likely this material will be hardsetting and prone to powdery/pulverescent behaviour, slaking and high erosion risk following disturbance. Salvaged materials are recommended only for replacement on level terrain or very low gradients. **Subsoil material below 0.1-0.2m** has unfavourable physical attributes. It is characterized by coarse, dense structure and a moderately to extremely sodic (ESP 12-36%) and dispersive (R 0.66-0.99), un-reactive clay fraction. Salvaged subsoil materials will be subject to dense packing and compaction, severe slaking and extreme dispersion, crusting and erosion risk post disturbance. Subsoil material below 0.1-0.2m is not recommended for stripping.

Soil 7d – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.1/0.2m	Strip loamy surface soil to between 0.1-0.2m (maximum) and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	nil	Subsoil clay below 0.1-0.2m is dispersive and should be avoided.
Single stage	Combined	0-0.1/0.2m	Strip loamy surface soil to between 0.1-0.2m (maximum) as topsoil/seed source material. Avoid dispersive subsoil clay below 0.1-0.2m. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.

Soil 7d – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e2, es4, m5, pm3, ps4, w2	-
Grazing	3	"Grower" country – suitable for improved pastures, but less productive than Classes 1 & 2	m3, ps2, w2, e2	C1

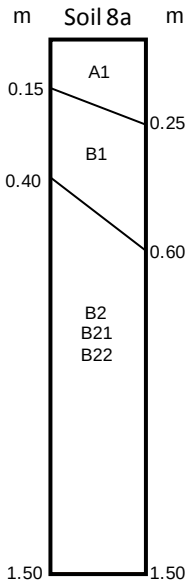
Soil 7d – Strategic Cropping Land – WCZ Zonal Criteria Assessment (Queensland Government 2011)									
Soil	ZC 1	ZC 2	ZC 3	ZC 4	ZC 5	ZC 6	ZC 7	ZC 8	SCL status
7d	Pass	Pass	Pass	Pass	Pass	Fail	Pass	Fail	**Decided non SCL**

Soil 8a — Deep loamy red earth on weathered Tertiary sandstone + eucalypt

Soil concept:	Hardsetting, massive, gradational loamy red earth overlying weathered Tertiary sandstone (>1.5m).			
Regional Soil Name:	Bills Hut (Bh)/Spear (Sp)			
Aust. Soil Classification:	Red kandosol	**Principal Profile Form:**	Gn2.11/2.12	
Landform:	Gently undulating to undulating, intact Tertiary plateau surface (lacking elevated mesa/scarp topography). Moderate dissection and footslope development occurs at the northern end of the unit. Slope range <1-5%.			
Geological landscape:	Medium to coarse grained Tertiary sandstone altered (to some extent) by Tertiary weathering (Ta, Tm). Substrate is weathered/ferruginised sandstone, but without evidence of lateritized profile features.			
Land zone:	Cainozoic to Proterozoic medium to coarse grained sediments (LZ 10).			
Vegetation:	Eucalypt.			
Runoff, perm., & drainage:	Slow to moderately rapid runoff; moderate permeability; well drained.			
Surface features:	Hardsetting; non-cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	moderate (0.07)	very low (1.0)	very low (0.307)	moderate (2.7)
Moisture Characteristics:	**ERD:** >1.0m (no salinity or ESP restrictions)		**PAWC:** 70-85mm/1.0m	
Investigation sites:	**Field sites** – 5, 20, 21, 38, 44, 51, 58, 91, 107		**Analysed sites** – 38	

Selectively cleared silver-leaved ironbark–bloodwood woodland on an intact, gently undulating remnant plateau surface (Site 38).

Deep loamy massive red earth developed on weathered Tertiary sandstone (below 1.5m) at Site 107.



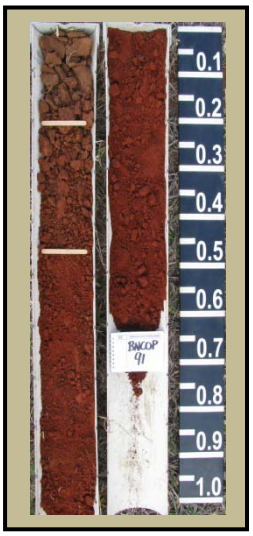
Profile description

The **surface soil** (A1) is a brown or red (2.5YR, 5YR, 7.5YR 3/3-3.4), sandy loam to sandy clay loam with massive structure; field pH 6.0-7.0. Clear change to

The transitional **sub-surface layer** (B1) is a red (2.5YR, 5YR 3/4-3/6, 4/4-4/6), sandy clay loam to clay loam sandy with massive structure; field pH 5.5-7.0. Gradual or diffuse change to

The **lower subsoil** (B2, B21, B22) is a red (10R, 2.5YR 3/6-4/6), clay loam sandy to sandy light clay with massive structure; field pH 5.5-7.0.

Profiles are typically very deep (>1.5-2.0m). Weathered substrate (B3) and/or associated deeply weathered/lateritized profile features (mottling, reticulite) do not present within this depth range.



Subsoil Chemistry – representative data from BNCOP Site 38								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.2	0.020	<5	4	2.7	0.99	0.307	0.021
0.25 – 0.35	6.3	0.010	<5	3	2.1	0.90	0.180	0.028
0.55 – 0.65	6.4	0.010	<5	6	3.2	2.4	0.215	0.043
0.85 – 0.95	6.2	0.011	<5	5	2.6	2.5	0.087	0.058
1.15 – 1.25	6.0	0.007	<5	-	-	-	-	-

pH, EC and Cl analyses (see Appendices 2 and 5) indicate profiles are slightly acidic, with consistently low salinity throughout (EC <0.1dS/m, Cl <5ppm). Similarly, CEC levels (3-6meq/100g) and CEC/clay ratios (0.12-0.27) are low to very low throughout and suggest the clay fraction is un-reactive and predominantly kaolinitic in nature. ESP data confirm both surface soil (ESP 1) and subsoil materials (ESP 1) are completely non-sodic. Magnesium (Mg) is co-dominant in the lower subsoil, but is unlikely to have any effect.

Physical Soil Characteristics – representative data from BNCOP Site 38										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	18	62	6	15	-	0.27	0.74	2.7	1	very low
0.25 – 0.35	16	57	8	20	-	0.15	0.51	2.3	1	very low
0.55 – 0.65	12	38	4	47	-	0.13	0.24	1.3	1	very low
0.85 – 0.95	12	42	5	43	-	0.12	0.17	1.0	1	very low

Clay content increases gradually between surface horizons (15-20%) and the underlying subsoil (43-47%). The surface soil to about 0.5m (A1/B1 horizons) lacks structure (massive), and has elevated levels of fine sand (57-62%) and limited coarse sand (16-18%). Salvaged materials will be pulverescent (when dry) and subject to dense packing, compaction and hardsetting behaviour following disturbance. Clayey subsoil materials below 0.5m are non sodic, non dispersive, strongly flocculated (high sesquioxide content) and completely benign. They are however, rigid and un-reactive and dominated by equivalent fine sand (38-42%) and clay fractions (43-47%). This suggests dense packing, severe compaction and poor establishment response is likely with exposed subsoil mediums post-disturbance. Laboratory measured dispersion is moderate (R1 0.51-0.74) in the surface soil (due to high levels of fine sand), but decreases to very low levels (R1 0.17-0.24) throughout the subsoil. Field morphology suggests sesquioxides play an active flocculation role in this soil.

Summary

Sandy to loamy surface soil material to 0.5m has very low to moderate fertility and is characterized by massive structure, low clay content (15-20%), very low salinity (EC <0.1dS/m), very low sodicity (ESP 1), moderate dispersion (R1 0.51-0.74) and elevated levels of fine sand (57-62%). It is likely this material will be powdery/pulverescent following disturbance and will be subject to dense packing, compaction and hardsetting behaviour. Salvaged materials are recommended only for replacement on level terrain or very low gradients because of potential issues with adverse physical behaviour and rehabilitation establishment. **Loamy/clayey subsoil material below 0.5m** has similar very low salinity and sodicity attributes, as well as a non-dispersive (R1 0.17-0.24), sesquioxide rich, kaolinitic clay fraction. Lower subsoil material is considered completely benign, but is likely to be prone to severe compaction, poor establishment response and elevated erosion risk post disturbance. Subsoil material below 0.5m is recommended for stripping, but only as root zone media for sub-surface replacement.

Soil 8a – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip sandy/loamy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional loamy/clayey root zone media between 0.3-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy/loamy surface soil to 0.5m as primary topsoil. Avoid clayey subsoil materials below this depth because of undesirable physical attributes and poor establishment response post disturbance.

Soil 8a – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e2-3, es1-3, m5, pm2, ps4	-
Grazing	4	Breeding country – marginal for improved pastures, suitable for grazing native pastures	m4, nd4, ps2, e2, v2	C2

Soil 8b — Sandy grey texture contrast soil on Tertiary sandstone + eucalypt

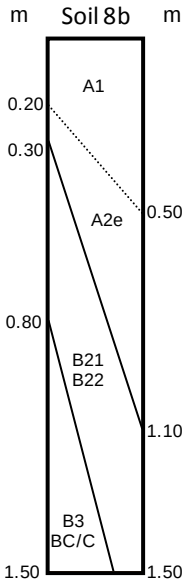
Soil concept:	Soft to loose, thick sandy surfaced (0.3-1.0m), bleached, strongly mottled, non-sodic grey texture contrast soil overlying insitu Tertiary sandstone from 0.8->1.5m.
Regional Soil Name:	Wyndham (Wm), affinities with Emoh (Em)
Aust. Soil Classification:	Grey (or occ. Brown) Chromosol **Principal Profile Form:** Dy5.41/43, Db4.41/43
Landform:	Elevated, moderately dissected, undulating to rolling remnant rises and associated colluvial pediments on relatively fresh, coarse grained Tertiary sandstone. Slope range <1-12%.
Geological landscape:	Little weathered, medium to coarse grained Tertiary sandstone, largely unaltered by Tertiary weathering (Ta, Tm).
Land zone:	Cainozoic to Proterozoic medium to coarse grained sediments (LZ 10).
Vegetation:	Eucalypt.
Runoff, perm., & drainage:	Slow to moderately rapid runoff; slow permeability; imperfectly drained.
Surface features:	Soft or loose sandy surface; non-cracking; non-gilgaied; no free surface gravel or stone; occ. sandstone outcrop on steeper dissected mid to upper slopes.

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	low-mod. (0.06)	very low (2.0)	very low (0.147)	moderate (2.3)

Moisture Characteristics:	**ERD:** 0.8->1.0m (no salinity or ESP restrictions)	**PAWC:** 50-80mm/1.0m
Investigation sites:	**Field sites** – 1, 4, 6, 26, 29, 32, 34, 40, 41, 89, 92, 112, 113	**Analysed sites** – 29, 40

Silver-leaved ironbark ± bloodwood ± blue gum with a shrubby quinine bush understorey on dissected Tertiary sandstone at Site 40.

Thick sandy surfaced, mottled, grey non-sodic texture contrast soil developed insitu on Tertiary sandstone and/or related colluvium (Site 29).



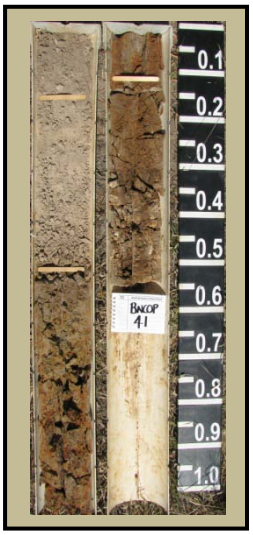
Profile description

The **surface soil** (A1) is a black or brown (10YR 3/2-3/3), sand or loamy sand (medium to coarse sand fraction) with massive structure; field pH 6.0-6.5. Clear or gradual change to

The **sub-surface layer** (A2e) is a conspicuously bleached, grey or brown (10YR 4/2-5/4; 6/2-7/3 when dry), medium to coarse sand with massive or single grain structure; field pH 5.5-6.5. Abrupt change to

The **subsoil** (B21, B22) is a grey or occ. brown (10YR 4/2-6/2, 5/4-6/4), strongly mottled (20-50% distinct or prominent red/orange), sandy light to sandy medium clay (medium to coarse sand fraction) with moderate to strong coarse prismatic to blocky structure; field pH 5.5-7.0. Clear change to

Substrate material (B3, BC/C) is a grey (10YR 5/2-6/2, 6/4), massive, coarse sandy loam to gritty clay loam sandy matrix with >20-90% soft crumbly medium to coarse grained sandstone weathering insitu; field pH 5.0-8.2; hard rock from 1.0->1.5m.



Subsoil Chemistry – representative data from BNCOP Site 40								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.1	0.016	<5	4	2.3	1.0	0.147	0.015
0.25 – 0.35	6.3	0.012	<5	3	1.6	1.4	0.069	0.062
0.55 – 0.65	6.1	0.018	<5	22	12.4	8.2	0.378	0.799
0.85 – 0.95	6.7	0.027	10	23	13.2	8.1	0.298	1.011
1.15 – 1.25	7.6	0.062	50	-	-	-	-	-

pH is acidic in the sandy surface soil and acidic to alkaline in the clayey subsoil. EC and Cl analyses (see Appendices 2 and 5) indicate profile salinity is consistently low throughout (EC <0.1dS/m, Cl <50ppm). CEC levels are very low (3-4 meq/100g) in surface horizons, but increase to moderate levels (22-23 meq/100g) in the clayey subsoil. CEC/clay ratios in the subsoil are moderate (0.46-0.52) and suggest the clay fraction has only limited reactivity and is of mixed mineralogy (mostly kaolinite and illite). Sodicity data indicates both the surface soil (0.3-1.1m) and the underlying clayey subsoil are non sodic (ESP 1-5).

Physical Soil Characteristics – representative data from BNCOP Site 40										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	60	29	3	9	-	0.44	0.89	2.3	1	low
0.25 – 0.35	65	22	5	10	-	0.30	0.87	1.1	2	low
0.55 – 0.65	34	13	8	48	-	0.46	0.38	1.5	4	low
0.85 – 0.95	34	13	10	44	-	0.52	0.63	1.6	5	low

Clay content increases sharply between sandy surface horizons (9-10%) and the underlying clay subsoil (44-48%). The surface soil is massive, dominated by coarse sand (60-65%) and is unlikely to exhibit dispersive tendencies either insitu or after disturbance. Reworked surface materials will be loose and incoherent, and not subject to pulverescent or hardsetting behaviour. In contrast, subsoil characteristics are dominated by a non-sodic (ESP 4-5), un-reactive clay fraction (44-48%), that is significantly moderated by sand content (coarse sand/fine sand - 47% combined). Subsoil materials are likely to be subject to slaking, dense packing, severe compaction and elevated erosion risk post disturbance. Laboratory measured dispersion in sandy surface horizons is high (R1 0.87-89) (due to fines associated with the sand fraction), but decreases to low or moderate levels (R1 0.38-63) in the structurally more competent, non-sodic clayey subsoil. Subsoil materials, whilst suitable for salvage, are recommended for subsurface replacement only.

Summary

Coarse sandy surface soil material varies significantly in thickness (0.3-1.1m), has very low fertility, massive structure, very low clay content (<10%), very low salinity (EC <0.1dS/m), low sodicity (ESP 1-2) and a significant coarse sand fraction (60-65%). It is considered benign and relatively stable, but is likely to experience loose/incoherent behaviour and elevated erosion risk following disturbance. Salvaged sandy material is recommended for replacement only on level terrain or low gradients. Potential exists to use coarse sandy material (to depths of 1.1m where present) as surrogate topsoil on steeper slopes, but such a strategy would require adequate mixing with competent sandstone spoil to increase surface roughness, topsoil resilience and slope integrity. **Clayey Subsoil material below 0.3-1.1m** has benign physical and chemical characteristics and represents a useful source of additional root zone media. It is characterized by a moderately structured, non-sodic (ESP 4-5), un-reactive clay fraction (without shrink swell characteristics) that is moderated by significant sand content (47%). Salvaged subsoil materials are likely to lack structural integrity following disturbance, and be subject to dense packing, compaction and elevated erosion risk. Clayey subsoil material below 0.3-1.1m is recommended for stripping, but only as root zone media for sub-surface replacement.

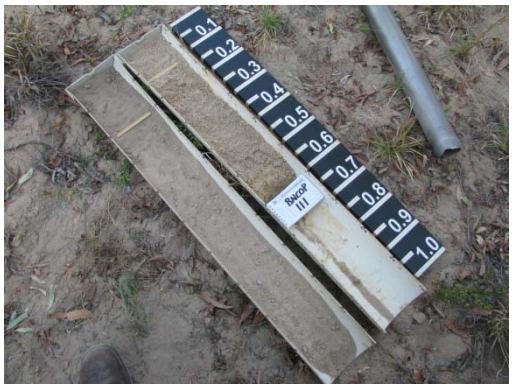
Soil 8b – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	0.3-0.8m or deeper	Strip additional sandy or clayey root zone media from 0.3m to depth of weathered rock (0.8->1.5m) for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy surface soil to 0.5m as primary topsoil. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.

Soil 8b – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e3-5, es1-5, m5, pm1-3, r3, w4	-
Grazing	4	Breeding country – marginal for improved pastures, suitable for grazing native pastures	m4, nd4, e2, v2	C2

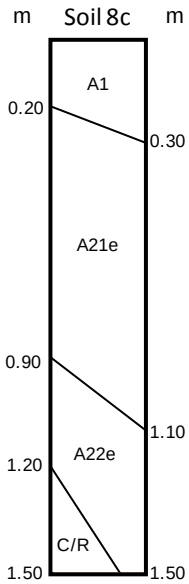
Soil 8c — Loose grey colluvial sand on Tertiary sandstone footslopes + eucalypt

Soil concept:	Loose, massive, bleached, grey coarse sand on steeper colluvial footslopes.			
Regional Soil Name:	Wyndham (Wm), affinities with Cherwell (Cw)			
Aust. Soil Classification:	Bleached-Orthic Tenosol	**Principal Profile Form:**	Uc2.12	
Landform:	Colluvial footslopes below elevated and moderately dissected, undulating to rolling remnant rises on relatively fresh, coarse grained Tertiary sandstone. Slope range 1-5%.			
Geological landscape:	Tertiary – Quaternary colluvium (TQr). Sandy colluvium derived from little weathered, medium to coarse grained Tertiary sandstone (largely unaltered by Tertiary weathering) (Ta, Tm).			
Land zone:	Cainozoic to Proterozoic medium to coarse grained sediments (LZ 10).			
Vegetation:	Eucalypt.			
Runoff, perm., & drainage:	Very slow to slow runoff; high permeability; moderately well drained.			
Surface features:	Loose coarse sandy surface; non-cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility: (relevant data from Soil 8b)	**Total N (%)** low-mod. (0.06)	**Available P (ppm)** very low (2.0)	**Ex. K (meq/100g)** very low (0.147)	**Ex. Ca (meq/100g)** low-moderate (2.3)
Moisture Characteristics:	**ERD:** >1.0m (no salinity or ESP restrictions)		**PAWC:** 40mm/1.0m	
Investigation sites:	**Field sites** – 45, 111		**Analysed sites** – see 29, 40	

Bloodwood ± blue gum ± -silver-leaved ironbark with a shrubby quinine bush understorey on a sandy colluvial footslope (Site 111).



Moderately deep to deep, bleached, grey, loose colluvial coarse sand at Site 111.

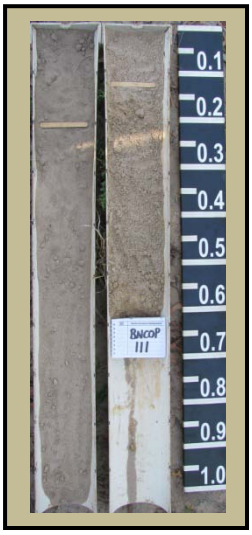


Profile description

The **surface soil** (A1) is a brown (10YR 4/3), loamy coarse sand with massive/single grain fabric; field pH 5.5-6.5. Clear change to

The **upper sub-surface layer** (A21e) is a bleached, brown (10YR 5/4-6/3; 7/2-7/3 when dry), coarse sand with massive/single grain fabric; field pH 5.5-6.5. Gradual or diffuse change to

The **lower sub-surface layer** (A22e) is a bleached, grey (10YR 6/3-6/4; 7/2 when dry), coarse sand with massive/single grain fabric ± <10% weak iron/manganese nodules and/or orange mottling above hard quartzose sandstone from 1.2->1.5m; field pH 5.0-6.5.



Subsoil Chemistry – relevant representative data from Soil 8b (colluvial) - BNCOP Site 29								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.9	0.031	<5	3	2.2	0.71	0.374	0.018
0.25 – 0.35	6.9	0.014	<5	2	1.3	0.37	0.233	0.015
0.55 – 0.65	6.6	0.014	<5	2	1.5	0.70	0.151	0.020

pH, EC and Cl analyses (see Appendices 2 and 5) indicate profiles are acidic to neutral, with consistently low salinity throughout (EC <0.1dS/m, Cl <5ppm). CEC levels are also very low throughout (2-3meq/100g) and reflect limited clay content (9-13%) and colluvial origins (Tertiary sandstone). CEC/clay ratios (0.15-0.33) indicate the clay fraction (albeit very small) is predominantly kaolinitic and non-reactive. Profile sodicity is very low (ESP <1), and reflects the absence of an effective clay fraction and the dominance of the sand fraction.

Physical Soil Characteristics – relevant representative data from Soil 8b (colluvial) - BNCOP Site 29										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	41	44	7	9	-	0.33	0.79	3.1	1	very low
0.25 – 0.35	43	42	7	10	-	0.20	0.85	3.5	1	very low
0.55 – 0.65	37	44	7	13	-	0.15	0.83	2.1	1	very low

Clay content is very low (9-13%) throughout, and the profile is dominated by an equivalent mix of coarse (37-43%) and fine sand (42-44%). The soil profile is unstructured (massive or single grain), highly permeable and unlikely to exhibit dispersive tendencies either insitu or after disturbance. Reworked materials will be loose, coarse sandy and incoherent, and not subject to compaction or pulverescent/hardsetting behaviour. Laboratory measured dispersion is relatively high (R1 0.79-85), but relates to elevated levels of fine sand rather than a dispersive clay fraction.

Summary

Sandy surface soil and subsurface material to about 1.2m (or depth to weathered rock where shallower) has very low fertility, massive/single grain structure, very low clay content (<13%), very low salinity EC <0.1dS/m), very low sodicity (ESP 1) and a significant coarse sand fraction (37-43%). It is considered completely benign and relatively stable, but is likely to experience loose/incoherent behaviour and elevated erosion risk following disturbance. Salvaged sandy material is recommended for replacement only on level terrain or low gradients. Potential exists to strip coarse sandy material to 1.2m (or depth to weathered rock where shallower) as surrogate topsoil for use on steeper slopes, but such a strategy would require adequate mixing with competent sandstone spoil to increase surface roughness, topsoil resilience and slope integrity.

Soil 8c – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional sandy root zone media between 0.3-1.2m (or depth to weathered rock where shallower) for sub-surface replacement only.
Single stage	Combined	0-1.2m	Strip sandy surface soil to 1.2m as surrogate topsoil material. Mix preferentially with competent sandstone spoil for use on low to moderate gradients. Where possible, segregate material to 0.3m to preserve seed source material.

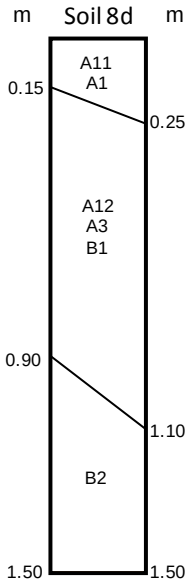
Soil 8c – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Summer cropping	5	Unsuitable due to extreme limitations	e3-4, es1-3, m5	-
Grazing	5	Seasonal breeding country – suitable for grazing native pastures, requires dry season destocking	m5, nd4, e2, v2	C2

Soil 8d — Red colluvial sandy soil on Tertiary sandstone pediments + eucalypt

Soil concept:	Loose, massive red or brown earthy sand grading to a very thick sandy surfaced (1.0->1.5m), red or brown non-sodic texture contrast soil on gentle colluvial pediments and outwash deposits.			
Regional Soil Name:	Wyndham (Wm), Bills Hut sandy variant (BhSv)			
Aust. Soil Classification:	Red/Brown-Orthic Tenosol, Red Chromosol	**Principal Profile Form:**	Uc5.21, Dr4.12	
Landform:	Gentle colluvial pediments and outwash deposits flanking less dissected, undulating remnant rises on relatively fresh, coarse grained Tertiary sandstone. Slope range <1-3%.			
Geological landscape:	Tertiary – Quaternary colluvium (TQr). Sandy colluvium derived from little weathered, medium to coarse grained Tertiary sandstone (largely unaltered by Tertiary weathering) (Ta, Tm).			
Land zone:	Cainozoic to Proterozoic medium to coarse grained sediments (LZ 10).			
Vegetation:	Eucalypt.			
Runoff, perm., & drainage:	Slow runoff; moderate to high permeability; well drained to rapidly drained.			
Surface features:	Loose coarse sandy surface; non-cracking; non-gilgaied; no surface gravel or stone.			
Surface soil fertility: (relevant data from Soil 8b)	**Total N (%)** low-mod. (0.06)	**Available P (ppm)** very low (2.0)	**Ex. K (meq/100g)** very low (0.374)	**Ex. Ca (meq/100g)** low-moderate (2.2)
Moisture Characteristics:	**ERD:** >1.0m (no salinity or ESP restrictions)		**PAWC:** 40mm/1.0m	
Investigation sites:	**Field sites** – 35, 42		**Analysed sites** – see 29	

Cleared Moreton Bay ash ± bloodwood ± -silver-leaved ironbark woodland on a gently undulating colluvial pediment (Site 35).

Deep, red, coarse sand on outwash colluvium derived from Tertiary sandstones (Site 35).

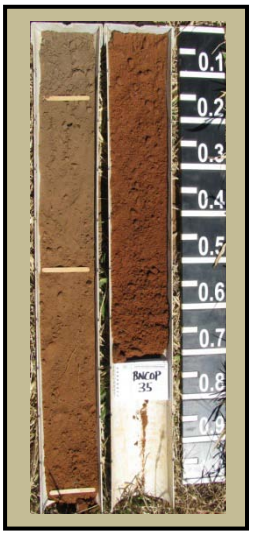


Profile description

The **surface soil** (A11, A1) is a brown (7.5YR 3/3), loamy sand (medium to coarse sand fraction) with massive/single grain fabric; field pH 6.0-6.5. Gradual change to

The **sub-surface layer** (A12, A3, B1) is a reddish brown (5YR, 7.5YR 3/3-4/4), loamy sand (medium to coarse sand fraction) with massive/single grain fabric; field pH 6.0-7.0. Clear change to

The **lower subsoil** (B2) is a red (2.5YR 4/4-4/6), sandy loam to sandy light medium clay (medium to coarse sand fraction) with massive or weak blocky structure; and occasional weak clay nodules in sandy profiles; field pH 6.5-7.5.



Subsoil Chemistry – relevant representative data from Soil 8b (colluvial) - BNCOP Site 29								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.9	0.031	<5	3	2.2	0.71	0.374	0.018
0.25 – 0.35	6.9	0.014	<5	2	1.3	0.37	0.233	0.015
0.55 – 0.65	6.6	0.014	<5	2	1.5	0.70	0.151	0.020
0.85 – 0.95	6.4	0.018	<5	12	8.0	3.6	0.518	0.204
1.15 – 1.25	6.6	0.016	5	-	-	-	-	-

pH, EC and Cl analyses (see Appendices 2 and 5) indicate profiles are slightly acidic to neutral, with consistently low salinity throughout (EC <0.1dS/m, Cl <5ppm). CEC levels are very low (2-3meq/100g) in sandy profiles, but increase marginally (12meq/100g) where clayey subsoils are developed. CEC/clay ratios in the clayey subsoil (where developed 0.29), indicate the clay fraction is non-reactive and of mixed mineralogy (mostly kaolinite and illite). Subsoil materials, whether sandy or clayey are non-sodic (ESP 1-2).

Physical Soil Characteristics – relevant representative data from Soil 8b (colluvial) - BNCOP Site 29										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	41	44	7	9	-	0.33	0.79	3.1	1	very low
0.25 – 0.35	43	42	7	10	-	0.20	0.85	3.5	1	very low
0.55 – 0.65	37	44	7	13	-	0.15	0.83	2.1	1	very low
0.85 – 0.95	26	28	6	41	-	0.29	0.51	2.2	2	very low

Clay content varies, depending whether a clayey subsoil is developed (before 1.5m). Clay content in deep sandy profiles is very low (9-13%); but increases markedly (41%) where gradational or texture contrast clayey subsoils are developed. The soil profile (whether sandy or texture contrast) is unstructured (massive or single grain), highly permeable and unlikely to exhibit dispersive tendencies either insitu or after disturbance. Reworked coarse sandy materials will be loose and incoherent, and not subject to compaction or pulverescent/hardsetting behaviour. In contrast, clayey subsoil materials are characterized by a non-sodic, un-reactive clay fraction (41%), which is significantly moderated by coarse sand/fine sand (54% combined). Clayey materials are likely to experience slaking, compaction and elevated erosion risk post disturbance. Laboratory measured dispersion in sandy material is high (R1 0.79-85) due to fines within the sand fraction, but decreases (R1 0.51) in the non-sodic clayey subsoil. Clayey materials are recommended for subsurface replacement only.

Summary

Sandy soil material varies significantly in thickness (0.9->1.5m), has very low fertility, massive/single grain structure, very low clay content (9-13%), very low salinity (EC <0.1dS/m), very low sodicity (ESP 1) and a significant coarse sand fraction (37-43%). It is considered completely benign and relatively stable, but is likely to experience loose/incoherent behaviour and elevated erosion risk following disturbance. Salvaged sandy material is recommended for replacement only on level terrain or low gradients. Potential exists to use coarse sandy material (down to 0.9->1.5m) as surrogate topsoil on steeper slopes, but such a strategy would require adequate mixing with competent sandstone spoil to increase surface roughness, topsoil resilience and slope integrity. **Clayey subsoil material below 0.9->1.5m** (where present) has benign physical/chemical characteristics and represents a useful source of additional root zone media. It is massive (to weakly structured) and non-sodic (ESP 2), with an un-reactive clay fraction that is moderated by significant sand content (54%). Salvaged subsoil material will lack structural integrity following disturbance, and be subject to compaction and elevated erosion risk. It is recommended for stripping, but only as root zone media for sub-surface replacement.

Soil 8d – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.5m	Strip additional sandy or clayey root zone media between 0.3-1.5m for sub-surface replacement only.
Single stage	Combined	0-1.0m	Strip sandy surface soil to 1.0m as surrogate topsoil material. Mix preferentially with competent sandstone spoil for use on low to moderate gradients. Where possible segregate material to 0.3m to preserve seed source material.

Soil 8d – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	5	Unsuitable due to extreme limitations	e3, m5	-
Grazing	5	Seasonal breeding country – suitable for grazing native pastures, requires dry season destocking	m5, nd4, v2	C2

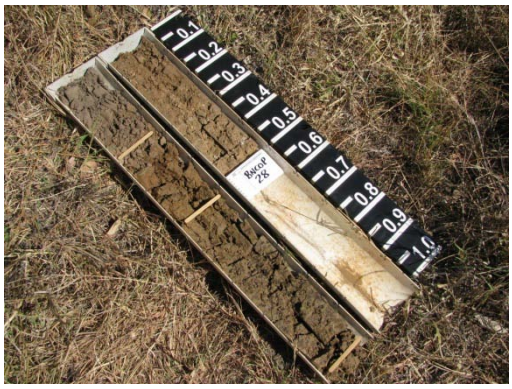
Soil 9a — Loamy brown texture contrast soil/clay on calcareous sediments + eucalypt

Soil concept:	Hardsetting, loamy to clay loamy surfaced (0.2-0.3m), brown non-sodic texture contrast soil grading to a structured, brown non-cracking clay overlying calcareous sediments from 0.7m->1.5m.
Regional Soil Name:	Mayfair (Mf), Kirkcaldy (Kc); affinities with Adeline (Ad) and Carlo (Cc)
Aust. Soil Classification:	Brown Chromosol, Brown Dermosol **Principal Profile Form:** Db1.33, Uf6.31
Landform:	Level to gently undulating plains and low rises associated with outcropping sub-labile calcareous sediments (either locally developed unconsolidated calcareous substrates; or outcropping calcareous upper Permian strata). Distribution is confined to small areas in the north of the BNCOP Disturbance Footprint. Slope range <1-3%.
Geological landscape:	Either unconsolidated calcareous Tertiary–Quaternary sediments (TQr); or outcropping calcareous upper Permian strata (Pwy - Gyranda Subgroup). Surficial lithology presents as sub-labile calcareous fine grained sediments ± marl and secondary carbonate.
Land zone:	Cainozoic clay deposits (LZ 4)/Cainozoic to Proterozoic fine grained sedimentary rocks (LZ 9).
Vegetation:	Eucalypt.
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.
Surface features:	Hardsetting; non-cracking; non-gilgaied; no surface gravel or stone.

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	mod.-high (0.10)	very low (4.0)	high (0.71)	high (5.7)

Moisture Characteristics:	**ERD:** >1.0m (no salinity or ESP restrictions)	**PAWC:** 85-100mm/1.0m
Investigation sites:	**Field sites** – 25, 28, 30	**Analysed sites** – 30

Cleared silver-leaved ironbark ± bloodwood ± ghost gum (with limebush) on gently undulating insitu calcareous sediments at Site 28.



Loamy surfaced, brown non-sodic texture contrast soil overlying insitu calcareous sediments at depth (Site 28).

Profile description

The **surface soil** (A1, A2j) is a black or brown (10YR 3/2-3/3), sandy loam to sandy light clay (fine sand fraction) with weak to moderate subangular blocky structure; typically with a thin bleached A2 horizon immediately above the subsoil contact; field pH 6.0-7.0. Clear or abrupt change to

The **upper subsoil** (B21) is a brown or reddish brown (7.5YR, 10YR 4/3-5/3), sometimes mottled (20% faint or distinct orange), light medium clay (fine to medium sand fraction) with moderate blocky structure; field pH 7.0-8.5. Gradual change to

The **lower subsoil** (B22, B23) is a brown (7.5YR, 10YR, 2.5Y 5/3-6/4), sometimes mottled (<20% faint or distinct orange), light medium clay (fine to medium sand fraction) with moderate blocky structure; and 10->20% soft or nodular carbonate; field pH 8.0-8.5. Clear change to

Substrate material (B3k, BCk) where present is a grey or brown (10YR, 2.5Y 5/4-6/2) clayey matrix with >50% soft, very weathered fine grained calcareous marl/soft or nodular carbonate; field pH 8.0-8.5.

Subsoil Chemistry – representative data from BNCOP Site 30

Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.7	0.048	5	12	5.7	5.5	0.710	0.071
0.25 – 0.35	7.9	0.041	5	22	9.7	12.6	0.370	0.303
0.55 – 0.65	8.9	0.196	85	25	9.3	16.7	0.255	0.835
0.85 – 0.95	9.1	0.301	215	21	7.5	16.0	0.196	0.865
1.15 – 1.25	9.0	0.355	353	-	-	-	-	-

pH is acidic to neutral in the surface soil and alkaline to strongly alkaline in the subsoil. EC and Cl analyses (see Appendices 2 and 5) indicate profile salinity is low (<0.3dS/m) to about 0.5-0.7m, with moderate levels (0.3-0.5dS/m) below 0.5-0.7m. Non-cracking behaviour, moderate CEC levels (21-25meq/100g) and moderately high CEC/clay ratios (0.54-0.62) in the subsoil suggest the clay fraction is of mixed mineralogy, with limited activity and lacks significant shrink-swell characteristics. Sodicity data indicates profiles are non-sodic throughout (ESP 1-4). Magnesium (Mg) dominates cation chemistry, but is unlikely to have a significant effect because of elevated calcium chemistry and low ESP.

Physical Soil Characteristics – representative data from BNCOP Site 30

Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	17	51	11	23	-	0.52	0.58	1.0	1	very low
0.25 – 0.35	11	40	10	41	-	0.54	0.42	0.8	1	very low
0.55 – 0.65	13	34	11	41	-	0.61	0.37	0.6	3	very low
0.85 – 0.95	33	21	15	34	-	0.62	0.77	0.5	4	low

Clay content in texture contrast profiles increases sharply between loamy surface horizons (<25%) and the underlying clay subsoil (35-45%). In heavier profiles (non-cracking clay), surface clay content is higher (30->35%) and the change less abrupt. The surface soil to 0.2-0.3m is hardsetting, non-sodic (ESP 1), relatively non-dispersive (R1 0.42-0.58), only weakly to moderately structured and characterized by high levels of fine sand/silt (50-62% combined). This suggests significant slaking, pulverescent behaviour and compaction is likely post disturbance. Subsoil clay to about 0.7-0.8m is moderately structured, non sodic (ESP 1-3), non dispersive (R1 0.37-0.42) and considered benign. This material has limited reactivity (shrink-swell behaviour), similarly elevated levels of fine sand/silt (45-50 combined) and will be subject to pulverescent behaviour, dense packing and significant compaction after reworking. Calcareous substrate below 0.7-0.8m is typically less clayey (34%) and subject to significantly higher dispersive behaviour (R1 0.77). It is not recommended for salvage.

Summary

Loamy/clayey surface soil material to 0.3m has low fertility, and is non-sodic (ESP 1), relatively non-dispersive (R1 0.42-0.58), weakly to moderately structured, hardsetting and characterized by high levels of fine sand/silt (50-62% combined). It is considered relatively benign, but is likely to be prone to pulverescent behaviour, severe compaction, slaking and high erosion risk following disturbance. Topsoil materials to 0.3m are suitable for replacement only on level terrain or low gradients. **Subsoil material between 0.3-0.8m** is also benign and is characterized by a moderately structured, non-sodic (ESP<3), relatively un-reactive clay fraction (lacking shrink swell characteristics) that is moderated by significant fine sand and silt (45-50% combined). Salvaged subsoil clay will lack structural integrity post disturbance and be subject to dense packing, compaction and elevated erosion risk. This material is recommended for stripping, but only as root zone media for sub-surface replacement. **Calcareous subsoil/substrate material below about 0.8m** is subject to elevated erosion risk because of increased dispersive behaviour (R1 0.77) and is not recommended for salvage.

Soil 9a – Stripping Recommendations

Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.3m	Strip loamy/clayey surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-0.8m	Strip additional root zone media between 0.3-0.8m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip a mix of surface soil and subsoil clay to 0.5m as primary topsoil.

Soil 9a – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)

Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	4	Marginal due to severe limitations	e2, m4, pm2, ps4, w2	B
Grazing	4	Breeding country – marginal for improved pastures, suitable for grazing native pastures	m3, nd4, ps2, v2	-

Soil 9b — Weakly self-mulching black clay on calcareous sediments + open grassland

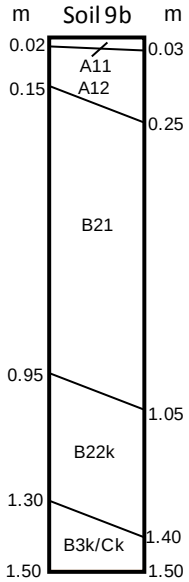
Soil concept:	Hardsetting to moderately self-mulching, black cracking clay with weak normal gilgai (VI <0.1-0.2m, HI 8-15m) overlying calcareous sediments from >1.2m.
Regional Soil Name:	Kirkcaldy (Kc); affinities with Carfax (Cx) and Mt Stuart (Ms)
Aust. Soil Classification:	Black Vertosol **Principal Profile Form:** Ug5.14
Landform:	Level to gently undulating plains associated with outcropping sub-labile calcareous sediments (either locally developed unconsolidated calcareous substrates; or outcropping calcareous upper Permian strata). Distribution is confined to small areas in the north of the BNCOP Disturbance Footprint. Slopes <1%.
Geological landscape:	Either unconsolidated calcareous Tertiary–Quaternary sediments (TQr); or outcropping calcareous upper Permian strata (Pwy - Gyranda Subgroup). Surficial lithology presents as sub-labile calcareous fine grained sediments ± marl and secondary carbonate.
Land zone:	Cainozoic clay deposits (LZ 4)/Cainozoic to Proterozoic fine grained sedimentary rocks (LZ 9).
Vegetation:	Open grassland.
Runoff, perm., & drainage:	Slow runoff; slow permeability; moderately well drained.
Surface features:	Hardsetting to moderately self-mulching (2-5mm); cracking; weakly gilgaied (VI 0.15m, HI 8-15m); no surface gravel or stone; <2-5% nodular carbonate on surface.

Surface soil fertility:	**Total N (%)**	**Available P (ppm)**	**Ex. K (meq/100g)**	**Ex. Ca (meq/100g)**
	high (0.135)	low-mod. (9.5)	high (0.676)	high (14.2)

Moisture Characteristics:	**ERD:** 0.7m (salinity >0.8dS/m or >800ppm Cl)	**PAWC:** 85mm/1.0m
Investigation sites:	**Field sites** – 43	**Analysed sites** – 43

Open grassland on localised black soils flats associated with insitu calcareous sediments at Site 43.

Hardsetting to moderately self mulching, black cracking clay overlying insitu calcareous sediments below 1.3m (Site 43).



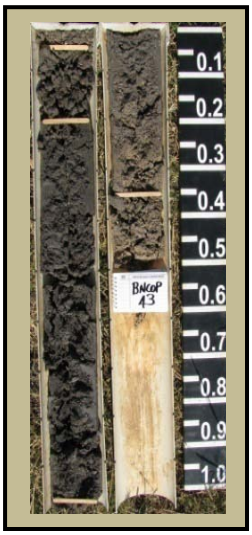
Profile description

The **surface soil** (A11, A12) is a black (2.5Y 3/1-3/2) light medium to medium clay with moderate to strong granular surface structure grading to strong fine blocky subsurface structure; field pH 7.0-8.0. Clear change to

The **upper subsoil** (B21) is a black (2.5Y 2/1-3/1), medium heavy clay with strong lenticular structure and minor (<5%) soft or nodular carbonate; field pH 8.0-8.5. Gradual change to

The **lower subsoil** (B22k) is a grey (10YR 4/1-4/2), medium heavy clay with strong coarse lenticular structure and >20% soft or nodular carbonate; field pH 8.0-8.5. Gradual change to

Substrate material (B3k, Ck) is a pale grey (10YR, 2.5Y 6/2) clayey matrix with >50% soft, very weathered fine grained calcareous sandstone, siltstone or shale ± 10% calcareous marl/soft or nodular carbonate; field pH 8.5-9.0.



Subsoil Chemistry – representative data from BNCOP Site 43								
Sample depth (m)	pH (1:5)	EC (dS/m)	Cl (mg/kg)	CEC/ECEC (meq/100g)	Exchangeable cations (meq/100g)			
					Ca	Mg	K	Na
0 – 0.1	6.5	0.060	30	23	14.2	7.0	0.676	0.726
0.25 – 0.35	8.4	0.069	25	28	16.7	10.6	0.290	1.9
0.55 – 0.65	9.0	0.502	475	37	16.4	17.8	0.308	5.5
0.85 – 0.95	8.9	0.760	900	37	16.8	19.3	0.329	5.9
1.15 – 1.25	9.0	0.715	810	-	-	-	-	-

pH is neutral in the immediate surface soil, and alkaline to strongly alkaline throughout the subsoil. EC and Cl analyses (see Appendices 2 and 5) indicate profile salinity is low (<0.3dS/m) to about 0.5m, with moderate levels (0.3-0.6dS/m) between 0.5-0.7m and increasing salinity below 0.7m. High CEC levels (23-37meq/100g), moderately high CEC/clay ratios (0.61-0.73) and the presence of cracking and strong lenticular structure suggest the clay fraction is active, with significant shrink-swell characteristics, and is of mixed mineralogy with a high proportion of smectites. ESP data indicate surface horizons to 0.2m (A11/A12 horizons) are non-sodic (ESP <3), upper subsoil materials to about 0.5m are weakly to moderately sodic (ESP 3-<15), while below 0.5m lower subsoil clay becomes highly sodic (ESP 15-16). Magnesium (Mg) co-dominates cation chemistry below 0.5m and is likely to enhance dispersive behaviour.

Physical Soil Characteristics – representative data from BNCOP Site 43										
Sample depth (m)	Particle size analysis				15 Bar	CCR	R1 Disp. Ratio	Ca/Mg ratio	ESP (%)	Sodicity rating
	CS %	FS %	Silt %	Clay %						
0 – 0.1	11	31	21	38	-	0.61	0.47	2.0	3	low
0.25 – 0.35	17	35	10	39	-	0.72	0.52	1.6	7	low-mod.
0.55 – 0.65	14	23	14	51	-	0.73	0.66	0.9	15	mod.-high
0.85 – 0.95	14	19	14	54	-	0.69	0.66	0.9	16	high

Clay content in immediate surface horizons to 0.2m is moderately high (38-39%), with significant levels of fine sand/silt (45-52%), moderate to strong structure, significant clay activity and strong cracking behaviour. The upper subsoil to about 0.5m is characterised by increasing clay content (39-51%), Ca dominant cation chemistry, low to moderate sodicity (ESP 3-<15) and increasing dispersion (R1 0.47-0.66). Below 0.5m, worsening sodicity and dispersion, increasing salinity and coarse macro lenticular structure suggest adverse physical behaviour and poor establishment response are likely post-disturbance.

Summary

Surface soil/upper subsoil material to 0.2m has moderate fertility and is strongly aggregated and finely structured. It is characterised by moderately high clay content (38-39%), active clay behaviour (CEC/Clay ratio 0.61-0.72), low salinity (<0.3dS/m), low sodicity (ESP <3), low dispersion (R1 0.47-0.52) and Ca dominant cation chemistry. These attributes suggest material to 0.2m will be relatively benign and physically stable/resilient post disturbance. It is likely however, to experience shrink-swell behaviour, strong cracking and significant root zone shearing (depending on replacement thickness). Salvaged topsoil materials to 0.2m are suitable for replacement on low to moderate gradients. **Upper subsoil material between 0.2-0.5m** is characterised by increasing clay content and shrink-swell capacity, weak to moderate sodicity (ESP 7-<15) and increasing dispersive behaviour (R1 0.52-0.66). Salvage of this material is recommended, but only as root zone media for sub-surface replacement. **Lower subsoil material below 0.5m** is considered undesirable, with high to very high levels of salinity (0.5->0.7dS/m, Cl >800ppm), and worsening sodicity and dispersive behaviour (ESP 15-16, R1 0.66). It is not recommended for salvage.

Soil 9b – Stripping Recommendations			
Method	Material	Depth	Stripping recommendation
Two stage	Topsoil	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.2-0.5m	Strip additional root zone media between 0.2-0.5m for sub-surface replacement only. Avoid undesirable subsoil material below 0.5m.
Single stage	Combined	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.2m.

Soil 9b – Land Suitability Assessment (DNRM/DSITIA 2013a, 2013b, QDME 1995)				
Land use	Suitability class		Limitation subclasses	ALC
Summer cropping	4	Marginal due to severe limitations	e2, es3, m4, ps2, tm2, w2	B
Grazing	3	"Grower" country – suitable for improved pastures, but less productive than Classes 1 & 2	m2, nd3, ps2, sa2, w2, ph2	-

8. Topsoil stripping and management recommendations

Topsoil stripping recommendations are primarily determined by inherent soil characteristics and spatial soil variability within the landscape. However, landform design, rehabilitation technique and in particular, proposed final end use clearly influence the physical conditions that stripped materials will be subjected to following reinstatement, and as such need to be considered whilst formulating stripping recommendations.

Assumptions

Stripping recommendations where post mining commitments undertake to reinstate pre-mining cropping or grazing suitability, will be very different to those where more passive, non agricultural final uses are planned.

- To realistically achieve reinstatement of cropping or grazing land uses requires not only appropriate landform design, but also the sequential removal and replacement of both topsoil and root zone material, in a number of separate layers, to at least the effective rooting depth of the crops/pastures being considered.
- If however, planned post mining commitments aim to achieve sustainable ecosystem uses with a view to achieving biodiversity outcomes and built landscape stability, then final landform design and rehabilitation techniques may differ significantly, and single stage or possibly two stage soil stripping may achieve the desired outcomes.

In effect, the suitability of materials available for stripping depends not only on the presence/absence and severity of inherent soil based limitations (such as salinity or dispersive behaviour) but also on proposed landform design and final desired outcomes to which the materials are likely to be subjected. Differing landform designs and final end uses will change individual stripping depths accordingly.

Stripping recommendations presented in this report have been purposefully designed to maximize the salvage of suitable soil resources (topsoil and root zone materials) for the establishment of a functional native vegetation ecosystem capable of sustainably rehabilitating and stabilizing low to moderate slopes. Soil materials recommended for salvage have been selected only to provide suitable growth media for the establishment and longer term survival of selected/adapted native tree and groundcover species.

It is important to note that stripping recommendations designed for the reinstatement of pre-mining land uses such as dryland cropping or grazing will differ significantly to those presented. To achieve targeted rehabilitation outcomes such as these would require, in addition to the design and reshaping of appropriate landforms, careful salvage and sequential placement of soil material from multi-stage stripping operations. In particular, the sequential placement of far greater quantities of subsoil root zone media would be required to ensure constructed soil profiles were of sufficient depth to support the end use envisaged. The success of any such re-instatement for cropping would require (as a minimum) landforms with gradients less than 3%, shortened slope lengths and controlled capture and disposal of surface flows.

Materials stripped using recommendations presented in this report are incompatible with achieving post mining cropping or grazing end uses. Salvage operations across the Bowen Basin typically employ single stage, non-sequential stripping and stripped volumes in general would be insufficient for such end uses. Poor outcomes in terms of very low productivity and excessive

erosion risk could be expected where attempts to implement pre-mining land uses (such as cropping) were undertaken without appropriate and purpose specific stripping and placement recommendations.

Revision of the topsoil stripping recommendations from this investigation would be required where end uses other than the stabilization of low to moderate slopes through the establishment of sustainable native vegetation cover are envisaged.

Topsoil management plan

In any topsoil stripping, stockpiling and replacement operation, planned activities need to carefully follow actions outlined in a detailed topsoil management plan. The aim of any such plan should be to ensure optimal allocation of available topsoil/root zone reserves across all future rehabilitation scenarios proposed for the mine. It is important ongoing topsoil management planning is implemented during the normal operation of the mine to ensure shortfalls in available rehabilitation media are not experienced leading towards mine closure. Topsoil/root zone requirements for planned activities need to take into account proposed landform designs, nature of the waste to be rehabilitated and intended rehabilitation methods to be employed. In addition, the management plan should outline the intended depth and surface treatment of topsoil/root zone media cover to be reinstated, and the intended type/nature of vegetative cover to be established.

In practice, a detailed topsoil management plan should clearly outline:

- delineation of areas to be disturbed;
- volumes/characteristics of topsoil/root zone materials available from identified disturbance;
- methodology for optimal soil management during stockpiling;
- delineation of areas for reinstatement and rehabilitation;
- physical conditions expected at each rehabilitation location (e.g. slope degree/length, spoil characteristics, proposed rehabilitation technique);
- selection methodology to identify the most appropriate materials from available stockpiled resources for different rehabilitation scenarios; and
- volumes/characteristics of topsoil/root zone media (or other cover materials) required for salvage to meet rehabilitation requirements.

General stripping and stockpiling guidelines

The following general recommendations may assist or guide stripping and stockpiling activities planned for disturbance areas within the BNCOP Disturbance Footprint:

- Where stripping depth exceeds 0.3-0.5m two **stage stripping and replacement** is recommended to minimize mixing of surface soil and subsoil materials. Materials stripped using a two stage process are referred to as **topsoil** and **root zone materials** respectively (as defined in the methodology section of this report). Separation of these materials will optimize physical conditions in stockpiled resources and assist in preserving seed source potential.
- Topsoil salvage should be maximized from all disturbed areas and **topsoil materials (optimal depth 0.1-0.3m) should be stockpiled separately** from subsoil based root zone media.
- **Topsoil materials which potentially contain significant native seed** (for example bluegrass downs or eucalypt woodlands where introduced grasses have not invaded) should be **segregated and stockpiled separately** from cropping or pasture improved topsoil resources which are likely to contain heavy loads of introduced pasture or weed seed.

- **Topsoil stockpiles which potentially contain significant native seed should be utilized preferentially** to maximize re-establishment of native species from available seed stores; providing this fits the requirements of the rehabilitation plan in terms of soil and vegetative cover required.
- **Topsoil stockpiles containing predominantly surface soil material** (typically stripped from the upper 0.1-0.3m of the soil profile) should ideally be **formed no more than 1.5m in height** and should be ripped and seeded to native species following stockpile laydown to stabilize and protect the material.
- Stripped materials (whether topsoil or root zone media) should be **segregated into stockpiles which have similar reuse or textural characteristics**. Soils with good surface physical characteristics should not be stockpiled with soils where poorer physical attributes are indicated; clays should not be stockpiled with loams or sands.
- **Root zone media** should be salvaged from all disturbed areas where suitable material has been identified, an**d stockpiled separately from topsoil materials.**
- **Root zone media** (typically stripped from below 0.3m) can be **stockpiled to greater depths than the 1.5m specified for topsoil materials.** Root zone material stockpiles should only be constructed in areas from which topsoil has first been stripped. Stockpiles should be ripped and seeded with native species following lay down to stabilize and protect the resource.

Topsoil stripping recommendations – topsoil/subsoil depths for salvage

Multi-stage stripping and replacement is widely accepted as best management practice for the salvage and reuse of soil/rehabilitation media from areas of mining disturbance. As such, a summary of t**wo stage stripping recommendations** for soil types mapped within the BNCOP Disturbance Footprint is presented in **Table 4** below.

It is recognized however that single stage stripping which involves the salvage of maximum quantities of useable soil material (i.e. combined topsoil and suitable subsoil) is often the preferred stripping methodology for many mines. As such, **recommendations for single stage stripping** outlining one off salvage depths for the retrieval of all useable materials are also presented in **Table 4**. It is important to recognise however that single stage stripping by its very nature will result in greater mixing of discordant materials and a reduction in soil quality, particularly less desirable physical and chemical characteristics and a dilution of surface fertility, topsoil organics and seed source potential. When compared with multi-stage reinstatement, single stage material will be subject to slower infiltration and higher runoff rates, while plant establishment will potentially be slower and less successful.

For most rehabilitation situations, subsoil clays with elevated levels of soluble salts or highly dispersive physical behaviour are not recommended for salvage either as topsoil or root zone media. Reinstatement of such materials, particularly as surface materials, will typically be subject to poor physical behaviour (sodicity, dispersion and coarse/dense structure) and limited plant establishment. Cumulatively, these effects restrict the development of ground and canopy cover and slow water relations and structural recovery in the surface soil. Such effects impact significantly on rehabilitation outcomes at a site and significantly increase erosion risk and the potential for localized rehabilitation failure. Where soil mapping indicates high levels of subsoil salinity may be present or significant spatial variability in salinity levels exists, localized field testing of materials prior to salvage is recommended.

Table 4. Summary of stripping depth recommendations for soils mapped within the BNCOP Disturbance Footprint.

Method	Material	Depth	Stripping recommendations
Soil – 2b			
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional root zone media 0.3-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.8m	Strip structured surface soil/subsoil clay to 0.8m as surrogate topsoil material. Avoid increasingly undesirable grey/brown clay below 0.8m.
Soil –3a			
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.0m	Strip additional root zone media 0.3-1.0m for sub-surface replacement only.
Single stage	Combined	0-0.7m	Strip structured surface soil/subsoil clay to 0.7m as surrogate topsoil material. Avoid increasingly undesirable grey or brown clay below 0.7m.
Soil –3b			
Two stage	Topsoil	0-0.35m	Strip loamy surface soil to 0.35m and segregate as primary topsoil to preserve topsoil/seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	nil	Subsoil clay below 0.35m is dispersive and should be avoided.
Single stage	Combined	0-0.35m	Strip loamy surface soil to 0.35m (maximum) as topsoil/seed source material. Avoid dispersive subsoil clay below 0.35m. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
Soil – 4c			
Two stage	Topsoil	0-0.3m	Strip structured surface soil/subsoil clay to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-0.8m	Strip additional root zone media between 0.3-0.8m for sub-surface replacement only. Avoid grey or brown clay below about 0.7-0.9m.
Single stage	Combined	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.4m.
Soil – 4d			
Two stage	Topsoil	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m and segregate as primary topsoil to preserve seed source material.
	Root zone	nil	Subsoil clay below 0.4m is undesirable and should be avoided.
Single stage	Combined	0-0.4m	Strip structured surface soil/subsoil clay to 0.4m as primary topsoil. Avoid undesirable subsoil clay below 0.4m. Melonhole gilgai (where present) require topsoil be stripped with an excavator and batter bucket; stripping depth should follow surface contours.
Soil –5			
Two stage	Topsoil	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.2-0.4m	Strip additional root zone media between 0.2-0.4m for sub-surface replacement only. Avoid undesirable subsoil material below 0.4m.
Single stage	Combined	0-0.2m	Strip surface soil/subsoil clay to 0.2m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.2m.
Soil – 7a			
Two stage	Topsoil	0-0.1m	Strip structured surface soil/subsoil clay to 0.1m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.1-0.4m	Strip additional root zone media between 0.1-0.4m for sub-surface replacement only. Avoid undesirable subsoil clay below 0.4m.
Single stage	Combined	0-0.1m	Strip surface soil/subsoil clay to 0.1m as primary topsoil. Avoid increasingly undesirable subsoil clay below 0.1m. Stripping with an excavator and batter bucket is recommended; stripping depth to follow surface contours.

Method	Material	Depth	Stripping recommendations
Soil – 7b			
Two stage	Topsoil	0-0.15m	Strip surface soil/upper subsoil clay to 0.15m and segregate as primary topsoil to preserve seed source material.
	Root zone	nil	Subsoil clay below 0.15m is undesirable and should be avoided.
Single stage	Combined	0-0.15m	Strip structured surface soil/subsoil clay to 0.15m. Avoid undesirable subsoil clay below this depth.
Soil – 7c			
Two stage	Topsoil	0-0.5m	Strip sandy surface soil to 0.5m and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	0.5-1.2m	Strip additional clayey root zone media between 0.5-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy surface soil to 0.5m as primary topsoil. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
Soil – 7d			
Two stage	Topsoil	0-0.1/0.2m	Strip loamy surface soil to between 0.1-0.2m (maximum) and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	nil	Subsoil clay below 0.1-0.2m is dispersive and should be avoided.
Single stage	Combined	0-0.1/0.2m	Strip loamy surface soil to between 0.1-0.2m (maximum) as topsoil/seed source material. Avoid dispersive subsoil clay below 0.1-0.2m. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
Soil – swp/7a			
Two stage	Topsoil	0-0.1m	Strip structured surface soil/subsoil clay to 0.1m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.1-0.4m	Strip additional root zone media between 0.1-0.4m for sub-surface replacement only. Avoid undesirable subsoil clay below 0.4m.
Single stage	Combined	0-0.1m	Strip surface soil/subsoil clay to 0.1m as primary topsoil. Avoid increasingly undesirable subsoil clay below 0.1m. Stripping with an excavator and batter bucket is recommended; stripping depth to follow surface contours.
Soil – 8a			
Two stage	Topsoil	0-0.3m	Strip sandy/loamy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional loamy/clayey root zone media between 0.3-1.2m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy/loamy surface soil to 0.5m as primary topsoil. Avoid clayey subsoil materials below this depth because of undesirable physical attributes and poor establishment response post disturbance.
Soil – 8b			
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
	Root zone	0.3-0.8m or deeper	Strip additional sandy or clayey root zone media from 0.3m to depth of weathered rock (0.8->1.5m) for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip sandy surface soil to 0.5m as primary topsoil. Use bleaching ± the presence of dense subsoil clay to guide stripping limit.
Soil – 8c			
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.2m	Strip additional sandy root zone media between 0.3-1.2m (or depth to weathered rock where shallower) for sub-surface replacement only.
Single stage	Combined	0-1.2m	Strip sandy surface soil to 1.2m as surrogate topsoil material. Mix preferentially with competent sandstone spoil for use on low to moderate gradients. Where possible, segregate material to 0.3m to preserve seed source material.

Method	Material	Depth	Stripping recommendations
Soil – 8d			
Two stage	Topsoil	0-0.3m	Strip sandy surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-1.5m	Strip additional sandy or clayey root zone media between 0.3-1.5m for sub-surface replacement only.
Single stage	Combined	0-1.0m	Strip sandy surface soil to 1.0m as surrogate topsoil material. Mix preferentially with competent sandstone spoil for use on low to moderate gradients. Where possible segregate material to 0.3m to preserve seed source material.
Soil – 9a			
Two stage	Topsoil	0-0.3m	Strip loamy/clayey surface soil to 0.3m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.3-0.8m	Strip additional root zone media between 0.3-0.8m for sub-surface replacement only.
Single stage	Combined	0-0.5m	Strip a mix of surface soil and subsoil clay to 0.5m as primary topsoil.
Soil – 9b			
Two stage	Topsoil	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m and segregate as primary topsoil to preserve seed source material.
	Root zone	0.2-0.5m	Strip additional root zone media between 0.2-0.5m for sub-surface replacement only. Avoid undesirable subsoil material below 0.5m.
Single stage	Combined	0-0.2m	Strip structured surface soil/subsoil clay to 0.2m as primary topsoil. Avoid increasingly undesirable subsoil material below 0.2m.

Topsoil stripping recommendations – topsoil/subsoil volumes for salvage

Assessment of topsoil resources for stripping and salvage within the BNCOP Disturbance Footprint (external to ML80169 and ML80170) provides the necessary framework to plan and secure sufficient volumes for prescribed future rehabilitation objectives, while guaranteeing only the most appropriate material is salvaged. The stripping recommendations and underlying soil data presented, both in **Table 4** and also the earlier Soil Characterization Section of this report, ensures appropriate data is available (ahead of mining) to quantify resources, optimize and balance selection decisions and inform future stockpile planning requirements. Topsoil (± benign subsoil) volumes (m^3) available for stripping and salvage from the 16 soils mapped within the BNCOP Disturbance Footprint are presented in **Table 5**. Final volumes have been calculated using recommended single stage stripping depths (m) combined with the spatial extent (m^2) each soil occupies.

Minimal single stage stripping depths (<0.2m) are available from Soils 5, 7a, 7b, 7d, swp/7a and 9b, moderate depths (0.2-0.5m) from Soils 3b, 4c, 4d, 7c, 8a, 8b, and 9a and significant depths (>0.5m) from Soils 2b, 3a, 8c and 8d. The largest volumes (>500,000m^3) are available from Soils 7c, 8a, 8b and 8d through a combination of greater depth and wider spatial extent. The combined volume of suitable topsoil/root zone media potentially available for salvage and stockpiling from within the BNCOP Disturbance Footprint is estimated at **5,825,600 m^3.**

Salvage volumes within already approved sections of the BNCOP EIS Operational Area (namely ML80169 and ML80170) have been presented previously and are available from the soil investigation report *Pre-mining Agricultural Land Suitability and Soil Reuse Recommendations - Wonbindi North area, Baralaba, Queensland* by NQSA (2011a), and also in *Appendix A – Topsoil Inventory* in the *Baralaba Central and Baralaba North Plan of Operations* released in 2013 (Cockatoo Coal Limited 2013). Data for areas external to the BNCOP Disturbance Footprint are not presented in this report.

Table 5. Summary of stripping volumes for soils mapped within the BNCOP Disturbance Footprint.

Soil	BNCOP Disturbance Footprint		
	Single stage stripping depth (m)	Spatial area (ha)	Salvage volume (m^3)
Soil – 2b	0.80	4.8	38,400
Soil –3a	0.70	13.5	94,500
Soil –3b	0.35	6.2	21,700
Soil – 4c	0.40	69.6	278,400
Soil – 4d	0.40	7.7	30,800
Soil –5	0.20	28.7	57,400
Soil – 7a	0.10	240.6	240,600
Soil – 7b	0.15	201.6	302,400
Soil – 7c	0.50	174.5	872,500
Soil – 7d	0.15	82.2	123,300
swp/7a	0.10	14.9	14,900
Soil – 8a	0.50	283.0	1,415,000
Soil – 8b	0.50	222.1	1,110,500
Soil – 8c	1.20	34.5	414,000
Soil – 8d	1.00	63.2	632,000
Soil – 9a	0.50	33.8	169,000
Soil – 9b	0.20	5.1	10,200
Total	**na**	**1486.0**	**5,825,600**

9. Pre-mining land suitability – dryland cropping and grazing

Pre-mining land suitability within the BNCOP Disturbance Footprint has been assessed for dryland cropping and grazing (the dominant existing land uses in the local area) and provides an important record of the agricultural potential of the land prior to disturbance or development. The assessment has utilised spatially accurate mapping (1:25000) and detailed soil attribute data, and follows the suitability methodology defined by the Queensland Government (DNRM/DSITIA 2013a, 2013b), in accordance with the requirements of the BNCOP Terms of Reference. Land suitability methodology and findings for the previously approved Baralaba/Wonbindi North Mine Lease (ML80169 and ML80170) have been presented in an earlier report by NQSA (2011a) and are not re-presented or discussed in this report.

Dryland cropping assessment

Land suitability assessment for summer and winter dryland cropping within the BNCOP Disturbance Footprint follows the methodology, criteria and decision rules defined by DNRM/DSITIA (2013a, 2013b). The study area lies within the boundaries of the Inland Fitzroy – South Burdekin Region (DNRM/DSITIA 2013b) and the classification rules for this area have been adopted in full (without change or addition) and applied as defined. The dryland cropping suitability data presented in **Tables 6 and 7** provides a clear record of the limitations, attributes and subclass rules used in the assessment.

The Inland Fitzroy – South Burdekin Region suitability framework (DNRM/DSITIA 2013b) evaluates the broadacre potential of land to grow a range of summer and winter crops (12 in total) under rainfed conditions within inland Central Queensland. Cropping systems in this region are largely opportunistic and are dependent upon the timing and variability of rainfall, previous cropping history and fallow management. The dominant crops grown are sorghum and wheat, and summer cropping is the dominant land use.

Similarity between the agronomic/crop management requirements (and associated subclass rule sets) listed for the 12 individual crops have been simplified in accordance with the DNRM/DSITIA (2013b) scheme to just summer and winter cropping classifications for the purposes of this investigation. As such, suitability findings presented below are on a summer and winter cropping basis only, and individual assessments on a crop by crop basis (whilst available) have not been reported.

Further to this, any realistic (yet robust) assessment of dryland cropping suitability in the Baralaba area is preferentially based on summer cropping suitability outcomes because of the greater likelihood and reliability of summer rainfall compared with winter rainfall across the region. Seasonal rainfall patterns strongly influence dryland cropping success in Central Queensland, and cropping cycles and planting opportunities are determined year to year by preceding rainfall history (Burgess 2003a). Summer cropping dominates long term cropping success (both spatially and temporally), and suitability criteria for winter cropping have been set at more conservative levels to reflect this. In response, all further discussion relating to suitable, marginal and unsuitable cropping land within the BNCOP Disturbance Footprint will primarily reference dryland summer cropping findings in the first instance.

Extreme climatic variability and the opportunistic nature of cropping in inland Central Queensland mean soil moisture is the primary determinant of cropping success. **Classes 1, 2 and 3** for dryland cropping (based on summer cropping criteria) have only been assigned to soils with the

capacity to store enough plant available moisture to effectively complete a crop cycle from planting to harvest with minimal in-crop rainfall. Soils in this category are largely restricted to self-mulching cracking clays that are at least 0.8m deep and have PAWC values >100mm/1.0m (Class 3 or better according to DNRM/DSITIA 2013b cropping suitability criteria).

Class 4 lands, which are considered marginal for dryland cropping (based on summer cropping criteria), include a range of clay soils that have adequate depth characteristics to store sufficient PAWC but have undesirable infiltration characteristics (i.e. clays that are hardsetting to only weakly self-mulching); or are constrained by limited effective rooting depth and marginal PAWC values (75-100 mm). Class 4 soils have difficulties growing a crop without significant additions of in-crop rainfall, and crop success is unreliable and directly dependent on seasonal conditions.

All other soils are considered **Class 5** and are unsuitable for dryland cropping (based on summer cropping criteria) because PAWC levels are <75 mm and/or one or more other extreme limitations preclude their use. Moisture availability is typically limited by unfavourable surface condition, reduced infiltration, excessive runoff, continued deep drainage, low clay content or shallow effective rooting depth (due to subsoil salinity, sodicity or rock).

Suitability findings for dryland cropping

Assessment of dryland cropping suitability for both summer and winter crops (determined in accordance with DNRM/DSITIA 2013b) provides a structured and robust scientific evaluation of pre-mining cropping potential for lands potentially affected by the BNCOP Disturbance Footprint. A summary of the spatial extent (ha) of cropping suitability classes (summer and winter) and contributing soils is presented below. Further detail including summer cropping suitability statements, final suitability classes and contributing limitation subclasses for all soils within the footprint is presented in **Tables 6 and 7** and displayed in **Figure 5**. Winter cropping findings are presented for comparison purposes only, and displayed in **Figure 6**. These findings are also summarized individually for each soil type in the **Soil Characterization Section** presented earlier in this report.

Closer analysis of the suitability findings below indicates land suitable for broadacre summer cropping (Classes 2 and 3) occupies only 96ha or 6.5% of the total Disturbance Footprint. No Class 1 land was identified. The remaining 93.5% is either marginal (Class 4 – 4.5%) or unsuitable (Class 5 – 89%) for summer cropping due to inherent soil and landscape constraints that directly limit cropping success. Marginal and unsuitable areas comprise a mix of soils, all of which are better suited to grazing uses, ranging from fattening through to breeding. Analysis of winter cropping findings suggests even less land is suitable for winter crops (i.e. a total of 5 ha of Class 3).

Suitability Class		Soils	Area (ha)
Summer cropping	Class 1 - suitable	none recorded	-
	Class 2 - suitable	2b	5
	Class 3 - suitable	3a, 4c, 4d	91
	Class 4 - marginal	5, 9a, 9b	68
	Class 5 - unsuitable	3b, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d, swp/7a	1322
Winter cropping	Class 1/2 - suitable	none recorded	-
	Class 3 - suitable	2b	5
	Class 4 - marginal	3a, 4c, 4d	91
	Class 5 - unsuitable	3b, 5, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d 9a, 9b, swp/7a	1390

Suitable cropping land (Classes 2 and 3) within the BNCOP Disturbance Footprint (based on summer cropping criteria), is restricted to just 4 of the 16 soils mapped, namely Soils 2b, 3a, 4c and 4d. Apart from a small occurrence of Soil 4d in the north, all are associated with a long term cropping paddock at the southern end of the Disturbance Footprint. This area has also been identified by the SCL trigger mapping (DNRM 2011a) and assessed accordingly for SCL status as part of this investigation. Three of the suitable soils (namely Soils 3a, 4c and 4d) are marginal for winter cropping however, because of limited plant available water capacity (PAWC) and more conservative moisture availability criteria during the winter dry season.

The **suitable summer cropping soils 2b, 3a, 4c and 4d (Classes 2 and 3)** are deep, relatively young, alluvial self mulching cracking clays that have effective rooting depths (ERD) ranging from 0.7->1.0m. Estimated equivalent PAWC values range from 85->120mm/1.0m and suggest stored moisture availability under normal seasonal conditions is sufficient to complete a crop cycle. Slopes are mostly <3% and the soils are moderately well drained, have acceptable surface conditions for germination and establishment, are easily cultivated, non-gilgaied and lack gravel or rock in the plough zone. Limitation subclasses recorded for these soils are only negligible (sub-class 1), minor (sub-class 2) or moderate (sub-class 3) at worst.

Soils 5, 9a and 9b are considered marginal for summer cropping (Class 4). Soils 5 and 9b are weakly self-mulching clays with restricted ERD and constrained PAWC values due to subsoil salinity (Cl >800ppm) below about 0.6-0.7m. Soil 9a is a sandy to loamy surfaced non-sodic texture contrast soil/non-cracking clay that has sufficient ERD (>1.0m), but limited water holding capacity. Estimated PAWC values for all 3 soils are only 70-100mm/1.0m indicating stored moisture availability under normal seasonal conditions may be insufficient to complete a crop cycle without significant in crop rainfall. Slopes are mostly <3% and all 3 soils are moderately well drained, have acceptable surface conditions for germination and establishment, are easily cultivated, non-gilgaied and lack gravel or rock in the plough zone. Limitations recorded for these soils range from negligible (sub-class 1) to severe (sub-class 4).

The remainder of soils mapped within the BNCOP Disturbance Footprint are considered **unsuitable for summer cropping** (Class 5). Soils include **3b, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d and swp/7a**, and collectively these soils occupy the majority of the land surface within the footprint. Soil characteristics include hardsetting sodic texture contrast soils (3b, 7b, 7d), hardsetting sodic non-cracking clays (7b), melonholed sodic grey cracking clays (7a, swp/7a), sandy surfaced non-sodic to weakly sodic texture contrast soils (7c, 8b), deep loamy red earths (8a) and deep loose colluvial sands (8c, 8d).

ERD constraints and water holding characteristics vary enormously across this group. All soils however, have estimated PAWC values between 30-85 mm/1.0m, and in all cases stored moisture availability under normal seasonal conditions is considered grossly inadequate to complete a crop cycle. Other limitations vary across the group (depending on soil and landscape characteristics) and limitations recorded range from negligible (sub-class 1) to extreme (sub-class 5).

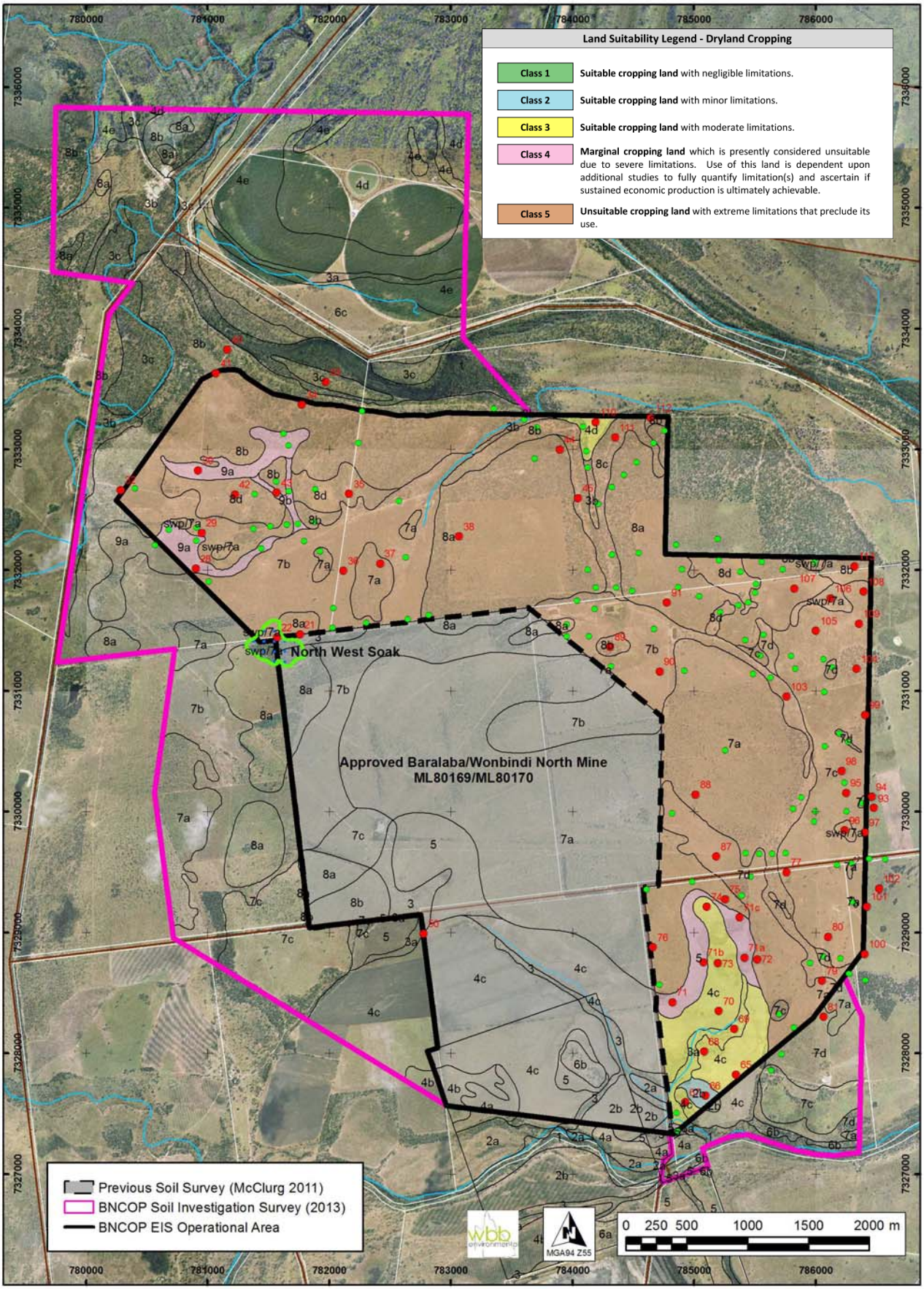


Figure 5. Dryland cropping suitability – summer crops within the BNCOP Disturbance Footprint.

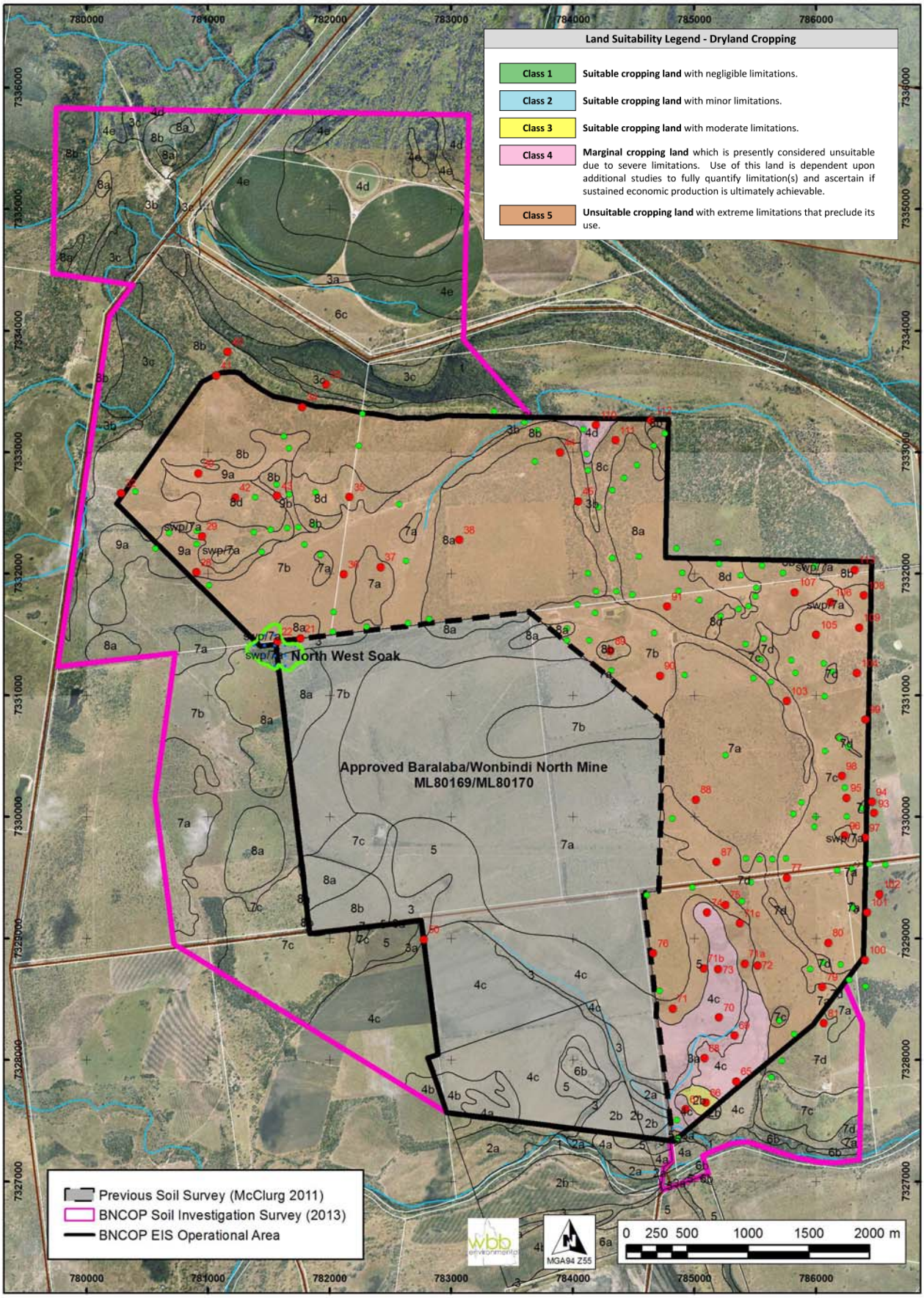


Figure 6. Dryland cropping suitability – winter crops within the BNCOP Disturbance Footprint.

Grazing assessment

Land suitability assessment for grazing within the BNCOP Disturbance Footprint follows the methodology, criteria and decision rules defined by QDME (1995). This scheme is relevant to the Central Queensland region and evaluates soils in terms of the potential to graze and finish cattle on improved pastures. The classification rules defined in the scheme are reproduced in **Appendix 8** and have been adopted in full (without change or addition) and applied as defined. The grazing suitability data presented in **Tables 8 and 9** provides a clear record of the limitations, attributes and subclass rules used in the assessment.

Typically, grazing systems in inland Central Queensland aim to produce young, finished, grassfed, export quality cattle without inputs other than pasture development. Most production is focused on improved pasture grass - legume pastures. Improved pasture development in many areas is dominated by buffel grass, although Rhodes grass and other introduced grasses (Indian bluegrass, creeping bluegrass, purple pigeon grass and panic species) play a role. Legume establishment and species vary significantly depending on soil characteristics and climate. Commonly used legumes include shrubby stylos species, Desmanthus species, Wynn cassia (sandy), butterfly pea (clay), siratro and leucaena (cropping soils).

Land that qualifies as **Classes 1 and 2** is considered suitable for grazing improved pastures and capable of attaining maximum grazing productivity (QDME 1995) in most seasons. In inland Central Queensland this can be defined as the production of young, finished, grassfed, export quality cattle in most seasons, and such country is termed 'fattening country'. **Class 3** land is suitable for grazing improved pastures but is generally less productive than Classes 1 and 2 and encompasses a range in productivity. Land in this class is often termed 'growing country' and is defined as country on which younger cattle perform well but may be difficult to finish at a young age, depending on seasonal conditions (i.e. cattle on Class 3 land may take longer to achieve the desired weight class or finished grade than equivalent cattle on Classes 1 and 2).

Class 4 land is considered marginal for grazing improved pastures, but is generally considered suitable for grazing native pastures of varying quality all year round, depending on soil characteristics (QDME 1995). In inland Central Queensland such country is typically termed 'breeding country'. It encompasses a range in productivity from the lower end of Class 3 'growing country' through to the poorer end of Class 4 'breeding country'. Shields and Williams (1991) suggest 3 possible subclasses exist within Class 4:

- land with native pasture of low productivity, which while physically capable of being developed to improved pasture, is subject to low soil fertility and doubtful long term productivity;
- land with high quality native pasture (typically black soil downs) on which improved pasture establishment is largely unsuccessful because of unfavourable soil characteristics and limited species; and
- land with native pasture of low productivity, which has physical limitations that preclude full improved pasture development, but allow oversowing of legumes such as shrubby stylo.

Class 5 land is unsuitable for any form of pasture improvement, and land use is limited to extensive grazing of native pastures of low productivity. In many cases, lands are of such poor quality they are considered marginal as 'breeding country' and may require destocking in the winter/dry season, unless grazed in conjunction with better quality country. Land in this class is mostly used as 'seasonal breeding country' during the summer/wet season when planes of nutrition are higher.

Suitability findings for grazing

Assessment of grazing suitability (determined in accordance with QDME 1995) is important as it provides a structured and robust scientific evaluation of pre-mining grazing potential for lands potentially affected by the BNCOP Disturbance Footprint. A summary of the spatial extent (ha) of grazing suitability classes and contributing soils is presented below. Further detail including grazing suitability statements, final suitability classes and contributing limitation subclasses are listed for all soils within the BNCOP Disturbance Footprint in **Tables 8 and 9** and displayed in **Figure 7**. These findings are also summarized individually for each soil type in the **Soil Characterization Section** presented earlier in this report.

Grazing Suitability Class	Soils	Area (ha)
Class 1 - suitable (fattening country)	none recorded	-
Class 2 - suitable (fattening country)	2b, 3a, 4c, 4d, 5, 7a	365
Class 3 - suitable (growing country)	3b, 7b, 7d, 9b, swp/7a	310
Class 4 - marginal (breeding country)	7c, 8a, 8b, 9a	713
Class 5 - unsuitable (seasonal breeding country)	8c, 8d	98

Closer analysis of the assessment findings indicates land suitable for improved pasture development and also capable of reliably fattening cattle in most seasons (Class 2) occupies about 365ha or 24.5% of the total Disturbance Footprint. Land suitable for improved pasture development but limited to "growing out" younger cattle in most seasons (Class 3) occupies a further 310ha or 21%. No Class 1 improved pasture fattening country was identified. Of the remaining area, 713ha or 48% is lower fertility country that is marginal for improved pasture development, but suited to year round breeding herd utilisation (Class 4), while the final 98 ha or 6.5% comprises sandy, infertile soils unsuitable for improved pasture development and limited to wet season breeding use only (Class 5 – requiring dry season destocking or co-access to better country).

All soils within the BNCOP Disturbance Footprint are suited to grazing of some form (fattening growing or breeding) and non-agricultural land that cannot be grazed at all is absent. **Soils suitable for grazing improved pastures and capable of fattening cattle** (**Classes 1-2** – production of young, finished, grassfed, export quality cattle in most seasons) include **Soils 2b, 3a, 4c, 4d, 5 and 7a**. These soils are deep, firm pedal to self mulching cracking clays on level to gently undulating landscapes with adequate PAWC characteristics (mostly 60-75mm/0.6m) and high to very high fertility status. Slopes for all soil landscapes listed are <3% and the soils are moderately well drained, have acceptable surface conditions for germination and establishment, are capable of being cultivated for pasture development and lack significant rock or coarse fragments. Limitation subclasses recorded for these soils are only negligible (sub-class 1) or minor (sub-class 2) at worst and final grazing suitability is Class 2.

Soils 3b, 7b, 7d, 9b and swp/7a are considered suitable for grazing improved pastures, but are less productive than soils in Classes 1 and 2. Typically, these soils are more suited for use as **'grower country' (Class 3)** on which younger cattle perform well but may be difficult to finish (at a young age) in most seasons (i.e. cattle exclusively grazed on Class 3 soils may take longer to achieve the desired weight class or finished grade than equivalent cattle on Class 1 and 2 soils). Soil 9b has similar PAWC levels to Class 1 and 2 soils (>60mm/0.6m), while soils 3b, 7b, 7d and swp/7a have significantly lower moisture availability characteristics (30-60mm/0.6m) due to restricted ERD associated with relatively shallow saline and/or sodic subsoil constraints. In addition, Soils 7b and 9b have significantly lower fertility status (<10ppm P) than soils in Classes 1 and 2. Slopes are typically <3% and all 4 soils are moderately well drained, have acceptable surface conditions for germination and establishment, are capable of being cultivated for pasture development and lack significant rock

or coarse fragments. Limitation subclasses recorded for these soils are either negligible (sub-class 1), minor (sub-class 2) or moderate (sub-class 3) at worst, and final grazing suitability is Class 3.

The remainder of soils mapped within the BNCOP Disturbance Footprint (with the exception of Soils 8c and 8d), are considered **marginal for improved pasture development, but suitable for grazing native pastures of varying quality all year round (Class 4)**. Soils in this category are considered typical of year round breeding country in Central Queensland and include **Soils 7c, 8a, 8b and 9a.** These soils are associated either with older relict alluvial sediments or outcropping insitu Tertiary sandstones, and dominate the landscape within the northern and eastern parts of the BNCOP Disturbance Footprint.

Soil characteristics are varied, and include sandy surfaced texture contrast soils (Soils 7c, 8b), sandy/loamy red earths (Soil 8a) and loamy surfaced non-sodic texture contrast soils/non-cracking clays (Soil 9a). PAWC values range from 30-60mm/0.6m, while fertility is consistently low or very low as a result of soil age, parent material characteristics and leaching status. Slopes associated with Soils 7c, 8a and 9a are mostly 1-<5%, but get as steep as 12% on more dissected insitu Tertiary sandstone rises associated with Soil 8b. All soils are imperfectly drained to moderately well drained or better, have acceptable surface conditions for germination and establishment, are capable of being cultivated for pasture development and lack significant rock or coarse fragments. Limitation subclasses recorded for these soils range from negligible (sub-class 1) to severe (sub-class 4) and final grazing suitability (for fattening cattle) is Class 4.

Soils 8c and 8d are deep sands that have very low fertility status and severely restricted moisture availability characteristics (PAWC <25mm). They are considered **unsuitable for improved pasture development, and are useful only for seasonal breeding herd utilisation (Class 5).** Native pasture species are low quality and pasture performance and grazing response is limited. Grazing (in isolation) is restricted to wet season utilisation (when planes of nutrition are higher) and would require destocking during the winter dry season. Limitation subclasses recorded range from negligible (sub-class 1) to extreme (sub-class 5) and final grazing suitability (for fattening cattle) is Class 5.

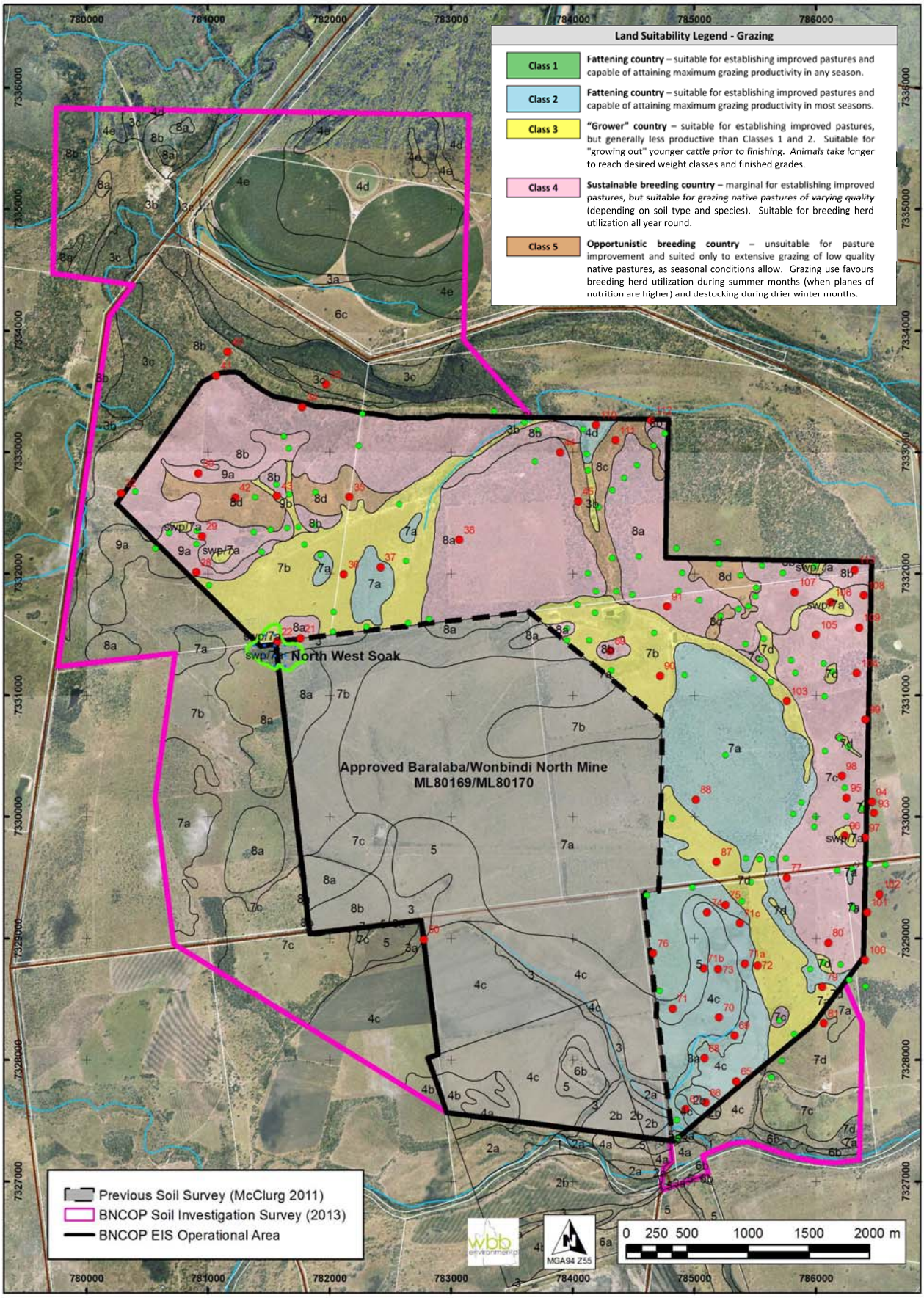


Figure 7. Grazing suitability within the BNCOP Disturbance Footprint.

Table 6. Dryland cropping limitation subclass ratings and final suitability classes (DNRM/DSITIA 2013b) for soils in the BNCOP Disturbance Footprint.

Unit	Soil landscape description	Limitation subclasses	Class	Suitability for dryland cropping
Soils derived from Quaternary alluvium (Qa)				
Active, channelled lower floodplain of the Dawson River and associated anabranches; relatively low lying, undulating unit adjacent to the main channel and subject to regular flooding				
2b	Moderately self-mulching, often silty, black cracking clay on level backplains within the lower floodplain.	**summer**: e2, es2, m2, ps2, w2 **winter**: e2, es2, m3, ps2, w2	**S: 2** **W: 3**	**Suitable** with minor limitations **Suitable** with moderate limitations
Active levees and alluvial plains of tributary drainage lines and floodplain drainage features within or at the margins of elevated terraces and backplains; subject to both local and wider flooding				
3a	Hardsetting to coarsely self-mulching, (poached), black cracking clay in narrow terrace drainage lines of the upper floodplain.	**summer**: e2, es2, m3, ps3, w2 **winter**: e2, es2, m4, ps3, w2	**S: 3** **W: 4**	**Suitable** with moderate limitations **Marginal** due to severe limitations
3b	Hardsetting, clay loamy surfaced (0.2-0.4m), bleached, brown sodic texture contrast soil on level alluvial plains of Saline Creek and associated tributaries.	**summer**: es3, m5, pm3, ps4, w2 **winter**: es3, m5, pm3, ps4, w2	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
Elevated, backplains, terraces and indistinct levees of the upper floodplain of the Dawson River and associated anabranches; typically level and extensive; commonly flooded				
4c	Moderately to strongly self-mulching, black cracking clay on elevated level backplains.	**summer**: e2, es2, m3, ps2, w2 **winter**: e2, es2, m4, ps2, w2	**S: 3** **W: 4**	**Suitable** with moderate limitations **Marginal** due to severe limitations
4d	Weakly to moderately self-mulching, grey cracking clay with weak to moderate melonhole gilgai (VI <0.3-0.6m, HI 10-25m) on level backplains of the Dawson River.	**summer**: e2, es3, m3, ps2, tm3, w2 **winter**: e2, es3, m4, ps2, tm3, w2	**S: 3** **W: 4**	**Suitable** with moderate limitations **Marginal** due to severe limitations
Gently undulating side slopes and dissected margins transitional between recent alluvium of the upper floodplain and older more elevated landscapes adjacent; rarely flooded				
5	Firm pedal or weakly to moderately self-mulching, black cracking clay on gently undulating sideslopes/plains that mark the transition from recent alluvium to older elevated plains.	**summer**: e3, es4, m4, ps2, w2 **winter**: e3, es4, m5, ps2, w2	**S: 4** **W: 5**	**Marginal** due to severe limitations **Unsuitable** due to extreme limitations
Soils derived from older unconsolidated Tertiary–Quaternary sediments (Cz/TQr – elevated Cainozoic clay sheets and relict sandy alluvial deposits)				
Older, elevated, level to gently undulating plains and low rises ; not flooded				
7a	Hardsetting or firm pedal to weakly self mulching, grey cracking clay with strongly developed melon-hole gilgai (VI 0.3-0.8m, HI 12-20m) on older clay sheets; saline, sodic and acidic at depth.	**summer**: e4, es3, m5, pm3, ps3, tm4, w2-4 **winter**: e4, es3, m5, pm3, ps3, tm4, w2-4	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
7b	Hardsetting, thin clay loamy surfaced (<0.05-0.2m), bleached, grey or brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occasional weak gilgai (VI 0.1m, HI 10m) on older unconsolidated sediments and clay sheets.	**summer**: e4, es3, m5, pm3-4, ps4, tm2, w2 **winter**: e4, es3, m5, pm3-4, ps4, tm2, w2	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
7c	Hardsetting, thick sandy surfaced (0.4-0.7m), bleached, often mottled, brown non-sodic to weakly sodic texture contrast soil on elevated relict alluvial deposits.	**summer**: e2, es3, m5, pm3, ps4, w2-4 **winter**: e2, es3, m5, pm3, ps4, w2-4	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
7d	Hardsetting, clay loamy surfaced (0.10-0.2m), bleached, black sodic texture contrast soil on older unconsolidated sediments and clay sheets.	**summer**: e2, es4, m5, pm3, ps4, w2 **winter**: e2, es4, m5, pm3, ps4, w2	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
Local seasonal swamps and closed depressions – occasional landscape features sitting between elevated sandstone units (Landscape 8) and lower lying clay sheets (Landscape 7)				
SWP (7a)	Hardsetting, silty surfaced, mottled, grey non-cracking/cracking clay ± weak gilgai (VI <0.1-0.3m, HI 8-12m) etched within the Cainozoic clay sheets and subject to localized alluvial deposition.	**summer**: es3, m5, pm3, ps3, tm2, w4 **winter**: es3, m5, pm3, ps3, tm2, w4	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations

Unit	Soil landscape description	Limitation subclasses	Class	Suitability for dryland cropping
Soils derived from older consolidated Tertiary sandstone (Ta/Tm)				
Elevated and only weakly dissected, level to gently undulating plateau surface				
8a	Hardsetting, massive, gradational loamy red earth overlying weathered Tertiary sandstone (>1.5m).	**summer**: e2-3, es1-3, m5, pm2, ps4 **winter**: e2-3, es1-3, m5, pm2, ps4	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
Elevated and strongly dissected, undulating to rolling remnant rises				
8b	Soft to loose, thick sandy surfaced (0.3-1.0m), bleached, strongly mottled, non-sodic grey texture contrast soil overlying insitu Tertiary sandstone from 0.8->1.5m.	**summer**: e3-5, es1-5, m5, pm1-3, r3, w4 **winter**: e3-5, es1-5, m5, pm1-3, r3, w4	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
Colluvial footslopes and pediments				
8c	Loose, massive, bleached, grey coarse sand on steeper colluvial footslopes.	**summer**: e3-4, es1-3, m5 **winter**: e3-4, es1-3, m5	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
8d	Loose, massive red or brown earthy sand grading to a very thick sandy surfaced (1.0->1.5m), red or brown non-sodic texture contrast soil on gentle colluvial pediments and outwash deposits.	**summer**: e3, m5 **winter**: e3, m5	**S: 5** **W: 5**	**Unsuitable** due to extreme limitations **Unsuitable** due to extreme limitations
Soils derived from older calcareous sediments (possibly Pwy)				
Level to gently undulating plains and low rises				
9a	Hardsetting, loamy to clay loamy surfaced (0.2-0.3m), brown non-sodic texture contrast soil grading to a structured, brown non-cracking clay overlying calcareous sediments from 0.7m->1.5m.	**summer**: e2, m4, pm2, ps4, w2 **winter**: e2, m5, pm2, ps4, w2	**S: 4** **W: 5**	**Marginal** due to severe limitations **Unsuitable** due to extreme limitations
9b	Hardsetting to moderately self-mulching, black cracking clay with weak normal gilgai (VI <0.1-0.2m, HI 8-15m) overlying calcareous sediments from >1.2m.	**summer**: e2, es3, m4, ps2, tm2, w2 **winter**: e2, es3, m5, ps2, tm2, w2	**S: 4** **W: 5**	**Marginal** due to severe limitations **Unsuitable** due to extreme limitations

Table 7. Cropping suitability – soil attributes contributing to limitation subclasses (DNRM/DSITIA 2013b) for soils in the BNCOP Disturbance Footprint.

Limitation	Attributes	2b		3a		3b		4c		4d		5		7a		7b		7c	
water erosion (E)	slope &disp.	<1% mod. SM + ESP 1	2	<1% mod. SM - HS + ESP 1	2	<1% HS +ESP 2	1	<1% mod.-str. SM + ESP 3	2	<1% weak-mod SM +ESP1	2	1-3% firm-mod SM + ESP 4	3	<1% HS-weak SM + ESP >4	4	<1% very HS + ESP 4-7	4	0.5-2% HS + ESP 1	2
erosion hazard (Es)	slope &disp.	subsoil ESP 2-9	2	subsoil ESP 3-13	2	subsoil ESP 6-19 (2tests >15)	3	subsoil ESP 8-18 (1 test >15)	2	subsoil ESP 6-21 (2 tests>15)	3	subsoil ESP 14-20 (2 tests>15)	4	subsoil ESP 14-28 (2 tests>15)	3	subsoil ESP 13-35 (2 tests>15)	3	subsoil ESP 1-7	3
soil water availability (M)	PAWC (1.0m)	S - >120mm W - >120mm	2 3	S - 95-120mm W - 95-120mm	3 4	S - 45-55mm W - 45-55mm	5 5	S - 90-120mm W - 90-120mm	3 4	S - 85-120mm W - 85-120mm	3 4	S - 70-85mm W - 70-85mm	4 5	S - 50-70mm W - 50-70mm	5 5	S - 30-60mm W - 30-60mm	5 5	S - 70-75mm W - 70-75mm	5 5
narrow moist range (Pm)	drainage and surface cond.	DC 4 mod. SM	1	DC 4 HS - mod. SM	1	DC 4 sodic TC <0.4m	3	DC 4 mod.-str. SM	1	DC 4 weak-mod. SM	1	DC 4 firm-mod. SM	1	DC 3-4 HS-weak SM	3	DC 4 HS sodic TC/NCC<0.4m	3 4	DC 3-4 ns TC 0.4-0.7m	3
surface condition (Ps)	surface cond.	mod. SM 2-5mm	2	HS - mod. SM 5-10mm	3	HS FS/Z >60%	4	mod.-str. SM 2-5mm	2	weak-mod. SM 2-5mm	2	firm-mod. SM 2-5mm	2	HS-weak SM 2-5mm	3	very HS FS/Z >60%	4	HS FS/Z >60%	4
rockiness (R)	abund.& size	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1
microrelief (Tm)	size & % land	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI <0.6m 30-70%	3	non-gilgaied	1	VI 0.3-0.8m >70%	4	VI <0.1m 30-70%	2	non-gilgaied	1
wetness (W)	drain./perm.	DC 4 slow	2	DC 4 slow	2	DC 4 slow	2	DC 4 slow	2	DC 4 slow	2	DC 4 slow	2	DC 4 slow DC 3 slow	2 4	DC 4 slow	2	DC 4 slow DC 3 slow	2 4
Suitability Class		**Summer Winter**	**2 3**	**Summer Winter**	**3 4**	**Summer Winter**	**5 5**	**Summer Winter**	**3 4**	**Summer Winter**	**3 4**	**Summer Winter**	**4 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**

Limitation	Attributes	7d		SWP/7a		8a		8b		8c		8d		9a		9b			
water erosion (E)	slope &disp.	<1-2% HS + ESP 3	2	<1% HS-weak SM + ESP <4	1	<1-5% massive HS + ESP 1	2 3	<1-12% loose or soft + ESP 1	3 5	1-5% loose + ESP 1	3 4	<1-3% loose + ESP 1	3	<1-3% HS + ESP 1	2	<1% HS - mod. SM + ESP 3	2		
erosion hazard (Es)	slope &disp.	subsoil ESP 12-36 (2 tests>15)	4	subsoil ESP 14-28 (2 tests>15)	3	subsoil ESP 1	1 3	subsoil ESP 2-5	1 5	subsoil ESP 1 (<20% clay)	1 3	subsoil ESP 1-2 (<20% clay)	1	subsoil ESP 1-4	1	subsoil ESP 7-16 (2 tests>15)	3		
soil water availability (M)	PAWC (0.1m)	S - 50mm W - 50mm	5 5	S - 50-70mm W - 50-70mm	5 5	S - 70-85mm W - 70-85mm	5 5	S - 50-80mm W - 50-80mm	5 5	S - 40mm W - 40mm	5 5	S - 40mm W - 40mm	5 5	S - 85-100mm W - 85-100mm	4 5	S - 85mm W - 85mm	4 5	S - summer W - winter	
narrow moist range (Pm)	drainage and surface cond.	DC 4 sodic TC<0.4m	3	DC 3 HS-weak SM	3	DC 5 HS, massive RE	2	DC 3 ns TC 0.3-1.1m	1 3	DC 4 deep sand	1	DC 5-6 deep sand	1	DC 4 HS loamy TC	2	DC 4 HS - mod. SM	1		
surface condition (Ps)	surface cond.	HS FS/Z >50%	4	HS-weak SM 2-5mm	3	HS FS/Z >60%	4	loose-soft sandy	1	loose sandy	1	loose sandy	1	HS FS/Z >60%	4	HS - mod. SM 2-5mm	2		
rockiness (R)	abund.& size	no rock	1	no rock	1	no rock	1	<2% outcrop	3	no rock	1	no rock	1	no rock	1	no rock	1		
microrelief (Tm)	size & % land	non-gilgaied	1	VI <0.3m 30-70%	2	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI 0.1-0.2m 30-70%	2		
wetness (W)	drain./perm.	DC 4 slow	2	DC 3 slow	4	DC 5 moderate	1	DC 3 slow	4	DC 4 high	1	DC 5-6 high	1	DC 4 slow	2	DC 4 slow	2		
Suitability Class		**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**5 5**	**Summer Winter**	**4 5**	**Summer Winter**	**4 5**		

Table 8. Grazing limitation subclass ratings and final suitability classes (QDME 1995) for soils in the BNCOP Disturbance Footprint.

Unit	Soil landscape description	Limitation subclasses	Class	Suitability for grazing
Soils derived from Quaternary alluvium (Qa)				
Active, channelled lower floodplain of the Dawson River and associated anabranches; relatively low lying, undulating unit adjacent to the main channel and subject to regular flooding				
2b	Moderately self-mulching, often silty, black cracking clay on level backplains within the lower floodplain.	m2, nd2, ps2, w2, f2, v2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
Active levees and alluvial plains of tributary drainage lines and floodplain drainage features within or at the margins of elevated terraces and backplains; subject to both local and wider flooding				
3a	Hardsetting to coarsely self-mulching, (poached), black cracking clay in narrow terrace drainage lines of the upper floodplain.	m2, nd2, ps2, w2, f2, v2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
3b	Hardsetting, clay loamy surfaced (0.2-0.4m), bleached, brown sodic texture contrast soil on level alluvial plains of Saline Creek and associated tributaries.	m3, nd2, ps2, w2, f2, v2	**3**	**Grower" country** – suitable for improved pastures, but less productive than Classes 1 and 2
Elevated, backplains, terraces and indistinct levees of the upper floodplain of the Dawson River and associated anabranches; typically level and extensive; commonly flooded				
4c	Moderately to strongly self-mulching, black cracking clay on elevated level backplains.	m2, ps2, sa2, f2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
4d	Weakly to moderately self-mulching, grey cracking clay with weak to moderate melonhole gilgai (VI <0.3-0.6m, HI 10-25m) on level backplains of the Dawson River.	m2, ps2, sa2, tm2, w2, f2, v2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
Gently undulating side slopes and dissected margins transitional between recent alluvium of the upper floodplain and older more elevated landscapes adjacent; rarely flooded				
5	Firm pedal or weakly to moderately self-mulching, black cracking clay on gently undulating sideslopes/plains that mark the transition from recent alluvium to older elevated plains.	m2, ps2, sa2, f2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
Soils derived from older unconsolidated Tertiary–Quaternary sediments (Cz/TQr – elevated Cainozoic clay sheets and relict sandy alluvial deposits)				
Older, elevated, level to gently undulating plains and low rises ; not flooded				
7a	Hardsetting or firm pedal to weakly self mulching, grey cracking clay with strongly developed melon-hole gilgai (VI 0.3-0.8m, HI 12-20m) on older clay sheets; saline, sodic and acidic at depth.	m2, ps2, sa2, tm2, w2, v2, ph2	**2**	**Fattening country** – suitable for improved pastures, attains max grazing productivity in most seasons
7b	Hardsetting, thin clay loamy surfaced (<0.05-0.2m), bleached, grey or brown sodic texture contrast soil grading to a grey or brown non-cracking/cracking clay ± occasional weak gilgai (VI 0.1m, HI 10m) on older unconsolidated sediments and clay sheets.	m3, nd3, ps2, sa2, w2, v2, ph2, esp2	**3**	**Grower" country** – suitable for improved pastures, but less productive than Classes 1 and 2
7c	Hardsetting, thick sandy surfaced (0.4-0.7m), bleached, often mottled, brown non-sodic to weakly sodic texture contrast soil on elevated relict alluvial deposits.	m4, nd3, ps2	**4**	**Breeding country** – marginal for improved pastures, suitable for grazing native pastures
7d	Hardsetting, clay loamy surfaced (0.10-0.2m), bleached, black sodic texture contrast soil on older unconsolidated sediments and clay sheets.	m3, ps2, w2, e2	**3**	**"Grower" country** – suitable for improved pastures, but less productive than Classes 1 and 2
Local seasonal swamps and closed depressions – occasional landscape features sitting between elevated sandstone units (Landscape 8) and lower lying clay sheets (Landscape 7)				
SWP (7a)	Hardsetting, silty surfaced, mottled, grey non-cracking/cracking clay ± weak gilgai (VI <0.1-0.3m, HI 8-12m) etched within the Cainozoic clay sheets and subject to localized alluvial deposition.	m2, nd2, ps2, sa2, w3, f2	**3**	**"Grower" country** – suitable for improved pastures, but less productive than Classes 1 and 2

Unit	Soil landscape description	Limitation subclasses	Class	Suitability for grazing
Soils derived from older consolidated Tertiary sandstone (Ta/Tm)				
Elevated and only weakly dissected, level to gently undulating plateau surface				
8a	Hardsetting, massive, gradational loamy red earth overlying weathered Tertiary sandstone (>1.5m).	m4, nd4, ps2, e2, v2	**4**	**Breeding country** – marginal for improved pastures, suitable for grazing native pastures
Elevated and strongly dissected, undulating to rolling remnant rises				
8b	Soft to loose, thick sandy surfaced (0.3-1.0m), bleached, strongly mottled, non-sodic grey texture contrast soil overlying insitu Tertiary sandstone from 0.8->1.5m.	m4, nd4, e2, v2	**4**	**Breeding country** – marginal for improved pastures, suitable for grazing native pastures
Colluvial footslopes and pediments				
8c	Loose, massive, bleached, grey coarse sand on steeper colluvial footslopes.	m5, nd4, e2, v2	**5**	**Seasonal breeding country** – suitable for grazing native pastures, requires dry season destocking
8d	Loose, massive red or brown earthy sand grading to a very thick sandy surfaced (1.0->1.5m), red or brown non-sodic texture contrast soil on gentle colluvial pediments and outwash deposits.	m5, nd4, v2	**5**	**Seasonal breeding country** – suitable for grazing native pastures, requires dry season destocking
Soils derived from older calcareous sediments (possibly Pwy)				
Level to gently undulating plains and low rises				
9a	Hardsetting, loamy to clay loamy surfaced (0.2-0.3m), brown non-sodic texture contrast soil grading to a structured, brown non-cracking clay overlying calcareous sediments from 0.7m->1.5m.	m3, nd4, ps2, v2	**4**	**Breeding country** – marginal for improved pastures, suitable for grazing native pastures
9b	Hardsetting to moderately self-mulching, black cracking clay with weak normal gilgai (VI <0.1-0.2m, HI 8-15m) overlying calcareous sediments from >1.2m.	m2, nd3, ps2, sa2, w2, ph2	**3**	**"Grower" country** – suitable for improved pastures, but less productive than Classes 1 and 2

Table 9. Grazing suitability – soil attributes contributing to relevant limitation subclasses (QDME 1995) for soils in the BNCOP Disturbance Footprint.

Limitation	Attributes	2b		3a		3b		4c		4d		5		7a		7b		7c	
water availability (M)	PAWC (0.6m)	70-75mm	2	70-75mm	2	45-55m	3	70-75mm	2	70-75mm	2	70-75mm	2	50-70mm	2	30-60mm	3	30-35mm	4
nutrient deficiency (Nd)	fertility (P)	P - 73ppm N - high	2	P - 83ppm N - high	2	P -28ppm N - high	2	P - 56ppm N - very high	1	P - 36ppm N - very high	1	P - 32ppm N - high	1	P - 20ppm N - high	1	P - 6-8ppm N - moderate	3	P - <11ppm N - moderate	3
soil physical factors (Ps)	surface cond.	mod. SM 2-5mm	2	HS - mod. SM 5-10mm	2	HS FS/Z >60%	2	mod.-str. SM 2-5mm	2	weak-mod. SM 2-5mm	2	firm-mod. SM 2-5mm	2	HS-weak SM 2-5mm	2	very HS FS/Z >60%	2	HS FS/Z >60%	2
root zone salinity (Sa)	mean EC (dS/m)	0.08	1	0.13	1	0.05	1	0.19	2	0.18	2	0.27	2	0.31	2	0.15-0.27	2	0.04	1
rockiness (R)	abund.& size	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1	no rock	1
microrelief (Tm)	size & % land	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI <0.6m 30-70%	2	non-gilgaied	1	VI 0.3-0.8m >70%	2	VI <0.1m 30-70%	1	non-gilgaied	1
wetness (W)	soil/landscape	low lying	2	low lying	2	level - sodic TC	2	elevated	1	level plain	2	undulating	1	level plain	2	level plain	2	undulating	1
water erosion (E)	slope &disp.	<1% cracking clay	1	<1% cracking clay	1	<1% sodic rigid TC	1	<1% cracking clay	1	<1% cracking clay	1	1-3% cracking clay	1	<1% cracking clay	1	<1% sodic TC/NCC	1	0.5-2% non-sodic rigid	1
flooding (F)	occurrence	reg. flooding	2	reg. flooding	2	occ. flooding	2	occ. flooding	2	occ. flooding	2	occ. flooding	2	flood free	1	flood free	1	flood free	1
vegetation (V)	veg. type	coolibah	2	coolibah	2	poplar box	2	brigalow	1	brigalow gilgai	2	brigalow	1	brigalow gilgai	2	shrubby box	2	Euc - softwood	2
surface pH (pH)	pH (0-0.1m)	7.5	2	6.7-7.7	2	5.9	1	7.4-8.7	2	7.8-8.5	2	7.8-8.7	2	7.0-8.0	2	6.4-7.4	2	6.0-6.7	1
surface ESP (ESP)	ESP (0-0.1m)	ESP 1	1	ESP 1	1	ESP 2	1	ESP 3	1	ESP 1	1	ESP 4	1	ESP 4	1	ESP 4-7	2	ESP 1	1
Final suitability Class			2		2		3		2		2		2		2		3		4

Limitation	Attributes	7d		SWP/7a		8a		8b		8c		8d		9a		9b			
water availability (M)	PAWC (0.6m)	50mm	3	50-70mm	2	35-45mm	4	30-35mm	4	25mm	5	25mm	5	50-60mm	3	70mm	2		
nutrient deficiency (Nd)	fertility (P)	P - 28ppm N - high	1	P - 20ppm N - high	2	P - 1ppm N - moderate	4	P - 2ppm N - low-mod.	4	P - 1-2ppm N - low-mod.	4	P - 1-2ppm N - low-mod	4	P - 4ppm N - mod-high	4	P - <10ppm N - high	3		
soil physical factors (Ps)	surface cond.	HS FS/Z >50%	2	HS-weak SM 2-5mm	2	HS FS/Z >60%	2	loose-soft sandy	1	loose sandy	1	loose sandy	1	HS FS/Z >60%	2	HS - mod. SM 2-5mm	2		
root zone salinity (Sa)	mean EC (dS/m)	0.13	1	0.16	2	0.04	1	0.04	1	<0.03	1	0.03	1	0.08	1	0.19	2		
rockiness (R)	abund.& size	no rock	1	no rock	1	no rock	1	<2% outcrop	1	no rock	1	no rock	1	no rock	1	no rock	1		
microrelief (Tm)	size & % land	non-gilgaied	1	VI <0.3m 30-70%	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	non-gilgaied	1	VI 0.1-0.2m 30-70%	1		
wetness (W)	soil/landscape	level - sodic TC	2	seasonal swp.	3	elevated plain	1	undulating	1	undulating	1	undulating	1	undulating	1	level plain	2		
water erosion (E)	slope &disp.	<1-2% sodic rigid TC	2	<1% cracking clay	1	<1-5% non-sodic rigid	1 2	<1-12% non-sodic rigid	1 2	1-5% non-sodic rigid	1 2	<1-3% non-sodic rigid	1	<1-3% non-sodic rigid	1	<1% cracking clay	1		
flooding (F)	occurrence	flood free	1	reg. inundation	2	flood free	1	flood free	1	flood free	1	flood free	1	flood free	1	flood free	1		
vegetation (V)	veg. type	brigalow - euc	1	forest red gum	1	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	eucalypt - no wattle	2	open grassland	1		
surface pH (pH)	pH (0-0.1m)	6.0-7.2	1	5.5-6.9	1	5.5-6.3	1	5.2-6.4	1	5.5-6.5	1	5.5-6.5	1	5.9-6.4	1	7.1	2	SC = median value of range	
surface ESP (ESP)	ESP (0-0.1m)	ESP 3	1	ESP <4	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 1	1	ESP 3	1		
Final suitability Class			3		3		4		4		5		5		4		3		

10. Agricultural Land Class (ALC) assessment

Agricultural Land Class (ALC) assessment

Agricultural Land Classification (ALC) in Queensland has recently been revised (DNRM/DSITIA 2013a) and now follows a simple, consistent hierarchical scheme that is applicable across the State. Three classes of agricultural land (Class A – Crop land; Class B – Limited crop land; Class C – Pasture land) and one class of non-agricultural land (Class D) are defined (DNRM/DSITIA 2013a). Further definition and description of these classes is available in the methodology section of this report and from DNRM/DSITIA (2013a). ALC assessment has used detailed land suitability outcomes for broadacre dryland cropping and grazing (see **Tables 6 and 7** and **Tables 8 and 9** respectively), and follows the latest methodology and conventions prescribed by DNRM/DSITIA (2013a).

Agricultural Land Class (ALC) findings

Agricultural Land Classes (ALC) simplify the detail and complexity typically associated with land suitability data, and provide a meaningful and concise summary as to the status of pre-mining agricultural potential within the BNCOP Disturbance Footprint. ALC findings are summarized in **Table 10** and displayed in **Figure 8**.

Table 10. Summary of ALC findings for soils within the BNCOP Disturbance Footprint.

ALC	Soils	Area (ha)
Class A1 Crop Land	Soils 2b, 3a, 4c, 4d	96
Class B Limited Crop Land	Soils 5, 9a, 9b	68
Class C1 Pasture Land	Soils 3b, 7a, 7b, 7d, swp/7a	546
Class C2 Pasture Land	Soils 7c, 8a, 8b, 8c, 8d	776

Class A1 – Crop Land occupies only 96ha or 6.5% of the BNCOP Disturbance footprint and is associated with **Soils 2b, 3a, 4c and 4d**. These soils are deep, self-mulching alluvial clays with adequate moisture holding capacity and high to very high inherent fertility (cropping suitability – Classes 1-3). Class A2 – Horticultural Crop Land is not relevant to the Baralaba region and was not recorded. **Class B – Crop Land** is relatively minor and occupies only 68ha or 4.5%. It is restricted to **Soils 5, 9a and 9b,** all of which are marginal for dryland cropping (cropping suitability – Class 4). These soils have limited effective rooting depth and restricted moisture holding capacity.

Class C1 – Pasture Land is significant within the BNCOP Disturbance Footprint and occupies 546ha or 37% of the total area. It is associated with **Soils 3b, 7a, 7b, 7d and swp/7a**, which include loamy surfaced texture contrast soils, brigalow clays and local seasonal swamps. These soils are unsuitable for dryland cropping, but have desirable fertility and moisture characteristics for pasture development and are suited to fattening or growing out younger cattle (Grazing suitability – Classes 2 and 3). **Class C2 – Pasture Land** is the dominant ALC unit (largest spatial extent) within the BNCOP Disturbance Footprint and occupies 776ha or 52% of the total area. It is associated with **Soils 7c, 8a, 8b, 8c and 8d,** all of which are sandy soils with low to very low inherent fertility and limited moisture holding characteristics. These soils occupy relatively gentle eucalypt landscapes that are unsuitable for fattening cattle (Grazing suitability – Class 4/5), but are accessible, easily managed and typically used as breeding country. Class C3 Pasture Land and Class D Non-agricultural Land do not occur within the BNCOP Disturbance Footprint.

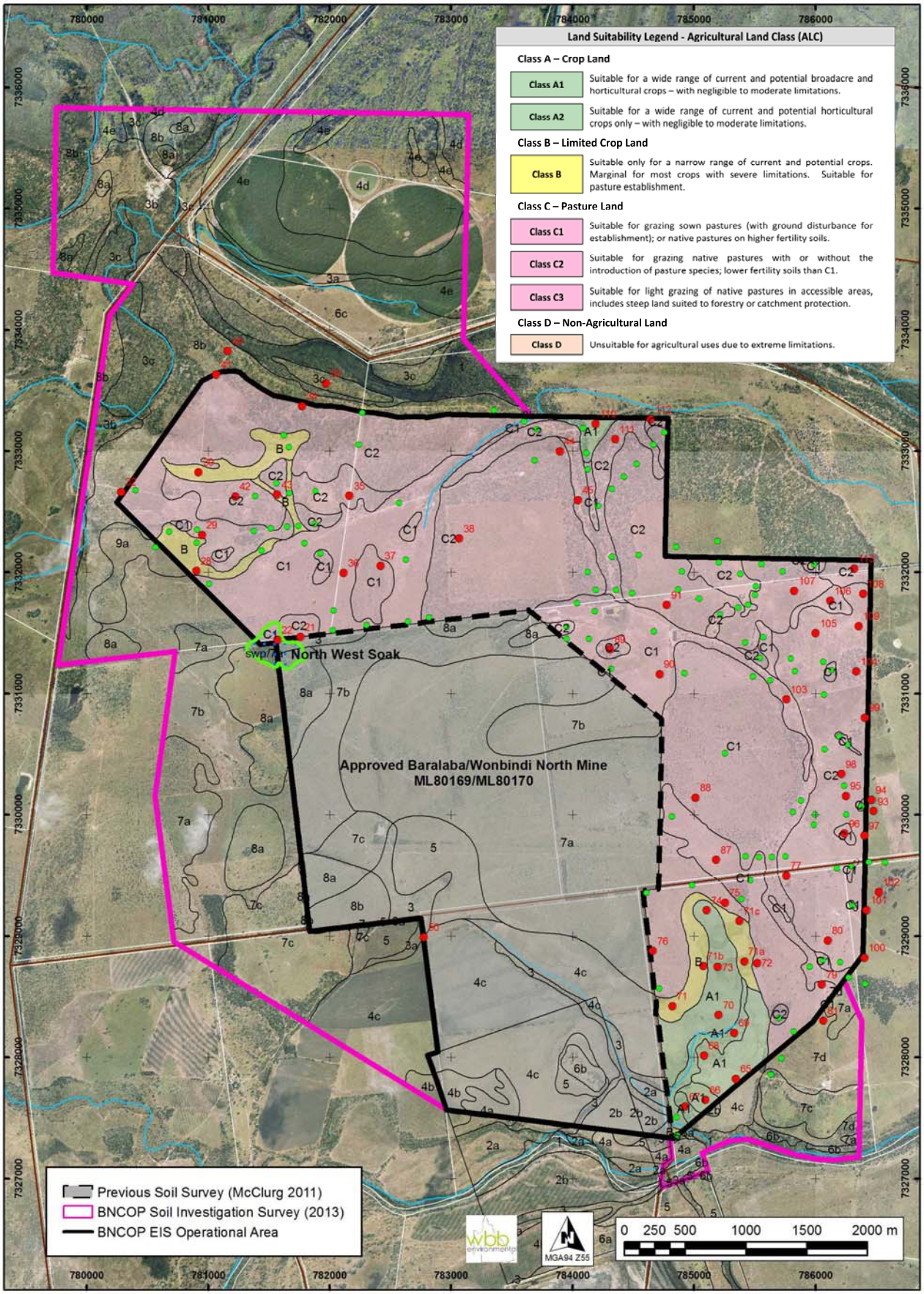


Figure 8. Agricultural Land Classes (ALC) (DNRM/DSITIA 2013a) within the BNCOP Disturbance Footprint.

11. Strategic Cropping Land (SCL) assessment

Within the wider 2013 BNCOP Soil Investigation survey area only those parts intersected by both the:

- BNCOP EIS Operational Area boundary; and
- the state wide Strategic Cropping Land (SCL) trigger mapping (DNRM 2011a);

are triggered for SCL assessment. Triggered areas that lie within the western section of the BNCOP EIS Operational Area (ML80169 and ML80170) have been previously mapped and assessed for SCL status and are subject to existing SCL mitigation determinations.

As such, the current investigation (as a contributing baseline study to the BNCOP Operational Area EIS) is concerned only with newly triggered areas external to ML80169 and ML80170. This effectively limits the current SCL assessment to lands within the BNCOP Disturbance Footprint (as defined in Figure 2). SCL findings for the already approved Baralaba/Wonbindi North Mine Lease (ML80169 and ML80170) have been reported previously by NQSA (2011a, 2011b) and are not re-presented or discussed in this report.

Strategic Cropping Land (SCL) assessment methodology

The SCL assessment has used detailed soil profile data, representative analytical data and large scale soil mapping (1:25000 scale) collected in accordance with recognized standard land resource survey methodologies and analytical procedures (Isbell 1996; McKenzie *et al* 2002; McKenzie *et al* 2008; National Committee on Soil and Terrain 2009 and Rayment and Lyons 2011). Relevant morphological and analytical soil profile data used in the required SCL calculations and criteria compliance assessments are presented in full in **Appendices 2-7,** and summarised in the **Soil Characterization Section** of this report. All recorded field data, measured analytical data and calculated parameters for detailed sites within the triggered area meet the necessary data requirements and follow the procedures and criteria prescribed by DNRM for SCL assessment as at December 2013 (DNRM 2011b, DNRM 2011d, Queensland Government 2011).

Strategic Cropping Land (SCL) zone and trigger mapping status

The BNCOP Disturbance Footprint (excluding ML80169 and ML80170) lies within the **Western Cropping Zone (WCZ)** of the **Strategic Cropping Management Area** (DNRM 2011a, DNRM 2011c). SCL trigger mapping from the DNRM website 2013 (DNRM 2011a) indicates 'likely' (or potential) SCL triggered by the footprint is restricted to an area of 118ha. The triggered land is confined to the southern end of the BNCOP Disturbance Footprint, and is wholly contained within one property (Lot 7, Plan KM44, Central Highlands RC), as defined in Sections 45 and 46 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011). The spatial extent of all triggered land in relation to the wider BNCOP Soil Investigation Survey Area is presented in **Figure 9**, while the location and extent of triggered land specific to the BNCOP Disturbance Footprint is presented in **Figure 10**.

Location of the triggered land within a Strategic Cropping Management Area, has required assessment against both relevant Cropping History criteria (Queensland Government 2011, DNRM 2012) and WCZ SCL Zonal Criteria 1-8 (DNRM 2011d, Queensland Government 2011) before SCL status can be decided.

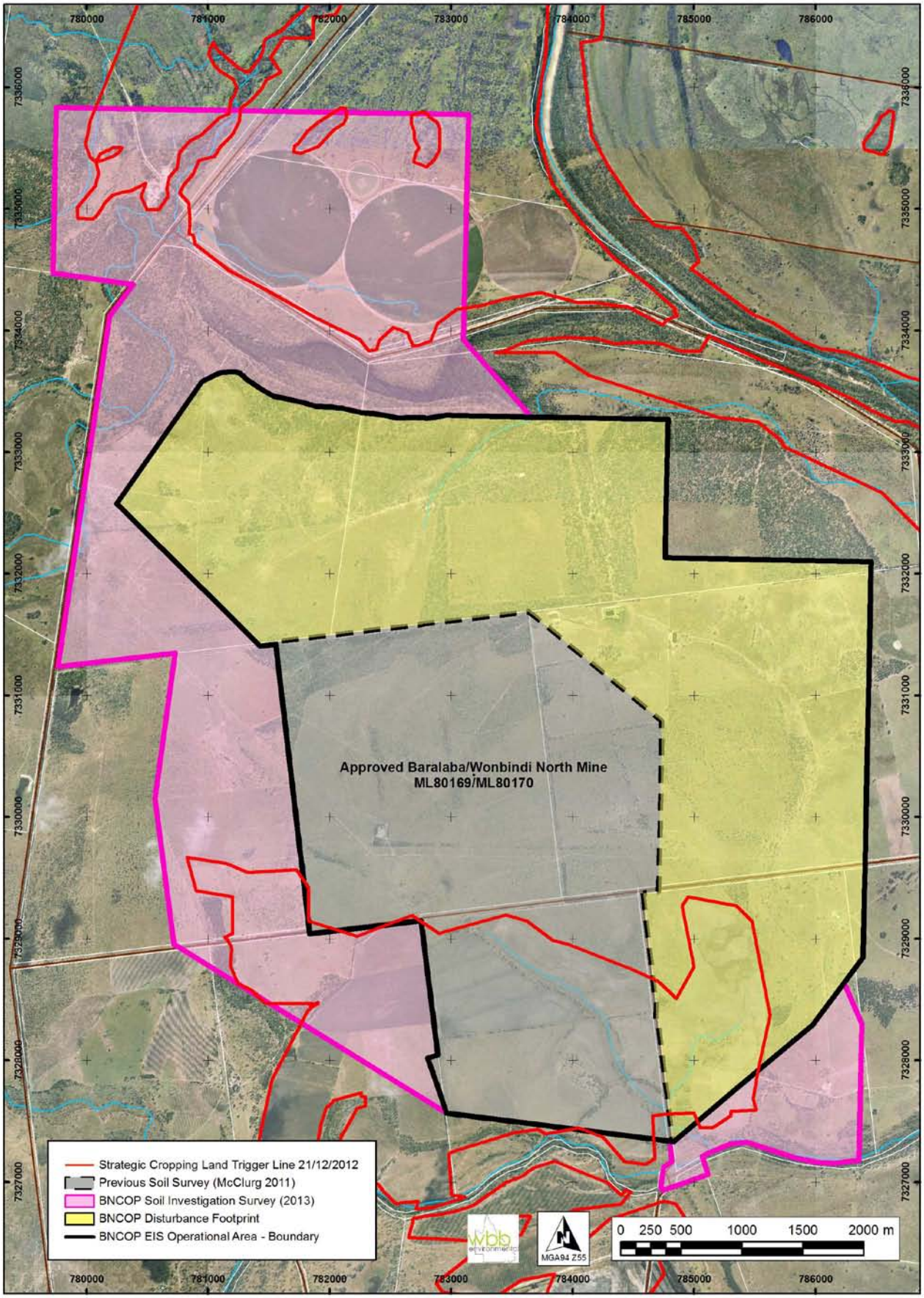


Figure 9. Location and extent of SCL trigger mapping as at 21/12/2012 (DNRM 2011a) in relation to the wider BNCOP Soil Investigation Survey Area.

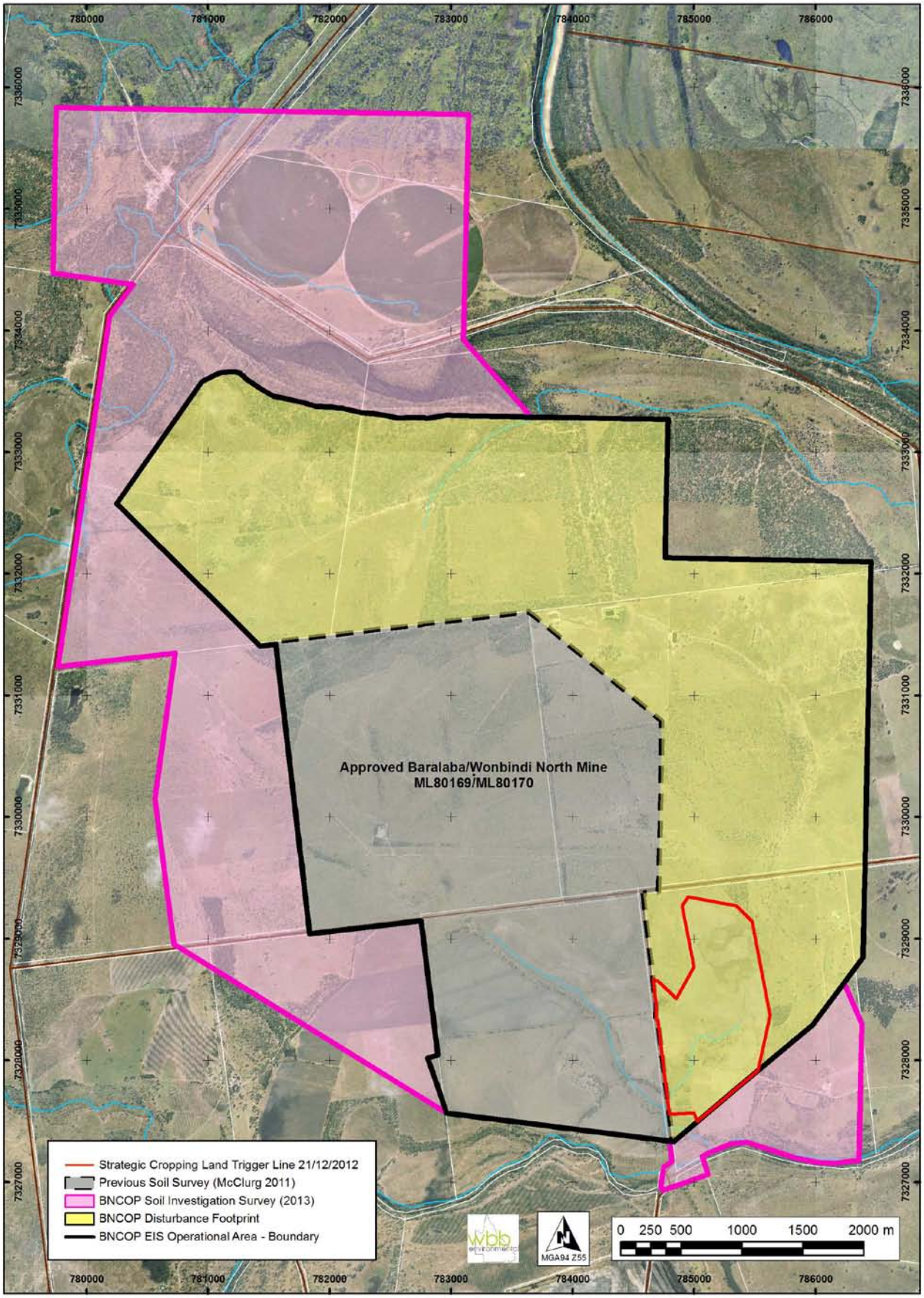


Figure 10. Location and extent of 'likely' (or potential) Strategic Cropping Land specifically triggered for assessment within the BNCOP Disturbance Footprint.

Cropping history assessment

Spatial examination of natural colour Landsat imagery covering the triggered property between the years 1999 and 2010 clearly indicates at least 8 autumn cropping events took place on the property. The extent of the cropping activity appears largely restricted to the triggered land. Autumn was selected as the most appropriate time of year to assess cropping history because of the traditional overlap between summer crop finishing and winter crop preparation during this period. The location and spatial extent of autumn cropping activity within the triggered property is presented for 4 typical years (1999, 2003, 2008 and 2010) in **Figures 11, 12, 13 and 14.**

As such, and in accordance with Section 49 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011) the property was deemed to have the required cropping history (3 or more cropping events between 1 January 1999 and 31 December 2010), and as a consequence has required further assessment against WCZ SCL Zonal Criteria 1-8 to fully determine SCL status.

Assessment against Strategic Cropping Land (SCL) WCZ Zonal Criteria 1-8

The SCL Zonal Criteria considered in the following assessment are those defined for the **Western Cropping Zone** of the **Strategic Cropping Management Area** (DNRM 2011d, Queensland Government 2011). The exact location and extent of detailed field sites within the triggered land are highlighted in **Figure 15.** Similarly, the spatial extent and distribution of soils triggered for SCL Zonal Criteria assessment within the triggered land are displayed in **Figure 16**.

Analytical data from analysed representative sites that occur within (or are relevant to) the triggered portion of the BNCOP Disturbance Footprint can be found in **Appendix 5**. The analytical data is also summarized and discussed in the **Soil Characterization Section** of this report. Morphological descriptions that accompany the analysed representative sites (a number of which occur within or are directly relevant to the triggered land) are presented in **Appendix 6**. Morphological descriptions for all detailed field sites within the triggered boundary (whether analysed or not) are presented in **Appendix 7.**

Relevant morphological and analytical soil data, calculations and identified constraints used in the determination of Effective Rooting Depth (ERD) and Soil Water Status (SWS), for assessment against Zonal Criteria 8, are presented in **Tables 13 and 14** respectively. ERD and SWS determinations are in accordance with defined soil depth criteria, physico-chemical limitation criteria and SWS calculations in the *Strategic Cropping Land Act 2011* (Queensland Government 2011). ERD determinations follow the procedure outlined in Section 4.8.2 of the SCL Guidelines (DNRM 2011d), while SWS calculations follow the procedure outlined in Section 4.8.3 of the SCL Guidelines (DNRM 2011d).

Final SCL Zonal Criteria compliance outcomes are presented in **Table 12**. These outcomes are also displayed spatially in **Figures 18-20.** These maps present a sequential series of images that visually display progressive compliance/non-compliance outcomes as each Zonal Criteria is addressed, for all land mapped within the triggered portion of the BNCOP Disturbance Footprint.

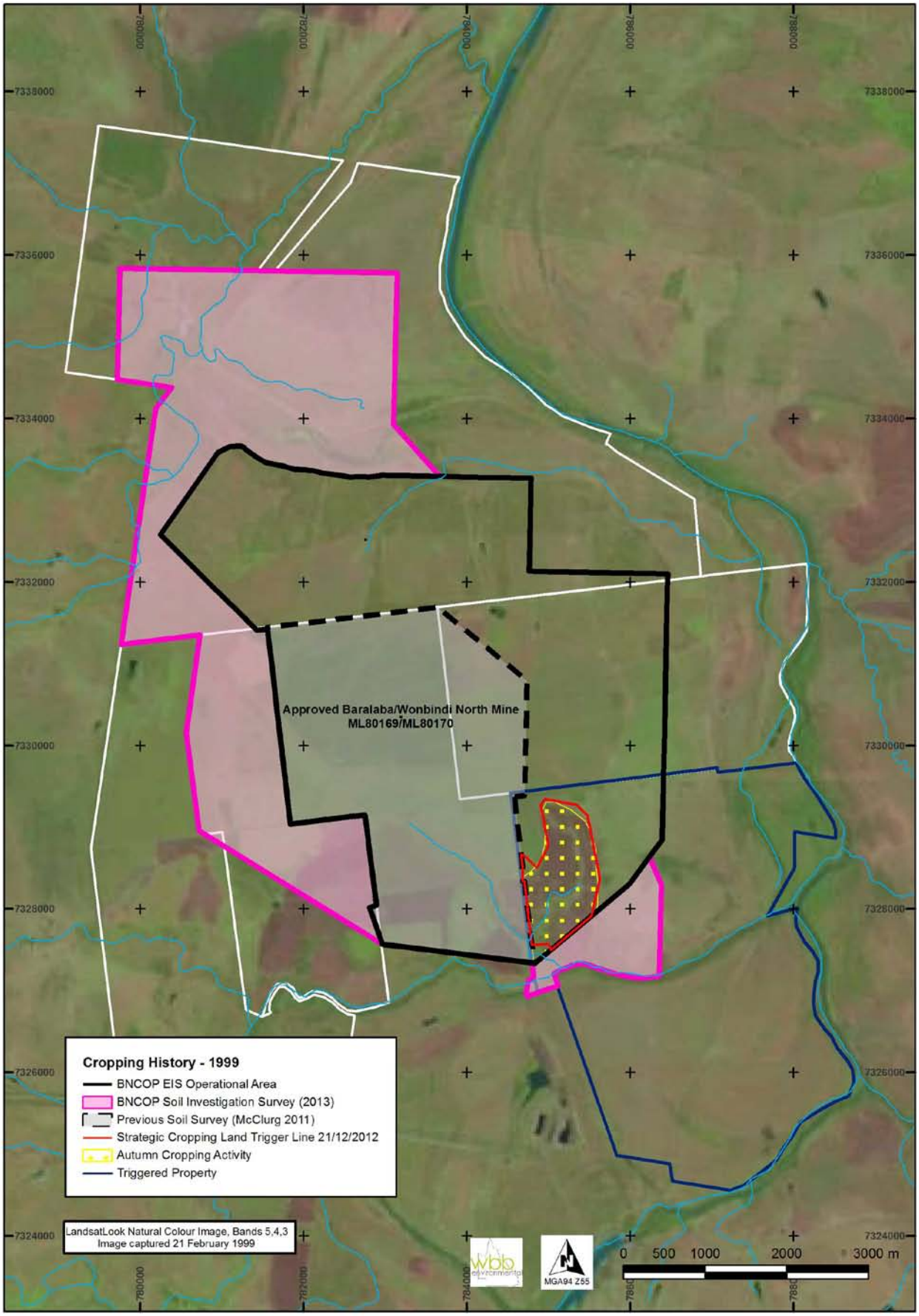


Figure 11. Landsat imagery from 1999 showing active autumn cropping activity within the triggered property. Cropping activity is closely associated with the triggered land.

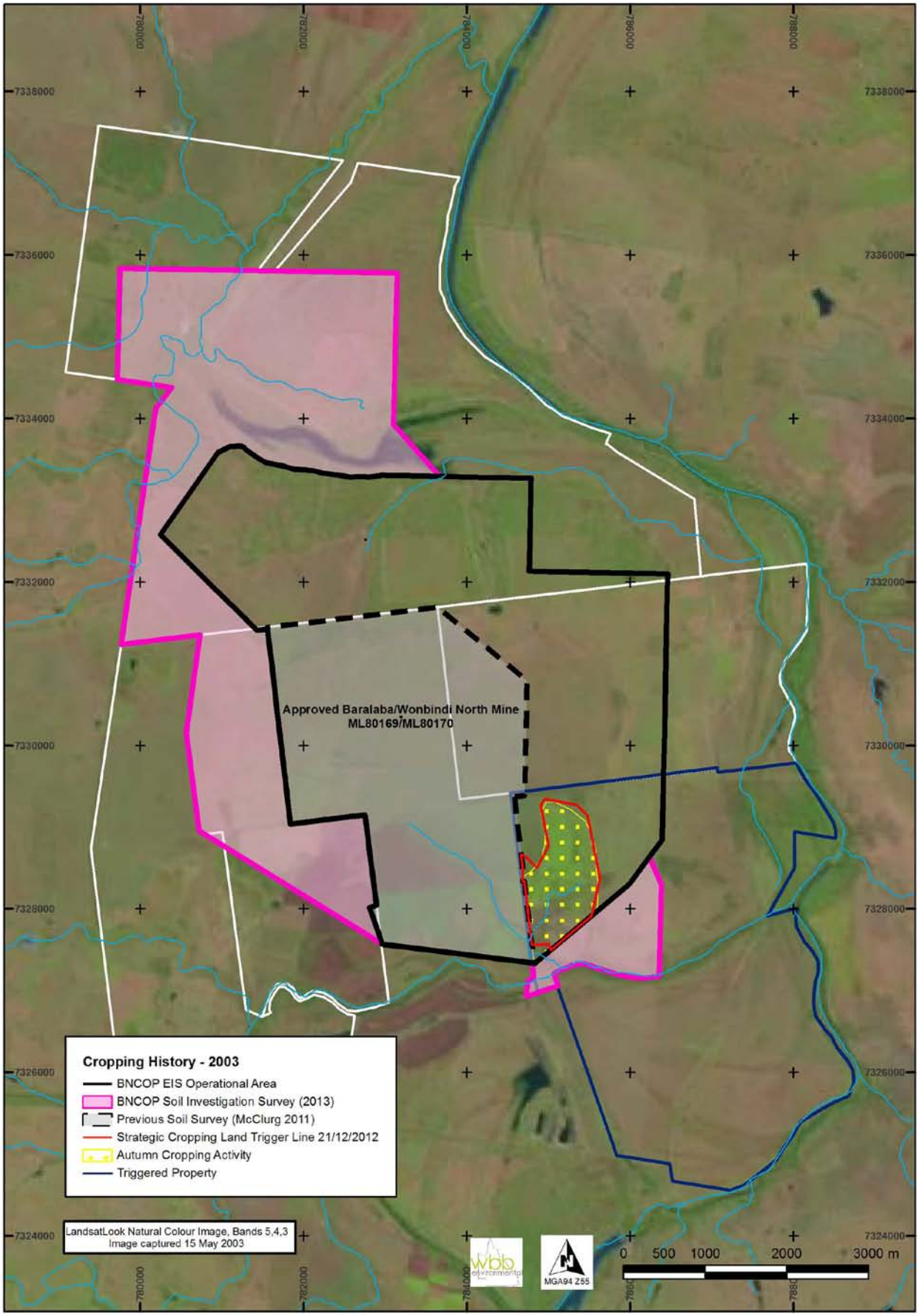


Figure 12. Landsat imagery from 2003 showing active autumn cropping activity within the triggered property. Cropping activity is closely associated with the triggered land.

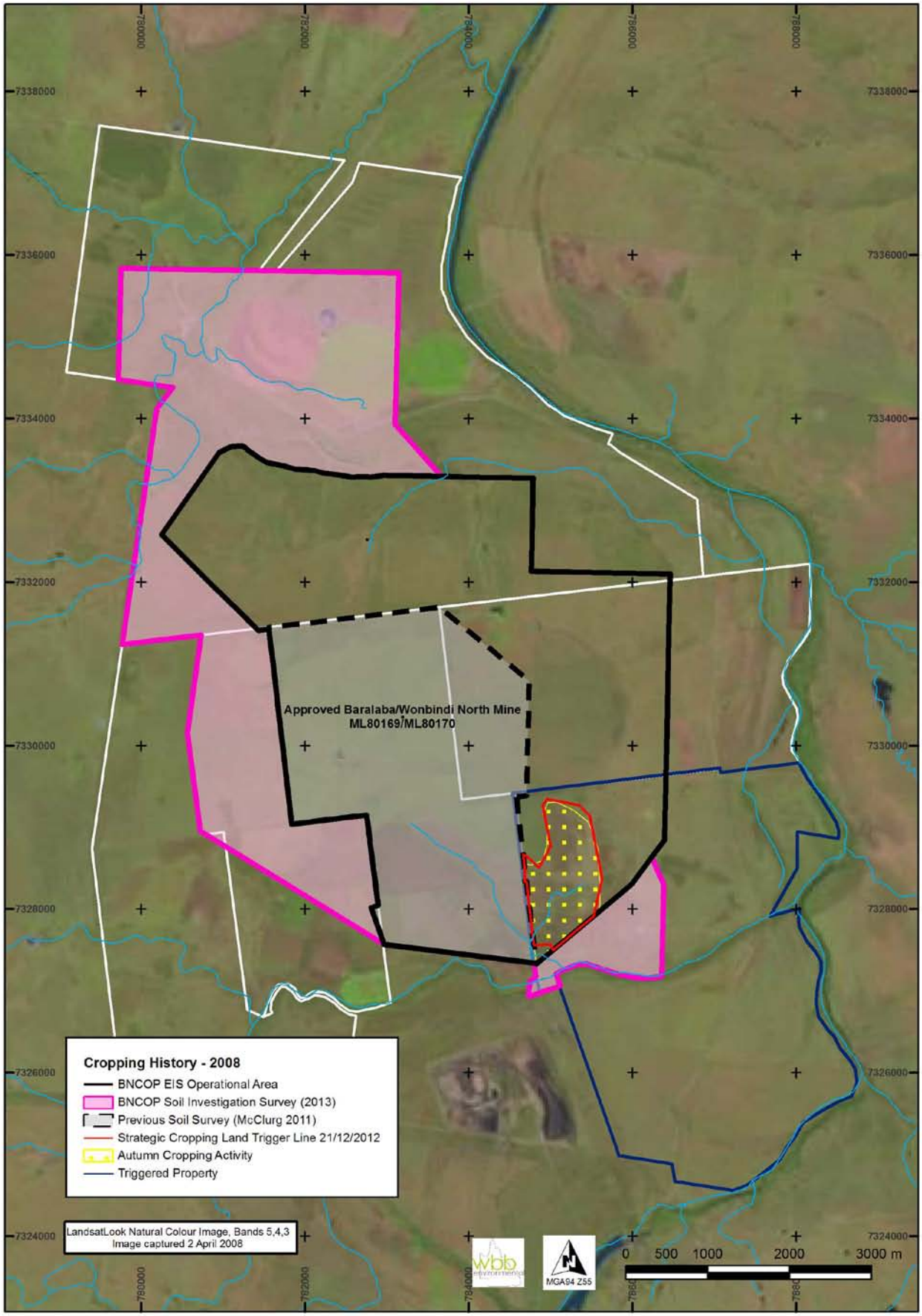


Figure 13. Landsat imagery from 2008 showing active autumn cropping activity within the triggered property. Cropping activity is closely associated with the triggered land.

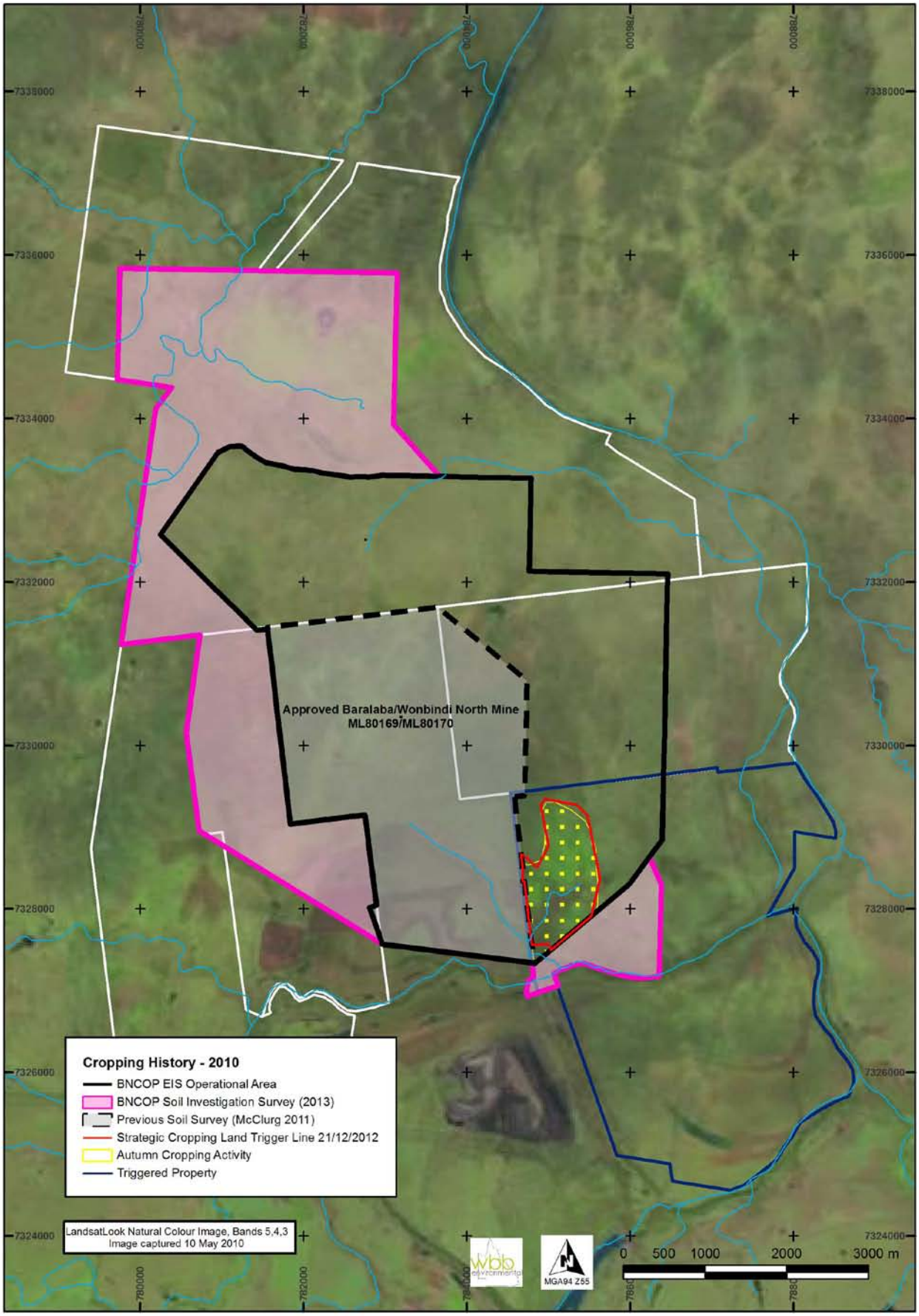


Figure 14. Landsat imagery from 2010 showing active autumn cropping activity within the triggered property. Cropping activity is closely associated with the triggered land.

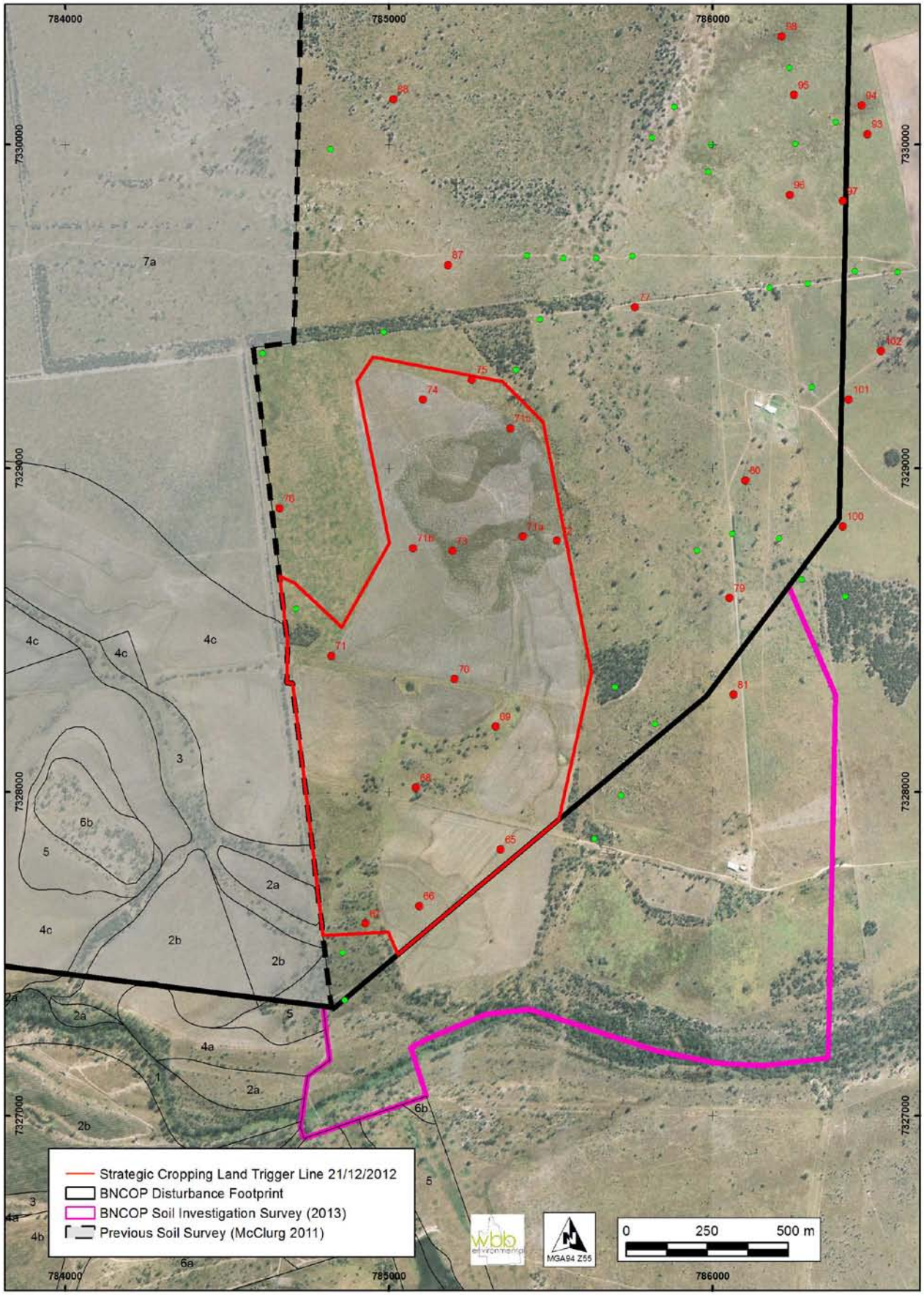


Figure 15. The exact location and extent of land triggered for SCL Zonal Criteria assessment within the BNCOP Disturbance Footprint.

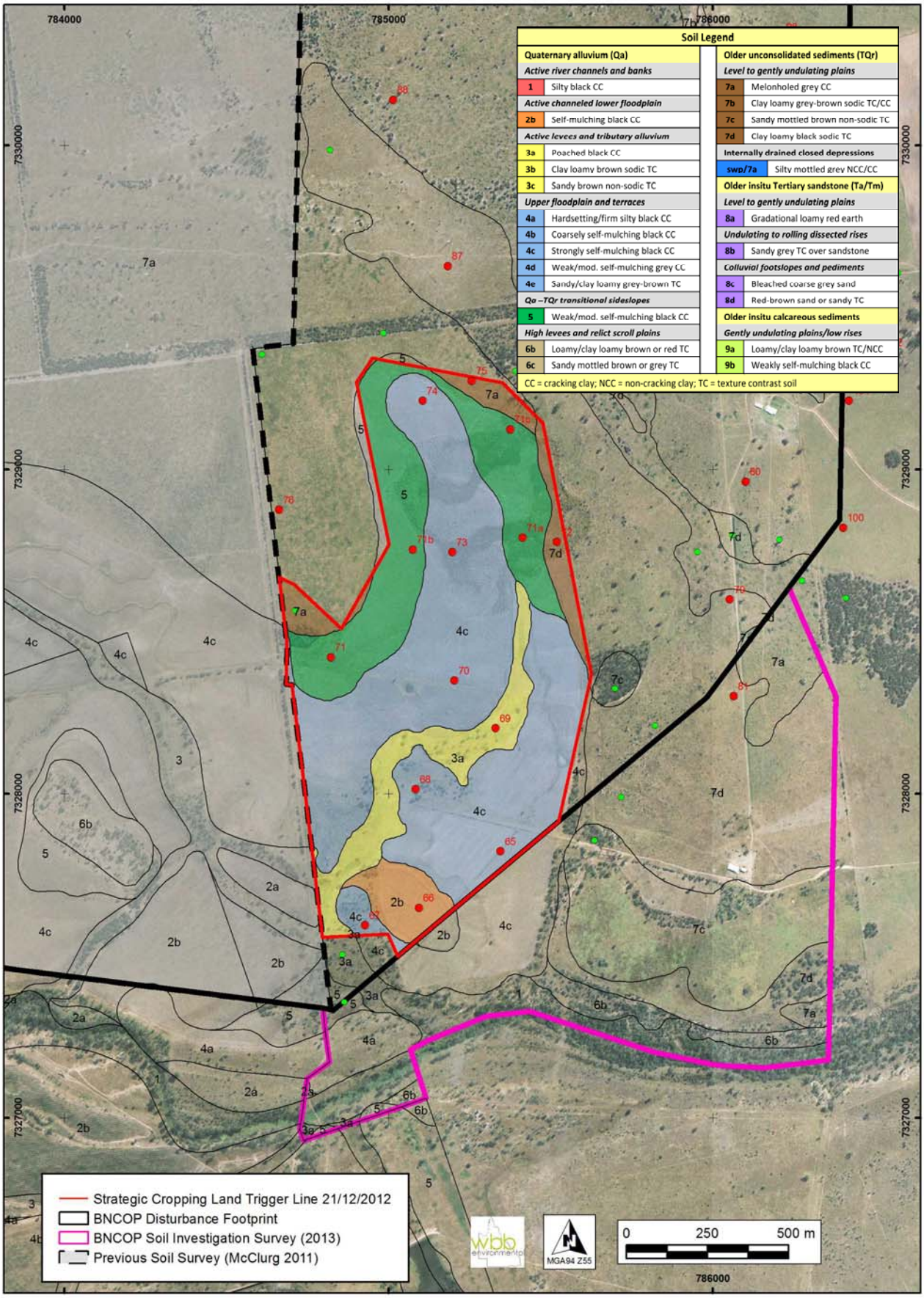


Figure 16. The spatial extent and distribution of soils triggered for SCL Zonal Criteria assessment within the BNCOP Disturbance Footprint.

SCL Zonal Criteria 1 – slope

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping land have gradients of 3% or less, as defined in the *Strategic Cropping Land Act* (Queensland Government 2011) and SCL guidelines (DNRM 2011d). Field data collection and reporting for SCL Zonal Criteria 1 are in line with specifications set out in the SCL Guidelines (DNRM 2011d), and accurate on-ground slope values (recorded by an experienced operator using a hand held Clinometer) are available for all detailed field sites within the trigger area.

However, in an effort to ensure uniform and accurate spatial assessment of Criteria 1 across the entire extent of the triggered land, DEM analysis has been used to better identify and screen areas with slopes >3%, from those with slopes ≤3%. The availability of an accurate and detailed DEM has meant a more complete and definitive spatial analysis has been possible, especially when compared with the potential inaccuracy/inconsistency likely with manual slope interpolation. The use of DEM based slope analysis is well established and is commonly used in government digital mapping programs in Queensland and elsewhere (for example Burgess and Ellis 2007).

Whilst on-ground slope measurements are available for all field sites, they have not been used in the spatial assessment of Criteria 1, other than as point source verification data. Manual slope assessments rely too heavily on the spatial interpolation skills of the assessor, and have the potential to produce skewed or inaccurate spatial estimates, as a result of operator inconsistency in the field or from unrepresentative on-ground locations.

The DEM used in the current assessment is purpose built, and was derived from a spline interpolation of over 2,000,000 LIDAR generated elevation points from across the greater study area. Source elevation points were modelled independently to derive DEMs of 5m and 20m pixel size for differing assessment purposes. The derived DEMs do not represent re-sampled data sets. The accuracy and reliability of the LIDAR generated DEM, in conjunction with the gentle topography common within the triggered area, suggest digital slope analysis is appropriate in this particular case. The interpreted hillshade DEM surface shown in **Figure 17** (interpreted for slopes >3%) clearly demonstrates the subtle elevation and related slope variability requiring clarification for any reasonable assessment of Criteria 1.

The trigger area essentially comprises a north-south trending weakly incised, flooded backplain that forms part of the upper floodplain surface of the Dawson River anabranch system (Soils 2b and 4c). Floodplain dissection has occurred along its central axis and resulted in the formation of a narrow depositional drainage line sourcing local alluvium (Soil 3a). Surrounding sideslopes (Soil 5) are transitional between the younger flood alluvium and the more elevated, level to gently undulating TQr landscapes that are widespread north of the anabranch. Landscape change is subtle at this boundary and the sideslopes which still occasionally flood, merge gradually at upper slope positions with the much older, relatively elevated, level TQr plains that surround (Soils 7a and 7d).

Slopes within the trigger area are mostly ≤3%, except at the lower end of the central floodplain towards the confluence with the main channel of the Dawson River anabranch. Flooding is typically deeper, more erosive and higher frequency in this area and has lead to greater incision and dissection. The severity and intensity of channel and bank/sideslope features increases significantly in this area, and spatial assessment of areas ≤ 3% and > 3% is more complex.

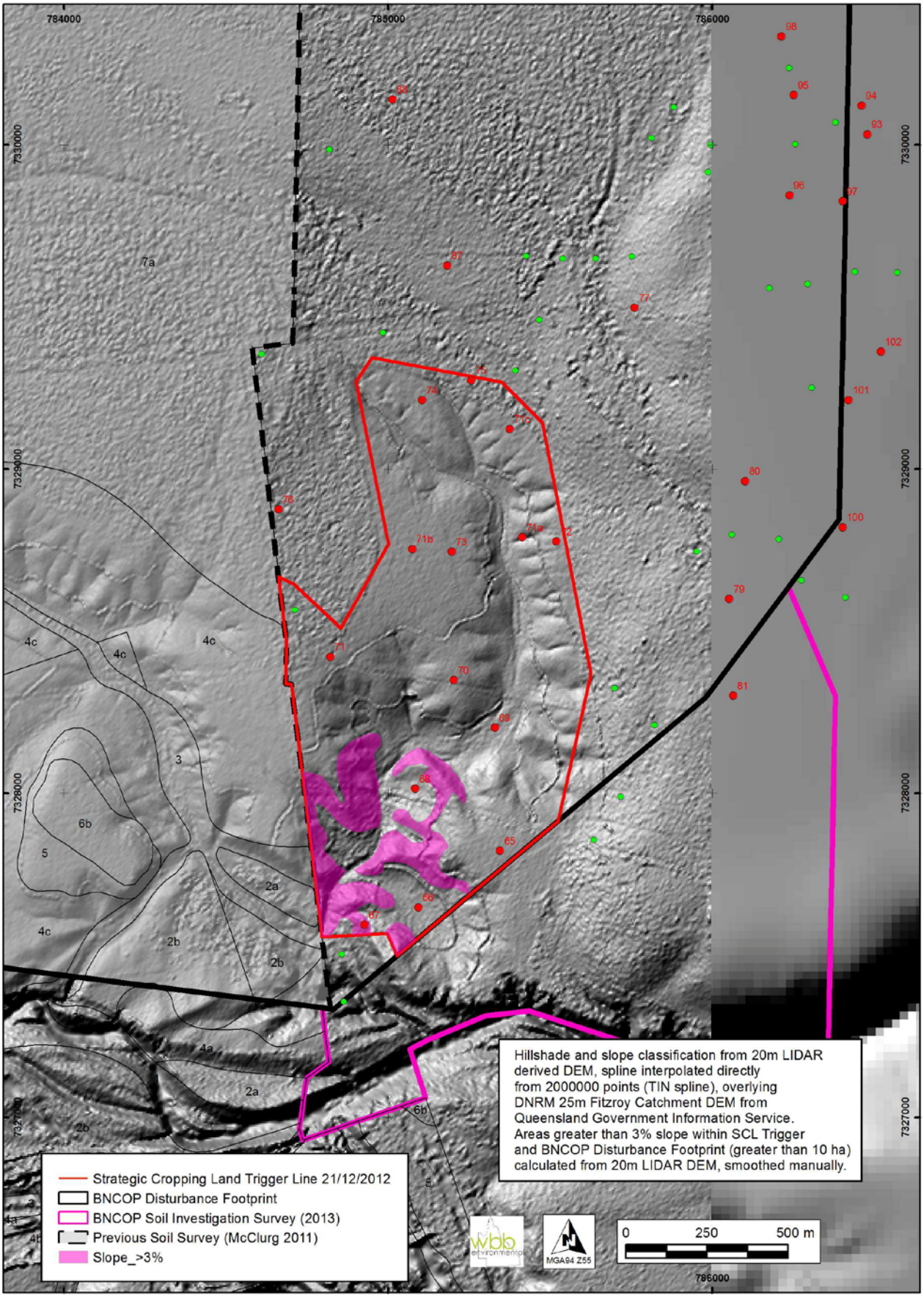


Figure 17. Lidar generated DEM analysis of sloping areas >3%, within lands intersected by the SCL trigger area and the BNCOP Disturbance Footprint.

The DEM analysis presented in **Figure 17** clearly identifies a convoluted land pattern in this area, where flatter areas ≤3% are mixed intimately with steeper dissected sideslopes >3%. Slope features delineated within the DEM surface match landscape features (and point source data) observed in the field. Clinometer measured slope values from field investigations verify the predicted slope ranges and confirm the accuracy of the DEM analysis (see detailed field site data in Appendix 7 for relevant sites – for example Site 67). The DEM surface and slope analysis displayed in Figure 17 (depicting areas >3%) has not been re-interpreted in any way, other than careful digitising to remove noise and edge effects associated with isolated pixel groups and splinters.

The spatial extent of soils mapped within the triggered area that have slopes ≤3% (and therefore comply with Criteria 1 requirements) is presented in **Figure 18**. Areas affected by slopes >3% occur exclusively in the south-west corner. They are limited to small portions of Soils 2b, 3a and 4c, and these portions are deemed non-compliant for Criteria 1. The remaining extent of Soils 2b, 3a and 4c however, have slopes that are ≤3% and these areas are deemed to comply with Criteria 1. The other soils within the trigger area, namely Soils 5, 7a and 7b have slopes ≤3% throughout their entirety and fully comply with Criteria 1.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 1 are presented in **Table 12,** and are incorporated spatially in **Figure 18.** The mapped areas displayed in **Figure 18** represent those soil areas that are deemed to comply with Zonal Criteria 1. All 6 soils (2b, 3a, 4c, 5, 7a and 7b) remain compliant to this point (comply with Zonal Criteria 1) but require further assessment against Zonal Criteria 2-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

SCL Zonal Criteria 2 – rockiness

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas with surface rocks >60mm diameter have an average surface rock density of ≤ 20%, as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d). Surface rock was not observed (and is unlikely) within the triggered portion of the BNCOP Disturbance Footprint. Soils are either young alluvial clays (Qa) or are developed from clayey unconsolidated sediments (TQr) that consistently lack coarse fragments, and as such are compliant with SCL Criteria 2 requirements.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 2 are presented in **Table 12** and are incorporated spatially in **Figure 18.** The mapped areas displayed in **Figure 18** represent those soil areas that are deemed to comply with Zonal Criteria 1 and 2. All 6 soils (2b, 3a, 4c, 5, 7a and 7d) remain compliant to this point (comply with Zonal Criteria 1 and 2) but require further assessment against Zonal Criteria 3-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

SCL Zonal Criteria 3 – gilgai microrelief

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas with gilgai microrelief >500mm depth have an average gilgai density of < 50% of the land surface, as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d). Gilgai microrelief was only observed in Soil 7a, and occurrence within the trigger area was restricted to 2 locations towards the northern end:

- in a narrow polygon mapped just inside the trigger line boundary in the north-east; and
- in a small triangular area adjacent to the trigger line boundary in the north-west.

Detailed field site data from Site 75 within the north-eastern polygon indicates small to moderate melonhole gilgai are well developed and likely in both areas. Field records indicate measured vertical intervals were consistently 0.5-0.6m, while horizontal intervals ranged from 12-20m (average = 15m). Density estimates recorded in the field indicate mounds/shelves are the dominant feature and occupy approximately 70% of the land surface, while depressions occupy only 30%. As such, the gilgai are within the specifications required for Criteria 3 compliance, and all soils mapped within the triggered portion of the BNCOP Disturbance Footprint are deemed to comply with Zonal Criteria 3.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 3 are presented in **Table 12** and are incorporated spatially in **Figure 18.** The mapped areas displayed in **Figure 18** represent those soil areas that are deemed to comply with Zonal Criteria 1-3. All 6 soils (2b, 3a, 4c, 5, 7a and 7d) remain compliant to this point (comply with Zonal Criteria 1-3) but require further assessment against Zonal Criteria 4-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

SCL Zonal Criteria 4 – soil depth

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas have a soil depth ≥600mm. Soil depth is defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d) as the depth to bedrock, hard pan, weathered rock (including partially weathered rock, saprolite and decomposed rock) or a continuous gravel layer. Soil depth findings used in the analysis of this criteria use the modal range and midpoint values for relevant horizon boundary depths and designations defined in the detailed soil profile class (SPC) descriptions presented in the **Soil Characterization Section** of this report. The modal range and midpoint values for soil depth to a defined substrate or other physical barrier for each soil are presented in **Table 12.**

Bedrock, hard pans, weathered rock (including partially weathered rock, saprolite and decomposed rock) or continuous gravel layers were not observed (and are unlikely) within the triggered portion of the BNCOP Disturbance Footprint. All soils are of transported origins, either young alluvial clays (Qa) or soils developed from clayey unconsolidated sediments (TQr), and are not developed insitu from (or underlain by) hardened substrates. As such, all soils are compliant with SCL Criteria 4 requirements.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 4 are presented in **Table 12** and are incorporated spatially in **Figure 18.** The mapped areas displayed in **Figure 18** represent those soil areas that are deemed to comply with Zonal Criteria 1-4. All 6 soils (2b, 3a, 4c, 5, 7a and 7d) remain compliant to this point (comply with Zonal Criteria 1-4) but require further assessment against Zonal Criteria 5-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

SCL Zonal Criteria 5 – soil wetness

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas have favourable drainage. This is defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d) as the absence of any waterlogged layers within the soil profile, assessed either to a defined natural soil depth or to a depth of 1000mm (whichever is shallowest).

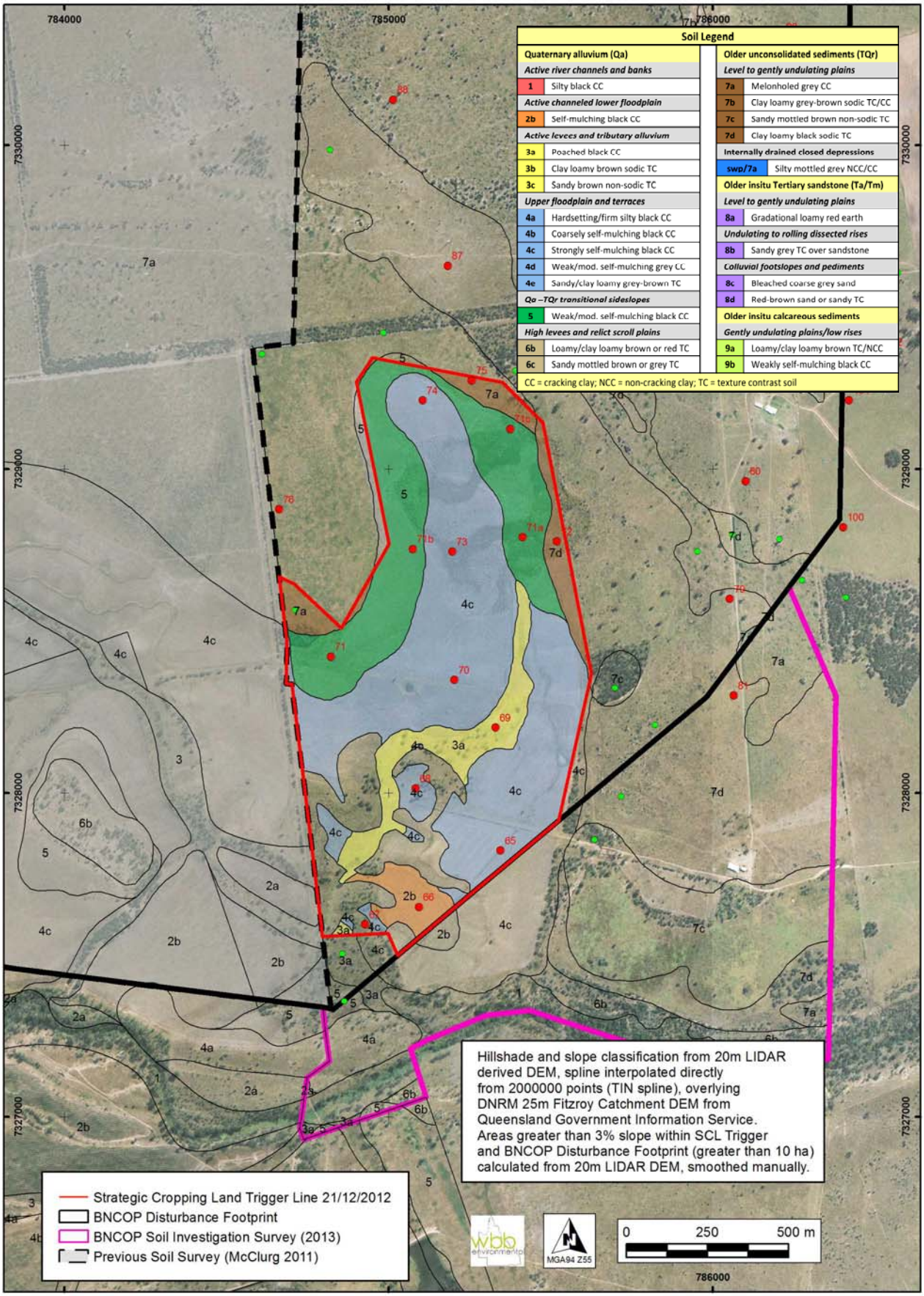


Figure 18. Remaining spatial extent of compliant soils following assessment against WCZ Zonal Criteria 1-5, within lands intersected by the SCL trigger area and the BNCOP Disturbance Footprint. All soils are compliant for Criteria 2-5.

A waterlogged layer is further defined as any layer or horizon within the soil profile that has a dominant soil colour that is gleyed; or has a dominant grey colour with at least 10% distinct or prominent orange or rusty mottling; or any other dominant colour with at least 10% distinct or prominent gley mottling; or has a conspicuous bleach >100mm thick that does not directly overlie bedrock or weathered rock.

Waterlogged layers as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d) were not recorded in any of the profile descriptions from the 13 detailed field sites recorded within the triggered land. As such, all soils mapped within the triggered portion of the BNCOP Disturbance Footprint are considered to comply with Zonal Criteria 5.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 5 are presented in **Table 12** and are incorporated spatially in **Figure 18.** The mapped areas displayed in **Figure 18** represent those soil areas that are deemed to comply with Zonal Criteria 1-5. All 6 soils (2b, 3a, 4c, 5, 7a and 7d) remain compliant to this point (comply with Zonal Criteria 1-5) but require further assessment against Zonal Criteria 6-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

SCL Zonal Criteria 6 – soil pH

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas have an acceptable soil pH for plant growth, at two specified depths (namely 300mm and 600mm) within immediate subsurface horizons. The acceptable pH range defined by the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d) for compliance with Zonal Criteria 6 varies according to whether soils exhibit rigid or non-rigid behaviour (pH 5.1-8.9 for rigid soils, pH >5.0 for non-rigid soils). Laboratory measured pH data at 300mm and 600mm for all detailed field sites recorded within the triggered portion of the BNCOP Disturbance Footprint is presented in **Table 11** and is also available in **Appendix 5**.

The majority of soils within the triggered portion of the BNCOP Disturbance Footprint are active cracking clays (Soils 2b, 3a, 4c, 5 and 7a) with pH levels >5.0 to depths >600mm. These soils clearly meet the pH requirements for **non-rigid soils** as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and are deemed to comply with Criteria 6. **Rigid soils** are restricted to a small area of Soil 7d located along the north-eastern boundary of the trigger area. Soil 7d is a thin clay loamy surfaced sodic texture contrast soil, and measured and observed subsoil characteristics confirm its rigid status as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011). Site 72, which is located within and is representative of the 7d polygon, has a laboratory measured pH value of 9.1 at 600mm, and as such fails to meet the requirements for Zonal Criteria 6. On this basis, Soil 7d is deemed non-compliant for Zonal Criteria 6 as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011), and it is the recommendation of this report that its spatial extent within the triggered land be recorded as decided non-SCL.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 6 are presented in **Table 12** and are incorporated spatially in **Figure 19.** The mapped areas displayed in **Figure 19** represent those soil areas that are deemed to comply with Zonal Criteria 1-6. Soils 2b, 3a, 4c, 5 and 7a remain compliant to this point (comply with Zonal Criteria 1-6) but require further assessment against Zonal Criteria 7-8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

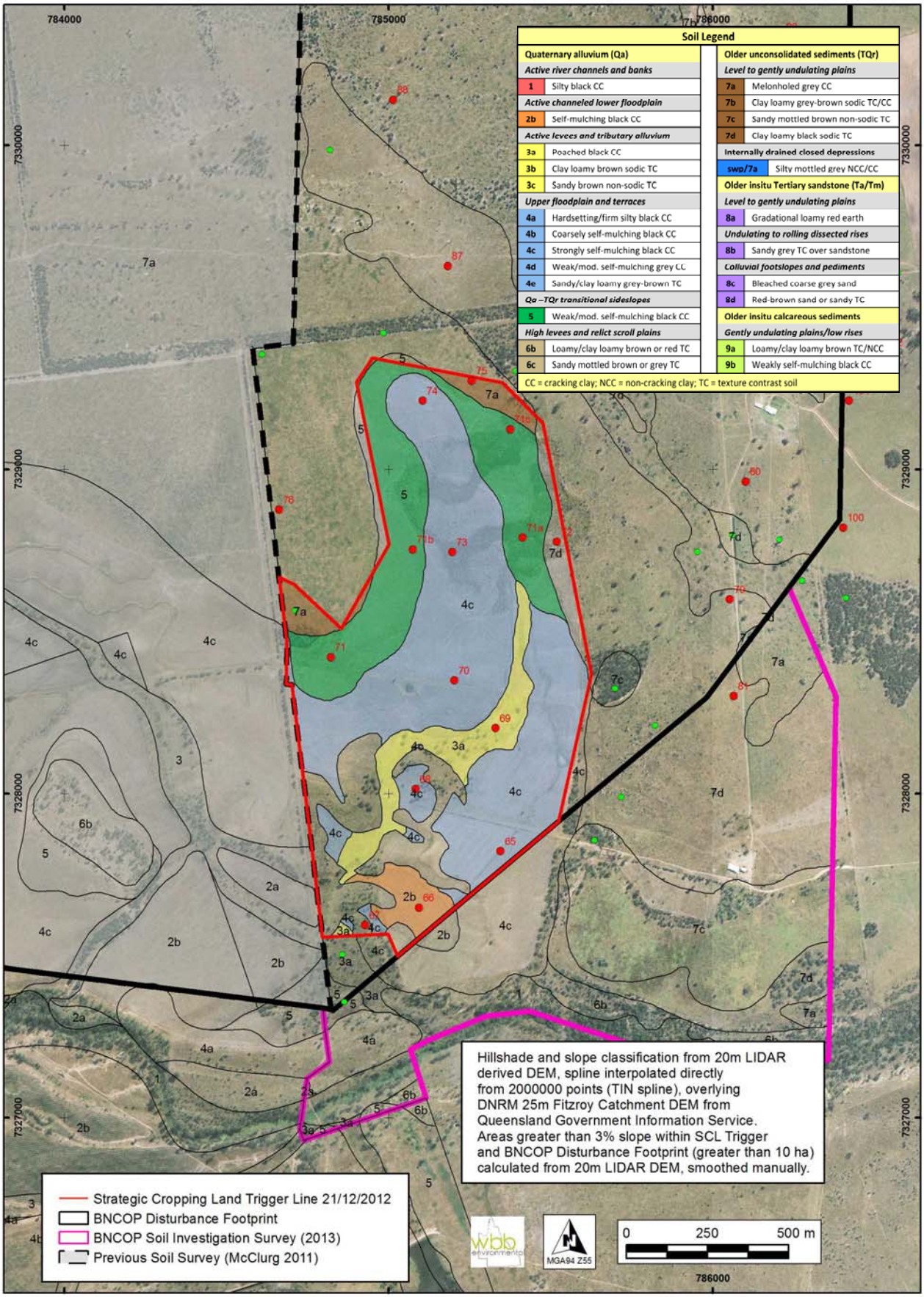


Figure 19. Remaining spatial extent of compliant soils following assessment against WCZ Zonal Criteria 1-6, within lands intersected by the SCL trigger area and the BNCOP Disturbance Footprint. Soil 7d is non-compliant for Criteria 6.

SCL Zonal Criteria 7 – salinity

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas have an acceptable level of sub-surface/subsoil salinity to allow satisfactory plant growth. This is further defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d) as a soluble Chloride content of <800 mg/kg Cl from the soil surface to at least a depth of 600mm. Laboratory measured chloride data (mg/kg) at 300mm and 600mm for all detailed field sites recorded within the triggered portion of the BNCOP Disturbance Footprint is presented in **Table 11** and is also available in **Appendix 5**.

Soils 2b, 3a and 4c are young flood-prone, relatively permeable alluvial clays that are well structured, with helpful chemistry and leaching profiles that lack significant subsoil salinity. Chloride levels across all detailed field sites associated with these soils are typically <150mg/kg at 300mm and increase only marginally to levels between 5-438mg/kg by 600mm. Soil 7d (as mapped within the triggered land) also has low Chloride levels (38mg/kg at 600mm at Site 72). As such, Soils 2b, 3a, 4c and 7d are deemed to comply fully with Criteria 7. Soils 5 and 7a however, have salinity levels ≥800mg/kg Cl at or before a depth of 600mm (Soil 5 - 820mg/kg Cl @ 600mm, Soil 7a - 1500mg/kg Cl @ 600mm). As such, both soils fail to meet the requirements defined within the *Strategic Cropping Land Act 2011* (Queensland Government 2011) for Zonal Criteria 7 and are deemed non-compliant. It is the recommendation of this report that the spatial extent of Soils 5 and 7a within the triggered land be recorded as decided non-SCL.

SCL Zonal Criteria compliance outcomes for each soil following assessment against Zonal Criteria 7 are presented in **Table 12** and are incorporated spatially in **Figure 20.** The mapped areas displayed in **Figure 20** represent those soil areas that are deemed to comply with Zonal Criteria 1-7. Soils 2b, 3a and 4c remain compliant to this point (comply with Zonal Criteria 1-7), but require further assessment against Zonal Criteria 8. Any further assessment of Soils 2b, 3a and 4c is restricted to areas of ≤3% slope.

Table 11. pH and Cl data (@ 300mm/600mm) used in the assessment of Zonal Criteria 6 and 7.

Site No.	pH @ 300mm >5 (NR) or 5.1-8.9 (R)	pH @ 600mm >5 (NR) or 5.1-8.9 (R)	Cl (mg/kg) @ 300mm Cl <800mg/kg	Cl (mg/kg) @ 600mm Cl <800mg/kg
Soil – 2b (non-rigid)				
66	8.0	8.5	<5	<5
Soil –3a (non-rigid)				
69	7.7	8.8	<5	25
Soil – 4c (non-rigid)				
65	8.8	8.9	38	85
67	8.6	8.7	5	155
68	8.4	8.8	133	130
70	8.8	8.7	10	245
73	8.7	8.4	15	215
74	8.9	8.7	28	438
Soil –5 (non-rigid)				
71	8.9	8.7	30	820
Soil – 7a (non-rigid)				
75	8.6	7.4	465	1500
Soil – 7d (rigid)				
72	8.8	9.1	<5	38

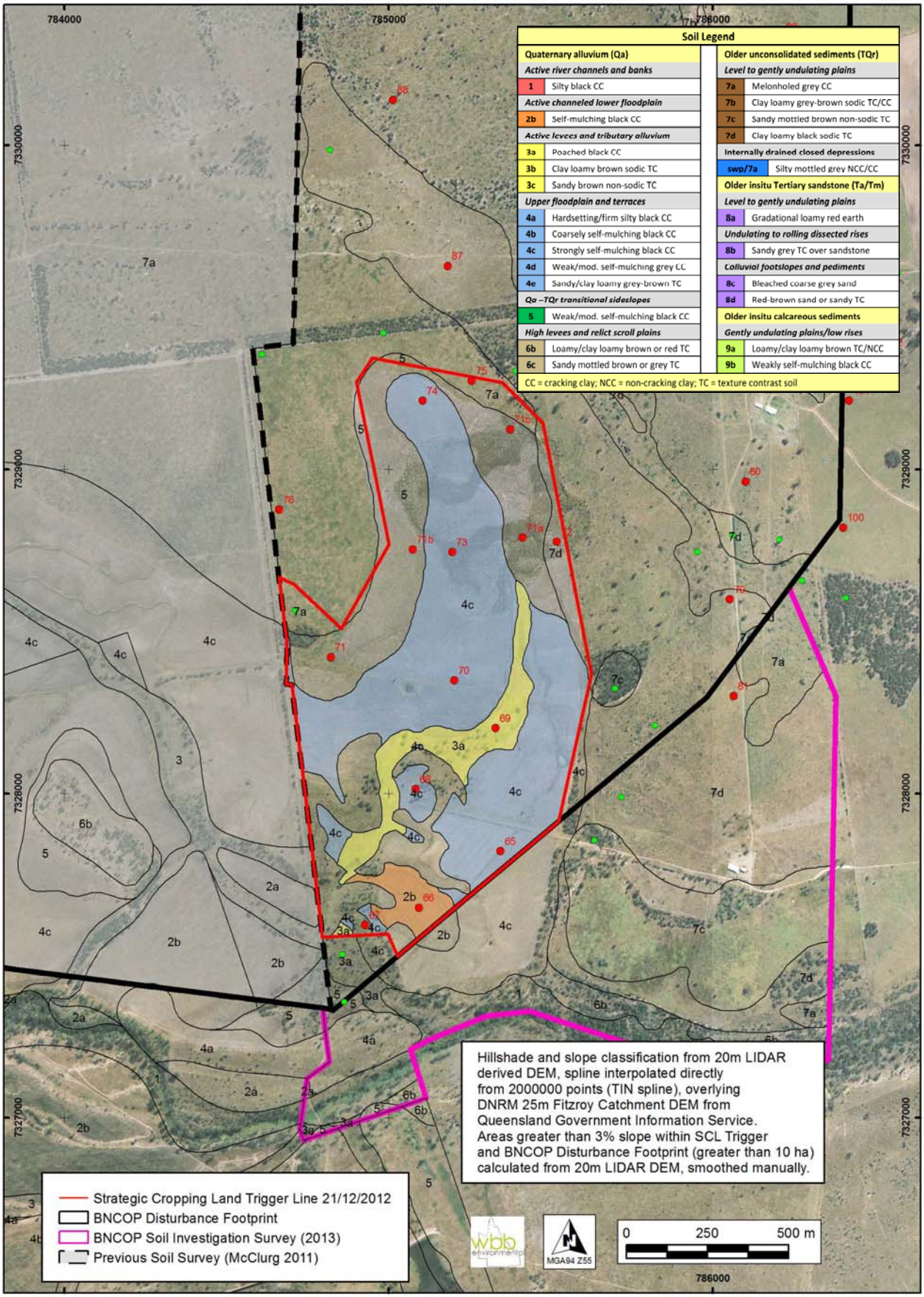


Figure 20. Remaining spatial extent of compliant soils following assessment against WCZ Zonal Criteria 1-7 and 1-8, within lands intersected by the SCL trigger area and the BNCOP Disturbance Footprint. Soils 5 and 7a are non-compliant for Criteria 7 and 8. Soil 7d is also non-compliant for Criteria 8.

SCL Zonal Criteria 8 – soil water storage

SCL Zonal Criteria compliance in the Western Cropping Zone requires potential cropping areas have an acceptable soil water storage of 100mm or greater, measured over a maximum depth of 1000mm or to a natural soil depth or a soil physico-chemical limitation where shallower, as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL guidelines (DNRM 2011d).

Representative field and analytical data appropriate to the assessment requirements for Zonal Criteria 8 are presented in the **Soil Characterization Section** of this report and also in **Appendices 5 and 7**. Relevant data and calculations used to determine **Effective Rooting Depth (ERD)** are presented in **Table 13**. ERD determinations are based on the soil depth and physico-chemical limitation criteria specified in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and Section 4.8.2 of the SCL guidelines (DNRM 2011d). Relevant data and calculations used to determine **Soil Water Status (SWS)** are presented in **Table 14.** SWS determinations have followed the requirements and procedures prescribed by the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and Section 4.8.3 of the SCL guidelines (DNRM 2011d) for estimating soil water storage using the soil texture look-up table.

ERD determinations vary significantly between the different soils mapped within the triggered land. Final ERD depends on the type, severity and depth of subsoil constraint (where present) identified in each soil (see Table 13). All 6 soils within the triggered area are developed either on deep alluvium or unconsolidated clayey sediments, and are not constrained by underlying hardened substrates. Absolute soil depths are consistently >1.0m. Soils 2b, 3a, 4c, 5, and 7a are non-rigid cracking clays, and ERD (as defined in the *Strategic Cropping Land Act 2011* Queensland Government 2011) is only limited where extreme acidity (pH ≤ 5) or excessive subsoil salinity (Chloride >800mg/kg) is developed. Soil 7d, in contrast, is a sodic rigid soil, and ERD may be further constrained (in addition to pH and salinity) where Exchangeable Sodium Percentage (ESP) values are >15 and/or Calcium/Magnesium ratios are <0.1 (Queensland Government 2011).

pH and Chloride data presented in **Table 13** and also **Appendix 5** indicates ERD for Soils 2b (Site 66) and 3a (Site 69) are consistently >1.0m. Soil 4c (Sites 65, 67, 68, 70, 73 and 74) is more variable and Chloride levels >800mg/kg in the lower subsoil of some profiles limit ERD to between 0.75->1.0m. Variability in Soil 4c is clearly related to position within the floodplain and proximity to surrounding TQr landscapes. Soil 5 which is transitional between the alluvium and surrounding TQR clay sheets is similarly constrained (Chloride >800mg/kg) but at shallower depths. ERD for Soil 5 is consistently between 0.6-0.7m (Site 71). Soil 7a which is developed on older elevated Cainozoic clay sheets is severely constrained by subsoil salinity (Chloride >800mg/kg), and ERD is limited to only 0.4-0.5mm (Site 75).

Soil 7d, in contrast, is a thin clay loamy surfaced, sodic texture contrast soil developed on elevated TQr sediments above floodplain alluvium. Field and laboratory data confirm it has soil characteristics consistent with those of a rigid soil, as defined in the *Strategic Cropping Land Act 2011* (Queensland Government 2011). Site 72, which is central to and representative of the triggered polygon, has a ph of 9.1 and an ESP value of 14% by 0.6m. Representative data for Soil 7d (from Site 87 located just north of the trigger area) indicates ESP values >30% can occur at relatively shallow depths within this soil. Detailed horizon data from both Site 72 (located within the trigger area) and Site 87 (just outside the trigger area) suggest strongly alkaline pH >8.9 and ESP levels >15% coincide with the start of the lower subsoil (B22 horizon). Estimated ERD for Soil 7d is 0.4-0.5m.

The necessary data and sequence of calculations required to generate **SWS estimates** for each soil (as per the procedure in Section 4.8.3 of the SCL Guidelines DNRM (2011d)) are set out clearly

and logically in **Table 14** to ensure findings are transparent and easy to follow. The younger alluvial clays, namely **Soils 2a and 3b**, have ERD values >1.0m and medium clay to heavy clay textures throughout their profiles. Estimated SWS status with these soils is 120mm and they are **deemed to comply with Zonal Criteria 8.**

Soil 4c is marginally older and more affected by subsoil salinity, with an ERD that varies between 0.75 to >1.0m. Clay textures are medium clay or heavier throughout, and SWS status ranges from 90-120mm. Values <100mm are spatially restricted and occur only in the most northerly mapped extent (Site 74) of the unit. Because the majority of sites (and associated mapped extent) are consistently >100mm, more detailed SWS measurements and calculations in line with the procedure outlined in Section 4.8.4 of the SCL Guidelines (DNRM 2011d) were not considered warranted. As such, Soil 4c, as mapped within the triggered portion of the BNCOP Disturbance Footprint, is **deemed to comply with Zonal Criteria 8.**

Soil 5 which is transitional between the alluvium and surrounding TQR clay sheets, has an ERD between 0.6-0.7m, medium clay to medium heavy clay textures throughout, and a SWS status of 80mm. **Soil 7a** which is widespread on the older, slightly elevated Cainozoic clay sheets sitting above the floodplain alluvium is subject to significant subsoil salinity and ERD is limited to 0.4-0.5m. Textures are medium clay or heavier throughout and SWS is estimated at 55mm. SWS estimates for Soil 7a are based preferentially on soil characteristics within mound profiles, because subsoil constraints are shallower, more severe and most limiting (in terms of soil water storage) in mound profiles (Burgess 2003a). **Soil 7d** is a thin clay loamy surfaced, sodic texture contrast soil that occurs adjacent to Soil 7a, and has a similar ERD between 0.4-0.5m. Surface textures (to 0.15m) are sandy clay loam to clay loam sandy and overlie sandy light medium to sandy medium clay textures in the upper subsoil. SWS is estimated at 50mm.

Estimated SWS status for Soils 5, 7a and 7d is collectively between 50-80mm. As such, all three soils are consistently below the 100mm threshold set for the Western Cropping Zone and also clearly below the 15% buffer requiring more detailed assessment (Section 4.8.4 of the SCL Guidelines DNRM 2011d). As such, **Soils 5, 7a and 7d** fail to meet the requirements defined within the *Strategic Cropping Land Act 2011* (Queensland Government 2011) for Zonal Criteria 8 and **are deemed non-compliant**. It is the recommendation of this report that the spatial extent of Soils 5, 7a and 7d within the triggered land be recorded as decided non-SCL.

SCL Zonal Criteria compliance outcomes for each soil following **assessment against Zonal Criteria 8** are presented in **Table 12** and are incorporated spatially in **Figure 20**. The mapped areas displayed in **Figure 20** represent those soil areas that are deemed to comply with Zonal Criteria 1-8. Only Soils 2b, 3a and 4c (in areas where slope is ≤3%) remain compliant after final assessment against Zonal Criteria 8.

SCL Zonal Criteria compliance outcomes

Findings from the SCL Zonal Criteria assessment presented in **Table 12** and **Figure 20** indicate **Soils 2b, 3a and 4c**, within the triggered portion of the BNCOP Disturbance Footprint, are compliant for all 8 Zonal Criteria defined for the Western Cropping Zone, and as such **meet the Zonal Criteria requirements of Schedule 1** of the *Strategic Cropping Land Act 2011* (Queensland Government 2011).

Soils 5, 7a and 7d however, failed at least one or more of Zonal Criteria 6, 7 and 8. In summary:

- Soils 5 was non-compliant for Zonal Criteria 7 and 8 due to excessive subsoil salinity, limited ERD and inadequate soil water storage;

- Soil 7a was non-compliant for Zonal Criteria 7 and 8 due to excessive subsoil salinity, limited ERD and inadequate soil water storage; and
- Soil 7d was non-compliant for Zonal Criteria 6 and 8 because of unfavourable subsoil pH and inadequate soil water storage.

As such, **Soils 5, 7a and 7d** are non-compliant for one or more Zonal Criteria defined for the Western Cropping Zone, and **do not meet the Zonal Criteria requirements of Schedule 1** of the *Strategic Cropping Land Act 2011* (Queensland Government 2011). Final Zonal Criteria compliance outcomes are presented in **Figure 20**.

SCL minimum size requirements

The *Strategic Cropping Land Act 2011* (Queensland Government 2011) requires SCL Zonal Criteria compliant land within the Western Cropping Zone meet minimum size requirements before SCL status can be decided. Prior to any decision, the Act requires criteria compliant polygons be >100ha in extent, at least 80m wide, and where <100ha be contiguous with decided SCL or potential SCL (either internal to or external to the triggered area) to ensure a collective SCL extent >100ha (DNRM 2011d, Queensland Government 2011).

In addition, the SCL Guidelines (Table 6, page 13 of the SCL Guidelines - DNRM (2011d)) require that the minimum map unit area within the Western Cropping Zone be at least 10ha or larger. Further to this requirement Figure 6, on page 18 of the SCL Guidelines (DNRM 2011d), indicates that narrow natural linear features (defined as <80m), such as local depositional drainage lines, should not fragment a larger surrounding compliant SCL polygon. The question of whether such narrow features (<80m wide) should be mapped or not depends entirely on project size and mapping scale. The intent of the SCL Guidelines is clear however, in that the presence of such narrow linear features (whether mapped or not) should be considered effectively invisible and should not fragment surrounding compliant SCL units (see Figure 6, pp 18 of the SCL Guidelines - DNRM (2011d)).

Application of the **minimum size requirements** specified within the *Strategic Cropping Land Act 2011* (Queensland Government 2011) is illustrated in **Figure 21**. Coloured soil polygons that are not hatched demonstrate the spatial extent of soil entities that are criteria compliant and satisfy minimum size requirements (>100ha contiguous area and >80m wide), as specified in Sections 62 and 68 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011). The remaining undersized coloured soil entities within the hatched area shown in Figure 21 demonstrate the extent of fragmented polygons that are recommended for excision. While floodplain dissection and slopes >3% are ultimately responsible for the fragmentation, it was the removal of sloping areas as part of the Criteria 1 assessment, that further isolated a small number of undersized (but otherwise criteria compliant) polygons making them no longer contiguous with nearby larger units. Undersized polygons to be excised total an area of just 3.5ha and include only those coloured soil entities that lie inside the hatched area shown in Figure 21. It is the recommendation of this report that the criteria compliant, but undersized and non-contiguous, soil polygons identified within the hatched area be deemed decided non-SCL.

The only other exception to minimum size requirements is the criteria compliant central 3a soil unit. This unit comprises a linear drainage feature (mostly >80m wide, but less than 80m in its most northern extent) that divides and is contiguous with larger compliant 4c units east and west. The SCL Guideline (2011d) states a narrow linear feature (such as the northern extent of unit 3a), "*cannot fragment an adjacent compliant soil area,*" and infers that the adjacent compliant land either side should remain contiguous, irrespective of whether the linear feature is mapped or not. As such, the central 3a polygon is considered contiguous and deemed to be decided SCL.

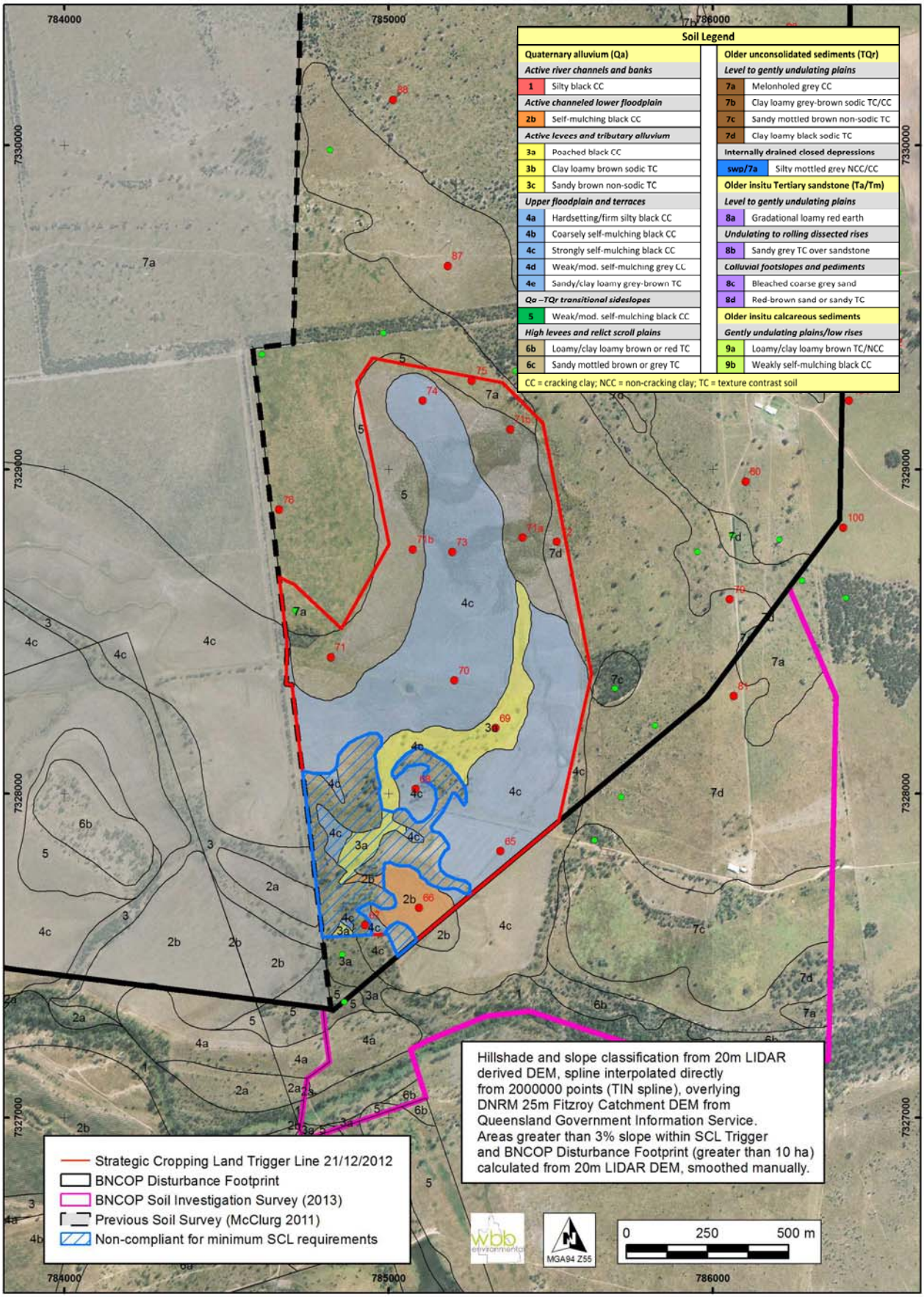


Figure 21. Hatching indicates the spatial extent of dissected, criteria compliant soil fragments that fail WCZ minimum size requirements (Queensland Government 2011), for lands intersected by the SCL trigger area and the BNCOP Disturbance Footprint.

The final spatial extent of the remaining SCL compliant soil polygons (Soils 2b, 3a and 4c) left following assessment against SCL minimum size criteria is presented in **Figure 22**. All remaining compliant polygons are individually <100ha, but seamlessly join adjacent compliant soil units (both inside and outside the trigger area) to form a contiguous wider aggregation that is >100ha. On this basis, the compliant soil polygons displayed in Figure 22 qualify as decided SCL. They have the required cropping history, are compliant with WCZ Zonal Criteria 1-8 and meet SCL minimum size requirements.

Strategic Cropping Land (SCL) status

The *Strategic Cropping Land Act 2011* (Queensland Government 2011) requires SCL Zonal Criteria compliant land within the Western Cropping Zone meet both minimum size requirements and required cropping history before SCL status can be decided. **Figure 22** illustrates the total extent of land that complies with all SCL assessment requirements within the triggered portion of the BNCOP Disturbance Footprint. Compliant land comprises 3 soils and 6 polygons which include the:

- Southern 2b/4c unit which is <100ha and >80 wide, and isolated from adjacent compliant polygons within the triggered area by dissected lands >3% slope. It is however, contiguous with adjacent compliant 2b and 4c soil units external to the trigger area to the south-east. These units run north, re-enter the trigger area and are contiguous with the compliant central 3a and western 4c units in the centre;
- Eastern 4c unit which is >80m wide, individually <100ha, but contiguous to the south-east and west, both inside and outside the trigger area;
- Central linear 3a/4c unit which is mostly >80m wide (<80m in northern parts), individually <100ha, but contiguous with larger 4c units east and west; and the
- Western 4c unit which is >80m wide, individually <100ha, but contiguous to the east and west, both inside and outside the trigger area.

Assessment against WCZ SCL Zonal Criteria 1-8 and minimum size requirements (as defined in Sections 66-68 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011)) indicates **66.1ha or approximately 56%** of the triggered land is compliant and **qualifies as decided SCL. Decided non-SCL** within the triggered area comprises **3.5ha** of otherwise compliant land that does not meet minimum size requirements, and a further **48.4 ha** of land that does not comply with WCZ Zonal Criteria 1-8. In total, non-compliant land covers **51.9ha or 44% of the triggered area**, and is either associated with localised dissection (slopes >3%) in the south-western corner or with soils 5, 7a and 7d that fail Criteria 6, 7 or 8 in northern parts. It is the **recommendation of this report**, in accordance with the requirements of Sections 66-68 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011), that the outcomes documented herein be recorded as decided SCL and decided non-SCL as described.

Central Queensland Regional Plan – Priority Agricultural Areas

The BNCOP Operational Area is subject to the planning requirements of the Central Queensland Regional Plan (DSDIP 2013) and is located within a designated Priority Agricultural Area (PAA) as shown in **Figure 23**. The land within this precinct is considered a strategic regional entity with significant potential for the continued or future development of highly productive agricultural land uses. Identified land uses of significance are known as Priority Agricultural Land Uses (PALU). The current intention of the planning framework will afford PALUs within a PAA primary land use status and likely planning priority over other proposed or competing uses. Assessment against proposed PAA co-existence criteria will inform the planning process and guide development decisions as to how and where compatible resource activities,such as the BNCOP, can co-exist concurrently with high value agricultural activities. DSDIP is yet to finalise any such criteria however.

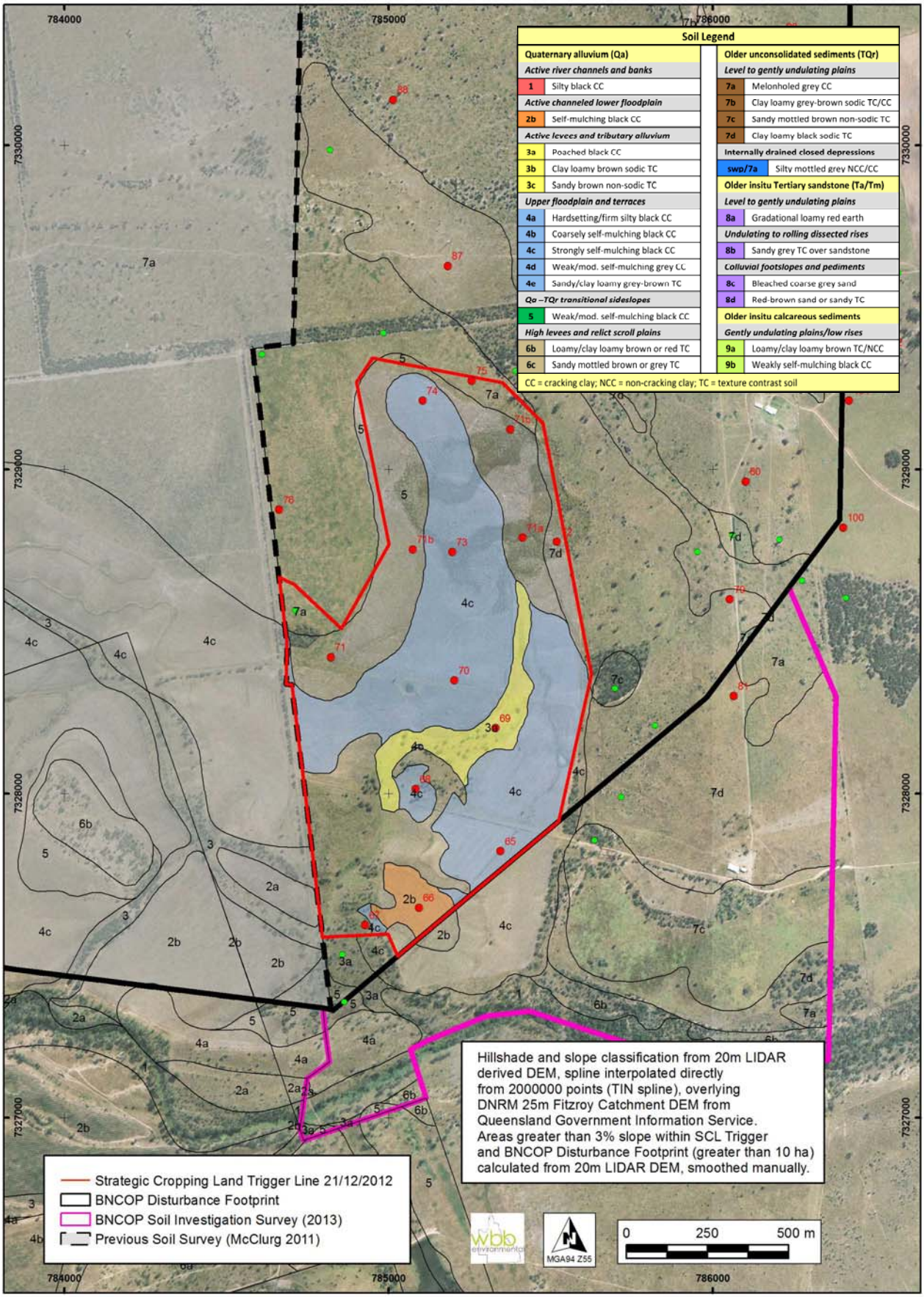
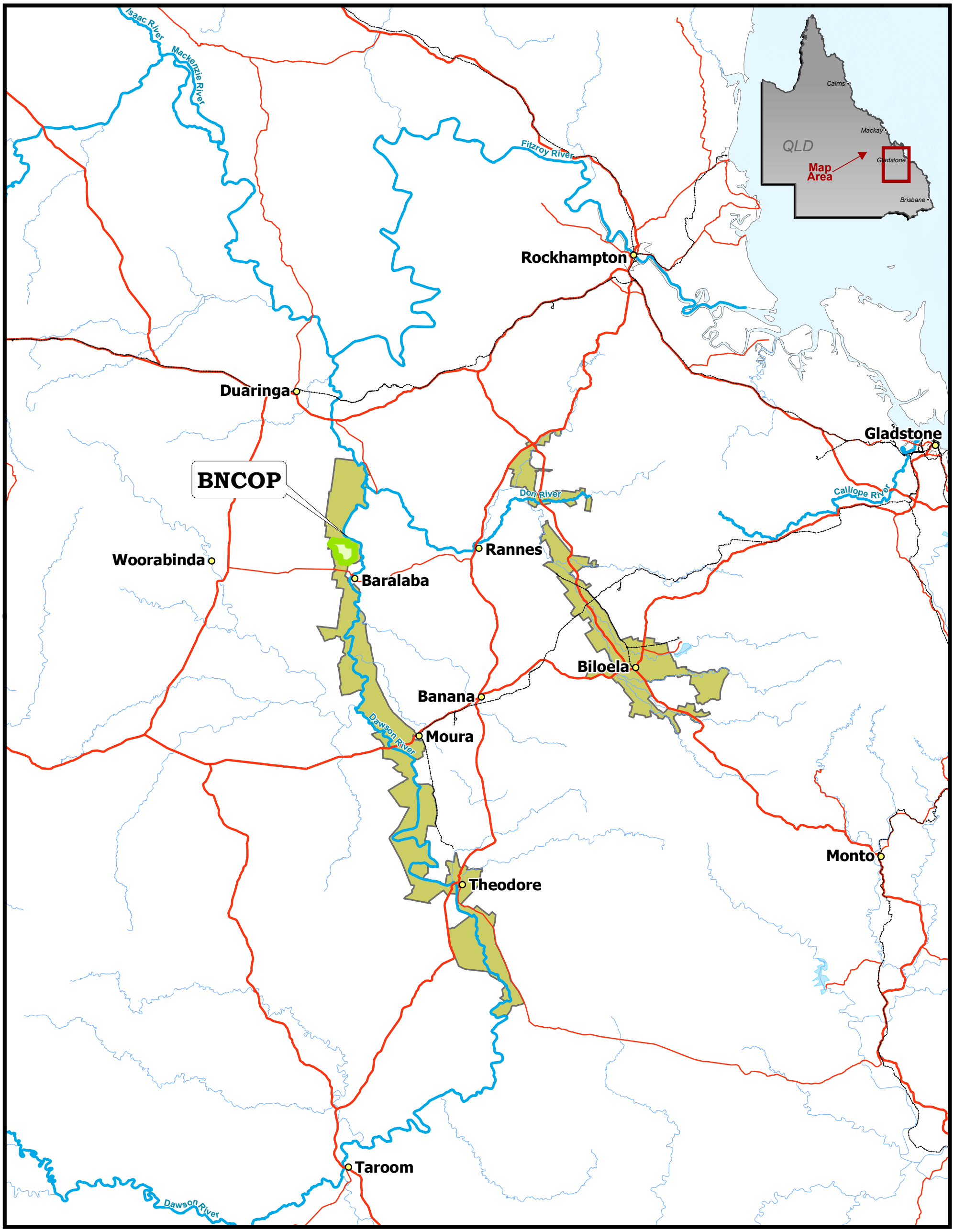


Figure 22. Final spatial extent of decided SCL within the BNCOP Disturbance Footprint. Mapped areas are compliant for Zonal Criteria 1-8, meet WCZ minimum size requirements and qualify for cropping history.



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BARALABA NORTH CONTINUED OPERATIONS PROJECT	Cockatoo Coal Ltd has exercised all due care in the production of this map. Cockatoo Coal Ltd makes no warranty or representation to the client or third parties (expressed or implied) in respect to the information conveyed on this map, particularly with regard to any commercial investment decision made on the basis of this map. Use of this map by the client or third parties shall be at their own risk, and extracts from this map may only be published with the permission of Cockatoo Coal Ltd.			N 0 10 20 30 40 50 Kilometres			VECTOR DATA: © DERM - LAND & PROPERTY DATA © GEOSCIENCE AUSTRALIA. *PUBLICLY ACCESSIBLE DATA HAS BEEN INCORPORATED INTO THIS MAP (ACCREDITED ABOVE). COCKATOO COAL PROVIDES NO WARRANTY TO THE ACCURACY, COMPLETENESS OR CURRENCY OF THIS DATA.*	
TITLE	REV	DESCRIPTION	DATE	SCALE **1:1,000,000**	CURRENT ISSUE SIGNATURES		**Legend**	
Figure 23 Priority Agricultural Areas	0	Original map output	19/03/14	SIZE A3	DRAWN	MJS	Populated Place..... Road..... Rail..... Watercourse..... BNCOP Operational Land. Priority Agricultural Area.	Soil Mapping & Monitoring Pty Ltd A.B.N. 81 074 297 741 A.C.N. 124 870 766
	1	Logo Update	01/04/14	DATUM GDA 94	CHECKED	BJD		STATUS **FINAL**
	2			PROJECTION	APPROVED	BJD		PROJECT NO Baralaba Nth / DRAWING NO BBN-091-12-01-140401

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Table 12. SCL Zonal Criteria assessment (WCZ – Zonal Criteria 1–8, Qld. Govt. 2011) for triggered soils within the BNCOP Disturbance Footprint.

Soil Unit	Zonal Criteria 1 Slope ≤3% (DEM Spatial Analysis)		Zonal Criteria 2 Surface Rocks (>60mm) ≤20%		Zonal Criteria 3 Gilgai Microrelief (>500mm) <50%		Zonal Criteria 4 Soil Depth to Physical Barrier ≥600mm		Zonal Criteria 5 Favourable Drainage Within Soil Depth		Zonal Criteria 6 pH @300mm/600mm >5 (NR) or 5.1-8.9 (R)		Zonal Criteria 7 Salinity @≤600mm Cl <800mg/kg		Zonal Criteria 8 Profile SWS (to ERD) ≥100mm/1.0m (see Tables 13 & 14)		Zonal Criteria Compliance [1]
2b	Figures 17 & 18 for areas ≤3%	P	Surface cobble, stone, boulders and outcrop absent	P	Non-gilgaied	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 8.0 600mm – 8.5 (non-rigid soil)	P	<5 mg/kg Cl (@ 600mm)	P	120mm	P	**Compliant where slope is ≤3%**
3a	Figures 17 & 18 for areas ≤3%	P	Surface cobble, stone, boulders and outcrop absent	P	Non-gilgaied	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 7.7 600mm – 8.8 (non-rigid soil)	P	25 mg/kg Cl (@ 600mm)	P	120mm	P	**Compliant where slope is ≤3%**
4c	Figures 17 & 18 for areas ≤3%	P	Surface cobble, stone, boulders and outcrop absent	P	Non-gilgaied	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 8.4-8.9 600mm – 8.4-8.9 (non-rigid soil)	P	85-438 mg/kg Cl (@ 600mm)	P	90-120mm	P	**Compliant where slope is ≤3%**
5	Figures 17 & 18 for areas ≤3%	P	Surface cobble, stone, boulders and outcrop absent	P	Non-gilgaied	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 8.9 600mm – 8.7 (non-rigid soil)	P	820 mg/kg Cl (@ 600mm)	F	80 mm	F	**Non-compliant**
7a	Figures 17 & 18 for areas ≤3%	P	Surface cobble, stone, boulders and outcrop absent	P	melonhole VI 0.5-0.6m HI 12-20m 70% - m/s 30% - d	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 8.6 600mm – 7.4 (non-rigid soil)	P	1500 mg/kg Cl (@ 600mm)	F	55 mm	F	**Non-compliant**
7d	Figures 17 & 18 for areas ≤3%	P	<2% surface cobble	P	Non-gilgaied	P	>1000mm	P	No gleyed, mottled or bleached horizons as defined in SCL Act	P	300mm – 8.8 600mm – 9.1 (rigid soil)	F	38 mg/kg Cl (@ 600mm)	P	50 mm	F	**Non-compliant**

Notes: Assessment uses Zonal Criteria 1-8 as defined for the Western Cropping Zone in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d).

Table 13. Contributing soil constraints and final ERD (Qld. Govt. 2011) for soils triggered for SCL assessment within the BNCOP Disturbance Footprint.

Soil unit	Soil classification and data source	Rep site	Soil horizon[1]	Modal depths (m)[1]	Sampled depths (m)[2]	Field texture range[3]	Measured clay (%)[4]	pH	Cl (mg/kg)	ESP (%)	Ca/Mg ratio	Estimated ERD (m)[5]	Identified ERD constraint[5]
2b	**Black Vertosol - NR** (all data comes from site 66)	**66**	Ap1	0-0.03	0-0.10	LMC-MC	66	7.2	210	na	na		
			Ap2/B21	0.03-0.25	↓	MHC							
			B22	0.25-0.80	0.25-0.35	MHC-HC	68	8.0-8.1	<5	na	na		
			↓	↓	0.55-0.65	↓	72	8.5	<5	na	na		
			B23k	0.80-1.00+	0.85-0.95	MHC-HC	75	8.7	5	na	na	**>1.0m**	**ERD not limited**
3a	**Black Vertosol - NR** (all data comes from site 69)	**69**	A11/Ap1	0-0.03	0-0.10	LMC-MC	61	6.6	30	na	na		
			A12/Ap2	0.03-0.20	↓	MHC							
			B21k	0.20-0.75	0.25-0.35	MHC-HC	52	7.5-7.7	<5	na	na		
			↓	↓	0.55-0.65	↓	59	8.4-8.8	10-25	na	na		
			B22k	0.75-1.00+	0.85-0.95	FSMC-FSMHC	52	8.6	280	na	na	**>1.0m**	**ERD not limited**

Soil unit	Soil classification and data source	Rep site	Soil horizon[1]	Modal depths (m)[1]	Sampled depths (m)[2]	Field texture range[3]	Measured clay (%)[4]	pH	Cl (mg/kg)	ESP (%)	Ca/Mg ratio	Estimated ERD (m)[5]	Identified ERD constraint[5]
4c	**Black Vertosol - NR** # (pH and Cl data ranges are from Sites 65, 67, 68, 70, 73, 74; remaining data is from Site 65 only)	**65 #**	A1/Ap1	0-0.04	0-0.10	MC	60	8.4	40	na	na		
			Ap2/B21p	0.04-0.20	↓	MHC-HC							
			B21k	0.20-0.60	0.25-0.35	MHC-HC	63	8.4-8.9	5-133	na	na		
			B22	0.60-1.00+	0.55-0.65	MHC-HC	65	8.4-9.0	80-438	na	na		
			↓	↓	0.85-0.95	↓	63	5.1-8.9	420-1165	na	na	**0.75->1.0m**	**Cl >800 mg/kg from 0.75->1.0m**
5	**Black Vertosol - NR** (all data comes from Site 71)	**71**	A1	0-0.03	0-0.10	MC	59	8.5	95	na	na		
			B21p/B21	0.03-0.35	0.25-0.35	MHC	60	8.9	30-155				
			B22	0.35-0.85	0.55-0.65	FSMC-FSMHC	66	8.7	790-820	na	na	**0.65m**	**Cl >800 mg/kg from 0.6-0.7m**
			B23	0.85-1.00+	0.85-0.95	FSMC-FSMHC	68	7.7	1600	na	na	↓	↓
7a	**Grey Vertosol - NR** (pH and Cl data ranges at 0.3m/0.6m are from Sites 75 and 88; remaining data is from Site 88 only)	**75/88**	A1	0-0.06	0-0.10	FSLMC-FSMC	45	6.8	45	na	na		
			B21k	0.06-0.45	0.25-0.35	FSMC-MHC	49	8.6-8.8	465-670	na	na		
			B22/B23	0.45-1.00+	0.55-0.65	FSMC	50	7.4-8.3	1440-1500	na	na	**0.45m**	**Cl >800 mg/kg from 0.4-0.5m**
			↓	↓	0.85-0.95	↓	52	5.3	1315	na	na	↓	↓
7d	**Black Sodosol - R** (pH, Cl and ESP data ranges at 0.3m/0.6m are from Sites 72 and 87; remaining data is from Site 87 only)	**72/87**	A1	0-0.12	0-0.10	SCL-CLS	27	6.4	5	3	1.9		
			A2je	0.12-0.15	↓	↓	↓	↓	↓	↓	↓		
			B21	0.15-0.45	0.25-0.35	SLMC-SMC	38	8.5-8.8	<5-60	5-12	1.0-2.3		
			B22k/B23	0.45-1.00+	0.55-0.65	SLC-SLMC	33	9.1	38-730	14-30	0.5-1.1	**0.45m**	**Rigid soil + pH >9.1 + inc. ESP >14% in B22 hor. from 0.4-0.5m**
			↓	↓	0.85-0.95	↓	29	9.2	1100	36	0.4	↓	↓

Notes:
1. NR = non rigid soil; R = rigid soil. Soil horizon nomenclature and modal depths are from the midpoint of modal soil profile class diagrams presented in the soil characterization section of this report.
2. Sampled depths for laboratory analysis are from the representative analytical site(s) listed for each soil group and discussed in the soil characterization section of this report.
3. Soil field texture range is from that recorded for each soil horizon from the modal soil profile class descriptions presented in the soil characterization section of this report; texture codes are in accordance with those defined in the NCST (2009).
4. Clay content (%) is that measured by laboratory PSA analysis for the relevant sample depth from the representative analytical site listed for each soil group and discussed in the soil characterization section of this report.
5. Estimated effective rooting depth (ERD) and contributing soil constraint(s) determined in accordance with the ERD definitions and criteria in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d).

Table 14. Estimation of profile soil water status (Qld. Govt. 2011) for soils triggered for SCL assessment within the BNCOP Disturbance Footprint.

Soil Unit	Soil Concept	Rep Site	Soil Horizon[1]	Modal Horizon Depths (m)[1]	Sampled Depths (m)[2]	Depth Factor[3]	Field Texture Range[4]	Measured Clay (%)[5]	Est. Field Text. SWS (mm/0.1m)[6]	Estimated ERD (m)[7]	Identified ERD Constraint[7]	Horizon SWS (mm)	Profile SWS (mm)	SWS to nearest 5mm
2b	**Black Vertosol - NR** SCL Site(s) - 66	**66**	Ap1	0-0.03	0-0.10	0.3	LMC-MC	66	12	↓	↓	3.6		
			Ap2/B21	0.03-0.25	↓	2.2	MHC		12	↓	↓	26.4		
			B22	0.25-0.80	0.25-0.35	5.5	MHC-HC	68	12	↓	↓	66.0		
			↓	↓	0.55-0.65	↓	↓	72	↓	↓	↓	↓		
			B23k	0.80-1.00+	0.85-0.95	2.0	MHC-HC	75	12	**>1.0m**	**ERD not limited**	24.0	**120**	**120**

Soil Unit	Soil Concept	Rep Site	Soil Horizon[1]	Modal Horizon Depths (m)[1]	Sampled Depths (m)[2]	Depth Factor[3]	Field Texture Range[4]	Measured Clay (%)[5]	Est. Field Text. SWS (mm/0.1m)[6]	Estimated ERD (m)[7]	Identified ERD Constraint[7]	Horizon SWS (mm)	Profile SWS (mm)	SWS to nearest 5mm
3a	**Black Vertosol - NR** SCL Site(s) - 69	**69**	A11/Ap1	0-0.03	0-0.10	0.3	LMC-MC	61	12	↓	↓	3.6		
			A12/Ap2	0.03-0.20	↓	1.7	MHC		12	↓	↓	20.4		
			B21k	0.20-0.75	0.25-0.35	5.5	MHC-HC	52	12	↓	↓	66.0		
			↓	↓	0.55-0.65	↓	↓	59	↓	↓	↓	↓		
			B22k	0.75-1.00+	0.85-0.95	2.5	FSMC-FSMHC	52	12	**>1.0m**	**ERD not limited**	30	**120**	**120**
4c	**Black Vertosol - NR** SCL Sites - 65, 67, 68, 70, 73, 74	**65**	A1/Ap1	0-0.04	0-0.10	0.4	MC	60	12	↓	↓	4.8		
			Ap2/B21p	0.04-0.20	↓	1.6	MHC-HC		12	↓	↓	19.2		
			B21k	0.20-0.60	0.25-0.35	4.0	MHC-HC	63	12	↓	↓	48.0		
			B22	0.60-1.00+	0.55-0.65	1.5-4.0	MHC-HC	65	12	↓	↓	18.0-48.0		
			↓	↓	0.85-0.95	↓	↓	63	↓	**0.75->1.0m**	**Cl >800 mg/kg from 0.75->1.0m**	↓	**90-120**	**90-120**
5	**Black Vertosol - NR** SCL Site(s) - 71	**71**	A1	0-0.03	0-0.10	0.3	MC	59	12	↓	↓	3.6		
			B21p/B21	0.03-0.35	0.25-0.35	3.2	MHC	60	12	↓	↓	38.4		
			B22	0.35-0.85	0.55-0.65	3.0	FSMC-FSMHC	66	12	**0.65m**	**Cl >800 mg/kg from 0.6-0.7m**	36.0	**78mm**	**80mm**
			B23	0.85-1.00+	0.85-0.95	na	FSMC-FSMHC	68	12	↓	↓	na		
7a	**Grey Vertosol - NR** SCL Site(s) - 75	**88**	A1	0-0.06	0-0.10	0.6	FSLMC-FSMC	45	12	↓	↓	7.2		
			B21k	0.06-0.45	0.25-0.35	3.9	FSMC-MHC	49	12	↓	↓	46.8		
			B22/B23	0.45-1.00+	0.55-0.65	na	FSMC	50	12	**0.45m**	**Cl >800 mg/kg from 0.4-0.5m**	na	**54mm**	**55mm**
			↓	↓	0.85-0.95	na	↓	52	↓	↓	↓	na		
7d	**Black Sodosol - R** SCL Site(s) - 72	**87**	A1	0-0.12	0-0.10	1.2	SCL-CLS	27	8	↓	↓	9.6		
			A2je	0.12-0.15	↓	0.3	↓	↓	8	↓	↓	2.4		
			B21	0.15-0.45	0.25-0.35	3.0	SLMC-SMC	38	12	↓	↓	36.0		
			B22k/B23	0.45-1.00+	0.55-0.65	na	SLC-SLMC	33	10	**0.45m**	**Rigid soil + pH >9.1 + inc. ESP>14% in B22 hor. from 0.4-0.5m**		**48mm**	**50mm**
			↓	↓	0.85-0.95	↓	↓	29	↓	↓	↓			

Notes:
1. Soil horizon nomenclature and modal depths are from the midpoint of modal soil profile class diagrams presented in the soil characterization section of this report. 2. Sampled depths are from representative analytical site(s) listed for each soil.
3. SWS multiplication factor is calculated from the difference between upper and lower modal midpoint horizon boundaries; the multiplication factor is used to quantify horizon thickness in profile SWS summations.
4. Soil field texture range is from that recorded for each soil horizon from the modal soil profile class descriptions presented in the soil characterization section of this report; texture codes are in accordance with those defined in the NCST (2009).
5. Clay content (%) is that measured by laboratory PSA analysis for the relevant sample depth from the representative analytical site listed for each soil group and discussed in the soil characterization section of this report.
6. Estimated effective rooting depth (ERD) and contributing soil constraint(s) come from Table 13; in accordance with the ERD criteria in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d).
7. Estimated average soil water status (SWS) per 100mm of soil depth increment uses the maximum value for the soil texture grades listed for each soil horizon from the look-up table in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d). Where a range is listed the maximum value is assumed to ensure profile SWS calculations do not underestimate potential SWS values within a soil group.

12. Inherent erosion potential

Inherent erosion potential (following insitu disturbance) has been assessed for soils within the BNCOP Disturbance Footprint (excluding ML80169 and ML80170), based on a range of surrogate soil characteristics thought to contribute to or influence surface erodibility (rill and gully erosion) and predisposition to tunnelling. The assessment qualitatively ranks soils within the BNCOP Disturbance Footprint in terms of inherent erosion potential and likely behaviour following insitu disturbance. It is not prescriptive however, and is not intended to directly inform or instruct the planning of rehabilitation scenarios on constructed final landforms, where elevation, gradient, slope length and water disposal options are unquantified.

Assessment of pre-mining erosion hazard specifically for cropping and grazing land uses is also available from the erosion limitation assessment undertaken as part of the pre-mining land suitability evaluation described earlier in this report.

Assessment of inherent erosion potential

Assessment of inherent erosion potential within the BNCOP Disturbance Footprint is based on the soil erodibility classes and criteria of Murphy (1984) and Charman and Murphy (2007), and considers only susceptibility to longer term post disturbance gully and tunnel erosion. It does not evaluate short term sheet erosion losses that are common immediately after insitu disturbance, or prior to and during rehabilitation (and the establishment of adequate surface cover) on constructed landforms. Where adequate remediation/control procedures are implemented in these situations (e.g. deep ripping, hay mulching, temporary earthworks/sediment control structures etc), the erosion risk from short term surficial processes is potentially manageable and less significant than longer term, spontaneous gully and tunnel processes (especially in unconsolidated landforms), where the extent and severity of the erosion threat is ongoing and can be difficult to predict, manage and control.

Processes contributing to the formation and ongoing development of gully and tunnel erosion are controlled predominantly by subsoil characteristics, particularly clay content, soil density, clay dispersion and the degree of aggregation and cracking (Charman and Murphy 2007). In most situations, factors controlling gully erosion relate primarily to the hydraulic energy of surface water flows versus the degree of cohesion in the soil material (critical shear stress). Factors contributing to sub-surface tunnel erosion are similar but rely more on the detachment, suspension and subsequent movement of dispersed clay material internally through the soil mass, usually by concentrated lateral water flow. Such flows are usually through cracks or voids in the soil mass. Strong cracking behaviour and the presence of impermeable, dispersive subsurface horizons are key factors promoting such activity (Charman and Murphy 2007). In both cases, predisposition to the development of these erosion processes is related to the presence of sodic, dispersive subsoil clay and the exposure and interaction of such material with some form of concentrated water flow; usually from changed or realigned local surface or sub-surface drainage.

Whilst assessment of inherent erosion potential within the BNCOP Disturbance Footprint follows the rationale and framework proposed by Murphy (1984) and Charman and Murphy (2007), the soil erodibility classes and criteria (originally proposed for New South Wales soils) applied during the assessment have been modified slightly and expanded to increase their relevance and applicability to Central Queensland landscapes. The scheme uses a range of inherent field and laboratory measured soil characteristics to qualitatively predict and rank potential gully and tunnel erodibility. Three classes of inherent erosion hazard (low, moderate and high) were originally proposed by Charman and Murphy (2007), but this has been expanded to include a fourth very high category to

cover extremely sodic and dispersive soils specific to the Bowen Basin. The four categories are explained in greater detail in the methodology section of this report.

It is important to recognize the assessment is an estimate of inferred post-disturbance, insitu erosion potential only, and is based on inherent characteristics of each soil as described and sampled insitu prior to disturbance. The methodology, attributes and criteria described by Charman and Murphy (2007) have been adopted in full, but modified slightly (as described in the methodology section of this report) to account for soils with strongly sodic and dispersive subsoils. Such soils are relatively common in Central Queensland but were not adequately defined in the original scheme. Interpretation within the BNCOP Disturbance Footprint has used the modified criteria definitions as presented. For further information as to the rationale and underlying principles behind the original scheme, the reader is directed to the source documents (Murphy 1984, Charman and Murphy 2007).

Inherent erosion potential findings

Inherent erosion potential (post disturbance) findings following assessment against the modified erodibility framework of Charman and Murphy (2007) is discussed below, for all soils within the BNCOP Disturbance Footprint. The spatial extent of each erosion hazard category is presented in **Figure 24** and findings are summarized in **Table 15**.

L**ow inherent erosion potential** is limited to Soils 8c and 8d (98ha). These soils are deep, relatively coarse, colluvial sands associated with insitu Tertiary sandstones in the north of the Disturbance Footprint. Both soils are highly permeable, non-dispersive and dominated by coarse sand. Associated terrain is typically only gently undulating (slopes 1-3%) and high infiltration and permeability rates minimize the movement and concentration of erodible surface flows.

Soils 2b, 3a, 7c, 8a, 8b and 9a (731ha) are considered to have **moderate erosion potential** and include self-mulching alluvial clays (Soils 2b and 3a), a hardsetting massive red earth (Soil 8a) and sandy/loamy non-sodic texture contrast soils (Soils 8b and 9a). The self mulching alluvial clays (Soils 2b and 3a) are well structured, with significant shrink swell characteristics, but are prone to slaking and exhibit weakly dispersive behaviour in the lower subsoil. Soils 8a and 9a are non-dispersive, but have high levels of fine sand/silt in the upper profile (>60%), while Soil 8b has a clay subsoil that is non-dispersive to weakly dispersive and prone to slaking.

Soils 4c, 4d, 5 and 9b (111ha) have **high inherent erosion potential**. They are all well structured, weakly to strongly self mulching, uniform clays with significant shrink swell characteristics, but are prone to slaking and have undesirable levels of sodicity and dispersion in the lower subsoil (i.e. moderately to strongly sodic and dispersive). They are inherently predisposed to high erosion potential post disturbance, and erosion risk will increase significantly where works that disturb and expose the lower subsoil are undertaken.

The remaining group of soils (Soils 3b, 7a, 7b and 7d – 546ha) have **very high inherent erosion potential** and are strongly to extremely sodic and dispersive throughout the subsoil. These soils should be flagged as difficult mediums to manage during disturbance. Soils in the very high category have the potential to develop severe gully and/or tunnel erosion post disturbance on insitu slopes as gentle as only 1-2%, particularly where surface flows are allowed to concentrate and slope lengths exceed recommended design specifications.

Table 15. Summary of inherent erosion potential findings for soils mapped within the BNCOP Disturbance Footprint.

Inherent erosion potential	Soils	Area (ha)
Low	Soils 8c, 8d	98
Moderate	Soils 2b, 3a, 7c, 8a, 8b, 9a	731
High	Soils 4c, 4d, 5, 9b	111
Very high	Soils 3b, 7a, 7b, 7d,	546

Assessment findings will inform and guide the design and implementation of erosion and sediment control practises and/or structures during mine operations, in accordance with the industry standards *Best Practice Erosion and Sediment Control* (International Erosion Control Association Australasia, 2008) and *Soil Erosion and Sediment Control Engineering Guidelines for Queensland Construction Sites* (International Erosion Control Association Australasia, 1996).

Management recommendations and proposed erosion control measures are discussed in greater detail in the BNCOP Site Water Balance and Surface Water Assessment report (WRM 2014), while Section 5 of the EIS details the rehabilitation methodology proposed for all disturbed lands within the BNCOP Operational Area.

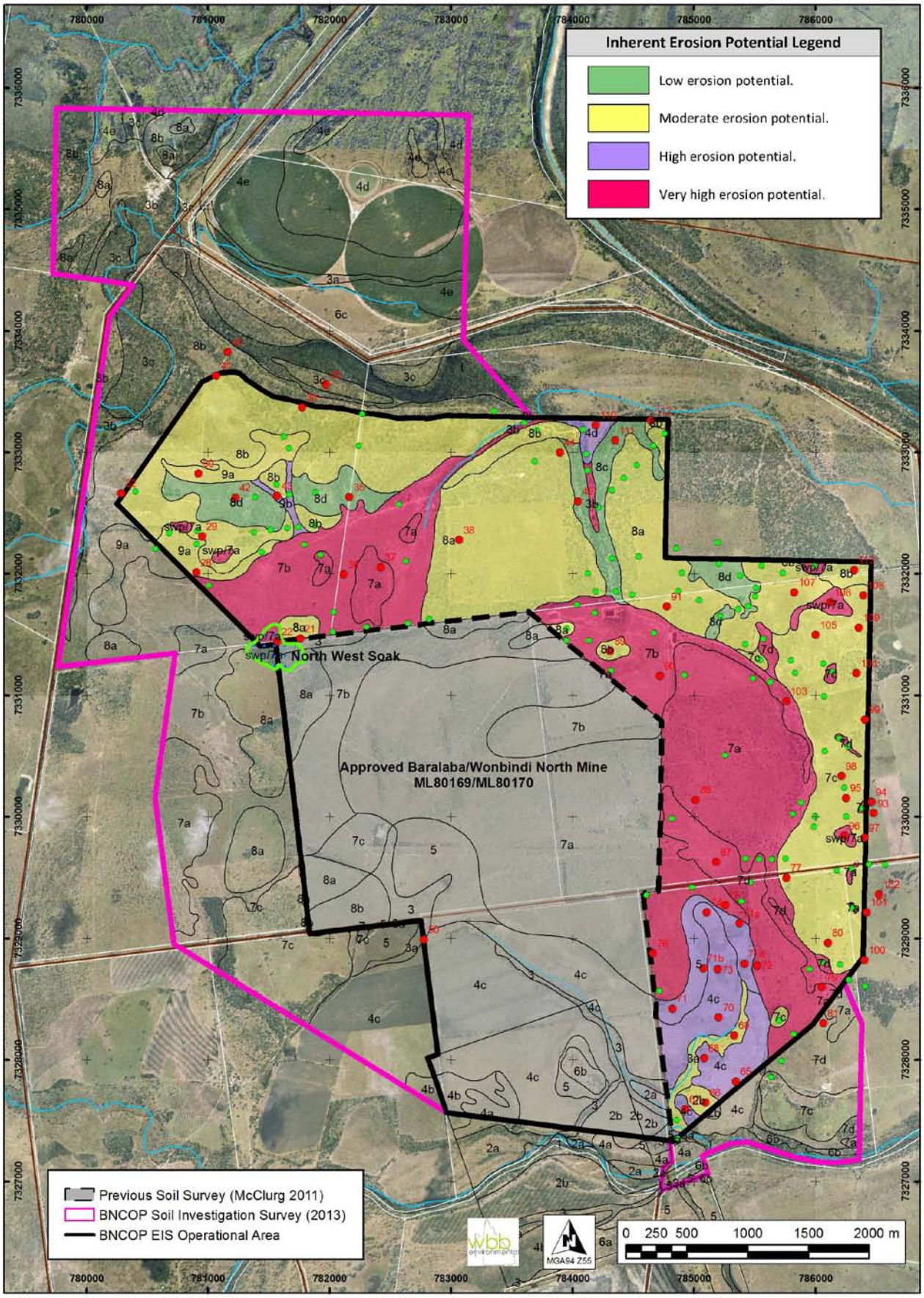

Figure 24. Inherent erosion potential for soils mapped within the BNCOP Disturbance Footprint.

13. Conclusions

The purpose of the investigation was firstly to define and quantify soil landscapes within the proposed BNCOP Disturbance Footprint (external to ML80169 and ML80170), and secondly to determine topsoil resources for salvage, and assess pre-mining land suitability, Agricultural Land Class status, Strategic Cropping Land (SCL) status and inherent erosion potential.

All soil data was collected in accordance with recognized standard land resource survey methodologies and analytical procedures (QDME (1995), Isbell (1996), McKenzie *et al* (2002), McKenzie *et al* (2008), National Committee on Soil and Terrain (2009), Rayment and Lyons (2011), and DNRM/DSITIA (2013a, 2013b)); and meets the specific data requirements prescribed by the *Guidelines for Applying the Proposed Strategic Cropping Land Criteria* (DNRM 2011d) and the *Strategic Cropping Land Act 2011* (Queensland Government 2011).

Twenty three soil types were recognized and mapped within the 2013 BNCOP Soil Investigation survey area. Of these, thirteen have been previously mapped and described within ML80169 and ML80170 (or other earlier mine expansion stages), while ten are newly described. In total, twenty soils are mapped within the actual BNCOP EIS Operational Area. Sixteen of these, occur specifically within the proposed BNCOP Disturbance Footprint (external to ML80169 and ML80170), of which seven are newly described.

Soils 1, 2a, 2b and 3a are associated with the lowest terraces and floodplains of the Dawson River anabranch, while Soils 3b and 3c (also on relatively young alluvium), are restricted to tributaries of the Dawson River, particularly Saline Creek. Soils 4a-4e are predominantly cracking clay soils of the upper terraces and floodplains of the Dawson River system, while soils 6a-6c are sandy or loamy surfaced profiles that occupy high level, elevated alluvium found on relict levees and scroll plains. Soils 7a-7d are extensive and occupy level to gently undulating plains developed on older unconsolidated Cainozoic (TQr) sediments. Soil 5 is transitional between the more recent floodplain landscapes and the older elevated Cainozoic surface, while Soils 8a-8d occupy undulating landscapes developed on insitu Tertiary sandstones in the north of the survey area. Soils 9a-9b are of limited occurrence, and appear related to outcropping calcareous sediments.

Assessment of topsoil resources for stripping has identified a range of soil materials for salvage. Minimal stripping depths (<0.2m) are available from Soils 5, 7a, 7b, 7d, swp/7a and 9b, moderate depths (0.2-0.5m) from Soils 3b, 4c, 4d, 7c, 8a, 8b, and 9a and significant depths (>0.5m) from Soils 2b, 3a, 8c and 8d. The largest volumes (>500,000m^3) are available from Soils 7c, 8a, 8b and 8d through a combination of greater depth and wider spatial extent. Cumulative stripping volumes for all lands within the BNCOP Disturbance Footprint suggest a total of 5,825,600 m^3 is potentially available for salvage and stockpiling.

Assessment of dryland cropping suitability within the BNCOP Disturbance Footprint, in accordance with DNRM/DSITIA (2013b), indicates 96 ha or 6.5% of the area (Soils 2b, 3a, 4c and 4d) is suitable for summer cropping (Classes 1-3), while a further 68 ha or 4.5% (Soils 5, 9a and 9b) is marginal (Class 4). The remaining 1322 ha or 89% (Soils 3b, 7a, 7b, 7c, 7d, 8a, 8b, 8c, 8d, swp/7a) is unsuitable (Class 5).

Assessment of grazing suitability within the BNCOP Disturbance Footprint, in accordance with QDME (1995), indicates land suitable for improved pasture development occupies about 675ha or 45.5% of the area. Of this, 365ha or 24.5% (Soils 2b, 3a, 4c, 4d, 5, 7a) is capable of reliably fattening cattle in most seasons (Classes 1-2), while a further 310ha or 21% (Soils 3b, 7b, 7d, 9b, swp/7a) is better suited to “growing out” younger cattle (Class 3). Of the remaining area, 713ha or 48% is

lower fertility country (Soils 7c, 8a, 8b, 9a) that is marginal for improved pasture development (and associated fattening/growing activities), but is suited to year round breeding herd utilisation (Class 4). A small area in the north (98ha or 6.5%) comprises very sandy, infertile soils (Soils 8c, 8d) that have limited grazing potential and are best suited to wet season breeding use only (Class 5 – requiring dry season destocking when grazed in isolation).

Assessment against revised 2013 state-wide Agricultural Land Class (ALC) criteria (DNRM/DSITIA 2013a) was undertaken to simplify the complexity associated with detailed suitability assessments and provide an accurate and succinct summary as to the pre-mining agricultural potential of lands within the BNCOP Disturbance Footprint. Assessment findings indicate there is 96 ha of Class A1 Crop Land (6.5%), 68 ha of Class B Limited Crop Land (4.5%), 546 ha of Class C1 Pasture Land (37%) and 776 ha of Class C2 Pasture Land (52%) that may be affected.

The *Strategic Cropping Land Act 2011* (Queensland Government 2011) requires triggered land within the Western Cropping Zone qualify for cropping history, comply with Zonal Criteria and meet minimum size requirements before Strategic Cropping Land (SCL) status can be decided. SCL trigger mapping (DNRM 2011a) indicated 118ha of likely (or potential) SCL required assessment within the BNCOP Disturbance Footprint. Spatial analysis of SCL findings indicates the triggered land comprises 66.1ha of decided SCL that complies with all SCL requirements (i.e. qualifies for relevant cropping history, complies with Zonal Criteria and meets minimum size criteria); 3.5ha of decided non-SCL that is otherwise compliant but does not meet minimum size requirements (i.e. excised land due to fragmentation by dissected slopes >3%); and 48.4ha of decided non-SCL that fails to comply with Zonal Criteria 1, 6, 7 or 8. It is the recommendation of this report, in accordance with the requirements of Sections 66-68 of the *Strategic Cropping Land Act 2011* (Queensland Government 2011), that the outcomes documented herein be validated and recorded as decided SCL and decided non-SCL as described.

Additionally, the BNCOP Disturbance Footprint lies within lands along the Dawson River mapped as a Priority Agricultural Area (PAA) under the Central Queensland Regional Plan (DSDIP 2013). This land has been identified as a strategic regional entity with significant potential for the continued or future development of highly productive agricultural land uses (known as *Priority Agricultural Land Uses* (PALUs)). The current intention of the planning framework will afford PALUs within a PAA primary land use status and likely planning priority over other proposed or competing uses. Assessment against proposed PAA co-existence criteria will inform the planning process and guide development decisions as to how and where compatible resource activities, such as the BNCOP, can co-exist concurrently with high value agricultural activities. DSDIP is yet to finalise any such criteria however.

Inherent erosion potential (following insitu disturbance) has been assessed for soils within the BNCOP Disturbance Footprint (excluding ML80169 and ML80170), based on the soil erodibility classes and criteria of Murphy (1984) and Charman and Murphy (2007). The assessment provides a qualitative evaluation of surface erodibility hazard (rill and gully activity) and predisposition to tunnelling. Four classes of inherent erosion hazard (low, moderate, high or very high) are recognized. Soils 8c and 8d (98ha) have low inherent erosion potential, Soils 2b, 3a, 7c, 8a, 8b, and 9a (731ha) are considered moderate, while Soils 4c, 4d, 5 and 9b (111ha) are inherently predisposed to high erosion potential following disturbance. The remaining group of soils, namely Soils 3b, 7a, 7b and 7d (546ha), are characterized by strongly sodic and extremely dispersive, shallow subsoils, and have very high inherent erosion potential. Assessment findings will inform and guide the design and implementation of erosion and sediment control practises and/or structures during mine operations (in accordance with *Best Practice Erosion and Sediment Control* (International Erosion Control Association Australasia, 2008) and *Soil Erosion and Sediment Control Engineering Guidelines for Queensland Construction Sites* (International Erosion Control Association Australasia, 1996)).

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Appendix 1 – AMG locations for all detailed field sites (113) within the 2013 BNCOP Soil Investigation survey area.

Detailed field site locations for field sites 1-113 – 2013 BNCOP Soil Investigation survey area

Site No	GDA94 easting	GDA94 northing	Zone
1	780719	7335559	55
2	780359	7335742	55
3	780179	7335680	55
4	779898	7335769	55
5	780169	7335229	55
6	779832	7334729	55
7	780873	7335193	55
8	781199	7335306	55
9	782909	7335146	55
10	782273	7334989	55
11	782468	7334104	55
12	782133	7334650	55
13	781898	7334441	55
14	781043	7334820	55
15	781038	7334956	55
16	781127	7334617	55
17	782015	7335712	55
18	781906	7335397	55
19	783263	7334711	55
20	780711	7335390	55
21	781760	7331466	55
22	781569	7331443	55
23	780890	7331361	55
24	780566	7331358	55
25	780156	7331780	55
26	780030	7331918	55
27	780342	7335402	55
28	780903	7332012	55
29	780951	7332307	55
30	780922	7332825	55
31	779867	7332241	55
32	780284	7332663	55
33	781969	7333559	55
34	781775	7333371	55
35	782164	7332630	55
36	782116	7331994	55
37	782419	7332054	55
38	783067	7332278	55
39	780276	7334391	55
40	781161	7333825	55
41	781067	7333631	55
42	781224	7332625	55
43	781568	7332640	55
44	783896	7332998	55
45	784046	7332595	55
46	781323	7329009	55
47	781656	7328700	55
48	782004	7328833	55
49	782506	7328940	55
50	782777	7328990	55
51	781534	7330596	55
52	782802	7327770	55
53	782833	7328275	55
54	782171	7328282	55
55	782299	7328592	55
56	782316	7329084	55
57	781583	7329278	55

Site No	GDA94 easting	GDA94 northing	Zone
58	781296	7329529	55
59	781344	7329289	55
60	781081	7329596	55
61	781090	7329350	55
62	780922	7329487	55
63	780641	7329799	55
64	781119	7330676	55
65	785346	7327822	55
66	785094	7327648	55
67	784928	7327594	55
68	785084	7328014	55
69	785330	7328202	55
70	785203	7328349	55
71	784822	7328421	55
71a	785414	7328789	55
71b	785075	7328753	55
71c	785376	7329123	55
72	785520	7328777	55
73	785197	7328745	55
74	785105	7329212	55
75	785257	7329274	55
76	784662	7328876	55
77	785761	7329498	55
78	786091	7327928	55
79	786053	7328599	55
80	786102	7328963	55
81	786065	7328301	55
82	786368	7327956	55
83	785787	7327683	55
84	785594	7327345	55
85	786185	7327581	55
86	785716	7327595	55
87	785183	7329628	55
88	785014	7330141	55
89	784310	7331365	55
90	784717	7331160	55
91	784777	7331730	55
92	780573	7335630	55
93	786479	7330033	55
94	786461	7330122	55
95	786252	7330154	55
96	786239	7329845	55
97	786403	7329827	55
98	786214	7330335	55
99	786406	7330801	55
100	786403	7328821	55
101	786421	7329213	55
102	786521	7329362	55
103	785761	7330951	55
104	786338	7331181	55
105	786003	7331496	55
106	786122	7331764	55
107	785826	7331847	55
108	786394	7331821	55
109	786357	7331556	55
110	784192	7333224	55
111	784353	7333098	55
112	784645	7333260	55
113	786318	7332030	55

Appendix 2 – pH and salinity ($EC_{1:5}$) screening data for determining ERD for all detailed field sites (113) within the 2013 BNCOP Soil Investigation survey area.

pH $_{1.5}$ data for all detailed field sites within the 2013 BNCOP Soil Investigation survey area.

Soil Lscape	Site No.	pH $_{1:5}$												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
1	na	-		-			-			-				
2a	na	-		-			-			-				
2b	66	7.54		7.76			8.61			8.69				
3a	13	7.72		8.41			8.59			8.59				
	15	-		-			-			-				
	50	6.83		7.85			7.98			6.56				
	69	6.77		7.41			8.72			8.52				
3b	27	5.87		5.56			6.57			7.54				
	31	-		-			-			-				
3c	2	5.96		5.94			6.25			6.06				
	7	6.45		6.76			6.86			9.61				
	33	6.84		6.52			6.47			6.28				
	39	6.12		6.16			6.24			5.98				
4a	na	-		-			-			-				
4b	52	8.33		8.59			8.90			8.92				
4c	53	8.17		8.40			8.66			8.73				
	54	8.15		8.57			8.86			8.83				
	55	8.28		8.78			8.84			8.76				
	65	8.42		8.72			8.79	8.92	8.69	8.43				
	67	7.37		8.71			8.85			8.70				
	68	7.40		8.68			8.97			8.92				
	70	8.25		8.74			8.58			6.33				
	73	8.22		8.64			8.47			6.66				
	74	8.69		8.94		8.84	8.72			6.72				
4d	9	7.96		8.20			7.90			8.64				
	10	7.84		8.61			9.01			8.93				
	18	8.46		8.54			8.74			8.81				
	110	8.27		8.71	9.09	8.74	8.67			8.48				
4e	3	6.56		5.81			6.81			8.30				
	8	6.43		7.37			8.66			8.88				
	12	6.38		6.61			7.30			7.71				
	14	-		-			-			-				
	17	6.05		6.40			7.13			8.78				
	19	-		-			-			-				
5	49	7.85		8.94			8.35			5.29				
	71	8.69		9.03	8.97	8.65	8.65	8.31		8.00				

Soil Lscape	Site No.	pH 1:5												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
6a	na	-		-			-			-				
6b	84	6.22		7.23			8.61			9.15				
6c	11	5.86		6.33			6.26			6.29				
	16	-		-			-			-				
7a	23	7.32		8.52			5.77			4.94				
	37	7.86		8.87		8.85	8.48			7.03				
	63	7.04		8.31			5.97			5.30				
	75	8.11	8.55	8.66	8.33	7.94	7.75			5.63				
	76	-		-			-			-				
	88	7.94	8.88	8.66	8.41	8.19	7.99			5.44				
7b	24	6.91		8.57			9.06			8.47				
	36	6.66		7.75		9.18	9.07	9.32	9.32	9.04				
	59	6.43		7.03			8.20			8.71				
	60	8.19		8.35			7.45			5.10				
	61	-		-			-			-				
	62	6.90		7.28			7.79			8.33				
	64	6.84		8.49			9.26			9.47				
	90	7.37	7.83	8.03	8.32	8.41	7.96			5.60				
	103	7.44		8.67	8.46	8.61	8.68			8.73				
7c	46	6.21		6.37			6.73			7.04				
	47	6.47		6.82			6.90			7.16				
	48	6.17		6.03			6.36			6.85				
	56	-		-			-			-				
	57	8.12		8.17			8.44			8.20				
	77	6.09		6.44			8.23			8.87				
	80	-		-			-			-				
	83	8.55		8.76			8.67			9.00				
	85	6.65		7.01			7.36			8.15				
	86	-		-			-			-				
	93	6.41		6.64			7.45			8.17				
	95	6.33		6.69			7.22			7.78				
	97	-		-			-			-				
	98	6.03		6.59			5.40			5.99				
	99	6.16		6.34			6.45			6.64				
	100	8.42		7.93			7.88			7.22				
	101	-		-			-			-				
	104	6.23		6.88			5.85			6.12				
	105	5.98		6.00			6.49			8.03				
	108	6.15		6.01			6.27			6.92				
	109	-		-			-			-				
7d	72	7.85		9.01			9.22		8.83	8.81				

Soil Lscape	Site No.	pH 1:5												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
	78	6.00		7.82			8.88			9.08				
	79	7.01		8.03		9.06	8.91	8.96	8.91	8.76				
	81	-		-			-			-				
	82	-		-			-			-				
	87	6.36		8.45	9.18	9.16	9.09	9.17		8.94				
	94	6.83		7.88			8.40		8.40	8.42				
	102	7.23		6.89			7.07			7.31				
swp 7a	**22**	5.69		6.85			7.15			7.33				
	96	6.91		7.57			8.35	8.42	7.92	8.20				
	106	5.50		6.80			7.34			8.46				
8a	**5**	5.72		5.80			5.99			6.01				
	20	-		-			-			-				
	21	8.15		8.41			8.40			8.42				
	38	5.75		6.08			6.27			6.23				
	44	-		-			-			-				
	51	6.26		5.67			5.40			5.37				
	58	5.52		5.27			5.77			5.93				
	91	-		-			-			-				
	107	5.67		6.18			6.17			6.02				
8b	**1**	5.42		6.14			7.67			8.77				
	4	5.60		5.44			5.12		5.28	-				
	6	4.79		5.26			5.12			5.12				
	26	-		-			-			-				
	29	6.39		6.13			5.97			6.10				
	32	-		-			-			-				
	34	6.42		5.51			5.63			6.09				
	40	5.81		5.84			6.10			6.36				
	41	5.17		4.99			6.46			6.92				
	89	5.52		5.34			7.07		8.09	8.41				
	92	5.53		5.88			5.90			5.13				
	112	-		-			-			-				
	113	6.20		5.96			6.38			6.21				
8c	**45**	-		-			-			-				
	111	-		-			-			-				
8d	**35**	6.42		6.49			6.57			6.64				
	42	-		-			-			-				
9a	**25**	5.92		7.08			8.89			8.81				
	28	6.11		5.90			6.83			7.50				
	30	6.37		7.24			8.66		9.02	8.79				
9b	**43**	7.09		8.06		9.05	9.16	8.87	8.75	8.98				

EC $_{1:5}$ data for field sites within the 2013 BNCOP Soil Investigation survey area.

Soil Lscape	Site No.	EC $_{1:5}$												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
1	na	-		-			-			-				
2a	na	-		-			-			-				
2b	66	0.069		0.062			0.119			0.124				
3a	13	0.119		0.188			0.251			0.355				
	15	-		-			-			-				
	50	0.049		0.058			0.274			0.919				
	69	0.086		0.045			0.107			0.294				
3b	27	0.043		0.028			0.071			0.108				
	31	-		-			-			-				
3c	2	0.030		0.028			0.034			0.026				
	7	0.049		0.048			0.046			0.045				
	33	0.050		0.033			0.027			0.025				
	39	0.030		0.024			0.022			0.020				
4a	na	-		-			-			-				
4b	52	0.107		0.150			0.215			0.241				
4c	53	0.082		0.091			0.133			0.145				
	54	0.078		0.088			0.125			0.119				
	55	0.070		0.104			0.113			0.087				
	65	0.139		0.192			0.255	0.281	0.293	0.513				
	67	0.079		0.154			0.276			0.677				
	68	0.431		0.238			0.273			0.511				
	70	0.132		0.160			0.328			0.609				
	73	0.101		0.141			0.261			0.810				
	74	0.142		0.202		0.392	0.483			0.913				
4d	9	0.183		0.161			0.093			0.162				
	10	0.109		0.166			0.442			0.729				
	18	0.184		0.193			0.267			0.467				
	110	0.134		0.182	0.344	0.510	0.724			1.431				
4e	3	0.055		0.051			0.109			0.278				
	8	0.063		0.088			0.173			0.179				
	12	0.068		0.048			0.078			0.108				
	14	-		-			-			-				
	17	0.053		0.070			0.098			0.370				
	19	-		-			-			-				
5	49	0.086		0.144			0.555			0.800				
	71	0.151		0.242	0.332	0.641	0.755	1.069		1.111				

Soil Lscape	Site No.	EC 1:5												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
6a	na	-		-			-			-				
6b	84	0.068		0.061			0.087			0.296				
6c	11	0.034		0.037			0.033			0.026				
	16	-		-			-			-				
7a	23	0.089		0.260			0.703			0.753				
	37	0.054		0.225		0.537	0.636			0.701				
	63	0.054		0.251			0.670			0.805				
	75	0.141	0.281	0.426	0.735	0.944	1.147			1.080				
	76	-		-			-			-				
	88	0.094	0.333	0.527	0.890	1.097	1.115			1.005				
7b	24	0.047		0.101			0.488			0.715				
	36	0.034		0.110		0.255	0.357	0.540	0.615	0.662				
	59	0.031		0.029			0.106			0.279				
	60	0.117		0.457			0.670			0.684				
	61	-		-			-			-				
	62	0.042		0.036			0.034			0.039				
	64	0.056		0.229			0.908			0.833				
	90	0.093	0.265	0.510	0.817	0.841	0.701			0.586				
	103	0.077		0.360	0.600	0.726	0.702			0.713				
7c	46	0.032		0.025			0.026			0.037				
	47	0.031		0.036			0.023			0.025				
	48	0.025		0.020			0.019			0.024				
	56	-		-			-			-				
	57	0.056		0.036			0.057			0.062				
	77	0.032		0.025			0.054			0.188				
	80	-		-			-			-				
	83	0.096		0.073			0.064			0.083				
	85	0.049		0.039			0.049			0.067				
	86	-		-			-			-				
	93	0.040		0.027			0.028			0.075				
	95	0.039		0.031			0.027			0.031				
	97	-		-			-			-				
	98	0.059		0.056			0.137			0.283				
	99	0.062		0.041			0.047			0.097				
	100	0.089		0.041			0.062			0.138				
	101	0.095		0.033			0.030			0.034				
	104	0.036		0.037			0.079			0.101				
	105	0.026		0.022			0.022			0.053				
	108	0.033		0.026			0.024			0.026				
	109	-		-			-			-				
7d	72	0.105		0.150			0.232		0.401	0.481				

Soil Lscape	Site No.	EC 1:5												
		0.1m	0.2m	0.3m	0.4m	0.5m	0.6m	0.7m	0.8m	0.9m	1.0m	1.1m	1.2m	1.5m
	78	0.083		0.072			0.150			0.521				
	79	0.050		0.101		0.397	0.502	0.719	0.776	0.776				
	81	-		-			-			-				
	82	-		-			-			-				
	87	0.034		0.087	0.178	0.409	0.648	0.836		1.011				
	94	0.032		0.071			0.190		0.333	0.405				
	102	0.095		0.033			0.030			0.034				
swp 7a	22	0.033		0.043			0.057			0.100				
	96	0.060		0.071			0.201	0.333	0.504	0.566				
	106	0.031		0.037			0.039			0.127				
8a	5	0.026		0.022			0.024			0.026				
	20	-		-			-			-				
	21	0.109		0.121			0.087			0.095				
	38	0.029		0.022			0.020			0.020				
	44	-		-			-			-				
	51	0.042		0.022			0.028			0.030				
	58	0.024		0.020			0.020			0.020				
	91	-		-			-			-				
	107	0.028		0.026			0.025			0.028				
8b	1	0.037		0.066			0.170			0.748				
	4	0.027		0.021			0.107		0.077	-				
	6	0.019		0.016			0.015			0.015				
	26	-		-			-			-				
	29	0.028		0.023			0.019			0.027				
	32	-		-			-			-				
	34	0.034		0.020			0.023			0.023				
	40	0.024		0.018			0.028			0.034				
	41	0.020		0.017			0.024			0.032				
	89	0.029		0.022			0.077		0.194	0.329				
	92	0.022		0.024			0.201			0.301				
	112	-		-			-			-				
	113	0.041		0.023			0.021			0.021				
8c	45	-		-			-			-				
	111	-		-			-			-				
8d	35	0.036		0.029			0.029			0.027				
	42	-		-			-			-				
9a	25	0.026		0.062			0.300			0.459				
	28	0.030		0.022			0.043			0.077				
	30	0.038		0.049			0.152		0.333	0.350				
9b	43	0.043		0.048		0.300	0.365	0.509	0.664	0.637				

Appendix 3 – Effective rooting depth (ERD) and PAWC calculations for soils mapped within the BNCOP Disturbance Footprint (DNRM 2011d, Queensland Government 2011).

Soil Unit	ERD [1]	Soil Horizon[2]	Modal Horizon Depths (m)[2]	Depth Factor[3]	Field Texture Range[4]	Est. Field Text. SWS (mm/0.1m)[5]	Horizon SWS (mm)	Profile SWS (mm)	SWS to nearest 5mm
2b	>1.0m	Ap1	0-0.03	0.3	LMC-MC	12	3.6		
	no restrictions	Ap2/B21	0.03-0.25	2.2	MHC	12	26.4		
		B22	0.25-0.80	5.5	MHC-HC	12	66.0		
		B23k	0.80-1.00+	2.0	MHC-HC	12	24.0	**120**	**120**
3a	0.8->1.0m	A11/Ap1	0-0.03	0.3	LMC-MC	12	3.6		
	salinity >0.8dS/m or Cl >800ppm	A12/Ap2	0.03-0.20	1.7	MHC	12	20.4		
		B21k	0.20-0.75	5.5	MHC-HC	12	66.0		
		B22k	0.75-1.00+	0.5-2.5	FSMC-FSMHC	12	30	**96-120**	**95-120**
3b	0.5-0.6m	A1/A2e	0-0.35	3.5	FSCL-CLFS	8	28.0		
	rigid soil + ESP >15%	B21	0.35-0.60	1.5-2.5	FSLC-FSLMC	10	15.0-25.0	**43-53**	**45-55**
4c	0.75->1.0m	A1/Ap1	0-0.04	0.4	MC	12	4.8		
	salinity >0.8dS/m or Cl >800ppm	Ap2/B21p	0.04-0.20	1.6	MHC-HC	12	19.2		
		B21k	0.20-0.60	4.0	MHC-HC	12	48.0		
		B22	0.60-1.00+	1.5-4.0	MHC-HC	12	18.0-48.0	**90-120**	**90-120**
4d	0.7->1.0m	A1	0-0.06	0.6	LMC-MC	12	7.2		
	salinity >0.8dS/m or Cl >800ppm	B21	0.06-0.40	3.4	MC-MHC	12	40.8		
		B22/B23	0.40-1.00+	3.0-6.0	MC-MHC	12	36.0-72.0	**84-120**	**85-120**
5	0.6-0.7m	A1	0-0.03	0.3	MC	12	3.6		
	salinity >0.8dS/m or Cl >800ppm	B21p/B21	0.03-0.35	3.2	MHC	12	38.4		
		B22	0.35-0.70	2.5-3.5	FSMC-FSMHC	12	30.0-42.0	**72-84**	**70-85**
7a	0.4-0.6m	A1	0-0.06	0.6	FSLMC-FSMC	12	7.2		
	salinity >0.8dS/m or Cl >800ppm	B21k	0.06-0.40	3.4	FSMC-MHC	12	40.8		
		B22/B23	0.40-0.60	2.0	FSMC	12	24.0	**48-72**	**50-70**
7b	0.3-0.5m	A1/A2je	0-0.13	1.3	FSCL-FSLC	6-10	7.8-13.0		
	salinity >0.8dS/m or Cl >800ppm	B21	0.13-0.50	1.7-3.7	FSMC-FSMHC	12	20.4-44.4	**28-57**	**30-60**
	Rigid soil ESP>15%								
7c	>1.0m	A1/A2je	0-0.55	5.5	LS-SL	4-5	22.0-27.5		
	no restrictions	B21	0.55-0.90	3.5	SLC-SLMC	10	35.0		
		B22	0.90-1.00+	1.0	SLMC-SMC	12	12.0	**69-75**	**70-75**

Soil Unit	ERD	Soil Horizon[1]	Modal Horizon Depths (m)[1]	Depth Factor[3]	Field Texture Range[4]	Est. Field Text. SWS (mm/0.1m)[6]	Horizon SWS (mm)	Profile SWS (mm)	SWS to nearest 5mm
7d	0.45m	A1	0-0.12	1.2	SCL-CLS	8	9.6		
	Rigid soil ESP>15%	A2je	0.12-0.15	0.3	SCL-CLS	8	2.4		
		B21	0.15-0.45	3.0	SLMC-SMC	12	36.0	**48**	**50**
8a	>1.0m	A1	0-0.20	2.0	SL-SCL	5-6	10.0-12.0		
	no restrictions	B1	0.20-0.50	3.0	SCL-CLS	6-8	18.0-24.0		
		B2	0.50-1.00+	5.0	CLS-SLC	8-10	40.0-50.0	**68-86**	**70-85**
8b	0.8->1.0	A1/A2e	0-0.50	5.0	S-LS	4	20.0		
	no restrictions	B21/B22	0.50-1.00+	3.0-5.0	SLC-SMC	10-12	30.0-60.0	**50-80**	**50-80**
8c	>1.0m - no restrictions	A1/A2e	0-1.00+	10.0	S-LS	4	40.0	**40**	**40**
8d	>1.0m - no restrictions	A11/A12/A3/B1	0-1.00+	10.0	S-LS	4	40.0	**40**	**40**
9a	>1.0m	A1/A2j	0-0.25	2.5	SL-SLC	5-10	12.5-25.0		
	no restrictions	B21	0.25-0.60	3.5	LMC	10	35.0		
		B22	0.60-1.00+	4.0	LMC	10	40.0	**87-100**	**85-100**
9b	0.7m	A11	0-0.03	0.3	LMC	10	3.0		
	salinity >0.8dS/m or Cl >800ppm	A12	0.03-0.20	1.7	MC	12	20.4		
		B21	0.20-0.70	5.0	MHC	12	60.0	**83**	**85**

Notes:
1. Effective rooting depth (ERD) and contributing soil constraint(s) are in accordance with the ERD definition and criteria in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d).
2. Soil horizon nomenclature and modal depths are from the midpoint of modal soil profile class diagrams presented in the soil characterization section of this report.
3. SWS multiplication factor is calculated from the difference between upper and lower modal midpoint horizon boundaries; the multiplication factor is used to quantify horizon thickness in profile SWS summations.
4. Soil field texture range is from that recorded for each soil horizon from the modal soil profile class descriptions presented in the soil characterization section of this report; texture codes are as defined in NCST (2009).
5. Estimated average soil water status (SWS) per 100mm of soil depth increment is for the soil texture grades listed for each soil horizon using values from the look-up table in the *Strategic Cropping Land Act 2011* (Queensland Government 2011) and SCL Guidelines (DNRM 2011d). Where a range in texture is listed the maximum value is assumed to ensure profile SWS calculations do not underestimate potential SWS values within a soil group.

Appendix 4 – Sampling depths and analytical methodologies used to characterise samples from the 2013 BNCOP Soil Investigation.

Sampling depths and analytical methodologies used in the investigation.

1. Profile analyses[1] – 0.1m sample depths taken at 0.3m intervals - representative profiles		
Sample depths(m) – 0-0.1, 0.25-0.35, 0.55-0.65, 0.85-0.95, 1.15-1.25	**Method**	**Moisture Status**
Analyses CEC[2]	15I3	Air dry @ 40ºC
Exchangeable cations pH 8.5 (Ca, Mg, Na, K, meq/100g) [2]	15C1	Air dry @ 40ºC
ECEC[2]	15J1	Air dry @ 40ºC
Exchangeable cations pH 7.0 (Ca, Mg, Na, K, meq/100g) [2]	15A1	Air dry @ 40ºC
Exchange acidity (Al, H meq/100g) [2]	15G1	Air dry @ 40ºC
Air dry moisture content (ADMC %)	2A1	Oven dry @ 105ºC
Particle size analysis (coarse sand, fine sand, silt, clay (%))	2Z2	Oven dry @ 105ºC
Dispersion ratio (R1)	2Z1	Oven dry @ 105ºC
Exchangeable sodium percentage (ESP %)	15N1	NA
Ca/Mg ratio	15M1	NA

2. pH and salinity analyses[1] – 0.1m sample depths taken at 0.3m intervals - representative profiles		
Sample depths(m) – 0-0.1, 0.25-0.35, 0.55-0.65, 0.85-0.95, 1.15-1.25	**Method**	**Moisture Status**
Analyses Soil pH $_{1:5}$	4A1	Air dry @ 40ºC
Electrical conductivity (EC $_{1:5}$ dS/m)	3A1	Air dry @ 40ºC
Soluble chloride (Cl ppm)	5A2	Air dry @ 40ºC

3. pH and salinity analyses[1] – 0.3m and 0.6m for SCL compliance - Criteria 6 and 7		
Sample depths(m) – 0.3 and 0.6	**Method**	**Moisture Status**
Analyses Soil pH $_{1:5}$	4A1	Air dry @ 40ºC
Soluble chloride (Cl ppm)	5A2	Air dry @ 40ºC

4. pH and salinity analyses[1] – 0.1m sample depths - ERD screening data/all detailed field sites		
Sample depths(m) – 0.1, 0.3, 0.6, 0.9, 1.2	**Method**	**Moisture Status**
Analyses Soil pH $_{1:5}$	4A1	Air dry @ 40ºC
Electrical conductivity (EC $_{1:5}$ dS/m)	3A1	Air dry @ 40ºC

5. surface soil fertility analyses[1] – sample depth 0-0.1 m (Bulk)		
Sample depths (m) – 0-0.1	**Method**	**Moisture Status**
Analyses Organic carbon (%)	8B1	Air dry @ 40ºC
Total Nitrogen (%)	7A2	Air dry @ 40ºC
Available Phosphorous (Colwell)(ppm)	9B2	Air dry @ 40ºC
Exchangeable Calcium and Potassium – pH 8.5 (Ca meq/100g)	15C1	Air dry @ 40ºC
Exchangeable Calcium and Potassium – pH 7.0 (Ca meq/100g)	15A1	Air dry @ 40ºC

1. Method codes from Rayment and Lyons (2011). Testing undertaken by Agricultural Chemistry Pty Ltd. ABN 73 147 287 372.
2. CEC, ECEC and exchangeable cations (15C1 and 15A1) are reported on an air dry basis @ 40°C.

Appendix 5 – Fertility, pH, salinity, cation chemistry, particle size and dispersion data for sampled representative sites within the 2013 BNCOP Soil Investigation survey area.

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Reference 13/81 Page: 1 of 11

Date Received: 18/10/2013
Date Completed:

FINAL REPORT

Project:

Baralaba North CO Project EIS Soils Investigation 2013

All results in this report relate only to the items tested. Results are expressed on an "as received basis".

Client Name: Soil Mapping

Contact: Jon Burgess

Sample Type: soil

Number of samples: 121

Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1144		65		0.3	8.8	0.230	38							
1145				0.6	8.9	0.301	85							
1179				0.9	8.6	0.458	420							
1352				1.0	8.4	0.655	660							
1180				1.2	7.1	0.907	1030							
1146		66		0.3	8.0	0.087	<5							
1147				0.6	8.5	0.164	<5							
1148		67		0.3	8.6	0.177	5							
1149				0.6	8.7	0.311	155							
1353				0.7	8.8	0.325	200							
1354				0.8	8.8	0.449	350							
1355				0.9	8.6	0.649	650							
1356				1.0	8.5	0.812	880							
1150		68		0.3	8.4	0.253	133							
1151				0.6	8.8	0.329	130							
1357				0.7	8.9	0.409	265							
1358				0.8	8.9	0.227	370							
1359				0.9	8.9	0.548	455							
1360				1.0	8.8	0.646	650							
1152		69		0.3	7.7	0.063	<5							
1153				0.6	8.8	0.192	25							
1154		70		0.3	8.8	0.234	10							
1155				0.6	8.7	0.312	245							
1361				0.7	8.0	0.374	370							
1362				0.8	7.3	0.474	560							
1363				0.9	6.1	0.595	770							
1364				1.0	5.7	0.741	1050							
1156		71		0.3	8.9	0.266	30							
1157				0.6	8.7	0.825	820							
1158		72		0.3	8.8	0.161	<5	16.6	7.3	0.191	1.08	23		5
1159				0.6	9.1	0.278	38	10.6	10.0	0.178	3.10	22		14
1160		73		0.3	8.7	0.200	15							
1161				0.6	8.4	0.316	215							
1365				0.7	7.3	0.422	335							
1366				0.8	5.5	0.634	545							
1367				0.9	5.1	0.886	890							
1368				1.0	4.3	1.034	1150							
1162		74		0.3	8.9	0.238	28							
1163				0.6	8.7	0.520	438							
1369				0.7	8.5	0.633	615							
1370				0.8	8.2	0.844	905							
1184				0.9	7.1	0.935	1165							
1185				1.2	5.0	1.251	1750							
1164		75		0.3	8.6	0.475	465							
1165				0.6	7.4	1.054	1500							

Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1166	2b	66	Ap1/Ap2	0 - 0.1	7.2	0.346	210	73	0.140	27.0	8.4	2.50	0.471	38		1
1167			B21	0.25 - 0.35	8.1	0.078	<5			34.1	9.3	0.999	0.814	41		2
1168			B21	0.55 - 0.65	8.5	0.160	<5			32.5	12.0	0.734	1.90	42		5
1169			B22k	0.85 - 0.95	8.7	0.180	5			27.7	13.9	0.672	3.74	43		9
1170				1.15 - 1.25	8.9	0.236	15									
1171	3a	69	A11/A12	0 - 0.1	6.6	0.081	30	83	0.195	18.1	9.8	1.33	0.418		30	1
1172			B21	0.25 - 0.35	7.5	0.057	<5			22.8	7.5	0.330	0.764	30		3
1173			B21k	0.55 - 0.65	8.4	0.094	10			23.8	10.1	0.273	1.85	33		6
1174			B22	0.85 - 0.95	8.6	0.288	280			17.6	10.9	0.230	3.91	30		13
1175				1.15 - 1.25	6.2	0.453	650									
1216	3b	27	A11	0 - 0.1	6.2	0.059	40	28	0.105	5.3	2.6	0.629	0.199		9	2
1217			A12	0.25 - 0.35	5.6	0.021	5			2.2	1.5	0.132	0.242		4	6
1218			B21	0.55 - 0.65	6.8	0.070	35			3.6	4.0	0.142	1.69		9	18
1219			B22	0.85 - 0.95	7.9	0.096	73			3.6	3.8	0.13	1.67	9		19
1220				1.15 - 1.25	8.3	0.255	265									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1166	2b	66	Ap1/Ap2	0 - 0.1	1	10	23	66	0.37	3.8
1167			B21	0.25 - 0.35	1	9	22	68	0.39	5.2
1168			B21	0.55 - 0.65	2	6	19	72	0.44	4.8
1169			B22k	0.85 - 0.95	1	6	18	75	0.58	4.2
1170				1.15 - 1.25						
1171	3a	69	A11/A12	0 - 0.1	2	17	18	61	0.44	3.4
1172			B21	0.25 - 0.35	10	24	15	52	0.36	3.4
1173			B21k	0.55 - 0.65	9	21	12	59	0.45	4.4
1174			B22	0.85 - 0.95	12	22	16	52	0.72	3.8
1175				1.15 - 1.25						
1216	3b	27	A11	0 - 0.1	8	45	29	21	0.65	1.0
1217			A12	0.25 - 0.35	9	49	25	21	0.75	1.1
1218			B21	0.55 - 0.65	14	46	13	29	0.99	1.2
1219			B22	0.85 - 0.95	19	50	10	24	0.92	1.0
1220				1.15 - 1.25						

All results for particle size analysis and R1 are reported on oven-dried basis (no pre-treatment applied to test samples)

Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1176	4c	65	A11p/A12p	0 - 0.1	8.4	0.165	40	56	0.149	34.1	7.5	1.33	0.966	37		3
1177			B21k	0.25 - 0.35	8.8	0.218	40			31.9	10.6	0.609	3.35	40		8
1178			B21k	0.55 - 0.65	9.0	0.307	80			24.7	12.1	0.496	5.24	39		13
1179			B22	0.85 - 0.95	8.6	0.458	420			19.0	11.9	0.462	6.17	35		18
1180				1.15 - 1.25	7.1	0.907	1030									
1221	4d	110	A1	0 - 0.1	7.4	0.128	10	36	0.255	22.2	4.9	1.02	0.089	28		<1
1222			B21k	0.25 - 0.35	9.0	0.189	18			17.5	11.1	0.407	1.45	26		6
1223			B22	0.55 - 0.65	9.0	0.829	525			12.2	14.7	0.37	5.06	28		18
1224			B22	0.85 - 0.95	8.8	1.391	1600			11.5	16.0	0.394	5.85	28		21
1225				1.15 - 1.25	8.4	1.700	2250									
1226	5	71	A11p/B21p	0 - 0.1	8.5	0.194	95	32	0.116	24.1	9.2	0.955	1.41	33		4
1227			B22	0.25 - 0.35	8.9	0.370	155			19.2	12.7	0.343	4.35	32		14
1228			B22	0.55 - 0.65	8.7	0.821	790			15.5	14.7	0.352	6.55	34		19
1229			B23	0.85 - 0.95	7.7	1.180	1600			12.7	14.7	0.382	6.77	34		20
1230			B23	1.15 - 1.25	5.5	1.305	1850									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1176	4c	65	A11p/A12p	0 - 0.1	2	14	23	60	0.39	3.7
1177			B21k	0.25 - 0.35	2	12	21	63	0.47	4.1
1178			B21k	0.55 - 0.65	3	11	22	65	0.68	3.7
1179			B22	0.85 - 0.95	1	12	27	63	0.79	3.4
1180				1.15 - 1.25						
1221	4d	110	A1	0 - 0.1	22	26	12	39	0.30	2.6
1222			B21k	0.25 - 0.35	18	21	13	49	0.50	3.0
1223			B22	0.55 - 0.65	16	20	14	54	0.70	3.9
1224			B22	0.85 - 0.95	14	21	9	53	0.61	3.6
1225				1.15 - 1.25						
1226	5	71	A11p/B21p	0 - 0.1	9	17	17	59	0.32	3.4
1227			B22	0.25 - 0.35	9	15	18	60	0.65	3.6
1228			B22	0.55 - 0.65	7	14	15	66	0.75	4.3
1229			B23	0.85 - 0.95	6	14	14	68	0.78	3.1
1230			B23	1.15 - 1.25						

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Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1186	7a	88	A1	0 - 0.1	6.8	0.071	45	20	0.140	12.3	7.9	0.336	0.782		21	4
1187			B21k	0.25 - 0.35	8.8	0.629	670			11.9	10.6	0.187	3.45	24		14
1188			B22	0.55 - 0.65	8.3	1.160	1440			9.5	11.1	0.208	4.02	23		17
1189			B23	0.85 - 0.95	5.3	1.004	1315			6.5	10.8	0.191	6.75		24	28
1190				1.15 - 1.25	4.9	0.968	1300									
1231	7b	36	A1	0 - 0.1	6.7	0.045	20	6.0	0.090	4.5	3.0	0.296	0.302		8	4
1232			B21	0.25 - 0.35	7.6	0.105	73			5.5	9.3	0.110	2.25	17		13
1233			B22k	0.55 - 0.65	9.2	0.393	315			4.9	8.0	0.091	2.32	13		18
1234			B22k	0.85 - 0.95	9.3	0.650	650			4.0	9.6	0.109	3.72	14		27
1235				1.15 - 1.25	7.9	0.602	800									
1236	7b	90	A1/B21	0 - 0.1	6.4	0.051	30	7.5	0.095	4.3	5.3	0.204	0.75		11	7
1237			B21	0.25 - 0.35	8.7	0.642	780			7.8	10.2	0.116	3.42	19		18
1238			B22	0.55 - 0.65	8.2	0.732	1080			5.3	9.0	0.111	3.88	16		24
1239			B22	0.85 - 0.95	5.2	0.597	880			2.9	5.9	0.069	4.71		14	35
1240				1.15 - 1.25	4.7	0.555	815									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1186	7a	88	A1	0 - 0.1	9	27	18	45	0.41	2.5
1187			B21k	0.25 - 0.35	11	28	16	49	0.60	3.0
1188			B22	0.55 - 0.65	10	27	15	50	0.62	2.8
1189			B23	0.85 - 0.95	9	24	16	52	0.74	2.5
1190				1.15 - 1.25						
1231	7b	36	A1	0 - 0.1	13	58	11	20	0.66	0.9
1232			B21	0.25 - 0.35	10	39	12	40	0.81	2.1
1233			B22k	0.55 - 0.65	17	43	10	34	0.86	1.3
1234			B22k	0.85 - 0.95	14	41	11	37	0.95	1.6
1235				1.15 - 1.25						
1236	7b	90	A1/B21	0 - 0.1	12	45	17	29	0.58	1.3
1237			B21	0.25 - 0.35	10	36	17	39	0.66	2.0
1238			B22	0.55 - 0.65	10	39	17	37	0.89	1.8
1239			B22	0.85 - 0.95	12	41	12	34	0.95	1.3
1240				1.15 - 1.25						

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Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1241	7c	99	A1	0 - 0.1	6.3	0.042	15	11	0.090	2.4	0.97	0.423	0.041		4	1
1242			A21	0.25 - 0.35	6.6	0.024	5			2.7	0.44	0.29	0.041		3	1
1243			B2	0.65 - 0.75	7.2	0.026	2			4.8	4.2	0.202	0.564		10	6
1244			B2	0.85 - 0.95	7.2	0.035	8			5.6	5.4	0.305	0.884		12	7
1245				1.15 - 1.25	8.1	0.073	35									
1191	7d	87	A1	0 - 0.1	6.4	0.034	5	28	0.140	6.5	3.4	0.194	0.330		10	3
1192			B21	0.25 - 0.35	8.5	0.087	60			7.4	7.3	0.130	1.83	15		12
1193			B22	0.55 - 0.65	9.1	0.672	730			3.0	6.6	0.140	3.63	12		30
1194			B22	0.85 - 0.95	9.2	0.976	1100			2.8	6.3	0.129	3.92	11		36
1195				1.15 - 1.25	9.3	0.991	1150									
1196	8a	38	A1	0 - 0.1	6.2	0.020	<5	1.0	0.070	2.7	0.99	0.307	0.021		4	1
1197			B1	0.25 - 0.35	6.3	0.010	<5			2.1	0.90	0.180	0.028		3	1
1198			B2	0.55 - 0.65	6.4	0.010	<5			3.2	2.4	0.215	0.043		6	1
1199			B2	0.85 - 0.95	6.2	0.011	<5			2.6	2.5	0.087	0.058		5	1
1200				1.15 - 1.25	6.0	0.007	<5									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1241	7c	99	A1	0 - 0.1	29	55	8	10	0.64	0.4
1242			A21	0.25 - 0.35	31	51	7	11	0.88	0.5
1243			B2	0.65 - 0.75	20	33	5	44	0.57	1.3
1244			B2	0.85 - 0.95	15	27	1	53	0.67	1.8
1245				1.15 - 1.25						
1191	7d	87	A1	0 - 0.1	18	42	11	27	0.50	1.4
1192			B21	0.25 - 0.35	17	35	7	38	0.66	1.9
1193			B22	0.55 - 0.65	19	39	8	33	0.99	1.3
1194			B22	0.85 - 0.95	18	40	11	29	0.99	1.8
1195				1.15 - 1.25						
1196	8a	38	A1	0 - 0.1	18	62	6	15	0.74	0.7
1197			B1	0.25 - 0.35	16	57	8	20	0.51	0.7
1198			B2	0.55 - 0.65	12	38	4	47	0.24	1.6
1199			B2	0.85 - 0.95	12	42	5	43	0.17	1.4
1200				1.15 - 1.25						

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Agricultural Chemistry Pty Ltd
Soil Analysis Report
Batch Number: 13/81

Date Received: 18/10/2013
Date Completed: 16/12/2013

Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1201	8b insitu	40	A1	0 - 0.1	6.1	0.016	<5	2.0	0.060	2.3	1.0	0.147	0.015		4	1
1202			A2e	0.25 - 0.35	6.3	0.012	<5			1.6	1.4	0.069	0.062		3	2
1203			B21	0.55 - 0.65	6.1	0.018	<5			12.4	8.2	0.378	0.799		22	4
1204			B22	0.85 - 0.95	6.7	0.027	10			13.2	8.1	0.298	1.011		23	5
1205				1.15 - 1.25	7.6	0.062	50									
1206	8b colluvial	29	A1	0 - 0.1	6.9	0.031	<5	2.0	0.060	2.2	0.71	0.374	0.018		3	1
1207			A21j	0.25 - 0.35	6.9	0.014	<5			1.3	0.37	0.233	0.015		2	1
1208			A22e/j	0.55 - 0.65	6.6	0.014	<5			1.5	0.70	0.151	0.020		2	1
1209			B2	0.85 - 0.95	6.4	0.018	<5			8.0	3.6	0.518	0.204		12	2
1210			B2	1.15 - 1.25	6.6	0.016	5									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1201	8b insitu	40	A1	0 - 0.1	60	29	3	9	0.89	0.5
1202			A2e	0.25 - 0.35	65	22	5	10	0.87	0.5
1203			B21	0.55 - 0.65	34	13	8	48	0.38	2.9
1204			B22	0.85 - 0.95	34	13	10	44	0.63	2.9
1205				1.15 - 1.25						
1206	8b colluvial	29	A1	0 - 0.1	41	44	7	9	0.79	0.4
1207			A21j	0.25 - 0.35	43	42	7	10	0.85	0.3
1208			A22e/j	0.55 - 0.65	37	44	7	13	0.83	0.5
1209			B2	0.85 - 0.95	26	28	6	41	0.51	2.4
1210			B2	1.15 - 1.25						

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Agricultural Chemistry Pty Ltd
Soil Analysis Report
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Client: Soil Mapping

Lab No	Soil Type	Site	Horizon	Depth	pH	EC	Cl	Pbic	Total-N	Ca	Mg	K	Na	CEC	ECEC	ESP
				m		mS/cm	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%
1211	9a	30		0 - 0.1	6.7	0.048	5	4.0	0.099	5.7	5.5	0.710	0.071		12	1
1212				0.25 - 0.35	7.9	0.041	5			9.7	12.6	0.370	0.303	22		1
1213				0.55 - 0.65	8.9	0.196	85			9.3	16.7	0.255	0.835	25		3
1214				0.85 - 0.95	9.1	0.301	215			7.5	16.0	0.196	0.865	21		4
1215				1.15 - 1.25	9.0	0.355	353									
1246	9b	43	A11/A12	0 - 0.1	6.5	0.060	30	9.5	0.135	14.2	7.0	0.676	0.726		23	3
1247			B21	0.25 - 0.35	8.4	0.069	25			16.7	10.6	0.290	1.9	28		7
1248			B21	0.55 - 0.65	9.0	0.502	475			16.4	17.8	0.308	5.5	37		15
1249			B21	0.85 - 0.95	8.9	0.760	900			16.8	19.3	0.329	5.9	37		16
1250			B22k	1.15 - 1.25	9.0	0.715	810									
1181	5	74	A1p/B21p	0 - 0.1	8.1	0.139	60									
1182			B21k	0.25 - 0.35	8.7	0.252	55									
1183			B22	0.55 - 0.65	8.6	0.473	400									
1184			B23	0.85 - 0.95	7.1	0.935	1165									
1185				1.15 - 1.25	5.0	1.251	1750									

Lab No	Soil Type	Site	Horizon	Depth	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	ADMC
				m	%	%	%	%		%
1211	9a	30		0 - 0.1	17	51	11	23	0.58	1.7
1212				0.25 - 0.35	11	40	10	41	0.42	2.7
1213				0.55 - 0.65	13	34	11	41	0.37	3.7
1214				0.85 - 0.95	33	21	15	34	0.77	2.8
1215				1.15 - 1.25						
1246	9b	43	A11/A12	0 - 0.1	11	31	21	38	0.47	2.8
1247			B21	0.25 - 0.35	17	35	10	39	0.52	2.9
1248			B21	0.55 - 0.65	14	23	14	51	0.66	3.7
1249			B21	0.85 - 0.95	14	19	14	54	0.66	4.2
1250			B22k	1.15 - 1.25						

All results for particle size analysis and R1 are reported on oven-dried basis (no pre-treatment applied to test samples)

Agricultural Chemistry Pty Ltd

METHOD DESCRIPTIONS

Soil

Reference: 13/81

Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	7C2	6.7	1.0	mg/kg	Nitrate-nitrogen	1:5 water extr, (AA) colorimetric
NH4-N	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	9B2	16.8	1.0	mg/kg	Bicarb.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
TN	7A2	12.9	0.01	%	Total Kjeldahl Nitrogen	Sulphuric acid digest, (AA) colorimetric
OC	8B1	9.7	0.02	%	Organic Carbon	Walkley & Black, (H2SO4/K2Cr2O7), titr.
Ca (Neut)	15A1	10.3	0.10	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
Mg (Neut)	15A1	6.6	0.10	meq/100g	Exchangeable magnesium	1M NH4Cl @ pH 7.0 shake, AAS
Na (Neut)	15A1	7.3	0.03	meq/100g	Exchangeable sodium	1M NH4Cl @ pH 7.0 shake, AAS
K (Neut)	15A1	3.9	0.02	meq/100g	Exchangeable potassium	1M NH4Cl @ pH 7.0 shake, AAS
ECEC	15J1	5.0	1	meq/100g	Effective cation ex.capacity	Sum of exchangeable cations
ESP	15N1	5.0	3	%	Exchangeable Na%	(Exchangeable Na/sum of exch.cations)%
Sand	no ref	22.1	1.0	%	Particle size, sand	Hydrometer, gravimetric
Silt	no ref	16.6	1.0	%	Particle size, silt	Hydrometer, gravimetric
Clay	no ref	12.7	1.0	%	Particle size, clay	Hydrometer, gravimetric

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager
Analytical Services: _____

Agricultural Chemistry Pty Ltd

METHOD DESCRIPTIONS

Soil

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Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
Ca (Alc)	15C1	7.2	0.18	meq/100g	Exchangeable calcium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Mg (Alc)	15C1	4.7	0.31	meq/100g	Exchangeable magnesium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Na (Alc)	15C1	9.6	0.09	meq/100g	Exchangeable sodium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
K (Alc)	15C1	4.8	0.02	meq/100g	Exchangeable potassium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
CEC	15I3	5.7	1.0	meq/100g	Cation Exchange Capacity	KNO3 + Ca(NO3)2 extr, (AA) colorimetric
DTPA-Cu	12A1	17.1	0.26	mg/kg	DTPA ext. copper	DTPA extraction, AAS
DTPA-Zn	12A1	16.4	0.10	mg/kg	DTPA ext. zinc	DTPA extraction, AAS
DTPA-Mn	12A1	9.0	0.32	mg/kg	DTPA ext. manganese	DTPA extraction, AAS
DTPA-Fe	12A1	13.0	0.23	mg/kg	DTPA ext. iron	DTPA extraction, AAS
ADMC	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
SO4-S	10B3	11.5	0.6	mg/kg	Sulfate sulfur	Ca(H2PO4)2 @ pH 4.0 extractable sulfate-sulfur, ICPOES
Al	15G1	NA	NA	meq/100g	Exchangeable Aluminium	Exch. Hydrogen and Aluminium by 1M KCl
H+	15G1	NA	NA	meq/100g	Exchangeable Acidity	Exch. Hydrogen and Aluminium by 1M KCl
15 Bar		NA	NA		15 Bar Analysis	Pressure Plate/Gravimetric oven dry @ 105C
1/3 Bar		NA	NA		15 Bar Analysis	Pressure Plate/Gravimetric oven dry @ 105C

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager
Analytical Services: _____

Agricultural Chemistry Pty Ltd

QUALITY CONTROL DATA

Reference: 13/81
Page: 11 of 11

Soil

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Test Method	Units		Actual Value	Acceptance Criteria [Range]
pH	pH	cane	5.3, 5.2,	4.9 - 5.4
EC	dS/m	cane	.041, .043	.031 - .050
Cl	mg/kg	cane	15, 15	12 - 18
NO3-N	mg/kg	cane		0.2 - 1.0
NH4-N	mg/kg	NA		NA
Bicarb.P	mg/kg	51-13	29.5	23 - 34
Total N	%	34-12	.044, .044	.040 - .050
Total P	%	ALS		
Organic Carbon	%	B		1.82 - 2.3
Ca (Exch. cations)pH7	meq/100g	52-13	7.6	7.12 - 8.84
Mg (Exch. cations)pH7	meq/100g	52-13	4.16	3.57 - 4.91
Na (Exch. cations)pH7	meq/100g	52-13	0.591	.463 - .659
K (Exch. cations)pH7	meq/100g	52-13	0.405	.361 - .444
Exch. Acidity	meq/100g			NA
ECEC	meq/100g	A		NA
CEC	meq/100g	S12		58 - 73
ESP	%	A		NA
Coarse sand	%	RD	31, 31, 31, 31	29 -33
Fine Sand	%	RD	31, 30, 30, 30	27 - 32
Silt	%	RD	12, 12, 13, 13	11 - 16
Clay	%	RD	28, 28, 27, 27	21 - 29
R1		RD	.46, .44, .47, .45	.40 - .57

Test Method	Units	Test Soil	Actual Value	Acceptance Criteria [Range]
DTPA-Cu	mg/kg	SB		2.37 - 3.25
DTPA-Zn	mg/kg	SB		3.15 - 3.81
DTPA-Mn	mg/kg	SB		97.7 - 145.0
DTPA-Fe	mg/kg	SB		23.3 - 32.6
Suflate-sulfur	mg/kg	B		6 - 12
ADMC	%			NA
15 Bar	%	G		23 - 30
0.33 Bar	%	G		32 - 51
Ca (Exch. cations)pH8.5	meq/100g	S12	34.7, 36.2	27.7 - 37.4
Mg (Exch. cations)pH8.5	meq/100g	S12	23.2, 24.3	22.88 - 26.5
Na (Exch. cations)pH8.5	meq/100g	S12	2.12, 2.10	2.0 - 2.28
K (Exch. cations)pH8.5	meq/100g	S12	1.769	1.64 - 2.09

Appendix 6 – Soil profile field data for sampled representative sites within the 2013 BNCOP Soil Investigation survey area.

BNCOP 2013 Soil Investigation – Soil 2b
Representative Field Site – 66

Similar to FLO soils @ Headley's.
– See sites 52, 53, 54 + 55 + different to 65
Alkaline throughout – + soft to core (no handle needed)
= Same as Headley – Unit 4C paper
Photos – 8858 – 8867

Becher Sol Finger Area

Soil 2b

SITE DESCRIPTION SHEET

Project: BNCOP | Site: 66 | Obs | TIS Type | Local Authority

Map Sheet | Sheet No | Scale | Rainfall | Geology: Qa | Slope: A05-42% F | Landform Element: PLA | Landform Pattern: FLO | Modal: LP | RMS: GP | Stream Channels | Site Land Use | LU1 | LU2 | E Geomorph | Agent | Mode | Patt Geomorph | Agent | Mode | Status

Desc By: BURJ | Date (ddmmyy): 06 09 13 | CM4 | POT | M Type | L Meas | Obs Reas: 224 | Runoff | Perm | Drainage | M Samp | Aggregin | Depth R Horiz: 999 | Depth to Free Water | Tax Unit: Type: SPC | Code | Map Unit: Type | Code | Photo Meas: East | North | Air Photos: Film No | Run No | Frame No | Obs Land Use | Obs Management Practices | Aspect | Inundation: Freq | Dur | Depth | ROV

Elevation: Elev | Drainage: Eval | Height | Rainforest: For Type | Scleno | Cmpx | FC | Ind | LS | TO | Distance | Conf | Depth: 999 | Substrate: G/S | Str | Por | Str F | Alt | Str | Lith | Gen T | Text | Mass: Str | MDS | MC1 | MC2 | Dat | Location: WGS84 | Zone: 3 | Easting/Latitude: 557850 | Northing/Longitude: 7327648 | Australian Soil Classification: Conf | Sub Ord | GG/ Ord | SG/ Ord2 | SO2 | F1 F2 F3 F4 F5 | PPF | GSG: eff

Microrelief | Erosion | Surf Coarse Frags | Outcrop | Community | Community 1 Details

Disturb | Surf Con | Type | Agent | Cmpt | Prop | VI | HI | Type | Statis | Deg | GD | Abun | Size | Shape | Lith | Str | Abun | Lith | No | Ref No | Name | Strata | Form | Ht C | Co C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

1 GZ (Cleared & cropped) | 2 M | 3 | 4 Strongly cracking

Cleared – brigalow + occ. coolibah

Horizon | Depth: Upper | Lower | Contd | Dist | Shape | Field Texture | Qual | Fabric | SWS | Stickiness | Plas: Type | Deg | Repel | Colour: Hue | V | C | Mottles: Moist | Type | Abun | Size | Contr | Col | Abun | Size | Coarse Fragments: Shape | Lith | Str | Structure: Dist | Grade | Size | Type | Segregations: Cmpd | Abun | Nat | Form | Size | Fabric | Cutans: Type | Abun | Dist | Cracks | Abun | Diam | Pores Strgth: SWS | Cons | Type | Pans: Cmnt | Cont | Str | Size | Abun | Roots: Abun | Sampled Sample

Horizon	Upper	Lower	Field Texture	Hue	V	C	Structure	Pores	Sample	
Ap1	0	0.3	LMC	10 YR	3	1 M	52GR	D4	0–0.1	0.05
Ap2	0.3	0.20	MHC	10 YR	3	1 M	M-53AB	D6	–	
B21	0.20	0.50	HC	2.5 Y	2	1 M	523LE 1KN1	T4	0.25–0.35	0.3
									0.55–0.65	0.6
B22K	0.50	1.50	MHC	2.5 Y	3	2 M	55LE 2KN1	T4	0.85–0.95	0.9
							52LE		1.15–1.25	1.2
						M				
						M				
						M				

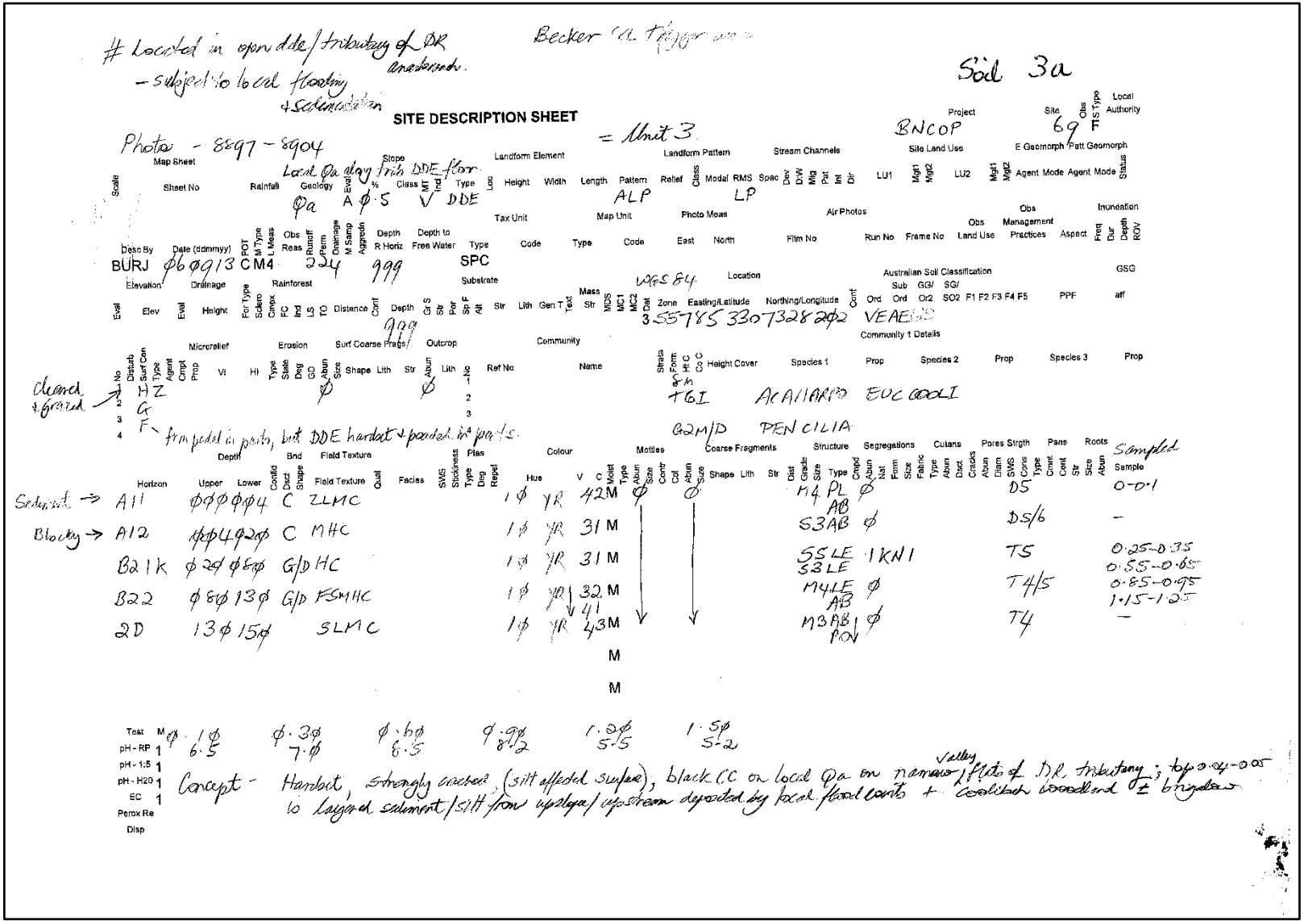
(textures not particularly greasy or slippery)

↑ very highly structured, soft to core + soft consistence

Test	M					
pH - RP	1	0.1 / 7.5	0.3 / 7.5	0.6 / 8.2	0.9 / 8.8	1.2 / 8.8	1.5 / 8.5
pH - 1:5	1					
pH - H20	1					
EC	1					
Perox Re						
Disp						

Concept – Similar to Site 65 but @ lower elevation + much softer + highly structured + alkaline throughout. Unit 4C
– Mod to strong, relatively coarse (52GR, but only <0.03m thick) SM, blank cracking clay on younger Qa – located on map
FLO/LP of DK amphibolite – alkaline @ depth, soft to core + highly structured. = Same as Headley = Unit 4C
See sites 3, 8, 9 Stage 2 + BNCOP 52, 53, 54 + 55.

BNCOP 2013 Soil Investigation – Soil 3a
Representative Field Site – 69



Soil 3a

SITE DESCRIPTION SHEET

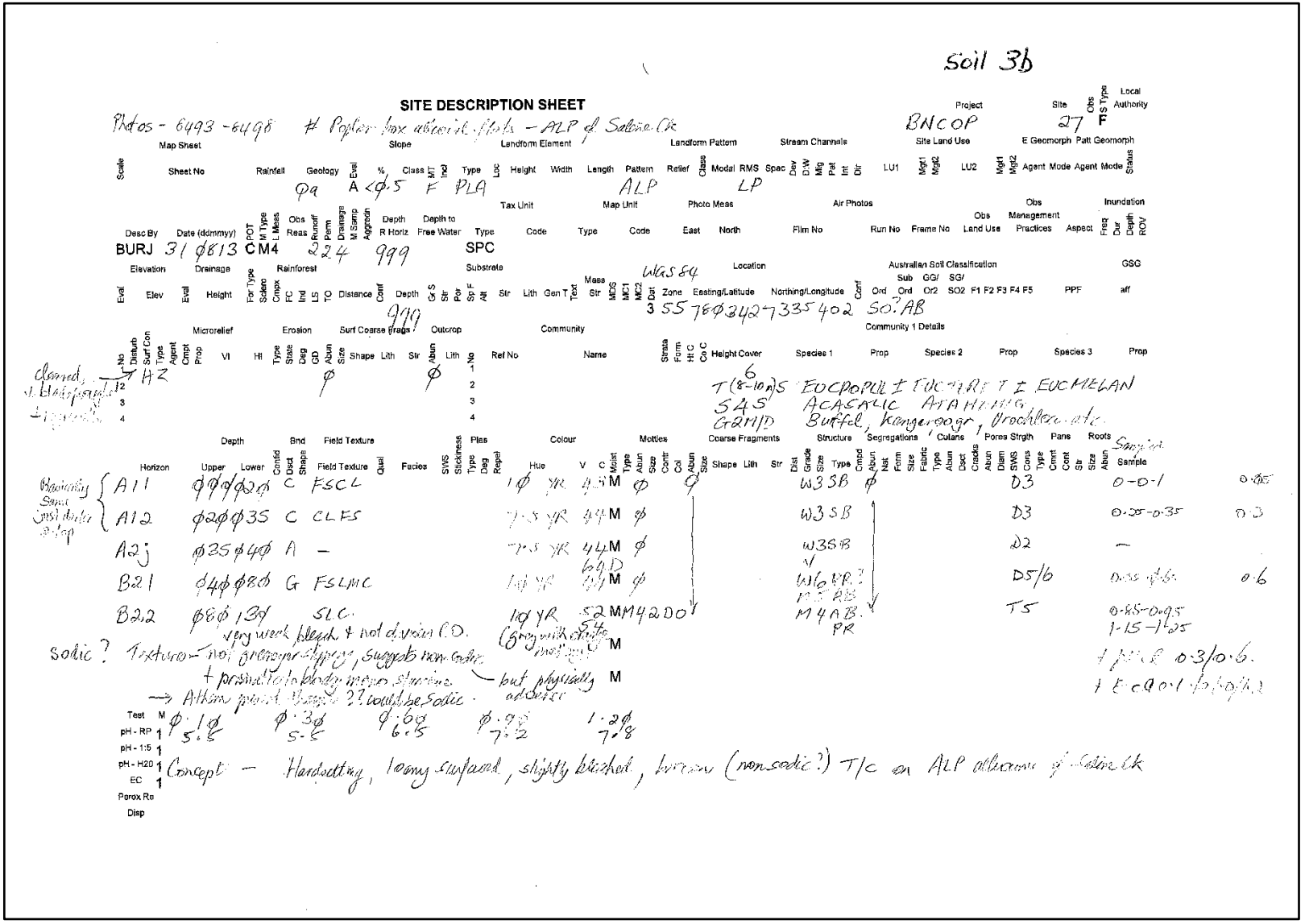
Project: BNCOP
Site: 69
Local Authority:
Photos - 8897 - 8904
= Unit 3
Map Sheet
Sheet No
Rainfall
Geology: Qa
Slope: A Ø·5
Landform Element: V DDE
Landform Pattern: ALP
Stream Channels: LP
Site Land Use
E Geomorph
Patt Geomorph
Desc By: BURJ
Date (ddmmyy): Ø6Ø913
Elevation
Drainage
Rainforest
Substrate: SPC
Depth R Horiz: 999
Depth to Free Water: 999
Tax Unit
Map Unit
Photo Meas
Air Photos
Film No
Run No
Frame No
Obs Land Use
Obs Management Practices
Aspect
Inundation
Location: WGS 84
Zone: 3
Easting/Latitude: 355785
Northing/Longitude: 3307328 2Ø2
Australian Soil Classification: VEAE
Community 1 Details
Microrelief
Erosion
Surf Coarse Frags
Outcrop
Community
Name
Height Cover
Species 1: ACAMARD
Prop: T6I
Species 2: EUCCOOLI
Prop
Species 3
Prop
Prop: G2M/D
Species 2: PENCILIA
Cleared & grazed
Hand pedal in parts, but DDE hardset & pedal in parts.
Sampled

Horizon	Upper	Lower	Field Texture	Hue	V	C	Mottles	Structure	Pores	Sample
Sediment → A11	ØØØØ4	C	ZLMC	1Ø YR	42	M	Ø	M4 PL AB Ø	D5	0-0·1
Blocky → A12	ØØ44Ø2Ø	C	MHC	1Ø YR	31	M		S3AB Ø	D5/6	–
B21k	Ø2Ø Ø6Ø	G/D	HC	1Ø YR	31	M		SSLE 1KN1 S2LE	T5	0·25-0·35 0·55-0·65
B22	Ø6Ø 13Ø	G/D	FSMHC	1Ø YR	32 41	M		M4LE AB Ø	T4/5	0·85-0·95 1·15-1·25
2D	13Ø 15Ø		SLMC	1Ø YR	43	M		M3AB RON Ø	T4	–

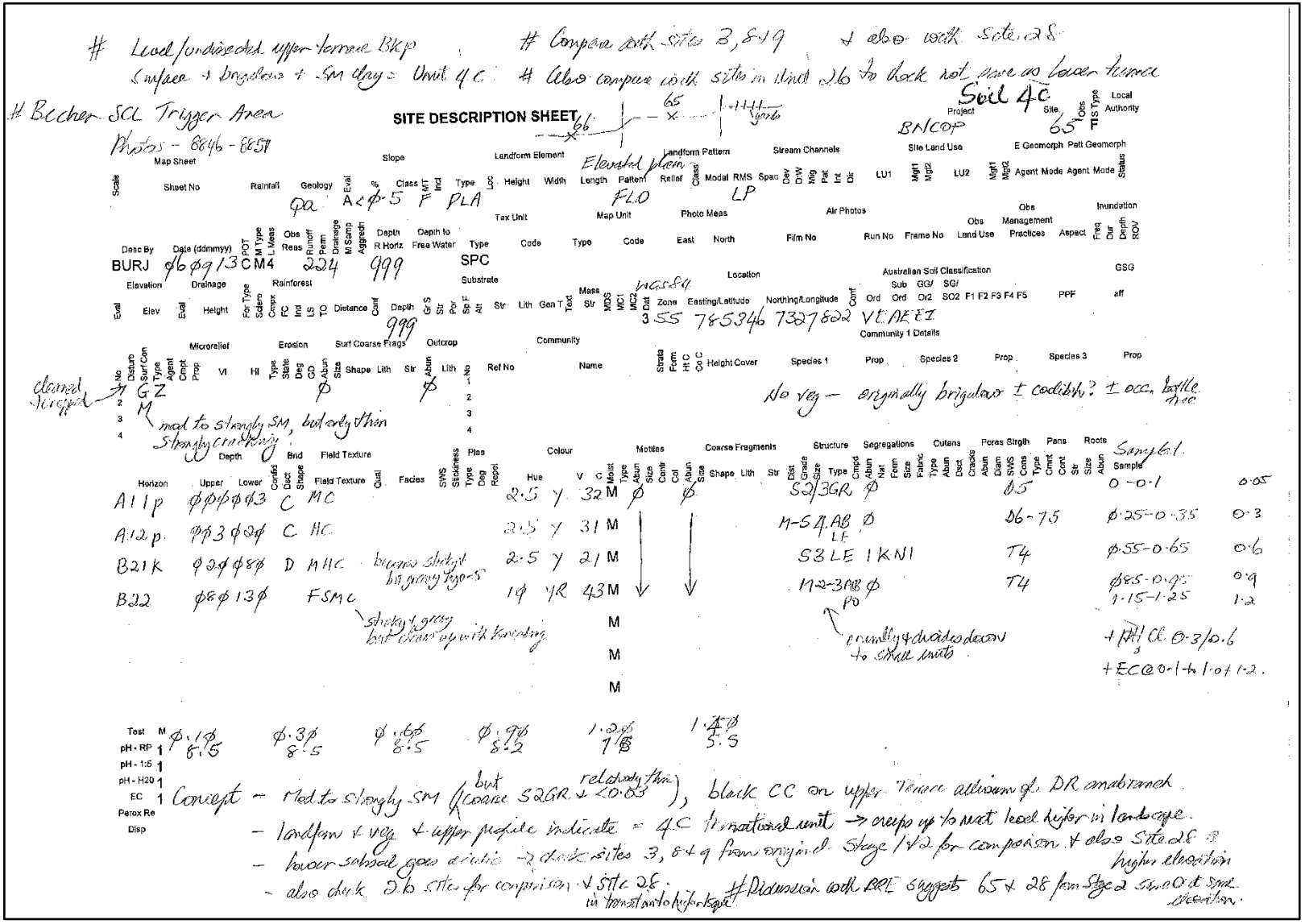
Test	M					
pH - RP	1	Ø·1Ø 6·5	Ø·3Ø 7·Ø	Ø·6Ø 6·5	Ø·9Ø 8·2	1·2Ø 5·5	1·5Ø 5·2
pH - 1:5	1						
pH - H2O	1						
EC	1						
Perox Re							
Disp							

Concept - Hardset, strongly cracked (silt affected surface), black CC on local Qa on narrow valley floor of D.R. tributary; top 0·04-0·05 to layered sediment/silt from upslope/upstream deposited by local flood events + Coolibah woodland ± brigalow

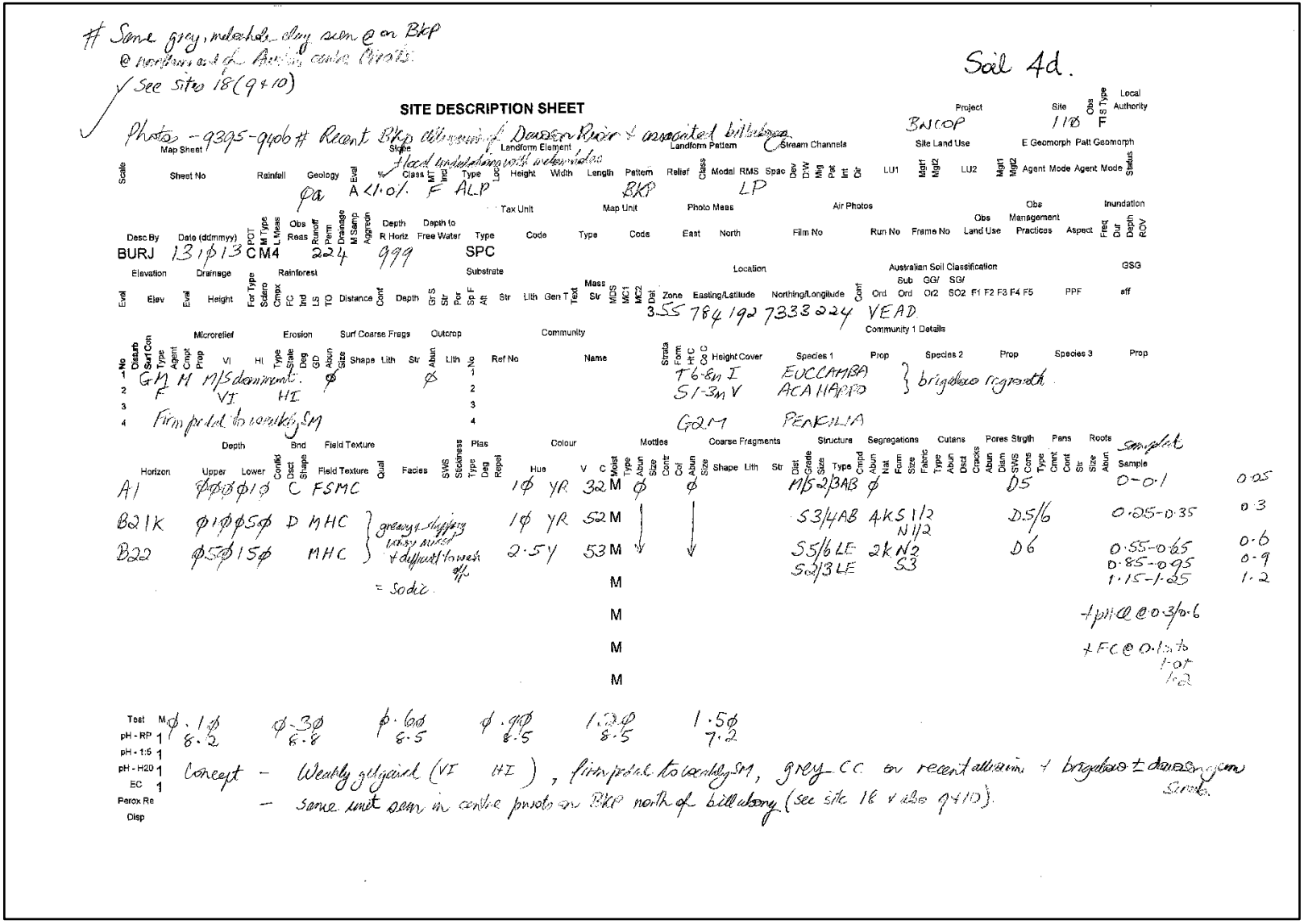
BNCOP 2013 Soil Investigation – Soil 3b
Representative Field Site – 27



BNCOP 2013 Soil Investigation – Soil 4c
Representative Field Site – 65



BNCOP 2013 Soil Investigation – Soil 4d
Representative Field Site – 110



Soil 4d.

SITE DESCRIPTION SHEET

Project: BNCOP
Site: 110

Desc By: BURJ
Date (ddmmyy): 131013
Map Sheet: CM4
Rainfall: 224
Geology: Qa
Slope: A <1.0%
Landform Element: F
Landform Pattern: ALP
Stream Channels: BKP
Relief: LP
Site Land Use: 999
Elevation: SPC
Drainage:
Rainforest:
Tax Unit:
Map Unit:
Photo Mess:
Air Photos:
Location: 3.55 784192 7333224
Easting/Latitude:
Northing/Longitude:
Australian Soil Classification: VEAD
Community 1 Details:
Microrelief:
Erosion:
Surf Coarse Frags:
Outcrop:
Community:
Substrate:
Mass:
Inundation:
GSG:

Soil 4d. Sample

Horizon	Upper	Lower	Field Texture	Colour	Structure	Sample	
A1	0	0.10	C FSMC	10YR 32 M	M/S 2/3AB	0–0.1	0.05
B21K	0.10	0.50	D MHC	10YR 52 M	S 3/4AB AKS 1/2 N 1/2	0.25–0.35	0.3
B22	0.50	1.50	MHC	2.5Y 53 M	S 5/6 LE 2k N2 S 2/3 LE S3	0.55–0.65	0.6
				M		0.85–0.95	0.9
				M		1.15–1.25	1.2
				M		+ pH @ 0.3/0.6	
				M		+ EC @ 0.1 to 1.0 1.2	
				M			

greyish, slightly wavy mottles + diffuse to weak effl. = Sodic

Test	M					
pH - RP 1	0.10 8.2	0.30 8.8	0.60 8.5	0.90 8.5	1.20 8.5	1.50 7.2
pH - 1:5 1						
pH - H20 1						
EC 1						
Perox Re						
Disp						

Concept – Weakly gilgaied (VI HI), firm pedal to weakly SM, grey CC on recent alluvium + brigalow ± dawson gum scrub.
– Same unit seen in centre pivot on BKP north of billabong (see site 18 + also 9+10).

Same grey, mottled clay seen @ on BKP @ northern end of Austin centre pivots. ✓ See sites 18 (9+10)

Photos – 9395–9406 # Recent BKP alluvium of Dawson River + associated billabong. Flood inundation with wetlands

BNCOP 2013 Soil Investigation – Soil 5
Representative Field Site – 71

Drilling photos - 8923 - 8928 Cattle - 8937-8939 Becker SA Trigger Area

See typical rep site for details - Site 87

Soil 5

SITE DESCRIPTION SHEET

8920-8922 veg

Photos - 8924 # Cza-Qa transitional unit. - dissected Cza plain

8936

Cza-Qa ?

Project: BNCOP | Site: 71 | Obs Type: F | Local Authority:

Map Sheet | Scale | Sheet No | Rainfall | Geology: Cza ? | Slope: A 1.0 | % | Class: F | MT Incl | Type: PLA | Loc | Landform Element: Height | Width | Length | Pattern: PLA | Relief | Landform Pattern: Class | Modal | RMS: LP | Stream Channels: Spec | Dev | D/W | Mig | Pat | Int | Dir | Site Land Use: LU1 | Mgt1 | Mgt2 | LU2 | Mgt1 | Mgt2 | E Geomorph: Agent | Mode | Patt Geomorph: Agent | Mode | Status

Desc By: BURJ | Date (ddmmyy): 160913 | POT M Type | L Meas | Obs Reas: CM4 | Runoff | Perm | Drainage | M Samp | Aggresh | Depth R Horiz: 224 | Depth to Free Water: 999 | Tax Unit Type: SPC | Code | Map Unit Type | Code | Photo Meas East | North | Air Photos Film No | Run No | Frame No | Obs Land Use | Obs Management Practices | Aspect | Inundation Freq | Dur | Depth | ROV

Elevation Eval | Elev | Drainage Eval | Height | Rainforest For Type | Sclero | Cmpx | FC | Ind | LS | TO | Distance | Conf | Depth: 999 | Substrate Gr S | Str | Por | Sp F | Alt | Str | Lith | Gen T | Text | Mass Str | MDS | MC1 | MC2 | Location Dat: WGS84 | Zone: 3 | Easting/Latitude: 557842 | Northing/Longitude: 7328421 | Conf | Australian Soil Classification Ord | Sub Ord | GG/ Or2 | SG/ SO2 | F1 | F2 | F3 | F4 | F5 | PPF | GSG aff

Microrelief Type | Slope | Erosion Type | Slope | Deg | GD | Abun | Size | Surf Coarse Frags Shape | Lith | Str | Abun | Outcrop Lith | Str | Abun | Community No | Ref No | Name | Strata Form | Ht | C | Co C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop | Community 1 Details

Disturb | Surf Con | Type | Agent | Cmpt | Prop | VI | HI

No	Disturb	Surf Con	Type	Agent	Cmpt	Prop	VI	HI
1		G						
2		M						
3								
4								

cleared & cropped (oats)

mod to strong cracking; mod thin SM

No	Ref No	Name	Strata Form	Ht	C	Co C	Height Cover	Species 1	Prop	Species 2	Prop	Species 3	Prop
1			(7m)										
2													
3													
4													

T6M ACAHARPO scrub.

Horizon	Depth Upper	Depth Lower	Conf	Dist	Bnd Shape	Field Texture	Qual	Facies	SWS	Stickiness	Plas Type	Deg	Repel	Colour Hue	V	C	Moist	Mottles Type	Abun	Size	Contr	Col	Abun	Coarse Fragments Size	Shape	Lith	Str	Structure Dist	Grade	Size	Type	Segregations Cmpd	Abun	Nat	Form	Size	Cutans Type	Abun	Dict	Cracks	Pores Abun	Diam	Strgth SWS	Cons	Pans Type	Cmnt	Cont	Str	Roots Size	Abun	Sampled Sample
A11p	0-0.03		C		MC									10 YR	3	1	M	0										S2GR	0												D4										0-0.1
B21p	0.03-0.20		C		MHC									10 YR	3	1	M											M4AB	1KN1												D6										—
B22	0.20-0.70		D		HC - slightly sticky									10 YR	3	2	M											S5LE	1KN1												T6										0.25-0.35
																																																		0.55-0.65
B23	0.70-0.15		F		MHC	slightly sticky, slightly plastic								7.5 YR	4	3	M	M 22DR										W5LE	0												T3										0.85-0.95
																												M4AB	0												T4										1.15-1.25
																		M																																
																		M																																
																		M																																

texture — poss sodic in B22/B23 — check EC bulge

this colour + acid pH typical in lower subsoil on transitional Cza-Qa terrace/plain dissected.

+ pHca 0.3/0.4

+ EC @ 0.1 to 1.0 & 1.2m

Test	M						
pH - RP	1	0.10	0.30	0.60	0.90	1.20	1.50
pH - 1:5	1	8.5	9.0	9.0	7.2	5.5	4.8
pH - H20	1						
EC	1						
Perox Re							
Disp							

Concept – Mod SM (S2GR), cracking, nongilgaied, black CC on Cza-Qa transition & dissected plain/terrace of DR analogue

thin Lo03 ✓ coarse in subsoil

+ brigalow sand (no Euc, stunted scrub)

- See also BB35 + Site 65 (Stage 2) = same unit.
- See site 65 = same as, but this site slightly more elevated & dissected (65 still 1m² below level of intact plain on eastern side)

BNCOP 2013 Soil Investigation – Soil 7a
Representative Field Site – 88

Typical melonhole Cza site for analysis

✓ # Typical melonhole gilgai 70-6 on Cza + brigalow.

Soil 7a

SITE DESCRIPTION SHEET

Photos – 9070-9078 # Located in large melonhole Cza plain

Project: BNCOP | Site: 88 | Obs Type: TI | Local Authority:

Map Sheet | Scale | Sheet No | Rainfall | Geology: Cza | Slope: A<0·5 | Landform Element: F PLA | Height | Width | Length | Landform Pattern: PLA | Relief | Stream Channels: LP | Site Land Use | E Geomorph | Patt Geomorph | Status

Desc By: BURJ | Date (ddmmyy): 090913 | POT | M Type: CM4 | L Mass | Obs Reas: M224 | Runoff: D113 | Perm | Drainage | M Samp | Aggregn: 999 | Depth R Horiz | Depth to Free Water | Tax Unit: SPC | Map Unit | Photo Maps | Air Photos | Obs Management Practices | Inundation Freq Dur Depth ROV

Elevation | Drainage | Rainforest | Substrate | Location: WGS84 | Australian Soil Classification

Eval | Elev | Eval | Height | For Type | Sidero | Cmpx | FC | Ind | LS | FO | Distance | Conf | Depth: 999 | Gr-S | Str | Por | Sp F | Alt | Str | Lith | Gen T | Text | Mass Str | MDS | MC1 | MC2 | Dat | Zone: 3 | Easting/Latitude: 557850 | Northing/Longitude: 7147330 | Conf | Ord | Sub Ord | GG/ Or2 | SG/ SO2 | F1 | F2 | F3 | F4 | F5 | PPF | aff

Microrelief | Erosion | Surf Coarse Frags | Outcrop | Community | Community 1 Details

No | Disturb | Surf Con | Type | Agent | Cmpt | Prop | VI | HI | Type | State | Deg | GD | Abun | Size | Shape | Lith | Str | Abun | Lith | No | Ref No | Name | Strata | Form | Ht C | Co C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

Closed depression

1 GMA M 0·7 12-15m. 0
2 F
3 H
4

mainly v. deep about equal deep relatively clayey spread + well defined

T6I EUCCAMBA (acc)
S4I ACAHARPO

Depth | Bnd | Field Texture | Plas | Colour | Mottles | Coarse Fragments | Structure | Segregations | Cutans | Pores Strgth | Pans | Roots | Sampled

Horizon | Upper | Lower | Comfld | Dist | Shape | Field Texture | Qual | Facies | SWS | Stickiness | Type | Deg | Repel | Hue | V | C | Moist | Type | Abun | Size | Contr | Col | Abun | Size | Shape | Lith | Str | Dist | Grade | Size | Type | Cmpd | Abun | Nat | Form | Size | Fabric | Type | Abun | Dist | Cracks | Abun | Diam | SWS | Cons | Type | Cmnt | Cont | Str | Size | Abun | Sample

Horizon	Upper	Lower	Field Texture	Facies	Colour	Structure	Pores Strgth	Sampled	
A1	0000	0·10	C LMC	Sticky	10YR 31 M	M/S3AB 0	D5	0–0·1	0·05
B21K	0·10	0·40	G MHC	Sticky grey	10YR 31 M	S3AB 1KS1	T6	0·25–0·35	0·3
B22	0·40	0·60	D MC		10YR 41 M	M5LE 0 / M3AB	T6	0·55–0·65	0·6
B23	0·60	1·40			10YR 52 M	M/S3AB PDJ 0	T5/6.	0·85–0·95 / 1·15–1·25	0·9
					M				
					M				
					M				

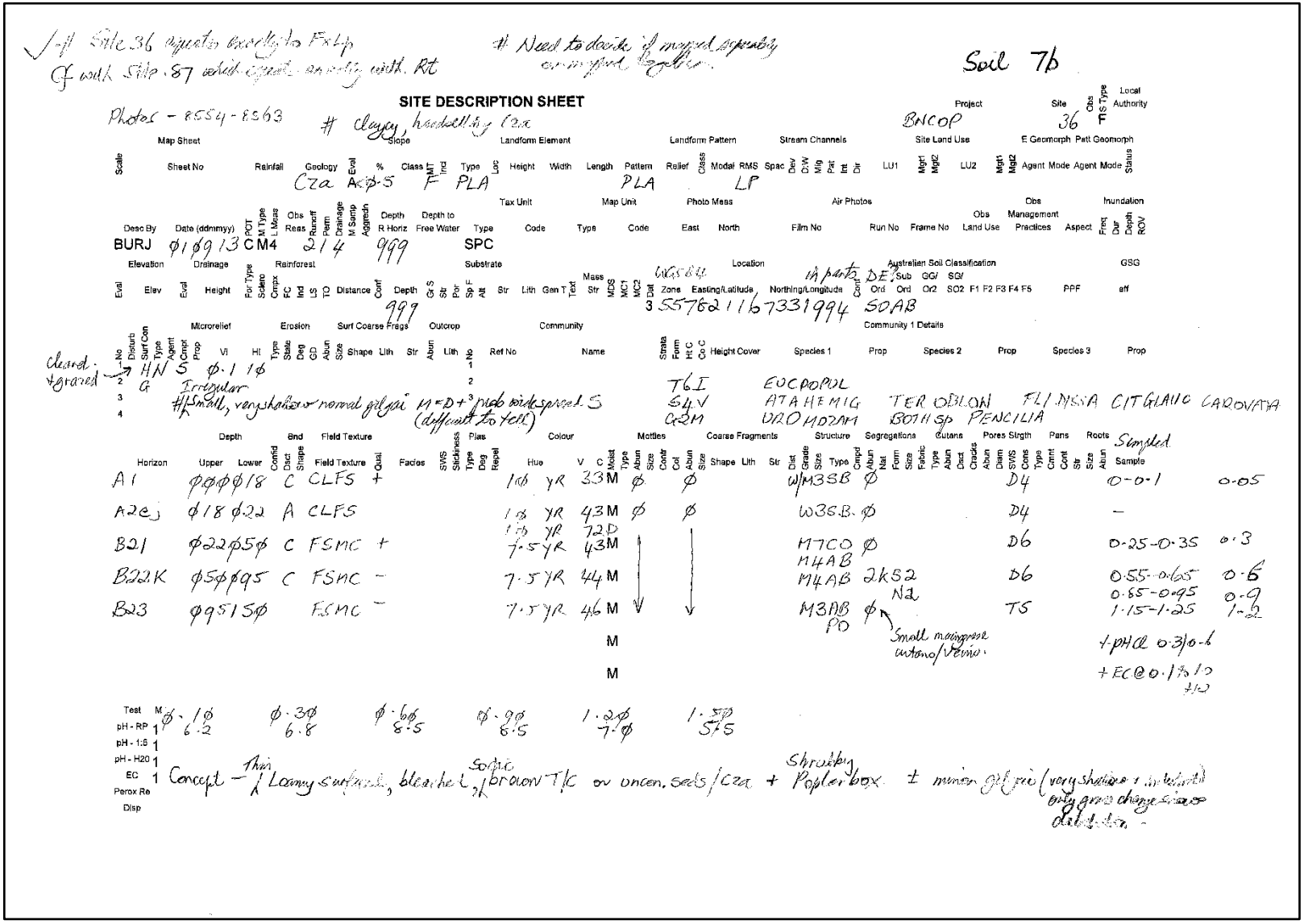
typical Cza acid subsoil clay.

+pHCa 0·3/0·6
+ECe 0·1 to 1·0m/1:10

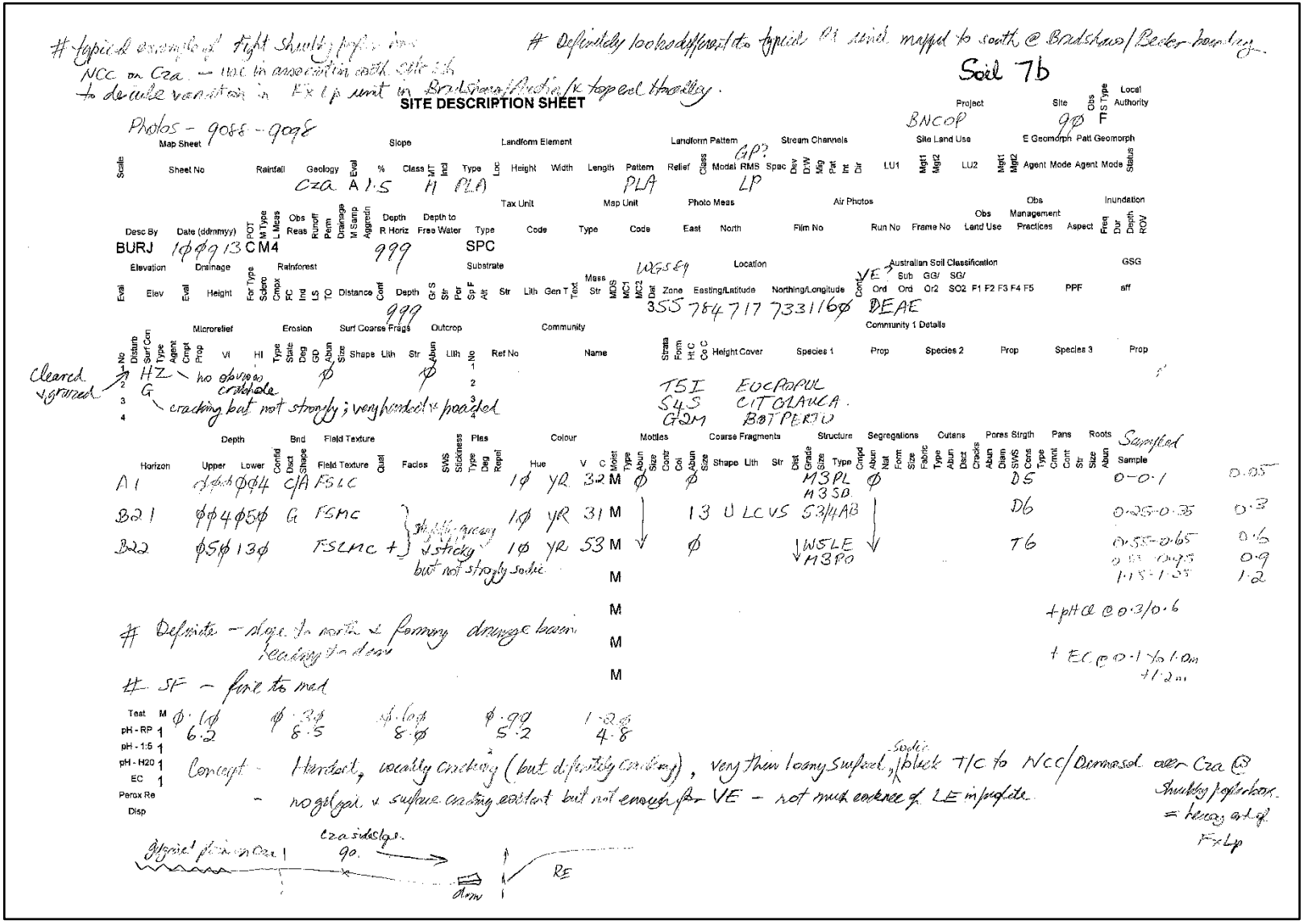
Test	M	0·10	0·20	0·60	0·90	1·20	1·50
pH - RP	1	6·2	8·5	8·0	5·5	5·2	4·8
pH - 1:5	1						
pH - H20	1						
EC	1						
Perox Re							
Disp							

Concept – Hardset to firm pedal (mainly v. deep), strongly cracking, grey CC w well developed melonhole gilgai on Cza with brigalow + ex blackbutt (not shrinking) – typical Cza melonhole. VI 0·6–0·8m HI 12–15m.

BNCOP 2013 Soil Investigation – Soil 7b
Representative Field Site – 36



BNCOP 2013 Soil Investigation – Soil 7b
Representative Field Site – 90



BNCOP 2013 Soil Investigation – Soil 7c
Representative Field Site – 99

Soil 7c

SITE DESCRIPTION SHEET

✓ Photos – 9288 – 9306 Relict Qa/Cza

Project: BNCOP Site: 99

Desc By: BURJ Date (ddmmyy): 11/ϕ13 POT: CM4 Obs Reas: 2/ϕ4 Runoff: Perm: Drainage: M Samp: Agg/eth: 999 Depth R Horiz: Depth to Free Water: Type: SPC

Map Sheet: Sheet No: Rainfall: Geology: Qa/Cza A Slope: % ϕ·5 Class: F Type: PLA Height: Width: Length: Pattern: R1S Relief: Modal RMS: GR

Tax Unit: Map Unit: Photo Meas: East: North: Air Photos: Flm No: Run No: Frame No: Obs Land Use: Management Practices: Aspect: Inundation: Freq: Dur: Depth: ROV:

Elevation: Elev: Drainage: Height: Rainforest: For Type: Distance: Substrate: Str: Lith: Gen T: Text: Mass Str: Location: Zone: 3 Easting/Latitude: 557864ϕ6 Northing/Longitude: 733ϕ8ϕ1 Australian Soil Classification: Ord: SO AB GSG: aff

Microrelief: VI: HI: Erosion: Type: State: Deg: GD: Abun: ϕ Surf Coarse Frags: Shape: Lith: Str: Outcrop: Abun: ϕ Community: Ref No: Name: Community 1 Details: Height Cover: Species 1: SLi ± Crows Ash ± BG Prop: Species 2: Prop: Species 3: Prop:

Cleared & grazed. HZ

Thin soft sandy veneer

shrubby woodland with thick shrubby understory ± bottle trees ≈ softwood scrub association.

Originally dark scrub like photo patterns.

Sampled.

Horizon	Upper	Lower	Confd	Dist	Shape	Field Texture	Qual	Facies	Colour Hue	V	C	Mottles Abun	Size	Coarse Fragments Abun	Size	Structure Grade	Size	Type	Segregations Abun	Pores Diam	Roots Abun	Sample	
A1	ϕϕϕ	ϕ2ϕ	C			LS			7·5 YR	32	M	ϕ		ϕ		W3SB			ϕ	D3		0–0·1	0·05
A21	ϕ2ϕ	ϕ5ϕ	G			SL	–		1ϕ YR	43	M									D3/4		0·25–0·35	0·3
A22j	ϕ5ϕ	ϕ65	A			LS			1ϕ YR	53	M 63	D								D3/4		–	–
B2	ϕ65	13ϕ				SMC		Slightly stony gritty but stony ϕ	1ϕ YR 2·5 Y	53 53	M M M	M32FG 32DO				M7CO M4AB				D6		0·65–0·75 0·85–0·95 1·15–1·25	0·7 0·9 1·2

Med. Sf throughout

+ pHCl 0·3/0·6

+ EC @ 0·1 to 1·0 +1·2m

Test	M				
pH - RP	1	ϕ·1ϕ 5·5	ϕ·3ϕ 5·8	ϕ·6ϕ 6·8	ϕ·9ϕ 6·8	1·2ϕ 7·8–8·0.
pH - 1:5	1					
pH - H20	1					
EC	1					
Perox Re						
Disp						

Concept – Thick sandy surfaced, spordically bleached, mottled, brown sodic? T/c on relict Qa/Cza + very shrubby SLi-softwood scrub association.

– Exactly same as site 93 ; same not as 77, 80, 83, 85, 86. ↓ 97

BNCOP 2013 Soil Investigation – Soil 7d
Representative Field Site – 87

Typical sample of heavy T/C of Cza Unit 7b = same as northern end of Hoadleys. (to represent site 72 etc)

lack of shrubby understorey is obvious; compare with Softwood Swamp shrubby influence to south in relict Qa units.

✓ all typical sites for brigalow & brigalow blackwood sites 78, 83, 84, 86 etc.

Soil 7d

SITE DESCRIPTION SHEET

Project: BNCOP | Site: 87 | Obs Ty: TI S | Local Authority:

Photos – 9059 – 9069

Map Sheet: Scale; Sheet No | Rainfall | Geology: Cza | Slope: Eval A; % ϕ5; Class F; MT; Ind | Landform Element: Type PLA; Loc; Height; Width; Length | Landform Pattern: Pattern PLA; Relief; Class | Stream Channels: Modal RMS LP; Spec; Dev; D-W; Mig; Pat; Int; Dir | Site Land Use: LU1; Mgt1; Mgt2; LU2; Mgt1; Mgt2 | E Geomorph: Agent Mode | Pat Geomorph: Agent Mode; Status

Desc By: BURJ | Date (ddmmyy): ϕ9ϕ913 | POT; M Type: CM4; L Meas | Obs Reas | Runoff; Perm; Drainage; M Samp; Aggrcdn | Depth R Horiz: 999 | Depth to Free Water | Tax Unit: Type SPC; Code | Map Unit: Type; Code | Photo Meas: East; North | Air Photos: Film No; Run No; Frame No | Obs Land Use | Obs Management Practices | Aspect | Inundation: Freq; Dur; Depth; ROV

Elevation: Eval; Elev | Drainage: Eval; Height | Rainforest: For Type; Sclero; Cmpx; FC; Ind; LS; TO; Distance | Conf; Depth 999 | Substrate: Gr S; Str; Por; Str F; Alt; Str; Lith; Gen T; Text; Mass Str; MDS; MC1; MC2 | Location: Dat WGS84; Zone 3; Easting/Latitude 557851; Northing/Longitude 7329628 | Australian Soil Classification: Conf; Ord; Sub Ord; GG/ Or2; SG/ SO2; F1 F2 F3 F4 F5 | PPF | GSG: aff

Microrelief: No; Disturb; Surf Con; Type H; Agent; Cmpt; Prop | Erosion: VI; HI; Type; State; Deg; GD; Abun ϕ; Size | Surf Coarse Frags: Shape; Lith; Str | Outcrop: Abun ϕ; Lith | Community: No 1 2 3 4; Ref No; Name | Community 1 Details: Stratum; Form; Ht C; Co C; Height Cover; Species 1; Prop; Species 2; Prop; Species 3; Prop

Cleared & grazed

Horizon	Depth Upper	Depth Lower	Bnd Confid	Bnd Dist	Bnd Shape	Field Texture	Qual	Facies	SWS	Stickiness	Plas Type	Plas Deg	Plas Repel	Colour Hue	V	C	Mottles Moist	Type	Abun	Size	Coarse Fragments Comf	Col	Abun	Size	Shape	Lith	Str	Structure Dist	Grade	Size	Type	Segregations Cmpd	Abun	Nat	Form	Size	Cutans Fabric	Type	Abun	Dist	Pores Strgth Cracks	Abun	Diam	SWS	Pans Coms	Type	Cmnt	Cont	Str	Roots Size	Abun	Sample
A1	ϕϕϕϕ18		C			CLFS								1ϕ YR	3	1	M		ϕ				ϕ					W3SB	ϕ													D4										0–0·1
A2j	ϕ18ϕ2ϕ		A			CLFS								1ϕ YR	4 / 6	1 / 1	M / D											W3SB	ϕ													D3										—
B21	ϕ2ϕϕ5ϕ		G			FSMC								1ϕ YR	3	1	M											M/S4AB	ϕ (W5CO)													D5/6										0·25–0·35
B22	ϕ5ϕ11ϕ		G			FSLMC+								7·5 YR	4	3	M	M	1	1	F	O						M/S3AB	1	K	S2												D5										0·55–0·65 0·85–0·95
B23	11ϕ15ϕ					FSLMC								1ϕ YR	5 / 6	3 / 3	M	M	1	2	F	O						M/S3AB	2	K	S2												D5										1·15–1·25

almost strong Pr in B22, B23.

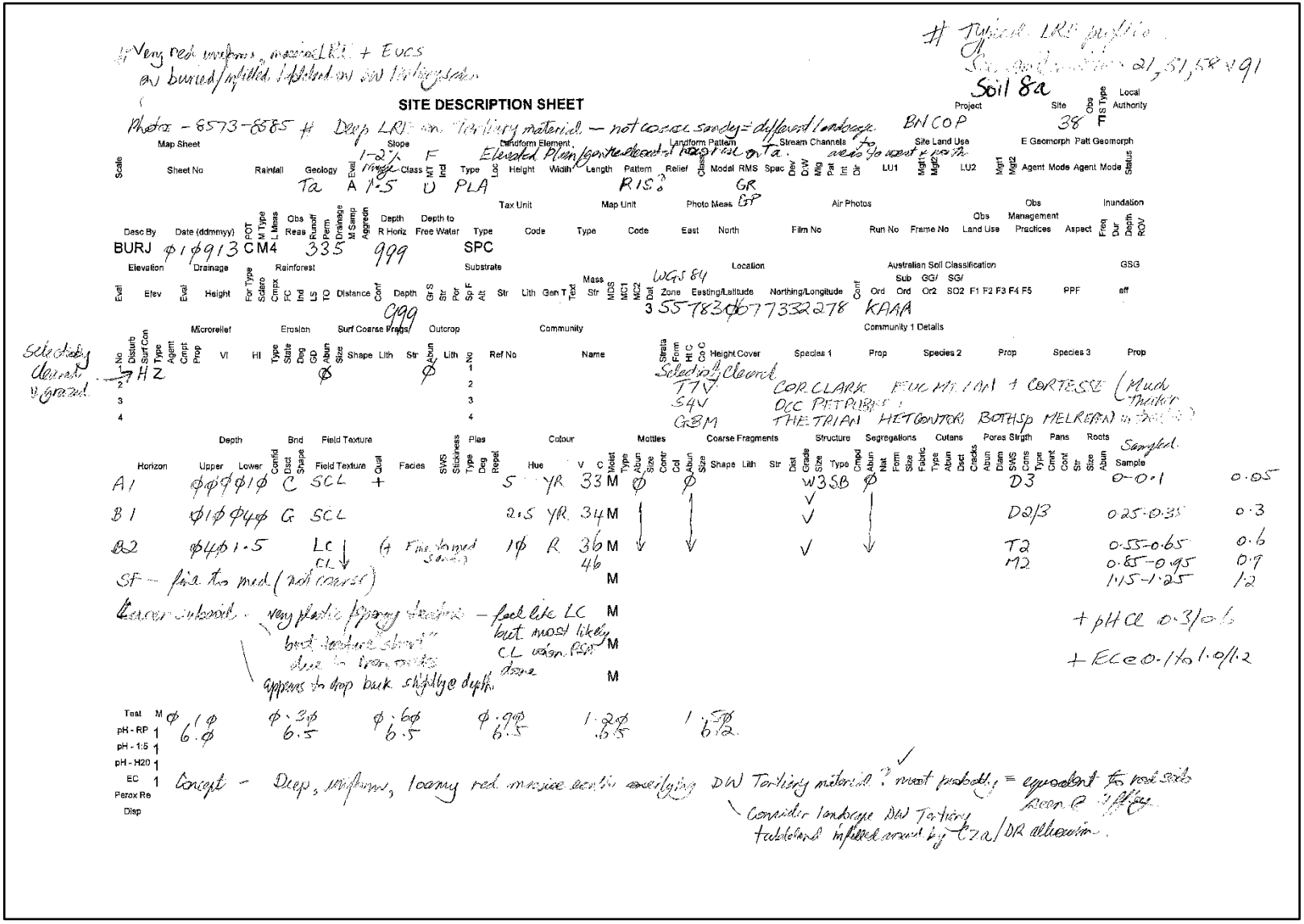
Sampled: 0–0·1; —; 0·25–0·35; 0·55–0·65; 0·85–0·95; 1·15–1·25; + pHc 0·3/0·6; + EC @ 0·1/0·1·0 +1·2

Test	M					
pH - RP	1	ϕ·1ϕ	ϕ·2ϕ	ϕ·6ϕ	ϕ·9ϕ	1·2ϕ	1·5ϕ
pH - 1:5	1	6·2	8·ϕ	9·ϕ	9·ϕ	8·5	7·8
pH - H20	1						
EC	1						
Perox Re							
Disp							

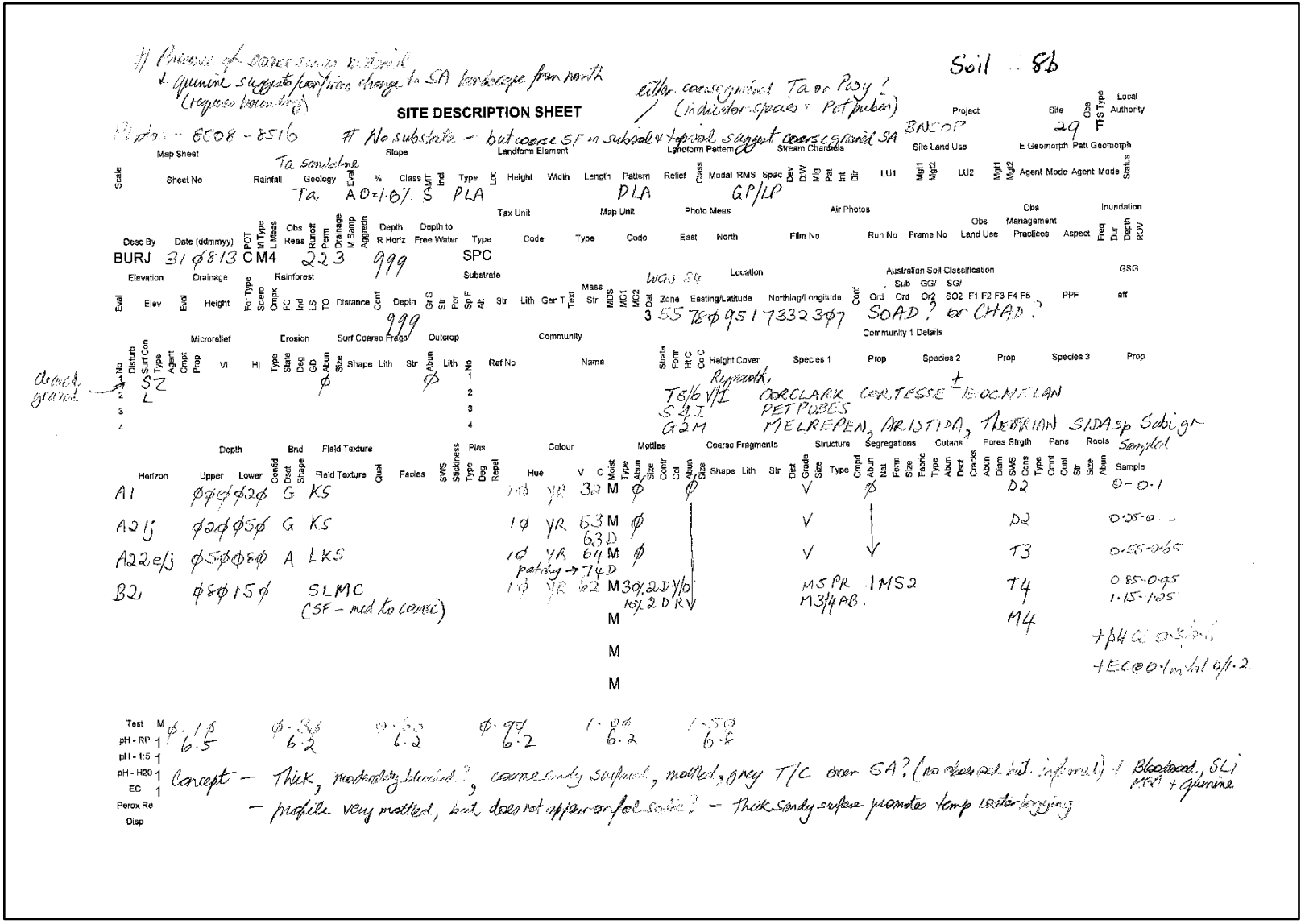
Concept. – Hardset loamy surface, sodic black T/C on Cza w brigalow & blackbutt scrub (not shrubby).
– appears to be distinction between this soil (site 87 ✓ possibly 79) & brigalow–limebush T/C south of Bechers house ✓ around his shed.
– suggests 2 soils ① classic hardset / slightly cracking Cza T/C or NCC + brigalow
② specific relict Qa? around loamy T/C (not SF) + limebush in relict Qa area near vicinity of anabranch. (See site 79) etc.

Site 72 could be either in wallumbilla – @ interface

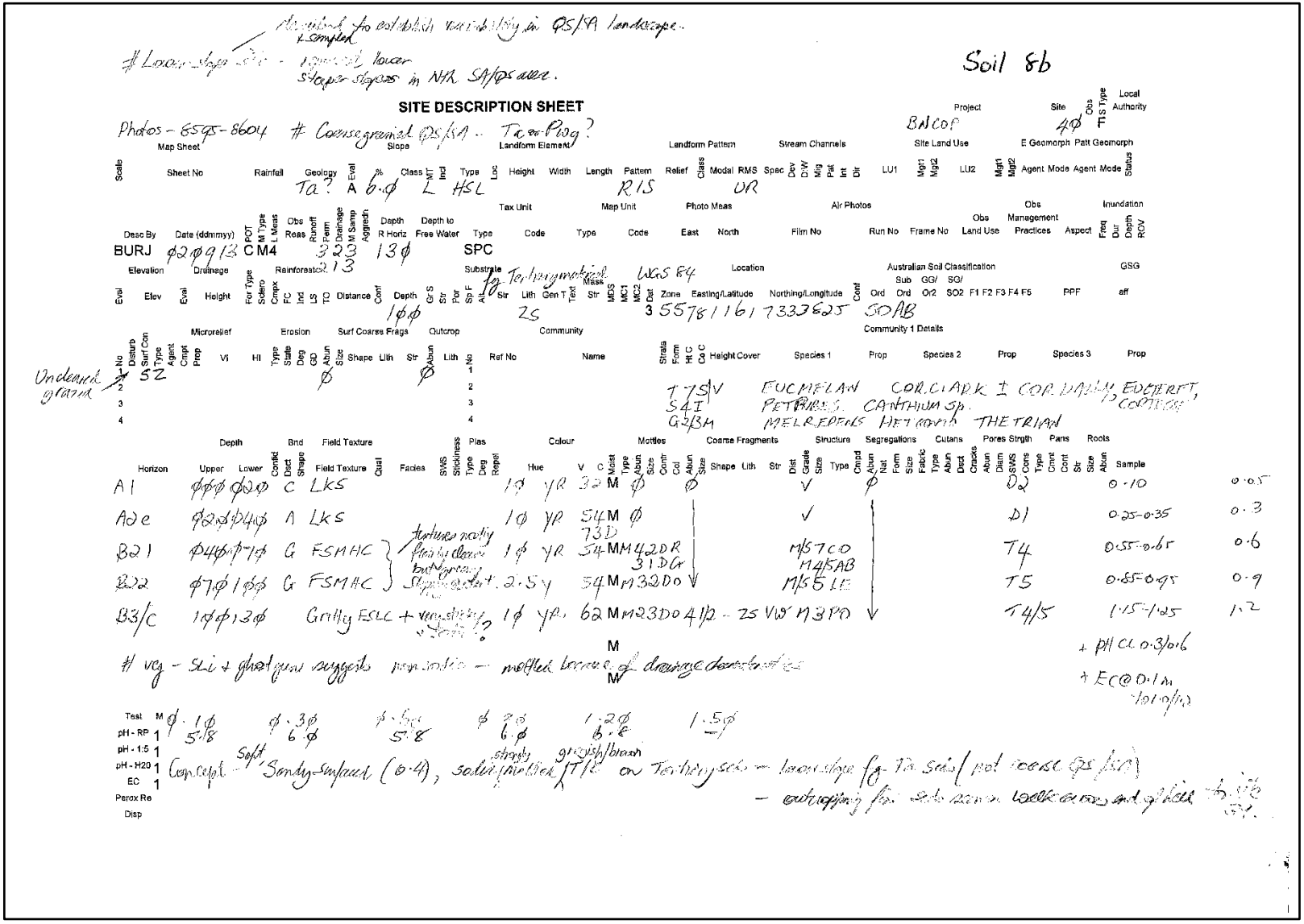
BNCOP 2013 Soil Investigation – Soil 8a
Representative Field Site – 38



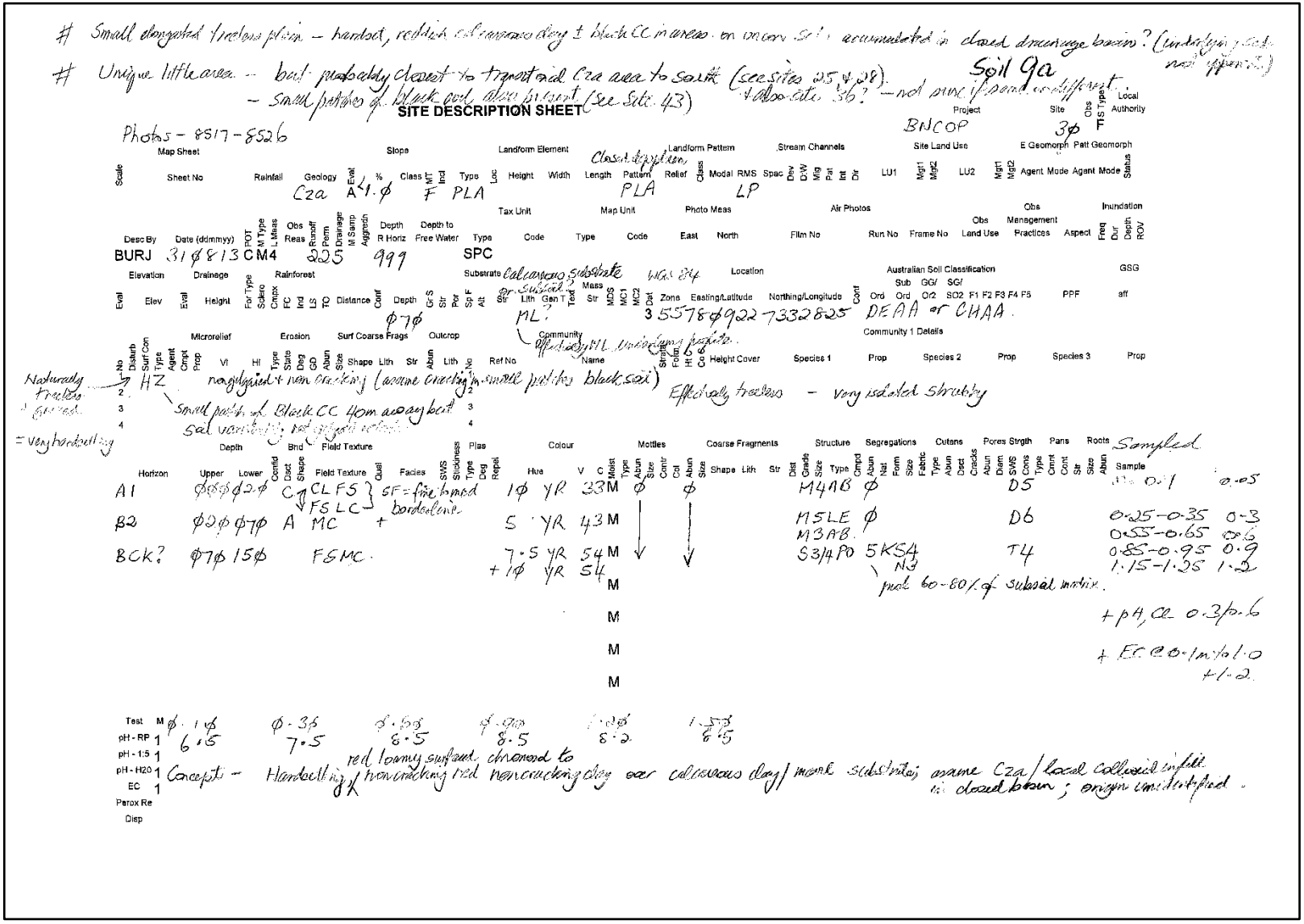
BNCOP 2013 Soil Investigation – Soil 8b
Representative Field Site – 29



BNCOP 2013 Soil Investigation – Soil 8b
Representative Field Site – 40



BNCOP 2013 Soil Investigation – Soil 9a
Representative Field Site – 30



BNCOP 2013 Soil Investigation – Soil 9b
Representative Field Site – 43

Narrow black soil open DDE/flat – part of treeless plain complex associated with softer Permian or Tertiary soils?

Soil 9b

SITE DESCRIPTION SHEET

Photos – 8618–8630 Tertiary Soils (Permian?) – mod lithy with outcropping Permian Soils – pale grey calc SA (very weathered sand grains visible in matrix)

Project: BNCOP | Site: 43 | Local Authority

Map Sheet | Slope | Landform Element | Landform Pattern | Stream Channels | Site Land Use | E Geomorph | Patt Geomorph

Scale | Sheet No | Rainfall | Geology ? | Eval A4b·5 | % | Class F | Type PLA | Height | Width | Length | Pattern PLA | Relief | Modal | RMS LP | Spac | LU1 | LU2 | Agent | Mode | Agent | Mode | Status

Tax Unit | Map Unit | Photo Meas | Air Photos | Obs Management | Inundation

Desc By BURJ | Date (ddmmyy) 02 09 13 | CM4 | Obs Reas 224 | Runoff | Perm | Drainage | Aggregth 999 | Depth R Horiz | Depth to Free Water | Type SPC | Code | Type | Code | East | North | Film No | Run No | Frame No | Obs Land Use | Management Practices | Aspect | Freq | Dur | Depth | ROV

Elevation | Drainage | Rainforest | Substrate | Location | Australian Soil Classification | GSG

Eval | Elev | Eval | Height | Distance | Depth | Str | Lith | Gen T | Text | Mass Str | Zone WGS 84 | Easting/Latitude 557615 | Northing/Longitude 6873264 | Conf | Ord | Sub Ord | GG/ Ord2 | SG/ SO2 | F1 F2 F3 F4 F5 | PPF | aff

Microrelief | Erosion | Surf Coarse Frags | Outcrop | Community | Community 1 Details

No | Disturb | Surf Con | Type | Agent | Cmpt | Prop | VI | HI | Type | State | Deg | GD | Abun | Size | Shape | Lith | Str | Abun | Lith | No | Ref No | Name | Strata | Form | Ht | C | Co | C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

Naturally treeless lagoon

1 GN M 0 15 8–15m 0

2 weak GM + minor Cubes on mounds

3 Hardsetting at dep

4

Cz3M/p No veg – thick Bothriochloa / Heteropogon.

Depth | End | Field Texture | Sampled

Horizon | Upper | Lower | Confid | Dist | Shape | Field Texture | Qual | Facies | SWS | Stickiness | Plas Type | Deg | Repel | Hue | V | C | Moist | Mottles Type | Abun | Size | Contr | Col | Abun | Size | Coarse Fragments Shape | Lith | Str | Structure Dist | Grade | Size | Type | Segregations Cmpd | Abun | Nat | Form | Size | Cutans Fabric | Type | Abun | Dist | Pores Strgth Cracks | Abun | Diam | SWS | Cons | Pans Type | Cmnt | Cont | Str | Roots Size | Abun | Sample

A11 0 0 0 0 3 C LMC 2·5 Y 3 1 M 0 0 M/S1–2GR 1KN2 D2 0–0·1 0·05

A12 0 0 3 0 2 0 C MC 2·5 Y 3 1 M S3AB 0 T5 –

B21 0 2 0 1 0 0 G MHC 2·5 Y 2 1 M 1KN1 T4/5 0·25–0·35 0·3

B02K 1 0 0 1 3 5 G MHC 10 YR 4 1 M 3KN2 M4 0·55–0·65 0·6; 0·85–0·95 0·9

B3/c 1 3 5 1 5 0 – 10 YR 6 2 M 4 – calc? SA? VW 2KN1 M4 1·15–1·25 1·2

pale calcareous SA. M M

+ pHca @ 0·3/0·6

+ EC @ 0·3/0·6 to 1·0/1·2

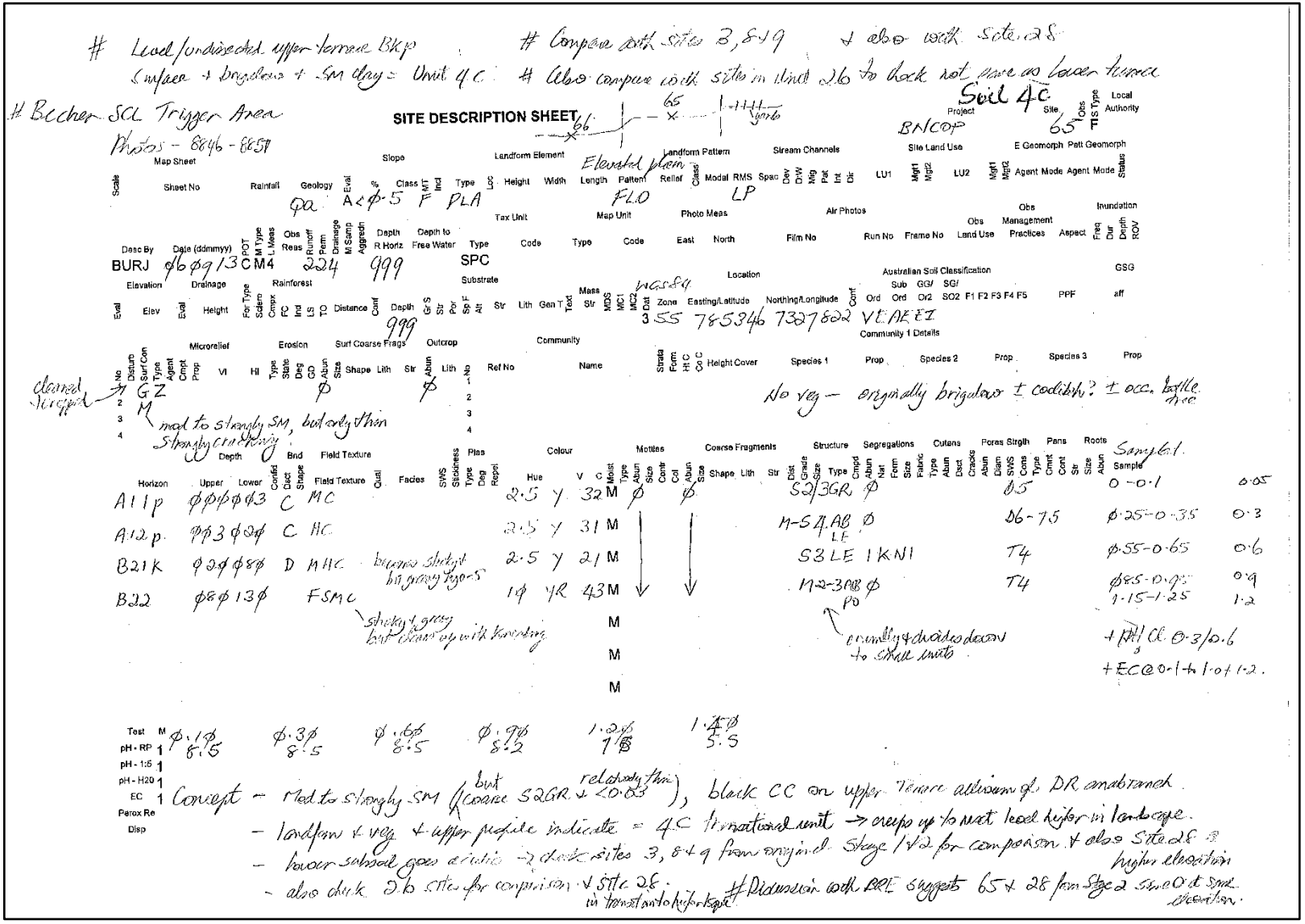
Test	M					
pH - RP	1	0·1 / 8·0	0·3 / 7·0	0·6 / 8·2	0·9 / 8·2	1·2 / 8·2	1·5 / 8·5
pH - 1:5	1					
pH - H20	1					
EC	1					
Perox Re						
Disp						

Concept – Weakly gilgaied, hardsetting to weak SM (on mounds), black cracking clay on treeless areas within colluvial slopes below Tertiary QS/SA landscape – possibly developed on ZS/MU soils – either Tertiary or Permian outcropping locally.

= consider a different unit to Shrubby poplar box – black soils widespread transect and CZa unit to south.

Appendix 7 – Soil profile field data for detailed sites described and sampled within the SCL trigger area – BNCOP Disturbance Footprint.

BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 65



BNCOP Disturbance Footprint – Soil 2b
SCL trigger area field site – 66

Similar to FLO soils @ Headley's.
– See sites 52, 53, 54 + 55 + different to 65
Alkaline throughout – + soft to core (no handle needed)
= Same as Headley – Unit 4C paper
Photos – 8858 – 8867

Becher Soil Trigger Area

Soil 2b

SITE DESCRIPTION SHEET

Project: BNCOP
Site: 66
Obs Type: TIS
Local Authority:
Map Sheet: Scale; Sheet No
Rainfall
Geology: Qa
Slope: Eval; % A05–42%; Class F; MT Incl; Type PLA
Landform Element: Loc; Height; Width; Length
Landform Pattern: Pattern FLO; Relief; Class; Model LP; RMS GP
Stream Channels: Spac; Dev; D/W; Mig; Pat; Int; Dir
Site Land Use: LU1; Mgt1; Mgt2; LU2; Mgt1; Mgt2
E Geomorph: Agent; Mode
Patt Geomorph: Agent; Mode
Status

Desc By: BURJ
Date (ddmmyy): 06 09 13
POT; M Type; L Meas; Obs Reas: C M4 224
Runoff; Perm; Drainage; M Samp; Aggregn
Depth R Horiz: 999
Depth to Free Water
Tax Unit: Type SPC; Code
Map Unit: Type; Code
Photo Meas: East; North
Air Photos: Film No; Run No; Frame No
Obs Land Use
Management Practices
Aspect
Inundation: Freq; Dur; Depth; ROV

Elevation: Eval; Elev
Drainage: Eval; Height
Rainforest: For Type; Sclero; Cmpx; FC; Ind; LS; TO; Distance
Substrate: Conf; Depth 999; Gr S; Str; Por; Sp F; Alt; Str; Lith; Gen T; Text; Mass Str; MDS; MC1; MC2; Qat
Location: WGS 84; Zone 3; Easting/Latitude 557850; Northing/Longitude 9473276 48
Australian Soil Classification: Conf; Ord; Sub Ord; GG/ Or2; SG/ SO2; F1 F2 F3 F4 F5; PPF
GSG: eff

Microrelief: Disturb; Surf Con; Type; Agent; Cmpt; Prop; VI; HI
Erosion: Type; State; Deg; GD; Abun; Size
Surf Coarse Frags: Shape; Lith; Str; Abun
Outcrop: Lith; Abun
Community: No; Ref No; Name
Community 1 Details: Strata; Form; Ht; C; Co; C; Height Cover; Species 1; Prop; Species 2; Prop; Species 3; Prop

Cleared & cropped → 1 GZ; 2 M; 3; 4 Strongly cracking

Cleared – brigalow + occ. coolibah

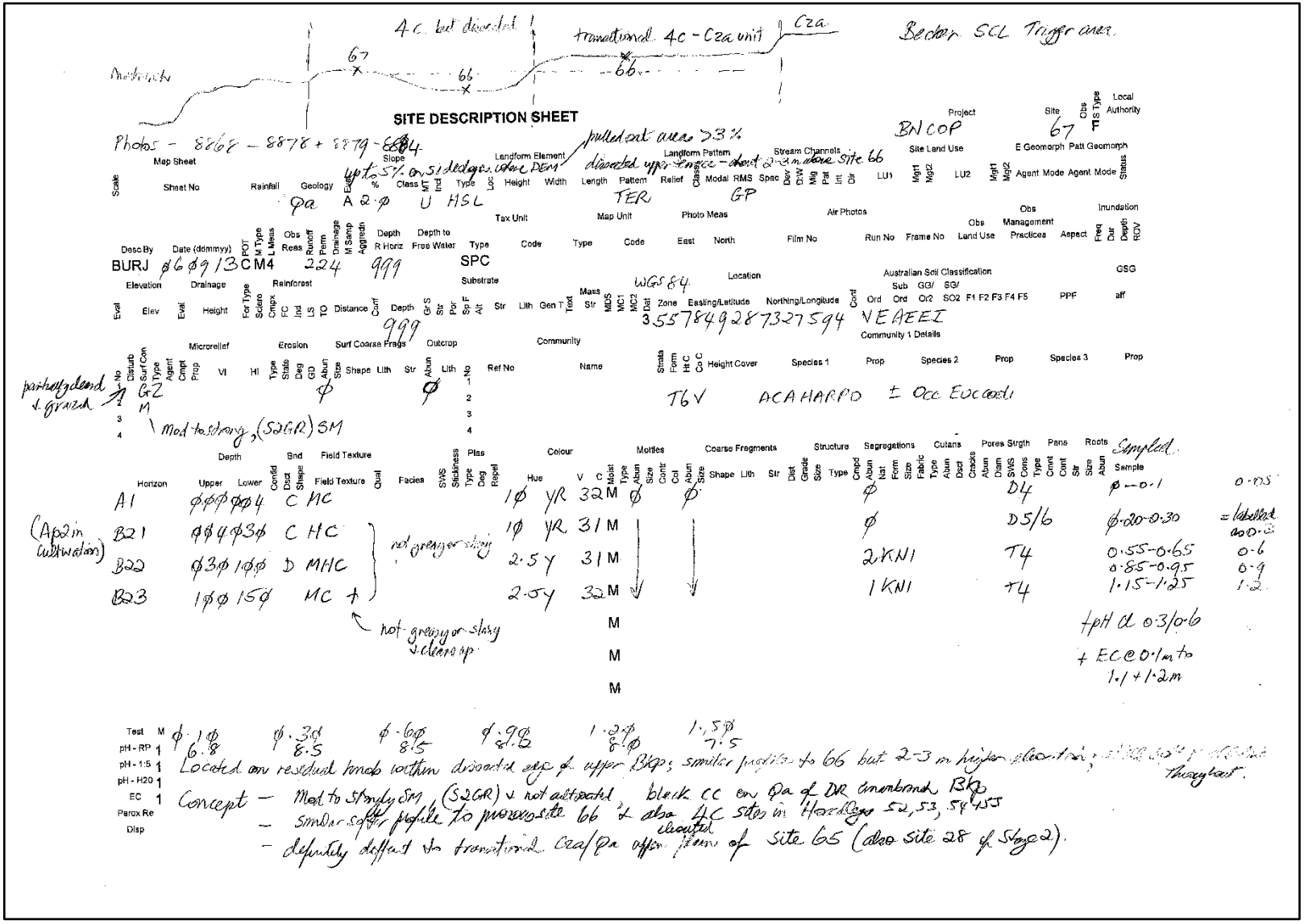
Horizon	Depth Upper	Depth Lower	Bnd Confid	Bnd Dist	Bnd Shape	Field Texture	Qual	Facies	SWS	Stickiness	Plas Type	Plas Deg	Plas Repel	Colour Hue	V	C	Mottles Moist	Type	Abun	Size	Contr	Coarse Fragments Col	Abun	Size	Shape	Lith	Str	Structure Dist	Grade	Size	Type	Segregations Cmpd	Abun	Nat	Form	Size	Fabric	Cutans Type	Abun	Dist	Pores Strgth Cracks	Abun	Diam	Pans SWS	Coms	Type	Cont	Roots Cont	Str	Size	Abun	Sample	
Ap1	00	03	C			LMC								10	YR	3	1	M	0				0					52	GR	0											D4											Sampled 0–0.1	0.05
Ap2	03	02	C			MHC								10	YR	3	1	M																							D6											–	
B21	02	05	G			HC								2.5	Y	2	1	M										M-5	3AB	0											T4											0.25–0.35	0.3
																																																				0.55–0.65	0.6
B22K	05	15				MHC								2.5	Y	3	2	M										5	5LE	2	KN1										T4											0.85–0.95	0.9
																												3	2LE																								1.15–1.25	1.2
																		M																																				
																		M																																				
																		M																																				

Coarse fragments: 1 0; 2 0; 3 0; 4 0
Structure: 1 0; 2 0; 3 5; 4 5
Very highly structured, soft to core + soft consistence

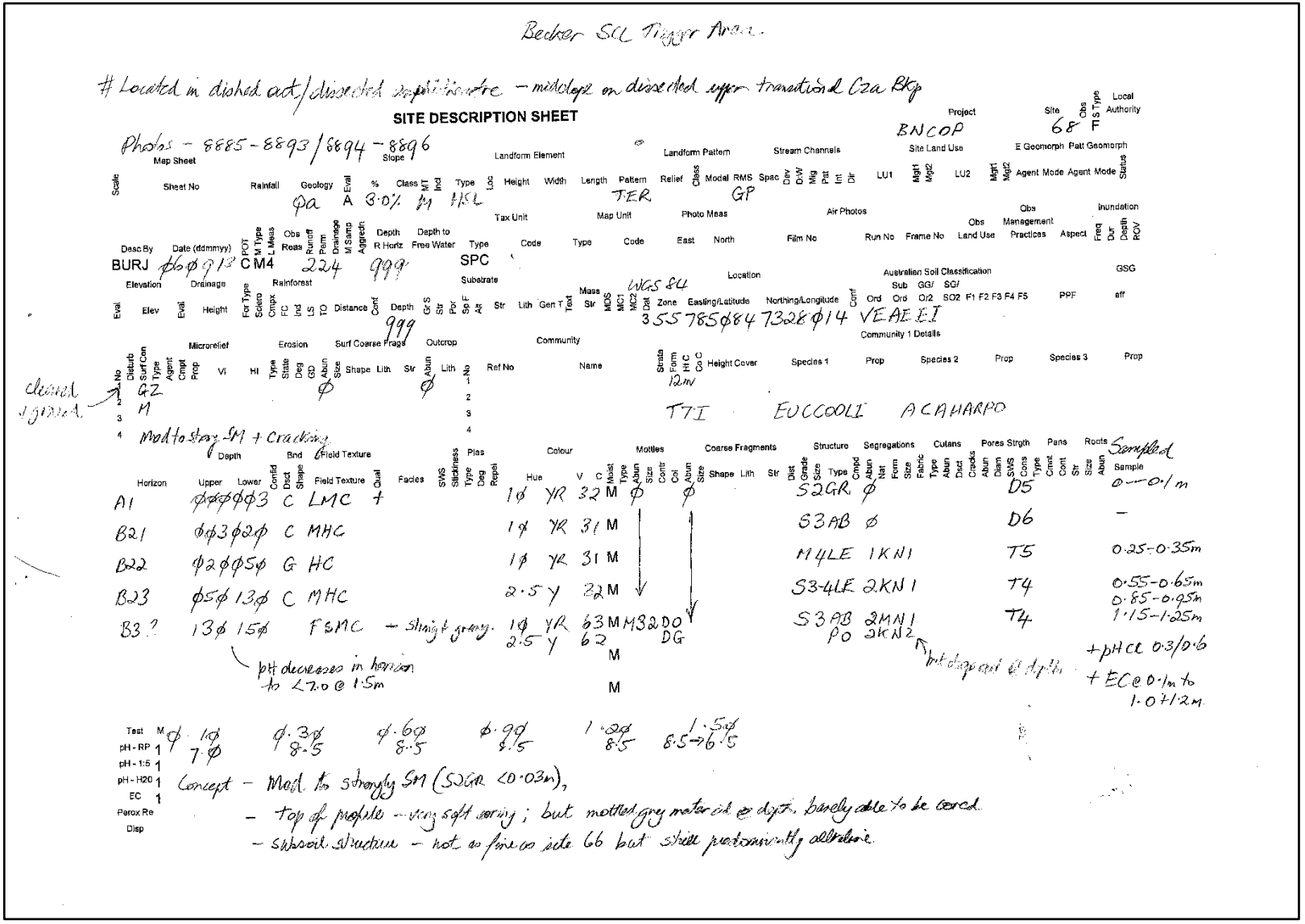
Test M: 0.1 / 7.5; 0.3 / 7.5; 0.6 / 8.2; 0.9 / 8.8; 1.2 / 8.8; 1.5 / 8.5
pH - RP 1
pH - 1:5 1
pH - H2O 1
EC 1
Perox Re
Disp

Concept – Similar to Site 65 but @ lower elevation + much softer + highly structured + alkaline throughout – Unit 4C
– Mod to strong, relatively coarse (52GR, but only <0.03m thick) SM, black cracking clay on younger Qa – located on paper
FLO/BLP of DK anabranch – alkaline @ depth, soft to core + highly structured – Same as Headley = Unit 4C
See sites 3, 8, 9 Stage 2
+ BNCOP 52, 53, 54 + 55.

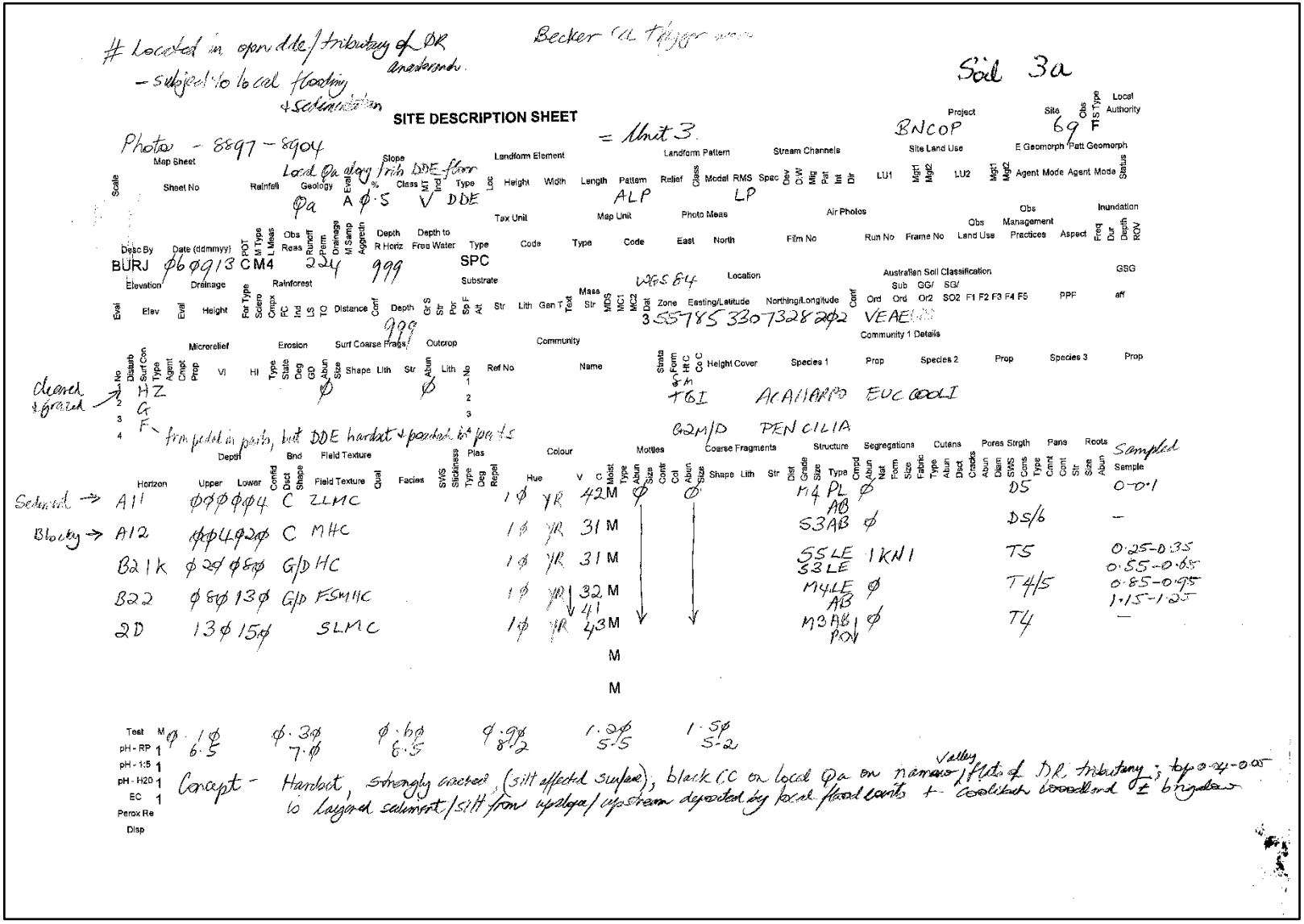
BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 67



BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 68



BNCOP Disturbance Footprint – Soil 3a
SCL trigger area field site – 69



BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 70

Becher SCL Trigger Area

Same elevation & Soil type as SITC 65 + also 28 in Stage 2

SITE DESCRIPTION SHEET

Photos – 8905 – 8919 # Elevated residual knob of highest terrace; dissected to north + south.

Project: BNCOP
Site: 7φ
Obs: T1S Type
Local Authority
Map Sheet
Slope
Landform Element
Landform Pattern
Stream Channels
Site Land Use
E Geomorph Patt Geomorph

Scale | Sheet No | Rainfall | Geology: Qa? | Eval | % Class: A0–1.0% | M/T | Incl | Type: U | Loc | Height | Width | Length | Pattern: TER | Relief | Class | Modal | RMS: GP | Spac | Dev | D/W | Mig | Pat | Int | Dir | LU1 | Mgt1 | Mgt2 | LU2 | Mgt1 | Mgt2 | Agent | Mode | Agent | Mode | Status

Tax Unit | Map Unit | Photo Meas | Air Photos | Obs Management | Inundation

Desc By: BURJ | Date (ddmmyy): φ6φφ13 | POT | M Type: CM4 | L Meas | Obs Reas | Runoff | Perm | Drainage | M Samp | Aggregatn | Depth R Horiz: 999 | Depth to Free Water | Type: SPC | Code | Type | Code | East | North | Film No | Run No | Frame No | Obs Land Use | Management Practices | Aspect | Freq | Dur | Depth | ROV

Elevation | Drainage | Rainforest | Substrate | Location | Australian Soil Classification | GSG

Eval | Elev | Eval | Height | For Type | Scleno | Cmpx | FC | Ind | LS | TO | Distance | Conf | Depth: 999 | Gr S | Str | Por | Sp F | Alt | Str | Lith | Gen T | Text | Mass Str | MDIS | MC1 | MC2 | Dat: WGS84 | Zone: 3 | Easting/Latitude: 355-852φ | Northing/Longitude: 7328349 | Conf | Ord | Sub Ord | GG/ Or2 | SG/ SO2 | F1 | F2 | F3 | F4 | F5 | PPF | aff

Microrelief | Erosion | Surf Coarse Frags | Outcrop | Community | Community 1 Details

No | Disturb | Surf Con | Type: GZ | Agent | Cmpt | Prop | VI | HI | Type | State | Deg | GD: φ | Abun | Size | Shape | Lith | Str | Abun: φ | Lith | No | Ref No | Name | Strata | Form | Ht | C | Co | C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

cleared + cropped (sub) — Mod to strong coarse SM — Originally brigalow-scrub.

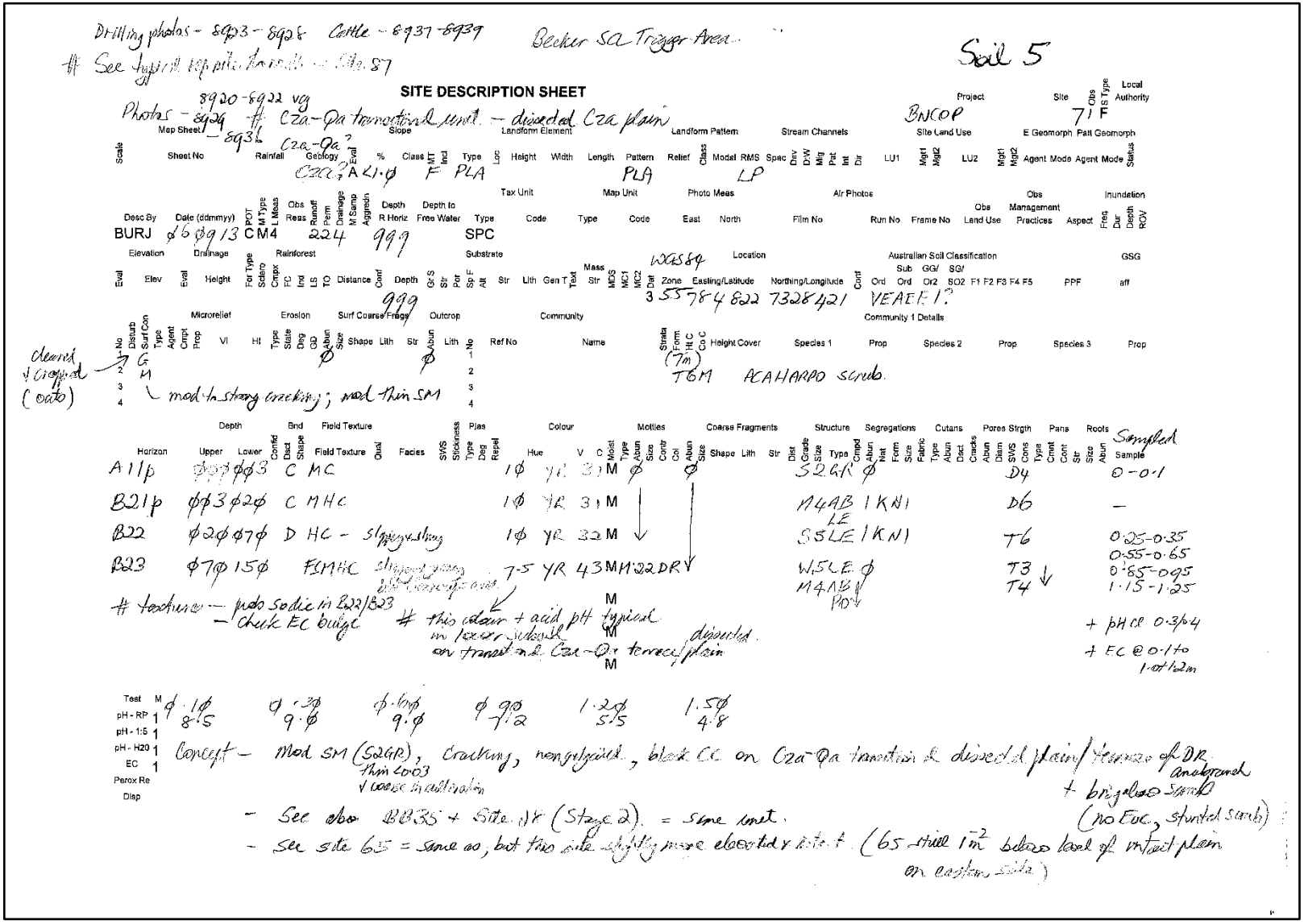
Horizon | Depth Upper | Lower | Bnd Confd | Dect | Shape | Field Texture | Qual | Facies | SWS | Stickiness | Plas Type | Deg | Repel | Colour Hue | V | C | Mottles Moist | Type | Abun | Size | Contr | Col | Abun | Size | Coarse Fragments Shape | Lith | Str | Structure Dist | Grade | Size | Type | Segregations Cmpd | Abun | Nat | Form | Size | Fabric | Cutans Type | Abun | Dist | Cracks | Abun | Diam | Pores Strgth SWS | Cons | Type | Pans Cmnt | Cont | Str | Size | Roots Abun | Sampled Sample

Horizon	Upper	Lower	Field Texture	Hue	V	C	Structure	Sample	
Ap1	φφφφ4	C	MC	1φ YR	31	M	S2-3GR φ AB1	D4	0–0.1	0.05
Ap2	φφ4φ2φ	CG	MHC (not greasy)	1φ YR	31	M	compacted M4AB.1KN1	D6	–	
B21	φ2φφ7φ	G	MHC (not greasy)	2.5Y	31	M	S4LE 1KN1	TS	0.25–0.35	0.3
									0.55–0.65	0.6
B22	φ7φ11φ	G	MHC → greasy + slippery	1φ YR	42	M	S4LE φ	T4	0.85–0.95	0.9
							S3LE			
B23/2D	11φ15φ		MHC → greasy but clears up because acid.	1φ YR	43	M	S1-2LE ↓	T3/4	1.15–1.25	
						M			+ pH @ 0.35, 0.6	
						M	very fine sdf LE similar to 4C sub @ Hoadley but acid + indicator of Cza		+ EC @ 0.1 to 1.0 + 1.2	

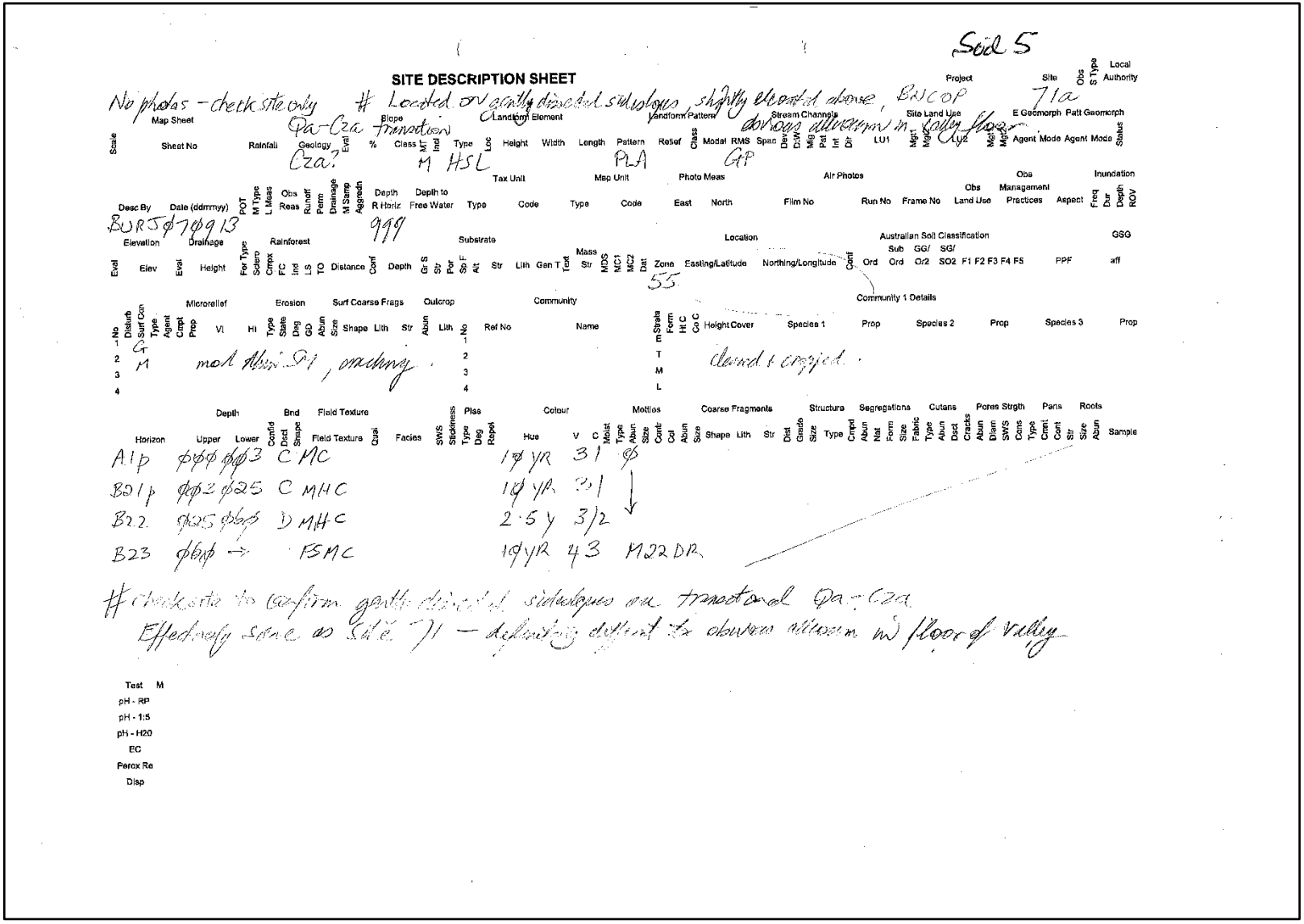
Test	M	φ	1φ	φ.3φ	φ.6φ	φ.9φ	1.2φ	1.5φ
pH - RP	1	7.φ	8.5	8.2	6.8		5.φ	4.8
pH - 1:5	1							
pH - H20	1							
EC	1							
Perox Re								
Disp								

Concept – acidic @ about 1.0m depth confirms underlain by Cza clay → transitional slope between Qa + Cza landscape
– Mod to strongly SM (coarse + <0.04 + cultivated), strongly cracked, black CC on transitional Qa/Cza slope/residual knob + brigalow.
– see also site 65 + 28 (Stage 2).
– lower to 1.5m without handle. – sdf cordy in lower profile (compare with 65 – much harder).

BNCOP Disturbance Footprint – Soil 5
SCL trigger area field site – 71



BNCOP Disturbance Footprint – Soil 5
SCL trigger area field site – 71a



Soil 5

SITE DESCRIPTION SHEET

Project: BNCOP | Site: 71a | Obs S Type | Local Authority

No photos – check site only # Located on gently dissected sideslopes, slightly elevated above, downslope alluvium in valley floor.

Map Sheet | Scale | Sheet No | Rainfall | Geology: Cza? | Eval | % | Slope Class: M | Mt Ind | Type: HSL | Loc | Landform Element | Height | Width | Length | Pattern: PLA | Relief | Landform Pattern | Class | Modal | RMS | Span | Stream Channels | Dev | D:W | Mig | Pat | Int | Dir | Site Land Use | LU1 | Mgt1 | Mgt2 | LU2 | Mgt3 | Mgt4 | E Geomorph: GP | Agent | Mode | Patt Geomorph | Agent | Mode | Status

Pa–Cza transition

Tax Unit | Map Unit | Photo Meas | Air Photos | Obs | Obs Management | Inundation

Desc By: BURS | Date (ddmmyy): 07 09 13 | POT | M Type | L Meas | Obs Reas | Runoff | Perm | Drainage | M Samp | Aggregdn | Depth R Horiz: 999 | Depth to Free Water | Type | Code | Type | Code | East | North | Film No | Run No | Frame No | Land Use | Practices | Aspect | Freq | Dur | Depth | ROV

Elevation | Drainage | Rainforest | Substrate | Location | Australian Soil Classification | GSG

Eval | Elev | Eval | Height | For Type | Sclero | Cmpx | FC | Ind | LS | TO | Distance | Conf | Depth | Gr S | Str | Por | Sp F | Alt | Str | Lith | Gen T | Text | Mass Str | MDS | MC1 | MC2 | Dat | Zone: 55 | Easting/Latitude | Northing/Longitude | Conf | Ord | Sub Ord | GG/ Or2 | SG/ SO2 | F1 F2 F3 F4 F5 | PPF | aff

Microrelief | Erosion | Surf Coarse Frags | Outcrop | Community | Community 1 Details

No | Disturb | Surf Con | Type | Agent | Cmpt | Prop | Vl | Hl | Type | State | Deg | GD | Abun | Size | Shape | Lith | Str | Abun | Lith | No | Ref No | Name | m Strata | Form | Ht | C | Co C | Height Cover | Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

1 G
2 M mod Abun 91, ordinary.
3
4

T closed + cropped.
M
L

Depth | Bnd | Field Texture | Plas | Colour | Mottles | Coarse Fragments | Structure | Segregations | Cutans | Pores Strgth | Pans | Roots

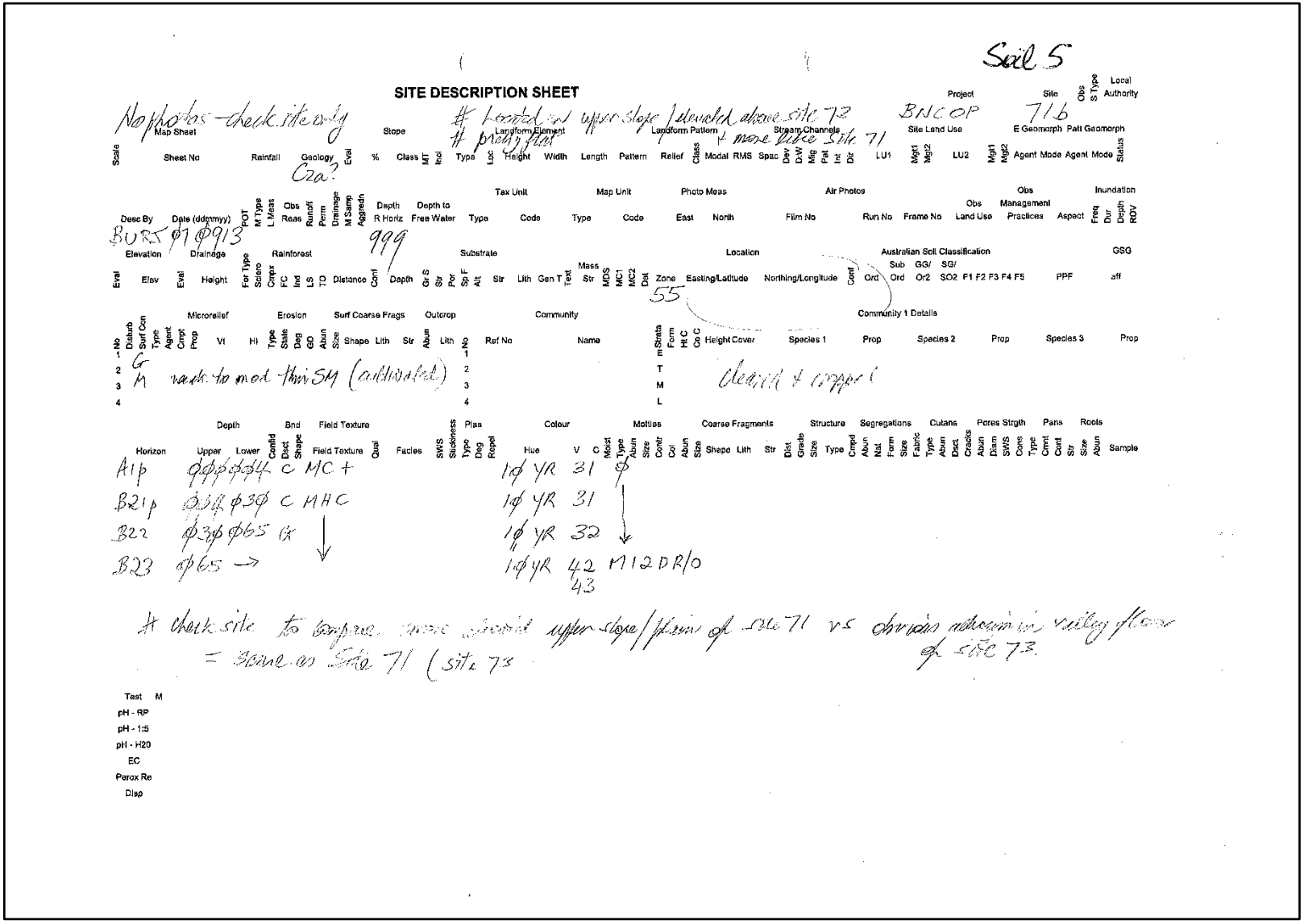
Horizon | Upper | Lower | Confid | Dsct | Shape | Field Texture | Qual | Facies | SWS | Stickiness | Type | Deg | Repel | Hue | V | C | Moist | Type | Abun | Size | Contr | Col | Abun | Size | Shape | Lith | Str | Dist | Grade | Size | Type | Cmpd | Abun | Nat | Form | Size | Fabric | Type | Abun | Dsct | Cracks | Abun | Diam | SWS | Cons | Type | Cmnt | Cont | Str | Size | Abun | Sample

A1p 00 03 C MC 10 YR 3 1 0
B21p 03 25 C MHC 10 YR 3 1
B22 25 60 D MHC 2.5 Y 3/2
B23 60 → FSMC 10 YR 4 3 M22DR

Check site to confirm gently dissected sideslopes on transitional Pa–Cza. Effectively same as Site 71 – definitely different to downslope alluvium in floor of valley.

Test M
pH - RP
pH - 1:5
pH - H20
EC
Perox Re
Disp

BNCOP Disturbance Footprint – Soil 5
SCL trigger area field site – 71b



Soil 5

SITE DESCRIPTION SHEET

No photos – check site only

Located on upper slope / elevated above site 72 # probably flat + more like site 71

Project: BNCOP Site: 71b

Map Sheet: Scale | Sheet No | Rainfall | Geology: Cza? | Eval

Slope: % | Class | MT | Incl

Landform Element: Type | Loc | Height | Width | Length

Landform Pattern: Pattern | Relief | Class

Stream Channels: Modal | RMS | Spac | Dev | D-W | Mag | Pat | Int | Dir

Site Land Use: LU1 | Mgt1 | Mgt2 | LU2

E Geomorph: Mgt1 | Mgt2 | Agent | Mode

Patt Geomorph: Agent | Mode | Status

Obs S Type | Local Authority

Desc By: BURS | Date (ddmmyy): 01 09 13 | POT | M Type | L Mass | Obs Reas | Runoff | Perm | Drainage | M Samp | Aggredn | Depth R Horiz: 999 | Depth to Free Water

Tax Unit: Type | Code

Map Unit: Type | Code

Photo Meas: East | North

Air Photos: Film No | Run No | Frame No

Obs: Land Use | Management Practices | Aspect

Inundation: Freq | Dur | Depth | RDV

Elevation: Eval | Elev

Drainage: Eval | Height

Rainforest: For Type | Sclero | Cmpx | FC | Ind | LS | TO | Distance

Substrate: Conf | Depth | Gr S | Str | Por | Sp F | Alt | Str | Lith | Gen T | Text | Mass Str | MDS | MC1 | MC2 | Dat

Location: Zone: 55 | Easting/Latitude | Northing/Longitude | Conf

Australian Soil Classification: Ord | Sub Ord | GG/ Or2 | SG/ SO2 | F1 | F2 | F3 | F4 | F5

PPF

GSG: aff

Microrelief: Disturb | Surf Con | Type | Agent | Cmpt | Prop | VI | HI

Erosion: Type | State | Deg | GD

Surf Coarse Frags: Abun | Size | Shape | Lith | Str

Outcrop: Abun | Lith

Community: No | Ref No | Name | mStrata | Form | Ht | C | Co | C | Height Cover

Community 1 Details: Species 1 | Prop | Species 2 | Prop | Species 3 | Prop

1 G
2 M
3
4

rank to mod this SM (cultivated)

Clearing + cropping

Horizon | Depth Upper | Lower | Bnd Confid | Dsct | Shape | Field Texture | Qual | Facies | SWS | Stickiness | Plas Type | Deg | Repel | Colour Hue | V | C | Moist | Mottles Type | Abun | Size | Contr | Col | Abun | Size | Coarse Fragments Shape | Lith | Str | Dist | Structure Grade | Size | Type | Segregations Cmpd | Abun | Nat | Form | Size | Fabric | Cutans Type | Abun | Dsct | Cracks | Pores Strgth Abun | Diam | SWS | Pans Cons | Type | Cmnt | Cont | Str | Size | Abun | Roots | Sample

A1p ϕϕϕϕϕ44 c MC +
B21p ϕϕϕ ϕ30 c MHC
B22 ϕ30 ϕ65 Gx
B23 ϕ65 →

1ϕ YR 31 ϕ
1ϕ YR 31
1ϕ YR 32
1ϕ YR 42 43 M12DR/O

check site to compare more should upper slope / plain of site 71 vs drainage depression in valley floor of site 73.
= same as site 71 (site 73

Test M
pH - RP
pH - 1:5
pH - H20
EC
Perox Re
Disp

BNCOP Disturbance Footprint – Soil 5
SCL trigger area field site – 71c

Soil 5

SITE DESCRIPTION SHEET

No photos - check site only

Located on upper part of dissected sideslope

Project: BNCOP

Site: 71C

Map Sheet

Geology: Qa - Czatransition zone? Cza?

Slope: U

Landform Element: HSL

Landform Pattern: PLA

Stream Channels: GP

Site Land Use

E Geomorph Pat Geomorph

Tax Unit

Map Unit

Photo Meas

Air Photos

Obs Management Practices

Inundation

Desc By: BDRS

Date (ddmmyy): 07 09 13

R Horiz: 999

Elevation

Drainage

Rainforest

Substrate

Location: Zone 55

Australian Soil Classification

GSG

Microrelief

Erosion

Surf Coarse Frags

Outcrop

Community

Community 1 Details

No	Disturb	Surf Con	Type	Agent	Crmpt	Prop	VI	HI	Type	Stake	Deg	GD	Abun	Size	Shape	Lith	Str	Abun	Lith	No	Ref No	Name	mStrata	Form	Ht C	Co C	Height Cover	Species 1	Prop	Species 2	Prop	Species 3	Prop
1		G																		1			T										
2		H																		2			M										
3																				3			L										
4																				4													

mod thin SM + cracking

cleared & cropping - on edge of cropping area

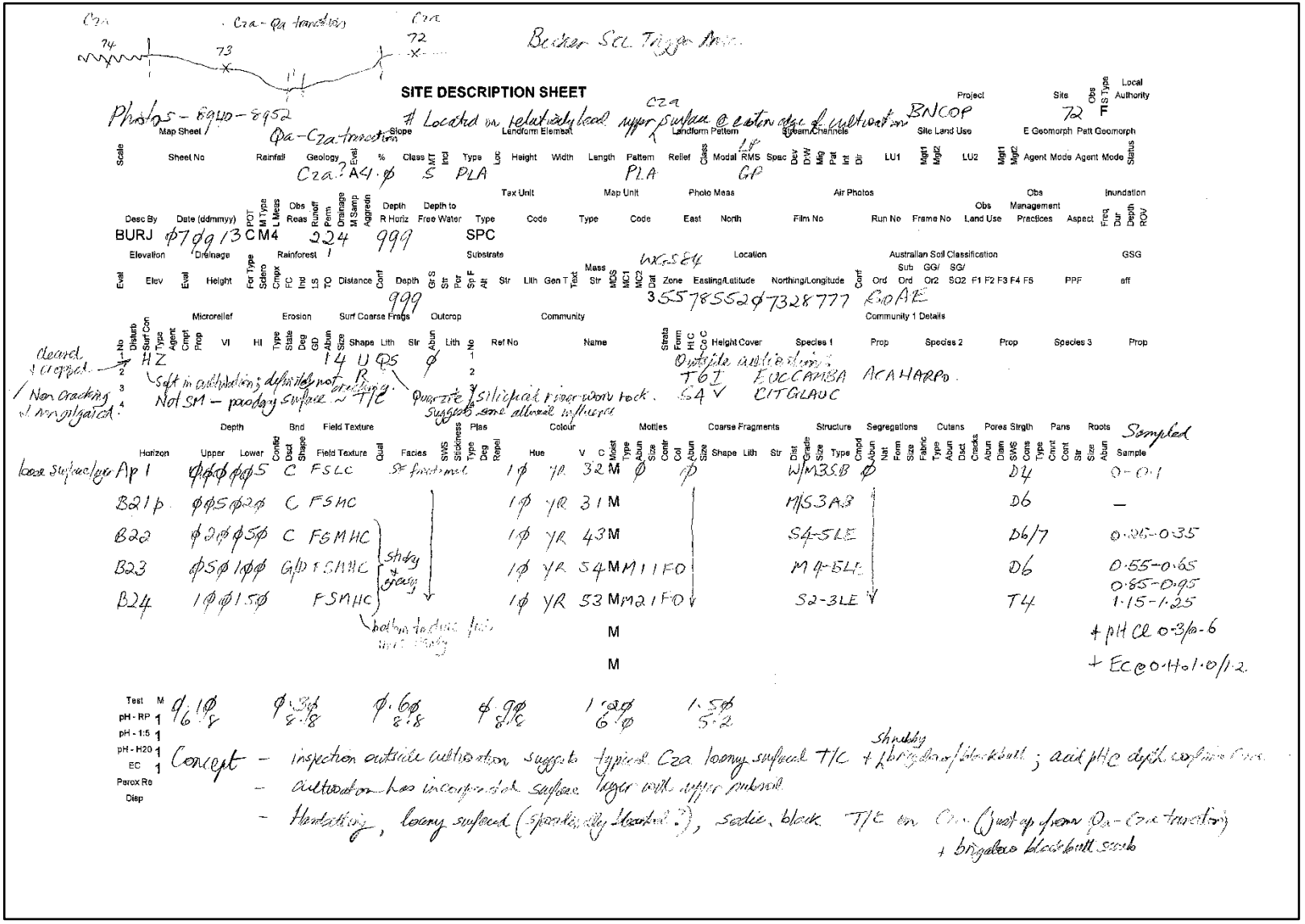
Horizon	Depth Upper	Depth Lower	Bnd Confid	Bnd Dact	Bnd Shape	Field Texture	Field Texture Qual	Facies	SWS	Stickiness	Plas Type	Plas Deg	Plas Repel	Colour Hue	Colour V	Colour C	Mottles Moist	Mottles Type	Mottles Abun	Mottles Size	Coarse Fragments Contr	Coarse Fragments Col	Coarse Fragments Abun	Coarse Fragments Size	Coarse Fragments Shape	Coarse Fragments Lith	Coarse Fragments Str	Structure Dist	Structure Grade	Structure Size	Structure Type	Segregations Compd	Segregations Abun	Segregations Nat	Segregations Form	Segregations Size	Segregations Fabric	Cutans Type	Cutans Abun	Cutans Dact	Pores Cracks	Pores Abun	Pores Diam	Strgth SWS	Strgth Cons	Pans Type	Pans Cmnt	Pans Cont	Pans Str	Pans Size	Roots Abun	Sample
Ap	0	0.02	C			MC								10 YR	3	2	0																																				
B21p	0.02	0.20	C			MHC								10 YR	3	1																																					
B22	0.20	0.60	D											10 YR	3	2																																				
B23	0.60	→												2.5Y	4	3	M	12	DR																																	

check site to decide whether gently dissected eastern side slope similar to 71 or 74

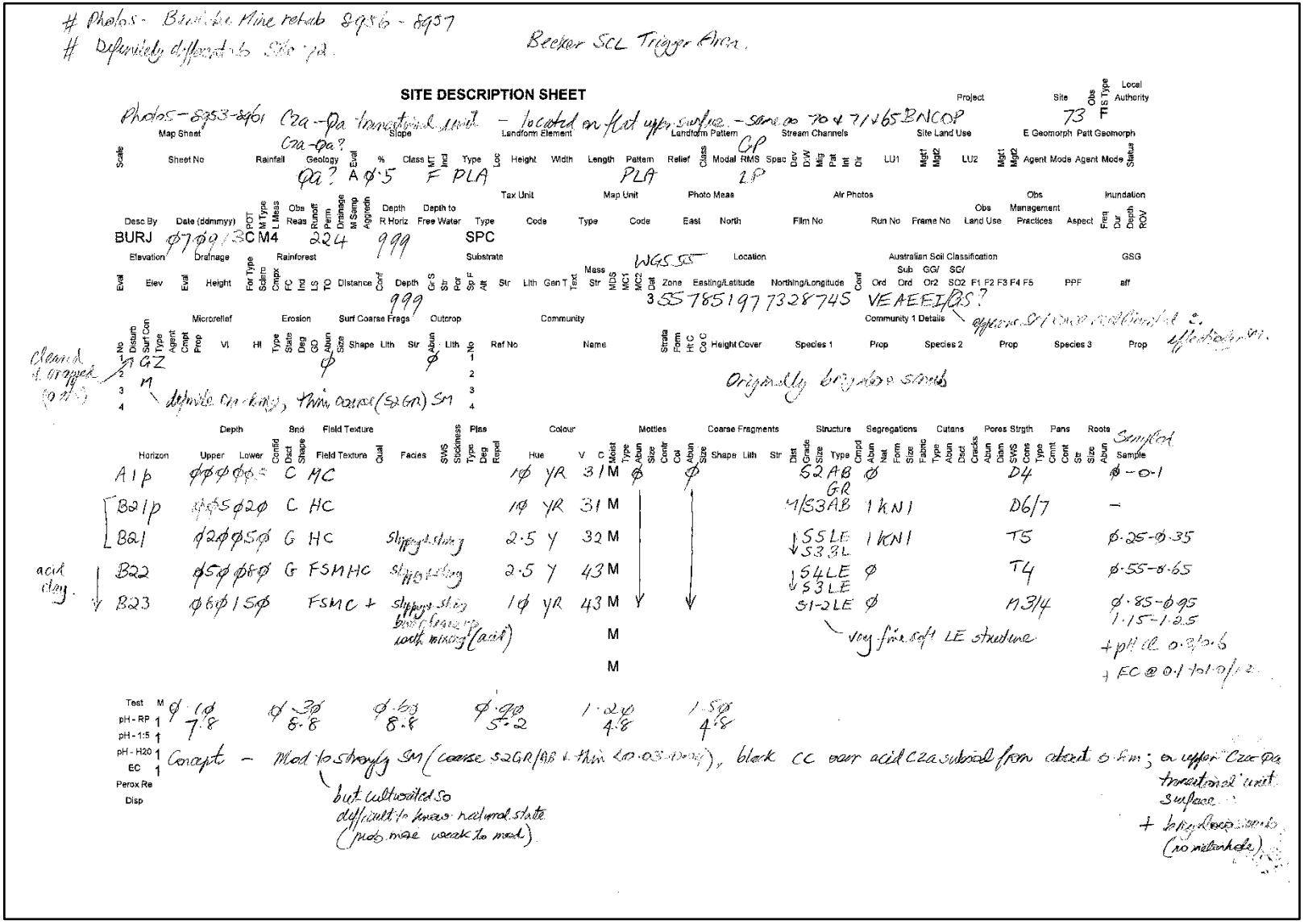
same as site 71 - suggests sloping now around northern edge of alluvial valley = transition Qa → Cza (lower elevation).

Test	M
pH - RP	
pH - 1:5	
pH - H20	
EC	
Perox Re	
Disp	

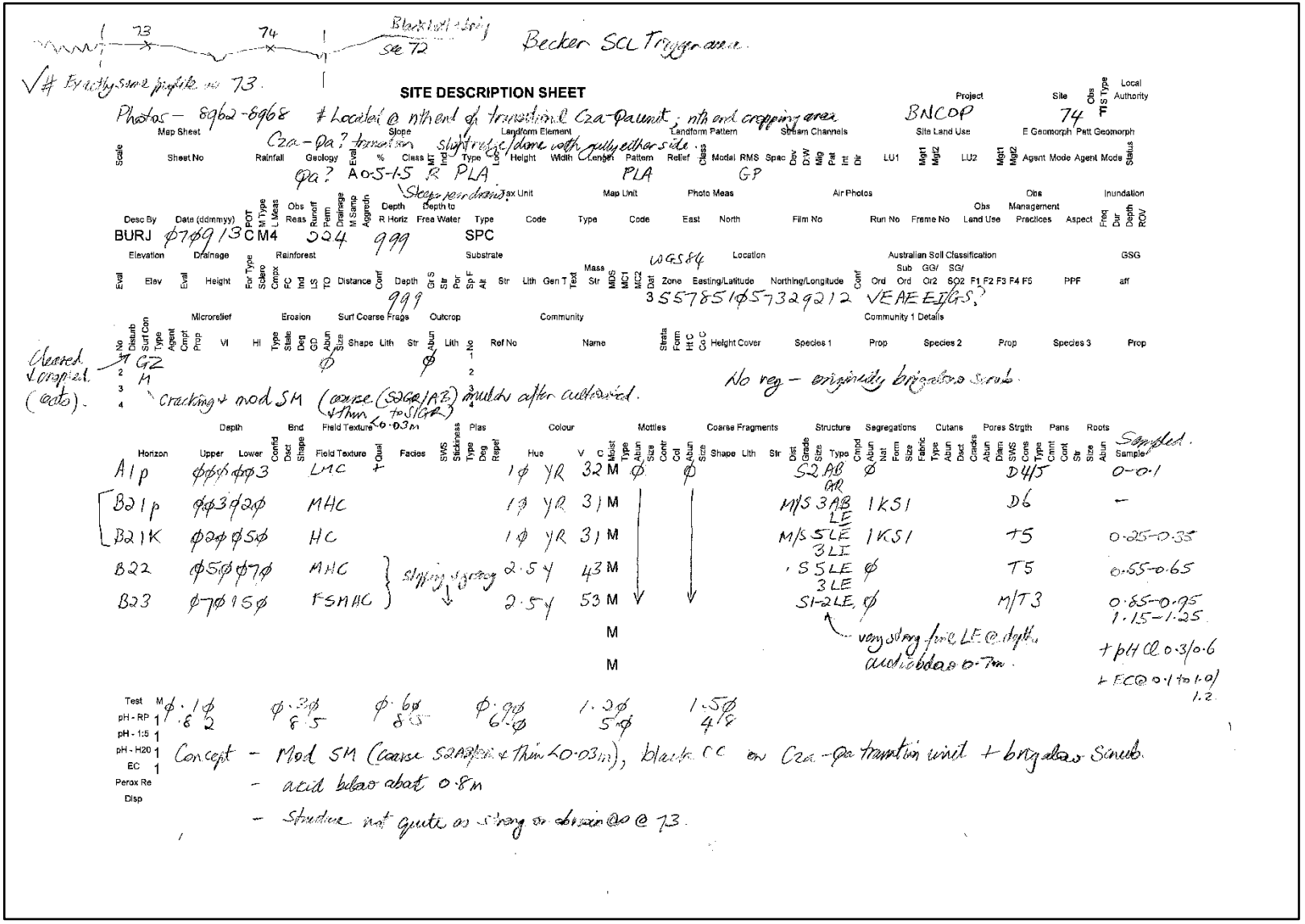
BNCOP Disturbance Footprint – Soil 7d
SCL trigger area field site – 72



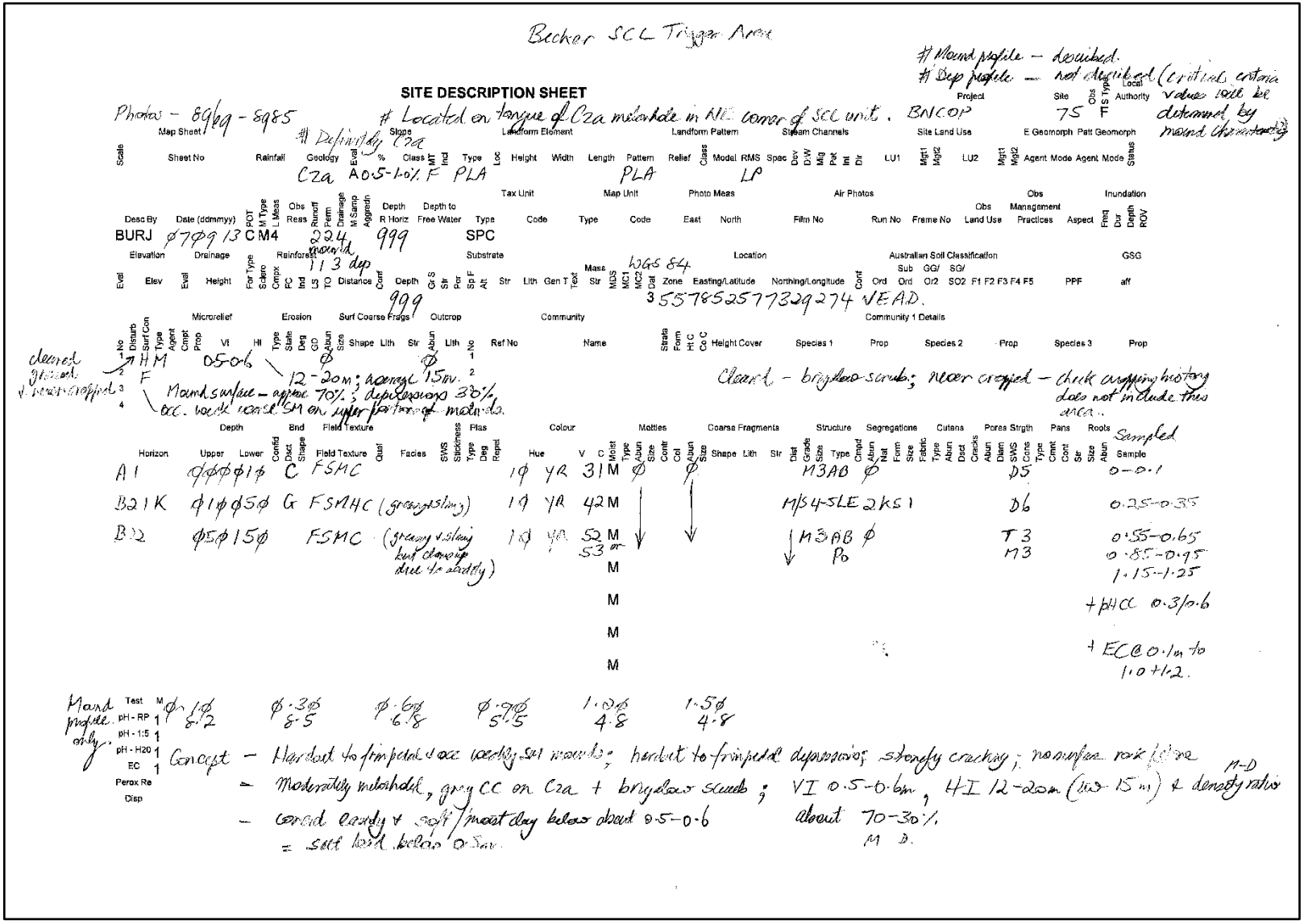
BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 73



BNCOP Disturbance Footprint – Soil 4c
SCL trigger area field site – 74



BNCOP Disturbance Footprint – Soil 7a
SCL trigger area field site – 75



Becker SCL Trigger Area

Mound profile – described.
Dep profile – not described (criteria values will be determined by mound characteristics)

SITE DESCRIPTION SHEET

Photos – 8986 – 8985 # Located on tongue of C2a materials in NE corner of SCL unit.

Project: BNCOP
Site: 75
Obs Type: T
Local Authority:
Map Sheet:
Scale:
Sheet No:
Rainfall:
Geology: C2a # Definitely C2a
Slope: Eval: A; % Class: 0.5-1.0% F
Landform Element: MT Ind Type: PLA; Loc; Height; Width; Length
Landform Pattern: Pattern: PLA; Relief; Class; Model; RMS: LP
Stream Channels: Spac; Dev; D/W; Mig; Pak; Int; Dir
Site Land Use: LU1; Mgt1; Mgt2; LU2
E Geomorph: Mgt1; Mgt2; Agent; Mode
Patt Geomorph: Agent; Mode; Status

Desc By: BURJ
Date (ddmmyy): 07 09 13
POT; M Type; L Meas; Obs Reas; Runoff; Perm; Drainage; M Samp; Aggregth
Depth R Horiz: 999
Depth to Free Water:
Tax Unit: Type: SPC; Code
Map Unit: Type; Code
Photo Meas: East; North
Air Photos: Film No; Run No; Frame No
Obs Land Use:
Obs Management Practices:
Aspect:
Inundation: Freq; Dur; Depth; ROV

Elevation: Eval; Elev
Drainage: Eval; Height
Reinforest: For Type; Sclero; Compx; FC; Ind; LS; TO; Distance: 1 1 3 dup (nearest)
Substrate: Conf; Depth: 999; Gr S; Str; Per; Sp F; Alt; Str; Lith; Gen T; Text; Mass Str; MDS; MC1; MC2; Dat; Zone: 3; Easting/Latitude: 557852; Northing/Longitude: 7329274 (WGS 84); Cont
Location
Australian Soil Classification: Ord; Sub Ord; GG/ Or2; SG/ SO2; F1 F2 F3 F4 F5; PPF
GSG: aff

Microrelief: No; Disturb; Surf Con; Type; Agent; Compt; Prop; Vt; Ht
Erosion: Type; Slate; Deg; GD; Abun; Size
Surf Coarse Frags: Shape; Lith; Str; Abun
Outcrop: Lith; No
Ref No
Community: Name; Strata; Form; Ht C; Co C; Height Cover
Community 1 Details: Species 1; Prop; Species 2; Prop; Species 3; Prop

1 HM 05-06 Ø
2 F
3
4

cleared ground & heavily cropped

12-20m; average 15m.
Mound surface – approx 70%; depressions 30%
acc. vacant coarse SM on upper portions of mounds.

Cleared – brigalow scrub; never cropped – check cropping history does not include this area.

Depth: Horizon; Upper; Lower
Confid; Dist; Shape
End
Field Texture: Field Texture; Qual; Facies
SWS; Stickiness; Plas: Type; Deg; Repel
Colour: Hue; V; C
Mottles: Moist; Type; Abun; Size; Contr; Col; Abun; Size
Coarse Fragments: Shape; Lith; Str
Structure: Dist; Grade; Size; Type
Segregations: Cmpd; Abun; Nat; Form; Size
Cutans: Fabric; Type; Abun; Dist
Pores: Cracks; Abun; Diam
Strgth: SWS; Cons
Pans: Type; Cmnt; Cont
Roots: Str; Size; Abun
Sample

Horizon	Upper	Lower	Field Texture	Hue	V	C	Structure	Pores	Sample
A1	ØØØØ1Ø	C	FSMC	1Ø YR	3	1 M	M3AB Ø	D5	0–0.1
B21K	Ø1ØØ5Ø	G	FSMHC (greyish clay)	1Ø YR	4	2 M	M/S4-SLE 2KS1	D6	0.25–0.35
B22	Ø5Ø15Ø		FSMC (greasy & silty but clay up due to sodicity)	1Ø YR	5	2 M	M3AB Ø / Po	T3 M3	0.55–0.65
					5	3 or M			0.85–0.95
						M			1.15–1.25
						M			+ pHCC 0.3/0.6
						M			
						M			+ EC @ 0.1m to 1.0 + 1.2.

Mound profile only.

Test	M					
pH - RP	1	Ø.1Ø 8.2	Ø.3Ø 8.5	Ø.6Ø 6.8	Ø.9Ø 5.5	1.2Ø 4.8	1.5Ø 4.8
pH - 1:5	1						
pH - H20	1						
EC	1						
Perox Re							
Disp							

Concept – Hardset to friable & acc vacant SM mounds; hardset to friable depressions; stonefly cracking; no surface rock fragments
– Moderately mottled, grey CC on C2a + brigalow scrub; VI 0.5-0.6m, HI 12-20m (avg 15m) & density ratio M-D about 70-30%.
– Cracked clayey & soft/moist clay below about 0.5-0.6
– soft hard below 0.5m.

Appendix 8 – Assessment methodology used to determine pre-mining grazing suitability within the BNCOP Disturbance Footprint (QDME 1995).

Assessment criteria including explanation of limitations, attribute values and subclass suitability rules for grazing come directly from the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland"* (QDME 1995), in full and without change or addition.

Assessment methodology for determining pre-mining grazing suitability in Queensland (QDME 1995)

The land suitability assessment methodology described in the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland*" (QDME 1995) presents definitions, limitations, attribute values and subclass suitability rules for assessing the agricultural potential for both dryland cropping and grazing of lands within inland Queensland (particularly the semi-arid sub tropics/inland Central Queensland), but only the grazing suitability framework is presented here. The scheme uses a five class land suitability classification (Land Resources Branch Staff 1990, DNRM/DSITIA 2013a) with a common set of attributes/limitations, but separate decision rules for each land use. The scheme assesses the climatic or land based limitations to production that an area may be subject to and allocates land into one of five possible classes. Final suitability class is a measure of the potential of a particular soil or land area to attain optimum production with minimal long-term degradation, for the land use being considered.

The land suitability framework described below including explanation of limitations, attribute values and subclass suitability rules comes directly from the "*Land Suitability Assessment Techniques*" section within the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland"* (QDME 1995). Attribute values and suitability subclass rules for grazing have been reproduced directly from "*Attachment 2*" of the same document without change or addition.

Land suitability classification definitions

The five standard suitability classes for semi arid land uses in Queensland (namely dryland cropping and grazing) defined within the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland*" (QDME 1995) are presented below. Recent updated definitions released by DNRM/DSITIA (2013a, 2013b) remain essentially unchanged.

Class 1 **Suitable land with negligible limitations –** land which is well suited to a proposed use;

Class 2 **Suitable land with minor limitations –** land which is suited to a proposed use but which may require minor changes in management to sustain the use;

Class 3 **Suitable land with moderate limitations –** land which is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use;

Class 4 **Marginally suitable land with severe limitations –** land which is marginally suited for a proposed use and would require major inputs to ensure sustainability; often the inputs required may not be justified in terms of the benefits to be gained from using the land for a proposed use and the land is considered presently unsuitable for that use; and

Class 5 **Unsuitable land with extreme limitations –** land which is unsuited and cannot be sustainably used for a proposed use.

Land is considered less suitable as the severity of limitations for a particular land use increase. Increasing limitations may reflect either (a) reduced potential for production, and/or (b) increased inputs to achieve an acceptable level of production and/or (c) increased inputs required to prevent land degradation. Suitability **Classes 1 to 3** are considered suitable for a specified land use because the benefits from using the land (for that particular use) outweigh the inputs required to initiate and maintain production.

Typically, the benefits from using **Class 4** land are similar in magnitude to the level of inputs required to achieve production and its long-term suitability for the specified land use is doubtful. Class 4 is also used in situations where reducing the effect of a particular limitation may indicate production is possible, but additional studies are needed to determine the feasibility of such actions (e.g., levelling of melonholes may assist cultivation and wetness problems but subsoil salinity levels require investigation).

In contrast, there is no doubt regarding the long-term suitability of Class 1–3 lands or the unsuitability of Class 5 land. **Class 5** land has limitations that in aggregate are so severe that the benefits do not justify the inputs required to initiate and maintain production. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the land use being considered. Many Class 5 lands have physical characteristics that totally preclude any form of development (e.g., mountains) and will always remain unsuitable for agriculture.

Grazing scheme

The **suitability classification for grazing** evaluates soils in terms of the potential to graze and finish cattle on improved pastures (QDME 1995, Shields and Williams 1991). Typically, grazing systems in inland Central Queensland aim to produce young, finished, grassfed, export quality cattle without inputs other than pasture development. Most production is based around improved pasture grass - legume pastures. Improved pasture development in many areas is dominated by buffel grass, although Rhodes grass, introduced bluegrasses (Indian bluegrass, creeping bluegrass), purple pigeon grass and panic species all have a role in certain situations. Legume establishment and species vary significantly depending on soil characteristics and climate. Commonly used legumes include shrubby stylos species, Desmanthus species, Wynn cassia (sandy), butterfly pea (clay), siratro, medics and leucaena (cropping soils).

Class 1 and 2 land is considered suitable for grazing improved pastures and is capable of attaining maximum grazing productivity (QDME 1995, Shields and Williams 1991). In inland Central Queensland this can be defined as the production of young, finished, grassfed, export quality cattle in most seasons, and such country is termed 'fattening country'. **Class 3** land is suitable for grazing improved pastures but is generally less productive than Classes 1 and 2 and encompasses a range in productivity. Land in this class is often termed 'growing country' and is defined as country on which younger cattle perform well but may be difficult to finish at a young age, depending on seasonal conditions (i.e. cattle on Class 3 land may take longer to achieve the desired weight class or finished grade than equivalent cattle on Classes 1 and 2).

Class 4 land is considered marginal for grazing improved pastures, but is generally considered suitable for grazing native pastures of varying quality all year round, depending on soil characteristics, (QDME 1995, Shields and Williams 1991). In inland Central Queensland such country is typically termed 'breeding country'. It encompasses a range in productivity from the lower end of Class 3 'growing country' through to the poorer end of Class 4 'breeding country'. Shields and Williams (1991) suggest 3 possible subclasses exist within Class 4:

- land with native pasture of low productivity, which while physically capable of being developed to improved pasture, is subject to low soil fertility and doubtful long term productivity;
- land with high quality native pasture (typically black soil downs) on which improved pasture establishment is marginal because of unfavourable soil characteristics and limited species; and
- land with native pasture of low productivity, which has physical limitations that preclude full improved pasture development, but allow oversowing of legumes such as shrubby stylo.

Class 5 land is unsuitable for any form of pasture improvement, and land use is limited to extensive grazing of native pastures of low productivity. In many cases, lands are of such poor quality they are considered marginal as 'breeding country' and may be destocked in the winter/dry season, unless grazed in conjunction with better quality country. Land in this class is mostly used, as 'breeding country' during the summer/wet season when planes of nutrition are higher.

Land use requirements, limitations and soil and land attributes

A set of land use requirements for plant growth, machinery use, land preparation, irrigation and the prevention of land degradation has been defined for agricultural land uses in Queensland (Land Resources Branch Staff 1990, QDME 1995). To assess the suitability of any parcel of land for a particular use, it is necessary that each of the relevant land use requirements be considered. Attributes of land which cause it to have less than optimal conditions for a particular use are known as limitations. Management is concerned with overcoming or reducing the effects of such limitations.

In inland Central Queensland, where dryland cropping and grazing are the predominant land uses, a total of 13 land use requirements and associated limitations have been identified as important by the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland*" (QDME 1995). These are listed below and are described more fully in the sections that follow.

Land use requirements	Limitations	Soil and land attributes used to assess each limitation
1. Adequate water supply	water availability (M)	PAWC, ERD (including effects of subsoil sodicity and inherent salinity), deep drainage losses, infiltration rate, crop modelling,
2. Adequate nutrient supply	nutrient deficiency (Nd)	surface soil (0.1 m) levels of Bicarb P (ppm) and Total N (%)
3. Ease of seedbed preparation and plant establishment	surface condition (Ps)	surface soil structure, surface condition, surface soil texture
4. Salinity free root zone	root zone salinity (Sa)	Average salinity within the root zone (ERD)
5. Rock-free	rockiness (R)	size and content (%) of coarse fragments, % rock outcrop
6. Level land surface	microrelief (Tm)	size and frequency of microrelief

Land use requirements		Limitations	Soil and land attributes used to assess each limitation
7.	Adequate soil aeration	wetness (W)	field based soil drainage and permeability classes
8.	Trafficable, stable land surface	topography (Tg)	size, depth and frequency of gullies
9.	Minimum soil loss from erosion	water erosion (E)	slope/soil stability group combinations
10.	Absence of damaging floods	flooding (F)	frequency of flooding based on average recurrence interval (ARI)
11.	Absence of undesirable vegetation	vegetation (V)	vegetation type, regrowth potential, potential for shrubby thickening
12.	Desirable surface soil pH	surface soil pH (0.1m)	1:5 soil water pH
13.	Absence of dispersive behaviour in the soil surface	surface soil dispersive potential (0.1m)	ESP

Limitations listed do not necessarily apply to all land uses or to all soils. The importance of each limitation and the soil and land attributes used in its assessment, as well as the limitation subclasses used in the assessment of final suitability ratings for each soil and land use are discussed more fully below. All explanation, terminology and abbreviations used come directly from or are consistent with the "*Technical guidelines for Environmental Management of Exploration and Mining in Queensland*" (QDME 1995) and the *Guidelines for Agricultural Land Evaluation in Queensland* (Land Resources Branch Staff 1990, DNRM/DSITIA 2013a, 2013b), as well as Mckenzie *et al* (2008), the National Committee on Soil and Terrain (2009) and Isbell (1996).

Water availability (M)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing		QDME (1995) specify max. ERD (in the absence of rock or salinity >800ppm Cl) be set at 0.6m for pastures. PAWC sub-class values listed below are calculated accordingly as 60% of the 1.0m soil depth values listed in Table 2.2 of the QDME scheme (1995).	
M	1	PAWC >75mm/0.6m soil (60% of PAWC >125mm/1.0m; see Table 2.2 QDME (1995))	1
M	2	PAWC 60-75mm/0.6m soil (60% of PAWC 100-125mm/1.0m; see Table 2.2 QDME (1995))	2
M	3	PAWC 45-60mm/0.6m soil (60% of PAWC 75-100mm/1.0m; see Table 2.2 QDME (1995))	3
M	4	PAWC 30-45mm/0.6m soil (60% of PAWC 50-75mm/1.0m; see Table 2.2 QDME (1995))	4
M	5	PAWC <30mm/0.6m soil (60% of PAWC ≤50mm/1.0m; see Table 2.2 QDME (1995))	5

The plant available water capacity (PAWC) of a soil is defined as the amount of stored water a soil is capable of retaining against drainage that is available for plant growth. It represents the total amount of moisture a soil can hold at any given time after free drainage and is calculated as the difference between the water in a soil when fully wet compared with that at wilting point. It is largely dependent on particle size distribution (particularly clay content and mineralogy), structure and pore space within a soil and is calculated as the sum of stored moisture within the effective rooting depth (ERD) of the soil, as determined by the presence or absence of subsoil constraints (i.e. depth to which plant roots can grow and function effectively). PAWC is normally quoted as a measure of equivalent depth of water in the soil in mm.

Stored soil moisture is less critical for grazing than it is for cropping because it grazing productivity is more dependent on continuous vegetative leaf production and harvest rather than maximizing flowering or grain filling potential at set times. Because of this, PAWC limits for each grazing subclass are set at lower levels expected for cropping (QDME 1995).

Nutrient deficiency (Nd)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing		**Bicarb. P (ppm)**	
Nd	1	Brigalow or softwood scrub soils >10ppm	1
Nd	2	Eucalypt soils or open downs >10ppm	2
Nd	3	Other soils 5-10ppm; except deep sands/loams >0.75m; shallow sands/loams on rock	3
Nd	4	Deep sands/loams >0.75m or shallow sands/loams on rock - 5-10ppm; other soils ≤4ppm	4
Nd	5	na	5

The inorganic nutrients phosphorus, potassium and calcium are the dominant nutrients controlling grazing productivity in inland Central Queensland (as defined by the QDME (1995) scheme) and combined levels of these three

nutrients provide a useful framework for evaluating overall nutrient availability. Phosphorus, potassium and calcium are the nutrients required in the largest quantities by plants. They are also critical for both plant and animal growth and metabolism, and are deficient in a number of Central Queensland soils. In general, the inorganic fertility, particularly the level of phosphorus, of a soil reflects the history of soil and landscape development, particularly the interactions between climate, geology, topography, vegetation and fire history over time.

Soil physical factors – surface condition (Ps)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
Ps	1	Cracking clays with very fine SM (<2mm); or rigid soils with loose, soft or firm surface	1
Ps	2	Cracking clays with fine SM (2-10mm); or rigid soils with hardsetting surface	2
Ps	3	Cracking clays with coarse peds at the surface (>10mm); or subject to crusting behaviour	3
Ps	4	na	4
Ps	5	na	5

Seedling emergence and establishment are affected by adverse physical conditions in the surface soil including hard setting, crusting or coarse self-mulching behaviour. Such conditions can reduce plant establishment either by failing to maintain adequate seed - soil contact or by providing a barrier to seedling emergence. High evaporation rates in the Bowen Basin mean it is critical for crop seeds to have adequate seed – soil contact (with moist soil) following planting to ensure desiccation during germination does not occur. In general, soil physical conditions associated with seedling germination and emergence are far less critical for grazing than for the establishment of crops.

Root zone salinity (Sa)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
Sa	1	Rootzone EC <0.15ds/m; or Rootzone Cl <300ppm	1
Sa	2	Rootzone EC 0.15 – 0.3ds/m; or Rootzone Cl 300 - 600ppm	2
Sa	3	Rootzone EC 0.3 – 0.9ds/m; or Rootzone Cl 600 - 900ppm	3
Sa	4	Rootzone EC 0.9 – 1.2ds/m; or Rootzone Cl 900 - 1500ppm	4
Sa	5	Rootzone EC >1.2ds/m; or Rootzone Cl >1500ppm	5

The salinity attribute provides a measure of the presence of soluble salts in the soil profile. Within inland Central Queensland inherent salt loads typically exist at some depth within the upper 2 m of many soil landscapes. Salt loads originate either from the weathering of underlying substrates; or from long term accumulations of cyclic salt (windblown ocean salt) that has built up within the catchments due to the combination of limited rainfall (<650 mm) and slowly drained, relatively low relief landscapes. Soluble salts affect plants through a number of mechanisms:

- osmotic effects that limit water uptake;
- toxicity effects caused by specific ions, principally sodium chloride; and
- restrictions to root development down the profile.

Leaching processes in soils often lead to a concentration of soluble salts in the upper 1-2m of soil landscapes because of subsoil drainage or permeability restrictions. These subsoil concentrations are often termed a salt bulge and provide an indication of the long term, maximum depth to which water typically moves through the soil mass. The depth to any significant salt bulge (>0.8dS/m or Cl >800ppm) is often used as a surrogate for determining effective rooting depth (QDME 1995).

Where significant levels of soluble salts are present within the rootzone (i.e. in the soil material sitting above the effective rooting depth) then effects on plant growth may limit production. Because plant response to soil salinity and effect on crop yield are species specific, comparisons of average or water uptake weighted root zone salinity values against yield reduction data (SalCon 1997) have not been considered as part of this limitation in the QDME (1995) scheme. Instead, a mean profile salinity value (dS/m) averaged across recorded $EC_{1:5}$ values at 0.1 m increments down the profile to the effective rooting depth (ERD) for each soil has been used to define Sa attribute levels (QDME 1995).

Rockiness (R)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
R	1	<20% coarse gravel (<6cm)/rock outcrop	1
R	2	20 – 50% coarse gravel (<6cm)/rock outcrop	2
R	3	50 – 90% cobble (6-20cm)/rock outcrop	3
R	4	>90% cobble (6-20cm)/rock outcrop	4
R	5	100% gravel, cobble (6-20cm),stone, boulders or rock outcrop	5

The rockiness limitation assesses the effect rock outcrop and coarse fragments within the plough zone may have on cultivation and machinery damage. Severity of the rockiness limitation is directly related to the size, quantity and hardness of coarse fragments within the plough zone. Attribute levels record the size and abundance of all coarse fragments (National Committee on Soil and Terrain 2009) described in the field. Coarse gravel refers to fragments that are 20 to 60 mm in size (average maximum dimension) and cobble/stone refers to fragments that are 60 to 600 mm in size. In situations where cultivation and seedbed preparation are required, QDME (1995) subclass criteria are based largely on the subclass limits documented by Shields and Williams (1991).

The presence of rock outcrop, boulders, stone, cobble or gravel has far less effect on grazing than for cropping. Significant rock within a paddock can however physically limit the area of land surface capable of growing pasture and may impact indirectly on the carrying capacity of the land in very rocky situations. In general, subclass criteria for grazing are determined more by the overall % of rock present and are less concerned with the actual size of the material.

Topography – microrelief (Tm)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
Tm	1	Melonholes (VI >0.3m) cover <20%	1
Tm	2	Melonholes (VI 0.3-0.6m) cover 20-50%	2
Tm	3	Melonholes (VI >0.6m) cover 20-50%	3
Tm	4	na	na
Tm	5	na	na

Microrelief refers to local relief of up to a few metres about the plane of the land surface (National Committee on Soil and Terrain 2009). Gilgai or melonhole microrelief are common on clay soils in inland Central Queensland and cause problems with uneven cultivation, reduced trafficability and detrimental effects to plant growth including high salinity loads at shallow depths in gilgai mounds, coarse self-mulching surface conditions and ponding in depressions. Normal, linear and lattice gilgai have a vertical interval of approximately 0.3 m or less and present only a negligible limitation to the use of machinery. Melonhole gilgai however, have a vertical interval greater than 0.3 m and can impede cultivation and trafficability significantly. The degree of limitation associated with melonhole gilgai depends upon the % of the land surface affected, as well as the amplitude (vertical interval (m)) and the relative proportion of mounds, depressions and flat areas. As such, attribute levels are based on a combination of microrelief type and vertical interval (m), as well as an estimate of the spatial extent and variability within a soil.

Microrelief impacts in grazing situations are only seen on severely melonholed soils. In such cases, ponding in depressions and scalding on mounds can result in reduced potential pasture yield and theoretical carrying capacity after significant rainfall events.

Wetness (W)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
W	1	Undulating terrain or elevated plains	1
W	2	Low lying level plains; or rigid soil with strongly sodic subsoil (ESP >15) <0.6m or non-sodic rigid soil with coarse grey/yellow mottling <0.5m	2
W	3	Shallow seasonal and permanent swamps	3
W	4	na	na
W	5	Permanent lakes and deep swamps	5

Wetness refers to excess water both on the soil surface and in the profile, as a direct result of rainfall or run on from adjacent land. Excess water can occur due to poor soil permeability, restricted surface drainage or a combination of both. This limitation does not however, consider excess water associated with overbank stream flow, which is normally considered as part of the flooding limitation. Waterlogged soils reduce plant growth and crop yield and delay effective machinery operation after rain. Excess water in the soil impedes oxygen supply to plant roots and promotes plant disease.

Excess water occurs intermittently in most clay soils in inland Central Queensland. In general, it is only a short-term problem but can result in denitrification due to anaerobic soil conditions, particularly with unseasonal winter rainfall when evaporation rates are low. Temporary waterlogging also occurs in the surface soil of all sodic texture contrast soils, due to problems with subsoil permeability. Bleached A2 horizons are indicative, and 'spewy' (i.e., boggy) conditions are common following rainfall due to super saturation of the surface soil. Frequent and prolonged wetness occurs in enclosed seasonal swamps and slowly drained alluvial backplains, and also on level (<1%), gilgaied clay plains. Melonholed clay plains (with microrelief between 0.6–>1.5 m deep) are normally relatively low-lying and very slowly drained compared with adjacent landscapes. Ponded surface water is often retained within deeper melonholes (>0.6 m) for periods of 3 months or more, particularly in Autumn. As such, QDME (1995) attribute levels for wetness are based largely on field observations of land surface terrain, presence of melonholes, subsoil sodicity and the presence of significant mottling. Landscape wetness is far less critical in grazing situations than for cropping and subclass criteria reflect this accordingly.

Topography – complex slopes/gullies (Tg)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
Tg	1	na	na
Tg	2	na	na
Tg	3	na	na
Tg	4	Many deep gullies make cultivation for pasture improvement impractical; or slopes >15% prevent contour cultivation	4
Tg	5	Strongly dissected terrain over >75% of area makes herd management difficult	5

This limitation only applies in severe or extreme situations where landscape dissection directly affects pasture establishment and/or carrying capacity/grazing productivity.

Water erosion (E)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
E	1	• Slopes <1% on sodic rigid soils • Slopes <3% on all other soils	1
E	2	• Slopes 1-3% on sodic rigid soils • Slopes 3-6% on all cracking clays • Slopes 3-12% on non-sodic rigid soils	2
E	3	• Slopes 3-6% on sodic rigid soils • Slopes 6-9% on all cracking clays • Slopes 12-20% on non-sodic rigid soils	3
E	4	• Slopes 6-12% on sodic rigid soils • Slopes 9-15% on all cracking clays • Slopes 20-45% on non-sodic rigid soils	4
E	5	• Slopes >45%	5

Factors affecting soil erosion are complex and depend on the interaction between rainfall amount, distribution and intensity, slope gradient and length, soil erodibility, infiltration and runoff, vegetative cover and management practices. Because variation in rainfall intensity across inland Central Queensland is relatively minor, and cover levels and management practices are temporal factors outside the scope of a suitability classification, assessment of erosion potential within the QDME (1995) classification considers only inherent soil profile characteristics (profile type, sodicity, surface texture) and slope (%).

Provided grazing lands are well managed, erosion presents only a negligible to moderate limitation (subclasses 1-3) on soil landscapes at slopes <6%; while grazing of any soil type at slopes >45% is unsuitable. Suitability for grazing at slopes between 6-45% is soil type dependent (QDME 1995).

Flooding (F)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
F	1	No flooding	1
F	2	Periodic flooding (includes only during abnormal 1 in 50-100 year events to whenever stream flows occur)	2
F	3	na	na
F	4	na	na
F	5	na	na

Land periodically inundated by water from over bank stream flow is defined as having a flooding limitation. Flooding can cause plant death or reduced growth due to submergence, high water temperatures, anaerobic soil conditions and silt deposition. In addition, severe soil erosion and infrastructure damage may result from high velocity, erosive flooding. The severity of flooding as a limitation for grazing depends largely on the frequency of flooding (rare, infrequent, occasional and regular), although duration, depth and velocity of the floodwaters are also important.

The effects of flooding on grazing are typically negligible to minor, except on major floodplains such as the lower Dawson, Comet, Nogoa, Isaac, Mackenzie and Fitzroy Rivers where inundation for periods of several weeks or more can occur. In these situations stock losses and lost grazing production are significant issues, but are managed effectively through strategic destocking (November to March/April). Even in these situations, subclass 3 would be the maximum limitation subclass recorded.

Vegetation (V) - regrowth management

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
V	1	• Softwood, brigalow, gidgee or blackwood scrub without melonholes • Queensland bluegrass grasslands • Mountain coolabah, bloodwood and ironbark open woodlands	1
V	2	• Brigalow, gidgee or blackwood scrub with melonholes • Box and ironbark woodlands without wattle understorey • Coolabah woodlands on flooded country	2
V	3	na	3
V	4	• Eucalypt woodlands with wattle understorey • Broad-leaved teatree woodlands	4
V	5	na	5

Surface soil (0.1m) pH $_{1:5}$

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
pH $_{1:5}$	1	5.6-6.6	1
pH $_{1:5}$	2	5.0-5.6 6.6-8.0	2
pH $_{1:5}$	3	4.5-5.0 8.0-9.0	3
pH $_{1:5}$	4	4.0-4.5 9.0-10.0	4
pH $_{1:5}$	5	<4.0 >10.0	5

Surface soil (0.1m) dispersive potential (ESP)

Attribute	Level	Description of attribute	Subclasses ratings
Grazing			
ESP (0.1m)	1	<5	1

Attribute	Level	Description of attribute	Subclasses ratings
ESP (0.1m)	2	5-10	2
ESP (0.1m)	3	10-15	3
ESP (0.1m)	4	15-30	4
ESP (0.1m)	5	>30	5

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Isbell RF (1996). *The Australian Soil Classification*. Australian Soil and Land Survey Handbook Series. CSIRO Publishing , Melbourne.

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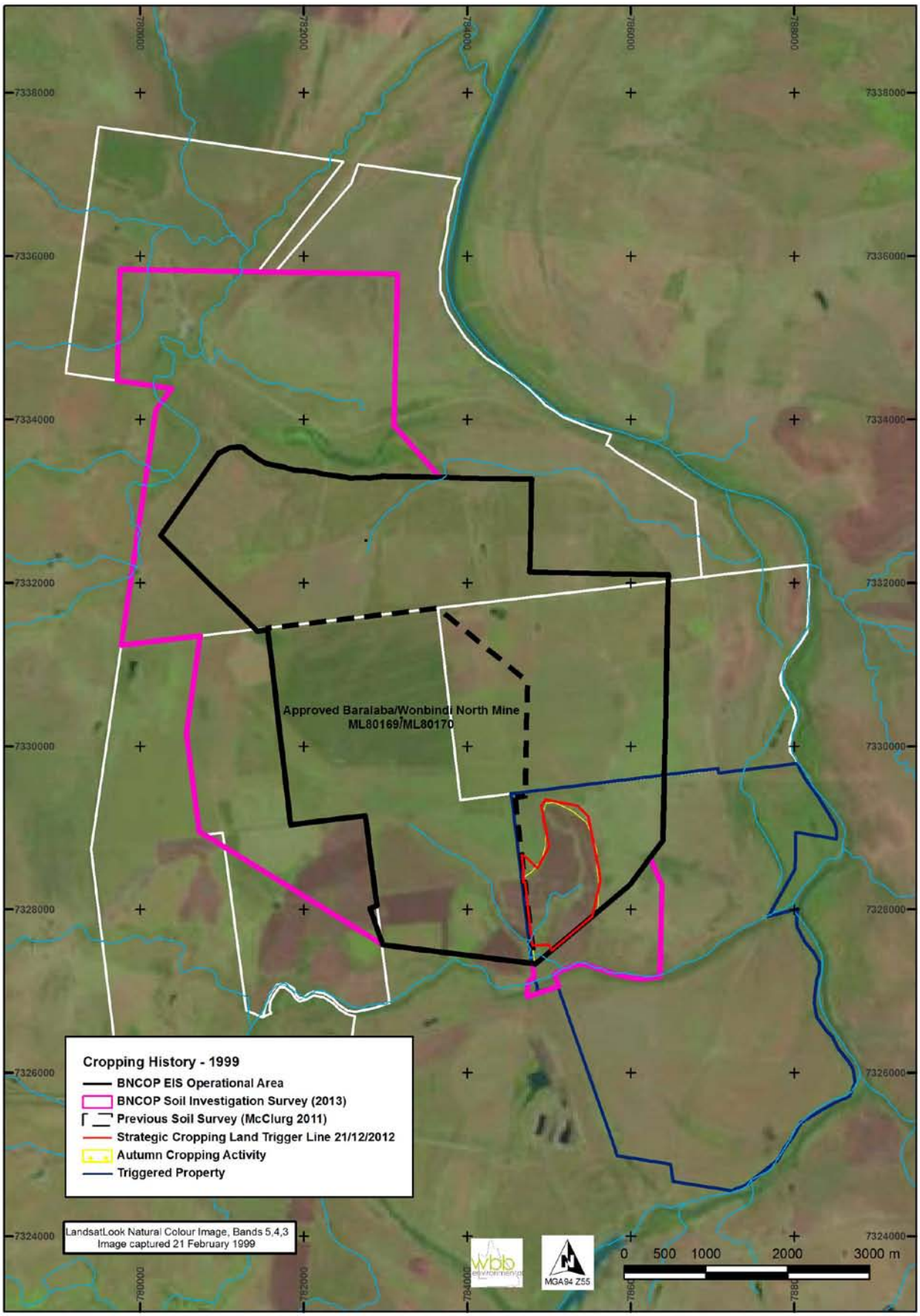
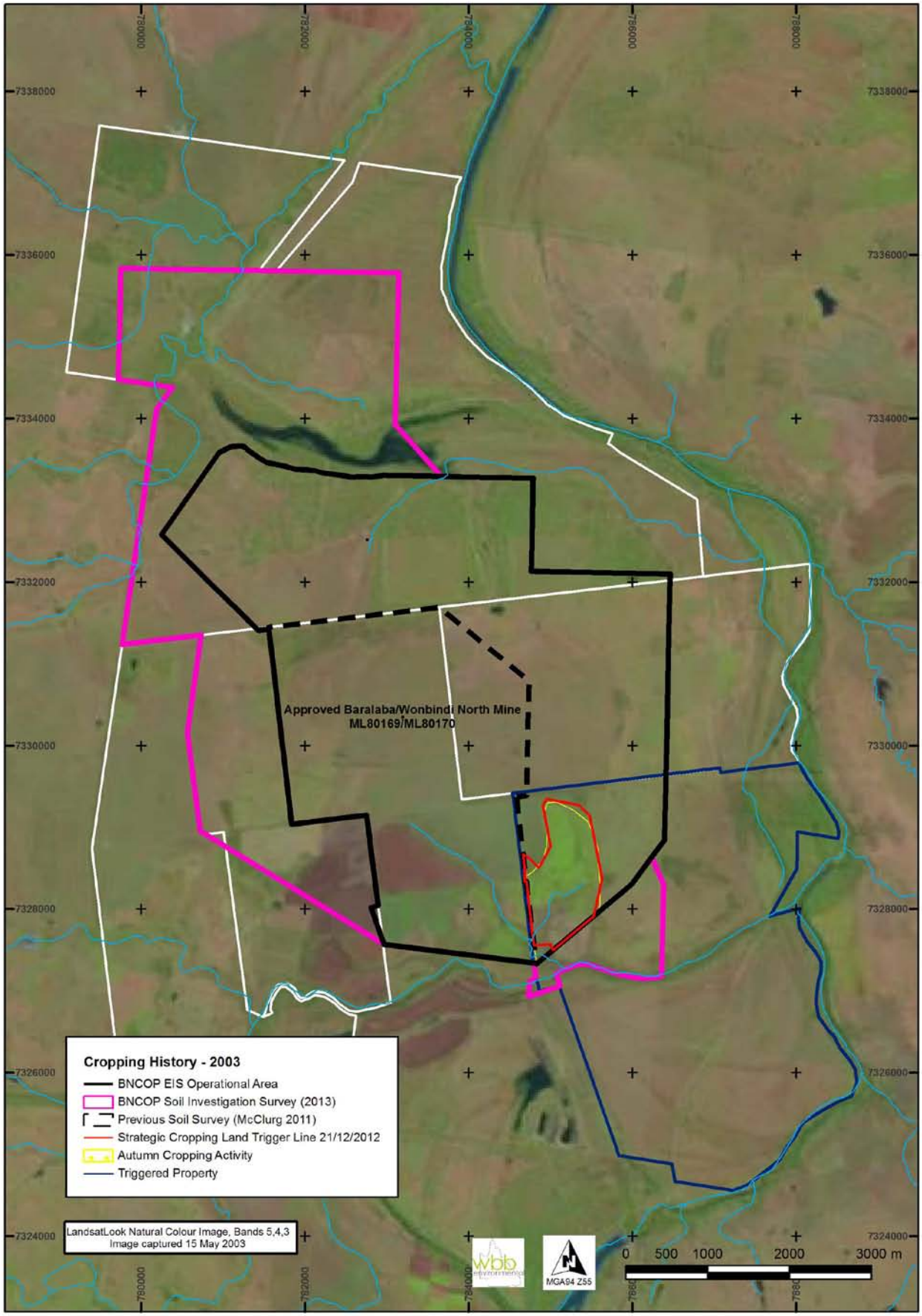
QDME (1995). *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Mines and Energy, Brisbane.

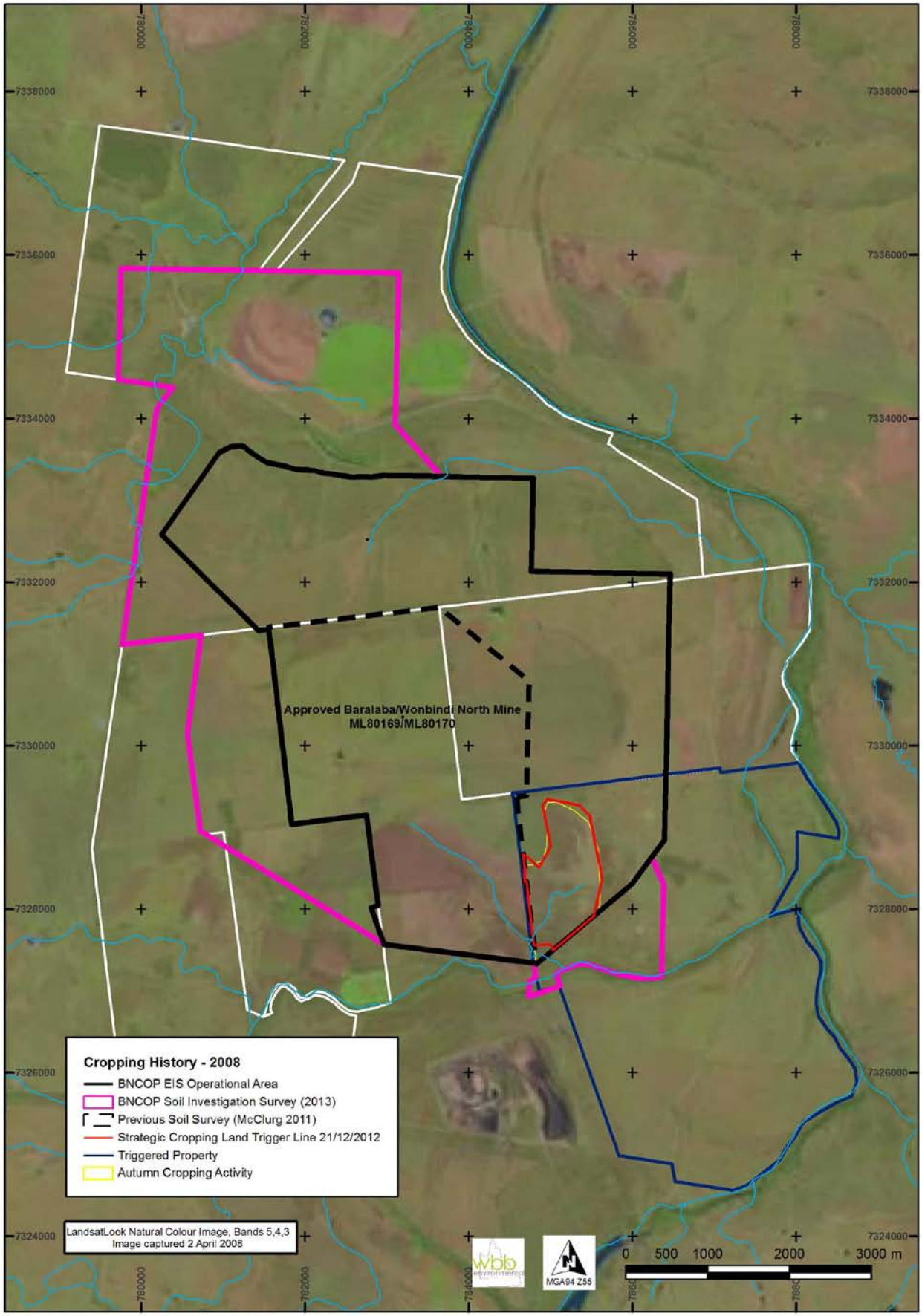
SalCon (1997). *Salinity management handbook*. Department of Natural Resources and Mines DNRQ97109, Queensland.

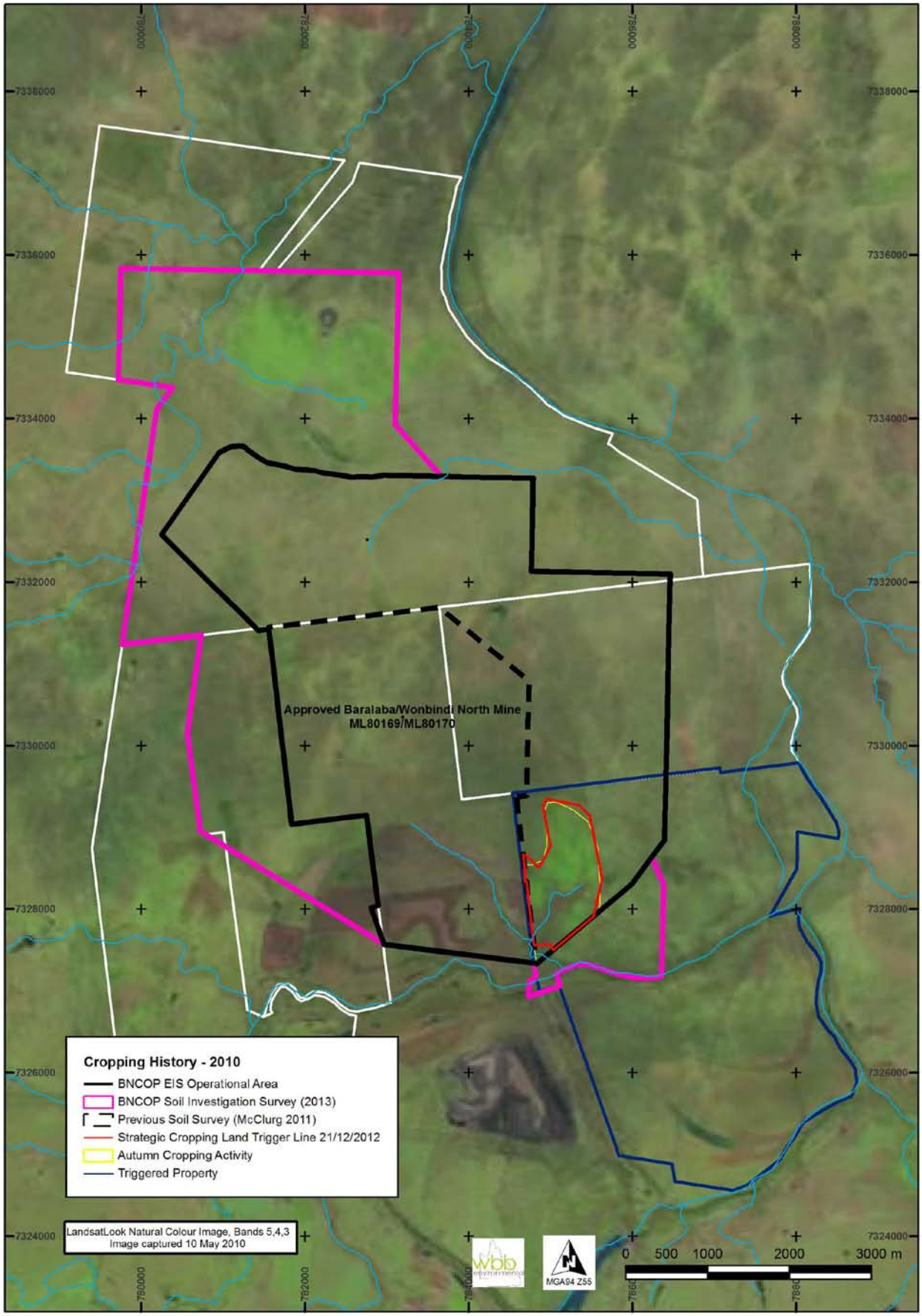
Shields PG and Williams BM (1991). *Land resource survey and evaluation of the Kilcummin area, Queensland*. Queensland Department of Primary Industries, Land Resources Bulletin QV91001.

Appendix 9 – Raw Landsat imagery used to establish cropping history status within properties triggered for SCL assessment by the BNCOP Disturbance Footprint.


Approved Baralaba/Wonbindi North Mine
ML80169/ML80170
Cropping History - 1999
BNCOP EIS Operational Area
BNCOP Soil Investigation Survey (2013)
Previous Soil Survey (McClurg 2011)
Strategic Cropping Land Trigger Line 21/12/2012
Autumn Cropping Activity
Triggered Property
LandsatLook Natural Colour Image, Bands 5,4,3
Image captured 21 February 1999
MGA94 Z55
0 500 1000 2000 3000 m


Approved Baralaba/Wonbindi North Mine
ML80169/ML80170
Cropping History - 2003
BNCOP EIS Operational Area
BNCOP Soil Investigation Survey (2013)
Previous Soil Survey (McClurg 2011)
Strategic Cropping Land Trigger Line 21/12/2012
Autumn Cropping Activity
Triggered Property
LandsatLook Natural Colour Image, Bands 5,4,3
Image captured 15 May 2003
MGA94 Z55
0 500 1000 2000 3000 m


Approved Baralaba/Wonbindi North Mine
ML80169/ML80170
Cropping History - 2008
BNCOP EIS Operational Area
BNCOP Soil Investigation Survey (2013)
Previous Soil Survey (McClurg 2011)
Strategic Cropping Land Trigger Line 21/12/2012
Triggered Property
Autumn Cropping Activity
LandsatLook Natural Colour Image, Bands 5,4,3
Image captured 2 April 2008
MGA94 Z55
0 500 1000 2000 3000 m


Approved Baralaba/Wonbindi North Mine
ML80169/ML80170
Cropping History - 2010
BNCOP EIS Operational Area
BNCOP Soil Investigation Survey (2013)
Previous Soil Survey (McClurg 2011)
Strategic Cropping Land Trigger Line 21/12/2012
Autumn Cropping Activity
Triggered Property
LandsatLook Natural Colour Image, Bands 5,4,3
Image captured 10 May 2010
MGA94 Z55
0 500 1000 2000 3000 m

Appendix C. PRCP Schedule and Stage Plans

PRCP schedule

Environmental Protection Act 1994

PRCP schedule P-PRCP-100908098_V1 Baralaba Coal Mine

This is the approved form for a PRCP schedule issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

PRCP schedule: P-PRCP-100908098

PRCP schedule holder(s)

Name(s)	Registered address
Baralaba Coal Pty Ltd (ACN 009 805 029); and, Wonbindi Coal Pty Ltd (ACN 114 668 941).	Level 20, 10 Eagle Street, BRISBANE CITY QLD 4000

Location details

Location(s)
ML5605, ML5580, ML5581, ML5590, ML80157, ML80169, ML80170, ML80200, ML80201, and ML700004

Take effect

In accordance with section 202B of the *Environmental Protection Act 1994* (EP Act), the PRCP schedule has effect on the day the environmental authority for carrying out relevant activities on land to which the schedule relates takes effect. Pursuant to section 202C of the EP Act, a PRCP schedule continues in force until the environmental authority for the relevant activities to which the PRCP schedule relates is cancelled or surrendered, even if the resource tenure expires or is cancelled and even if the relevant environmental authority is suspended under Chapter 5, part 11 or 11A of the EP Act.

Signature	Date
	21 October 2025

Ben Byrd
Department of the Environment, Tourism, Science and Innovation
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Business Centre Coal
PO Box 3028 EMERALD QLD 4720
Phone: (07) 4987 9320
Email: CRMining@detsi.qld.gov.au

Queensland Government

Obligations under the *Environmental Protection Act 1994*

Pursuant to section 202E of the EP Act, if there is an inconsistency between an environmental authority and a PRCP schedule, the environmental authority prevails to the extent of the inconsistency.

Pursuant to section 285 of the EP Act:

- the holder of a PRCP schedule must commission an audit of the schedule by a rehabilitation auditor for the following periods (each an audit period) —

  (a) the 3-year period starting on the day the schedule takes effect

  (b) each 3-year period starting on the day after the previous audit period ended.
- the holder must, within 4 months after the end of each audit period, give the administering authority -

  (a) the rehabilitation auditor's report (an audit report) about the audit that complies with section 286 of the EP Act, and

  (b) a declaration for the audit report that complies with section 285 of the EP Act.

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

PRCP schedule

The PRCP schedule incorporates the following sections:

- Section A - Conditions of PRCP schedule
- Section B – Definitions
- Section C - Final site design and reference maps
- Section D - Post mining land uses
- Section E - Non-use management areas.
- Section F - Appendices

Section A - Conditions of PRCP schedule

Pursuant to section 206A of the EP Act:

- it is a condition of this PRCP schedule that, in carrying out a relevant activity under the schedule, the holder must comply with a requirement stated in the environmental authority relevant to carrying out the activity.
- it is a condition of this PRCP schedule that the holder must comply with the following matters stated in the schedule -

  (a) each rehabilitation milestone and management milestone

  (b) when each rehabilitation milestone and management milestone is to be achieved

General conditions

PRCP1 All mining disturbance authorised under environmental authority EPML00223213 must have an associated rehabilitation outcome provided in this PRCP Schedule.

PRCP2 The holder must for each rehabilitation area and improvement area, achieve the corresponding rehabilitation or management milestone criterion (milestone reference):

(a) for the cumulative area available specified in this schedule; and

(b) by the milestone completion date specified in this schedule.

PRCP3 Where land becomes ‘available for rehabilitation’ earlier than the date nominated in this schedule, the holder must:

(a) notify the administering authority in writing within 30 days of the land becoming ‘available for rehabilitation’; and

(b) describe in the notification why or why not it considers that it would be reasonable and appropriate to apply to the administering authority to amend this schedule; and

(c) unless otherwise agreed to by the administering authority in writing, apply to the administering authority within sixty (60) days of the notification to amend this schedule in a way that maximises the progressive rehabilitation to a stable condition.

Note:

(1) Reference to "earlier than the nominated date in the schedule" means a date that is greater than 1 year prior to the date nominated in the schedule.

(2) Assessment of land becoming available is undertaken on a nominally annual basis.

(3) Rehabilitation of land size must be practicable and economical.

(4) The dates by which milestones are to be completed is brought forward, to the extent it is reasonably practicable to do so, by the same amount of time as the commencement was brought forward.

PRCP4 Where an area achieves a rehabilitation or management milestone, the holder must continue to achieve the milestone criteria for that rehabilitation milestone until:

(a) A progressive certification area has satisfied the provisions of section 318ZB(4) of the EP Act; or

(b) Until a surrender is approved.

PRCP5 The holder must maintain a risk register that identifies the risks to not achieving:

(a) a stable condition for post-mining land uses.

(b) sufficient improvement for non use management areas.

(c) how the risks are being managed or minimised.

PRCP6 The risk register (**PRCP5**) must be reviewed every three (3) years and include consideration of the outcomes of PRCP monitoring data.

PRCP7 The holder must carry out monitoring of the rehabilitation activities in the rehabilitation areas in accordance with:

(a) the monitoring and maintenance program described in the rehabilitation planning part for the activity titled *Baralaba Coal Mine: Transitional Progressive Rehabilitation and Closure Plan*;

(b) any requirement under this schedule; and,

(c) as necessary to demonstrate achievement of each rehabilitation milestone or management milestone criteria.

Note: Where there is any inconsistency between this schedule and the rehabilitation planning part the schedule criteria prevail to the extent of the inconsistency.

PRCP8 The holder must make and keep up to date records on:

(a) Achievement and maintenance of each rehabilitation milestone criteria of this schedule.

(b) Rehabilitation activities and the results of those activities (including but not limited to, actions taken, date, location, methods, data collected, Quality Assurance/Quality Control, photos, waste tracking and disposal records, appropriately qualified person details and assumptions);

(c) Maintenance of rehabilitation and the results of maintenance activities;

(d) Monitoring of rehabilitation and the results of monitoring;

(e) Details and results of rehabilitation trials;

(f) Designs, drawings, specifications and any similar documents developed in accordance with good professional practice in relation to rehabilitation milestones or milestone criteria;

(g) All documents in relation to the requirements of this schedule, including reports (e.g. site investigation report), statements (e.g. site suitability statement), certifications, assessments, investigations, inspections, audits or any similar documents developed in relation to rehabilitation milestones or milestone criteria;

(h) Landholder agreements;

(i) Details of community consultation in the community consultation register relating to rehabilitation and closure activities.

PRCP9 Records made under **PRCP8** must be kept until the relevant environmental authority has been surrendered.

PRCP10 Records made under **PRCP8** must be provided to the administering authority in the specified format within 10 business days of a written request, or a timeframe agreed to by the administering authority.

PRCP11 All AQP designs, specifications, certifications, assessments and any similar documents developed in accordance with good professional practice must include documented consideration of any relevant guideline or publication material.

PRCP12 Disturbance due to exploration and minor ancillary activities in areas not planned to be mined and not within a Rehabilitation Area in this Schedule must be rehabilitated in accordance with the provisions detailed in the 'Eligibility criteria and standard conditions for exploration and mineral development projects' or its successor, with the exception that land must be rehabilitated to a stable condition which includes achieving the relevant post mining land use for the disturbance location as detailed in **Figure 1 – Final Site Design**.

PRCP13 The groundwater model and long-term water balance model must be recalibrated and predictions rerun as required under Environmental Authority EPML00223213.

PRCP14 Where the modelling conducted under **PRCP13** indicates a risk to achieving stable condition, an amendment application to this PRCP Schedule must be submitted to the administering authority to address the risk within three (3) months of the risk being identified.

PRCP15 An up-to-date groundwater model and long-term water balance model must be maintained with predictions rerun at least as required under Environmental Authority EPML00223213 and within a year of any surrender application.

PRCP16 A pre-construction detailed landform design plan and report must have been developed and certified by an AQP as being safe, erosionally and structurally stable, and appropriate for the PMLU, with regard to the material properties and local conditions as it applies to a geotechnical and erosional stability risk. The detailed landform design plan and report must demonstrate that the landform will support the achievement of a stable condition.

PRCP17 The requirements of **PRCP16** must confirm, through an analysis of future landform stability, that the final landform configuration is able to achieve the criteria of this PRCP schedule across all areas of the landform. The modelling must:

(a) be calibrated against existing performance to support the methodology and parameters adopted in the models; and

(b) demonstrate stability of the final landform.

(c) be undertaken in accordance with the latest version of the Queensland Government's '*Applying erosion and Landscape Evolution Models to assess post-mining landform stability: Technical Paper*'.

PRCP18 The requirements of **PRCP16** must confirm, through an assessment of long-term geotechnical safety and stability, that the final landform configuration is able to achieve stable condition across all areas of the landform. The assessment must:

(a) Develop of a geotechnical model for the entire site;

(b) Consider all credible potential instability mechanisms:

(c) Include a stability analysis using quantitative methods such as Factor of Safety (FOS), Probability of Failure (POF), or Strength Reduction Factor (SRF) including consideration of the implication of achieving a FOS of 1.5 on all constructed landforms;

(d) A consequence assessment to evaluate the potential impacts of slope failure; and

(e) Consider the requirements and limitations, including evaluation of model uncertainty and development of stability acceptance criteria, discussed in of ACARP Project C34028 – *Guidelines for Assessment of Geotechnically Safe and Stable Post-Mining Landforms*.

PRCP19 The detailed landform design plan and report that has met the requirements of **PRCP16** to **PRCP18** inclusive, and any modelling and modelling results relevant to **PRCP17** and **PRCP18**, must be provided to the administering authority no later than **10 December 2026.**

PRCP20 Prior to the commencement of tailings or rejects disposal, a rehabilitation strategy and supporting report must be developed and certified by an AQP. The strategy must provide a plan for the rehabilitation of tailings and rejects that is safe, erosionally and structurally stable, and appropriate for the intended PMLU, having regard to the material properties and local site conditions.

PRCP21 The rehabilitation strategy and report required under **PRCP20** must include an assessment of the long-term geotechnical and geochemical safety and stability of the final landform configuration, including seepage and leachate considerations. The assessment must demonstrate that the proposed rehabilitation strategy will not compromise the landform's ability to achieve a stable condition and meet all relevant criteria specified in this PRCP Schedule.

PRCP22 The rehabilitation strategy and supporting report, including all relevant modelling and sampling data prepared in accordance with **PRCP20** and **PRCP21**, must be submitted to the administering authority prior to the commencement of tailings and rejects disposal.

PRCP23 Three months prior to the commencement of tailings or rejects disposal, an amendment application to this PRCP Schedule must be submitted to the administering authority inclusive of the rehabilitation strategy and report described **PRCP20** and **PRCP21**.

END OF CONDITIONS

Section B – Definitions

Appropriately qualified person (AQP)	means a person who has professional qualifications, training, skills and 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.
Activity (EP Regulation)	includes that part, if any, of an activity relating to the following— (a) preparing a place for the activity before carrying out the activity; (b) rehabilitating a place after it has been used for carrying out the activity.
Ancillary activities	see section 19A of the *Environmental Protection Act 1994*.
BioCondition	refers to the *BioCondition Assessment Manual* (Eyre, T.J., Kelly, A.L, Neldner, V.J., Wilson, B.A., Ferguson, D.J., Laidlaw, M.J. and Franks, A.J. (2015)) and *BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2* (Queensland Herbarium, Department of Science, Information Technology, Innovation and Arts, Brisbane) or version thereof that is current on the first date area is available for **RA6**.
Contaminants	can be a gas, liquid or solid; or an odour; or an organism (whether alive or dead), including a virus; or energy, including noise, heat, radioactivity and electromagnetic radiation; or a combination of contaminants.
Environmentally problematic material	means material that will negatively impact water quality and stability or vegetation growth.
Flood stress	is the pressure on structures from rapid water rise, erosion, and saturation during extreme floods, risking instability.
Growth media	is defined as all soil and soil-like material that will support the final vegetation cover. This includes the topsoil and subsoil where these materials are applied independently. Where the topsoil is incorporated into the underlying subsoil/spoil, topsoil refers to the depth of incorporation and the remaining depth is regarded as subsoil. The total depth of growth media is nominally considered to be the effective plant root zone
Gully	A gully is a channel excavated by water, more than 0.3 m deep.
Potentially acid forming (PAF)	means material with either a Net Acid Producing Potential of greater than 5 kg of H_2SO_4/tonne or a Net Acid Generation oxidation pH of less than 4.5 (pH unit).
Rehabilitation activity	means any activity that the holder is required to carry out in relation to this PRCP schedule.
Relevant material	includes: (a) Final landform design report, (b) Durability assessment/ report, (c) “As Constructed” report; (d) All monitoring data (e) Assessment of monitoring data,

	(f) All maintenance records; and (g) Modelling and technical assessments.
Relevant structure	To be defined during the assessment and listed here. Typically includes TSF and higher risk structures, including WRDs.
Rill	A rill is a channel excavated by water, less than 0.3 m deep.
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 environmental context, geotechnical stability, settlement and consolidation allowances, bearing capacity (trafficability), erosion resistance and geochemical stability with respect to seepage, leachate and related contaminant generation.
Stabilised	means one or both of the following conditions apply: no evidence of sediment movement; sides and/or floors of erosion form are revegetated (Australian Soil and Land Survey Field Handbook Third Edition).
Stable condition	see section 111A of the *Environmental Protection Act 1994*.
Suitably qualified person (SQP)	for performing a regulatory function under chapter 7, part 8 (Contaminated Land) of the EP Act or another function prescribed under a regulation, means a person who— (a) has qualifications and experience relevant to performing the function; and (b) if a regulation prescribes an organisation for this paragraph—is a member of the organisation.
Vegetative groundcover	Means plants, plant litter, tree leaf litter, twigs and woody debris capable of protecting the soil surface from erosion

Section C - Final site design and reference maps

List of figures:

Figure 1 – Final Site Design

Figure 2 – Reference Map

Figure 1: Final Site Design

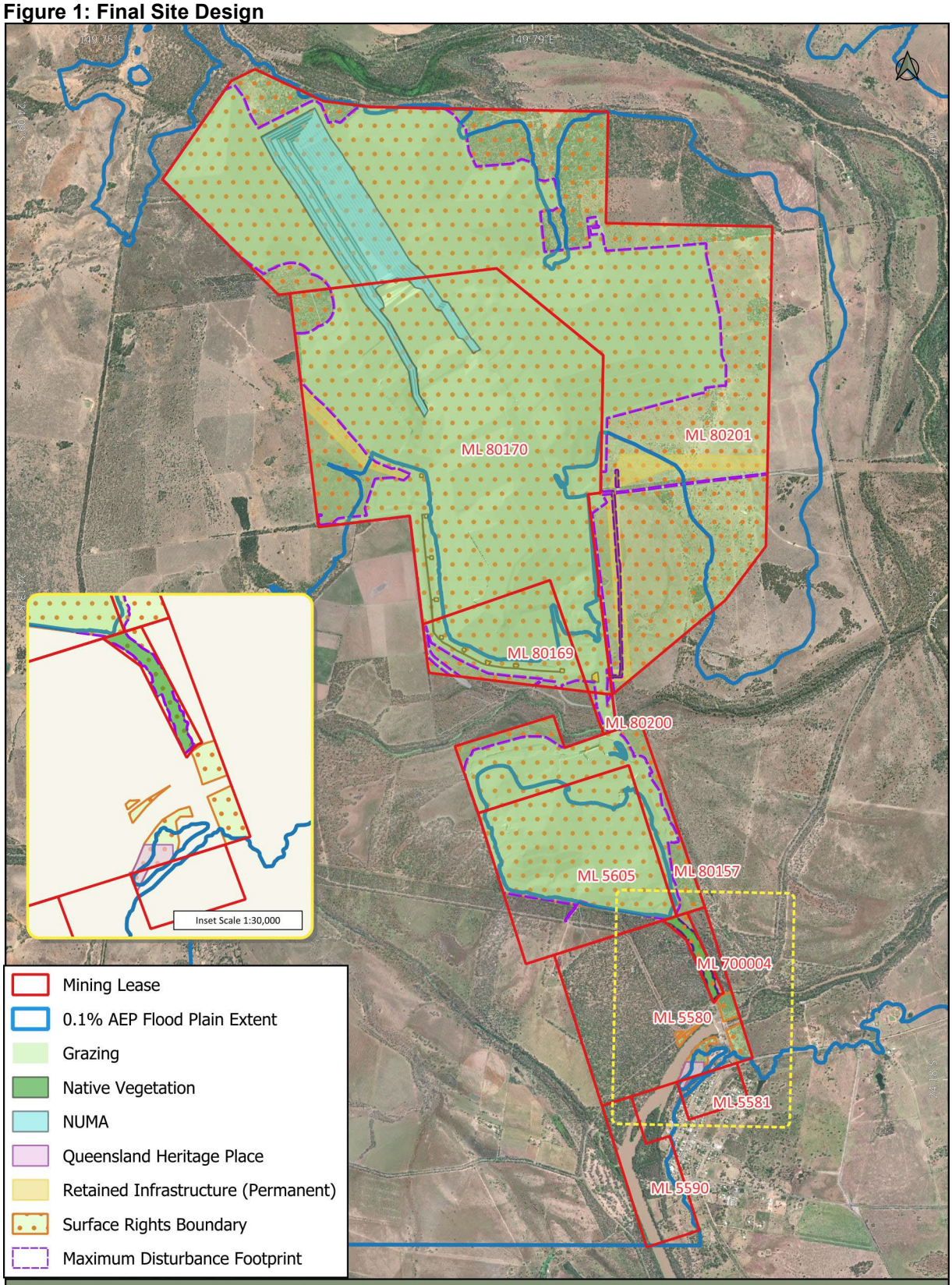


Figure 1: Conceptual Final Landform

Baralaba Coal Mine

Client	Baralaba Coal Pty Ltd
Author	C.An
Date	19/09/2025
Revision	5
Map Projection	GDA2020 / MGA zone 55

0 500 1,000 m

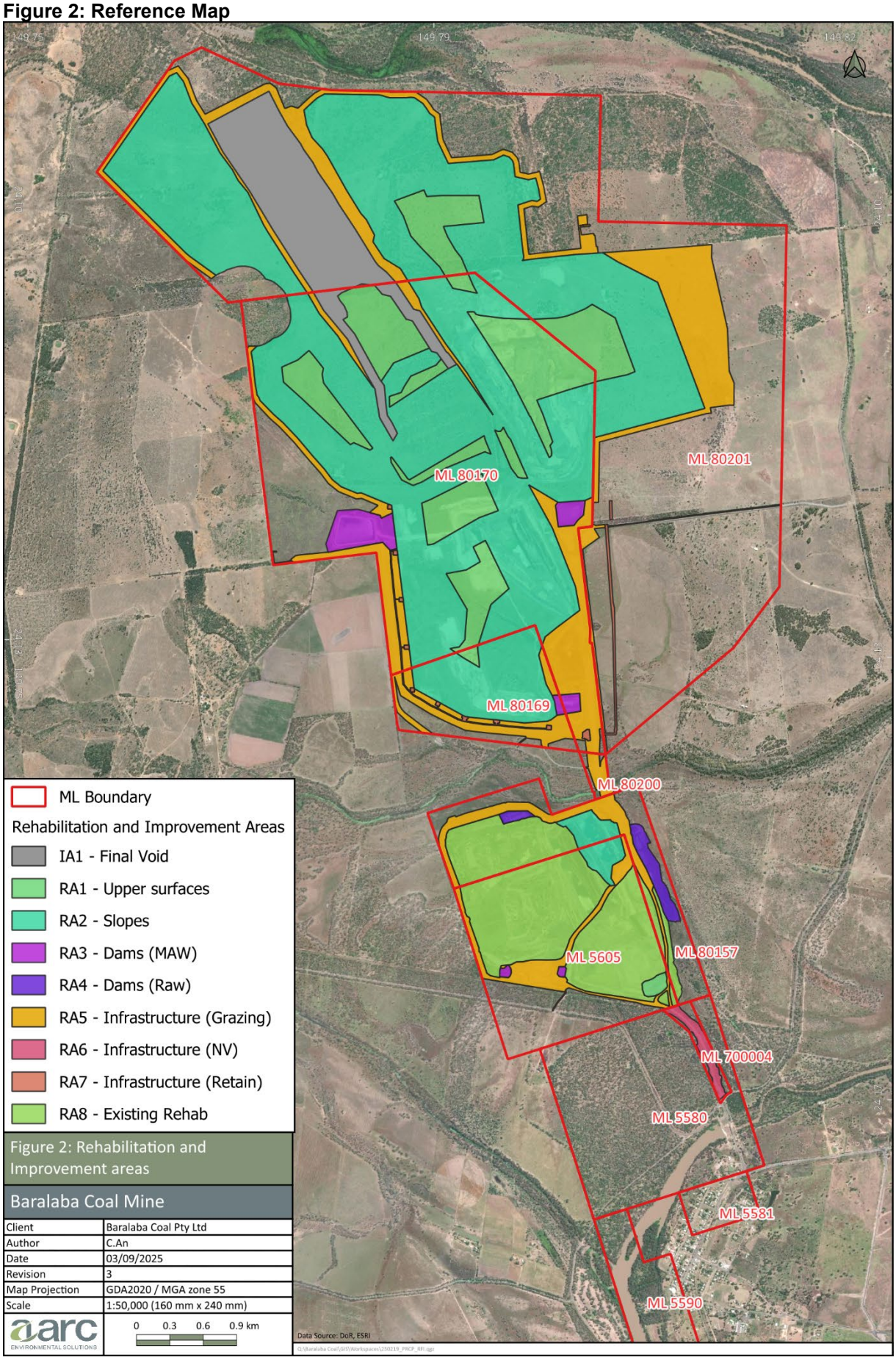
Scale: 1:60,000 (160 mm x 240 mm)

Data Source:

Q:\Baralaba Coal\GIS\Workspaces\250219_PRCP_RFI.qgz

arc ENVIRONMENTAL SOLUTIONS

Figure 2: Reference Map



Section D – Post mining land uses

(RA1) Rehabilitation area 1

Post-mining land uses (PMLU)							
Rehabilitation area	RA1						
Relevant activities	Upper Surfaces - Baralaba North, Central Waste Dumps, and backfilled void						
Total rehabilitation area size (ha)	249						
Commencement of first milestone: RM1	10/12/2026						
PMLU	Low intensity grazing						
Date area is available	10/12/2026	10/12/2030	10/12/2032	10/12/2036			
Cumulative area available (ha)	10	45	77	249			
Milestone completed by	10/12/2027	10/12/2032	10/12/2037	10/12/2042	10/12/2047	10/12/2052	10/12/2057
Milestone Reference	**Cumulative area achieved (ha)**						
RM1	10	45	77	249			
RM2		45	77	249			
RM3		22	77		249		
RM4		10	77		249		
RM5		10	77		249		
RM7			10	77		249	
RM9				10	77		249

(RA2) Rehabilitation area 2

Post-mining land uses (PMLU)							
Rehabilitation area	RA2						
Relevant activities	Slopes - Baralaba North and Central Spoil Waste Dumps, backfilled void						
Total rehabilitation area size (ha)	1023						
Commencement of first milestone: RM1	10/12/2026						
PMLU	Low intensity grazing						
Date area is available	10/12/2026	10/12/2029	10/12/2031	10/12/2036			
Cumulative area available (ha)	50	244	578	1023			
Milestone completed by	10/12/2027	10/12/2032	10/12/2037	10/12/2042	10/12/2047	10/12/2052	10/12/2057
Milestone Reference	**Cumulative area achieved (ha)**						
RM1	50	244	578	1023			
RM2		244	578	1023			
RM3		143	504	978	1023		
RM4		93	404	878	1023		
RM5		50	304	778	1023		
RM7			50	304	778	1023	
RM9				50	304	778	1023

(RA3) Rehabilitation area 3

Post-mining land uses (PMLU)				
Rehabilitation area	RA3			
Relevant activities	MAW Dams (Mine Dam 1, Mine Dam 4a, Sediment Dam D, ROM Sediment Dam, Central ROM Dam)			
Total rehabilitation area size (ha)	28.6			
Commencement of first milestone: RM1	10/12/2042			
PMLU	Low intensity grazing			
Date area is available	10/12/2042			
Cumulative area available (ha)	28.6			
Milestone completed by	10/12/2043	10/12/2047	10/12/2052	10/12/2057
Milestone Reference	**Cumulative area achieved (ha)**			
RM1	28.6			
RM2		28.6		
RM3		28.6		
RM4		28.6		
RM5		28.6		
RM7			28.6	
RM9				28.6

(RA4) Rehabilitation area 4

Post-mining land uses (PMLU)				
Rehabilitation area	RA4			
Relevant activities	Dams (Farm Dam, Lagoon)			
Total rehabilitation area size (ha)	12.9			
Commencement of first milestone: RM1	10/12/2042			
PMLU	Low intensity grazing			
Date area is available	10/12/2042			
Cumulative area available (ha)	12.9			
Milestone completed by	10/12/2043	10/12/2048	10/12/2053	10/12/2058
Milestone Reference	**Cumulative area achieved (ha)**			
RM1	12.9			
RM2		12.9		
RM3		12.9		
RM4		12.9		
RM5		12.9		
RM7			12.9	
RM9				12.9

(RA5) Rehabilitation area 5

Post-mining land uses (PMLU)					
Rehabilitation area	RA5				
Relevant activities	Infrastructure (Roads, Hard Dams, MIA, Workshop Areas, Haul Roads) and backfilled void				
Total rehabilitation area size (ha)	350				
Commencement of first milestone: RM1	10/12/2042				
PMLU	Low intensity grazing				
Date area is available	10/12/2042				
Cumulative area available (ha)	350				
Milestone completed by	10/12/2043	10/12/2048	10/12/2053	10/12/2058	10/12/2063
Milestone Reference	**Cumulative area achieved (ha)**				
RM1	350				
RM2		350			
RM3		350			
RM4		250	350		
RM5		150	350		
RM7			150	350	
RM9				150	350

(RA6) Rehabilitation area 6

Post-mining land uses (PMLU)				
Rehabilitation area	RA6			
Relevant activities	Infrastructure (ML700004 Haul Road)			
Total rehabilitation area size (ha)	8.4			
Commencement of first milestone: RM1	10/12/2042			
PMLU	Native Vegetation			
Date area is available	10/12/2042			
Cumulative area available (ha)	8.4			
Milestone completed by	10/12/2043	10/12/2048	10/12/2053	10/12/2068
Milestone Reference	**Cumulative area achieved (ha)**			
RM1	8.4			
RM2		8.4		
RM3		8.4		
RM4		8.4		
RM6		8.4		
RM8			8.4	
RM10				8.4

(RA7) Rehabilitation area 7

Post-mining land uses (PMLU)	
Rehabilitation area	RA7
Relevant activities	Infrastructure (Powerline Permanent Infrastructure)
Total rehabilitation area size (ha)	8.1
Commencement of first milestone: RM1	10/12/2034
PMLU	Permanent Infrastructure
Date area is available	10/12/2034
Cumulative area available (ha)	8.1
Milestone completed by	10/12/2035
Milestone Reference	**Cumulative area achieved (ha)**
RM11	8.1

(RA8) Rehabilitation area 8

Post-mining land uses (PMLU)		
Rehabilitation area	RA8	
Relevant activities	MAW Dams, Infrastructure (Roads, Hard stands), Waste Dump, Backfilled Void	
Total rehabilitation area size (ha)	216	
Commencement of first milestone: RM1	10/12/2023	
PMLU	Low intensity grazing	
Date area is available	10/12/2022	
Cumulative area available (ha)	216	
Milestone completed by	10/12/29	10/12/34
Milestone Reference	**Cumulative area achieved (ha)**	
RM7	216	
RM9		216

Rehabilitation area milestones

Milestone reference	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal	(1.1) With the exception of any infrastructure to remain as part of the post-mining land use (PMLU), where agreed to be retained by the landholder as evidenced by a signed landholder agreement, or required for rehabilitation activities, the following are complete: (a) All services disconnected, terminated and removed. (b) All buildings and associated infrastructure dismantled and removed offsite. (c) All hardstand, concrete areas and roads (bitumen, blue metal, aggregate etc) removed. (d) All fencing that is not part of PMLU requirements removed. (e) All pipelines drained and removed. (f) All waste not authorised to be disposed of on-site under Environmental Authority EPML00223213 removed. (g) All surface water drainage infrastructure not required for the PMLU is removed. (h) All drillholes, bores, sediment ponds and sumps decommissioned. (i) All machinery and equipment removed from site. (j) All clean water dams dewatered and backfilled.
RM2	Identification, remediation and removal of contaminated land	(2.1) Contaminated or hazardous material either remediated in-situ or removed/transported to a facility lawfully able to accept the material. (2.2) Contaminated Land Investigation Document completed in accordance with the EP Act, including a site investigation report, and, where required, a Validation Report and/or a draft Site Management Plan. (2.3) SQP certifies that: (a) contaminated materials other than approved waste materials have been removed or rehabilitated and that no contamination unsuitable for the PMLU remains or is occurring; and,

Milestone reference	Rehabilitation milestone	Milestone criteria
		(b) approved waste materials are appropriately encapsulated such that there is no release of general waste materials, leachate, landfill gas or other contaminants that will cause environmental harm from the landfill activities.
RM3	Landform development and reshaping	(3.1) All earthworks completed to final detailed landform design with an 'As constructed' survey plan showing surveyed area and finished slopes conform to the designed landform and drainage for each sub-area. (3.2) Landform surface drainage has been designed and installed as follows: (a) Landforms sheet flow to either existing drainage gullies or constructed drains integrated into the final landform. (b) Existing drainage gullies will not receive excess catchment runoff that may impact the stability of the existing waterway. (c) Where required, drains are constructed at a suitable longitudinal grade and cross-sectional area to convey the upstream catchment without causing erosion or instability. (d) Where locations of high velocity are expected (steep concentrated flow locations or drainage tie in locations with existing drainage features) rock protection is installed to prevent erosion. (e) Surface has been shaped to prevent ponding and concentration of surface water flow. (3.3) Diversions/drainage and erosion and sediment control systems are installed as per the engineering and construction design and verified by an appropriately qualified person (AQP). (3.4) AQP certifies that as constructed landform achieves design criteria for geotechnical stability as determined under **PRCP18**. (3.5) All slopes achieve the following: (a) **RA1, RA2**, **RA3** and **RA4**, disturbed slopes not steeper than 9 degrees (15%). (b) **RA5 and RA6**, disturbed slopes not steeper than 3 degrees (5%). **Additional criteria for spoil dumps within RA1, RA2 and RA5:** (3.6) Spoil dumps have erosion management systems in place as per AQP design to minimise erosion from runoff and to reduce the total catchment area reporting to the final void.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(3.7) Surfaces on top of spoil dumps reshaped to be free draining to prevent rainfall infiltration to the landform. **Additional criteria applicable to in-pit spoil and voids within RA1, RA2 and RA5:** (3.8) Spoil settlement analysis of in-pit spoil completed by an AQP certifies that the long-term landform is stable and functioning as per design intent. (3.9) Assessment from an AQP that that void areas (excluding IA1) are backfilled above the modelled groundwater equilibrium levels. (3.10) Exposed coal seams at the floor of voids have been treated, removed, or covered with ≥ 2 m of Non-Acid Forming (NAF) material in the backfilling process. (3.11) To the maximum extent reasonable, drainage outward away from voids towards original topographic drainage paths, other than for internal void slopes. **Additional criteria applicable to the waste disposal area cover:** (3.12) A final capping system to the landfill area must be designed by an AQP and installed to: (a) minimise infiltration of water into the landfill area and water ponding on the surface; (b) minimise the likelihood of any erosion occurring to either the final capping system or the landfilled materials; and (c) ensure the contaminant concentrations are appropriate for the final land use and in accordance with the 'National Environmental Protection (Assessment of Soil Contamination) Measure 1999'.
RM4	Surface preparation	(4.1) Assessment of growth media characteristics and the development of an amelioration and physical treatment plan is completed by an AQP. (4.2) Ameliorants and physical treatments, such as fertiliser, lime, gypsum and/or organic matter, are added to improve soil quality characteristics, at rates recommended by an AQP in alignment with criterion in **RM 4.1**. (4.3) Ripping of compacted surfaces into the soil/subsoil profile along contour of slopes. (4.4) Topsoil placement of a minimum of 200 mm.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(4.5) Following amelioration as per **RM 4.1** and **RM 4.2**, representative soil testing of growth media confirms, for **RA1**, **RA2**, **RA3**, **RA4, RA5** and **RA6** that the relevant depths within the effective root zone (0–200mm) meet the following suitability targets: (a) Emerson aggregate class: 3; (b) pH in the range of >5.6 and <8.4; (c) Available Phosphorous (P): ≥4 mg/kg (d) ECe (Electrical conductivity from a saturated extracted) ≤1.5 dS/cm; and (e) Exchangeable sodium percentage (ESP%) < 6 %. (4.6) For the relevant depths within the effective root zone (200mm – 300mm), for **RA1**, **RA2**, **RA3**, **RA4, RA5** and **RA6** representative soil testing of the growth media demonstrates the materials are stable, and have been assessed and documented by an AQP as being suitable for the PMLU and target vegetation establishment. (4.7) Where soil assessment results identify that the characteristics specified in **RM 4.5** and **RM 4.6** have not been met, soil is treated with ameliorants and / or fertilisers, as per recommendations made by an AQP. (4.8) The surface and groundwater monitoring, as required by RM 9 and RM 10, is underway (at least one year of sampling undertaken).
RM5	Revegetation (Low-intensity grazing)	(5.1) With the exception of a non-permanent cover crop species, the seed mix must be spread at the minimum seeding rates of 14 kg/ha of seed unless adjusted by an AQP, and contain only those species listed in, **Table 1 – Low-intensity grazing PMLU Seed Mix** of **Appendix 1 –Seed Mix Species List Tables**. (5.2) Stock exclusion fencing has been established to prevent stock from grazing newly seeded areas. (5.3) No evidence of erosion classified as 'moderate' or 'severe' as defined by **Appendix 2 - Erosion classification framework**.
RM6	Revegetation (Native Vegetation)	(6.1) With the exception of a non-permanent cover crop species, the seed mix contains only those species listed in **Table 2 – Native Vegetation PMLU Seed Mix** of **Appendix 1 – Seed Mix Species List Tables.** (6.2) Seed spread at a minimum seeding rate of 6kg/ha for tree species, 4 kg/ha for woody understory species and 7 kg/ha for grasses, unless adjusted by an AQP.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(6.3) Stock exclusion fencing has been established to prevent stock from grazing newly seeded areas. (6.4) No evidence of erosion classified as 'moderate' or 'severe' as defined by **Appendix 2 - Erosion classification framework**.
RM7	Achievement of surface requirements (Low-intensity grazing)	(7.1) Total percentage of vegetative groundcover over a 3-year average is ≥70%. (7.2) Presence of weeds classified as a prohibited or restricted matter (as defined under the *Biosecurity Act 2014*) or classified as Weeds of National Significance are ≤10% of total vegetative cover, confirmed by an AQP. - (7.3) At least five of the species used in revegetation as listed in **RM5.1**, or as planted for **RA8**, remain present from monitoring data (7.4) Surface water runoff has been collected across representative areas of rehabilitation when surface flows occur and it is safe to do so. (7.5) Surface water runoff collected under **RM 7.4** is assessed for interpretation only against **Appendix 4 – Surface water quality limits.** Surface water runoff is non-polluting to the receiving waters and complies with the criteria presented below: (a) pH- 6.5 - 8.5 (b) EC- 340 µS/cm (c) Sulfate - 25 mg/L. (7.6) With respect to erosion: (a) No evidence of erosion classified as 'moderate' or 'severe' as defined by **Appendix 2 - Erosion classification framework**. (b) Average erosion rate of <5 t/ha/yr with the maximum erosion rate at any point on the landform of <10 t/ha/yr. (c) Any erosion present will not compromise the achievement of a PMLU to a stable condition. (7.7) All contour banks and other temporary erosion and sediment control structures have been removed.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(7.8) Any erosion and sediment control or drainage structures to be retained as permanent features are certified by an AQP to remain stable with no increased risk of erosion. (7.9) The assessment required as per **RM 7.8** must consider performance, maintenance requirements and residual risk post closure.
RM8	Achievement of surface requirements (Native Vegetation)	(8.1) Presence of weeds classified as a prohibited or restricted matter (as defined under the *Biosecurity Act 2014)* or classified as Weeds of National Significance are ≤10% of total vegetative cover, confirmed by an AQP in annual wet season monitoring. (8.2) A BioCondition assessment is completed by an AQP using the methodology outlined in the Queensland Herbarium's 'BioCondition Assessment Manual' that is current on the first date area is available for **RA6**. (8.3) Modified BioCondition score assessed under **RM 8.2** achieves the >20/60 PRCP Benchmark average of RE 11.3.2 and 11.3.3 as described in **Appendix 3 - BioCondition Benchmark Criteria** (8.4) Species used in revegetation remain present and showing evidence of natural recruitment from rehabilitation monitoring data. (8.5) Surface water runoff has been collected across representative areas of rehabilitation when surface flows occur, and it is safe to do so. (8.6) Surface water runoff collected under **RM 8.5** is assessed for interpretation only against **Appendix 4 – Surface water quality limits.** Surface water runoff is non-polluting to the receiving waters and complies with the criteria presented below: (a) pH- 6.5 - 8.5 (b) EC- 340 µS/cm (c) Sulfate - 25 mg/L. (8.7) With respect to erosion: (a) No evidence of erosion classified as 'moderate' or 'severe' as defined by **Appendix 2 - Erosion classification framework.**

Milestone reference	Rehabilitation milestone	Milestone criteria
		(b) Average erosion rate of <5 t/ha/yr with the maximum erosion rate at any point on the landform of <10 t/ha/yr. (c) Any erosion present will not compromise the achievement of a PMLU to a stable condition. (d) Erosion requiring intervention has been remediated.
RM9	Achievement of post mining land use to stable condition (Low-intensity grazing)	(9.1) Land suitability assessment by an AQP confirms that the rehabilitated land meets land suitability Class 4 or better for grazing according to the *Guidelines for agricultural land evaluation in Queensland* (DSITI & DNRM, 2015)[1]. (9.2) Any remaining infrastructure rehabilitated or removed in accordance with **RM1.1**. (9.3) The landform is free draining and there is no evidence of any of the following: (a) Vegetation die-back localised in low points on the landform surface; or (b) Salt rise as evidenced by salt deposition at the landform surface. (9.4) With the exception of RA8, minimum composition of the following, present per hectare (averaged): (a) Four species of 3P pasture species. (b) Two native legumes. (c) Native shade tree species with a density of 2 stems per hectare (density). (d) At least 6% vegetative groundcover from native pasture species. (9.5) For RA8 only, minimum composition of four species of 3P pasture species present per hectare (averaged). (9.6) Hazard assessment by an AQP confirms the hazards in the grazing areas has no significant difference to hazards in local grazing lands in surrounding unmined landscapes, as identified through reference site monitoring. (9.7) Surface water quality is monitored, within 24 hrs of a rainfall event which produced runoff from the corresponding rehabilitated landform into a flowing receiving environment at, but not limited to, downstream

[1] DSITI & DNRM (Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines) (2015). *Guidelines for agricultural land evaluation in Queensland* (2nd edn.). Queensland Government: Brisbane, Queensland.

Milestone reference	Rehabilitation milestone	Milestone criteria
		locations specified in **Appendix 5 - Surface water monitoring locations**. Results must not exceed the limits in **Appendix 4 - Surface water quality limits**, for a minimum of **five (5) consecutive years**. (9.8) Following achievement of **RM9.7**, continued surface water quality monitoring frequency may be reduced to at least once per year within 24 hrs of a rainfall event which produces runoff from the corresponding rehabilitated landform into a flowing receiving environment. (9.9) With respect to surface water as monitored according to **RM 9.7** and **RM9.8** the following must be demonstrated: (a) Surface water quality must not exceed the limits specified in **Appendix 4 – Surface Water Quality Limits** within the five-year period immediately prior to the milestone completed by date for the rehabilitation area; (b) If the surface water quality exceeds criteria a), the applicable upstream site must be compared to the downstream site result; and quality result measured at a downstream site must be equal to or less than the quality result measured at the applicable upstream site[2]. (9.10) Where the surface water quality at the downstream site exceeds the upstream site result **RM 9.9 (b),** an AQP must complete an assessment of the cause and risk of rehabilitation not achieving a stable condition within the schedule timeframe and: (a) Where there is a low risk to achieving a stable condition from, then no further action is to be taken; or, (b) Where there is a risk greater than low to achieve a stable condition, then an assessment of potential environment harm and any changes or rectification actions to rehabilitation activities must be determined and implemented. **RM 9.10 (a)** can only be triggered 3 times over 5 consecutive years for all data collected after 10 December 2030.

[2] For pH, quality measured at the downstream location must be within the prescribed range limits. However, where pH quality measured at the downstream location is greater-than (>) the highest limit in the range, pH measured at the applicable upstream location must be greater-than or equal-to (≥) the downstream location. Conversely, where pH measured at the downstream location is less than (<) the lowest limit in the range, the upstream pH measured at the applicable upstream location must be less-than or equal-to (≤) the downstream location.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(9.11) The assessment/s under **RM 9.10** must be completed and provided to the administering authority within 3 months of receiving the relevant sampling results. (9.12) If **RM 9.10 (b)** is triggered, the 5-year timeframe is reset. (9.13) For a minimum of five (5) consecutive years groundwater quality must be monitored quarterly at the locations identified **Appendix 6 - Groundwater monitoring bores**, for all quality characteristics listed in **Appendix 7 – Groundwater quality limits.** (9.14) Groundwater quality results must not exceed the limits in **Appendix 7 – Groundwater quality limits,** for **three (3) consecutive quarterly results**. (9.15) Groundwater level is monitored quarterly at the location specified in **Appendix 8 - Groundwater level threshold**, and all results must not exceed the Level Trigger Thresholds outlined in **Appendix 8 - Groundwater level threshold** for a minimum of 10 consecutive years. (9.16) Water within any retained water storages / dams must be of a suitable quality for native wildlife and/or livestock ingestion and must not exceed the stock water guidelines (ANZECC 2000), for a minimum of five (5) consecutive years. (9.17) For infrastructure that is to be retained subject to a landholder agreement: (a) Infrastructure to be transitioned to a future landholder is deemed fit for purpose, as verified by an AQP. (b) Transfer of ownership agreements in place for all infrastructure to be retained. (c) An AQP certifies that all retained infrastructure is in a condition that is safe, stable, non-polluting and will not cause environmental harm. (d) All fencing removed, other than those that form part of a landholder agreement.
RM10	Achievement of post mining land use to stable condition (Native Vegetation)	(10.1) A BioCondition assessment is completed by an AQP using the methodology outlined in the Queensland Herbarium's 'BioCondition Assessment Manual' that is current on the first date area is available for **RA6**. (10.2) Modified BioCondition score assessed under **RM 10.1** achieves the >40/60 PRCP Benchmark average of RE 11.3.2 and 11.3.3 as described in **Appendix 3 - BioCondition Benchmark Criteria**

Milestone reference	Rehabilitation milestone	Milestone criteria
		(10.3) Hazard assessment by an AQP confirms that the hazard has no significant difference to hazards in local regional ecosystems in surrounding unmined landscapes, as identified through appropriate and representative reference site monitoring. (10.4) Any remaining infrastructure rehabilitated or removed in accordance with **RM1.1**. (10.5) Surface water quality is monitored, within 24 hrs of a rainfall event which produced runoff from the corresponding rehabilitated landform into a flowing receiving environment at, but not limited to, downstream locations specified in **Appendix 3 - Surface water monitoring locations**. Results must not exceed the limits in **Appendix 4 - Surface water quality limits**, for a minimum of **five (5) consecutive years.** (10.6) Following achievement of **RM 10.5**, continued surface water quality monitoring frequency may be reduced to at least once per year within 24 hrs of a rainfall event which produces runoff from the corresponding rehabilitated landform into a flowing receiving environment. (10.7) With respect to surface water as monitored according to **RM 10.5** and **RM 10.6** the following must be demonstrated prior to surrender: (a) Surface water quality must not exceed the limits specified in **Appendix 4 – Surface Water Quality Limits** within the five-year period immediately prior to the milestone completed by date for the rehabilitation area; (b) If the surface water quality exceeds criteria a), the applicable upstream site must be compared to the downstream site result; and quality result measured at a downstream site must be equal to or less than the quality result measured at the applicable upstream site[3]. (10.8) Where the surface water quality at the downstream site exceeds the upstream site result **RM 10.7 (b),** an AQP must complete an assessment of the cause and risk of rehabilitation not achieving a stable condition within the schedule timeframe and: (a) Where there is a low risk to achieving a stable condition from, then no further action is to be taken; or,

[3] For pH, quality measured at the downstream location must be within the prescribed range limits. However, where pH quality measured at the downstream location is greater-than (>) the highest limit in the range, pH measured at the applicable upstream location must be greater-than or equal-to (≥) the downstream location. Conversely, where pH measured at the downstream location is less than (<) the lowest limit in the range, the upstream pH measured at the applicable upstream location must be less-than or equal-to (≤) the downstream location.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(b) Where there is a risk greater than low to achieve a stable condition, then an assessment of potential environment harm and any changes or rectification actions to rehabilitation activities must be determined and implemented. **RM 10.8 (a)** can only be triggered 3 times over 5 consecutive years for all data collected after December 2030. (10.9) The assessment/s under **RM 10.8** must be completed and provided to the administering authority within 3 months of receiving the relevant sampling results. (10.10) If **RM 10.8 (b)** is triggered, the 5-year timeframe is reset. (10.11) For a minimum of five (5) consecutive years groundwater quality must be monitored quarterly at the locations identified **Appendix 6 - Groundwater monitoring bores**, for all quality characteristics listed in **Appendix 7 – Groundwater quality limits.** (10.12) Groundwater quality results must not exceed the limits in **Appendix 7 – Groundwater quality limits**, for three (3) consecutive quarterly results. (10.13) Groundwater level is monitored quarterly at the locations specified in **Appendix 8 - Groundwater level threshold**, and all results must not exceed the Level Trigger Thresholds outlined in **Appendix 8 - Groundwater level** threshold for a minimum of ten (10) consecutive years. (10.14) For infrastructure that is to be retained subject to a landholder agreement: (a) Infrastructure to be transitioned to a future landholder is deemed fit for purpose, as verified by an AQP. (b) Transfer of ownership agreements in place for all infrastructure to be retained. (c) An AQP certifies that all retained infrastructure is in a condition that is safe, stable, non-polluting and will not cause environmental harm. (d) All fencing removed, other than those that form part of a landholder agreement or the final PMLU.
RM11	Achievement of post-mining land use (Permanent Infrastructure)	(11.1) No infrastructure remaining other than those that form part of the landholder agreement. (11.2) Transfer of ownership agreements in place for all infrastructure to be retained. (11.3) Final landform survey confirms no built structures remain other than those that form part of a landholder agreement.

Milestone reference	Rehabilitation milestone	Milestone criteria
		(11.4) Disturbed slopes not steeper than 3 degrees (5%). (11.5) No evidence of erosion classified as ‘moderate’ or ‘severe’ as defined by **Appendix 2 – Erosion classification framework**.

Section E – Non-use management areas

(IA1) Improvement area 1

Non-use management area (NUMA)	
Improvement area	IA1
Relevant activities	Final Void
Total size (ha)	144
Commencement of first milestone: MM1	10/12/2036
NUMA	Final Void
Date area is available	10/12/2036
Cumulative area available (ha)	144
Milestone completed by	10/12/2041
Milestone Reference	**Cumulative area achieved (ha)**
MM1	144
MM2	144
MM3	144

Improvement area milestones

Milestone reference	Management milestone	Milestone criteria
MM1	Achievement of final landform design	(1.1) Detailed design plan and report for final landform completed by an AQP based on the latest flood modelling and materials data prior to achieving final position. (1.2) All final pit walls battered to achieve the nominated stable slope range of: (a) maximum of 9 degrees (15%) to the base of tertiary. (b) maximum of 70 degrees (274%) below the base of tertiary. (1.3) Predictive modelling is undertaken by an AQP, confirming that: the voids will remain as a groundwater sink in perpetuity and that there is no risk of contamination to the receiving environment or post mining land use surrounding the NUMA post mining, or outside of the tenure boundaries. (1.4) Final detailed landform design has a minimum overtopping level of 96 m AHD at the southern end of the final void and 89m AHD at the northern end of the final void to provide 2 m and 1.5 m freeboard above the Probable Maximum Flood (PMF) at the southern and northern ends of the void respectively. (1.5) NUMA contains 100% of runoff generated from the catchment of the NUMA. (1.6) Drainage measures and structures have been implemented and are directing overland flow away from the highwall and low wall edges. (1.7) Voids (including highwalls, end walls and low walls) assessed to be erosionally and geotechnically stable by an AQP, modelled to achieve a factor of safety of ≥ 1.2. (1.8) The location of and erosion of the NUMA and associated safety bunds does not cause instability or degradation to the land outside the NUMA extent.
MM2	Achievement of surface requirements	(2.1) Safety bund constructed from non-weathered and non-dispersive material and to a geometry that prevents traversing by vehicles. (2.2) Safety bund constructed accordance with engineering requirements and calculated geotechnical factor of safety including the following specifications: (a) A minimum height of 2 m. (b) A minimum base width of 5 m.

Milestone reference	Management milestone	Milestone criteria
		(c) minimum of 20m offset from the pit perimeter. (d) 1 (V) in 3 (H) batters. (2.3) Perimeter fencing erected at a distance from slope crest to “zone of void influence” has been established around all NUMA walls to prevent access to humans, cattle and wildlife. (2.4) Warning signage to deter public access and warn of void related risks are designed in accordance with Australian Standard AS1319-1994 and are erected at 100 m intervals around the perimeter fence.
MM3	Achievement of sufficient improvement	(3.1) The landform has been constructed in accordance with the final detailed landform design plan and report. (3.2) The residual void has in place effective management measures to ensure it is safe to humans, wildlife and livestock. (3.3) Voids retain flood immunity up to a PMF event, supported by flood modelling re-run at end of life and calibrated against the final landform. (3.4) Hazard assessment by an AQP confirms the NUMA will have no impacts extents of land within ML5605, ML5580, ML5581, ML5590, ML80157, ML80169, ML80170, ML80200, ML80201, and ML700004.

Section F – Appendices

Appendix 1 – Seed Mix Species List Tables

This Appendix articulates the list of species which are permitted to be included in the seed mix for Rehabilitation Areas (RAs). For Rehabilitation Areas (RAs), the list of species is further specific to the PMLU to be achieved.

Table 1 - Low-intensity grazing PMLU Seed Mix

Species	Common Name
Bothriochloa bladhii	Forest Bluegrass
Bothriochloa decipiens	Pitted Bluegrass
Bothriochloa ewartiana	Desert Bluegrass
Capillipedium parviflorum	Scented-top Grass
Chrysopogon fallax	Golden Beard Grass
Desmanthus spp	Desmanthus
Dichanthium sericeum	Silky/Queensland Bluegrass
Digitaria spp.	Digitaria
Eucalyptus coolabah	Coolabah
Eucalyptus populnea	Bimble Box
Eucalyptus tereticornis	Forest Red Gum
Heteropogon contortus	Black Speargrass
Macroptilium bracteatum	Burgundy Bean
Megathyrsus maximus	Guinea Grass
Panicum ssp. (Native)	Panics
Stylosanthes spp (Native)	-
Themeda triandra	Kangaroo Grass
Chloris gayana	Rhodes Grass
Megathyrsus maximus	Gatton Panic

Species	Common Name
Digitaria spp. (Native)	Digitaria
Bothriochloa insculpta	Bisset Creeping Bluegrass
Stylosanthes scabra	Seca Stylo
Echinochloa esculenta	Japanese Millet
Themeda triandra	Kangaroo Grass
Cynodon dactylon	Couch Grass
Lomandra multiflora	Many-flowered Mat-rush
Lomandra longifolia	Spiny-headed Mat-rush
Lomandra confertifolia	Lomandra Mist
Chrysopogon fallax	Golden Beard Grass
Neptunia gracilis	Native Sensitive Plant

Table 2 - Native Vegetation PMLU Seed Mix

For the Native Vegetation PMLU, the seed mix must be selected and apportioned with appreciation for the BioCondition benchmarks at later milestones (refer **Appendix 3 - BioCondition Benchmark Criteria**). Hence, the proportion of each species (kg/ha) within the seed mix must reflect the relative cover and frequency of the relevant Regional Ecosystems (REs) Technical Description (https://publications.qld.gov.au/dataset/re-technical-descriptions).

Despite introduced species occurring in the RE Technical Descriptions, introduced species must not be included in the seed mix. Finally, the seed mix must not include Indian Couch *Bothriochloa pertusa* or *Seca Stylosanthes* spp, both of which have significant impacts on surrounding native remnant vegetation.

PMLU	Regional Ecosystem	Trees	Shrubs	Grasses	Forbs
Native Vegetation	11.3.2	*Acacia conferta* *Acacia excelsa* *Acacia fasciculifera* *Acacia harpophylla* *Acacia salicina* *Amyema indet.* *Amyema pendula subsp. longifolia Brachychiton populneus* *Atalaya hemiglauca* *Callitris glaucophylla* *Cassia brewsteri* *Casuarina cristata* *Citrus glauca* *Corymbia clarksoniana* *Cymbidium canaliculatum* *Eremophila mitchellii* *Eucalyptus camaldulensis* *Eucalyptus crebra* *Eucalyptus melanophloia* *Eucalyptus populnea* *Eucalyptus tereticornis* *Geijera parviflora* *Grevillea striata* *Lysiphyllum carronii* *Psydrax oleifolia* *Ventilago viminalis*	*Acacia conferta* *Acacia crassa* *Acacia decora* *Acacia excelsa* *Acacia harpophylla* *Acacia oswaldii* *Acacia salicina* *Alectryon diversifolius* *Alectryon oleifolius* *Atalaya hemiglauca* *Capparis lasiantha* *Corymbia clarksoniana* *Dodonaea viscosa* *Eremophila deserti* *Eremophila glabra subsp. glabra* *Eremophila mitchellii* *Erythroxylum australe* *Eucalyptus populnea* *Ficus opposita* *Geijera parviflora* *Grevillea striata* *Grewia retusifolia* *Hakea chordophylla* *Indigofera indet* *Lysiphyllum carronii* *Owenia acidula* *Owenia venosa* *Pimelea neoanglica* *Psydrax oleifolia* *Salsola australis* *Sida hackettiana* *Tephrosia indet.* *Terminalia oblongata subsp. oblongata Ventilago viminalis*	*Aristida calycina* *Aristida indet.* *Aristida personata* *Aristida ramosa* *Austrostipa verticillata* *Bothriochloa bladhii* *Bothriochloa decipiens var. decipiens* *Chloris divaricata* *Chloris truncata* *Chloris ventricosa* *Chrysopogon fallax* *Cymbopogon refractus* *Cyperus fulvus* *Cyperus gracilis* *Dichanthium sericeum subsp. sericeum* *Digitaria brownii* *Digitaria hystrichoides* *Dinebra decipiens* *Enneapogon gracilis* *Enneapogon indet.* *Enneapogon intermedius* *Enneapogon lindleyanus* *Enneapogon polyphyllus* *Enneapogon virens* *Enteropogon acicularis* *Enteropogon ramosus* *Eragrostis brownii* *Eragrostis elongata* *Eragrostis lacunaria* *Eragrostis leptostachya* *Eragrostis sororia* *Eremochloa bimaculata* *Eriochloa crebra*	*Abutilon oxycarpum* *Achyranthes aspera* *Alternanthera nana* *Boerhavia dominii* *Breynia oblongifolia* *Brunoniella australis* *Calotis cuneata* *Calotis lappulacea* *Capparis lasiantha* *Carissa ovata* *Chrysocephalum apiculatum* *Clematicissus opaca* *Cyanthillium cinereum* *Desmodium rhytidophyllum* *Desmodium varians* *Einadia hastata* *Einadia nutans subsp. linifolia* *Enchylaena tomentosa* *Eremophila debilis* *Euphorbia dallachyana* *Euphorbia drummondii* *Evolvulus alsinoides* *Galactia tenuiflora* *Glossocardia bidens* *Glycine tabacina* *Grewia latifolia* *Hibiscus sturtii* *Indigofera indet.* *Jasminum didymum* *Maireana microphylla* *Marsdenia viridiflora* *Melhania oblongifolia* *Murdannia graminea* *Neptunia gracilis* *Nyssanthes diffusa*

PMLU	Regional Ecosystem	Trees	Shrubs	Grasses	Forbs
			Zieria smithii	*Eriochloa pseudoacrotricha* *Eulalia aurea* *Fimbristylis dichotoma* *Heteropogon contortus* *Leptochloa digitata* *Panicum decompositum* *Panicum effusum* *Panicum simile* *Paspalidium caespitosum* *Paspalidium gracile* *Sporobolus caroli* *Sporobolus creber* *Sporobolus elongatus* *Themeda triandra* *Tragus australianus* *Urochloa foliosa*	*Nyssanthes erecta* *Parsonsia lanceolata* *Peripleura hispidula* *Phyllanthus virgatus* *Pseuderanthemum variabile* *Psydrax oleifolia* *Pterocaulon redolens* *Rhagodia spinescens* *Rhynchosia minima* *Rostellularia adscendens* *Salsola australis* *Sclerolaena birchii* *Sclerolaena muricata* *Sida hackettiana* *Sida indet.* *Sida pleiantha* *Sida rohlenae* *Sida sp. (Musselbrook M.B.Thomas+ MRS437)* *Sida trichopoda* *Stackhousia muricata* *Tribulus terrestris* *Tricoryne elatior* *Verbena indet.* *Vittadinia pustulata* *Vittadinia sulcata* *Wahlenbergia gracilis*
Native Vegetation	11.3.3	*Acacia cambagei* *Acacia harpophylla* *Acacia pendula* *Acacia salicina* *Alectryon oleifolius subsp. elongatus* *Amyema congener* *Amyema quandang* *Apophyllum anomalum* *Casuarina cristata* *Casuarina cunninghamiana* *Corymbia tessellaris* *Cymbidium canaliculatum* *Dodonaea viscosa* *Eremophila mitchellii* *Eucalyptus camaldulensis*	*Acacia excelsa* *Acacia harpophylla* *Acacia oswaldii* *Acacia pendula* *Acacia salicina* *Acacia stenophylla* *Alectryon diversifolius* *Alectryon oleifolius subsp. elongatus* *Atalaya hemiglauca* *Avicennia marina* *Bursaria spinosa subsp. spinosa* *Capparis lasiantha* *Carissa ovata* *Cassia brewsteri*	*Aristida leptopoda* *Bothriochloa bladhii subsp. bladhii* *Bothriochloa decipiens* *Bothriochloa ewartiana* *Cenchrus ciliaris* *Chloris divaricata* *Chloris ventricosa* *Chrysopogon fallax* *Cymbopogon refractus* *Cyperus exaltatus* *Cyperus gracilis* *Cyperus indet.* *Cyperus javanicus* *Dichanthium sericeum subsp. sericeum*	*Abutilon fraseri* *Abutilon oxycarpum* *Achyranthes aspera* *Alectryon diversifolius* *Alternanthera denticulata* *Alternanthera nodiflora* *Atriplex muelleri* *Basilicum polystachyon* *Boerhavia dominii* *Boerhavia indet.* *Brunoniella australis* *Calotis cuneata* *Camptacra barbata* *Capparis lasiantha* *Citrus glauca* *Crotalaria indet.*

PMLU	Regional Ecosystem	Trees	Shrubs	Grasses	Forbs
		Eucalyptus coolabah *Eucalyptus melanophloia* *Eucalyptus populnea* *Eucalyptus tereticornis* *Exocarpos aphyllus* *Geijera parviflora* *Lysiphyllum hookeri* *Melaleuca bracteata* *Myoporum acuminatum* *Owenia acidula* *Psydrax oleifolia* *Terminalia oblongata subsp. oblongata* *Ventilago viminalis*	*Casuarina cristata* *Citrus glauca* *Clematicissus opaca* *Denhamia indet.* *Diospyros humilis* *Dodonaea lanceolata* *Duma florulenta* *Ehretia membranifolia* *Eremophila bignoniiflora* *Eremophila deserti* *Eremophila mitchellii* *Eucalyptus coolabah* *Eucalyptus tereticornis* *Enchylaena tomentosa* *Excoecaria agallocha* *Ficus opposita* *Geijera parviflora* *Grewia latifolia* *Lysiphyllum carronii* *Lysiphyllum hookeri* *Melaleuca bracteata* *Myoporum acuminatum* *Notelaea microcarpa* *Pittosporum angustifolium* *Psydrax forsteri* *Psydrax johnsonii* *Psydrax oleifolia* *Santalum lanceolatum* *Senna barclayana* *Sesbania cannabina var. cannabina* *Terminalia oblongata subsp. oblongata* *Ventilago viminalis*	*Digitaria brownii* *Dinebra decipiens* *Eleocharis acuta* *Eleocharis pallens* *Enteropogon acicularis* *Enteropogon ramosus* *Eragrostis lacunaria* *Eriochloa crebra* *Eriochloa procera* *Eriochloa pseudoacrotricha* *Eulalia aurea* *Heteropogon contortus* *Leptochloa digitata* *Panicum decompositum* *Panicum laevinode* *Paspalidium caespitosum* *Paspalidium distans* *Paspalidium gracile* *Paspalidium indet.* *Paspalidium jubiflorum* *Sporobolus caroli* *Sporobolus creber* *Sporobolus mitchellii* *Thellungia advena* *Themeda avenacea*	*Cyanthillium cinereum* *Cymbidium canaliculatum* *Eclipta prostrata** *Duma florulenta* *Einadia nutans subsp. linifolia* *Enchylaena tomentosa* *Eremophila debilis* *Euphorbia dallachyana* *Euphorbia drummondii* *Euphorbia indet.* *Euphorbia psammogeton* *Eustrephus latifolius* *Glycine tabacina* *Haloragis aspera* *Jasminum didymum subsp. racemosum* *Jasminum didymum subsp.didymum* *Lomandra longifolia* *Maireana microphylla* *Marsilea drummondii* *Marsilea hirsuta* *Melhania oblongifolia* *Neptunia gracilis* *Oxalis perennans* *Phyllanthus maderaspatensis* *Rhagodia spinescens* *Rhynchosia minima* *Rostellularia adscendens* *Salsola australis* *Sclerolaena muricata* *Sclerolaena tetracuspis* *Senna barclayana* *Sida hackettiana* *Sida indet.* *Sida trichopoda* *Tetragonia tetragonoides* *Verbena indet.* *Wahlenbergia gracilis* *Zaleya galericulata subsp. Galericulata*

Appendix 2 - Erosion classification framework

Erosion classification	Minor	Moderate	Severe
Sheet erosion	Shallow soil deposits downslope.	Partial exposure of roots; moderate soil deposits downslope.	Loss of surface horizon; subsoil exposure; root exposure; substantial soil deposits downslope.
Rill	<15 rills per transect*	15–30 rills per transect*	>30 rills per transect*
Gully erosion	Absent	Absent	Present
Tunnel erosion	Absent	Absent	Present
Mass movement	Absent	Absent	Present

Source: NCST (2024) *Australian Soil and Land Survey Field Handbook, 4th edition*. The National Committee on Soil and Terrain. CSIRO Publishing, Collingwood, Australia.
*Transect 100 m across the contour (Source: Tongway, D. J. and Hindley, N. L. 2005. Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes. CSIRO Publishing, Canberra, Australia.

Appendix 3 – BioCondition Benchmark Criteria

This Appendix articulates the benchmark criteria to be achieved for each assessable attribute. The benchmark criteria for each RA are determined by the corresponding PMLU. Benchmark criteria and assessable attributes are derived from the Queensland Government's BioCondition benchmark database[4]. Some attributes (i.e. large trees) of the full BioCondition assessment are not likely to be attainable in the timeframe between seeding and achievement of the PMLU, hence only a subset is included here. The reference Regional Ecosystems (REs) are also included for interpretation purposes only.

BioCondition Assessable Attributes	**BioCondition Assessable Attribute Weighting**	**Hybrid Regional Ecosystem RE 11.3.2 / 11.3.3** Rehabilitated Eucalyptus populnea / *Eucalyptus conica* woodland on alluvial plains		
		Average benchmark	**Indicative benchmark**	
			RM8	**RM10**
Recruitment	5	100%	0	20% (=3 out of 5 weighting)
Non-native plant cover	10	0%	<25% (=5 out of 10 weighting)	<25% (=5 out of 10 weighting)
Native tree species richness	5	3	≥1 (=2.5 out of 5 weighting)	≥3 (=5 out of 5 weighting)
Native shrub species richness	5	4	≥1 (=2.5 out of 5 weighting)	≥4 (=5 out of 5 weighting)
Native grass species richness	5	11	≥3 (=2.5 out of 5 weighting)	≥3 (=2.5 out of 5 weighting)
Native forb / other native species richness	5	15	≥4 (=2.5 out of 5 weighting)	≥4 (=2.5 out of 5 weighting)
Tree canopy height	5	18m	0	≥4.5m (=3 out of 5 weighting)
Tree canopy cover	5	32.5%	≥3.25% (=2 out of 5 weighting)	≥16.25% (=5 out of 5 weighting)
Shrub canopy cover	5	4%	≥0.4% (=3 out of 5 weighting)	≥0.4% (=3 out of 5 weighting)
Native perennial grass	5	35.5%	≥17.75% (=3 out of 5 weighting)	≥17.75% (=3 out of 5 weighting)
Organic litter ground cover	5	32.5%	0	≥3.25% (=3 out of 5 weighting)
Total BioCondition Assessable attribute weighting score	**60**		**Overall BioCondition score required >20**	**Overall BioCondition score required >40**

Appendix 4 - Surface water quality limits

Quality characteristic (units) (1)(2)(3)	Limit (2)(3)	Comment on limit
pH	6.5–8.5	Lower Dawson River Sub-basin fresh waters WQO
Electrical Conductivity (µS/cm)	340	Lower Dawson River Sub-basin fresh waters WQO. Baseflow
Suspended Solids (mg/L)	10	Lower Dawson River Sub-basin fresh waters WQO
Sulfate (mg/L)	25	Lower Dawson River Sub-basin fresh waters WQO
Aluminium - dissolved (µg/L)	55	ANZG 2018
Antimony – dissolved (µg/L)	9	ANZG 2018
Arsenic - dissolved (µg/L)	13	ANZG 2018
Manganese - dissolved (µg/L)	1,900	ANZG 2018
Molybdenum - dissolved (µg/L)	34	ANZG 2018
Selenium - dissolved (µg/L)	5	ANZG 2018
Uranium - dissolved (µg/L)	0.5	ANZG 2018
Zinc - dissolved (µg/L)	8	ANZG 2018
Ammonia (µg/L)	900	ANZG 2018
Nitrate (µg/L)	1,100	For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for Total Nitrate
Total recoverable hydrocarbons (C6-C9) (µg/L) (6)	20	For aquatic ecosystem protection, based on LOR for GCMS (4)(5)
Total recoverable hydrocarbons (C10-C36) (µg/L) (6)	100	For aquatic ecosystem protection, based on LOR for GCMS(4)(5)
Major ions (mg/L) Calcium, chloride, potassium, magnesium, sodium, bicarbonate, carbonate	For interpretation purposes	-

Notes:

(1) All metals and metalloids must be measured as ‘dissolved’ (from analysis of a field filtered sample) and total (unfiltered).
(2) Limits for metals and metalloids apply to dissolved results.
(3) ANZG (2018) Aquatic ecosystem protection for moderately disturbed system (95% protection)
(4) LOR (limit of reporting) – typical reporting for method stated.
(5) GCMS – analytical method required to achieve LOR
(6) Silica Gel Cleanup, SW-846 Method 3630C, December 1996, US EPA

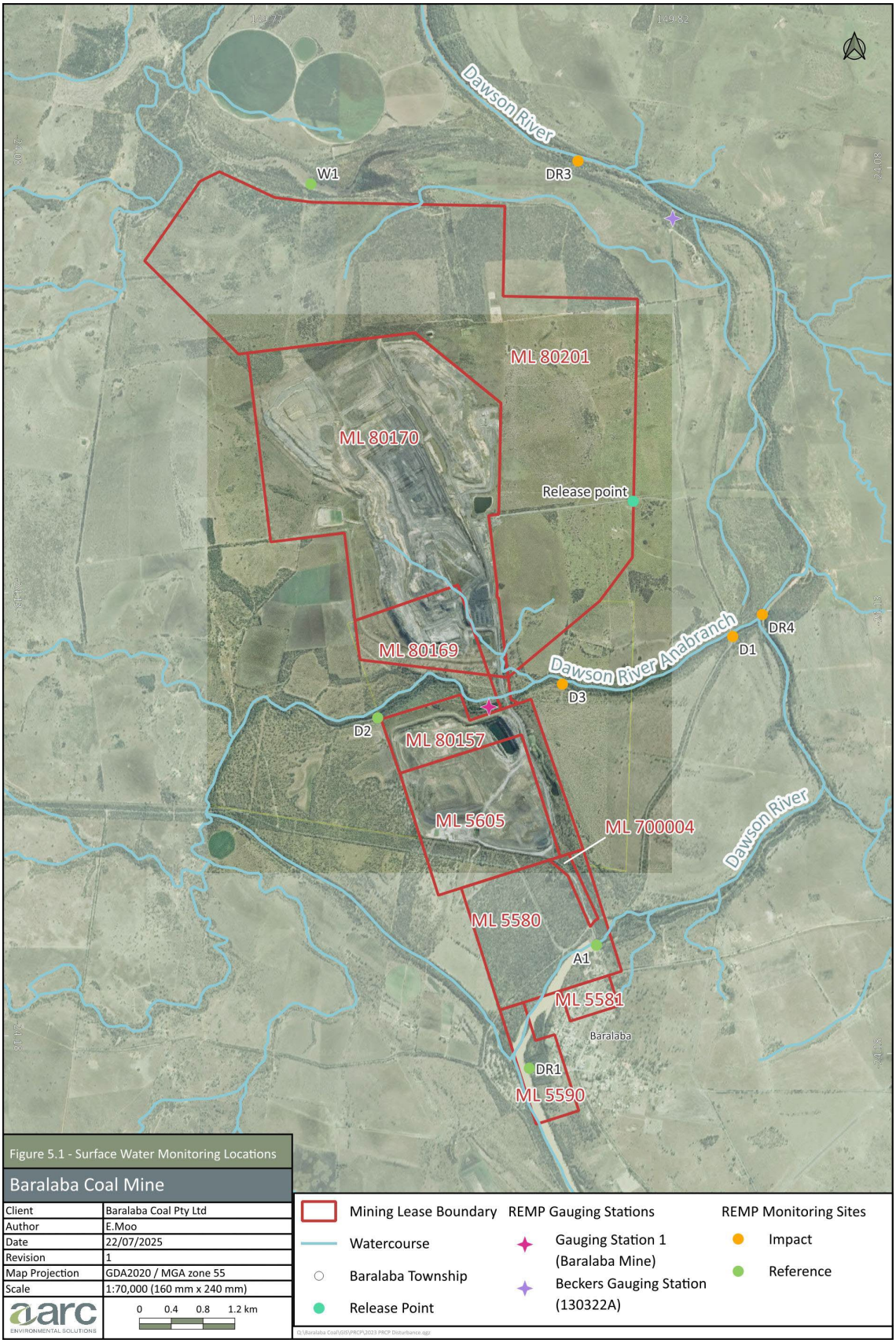
Appendix 5 - Surface water monitoring locations

Monitoring Locations	Receiving waters location description	Latitude (decimal degree, GDA2020)	Longitude (decimal degree, GDA2020)
Upstream monitoring locations			
A1	Dawson River, between the two confluences with the Dawson River Anabranch and downstream of the Neville Hewitt Weir	-24.170934	149.814274
D2	Dawson River Anabranch located near the boundary of the mining lease on the Anabranch, upstream of the mine	-24.145636	149.786631
DR1	Dawson River upstream	-24.185062	149.806264
Downstream monitoring locations			
D1	Downstream of the mine along Dawson River Anabranch.	-24.135547	149.830368
DR3	Dawson River downstream of Beckers gauging station	-24.081964	149.810034
DR4	Dawson River within 8 km downstream of the confluence with the Dawson River Anabranch.	-24.133027	149.833979
D3	Downstream of the mine along Dawson River Anabranch.	-24.141387	149.809407
W1	Located at the palustrine wetland in between the Dawson River and Saline Creek, downstream of the mine	-24.085191	149.777049

Notes:

(1) Monitoring locations illustrated in **Figure 4.1 – Surface Water Monitoring Locations**

Figure 5.1 – Surface Water Monitoring Locations

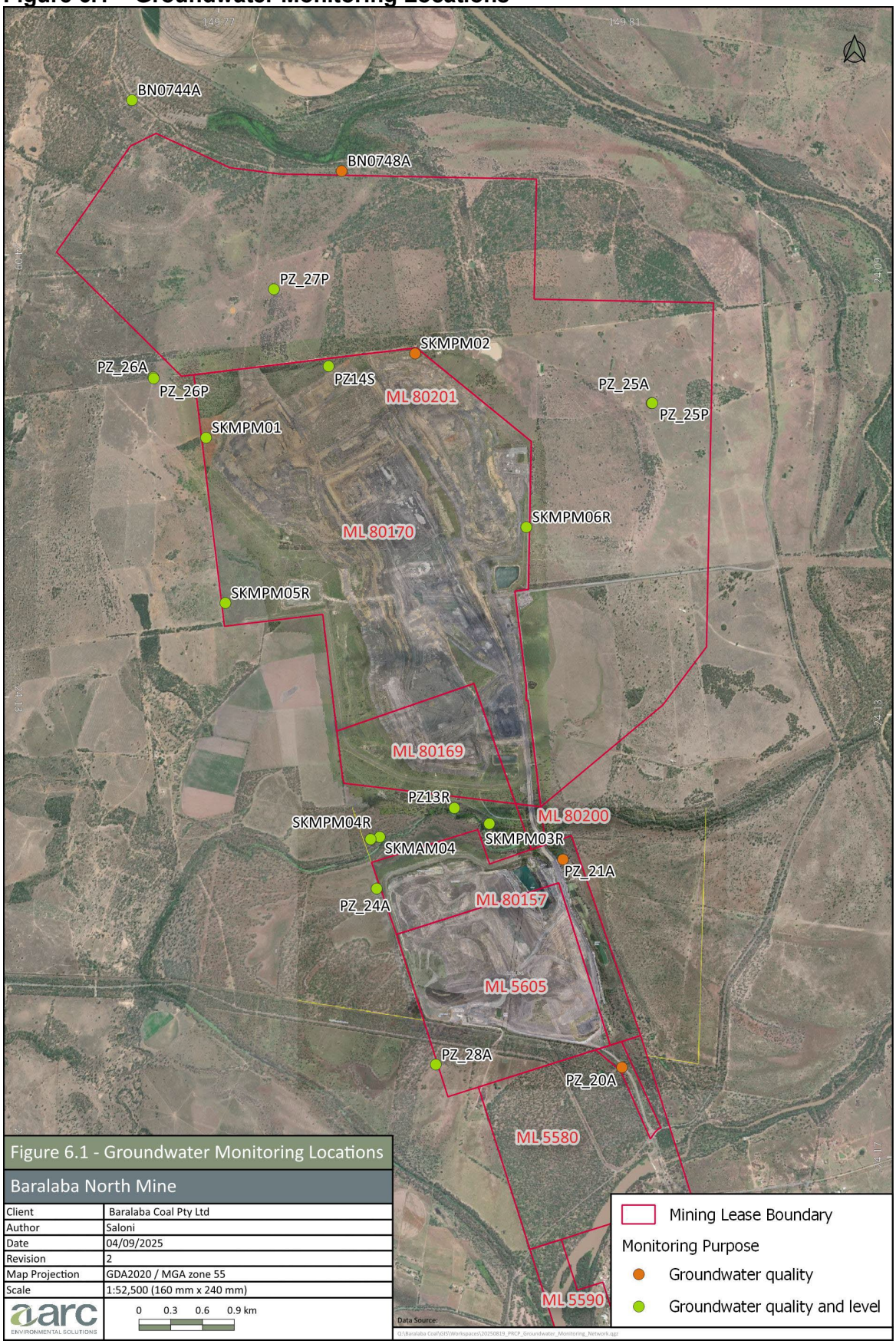


Appendix 6 - Groundwater monitoring bores

Site*	Latitude(GDA94)	Longitude(GDA94)	Geologic Unit
BN0744A	-24.08124	149.76338	Alluvium
BN0748A	-24.08693	149.78298	Alluvium
PZ_20A	-24.162861	149.810683	Alluvium
PZ_21A	-24.145238	149.804817	Alluvium
PZ_25A	-24.106175	149.812200	Alluvium
PZ_26A	-24.10480422	149.76588386	Alluvium
PZ_28A	-24.1629163	149.7933958	Alluvium
PZ14S[A]	-24.10359	149.78213	Alluvium
SKMAM04	-24.14363	149.78775	Alluvium
PZ_24A	-24.14804	149.787564	Alluvium
PZ13R	-24.1409891	149.7946627	Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone
PZ_25P	-24.106182	149.81225	Permian (Gyranda Formation)
PZ_26P	-24.104924	149.765911	Baralaba Coal Measures – Coal Seam Interburden
PZ_27P	-24.097118	149.776907	Baralaba Coal Measures – Coal seam (Sub Dirty Seam)
SKMPM01	-24.10989	149.77088	Baralaba Coal Measures – Interburden
SKMPM02[A]	-24.10236	149.79014	Permian (Gyranda Formation)
SKMPM03R	-24.1423084	149.7979088	Baralaba Coal Measures – Interburden
SKMPM04R	-24.143826	149.7869114	Baralaba Coal Measures – Interburden
SKMPM05R	-24.123947	149.772979	Baralaba Coal Measures – Interburden
SKMPM06R	-24.116973	149.800797	Permian (Gyranda Formation)

Notes:
* Monitoring locations illustrated in **Figure 6.1 – Groundwater Monitoring Locations**
A To be monitored as per frequency listed until destroyed by mining

Figure 6.1 – Groundwater Monitoring Locations



Appendix 7 – Groundwater quality limits

Geologic Unit	Quality Characteristic	pH (field)	Electrical Conductivity (Lab)	Aluminium (dissolved)	Antimony (dissolved)	Arsenic (dissolve d)	Manganese (dissolved)	Molybdenum (dissolved)	Selenium (dissolve d)	Uranium (dissolved)	Zinc (dissolved)	Sulfate (dissolved)	TRH C10 - C16 Fraction[K]	TRHC16 -C34 Fraction [K]	TRHC34 -C40 Fraction [K]	Bicarbonate, sodium, carbonate, calcium, chloride, Interpretation Only
	Monitoring Bore	pH units	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L
Alluvium	BN0744A	6.4 – 6.7[A]	731[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	150[A]	4.5[A]	50[C]	100[C]	100[C]	N/A
Alluvium	BN0748A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_20A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_21A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_24A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	145[M]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_25A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_26A	6.5-8.5	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	3.5[AL]	154[A]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ_28A	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5[A]	25 [A]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	PZ14S	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Alluvium	SKMAM04	6.9 - 8.4[B]	953[B]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	62[B]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone	PZ13R[3]	7.4 - 8.6[B]	20,000[A]	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	72[A]	6.0[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	PZ_25P	6.6 - 7.1[A]	6,200 [A]	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5.0[A]	140[A]	51[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal Seam Interburden	PZ_26P	6.5-8.5	2,880[A]	50[B]	9[D]	13[D]	1,900[D]	34[D]	11[D]	2[A]	20[AL]	113[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Coal seam (Sub Dirty Seam)	PZ_27P	7.4 - 8.6[B]	1,355[A]	50[B]	9[D]	85[A]	1,900[D]	34[D]	11[D]	0.5[DN]	13[AL]	13[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM01	10-12	4,268[A]	178[A]	9[D]	13[D]	1,900[D]	47[A]	11[D]	0.5[D]	14[A]	18[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	SKMPM02	7.3 - 8.5[B]	3,542[I]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[D]	8[D]	6[O]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM03R	7.3 - 8.5[B]	2,112[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	27[A]	132[A]	50[C]	100[C]	100[C]	N/A
Baralaba Coal Measures – Interburden	SKMPM04R	7.3 - 8.5[B]	19,470[A]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	0.5[DN]	130[A]	63[A]	50[C]	100[C]	100[C]	N/A

Geologic Unit	Quality Characteristic	pH (field)	Electrical Conductivity (Lab)	Aluminium(dissolved)	Antimony (dissolved)	Arsenic (dissolve d)	Manganese (dissolved)	Molybdenum (dissolved)	Selenium (dissolve d)	Uranium (dissolved)	Zinc (dissolved)	Sulfate (dissolved)	TRH C10 - C16 Fraction[K]	TRHC16 -C34 Fraction [K]	TRHC34 -C40 Fraction [K]	Bicarbonate, sodium, carbonate, calcium, chloride, Interpretation Only
	Monitoring Bore	pH units	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L
Baralaba Coal Measures – Interburden	SKMPM05R	7.3 - 8.5[B]	3,542[I]	55[D]	9[D]	18[A]	1,900[D]	62[A]	11[D]	0.5[D]	85[ALN]	6[A]	50[C]	100[C]	100[C]	N/A
Permian (Gyranda Formation)	SKMPM06R	6.6 – 7.1[A]	20,750[H]	55[D]	9[D]	13[D]	1,900[D]	34[D]	11[D]	5[A]	76[A]	179[A]	50[C]	100[C]	100[C]	N/A

Note:
A. 95th percentile of site specific value
B. 95th percentile of aquifer group specific value (Alluvium, Permian Coal Seam, Permian Interburden)
C. Limit of reporting available for TPH fractions for ALS laboratories
D. ANZG (2018) 95% Protection aquatic species (fresh water)
E. Fitzroy Plan WQ1310 groundwater water quality objectives (aquatic ecosystem) Zone 34 (shallow) 80th percentile - Dawson River Sub-basin Environmental Values and Water Quality Objectives
F. Fitzroy Plan WQ1310 groundwater water quality objectives (aquatic ecosystem) Zone 34 (deep) 80th percentile - Dawson River Sub-basin Environmental Values and Water Quality Objectives
G. 95th percentile of BN0744C and BN0744CR_2
H. 95th percentile of SKMPM04 and SKMPM06R
I. 95th percentile of SKMPM02 and SKMPM05R
J. 95th percentile of SKMPM01, SKMPM04, SKMPM05, SKMPM05R, SKMPM06R
K. Silica Gel Cleanup, SW-846 Method 3630C, December 1996, US EPA
L Site specific data trigger has been set on a small number of data points, outside the QWQG recommended minimum dataset. Once sufficient data is available this trigger should be reconsidered.
M 95th percentile of BN0744A and PZ_24A
N Due to insufficient data, this limit is interim until a sufficient data set has been collected and a site specific or grouped specific trigger can be applied.
O Due to insufficient data this interim trigger has been calculated based on data collected from SKMPM05R

Appendix 8 - Groundwater level threshold

Site	Geologic Unit	Starting Water Level for purposeof Trigger Level Assessment		Maximum Modelled Drawdown (m)	Maximum Permissible Impacted Water Level	
		(mTOC)	mAHD		(mTOC)	mAHD
BN0744A	Alluvium	12.5	68.96	1	13.5	67.96
PZ_23A	Alluvium	12.51	70.294	0	12.51	70.294
PZ_24A [A]	Alluvium	10.84	71.56	0	10.84	71.56
PZ_26A	Alluvium	22.91	74.34	0	22.91	74.34
PZ_28A [A]	Alluvium	Dry	Dry	0	n/a - dry	n/a - dry
SKMAM04	Alluvium	Dry	Dry	0	n/a - dry	n/a - dry
BN0744C	Baralaba Coal Measures – Coal Seam (Reid Seam)	14.65	*	7.13	21.78	*
BN0744CR_2	Baralaba Coal Measures – Coal Seam (Reid Seam)	17.41	64.09	7.13	24.54	56.96
PZ_25P	Permian (Gyranda Formation)	19.79	73.61	0	19.79	73.61
PZ_26P	Baralaba Coal Measures – Coal Seam Interburden	22.29	74.96	2.82	25.11	72.14
PZ_27P	Baralaba Coal Measures – Coal seam (Sub Dirty Seam)	24.12	70.88	53.35	77.47	17.53
PZ13R	Baralaba Coal Measures – Coal Seam Interburden – Sandstone Fault Zone	12.77	69	24.63	37.4	44.37
PZ14D	Baralaba Coal Measures - Coal Seam (Coolum Seam)	23.86	67.6	50.94	74.8	16.66
SKMPM01	Baralaba Coal Measures – Interburden	30.6	65.34	4.12	34.72	61.22
SKMPM03R	Baralaba Coal Measures – Interburden	13.35	66.27	20.28	33.63	45.99
SKMPM04R[A]	Baralaba Coal Measures – Interburden					
SKMPM05R	Baralaba Coal Measures – Interburden	28.38	64.82	5.15	33.53	59.67
SKMPM06R	Permian (Gyranda Formation)	25.1	63.5	0.09	25.19	63.41

[A] Monitoring bores to be updated in accordance with the requirements of Conditions D11 to D16 of environmental authority EPML00223213, dated 6 June 2025* Relative water level (mAHD) must be reviewed, prior to November 2025, on collection of a validated collar height RL by an AQP surveyor.

END OF **PRCP** SCHEDULE

Appendix D. Statutory declaration - Transmission Network Assets Relocation Agreement

Oaths Act 1867

Statutory Declaration

QUEENSLAND

TO WIT

I, Trent Lockhart of 12 McIlwraith Avenue, Balmoral QLD 4171, in the State of Queensland, Chief Financial Officer of Baralaba Coal Company Pty Ltd, do solemnly and sincerely declare that:

1. A 'Transmission Network Assets Relocation Agreement for the Baralaba North Expansion Project Affecting Feeders 7113 and 7114/1' dated 17 December 2019 ("**Agreement**") exists between Queensland Electricity Transmission Corporation Ltd (trading as "Powerlink Queensland") (ABN 82 078 849 233) ("**Powerlink**") and Wonbindi Coal Pty Limited (ABN 62 114 668 941) ("**Proponent**").
2. At Page 24, Clause 4.18(b) of the Agreement, Powerlink and the Proponent agree that Powerlink owns all rights, title and interest in the Relocated Transmission Network Assets.
3. The Relocated Transmission Network Assets includes the Power Pole and Transmission Line that are on the land on which activities contemplated by the Agreement are likely to occur.

And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of the *Oaths Act 1867.*

Signed and Declared by the Declarant at Brisbane on this 1st day of April 2021 before me

ankita	
Signature of witness	Signature of declarant
ANKITA BELLARY	TRENT EDWARD LOCKHART
Full name of witness (print)	Full name of declarant (print)
43 Norfolk Place, Wishart QLD 4122	
Address of witness	
Solicitor	
Capacity of witness	

This declaration was made, signed and witnessed in accordance with the *Justice Legislation (COVID-19 Emergency Response—Documents and Oaths) Regulation 2020*.

The contents of the declaration are true.

I understand that a person who provides a false matter in a declaration is committing an offence.

Appendix E. Floodplain Modelling Report

Baralaba North Continued Operations Project

Environmental Impact Statement

APPENDIX F

FLOOD MODELLING AND ASSESSMENT

Water Solutions
Certainty in Water

Report to

COCKATOO COAL LIMITED

on

BARALABA NORTH CONTINUED OPERATIONS PROJECT

FLOOD STUDY

Job Number	WS0715.1305.001
Doc Number	WS130231
Revision	3
Date	4 April 2014

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Water Solutions
Certainty in Water

Cockatoo Coal Limited
Baralaba North Continued Operations Project
Flood Study

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Document Quality Control

Job No. WS0715.1305.001
Document No. WS130231

Revision	Date	Revision Details	Author	Reviewer
0	19/12/2013	Draft calibration report for client review	BM/TM	JM
1	18/02/2014	Draft full report for client review	BM/TM	JM
2	10/03/2014	Revised draft report	BM/TM	JM
3	4/04/2014	Final Report	BM/TM	JM

Cover Image: Gauge boards at Beckers gauging station.

A person using Water Solution Pty Ltd documents or data accepts the risk of:

a. Using the documents or data in electronic form without requesting and checking them for accuracy against the original hard copy version.

b. Using the documents or data for any purpose not agreed to in writing by Water Solutions Pty Ltd.

Engineering Excellence Award 2003 • WINNER • Queensland Division

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Executive Summary

The Baralaba Coal Mine, operated by Cockatoo Coal Limited (CCL) is located approximately 2km to the north of the Baralaba Township. The existing mining area, referred to as Baralaba Central, is on the Dawson River floodplain and is surrounded by a levee to provide protection from flooding. CCL have an existing approval to expand north of the anabranch for the Baralaba North/ Wonbindi North Mine, including an additional levee bank to provide flood protection.

CCL have been conducting an active exploration program further to the north and south of this area in order to expand the economic mining life of the site. Following a bankable feasibility study, the Baralaba North Continued Operations Project (BNCOP) has been selected as the preferred option for the next phase of development. The BNCOP extends active mining operations further north of the Baralaba North/ Wonbindi North Mine, with some of this area within the floodplain of the Dawson River.

This flood study has been prepared to assess flooding related issues associated with the proposed BNCOP to meet the requirements of the EIS Terms of Reference.

In this study previously developed flood models have been reviewed and updated, including a review of stream gauge rating curves, extension and calibration of the hydraulic and hydrology models, and an updated flood frequency analysis. The hydraulic and hydrology models were calibrated and verified against a range of recorded data for the large December 2010 event. The developed hydraulic and hydrology models are considered to be suitable for the purposes of evaluating potential flooding impacts related to the BNCOP for the EIS.

Design flood hydrographs for the AEP 1 in 20, 1 in 50, 1 in 100, and 1 in 1000 events have been developed based on CRC-FORGE design rainfalls and the calibrated hydrology model for Dawson River and Saline Creek floods. The BOM GTSMR method was used to estimate the peak flow for the PMF in the Dawson River. Three cases have been modelled, the Existing/Approved Case, Operational BNCOP Mine Case, and the Post Mine Case. The impact of the BNCOP on flood levels, flow velocity and stream morphology has been evaluated.

The key conclusions of this study are as follows:

- The BNCOP is not considered to result in any significant change to the flood risk for surrounding properties or infrastructure.
- This study identifies a number of control strategies to mitigate and address flooding impacts and risks. This includes construction, maintenance and monitoring of levee banks (or sufficiently robust spoil piles) to provide AEP 1 in 1000 protection, with appropriate freeboard allowances and provision for preferential failure.
- The risk of increased erosion and geomorphologic change to the river from the project is considered low.
- In the post-mining scenario, flood water abuts the final landform spoil piles in some places in the assessed events, but does not overtop the spoil piles in any event. Flood water does not enter the residual void in events up to the AEP 1 in 1000 event.

In conclusion, provided the BNCOP is developed in accordance with the features and control strategies identified in this report, the flooding impacts of the proposed BNCOP on people, property and the environment are considered to be avoided, minimised or mitigated.

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Nomenclature

Term	Description
AHD	Australian Height Datum
AWBM	Australian Water Balance Model
BNCOP	Baralaba North Continued Operations Project
BSCP	Baralaba South Coal Project
C	WBNM Routing Parameter
CCL	Cockatoo Coal Limited
CH	Chainage
CL	Continuing Loss
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEHP	Department of Environment and Heritage Protection
DERM	Department of Environment and Resource Management
DME	Department of Mining and Environment
DNRM	Department of Natural Resources and Mines
DSDIP	Department of State Development, Infrastructure and Planning
DTM	Digital Terrain Model
EA	Environmental Authority
EL	Elevation
EIS	Environmental Impact Statement
F	WBNM Routing Parameter – Stream Lag Factor
GS	Gauging Station
IL	Initial Loss
ML	Mining lease
MLA	Mining lease application
n	Mannings n
NHW	Neville Hewitt Weir
PMF	Probable Maximum Flood
QRA	Queensland Reconstruction Authority
RMS	Root Mean Square
SPP	State Planning Policy
SRTM	Shuttle Radar Topography Mission
TOR	Terms of Reference
USGS	United States Geological Survey
WBNM	Watershed Bounded Network Model
WS	Water Solutions

1 Introduction

1.1 Introduction

The Baralaba Coal Mine, operated by Cockatoo Coal Limited (CCL) is located approximately 2km to the north of the Baralaba Township, about 110 km south-west of Rockhampton, as shown on Figure 1.1.

The existing mining area, referred to as Baralaba Central, is on the Dawson River floodplain between the Dawson River and a major anabranch of the Dawson River. The Baralaba Central Mine is surrounded by a levee to provide protection from flooding.

CCL have an existing approval to expand north of the anabranch for the Baralaba North/ Wonbindi North Mine. This expansion includes a levee bank to protect Baralaba North/ Wonbindi North Mine, just over the anabranch from the Baralaba Central Mine.

CCL have been conducting an active exploration program further to the north and south of this area in order to expand the economic mining life of the site. Following a bankable feasibility study, the Baralaba North Continued Operations Project (BNCOP) has been selected as the preferred option for the next phase of development.

Figure 1.2 provides an appreciation of the indicative layout of the BNCOP site. The BNCOP is described in detail in Section 2 of the main report of the Environmental Impact Statement. In brief, the project will extend open cut mining operations to the north-north-west of the existing Baralaba Central Mine and the approved Baralaba North/ Wonbindi North Mine, extending over some elevated terrain and ending just south of the Dawson River anabranch on the next meander of the Dawson River downstream. A number of spoil dumps will surround the open cut, and the operational area will be protected by a flood levee where required.

This flood study has been prepared to assess flooding related issues associated with the proposed BNCOP to meet the requirements of the EIS Terms of Reference.

1.2 Final Terms of Reference for the Baralaba North Continued Operations Project Environmental Impact Statement (EIS)

This report provides information to address the flooding related requirements of the *Final Terms of Reference (TOR) for the Baralaba North Continued Operations Project Environmental Impact Statement (EIS)* (DEHP April 2014). The key flood related clauses are shown below for ease of reference, with parts not applicable to this study being greyed out:

> ***7.3.3*** *Describe and illustrate where final voids and uncompacted overburden and workings at the end of operations would lie in relation to flood levels up to and including the 'probable maximum flood level' based on the Bureau of Meteorology's 'probable maximum precipitation' forecast for the locality.*
>
> ***7.6*** *Flooding and regulated dams - Objective - The construction and operation of the project should aim to ensure the risk of, and the adverse impacts from flooding hazards or dam failure are avoided, minimised or mitigated to protect people, property and the environment.*
>
> ***7.6.1*** *Describe current flood risk for a range of a range of annual exceedance probabilities up to the probable maximum flood, for potentially affected waterways, and*

assess (through flood modelling) how the project may potentially change flooding characteristics. The assessment should consider all infrastructure associated with the project including levees, roads and linear infrastructure and all proposed measures to avoid or minimise impacts.

8.13.1 *Describe the potential risks to people and property that may be associated with the project in the form of a preliminary risk assessment for all components of the project and in accordance with relevant standards. The assessment should include:*

- *potential hazards, accidents, spillages, fire and abnormal events that may occur during all stages of the project, including estimated probabilities of occurrence*
- *identifying all hazardous substances to be used, stored, processed or produced and the rate of usage*
- *potential wildlife hazards, natural events (e.g. cyclone, storm tide inundation, flooding, bushfire) and implications related to climate change.*
- *how the project may potentially affect hazards away from the project site (e.g. changing flooding characteristics).*

1.3 Study Area

The BNCOP area shown in Figure 1.1 and Figure 1.2 is situated in the Dawson River catchment, part of the Fitzroy River Basin, in Central Queensland. The catchment area of the Dawson River upstream (south) of the site is some 40,500 km^2. Land use in this catchment above the BNCOP site is largely rural with a number of smaller urban centres including Moura, Theodore and Taroom, and the upper reaches of the catchment includes a number of National Parks. Neville Hewitt Weir is situated between the Baralaba Central Mine and the town of Baralaba, and a number of other weirs and offstream storages line the Dawson River upstream of the site. No large dams are situated upstream of the site. However it is noted that significant investigations into Nathan Dam, a potential 888,000 ML dam site some 230km upstream of Baralaba, have been undertaken in recent decades, with an EIS released in 2012.

Figure 1.2 provides an overview of the project site. The project site itself is mostly rural land. The southern extent of the BNCOP is situated on the Dawson River floodplain, adjacent to the (upper) Dawson River anabranch. The terrain rises north of here, and much of the BNCOP site is on elevated terrain. The terrain drops again as it approaches another anabranch of the Dawson River to the north, and the northern boundary of the BNCOP operational area is located just south of the downstream anabranch. A local creek, Saline Creek, runs adjacent to the north-west side of the proposed BNCOP operational area, joining the Dawson River just downstream of the project site. The area of Saline Creek upstream of the site is approximately 132km^2.

Figure 1.3 shows the interim floodplain assessment overlay identified by the DSDIP SPP Interactive Mapping System (http://www.dsdip.qld.gov.au/about-planning/spp-mapping-online-system.html), confirming that flooding is an issue that requires assessment for the BNCOP.

In addition to regional flooding from the Dawson River, local flooding from Saline Creek may also impact on the northern extent of the BNCOP. Hence modelling of floods from both sources has been included in this study.

1.4 Previous Flood Studies

Water Solutions has undertaken a number of previous flood studies associated with the Baralaba Coal Mine, the Baralaba North Flood Study (Water Solutions Nov 2012) being the most relevant.

The Baralaba North Flood Study investigated the potential flood-related impacts of the Baralaba North proposal. This study resulted in the U shaped levee bank (the Baralaba North / Wonbindi North Mine Levee) around the southern end of the BNCOP pits (as shown on Figure 1.2). An undisturbed corridor for the Anabranch waterway was maintained between this levee and Baralaba Central. Earlier investigations and consultation with the local community identified a corridor width of at least 600m as the best scenario that balances potential impacts on the local community and environment during periods of flooding while allowing maximum use of the coal resource. The study included hydrology and hydraulic model development, and a number of recommendations were included in the report for future investigations. This previous study was reviewed and accepted by the regulator as part of the approval process for the Baralaba North / Wonbindi North Mine Levee.

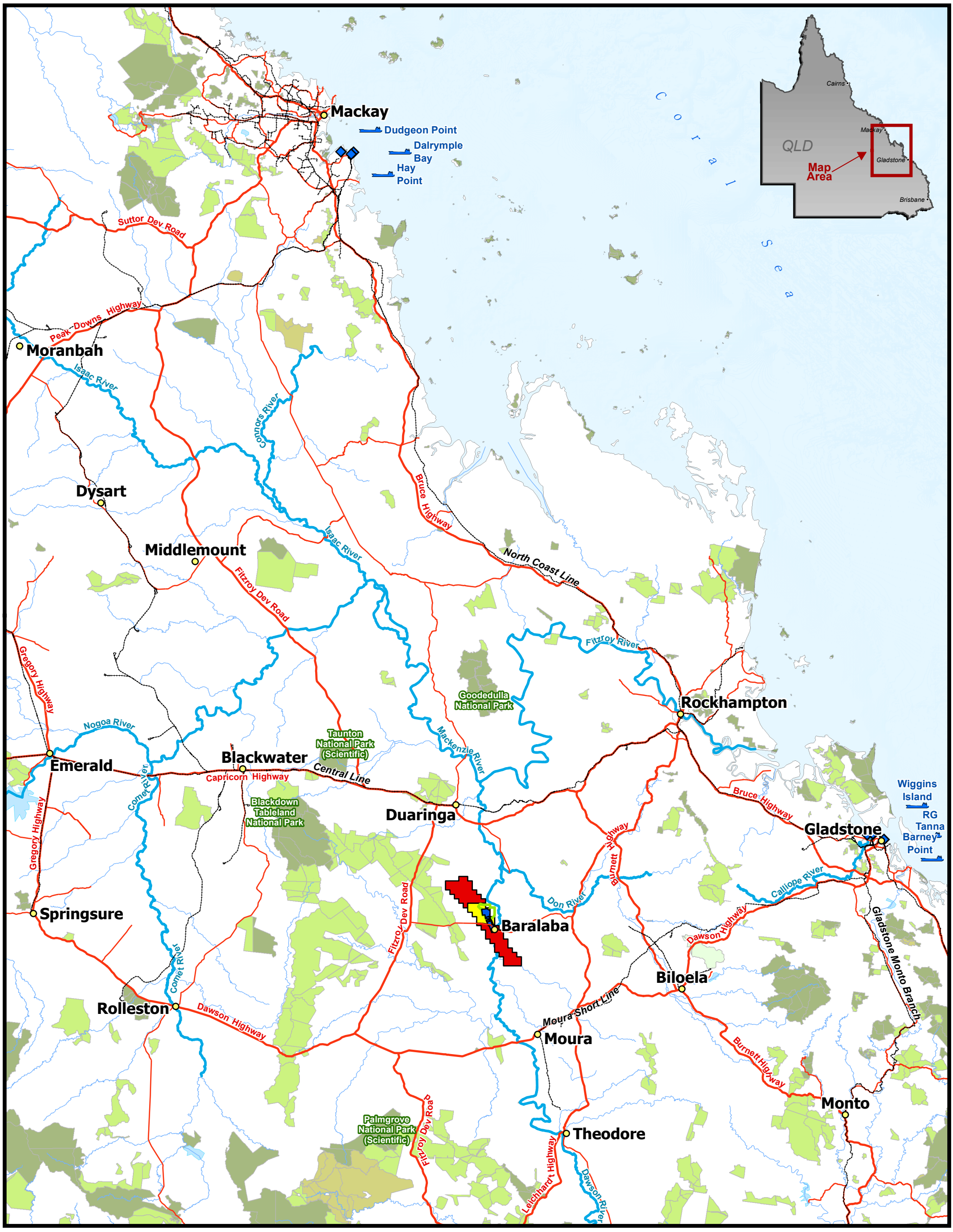
The Baralaba North Flood Study covered the upstream end of the area of interest for the BNCOP, and thus the models used in the Baralaba North Flood Study were selected as the basis for the current study. These models have been extensively upgraded to meet the objective of this study, including extension of the models downstream and calibration to the large 2010 flood event. This report fully describes the upgrade of the models from those used in the Nov 2012 Baralaba North Flood Study.

It is noted that Water Solutions has also undertaken flooding investigations for the Baralaba South Coal Project, reported in Water Solutions (Dec 2012). This study included the development of a large scale hydrodynamic flood model covering both the Baralaba Central and South sites. With the focus of the current investigation on the BNCOP area, the more detailed Baralaba North Flood Study model was used in preference to the larger scale Baralaba South model as the basis for the current investigation.

1.5 Report Structure

The remainder of this report is structured as follows:

- Section 2 describes the investigation undertaken on stream gauging stations, including the development of Rating Curves for Beckers and Bindaree gauging stations.
- Section 3 describes the development and calibration of the hydraulic model, Tuflow.
- Section 4 describes the development and calibration of the hydrology model, WBNM.
- Section 5 describes the flood frequency analysis undertaken on the recorded annual peaks at the Beckers Gauging Station.
- Section 6 describes the design flood hydrology for the AEP 1 in 20, 1 in 50, 1 in 100, 1 in 1000 and PMF events.
- Section 7 describes the development of the three scenarios modelled in this study, the Existing/Approved Case, Operational BNCOP Mine Case and Post Mine Case.
- Section 8 provides the results of the scenario modelling for the design events, and discusses the flooding related impacts of the BNCOP.
- Section 9 summarises the study's identified control strategies to mitigate and address flooding impacts and risks.
- Section 10 provides the conclusions of this study.
- Section 11 lists relevant references.



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N

0 20 40 60
Kilometres

Legend

- Populated Place
- Road
- Rail
- Watercourse
- Cockatoo Coal ML
- Cockatoo Coal MDL
- Cockatoo Coal EPC
- BNCOP Operational Land
- Coal Terminal

Protected Areas

- National Park
- Forest Reserve
- State Forest
- Timber Reserve
- Other

Water Solutions

TITLE	REV	DESCRIPTION	DATE	SCALE 1:1,500,000	CURRENT ISSUE SIGNATURES	
Figure 1.1 Regional Location	0	Original map output	01/04/14	SIZE A3	DRAWN	MJS
	1	Figure Update	02/04/14	DATUM GDA 94	CHECKED	BJD
	2			PROJECTION	APPROVED	BJD

STATUS **FINAL**

PROJECT NO	DRAWING NO
Baralaba Nth	BBN-091-27-01-140402

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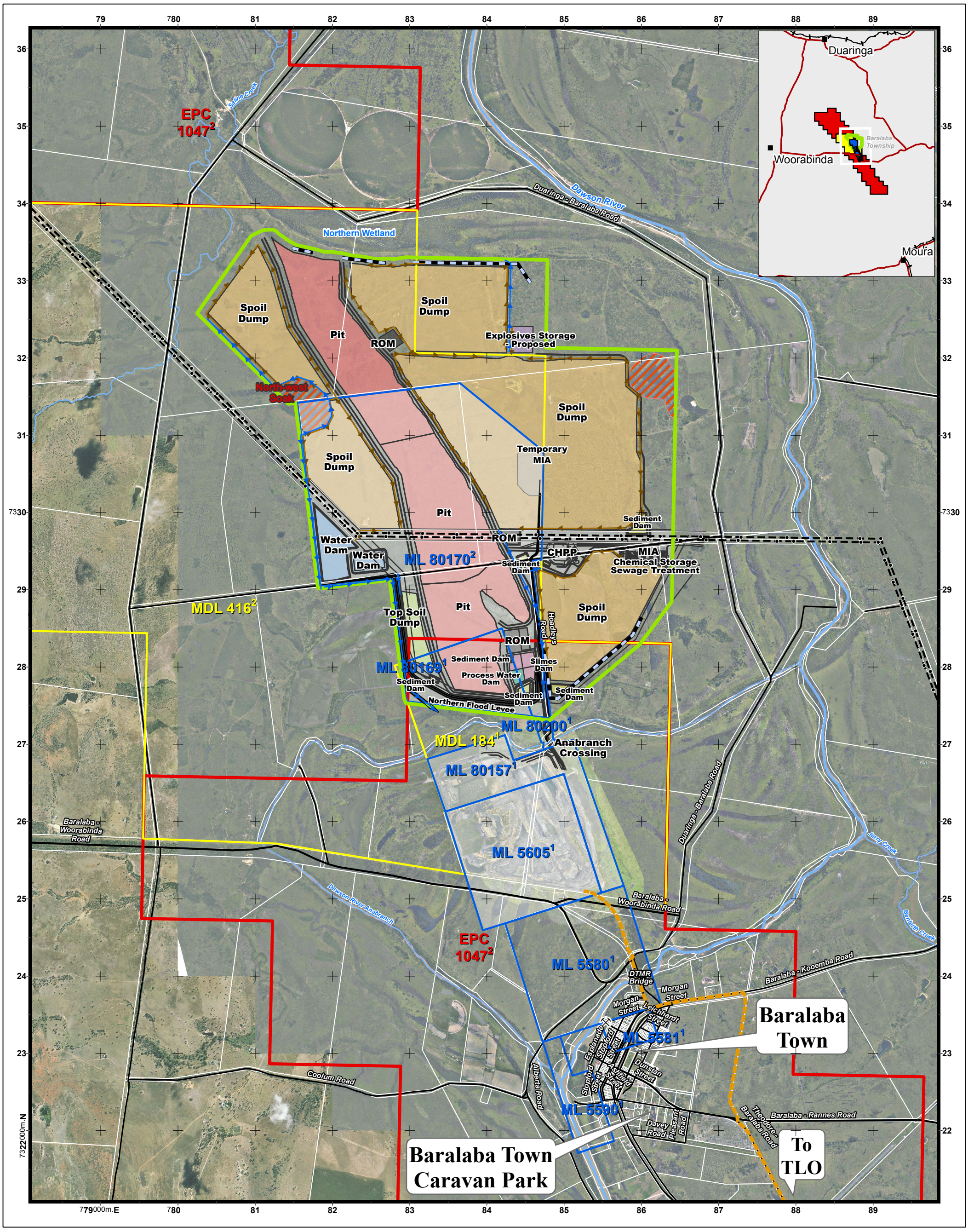

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TITLE	REV	DESCRIPTION	DATE	SCALE 1:45,000	CURRENT ISSUE SIGNATURES
Figure 1.2 Indicative Project Layout	0	Original map output	01/04/14	SIZE A3	DRAWN MJS
	1	Figure Update	02/04/14	DATUM GDA 94	CHECKED BJD
	2			PROJECTION MGA Zone 55	APPROVED BJD

N

0 500 1,000 1,500 2,000

Metres

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NOTE:
¹ : HELD BY BARALABA COAL PTY LTD
² : HELD BY WONBINDI COAL PTY LTD

Legend

Road.....
Watercourse.....
Cadastre.....
Cockatoo Coal ML.....
Cockatoo Coal MDL.....
Cockatoo Coal EPC.....
Area of Exclusion of Mining Activities.....
Product Road Transport Route.
Powerline & Power Pole.....
BNCOP Operational Land.....
Clean Water Drain.....
Dirty Water Drain.....
Proposed Flood/Erosion Protection Levee.....

Water Solutions

STATUS **FINAL**

PROJECT NO	DRAWING NO
Baralaba Nth	BBN-091-28-01-140402

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Figure 1.3 – Interim Floodplain Assessment Overlay (Source: DSDIP SPP Interactive Mapping System)

2 Stream Gauging Station Review

There are a number of stream gauging stations along the Dawson River in the vicinity of the mine and in the Dawson River catchment that provide useful information for this study. A summary of key gauges is provided in Table 2.1.

Some notes on the gauging stations follow:

- The key gauge for this study is GS 130322A Dawson River at Beckers, used in both the hydrology and hydraulic model calibration. See below for further discussion on this site.
- The Bindaree gauge captures about 95% of the catchment area to Beckers, However it has only been in existence since 2005, and the cross-section is not well confined at high stage, and hence there is more uncertainty associated with the high stage rating. Bindaree was used to provide some verification to the refinement of the Beckers rating curve.
- Utopia Downs, Mimosa Creek, Robinson Crrek, Palm Tree at La Palma and Roundstone Creek are a range of headwater gauges scattered around the catchment that were used to assist in the hydrology model calibration.
- Taroom and Woodleigh are main Dawson River gauges capturing about 40% and 70% of the catchment to Beckers. Both sites were used to assist in the hydrology model calibration.
- 130304B Dawson R at Neville Hewitt Weir HW and 130261A Dawson R at Neville Hewitt Weir TW are not included in the table above. The high stage ratings for these sites have been affected by the construction of the mine, and the recorded peak for the 2010 event at Neville Hewitt Weir appears high given other points around the weir (see Section 3.8.3). Other than considering the peak level recorded in 2010, these sites were not further evaluated in this study.

The key gauge for this study is GS 130322A Dawson River at Beckers, shown in Figure 2.1. It is situated between the Baralaba Central Mine and the northern end of the BNCOP, and thus is in an ideal location for this study. It has a reasonably long record, having operated continuously since 1964. The site is also fairly well contained, without the extensive floodplains and significant anabranches present upstream and downstream. A large number of gaugings have been performed on this site, which provides a level of confidence in the rating curve up to the highest gauged flow at this site.

Table 2.1 – Key Stream Gauging Stations

Number	130322A	130374A	130304A	130302A	130317B	130324A	130316A	130375A	130313A	130363A
Name	Dawson R at Beckers	Dawson R at Bindaree	Dawson R at Baralaba[2]	Dawson R at Taroom	Dawson R at Woodleigh	Dawson R at Utopia Downs	Mimosa Ck	Robinson Ck	Palm Tree at La Palma	Roundstone Ck
Opened	30/06/1964	6/04/2005	1/10/1924	1/01/1911	1/10/1985	17/06/1966	15/01/1957	20/04/2006	12/12/1956	3/06/1999
Closed	-	-	1/06/1961	-	-	-	-	-	-	-
Zero Gauge (m)	64.5	78.7	71.9	180.8	110.0	216.1	116.9	207.8	200.8	105.7
Datum	AHD	AHD	SD	AHD	AHD	AHD	AHD	AHD	AHD	AHD
Control	Gravel	Sand	Sand Gravel	Control Weir	Gravel Crossing	Sand	Sand	Sand	Sand	bedrock and gravel
AMTD (km)	71	110.5	84.7	384.6	193.6	453.5	55.5	32.4	49.4	160
Catchment Area (km^2)	40500	38690	40110	15850	28500	6039	2473	1597	2660	999
Max Gauged Level	14.2	14.3	8.9	6.6	16.2	9.08	2.28	3.6	4.1	4.8
Max Gauged flow	2000	1900	868	1110	1819	378	57	4	32	116
Max Gauged Date	12/03/2010	10/03/2010	23/03/1937	29/04/1989	9/03/2010	3/06/1981	22/02/1958	10/02/2011	13/11/1973	15/01/2004
Max Recorded Level	19.4	15.8	15.7	7.9	18.6	14.6	9.0	12.9	7.7	9.2
Max Recorded Flow[1]	6100	6030	-	1750	3750	1467	1036	1025	250	1263
Max Recorded Date	29/12/2010	29/12/2010	24/04/1928	16/02/1911	2/01/2011	3/01/1967	18/02/1959	27/12/2010	28/12/2010	23/12/2010
No of Gaugings	273	44	not available	472	108	221	213	29	207	65

Notes: 1 – Max recorded flow is based on the DNRM rating curve for all sites except Beckers and Bindaree, which are based on the derived rating curves shown in Section 2.2.4.

Figure 2.1 – Beckers Gauging Station Looking Upstream (Oct 2013)

2.1 Calibration Event

A preliminary review of the available data was undertaken in order to identify appropriate calibration events for this study. GS 130322A Dawson R at Beckers is the key gauge for this study, and the available record for this site is summarized in Figure 2.2.

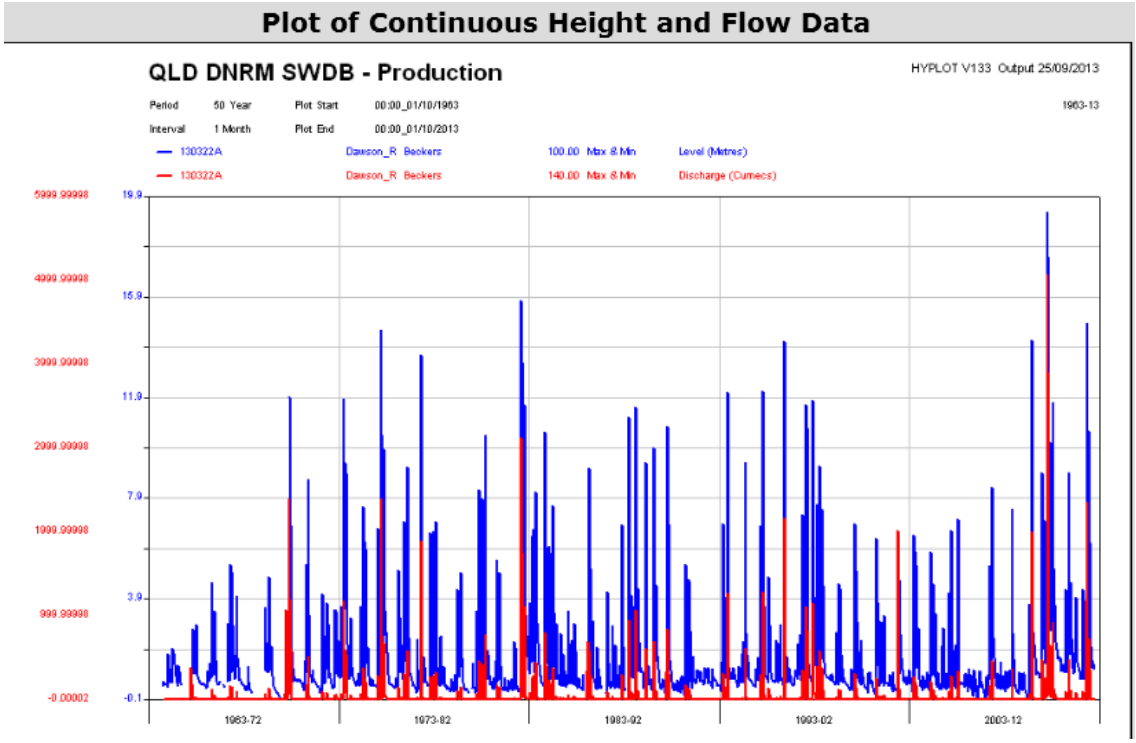

Figure 2.2 – GS 130322A Dawson R at Beckers – Height and Flow Record (Source: DNRM Website)

The largest event is the December 2010 event, clearly significantly larger than any other event since this gauge opened in 1964. Being fairly recent, there is also reasonable data available for this event. The December 2010 event thus was selected as the key calibration event for this study.

Consideration was given to calibration for other historical events, however the other events in the record are significantly smaller than 2010, and much less data appears to be available for calibration to these smaller events. Given these limitations and the project objectives, the calibration of the hydrology and hydraulic models were focused on the 2010 event.

2.2 Rating Curve Analysis

Given the criticality of the peak flow of the 2010 event for this study a review of the Beckers Rating Curve and the upstream gauging station, Bindaree was undertaken as described below.

Beckers Gauging Station – GS130322A

A stream gauge records water level, and this level is converted into flow via a rating curve. The DNRM Rating Curve for Beckers is shown in Figure 2.3.

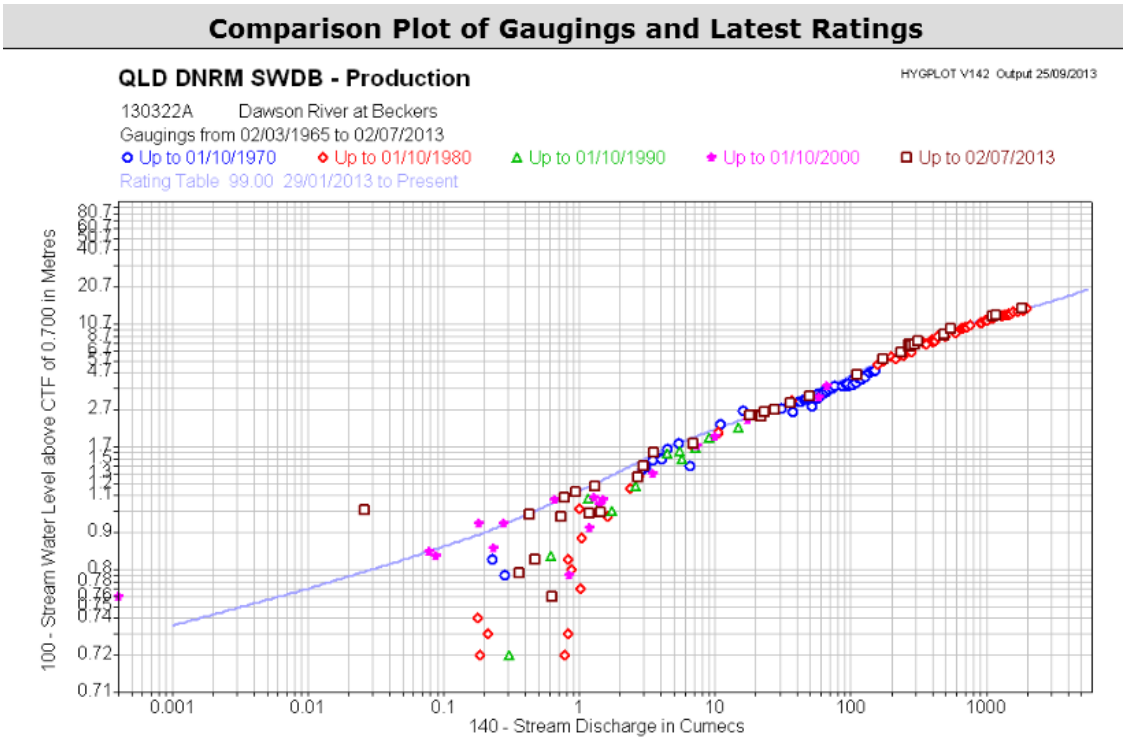

Figure 2.3 – GS 130322A Dawson R at Beckers - Comparison Plot of Gaugings and Latest Ratings (Source: DNRM Website)

A rating curve is developed from a series of gaugings taken manually at the site by DNRM hydrographers measuring flow velocity, and then using the velocity and the surveyed cross-section to estimate flow. The cross-section used by DNRM is shown in Figure 2.4, and the gaugings are the points shown on Figure 2.3.

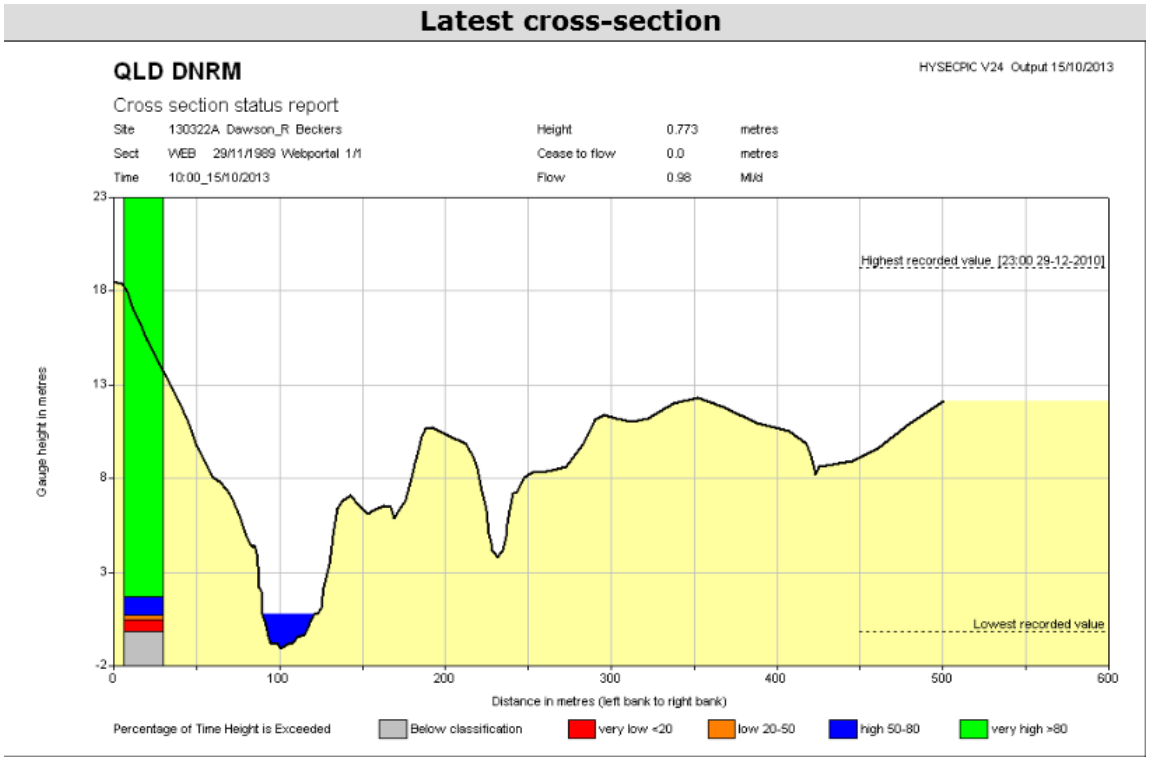

Figure 2.4 – GS 130322A Dawson R at Beckers – Cross-section (Source: DNRM Website)

DNRM hydrographers have advised that the latest gauge zero for Beckers is 64.255 m AHD. (It is noted that the gauge zero given on the DNRM website at the time of this study were superseded values).

The highest gauged flow is approximately 2000 m^3/s at a gauge level of approximately 14.08 m, as shown on Figure 2.3.

The highest recorded flow at Beckers is during the 2010 event (see Figure 2.2). This is over 5m higher than the peak gauged flow at Beckers, and from Figure 2.4 it can be seen that the cross-section used for the DNRM rating curve is considerably exceeded at this level. The DNRM rating curve indicates about 5000 m^3/s at the peak recorded level for the 2010 event. However there is considerable uncertainty associated with the flow assigned to the peak level for the 2010 event, given the lack of high stage gauging and the poor cross-section definition at this elevated level.

<u>Bindaree Gauge Station – GS130374A</u>

The DNRM Rating Curve for Bindaree is shown in Figure 2.5, the cross-section in Figure 2.6, and some photos of the site in Figure 2.7 and Figure 2.8.

Based on the gaugings shown in Figure 2.5 the rating curve is considered to be reasonably reliable up to a flow rate of about 1900 m^3/s, although the small number of points at higher flow rates means less confidence in 250 m^3/s to 1900 m^3/s range.

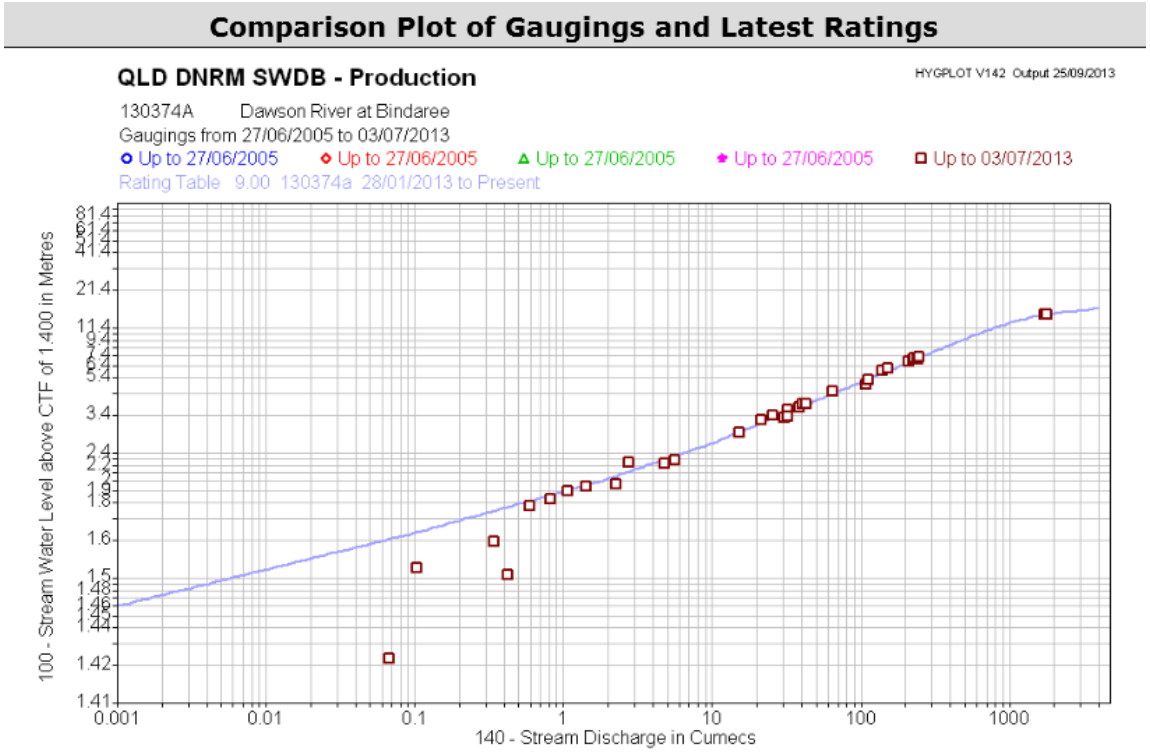

Figure 2.5 – GS 130374A Dawson R at Bindaree - Comparison Plot of Gaugings and Latest Ratings (Source: DNRM Website)

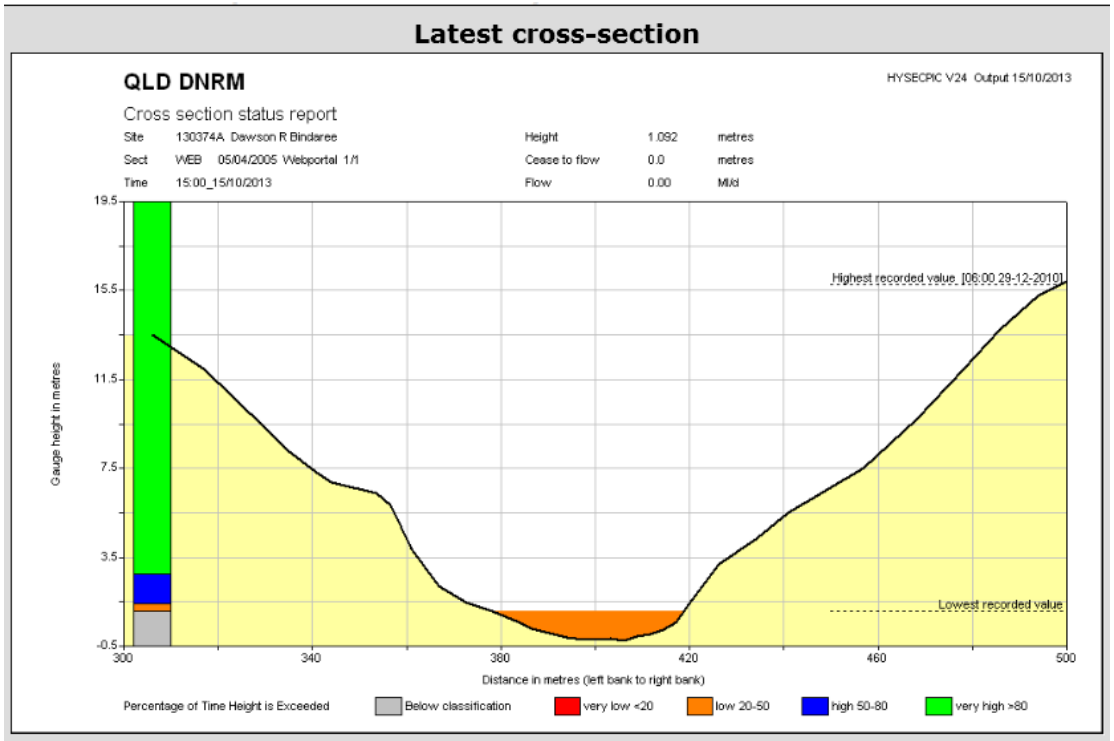

Figure 2.6 – GS 130374A Dawson R at Bindaree – Cross-section (Source: DNRM Website)

Figure 2.7 – GS 130374A Dawson R at Bindaree - Control (Source: DNRM Website)

Figure 2.8 – GS 130374A Dawson R at Bindaree - Site (Source: DNRM Website)

Based on the DNRM rating curves, the peak flows at these two sites are shown in Table 2.2. Bindaree commands 95% of the catchment of Beckers, and so would you expect a closer match between the peak flows at these two sites. The following sections describe the analysis undertaken to resolve this difference and develop revised rating curves for the Beckers and Bindaree sites.

Table 2.2 – December 2010 Peak Levels and Flow

Gauging Station	Gauge Zero (m AHD)	December 2010 Peak Level (m)	Peak Flow - DNRM Rating Curve (m^3/s)
Bindaree Gauge	78.71	15.75	3760
Beckers Gauge	64.255	19.28	5070

2.2.1 Data

Relevant data sourced from the Department of Natural Resources and Mines (DNRM) was utilised for the generation of rating curves about the Beckers and Bindaree gauging stations (GS130322A and GS130374A respectively), including:

- DNRM generated rating curves
- Historic stream gauged flow data (i.e. recorded depths, flows, etc.)
- Manual gauged flow recordings
- Cross-sectional data about the gauging stations

Topographical data (the 2011 Vekta LIDAR data described in Section 3.2) about the Baralaba Mine Site was also used to extract cross-sectional data at the gauge station locations.

2.2.2 Cross-Section Comparison

<u>Beckers Gauging Station – GS130322A</u>

The location of Beckers Gauging Station is shown on Figure 2.9. A cross-sectional profile extracted from the LIDAR data at the Beckers gauging station location is presented in Figure 2.10, with the DNRM cross-sectional profile (from Figure 2.4) shown for comparison purposes.

Review of Figure 2.10 indicates that LIDAR data did not capture the channel invert of the Dawson River. This is a common feature of LIDAR data, which typically does not penetrate below the water surface and has difficulty picking up the ground level in heavily vegetated bed and banks of watercourses.

For the purposes of rating curve development, a composite cross-section was created incorporating DNRM cross-sectional data for the main channel.

It was also noted that the right channel batter (CH2100 – CH2900) presented in Figure 2.10 is not representative of the channel cross-sectional geometry about the Becker gauge station location as it captures local gullies entering the Dawson River. These dips are not considered to be representative of the active flow conveyance area of the Dawson River. The right bank of the cross-section was “smoothed” based on an inspection of the topography upstream and downstream of this area. The final composite cross-section incorporating DNRM cross-sectional data, LIDAR data and the “smoothed” right channel batter is presented in Figure 2.11.

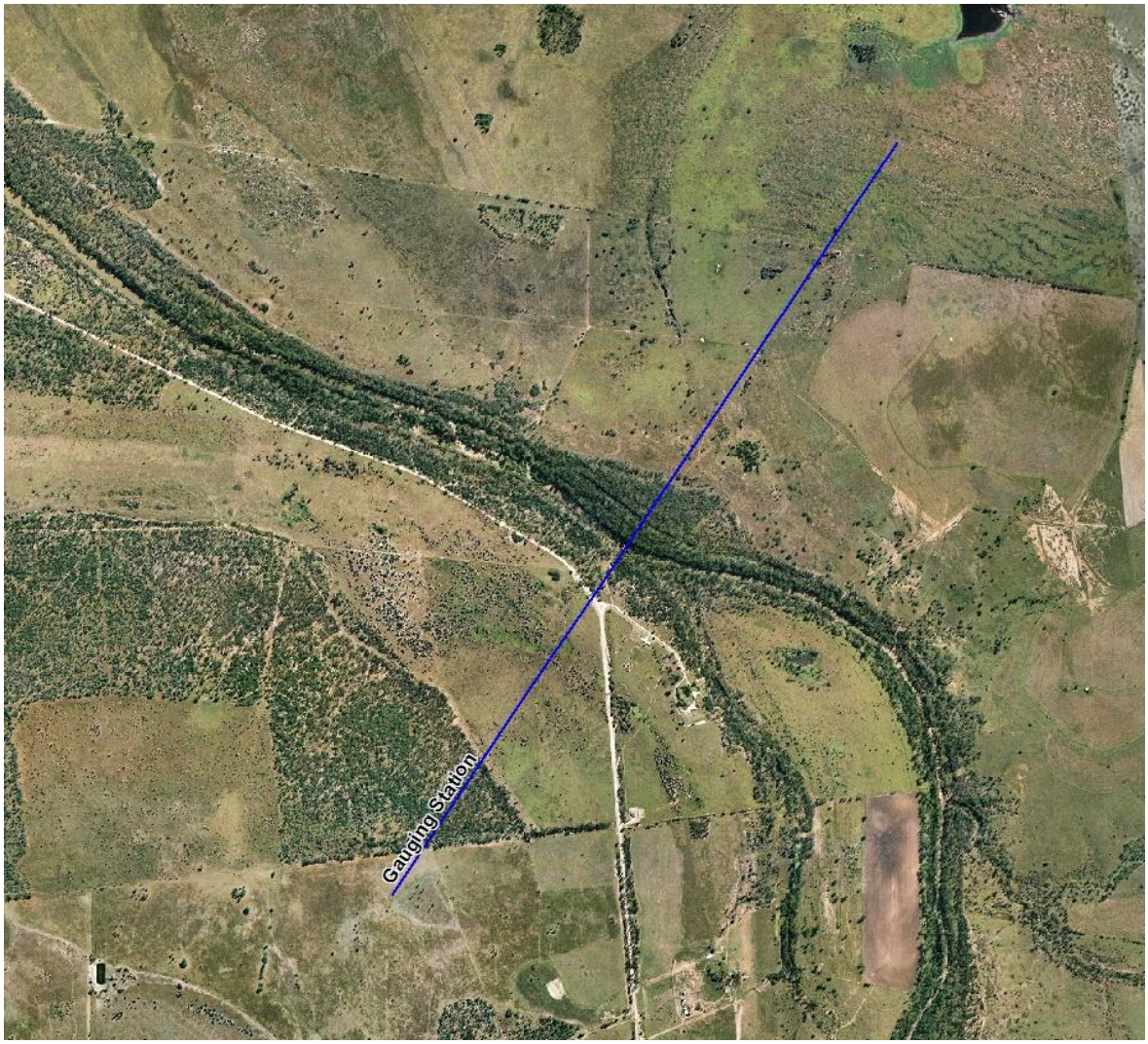

Figure 2.9 – Beckers GS Location

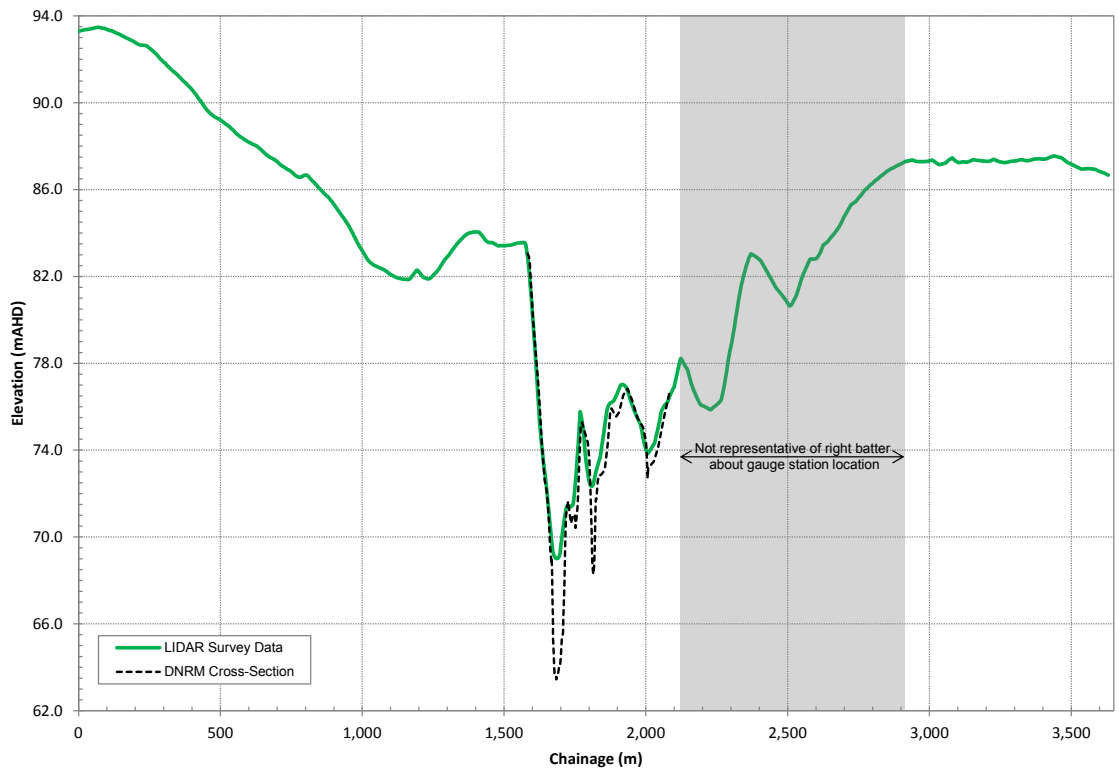

Figure 2.10 – Becker GS (GS130322A) Cross-sectional Profile

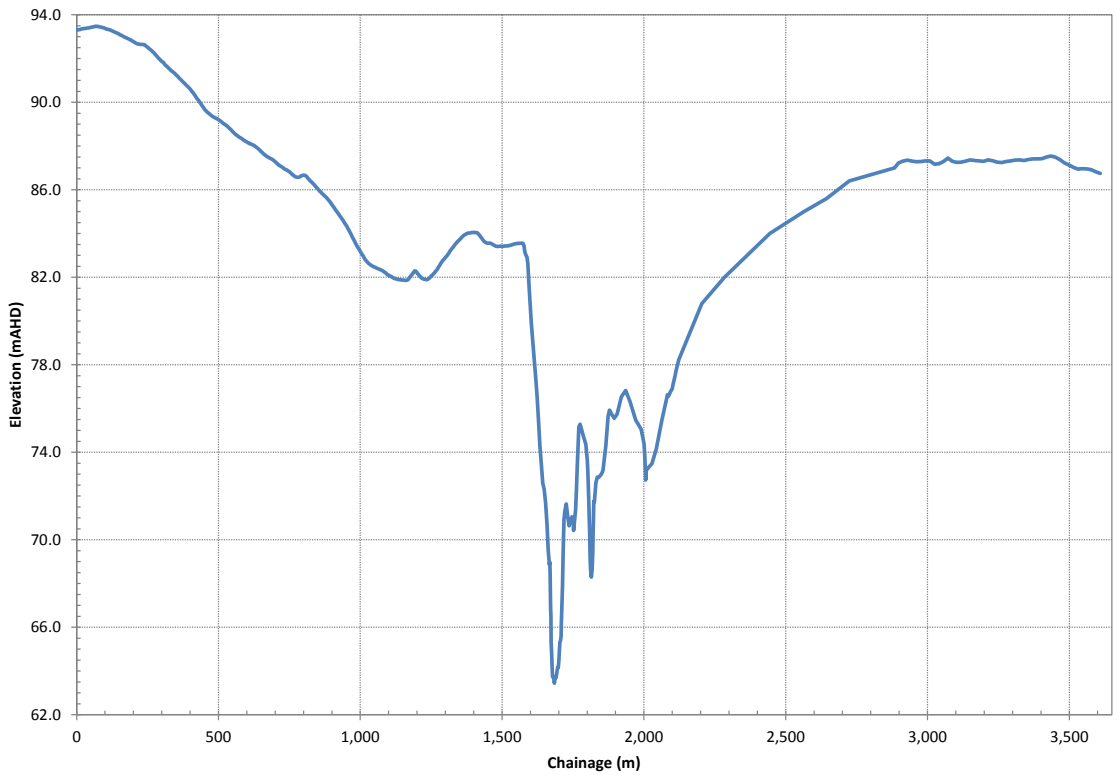

Figure 2.11 – Final Composite Cross-Sectional Profile (Beckers GS)

Bindaree Gauging Station – GS130374A

A cross-sectional profile extracted from the LIDAR data at the Bindaree gauging station location is presented in Figure 2.12. The DNRM cross-sectional profile has also been shown for comparison purposes.

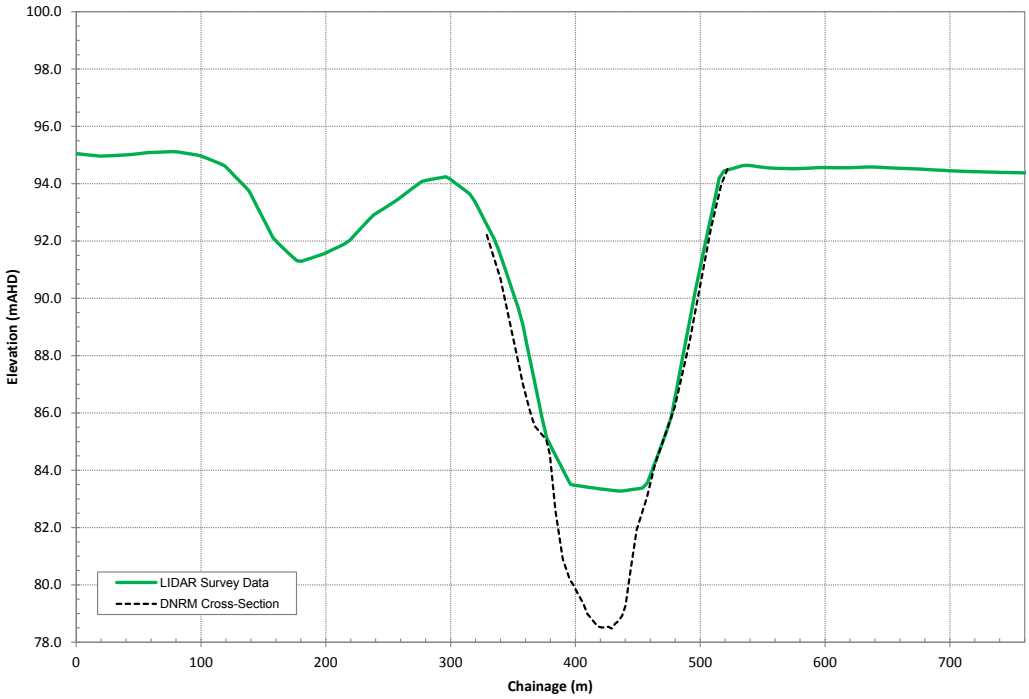

Figure 2.12 – Bindaree GS (GS130374A) Cross-Sectional Profile

Similar to Beckers, review of Figure 2.12 indicates that the LIDAR data does not capture the channel invert of the Dawson River. The cross-section only covered about 750m of the ~10,000 m wide floodplain at this location. For the purposes of rating curve development, a composite cross-section was created incorporating DNRM cross-sectional data for the main channel and LIDAR data across the floodplain, as shown in Figure 2.13

The location of this cross-section is shown in Figure 2.14.

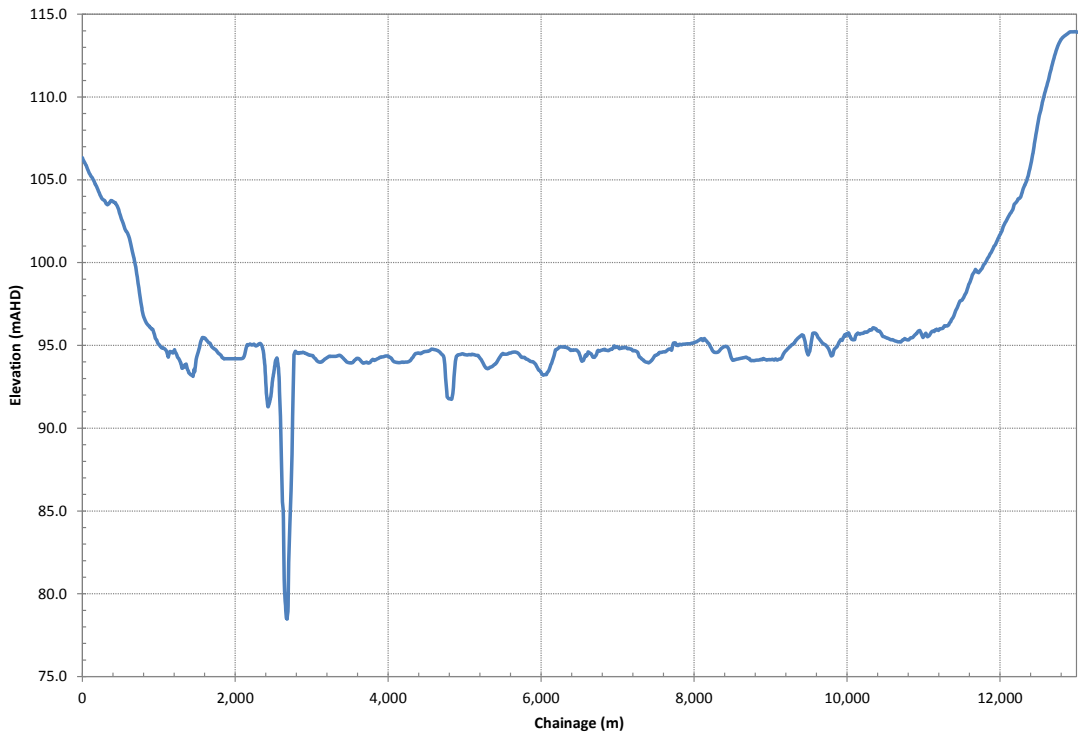

Figure 2.13 – Final Composite Cross-Sectional Profile (Bindaree GS)

Figure 2.14 – Bindaree GS – Cross-section Location

As can be seen from Figure 2.13 and Figure 2.14 the floodplain is extremely wide at the Bindaree site. Once the flood waters rise above about 92m AHD it is higher than some of the flood runners and minor creeks crossing this 10km wide floodplain, and above about 94-95 m AHD floodwaters are likely to cover the majority of the floodplain. The rating curve at this site is thus likely to be considerably uncertain in this range. The December 2010 peak level was 94.46m, firmly within this area of uncertainty. The December 2010 event peak level (83.54m AHD) at the Beckers site is much more confined, and hence the high stage rating at Beckers is likely to be more accurate than the high stage rating at Bindaree.

2.2.3 Average Velocity Calculation

The velocity-area method is a common technique for determining the discharge in a stream, described in many hydrographic guidelines such as USGS (2010). A number of gaugings are taken measuring the velocity of the water flow across the river, and the velocity is multiplied by the area to give the flow rate. The resultant level vs flow points are plotted, and a rating curve drawn through the points, as illustrated on Figure 2.3.

By dividing the rating curve flows by the cross-sectional area at each elevation, the average cross-sectional velocity corresponding to the DNRM rating curve can be back-calculated. This technique was used to calculate the average cross-sectional velocity for flows up to the highest gauged flow (2000 m^3/s for Beckers, 1800 m^3/s for Bindaree). It was estimated that the average cross-sectional velocity increased, on average, at a rate of 0.054m/s and 0.08m/s per m of elevation for the cross-section at Beckers and Bindaree gauging stations. It is noted that the average cross-sectional velocity does vary with the shape of the cross-section as the water level increases, but it was considered that this average rate of increase would provide a fair estimate of the peak flow rate for the December 2010 event.

2.2.4 Developed Rating Curves

The determined average cross-sectional velocity was then multiplied by the area on the final composite cross-section for both sites to estimate the rating curves above the highest gauged flow and the peak flow rate for the recorded level of the December 2010 event. The resultant rating curves are shown in Figure 2.15 and Figure 2.16.

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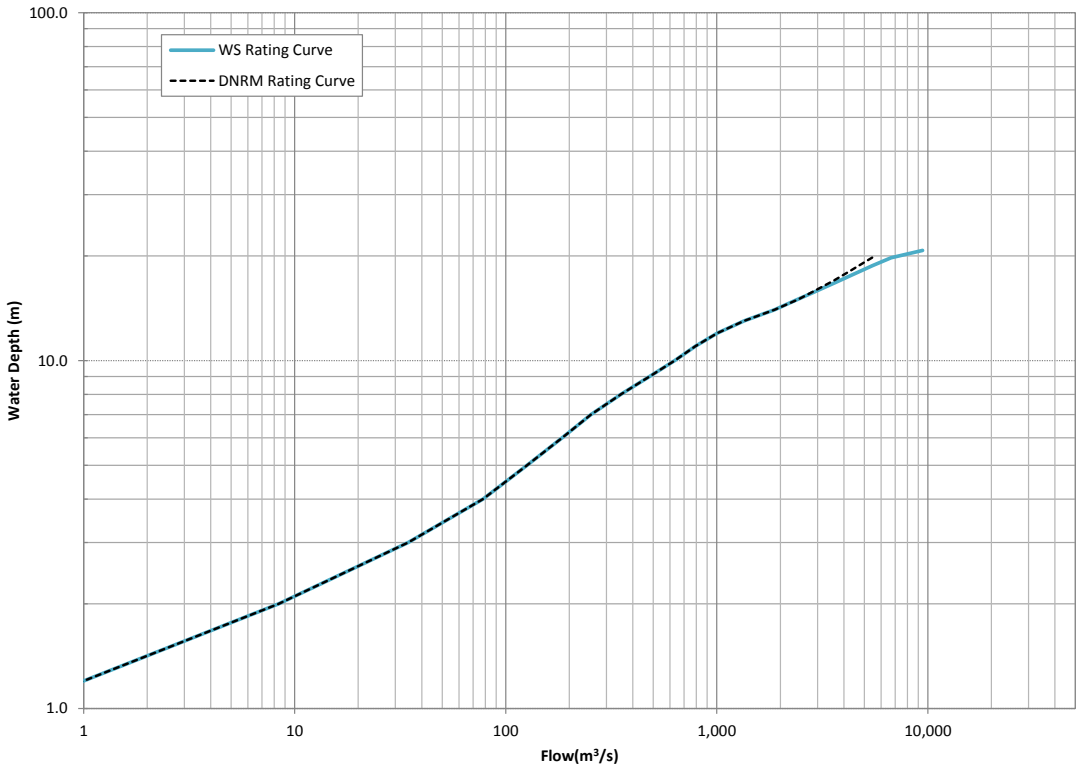


Figure 2.15 – Beckers GS (GS130322A) Rating Curve

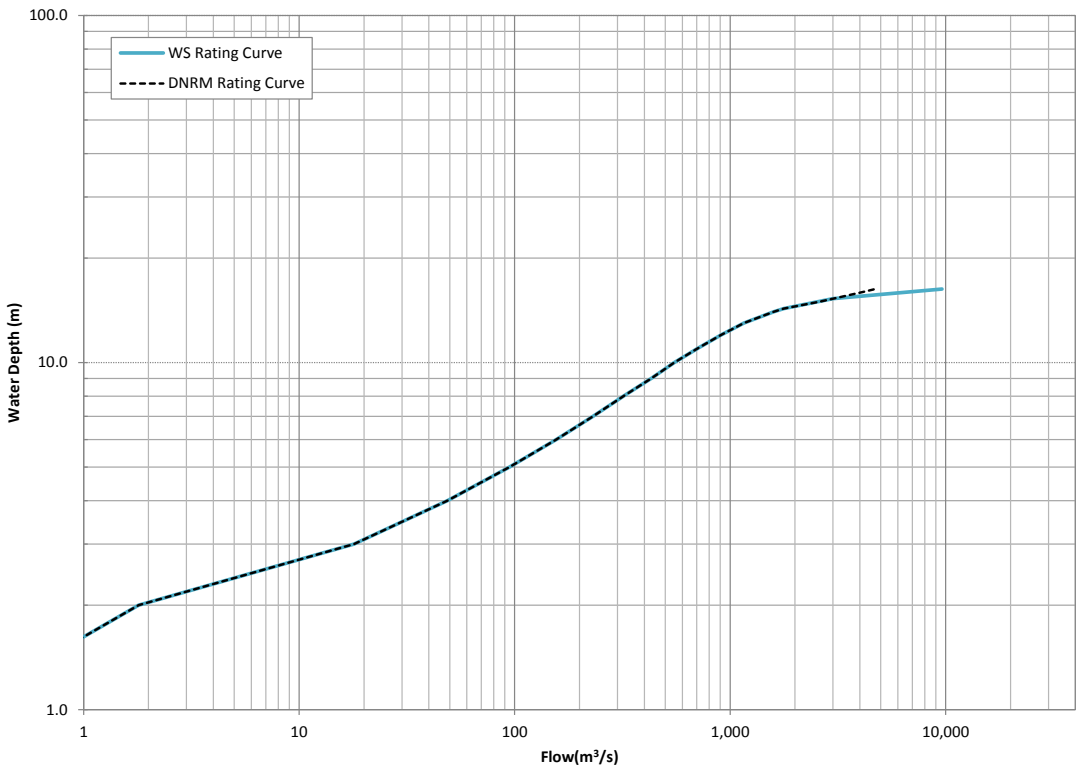


Figure 2.16 – Bindaree GS (GS130374A) Rating Curve

Based on these rating curves, the peak flow for the December 2010 event for Beckers was calculated to be 6100 m^3/s, while at Bindaree it was calculated to be 6000 m^3/s. Bindaree GS is some 40km upstream of Beckers, and controls 95% of the catchment area of Beckers. Given the differences in the location of these sites, and the uncertainties associated with flow rates for large floods (particularly at Bindaree), this is considered an excellent match.

Table 2.3 – December 2010 Peak Levels and Flow – With Revised Rating Curves

Gauging Station	Gauge Zero (m AHD)	December 2010 Peak Level (m)	Peak Flow - DNRM Rating Curve (m^3/s)	Peak Flow - Revised Rating Curves (m^3/s)
Bindaree Gauge	78.71	15.75	3760	6000
Beckers Gauge	64.255	19.28	5070	6100

Hence the developed rating curve shown in Figure 2.15 was adopted for the purposes of this study.

2.3 Other Key Rating Curves

The Taroom and Woodleigh gauges were key sites in the calibration of the hydrology model, see Section 4.3.2. The DNRM cross-sections and rating curves for these sites are shown in the figures below. Note that DNRM rating curves for sites other than Beckers and Bindaree were adopted 'as is' for this study.

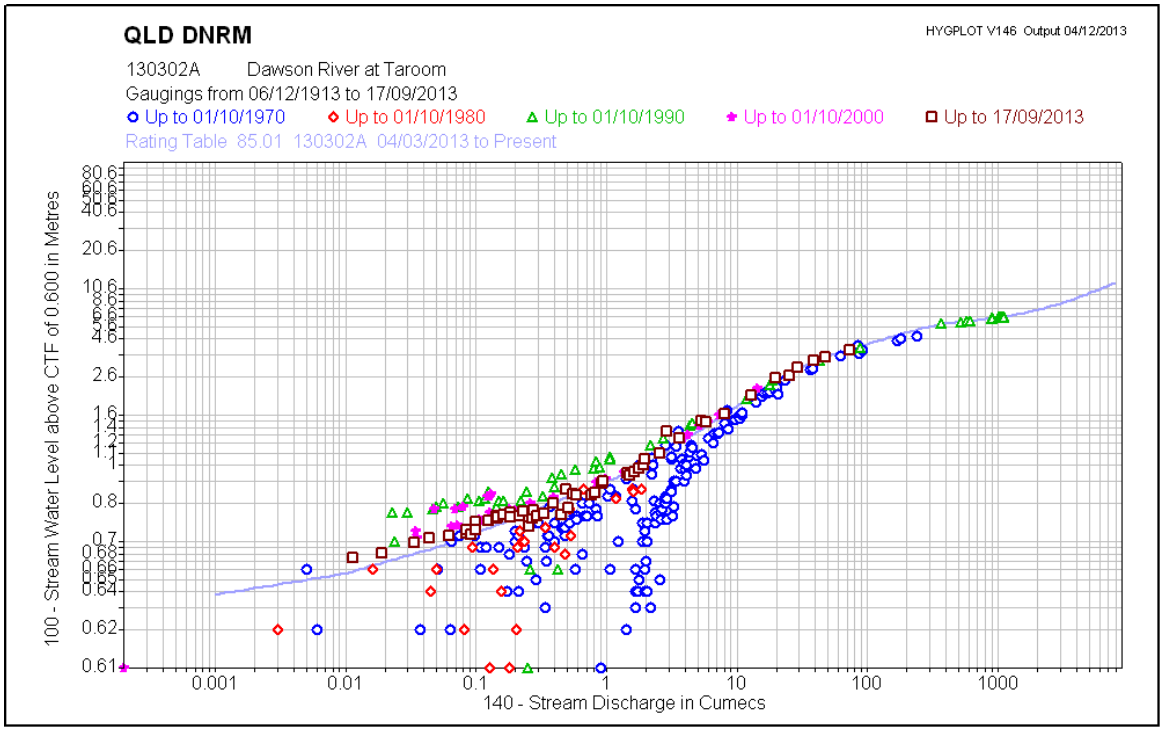


Figure 2.17 – GS 130302A Dawson R at Taroom - Comparison Plot of Gaugings and Latest Ratings (Source: DNRM Website)

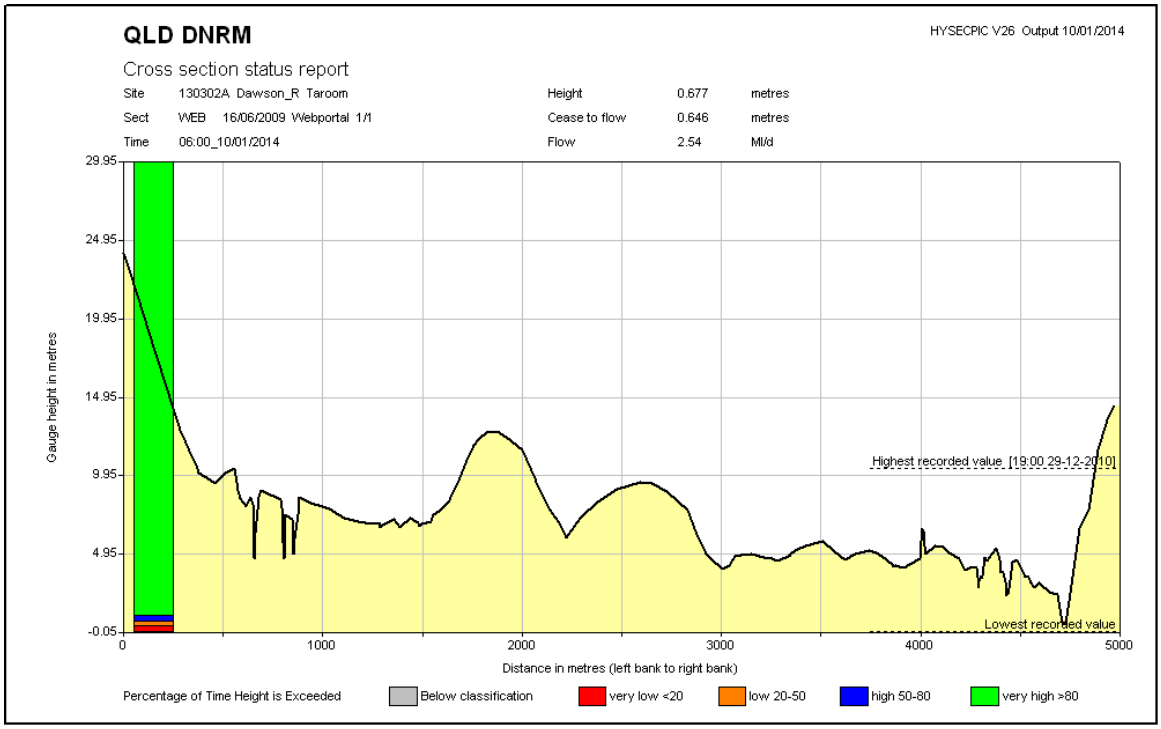


Figure 2.18 – GS 130302A Dawson R at Taroom – Cross-section (Source: DNRM Website)

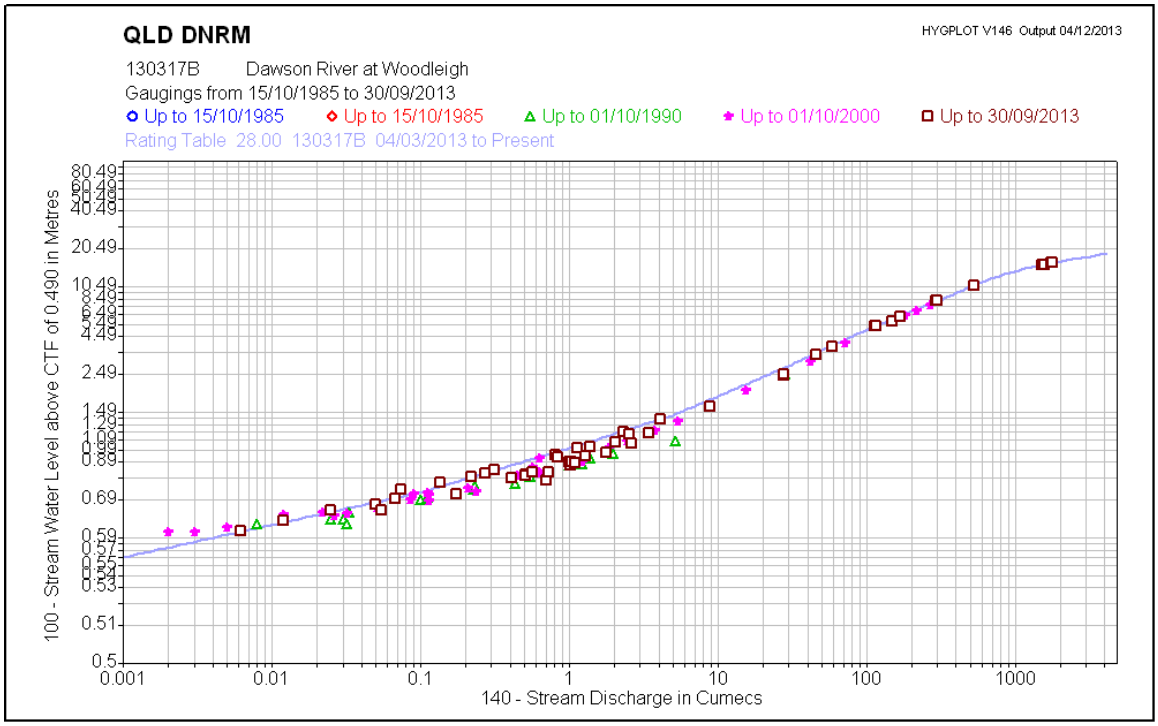


Figure 2.19 – GS 130317B Dawson R at Woodleigh - Comparison Plot of Gaugings and Latest Ratings (Source: DNRM Website)

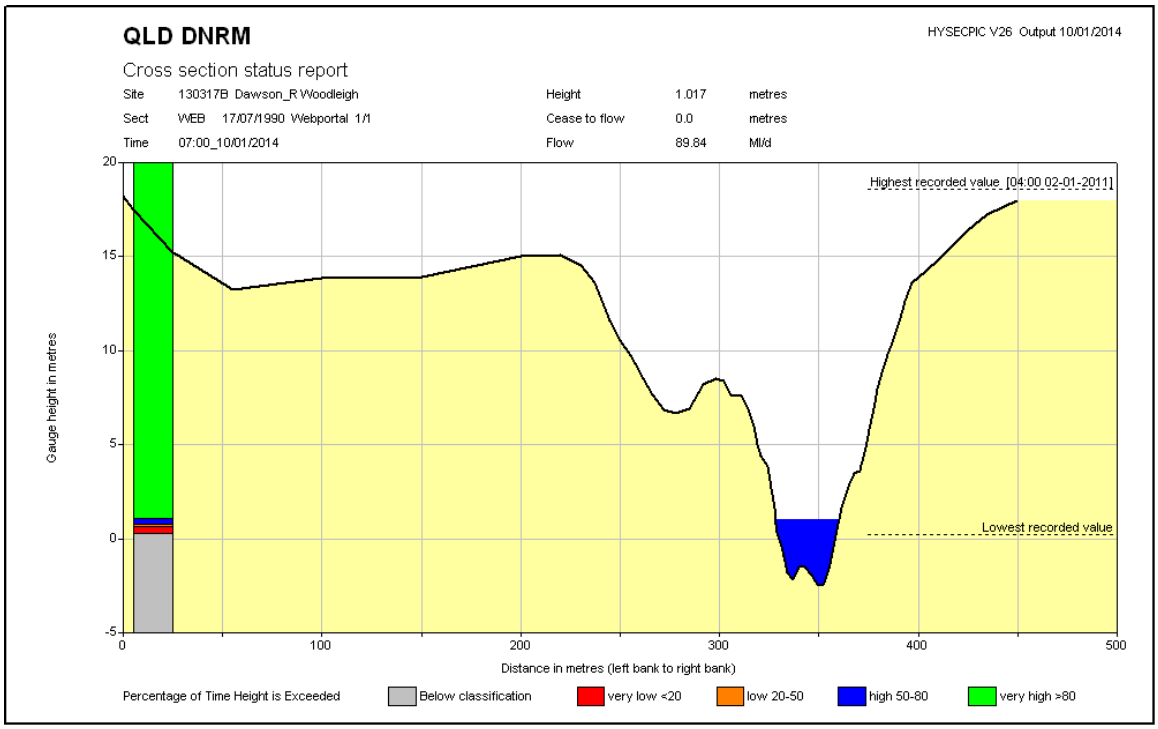


Figure 2.20 – GS 130317B Dawson R at Woodleigh – Cross-section (Source: DNRM Website)

3 Hydraulic Model Development and Calibration

The Tuflow 2D hydrodynamic modelling platform was used for the hydraulic modelling in this study. This model has been used extensively for previous flooding investigations associated with the Baralaba Coal Mine, and is considered eminently suitable for the objectives of this project.

As described in Section 1.4, the hydraulic model used in this study has been developed based on the hydraulic model used in the Baralaba North Flood Study (Water Solutions Nov 2012). The key changes have included extending the model extent further downstream, revision of the roughness map, and calibration to the 2010 event. The sections below describe the development and calibration of the hydraulic model used in this study.

3.1 Hydraulic Model Extent

A review of the study area topography was undertaken in order to determine the appropriate hydraulic model extent to enable this project's objectives to be met.

The upstream hydraulic model boundary used in the Nov 2012 Baralaba North Flood Study was considered appropriate for this study and was thus retained. The downstream boundary was moved further downstream in order to enable impacts at the northern end of the BNCOP to be assessed. The downstream boundary was selected between two elevated areas just downstream of where the downstream anabranch rejoins the main river. The Dawson River has a wide floodplain around this location, but the river is comparatively well confined compared to areas further downstream, and it was considered sufficiently far downstream of the northern boundary of the site (some 5-7km) to provide reasonable results at the mine site.

Consideration was given to the potential effect of the Don River catchment on flooding at the location of the BNCOP. The Don River joins the Dawson River some 15km downstream of the BNCOP site. The catchment area of the Don River is relatively small, being approximately 20% of the area of the Dawson River catchment above the junction. Preliminary review of the GS 130322A Dawson River at Beckers rating curve (See Figure 2.3) shows little scatter in points at high levels. If the Don River had a strong backwater effect on the Beckers site in some floods, you would expect a larger scatter in gauging. It was thus considered unlikely that the Don River would significantly affect flood levels at the site in the large Dawson River floods being considered in this study, and thus extension of the model to include the Don River was not considered to be required.

Figure 3.3 shows the selected spatial extent of the hydraulic model.

It is noted that some issues were experienced with the downstream boundary condition in this study, see Section 3.10 for further details.

3.2 Topography

The model was initially developed with topography suitable for calibration to the 2010 event.

The base topography used in the model was principally based on data from aerial survey flown on 25 March 2011 provided by Vekta Pty Ltd, as was used in Water Solutions (Nov 2012). This topography was assumed to reasonably represent conditions at the time of the December 2010 event.

The stated accuracy of this information from Vekta is as follows:

- Horizontal Accuracy +/- 0.45m (Survey check +/-0.42m RMS)

- Vertical Accuracy +/- 0.15m (Survey check +/-0.08m RMS)
- Reliability – All Data complies with the above accuracies except within heavily vegetated areas. The ground surface in these vegetated areas may not comply with the accuracies stated above due to the inability of LiDAR technology to penetrate dense vegetation.

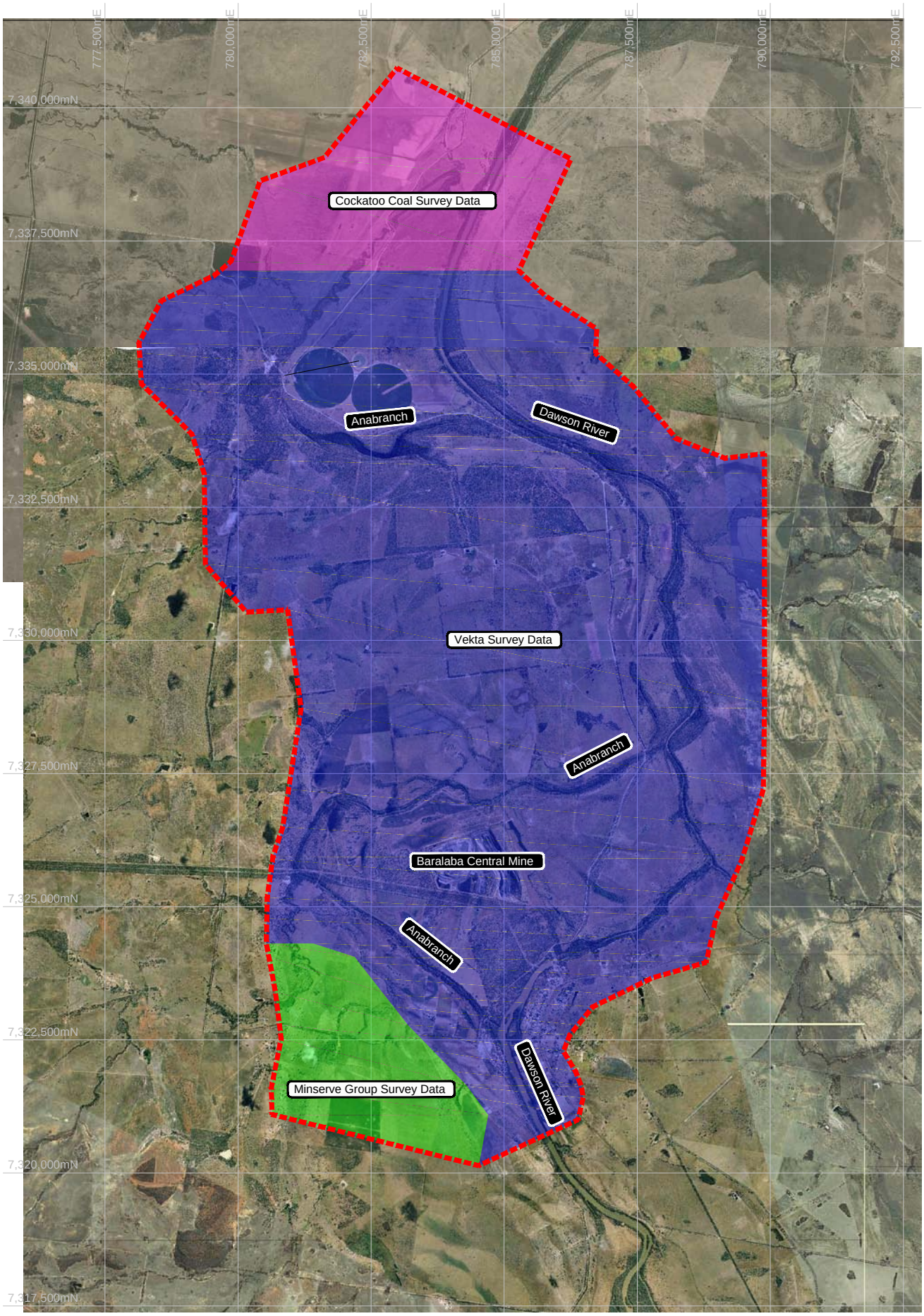
The Vekta data covered the majority of the floodplain of interest for this study as shown on Figure 3.1, however some areas were not covered by this data. These areas were addressed as follows:

- The major area missing from the Vekta data was the area near the downstream extent of the hydraulic model. Cockatoo Coal obtained additional topographic data of this area via aerial drone and provided this data in Nov 2013. Cockatoo Coal have compared this data to the LIDAR along the interface, and confirmed the drone data is within 0.15m of the LIDAR data.
- There was a small section of the digital terrain model (DTM), on the left bank near the upstream boundary of the hydraulic model that was not covered in the 2011 survey. Topography for this area was sourced from the older 2009 photogrammetry data from Minserve Group Pty Ltd. This area is small and some distance from the BNCOP area. Inaccuracies in this older dataset are unlikely to significantly affect the results of this study.
- There are some small areas of side storage not covered by the Vekta data, the main one being downstream of the town of Baralaba. Data for these areas was planned to be collected by Cockatoo Coal via aerial drone, but was not available in time for this study. These areas are small relative to the conveyance area and storage in the main floodplain, and hence these areas were conservatively not included in the hydraulic model.

WaterRIDE was used to process the provided Vekta LIDAR data, Minserve photogrammetry data and the Drone data to a 10m grid resolution for use in the Tuflow model.

Initial runs in Tuflow were done with the 10m grid, however the resultant run times were excessive, and thus the grid size was adjusted to 20m within Tuflow. As described in Section 3.2.2, the 20m DTM was reviewed to verify it reasonably matched critical features of the floodplain.

Water Solutions



LEGEND
Active Modelling Area
Minserve Survey Data
Vekta Survey Data
Cockatoo Coal Survey Data

Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Survey Data Boundaries

Job No. WS0715.1305	Revision: 3	Figure 3.1

File Name: WS130231_Fig3_1.dwg

3.2.1 Topography Verification – Comparison to Drill Hole Data

The levels of the Vekta data DTM was compared to levels for 688 drillholes across the BNCOP project area provided by Cockatoo Coal. Figure 3.2 shows the level of the drillholes is on average 0.25m (stdev of 0.26m) lower than the DTM elevation.

This analysis indicated that the LIDAR data may be slightly higher than the actual natural surface, assuming that the drill hole data is representative of the natural ground level. Slightly high topography is most likely conservative for flood modelling. Relative results (e.g. afflux) will tend to be unaffected by higher topography, but absolute results (e.g. resultant levee crest levels) may be increased slightly by the higher topography.

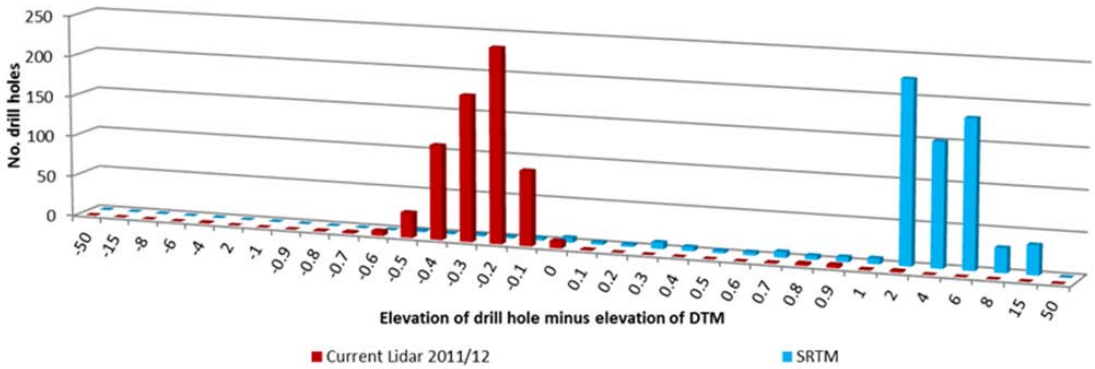


Figure 3.2 – Drillhole comparison: Drillhole minus DTM elevation

Based on this analysis, the topographic data was adopted as being of acceptable accuracy for this study.

For interest, the Shuttle Radar Topography Mission (SRTM) data was also compared to the drillhole information. The SRTM data has an average error of about 4.0m (stdev of 2.6m) in this area. Consideration was given to using SRTM data to supplement the LIDAR and Drone data, however given the poor accuracy of the SRTM data it was not used in the hydraulic model.

3.2.2 Topography Verification – Review of DTM

The 20m grid model DTM was developed based on the available topographic data as described above, and reviewed to verify it reasonably matched critical features of the floodplain.

The main river channels were checked to ensure they were reasonably continuous, without interpolation artefacts or obvious erroneous points which would cause large errors. It was noted that the section of channel upstream of the Neville Hewitt Weir contained ponded water at the time of aerial flyover. This section of channel was adjusted to better reflect the actual channel cross-sectional geometry of the Dawson River.

It was also noted that the Neville Hewitt Weir crest (80.3 m AHD, DNRM 2013) was not adequately captured through the provided survey data. As a result, this feature was manually incorporated in the DTM. As seen in Figure 2.10, the LIDAR data does not pick up the bottom of the channels well generally, especially if there is water present. Consideration was given to modifying the river channel in the DTM based on the differences observed at the Beckers site, but with only one cross-section to go on it was considered that this may introduce more errors than it would address. The lower part of the river channel does not have a large effect on large floods extending across the floodplain, and any effect is likely to be conservative, and hence the LIDAR channel was (aside from the correction to the Neville Hewitt Weir pond described above) left as is.

The final model topography for the 2010 Calibration Case is shown in Figure 3.3.

3.3 Roughness

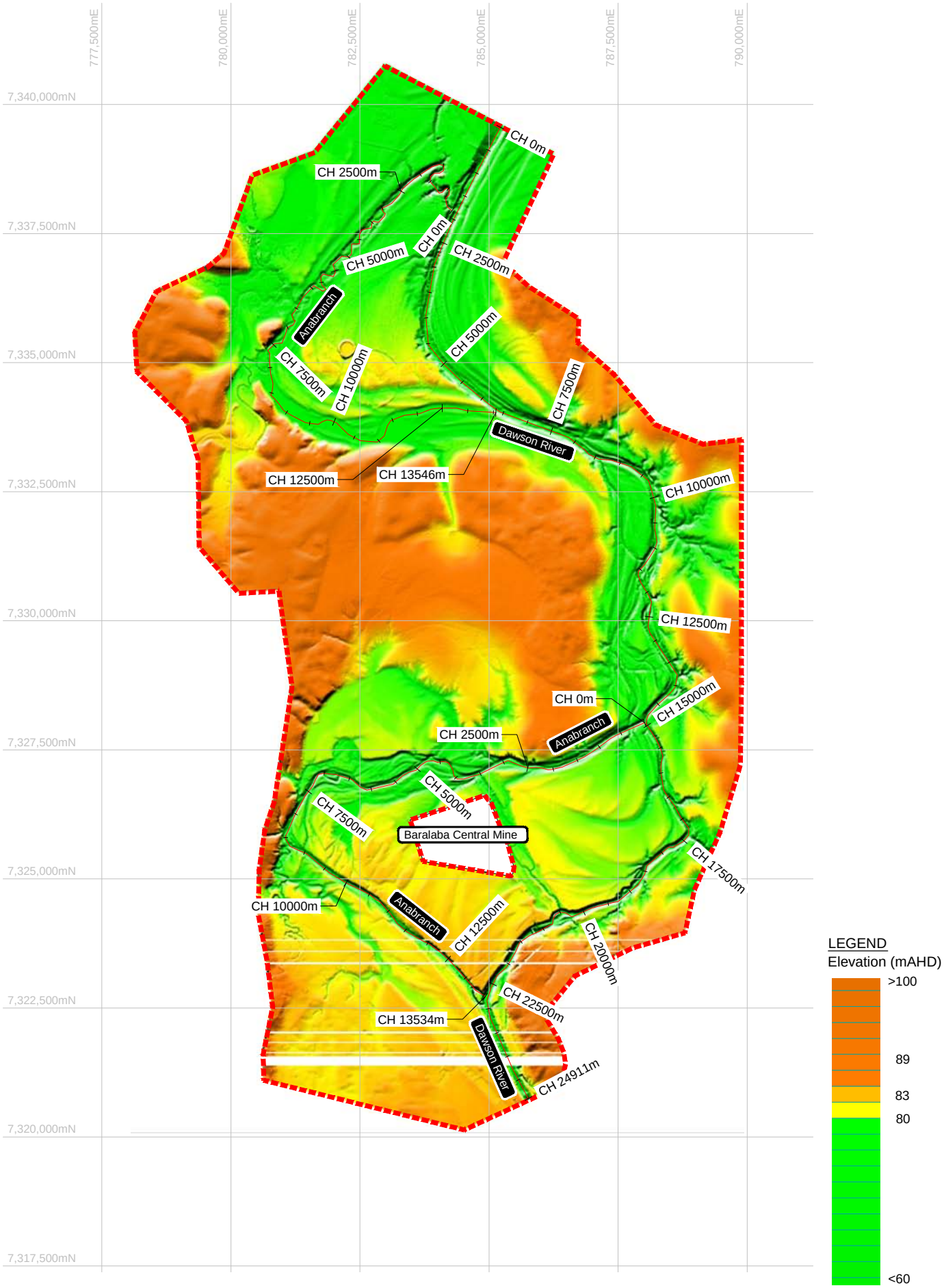
A roughness map was developed for the model extent based on ground cover identified from aerial photography and from site inspection. The developed roughness map is shown in Figure 3.4. Seven zones of roughness were developed, as shown in the table below. Initial roughness values were assigned based on the relative roughness of the various zones and Chow (1959).

Please note that these zones have been defined only for the purposes of assigning roughness values for use in the hydrodynamic modelling. The zones are not intended to represent ecosystem types, town planning zones or cadastral boundaries of watercourses, etc.

Table 3.1 – Roughness Zones

Name	Notes
Open	Open terrain on the floodplain, including grazing land and cropping areas
Dawson River Banks and Riparian Zone	Dense vegetation along the banks of the Dawson River
Anabranch	Vegetation and open water areas along the two main anabranches
Treed	Moderate density areas of trees on the floodplain
Town	Urban area of Baralaba. Barely in the floodplain so not expected to influence the results significantly
Dawson River Main Channel	Central area of the river channel without significant trees.
Neville Hewitt Weir	Smooth crest of the weir, which is included in the DTM

Water Solutions



LEGEND
Active Modelling Area

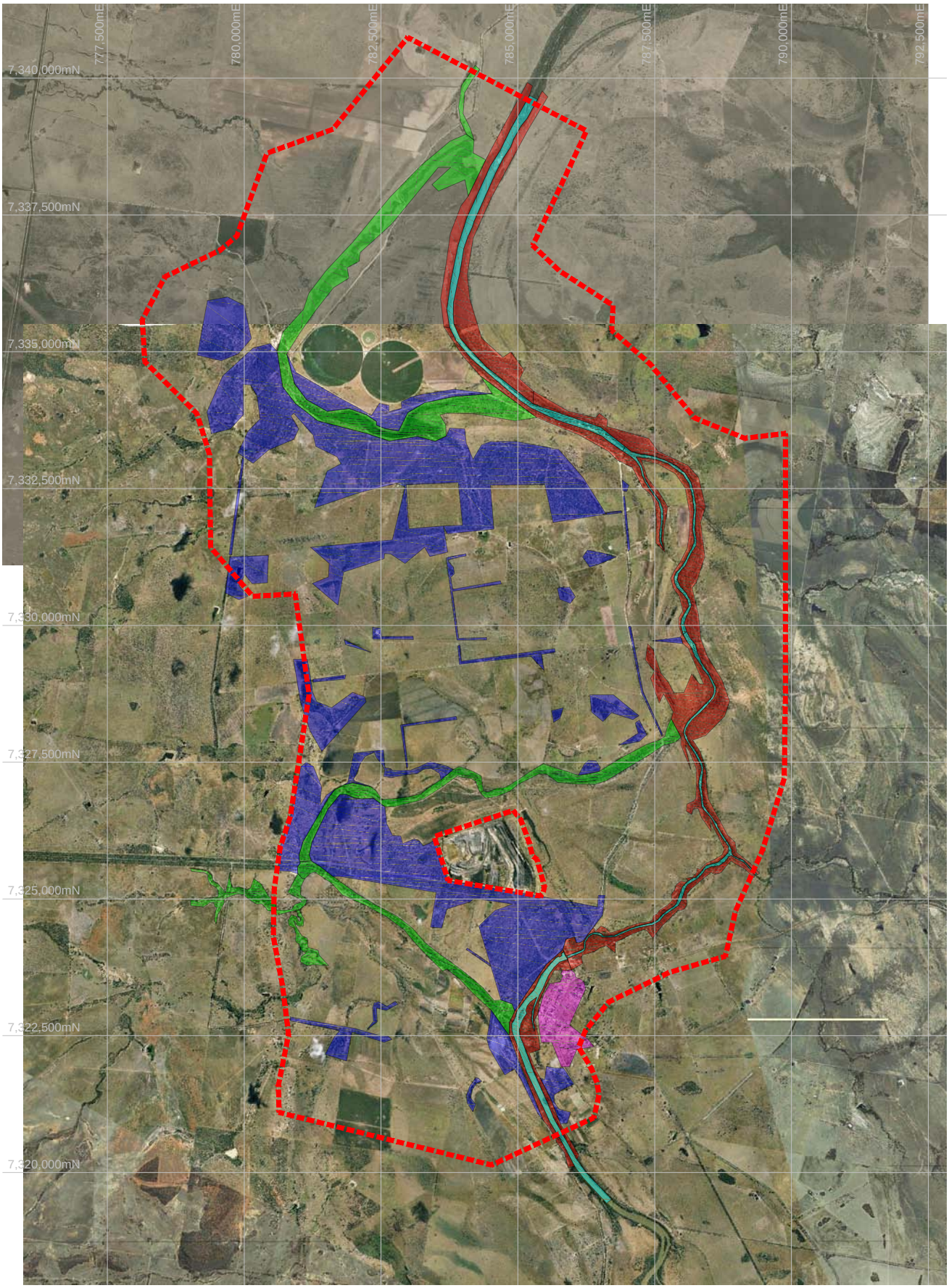
Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Calibration Case - Dec 2010 Topography

Job No. WS0715.1305 | Revision: 3 | Figure 3.3

File Name: WS130231_Fig3_3.dwg

Water Solutions



Mannings 'n' Values	
Dawson River Main Channel	0.038
Dawson River Banks and Riparian Zone	0.114
Treed	0.075
Anabranch	0.09
Town	1.1
Open (Unhatched areas within active modelling area)	0.05

LEGEND
Active Modelling Area

Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study

Mannings "n" Roughness Map

Job No. WS0715.1305 | Revision: 3 | Figure 3.4

File Name: WS130231_Fig3_4.dwg

3.4 Mine

The extent of the Baralaba Central Mine at the time of the 2010 event has been included in the model as an inactive modelling area. The outline of the area taken out of the floodplain is shown in Figure 3.4. During the 2010 event flood waters entered the mine pits through a breach in the levee. A sensitivity assessment has been conducted to evaluate the potential effect of the flooding of the mine site on the calibration case, see Section 3.9 for details.

3.5 Structures

Aside from the mine and Neville Hewitt Weir, at the time of the 2010 event, other structures on the floodplain were relatively minor and thus were not explicitly included in the model.

It is noted that, post the 2010 event, a larger bridge was constructed downstream of Neville Hewitt Weir, and a larger Haul Road Crossing is included in the mine development plan, and these structures have been included in other modelled scenarios as described in Section 7.

3.6 Downstream Boundary Condition

The downstream boundary condition was modelled based on an assumed slope, adopting a value of 0.003. This is likely to be a steeper flood slope than would actually be present at this location, but was adopted in order to limit instabilities and the run time of the model. Results near the downstream boundary (within about 4km) are not presented in this report as they are significantly affected by the boundary condition.

A sensitivity analysis on the potential impacts of the assumed boundary condition is presented in Section 3.10.

3.7 Upstream Boundary Condition

One upstream boundary is included in the model in the calibration case, at the upstream end of the Dawson River in the model extent. (A second is added for Saline Creek in the design scenarios, see Section 6.9.)

Calibration was undertaken using three steady state upstream boundary conditions, 1000, 2000, and 6100 m^3/s (peak flow for the 2010 event) as well as the hydrograph of the 2010 event.

The 2010 event hydrograph was developed by transforming the recorded levels at the Beckers site through the rating curve shown in Figure 2.15. The resultant hydrograph is shown in Figure 3.5.

The upstream boundary hydrograph was based on the hydrograph in Figure 3.5, moved back 10 hours to allow for the travel time from the upstream boundary of the model to the Beckers site, and with an initial ramp up period to the starting flow of approximately 1200 m^3/s. The 10 hour travel time adjustment was determined based on the modelled travel time in the Tuflow model. It is noted that there is some storage within the model which means that the hydrograph will transform slightly between the upstream boundary and Beckers, however this effect is small and unlikely to significantly affect the results.

Note that results near the upstream boundary (within about 1km) are not presented in this report as they may be significantly affected by the boundary condition.

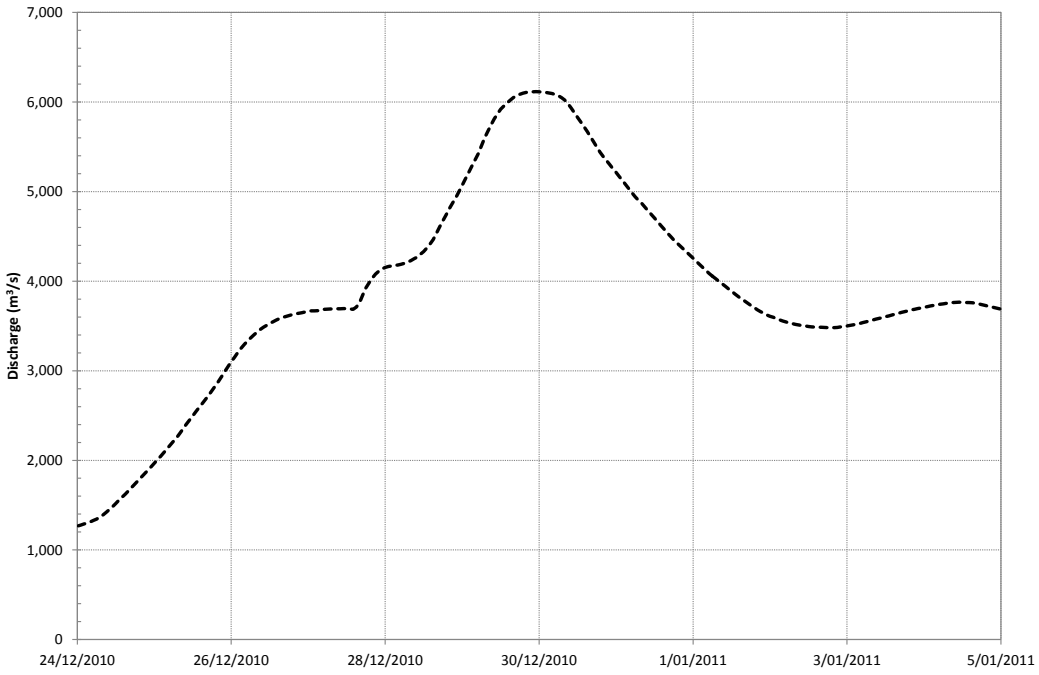


Figure 3.5 – December 2010 Event Hydrograph At Beckers

3.8 Model Calibration and Verification

Following configuration of the model with the topography, structures, boundary conditions and roughness zones as described previously, calibration of the model was commenced. Calibration of the hydraulic model was a challenging task, involving the adjustment of the Manning's n values over the model domain to match selected flows from the rating curve and the 2010 event peak flow at Beckers. The calibrated model was then verified against:

- the full 2010 event hydrograph at Beckers,
- the adopted rating curve at Beckers,
- other recorded flood levels upstream of Beckers and
- aerial photography of the flooding extent near Baralaba floodplain.

This process is further described in the sections following.

3.8.1 Calibration to the Rating Curve and 2010 Peak Flow

A series of iterative steady state runs were undertaken to match the modelled level at Beckers to selected levels from the developed rating curve.

As described in Section 2, the highest gauged flow at Beckers is about 2000 m^3/s. Flow rates at 1000 m^3/s and 2000 m^3/s were chosen to enable calibration to the flows in the area where the rating curve is considered reasonably reliable. Additionally, a steady state flow rate of 6100 m^3/s was used, the estimated peak flow rate for the December 2010 event.

The zones more prominent in the lower part of the channel, the Dawson River Main Channel Zone and the Dawson River Banks and Riparian Zone were the key roughness zones adjusted to match the level for the 1000 m^3/s flow rate. Once an approximate match was made, focus turned to the 2000 m^3/s flow rate, and the roughness values adjusted to improve the match at 2000 m^3/s while maintaining the match at the 1000 m^3/s flow. A similar approach was then applied at the 6100 m^3/s flow rate, where the anabranch, open and treed zones had a larger impact. The relativity of the roughness zones was maintained in the calibration. The roughness values for the town and Neville Hewitt Weir had limited effect on the calibration at Beckers, and thus were maintained at representative values adopted from the guidance in Chow (1959).

Once an acceptable calibration was achieved at these three flow rates, the December 2010 hydrograph was simulated. Further minor adjustments were made to the roughness parameters to improve the fit for the unsteady peak flow at Beckers, without substantially reducing the match at 1000 and 2000 m^3/s.

The final parameters arrived at are shown in Table 3.2, and the steady and unsteady calibration results in Table 3.3.

Table 3.2 – Calibrated Roughness

Name	Calibrated Roughness Values
Open	0.05
Dawson River Banks and Riparian Zone	0.114
Anabranch	0.09
Treed	0.075
Town	1.1
Dawson River Main Channel	0.038
Neville Hewitt Weir	0.01

Table 3.3 – Rating Curve Calibration Results

Flow Rate (m^3/s)	Recorded Level at Beckers (m AHD)	Modelled Level at Beckers - Steady (m AHD)	Modelled Level at Beckers - Unsteady (m AHD)
1000	76.23	76.15	76.04
2000	78.48	78.67	78.65
6100	83.53	83.58	83.54

The Mannings n values are considered to be within the acceptable range for each land cover type, in reference to the guidance in Chow (1959). The fit at these three flow rates is within 0.2m, which is considered to be a good result.

3.8.2 Verification to the 2010 Hydrograph and Rating Curve

The calibration was verified against the full 2010 hydrograph and against the adopted rating curve (see Section 2.2). Figure 3.6 shows the recorded and modelled hydrograph at Beckers. Figure 3.7 shows a rating curve extracted from the rising limb of the hydrograph in the Tuflow model, compared to the adopted rating curve at Beckers.

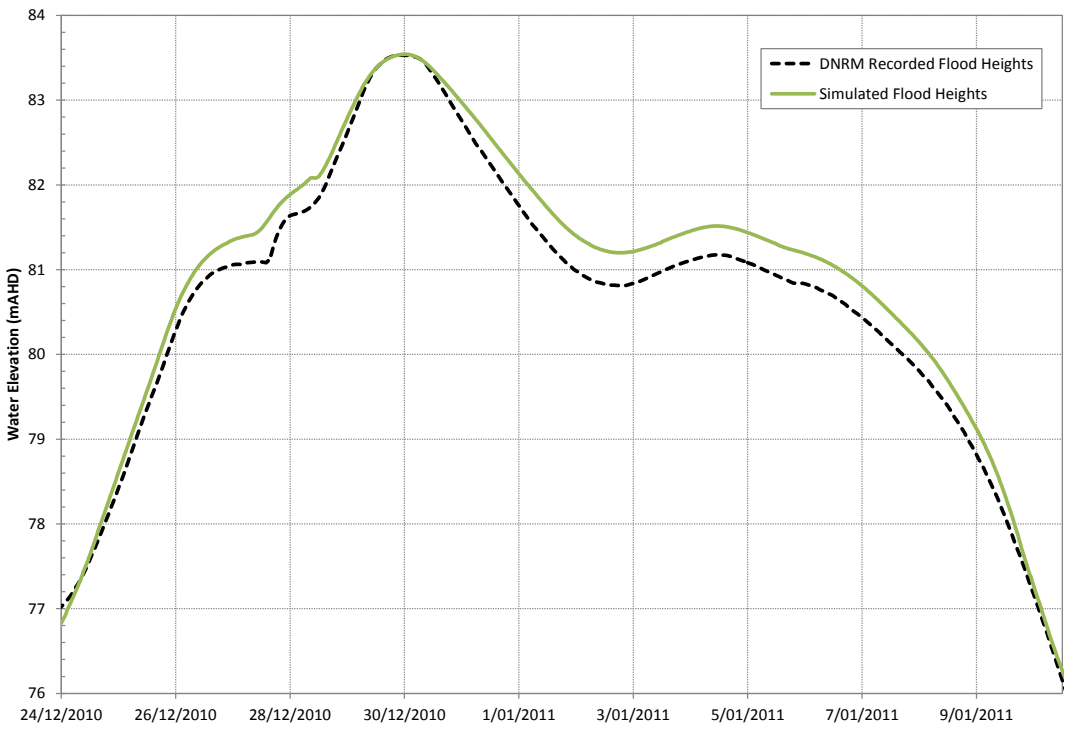


Figure 3.6 – December 2010 Event – Simulated vs Recorded Flood Levels at Beckers

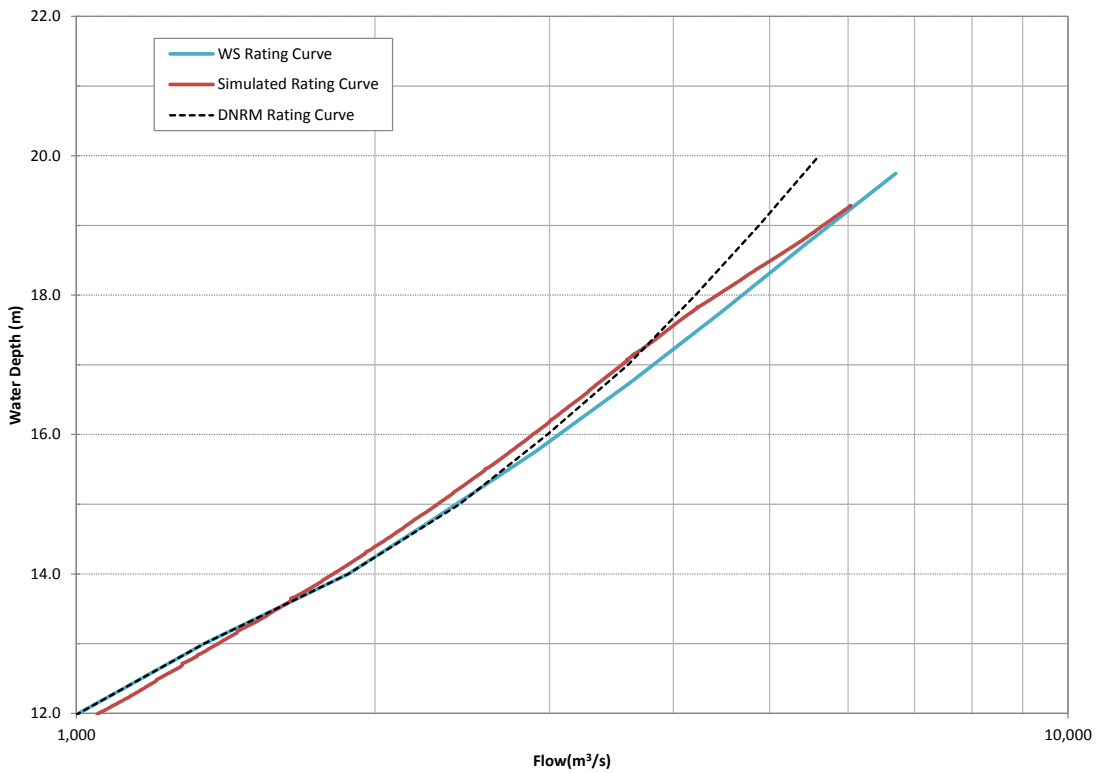


Figure 3.7 – Comparison with Adopted Rating Curve

Review of Figure 3.6 indicates good agreement for the peak flow and timing in the hydraulic model. The match on the rising and falling limb is considered fair. The hydraulic model is giving slightly higher flood levels for flows between about 2000 and 6000 m^3/s, which means the model will tend to be slightly conservative for flows in this range. The match with the adopted rating curve on Figure 3.7 is similarly considered to be reasonable.

There are a number of complicating factors which mean that some differences in the rating curve from the hydraulic model and that derived in Section 2.2.4 are expected. This includes the hydraulic effects of flood slope, storage, roughness and topography on the flows at various stages of the flood, and the simplifications involved in the Manning's n and average velocity assumptions. While extensive additional model development and calibration could be undertaken in an attempt to improve this match, it is considered that this additional effort is not warranted given the objectives of this study.

In conclusion, the match between the hydraulic model and the recorded 2010 hydrograph and the adopted rating curve was considered to be acceptable for the purposes of this study.

3.8.3 Verification to the 2010 Recorded Levels

The Baralaba North Flood Study (Water Solutions Nov 2012) includes a number of recorded peak flood levels across the Dawson River floodplain in the 2010 event. The modelled peak flood levels for the December 2010 case are compared to these recorded points on a map in Figure 3.10, and on long-sections in Figure 3.8 and Figure 3.9.

The calibrated model provides a reasonable match to the recorded peak flood levels. Some significant scatter in the recorded flood levels is evident, and the calibrated model appears to provide a reasonable compromise between the recorded levels, with a good match to the key location at Beckers.

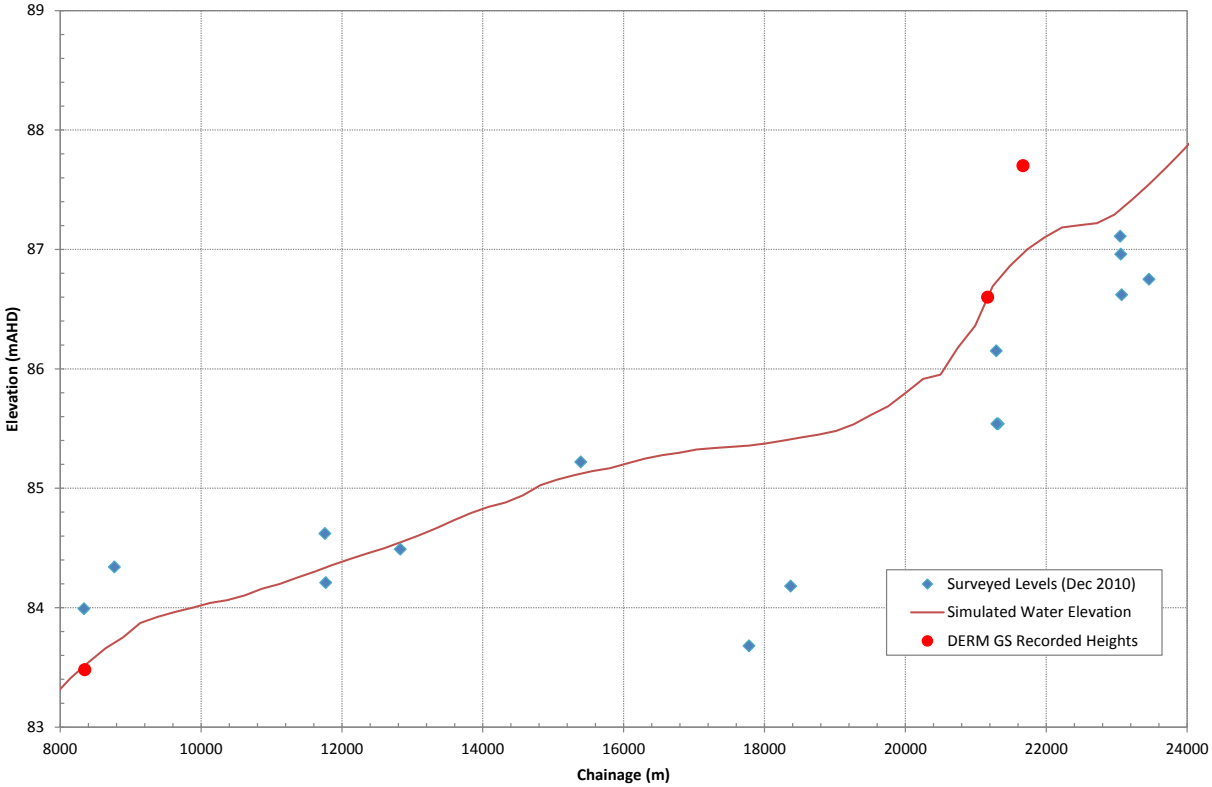


Figure 3.8 – December 2010 Event – Simulated vs Recorded Levels (Dawson River)

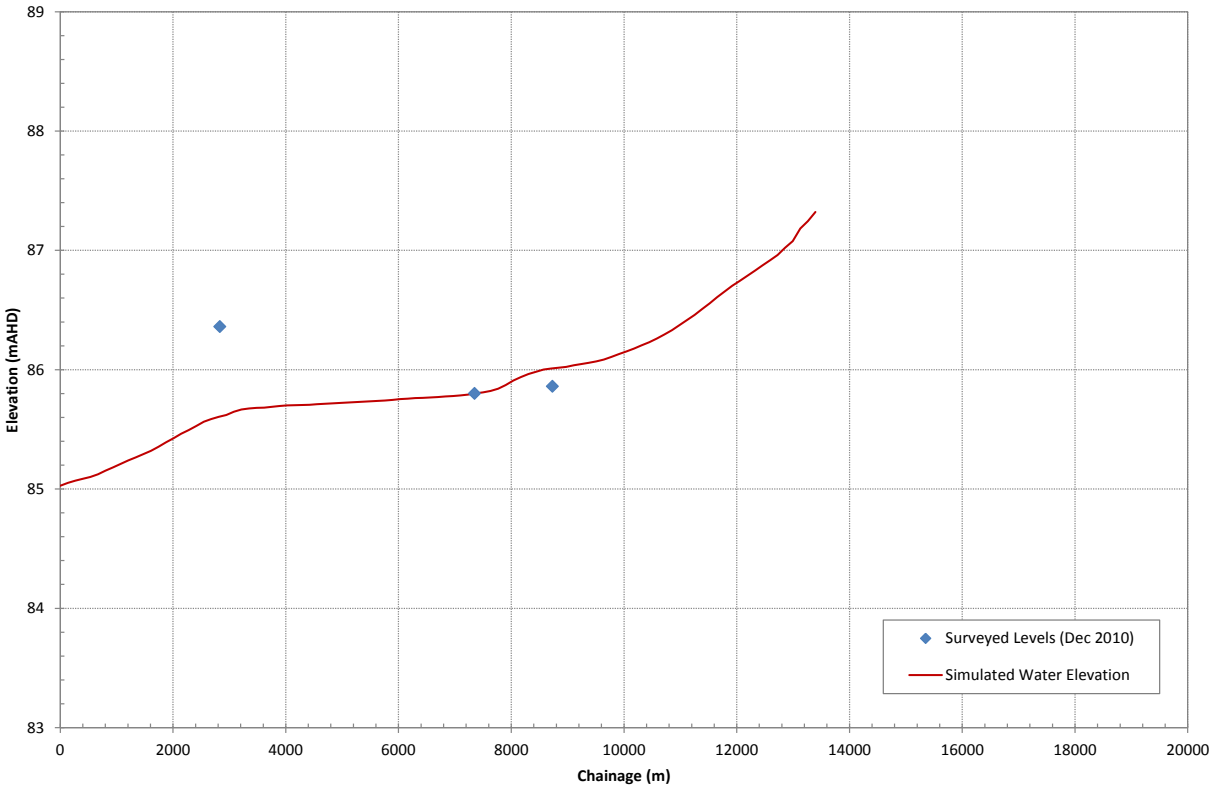
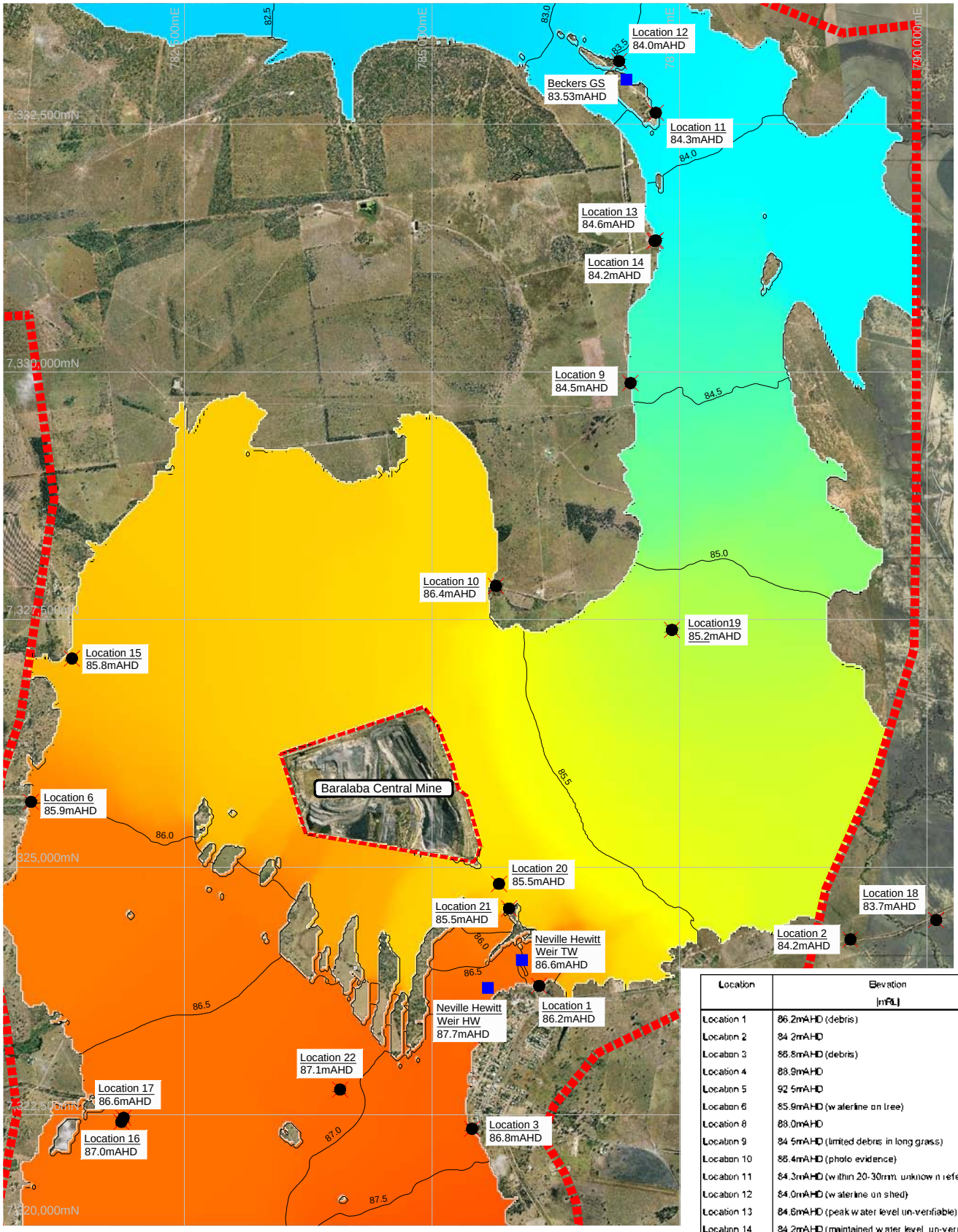


Figure 3.9 – December 2010 Event – Simulated vs Recorded Levels (Upper Anabranch)

Water Solutions



Location	Elevation [mRL]
Location 1	86.2mAHD (debris)
Location 2	84.2mAHD
Location 3	86.8mAHD (debris)
Location 4	88.9mAHD
Location 5	92.5mAHD
Location 6	85.9mAHD (waterline on tree)
Location 8	88.0mAHD
Location 9	84.5mAHD (limited debris in long grass)
Location 10	86.4mAHD (photo evidence)
Location 11	84.3mAHD (within 20-30mm, unknown reference)
Location 12	84.0mAHD (waterline on shed)
Location 13	84.6mAHD (peak water level un-verifiable)
Location 14	84.2mAHD (maintained water level, un-verifiable)
Location 15	85.8mAHD (water line on tree)
Location 16	87.0mAHD (water line on fence post)
Location 17	86.6mAHD (water line on fence post)
Location 18	83.7mAHD (water line on fence)
Location 19	85.2mAHD (debris in tree)
Location 20	85.5mAHD (water line on haul road)
Location 21	85.5mAHD (water line on haul road)
Location 22	87.1mAHD (water line on shed)

LEGEND	
----	Active Modelling Area

Location	Elevation [mRL]
Beckers GS	83.53mAHD
Neville Hewitt Weir HW	87.7mAHD
Neville Hewitt Weir TW	86.6mAHD

File Name: WS130231_Fig3_10.dwg

Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Model Verification - December 2010 Peak Flood Levels

Job No. WS0715.1305 | Revision: 3 | Figure 3.10

3.8.4 Verification to the QRA Aerial Photography of 2010 Event

Aerial photography of the December 2010 event near Baralaba was obtained from the Queensland Reconstruction Authority website as reported in Water Solutions (Nov 2012). It is understood that this photo was taken after the peak flood level had occurred. The maximum flood extent can be estimated from Figure 3.11 based on the extent of the brown flood water and the darker dead grass around the edge of the muddy water.

Simulated flood extents for the steady state peak flow December 2010 event have been presented in Figure 3.12, coloured brown to match the water in the aerial photo.

Comparison of Figure 3.11 and Figure 3.12 shows a good match. In particular, significant similarity may be observed around the right bank near the town of Baralaba and downstream, and also the patches of land not flooded to the north-west of Baralaba township.

This comparison provides reassurance that the calibrated hydraulic model is reasonably representing the December 2010 event.

Figure 3.11 – Aerial Photo of December 2010 Flood Extents (Source: QRA Website)

Figure 3.12 – December 2010 Event – Modelled Flood Extent

3.9 Calibration Sensitivity – Flooding of the Mine Site in December 2010

The Baralaba Central mining pits were flooded during the December 2010 flood event. The calibration presented in earlier sections did not include modelling of the water entering the pits. Consideration was therefore given to the potential effect of the flooding of the mine pits on the calibration for this event.

It is understood that water started entering the mining pits on the morning of 29/12/2010. Figure 3.13 below shows the recorded flood levels at the Beckers, Neville Hewitt tailwater gauge, and Bindaree gauge. There is no obvious discontinuity in the recorded levels at these three gauges, indicating a major change in flood level caused by water entering the mine pits.

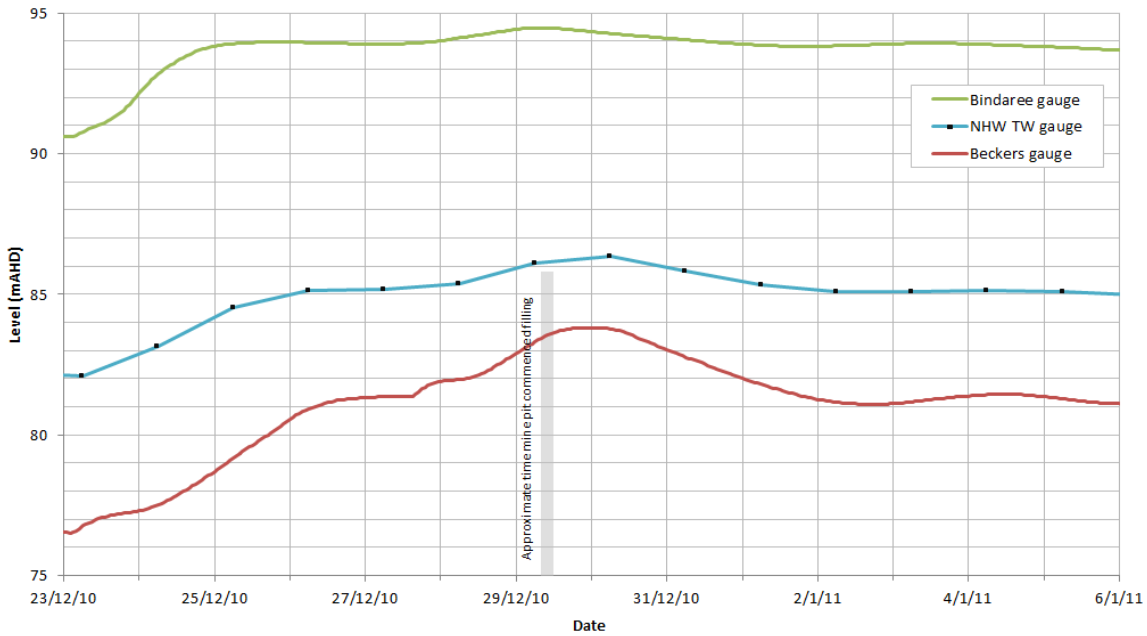


Figure 3.13 – Recorded Flood Levels December 2010

Some approximate calculations have been performed in order to obtain an order of estimate of the potential impact of the filling of the mine pits on the model calibration. The air space in the mining pits in December 2010 has been estimated to be in the range of 10 to 26 million m³, meaning that some 10 to 26 GL of flood water may have been temporarily trapped in the mining area until after the peak. Using the rating curve derived in this study, approximately 5600 GL flowed past the mine site in the 2010 event between 21 December and 15 January, with 520 GL in the peak 24 hour period around 30 December. The volume of water potentially affected is thus small compared to the flow in this event.

Based on the above it is considered that the flooding of the mine pits is not likely to have significantly affected the peak levels of the flood at the primary calibration location in this study at Beckers gauging station, meaning that detailed modelling of the filling of the pits is not necessary for the purposes of this project.

3.10 Calibration Sensitivity – Downstream Boundary Condition

As mentioned in Section 3.6, a steep downstream boundary condition slope of 0.003 was used in the model to avoid model instabilities at the downstream boundary.

To provide an appreciation of the potential error introduced by this steep boundary condition, a sensitivity case was undertaken with a slope of 0.001, determined from the average slope of the channel topography in the section of the Tuflow model downstream of the Beckers GS. The results of the flood profile downstream of Beckers to the model boundary is shown in Figure 3.14.

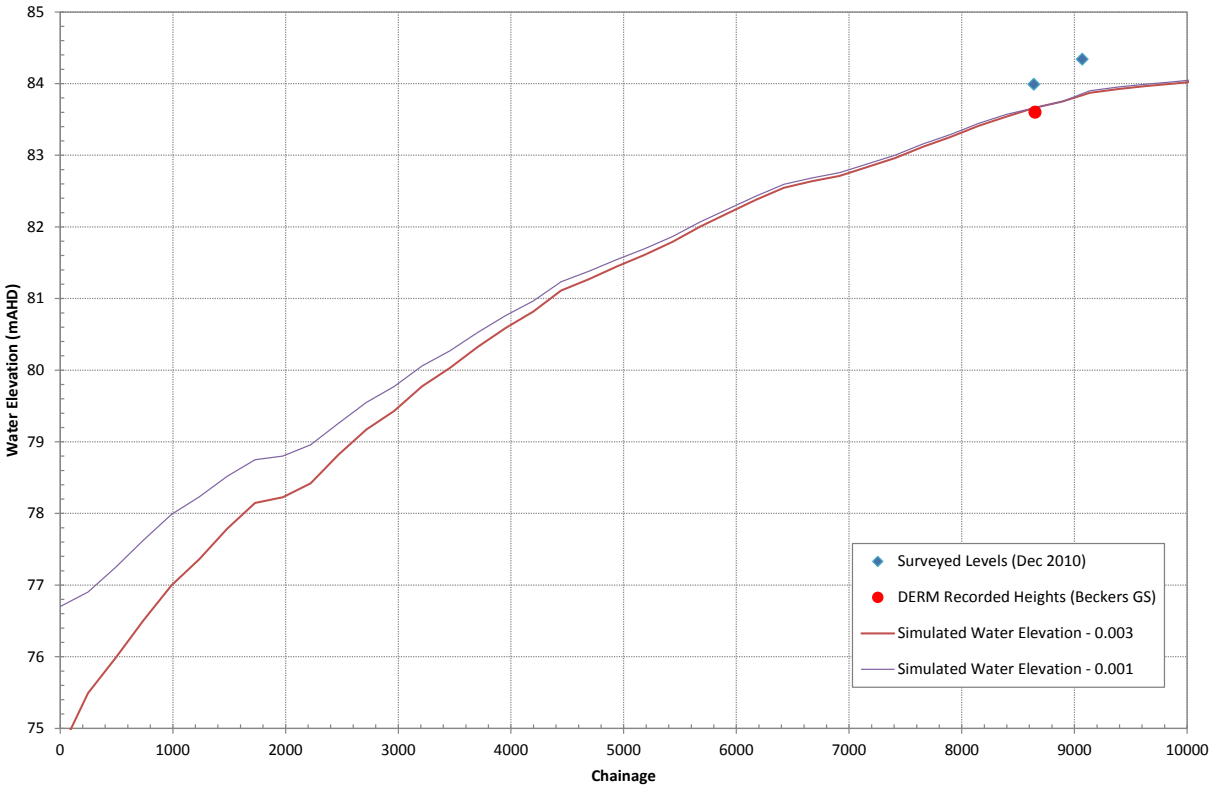


Figure 3.14 – Downstream Boundary Sensitivity

Figure 3.14 shows the model is quite sensitive to the downstream boundary condition, with differences in water level of several metres right at the boundary. However the difference has dropped below 0.5m within 2.5km upstream, and below 0.15m by 4km upstream. At Beckers, some 8.8km upstream, the difference is approximately 0.03m.

Additionally, it is noted that the different source of topography data at the lower end of the model may be having an influence on the flood profile at the downstream end of the model. Figure 3.15 shows a longsection of the Dawson River with the approximate bed level and flood level drawn from the Tuflow model. On this plot a distinct difference may be seen in the bed profile at about chainage 3000m. The topography above this point is drawn from the Vekta LIDAR data, while the section below chainage 3000m is from the recently flown drone data (see Section 3.2). In conjunction with the cross-section shown in Figure 2.10 it is apparent that the bed of the main channel of the Dawson River is not consistently well captured in these data sets. While not warranted for the purposes of this study, surveyed river cross-sections would be required to address this difference.

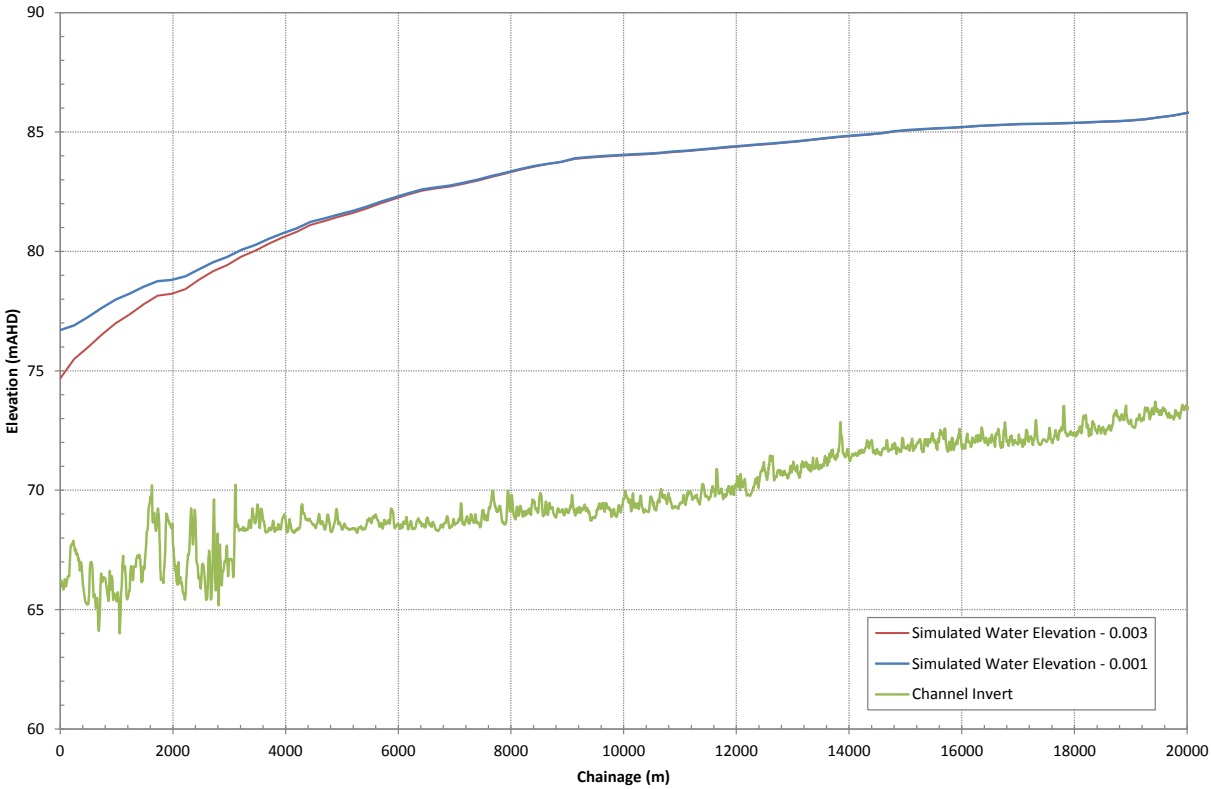


Figure 3.15 – Dawson River Bed and Flood Profile – December 2010 Event

It is noted that the flood profile with an assumed boundary condition slope of 0.001 is still showing the water level dipping towards the downstream boundary. While the river cross-section downstream of Beckers does open up, which means some increase in flood slope may be realistic, this increased slope may indicate that the 0.001 slope boundary condition is inappropriately affected levels within the model domain.

To address this issue, an indicative level versus flow relationship was estimated for the downstream boundary condition using the following method.

- A cross-section was extracted at the downstream end of the model, see Figure 3.16, and the cross-sectional area determined at various water levels.
- An adjustment was made in the bed of the channel to allow for the lower part of the channel likely missed by the aerial drone data. The bed of the channel was assumed to be at EL62m, approx. 4-5m below the lowest point in the drone data cross-section.
- The average velocity increase with height, 0.054 m/s /m height, from the Beckers rating curve analysis, was used to derive flow rates at various flow levels at the downstream boundary.

The derived indicative level-flow relationship at the downstream boundary is shown in Table 3.4.

Figure 3.16 – Cross-section at Downstream Boundary

Table 3.4 – Indicative Downstream Boundary Level – Flow Relationship

Level (m AHD)	Flow (m^3/s)
62	0
67	110
68	170
69	230
70	320
71	430
72	580
73	780
74	1000
75	1300
76	1700
77	2400
78	3400
79	5100
80	8200
81	12000
82	17000
84	26000
86	38000
90	65000

From this table it can be deduced that the peak flow for the 2010 event, 6100 m^3/s, should result in a level at the boundary of about 79.3m AHD. Model instabilities prevented this relationship being included directly in the model in this study.

With an assumed boundary level of about 79.3m, an approximate flood profile was drawn manually, using the flood profiles shown in Figure 3.15 as a guide. This profile is shown in the figure below.

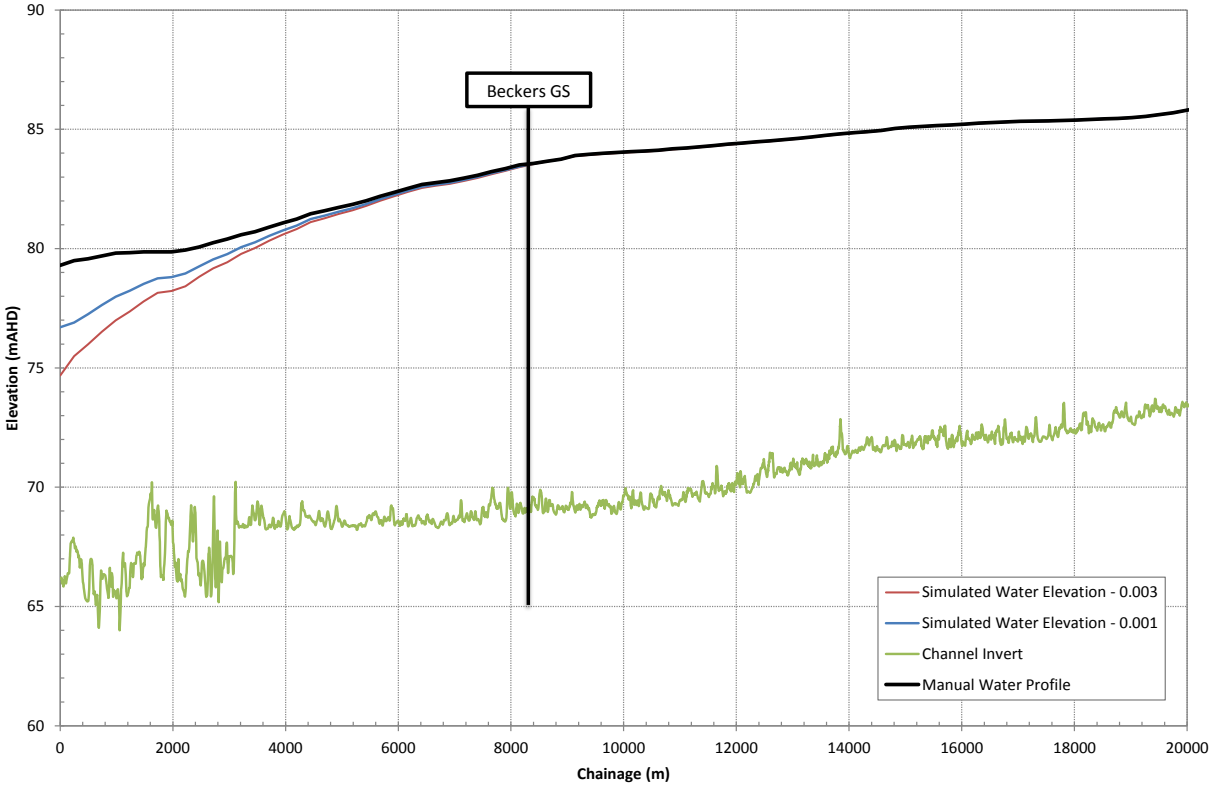


Figure 3.17 – Cross-section at Downstream Boundary

This plot shows that the boundary condition is significantly affecting results within about 4km of the boundary, with some minor differences perhaps up to about 8km into the model. The impact of the assumed 0.003 boundary condition slope on the calibration at Beckers (at about chainage 8500m) and above is small, and considered acceptable for the purposes of the calibration performed in this study.

With the project site starting some 5km upstream of the downstream boundary, the limited extension of the site into the floodplain, and the same boundary condition assumption being used for both the existing and proposed cases, errors introduced by the downstream boundary are likely to largely cancel out for results such as velocity change and afflux.

The impact on absolute results, in particular the required levee levels in areas downstream of Beckers, may be more significant. See Section 9.1 for how this uncertainty has been addressed.

Based on this sensitivity analysis, results in this report will not be presented for the lower ~4km of the model where the results may be significantly affected by the boundary condition.

3.11 Hydraulic Model Development and Calibration Summary

The above sections have described the calibration of the 2D hydrodynamic flood model used in this study, starting from an assessment of the high stage rating curve at Beckers and calibration of the model to match the selected flow rates from the rating curve. The calibration has been verified against the full 2010 hydrograph and rating curve, a range of recorded peak flood levels across the floodplain, and aerial photography taken shortly after the peak. The potential effect of the flooding of the Baralaba central mine pits and the assumed downstream boundary condition has been considered.

The model development and calibration described in this report represents a substantial step forward from the hydraulic model development described in Water Solutions (Nov 2012). It is considered that the hydraulic model configuration and calibration is suitable for the purposes of this study, and thus further model development is not warranted.

4 Hydrology Model Development and Calibration

The WBNM model was the hydrology model used in this study. This model has been used extensively for previous flooding investigations associated with the Baralaba Coal Mine, and is considered suitable for the objectives of this project.

As described in Section 1.4, the hydrology model used in this study has been developed based on the hydrology model used in the Baralaba North Flood Study (Water Solutions Nov 2012). The key changes have included extending the model extent further downstream to cover the Beckers gauging station and the Saline Creek catchment and calibration to the December 2010 event.

The sections below describe the development and calibration of the hydrology model used in this study.

4.1 Hydrology Model Development

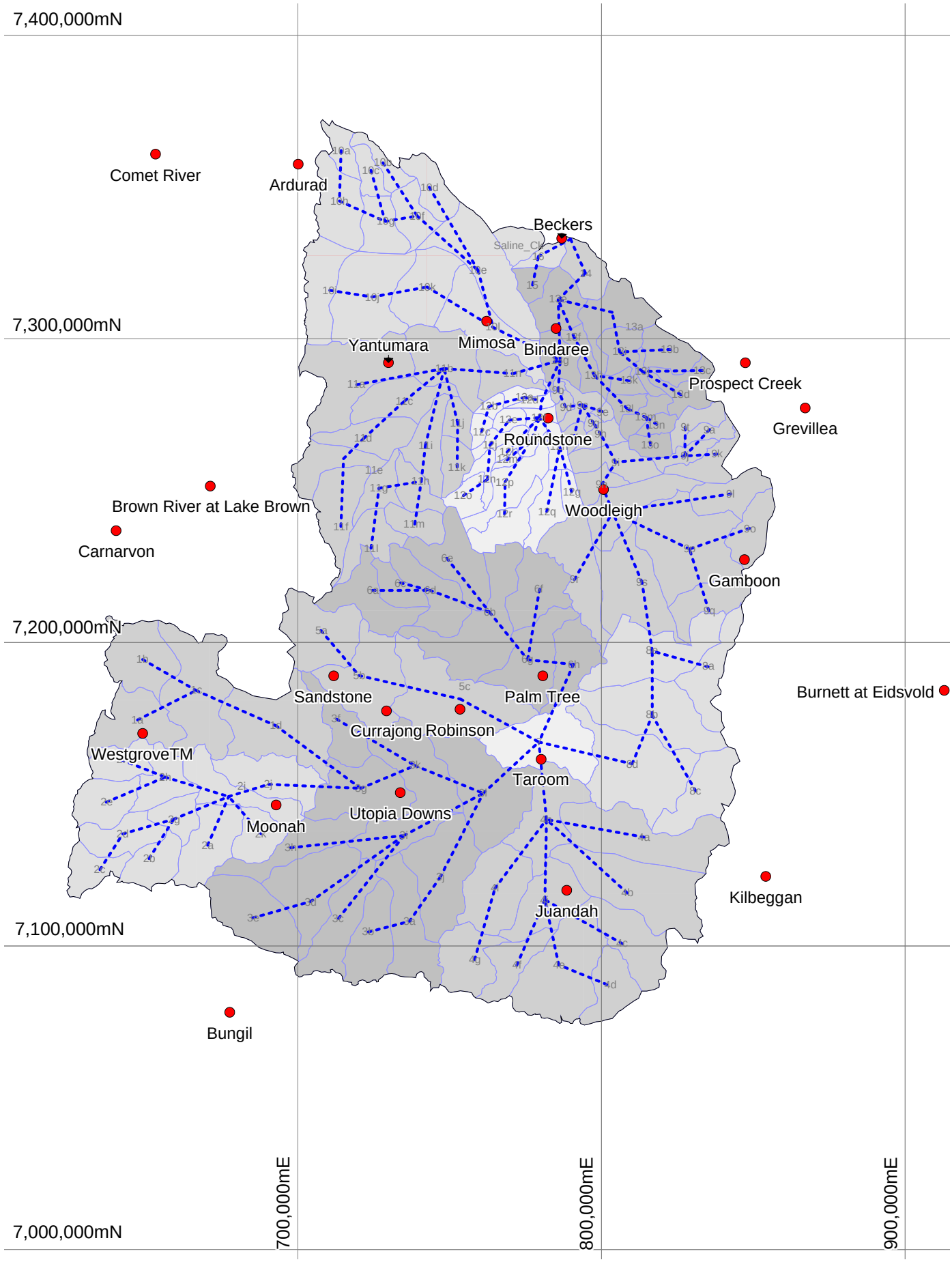
The hydrology model covered the catchment of the Dawson River to GS 130322A Dawson River at Beckers. Additionally the small catchment of Saline Creek, which joins the Dawson River just downstream of the Beckers Gauging Station, was included in the hydrology model. The model extent was broken up into sub-catchments as shown on Figure 4.1. with the detail of the sub-catchments used for Saline Creek shown on Figure 4.2.

4.2 Rainfall Data – December 2010 Event

The period of rainfall used for the December 2010 event is from 21/12/2010 to 16/01/2011. The start date was selected to just before the rain that lead to the peak flood levels experienced at Baralaba in late December. Examination of the recorded rainfall in the period up to the selected start shows that significant rainfall had fallen over parts of the catchment, with falls over the previous month totalling between about 140 and 360mm.

The rainfall stations used for the calibration of the December 2010 event are shown on Figure 4.1. The spatial pattern of rainfall in the December 2010 event is shown in Figure 4.3, and the temporal distribution of the rainfall on a selected subarea in this event near Beckers is shown on Figure 4.4.

The spatial pattern shows that December 2010 was more intense towards the downstream end of the catchment, while the temporal pattern shows two main intense periods of rainfall, the first around 23 December, and the second more intense period around 27 December.



LEGEND

- Raingauge
- Catchment link
- Subcatchment delineation

Water Solutions

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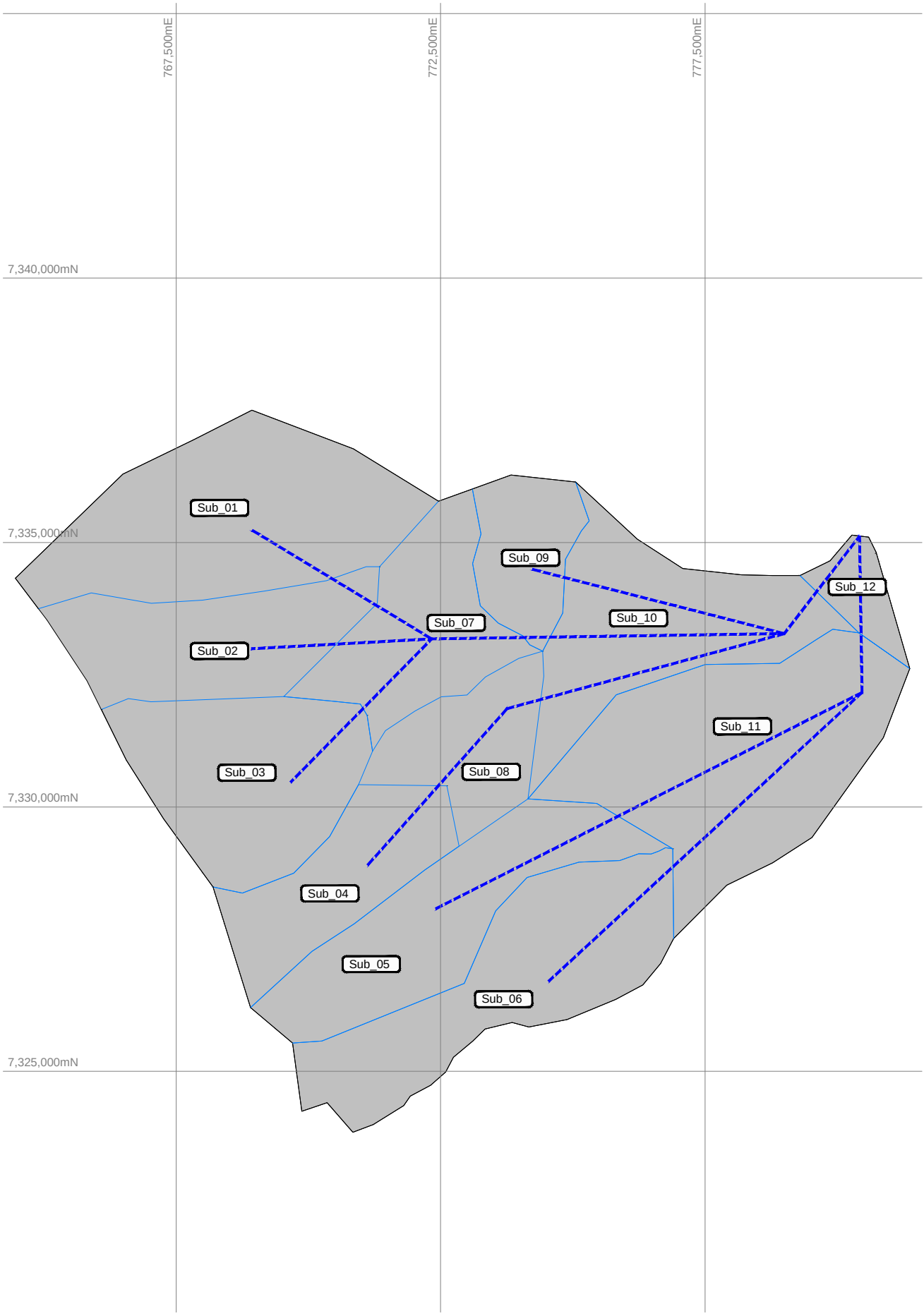
Baralaba North Continued Operations Project
Flood Study

WBNM Configuration - Beckers Catchment

Job No. WS0715.1305	Revision: 3	**Figure 4.1**

File Name: WS130231_Fig4_1.wor

Water Solutions



LEGEND	
Catchment Link	
Subcatchment Delineation	

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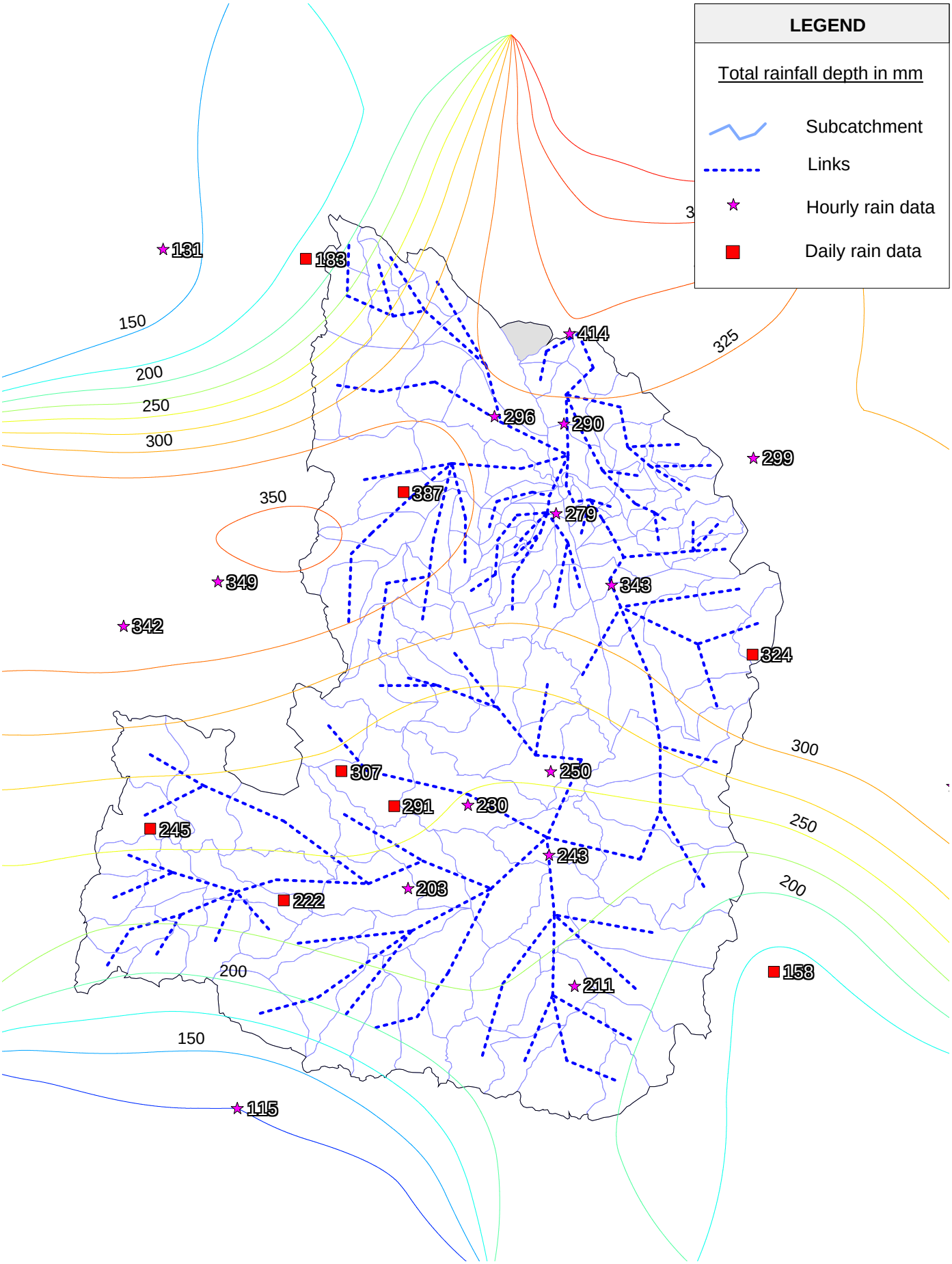
Baralaba North Continued Operations Project
Flood Study
WBNM Configuration - Saline Creek

Job No. WS0715.1305	Revision: 3	Figure 4.2

File Name: WS130231_Fig4_2.dwg



Water Solutions

Cockatoo Coal Ltd

Baralaba North Continued Operations Project
Flood Study

Dec 2010 Spatial Rainfall Distribution (21/12 - 17/01)

Job No. WS0789.1305 | Revision: 3 | **Figure 4.3**

File Name: WS120231_Fig4_2.WOR

4.3 Model Calibration

Calibration of the hydrology model for this project turned out to be an extremely complex process.

Initially, calibration focused just at achieving an acceptable fit at the Beckers gauging station without spatial variation to the model parameters. This initial calibration process is described in Section 4.3.1 below. The calibration achieved by this initial process matched the peak of the event well, but the shape of the hydrograph was not well matched.

Following review, the calibration was further developed considering spatially variable parameters. This process is described in Section 4.3.2.

4.3.1 Initial Calibration

A series of iterative runs were undertaken to match the hydrograph at Beckers to the flow indicated by the developed rating curve for the Beckers site. The final parameters from this process are shown in Table 4.1, and the calibration results in Figure 4.4.

Table 4.1 – Calibrated WBNM Parameters – Initial Calibration

Parameter	Value
Lag Parameter (C)	2.8
Stream Lag Factor (F)	1
Initial Loss (IL) - mm	100
Continuous Loss (CL) - mm	0.75

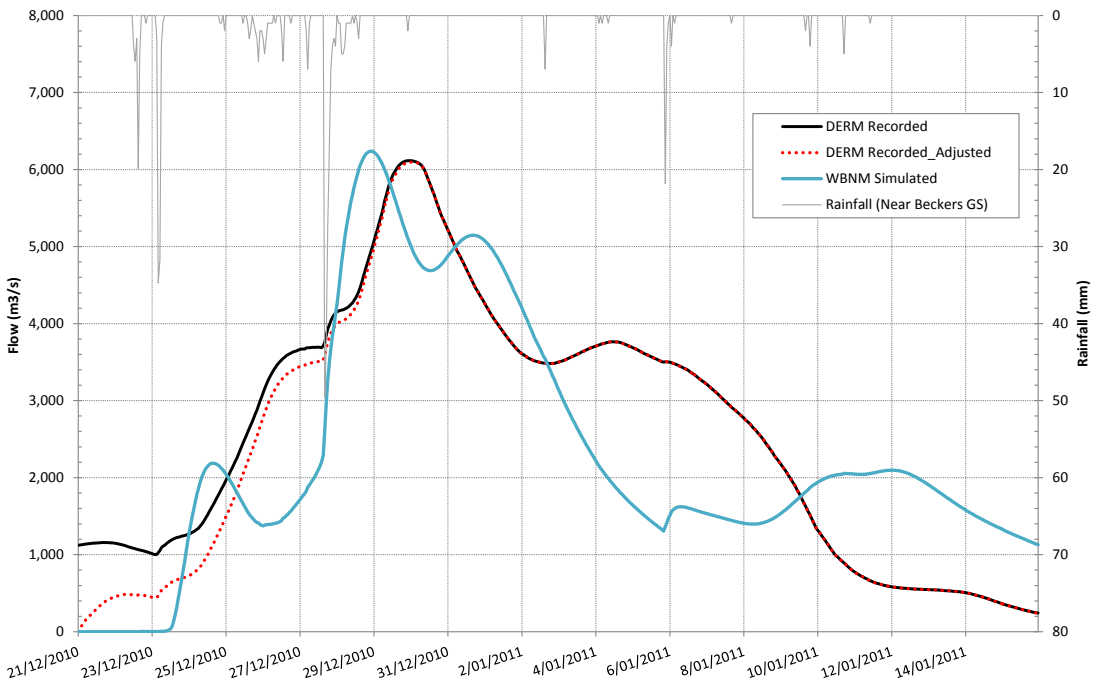


Figure 4.4 – December 2010 Event – Initial Hydrology Model Calibration - Beckers

Note the rainfall shown in Figure 4.4 is for a representative subcatchment near Beckers, providing an indication of when the heavy bursts of rainfall occurred.

Figure 4.4 shows two 'recorded' hydrographs. The solid line is the flows at Beckers calculated from the recorded levels through the rating curve derived in this study. It is noted that there was about 1000 m^3/s in the river at the start of this event, caused by rainfall in the weeks before the start of the modelled period. An approximate recession was developed for flows deriving from rainfall before the start of the modelled period, and this was subtracted from the recorded hydrograph at Beckers, the result shown as the red dotted line on Figure 4.4.This illustrates that rainfall prior to the start of the modelled period is unlikely to have had a significant direct effect on the peak of the December 2010 event on 29 December 2011.

Calibration of the hydrology model to this event took considerable effort. The recommended value of C in the WBNM user manual for un-calibrated catchments is 1.6 to 1.8. Boyd and Bodhinayake (2006) summarise calibrated parameters for 54 catchments with C in the range 0.7 to 2.8. The Dawson River catchment to Beckers is some 40,500 km^2, considerably larger than the 54 catchments (maximum 7000 km^2) summarised in the 2006 paper, and thus a value of C outside this range may be appropriate. Higher values were trialled, but the final value arrived at, C=2.8, is at the upper end of the range of previous values listed in the 2006 paper.

The F parameter is an adjustment that is applied for channel routing to allow for modified channels, such as straightened, concrete lined channels, where flood waters travel more quickly than is typical in natural streams. However the parameter does allow an adjusted differentiation to be applied between catchment and channel routing, and hence some values other than 1 were trialled. Calibration performance did not improve, and so the value of 1.0 recommended by the WBNM manual was adopted.

The period leading up to the December 2010 event did see a series of rainfall events separated by several days of no or limited rainfall. Consideration was given to including earlier rainfall bursts in the model, however the limitations of the IL/CL loss model used in most design flood studies models does not typically do well in a more continuous simulation application. The start of this event was chosen just before the main peak started to rise. Losses were determined through calibration to be 100mm IL and 0.75mm/hr CL. The initial loss is perhaps higher than might be expected, and the continuous loss perhaps low. A possible explanation for this is that the rainfall events prior to the start of this event filled deeper soil moisture stores, meaning continuing loss was small, while the week or so of no rain before the start of the selected period mean that a reasonable IL was present.

The calibration provides a good match on the peak flow of the event, and the shape of the peak of the event (above ~5000 m^3/s) is well matched, which are the primary areas of interest for this study. However there is a secondary peak in the modelled event that is not apparent in the recorded hydrograph, and the modelled hydrograph does not capture some flood volume on the rising and falling limbs.

4.3.2 Spatial Calibration

With the shape of the calibration achieved from the spatially constant parameter set not being well matched, further calibration was undertaken to determine if an improved calibration could be achieved by varying the model parameters over the catchment.

Initially an Antecedent Precipitation Index (API Index) was developed to provide a guide to the model initial losses. The model was rerun with varying initial losses based on the API Index,

however this did not show an appreciable improvement in the calibration. The developed API Index was considered in the calibration process described below, but it quickly became apparent that other factors were more important in achieving an acceptable fit.

Next, the model performance at selected headwater gauges in the catchment was examined (Utopia Downs, Robinson, Palm Tree, Roundstone and Mimosa), and the model parameters adjusted to provide some improvement in the fit at these sites. The calibrated parameters for these catchments are given in Table 4.2. The calibrated hydrograph at these sites are provided in Figure 4.5 to Figure 4.12.

It is highlighted that the calibration undertaken at these upstream sites has been performed for only one purpose, in order to provide an improved result at the BNCOP site near Beckers. Hence these calibrations were only taken to the extent necessary in order to provide an acceptable result at Beckers to meet the objectives of this study.

Table 4.2 – Calibrated WBNM Parameters – Spatial Calibration

		Stream Flow Routing				
Sub-catchment	Lag Parameter	Stream Lag Factor (F)	Muskingum (k) (min)	Muskingum (x)	Initial Loss (IL) (mm)	Continuous Loss (CL) (mm)
Utopia Downs	2.4	1	-	-	113	2.75
Taroom	2.9	-	1000	0.5	20	0.3
Robinson	1.2	1	-	-	0	3.8
Palm Tree	2.8	1	-	-	125	4.0
Side tributaries (ungauged) – Taroom-Woodleigh	0.4	1	-	-	0	0.0
Woodleigh	5.4	1	-	-	0	4.0
Roundstone	2.6	1	-	-	30	0.3
Mimosa	2.8	1	-	-	80	0.3
Side tributaries (ungauged) – Woodleigh - Beckers	4.2	1	-	-	120	0.3
Beckers	6.9	1	-	-	120	4.0

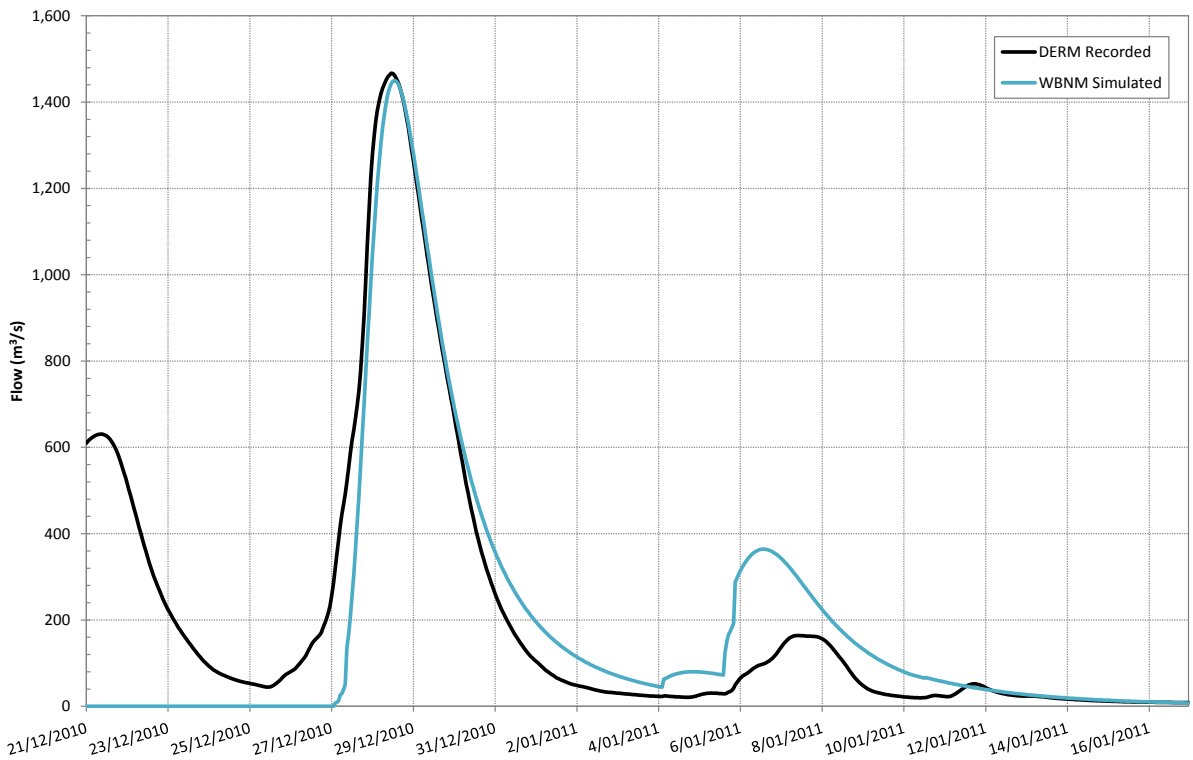


Figure 4.5 – December 2010 Event – Hydrology Model Calibration – Utopia Downs

The calibration at Utopia Downs provides an excellent match to the 1500 m^3/s peak in timing, shape and peak flow, although it is noted that with the highest gauged flow of only 378 m^3/s the rating at such high flows must be considered indicative only.

The poor match for the other two peaks is not important for the purposes of this study, with the first peak likely missed owing to rainfall before the start of this modelled event, and the third peak owing to the simplifications inherent in the IL/CL model.

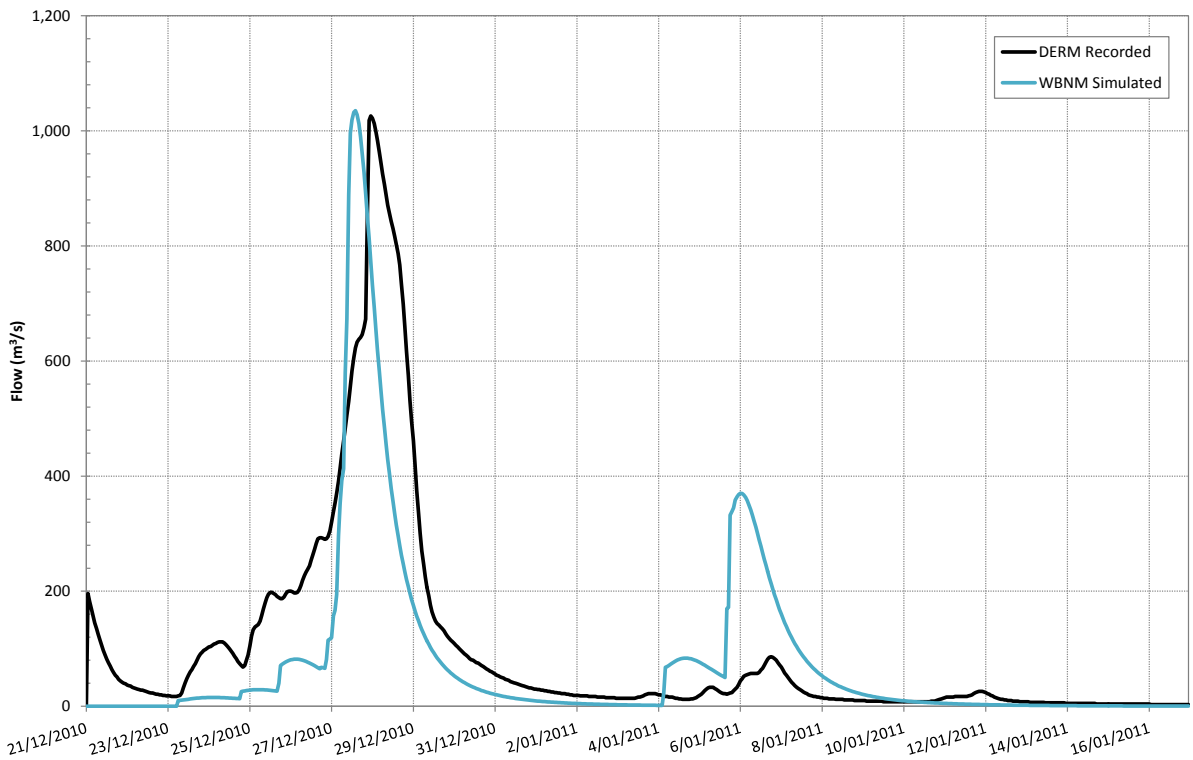


Figure 4.6 – December 2010 Event – Hydrology Model Calibration – Robinson

The match for the peak at Robinson is quite good in flow rate and shape, although the timing is a little out. Once again, the maximum gauged flow at Robinson of 4 m^3/s means that the rating at about 1000 m^3/s is at best indicative. The overestimation for the small second peak, likely owing to the simplifications inherent in the IL/CL model, is not important for the purposes of this study.

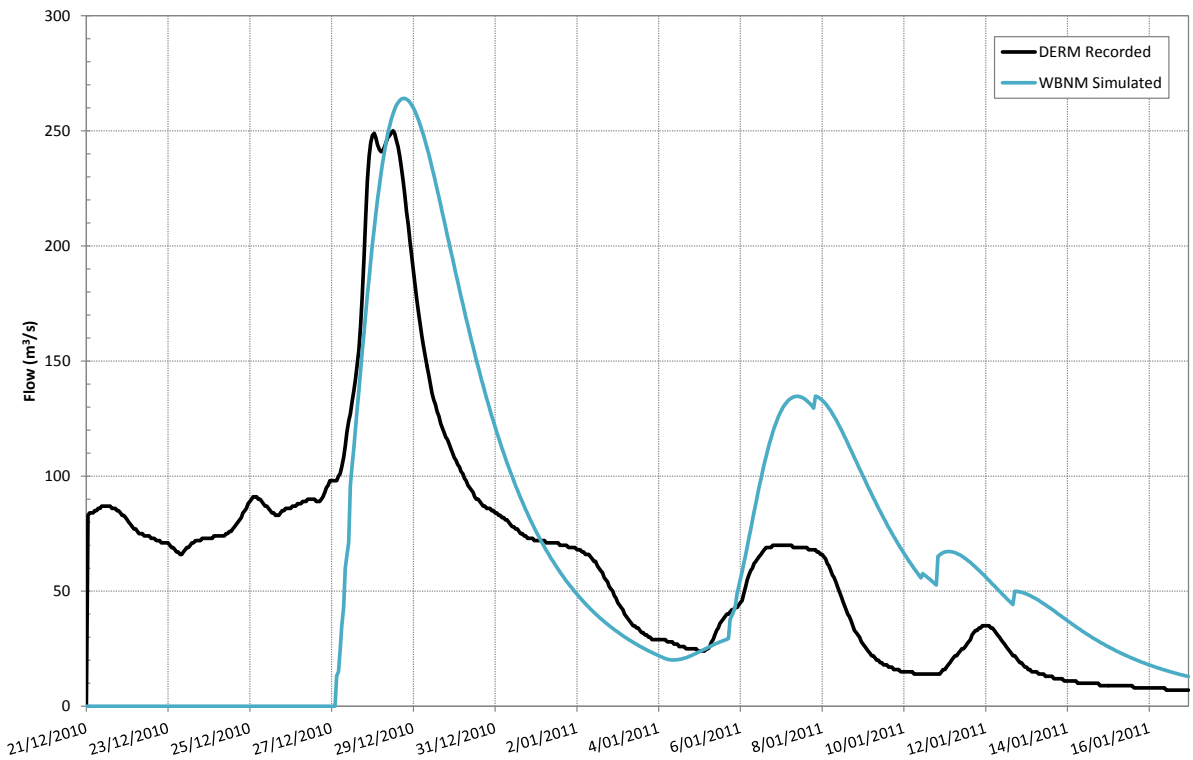


Figure 4.7 – December 2010 Event – Hydrology Model Calibration – Palm Tree

The match for the peak flow at Palm Tree is reasonable, although the timing is a little late and the volume a little high. The slight fall in the recorded peak flow at Palm Tree looks a little unusual – it may represent a partial failure of the level recorder. As is common with these smaller catchment sites, the max gauged flow of 32 m^3/s means the peak recorded flow of about 250 m^3/s should be treated as indicative only. The overestimation for the small second peak, likely owing to the simplifications inherent in the IL/CL model, is not important for the purposes of this study.

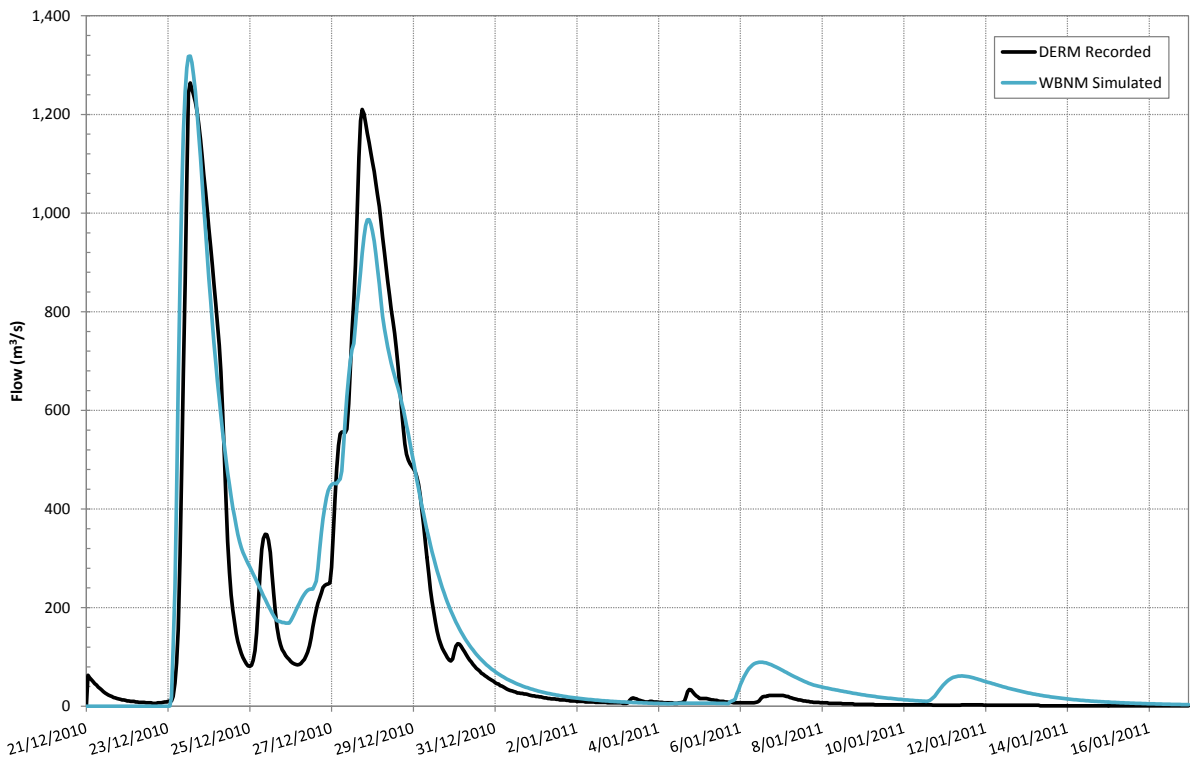


Figure 4.8 – December 2010 Event – Hydrology Model Calibration – Roundstone

The record at Roundstone, further down the catchment, is showing a distinct double peak in late December not present at the upstream sites, owing to the different pattern of rainfall experienced in this part of the catchment. The two main peaks are well matched in timing and shape, and the match in peak flow rate is considered reasonable. The max gauged flow of 116 m^3/s at Roundstone means that the peak recorded flow of about 1200 m^3/s should be taken as indicative only.

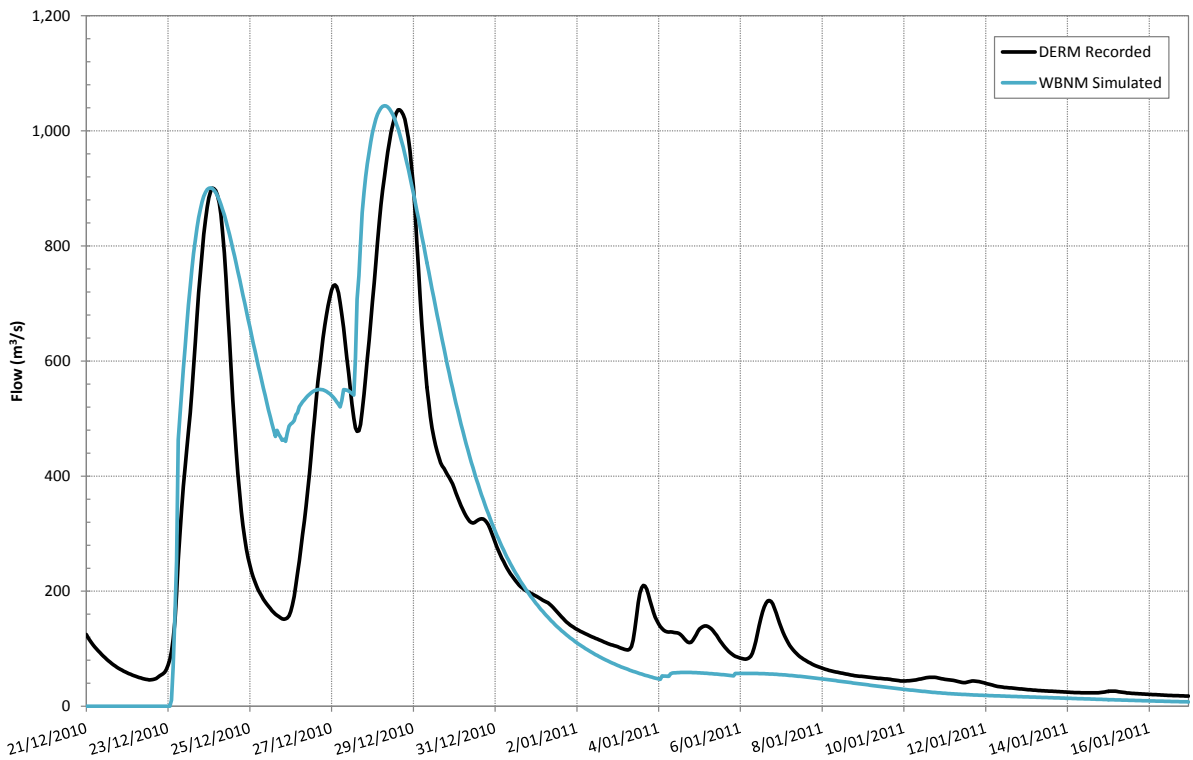


Figure 4.9 – December 2010 Event – Hydrology Model Calibration - Mimosa

Mimosa also shows a multi-peak in the level record, with a more prominent third peak between the two main peaks. The peak flow rate of the larger two peaks are well matched, and the timing is reasonable. The match on the smaller middle peak is poor. The max gauged flow of 57 m^3/s at Mimosa, means that the peak recorded flow of about 1000 m^3/s should be taken as indicative only.

With the calibrations at the headwater sites considered acceptable, the model fit was then checked at Taroom and further adjustments made to improve the calibration. Considerable difficulty was encountered in achieved in an acceptable fit at Taroom. The final calibration parameters included additional Muskingum routing on a dummy reach to enable the timing of the peak at Taroom to be reasonably matched. The low calibrated losses in this area may indicate that the rainfall stations did not well capture the rainfall between Utopia Downs and Taroom. The figure below provides the result of the calibration at Taroom.

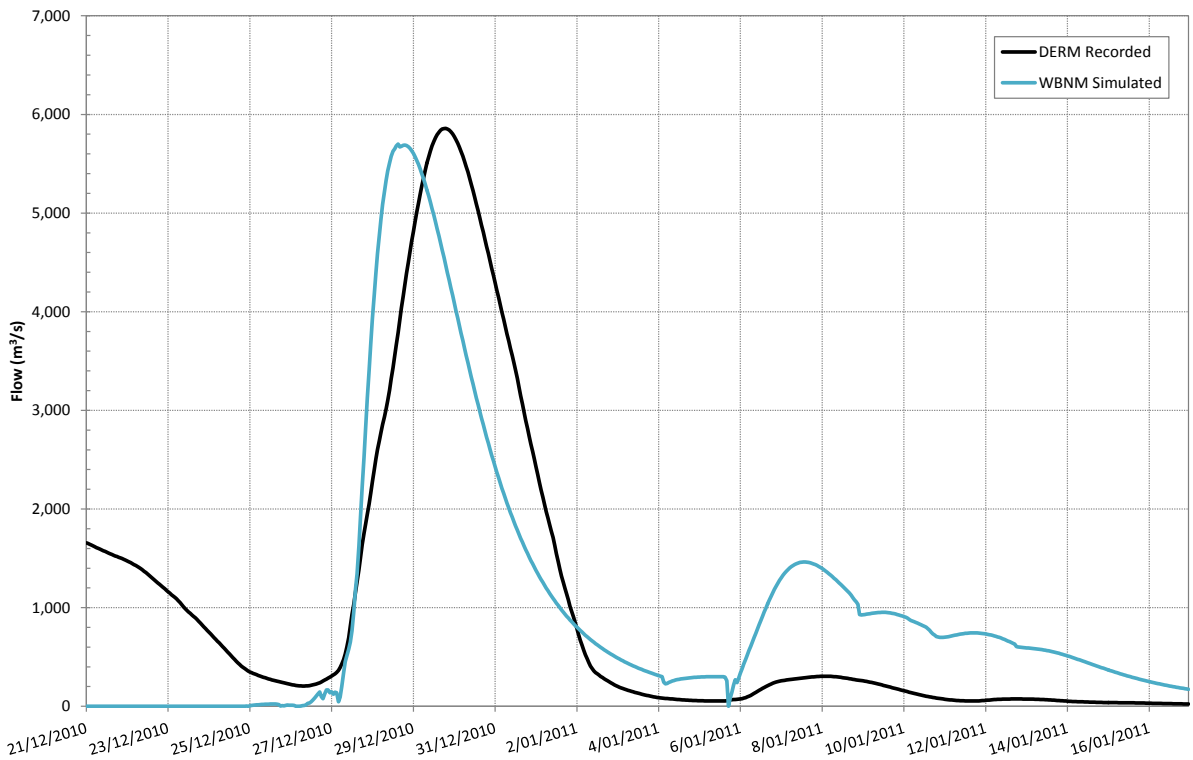


Figure 4.10 – December 2010 Event – Hydrology Model Calibration - Taroom

The peak flow rate and shape are reasonably well matched, although the timing is early. The maximum gauged flow at Taroom is 1110 m^3/s, a larger proportion of the peak flow than for most of the headwater gauges, but nevertheless the high stage rating should be treated as indicative only.

The next location checked was Woodleigh, which showed a distinctive double peak in the recorded hydrograph. Based on the timing, it is likely that the second peak at Woodleigh is driven by flow from the upper catchment above Taroom, while the first peak is perhaps more subject to flow from tributaries between Taroom and Woodleigh.

Calibration of the model to match the second peak at Woodleigh was fairly successful, as can be seen on Figure 4.11. The lag parameter for the main river catchments were set based on matching the second peak.

However, great difficulty was encountered in matching the first peak at Woodleigh. The first peak is important, as it drives the peak flood level experienced down at Beckers. With the matches at Robinson and Palm Tree appearing reasonable, parameters for the remainder of the catchment were set to provide some a small peak at the timing of the earlier peak. Even with 0mm IL and 0mm/hr CL and a low C, the first peak could not be well matched. It is thought that there may be additional rainfall in this reach which has not been captured by the rainfall stations. However this residual area is not large in the context of the Dawson River catchment, and thus approximations in this area are unlikely to significantly affect the model results. Given the objectives of this study, the selected parameters for this area were considered acceptable.

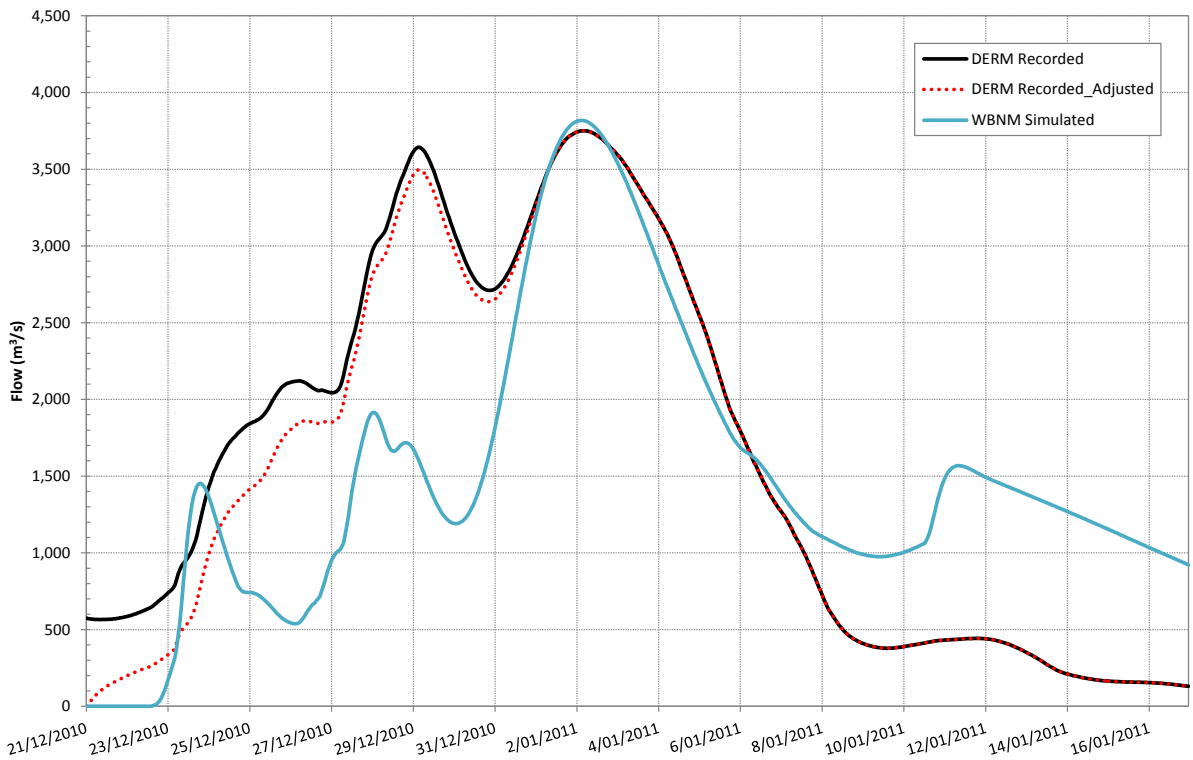


Figure 4.11 – December 2010 Event – Hydrology Model Calibration - Woodleigh

Note an adjustment was made to the recorded hydrograph at Woodleigh to remove the residual flow from the event prior to the start of the modelled period (see Section 4.3.1), with the resultant adjusted recorded hydrograph shown as the dotted red line.

For the lowest reach between Woodleigh and Beckers, the adjusted recorded hydrograph at Woodleigh was used at the top of this reach in the hydrology model, to prevent the errors in the fit to the first peak at Woodleigh propagating downstream, potentially causing biased model parameters in the downstream reach.

With the fits at Roundstone and Mimosa appearing reasonable, firstly the main river sub-catchments were calibrated to approximately match the recorded hydrograph at Beckers. Then the ungauged side tributaries were adjusted to improve the fit. The final calibration at Beckers is shown in Figure 4.12.

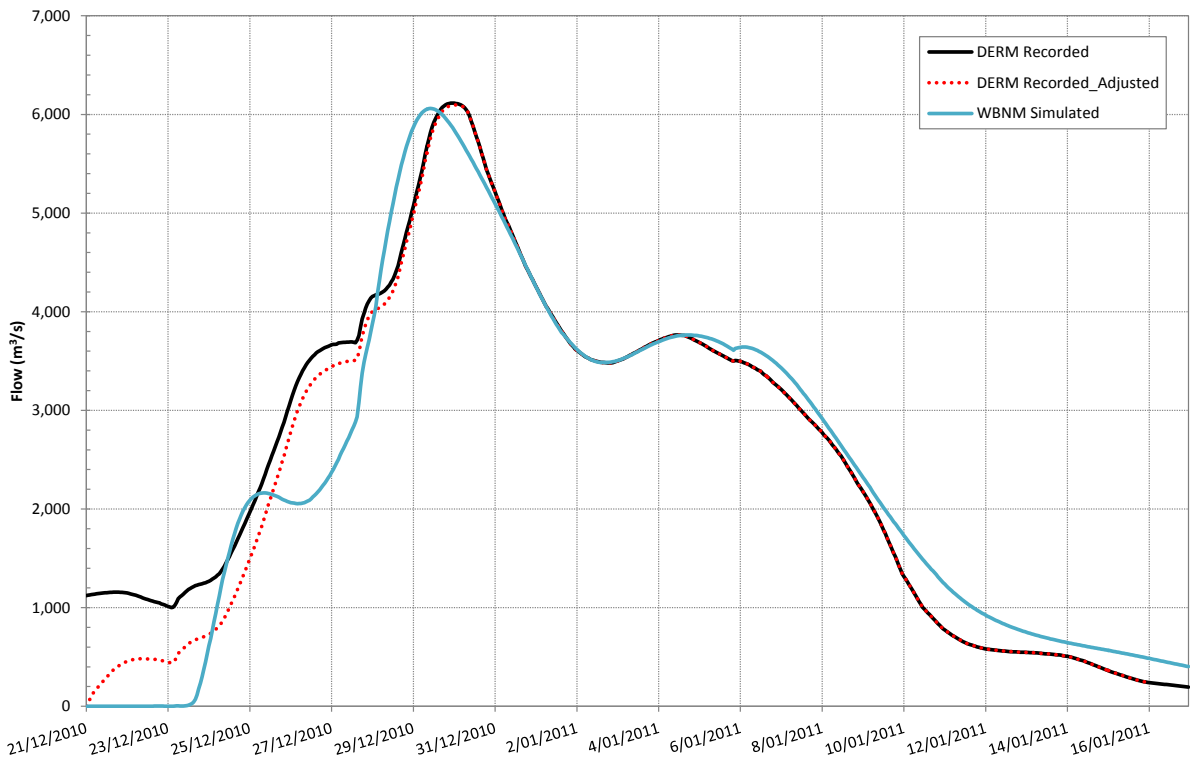


Figure 4.12 – December 2010 Event – Hydrology Model Calibration - Beckers

Note an adjustment was made to the recorded hydrograph at Beckers to remove the residual flow from the event prior to the start of the modelled period, (see Section 4.3.1), with the resultant adjusted recorded hydrograph shown as the dotted red line.

The high stage rating curve at Beckers is considered to be substantially more robust that the rating curves used for the other sites, owing to the analysis described in Section 2. The match to the peak flow at Beckers is considered good, although the timing is a little early. The match on the falling limb is considered good, and on the rising limb the match is considered acceptable.

It is highlighted that the official DNRM rating curves were adopted unchanged for all hydrology model calibration sites other than Beckers, and that (as shown in Table 2.1) the highest gauged flow at most sites is considerably lower than the flow gauged in the 2010 event. Rating curves at the high flows experienced in this event are likely to include significant error. Focus in the calibration was thus placed on the timing of the peaks rather than on the peak flow rate or volume. Also, the focus on this study is at Beckers, to enable the assessment of the BNCOP, and hence the calibrations at other sites were only developed to the extent necessary to provide support to the calibration at Beckers.

4.4 Hydrology Model Development and Calibration Summary

The above sections have described the calibration of the hydrology model used in this study on the large Dec 2010 event. Calibration of the hydrology model for this large catchment for such a spatially and temporally diverse event was not straightforward. Initially calibration was undertaken with a spatially constant set of parameters, however the resultant sub-optimal fit led to a spatially variable calibration being undertaken to a number of internal locations in the catchment, which resulted in a substantial improvement in confidence in the resultant hydrograph at Beckers.

The hydrology model development and calibration described in this report represents a substantial step forward from the model development described in Water Solutions (Nov 2012). It is considered that the hydrology model configuration and calibration is suitable for the purposes of this study, and thus further model development is not warranted.

5 Flood Frequency Analysis

A preliminary flood frequency analysis at Beckers has been undertaken to provide an alternate estimate of peak design flow rates for events up to AEP 1 in 100. A peak annual flow series, based on a water year of October to September, was calculated at Beckers using the recorded levels at the gauge and the developed rating curve in Figure 2.15. The resultant 49 year peak flow series is shown in Table 5.1.

Table 5.1 – Annual Peak Flows at Beckers

Year	Peak Recorded Level (m)	Estimated Peak Flow (m^3/s)	Year	Peak Recorded Level (m)	Estimated Peak Flow (m^3/s)
1964	1.930	8	1989	9.887	615
1965	2.870	31	1990	10.740	750
1966	4.560	105	1991	5.281	143
1967	5.240	140	1992	1.181	2
1968	1.190	2	1993	12.106	1041
1969	4.770	115	1994	9.301	526
1970	11.920	988	1995	12.154	1058
1971	8.630	432	1996	14.142	1954
1972	4.100	83	1997	11.769	956
1973	11.830	969	1998	9.157	504
1974	7.560	308	1999	4.491	102
1975	14.570	2178	2000	6.860	243
1976	9.120	498	2001	6.316	206
1977	13.600	1666	2002	4.674	110
1978	6.990	252	2003	6.450	216
1979	4.940	123	2004	5.763	171
1980	10.390	694	2005	7.072	260
1981	5.420	151	2006	1.121	1
1982	15.750	2900	2007	8.311	391
1983	10.550	720	2008	7.465	299
1984	7.610	313	2009	14.190	1979
1985	3.410	52	2010	19.276	6115
1986	9.110	497	2011	8.918	469
1987	6.820	241	2012	14.853	2337
1988	11.510	901			

Several flood frequency distributions were tested to determine which provides the best fit to these annual peaks, including Log Pearson III, Log-normal, Gumbel, Generalised Pareto, and Generalised Extreme Value. Fitting algorithms were used as discussed in the following papers (Kuczera 1996, 1998, 1999). Annual peaks considered not representative of large floods (below 100 m^3/s) were removed from the distribution fitting process. The Log Normal distribution gave

the best fit to the annual maxima data, and was adopted for the purposes of this investigation. The results are presented in the table below.

Table 5.2 – Flood Frequency Analysis Flows

Design Event (AEP)	Flood Frequency Peak Flow (m^3/s)	90% Confidence Limits (m^3/s)	
1 in 2	350	250	470
1 in 5	1000	730	1500
1 in 10	1800	1200	2800
1 in 20	2800	1800	4800
1 in 50	4700	2800	8800
1 in 100	6600	3800	13000

With an estimated peak flow of 6100 m^3/s, the Dec 2010 flood is between a 1 in 50 and 1 in 100 event based on the flood frequency shown above.

It is noted that this flood frequency has been based on the record of the Beckers Gauging Station. Manual and gauged flood levels at the Baralaba gauging station, close upstream, are available from 1924 to the construction of Neville Hewitt Weir in 1975, as described in Water Solutions (Nov 2012). It would be possible to combine the two records, and the additional 40 years of data may provide an increased level of confidence in the flood frequency results for the larger events, particularly as the Baralaba record appears to contain two events (April 1928, February 1954) larger than the Dec 2010 event. However use of the Baralaba data introduces additional uncertainty associated with these earlier records and the less reliable rating curve at the Baralaba site. Additionally, flood frequency techniques are only applicable to events up to about the AEP 1 in 100 event, and thus the flood frequency analysis has little influence on this study's estimated levee crest levels. Taking these factors and the objectives of the project into account, it is considered that this flood frequency is of sufficient quality to assist in determining design flood peaks, as described in Section 6.

6 Design Flood Hydrology

This study includes the modelling of 5 design events, the AEP 1 in 20, 1 in 50, AEP 1 in 100 and AEP 1 in 1000 events and the Probable Maximum Flood (PMF). The assumption and methods used to develop the design flood hydrographs for these events are described in the following sections.

6.1 Areal Reduction Factors (ARF)

Areal Reduction Factors are used to adjust point design rainfall estimates to values appropriate to apply over the area of a catchment, reflecting that average intensities over a large area are likely to be smaller than what might be experienced at a point.

ARFs for the Dawson River (40,500 km^2) and Saline Creek (132 km^2) were extracted from the recently released final report for Project 2 of the AR&R Revision Project (Engineers Australia 2013). The Dawson River catchment is much larger than the catchments used in deriving the equations presented in this report, and thus the ARF for the Dawson River catchment was determining using an area of 10,000 km^2 in accordance with the guidelines in the report.

The suggested procedure in the Project 2 report for determining ARFs for durations less than 24 hours was trialled, but gave extremely low ARFs for the very large Dawson River catchment. The report indicates that the ARFs for durations less than 24 hours is based on a much smaller database of research, and is thus considered less reliable. While such durations are unlikely to be critical for this large catchment, the 24 hour duration ARF was conservatively adopted for all durations less than 24 hours.

Table 6.1 – Areal Reduction Factors

	Areal Reduction Factor (ARF)	
Duration (hrs)	Saline Creek	Dawson River
3	0.92	0.77
6	0.92	0.77
12	0.92	0.77
24	0.92	0.77
36	0.95	0.82
48	0.96	0.84
72	0.97	0.87
96	0.98	0.89
120	0.99	0.90

As a check, the technique given in Hargraves (2005) was used to verify the ARF's and showed good agreement. The ARFs shown above were thus adopted for this study.

6.2 Rainfall Intensity – Frequency - Duration

There are a number of methods currently available for determining design rainfall intensity – frequency – duration (IFD). The traditional method is the original AR&R IFD method (Pilgrim 1998). The CRC FORGE method was applied in the 2000's by Hargraves (2005), and provides rainfall IFD over a wide range of durations and AEPs. Engineers Australia is currently running a

project to update AR&R, and interim IFD data were issued by the BOM during 2013 (http://www.bom.gov.au/water/designRainfalls/ifd/index.shtml).

Point rainfall depths were derived according to these three methods for two locations in the Dawson River catchment, near the Baralaba Central Mine, and near the centre of the Dawson River catchment. The resultant depths for sample durations and AEPs are shown in the tables below.

Table 6.2 – IFD (AEP 1 in 20)

	Baralaba Central Mine (mm)			Catchment Centroid (mm)		
Duration (hrs)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)
3	94	99	90	93	96	93
6	110	117	108	108	112	111
12	133	139	133	128	132	135
24	170	182	169	162	169	167
48	221	230	218	207	215	209
72	245	259	248	227	244	237

Table 6.3 – IFD (AEP 1 in 50)

	Baralaba Central Mine (mm)			Catchment Centroid (mm)		
Duration (hrs)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)
3	113	118	107	112	114	112
6	132	140	129	130	134	134
12	160	166	160	155	158	161
24	205	218	205	194	203	198
48	269	277	266	248	258	248
72	299	311	305	271	292	282

Table 6.4 – IFD (AEP 1 in 100)

	Baralaba Central Mine (mm)			Catchment Centroid (mm)		
Duration (hrs)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)	AR&R (Old Method)	CRC Forge (Point)	AR&R (2013 Method)
3	127	133	122	126	129	127
6	149	157	147	146	151	152
12	181	187	183	174	178	182
24	233	246	235	220	228	223
48	307	310	307	280	290	278
72	341	348	353	306	328	317

The tables above shown that all three methods give reasonably consistent results at these two locations. The tables also show that there is a fair variation in design rainfall depths across the very large catchment of the Dawson River above Baralaba.

Careful consideration was given as to which method to adopt for this study, as follows:

- The old AR&R method is based on rainfall records up to about the 1970s, so is somewhat dated. It also does not supply rainfall depths for long duration events (over 72hrs) and for AEPs more rare than 1 in 1000. It was thus not chosen for this study.
- The CRC-FORGE method is based on rainfall records up to about the year 2000 and does supply rainfall depth estimates out to 5 days and for AEPs up to around 1 in 2000. The CRC-FORGE depths also tend to be slightly higher than the old AR&R depths at these locations, thus are perhaps slightly more conservative. The program developed by Hargraves (2005) also provides the spatial average of the design rainfall depths over the catchment, which allows the spatial variability of design rainfalls to be incorporated. The CRC-FORGE design rainfall depths were thus adopted for this study.
- The recently released 2013 IFD rainfall by the BOM is only part of the package of revised design flood techniques to be issued as part of the revision of AR&R. Engineers Australia advise that 'You cannot assume that using the 2013 IFD design rainfalls with AR&R87 techniques and design parameters will deliver a more reliable estimate of the design flood.' The 2013 design rainfall depths are generally lower than the CRC-FORGE estimates, and thus it will be less conservative to adopt them without the (yet to be released) other outputs of the AR&R revision projects. Hence the 2013 IFD data was not used in this study.

The CRC-FORGE design rainfall depths for the Dawson River catchment to Beckers were extracted from the program developed by Hargraves (2005). CRC-FORGE design rainfall depths were also extracted for the Saline Creek catchment, with the catchment taken to the point where Saline Creek enters the hydraulic model domain, not far from the north-west corner of the BNCOP. The inbuilt ARFs in the Hargraves program were removed from the average catchment rainfall depths in order to provide values that could be compared to the point values given in Table 6.2 to Table 6.4.

The resultant average rainfall depths over the two catchments (without the ARFs being applied) are tabulated in Table 6.5. As can be seen, the Saline Creek average depths are close to the values at the Baralaba Mine in Table 6.2 to Table 6.4 as expected. The values for the Dawson River catchment are lower than the values at Baralaba and the centroid, as design rainfall depths are generally lower in the southern part of the Dawson River catchment.

Table 6.5 – Adopted Design Rainfall IFDs (Without ARF)

	Dawson River Catchment (to Beckers) (mm)				Saline Creek Catchment (to hydraulic model boundary) (mm)			
Duration (hrs)	AEP 1 in 20	AEP 1 in 50	AEP 1 in 100	AEP 1 in 1000	AEP 1 in 20	AEP 1 in 50	AEP 1 in 100	AEP 1 in 1000
3	85	101	114	160	96	114	129	183
6	100	119	134	189	113	135	153	217
12	118	140	158	223	134	161	182	257
24	150	180	202	286	176	212	240	340
48	184	221	248	343	218	263	295	410
72	204	245	275	380	245	295	332	460
96	216	259	290	400	260	313	351	484
120	224	268	300	412	271	326	366	502

The areal reduction factors in Table 6.1 were applied to the average catchment depths in the table above to provide the areal reduced catchment design rainfall depths for use in WBNM modelling.

6.3 Probable Maximum Precipitation (PMP) Rainfall Estimates

Probable Maximum Precipitation (PMP) estimates were derived for the Dawson River catchment above the mine site in accordance with the following Bureau of Meteorology (BOM) guideline:

- GTSMR - Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method, November 2003

Estimated PMP depths for storm durations of 24 hours to 120 hours were derived using the GTSMR method. Adopted parameters used to determine the PMP estimates are provided in the table below.

Table 6.6 – Adopted GTSMR parameters

Parameter	Assignment
Zone	Coastal
Season	Annual
Tropical Adjustment Factor	1.03
Decay Amplitude Factor	0.95
Moisture Adjustment Factor	0.72

The resulting PMP estimates based off the adopted GTSMR parameters have been provided in the table below.

Table 6.7 – PMP Estimates – Dawson River to Baralaba Mine

Duration (hrs)	Preliminary PMP Estimates (mm)
24	430
36	530
48	620
72	870
120	900

PMP estimates were not derived for Saline Creek on its own, as it was considered likely that flooding from the very large Dawson River catchment will dominate at the BNCOP site in this extreme event.

6.4 Temporal Patterns

Standard temporal patterns are provided in AR&R (1998) for durations up to 72 hours, and in BOM (2003) for durations up to 120 hours. A sample comparison of the temporal patterns from these two sources (for the 72 hour storm, AR&R pattern for ARI > 30 years) is provided below.

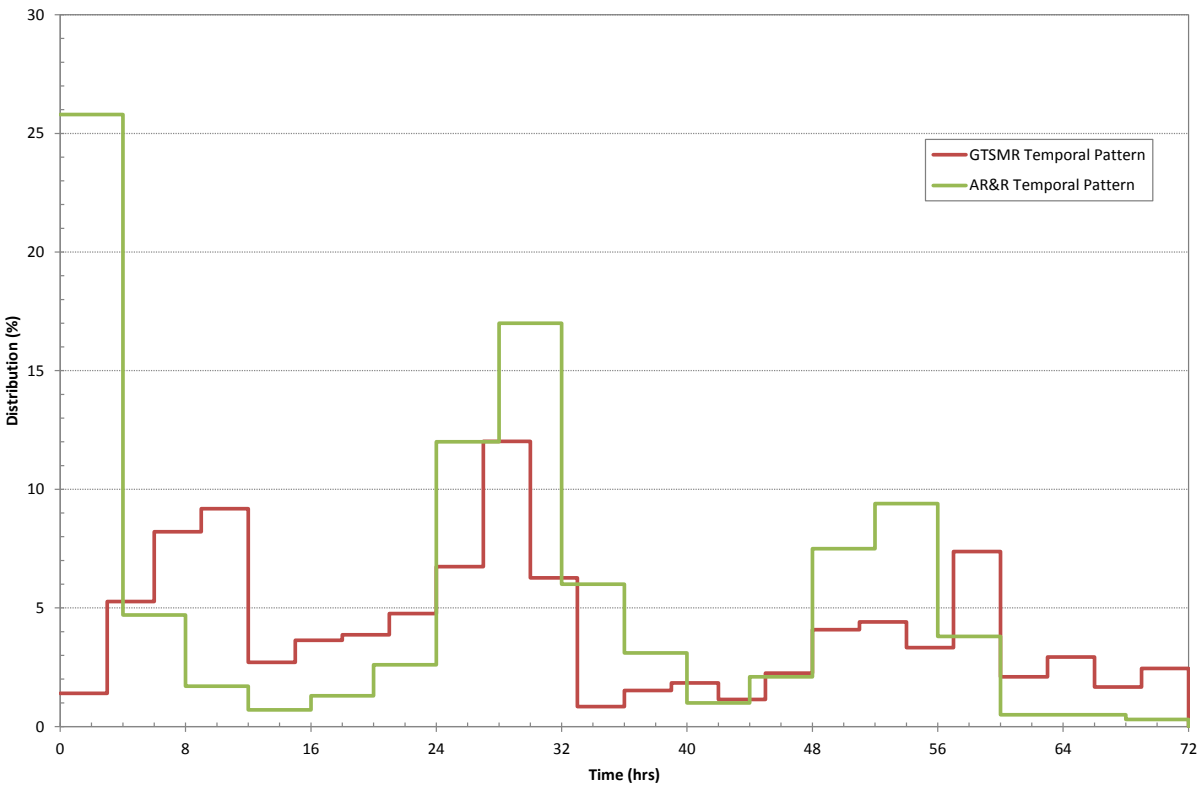


Figure 6.1 – Temporal Pattern Comparison – 72 Hour Storm

Careful consideration was given to the choice of temporal patterns for this study, as temporal patterns can be a considerable area of uncertainty. Preliminary analysis indicated that the critical duration for the Dawson River catchment was likely to be 72 hours or larger, and AR&R does not provide patterns for longer events. The GTSMR patterns were developed about a decade ago based on a database of large storms, whereas the AR&R patterns were developed around 3 decades ago on a more limited dataset. Using one set of patterns for some durations, and then another for others, may lead to discontinuities. On this basis the GTSMR patterns were used for Dawson River floods.

The smaller Saline Creek critical duration was considered likely to be under 24 hours, and the GTSMR patterns are only available for 24 hours and longer durations. Hence the AR&R temporal patterns were adopted for the Saline Creek design floods.

6.5 WBNM Model and Parameters

The subcatchment breakup and model parameters (C, F) in the WBNM model were unchanged from the calibration model presented in Section 3.

For the Saline Creek catchment, which joins the Dawson River below Beckers, no local gauging station is present on Saline Creek to allow calibration. The calibrated parameters for the adjacent Mimosa Creek catchment were adopted for Saline Creek. Note that, without local calibration, the results of the Saline Creek design flood modelling are considered to be of lower accuracy than the modelling of Dawson River floods.

6.6 Continuing Loss

Consideration was given to the appropriate continuing losses to adopt for design. The calibrated continuing losses show large variability across the catchment with the CL varying from 0 to 4mm/hr. Given the long duration of the calibration event, the continuing loss is perhaps being more driven by uncertainties in the recorded rainfall rather than differences in saturated catchment infiltration in each sub-area. It is also noted that the IL/CL loss model is a considerable simplification on the extremely complex physics involved in rainfall runoff processes. Hence it was considered appropriate to adopt a single design CL for the entire catchment for the purposes of this study.

The generic value recommended by AR&R for Queensland (in the absence of calibration data) for the Continuing Loss (CL) is 2.5mm/hr. The simple average of the continuing losses adopted across the catchment is approximately 2 mm/hr. With 2 mm/hr being a little conservative compared to the AR&R recommendation, it was initially trialled to see if it provided an acceptable match to the flood frequency (see below). However 2mm/hr proved to not provide sufficient rainfall to enable the flood frequency to be matched, and hence the adopted continuing loss for design was set to 1.3mm/hr. 1.3mm/hr is within the range of the calibrated values determined in this study, is conservative compared to guideline values in AR&R, and was thus considered to be appropriate for the purposes of this study.

6.7 Initial Loss

For design, initial losses for the more common events were adopted in order to provide consistent peak flow rates with those determined from the flood frequency in Section 5. For events larger than the AEP 1 in 100, a conservative 0mm initial loss was adopted, reflecting that extreme events will often occur within the context of more general rainfall.

The adopted initial losses are shown in the table below.

Table 6.8 – Adopted Initial Losses

Duration (hrs)	Initial Loss (mm)*	Flood Frequency Peak Flow (m^3/s)	WBNM Peak Flow (m^3/s)
20	30	2800	2,700
50	20	4700	4,680
100	0	6600	6,630
1000	0	-	11,860
PMF	0	-	46,430

It is noted that the calibration of the Dec 2010 event resulted in initial losses from 0 to 125mm, and that the adopted design losses are within this range.

6.8 Routing Parameters

The routing parameters (Lag Parameter, Stream Lag Factor and Muskingum routing parameters) from the calibration (see Table 4.2) were adopted for all design events.

6.9 Design Hydrographs

Using the data and assumptions described in the preceding sections the model was run for the range of durations for each selected AEP for regional Dawson River floods and local Saline Creek floods.

The critical duration was determined for each AEP event for each catchment. A sample set of results for various durations for the AEP 1 in 50 event shown in Figure 6.2. It is noted that for some AEPs the peak flow for the 48 hour and 72 hour durations were very similar, in these cases the 72 hour duration was chosen as the critical duration to provide consistency.

The resultant critical durations and peak flow rates are presented in Table 6.9. Figure 6.3 shows the hydrographs for the critical duration events in the Dawson River. Figure 6.4 shows the critical duration hydrographs for the Saline Creek floods.

To simplify the hydraulic modelling required in this study, a modified Saline Creek hydrograph was created including both the 6 hour and 72 hour rainfall patterns, as shown in Figure 6.5. The first peak in this hydrograph is the 6 hour critical duration flows from Saline Creek, while the remainder of the hydrograph is drawn from the 72 hour duration runs for Saline Creek, which provides consistent inflows from Saline Creek during the peak of the Dawson River critical duration runs. This method allows the peak level or velocity to be drawn from a single hydraulic model run at any point along Saline Creek, whether or not that result is driven by the Saline Creek 6 hour inflows or the Dawson River 72 hour inflows.

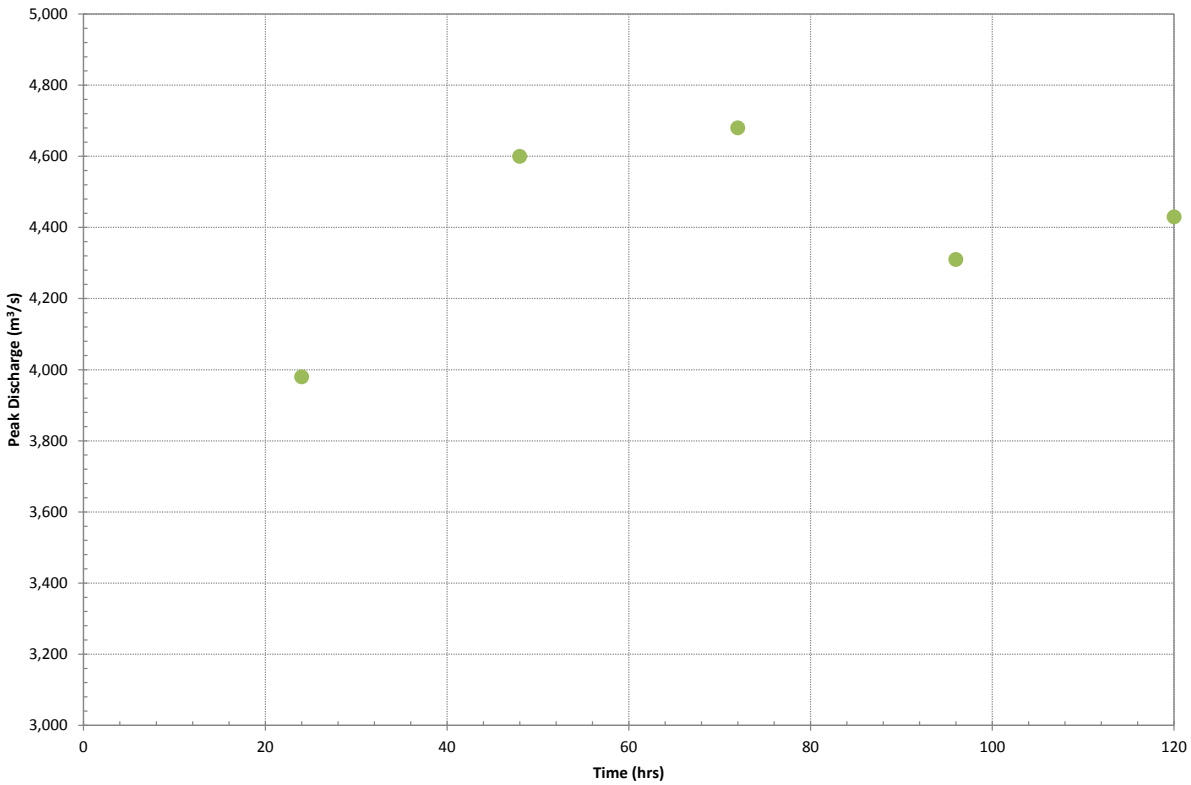


Figure 6.2 – Critical Duration (AEP 1 in 50)

Table 6.9 – Peak Discharges

	Dawson River at Beckers		Saline Creek (at hydraulic model boundary)	
Design Event (AEP 1 in X)	Critical Duration (hrs)	Peak Discharge (m^3/s)	Critical Duration (hrs)	Peak Discharge (m^3/s)
20	72	2,700	6	200
50	72	4,680	6	300
100	72	6,630	6	420
1000	72	11,860	6	650
PMF	96	46,430	-	-

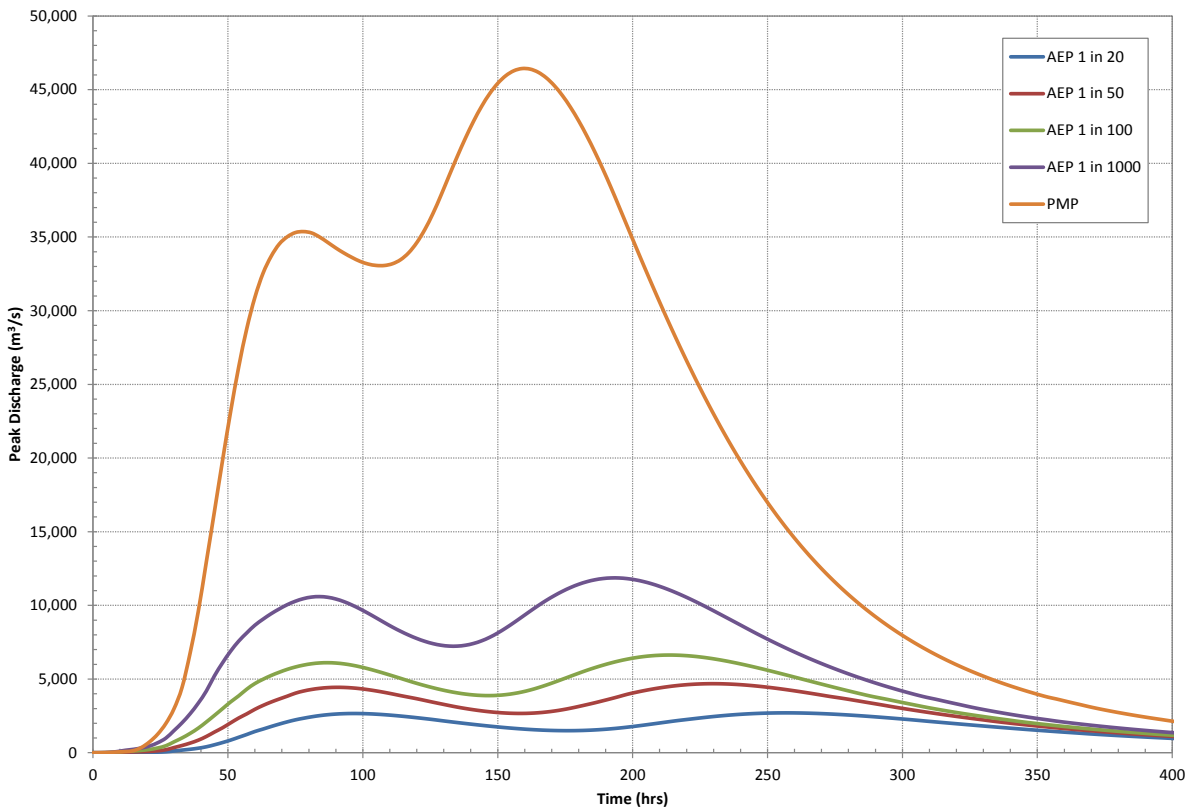


Figure 6.3 – Modelled Hydrographs (Dawson River)

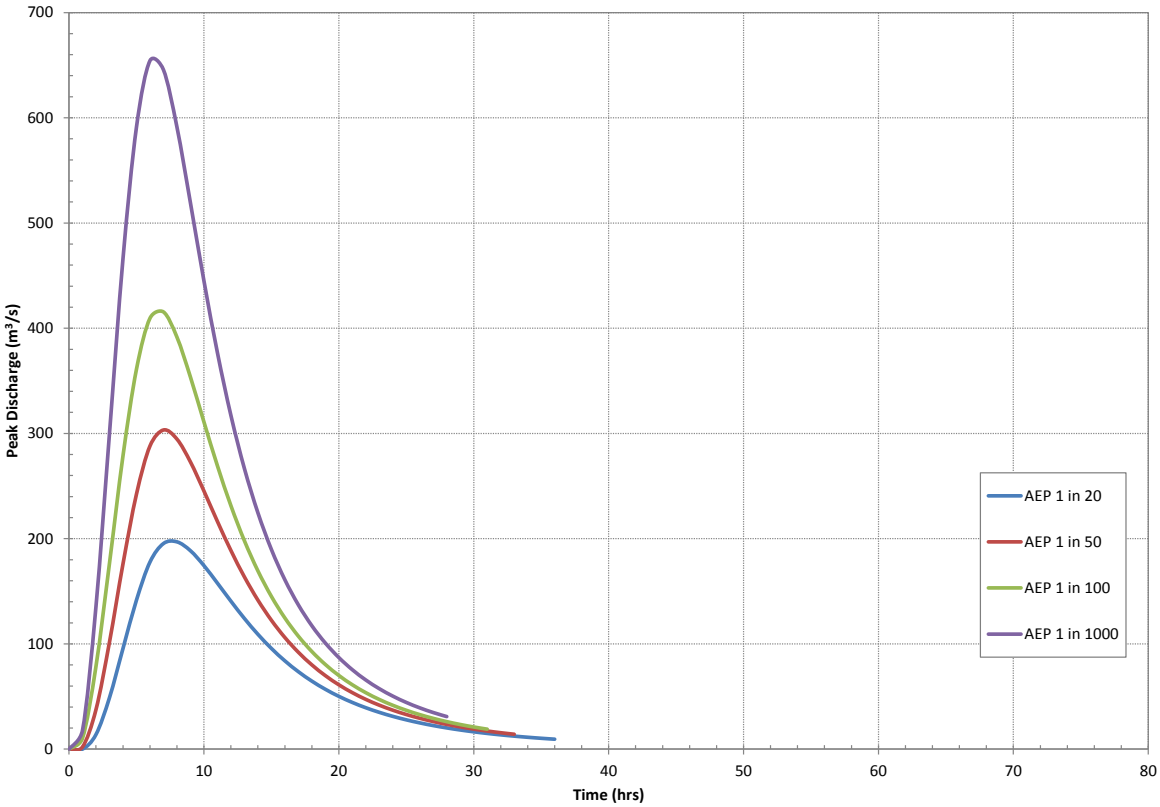


Figure 6.4 – Modelled Hydrographs (Saline Creek) – 6hrs (Critical Duration)

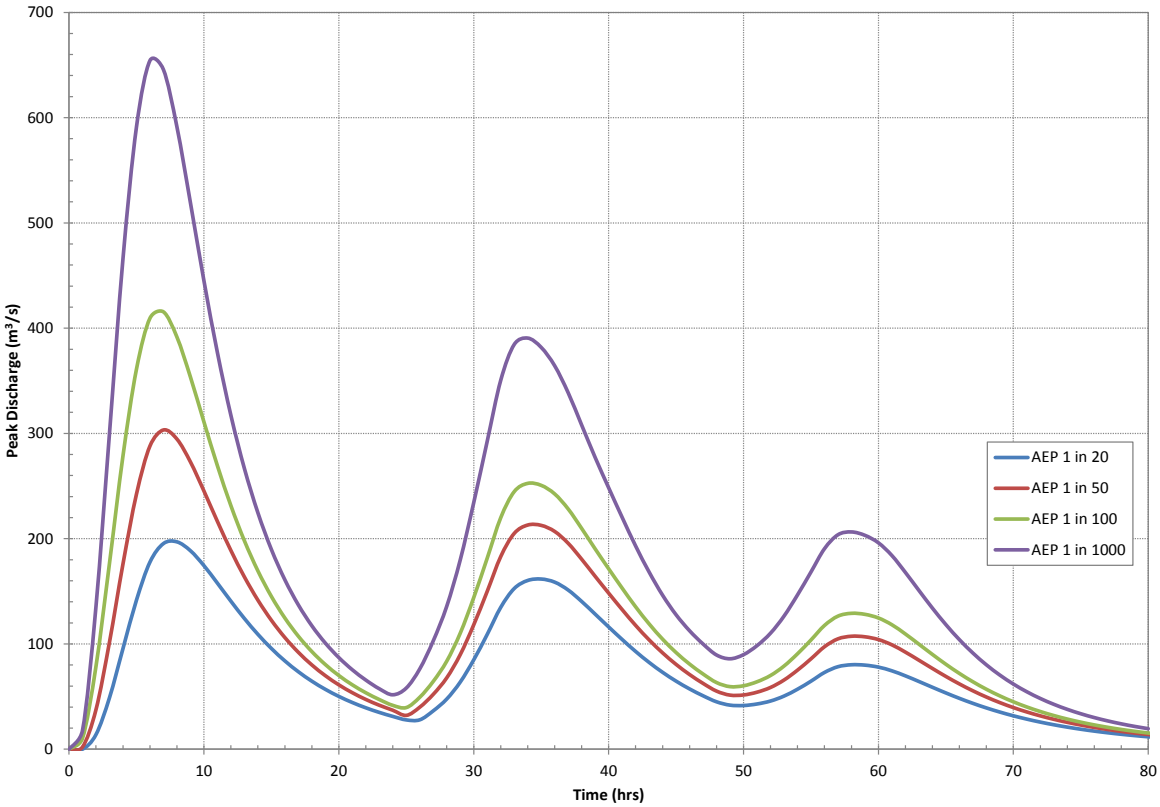


Figure 6.5 – Modelled Hydrographs (Saline Creek) – 72hrs (Dawson River Critical Duration)

It is noted that the Dawson River design flood hydrographs in Figure 6.3 show a distinctive double peak. This double peak is partially caused by the multiple peaks in the design rainfall temporal pattern for the 72 hour event, but is also caused by the elongated shape of the catchment. As seen in the calibration event at Woodleigh, it takes some time for rainfall from the upper catchment to make it down the river. A single burst of rainfall over the catchment will tend to create multiple peaks, an early peak from downstream areas such as Mimosa and Roundstone Creeks, and a later peak from rainfall in the upper catchment above, say, Taroom. Multiple bursts of rainfall across the catchment may reinforce peaks from earlier rainfall events to various degrees, depending on the timing and location of the rainfall. These effects are partially present in the 2010 calibration event and the design events, but it is possible that a different temporal or spatial pattern will mean that the same depth of rainfall will lead to a higher or lower peak at a selected location in the catchment such as Beckers. Further investigation of these effects are not warranted for the purposes of this study, however this is an area for consideration in future flood studies in this area.

In summary, the design inflow hydrographs for the Tuflow model for the AEP 1 in 20 to 1 in 1000 events are those shown in Figure 6.3 and Figure 6.5. For the PMF, a steady state hydraulic model run was performed in order to provide an indication of the extent of flooding in this extremely rare event, using the peak flow rate from Figure 6.3. As described in Section 6.3, PMP estimates were not derived for Saline Creek. The peak flow for the AEP 1 in 1000 event was used as a nominal steady state inflow for Saline Creek in the PMF case.

7 Mine Development Case Modelling

Following the hydraulic modelling of the 2010 calibration case presented in Section 3, this study has modelled three mine development cases in order to assist with the assessment of flooding issues associated with the proposed BNCOP. These cases are the Existing/Approved Case, the Operational BNCOP Mine Case, and the Post Mine Case. These cases are described in the following sections.

7.1 Existing/Approved Case

This case is the base case for the assessment of the impact of the BNCOP, and thus represents the current floodplain with all currently approved mine structures in place.

The Existing/Approved Case is the same as the 2010 calibration case, with the following changes added:

- The existing extent of the Baralaba Central Levee
- The approved Haul Road Crossing of the Dawson River Anabranch
- The approved Baralaba North / Wonbindi North Mine Levee
- The existing new bridge downstream of Neville Hewitt Weir

The extent of the Baralaba Central Levee and the location of the proposed Baralaba North / Wonbindi North Mine Levee are drawn from the Baralaba North Flood Study (Water Solutions Nov 2012). The location of these levees is shown on Figure 1.2. Both levees have been modelled as inactive flow areas (i.e. vertical walls) which follow the outline of the levee footprints.

The Haul Road Crossing has been included in the model based on the latest configuration supplied by Cockatoo Coal, as shown in Figure 7.1. A blockage allowance of 20% was conservatively included in the model, based on advice in AR&R – Blockage of Hydraulic Structures (Feb 2013).

The new bridge downstream of Neville Hewitt Weir has been included in the model based on the conceptual design configuration supplied by Cockatoo Coal, as shown in Figure 7.2. A blockage allowance of 1m per pier was included in the model, based on advice AR&R – Blockage of Hydraulic Structures (Feb 2013).

The model topography for this case is illustrated in Figure 7.3.

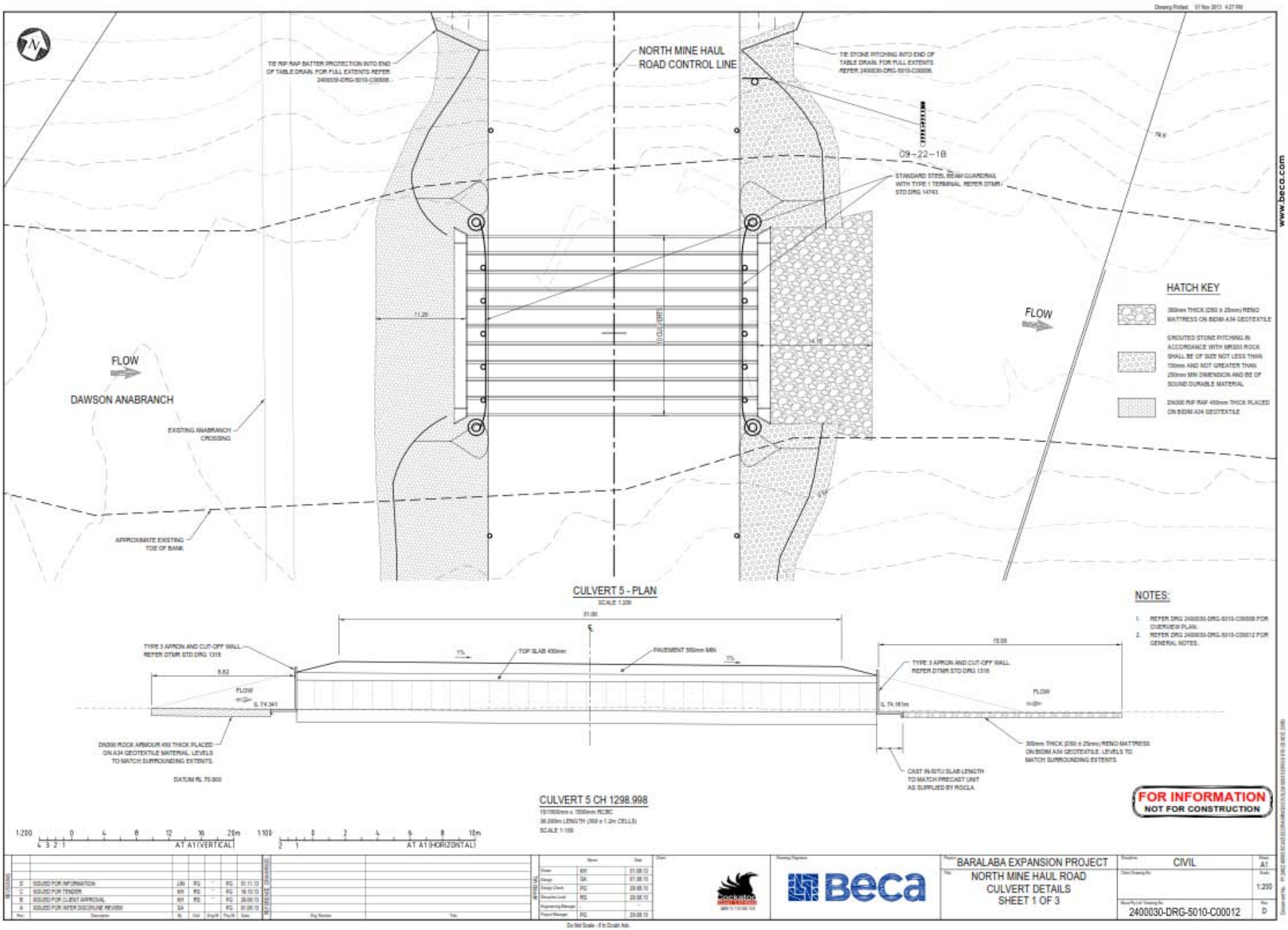


Figure 7.1 - Haul Road - General Arrangement

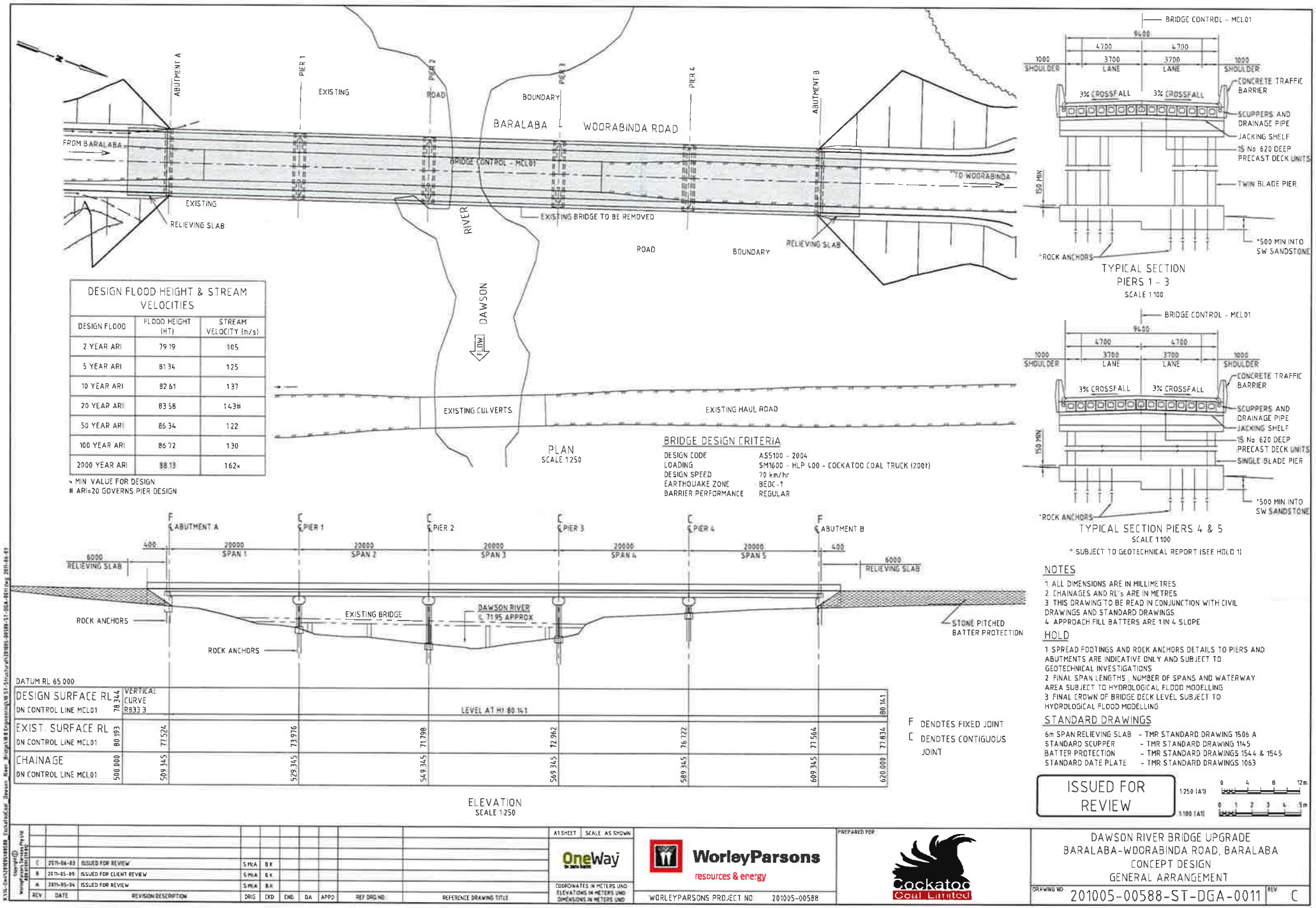
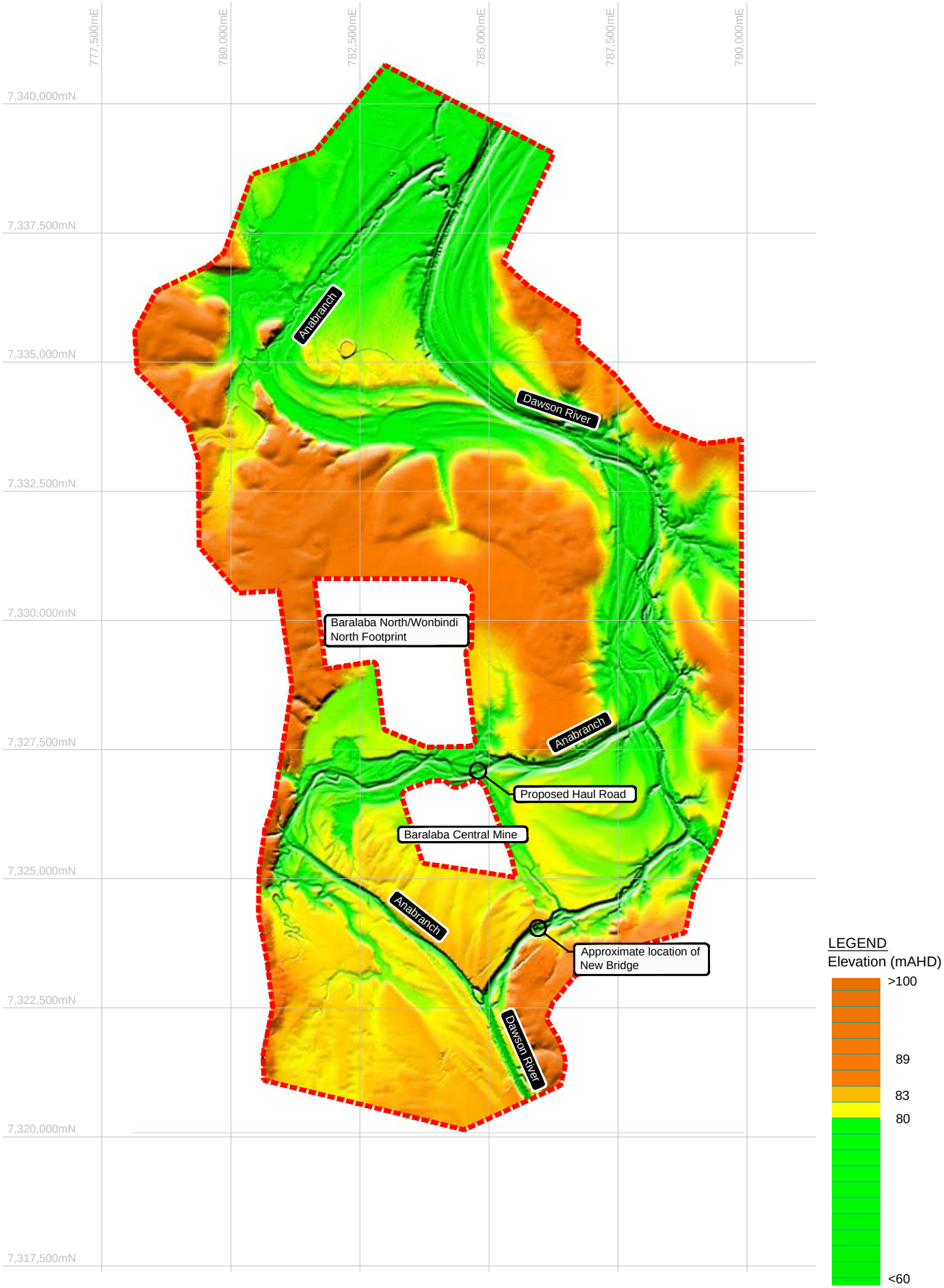


Figure 7.2 - Baralaba-Woorabinda Road Bridge - General Arrangement

Water Solutions



LEGEND
Active Modelling Area

Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Existing/Approved Case - Modelled Topography

Job No. WS0715.1305	Revision: 3	Figure 7.3

File Name: WS130231_Fig7_3.dwg

7.2 Operational BNCOP Mine Case

This case represents the outer footprint of the mine during the operational phase of its development. This case is the same as the Existing/Approved Case with the addition of the new features associated with the BNCOP. The extent of the BNCOP is as shown on Figure 1.2.

For the purposes of this project the outer toe of the BNCOP affected area was assumed to follow the green line outline of the BNCOP on Figure 1.2, except along the southern border of the site. On the southern side of the BNCOP area, the alignment of the Baralaba North / Wonbindi North Mine Levee was maintained, and the edge of the south-east spoil pile was adopted as the edge of the BNCOP area.

Note that the BNCOP affected area edge has been assumed to be watertight (or of low permeability), e.g. either a levee will be provided, a sufficiently robust spoil pile will be provided to act as a levee, or the natural terrain will be high enough to keep floods out of the project area.

The topography used for this case is shown in Figure 7.4.

7.3 Post Mine Case

This case represents the final landform of the BNCOP and existing mine after mining is complete.

Cockatoo Coal has provided the terrain for the post-mine landform, and it is shown in Figure 7.5.

This case is the same as the Existing/Approved Case and Operational BNCOP Mine Case, except the mine terrain has been altered to match the landform provided by Cockatoo Coal, and the Haul Road Crossing of the anabranch has been removed.

It is noted that the model results for the post mine case are based on the post mine landform as described above. Should any changes be made to the proposed post mine landform, a reassessment of flooding impacts may be required.

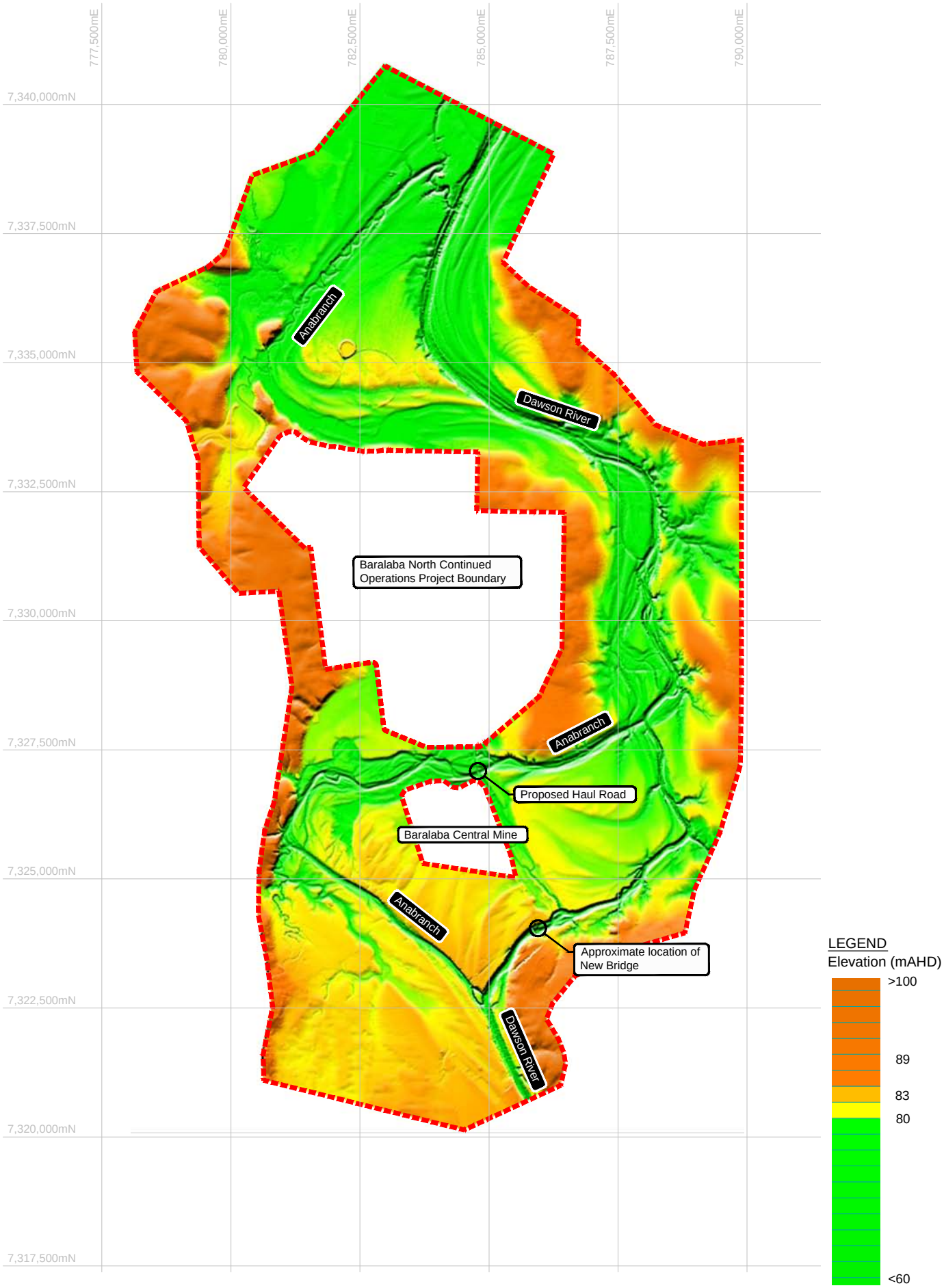
7.4 Other Model Parameters

Aside from the topography and structures changes described in the preceding three sections, the only additional changes made to the calibration model described in Section 3 for the design runs are as follows:

- An additional upstream boundary was included for the Saline Creek inflows.
- The design flood hydrographs (presented in Section 6.9) were used as the upstream boundaries for the model.

Results for the design cases are presented in the following section.

Water Solutions



LEGEND
Active Modelling Area

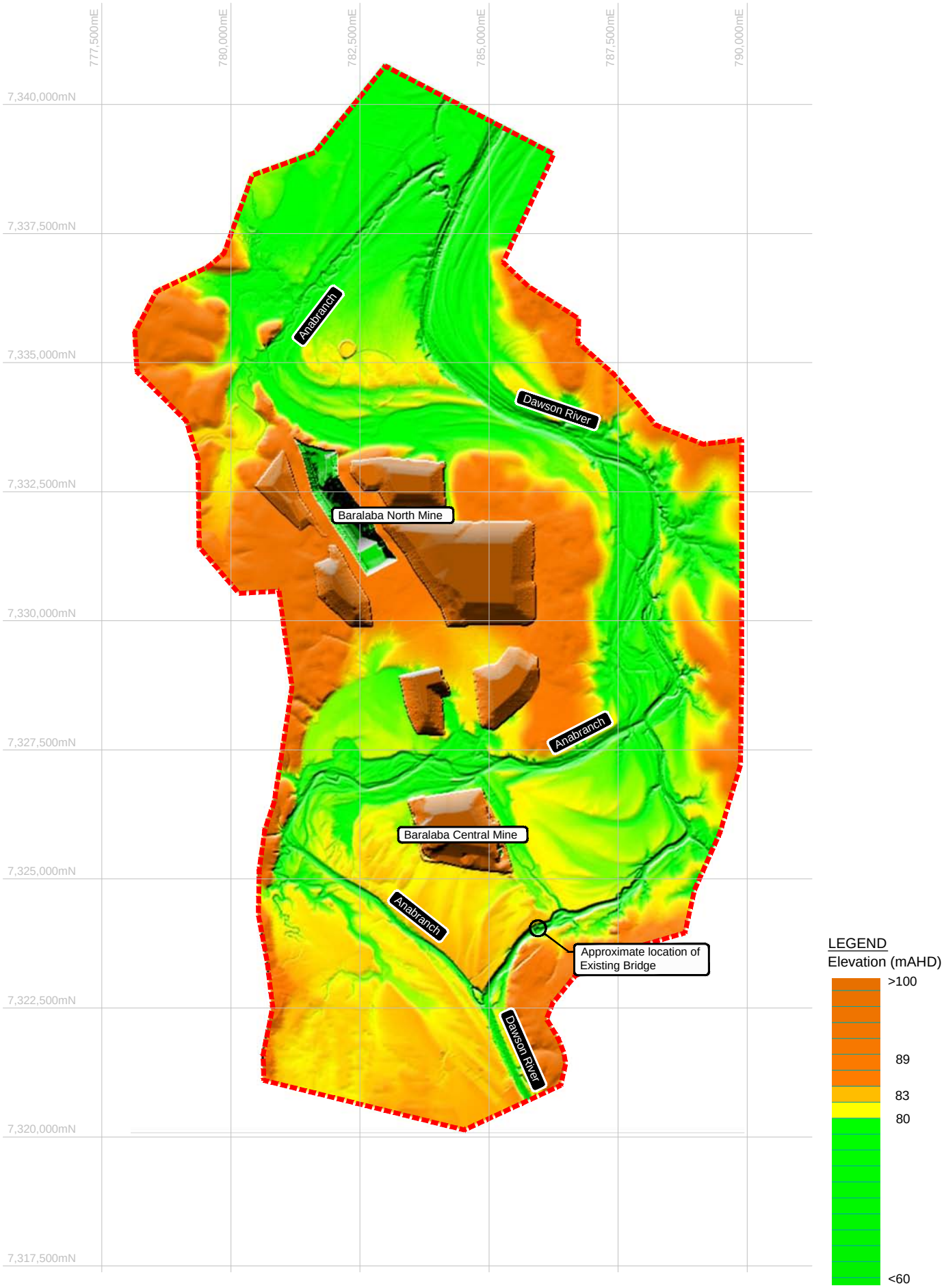
Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Operational Case - Modelled Topography

Job No. WS0715.1305 | Revision: 3 | Figure 7.4

File Name: WS130231_Fig7_4.dwg

Water Solutions



LEGEND	
- - - -	Active Modelling Area

Cockatoo Coal Limited

Baralaba North Continued Operations Project
Flood Study
Proposed Case - Modelled Topography

Job No. WS0715.1305	Revision: 3	Figure 7.5

File Name: WS130231_Fig7_5.dwg

8 Results

8.1 Flood Levels and Flow Patterns

Water level contour and velocity mapping output from the hydraulic model for the modelling scenarios is presented in Appendix A to C. A summary of the presented figures is contained in the table below.

Table 8.1 – Water level and velocity mapping figures

Model Scenario	Design Event (AEP 1 in x)	Figure
Existing/Approved Case	20	A.1
	50	A.2
	100	A.3
	1,000	A.4
	PMF	A.5
Operational BNCOP Mine Case	20	B.1
	50	B.2
	100	B.3
	1,000	B.4
	PMF	B.5
Post Mine Case	20	C.1
	50	C.2
	100	C.3
	1,000	C.4
	PMF	C.5

The results on these maps appear to be reasonable. Some observations on these maps are provided below:

- In the AEP 1 in 20 event flow is not entering the lower anabranch from the Dawson River, although some water is present in the anabranch from the Saline Creek inflow. Based on the topography, this anabranch appears to be a higher level flow channel compared to the upstream anabranch. Note there is only a small strip of dry land near the road separating the Dawson River from the anabranch, and that culverts along this road (if any) are not modelled. At the AEP 1 in 50 event and larger, the Dawson River is clearly breaking out to the lower anabranch.
- There are some elevated velocities in the main river close to the upstream and downstream boundaries in most events. As these areas may be affected by the boundary condition, caution should be used in using results in these areas.
- Homesteads and buildings are generally not flooded in the AEP 1 in 20 event, but some structures are significantly flooded in the AEP 1 in 50 event and larger.
- The BNCOP occupies a slight saddle on the left bank between the two anabranches. Flows up to the AEP 1 in 1000 event do not flow over the saddle in these cases, however the PMF is showing some flow through this area in the Existing/Approved Case and Post Mine Case.
- Local Saline Creek flows are controlling levels in the upper (modelled) part of Saline Creek in most events.

- Flood waters do not enter the final void in the Post Mine Case for events up to the AEP 1 in 1000 event, see Figure C.4. The AEP 1 in 1000 event is more than 1m below the lowest edge of the final void, which provides a factor of safety for this event. Flood waters do enter the final void in the Post Mine Case in the PMF case, see Figure C.5, and high velocities occur where the water enters and exits the pits, which is likely to lead to erosion. High velocities are also present in a number of other areas along the Dawson River in the PMF event in all three cases, see Figures A.5, B.5, and C.5. It would be expected that significant erosion will occur in a number of locations in such an extremely rare event.
- The PMF event has been performed to provide an indication of the affected floodplain in this extremely rare event. While it is problematic to assign an AEP to the PMF, the nominal AEP for the PMF is 1 in 70,000, according to Figure 6 in Book 6 of AR&R. Impacts of the proposal on such a rare event are considered only to be significant if they are catastrophic in nature. A number of simplification have been used in the modelling of the PMF, summary below, and hence results should be viewed as indicative only:
  - The PMF has some eight times the flow of the calibration case.
  - The PMF event has been modelled in steady state
  - The PMF event has some significant depths of water against the side boundaries of the model. The storage effects of these side areas are not included, and in some places (such as near the downstream boundary) additional conveyance area may open up at the very high flood levels in the PMF.
  - The mine levees are likely to be overtopped in the PMF.
  - Significant erosion is likely to occur in such a large event.

8.2 Dawson River Longsection

Figure 8.1 presents a long section down the Dawson River showing peak water levels for each event from the hydraulic model. See Figure 3.3 for the location of the chainages used on the x-axis of this plot.

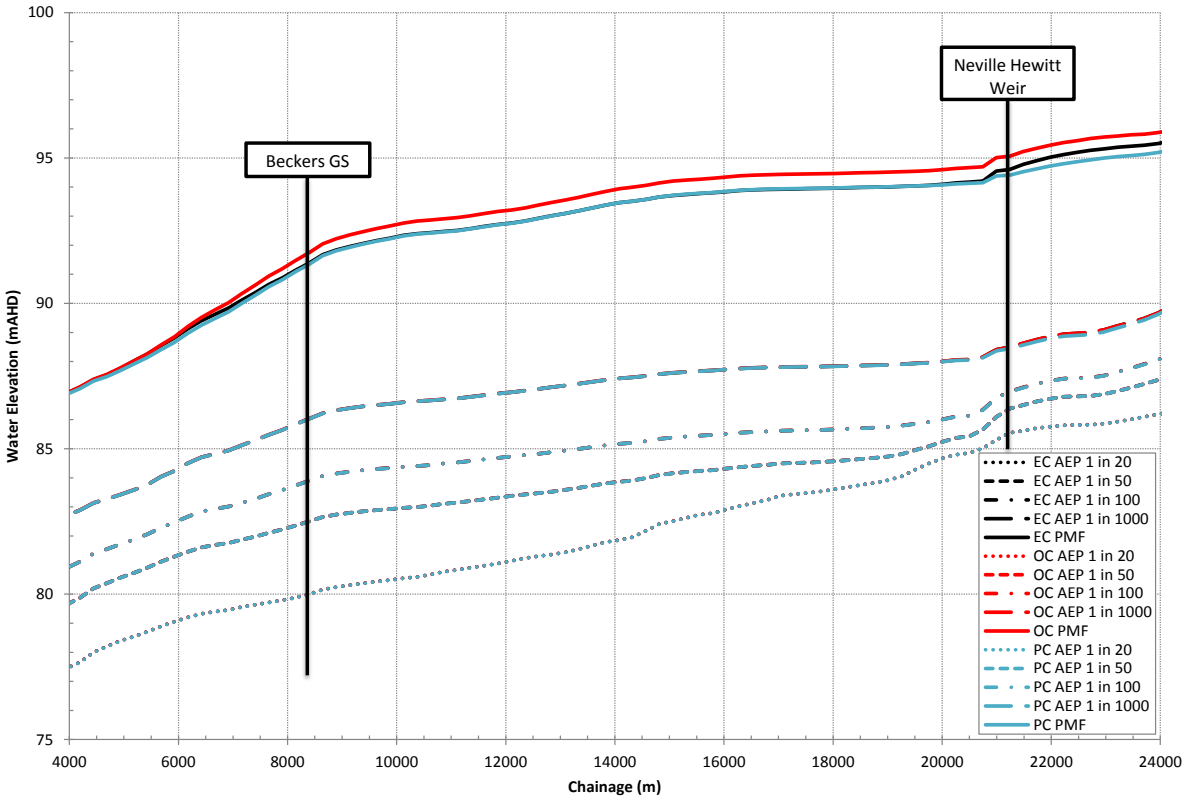


Figure 8.1 – Dawson River Longsection – Design Flood Levels

The flood profiles for all events are relatively smooth and show reasonable differences between the AEP events, which provides reassurance that the model is reasonably reflecting flood conditions. The level of flood profile towards the downstream end of the model may be affected by the downstream boundary condition, as discussed in Section 3.10, so some care should be used in interpreting absolute values near the downstream boundary.

The longsection shows that the Dawson River flood profile does not significantly change for the AEP 1 in 20 to AEP 1 in 1000 events between the Existing/Approved Case (EC), the Operational BNCOP Mine Case (OC) and the Post Mine Case (PC), with the flood profiles for these events plotting on top of each other in Figure 8.1.

For the PMF event there is some increase in flood levels for the OC case compared to the other two cases. This is due to the blockage of the additional flow path on the left side of the Dawson River through the BNCOP site. In the AEP 1 in 1000 event and lower events, as seen on the figures in Appendix A to C, no flood water flows over this area in any of the cases. However in the PMF event the model is showing some flow through this area in the EC and PC results. It is highlighted that this result is a consequence of the technique used to model the mine site in the EC and OC cases, which does not allow water to enter the mining areas. In reality, the PMF would overtop the levees and flow would occur through the mine site. Actual differences in the Dawson River flood profile once the mine site is flooded in a PMF event are unlikely to be significant.

8.3 Modelled Hydrograph at Beckers

Figure 8.2 presents hydrographs of the design events at Beckers for the AEP 1 in 20 to 1 in 1000 events from the hydraulic model. (The PMF event is not shown as it was modelled in steady state.)

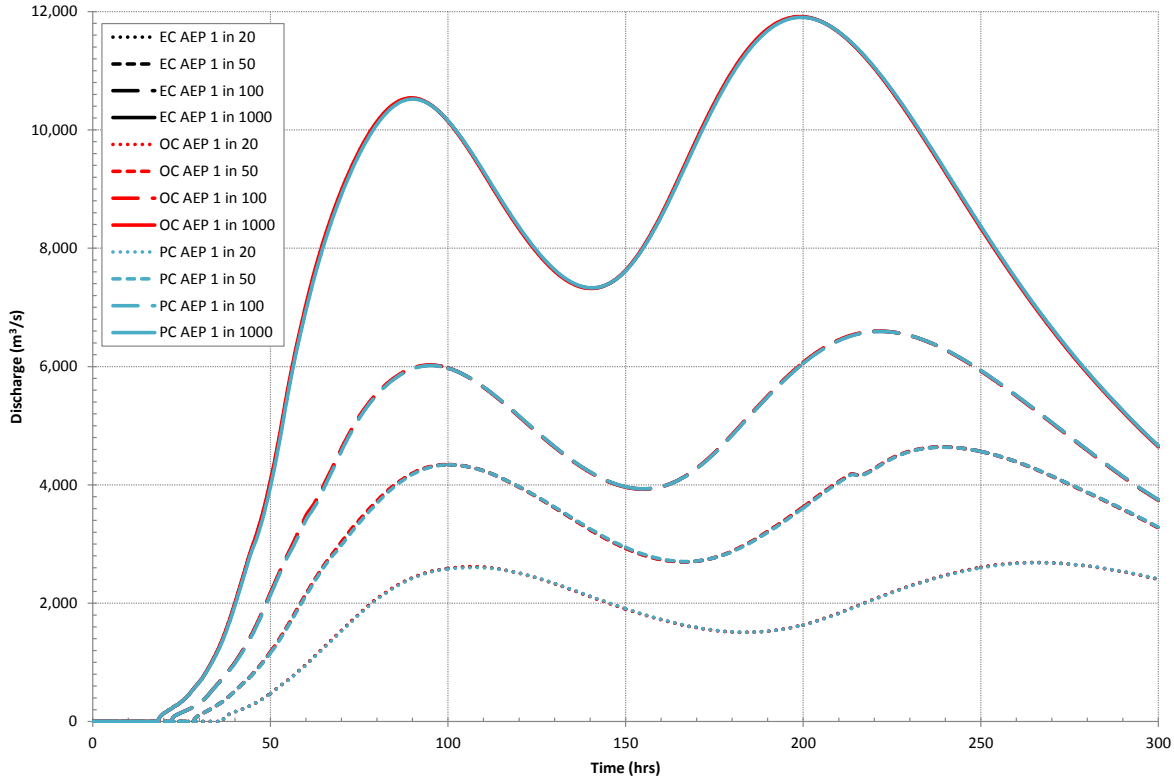


Figure 8.2 – Modelled Hydrographs at Beckers

The hydrographs shown in Figure 8.2 are smooth and match well with the input hydrographs, which provides reassurance that the model is reasonably reflecting flood conditions.

8.4 Geomorphology

Figure 8.3 and Figure 8.4 present long-sections along the upstream and downstream anabranches for the AEP 1 in 50 event. The chainages used for these longsections are shown on Figure 3.3.

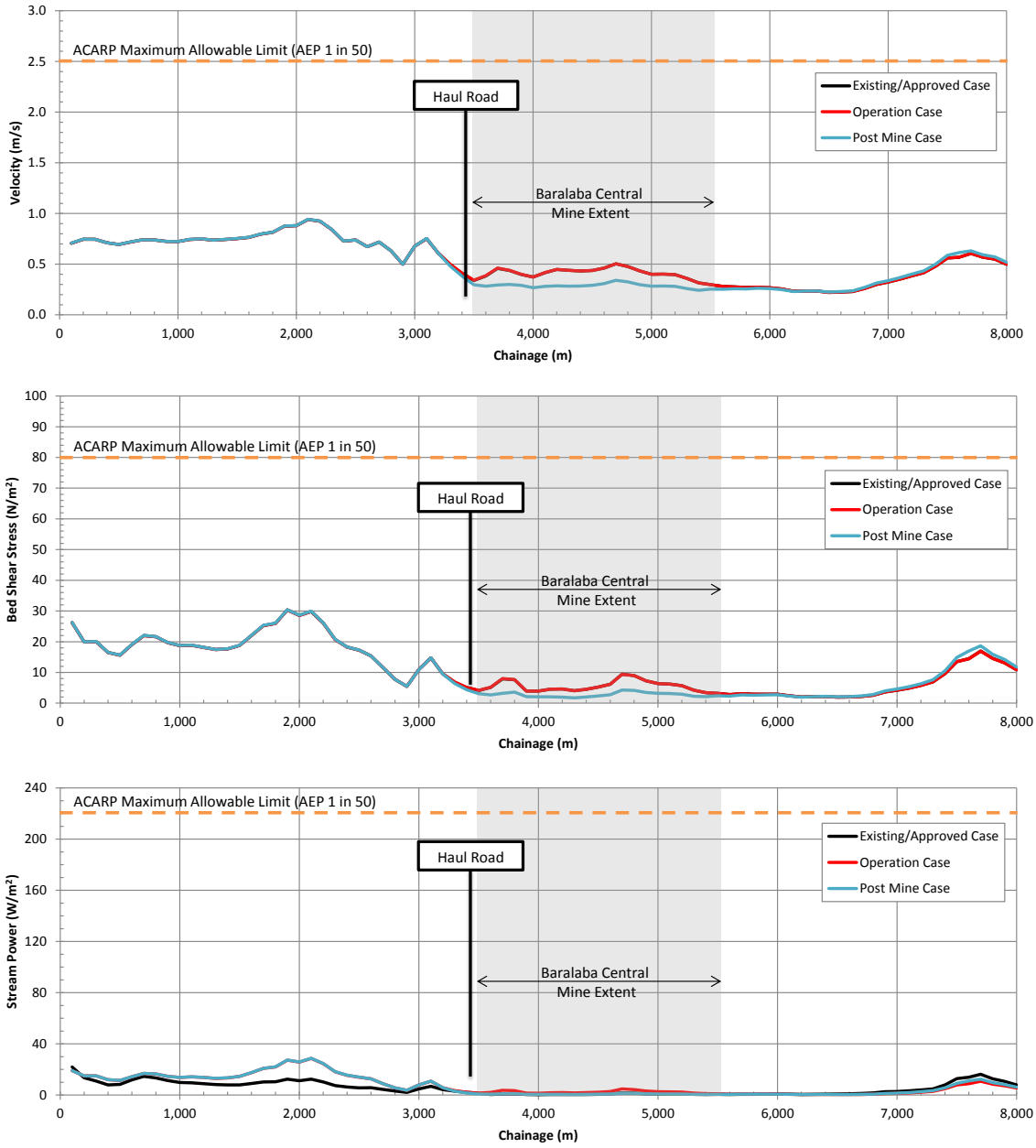


Figure 8.3 – Dawson River Upper Anabranch Longsection – Hydraulic Characteristics

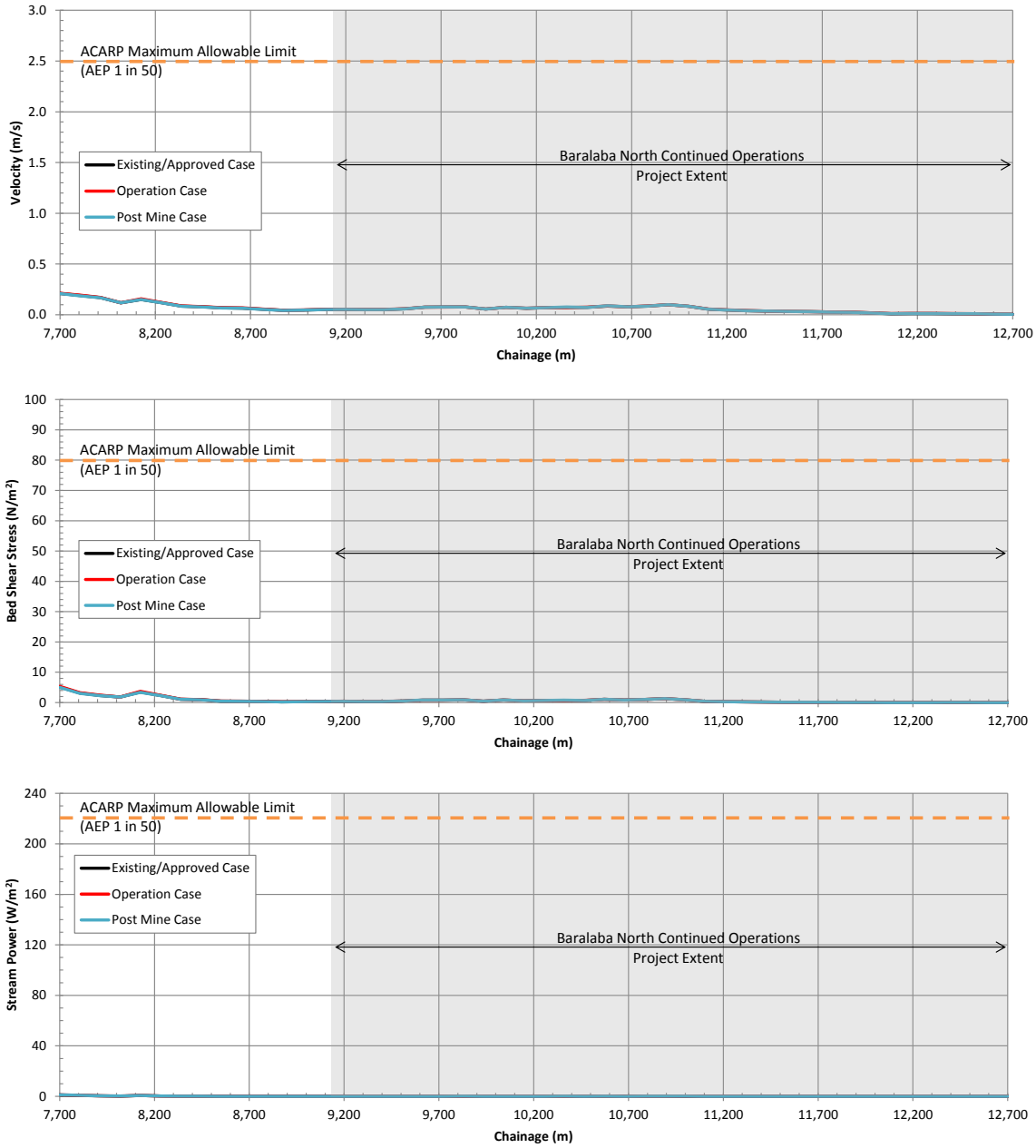


Figure 8.4 – Dawson River Lower Anabranch Longsection – Hydraulic Characteristics

Design guideline limits indicating the potential for significant erosion and geomorphological change were sourced from the DERM *Guideline for Watercourse Diversion – Central Queensland Mining Industry* (DERM 2008), which based its guidance on the earlier Australian Coal Association Research Program (ACARP) findings for the 'Bowen Basin River Diversions – Design and Rehabilitation Criteria (July 2002). These guidelines are shown in the table below.

Table 8.2 – ACARP Design Guideline Limits

Scenario	Flow Velocity (m/s)	Bed Shear Stress (N/m^2)	Stream Power (W/m^2)
AEP 1 in 2 (no vegetation)	< 1.0	< 40	< 35
AEP 1 in 2 (vegetated)	< 1.5	< 40	< 60
AEP 1 in 50	< 2.5	< 80	< 220

Figure 8.3 and Figure 8.4 show that the BNCOP Operational Case has little impact on velocities, bed shear stress and stream power in the two anabranches. The Post-Mine Case is showing a reduction in velocities, bed shear stress and stream power in the section between the two levees near Baralaba Central. This reduction is caused by the widening of the anabranch corridor in the Post Mine Case.

Additionally, the velocities, bed shear stress and stream power in these two anabranches are significantly below the ACARP design limits presented in Table 8.2.

It is noted that the AEP 1 in 2 event has not been modelled in this study. It is quickly apparent from the location of the BNCOP and the AEP 1 in 20 results presented in this report that the BNCOP would have insignificant impact on events less than the AEP 1 in 20 event,

Based on these results it is considered unlikely that the BNCOP will cause significant impact on the geomorphological stability of the Dawson River and Anabranches.

8.5 Afflux and Velocity Change

As described in Section 7.1, the base case for this study is the Existing/Approved Case, which represents the existing approved infrastructure on the floodplain before the construction of the BNCOP. Two stages of the proposed BNCOP have been modelled, the Operational BNCOP Mine Case representing the outer footprint during operation of the mine, and the Post Mine Case representing the landform once mining is complete. The impact of the mine has been evaluated by comparison of these two cases to the base case, the Existing/Approved Case.

Maps of the afflux and velocity change for the AEP 1 in 100 event for the two proposed cases, compared to the base case, are contained in Appendix D, with a summary of these maps in Table 8.3 below.

Table 8.3 – Afflux and Velocity Change Figures – AEP 1 in 100 Event

Model Scenario	Type	Figure
Operational BNCOP Mine Case	Afflux Velocity Change	D.1 D.3
Post Mine Case	Afflux Velocity Change	D.2 D.4

From Figure D1 and D2 it can be seen that the BNCOP has no significant effect on the AEP 1 in 100 flood levels, with close to zero afflux over the whole model domain, including in Baralaba Township and at the locations of identified homesteads. Examination of the model outputs for the

AEP 1 in 20 and 1 in 50 events show a similar result. Maximum afflux over the model domain for these events are presented in Table 8.4.

For velocity change, it can be seen that there are some small areas of increased velocity to the east of the Baralaba North/Wonbindi North levee, north-east of Baralaba Central. These areas are away from the river and anabranch. The area is within or very close to Cockatoo Coal's operations and no houses or other built infrastructure appears to be in this location. Additionally, the resultant velocities (see Figures B3 and C3) are low, so significantly increased safety or erosion impacts are not likely. Examination of the model outputs for the AEP 1 in 20 and 1 in 50 events show a similar result. Maximum velocity change in the area east of the Baralaba North/Wonbindi North levee, and in the rest of the model domain, for these events are presented in Table 8.5.

Table 8.4 – Maximum Afflux

	Afflux (m)	
Design Event (AEP 1 in X)	Operational BNCOP Mine Case	Post Mine Case
20	<0.1	<0.1
50	<0.1	<0.1
100	<0.1	<0.1

Table 8.5 – Maximum Velocity Change

	Velocity Change (m/s)			
	Operational BNCOP Mine Case		Post Mine Case	
Design Event (AEP 1 in X)	East of Baralaba North/Wonbindi North Levee	Rest of Model Domain	East of Baralaba North/Wonbindi North Levee	Rest of Model Domain
20	0.7	<0.1	0.3	<0.1
50	0.7	<0.1	1.0	<0.1
100	1.0	<0.1	1.3	<0.1

Based on these very small impacts, it is considered that the BNCOP does not cause significant additional flooding impacts or risks for the town of Baralaba or surrounding properties.

8.6 Cumulative Impacts with Baralaba South

As mentioned in Section 1.1, CCL have been conducting an active exploration program further to the north and south of the Baralaba Central Mine in order to expand the economic mining life of the site. While CCL considers the BNCOP as the next option for development, CCL have previously undertaken investigations into the Baralaba South Coal Project (BSCP), on a site some 10 km to the south of Baralaba Central.

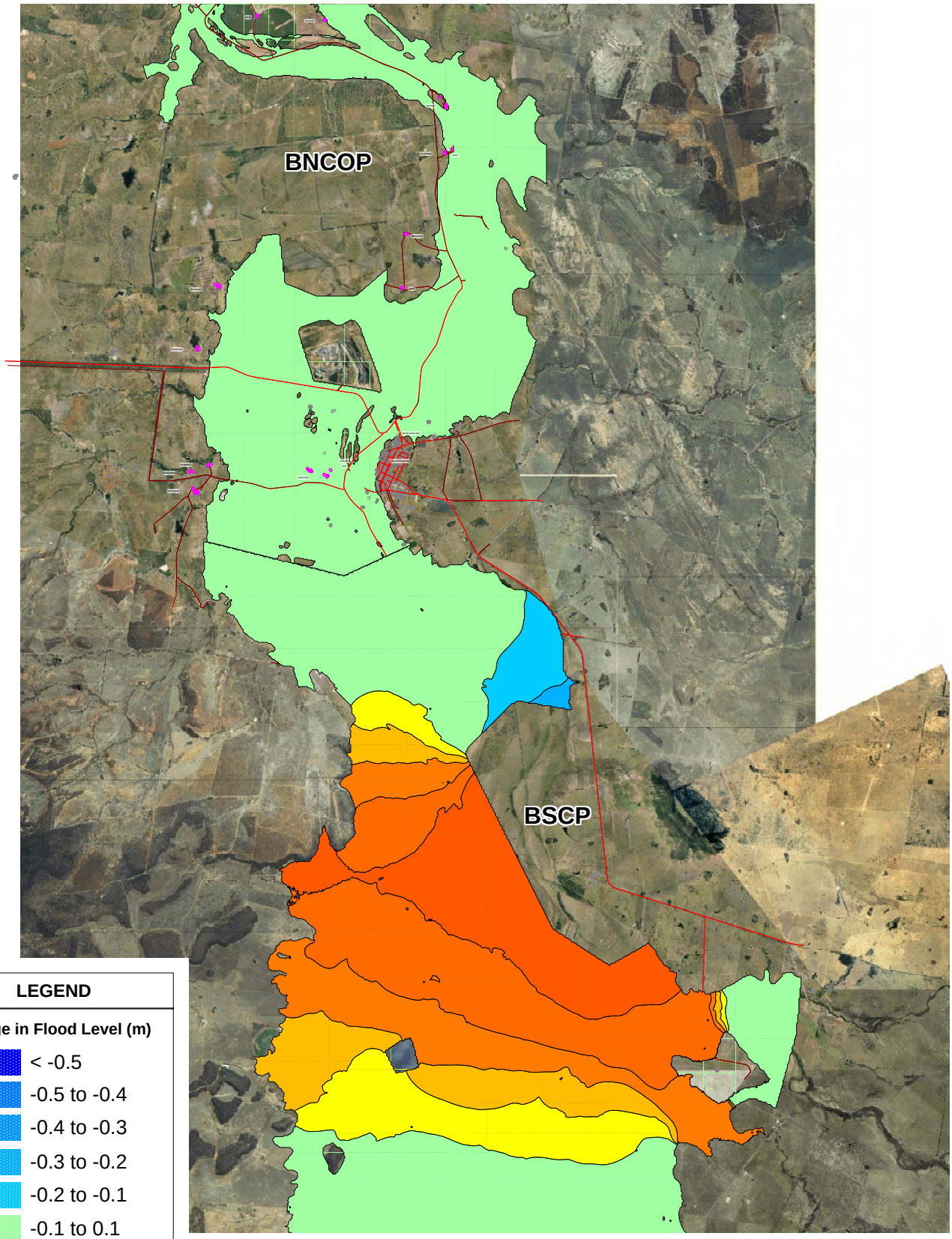
The latest flood study for the Baralaba South Coal Project is the draft Baralaba South Coal Project EIS Flood Impact Assessment (Water Solutions Dec 2012, unpublished), which provides a preliminary assessment of the flooding related impacts of that project.

With these two sites relatively close together on the same major river, an assessment has been undertaken of any likely interaction of the two proposals, with the aim of identifying any issues for the current BNCOP proposal, noting that issues solely related to the Baralaba South Coal Project may be addressed when that project is taken to the next stage.

The draft Baralaba South Coal Project EIS Flood Impact Assessment shows that the proposed levee surrounding the mine would impact on flood levels for a range of events, but that the impact dissipates well upstream of the Baralaba Central Mine site.

As an example, the change in the AEP 1 in 1000 flood level between the proposed and existing case for each report is plotted on a single map in Figure 8.5. It is noted that the two reports are based on models with different assumptions and parameters, however the relative change in a particular AEP event should be reasonably comparable between the two studies. This plot demonstrates that the impact of BSCP stops well upstream of the BNCOP.

As the impacts of the two proposals do not significantly interact, the later potential construction of the BSCP is not likely to affect the levee crest levels or flooding impacts of the BNCOP.



LEGEND

Change in Flood Level (m)

- < -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- > 1.0

Water Solutions

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Baralaba North Continued Operations Project
Flood Study

Indicative Cumulative Impacts with BSCP - AEP 1 in 1000

Job No. WS0715.1305	Revision: 3	**Figure 8.5**

File Name: WS130231_Fig8_5.wor

8.7 Sensitivity of Results to Climate Change

Estimates of the impact of climate change on rainfall and evaporation are progressively being updated as climate science evolves. CSIRO (2007) provides estimates of the change in rainfall and evaporation in the BNCOP regional area. Climate projections for the year 2030 were considered the most relevant projections given the proposed 15 year lifetime (Cockatoo Coal Sept 2013) of the BNCOP. Assuming a medium emissions scenario, the BNCOP region could expect to see mean annual rainfall levels drop by up to 5%. Whilst predictions suggest a lower mean annual rainfall, it is also predicted that rainfall in the wet season may actually increase by up to 2% (CSIRO, 2007). This suggests that rainfall events could have higher than average intensity or longer duration in the wet months. Under the same emissions scenario, the BNCOP region could expect to see mean evaporation increase by 2% (CSIRO, 2007).

However the CSIRO predicted changes are seasonal in nature, and do not directly provide advice on likely changes to the intensity of the rainfall events that lead to large, rare and extreme floods such as the AEP 1 in 20 to AEP 1 in 1000 events.

The Inland Flood Study (Qld Govt 2010) attempts to provide some advice on adjustments to design rainfall for climate change, proposing a 5 per cent increase in design rainfall intensity per degree of global warming, with the following temperature increases and planning horizons proposed: 2°C by 2050, 3°C by 2070 and 4°C by 2100.

Based on CSIRO's (2007) suggested average warming of 1°C by 2030, this means a possible increase in design rainfalls of 5% over the life of the mine. Increases in design rainfall would lead to increases in the peak flows, velocities and levels for design events.

The relative impact of the BNCOP (on flood levels and flow velocities) is not likely to change significantly with a 5% increase in design rainfalls, but a 5% increase in the design rainfalls would increase absolute flow velocities and levels. The main results of relevance for this study is the AEP 1 in 1000 flood level, which drives the required height of the levee. Increased design rainfalls from climate change will thus increase the risk of the levee overtopping slightly.

As a preliminary order of estimate, if the 5% increase in design rainfall led to a 5% increase in peak flow, this might translate to an increase in the AEP 1 in 1000 flood level of less than 0.1m, based on an approximate linear interpolation between the AEP 1 in 1000 and PMF results.

However the science on the quantification of climate change impacts on design rainfall is not strong, as acknowledged by the BOM in their 2003 review of the potential impact of climate change on the PMP:

> *In conclusion, although there is considerable uncertainty related to how rainfall may change in a warmer climate, there is an indication from both theoretical and climate models that changes in rainfall resulting from thermodynamic processes will lead to more frequent and perhaps more intense extreme events. In particular this will occur in regions with increase in mean precipitation. However, currently a quantitative assessment of changes to rainfall extremes cannot be made with the same level of confidence as for changes to atmospheric surface temperature. Improvements to the model dynamics of atmospheric process and parameterisation schemes, as well as increased model resolution will assist in providing better assessments of projected changes to extreme rainfall. Incorporation of more relevant downscaling approaches (statistical, dynamical and stochastic) will be useful for future assessments. (BOM 2003)*

In conclusion, the level of uncertainty is extremely large, but this very preliminary analysis suggests that a 0.1m increase in the levee crest may achieve an AEP 1 in 1000 flood immunity under projected 2030 climate conditions.

This very small increase is well within the accuracy of this study. The 0.5m freeboard recommended by DEHP (Feb 2012) is an allowance for a host of uncertainties in the flood and levee levels, including: the accuracy of data and models, effects of land use change on flood levels, riverine erosion and sedimentation, wave action and turbulence, erosion and settlement of the levee, changes in design rainfall techniques and climate change. With the estimated increase in flood levels from climate change being significantly less than the freeboard given in DEHP 2012, the standard allowance is considered to provide a reasonable safety factor for climate change over the design life of the mine.

8.8 Residual Risk

The design standard for mine sites is to construct a barrier (typically a levee or a sufficiently robust spoil pile) to prevent floods up to AEP 1 in 1000 from entering the mine site, as provided in DEHP (Feb 2012). This study has assumed that such a barrier is provided.

While it is extremely rare, events larger than the AEP 1 in 1000 may occur. In a larger event, it is likely that the levee will be overtopped and water will enter the operational mine area. Experience in historical events has shown that the flooding of mine operations can cause significant impacts on the mine and on third parties. The high regulatory design standard of AEP 1 in 1000 for protection against flood water ingress to mine sites reflects these potential impacts, however it is recognised that some residual risk remains.

Note that Section 8.9 includes a number of identified control strategies to minimise risks, including monitoring of the structure to ensure the AEP 1 in 1000 protection is not degraded over time, and consideration of preferential failure for events larger than AEP 1 in 1000 in the design to minimise the impacts of the unlikely, but possible, more extreme events. With these identified control strategies implemented, it is considered that the residual risk has been minimised.

8.9 Summary of Study Results Versus TOR

As indicated in Section 1.2, this report provides information to address the flooding related requirements of the *Final Terms of Reference (TOR) for the Baralaba North Continued Operations Project Environmental Impact Statement (EIS)* (DEHP 2014). The table below provides a summary of the study's conclusions against each of the relevant terms in the TOR.

Table 8.6 – Summary of Results against the Terms of Reference

Terms of Reference	Summary of Study Results
7.3.3 *Describe and illustrate where final voids and uncompacted overburden and workings at the end of operations would lie in relation to flood levels up to and including the 'probable maximum flood level' based on the Bureau of Meteorology's 'probable maximum precipitation' forecast for the locality.*	The flood maps in Appendix C for the final landform case illustrate the relation of the final landform features to a range of floods up to the PMF. In summary, flood water abuts the final landform spoil piles in some places in the assessed events, but does not overtop the spoil piles in any event. Flood water does not enter the residual void in events up to the AEP 1 in 1000 event.
7.6 *Flooding and regulated dams - Objective - The construction and operation of the project should aim to ensure the risk of, and the adverse impacts from flooding hazards or dam failure are avoided, minimised or mitigated to protect people, property and the environment.*	Section 8 describes the assessed flooding impacts of the proposed BNCOP. Section 9 identifies a number of control strategies to mitigate and address flooding impacts and risks identified in this study. With the implementation of the identified control strategies in Section 9, the flooding impacts of the proposed BNCOP on people, property and the environment are avoided, minimised or mitigated.
7.6.1 *Describe current flood risk for a range of annual exceedance probabilities up to the probable maximum flood, for potentially affected waterways, and assess (through flood modelling) how the project may potentially change flooding characteristics. The assessment should consider all infrastructure associated with the project including levees, roads and linear infrastructure and all proposed measures to avoid or minimise impacts.*	The flood risk of the site is described for a range of annual exceedance probabilities up to the PMF in Section 8 for three cases, the Existing/Approved Case, the Operational BNCOP Mine Case, and the Post Mine Case. The assessment has included the topography and infrastructure for each case as described in Section 7. Based on the assessment in this report, the project is not considered to significantly change the flood risk for surrounding properties or infrastructure.
8.7.1 *Describe the potential risks to people and property that may be associated with the project in the form of a preliminary risk assessment for all components of the project and in accordance with relevant standards. The assessment should include:* ▪ *potential hazards, accidents, spillages, fire and abnormal events that may occur during all stages of the project, including estimated probabilities of occurrence* ▪ *identifying all hazardous substances to be used, stored, processed or produced and the rate of usage* ▪ *potential wildlife hazards, natural events (e.g. cyclone, storm tide inundation, flooding, bushfire) and implications related to climate change.* ▪ *how the project may potentially affect hazards away from the project site (e.g. changing flooding characteristics).*	The assessed impacts of flooding associated with the project on people and property, both near and away from the site, are described in Section 8. Risks are considered to be minimised by the implementation of the identified control strategies in Section 9, although it is noted that some very low probability risks remain, as described in Section 8.8. Implications for flooding related to climate change described in Section 8.7. Over the projected life of the BNCOP, climate change is considered unlikely to significantly change the assessed flooding impacts of the BNCOP.

9 Identified Control Strategies

The following sections outline a number of identified control strategies to mitigate and address flooding impacts and risks identified in this study.

9.1 Flood Protection Levee Crest Level

Development of the BNCOP mining area will require a flood protection levee to protect against the estimated AEP 1 in 1000 flood, in accordance with the guidance in the DEHP (Feb 2012). The levee may take the form of a purpose built levee, or alternatively a sufficiently robust spoil pile may act as a levee to provide the necessary protection.

Figure B.4 shows the flood levels for the AEP 1 in 1000 event. The southern part of the BNCOP is protected by the previously approved Baralaba North/Wonbindi North levee. From this figure it can be seen that AEP 1 in 1000 event levels along the Baralaba North/Wonbindi North levee is between 88 and 88.5m AHD. The Hydraulic Certification of this levee (Water Solutions July 2013) showed the AEP 1 in 1000 levels along this levee were 88.4 to 89.1m AHD, and assessed that the design crest levels of the levee met the AEP 1 in 1000 plus freeboard requirement. While the previously approved Baralaba North/Wonbindi North levee is not the subject of this EIS, the Baralaba North/Wonbindi North levee is assessed to provide AEP 1 in 1000 flood protection to the southern side of the BNCOP based on these results.

On the northern side of the BNCOP, Figure B.4 shows the modelled AEP 1 in 1000 flood level is between about 83.8m and 84.7m AHD. It is noted that the downstream boundary may significantly affect absolute flood levels in this location, see the discussion in Section 3.10. At this stage it is considered prudent to add an additional 1m to the AEP 1 in 1000 levels in this location to provide a safety factor for the boundary effect. This allowance may be able to be refined in the detailed design stage.

The terrain along the boundary undulates across a number of small gullies, and levees will be required in a number of these gullies to provide the required flood protection, while in other locations the natural terrain will be sufficient.

The AEP 1 in 1000 flood level in Saline Creek is a little higher, up to 86.5m AHD, however the terrain is steep in this section and the flood extent does not reach the BNCOP boundary, so no levee is required adjacent to Saline Creek.

A minimum freeboard should be added to the estimated AEP 1 in 1000 flood levels to set the levee embankment crest levels. Freeboard accounts for a wide range of factors that are not accurately modelled in the hydraulic model, such as minor settlement and erosion of the levee, modelling uncertainties and wave action. The Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM Feb 2012) specifies that a minimum freeboard of 0.5m should be applied to regulated levees. Given the standard of analysis undertaken in this study, a minimum freeboard of 0.5 is considered appropriate. Hence the levee crest level should be a minimum of 0.5m higher that the levels provided.

Events larger than the AEP 1 in 1000 year event are rare but can occur, and it is prudent to consider a preferential failure strategy for larger events that provides additional protection to more important areas and encourages the levees to fail in a position where damage is limited. The Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM Feb 2012) recommends that “in at least one place in the levee crest, there must be a restricted length of low

crest, limiting the freeboard at that point, such that a flood exceeding the design protection level of the levee will be directed to a planned area."

Thus the levee system should include a low spot (relative to the flood slope for the design event) to initiate failure in the least damaging location. This location will typically be on the downstream side of the levee, not immediately adjacent to the main river, and away from sensitive locations, for example, equipment stores and offices. The low spot should be sufficiently lower that the next lowest point on the levee (relative to the flood slope) to ensure failure in the planned location.

The detailed design of the levee should include the design of an appropriate preferential failure strategy. Note that from a flood performance point of view, the as-constructed crest level of the levee may be higher than the minimum levels given in this report, which might be desirable to, for example, simplify construction. However care should be taken to maintain sufficient difference to encourage overtopping to occur at the designated preferential failure location.

9.2 Erosion Protection of the Levee

While the previously approved Baralaba North/Wonbindi North levee is not the subject of this assessment, velocities along the Baralaba North/Wonbindi North levee are lower than previous estimates, and thus it is unlikely that additional erosion protection will be required on this levee.

Velocities along the northern boundary of the levee for events up to the AEP 1 in 1000 are moderate, under 1.5m/s, and thus extensive erosion protection measures are unlikely to be required.

9.3 Erosion Protection of the Final Landform

Velocities in the final landform case up to the AEP 1 in 1000 case are moderate. Some small sections of velocities approaching 1.5m/s are present on some of the corners of the final landform feature on top of the former Baralaba Central site, see Figure C.4. (These areas are highlighted in the massive PMF flood, see Figure C.5, although it is noted that providing full protection against erosion in such a large event is not feasible.)

The areas of high velocity in the AEP 1 in 1000 event are small, and there are areas downstream in the natural section of the stream with higher velocities. Some minor erosion may occur on the corner of the final landform features. Ensuring good vegetation is established on these features is likely to provide sufficient protection against erosion. Additionally, consideration may be given to some slight smoothing of the corners of the final Baralaba Central landform to reduce the risk of erosion in the detailed design.

It is noted that the above discussion is focused on erosion originating from major Dawson River floods. Erosion from other sources (such as direct rainfall, local runoff and wind) will also need to be considered in the detailed design.

9.4 Monitoring

A monitoring program should be implemented to address residual risks and identify issues related to flooding before they become major problems. The monitoring program should include regular monitoring of flood levees to identify any issues that might affect its performance, and also after major flood events. Such monitoring should include a visual inspection and a survey of levee crest levels to identify any issues with erosion, settlement or slumping.

If a significant flood event occurs in the future, records of flood levels, effects and timing should be obtained to assist with future flooding investigations at this site.

10 Conclusions

This flood study has been prepared to assess flooding related issues associated with the proposed BNCOP to meet the requirements of the EIS Terms of Reference.

In this study previously developed flood models have been reviewed and updated, including a review of stream gauge rating curves, extension and calibration of the hydraulic and hydrology models, and an updated flood frequency analysis. The hydraulic and hydrology models were calibrated and verified against a range of recorded data for the large December 2010 event. The developed hydraulic and hydrology models are considered to be suitable for the purposes of evaluating potential flooding impacts related to the BNCOP for the EIS.

Design flood hydrographs for the AEP 1 in 20, 1 in 50, 1 in 100, and 1 in 1000 events have been developed based on CRC-FORGE design rainfalls and the calibrated hydrology model for Dawson River and Saline Creek floods. The BOM GTSMR method was used to estimate the peak flow for the PMF in the Dawson River. Three cases have been modelled, the Existing/Approved Case, Operational BNCOP Mine Case, and the Post Mine Case. The impact of the BNCOP on flood levels, flow velocity and stream morphology has been evaluated.

The key conclusions of this study are as follows:

- The BNCOP is not considered to result in any significant change to the flood risk for surrounding properties or infrastructure.
- This study identifies a number of control strategies to mitigate and address flooding impacts and risks. This includes construction, maintenance and monitoring of levee banks (or sufficiently robust spoil piles) to provide AEP 1 in 1000 protection, with appropriate freeboard allowances and provision for preferential failure.
- The risk of increased erosion and geomorphologic change to the river from the project is considered low.
- In the post-mining scenario, flood water abuts the final landform spoil piles in some places in the assessed events, but does not overtop the spoil piles in any event. Flood water does not enter the residual void in events up to the AEP 1 in 1000 event.

In conclusion, provided the BNCOP is developed in accordance with the features and control strategies identified in this report, the flooding impacts of the proposed BNCOP on people, property and the environment are considered to be avoided, minimised or mitigated.

11 References

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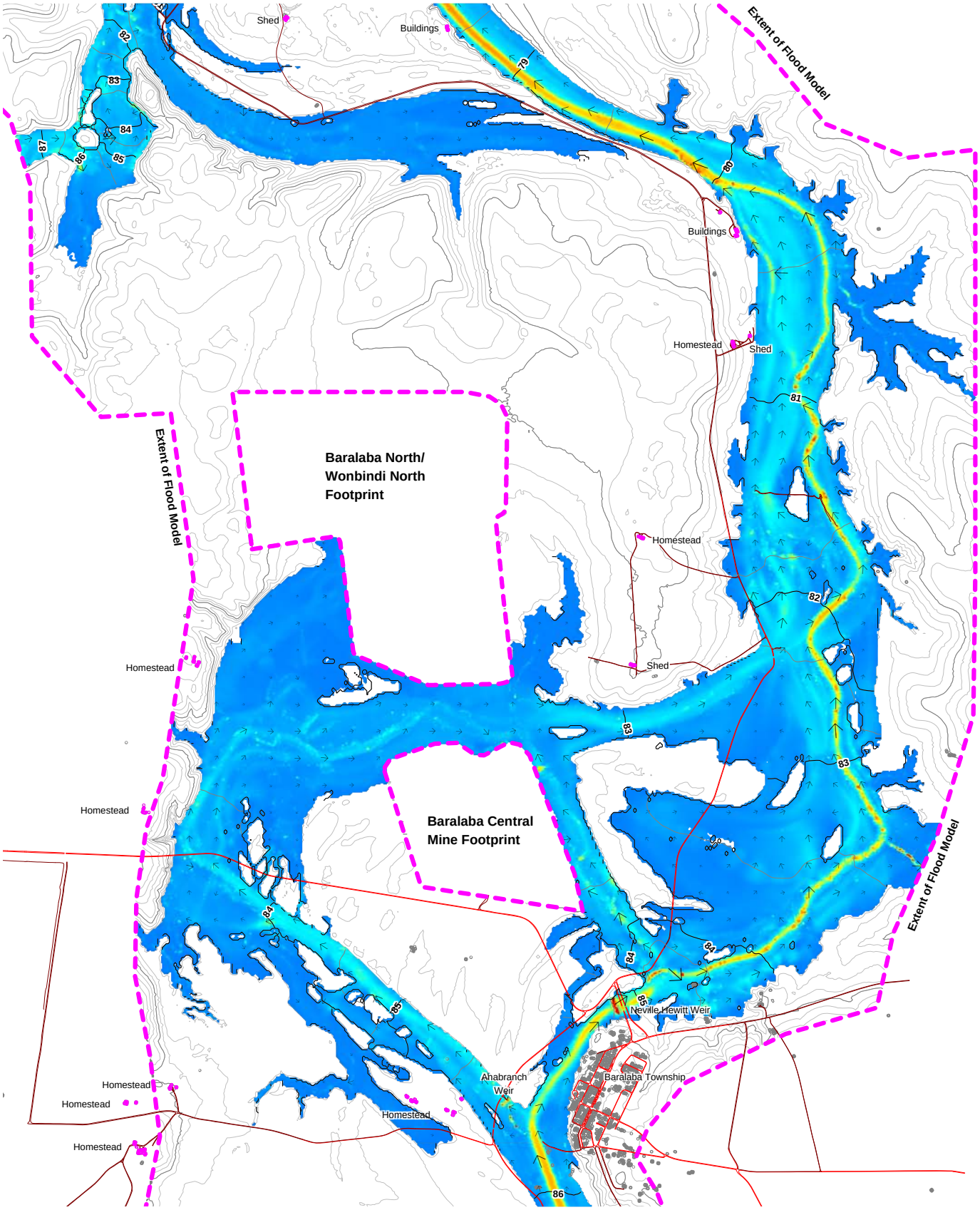
Appendix A

Water Level and Velocity Maps – Existing/Approved Case



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

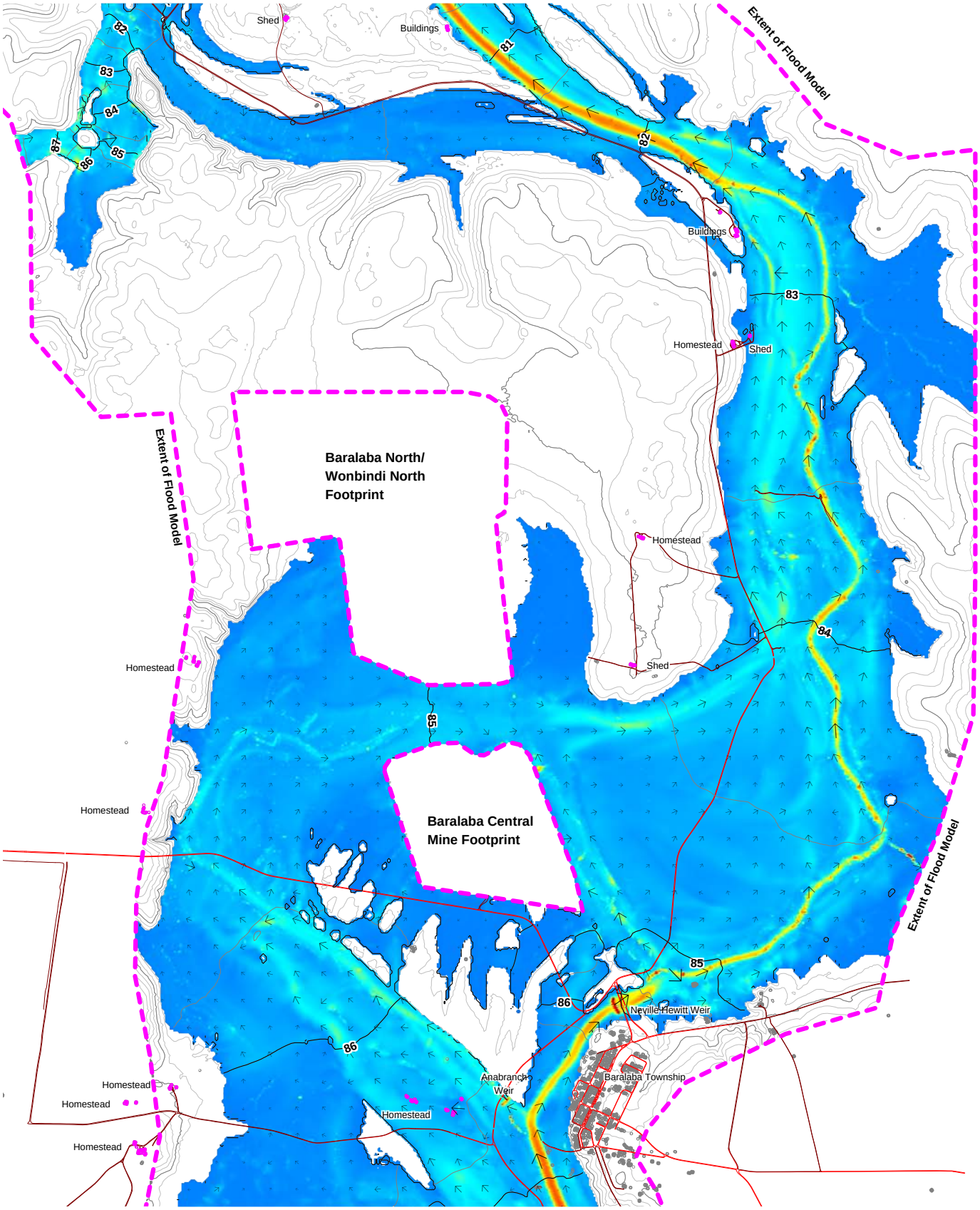
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Existing/Approved Case - AEP 1 in 20 Velocity & Water Level

Job No. WS0715.1305	Revision: 3	**Figure A.1**

File Name: WS130231_FigA_1.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

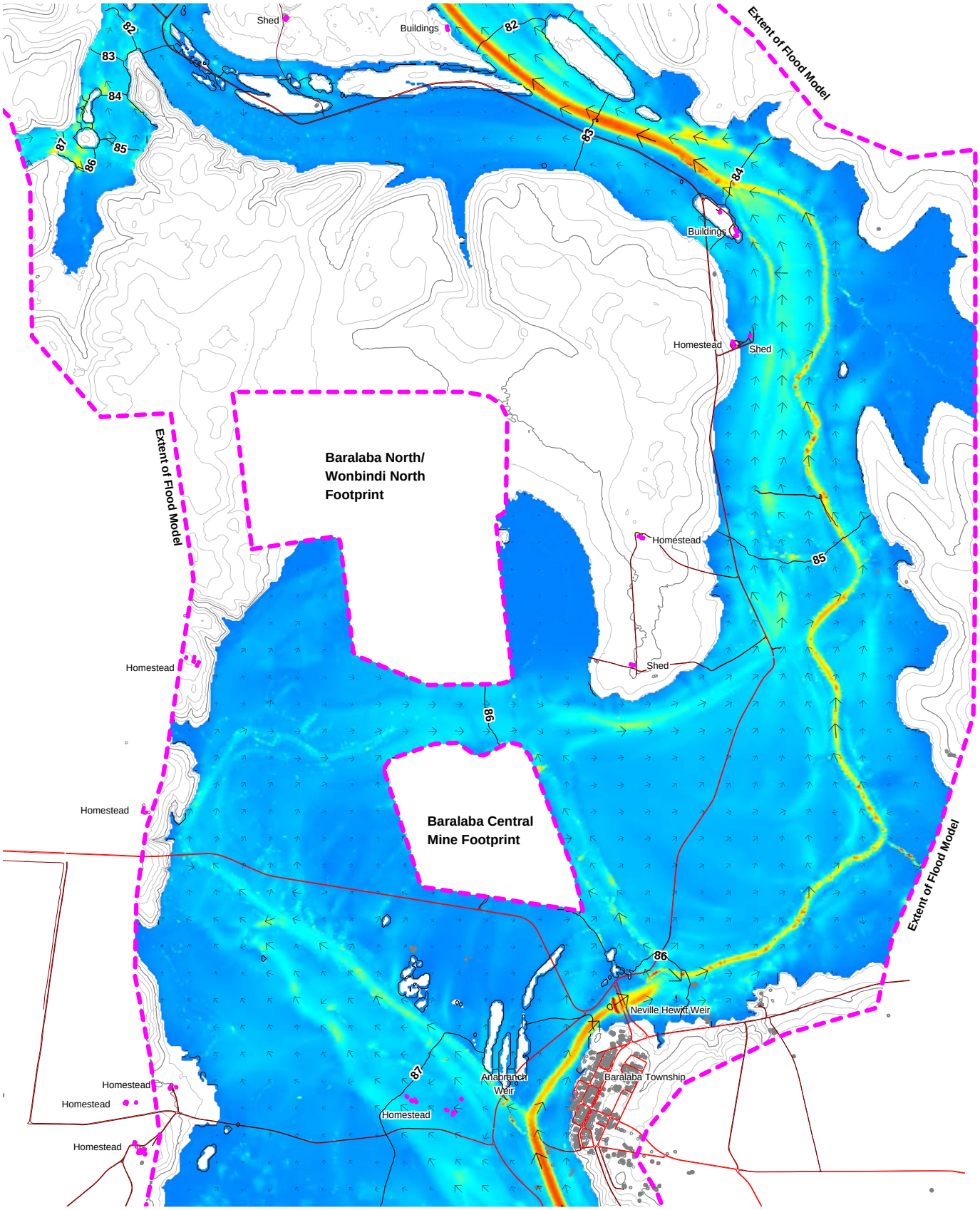
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Existing/Approved Case - AEP 1 in 50 Velocity & Water Level

Job No. WS0715.1305	Revision: 3	**Figure A.2**

File Name: WS130231_FigA_2.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

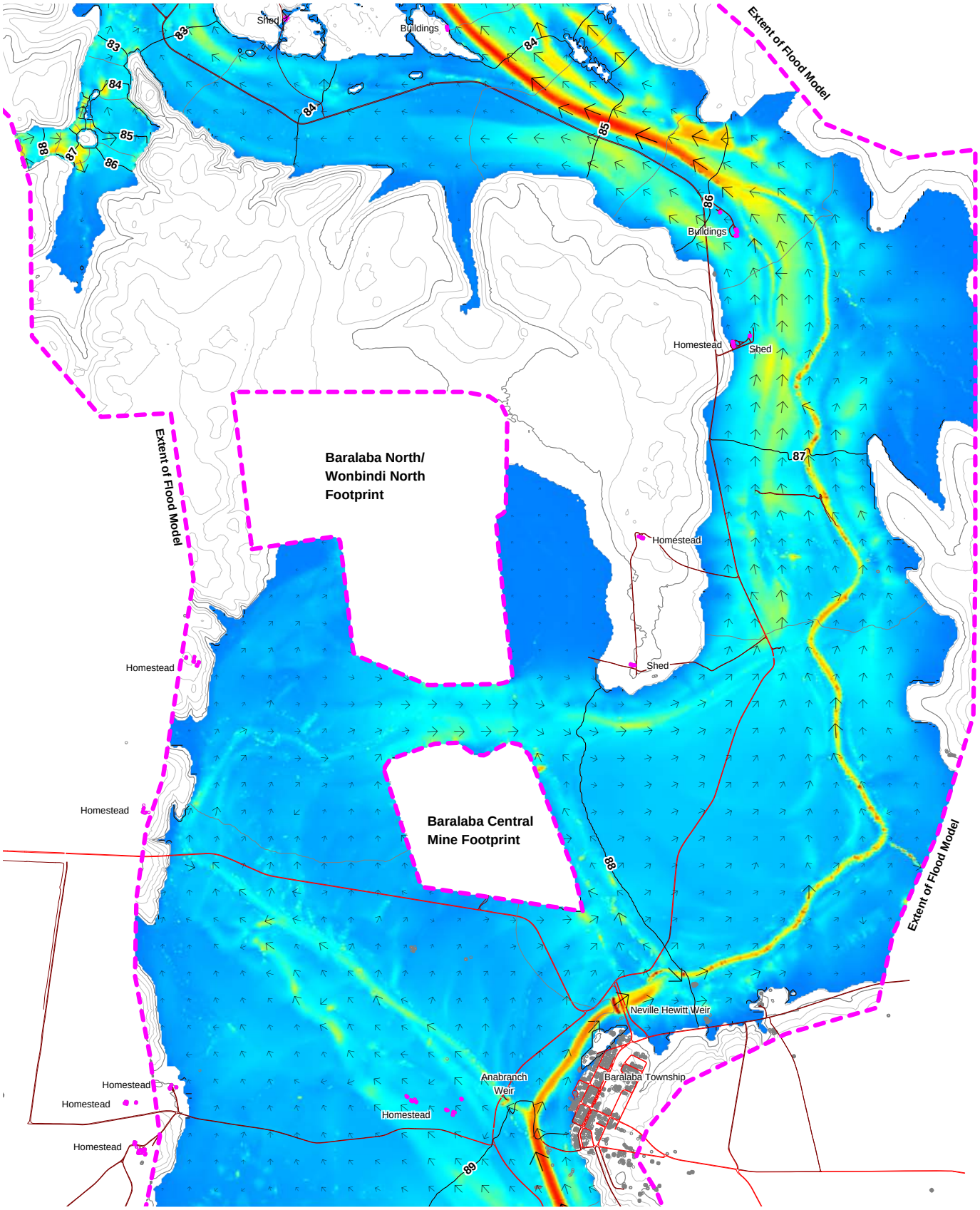
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Existing/Approved Case - AEP 1 in 100 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure A.3**

File Name: WS130231_FigA_3.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

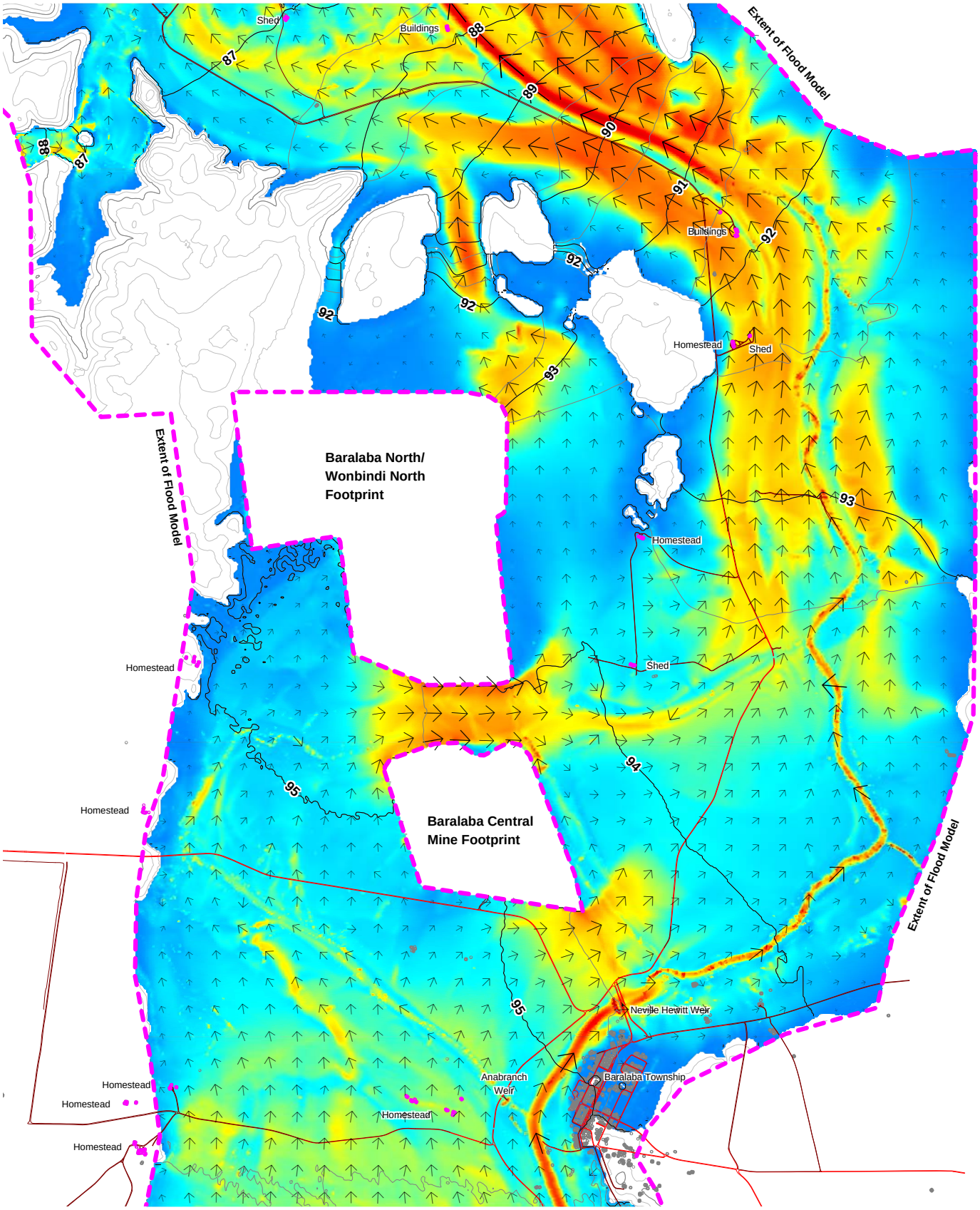
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Existing/Approved Case - AEP 1 in 1000 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure A.4**

File Name: WS130231_FigA_4.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

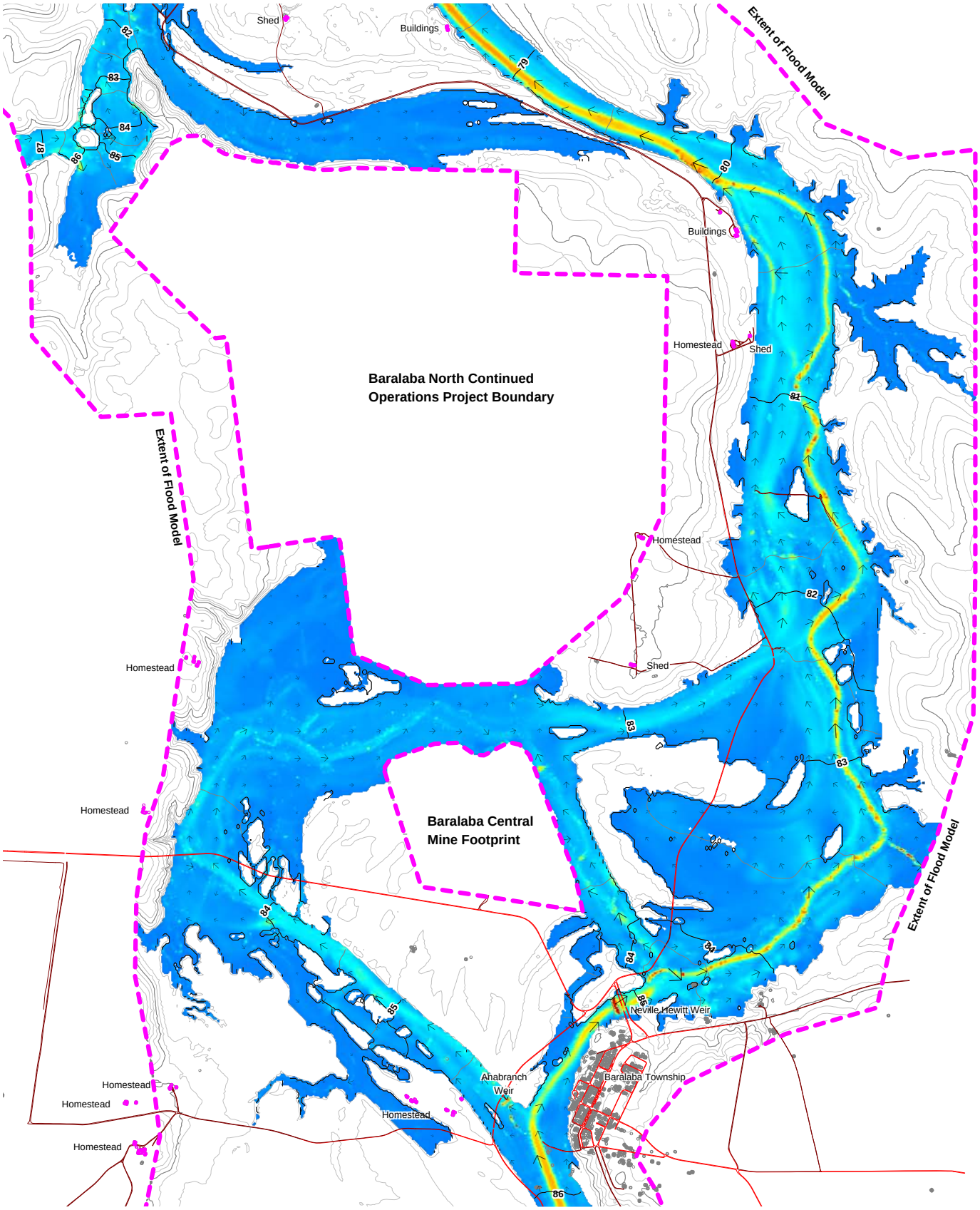
Existing/Approved Case - PMF Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure A.5**

File Name: WS130231_FigA_5.wor

Appendix B

Water Level and Velocity Maps – Operational BNCOP Mine Case



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

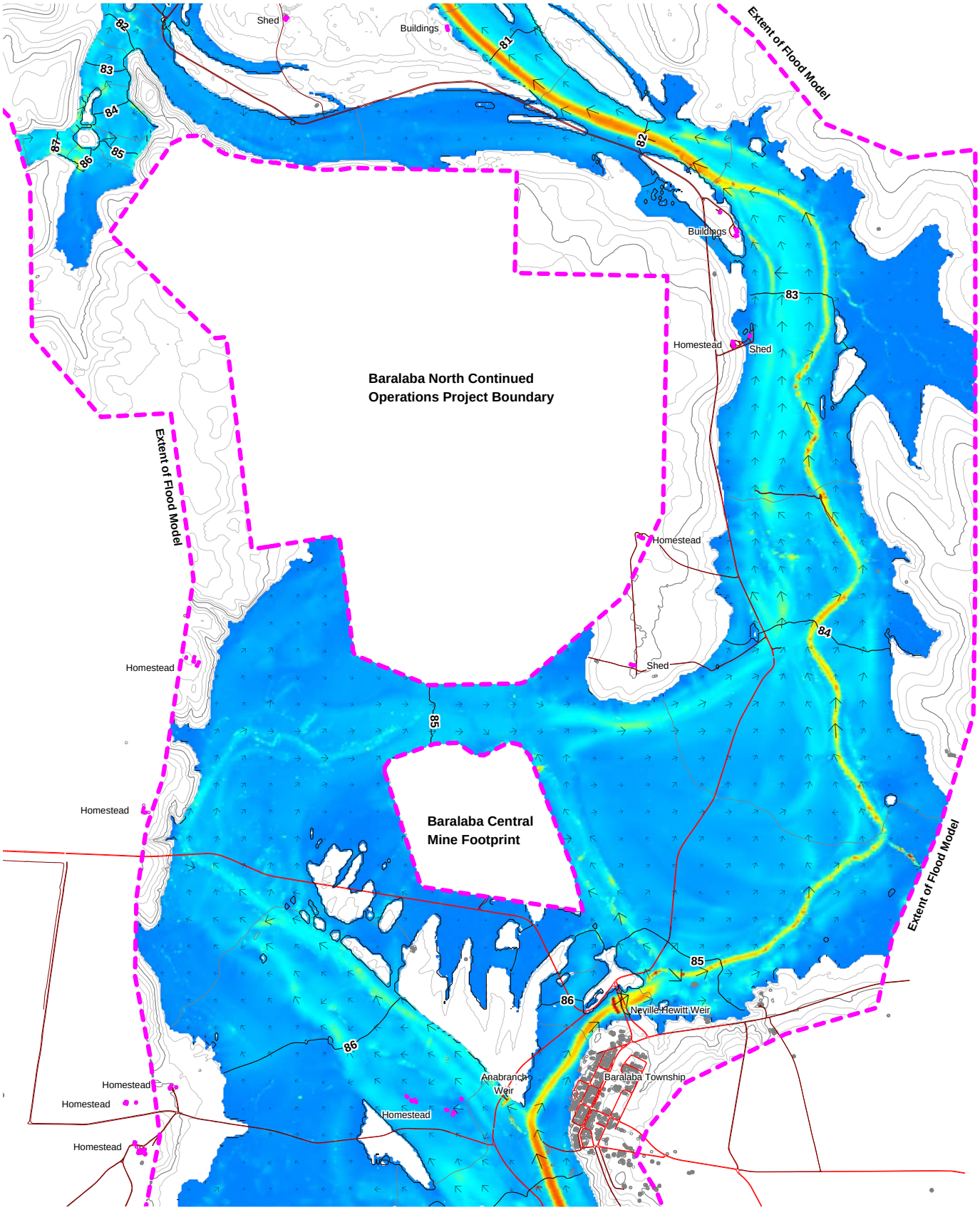
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Operational Case - AEP 1 in 20 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure B.1**

File Name: WS130231_FigB_1.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Operational Case - AEP 1 in 50 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure B.2**

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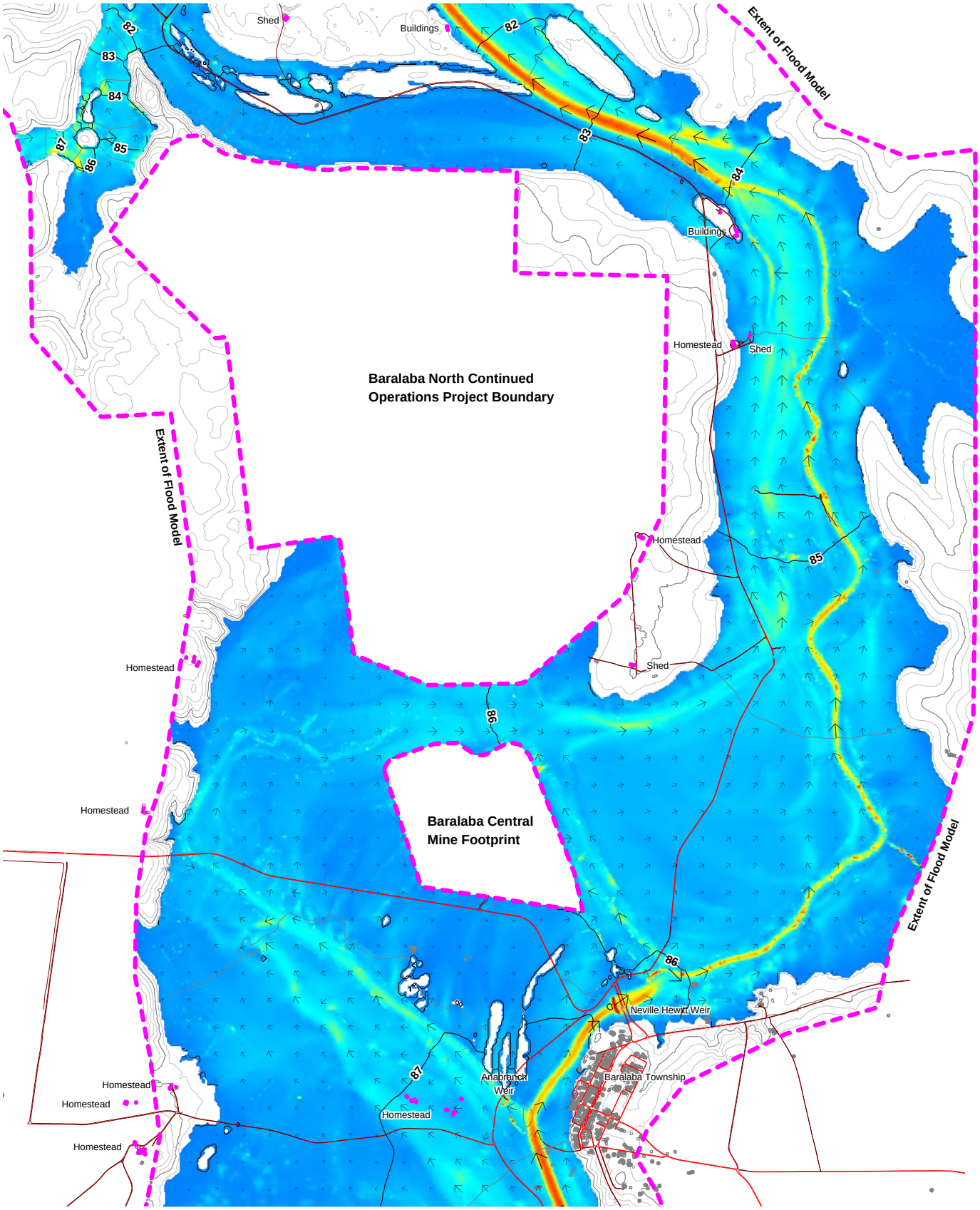

0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Operational Case - AEP 1 in 100 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure B.3**

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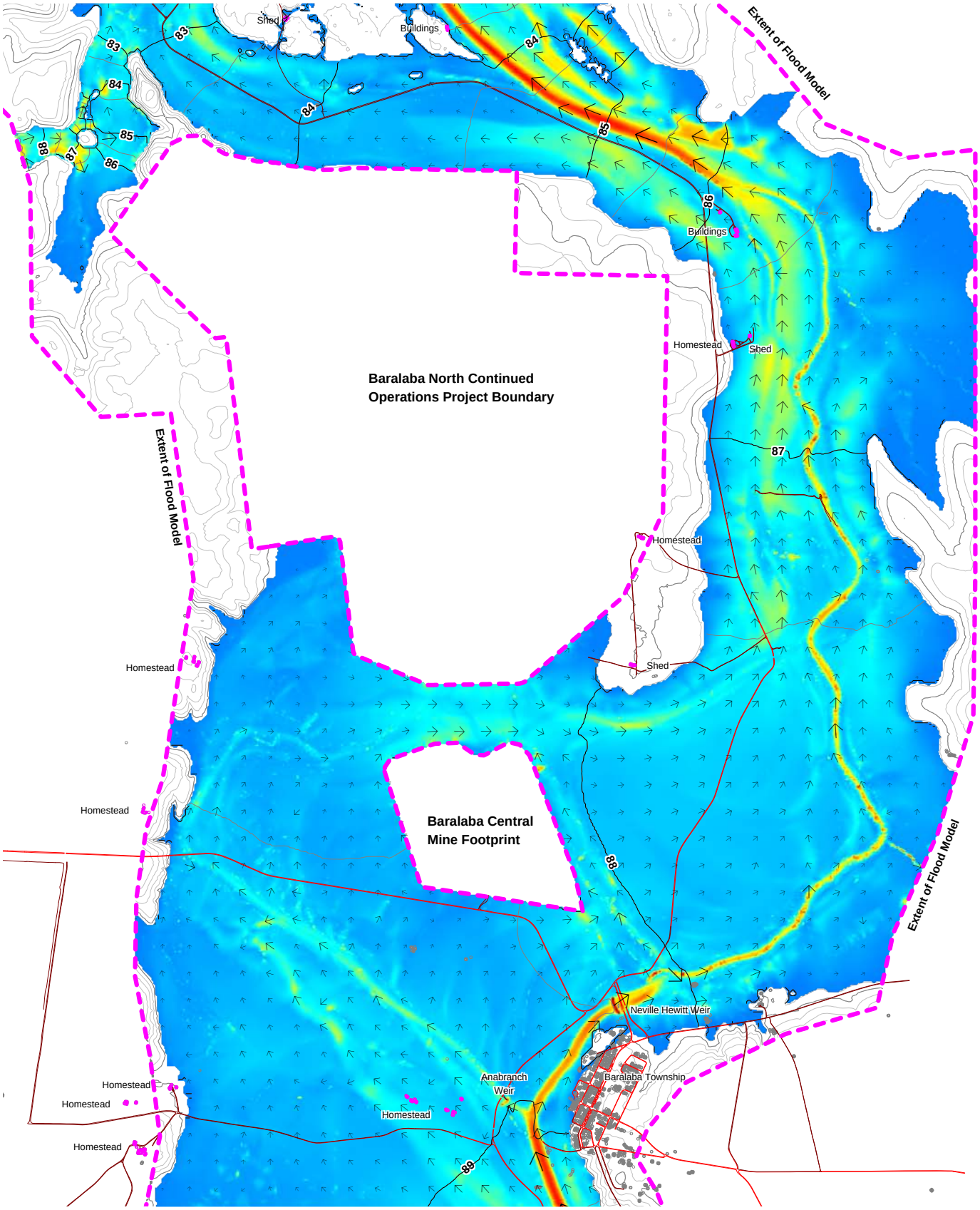

0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Operational Case - AEP 1 in 1000 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure B.4**

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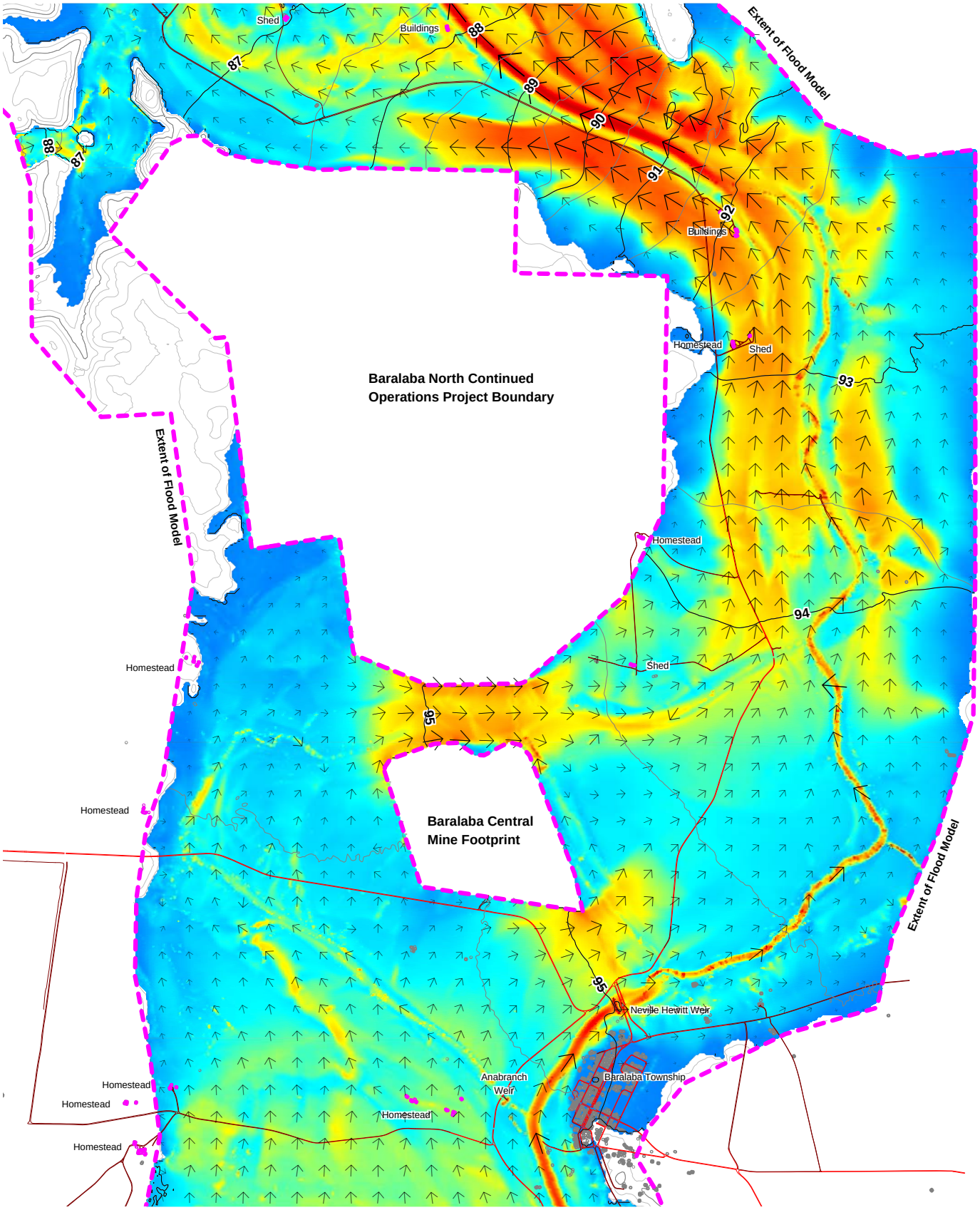


0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

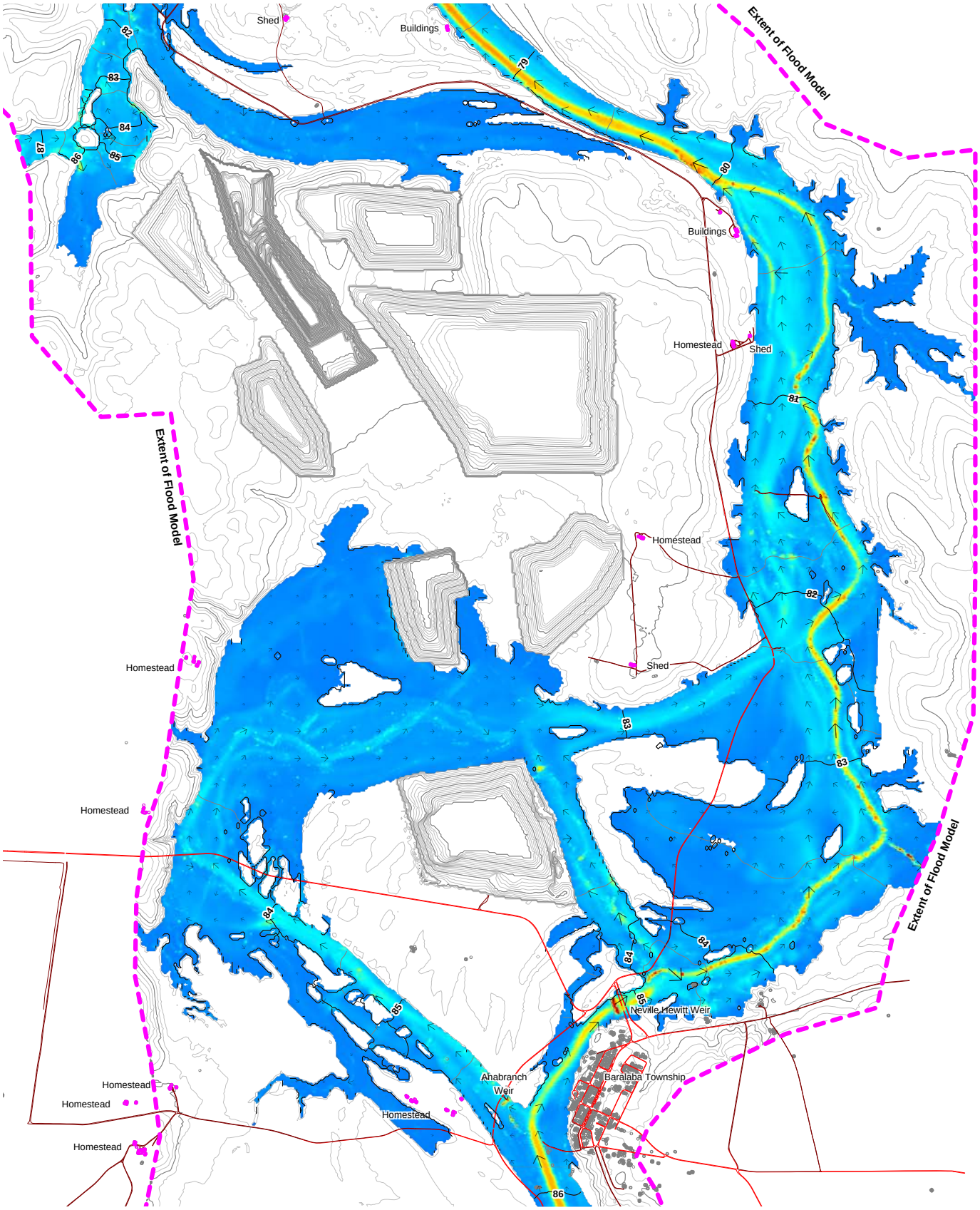
Operational Case - PMF Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure B.5**

File Name: WS130231_FigB_5.wor

Appendix C

Water Level and Velocity Maps – Post Mine Case



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

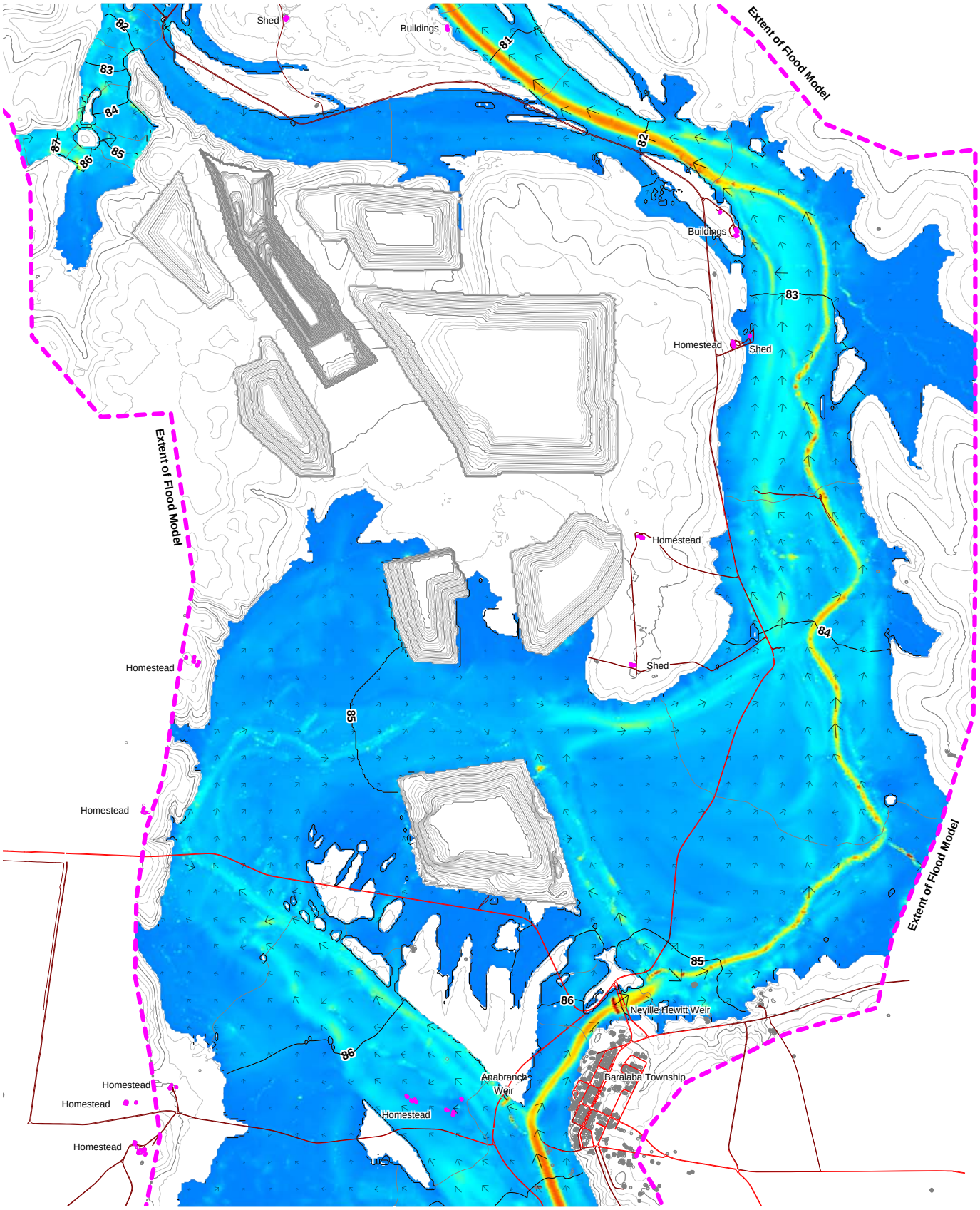
Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Post Mine Case - AEP 1 in 20 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure C.1**

File Name: WS130231_FigC_1.wor



0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Post Mine Case - AEP 1 in 50 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure C.2**

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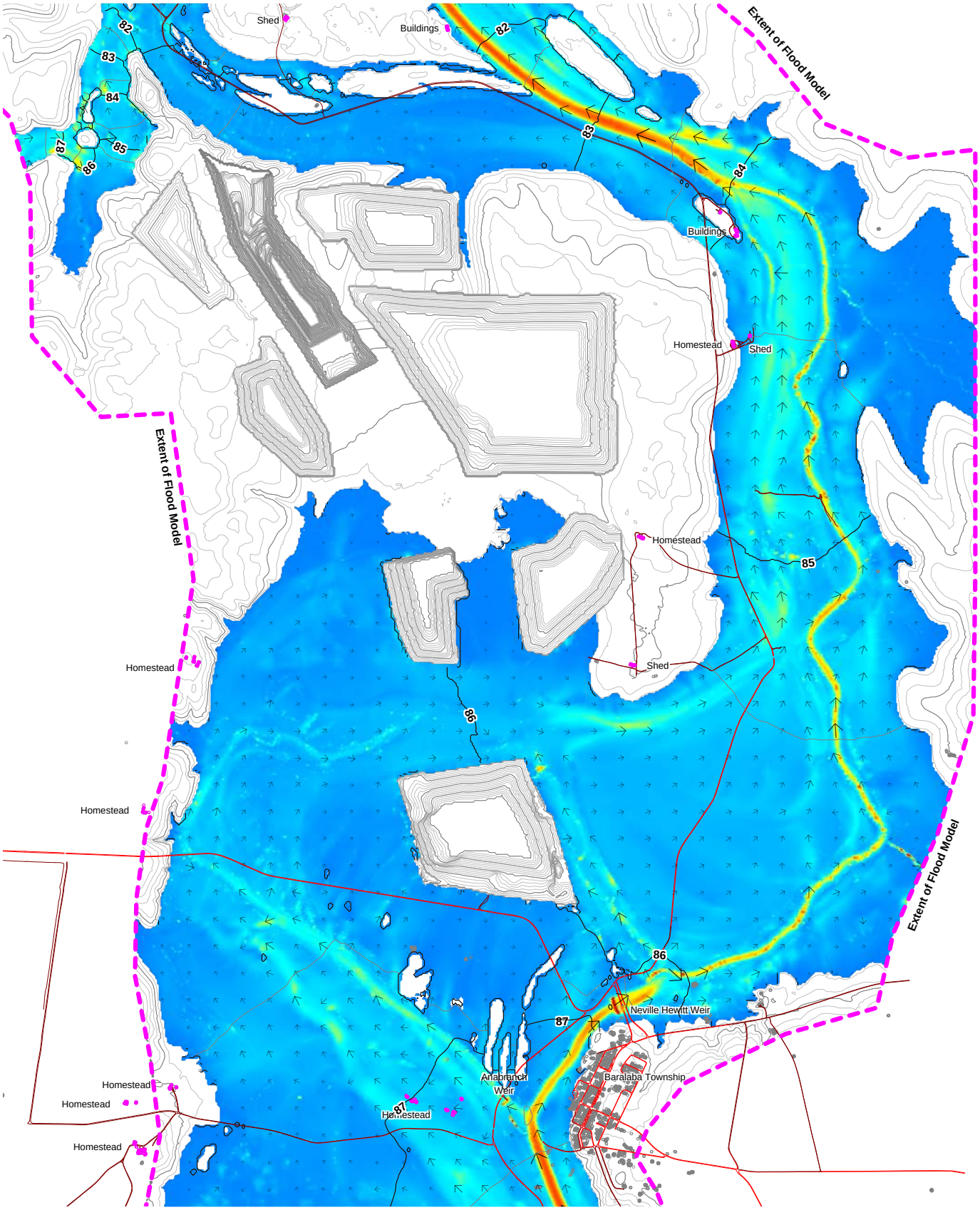

0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Post Mine Case - AEP 1 in 100 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure C.3**

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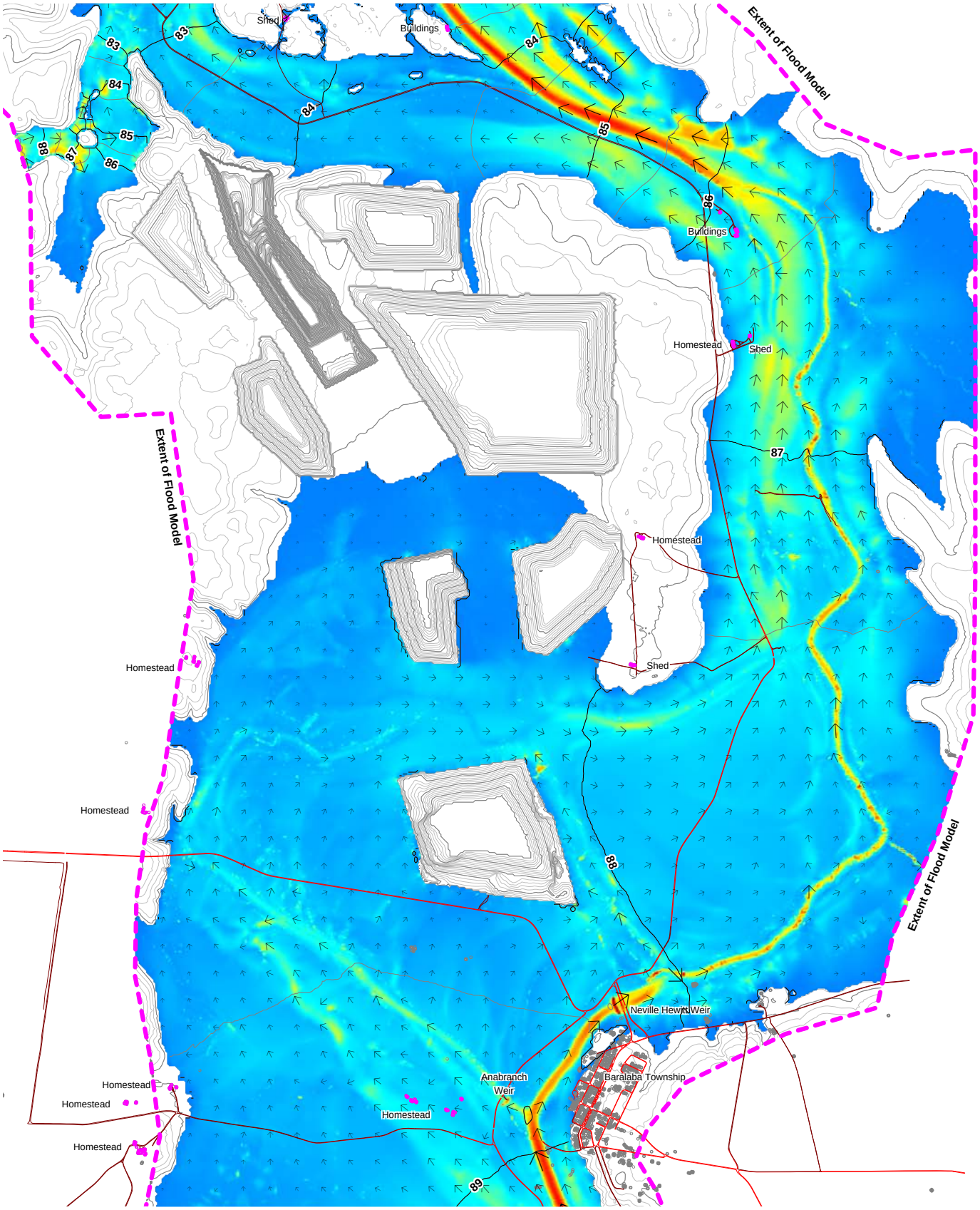

0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

Post Mine Case - AEP 1 in 1000 Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure C.4**

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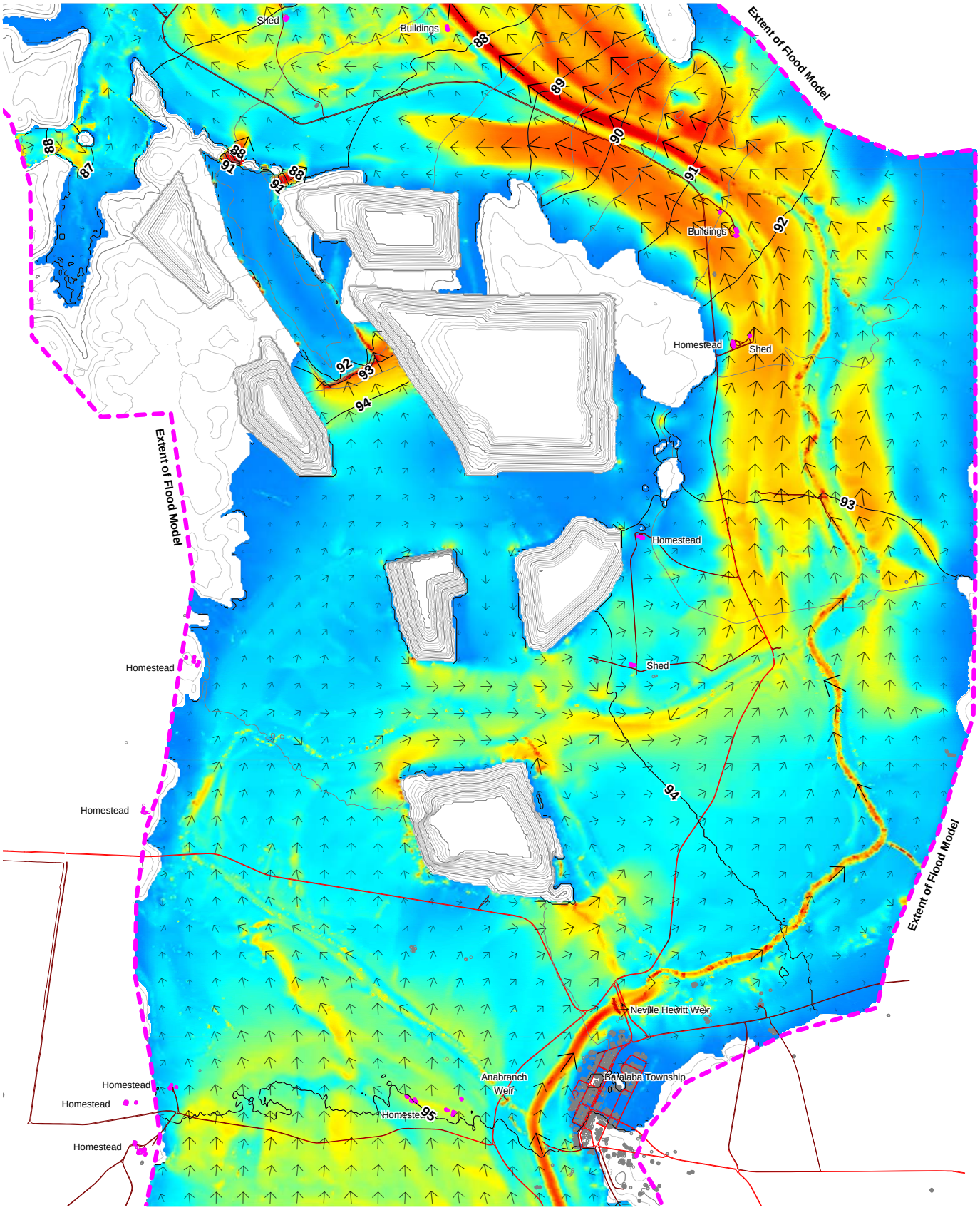


0 1 2
kilometres

LEGEND

Velocity (m/s)

- 3.5
- 2.5
- 1.5
- 1.0
- 0

Flow Direction

Water level contour

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

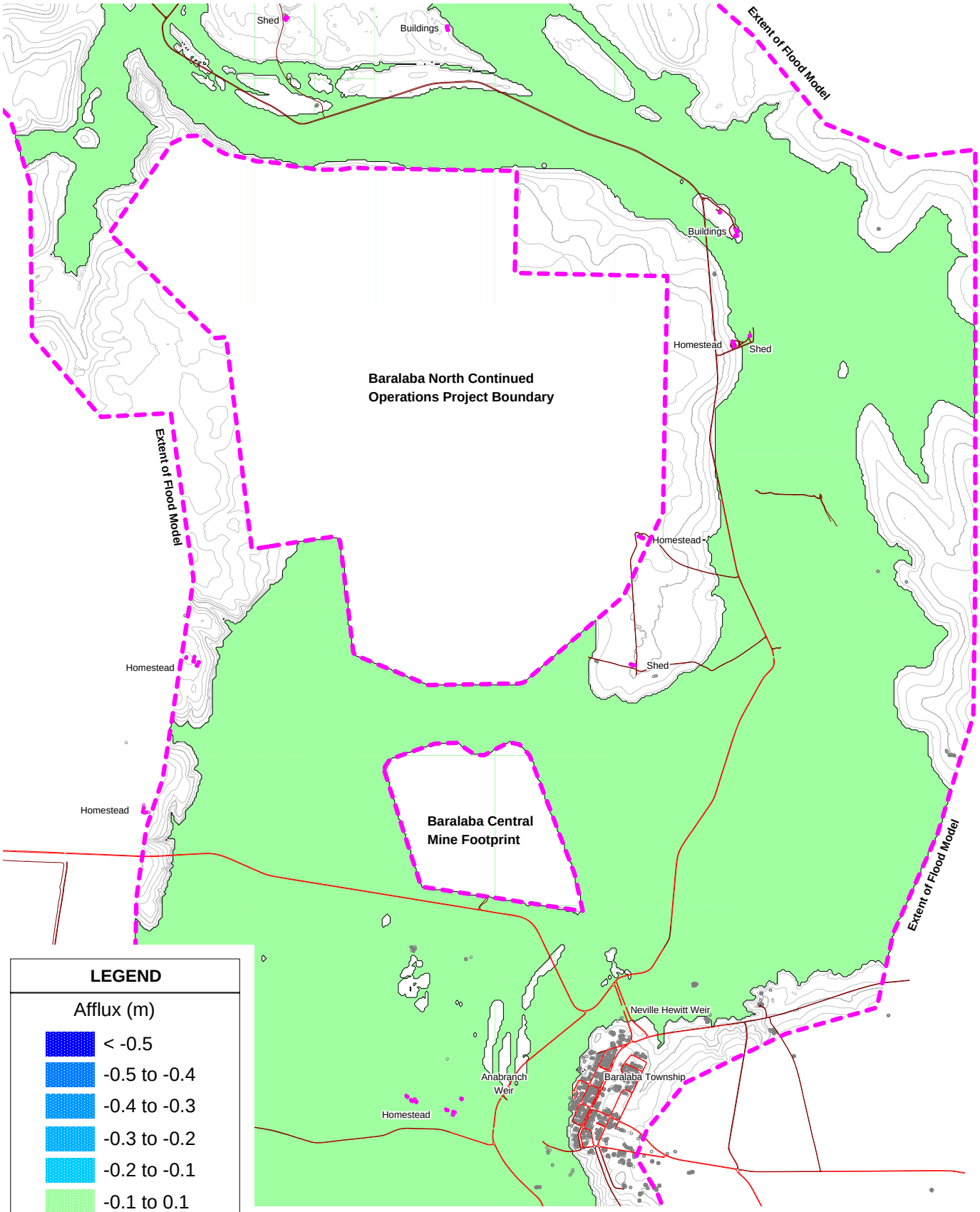
Post Mine Case - PMF Velocity & Water Level

Job No. WS0715.1305 | Revision: 3 | **Figure C.5**

File Name: WS130231_FigC_5.wor

Appendix D

Afflux and Velocity Change Maps – AEP 1 in 100 Event



LEGEND

Afflux (m)

- < -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- > 1.0

0 1 2
kilometres

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

AEP 1 in 100 Afflux (Operation Case - Existing/Approved Case)

Job No. WS0715.1305 | Revision: 3 | **Figure D.1**

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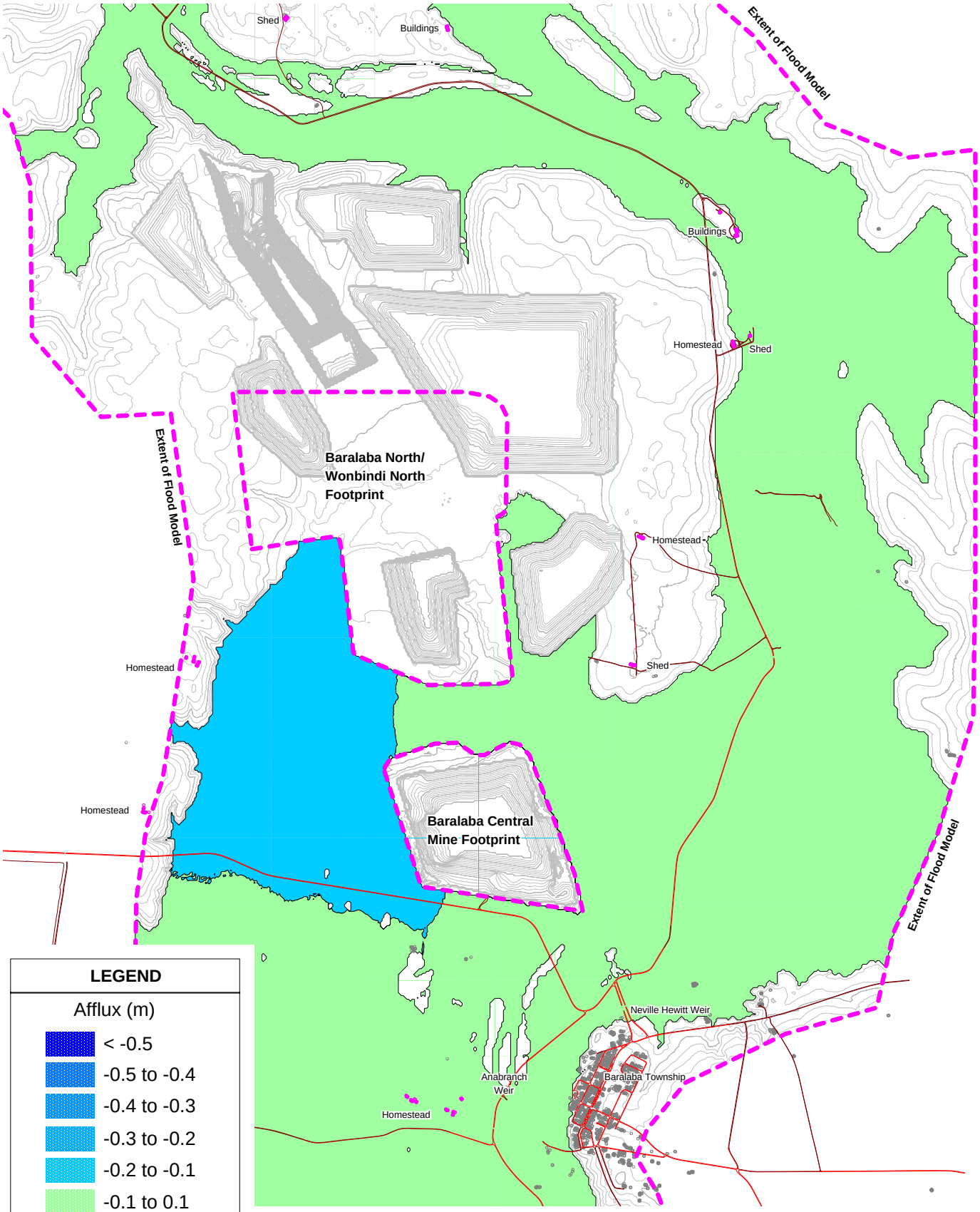

LEGEND

Afflux (m)

- < -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- > 1.0

0 1 2
kilometres

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

AEP 1 in 100 Afflux (Post Mine Case - Existing/Approved Case)

Job No. WS0715.1305 | Revision: 3 | **Figure D.2**

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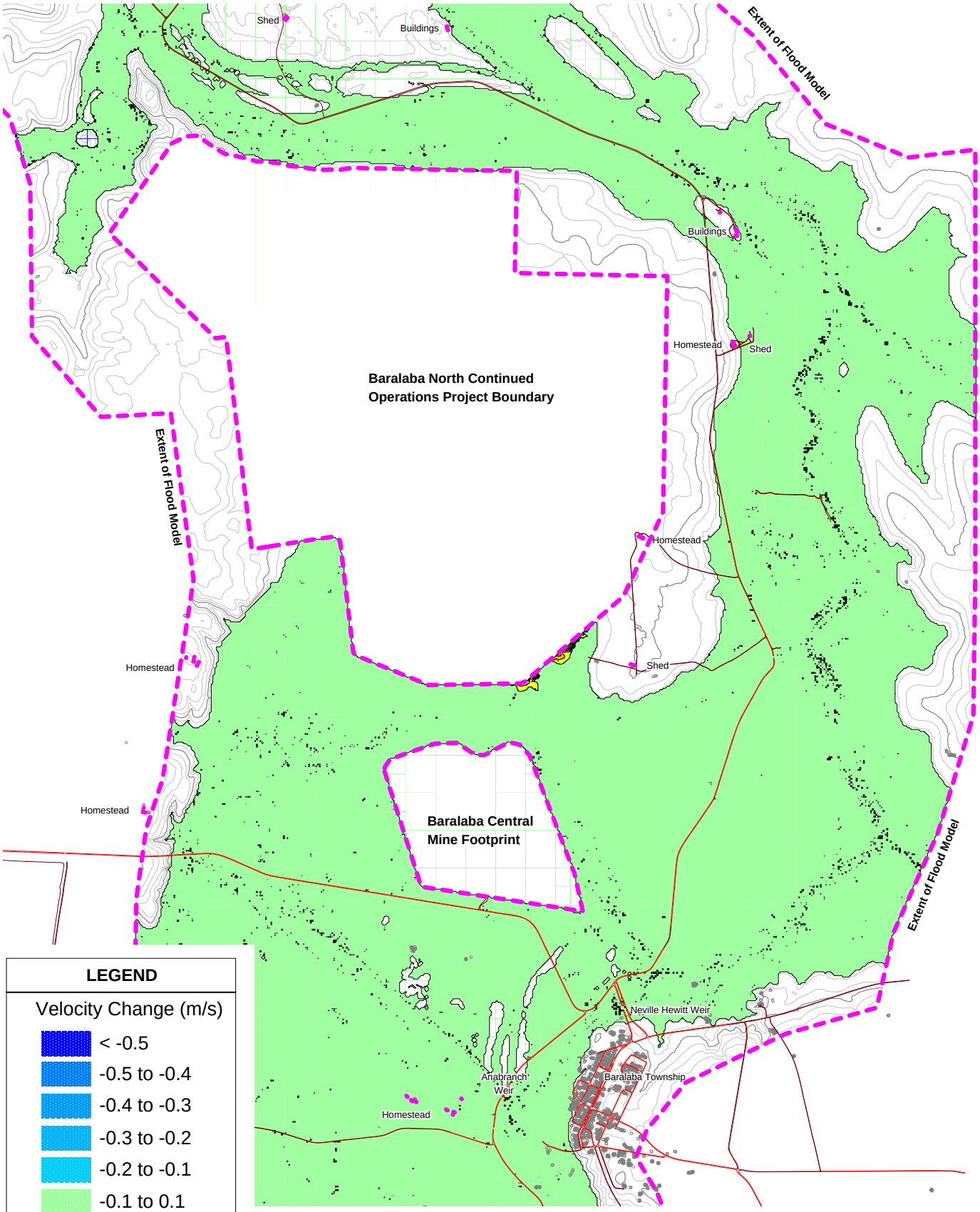

LEGEND

Velocity Change (m/s)

- < -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- > 1.0

0 1 2
kilometres

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

AEP 1 in 100 Velocity Change (Operation Case - Existing/Approved Case)

Job No. WS0715.1305 | Revision: 3 | **Figure D.3**

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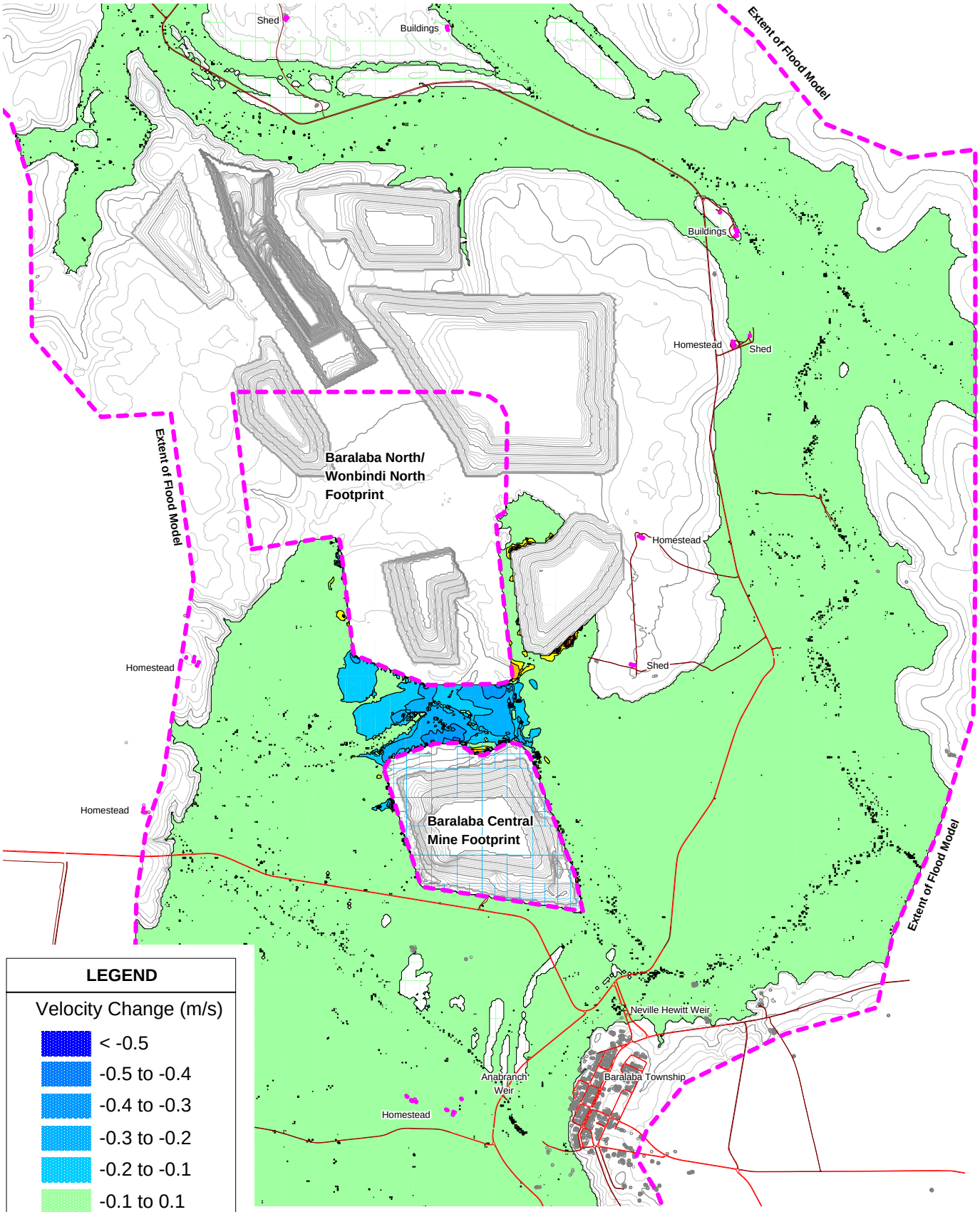

LEGEND

Velocity Change (m/s)

- < -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.7
- 0.7 to 1.0
- > 1.0

0 1 2
kilometres

Water Solutions

Cockatoo Coal Ltd.

Baralaba North Continued Operations Project
Flood Study

AEP 1 in 100 Velocity Change (Post Mine Case - Existing/Approved Case)

Job No. WS0715.1305 | Revision: 3 | **Figure D.4**

File Name: WS130231_FigD_4.wor

Appendix F. Geochemistry Assessment

TERRENUS
EARTH SCIENCES

Geochemistry Assessment

BARALABA NORTH CONTINUED OPERATIONS PROJECT

April 2014

Prepared for:

Cockatoo Coal Limited

Geochemistry Assessment

BARALABA NORTH CONTINUED OPERATIONS PROJECT

Prepared for:

Cockatoo Coal Limited

DOCUMENT CONTROL			
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Project Name	Baralaba North Continued Operations Project		
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Report Number	13-017-63 / R001		
Author	Dr. Ian P. Swane (Terrenus Earth Sciences)		
Technical Review	Dr. Alan M. Robertson (RGS Environmental)		

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EXECUTIVE SUMMARY

Terrenus Earth Sciences (Terrenus) has completed a geochemical assessment of potential mining waste materials from the proposed northern expansion of the existing Baralaba Coal Mine. The northern expansion is referred to as the Baralaba North Continued Operations Project (BNCOP; the project). The geochemical assessment is intended to assist Cockatoo Coal Ltd (the proponent) with the management of mining waste materials that are likely to be generated by the project and also as part of the environmental regulatory approvals process for the project.

The project would comprise the extraction of coal by open-cut mining methods from several folded and faulted coal seams within the Baralaba Coal Measures; a relatively small coal deposit located in the south-eastern limb of the Bowen Basin, Queensland. Run-of-mine (ROM) coal would be processed at a coal handling and preparation plant (CHPP) located on site and dewatered coal reject disposed in-pit amongst spoil. Coal reject is expected to comprise less than 1% of all mining waste for the project.

Terrenus has geochemically assessed overburden and interburden (collectively called spoil) and potential coal reject materials (potential reject obtained as coal seam immediate roof, parting and floor samples).

Geochemical data was derived from new exploration drill-core and cutting samples collected from the project area and supplemented by geochemical data from an earlier (initial) geochemical assessment of samples associated with the existing Baralaba Coal Mine. The geochemical data from the initial assessment (Terrenus-RGS, 2012) is included herein as part of this assessment. All samples were collected by the proponent's geologists, following sampling specifications provided by Terrenus.

The environmental geochemical characteristics and management of the spoil and potential coal reject materials can be summarised as follows. In considering these characteristics and management measures it should be noted that coal reject is expected to comprise less than 1% of all mining waste generated at the project.

Geochemical Characteristics of Spoil

The geochemical characteristics of spoil materials are discussed as a bulk material, since there is little differentiation between the geochemical characteristics of materials from the southern end of the pit (Baralaba Coal Mine – the existing mining operations) compared to those from the northern end (BNCOP – the expansion project).

- Spoil, as a bulk material, is expected to generate pH-alkaline, low-salinity surface run-off and seepage following surface exposure. Weathered spoil can be expected to have similar geochemical characteristics to unweathered spoil.
- The total sulfur concentration of spoil is very low and essentially all spoil samples (161 out of 162 samples) are classified as non-acid forming (NAF). Most of these NAF samples were further classified as 'barren' with respect to sulfur concentrations. Only one sample was classified as potentially acid forming (PAF).

- Total metal and metalloid concentrations in spoil samples are low – below the applied health-based guideline 'level C' for soils (NEPC, 1999). About one third of spoil samples tested had concentrations of total manganese that exceeded the applied ecological investigation level for this element (NEPC, 1999). Two spoil samples also had slightly 'elevated' concentrations of total arsenic and barium with respect to the applied ecological investigation level for soils.

- Soluble multi-element results indicate that some spoil materials *may* produce leachate containing slightly elevated concentrations of some soluble elements (such as aluminium, arsenic and selenium) compared to applied ANZECC (2000) livestock drinking water quality guideline concentrations and aquatic ecosystem water quality guideline concentrations.

  It is important to note that the results presented in this report represent an 'assumed worst case' scenario as the samples are pulverised prior to testing, and therefore have a very high surface area compared to materials in the field. Individual materials would also be well mixed at storage locations. Hence, it is expected that the concentration of metal/metalloids in surface run-off and seepage from spoil materials will be less than the applied water quality guideline concentrations in the field.

  The applied guideline values are provided for context and are not intended as 'trigger values' or 'maximum permissible concentrations' with respect to total and soluble metals/metalloids in spoil materials. Due to a number of factors in the field (compared to the laboratory), including scale-up and dilution, any direct comparison of soluble multi-element concentrations from spoil is strictly not valid and should be used with caution.

- As a bulk material, most spoil has relatively low sodicity and is generally non-dispersive. Weathered spoil has a greater propensity to be dispersive, and spoil materials from the southern end of the pit area are generally more sodic compared to spoil materials from the northern end of the pit area. Therefore, spoil materials mined later in the mine life, which would more likely report to final landform surfaces and be used/disturbed in rehabilitation activities, are generally non-sodic (or have low sodicity) and non-dispersive.

Geochemical Characteristics of Potential Coal Reject

The geochemical characteristics of potential coal reject materials are discussed as a bulk material and not distinguished by seam or by location within the pit, since the assessment has found that there is generally little difference between the properties of potential coal reject materials from different seams or pit location, or between those from the existing Baralaba Coal Mine compared to those expected to be generated by the project. Furthermore, the quantity of coal reject produced by the project per annum and over the life of mine is very small.

- Potential coal reject is expected to generate pH-alkaline, low-salinity run-off and seepage following initial surface exposure.

- About 70% of potential coal reject samples were classified as NAF and about 30% were classified as PAF or Uncertain – with most of the PAF samples regarded as having a 'Low Capacity' to generate significant acidity. Overall, the sulfur concentration in potential coal reject materials is low, with over 50% of samples having total sulfur concentrations below 0.3% and 77% of samples having total sulfur concentrations below 0.5%.

- Total metal and metalloid concentrations in potential coal reject samples are low – below the applied health-based guideline 'level C' for soils (NEPC, 1999). A small number of samples had concentrations of total manganese and one additional sample had total barium concentration that exceeded the applied ecological investigation level (NEPC, 1999) for these elements.

- The soluble multi-element results indicate that some coal reject materials *may* produce leachate containing slightly elevated concentrations of some soluble elements (such as aluminium, arsenic, molybdenum and selenium) compared to applied ANZECC (2000) livestock drinking water quality guideline concentrations and aquatic ecosystem water quality guideline concentrations.

  Again, it is expected that the concentration of metal/metalloids in surface run-off and seepage from coal reject materials will be less than the applied water quality guideline concentrations in the field. As all coal reject is essentially 'mixed' during disposal into in-pit disposal areas amongst NAF and alkaline spoil, small proportions of PAF coal reject and/or elevated concentrations of soluble metals from isolated coal reject sources would be significantly diluted amongst the bulk reject and in-pit spoil material.

Management and Mitigation of Spoil Piles

Spoil is overwhelmingly NAF with relatively low concentration of metals/metalloids and has a negligible risk of developing acid, saline or metalliferous drainage. Some weathered spoil may have an increased potential for dispersion, however most unweathered spoil, particularly from the northern end of the pit, is expected to have low sodicity and be non-dispersive.

Typically in an open-pit mining operation, weathered spoil would be mined before unweathered materials. At the project this is likely to be the case with weathered spoil most likely reporting to the base of spoil piles or back into pit voids and being covered by unweathered spoil. Therefore, weathered spoil (not including topsoil) should not report to final surfaces to any significant extent, and should not pose significant management issues for the project. Spoil used for final landform covering would primarily comprise unweathered Permian material, which has a low salinity, generally low sodicity and low potential for dispersion.

Where spoil is used for construction activities, this should be limited to unweathered materials (where practical). Regardless of the spoil type, especially where engineering or geotechnical stability is required, testing should be undertaken by the proponent to determine the propensity of such materials to erode/disperse.

Surface run-off and seepage from spoil piles, including any rehabilitated areas, should be monitored for 'standard' water quality parameters including, but not limited to, pH, EC, major anions (sulfate, chloride and alkalinity), major cations (sodium, calcium, magnesium and potassium), total dissolved solids (TDS) and a broad suite of soluble metals/metalloids.

These management principles are currently successfully adopted at the site, and documented in the existing Waste Management Program for Baralaba Coal Mine (EMM, 2013). The 'new' spoil from the project will have essentially the same geochemical characteristics to the existing spoil from the Baralaba Coal Mine, therefore the current management measures for spoil are expected to be appropriate for managing 'new' spoil generated by the project.

With the implementation of the proposed management and mitigation measures, the spoil is regarded as posing a low risk of environmental harm.

Management and Mitigation of In-Pit Coal Reject Disposal Areas

The proposed strategy for coal reject disposal is for all coal reject to be disposed, as a dewatered reject, into mined-out pit areas and buried beneath spoil.

Up to 30% of the relatively small amount of coal reject materials (compared to spoil) may have some degree of risk associated with potential acid generation, however as a bulk material, coal reject is regarded as posing a low risk of environmental harm. This is primarily due to the generally low sulfur (and sulfide) concentration within this material (and also the low metals concentrations), which suggests that the magnitude of any localised acid, saline or metalliferous drainage, if it occurs, is likely to be small, and would be confined to the pit area. Therefore, when disposed amongst alkaline NAF spoil within in-pit disposal areas the overall risk of environmental harm and health-risk that disposed (in-pit buried) coal reject poses is very low.

Operational monitoring of coal reject and in-pit disposal areas

The proponent should undertake further assessment of actual coal reject materials from the CHPP as the project develops. Coal reject disposed into the pit would be placed below the expected final (post-closure) groundwater level and buried by at least five metres (cover thickness) of spoil within one month of placement.

Decommissioning, rehabilitation and closure of the in-pit coal reject disposal areas

The decommissioning, closure and post-closure aspects of the back-filled pit (and final void) would be addressed by a Mine Closure Plan. However, as coal reject would be covered by a minimum of five metres final thickness of spoil, and would not report to final landform surfaces (or near-surfaces), the management of in-pit coal reject would not be expected to be relevant to mine or pit decommissioning and rehabilitation.

Geochemical Characteristics of ROM Coal and Management of ROM Pad

ROM coal is not mining waste, and run-off and seepage from ROM pads does not report off-site, therefore ROM coal has not undergone detailed geochemical characterisation. However, total sulfur data from coal quality testing from the existing Baralaba Coal Mine since 2011 indicates that ROM coal can be expected to have similar environmental geochemical characteristics to coal reject materials.

ROM and Product coal is typically stored at the site for a relatively short period of time (weeks) compared to mining waste materials, which would be stored at the site in perpetuity. Management practices are therefore different for coal and would largely be based around managing seepage and run-off water quality from ROM pads and coal stockpiles (and managing dust control) – as is currently accepted practice at coal mines in Australia.

Surface run-off and seepage from ROM and Product coal stockpiles should be monitored for ‘standard’ water quality parameters including, but not limited to, pH, EC, major anions (sulfate, chloride and alkalinity), major cations (sodium, calcium, magnesium and potassium), total dissolved solids (TDS) and a broad suite of soluble metals/metalloids.

Geochemistry Assessment

BARALABA NORTH CONTINUED OPERATIONS PROJECT

April 2014

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GLOSSARY of TERMS

Acid	A measure of hydrogen ion (H^+) concentration; generally expressed as pH.
Acid-Base Account	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below. See also "MPA" and "ANC".
AMD	Acid and Metalliferous Drainage from mining waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity. The term AMD is used more recently to replace the term ARD (see "ARD") as metalliferous and saline drainage can occur under pH-neutral conditions.
ANC	Acid Neutralising Capacity, expressed as kg H_2SO_4 per tonne of sample. 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".
ARD	Acid Rock Drainage from mining waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity. See also "AMD".
Barren	A sample classified as barren essentially has no acid generating capacity (and the definition is commonly extended to materials lacking acid neutralising capacity). This category is most likely to apply to highly weathered materials. In essence, it represents an 'inert' material with respect to acid generation.
CHPP	Coal Handling and Preparation Plant.
Coal Reject	Solid waste produced during the processing of coal, typically from a CHPP. Coal reject typically comprises crushed siltstone, mudstone and fine-grained sandstone, which is mined as coal seam roof, parting or floor material during the extraction of ROM coal. Coal reject is commonly produced in different size fractions – fine and coarse reject.
Coarse Reject	Coarse solid waste materials (typically greater than 1.5 mm grain size) produced from the CHPP as part of the processing of coal. See also "Fine Reject".
EC	Electrical Conductivity, expressed as µS/cm.
Fine Reject	Fine-grained mining waste materials (typically less than 1.5 mm grain-size) produced from the CHPP as part of the processing and washing of coal. Fine reject typically comprises mud/clay and silt present in CHPP wastewater.

Interburden	Waste rock material between mined coal seams. See also "Overburden", "Mining Waste" and "Spoil".
Kinetic test	Procedure used to measure the geochemical/weathering behaviour of a sample of mine material over time.
MPA	Maximum Potential Acidity. Calculated by multiplying the total sulfur (S) or sulfide-sulfur (Scr) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne.
Mining Waste	Overburden, interburden and similar 'waste rock' (spoil) material mined and disposed during extraction of coal or ore. In this report, the definition of Mining Waste also extends to coal reject from the CHPP. See "Coal Reject".
NAF	Non Acid Forming. Geochemical classification criterion for a sample that will not generate acid conditions. A sample classified as NAF may, or may not, have a significant sulfur 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 sulfide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage.
NAPP	Net Acid Producing Potential, expressed as kg H_2SO_4 per tonne. Calculated by subtracting the ANC from the MPA.
NATA accreditation	Accreditation by the National Association of Testing Authorities (Australia). NATA accreditation for a specific analytical test indicates that the test method and means of undertaking the test (following the method and achieving valid results) by the laboratory has been independently recognised by NATA. Accreditation provides a means of determining and formally recognising the competence of facilities to perform specific types of testing, inspection, calibration, and other related activities, on a routine basis.
Overburden	Waste rock material overlying the uppermost mined (economic) coal seam. See also "Spoil".
PAF	Potentially Acid Forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions. A sample classified as PAF almost always has a significant sulfur content, the acid generating potential (MPA) of which exceeds the inherent acid neutralising capacity (ANC) of the material. This means there is a high risk that such a material, even if pH circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage 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 weak acidity.
ROM	Run of Mine. Coal as it comes from the mine prior to screening or processing. ROM coal is typically trucked from the mine and dumped

	onto a ROM pad (or into a ROM hopper), and from there it typically undergoes some degree of crushing, screening and washing.
S	Sulfur.
Scr	Chromium reducible sulfur. Analytical procedure to determine the sulfide-sulfur concentration in a sample.
SO_4	Sulfate.
Spoil	Waste rock material overlying and between coal seams. Spoil overlying a mined coal seam is called overburden. Spoil between mined coal seams is called interburden.
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.
Uncertain	In the context of classifying a material (sample) as NAF or PAF. An 'Uncertain' classification (UC) applies when there is an apparent conflict in results such that neither NAF or PAF classification can be given. Uncertain samples are sometimes given a tentative sub-classification, such as UC-NAF or UC-PAF.
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 is combined with 50 grams of de-ionised water into a glass bottle. The 1:5 solution (1 part solid to 5 parts water) is tumbled end-over-end for one hour. Solutes are leached from the soil by the continuous suspension. Samples are settled and the water is filtered off for analysis.

1 Introduction, Background and Context

Terrenus Earth Sciences (Terrenus) has undertaken a geochemical assessment of potential mining waste materials from the proposed Baralaba North Continued Operations Project (BNCOP; the project). The geochemical assessment was completed as part of the environmental regulatory approvals documentation for the project.

The project is a northern expansion of the existing Baralaba Coal Mine located on the south-eastern limb of the Bowen Basin in Central Queensland, approximately 150 km west of Gladstone. A schematic map showing the mine and pit layout (total extent) is presented in **Figure 1**.

The project is being developed by Cockatoo Coal Ltd (the proponent). The existing Baralaba Coal Mine extracts up to 1.75 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal by open-cut mining methods (average 1 Mt/a of product coal). The project seeks to increase the total extraction of ROM coal by an additional 2.3 Mt/a (maximum), over a 15 year mine life, to a combined total maximum of 4.1 Mt/a of ROM coal. The project would be augmented by a new coal handling and preparation plant (CHPP) to process the coal.

Terrenus has geochemically assessed overburden and interburden (collectively called spoil) and potential coal reject materials. Coal reject materials are derived from the processing of ROM coal at the CHPP and primarily comprise immediate coal seam roof, coal seam floor and coal parting materials.

Geochemical data was derived from new exploration drill-core and cutting samples collected from the project area and supplemented by geochemical data from an earlier geochemical assessment of samples associated with the existing Baralaba Coal Mine. The geochemical data from the initial assessment (Terrenus-RGS, 2012) is included herein as part of this assessment. All samples were collected by the proponent's geologists, following sampling specifications provided by Terrenus.

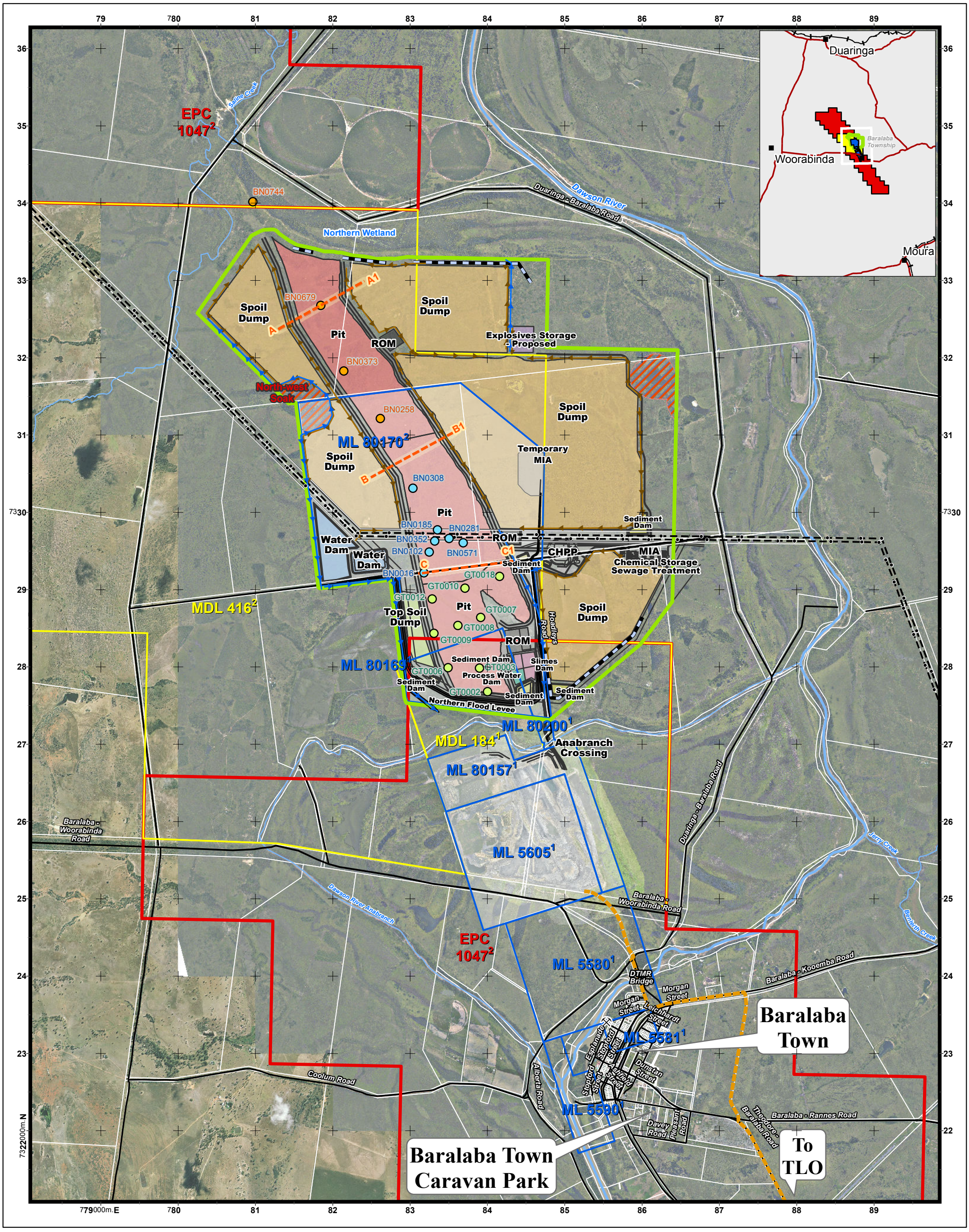
In the context of this report the term 'spoil' refers to overburden and interburden material, unless otherwise stated.

1.1 Objective

The overall objective of this assessment was to:

Evaluate the geochemical nature of spoil and potential coal reject materials likely to be produced from the project and identify potential environmental issues that may be associated with mining, handling and storing these materials.

The scope of the Geochemistry Assessment is consistent with the relevant requirements (eg. relating to water quality of surface water run-off and rehabilitation) of the final Terms of Reference for the BNCOP.



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TITLE	REV	DESCRIPTION	DATE	SCALE 1:45,000	CURRENT ISSUE SIGNATURES	
Figure 1 Indicative Project Layout and Drill-hole Sample Locations	0	Original map output	31/01/14	SIZE A3	DRAWN	MJS
	2	Data & Text Updates	01/04/14	DATUM GDA 94	CHECKED	BJD
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Legend

Road
Watercourse
Product Road Transport Route
Powerline & Power Pole
Cadastre
Cockatoo Coal ML
Cockatoo Coal MDL
Cockatoo Coal EPC
Area of Exclusion of Mining Activities
Drill Hole Location 2011
Drill Hole Location 2012
Drill Hole Location 2013
Geological Cross-Section
BNCOP Operational Land
Clean Water Drain
Dirty Water Drain
Proposed Flood/Erosion Protection Levee

Cockatoo Coal Limited

STATUS: **FINAL**

PROJECT NO	DRAWING NO
Baralaba Nth	BBN-091-01-03-140402

Path: N:\Baralaba\Baralaba_North\PROJECTS\1403\BBN_091_140311_EIS_Appendices\BBN_091_01_03_140402_EIS_AppE_Geochem_Project_Layout_A3P.mxd

1.2 Background to the project

With respect to mining waste geochemistry, the key components of the project are:

- An open-cut coal mining operation mining several folded and faulted seams (and associated plys) from a single pit over a 15 year (approximate) mine life.
- The project would mine approximately 544 million bank cubic metres (Mbcm) of overburden and interburden (approximately 979 million tonnes (Mt) at an assumed bulk density of 1.8) over the life-of-mine. This total quantity equates to about 65 Mt per annum (Mt/a) of spoil (on average) over the 15 year mining period. Most of the spoil would be disposed into in-pit spoil dumps (backfilled behind active mining), with the remainder disposed into out-of-pit spoil dumps located adjacent to the pit extents (**Figure 1**).
- Approximately 52 Mt of ROM coal would be mined over the 15 year mine life, at a maximum rate of up to 4.1 Mt/a. Of the approximately 52 Mt of ROM coal mined, about 24 Mt would be processed through a new CHPP located on site[1], with the remaining 28 Mt bypassing the CHPP as Bypass Product Coal.
- The CHPP would produce product coal and coal reject. The CHPP will process about 24 Mt of ROM coal (over 15 years) and produce less than 5 Mt of coal reject over this period (*ie*. an average coal reject production rate of about 0.3 Mt/a).
- Coal rejects would be dewatered and disposed (truck-dumped) on-site within mine voids behind the advancing open cut mining operations and/or within the Baralaba Central final void.
- Based on an average spoil generation rate (over 15 years) of about 65 Mt/a (36 Mbcm) and an average coal reject generation rate of about 0.3 Mt/a, coal reject is expected to comprise approximately 0.5% of the average annual mining waste quantity.

1.3 Project geology

The project is located within the Bowen Basin in south-east Queensland. The Bowen Basin is part of a connected group of Permian-Triassic basins in eastern Australia, that includes the Sydney and Gunnedah Basins. The Bowen Basin contains large reserves of Permian coals, which have been mined on a large scale by open-cut and underground methods since the 1970s.

The principal coal bearing sequence at the project is the Permian Baralaba Coal Measures, lateral equivalent of the Rangal Coal Measures.

Immediately underlying the Baralaba Coal Measures is the Burngrove Formation (Kaloola Formation) also containing minor coal horizons. Overlying the Baralaba Coal Measures is the Rewan Formation of Triassic age, which in turn is overlain by Quaternary sediments.

The project is situated on the eastern flank of the Mimosa Syncline; a major north trending structural feature of the southern Bowen Basin affecting rocks of the Permian and Triassic age.

[1] Until the CHPP is commissioned and other relevant approvals and upgrades in place, the BNCOP would make continued use of the existing on-site ROM coal handling and crushing facilities at Baralaba Coal Mine.

This structurally complex zone is also referred to as the Dawson Tectonic Zone, which is characterized by a complex pattern of northerly trending folds and thrust (reverse) faults with displacements of up to 200 m. As such, the Baralaba Coal Measures are folded and faulted and exhibit dips of up to 45° and strata repetition is also common.

In the project area the lithology is characterised by typical basin-fill sediments, comprising mudstones, siltstones, sandstones and coal seams. The depth to base of weathering averages about 30 m below natural surface, but does vary depending on the local topography.

Coal seams

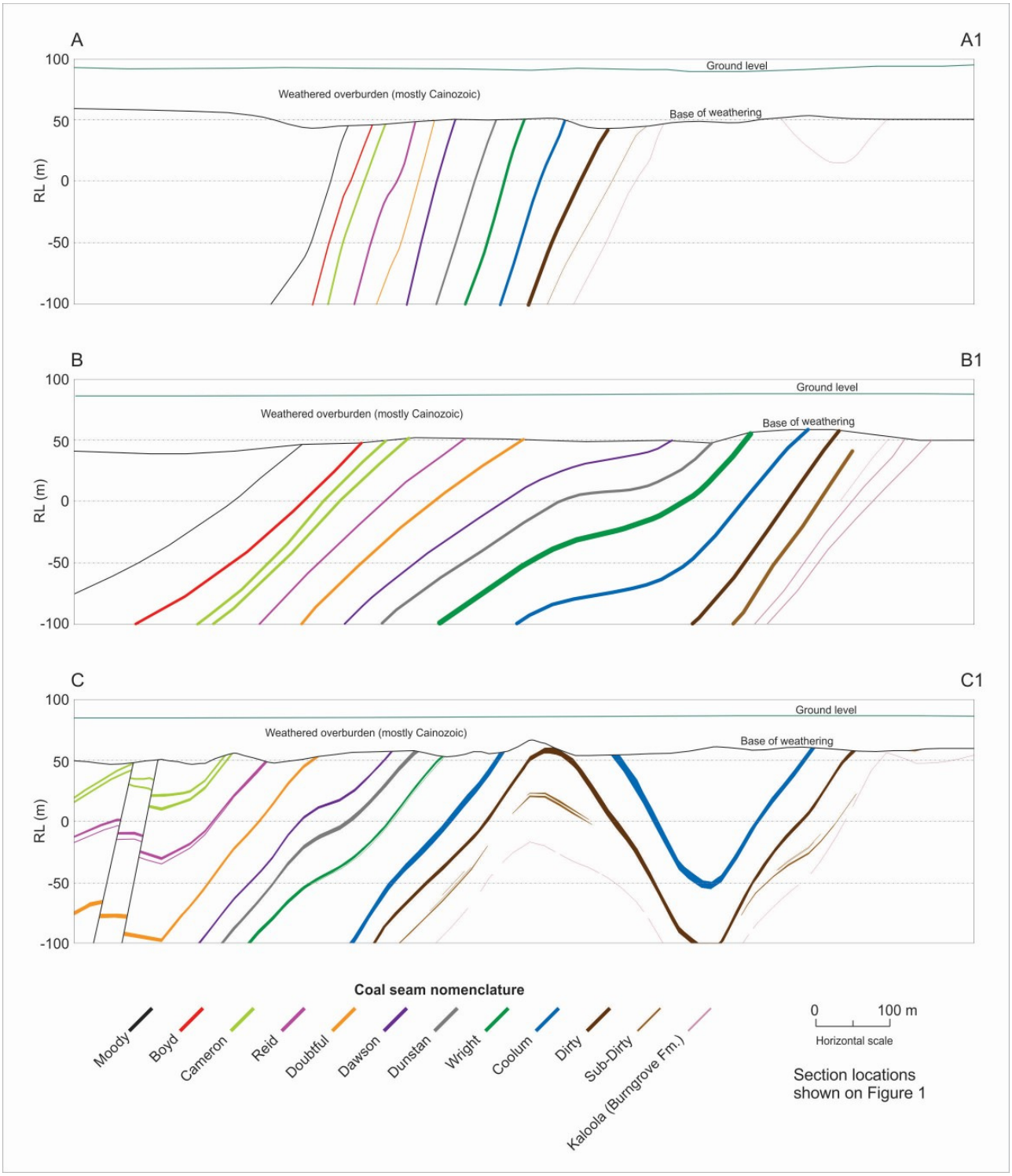
The Baralaba Coal Measures at the project contain nine major coal-bearing seams, listed in stratigraphic order from youngest to oldest: Boyd, Cameron, Reid, Doubtful, Dawson, Dunstan, Wright, Coolum and Dirty seams. The coal seam thicknesses for each of these seams in the project area range from less than 0.5 m to approximately 4.5 m and are separated by fine to coarse sandstone, siltstone and mudstone interburden. Minor seams are also present, such as the Moody seam (above the Boyd seam), the Double seam (between the Wright and Coolum seams) and the Sub-Cameron, Sub-Dunstan and Sub-Dirty seams (immediately below the Cameron, Dunstan and Dirty seams, respectively). Thin coal seams from the Kaloola Formation (part of the underlying Burngrove Formation) are also present. The target seams vary with location (north to south and east to west) throughout the pit area.

The project proposes to mine coal from all seams where coal thickness and quality is economic, although the folded and faulted nature of the area dictates that not all seams and plys are present in all areas of the project at a suitable (economic) thickness or with the appropriate coal quality attributes.

The approximate seam positions in the proposed project pit are shown in three geological cross-sections (**Figure 2**). Refer to **Figure 1** for the locations of these cross-sections.

Coal seam roof and floor zones, and minor interseams between plys, of the Baralaba Coal Measures are typically comprised of fine-grained sedimentary lithologies, such as mudstones, siltstones and very fine-grained sandstone, which is typical of the ‘low energy’ depositional environment of coal. These thin roof and floor zones are also commonly carbonaceous, containing wispy coal laminations.

Figure 2. Typical geological cross-sections through the pit
(cross-section locations shown on Figure 1)



2 Geochemical Assessment Methodology

This section provides the methodology used for the geochemical characterisation and assessment of spoil and potential coal reject materials that could potentially be produced by the project.

2.1 Desktop review of existing information

A desktop review of available project data and information was completed to provide a better understanding of the project. The review included geological data, coal exploration drilling programs, proposed mining methods and mine plan, coal handling and processing methods, and mining waste disposal and management strategies. Discussions were held with proponent personnel (predominantly Cockatoo Coal geologists) to identify and discuss relevant technical information and to understand the Project Description.

Geological information was obtained from historic and recent exploration drill-hole logs from the Baralaba Coal Mine and the BNCOP, coupled with discussions with the project geologist[2]. Overall, the detailed lithological logs were reviewed for over 40 drill-holes within the pit area and immediate surrounds.

Based on this information, a good understanding of the geological environment (lithology and structure) at the project site was gained.

2.2 Sampling strategy

Terrenus developed a geochemical sampling and testing program specific for this assessment that integrated with the exploration (resource definition) drilling program, and also considered the results of the Terrenus-RGS (2012) geochemical assessment for the Baralaba Coal Mine. This assessment is based on all available data (existing and new) that is relevant to assessing the environmental geochemical characteristics of the project.

There are currently no specific regulatory requirements regarding the number of samples required to be obtained and tested for coal, spoil or potential coal reject materials at mines in Queensland. Whilst historical guidelines do exist in Queensland (DME, 1995), more recent Australian and international guidelines (DITR, 2007; INAP, 2009) advocate a risk-based approach to sampling, especially for proposed coal mines where the geology is well understood and existing information is available on similar mining waste and coal materials.

The number and type of samples for the current assessment were selected based on a number of factors including the geological variability and complexity in rock types; the size of the operation; the proposed mining schedule; the potential for significant environmental or health impacts (based on the desktop review of available data); sample representation requirements; the volume of materials; the representativeness of drill-core and cutting samples; the level of confidence in predictive ability; and cost. The types of samples collected and assessed are outlined below.

[2] Personal communications with Alex Bell: Senior Geologist - Resources (Cockatoo Coal).

The samples used in the geochemical assessment for the project were derived from 21 drill-holes located within the project area. The majority of the holes are located in the southern half of the proposed pit area (on tenement ML80170) (**Figure 1**), since this is the tenement with current mining approval (and will be mined for the first 5 to 8 years). Also, the initial geochemical assessment of the southern part of the project area found that the mining waste materials posed a low environmental risk (Terrenus-RGS, 2012). Since the geology in the northern part of the proposed pit is consistent with the southern area, the environmental geochemistry of the northern pit area was expected to be consistent with the southern area. Hence, based on the INAP (2009) risk-based approach to sampling (where existing data is already available to form a valid understanding), northern area sampling was undertaken primarily as confirmatory data. Notwithstanding the findings of this current assessment, the proponent should continue to assess the geochemical characteristics of mining waste materials from the northern end of the pit as the project develops.

In total, detailed geochemical data directly relevant to the project is available for 210 predominantly drill-core samples. Twenty-five (25) of the 210 samples were collected from fresh drill-chips. However, the overwhelming majority of samples (88% of all samples) were obtained from fresh drill-core.

Samples collected

Geochemical characterisation was undertaken on 210 samples, which comprise:

- 162 'spoil' samples:
  - 7 weathered overburden samples (mostly moderately to highly weathered);
  - 34 unweathered overburden samples (between 'weathered zone' and top fresh coal); and
  - 121 interburden samples (unweathered, between seams).
- 48 potential coal reject samples, comprising roof, parting and/or floor samples from all seams between Boyd to Dirty, inclusive.

As indicated in **Section 1.2** coal reject is expected to represent approximately 0.5% of the total mining waste material generated over the life of mine. Therefore, from a statistical point-of-view the potential coal reject samples subjected to testing should only represent a very small proportion of all samples. However, typically in Permian deposits in the Bowen Basin it is the coal reject materials that contain the greatest concentration of sulfur (as reactive sulfide) and can sometimes have a comparatively greater concentration of metals/metalloids. Therefore, from an environmental risk perspective, they are equally as important as spoil. Hence, it was decided to significantly increase the proportion of potential coal reject samples, relative to spoil.

Drill-hole information is provided in **Appendix A – Table A1** and the drill-hole (sampling) locations are shown on **Figure 1**. Sample information is provided in **Appendix B – Table B1** (spoil) and **Table B2** (potential coal reject).

2.3 Geochemical tests

The environmental geochemical assessment of spoil and potential coal reject materials was based on the characterisation of samples using static geochemical test methods.

Static testing provides the fundamental geochemical characteristics of a sample. Static testing involved discrete analytical tests undertaken on samples, where the results represent the geochemical characteristics of the sample at a single time period and under simple experimental conditions as a 'snapshot' of the sample's likely environmental geochemical characteristics.

Kinetic leaching tests have not been undertaken as part of this assessment, as the static test results alone have been adequate and defining, in the context of the assessment objectives for the purposes of the EIS.

Static test methodology

The test methods employed on all samples comprised:

- pH and electrical conductivity (EC) (1:5 w:v);
- Total sulfur [high temperature combustion analyser]; and
- Acid neutralising capacity (ANC) [AMIRA, 2002].

Samples with total sulfur values of greater than 0.1% underwent additional analysis for:

- Sulfide (chromium reducible sulfur – Scr) [AS 4969.7-2008 method]

From the total sulfur (or Scr where available) and ANC results, maximum potential acidity (MPA) and net acid producing potential (NAPP) was calculated. Where available, the MPA and NAPP of these samples were calculated using the Scr data instead of total sulfur data. The use of Scr data (for fresh samples) provides a more accurate representation of the MPA that could theoretically be generated, as acid generation primarily occurs from reactive sulfide, whereas total sulfur includes other sulfur forms such as sulfate and organic sulfur.

Based on the results of the initial screening tests selected individual and composite samples were subjected to several or all of the following tests:

- Total metals and metalloids analyses by [HCl and HNO_3 acid digest followed by FIMS for Hg and ICP-MS / ICP-AES for all other elements];
- Exchangeable cations (Ca, Mg, Na, K) (with pre-treatment for salinity). Results were used to calculate the cation exchange capacity (CEC);
- Soluble metals and metalloids ICP-AES/-MS and FIMS (1:5 w:v water extracts);
- Soluble cations and anions ICP-AES (1:5 w:v water extracts); and
- Emerson Class testing [Standards Australia method AS1289-3.8.1].

Composite samples were created for the Baralaba North/Wonbindi North (2011-2012) samples only. Each composite spoil sample comprised between 2 and 3 individual samples from the same drill-hole, where each individual sample had the same lithology and basic geochemical characteristics. Each composite potential coal reject sample comprised between 2 and 4 individual samples of the same potential coal reject type (*eg*. Wright floor, Dawson roof, etc.). Composite sample details are provided in **Appendix B – Table B3**.

All laboratory test work was undertaken by ALS Brisbane, using NATA accredited methods (where such accreditation exists). The geochemical test work program is summarised in **Table 1**.

Table 1. Summary of the geochemical test program
(number of individual and composite samples subjected to each test regime)

Analytical tests	Spoil	Potential Coal Reject
pH, EC, total sulfur, ANC	All (162) samples	All (48) samples
Scr (sulfide sulfur)	17 individual samples	32 individual samples
Total elements in solids	35 individual and 4 composite samples	12 individual and 8 composite samples
Soluble elements and major ions in 1:5 water extracts	35 individual and 4 composite samples	12 individual and 8 composite samples
Exchangeable cations[3]	43 individual and 4 composite samples	-
Emerson class[3]	30 individual samples	-

Assessment of element enrichment and solubility

Multi-element scans are typically carried out to identify any elements (particularly metals and metalloids) present in a material at concentrations that may be of environmental concern with respect to revegetation and surface water or groundwater quality. The assay result for each element can be compared to potentially relevant guideline criteria to provide context and to determine any potential issues related to mine operation, environmental management and final rehabilitation. Elements identified as enriched may not necessarily be a concern for revegetation, human/animal health or water quality, but their significance should be evaluated. Similarly, if an element is not enriched it does not mean it will never be a concern, because under some conditions (*eg*. low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd and Zn can change significantly.

There are no guidelines and/or regulatory criteria specifically related to total metal/metalloid concentrations in mining waste materials, such as spoil, coal and potential coal reject materials. In the absence of these, and to provide relevant context for this assessment, the total concentration of each element reported in mining waste samples (solids) has been compared to NEPC (1999) ecological investigation levels (EILs) and NEPC (1999) health-based investigation levels (HIL) category 'C' for public open space. The applicability of the NEPC (1999a) HIL(C) guideline for 'open spaces' stems from the potential final land use of the mine following closure (*ie*. low-intensity livestock grazing).

[3] Exchangeable cation and Emerson class tests have only been determined on 'spoil' samples, as spoil materials are those likely to report to final landform surfaces and be used in rehabilitation and revegetation activities. Coal reject will not report to final surfaces and not be used in final rehabilitation and revegetation activities.

Note: It is very important to recognise that there is no land-use scenario in the NEPC (1999) guidelines applicable to mining, or even closely related, therefore the selection of the 'open space' land-use scenario by Terrenus is provided for general context only. The guideline values provided are not intended as 'trigger values' or 'maximum permissible concentrations' with respect to metals/metalloids in spoil or coal reject materials.

The total metal/metalloid concentrations for individual elements in mining waste materials can also be relevant for revegetation activities and/or where the potential exists for human contact (*eg*. if the material was to be used off-site).

Furthermore, under certain circumstances, mining waste and coal materials can potentially leach soluble metals at concentrations that may have the potential to impact the environment or human health. Water extract tests are used to determine the immediate solubility and potential mobility of elements under existing pH and oxygen (redox) conditions. Soluble element concentrations can be compared with those recommended in relevant surface water and groundwater guideline criteria in order to provide some context.

Again, there are no guidelines and regulatory criteria specifically related to surface run-off and/or seepage from spoil, potential coal reject and coal materials since guidelines (and regulatory criteria) will depend upon the end-use and receiving environment of the seepage. Therefore, to provide relevant context, the soluble concentration of each element extracted from mining waste and coal materials has been compared to livestock drinking water guidelines (ANZECC, 2000) and freshwater aquatic ecosystem guidelines for 'slightly to moderately disturbed systems' (ANZECC, 2000).

Note: It is very important to recognise that the comparison with applied water quality guidelines is provided for general context only. The guideline values provided in ANZECC (2000) are for receiving water environments, 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 an assumed 'maximum' concentration. Due to a number of factors in the field (compared to the laboratory), including scale-up and dilution, any direct comparison of soluble multi-element concentrations in leachate from spoil is strictly not valid and should be used with caution. Therefore, the guideline values provided are not intended as 'trigger values' or 'maximum permissible concentrations' with respect to soluble metals/metalloids in spoil or potential coal reject materials.

2.4 Sample classification criteria

Sample classification of mining waste materials follows some general rules, however the classification has to take into account the site geology and other site-specific geochemical characteristics that may influence the classification criteria.

Samples were classified, with respect to acid generation, using total sulfur (or Scr, where available), NAPP and ANC/MPA ratio data into three broad categories:

- NAF — Non-acid Forming;
- Uncertain — Those samples with inconclusive results, leading to a degree of uncertainty about their ability to generate acid; and
- PAF — Potentially acid forming.

Within these three broad categories, the sample classification was refined as follows:

***NAF – Barren*[4]:**

Total sulfur (S) ≤0.1 %

***NAF*:**

Total sulfur (S) ≤0.2 % [or Scr ≤0.2 %] and ANC/MPA ratio >2 *or*

NAPP <0 kg H_2SO_4/t and ANC/MPA ratio >2

***PAF – Low Capacity (PAF-LC)*:**

Total sulfur (S) >0.2 % [or Scr >0.2 %] and NAPP between 0 and +10 kg H_2SO_4/t

***PAF*:**

NAPP >+10 kg H_2SO_4/t and ANC/MPA ratio <2

Uncertain:

Any result outside of the above criteria or

Results that appear to significantly conflict with the expected result based on lithology or mineralogy.

Heterogeneity is a characteristic of natural geology materials. Sometimes an analytical result for a rock sample can vary to that which would be expected based on the known rock type (from information contained in the lithological logs). In this case, a degree of conservatism is applied to the result (*ie*. the precautionary principle prevails) and the sample is classified as 'Uncertain' until further information becomes available. Depending on the level of risk, from a mining waste management perspective 'Uncertain' samples are usually managed conservatively (in a similar manner to PAF materials).

[4] Samples with a total sulfur content of ≤0.1 % are essentially barren of sulfur and have negligible capacity to generate acidity, even in the absence of significant ANC.

3 Geochemical Test Results

As discussed in **Section 2.2**, existing geochemical data was available from an initial geochemical assessment undertaken by Terrenus-RGS (2012) of samples collected from the southern area of ML80170 (from the GT-series drill-holes; marked '2011' in **Figure 1**). These samples are referred to herein as 'Baralaba North/Wonbindi North' samples. New samples, as part of this project, were collected from additional drill-holes in the centre of ML80170 (those drill-holes marked '2012' in **Figure 1**) and from four drill-holes at the northern end north of ML80170 (those drill-holes marked '2013' in **Figure 1**). These 'new' (2012-2013) samples are referred to herein as 'BNCOP' samples.

The proponent has an existing environmental approval to mine ML80170, and the EIS application is to increase the production rate and extract coal from north of ML80170. Hence, the results in this section are presented and discussed with respect to the two data sets: the 'Baralaba North/Wonbindi North' samples and the 'BNCOP' samples. As will be shown in this assessment, the geochemical results between the two datasets are comparable, therefore the various graphs and tables presented in this section, which differentiate between the two datasets, are provided for context to illustrate that the geochemical characteristics of mining waste materials for the entire Baralaba North/Wonbindi North and BNCOP project are consistent throughout the entire project area.

3.1 Acid-Base Account results for spoil samples

The Acid-Base Account (ABA) is the theoretical balance between the potential for a sample to generate acid and neutralise acid, and in Australia is commonly expressed in units of kilograms of sulfuric acid per tonne of sample (kg H_2SO_4/t).

ABA results for the 162 spoil samples that underwent geochemical characterisation are presented in **Appendix B – Table B1** and summarised as follows. The laboratory certificates for these samples are provided in **Appendix D**. The sample results presented in this section comprise:

- 7 moderately weathered to highly weathered overburden samples;
- 34 unweathered overburden samples (between 'weathered zone' and top fresh coal); and
- 121 interburden samples (unweathered, between seams).

With some minor exceptions, there is little difference in the results between the three types of spoil materials to warrant a separate detailed discussion on the basis of weathered versus unweathered overburden or interburden material. Therefore, the results are discussed as a 'bulk' spoil material, unless specifically noted.

Electrical conductivity and pH of spoil

The $EC_{1:5}$ values of spoil samples are generally low and span a broad range from 25 to 676 µS/cm, with a median EC value (for all samples) of 287 µS/cm and 10th and 90th percentile values of 153 and 397 µS/cm, respectively (**Figure 3** – left; and **Figure 4**).

Spoil samples are pH-neutral to alkaline, producing $pH_{1:5}$ values ranging from pH 7.3 to pH 10.1, with most samples being alkaline (**Figure 3** – right; and **Figure 5**).

As evident in **Figure 3**, the Baralaba North/Wonbindi North samples have a slightly higher range of soil salinity (EC) and pH values compared the BNCOP samples.

Figure 3. Statistical distribution of EC1:5 and pH1:5 values for spoil samples

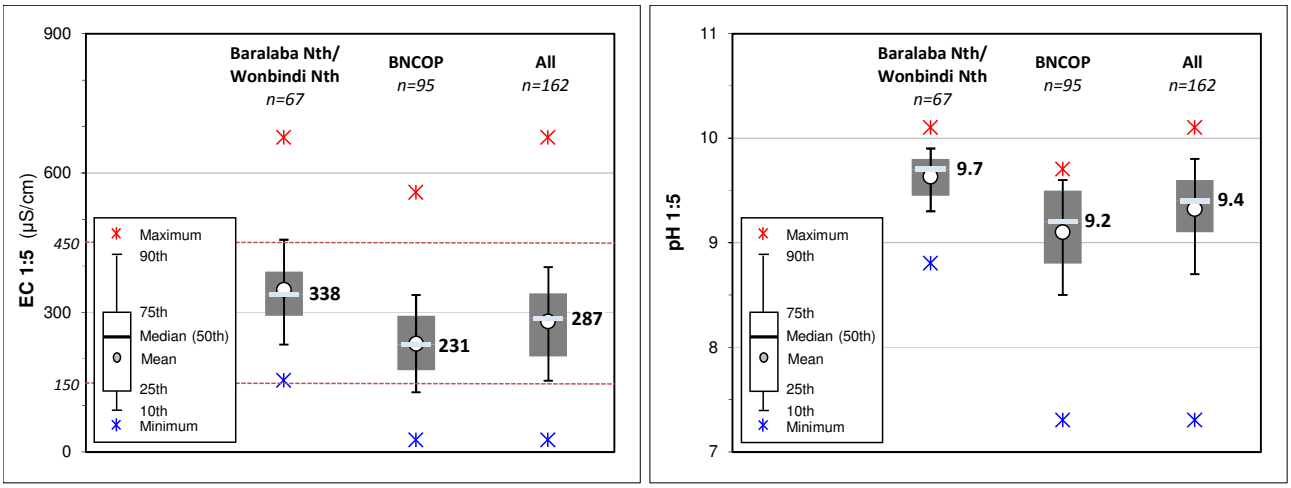


Figure 4. Electrical conductivity of spoil samples
The EC classifications shown correspond to the soil salinity classifications from DME, 1995

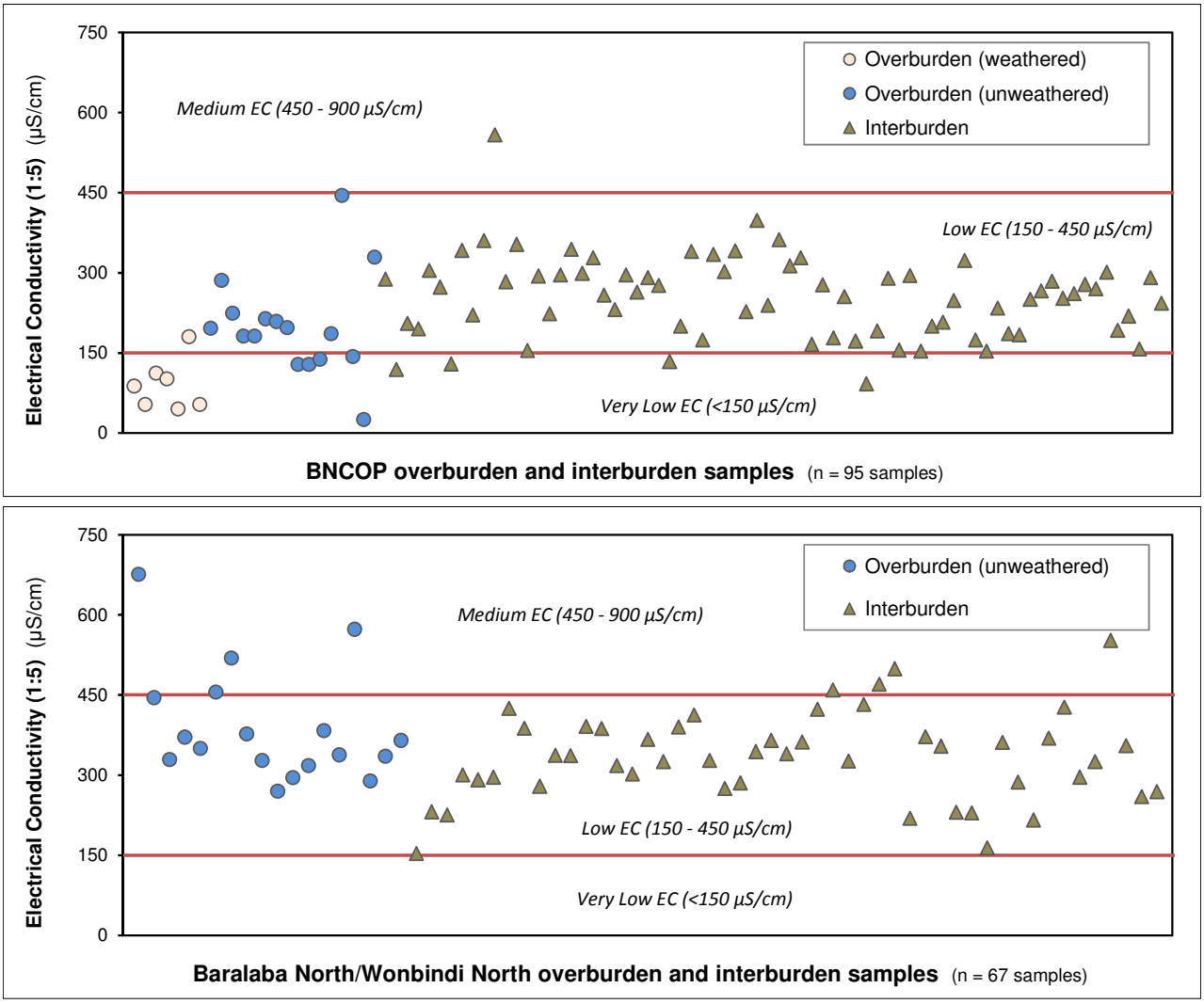
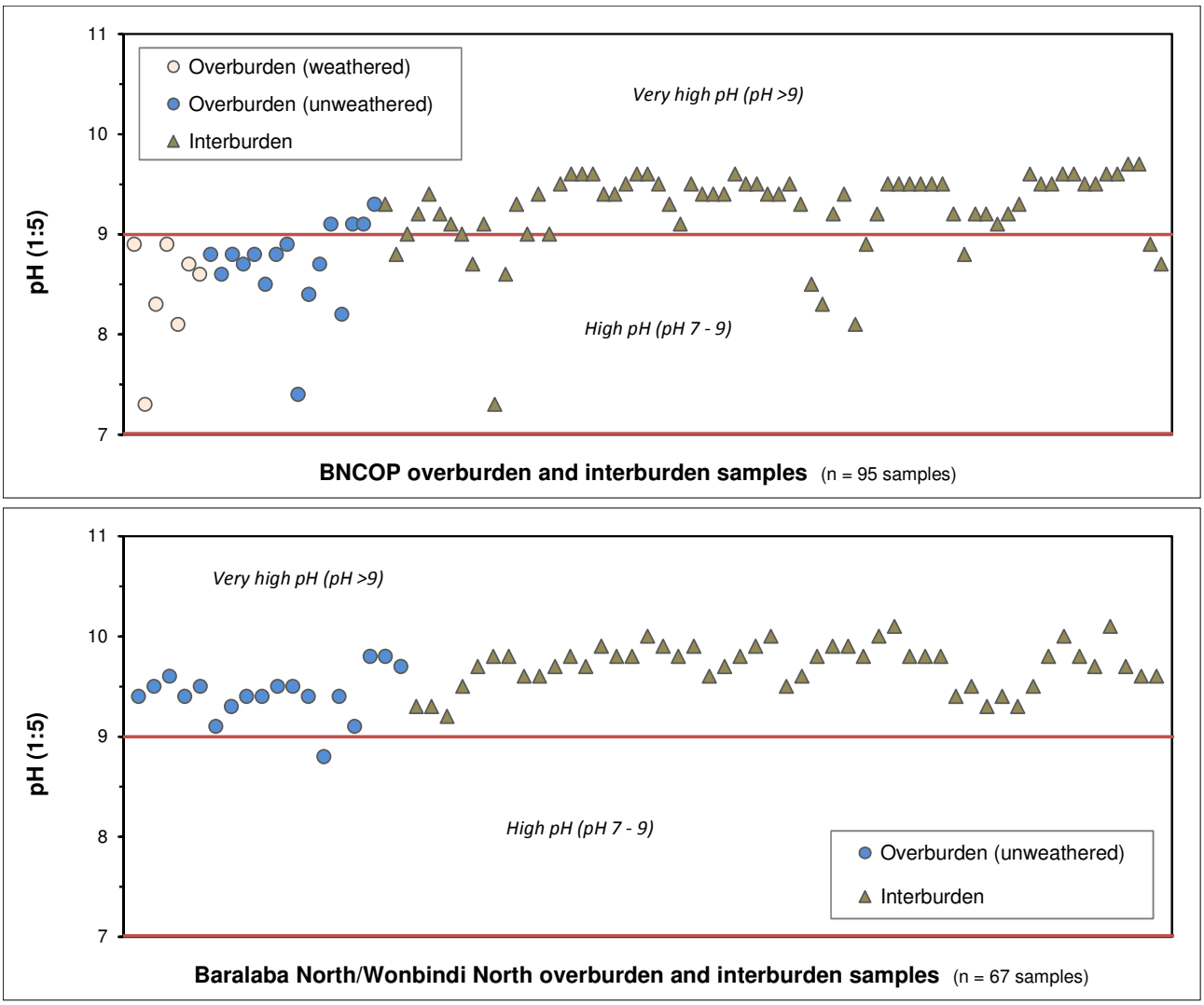


Figure 5. pH of spoil samples

The pH classifications shown correspond to the soil pH classifications from DME, 1995



To provide context to the results, the $EC_{1:5}$ and $pH_{1:5}$ results in **Figures 4 and 5** are plotted against salinity and pH criteria for mine waste materials, as defined by the Queensland DME (1995) technical guideline for the environmental management of exploration and mining in Queensland. These criteria are outlined in **Table 2**.

Based on the median EC and pH values for spoil samples overall, and also the median EC and pH values for the Baralaba North/Wonbindi North versus BNCOP samples, spoil samples are generally regarded as having 'Very High' soil pH and 'Low' salinity values, as evident by the distribution of samples corresponding to each pH and salinity class.

As evident in **Figures 4 and 5**, there is little significant difference in the overall pH or EC values between the fresh overburden versus fresh interburden samples, however the weathered samples (albeit from a small number of BNCOP samples), tend to be less saline and have generally lower soil pH compared to the fresh samples. In the BNCOP dataset, the unweathered overburden samples are slightly less saline (overall) compared to the interburden samples.

Table 2. Salinity and pH criteria for assessment of spoil samples
Adapted from DME, 1995

	Very Low	Low	Medium	High	Very High
All spoil samples (n= 162)					
$EC_{1:5}$ (sample:water) µS/cm	**< 150**	**150 – 450** (median=287)	**450 - 900**	**900 – 2,000**	**> 2,000**
No. and (%) of samples corresponding to each salinity classification	15 (9%)	138 (85%)	9 (6%)	-	-
$pH_{1:5}$ (sample:water)	**< 4.5**	**4.5 – 5.5**	**5.5 – 7.0**	**7.0 – 9.0**	**> 9.0** (median=9.4)
No. and (%) of samples corresponding to each soil pH classification	-	-	-	35 (22%)	127 (78%)
Baralaba North/Wonbindi North spoil samples (n=67)					
$EC_{1:5}$ (sample:water) µS/cm	**< 150**	**150 – 450** (median=338)	**450 – 900**	**900 – 2,000**	**> 2,000**
No. and (%) of samples corresponding to each salinity classification	-	59 (88%)	8 (12%)	-	-
$pH_{1:5}$ (sample:water)	**< 4.5**	**4.5 – 5.5**	**5.5 – 7.0**	**7.0 – 9.0**	**> 9.0** (median=9.7)
No. and (%) of samples corresponding to each soil pH classification	-	-	-	1 (1%)	66 (99%)
BNCOP spoil samples (n=95)					
$EC_{1:5}$ (sample:water) µS/cm	**< 150**	**150 – 450** (median=231	**450 - 900**	**900 – 2,000**	**> 2,000**
No. and (%) of samples corresponding to each salinity classification	15 (16%)	79 (83%)	1 (1%)	-	-
$pH_{1:5}$ (sample:water)	**< 4.5**	**4.5 – 5.5**	**5.5 – 7.0**	**7.0 – 9.0**	**> 9.0** (median=9.2)
No. and (%) of samples corresponding to each soil pH classification	-	-	-	34 (36%)	61 (64%)

Note: Highlighted cells in Table 2 show the category corresponding to the median EC (orange shading) and median pH (purple shading) for each of the three spoil categories (all spoil, Baralaba North/Wonbindi North spoil and BNCOP spoil).

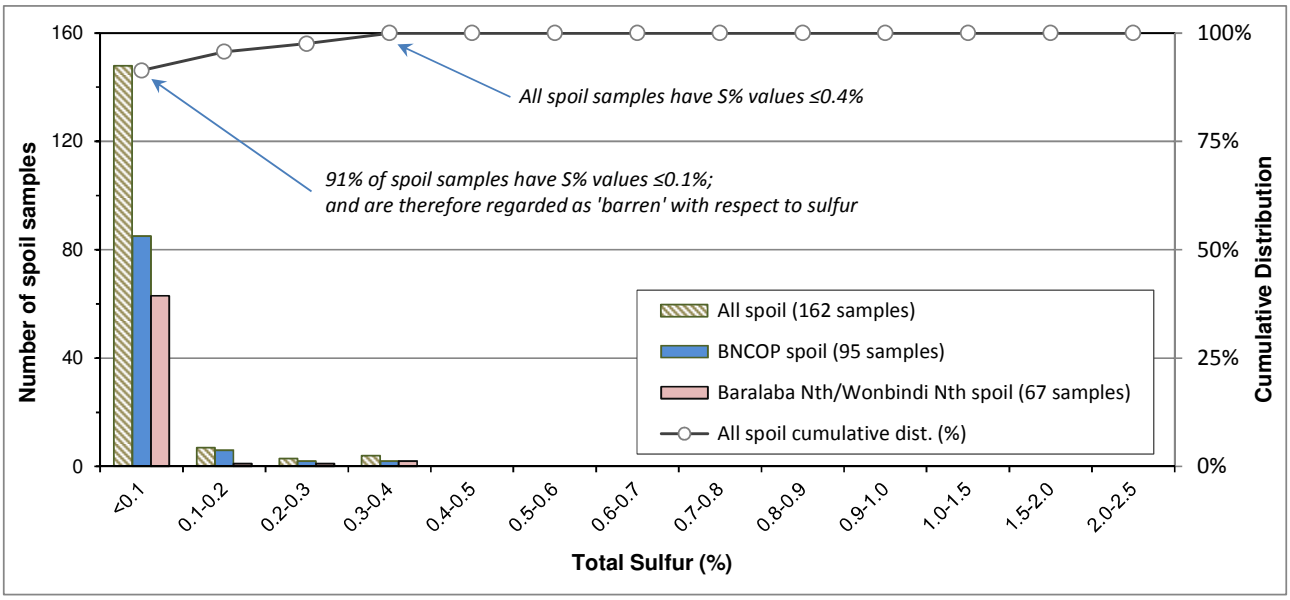
Sulfur in spoil

The total sulfur concentration of spoil samples from both Baralaba North/Wonbindi North and BNCOP samples is very low, as shown in **Figure 6**. Values range from less than 0.01% to 0.40%, with 91% of all spoil samples having a total sulfur concentration below 0.1%, thus rendering them 'barren' with respect to sulfur.

Since the total sulfur concentration is very low in most spoil samples, sulfide-sulfur (as Scr) concentration was measured in 17 of the 162 samples (mostly those samples with total sulfur concentrations greater than 0.1%).

As evident in **Figure 6**, there is little difference between the sulfur concentrations in the Baralaba North/Wonbindi North versus BNCOP spoil samples.

Figure 6. Distribution and cumulative distribution of total sulfur in spoil samples



Maximum potential acidity and acid neutralising capacity of spoil

The ANC and MPA that could be generated by these spoil samples (MPA calculated from Scr, where available) is summarised in **Table 3** with the statistical distribution of MPA and ANC values shown in **Figure 7**.

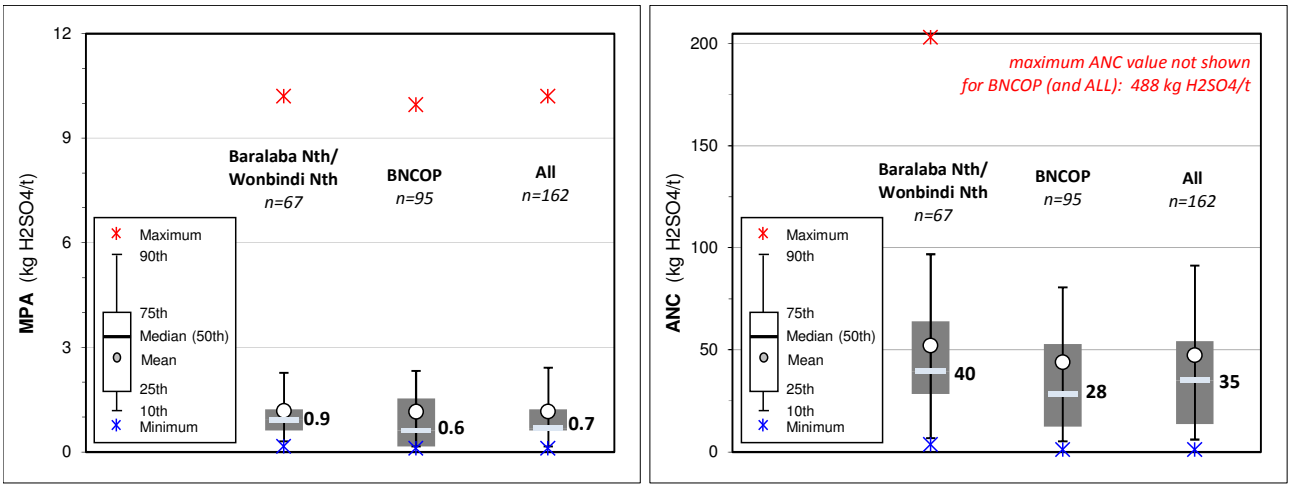
Due to the very low total sulfur values the MPA for all spoil samples is also very low, with a median MPA of <1 kg H_2SO_4/t and a maximum MPA of 10 kg H_2SO_4/t. Almost all samples (97% of samples) have MPA values below 5 kg H_2SO_4/t.

The ANC values are typically well in excess of the MPA values and span a relatively large range, from 1 to 488 kg H_2SO_4/t, with a median ANC value of 35 kg H_2SO_4/t and moderate 25th, 75th and 90th percentile values of 14, 54 and 91 kg H_2SO_4/t, respectively.

Table 3. Summary maximum potential acidity (MPA) and acid neutralising capacity (ANC) values for spoil samples

Sample Material	Min.	Max.	Median	25th / 75th percentile	General Comments
Maximum potential acidity (MPA) *kg H_2SO_4/t*					
All spoil samples (n=162)	<0.1	10	**0.7**	**0.6** / **1.2**	Very low (negligible)
Baralaba North/Wonbindi North spoil samples (n=67)	<0.2	10	**0.9**	**0.6** / **1.2**	Very low (negligible)
BNCOP spoil samples (n=95)	<0.1	10	**0.6**	**0.2** / **1.5**	Very low (negligible)
Acid neutralising capacity (ANC) *kg H_2SO_4/t*					
All spoil samples (n=162)	1.0	488	**35**	**14** / **54**	Moderate
Baralaba North/Wonbindi North spoil samples (n=67)	3.5	203	**40**	**29** / **64**	Moderate
BNCOP spoil samples (n=95)	1.0	488	**28**	**12** / **53**	Moderate

Figure 7. Statistical distribution of maximum potential acidity (MPA) and acid neutralising capacity (ANC) values for spoil samples



Net acid producing potential of spoil

The calculated NAPP values for spoil samples are summarised in **Table 4** and **Figure 8**.

Based on the very low MPA and significantly higher ANC values, the calculated NAPP values are negative for all samples except one, and strongly negative for most samples. This indicates a significantly greater proportion of neutralising capacity (ANC) compared to potential acidity (MPA). NAPP values range from -488 to +1.5 kg H_2SO_4/t with a median NAPP value of -34 kg H_2SO_4/t and 10th and 90th percentile values of -5 and -90 kg H_2SO_4/t, respectively.

Table 4. Summary net acid producing potential (NAPP) values for spoil samples

Sample Material	Min.	Max.	Median	10th / 90th percentile	General Comments
Net acid producing potential (NAPP) *kg H_2SO_4/t*					
All spoil samples (n=162)	-488	+1.5	**-34**	**-5** / **-90**	Very low (strongly negative). 1 sample has +ve NAPP (+1.5)
Baralaba North/Wonbindi North spoil samples (n=67)	-203	+1.5	**-39**	**-6** / **-95**	Very low (nearly all negative)
BNCOP spoil samples (n=95)	-488	-0.8	**-25**	**-4** / **-80**	Very low (all negative).

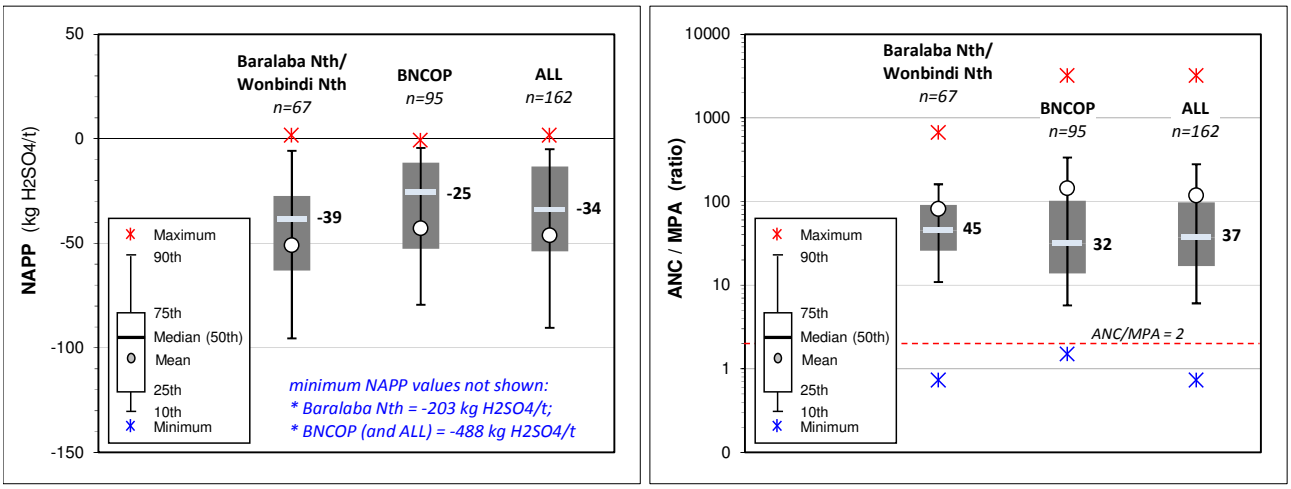
ANC/MPA ratios of spoil

Generally, those samples with an ANC/MPA mass ratio greater than two are considered to have a negligible/low risk of acid generation and a high factor of safety in terms of potential for AMD (DITR, 2007; INAP, 2009[5]). The results in **Table 5** and **Figures 8 and 9** show that 97% of spoil samples have an ANC/MPA ratio greater than two and 93% of spoil samples have ANC/MPA ratios greater than five.

Table 5. Summary ANC/MPA ratios for spoil samples

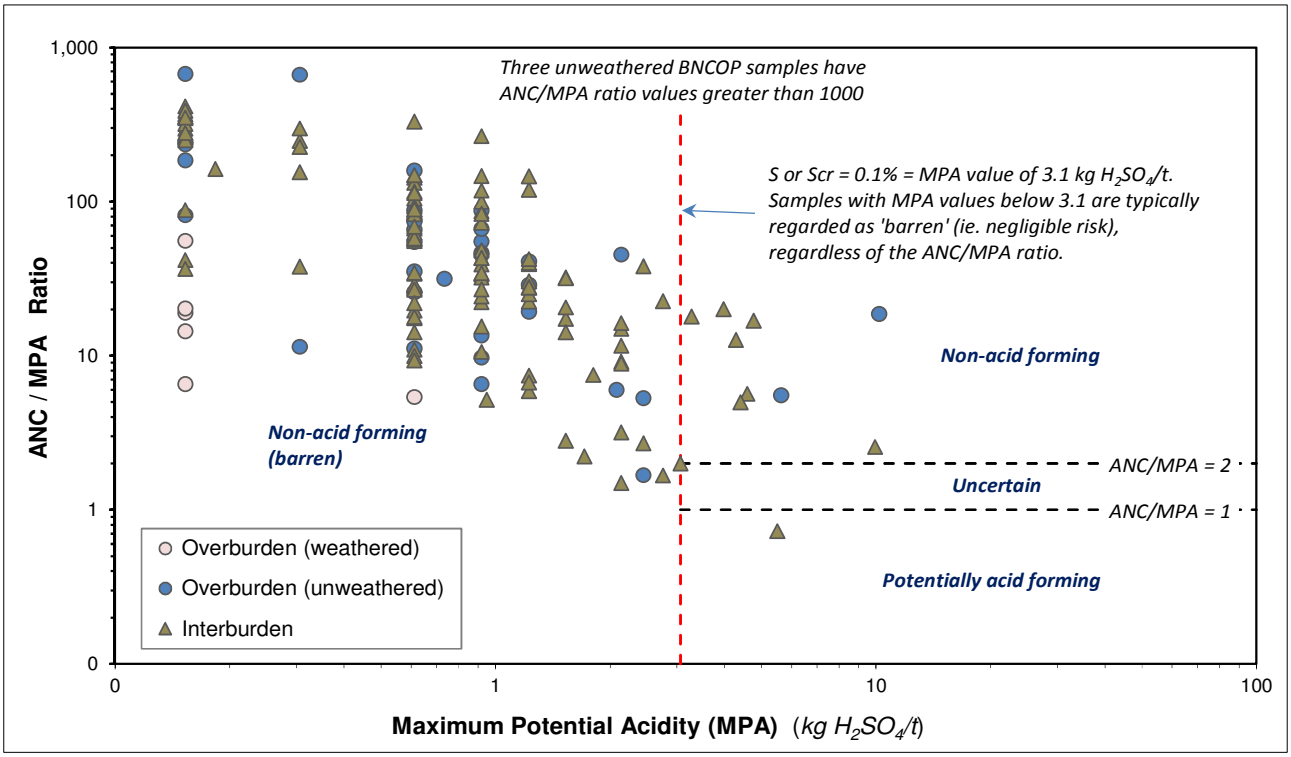
Sample Material	Min.	Max.	Median	Number and (%) of samples with ANC/MPA ratios:			
				Less than 1	Between 1 and 2	Between 2 and 5	Greater than 5
All spoil samples (n=162)	0.7	>3000	**37**	1 (<1%)	4 (~2%)	6 (~4%)	151 (93%)
Baralaba North/Wonbindi North spoil samples (n=67)	0.7	663	**45**	1 (~1%)	2 (~3%)	2 (~3%)	62 (93%)
BNCOP spoil samples (n=95)	1.5	>3000	**32**	-	2 (~2%)	4 (~4%)	89 (94%)

Figure 8. Statistical distribution of net acid producing potential (NAPP) and ANC/MPA ratio for spoil samples



5 INAP (2009) considers that mine materials with an ANC/MPA ratio greater than 2 are likely to be NAF unless significant preferential exposure of sulfides along fracture planes occurs in combination with insufficiently reactive ANC.

Figure 9. ANC/MPA ratio versus maximum potential acidity for spoil samples



Only five samples (~3% of samples) have ANC/MPA ratios less than two, however four of these samples have total sulfur values of 0.1% or less, and are therefore regarded as 'barren' with respect to sulfur concentration. Therefore, bulk spoil materials represented by these samples are considered to have a very low risk of acid generation, excess ANC, and a high factor of safety with respect to acid generation.

Geochemical classification of spoil

The ABA results presented in this section have been used to classify the acid forming nature of spoil samples as shown in **Appendix B – Table B1**. The geochemical classification (acid forming nature) of these samples is summarised in **Table 6**.

Table 6. Geochemical classification of spoil samples

	Geochemical Classification				
	NAF-barren	NAF	Uncertain	PAF-LC	PAF
Number and (%) of Baralaba North/Wonbindi North spoil samples (n=67)	63 (94%)	3 (~4%)	-	1 (~2%)	-
Number and (%) of BNCOP spoil samples (n=95)	85 (89%)	10 (11%)	-	-	-
Number and (%) of **all** spoil samples (n=162)	148 (91%)	13 (~8%)	-	1 (~1%)	-
% of **all** spoil samples (n=162)	**99 %**		**-**	**1 %**	

The results in **Table 6** show that almost all spoil samples tested (99%) fall in the NAF-Barren or NAF categories, and spoil materials represented by these samples have very low sulfur values, excess ANC and clearly have little to no capacity to generate acidity. One of the Baralaba North/Wonbindi North samples was classified as PAF-LC (PAF-low capacity).

From an acid generating perspective, spoil (as a bulk material) will be overwhelmingly NAF. This has implications for soluble metals transport, as pH neutral to alkaline spoil will inhibit the release of soluble metals, compared to the relatively high soluble metals concentrations possible in acidic drainage. Furthermore, the very low sulfur concentrations in spoil indicate that the sulfate concentration that could be generated in spoil from sulfide oxidation (in addition to any existing sulfate) will also be very low.

3.2 Acid-Base Account results for potential coal reject samples

ABA results for the 48 potential coal reject samples that underwent geochemical characterisation are presented in **Appendix B – Table B2** and summarised as follows. The laboratory certificates for these samples are provided in **Appendix D**. The samples comprised 25 'Baralaba North/Wonbindi North' samples and 23 'BNCOP' samples.

The results in this section are presented by coal seam (*eg*. Boyd, Cameron, *etc*.), however are generally discussed as a 'bulk' potential coal reject material, unless specifically noted.

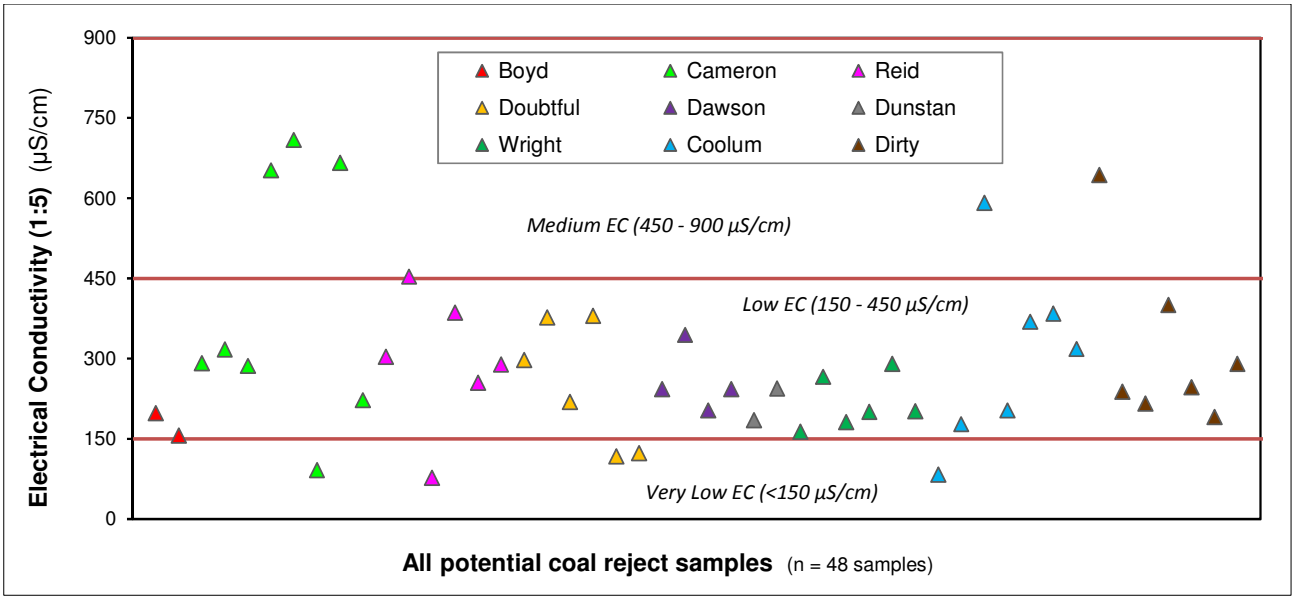
Electrical conductivity and pH of potential coal reject

The $EC_{1:5}$ values for potential coal reject samples span a broad range from 77 to 709 µS/cm (**Figure 10** top), with a median EC of 251 µS/cm and similarly low 90th percentile value of 494 µS/cm. Based on the DME (1995) soil salinity (EC) classification, potential coal reject, as a bulk material, is expected to have 'Low' soil salinity.

The $pH_{1:5}$ of potential coal reject samples span a broad range from pH 7.2 to pH 10.0 (**Figure 10** bottom), with 10th, 50th and 90th percentile values of pH 7.2, 9.5 and 9.8, respectively. Based on the DME (1995) soil pH classification, potential coal reject, as a bulk material, is expected to have 'Very High' soil pH.

Note: the actual salinity and pH of coal reject at the time of disposal may be different to the values shown, depending on any process additives used in the coal washing process.

Figure 10. Electrical conductivity (EC) and pH of potential coal reject samples
The EC and pH classifications shown correspond to DME (1995) soil salinity and soil pH classifications



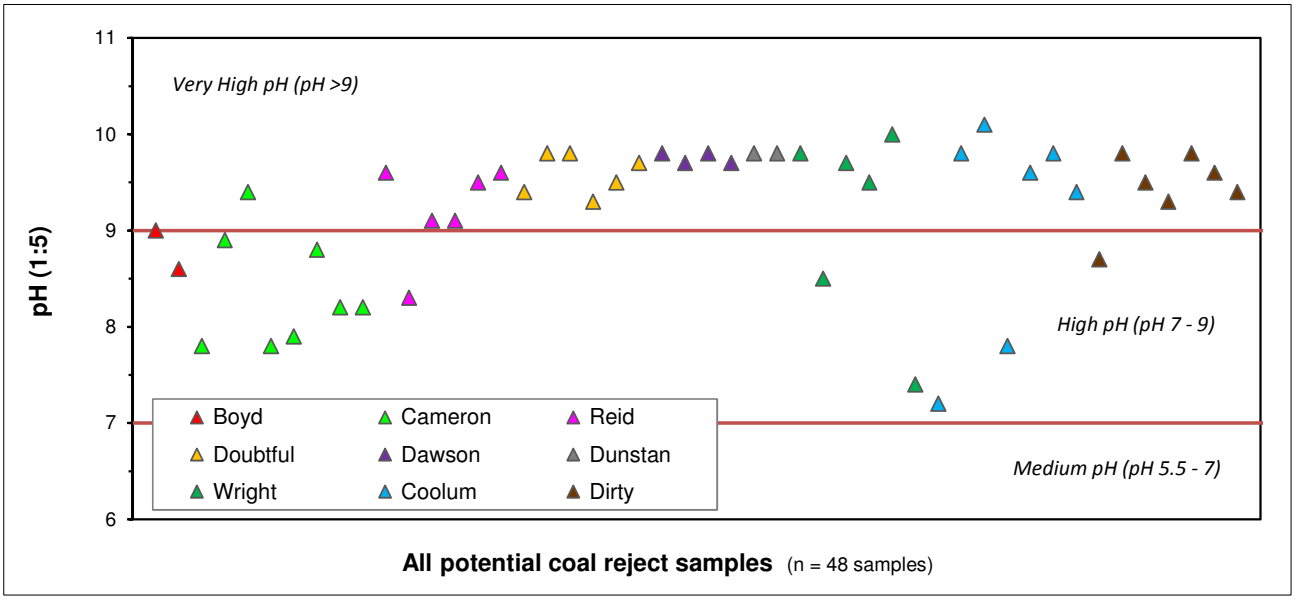


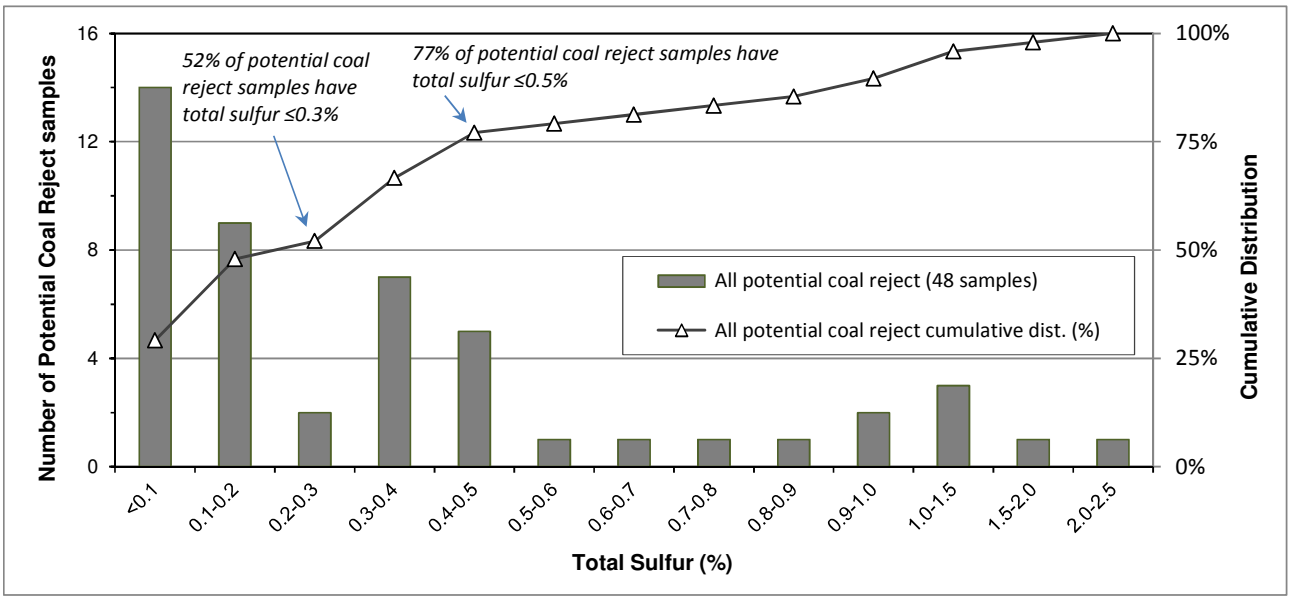
Figure 10 illustrates that there are some distinctions, on the basis of $EC_{1:5}$ or $pH_{1:5}$ values, between the various coal reject types (ROM coal source). For example, potential coal reject from the Cameron seam generally has less alkaline pH compared to most other potential coal reject samples. Also, some seams have a greater distribution of EC and pH values compared to other seams. For example, samples from the Cameron and Coolum seams have a greater range of EC values compared to, say, samples from the Wright and Dawson seams.

Overall, coal reject (as a bulk material) is be expected to have 'Low' EC and a 'Very High' pH, based on the DME (1995) soil salinity and pH classification criteria previously provided at **Table 2** in **Section 3.1**.

Sulfur in potential coal reject

The total sulfur concentration of the potential coal reject samples spans a broad range of values from 0.02% to 2.11%, with median (50th), 75th and 90th percentile values of 0.24, 0.44 and 0.99%, respectively. The distribution and cumulative distribution of sulfur in potential coal reject samples is shown in **Figure 11**.

Figure 11. Distribution and cumulative distribution of total sulfur in potential coal reject samples

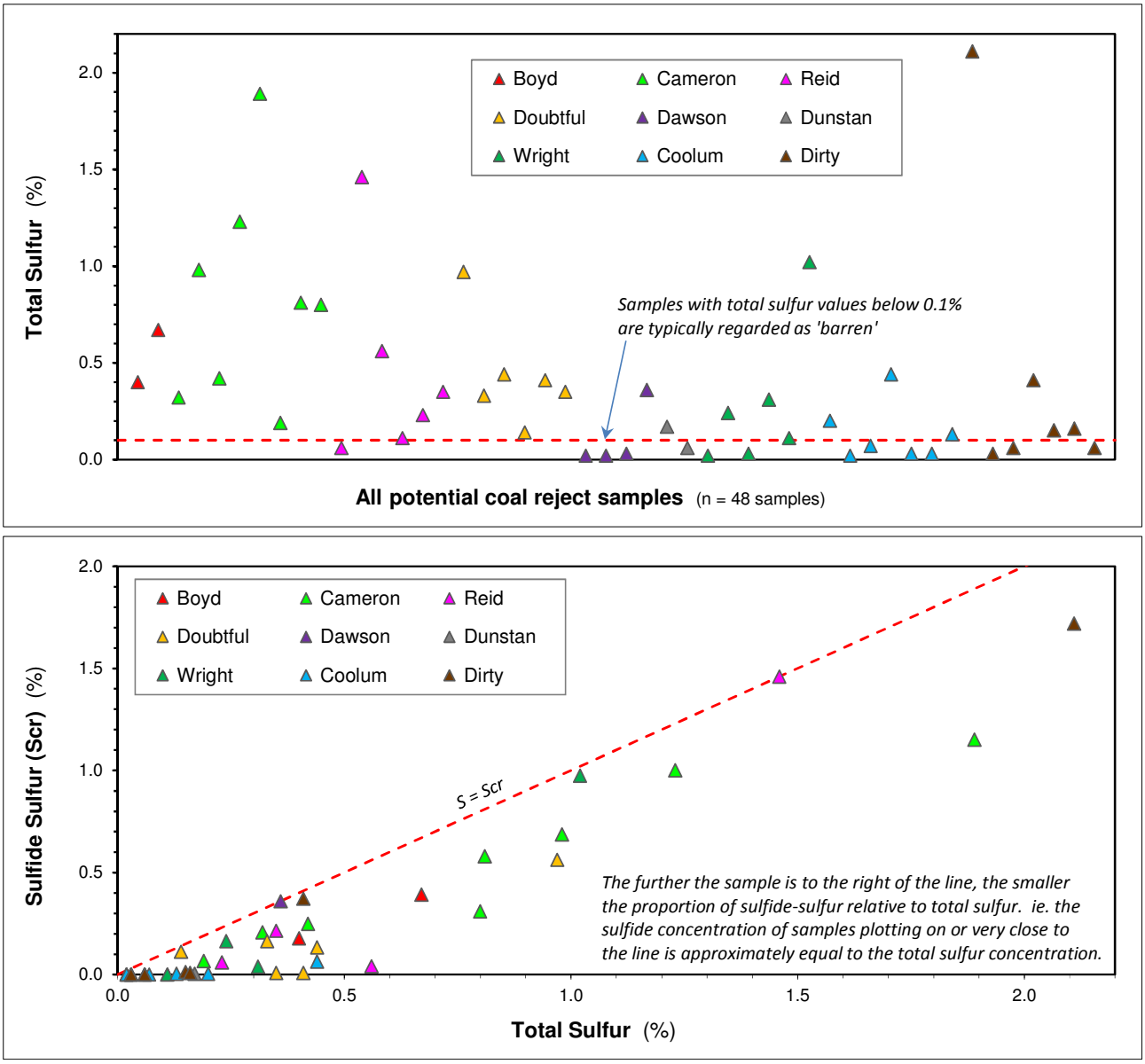


Of all 48 samples, 14 samples (29%) have total sulfur values less than or equal to 0.1% and therefore are regarded as 'barren'. 77% of samples (37 out of 48 samples) have total sulfur values less than or equal to 0.5%.

The relationship between the various coal reject 'sources' being discussed (with respect to sulfur and sulfide concentration) is shown in **Figure 12**, which illustrates that sulfur distribution is greater in potential coal reject samples from the Cameron seam (although most seams had samples with 'outlier' total sulfur values).

Sulfide-sulfur (as Scr) concentration was measured in 32 of the 48 potential coal reject samples. Scr values in the potential coal reject samples ranged from <0.01% to 1.72%, with 75th and 90th percentile values of 0.56% and 1.03%, respectively. On average, Scr comprises about 46% (average) of the total sulfur concentration, however the proportions ranged from 2% to 100% - as evident in **Figure 12** (bottom graph) by the scatter of data both along (close to) and further to the right of the unity line (the dashed line showing total sulfur = sulfide sulfur).

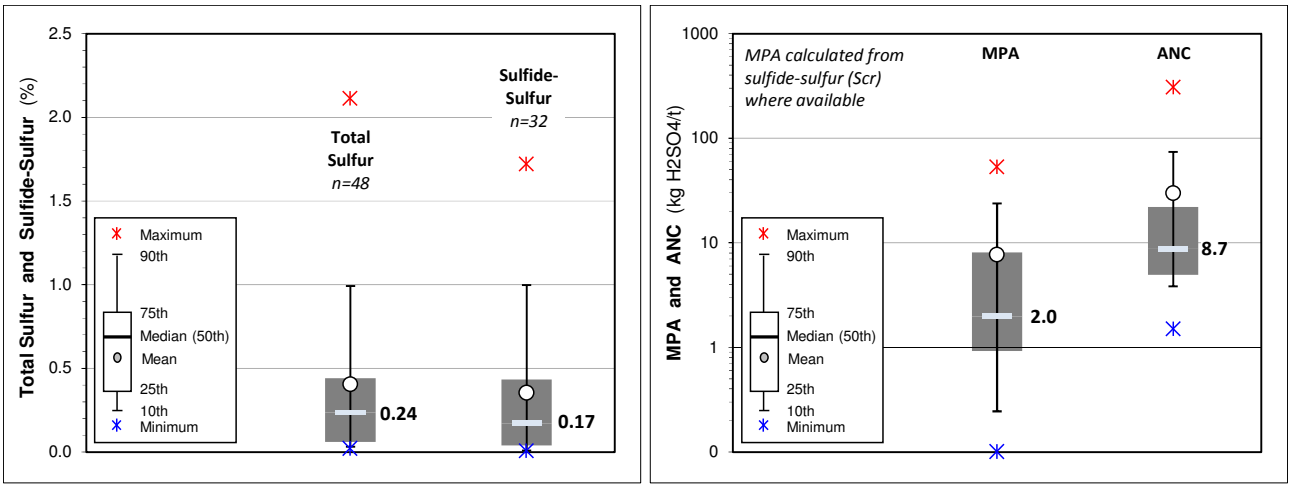
Figure 12. Total sulfur concentrations and total sulfur vs sulfide-sulfur concentrations for potential coal reject samples



The statistical distribution (a range of percentile values) of sulfur and sulfide values for potential coal reject samples is shown in **Figure 13** (left figure). The potential coal reject samples are presented as a 'bulk' material (*ie*. not differentiated by coal seam).

The box and whisker plot shows, with respect to total sulfur and sulfide-sulfur (Scr) concentrations, that the differences between total sulfur and sulfide-sulfur distribution are generally not significant.

Figure 13. Statistical distribution of total sulfur, sulfide-sulfur, maximum potential acidity and acid neutralising capacity values for potential coal reject samples



Maximum potential acidity and acid neutralising capacity of potential coal reject

The ANC and MPA that could be generated by potential coal reject samples (MPA calculated from Scr, where available) is summarised in **Table 7** and shown in **Figure 13** (above right) and **Figure 14**. As previously mentioned, Scr was determined on all samples with total sulfur values greater than 0.1%, which was about two-thirds of the potential coal reject samples. Therefore, the MPA values for about two-thirds of the potential coal reject samples were calculated using the Scr value. For the potential coal reject samples with very low sulfur concentrations (≤ 0.1%), MPA was calculated using the total sulfur value.

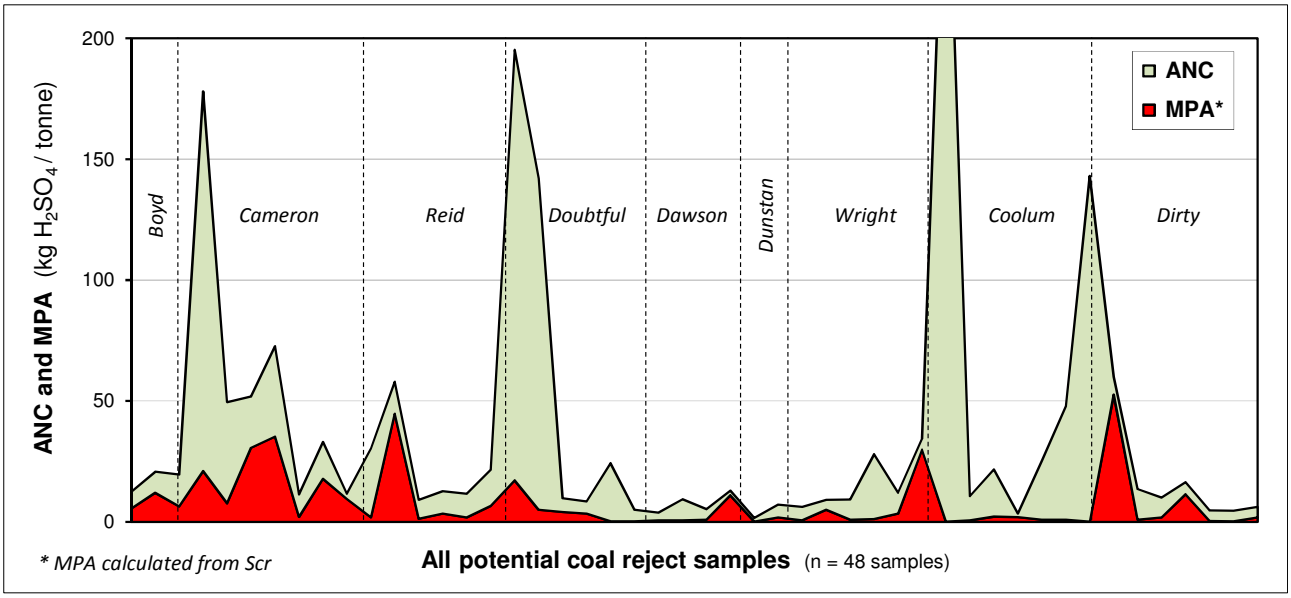
Table 7. Summary maximum potential acidity (MPA) and acid neutralising capacity (ANC) values for potential coal reject samples

MPA and ANC	Min.	Max.	Median	25th / 75th / 90th percentiles	General Comments
MPA (kg H_2SO_4/t)	0.1	53	**2.0**	**0.9** / **8.1** / **24**	Generally low
ANC (kg H_2SO_4/t)	1.5	305	**8.7**	**4.9** / **22** / **74**	Generally moderate

The MPA values for potential coal reject samples are generally low, with a very low median MPA of 2.0 kg H_2SO_4/t and relatively low 75th percentile value of 8.1 kg H_2SO_4/t, however MPA values are widely distributed (**Figure 13 and Table 7**).

Similarly, the ANC values for potential coal reject samples are also widely distributed (from 1.5 to 305 kg H_2SO_4/t), however generally the ANC values are moderate. The samples have a median ANC value of 8.7 kg H_2SO_4/t, and 75th and 90th percentile values of 22 and 74 kg H_2SO_4/t, respectively. That is, 75% of potential coal reject samples have ANC values below 22 kg H_2SO_4/t.

Figure 14. Maximum potential acidity (MPA) and acid neutralising capacity (ANC) for potential coal reject samples



Despite the low MPA and modest ANC values, there is a general excess of ANC compared to MPA in most of the potential coal reject samples and, as a 'bulk' material, coal reject is expected to have neutralising capacity. This is highlighted by the NAPP values and ANC/MPA ratios discussed below.

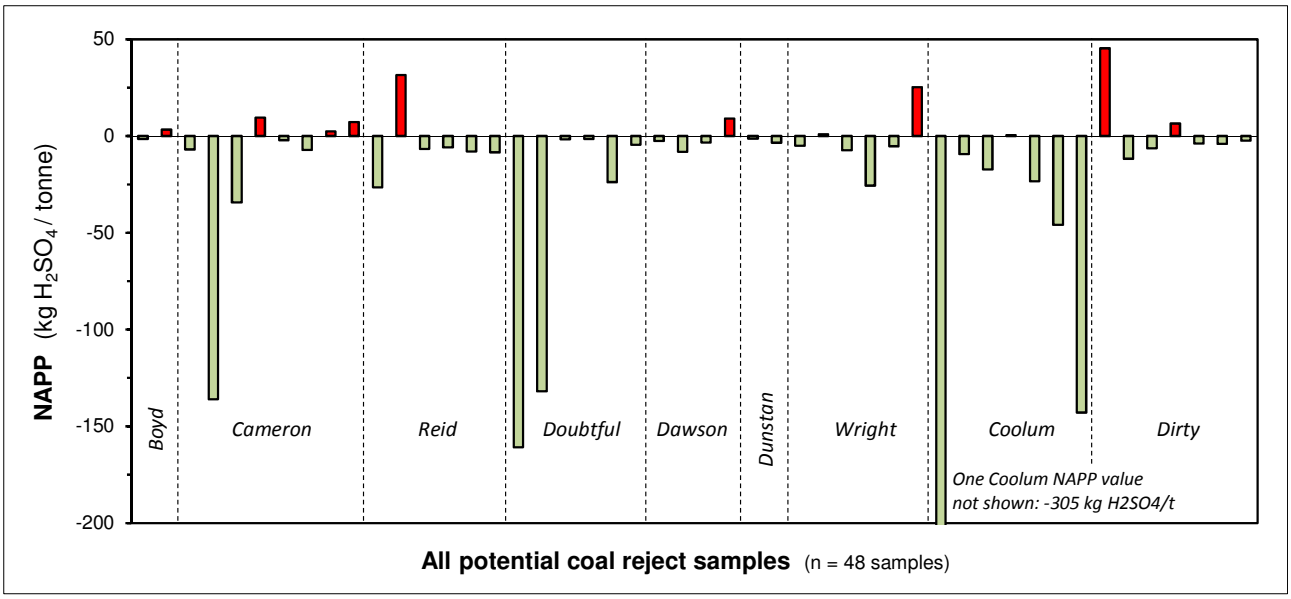
Net acid producing potential of potential coal reject

The NAPP values for potential coal reject samples are summarised in **Table 8** and shown in **Figure 15**. Based on the generally low MPA and generally modest ANC values the calculated NAPP values for the potential coal reject samples is also generally modest, with only 50% of samples having NAPP values less than -5 kg H_2SO_4/t, although 77% of samples have a negative NAPP value. Of the 48 potential coal reject samples, 11 samples had positive NAPP values. Of these, 3 samples had NAPP values greater than +10 kg H_2SO_4/t.

Table 8. Summary net acid producing potential (NAPP) values for potential coal reject samples

NAPP	Min.	Max.	Median	25th / 75th / 90th percentiles	General Comments
NAPP (kg H_2SO_4/t)	-305	+45	**-5.2**	**-13** / **-1.5** / **+7.8**	Generally low

Figure 15. Net acid producing potential (NAPP) for potential coal reject samples



ANC/MPA ratios of potential coal reject

Generally those samples with an ANC/MPA mass ratio greater than two are considered to have a negligible/low risk of acid generation and a high factor of safety in terms of potential for AMD (DITR, 2007; INAP, 2009[6]).

The results, which are summarised in **Table 9**, show that over two thirds of the potential coal reject samples (69%) have an ANC/MPA ratio greater than two and 50% of potential coal reject samples have ANC/MPA ratios greater than five.

Table 9. Summary ANC/MPA ratios for potential coal reject samples

ANC/MPA ratio	Min.	Max.	Median	Number and (%) of samples with ANC/MPA ratios:			
				Less than 1	Between 1 and 2	Between 2 and 5	Greater than 5
ANC / MPA ratio	0.1	>3000	**5.0**	11 (23%)	4 (~8%)	9 (19%)	24 (50%)

Fifteen (15) potential coal reject samples (31% of samples) have ANC/MPA ratios less than two, and about one-quarter of these samples (about 8% of all samples) have an ANC/MPA ratio of between one and two, indicating that these 8% of samples have a 'theoretical' excess of ANC relative to MPA, however it cannot be assumed that all of this ANC will be available to neutralise potential acidity. Of the 15 potential coal reject samples with ANC/MPA ratios less than two, 11 samples (23% of all samples) have ANC/MPA ratios less than one.

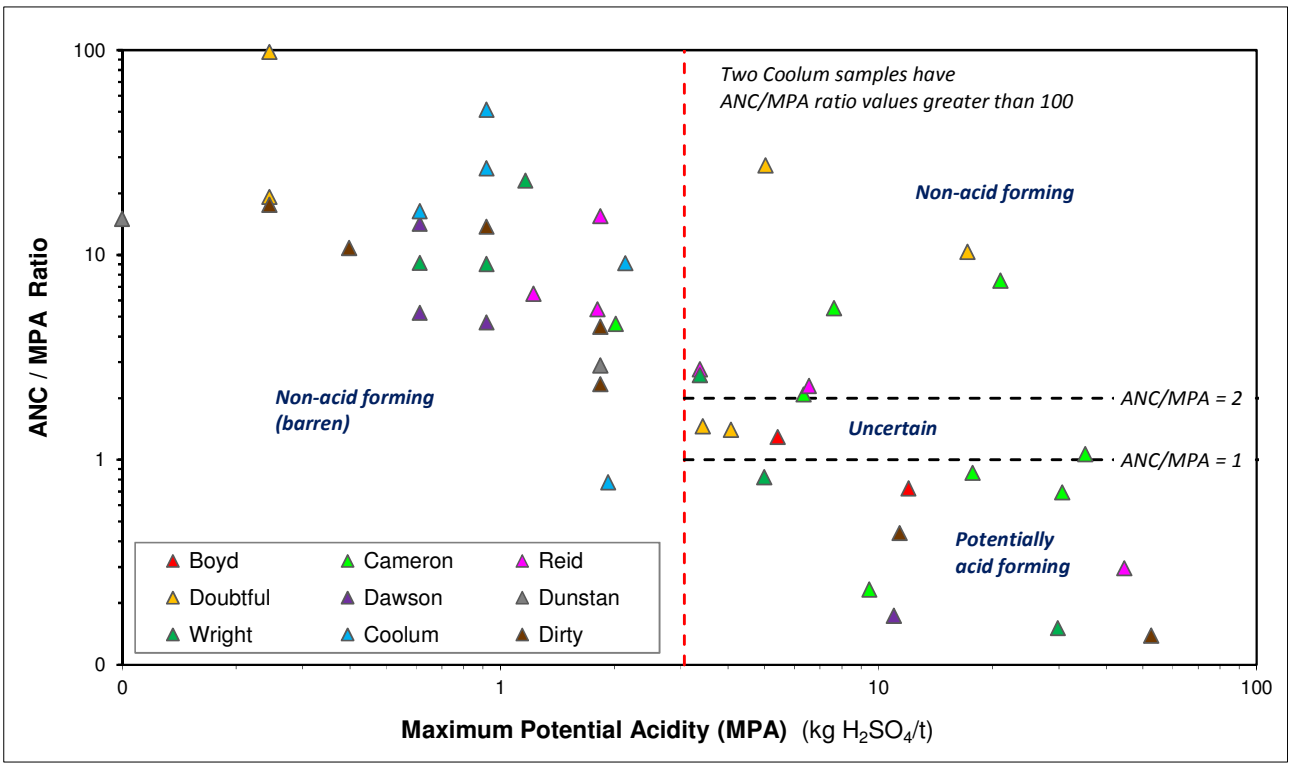
[6] INAP (2009) considers that mine materials with an ANC/MPA ratio greater than 2 are likely to be NAF unless significant preferential exposure of sulfides along fracture planes occurs in combination with insufficiently reactive ANC.

Most of the samples with ANC/MPA ratios less than one have relatively low sulfur (and sulfide) concentrations, resulting in low positive NAPP values (between 0 and 10 kg H_2SO_4/t). Therefore, materials represented by these materials are regarded as having a 'Low Capacity' to generate significant acidity.

Put simply, about two-thirds of potential coal reject samples have significant excess of ANC relative to MPA, and about one quarter of potential coal reject samples have excess MPA (relative to ANC) – however most of these 'low ANC/MPA ratio' samples also have a 'low capacity' to generate significant acidity. Therefore, as a bulk material, coal reject materials represented by these samples are considered to generally have a relatively low risk of acid generation.

The relationship between ANC/MPA ratios and MPA results are shown in **Figure 16** presented by individual coal seam. As evident in **Figure 16** there is no significant difference between the individual coal seams with respect to MPA and ANC/MPA ratios.

Figure 16. ANC/MPA ratio versus maximum potential acidity (MPA) for potential coal reject samples



Geochemical classification of potential coal reject

The ABA results presented in this section have been used to classify the acid forming nature of the potential coal reject samples as shown in **Appendix B – Table B2**. The geochemical classification (acid forming nature) of these samples is summarised in **Table 10**.

With respect to the potential coal reject samples, about 70% of samples tested fall in the NAF-Barren or NAF categories (**Table 10**), and coal reject materials represented by these samples have very low sulfur values, excess ANC (generally) and have little to no capacity to generate acidity.

Eleven (11) potential coal reject samples (about 23% of all potential coal reject samples) were classified as PAF, with most of these further classified as low capacity PAF (PAF-LC). The remaining 8% of samples had an 'Uncertain' classification due to a conflicting relationship between near-zero NAPP values, sulfur (or Scr) and ANC values, as discussed in **Section 4**. From a coal reject management point of view, it is conservatively assumed that up to 30% of potential coal reject could have some potential to generate acid (with no management controls in place).

Since spoil is NAF, any un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would not have any significant impact on the overall geochemical characteristics of bulk spoil, since the proportion of uneconomic seams (volume/tonnage), relative to non-seam overburden and interburden, is very small.

Table 10. Geochemical classification of potential coal reject samples

	Geochemical Classification				
	NAF-barren	NAF	Uncertain	PAF-LC	PAF
No. and (%) of potential coal reject samples (n =48)	14 (29%)	19 (40%)	4 (~8%)	8 (17%)	3 (~6%)
% of potential coal reject samples (n=48)	**69 %**		**8 %**	**23 %**	

From an acid generating perspective, coal reject (as a bulk material) is generally expected to be NAF. However since about one quarter of samples are classified as PAF and about 8% of samples classified as 'Uncertain' (and would need to be assumed as PAF as 'worst' case'), then the implication is that coal reject materials are regarded as having a potentially greater environmental 'risk' profile compared to spoil samples. Regardless, the generally low sulfide concentrations of the large majority of coal reject materials (as bulk materials) indicate that the sulfate concentration that could be generated by these materials is also expected to be relatively low.

3.3 Metals and metalloids in spoil and potential coal reject

Selected spoil and potential coal reject samples were subjected to a partial (two acid) digest to determine the concentration of a broad suite of metal and metalloid elements. A partial digest more accurately simulates the effects of a 'natural' acid on soil materials, such as the acidification that could theoretically occur due to AMD. The multi-element (solid) test results for 59 samples, comprising 39 spoil and 20 potential coal reject samples are presented in **Appendix B – Table B4** (spoil samples) and **Table B5** (potential coal reject samples), and summarised below. The ALS laboratory certificates for these 59 samples subjected to multi-element analysis are provided in **Appendix D**.

The results show that total metal and metalloid (solid) concentrations in all samples are typically low. All samples have total metals and metalloid concentrations below the applied NEPC (1999) health-based investigation levels (HILs) (C) for soils. However 14 spoil samples and 3 potential coal reject samples had 'elevated' manganese (Mn) concentrations with respect to the NEPC (1999) applied ecological investigation levels (EILs).

The EIL for Mn is 500 mg/kg, and values in the 17 'elevated' spoil samples range from 509 to 3770 mg/kg. One of these spoil samples also has barium (Ba) concentration (310 mg/kg) slightly greater than the applied EIL for Ba (300 mg/kg), and another separate spoil sample had an 'elevated' arsenic (As) concentration (52 mg/kg) with respect to the applied EIL for As (20 mg/kg). One potential coal reject sample is also 'elevated' in Ba (690 mg/kg) with respect to the applied EIL for Ba.

The environmental significance of identified metal concentrations in spoil and potential coal reject materials and their water solubility in terms of risk is discussed in **Section 4**.

3.4 Initial solubility of spoil and potential coal reject

To evaluate the initial solubility of multi-elements in solids, water extract (1:5 sample:water) tests were completed for each of the 59 samples that also underwent 'total element' analysis. The results from these tests are provided in **Appendix B – Table B6** (spoil samples) and **Table B7** (potential coal reject samples) and summarised below. The ALS laboratory certificates for the samples subjected to soluble multi-element analysis are provided in **Appendix D**.

Over half of the samples (both spoil and potential coal reject) have soluble metals concentrations that are 'elevated' with respect to the ANZECC (2000) aquatic ecosystem guideline level (for slightly to moderately disturbed systems) and/or the ANZECC (2000) livestock drinking water quality level for one or more of aluminium (Al), arsenic (As) and selenium (Se). One spoil and one potential coal reject sample each have soluble molybdenum (Mo) concentration above the applied livestock drinking water quality guideline level for Mo.

With regard to soluble Al, As and Se the laboratory limit of reporting (LOR) is higher than the applied aquatic ecosystem guideline concentration for each of these three elements, therefore any result above the laboratory LOR results in an 'exceedance' of the applied aquatic ecosystem guideline value. In most cases where samples exceed the applied livestock drinking water quality guideline levels the 'exceedance' is minor (*ie*. values typically just above the livestock drinking water quality guideline value).

The remaining soluble elements and ions are at concentrations below the applied livestock drinking water quality and aquatic ecosystem quality guidelines (where guideline values exist), and in most cases, below the laboratory LOR.

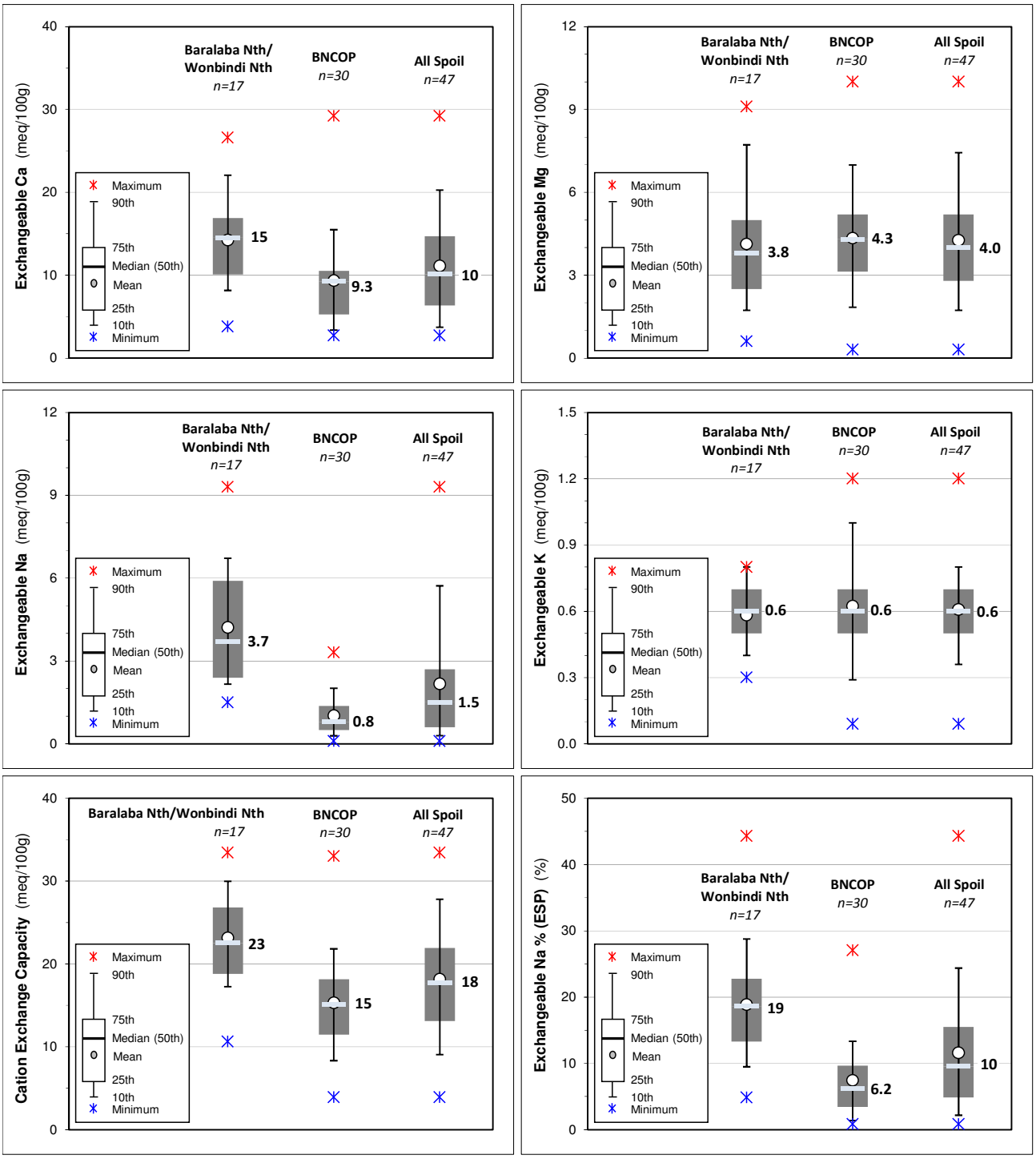
The environmental significance of identified soluble metal concentrations in spoil and coal reject materials in terms of risk is discussed in **Section 4**, however it is important to note that the soluble metal/metalloid results presented in this report represent an 'assumed worst case' scenario as the samples are pulverised (to minus 75 micron) prior to testing. Therefore, samples have a very high surface area compared to likely materials in the field. Materials would also be well mixed at storage locations. Hence, it is expected that the concentration of metal/metalloids in surface run-off and seepage from spoil (and coal reject) materials would be significantly less than the laboratory results from these 'pulped' samples and also less than applied guideline concentrations in the field.

It should be noted that the applied guideline values are provided to place the results into context. The applied guideline values are not intended as 'trigger values' or 'maximum permissible concentrations' with respect to total and soluble metals/metalloids in spoil (and coal reject) materials.

3.5 Cation exchange capacity, sodicity and dispersion of spoil

To evaluate the potential 'soil quality' of spoil materials, exchangeable cation concentrations were measured on 47 spoil samples and the results are presented in **Appendix B – Table B8** and summarised below. The statistical distribution of exchangeable cation, cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) values shown in **Figure 17**. The laboratory certificates for these samples are provided in **Appendix D**.

Figure 17. Statistical distribution of exchangeable cations (Ca, Mg, Na and K), cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) values for spoil samples



From a soil chemistry viewpoint the spoil materials have different soil characteristics compared to the potential coal reject materials, and coal reject materials would not report to final landform surfaces as they would be covered by spoil material. Furthermore, over 99% of all mining waste would be mined spoil. With this in mind, the suitability of mining waste materials for use in revegetation and rehabilitation is focused on the spoil materials.

The CEC of spoil samples (all 47 samples) range from 3.9 to 33 meq/100g, with a moderate median CEC value of 18 meq/100g . The exchangeable sodium percentage (ESP) results span a broad range, from a low 1% to a very high 44%, however the results are generally moderate - with a median ESP of 10% and 25th and 75th percentile values of 5% and 15%, respectively.

Most of the existing Baralaba North/Wonbindi North spoil samples have moderate to high ESP values (median 19%), whereas the BNCOP samples have much lower ESP values (median 6.2%), with 23 of the 30 BNCOP samples returning an ESP value below 10%.

To put these results into context, an ESP value of 6% or greater generally indicates that soil materials are regarded as sodic and *may* be prone to dispersion (Isbell, 2002) and soil with an ESP value greater than 14% is regarded as strongly sodic (Northcote and Skene, 1972). Strongly sodic materials are likely to have structural stability problems related to potential dispersion (Van de Graaff and Patterson, 2001). However, other important factors such as clay mineralogy, soil sodium concentration, soil salinity and irrigation water (rainwater) chemistry 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 and should not be taken as definitive.

With regard to the 6% and 14% 'guide' values, 13 of the 47 spoil samples (*ie*. 28% of spoil samples tested) have ESP values greater than 14%, of which 10 were from the southern end of the project area (Baralaba North/Wonbindi North) and only 3 from the northern part of the project area (BNCOP). The overall soil salinity and soil pH values are similar between the southern and northern project areas, as discussed in **Section 3.1**. However, spoil samples from southern area (Baralaba North/Wonbindi North samples) do have a slightly higher average and median soil salinity and soil pH compared to spoil samples from the northern project area (BNCOP samples) – although the differences between the southern and northern areas with respect to soil salinity and pH are relatively minor.

All 30 BNCOP spoil samples subjected to exchangeable cation tests also underwent Emerson class tests to determine whether these samples were dispersive. The results are presented in **Appendix B – Table B8**, and summarised in **Table 11**. Emerson 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.

Of the 30 spoil samples that underwent Emerson class tests almost all (27 out of 30) are non-dispersive (classes 7 and 8). Only three samples are dispersive (Classes 2 and 3), and of these three 'dispersive' samples, two are highly weathered. The Emerson class test results for BNCOP samples support the ESP results for BNCOP samples, in that the BNCOP spoil is generally not regarded as being highly sodic.

Table 11. Emerson Class results for BNCOP spoil samples

Emerson Class and Class Description		BNCOP Spoil *n=30*	Comments
1	Dispersive (strong)	-	Two of the three highly weathered samples tested were dispersive. One unweathered interburden sample was dispersive.
2	Dispersive (slight to moderate)	1	
3	Dispersive (when remoulded to plastic limit)	2	
4	Non-dispersive (calcite or gypsum present)	-	-
5	Non-dispersive (non-flocculating)	-	
6	Non-dispersive (flocculates)	-	
7	Non-dispersive, non-slaking (swelling)	7	Two-thirds of samples were non-dispersive, non-slaking and non-swelling. Four of the seven 'swelling' samples (class 7) were shallow interburden or overburden.
8	Non-dispersive, non-slaking (non-swelling)	20	

Ideally, highly sodic and dispersive materials should be identified, selectively handled and placed within the core of spoil piles away from final surfaces, or returned to voids during mining. The highly weathered material (and spoil from the southern part of the project area – Baralaba North/Wonbindi North) may be sodic and potentially dispersive, and this material would be mined first (either as pre-strip, in the case of weathered material, or in the earlier years, in the case of the Baralaba North/Wonbindi North materials). Therefore, most 'Baralaba North/Wonbindi North' spoil and/or weathered spoil would be 'buried' well away from final landform surfaces, if required. Regardless, any material designated for use on final surfaces would potentially require a topsoil cover or potentially a soil amendment if 'low nutrient' spoil was to be used as an additional source of topsoil in rehabilitation activities.

The environmental significance of exchangeable cation values and sodicity levels in spoil materials in terms of risk and potential revegetation management is outlined in **Section 4**, however readers are urged to consult the separate soils assessment undertaken as part of the environmental approvals for the BNCOP for a detailed assessment of soil properties with regard to rehabilitation.

4 Geochemical Characteristics of Spoil and Coal Reject

The geochemical characteristics of spoil (overburden and interburden) and potential coal reject materials have been assessed.

The characterisation and assessment program has been undertaken to enable the proponent to understand the existing environmental geochemical characteristics of these materials, the potential operational impacts these materials may have on the project and the potential environmental impacts these materials may have on the project and neighbouring area during operations and closure (post-closure).

The environmental geochemical characteristics of the materials are summarised below.

The main focus of the assessment is on spoil materials, as these materials would comprise almost all of the mining waste for the BNCOP, with coal reject materials comprising a very small proportion (less than 1% of all mining waste). To place this into perspective, spoil would be mined at an average annual rate of about 65 Mt/a and coal reject will be produced (from the CHPP) at a low average annual rate of about 0.3 Mt/a. Therefore, spoil would comprise over 99% of the mining waste generated by the BNCOP.

The geochemical characteristics of spoil materials are discussed as a bulk material, since there is little differentiation between the geochemical characteristics of materials from the southern end of the pit (Baralaba North/Wonbindi North – the existing mining operations) compared to those from the northern end (BNCOP – the expansion project).

The geochemical characteristics of potential coal reject materials are also outlined as bulk materials and not separated by seam or by location within the pit, since the assessment has found that there is generally little difference between the properties of potential coal reject materials from different seams or pit location, or between those from the existing Baralaba Coal Mine compared to those expected to be generated by the project. Furthermore, the quantity of coal reject produced by the project per annum and over the life of mine is very small.

Spoil

- Spoil, as a bulk material, is expected to generate pH- alkaline, low-salinity surface run-off and seepage following surface exposure. Weathered spoil can be expected to have similar geochemical characteristics to unweathered spoil.
- The total sulfur concentration of spoil is very low and all samples have a total sulfur concentration below 0.4%. Essentially all spoil samples (161 out of 162 samples) are classified as NAF and most (91%) of these NAF samples are further classified as ‘barren’ with respect to sulfur concentrations. Only one sample is classified as PAF–Low Capacity.
- Total metal and metalloid concentrations in spoil samples are generally low and well below the applied health-based guideline ‘level C’ for soils (NEPC, 1999). About 36% of spoil samples tested for metals and metalloids have total manganese concentration that exceeded the applied NEPC (1999) ecological investigation level for manganese. Two spoil samples also have slightly ‘elevated’ concentrations of total arsenic and barium with respect to the applied ecological investigation level for soils.

- Soluble multi-element results indicate that leachate from some bulk spoil has the potential to contain slightly elevated soluble aluminium, arsenic and selenium concentrations compared to applied ANZECC (2000) aquatic ecosystem protection and livestock drinking water quality guideline concentrations. Slightly elevated concentrations for some metals are common for spoil and coal reject materials at coal mines in the Bowen Basin and generally do not result in any significant water quality issues[7].

  It is important to note that the results presented in this report represent an 'assumed worst case' scenario as the samples are pulverised (to minus 75 micrometres) prior to testing. Therefore, samples have a very high surface area compared to materials in the field. Materials would also be well mixed at storage locations. Hence, it is expected that the concentration of metal/metalloids in surface run-off and seepage from spoil (and coal reject) materials would be significantly less than the laboratory results from these 'pulped' samples and also less than applied guideline concentrations in the field.

  The applied guideline values are provided for context and are not intended as 'trigger values' or 'maximum permissible concentrations' with respect to total and soluble metals/metalloids in spoil materials. Due to a number of factors in the field (compared to the laboratory), including scale-up and dilution, any direct comparison of soluble multi-element concentrations in leachate from spoil is strictly not valid and should be used with caution.

- Most spoil materials from the BNCOP have relatively low sodicity and are generally non-dispersive. Weathered spoil has a greater propensity to be dispersive, and spoil materials from the southern end of the pit area are generally more sodic compared to spoil materials from the northern end of the pit area. Therefore, spoil materials mined later in the mine life, which would report to final landform surfaces and be used/disturbed in rehabilitation activities, are generally non-sodic (or have low sodicity) and are non-dispersive.

Potential coal reject

- Potential coal reject materials are expected to generate pH-alkaline, low-salinity surface run-off and seepage following initial surface exposure (assuming any process additives used in the CHPP do not significantly alter the 'inherent' pH and salinity of the natural materials).

- About 70% of potential coal reject samples are classified as NAF and about 30% are classified as PAF or Uncertain – with most of the PAF samples regarded as having a 'Low Capacity' to generate significant acidity. Overall, the sulfur concentrations in potential coal reject materials is relatively low, with over 50% of samples having total sulfur concentrations below 0.3% and 77% of samples having total sulfur concentrations below 0.5%. Therefore, coal reject materials (as a bulk material) are regarded as relatively low risk, but may have some potential to generate relatively low concentrations of sulfate.

- Total metal and metalloid concentrations in potential coal reject samples are generally low and well below the applied health-based guideline 'level C' for soils (NEPC, 1999). Three samples tested for metals have concentrations of total manganese and one additional sample has a total barium concentration that exceed the applied NEPC (1999) ecological investigation level for these elements.

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[7] Based on Terrenus' experience undertaking environmental geochemical assessments within the Bowen Basin for numerous coal projects and mines extracting spoil and coal and producing coal reject.

- Some potential coal reject materials *may have the potential to* produce leachate containing slightly elevated soluble aluminium, arsenic, molybdenum and/or selenium concentrations, as is common from Permian coal measures in the Bowen Basin[7]. As discussed above, the results presented in this report represent an 'assumed worst case' scenario. Therefore, it is expected that the concentration of metals/metalloids in surface run-off and seepage from coal reject materials would be less than the applied ANZECC (2000) aquatic ecosystem protection and livestock drinking water quality guideline concentrations in the field.

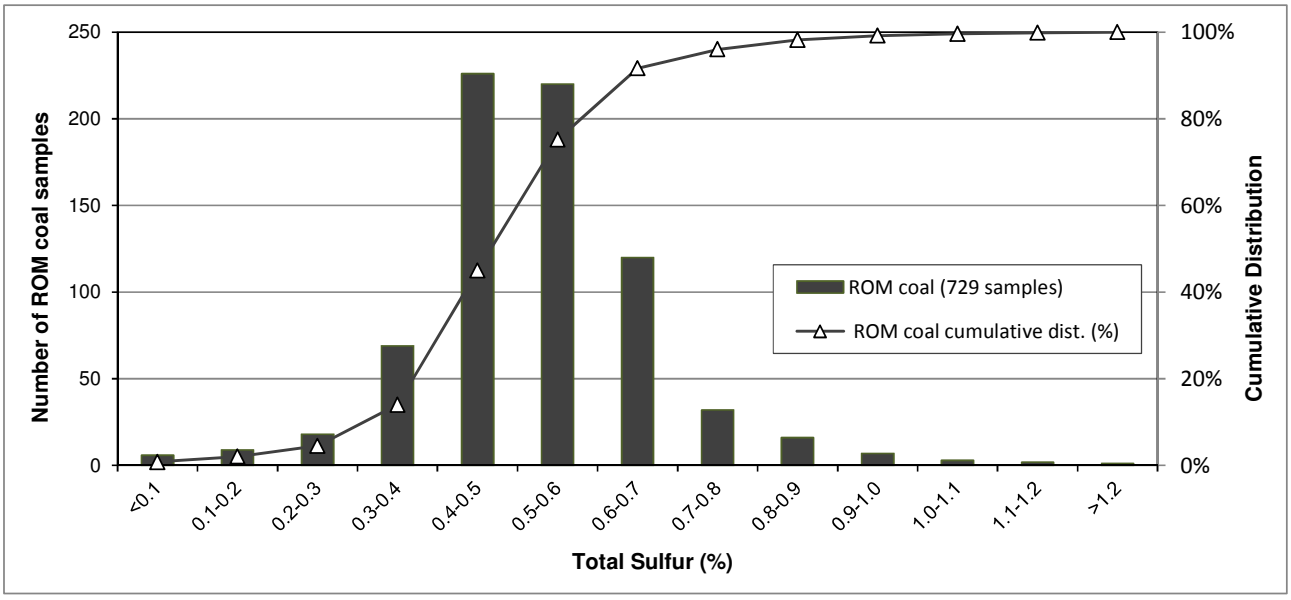
- Coal reject materials from individual and discrete seams (and plys/zones) display subtle geochemical variations, however the differences do not warrant selective handling and processing. As all coal reject is essentially 'mixed' during disposal into in-pit disposal areas amongst NAF and alkaline spoil, small proportions of potentially PAF materials and any elevated concentrations of soluble metals/metalloids from isolated coal reject sources would be significantly diluted amongst the bulk reject material.

- The discussion of potential coal reject materials within this report must be read in context. Firstly, the quantity of coal reject materials produced will be very low (about 0.3 Mt/a and about 5 Mt over mine life) and secondly, actual CHPP coal reject from the operational CHPP may have slightly different geochemical characteristics to these potential coal reject materials obtained from drill-core roof, parting and floor samples.

Potential ROM coal

Potential ROM coal samples have not been assessed (as part of this assessment), as these materials are not regarded as waste and would remain on site for a relatively short period of time. However, total sulfur data from coal quality testing from the existing Baralaba Coal Mine since 2011 (from 729 samples collected over three years) indicates that ROM coal generally has low sulfur values (median 0.52%; 90% percentile 0.68%) (**Figure 18**), and can be expected to have similar environmental geochemical characteristics to coal reject materials.

Figure 18. Distribution and cumulative distribution of total sulfur in ROM coal from Baralaba Coal Mine



There is no water quality data available from direct run-off alone from ROM coal at the existing Baralaba Coal Mine. However, mixed water quality data from the current ROM pad and mining areas at the Baralaba Coal Mine is available (from Sept. 2012 to Sept. 2013), and is briefly discussed below. An assessment of surface water and groundwater quality and potential impacts is addressed by others in the groundwater and surface water chapters of the EIS.

The water quality in the ROM Dam, which receives water from several sources including run-off from the ROM pad and recycled water from the mine dams and pit, is slightly alkaline (average pH 8.1) and saline (average 5,834 mg/L total dissolved solids). Sulfate concentrations are moderate (average 650 mg/L) and total aluminium and total iron concentrations are relatively low (average 0.14 mg/L and 0.98 mg/L, respectively). Other metals concentrations (as total soluble concentrations) are also relatively low, for example manganese (average 0.15 mg/L), molybdenum (average 0.03 mg/L), nickel (average 0.02 mg/L) and selenium (average 0.03 mg/L).

As is common practice at coal mines throughout the Bowen Basin, water from the ROM Dam and mining area dams are used on the ROM pad for dust suppression and have likely been subjected to evapo-concentration. Therefore, taking into account that the ROM Dam water is evapo-concentrated and receives water from other sources, including brackish-saline groundwater from the pit, it can be reasonably assumed that potential ROM coal from the project would probably produce run-off water with similar or lower concentration to that observed in the existing ROM Dam at Baralaba Coal Mine.

The environmental management of coal (ROM coal and/or product coal) is focused on run-off and seepage collection and dust control – all of which are ‘standard’ management practices for ROM and product coal stockpiles, and are outlined in **Section 5** below.

5 Management and Mitigation Measures

5.1 Spoil and coal reject management planning

A Waste Management Program (EMM, 2013) has been adopted for the Baralaba Coal Mine to address the relevant condition(s) of the site Environmental Authority. 'New' spoil and 'new' coal reject materials generated by the project are proposed to be managed on site under the existing Waste Management Program for Baralaba Coal Mine.

The existing Waste Management Program has the following broad management strategies:

- Topsoil is selectively mined, stockpiled and segregated from spoil and coal reject;
- Spoil is initially stored in out-of-pit emplacement facilities and levees and then stored (back-filled) within in-pit spoil piles behind the active mining strip as the mining activity progresses;
- Coal reject is disposed amongst spoil within the in-pit spoil piles. Coal reject does not report to final landform surfaces.

Spoil generated at the project is expected to be benign with a negligible risk of acid generation, low salinity and generally low metal/metalloid concentrations. Hence, the broad management strategy would be to ensure that uneconomic coal seams/plys mined as spoil do not report to final surfaces, as these 'carbonaceous' zones can be associated with sulfide minerals. Such pit control would be determined and dictated by the site geologists as part of the waste scheduling and day-to-day mining operations.

All coal reject should be disposal back into the mine pit to be buried amongst in-pit spoil. Generally, such a disposal strategy would require coal reject to be covered by a minimum of five metres final thickness of spoil (which takes into account re-shaping of spoil areas during rehabilitation activities), such that coal reject does not report to final surfaces.

5.2 Spoil management strategy

Spoil is overwhelmingly NAF with excess ANC and has a negligible risk of developing acid conditions. Furthermore, spoil is expected to generate relatively low-salinity surface run-off and seepage and have a low potential for dispersion. Some weathered spoil materials may have a higher propensity to disperse and erode. Spoil from the southern end of the pit area may be more sodic compared to spoil from the northern end of the pit area.

Typically in an open-pit mining operation weathered spoil would be mined before unweathered materials. At the project this is likely to be the case with weathered spoil reporting to the base of spoil piles or back into pit voids and being covered by unweathered spoil. Therefore, weathered spoil (not including topsoil) should not report to final surfaces to any significant extent, and should not pose significant environmental management issue for the project. Spoil used for final landform covering would primarily comprise unweathered material, which has a relatively low salinity and low potential for dispersion.

Where spoil is used for construction activities, this should be limited to unweathered materials. Regardless of the spoil type, especially where engineering or geotechnical stability is required, testing should be undertaken by the proponent to determine the propensity of such materials to erode.

Surface run-off and seepage from spoil piles, including any rehabilitated areas, should be monitored for 'standard' water quality parameters including, but not limited to, pH, EC, major anions (sulfate, chloride and alkalinity), major cations (sodium, calcium, magnesium and potassium), total dissolved solids (TDS) and a broad suite of soluble metals/metalloids.

These management principles are currently successfully adopted at the site, and documented in the existing Waste Management Program for Baralaba Coal Mine (EMM, 2013). The 'new' spoil from the project would have essentially the same (or similar) geochemical characteristics to the existing spoil from the Baralaba Coal Mine, therefore the current management measures for spoil are expected to be appropriate for managing 'new' spoil generated by the project.

Although this assessment had a large number of sample drill-holes in the southern and central areas of the proposed pit, the geological and geochemical data shows no significant difference between the southern and northern mining areas with respect to overall geology (seams and overburden/interburden lithologies) and the geochemical characteristics of spoil and potential coal reject. Therefore, management strategies for spoil and coal reject materials from the entire pit area are expected to be the same.

With the implementation of the proposed management and mitigation measures, the spoil is regarded as posing a low risk of environmental harm.

5.3 Coal reject management strategy

The proposed strategy for coal reject disposal is for all coal reject to be disposed, as a dewatered reject, into mined-out pit areas and buried beneath spoil.

Up to 30% of coal reject materials may have a relatively low degree of risk associated with potential acid generation, however as a bulk material (of relatively small total quantity), coal reject is regarded as posing a low risk of environmental harm. This is primarily due to the generally low sulfur (and sulfide) concentration within this material (and also the low metals concentrations), which suggests that the magnitude of any localised acid, saline or metalliferous drainage, if it occurs, is likely to be small, and would be confined to the pit area. Therefore, when disposed amongst alkaline NAF spoil within in-pit disposal areas the overall risk of environmental harm and health-risk that disposed (in-pit buried) coal reject poses is very low.

Operational monitoring of coal reject and in-pit disposal areas

The proponent should undertake further assessment of actual coal reject materials from the CHPP as the project develops. Coal reject disposed into the pit would be placed below the expected final (post-closure) groundwater level and buried by at least five metres (cover thickness) of spoil within one month of placement.

Decommissioning, rehabilitation and closure of the in-pit coal reject disposal areas

The decommissioning, closure and post-closure aspects of the back-filled pit (and final void) would be addressed by a Mine Closure Plan. However, as coal reject would be covered by a minimum of five metres final thickness of spoil, and would not report to final landform surfaces (or near-surfaces), the management of in-pit coal reject would not be expected to be relevant to mine or pit decommissioning and rehabilitation.

5.4 ROM pad and CHPP

ROM coal is expected to have similar characteristics to BNCOP potential coal reject materials and to current ROM coal at the Baralaba Coal Mine. The proponent should undertake periodic assessment of ROM coal and Product Coal materials as the project develops to assist with their management plans for ROM and Product coal pads (*ie*. to inform about potential water quality and allow appropriate management measures to be implemented).

ROM coal and Product coal is typically stored at the site for a relatively short period of time (weeks) compared to mining waste materials, which would be stored at the site in perpetuity. Management practices are therefore different for coal and would largely be based around the operational (day-to-day) management of surface run-off and seepage water from ROM pads and coal stockpiles – as is currently accepted practice at coal mines in Australia, including the existing Baralaba Coal Mine.

Surface run-off and seepage from ROM and Product coal stockpiles should be monitored for 'standard' water quality parameters including, but not limited to, pH, EC, major anions (sulfate, chloride and alkalinity), major cations (sodium, calcium, magnesium and potassium), total dissolved solids (TDS) and a broad suite of soluble metals/metalloids.

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Appendix A

Summary Information for Drill-holes Utilised
in the Geochemistry Assessment

Table A1. Drill-hole summary information

Drill-hole ID	**Easting** (m) GDA94, zone 55	**Northing** (m) GDA94, zone 55	**Collar elevation** (mRL)	**Depth** (m)	**Completion Date**	**Hole type** Cored intervals (m) indicated. Remaining intervals are chipped
GT0002	784,004	7,327,679	82.9	206.43	2 Aug 2011	59.6 to end of hole (206.43)
GT0003	783,898	7,327,983	82.6	151.96	8 Oct 2011	23.4 to end of hole (151.96)
GT0006	783,493	7,327,988	82.2	192.87	22 Sep 2011	34.4 to end of hole (192.87)
GT0007	783,913	7,328,638	80.6	50.40	15 Oct 2011	8.0 to end of hole (50.4)
GT0008	783,619	7,328,535	85.0	225.0	31 Oct 2011	70.0 to end of hole (225.0)
GT0009*	783,310	7,328,434	82.0	209.70*	2 Nov 2011	29.7 to end of hole (209.70)
GT0010	783,710	7,329,018	82.1	125.97	12 Oct 2011	9.3 to end of hole (125.97)
GT0012	783,287	7,328,877	85.0	212.70	18 Oct 2011	30.0 to end of hole (212.70
GT0018	784,158	7,329,169	86.8	136.39	3 Oct 2011	40.0 to end of hole (136.39)
BN0016CH	783,181	7,329,215	85.4	50.0	21 Aug 2012	35.4 to end of hole (50.0)
BN0102CH	783,249	7,329,484	84.7	65.00	30 Sep 2012	43.0 to 58.4
BN0185CH	783,351	7,329,770	87.7	131.0	18 Oct 2012	29.9 to 43.9; 86.0 to 99.0; 111.0 to 124.3
BN0185CHR1	783,356	7,329,771	87.7	75.00	28 Oct 2012	52.0 to 68.9
BN0281CH	783,505	7,329,660	87.3	74.03	05 Oct 2012	62.0 to end of hole (74.0)
BN0308CH	783,038	7,330,311	89.6	101.00	07 Sep 2012	40.1 to 46.6; 85.1 to 95.2
BN0352CH	783,320	7,329,627	86.1	66.00	05 Sep 2012	50.2 to 62.9
BN0571CH	783,687	7,329,603	87.4	131.52	22 Oct 2012	100.1 to end of hole (131.52)
BN0744CH	780,966	7,334,017	96.0	104.57	03 Sep 2013	36.1 to 52.0; 84.2 to end of hole (104.57)
BN0258CHR1	782,615	7,331,213	106.0	149.00	11 Oct 2013	60.0 to 80.2; 90.6 to 112.8; 126.2 to 142.6
BN0373CH	782,144	7,331,827	94.5	179.71	08 Sep 2013	39.0 to 49.6; 77.2 to 90.6; 118.1 to 121.2; 165.0 to 174.0
BN0679CHR1	781,845	7,332,675	91.0	198.00	23 Sep 2013	42.0 to 61.4; 129.8 to 189.3

* All drill-holes are vertical (dip = 90 degrees), except for GT0009, which has dip 60 degrees and azimuth 76 degrees. GT0009 depth shown is uncorrected for dip. Corrected depth = 181.61 m.

Appendix B

Static Geochemical Results Tables

- Table B1 – Acid-base characteristics of spoil
- Table B2 – Acid-base characteristics of potential coal reject
- Table B3 – Composite sample details (sample composition) for 'Baralaba North/Wonbindi North' samples
- Table B4 – Multi-element concentrations in spoil
- Table B5 – Multi-element concentrations in potential coal reject
- Table B6 – Soluble multi-element concentrations in 1:5 water extracts from spoil
- Table B7 – Soluble multi-element concentrations in 1:5 water extracts from potential coal reject
- Table B8 – Exchangeable cations and Emerson class number test results

Table B1. Acid-base characteristics of spoil (BNCOP samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
Overburden and Interburden (likely spoil - mining waste) BNCOP samples														
EB1326024024	86008	BN0679CHR1	10.00 - 11.00	Overburden (highly weath.)	Sand, f	8.9	88	<0.01	-	0.2	1	-0.8	6.5	NAF (barren)
EB1326024001	86037	BN0258CHR1	12.00 - 14.00	Overburden (highly weath.)	Sand, f; and Clay	7.3	53	<0.01	-	0.2	2	-2.0	14	NAF (barren)
EB1326024025	86009	BN0679CHR1	23.00 - 24.00	Overburden (highly weath.)	Sandstone, f	8.3	112	<0.01	-	0.2	3	-2.7	19	NAF (barren)
EB1326024026	86010	BN0679CHR1	32.00 - 33.00	Overburden (highly weath.)	Sandstone, f	8.9	101	<0.01	-	0.2	3	-2.9	20	NAF (barren)
EB1324288039	86011	BN0373CH	39.09 - 39.44	Overburden (mod. weath.)	Sandstone, f	8.1	45	<0.01	-	0.2	9	-8.3	56	NAF (barren)
EB1326024002	86038	BN0258CHR1	32.86 - 33.64	Overburden (slightly weath.)	Sandstone, m	8.7	180	<0.01	-	0.2	37	-37	242	NAF (barren)
EB1328300001	86001	BN0679PZ	41.10 - 41.30	Overburden (slightly weath.)	Sandstone, f	8.6	53	0.02	<0.005	0.1	3	-3.2	36	NAF (barren)
EB1324288029	86128	BN0744CH	36.40 - 36.55	Overburden	Siltstone	8.8	196	<0.01	-	0.2	103	-103	673	NAF (barren)
EB1324288001	86047	BN0016CH	36.84 - 37.22	Overburden	Mudstone	8.6	286	0.03	-	0.9	12	-11	13	NAF (barren)
EB1324288009	86105	BN0185CH	37.23 - 37.5	Overburden (near DBTUA)	Sandstone, vf-f	8.8	224	0.02	-	0.6	22	-21	35	NAF (barren)
EB1326024003	86039	BN0258CHR1	38.00 - 39.00	Overburden	Sandstone, m-c	8.7	181	<0.01	-	0.2	36	-36	234	NAF (barren)
EB1324288030	86002	BN0744CH	39.26 - 39.54	Overburden	Sandstone, f-m; carbonaceous	8.8	181	<0.01	-	0.2	488	-488	3187	NAF (barren)
EB1326024004	86040	BN0258CHR1	41.15 - 42.30	Overburden (BYD roof)	Siltstone	8.5	214	<0.01	-	0.2	13	-12	82	NAF (barren)
EB1324288048	86123	BN0373CH	41.60 - 41.75	Overburden	Siltstone; and Sandstone, f	8.8	209	<0.01	-	0.2	170	-170	1110	NAF (barren)
EB1324288019	86113	BN0308CH	41.68 - 41.89	Overburden (near DBTUA)	Sandstone, vf; and Siltstone	8.9	197	0.02	-	0.6	33	-33	55	NAF (barren)
EB1326024005	86041	BN0258CHR1	42.30 - 43.19	Overburden (BYD)	Coal; and Carb. Siltstone	7.4	128	0.35	0.02	0.7	23	-22	31	NAF
EB1326024006	86042	BN0258CHR1	44.07 - 45.06	Overburden (BYD floor)	Siltstone	8.4	128	0.12	0.07	2.1	13	-10	6.0	NAF
EB1324288049	86124	BN0373CH	44.20 - 44.35	Overburden	Sandstone, f.; and Siltstone	8.7	138	0.02	-	0.6	16	-15	26	NAF (barren)
EB1324288031	86003	BN0744CH	44.24 - 44.54	Overburden	Siltstone	9.1	186	<0.01	-	0.2	28	-28	185	NAF (barren)
EB1324288005	86101	BN0102CH	49.70 - 49.86	Overburden	Sandstone, vf; with carb. wisps	8.2	445	0.08	-	2.5	13	-11	5.3	NAF (barren)
EB1328300002	86020	BN0679CHR1	51.77 - 51.96	Overburden	Sandstone, c-vc	9.1	143	0.05	0.02	0.6	40	-39	65	NAF (barren)
EB1324288024	86118	BN0352CH	55.01 - 55.19	Overburden (near REIU)	Sandstone, vf; and Siderite	9.1	25	0.03	-	0.9	9	-8.0	10	NAF (barren)
EB1324288016	86110	BN0281CH	64.08 - 64.27	Overburden (near WRIU)	Sandstone, vf-f; some calcite	9.3	329	0.26	0.18	5.6	31	-25	5.5	NAF
EB1324288040	86012	BN0373CH	80.90 - 81.21	BYD-CAM interb.	Sandstone, m	9.3	288	0.02	-	0.6	54	-54	88	NAF (barren)
EB1326024007	86043	BN0258CHR1	49.03 - 50.03	BYD-CAM interb.	Siltstone	8.8	119	0.07	-	2.1	20	-17	9.1	NAF (barren)
EB1326024008	86044	BN0258CHR1	57.02 - 58.03	BYD-CAM interb.	Sandstone, m	9.0	205	0.27	0.13	4.0	80	-76	20	NAF
EB1326024009	86167	BN0258CHR1	68.40 - 68.60	BYD-CAM interb.	Siltstone; and Sandstone, f	9.2	195	0.07	-	2.1	32	-30	15	NAF (barren)
EB1326024045	86143	BN0373CH	77.60 - 77.75	BYD-CAM interb.	Sandstone, c	9.4	304	0.03	-	0.9	79	-78	86	NAF (barren)
EB1326024010	86125	BN0258CHR1	74.62 - 74.96	BYD-CAM interb. (near CAM)	Siltstone; minor Calcite	9.2	273	0.40	0.33	10.0	25	-15	2.6	NAF
EB1324288041	86013	BN0373CH	85.08 - 85.42	BYD-CAM interb. (near CAM)	Sandstone, f; and carb. Siltstone	9.1	129	0.02	-	0.6	17	-16	27	NAF (barren)
EB1324288002	86048	BN0016CH	40.57 - 40.86	CAM-SCA interb.	Sandstone, vf	9.0	342	0.05	-	1.5	27	-25	17	NAF (barren)
EB1324288006	86102	BN0102CH	52.63 - 52.9	CAM-SCA interb.	Sandstone, vf; with calcite veins	8.7	221	0.04	-	1.2	9	-7.9	7.4	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B1 (cont.) Acid-base characteristics of spoil (BNCOP samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
...continued Overburden and Interburden (likely spoil - mining waste) BNCOP samples														
EB1324288003	86049	BN0016CH	41.88 - 42.13	CAM-SCA interb. (near SCA)	Sandstone, f	9.1	360	0.05	-	1.5	22	-20	14	NAF (barren)
EB1324288004	86050	BN0016CH	44.26 - 44.52	SCA-REI interb. (near SCA)	Sandstone, vf	7.3	558	0.11	0.06	1.7	4	-2.1	2.2	NAF
EB1324288007	86103	BN0102CH	55.49 - 55.81	SCA-REI interb. (near SCA)	Sandstone, vf; with calcite veins	8.6	283	0.10	0.03	0.9	5	-4.0	5.2	NAF (barren)
EB1326024046	86144	BN0373CH	90.20 - 90.35	SCA-REI interb. (near SCA)	Carbonaceous Siltstone	9.3	353	0.16	0.15	4.6	26	-21	5.6	NAF
EB1324288008	86104	BN0102CH	55.81 - 56.11	SCA-REI interb.	Sandstone, vf-f	9.0	154	0.02	-	0.6	7	-6.1	11	NAF (barren)
EB1324288042	86015	BN0373CH	103.00 - 104.00	SCA-REI interb.	Sandstone, m	9.4	294	0.09	-	2.8	62	-59	23	NAF (barren)
EB1324288032	86129	BN0744CH	51.20 - 51.35	CAM-REI interb.	Siltstone	9.0	223	0.10	0.06	1.8	14	-12	7.5	NAF (barren)
EB1324288033	86130	BN0744CH	85.00 - 85.15	CAM-REI interb.	Siltstone	9.5	296	0.02	-	0.6	52	-51	85	NAF (barren)
EB1324288034	86004	BN0744CH	88.30 - 88.69	CAM-REI interb.	Sandstone, f; and carb. Siltstone	9.6	344	0.02	-	0.6	87	-87	142	NAF (barren)
EB1324288035	86005	BN0744CH	92.37 - 92.64	CAM-REI interb.	Sandstone, f. Siltstone	9.6	299	0.02	-	0.6	53	-52	86	NAF (barren)
EB1324288036	86006	BN0744CH	95.13 - 95.45	CAM-REI interb.	Sandstone, f. Siltstone	9.6	328	0.02	-	0.6	64	-63	104	NAF (barren)
EB1326024012	86127	BN0258CHR1	83.11 - 84.05	CAM-REI interb.	Siltstone	9.4	258	0.05	-	1.5	49	-48	32	NAF (barren)
EB1326024013	86138	BN0258CHR1	89.00 - 90.00	CAM-REI interb.	Sandstone, m	9.4	231	0.03	-	0.9	91	-90	99	NAF (barren)
EB1326024014	86132	BN0258CHR1	90.90 - 91.26	CAM-REI interb.	Sandstone, m	9.5	296	0.01	-	0.3	76	-75	247	NAF (barren)
EB1326024015	86133	BN0258CHR1	98.79 - 99.01	CAM-REI interb.	Sandstone, m.; with Siltstone	9.6	264	0.04	-	1.2	37	-36	30	NAF (barren)
EB1326024016	86134	BN0258CHR1	102.03 - 102.25	CAM-REI interb.	Siltstone; with Sandstone, f	9.6	291	0.04	-	1.2	48	-47	39	NAF (barren)
EB1326024017	86135	BN0258CHR1	108.25 - 108.63	REI-DBT interb. (near REIL)	Siltstone, slightly carbonaceous	9.5	276	0.05	-	1.5	49	-47	32	NAF (barren)
EB1324288043	86014	BN0373CH	120.81 - 121.25	REI-DBT interb. (near REIL)	Sandstone, f; and Siltstone	9.3	134	<0.01	-	0.2	14	-13	88	NAF (barren)
EB1324288025	86119	BN0352CH	60.37 - 60.62	REI-DBT interb.	Sandstone, vf-f; and Siltstone	9.1	200	0.02	-	0.6	21	-20	34	NAF (barren)
EB1324288037	86007	BN0744CH	102.43 - 102.76	REI-DBT interb.	Siltstone; and carb. Siltstone	9.5	340	<0.01	-	0.2	63	-63	413	NAF (barren)
EB1324288038	86131	BN0744CH	104.0 - 104.15	REI-DBT interb.	Siltstone; and Sandstone, f	9.4	174	0.07	-	2.1	19	-17	8.9	NAF (barren)
EB1324288044	86016	BN0373CH	157.00 - 158.00	REI-DBT interb.	Siltstone	9.4	334	0.05	-	1.5	32	-30	21	NAF (barren)
EB1324288045	86017	BN0373CH	164.02 - 165.02	REI-DBT interb.	Sandstone, m	9.4	302	0.02	-	0.6	81	-80	132	NAF (barren)
EB1324288046	86018	BN0373CH	165.43 - 165.71	REI-DBT interb.	Sandstone, m	9.6	341	0.01	-	0.3	91	-91	298	NAF (barren)
EB1326024018	86136	BN0258CHR1	111.13 - 111.44	REI-DBT interb.	Sandstone, f; some Siltstone	9.5	227	0.03	-	0.9	44	-43	48	NAF (barren)
EB1326024019	86137	BN0258CHR1	118.00 - 119.00	REI-DBT interb.	Siltstone	9.5	398	0.07	-	2.1	35	-33	16	NAF (barren)
EB1326024020	86139	BN0258CHR1	128.05 - 128.32	REI-DBT interb.	Siltstone; with Sandstone, f.	9.4	239	0.03	-	0.9	20	-19	22	NAF (barren)
EB1326024021	86140	BN0258CHR1	134.57 - 134.87	REI-DBT interb.	Siltstone; and Sandstone, f.	9.4	362	0.04	-	1.2	146	-145	119	NAF (barren)
EB1326024047	86145	BN0373CH	167.00 - 167.15	REI-DBT interb.	Siltstone	9.5	313	0.07	-	2.1	25	-23	12	NAF (barren)
EB1326024022	86141	BN0258CHR1	137.51 - 137.82	REI-DBT interb. (near DBTU)	Siltstone; with Sandstone, f.	9.3	328	0.03	-	0.9	244	-243	266	NAF (barren)
EB1324288010	86106	BN0185CH	40.80 - 41.09	DBT-SDB interb. (near DBTL)	Sandstone, vf-f	8.5	166	0.05	-	1.5	4	-2.8	2.8	NAF (barren)
EB1324288020	86114	BN0308CH	46.37 - 46.54	DBT-SDB interb.	Sandstone, vf; with pyrite	8.3	277	0.09	-	2.8	5	-1.8	1.7	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B1 (cont.) Acid-base characteristics of spoil (BNCOP samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
...continued Overburden and Interburden (likely spoil - mining waste) BNCOP samples														
EB1324288021	86115	BN0308CH	87.57 - 87.88	DBT-SDB interb.	Sandstone, f	9.2	178	0.03	-	0.9	14	-13	15	NAF (barren)
EB1324288022	86116	BN0308CH	88.07 - 88.36	DBT-SDB interb.	Sandstone, f; some pyrite	9.4	255	0.02	-	0.6	41	-40	67	NAF (barren)
EB1324288014	86045	BN0185CHR1	61.29 - 61.54	DBT-SDB interb.	Very fine sandstone/ Siltstone	8.1	172	0.07	-	2.1	3	-1.1	1.5	NAF (barren)
EB1324288015	86046	BN0185CHR1	67.33 - 67.46	SDB-DAW interb.	Very fine sandstone/ Siltstone	8.9	92	<0.01	-	0.2	6	-6.2	42	NAF (barren)
EB1324288023	86117	BN0308CH	94.53 - 94.69	SDB-DAW interb.	Sandstone, f	9.2	191	0.02	-	0.6	12	-11	20	NAF (barren)
EB1324288011	86107	BN0185CH	93.59 - 93.85	SDB-DAW interb. (near DAWU)	Sandstone, vf; and Siltstone	9.5	290	0.02	-	0.6	17	-17	28	NAF (barren)
EB1324288047	86019	BN0373CH	171.69 - 171.93	DBT-DAW interb.	Siltstone	9.5	155	0.02	-	0.6	6	-5.5	10	NAF (barren)
EB1326024023	86142	BN0258CHR1	142.68 - 142.94	DBT-DAW interb.	Sandstone, f; minor Siltstone	9.5	295	0.03	-	0.9	31	-30	34	NAF (barren)
EB1324288012	89108	BN0185CH	117.52 - 117.71	DAW-DUN interb. (near DUNUA)	Sandstone, f-m; coaly wisps	9.5	153	<0.01	-	0.2	6	-5.4	37	NAF (barren)
EB1324288013	86109	BN0185CH	122.55 - 122.84	DUN-SDUN interb. (near DUNL)	Sandstone, vf-f	9.5	200	0.02	-	0.6	6	-5.1	9.3	NAF (barren)
EB1324288017	86111	BN0281CH	68.73 - 69.12	WRI-DBL interb. (near WRIMB)	Sandstone, vf-f; trace calcite & pyrite	9.5	207	0.03	-	0.9	22	-21	24	NAF (barren)
EB1324288018	86112	BN0281CH	69.12 - 69.30	WRI-DBL interb. (near WRIMB)	Sandstone, vf; some pyrite	9.2	248	0.02	-	0.6	18	-17	29	NAF (barren)
EB1324288026	86120	BN0571CH	113.34 - 113.53	DBL-COO interb.	Sandstone, vf-f	8.8	323	0.02	-	0.6	38	-38	63	NAF (barren)
EB1326024029	86021	BN0679CHR1	72.00 - 76.00	WRI-COO interb.	Sandstone, m	9.2	174	0.04	-	1.2	49	-48	40	NAF (barren)
EB1326024030	86022	BN0679CHR1	80.00 - 81.00	WRI-COO interb.	Sandstone, m	9.2	153	<0.01	-	0.2	55	-54	357	NAF (barren)
EB1326024031	86023	BN0679CHR1	89.00 - 92.00	WRI-COO interb.	Sandstone, m	9.1	234	0.14	0.11	3.3	59	-56	18	NAF
EB1326024032	86024	BN0679CHR1	102.00 - 103.00	WRI-COO interb.	Sandstone, m	9.2	186	<0.01	-	0.2	53	-53	347	NAF (barren)
EB1326024033	86025	BN0679CHR1	121.00 - 126.00	WRI-COO interb.	Sandstone, m; some Siltstone	9.3	184	<0.01	-	0.2	46	-45	297	NAF (barren)
EB1326024034	86026	BN0679CHR1	130.17 - 130.51	WRI-COO interb.	Sandstone, f; some Siltstone	9.6	250	<0.01	-	0.2	43	-42	278	NAF (barren)
EB1326024035	86027	BN0679CHR1	134.61 - 134.99	WRI-COO interb.	Sandstone, f	9.5	266	0.15	0.14	4.4	22	-17	5.0	NAF
EB1326024036	86028	BN0679CHR1	139.40 - 139.61	WRI-COO interb.	Sandstone, m; calcitic	9.5	284	0.18	0.16	4.8	80	-75	17	NAF
EB1326024037	86029	BN0679CHR1	146.82 - 147.11	WRI-COO interb.	Sandstone, m-c	9.6	252	<0.01	-	0.2	54	-54	353	NAF (barren)
EB1326024038	86030	BN0679CHR1	152.05 - 152.33	WRI-COO interb.	Sandstone, m-c	9.6	261	<0.01	-	0.2	41	-41	268	NAF (barren)
EB1326024039	86031	BN0679CHR1	154.58 - 154.80	WRI-COO interb.	Sandstone, f-m	9.5	278	<0.01	-	0.2	56	-56	368	NAF (barren)
EB1326024040	86032	BN0679CHR1	158.60 - 158.86	WRI-COO interb.	Sandstone, m	9.5	270	<0.01	-	0.2	49	-49	319	NAF (barren)
EB1326024041	86033	BN0679CHR1	163.57 - 163.90	WRI-COO interb.	Sandstone, m	9.6	301	<0.01	-	0.2	59	-59	387	NAF (barren)
EB1326024042	86034	BN0679CHR1	169.69 - 169.93	WRI-COO interb.	Sandstone, f; with Siltstone	9.6	192	0.01	-	0.3	12	-11	38	NAF (barren)
EB1326024043	86035	BN0679CHR1	170.71 - 171.03	WRI-COO interb.	Sandstone, f; with Siltstone	9.7	219	0.04	-	1.2	7	-6.0	5.9	NAF (barren)
EB1326024044	86036	BN0679CHR1	189.52 - 189.79	COO-DRT interb. (near COOL)	Carb. Shale and Siltstone	9.7	157	0.04	-	1.2	8	-7.0	6.7	NAF (barren)
EB1324288027	86121	BN0571CH	128.51 - 128.70	COO-DRT interb.	Siltstone	8.9	291	0.02	-	0.6	11	-10	17	NAF (barren)
EB1324288028	86122	BN0571CH	130.09 - 130.24	COO-DRT interb.	Sandstone, vf; and Siderite; trace calcite	8.7	243	<0.01	-	0.2	214	-214	1398	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B1 (cont.) Acid-base characteristics of spoil (Baralaba North/Wonbindi North samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
...continued				Overburden and Interburden (likely spoil - mining waste)		Baralaba North/Wonbindi North samples								
EB1127393-062	GT0010-GC01	GT0010	23.95 - 24.25	Overburden (slightly weath.)	Sandstone, f	9.4	676	0.04	-	1.2	50	-48.8	41	NAF (barren)
EB1127393-063	GT0010-GC02	GT0010	30.65 - 30.85	Overburden (slightly weath.)	Sandstone, f; Ferruginous (10%)	9.5	445	0.03	-	0.9	51	-49.7	55	NAF (barren)
EB1127393-072	GT0012-GC03	GT0012	31.00 - 32.00	Overburden	Sandstone, c	9.6	329	0.02	-	0.6	46	-45.1	75	NAF (barren)
EB1127393-031	GT0007-GC01	GT0007	31.72 - 31.93	Overburden	Sandstone, f-m	9.4	371	0.03	-	0.9	61	-60.2	67	NAF (barren)
EB1127393-015	GT0006-GC01	GT0006	33.98 - 34.29	Overburden	Sandstone, m; and Siltstone	9.5	350	0.08	-	2.5	4.1	-1.7	1.7	NAF (barren)
EB1127393-032	GT0007-GC02	GT0007	34.54 - 34.80	Overburden (near DRT)	Carbonaceous Siltstone	9.1	455	0.03	-	0.9	6.0	-5.1	6.5	NAF (barren)
EB1127393-064	GT0010-GC03	GT0010	35.45 - 35.75	Overburden	Sandstone, f; some Carb. Shale	9.3	519	0.03	-	0.9	43	-41.7	46	NAF (barren)
EB1127393-053	GT0009-GC01	GT0009	37.10 - 37.42	Overburden	Sandstone, vf	9.4	377	0.03	-	0.9	80	-79.3	87	NAF (barren)
EB1127393-016	GT0006-GC02	GT0006	38.45 - 38.72	Overburden	Sandstone, vf-m	9.4	327	0.01	-	0.3	3.5	-3.2	11	NAF (barren)
EB1127393-073	GT0012-GC04	GT0012	40.49 - 41.04	Overburden	Sandstone, f	9.5	270	0.01	-	0.3	203	-202.7	663	NAF (barren)
EB1127393-017	GT0006-GC03	GT0006	45.48 - 45.82	Overburden	Sandstone, m; some coal	9.5	295	0.02	-	0.6	97	-96.3	158	NAF (barren)
EB1127393-054	GT0009-GC02	GT0009	46.36 - 46.72	Overburden	Sandstone, f; and Siltstone	9.4	318	0.03	-	0.9	41	-40.5	45	NAF (barren)
EB1127393-087	GT0018-GC01	GT0018	50.01 - 50.34	Overburden (near COO)	Siltstone; and Sandstone, f	8.8	383	0.02	-	0.6	6.8	-6.2	11	NAF (barren)
EB1127393-018	GT0006-GC04	GT0006	52.22 - 52.53	Overburden	Sandstone, c; Calcite vein	9.4	338	0.37	0.33	10.2	190	-179.8	19	NAF
EB1127393-095	GT0009-GC03	GT0009	57.33 - 57.66	Overburden (near RCAM)	Sandstone, f; some Siltstone	9.1	573	0.04	-	1.2	35	-34.0	29	NAF (barren)
EB1127393-019	GT0006-GC05	GT0006	59.54 - 59.80	Overburden	Sandstone, m; Carb. Shale	9.8	289	0.02	-	0.6	54	-53.1	88	NAF (barren)
EB1127393-020	GT0006-GC06	GT0006	71.90 - 72.27	Overburden	Sandstone, vf-m	9.8	335	0.04	-	1.2	24	-22.4	19	NAF (barren)
EB1127393-021	GT0006-GC07	GT0006	81.84 - 82.16	Overburden	Sandstone, vf-f	9.7	365	0.07	-	2.1	97	-94.8	45	NAF (barren)
EB1127393-055	GT0009-GC04	GT0009	72.84 - 73.14	CAMR-CAM interb.	Carbonaceous Siltstone	9.3	153	0.07	-	2.1	6.8	-4.7	3.2	NAF (barren)
EB1127393-056	GT0009-GC05	GT0009	80.40 - 80.59	CAMR-CAM interb.	Carb. Siltstone; some Coal	9.3	231	0.32	0.18	5.5	4.0	1.5	0.7	PAF (low cap.)
EB1127393-057	GT0009-GC06	GT0009	102.90 - 103.18	SCAM-REI interb.	Siltstone; with calcitic veins	9.2	225	0.10	-	3.1	6.1	-3.0	2.0	NAF (barren)
EB1127393-058	GT0009-GC07	GT0009	122.09 - 122.43	SCAM-REI interb.	Sandstone, vf; some Siltstone	9.5	300	0.03	-	0.9	108	-107.1	118	NAF (barren)
EB1127393-059	GT0009-GC08	GT0009	148.80 - 149.09	SCAM-REI interb.	Sandstone, vf; Siltstone; calcitic veins	9.7	291	0.04	-	1.2	178	-176.8	145	NAF (barren)
EB1127393-060	GT0009-GC09	GT0009	166.36 - 166.63	REI-DBT interb.	Sandstone, vf; Siltstone; Carb. Shale	9.8	296	0.03	-	0.9	36	-35.1	39	NAF (barren)
EB1127393-061	GT0009-GC10	GT0009	187.56 - 187.75	REI-DBT interb.	Sandstone, vf-m; minor calcitic veins	9.8	425	0.03	-	0.9	67	-65.8	73	NAF (barren)
EB1127393-075	GT0012-GC01	GT0012	61.98 - 62.33	REI-DBT interb.	Sandstone, vf-m; some Carb.	9.6	388	0.04	-	1.2	34	-32.7	28	NAF (barren)
EB1127393-076	GT0012-GC01A	GT0012	80.71 - 81.02	REI-DBT interb.	Siltstone; and Sandstone, f	9.6	279	0.03	-	0.9	31	-30.0	34	NAF (barren)
EB1127393-079	GT0012-GC11	GT0012	105.00 - 106.00	DBT-DAW interb.	Sandstone, f-m	9.7	337	0.02	-	0.6	34	-33.3	55	NAF (barren)
EB1127393-094	GT0009-GC11	GT0009	203.13 - 203.36	DBT-DAW interb.	Siltstone; some carb.; some coal	9.8	336	0.08	-	2.5	6.6	-4.2	2.7	NAF (barren)
EB1127393-080	GT0012-GC02	GT0012	127.36 - 127.66	DBT-DAW interb.	Sandstone c; some Coal	9.7	391	0.03	-	0.9	77	-75.6	83	NAF (barren)
EB1127393-081	GT0012-GC12	GT0012	140.00 - 141.00	DBT-DAW interb.	Sandstone, c	9.9	387	0.01	-	0.3	69	-68.8	226	NAF (barren)
EB1127393-024	GT0006-GC08	GT0006	109.12 - 109.36	DAW-DUN interb.	Sandstone, c	9.8	318	0.02	-	0.6	57	-56.2	93	NAF (barren)
EB1127393-025	GT0006-GC09	GT0006	122.56 - 122.84	DAW-DUN interb.	Sandstone, c; Conglomerate	9.8	302	0.02	-	0.6	51	-50.0	83	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B1 (cont.) Acid-base characteristics of spoil (Baralaba North/Wonbindi North samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
...continued				Overburden and Interburden (likely spoil - mining waste)		Baralaba North/Wonbindi North samples								
EB1127393-026	GT0006-GC10	GT0006	147.01 - 147.30	DAW-DUN interb.	Sandstone, m-c	10.0	367	<0.01	-	0.2	54	-53.5	351	NAF (barren)
EB1127393-027	GT0006-GC11	GT0006	162.53 - 162.81	DAW-DUN interb.	Sandstone, f-m	9.9	325	0.03	-	0.9	40	-38.6	43	NAF (barren)
EB1127393-084	GT0012-GC15	GT0012	173.79 - 174.65	DAW-DUN interb.	Sandstone, c	9.8	390	0.02	-	0.6	54	-53.7	89	NAF (barren)
EB1127393-085	GT0012-GC16	GT0012	187.39 - 187.86	DAW-DUN interb.	Sandstone , f; some Siltstone	9.9	412	0.01	-	0.3	48	-47.2	155	NAF (barren)
EB1127393-001	GT0002-GC01	GT0002	69.55 - 70.20	DUN-WRI interb.	Sandstone, c; trace Coal	9.6	327	0.02	-	0.6	91	-90.1	148	NAF (barren)
EB1127393-002	GT0002-GC02	GT0002	85.85 - 86.80	DUN-WRI interb.	Sandstone, f; and Siltstone	9.7	275	0.02	-	0.6	35	-34.1	57	NAF (barren)
EB1127393-037	GT0008-GC01	GT0008	79.51 - 79.79	DUN-WRI interb.	Siltstone; and Sandstone, f	9.8	285	0.04	-	1.2	27	-26.2	22	NAF (barren)
EB1127393-038	GT0008-GC02	GT0008	90.11 - 90.46	DUN-WRI interb.	Sandstone, vf-c; some Siltstone	9.9	344	0.04	-	1.2	52	-50.6	42	NAF (barren)
EB1127393-039	GT0008-GC03	GT0008	94.37 - 94.67	DUN-WRI interb.	Sandstone, m; with Siltstone	10.0	365	0.02	-	0.6	71	-70.4	116	NAF (barren)
EB1127393-007	GT0003-GC01	GT0003	35.14 - 35.39	DUN-WRI interb.	Sandstone, c	9.5	340	0.08	-	2.5	93	-90.8	38	NAF (barren)
EB1127393-008	GT0003-GC02	GT0003	73.40 - 73.71	DUN-WRI interb.	Sandstone f-m	9.6	362	0.02	-	0.6	91	-90.1	148	NAF (barren)
EB1127393-030	GT0006-GC12	GT0006	184.26 - 184.57	DUN-WRI interb.	Sandstone, c; some Coal	9.8	423	0.14	-	4.3	54	-50.0	13	NAF
EB1127393-003	GT0002-GC05	GT0002	139.46 - 140.48	WRI-COO interb.	Sandstone, m; and Siltstone	9.9	459	0.02	-	0.6	70	-69.1	114	NAF (barren)
EB1127393-011	GT0003-GC03	GT0003	100.42 - 100.69	WRI-COO interb.	Siltstone; Sandstone, vf	9.9	326	0.02	-	0.6	16	-15.8	27	NAF (barren)
EB1127393-012	GT0003-GC07	GT0003	117.86 - 118.69	WRI-COO interb.	Sandstone, f-m	9.8	432	0.02	-	0.6	35	-34.6	57	NAF (barren)
EB1127393-042	GT0008-GC05	GT0008	111.55 - 111.87	WRI-COO interb.	Siltstone; trace Coal	10.0	470	0.03	-	0.9	30	-28.7	32	NAF (barren)
EB1127393-043	GT0008-GC06	GT0008	121.47 - 121.83	WRI-COO interb.	Sandstone, vc; Coal	10.1	499	0.03	-	0.9	134	-133.1	146	NAF (barren)
EB1127393-044	GT0008-GC07	GT0008	159.82 - 160.14	WRI-COO interb. (near COO)	Siltstone	9.8	219	0.02	-	0.6	11	-10.3	18	NAF (barren)
EB1127393-005	GT0002-GC08	GT0002	180.00 - 180.85	COO-DRT interb.	Siltstone; some Sandstone, vf	9.8	372	0.04	-	1.2	31	-29.4	25	NAF (barren)
EB1127393-047	GT0008-GC15	GT0008	186.28 - 187.00	COO-DRT interb.	Siltstone; with Sandstone, vf	9.8	354	0.04	-	1.2	34	-32.7	28	NAF (barren)
EB1127393-066	GT0010-GC04	GT0010	68.25 - 68.49	COO-DRT interb.	Siltstone; some Coal; Carb.	9.4	230	0.02	-	0.6	21	-20.5	34	NAF (barren)
EB1127393-067	GT0010-GC05	GT0010	76.35 - 76.62	COO-DRT interb.	Sandstone, vf; trace Siltstone	9.5	229	0.03	-	0.9	32	-30.6	34	NAF (barren)
EB1127393-088	GT0018-GC02	GT0018	61.35 - 61.66	COO-DRT interb.	Siltstone; some Carb. Shale	9.3	164	0.02	-	0.6	13	-12.8	22	NAF (barren)
EB1127393-089	GT0018-GC03	GT0018	76.97 - 77.28	COO-DRT interb.	Sandstone, vf-m; minor coal	9.4	361	0.02	-	0.6	202	-201.4	330	NAF (barren)
EB1127393-090	GT0018-GC04	GT0018	92.82 - 93.09	COO-DRT interb.	Siltstone; and Sandst., vf; trace calcitic	9.3	287	0.04	-	1.2	34	-32.7	28	NAF (barren)
EB1127393-068	GT0010-GC06	GT0010	96.20 - 96.60	COO-DRT interb. (near DRT)	Sandstone, f; and Siltstone; Carb.	9.5	216	0.03	-	0.9	9.7	-8.8	11	NAF (barren)
EB1127393-048	GT0008-GC08	GT0008	202.52 - 202.80	COO-DRT interb. (near DRT)	Siltstone	9.8	369	0.03	-	0.9	40	-38.6	43	NAF (barren)
EB1127393-051	GT0008-GC10	GT0008	207.94 - 208.21	DRT-SDR interb. (near DRT)	Carbonaceous Mudstone; some Coal	10.0	427	0.26	0.01	0.2	30	-29.7	163	NAF
EB1127393-035	GT0007-GC03	GT0007	42.20 - 42.52	DRT-SDR interb.	Sandstone, f; Siliceous	9.8	296	<0.01	-	0.2	38	-38.1	250	NAF (barren)
EB1127393-036	GT0007-GC04	GT0007	47.04 - 47.30	DRT-SDR interb.	Carbonaceous Siltstone; minor Coal	9.7	325	0.03	-	0.9	25	-23.8	27	NAF (barren)
EB1127393-052	GT0008-GC11	GT0008	211.16 - 211.47	DRT-SDR interb.	Sandstone, vf; some Tuff	10.1	552	<0.01	-	0.2	43	-42.4	278	NAF (barren)
EB1127393-071	GT0010-GC11	GT0010	108.04 - 108.98	DRT-SDR interb.	Mudstone; and Siltstone	9.7	355	0.02	-	0.6	35	-34.6	57	NAF (barren)
EB1127393-092	GT0018-GC05	GT0018	101.69 - 101.90	DRT-SDR interb.	Sandstone, vf-f	9.6	260	0.02	-	0.6	8.7	-8.1	14	NAF (barren)
EB1127393-093	GT0018-GC06	GT0018	106.42 - 106.67	DRT-SDR interb.	Sandstone, f-m	9.6	269	0.02	-	0.6	42	-41.4	69	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B2. Acid-base characteristics of potential coal reject (BNCOP samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
Coal Seam Roof, Floor and Parting (potential coal reject) BNCOP samples														
EB1326024058	90528	BN0373CH	46.05 - 46.20	BYDU roof	Carbonaceous Shale	9.0	198	0.40	0.18	5.4	7	-1.6	1.3	Uncertain
EB1326024059	90531	BN0373CH	48.28 - 48.44	BYDL floor	Carbonaceous Shale	8.6	156	0.67	0.39	12.0	9	3.3	0.7	PAF (low cap.)
EB1324288050	90513	BN0744CH	47.77 - 47.97	CAM roof	Siltstone	7.8	291	0.32	0.21	6.3	13	-6.9	2.1	NAF
EB1326024048	86168	BN0258CHR1	75.90 - 76.06	CAM roof	Carb. Siltstone, Shale, and Stoney Coal	8.9	317	0.98	0.69	21.0	157	-136	7.5	NAF
EB1326024060	90532	BN0373CH	85.78 - 85.93	CAM roof	Carb. Siltstone; trace Pyrite	9.4	286	0.42	0.25	7.6	42	-34	5.5	NAF
EB1326024049	86169	BN0258CHR1	77.34 - 77.60	CAM-SCA parting	Carbonaceous Siltstone	7.8	652	1.23	1.00	30.6	21	9.4	0.7	PAF (low cap.)
EB1326024061	90535	BN0373CH	86.65 - 86.99	CAM-SCA parting	Carb. Shale, Siltstone and Coal; pyritic	7.9	709	1.89	1.15	35.2	37	-2.2	1.1	Uncertain
EB1324288051	90518	BN0744CH	49.52 - 49.62	CAM floor	Carb. Siltstone; and Coal	8.8	91	0.19	0.07	2.0	9	-7.3	4.6	NAF
EB1326024011	86126	BN0258CHR1	79.51 - 79.73	CAM floor	Carbonaceous Siltstone	8.2	666	0.81	0.58	17.8	15	2.5	0.9	PAF (low cap.)
EB1326024062	90538	BN0373CH	89.15 - 89.30	SCA floor	Carbonaceous Shale; and Coal (dull)	8.2	222	0.80	0.31	9.5	2	7.3	0.2	PAF (low cap.)
EB1324288052	90519	BN0744CH	96.48 - 96.68	REIUM roof	Sandstone, f; and Siltstone	9.6	303	0.06	-	1.8	28	-27	15	NAF (barren)
EB1326024050	86170	BN0258CHR1	104.89 - 105.05	REIU roof	Carb. Siltstone and Shale	8.3	453	1.46	1.46	44.7	13	32	0.3	PAF
EB1326024063	86163	BN0373CH	119.49 - 119.68	REIL seam	Coal (dull); some Carb. Siltstone	9.1	77	0.56	0.04	1.2	8	-6.7	6.4	NAF
EB1324288053	90525	BN0744CH	99.20 - 99.40	REIL floor	Carbonaeous Shale	9.5	255	0.23	0.06	1.8	10	-8.0	5.4	NAF
EB1326024051	86171	BN0258CHR1	107.57 - 107.72	REIL floor	Carbonaceous Siltstone	9.6	289	0.35	0.21	6.6	15	-8.4	2.3	NAF
EB1326024052	86172	BN0258CHR1	138.36 - 138.51	DBTUA roof	Carb. Siltstone; some Calcite	9.8	377	0.33	0.16	5.0	137	-132	27	NAF
EB1326024064	90540	BN0373CH	169.05 - 169.20	DBTUA roof	Siltstone; mostly Carbonaceous	9.8	219	0.44	0.13	4.1	6	-1.6	1.4	Uncertain
EB1326024053	86173	BN0258CHR1	140.25 - 140.41	DBTL floor	Carb. Siltstone; and Siltstone	9.5	117	0.41	0.01	0.2	24	-24	112	NAF
EB1326024065	90544	BN0373CH	170.47 - 170.68	DBTL floor	Carb. Siltstone, Shale and Coal	9.7	123	0.35	0.01	0.2	5	-4.5	19	NAF
EB1326024054	86174	BN0679CHR1	53.85 - 54.00	WRIU roof	Carbonaceous Shale	8.5	266	0.24	0.16	5.0	4	0.9	0.8	PAF (low cap.)
EB1326024055	86175	BN0679CHR1	60.28 - 60.43	WRIL floor	Carbonaceous Shale	7.4	201	1.02	0.97	29.8	5	25	0.2	PAF
EB1326024056	86176	BN0679CHR1	172.96 - 173.11	COOU roof	Carbonaceous Siltstone	7.2	83	0.20	<0.005	6.1	305	-299	50	NAF
EB1326024057	86177	BN0679CHR1	188.14 - 188.29	COOL floor	Carbonaceous Shale	9.4	318	0.13	<0.005	4.0	143	-139	36	NAF

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B2 (cont.) Acid-base characteristics of potential coal reject (Baralaba North/Wonbindi North samples)

ALS Laboratory Sample ID	Sample ID	Drillhole	Depth	Zone	Lithology	pH[1]	EC[1]	Tot. S	Scr[2]	MPA[2]	ANC[2]	NAPP[2]	ANC/MPA ratio	Sample Classification
							µS/cm	%		kg H_2SO_4/t				
			...continued	Coal Seam Roof, Floor and Parting (potential coal reject)	Baralaba North/Wonbindi North samples									
EB1127393-074	GT0012-GC08	GT0012	50.00 - 50.25	REIL floor	Siltstone; and Sandstone vf-f	9.1	386	0.11	-	3.4	9.3	-5.9	2.8	NAF
EB1127393-077	GT0012-GC09	GT0012	87.38 - 87.58	DBTU roof	Siltst.; Stony Coal; trace Py and calc.	9.4	297	0.97	0.56	17.2	178	-160.8	10	NAF
EB1127393-078	GT0012-GC10	GT0012	89.39 - 89.64	DBTL floor	Siltstone; and Sandstone, vf; minor Coal	9.3	380	0.14	0.11	3.4	5.0	-1.6	1.5	Uncertain
EB1127393-022	GT0006-GC13	GT0006	83.94 - 84.14	DAW roof	Sandst., f; minor Coal; Carb. Siltst.	9.8	243	0.02	-	0.6	3.2	-2.6	5.2	NAF (barren)
EB1127393-082	GT0012-GC13	GT0012	156.80 - 157.08	DAW roof	Sandstone, vf; minor Carb. Shale	9.7	344	0.02	-	0.6	8.7	-8.1	14	NAF (barren)
EB1127393-023	GT0006-GC14	GT0006	87.87 - 88.17	DAW floor	Sandstone, f; minor Coal	9.8	203	0.03	-	0.9	4.3	-3.4	4.7	NAF (barren)
EB1127393-083	GT0012-GC14	GT0012	159.90 - 160.07	DAW floor	Carb. Shale & Coal; some Sandstone, vf	9.7	243	0.36	0.36	11.0	1.9	9.1	0.2	PAF (low cap.)
EB1127393-028	GT0006-GC15	GT0006	165.81 - 166.02	DUNU roof	Sandstone, vf; trace Coal	9.8	185	0.17	<0.005	0.1	1.5	-1.4	16	NAF
EB1127393-086	GT0012-GC17	GT0012	202.37 - 202.57	DUN floor	Siltstone; and Sandstone, vf; carb.	9.8	244	0.06	-	1.8	5.3	-3.5	2.9	NAF (barren)
EB1127393-040	GT0008-GC04	GT0008	102.81 - 103.13	WRIU roof	Sandstone, vf; some Carb. Siltstone	9.8	163	0.02	-	0.6	5.6	-5.0	9.1	NAF (barren)
EB1127393-009	GT0003-GC05	GT0003	82.94 - 83.23	WRIUM roof	Sandstone, vf; some Carb. Shale	9.7	181	0.03	-	0.9	8.3	-7.4	9.0	NAF (barren)
EB1127393-010	GT0003-GC06	GT0003	85.77 - 86.01	WRIUM floor	Carb. Shale; with Coal; Sandstone, vf	9.5	200	0.31	0.04	1.2	27	-25.6	23	NAF
EB1127393-041	GT0008-GC12	GT0008	104.89 - 105.14	WRIMA floor	Carbonaceous Shale; some Coal	10.0	290	0.11	-	3.4	8.7	-5.3	2.6	NAF
EB1127393-013	GT0003-GC08	GT0003	137.17 - 137.47	COO roof	Sandstone, f; minor Carb. Shale	9.8	177	0.02	-	0.6	10	-9.4	16	NAF (barren)
EB1127393-045	GT0008-GC13	GT0008	160.14 - 160.40	COO roof	Siltstone, laminated	10.1	591	0.07	-	2.1	20	-17.4	9.1	NAF (barren)
EB1127393-065	GT0010-GC08	GT0010	54.27 - 54.57	COO roof	Siltstone; some Coal	7.8	203	0.44	0.06	1.9	1.5	0.4	0.8	PAF (low cap.)
EB1127393-014	GT0003-GC09	GT0003	144.33 - 144.63	COO floor	Sandstone, vf; Siltstone; minor Carb.	9.6	369	0.03	-	0.9	24	-23.4	26	NAF (barren)
EB1127393-046	GT0008-GC14	GT0008	167.11 - 167.36	COO floor	Carbonaceous Shale	9.8	384	0.03	-	0.9	47	-46.0	51	NAF (barren)
EB1127393-033	GT0007-GC07	GT0007	35.29 - 35.54	DRT roof	Mudstone; and Carb. Shale; pyritic	8.7	643	2.11	1.72	52.7	7.3	45.4	0.1	PAF
EB1127393-049	GT0008-GC09	GT0008	202.97 - 203.33	DRT roof	Siltstone; and Sandstone, vf	9.8	238	0.03	-	0.9	13	-11.7	14	NAF (barren)
EB1127393-069	GT0010-GC09	GT0010	96.60 - 96.78	DRT roof	Sandstone, f; and Siltstone; Carb.	9.5	216	0.06	-	1.8	8.2	-6.4	4.5	NAF (barren)
EB1127393-034	GT0007-GC08	GT0007	39.81 - 40.11	DRT floor	Carb. Shale; Coally with Mudstone	9.3	400	0.41	0.37	11.4	5.0	6.4	0.4	PAF (low cap.)
EB1127393-050	GT0008-GC16	GT0008	207.39 - 207.88	DRT floor	Carbonaceous Mudstone; some Coal	9.8	246	0.15	0.01	0.4	4.3	-3.9	11	NAF
EB1127393-070	GT0010-GC10	GT0010	102.76 - 103.00	DRT floor	Carbonaceous Shale	9.6	191	0.16	0.01	0.2	4.3	-4.1	18	NAF
EB1127393-091	GT0018-GC10	GT0018	98.79 - 99.10	DRT floor	Siltstone; pyritic; Carbonaceous	9.4	290	0.06	-	1.8	4.3	-2.5	2.3	NAF (barren)

1. pH and EC provided for 1:5 sample:water extracts. 2. Scr = Chromium reducible sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential.

Table B3. Composite sample details (sample composition) for 'Baralaba North/Wonbindi North' samples (for multi-element analysis)

Drill Hole ID	Sample ID	Depth Interval (m)		Lithology	Sample Waste Type	Composite Sample ID
		From	To			
Spoil Samples						
GT0010	GT0010-GC01	23.95	24.25	Sandstone, f (weathered)	Weath. Spoil: above COO	ME01
GT0010	GT0010-GC02	30.65	30.85	Sandstone, f; Ferruginous (10%) (slightly weath.)	Weath. Spoil: above COO	
GT0009	GT0009-GC05	80.40	80.59	Siltstone; some Coal (20%); carb.	Spoil: between SCAMR-CAM	ME02
GT0012	GT0012-GC01	61.98	62.33	Sandstone, vf-m; some Carbonaceous (5%)	Spoil: between RDL-DBTU	ME03
GT0012	GT0012-GC11	105.00	106.00	Sandstone, f-m	Spoil: between DBTL-UNA	ME04
GT0006	GT0006-GC04	52.22	52.53	Sandstone, c; Calcite vein (10%)	Spoil: between UNA-DAW	ME05
GT0006	GT0006-GC06	71.90	72.27	Sandstone, vf-m	Spoil: between UNA-DAW	ME06
GT0006	GT0006-GC07	81.84	82.16	Sandstone, vf-f	Spoil: between UNA-DAW	
GT0006	GT0006-GC08	109.12	109.36	Sandstone, c	Spoil: between DAW-DUNU	ME07
GT0006	GT0006-GC09	122.56	122.84	Sandstone, c; Conglomerate	Spoil: between DAW-DUNU	
GT0006	GT0006-GC10	147.01	147.30	Sandstone, m-c	Spoil: between DAW-DUNU	
GT0012	GT0012-GC16	187.39	187.86	Sandstone , f; some Siltstone	Spoil: between DAW-DUN	ME08
GT0008	GT0008-GC01	79.51	79.79	Siltstone; and Sandstone, f (20%);	Spoil: between DUN-WRIU	ME09
GT0008	GT0008-GC02	90.11	90.46	Sandstone, vf-c; some Siltstone (10%)	Spoil: between DUN-WRIU	
GT0008	GT0008-GC03	94.37	94.67	Sandstone, m; with Siltstone (20%)	Spoil: between DUN-WRIU	
GT0003	GT0003-GC03	100.42	100.69	Siltstone; Sandstone, vf (30%);	Spoil: between WRIUM-COO	ME10
GT0008	GT0008-GC06	121.47	121.83	Sandstone, vc; Coal (10%)	Spoil: between WRIMA-COO	ME11
GT0008	GT0008-GC15	186.28	187.00	Siltstone; with Sandstone, vf (20%)	Spoil: between COO-DRT	ME12
GT0018	GT0018-GC03	76.97	77.28	Sandstone, m; Sandstone vf-f; Coal (1%)	Spoil: between COO-DRT	ME13
GT0007	GT0007-GC01	31.72	31.93	Sandstone, f-m	Spoil: above DRT	ME14
GT0008	GT0008-GC11	211.16	211.47	Sandstone, vf; some Tuff	Spoil: below DRT	ME15
GT0008	GT0008-GC10	207.94	208.21	Carbonaceous Mudstone; some Coal (5%)	Spoil: DRT Near floor	ME16
GT0018	GT0018-GC06	106.42	106.67	Sandstone, f-m	Spoil: between DRT-SDRUA	ME17
Potential Reject Samples (coal seam immediate roof and floor)						
GT0006	GT0006-GC13	83.94	84.14	Sandstone, f; minor Coal; Carb. Siltstone	DAW (Dawson) Roof	ME18
GT0012	GT0012-GC13	156.80	157.08	Sandstone, vf; minor Carb. Shale (5%)	DAW (Dawson) Roof	
GT0006	GT0006-GC14	87.87	88.17	Sandstone, f; minor Coal	DAW (Dawson) Floor	ME19
GT0012	GT0012-GC14	159.90	160.07	Carb. Shale & Coal (50%); Sndst, vf (50%)	DAW (Dawson) Floor	
GT0008	GT0008-GC04	102.81	103.13	Sandstone, vf; some Carb. Siltstone (5%)	WRIU (Wright) Roof	ME20
GT0003	GT0003-GC05	82.94	83.23	Sandstone, vf; with Carb. Shale (10%)	WRIUM (Wright) Roof	
GT0003	GT0003-GC06	85.77	86.01	Carb. Shale; with Coal (20%); Sandstone, vf	WRIUM (Wright) Floor	ME21
GT0008	GT0008-GC12	104.89	105.14	Carbonaceous Shale; some Coal	WRIMA (Wright) Floor	
GT0003	GT0003-GC08	137.17	137.47	Sandstone, f; minor Carb. Shale (1%)	COO (Coolum) Roof	ME22
GT0008	GT0008-GC13	160.14	160.40	Siltstone, laminated	COO (Coolum) Roof	
GT0010	GT0010-GC08	54.27	54.57	Siltstone; some Coal (10%)	COO (Coolum) Roof	
GT0003	GT0003-GC09	144.33	144.63	Sandstone, vf; Siltstone (20%); minor Carb.	COO (Coolum) Floor	ME23
GT0008	GT0008-GC14	167.11	167.36	Carbonaceous Shale	COO (Coolum) Floor	
GT0007	GT0007-GC07	35.29	35.54	Mudstone; and Carbonaceous Shale; pyritic	DRT (Dirty) Roof	ME24
GT0008	GT0008-GC09	202.97	203.33	Siltstone; and Sandstone, vf (30%)	DRT (Dirty) Roof	
GT0010	GT0010-GC09	96.60	96.78	Sandstone, f; and Siltstone (35%); Carb.	DRT (Dirty) Roof	
GT0007	GT0007-GC08	39.81	40.11	Carb. Shale; Coal (20%); Mudstone (10%)	DRT (Dirty) Floor	ME25
GT0008	GT0008-GC16	207.39	207.88	Carbonaceous Mudstone; some Coal (10%)	DRT (Dirty) Floor	
GT0010	GT0010-GC10	102.76	103.00	Carbonaceous Shale	DRT (Dirty) Floor	
GT0018	GT0018-GC10	98.79	99.10	Siltstone; pyritic (1%); Carbonaceous	DRT (Dirty) Floor	

Table B4. Multi-element concentrations in spoil (BNCOP samples)

				Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
			Units:	all units mg/kg																	
			Laboratory LOR:	50	5	5	10	1	50	1	2	2	5	5	5	0.1	2	2	5	5	5
			NEPC Ecological Investigation Level[1]:	-	-	20	300	-	-	3	-*	50	100	600	500	1	40	60	-	50	200
			NEPC Health-based Investigation Level C[1]:	-	-	300	-	90	20000	90	-*	300	17000	600	19000	80	-	1200	700	-	30000
Sample ID	**Drillhole**	**Zone / Depth**	**Description**	**Overburden and Interburden (likely spoil - mining waste) BNCOP samples**																	
86008	BN0679CHR1	Overburden	Sand, f; (highly weathered)	890	<5	<5	30	<1	<50	<1	<2	<2	<5	<5	114	<0.1	<2	<2	<5	<5	<5
86037	BN0258CHR1	Overburden	Sand, f; and Clay; (highly weath.)	1950	<5	<5	100	<1	<50	<1	<2	5	<5	<5	250	<0.1	<2	3	<5	6	6
86011	BN0373CH	Overburden	Sandstone, f; (mod. weathered)	6710	<5	12	50	<1	<50	<1	5	15	35	12	125	<0.1	<2	15	<5	13	58
86047	BN0016CH	Overburden	Mudstone	9810	<5	16	90	<1	<50	<1	9	10	49	19	305	<0.1	<2	22	<5	22	104
86002	BN0744CH	Overburden	Sandstone, f-m; carbonaceous	11400	<5	11	310	<1	<50	<1	10	7	24	7	3770	<0.1	<2	10	<5	37	47
86124	BN0373CH	Overburden	Sandstone, f.; and Siltstone	12100	<5	13	30	1	<50	<1	9	8	72	22	169	<0.1	<2	15	<5	26	52
86110	BN0281CH	Overburden (near WRIU)	Sandstone, vf-f; some calcite	1150	<5	11	90	<1	<50	<1	<2	12	27	19	134	0.2	3	10	<5	<5	70
86125	BN0258CHR1	BYD-CAM interb. (near CAM)	Siltstone; minor Calcite	9370	<5	14	100	<1	<50	<1	8	5	59	16	323	<0.1	<2	15	<5	21	96
86050	BN0016CH	SCA-REI interb. (near SCA)	Sandstone, vf	2340	<5	5	180	1	<50	<1	<2	<2	46	31	35	0.1	<2	3	<5	<5	55
86103	BN0102CH	SCA-REI interb. (near SCA)	Sandstone, vf; with calcite veins	1110	<5	<5	150	<1	<50	<1	<2	<2	33	20	34	<0.1	<2	<2	<5	<5	56
86144	BN0373CH	CAM-REI interb. (near SCA)	Carbonaceous Siltstone	3070	<5	<5	160	1	<50	<1	<2	2	53	30	78	<0.1	<2	4	<5	<5	86
86129	BN0744CH	CAM-REI interb.	Siltstone	11200	<5	13	280	<1	<50	<1	8	7	56	24	142	<0.1	<2	15	<5	24	101
86006	BN0744CH	CAM-REI interb.	Sandstone, f. Siltstone	7680	<5	52	160	<1	<50	<1	7	50	63	28	387	<0.1	2	50	<5	21	92
86133	BN0258CHR1	CAM-REI interb.	Sandstone, m.; with Siltstone	1280	<5	12	80	<1	<50	<1	2	11	29	18	1260	<0.1	<2	10	<5	35	61
86016	BN0373CH	REI-DBT interb.	Siltstone	2890	<5	11	300	1	<50	<1	2	11	61	27	389	<0.1	<2	12	<5	11	87
86140	BN0258CHR1	REI-DBT interb.	Siltstone; and Sandstone, f.	8680	<5	9	300	<1	<50	<1	6	13	44	16	1860	<0.1	<2	15	<5	35	72
86115	BN0308CH	DBT-SDB interb.	Sandstone, f	930	<5	6	70	1	<50	<1	<2	5	30	20	2740	<0.1	<2	5	<5	27	44
86107	BN0185CH	SDB-DAW interb. (near DAW)	Sandstone, vf; and Siltstone	5440	<5	15	240	1	<50	<1	3	11	68	28	80	<0.1	<2	13	<5	10	99
86109	BN0185CH	DUN-SDUN interb. (near DUN)	Sandstone, vf-f	1180	<5	5	100	<1	<50	<1	<2	7	40	18	9	<0.1	<2	10	<5	<5	138
86120	BN0571CH	DBL-COO interb.	Sandstone, vf-f	4560	<5	12	<10	<1	<50	<1	2	7	60	18	272	0.2	<2	11	<5	8	107
86027	BN0679CHR1	WRI-COO interb.	Sandstone, f	510	<5	<5	30	<1	<50	<1	<2	3	12	10	266	<0.1	<2	<2	<5	<5	38
86032	BN0679CHR1	WRI-COO interb.	Sandstone, m	1210	<5	6	50	<1	<50	<1	3	4	12	22	509	<0.1	<2	3	<5	6	44

Notes: '<' indicates less than the laboratory limit of reporting. Shaded cells indicates values that exceed the applied EIL and/or HIL(C) investigation level.

1. NEPC (1999). Assessment levels for soil. EIL; and HIL(C) - open space. * Guideline level for Cr(VI) = 200 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

Table B4 (cont.) Multi-element concentrations in spoil (Baralaba North/Wonbindi North samples)

				Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
			Units:	all units mg/kg																	
			Laboratory LOR:	50	5	5	10	1	50	1	2	2	5	5	5	0.1	2	2	5	5	5
			NEPC Ecological Investigation Level[1]:	-	-	20	300	-	-	3	-*	50	100	600	500	1	40	60	-	50	200
			NEPC Health-based Investigation Level C[1]:	-	-	300	-	90	20000	90	-*	300	17000	600	19000	80	-	1200	700	-	30000
Sample ID	**Drillhole**	**Zone / Depth**	**Description**	**...continued**			**Overburden and Interburden (likely spoil - mining waste)**								**Baralaba North/Wonbindi North samples**						
ME01	GT0010	Overburden	Sandstone, f.; part ferrug.; (weath.)	9,890	<5	11	-	-	<50	<1	6	14	51	14	598	<0.1	<2	12	<5	24	78
ME02	GT0009	SCAMR-CAM interb.	Siltstone; some Coal (20%); carb.	2,880	<5	<5	-	-	<50	<1	2	<2	29	11	30	<0.1	<2	<2	<5	7	56
ME03	GT0012	RDL-DBTU interb.	Sandstone, vf-m; some Carb. (5%)	8,110	<5	15	-	-	<50	<1	6	25	51	14	326	<0.1	<2	21	<5	19	98
ME04	GT0012	DBTL-UNA interb.	Sandstone, f-m	1,550	<5	6	-	-	<50	<1	4	3	22	20	393	<0.1	<2	2	<5	8	51
ME05	GT0006	UNA-DAW interb.	Sandstone, c; Calcite vein (10%)	4,970	<5	10	-	-	<50	<1	9	8	15	15	550	<0.1	<2	6	<5	16	45
ME06	GT0006	UNA-DAW interb.	Sandstone, vf-m	2,200	<5	7	-	-	<50	<1	3	9	30	22	622	<0.1	<2	8	<5	8	52
ME07	GT0006	DAW-DUNU interb.	Sandstone, m-c; some Conglom.	1,900	<5	7	-	-	<50	<1	11	18	15	15	913	<0.1	<2	18	<5	15	50
ME08	GT0012	DAW-DUN interb.	Sandstone , f; some Siltstone	1,470	<5	7	-	-	<50	<1	5	6	26	12	558	<0.1	<2	5	<5	8	65
ME09	GT0008	DUN-WRIU interb.	Sandstone, vf-c; some Siltstone	4,290	<5	12	-	-	<50	<1	5	23	32	14	487	<0.1	<2	19	<5	16	69
ME10	GT0003	WRIUM-COO interb.	Siltstone; Sandstone, vf (30%);	8,590	<5	6	-	-	<50	<1	6	11	54	16	282	<0.1	<2	12	<5	21	81
ME11	GT0008	WRIMA-COO interb.	Sandstone, vc; Coal (10%)	6,340	<5	12	-	-	<50	<1	11	12	19	8	1,330	<0.1	<2	12	<5	38	54
ME12	GT0008	COO-DRT interb.	Siltstone; with Sandstone, vf (20%)	8,320	<5	6	-	-	<50	<1	6	8	59	12	454	<0.1	<2	12	<5	24	74
ME13	GT0018	COO-DRT interb.	Sandstone, vf-m; Coal (1%)	4,440	<5	14	-	-	<50	<1	4	8	26	9	1,470	<0.1	<2	9	<5	14	60
ME14	GT0007	COO-DRT interb. (near DRT)	Sandstone, f-m	9,710	<5	11	-	-	<50	<1	7	9	40	11	631	<0.1	<2	12	<5	23	73
ME15	GT0008	DRT (near floor) interb.	Sandstone, vf; some Tuff	1,750	<5	<5	-	-	<50	<1	4	<2	<5	28	532	<0.1	<2	<2	<5	<5	47
ME16	GT0008	DRT (near floor) interb.	Carb. Mudstone; some Coal (5%)	1,290	<5	<5	-	-	<50	<1	<2	<2	34	11	79	<0.1	<2	<2	<5	<5	38
ME17	GT0018	DRT-SDRUA interb.	Sandstone, f-m	2,910	<5	<5	-	-	<50	<1	<2	<2	<5	29	289	<0.1	<2	<2	<5	<5	28

Notes: '<' indicates less than the laboratory limit of reporting. Shaded cells indicates values that exceed the applied EIL and/or HIL(C) investigation level.

1. NEPC (1999). Assessment levels for soil. EIL; and HIL(C) - open space.

* Guideline level for Cr(VI) = 200 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

Table B5. Multi-element concentrations in potential coal reject

				Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
			Units:	all units mg/kg																	
			Laboratory LOR:	50	5	5	10	1	50	1	2	2	5	5	5	0.1	2	2	5	5	5
			NEPC Ecological Investigation Level[1]:	-	-	20	300	-	-	3	-*	50	100	600	500	1	40	60	-	50	200
			NEPC Health-based Investigation Level C[1]:	-	-	300	-	90	20000	90	-*	300	17000	600	19000	80	-	1200	700	-	30000
Sample ID	**Drillhole**	**Zone / Seam**	**Description**	**Coal Seam Roof, Floor and Parting (potential coal reject)**																	
90528	BN0373CH	BYDU roof	Carbonaceous Shale	2250	<5	<5	20	<1	<50	<1	<2	<2	39	8	21	<0.1	<2	<2	<5	<5	10
90531	BN0373CH	BYDL floor	Carbonaceous Shale	7770	<5	<5	100	<1	<50	<1	8	8	50	12	84	<0.1	2	7	<5	18	74
90513	BN0744CH	CAM roof	Siltstone	16000	<5	10	130	<1	<50	<1	12	5	60	19	171	<0.1	<2	14	<5	38	74
90535	BN0373CH	CAM-SCA parting	Carb. Shale, Siltstone and Coal; pyritic	3920	<5	<5	90	<1	<50	<1	<2	<2	34	12	1190	<0.1	<2	2	<5	14	24
90518	BN0744CH	CAM floor	Carb. Siltstone; and Coal	6850	<5	<5	50	<1	<50	<1	5	4	52	16	330	<0.1	<2	6	<5	13	88
86126	BN0258CHR1	CAM floor	Carbonaceous Siltstone	2240	<5	<5	220	<1	<50	<1	<2	2	46	24	288	<0.1	<2	3	<5	6	44
90525	BN0744CH	REIL floor	Carbonaeous Shale	7020	<5	<5	690	<1	<50	<1	7	2	45	12	113	<0.1	<2	7	<5	17	61
86172	BN0258CHR1	DBTUA roof	Carb. Siltstone; some Calcite	6700	<5	12	230	<1	<50	<1	4	8	44	15	1520	<0.1	<2	10	<5	24	48
ME18	GT0006/12	DAW roof	Sandstone, vf-f; minor Coal & Carb. Shale	3,940	<5	<5	-	-	<50	<1	2	<2	41	19	33	<0.1	<2	4	<5	7	70
ME19	GT0006/12	DAW floor	Sandstone, f; Carb. Shale; minor Coal	1,690	<5	<5	-	-	<50	<1	<2	<2	36	14	96	<0.1	<2	3	<5	<5	36
86174	BN0679CHR1	WRIU roof	Carbonaceous Shale	1310	<5	<5	60	1	<50	<1	<2	<2	42	27	12	<0.1	2	2	<5	<5	36
ME20	GT0003/08	WRIU roof	Sandstone, vf; with Carb. Siltst./ Shale	4,360	<5	7	-	-	<50	<1	4	2	41	18	53	<0.1	<2	8	<5	10	83
86175	BN0679CHR1	WRIL floor	Carbonaceous Shale	690	<5	9	30	<1	<50	<1	<2	3	32	11	5	<0.1	<2	4	<5	<5	16
ME21	GT0003/08	WRIU-M floor	Carb. Shale; some Coal; some Sandst., vf	5,810	<5	<5	-	-	<50	<1	5	6	33	19	188	<0.1	<2	8	<5	13	43
86176	BN0679CHR1	COOU roof	Carbonaceous Siltstone	840	<5	<5	70	1	<50	<1	<2	<2	24	10	33	0.1	<2	<2	<5	<5	26
ME22	GT0003/08/10	COO roof	Sandst., f; and Siltst.; some Coal	3,110	<5	<5	-	-	<50	<1	<2	2	39	13	61	<0.1	<2	4	<5	7	48
ME23	GT0003/08	COO floor	Sandstone, vf; and Carb. Shale	4,040	<5	5	-	-	<50	<1	5	10	48	14	1,360	<0.1	<2	14	<5	46	127
86177	BN0679CHR1	COOL floor	Carbonaceous Shale	3910	<5	<5	120	<1	<50	<1	3	2	44	10	102	<0.1	<2	4	<5	10	51
ME24	GT0007/08/10	DRT roof	Mudst.; Siltst.; Sandst., vf; carb.	6,440	<5	<5	-	-	<50	<1	5	8	59	16	48	<0.1	<2	10	<5	15	91
ME25	GT0007/08/10/18	DRT floor	Carb. Mudstone & Siltstone; some Coal	2,880	<5	<5	-	-	<50	<1	2	3	49	14	44	<0.1	4	3	<5	6	56

Notes: '<' indicates less than the laboratory limit of reporting. Shaded cells indicates values that exceed the applied EIL and/or HIL(C) investigation level.

1. NEPC (1999). Assessment levels for soil. EIL; and HIL(C) - open space. * Guideline level for Cr(VI) = 200 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

Table B6. Soluble multi-element concentrations in 1:5 water extracts from spoil (BNCOP samples)

		Total Alkalinity (as $CaCO_3$)	Bicarb. Alkalinity (as $CaCO_3$)	Carb. Alkalinity (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
Units:		all units mg/L																											
Laboratory LOR:		0.2	0.2	0.2	2	2	2	2	2	2	0.2	0.02	0.02	0.2	0.02	0.2	0.02	0.02	0.02	0.02	0.2	0.02	0.02	0.0001	0.02	0.02	0.02	0.02	0.02
Aquatic ecosystems (slight.-mod. disturbed)[1]:		-	-	-	-	-	-	-	-	-	0.055	-	0.013	-	-	0.37	0.0002	-	-	0.0014	-	0.0034	1.9	0.00006	-	0.011	0.005	-	0.008
Livestock drinking water quality[2]:		-	-	-	1000	-	-	-	1000	-	5	-	0.5	-	-	5	0.01	1	1	0.5	-	0.1	-	0.002	0.15	1	0.02	-	20
Sample ID	**Zone**	**Overburden and Interburden (likely spoil - mining waste) BNCOP samples**																											
86008	Overburden	41	27	14	4	<2	10	4	4	2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
86037	Overburden	24	24	<0.2	<2	<2	8	<2	<2	6	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
86011	Overburden	44	44	<0.2	<2	<2	8	<2	<2	<2	0.2	<0.02	0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
86047	Overburden	89	85	3.4	<2	<2	64	2	32	38	<0.2	<0.02	0.30	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.04	<0.02	<0.02
86002	Overburden	96	82	14	6	4	24	4	6	<2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
86124	Overburden	84	77	6.8	<2	<2	32	2	16	<2	<0.2	<0.02	0.38	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.10	<0.02	0.04	<0.02	<0.02
86110	Overburden (near WRIU roof)	99	44	55	2	<2	64	10	96	4	<0.2	<0.02	0.08	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.12	<0.02	0.04	<0.02	<0.02
86125	BYD-CAM interb. (near CAM roof)	120	72	48	<2	<2	54	4	50	2	<0.2	<0.02	0.58	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.06	0.02	<0.02
86050	SCA-REI interb. (near SCA floor)	14	14	<0.2	4	4	100	12	192	24	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.02	<0.02	<0.02
86103	SCA-REI interb. (near SCA floor)	51	48	3.4	<2	<2	56	6	80	18	<0.2	<0.02	0.08	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.02	<0.02	<0.02
86144	CAM-REI interb. (near SCA floor)	181	130	51	<2	<2	68	10	38	<2	0.2	<0.02	0.18	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	<0.02	0.04	<0.02
86129	CAM-REI interb.	89	68	20	2	<2	42	4	26	<2	<0.2	<0.02	0.42	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	<0.02	0.02	<0.02
86006	CAM-REI interb.	164	92	72	<2	<2	78	2	36	4	0.4	<0.02	2.04	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.18	<0.02	0.04	0.04	<0.02
86133	CAM-REI interb.	178	113	65	<2	<2	56	8	16	<2	0.4	<0.02	0.58	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.12	<0.02	<0.02	0.04	<0.02
86016	REI-DBT interb.	160	89	72	<2	<2	66	12	28	8	0.2	<0.02	0.14	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.10	<0.02	0.04	0.04	<0.02
86140	REI-DBT interb.	234	159	75	<2	<2	88	6	12	4	0.2	<0.02	0.06	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	<0.02	0.02	<0.02
86115	DBT-SDB interb.	140	92	48	<2	<2	42	4	20	<2	0.4	<0.02	0.18	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.14	<0.02	0.04	<0.02	<0.02
86107	SDB-DAW interb. (near DAW roof)	220	138	82	<2	<2	62	4	16	<2	0.4	<0.02	0.88	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	0.04	0.04	<0.02
86109	DUN-SDUN interb. (near DUN floor)	171	116	55	<2	<2	38	4	36	<2	0.4	<0.02	0.58	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.10	<0.02	0.08	0.04	<0.02
86120	DBL-COO interb.	113	92	20	<2	<2	70	2	34	32	<0.2	<0.02	0.36	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.06	<0.02	<0.02
86027	WRI-COO interb.	113	65	48	<2	<2	48	16	42	<2	<0.2	<0.02	0.04	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	0.04	<0.02
86032	WRI-COO interb.	167	106	61	<2	<2	48	18	8	<2	<0.2	<0.02	0.12	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	<0.02	0.02	<0.02

Notes: '<' indicates less than the laboratory limit of reporting. '-' indicates no result (no analysis) for the given element. Shaded cells indicates values that exceed one or more of the applied ANZECC/NEPC trigger values

1. ANZECC (2000). Aquatic Ecosystems: Freshwater trigger values for slightly to moderately disturbed systems.
2. ANZECC (2000). Livestock drinking water quality guidelines.

Table B6 (cont.) Soluble multi-element concentrations in 1:5 water extracts from spoil (Baralaba North/Wonbindi North samples)

		Total Alkalinity (as $CaCO_3$)	Bicarb. Alkalinity (as $CaCO_3$)	Carb. Alkalinity (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
Units:		all units mg/L																											
Laboratory LOR:		0.2	0.2	0.2	2	2	2	2	2	2	0.2	0.02	0.02	0.2	0.02	0.2	0.02	0.02	0.02	0.02	0.2	0.02	0.02	0.0001	0.02	0.02	0.02	0.02	0.02
Aquatic ecosystems (slight.-mod. disturbed)[1]:		-	-	-	-	-	-	-	-	-	0.055	-	0.013	-	-	0.37	0.0002	-	-	0.0014	-	0.0034	1.9	0.00006	-	0.011	0.005	-	0.008
Livestock drinking water quality[2]:		-	-	-	1000	-	-	-	1000	-	5	-	0.5	-	-	5	0.01	1	1	0.5	-	0.1	-	0.002	0.15	1	0.02	-	20
Sample ID	**Zone**	**...continued**									**Overburden and Interburden (likely spoil - mining waste)**																		**Baralaba North/Wonbindi North samples**
ME01	Overburden	109	44	65	<2	<2	110	2	32	90	<0.2	<0.02	0.14	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.06	<0.02	<0.02
ME02	SCAMR-CAM interb.	35	22	13	<2	<2	44	<2	28	22	<0.2	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
ME03	RDL-DBTU interb.	105	52	52	<2	<2	72	<2	36	24	0.2	<0.02	0.36	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.14	<0.02	0.04	0.02	<0.02
ME04	DBTL-UNA interb.	133	50	83	<2	<2	62	8	12	8	0.4	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	0.02	<0.02	<0.02
ME05	UNA-DAW interb.	68	20	48	4	<2	54	6	42	24	<0.2	<0.02	0.10	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
ME06	UNA-DAW interb.	131	61	70	<2	<2	62	6	12	8	0.2	<0.02	0.06	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.08	<0.02	<0.02	<0.02	<0.02
ME07	DAW-DUNU interb.	170	74	96	<2	<2	64	6	12	6	0.4	<0.02	0.08	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	<0.02	<0.02	<0.02
ME08	DAW-DUN interb.	179	65	113	<2	<2	72	4	8	6	0.4	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.08	<0.02	<0.02	<0.02	<0.02
ME09	DUN-WRIU interb.	157	57	100	<2	<2	72	<2	22	8	0.4	<0.02	0.18	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	0.02	<0.02	<0.02
ME10	WRIUM-COO interb.	113	52	61	<2	<2	56	<2	16	6	0.4	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	<0.02	0.04	<0.02
ME11	WRIMA-COO interb.	240	70	170	<2	<2	108	<2	14	6	0.4	<0.02	0.14	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	0.02	<0.02
ME12	COO-DRT interb.	170	83	87	<2	<2	78	<2	12	6	0.4	<0.02	0.12	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.02	0.02	<0.02
ME13	COO-DRT interb.	131	52	78	2	<2	70	4	14	18	<0.2	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	0.02	<0.02	<0.02
ME14	COO-DRT interb. (near DRT roof)	94	11	83	<2	<2	78	2	22	48	<0.2	<0.02	0.20	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.02	<0.02	<0.02
ME15	DRT (near floor) interb.	224	46	179	<2	<2	106	<2	4	22	0.2	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
ME16	DRT (near floor) interb.	187	65	122	<2	<2	90	<2	2	6	<0.2	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.12	<0.02	0.04	0.02	<0.02
ME17	DRT-SDRUA interb.	105	52	52	<2	<2	50	4	2	16	0.4	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02

Notes: '<' indicates less than the laboratory limit of reporting. '-' indicates no result (no analysis) for the given element. Shaded cells indicates values that exceed one or more of the applied ANZECC/NEPC trigger values

1. ANZECC (2000). Aquatic Ecosystems: Freshwater trigger values for slightly to moderately disturbed systems.
2. ANZECC (2000). Livestock drinking water quality guidelines.

Table B7. Soluble multi-element concentrations in 1:5 water extracts from potential coal reject

Sample ID	Zone	Total Alkalinity (as $CaCO_3$)	Bicarb. Alkalinity (as $CaCO_3$)	Carb. Alkalinity (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Vanadium (V)	Zinc (Zn)
Units:		all units mg/L																											
Laboratory LOR:		0.2	0.2	0.2	2	2	2	2	2	2	0.2	0.02	0.02	0.2	0.02	0.2	0.02	0.02	0.02	0.02	0.2	0.02	0.02	0.0001	0.02	0.02	0.02	0.02	0.02
Aquatic ecosystems (slight.-mod. disturbed)[1]:		-	-	-	-	-	-	-	-	-	0.055	-	0.013	-	-	0.37	0.0002	-	-	0.0014	-	0.0034	1.9	0.00006	-	0.011	0.005	-	0.008
Livestock drinking water quality[2]:		-	-	-	1000	-	-	-	1000	-	5	-	0.5	-	-	5	0.01	1	1	0.5	-	0.1	-	0.002	0.15	1	0.02	-	20
		Coal Seam Roof, Floor and Parting (potential coal reject)																											
90528	BYDU roof	61	48	14	4	2	36	2	42	<2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	0.02	0.02	<0.02
90531	BYDL floor	36	36	<0.2	<2	<2	34	<2	42	<2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.06	<0.02	<0.02	0.02	<0.02
90513	CAM roof	39	39	<0.2	4	4	52	4	114	2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.08	<0.02	0.04	<0.02	<0.02
90535	CAM-SCA parting	96	34	61	<2	<2	62	2	48	4	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	0.02	<0.02
90518	CAM floor	27	27	<0.2	<2	<2	16	<2	12	2	<0.2	<0.02	0.08	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.12	<0.02	0.04	0.02	<0.02
86126	CAM floor	68	68	<0.2	32	14	86	14	276	4	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	0.02	<0.02	<0.02
90525	REIL floor	89	55	34	<2	<2	60	<2	40	4	0.2	<0.02	0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	0.02	0.04	<0.02
86172	DBTUA roof	164	68	96	<2	<2	86	2	28	4	<0.2	<0.02	0.12	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.12	<0.02	0.02	0.06	<0.02
ME18	DAW roof	105	39	65	<2	<2	52	2	6	12	0.4	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.02	0.02	<0.02
ME19	DAW floor	74	26	48	<2	<2	40	<2	10	4	0.4	<0.02	0.16	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.02	0.02	<0.02
86174	WRIU roof	50	50	<0.2	16	8	12	20	78	<2	<0.2	<0.02	0.06	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.24	<0.02	0.04	<0.02	<0.02
ME20	WRIU roof	70	26	44	<2	<2	32	<2	6	8	0.4	<0.02	0.32	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.02	<0.02	0.02	0.02	<0.02
86175	WRIL floor	8	8	<0.2	18	12	10	8	120	<2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	0.14	<0.0001	<0.02	<0.02	<0.02	<0.02	<0.02
ME21	WRIU-M floor	113	48	65	<2	<2	56	<2	4	4	0.2	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	<0.02	0.02	<0.02
86176	COOU roof	68	51	17	4	<2	16	2	4	<2	<0.2	<0.02	<0.02	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	0.16	<0.02
ME22	COO roof	185	111	74	<2	<2	76	<2	22	10	0.2	<0.02	0.12	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	0.02	0.02	<0.02
ME23	COO floor	140	57	83	<2	<2	76	<2	6	10	0.4	<0.02	<0.02	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	<0.02	<0.02	<0.02	0.04	<0.02
86177	COOL floor	174	99	75	<2	<2	66	<2	4	<2	<0.2	<0.02	0.04	<0.2	<0.02	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	0.02	0.04	<0.02
ME24	DRT roof	70	26	44	<2	<2	70	<2	30	44	<0.2	<0.02	0.08	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.04	<0.02	0.04	0.06	<0.02
ME25	DRT floor	61	35	26	<2	<2	52	<2	14	24	0.4	<0.02	0.04	-	-	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.0001	0.08	<0.02	<0.02	<0.02	<0.02

Notes: '<' indicates less than the laboratory limit of reporting. '-' indicates no result (no analysis) for the given element. Shaded cells indicates values that exceed one or more of the applied ANZECC/NEPC trigger values

1. ANZECC (2000). Aquatic Ecosystems: Freshwater trigger values for slightly to moderately disturbed systems.
2. ANZECC (2000). Livestock drinking water quality guidelines.

Table B8. Exchangeable cations and Emerson class number (BNCOP samples)

				Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Cation Exch. Cap. (CEC)	Exch. Na % (ESP)	Emerson Class
			Units:	meq/100g					%	n/a
			Laboratory LOR:	0.1	0.1	0.1	0.1	0.1	0.1	n/a
Sample ID	**Drillhole**	**Zone**	**Description**	**Overburden and Interburden (likely spoil - mining waste) BNCOP samples**						
86008	BN0679CHR1	Overburden	Sand, f; (highly weathered)	3.6	0.3	<0.1	<0.1	3.9	<1%	3
86037	BN0258CHR1	Overburden	Sand, f; and Clay; (highly weath.)	3.4	5.3	0.6	0.2	9.5	6%	3
86011	BN0373CH	Overburden	Sandstone, f; (mod. weathered)	10.3	10	1.4	0.3	22	6%	7
86105	BN0185CH	Overburden (near DBTUA)	Sandstone, vf-f	10.6	7.8	1.1	0.8	20.3	5%	8
86113	BN0308CH	Overburden (near DBTUA)	Sandstone, vf; and Siltstone	9.7	6.9	1.1	0.6	18.2	6%	8
86118	BN0352CH	Overburden (near REIU)	Sandstone, vf; and Siderite	2.8	3	0.5	0.7	7.1	7%	8
86047	BN0016CH	Overburden	Mudstone	5.5	5.7	1.8	0.6	13.6	13%	8
86002	BN0744CH	Overburden	Sandstone, f-m; carbonaceous	29.2	3.6	<0.1	0.2	33	<1%	7
86124	BN0373CH	Overburden	Sandstone, f.; and Siltstone	8.4	6.9	0.8	0.4	16.4	5%	8
86110	BN0281CH	Overburden (near WRIU)	Sandstone, vf-f; some calcite	9.6	2.4	0.3	0.5	12.8	2%	8
86125	BN0258CHR1	BYD-CAM interb. (near CAM)	Siltstone; minor Calcite	20.8	5.1	0.5	0.5	26.9	2%	8
86050	BN0016CH	SCA-REI interb. (near SCA)	Sandstone, vf	3.8	4.3	0.6	0.7	9.5	6%	8
86103	BN0102CH	SCA-REI interb. (near SCA)	Sandstone, vf; with calcite veins	3.2	3.7	0.8	0.7	8.4	10%	8
86015	BN0373CH	SCA-REI interb.	Sandstone, m	11.4	3.2	0.5	0.5	15.6	3%	7
86144	BN0373CH	CAM-REI interb. (near SCA)	Carbonaceous Siltstone	9.1	4.4	0.9	1.1	15.5	6%	8
86129	BN0744CH	CAM-REI interb.	Siltstone	6.6	4.8	0.3	0.6	12.3	2%	8
86006	BN0744CH	CAM-REI interb.	Sandstone, f. Siltstone	10.1	5.2	2.1	0.6	18	12%	7
86133	BN0258CHR1	CAM-REI interb.	Sandstone, m.; with Siltstone	9.7	3.4	0.6	0.6	14.3	4%	8
86016	BN0373CH	REI-DBT interb.	Siltstone	6.1	3.2	0.8	1	11.2	7%	8
86140	BN0258CHR1	REI-DBT interb.	Siltstone; and Sandstone, f.	15	4.6	0.9	0.6	21	4%	8
86131	BN0744CH	REI-DBT interb.	Siltstone; and Sandstone, f	5.2	3.1	3.3	0.6	12.2	27%	8
86018	BN0373CH	REI-DBT interb.	Sandstone, m	9.4	4.2	0.6	0.6	14.7	4%	2
86136	BN0258CHR1	REI-DBT interb.	Sandstone, f; some Siltstone	8.8	4.3	2.3	0.7	16.1	14%	8
86115	BN0308CH	DBT-SDB interb.	Sandstone, f	4.1	2.5	0.9	0.8	8.4	11%	8
86107	BN0185CH	SDB-DAW interb. (near DAW)	Sandstone, vf; and Siltstone	10.7	4.3	2	1	17.9	11%	8
86046	BN0185CHR1	SDB-DAW interb.	Very fine sandstone/ Siltstone	6.1	5.2	1.3	0.8	13.4	10%	8
86109	BN0185CH	DUN-SDUN interb. (near DUN)	Sandstone, vf-f	2.7	1.9	1.9	1.2	7.7	25%	8
86120	BN0571CH	DBL-COO interb.	Sandstone, vf-f	10.3	8.5	2	0.6	21.3	9%	7
86027	BN0679CHR1	WRI-COO interb.	Sandstone, f	14.2	1.3	0.2	0.5	16.2	1%	7
86032	BN0679CHR1	WRI-COO interb.	Sandstone, m	19.9	1.1	0.3	0.6	21.8	1%	7

Table B8 (cont.) Exchangeable cations (Baralaba North/Wonbindi North samples)

				Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Cation Exch. Cap. (CEC)	Exch. Na % (ESP)	Emerson Class
			Units:	meq/100g					%	n/a
			Laboratory LOR:	0.1	0.1	0.1	0.1	0.1	0.1	n/a
Sample ID	**Drillhole**	**Zone**	**Description**	**Overburden and Interburden (likely spoil - mining waste) Baralaba Nth/Wonbindi Nth samples**						
ME01	GT0010	Overburden	Sandstone, f.; part ferrug.; (weath.)	14.5	8.5	5.6	0.6	29.2	19	-
ME02	GT0009	SCAMR-CAM interb.	Siltstone; some Coal (20%); carb.	3.8	3.8	2.6	0.5	10.6	25	-
ME03	GT0012	RDL-DBTU interb.	Sandstone, vf-m; some Carb. (5%)	11.3	6.2	5.9	0.8	24.3	24	-
ME04	GT0012	DBTL-UNA interb.	Sandstone, f-m	11.4	2.7	2.3	0.8	17.3	13	-
ME05	GT0006	UNA-DAW interb.	Sandstone, c; Calcite vein (10%)	26.6	2.5	1.5	0.4	31	5	-
ME06	GT0006	UNA-DAW interb.	Sandstone, vf-m	10.1	4	2.4	0.8	17.2	14	-
ME07	GT0006	DAW-DUNU interb.	Sandstone, m-c; some Conglom.	16.9	1.8	2.2	0.6	21.5	10	-
ME08	GT0012	DAW-DUN interb.	Sandstone , f; some Siltstone	11.3	2.3	3.3	0.7	17.7	19	-
ME09	GT0008	DUN-WRIU interb.	Sandstone, vf-c; some Siltstone	14.9	5	4.1	0.6	24.6	17	-
ME10	GT0003	WRIUM-COO interb.	Siltstone; Sandstone, vf (30%);	8.1	3.4	6.6	0.7	18.8	35	-
ME11	GT0008	WRIMA-COO interb.	Sandstone, vc; Coal (10%)	22.3	3.8	6.9	0.4	33.4	21	-
ME12	GT0008	COO-DRT interb.	Siltstone; with Sandstone, vf (20%)	8.2	2.9	9.3	0.6	21	44	-
ME13	GT0018	COO-DRT interb.	Sandstone, vf-m; Coal (1%)	16.8	9.1	2.8	0.6	29.3	10	-
ME14	GT0007	COO-DRT interb. (near DRT)	Sandstone, f-m	9.9	7.2	4.2	0.6	21.8	19	-
ME15	GT0008	DRT (near floor) interb.	Sandstone, vf; some Tuff	18.7	1.6	6.1	0.4	26.8	23	-
ME16	GT0008	DRT (near floor) interb.	Carb. Mudstone; some Coal (5%)	21.9	0.6	3.7	0.3	26.5	14	-
ME17	GT0018	DRT-SDRUA interb.	Sandstone, f-m	15.2	4.7	2.1	0.5	22.5	9	-

Appendix C

Evaluation and Interpretation of Geochemical Test Data

C1. Acid Generation and Prediction

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic sulfur content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$$\mathbf{FeS_2 + \tfrac{15}{4} O_2 + \tfrac{7}{2} H_2O \longrightarrow Fe(OH)_3 + 2\ H_2SO_4}$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing one per cent sulfur as pyrite would be 30.6 kg H_2SO_4/t; *ie*. 30.6 kg of acid generated per tonne of rock.

The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralisation, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Determination of pH and Electrical Conductivity

pH and electrical conductivity (EC) are measured (and reported) on 1:5 weight/weight water extract. This gives an indication of the inherent acidity and salinity of the mining waste material when initially exposed in an emplacement area.

Total sulfur (S), chromium-reducible sulfur (Scr) and Maximum Potential Acidity (MPA)

Total sulfur concentration is determined by a high temperature combustion method (*eg*. High temperature carbon-sulfur analyser).

The total sulfur is typically used to calculate the Maximum Potential Acidity (MPA), which is based on the assumption that all sulfur is present as reactive pyrite.

Where samples are ‘fresh’ and have not begun to oxidise, a more accurate estimate of the MPA is achieved by determining pyritic sulfur and other sulfide forms directly, such as by determining Scr (chromium reducible sulfur). Scr is determined by the reduction of inorganic sulfur in a hot acidic chromous chloride solution, where evolved H_2S is carried in nitrogen gas and trapped in a zinc acetate trapping solution as zinc sulfide. This solution is then titrated with iodine.

All samples were collected ‘fresh’ (*ie*. new drill-core collected specifically for this assessment). Therefore, sulfide concentration measured in samples is expected to be representative of the sulfide concentration likely to be present in mining waste materials (and ROM coal). Scr was measured on all samples where total sulfur concentration exceeded 0.1% (which mainly applied to the potential coal reject samples), and for such samples, MPA was calculated from Scr instead of total sulfur (*ie*. where Scr results were determined).

Acid neutralising capacity (ANC)

The ANC measures the capacity of a sample to react with and neutralise acid by addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid.

Net acid producing potential (NAPP)

Calculated from the MPA and ANC results. The NAPP represents the balance between a samples inherent capacity to generate acid (MPA) and neutralise acid (ANC). If the MPA is greater than the ANC (*ie*. a net excess of acidity) then the NAPP is positive. If the MPA is less than the ANC (*ie*. a net excess of alkalinity) then the NAPP is negative. A strongly positive NAPP result generally indicates that

a sample is PAF, whereas a strongly negative NAPP generally indicates that a sample is NAF. By Australian convention, the NAPP result is expressed in units of kg H_2SO_4/t sample.

C2. Assessment of Element Enrichment and Solubility

In mineralised areas, including coal deposits, it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material at concentrations that may be of environmental concern with respect to surface water quality and revegetation. The samples are typically analysed for a broad suite of elements, such as the following, although the actual suite of elements tested is project specific.

Typical major elements	Al, Ca, Fe, K, Mg, Na, and S
Typical minor elements	As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se, V and Zn

The assay result for each element is compared to either average background concentrations to evaluate any potential concerns related to rock emplacement or process residue facility operation and final rehabilitation, or compared to soil quality guidelines where applicable.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality, or public health but their significance should be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (*eg.* low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

Water extracts or leaching tests can be used to determine the element solubilities under the existing pH conditions of the sample (*eg.* bottle leaching tests) or under changing conditions (*eg.* kinetic leach column tests). Where applicable, element concentrations in water extracts or leachates have been compared with applied water quality guidelines to determine their potential environmental significance.

Appendix D

Laboratory Certificates of Analysis

Baralaba North/Wonbindi North samples (2011-2012; from GT-series drill-holes)

- ALS Batch EB1127393: ABA (pH, EC, S and ANC)
- ALS Batch EB1201048: Scr, total and soluble metals, and exchangeable cations

BNCOP samples (2012-2013; from all drill-holes except GT-series above)

- ALS Batch EB1324288: ABA (pH, EC, S and ANC) [batch 1]
- ALS Batch EB1326024: ABA (pH, EC, S and ANC) [batch 2]
- ALS Batch EB1328300: ABA (pH, EC, S and ANC) and Scr [batch 3]
- ALS Batch EB1328277: Scr, total and soluble metals, exchangeable cations and Emerson classification

ALS Group
Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB1127393**	Page	: 1 of 21
Amendment	: **1**		
Client	: **TERRENUS EARTH SCIENCES PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR IAN SWANE	Contact	: Customer Services
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Telephone	: +61 07 3857 7009	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: Baralaba (Cockatoo Coal)	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 16-DEC-2011
Sampler	: ----	Issue Date	: 13-JAN-2012
Site	: ----		
		No. of samples received	: 92
Quote number	: BN/103/11	No. of samples analysed	: 92

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
		Brisbane Acid Sulphate Soils
		Brisbane Inorganics
Jonathon Angell	Inorganic Coordinator	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Stafford Minerals - AY
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**
- **This report has been amended following changes to the analytical data reported. The quality system is being utilised to resolve this issue. The specific data affected includes sample GT0002-GC02 EC result.**

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0002-GC01	GT0002-GC02	GT0002-GC05	GT0002-GC08	GT0003-GC01
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-001	EB1127393-002	EB1127393-003	EB1127393-005	EB1127393-007
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.7	9.9	9.8	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	0.6	0.6	1.2	2.4
Net Acid Production Potential	----	0.5	kg H2SO4/t	-90.1	-34.1	-69.1	-29.4	-90.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	327	275	459	372	340
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	90.7	34.7	69.7	30.6	93.2
ANC as CaCO3	----	0.1	% CaCO3	9.2	3.5	7.1	3.1	9.5
Fizz Rating	----	0	Fizz Unit	2	1	2	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.04	0.08

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0003-GC02	GT0003-GC05	GT0003-GC06	GT0003-GC03	GT0003-GC07
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-008	EB1127393-009	EB1127393-010	EB1127393-011	EB1127393-012
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.7	9.5	9.9	9.8
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	0.9	9.5	0.6	0.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-90.1	-7.4	-17.3	-15.8	-34.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	362	181	200	326	432
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	90.7	8.3	26.8	16.4	35.2
ANC as CaCO3	----	0.1	% CaCO3	9.2	0.8	2.7	1.7	3.6
Fizz Rating	----	0	Fizz Unit	2	0	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.03	0.31	0.02	0.02

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0003-GC08	GT0003-GC09	GT0006-GC01	GT0006-GC02	GT0006-GC03
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-013	EB1127393-014	EB1127393-015	EB1127393-016	EB1127393-017
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.6	9.5	9.4	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	0.9	2.4	<0.5	0.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-9.4	-23.4	-1.6	-3.2	-96.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	177	369	350	327	295
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	10.0	24.3	4.1	3.5	96.9
ANC as CaCO3	----	0.1	% CaCO3	1.0	2.5	0.4	0.4	9.9
Fizz Rating	----	0	Fizz Unit	0	1	0	0	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.03	0.08	0.01	0.02

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0006-GC04	GT0006-GC05	GT0006-GC06	GT0006-GC07	GT0006-GC13
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-018	EB1127393-019	EB1127393-020	EB1127393-021	EB1127393-022
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.4	9.8	9.8	9.7	9.8
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	11.3	0.6	1.2	2.1	0.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-179	-53.1	-22.4	-94.8	-2.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	338	289	335	365	243
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	190	53.7	23.6	96.9	3.2
ANC as CaCO3	----	0.1	% CaCO3	19.4	5.5	2.4	9.9	0.3
Fizz Rating	----	0	Fizz Unit	3	2	1	2	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.37	0.02	0.04	0.07	0.02

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0006-GC14	GT0006-GC08	GT0006-GC09	GT0006-GC10	GT0006-GC11
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-023	EB1127393-024	EB1127393-025	EB1127393-026	EB1127393-027
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.8	9.8	10.0	9.9
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.9	0.6	0.6	<0.5	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.4	-56.2	-50.0	-53.7	-38.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	203	318	302	367	325
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	4.3	56.8	50.6	53.7	39.5
ANC as CaCO3	----	0.1	% CaCO3	0.4	5.8	5.2	5.5	4.0
Fizz Rating	----	0	Fizz Unit	0	2	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.02	0.02	<0.01	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0006-GC15	GT0006-GC12	GT0007-GC01	GT0007-GC02	GT0007-GC07
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-028	EB1127393-030	EB1127393-031	EB1127393-032	EB1127393-033
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.8	9.4	9.1	8.7
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	5.2	4.3	0.9	0.9	64.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	3.7	-50.0	-60.2	-5.1	57.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	185	423	371	455	643
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	1.5	54.3	61.1	6.0	7.3
ANC as CaCO3	----	0.1	% CaCO3	0.2	5.5	6.2	0.6	0.7
Fizz Rating	----	0	Fizz Unit	0	2	2	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.17	0.14	0.03	0.03	2.11

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0007-GC08	GT0007-GC03	GT0007-GC04	GT0008-GC01	GT0008-GC02
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-034	EB1127393-035	EB1127393-036	EB1127393-037	EB1127393-038
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.8	9.7	9.8	9.9
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	12.5	<0.5	0.9	1.2	1.2
Net Acid Production Potential	----	0.5	kg H2SO4/t	7.5	-38.3	-23.8	-26.2	-50.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	400	296	325	285	344
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.0	38.3	24.7	27.4	51.8
ANC as CaCO3	----	0.1	% CaCO3	0.5	3.9	2.5	2.8	5.3
Fizz Rating	----	0	Fizz Unit	0	2	1	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.41	<0.01	0.03	0.04	0.04

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0008-GC03	GT0008-GC04	GT0008-GC12	GT0008-GC05	GT0008-GC06
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-039	EB1127393-040	EB1127393-041	EB1127393-042	EB1127393-043
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	10.0	9.8	10.0	10.0	10.1
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	0.6	3.4	0.9	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-70.4	-5.0	-5.3	-28.7	-133
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	365	163	290	470	499
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	71.0	5.6	8.7	29.6	134
ANC as CaCO3	----	0.1	% CaCO3	7.2	0.6	0.9	3.0	13.6
Fizz Rating	----	0	Fizz Unit	2	0	0	2	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.11	0.03	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0008-GC07	GT0008-GC13	GT0008-GC14	GT0008-GC15	GT0008-GC08
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-044	EB1127393-045	EB1127393-046	EB1127393-047	EB1127393-048
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	10.1	9.8	9.8	9.8
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	2.1	0.9	1.2	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-10.3	-17.4	-46.0	-32.7	-38.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	219	591	384	354	369
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	10.9	19.5	46.9	33.9	39.5
ANC as CaCO3	----	0.1	% CaCO3	1.1	2.0	4.8	3.5	4.0
Fizz Rating	----	0	Fizz Unit	1	1	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.07	0.03	0.04	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0008-GC09	GT0008-GC16	GT0008-GC10	GT0008-GC11	GT0009-GC01
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-049	EB1127393-050	EB1127393-051	EB1127393-052	EB1127393-053
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.8	10.0	10.1	9.4
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.9	4.6	8.0	<0.5	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.7	<0.5	-21.9	-42.6	-79.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	238	246	427	552	377
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	12.6	4.3	29.9	42.6	80.2
ANC as CaCO3	----	0.1	% CaCO3	1.3	0.4	3.0	4.3	8.2
Fizz Rating	----	0	Fizz Unit	1	0	1	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.15	0.26	<0.01	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0009-GC02	GT0009-GC04	GT0009-GC05	GT0009-GC06	GT0009-GC07
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-054	EB1127393-055	EB1127393-056	EB1127393-057	EB1127393-058
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.4	9.3	9.3	9.2	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.9	2.1	9.8	3.1	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-40.5	-4.6	5.8	-3.0	-107
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	318	153	231	225	300
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	41.4	6.8	4.0	6.1	108
ANC as CaCO3	----	0.1	% CaCO3	4.2	0.7	0.4	0.6	11.1
Fizz Rating	----	0	Fizz Unit	2	0	0	0	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.07	0.32	0.10	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0009-GC08	GT0009-GC09	GT0009-GC10	GT0010-GC01	GT0010-GC02
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-059	EB1127393-060	EB1127393-061	EB1127393-062	EB1127393-063
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.7	9.8	9.8	9.4	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	1.2	0.9	0.9	1.2	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-177	-35.1	-65.8	-48.8	-49.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	291	296	425	676	445
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	178	36.0	66.7	50.0	50.6
ANC as CaCO3	----	0.1	% CaCO3	18.1	3.7	6.8	5.1	5.2
Fizz Rating	----	0	Fizz Unit	3	1	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.03	0.03	0.04	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0010-GC03	GT0010-GC08	GT0010-GC04	GT0010-GC05	GT0010-GC06
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-064	EB1127393-065	EB1127393-066	EB1127393-067	EB1127393-068
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	7.8	9.4	9.5	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.9	13.5	0.6	0.9	0.9
Net Acid Production Potential	----	0.5	kg H2SO4/t	-41.7	12.0	-20.5	-30.6	-8.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	519	203	230	229	216
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	42.6	1.5	21.1	31.5	9.7
ANC as CaCO3	----	0.1	% CaCO3	4.3	0.2	2.2	3.2	1.0
Fizz Rating	----	0	Fizz Unit	2	0	1	2	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.44	0.02	0.03	0.03

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0010-GC09	GT0010-GC10	GT0010-GC11	GT0012-GC03	GT0012-GC04
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-069	EB1127393-070	EB1127393-071	EB1127393-072	EB1127393-073
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.6	9.7	9.6	9.5
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	1.8	4.9	0.6	0.6	<0.5
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.4	0.6	-34.6	-45.1	-203
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	216	191	355	329	270
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.2	4.3	35.2	45.7	203
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.4	3.6	4.6	20.7
Fizz Rating	----	0	Fizz Unit	0	0	2	2	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.06	0.16	0.02	0.02	0.01

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0012-GC08	GT0012-GC01	GT0012-GC01A	GT0012-GC09	GT0012-GC10
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-074	EB1127393-075	EB1127393-076	EB1127393-077	EB1127393-078
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.1	9.6	9.6	9.4	9.3
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	3.4	1.2	0.9	29.7	4.3
Net Acid Production Potential	----	0.5	kg H2SO4/t	-5.9	-32.7	-30.0	-148	-0.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	386	388	279	297	380
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	9.3	33.9	30.9	178	5.0
ANC as CaCO3	----	0.1	% CaCO3	0.9	3.5	3.1	18.1	0.5
Fizz Rating	----	0	Fizz Unit	0	2	2	3	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.11	0.04	0.03	0.97	0.14

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0012-GC11	GT0012-GC02	GT0012-GC12	GT0012-GC13	GT0012-GC14
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-079	EB1127393-080	EB1127393-081	EB1127393-082	EB1127393-083
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.7	9.7	9.9	9.7	9.7
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	0.9	<0.5	0.6	4.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-33.3	-75.6	-68.8	-8.1	2.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	337	391	387	344	243
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	33.9	76.5	69.1	8.7	1.9
ANC as CaCO3	----	0.1	% CaCO3	3.5	7.8	7.0	0.9	0.2
Fizz Rating	----	0	Fizz Unit	2	2	2	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.03	0.01	0.02	0.15

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0012-GC15	GT0012-GC16	GT0012-GC17	GT0018-GC01	GT0018-GC02
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-084	EB1127393-085	EB1127393-086	EB1127393-087	EB1127393-088
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.9	9.8	8.8	9.3
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	<0.5	1.8	0.6	0.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-53.7	-47.2	-3.5	-6.2	-12.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	390	412	244	383	164
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	54.3	47.5	5.3	6.8	13.4
ANC as CaCO3	----	0.1	% CaCO3	5.5	4.8	0.5	0.7	1.4
Fizz Rating	----	0	Fizz Unit	2	2	0	0	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.01	0.06	0.02	0.02

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0018-GC03	GT0018-GC04	GT0018-GC10	GT0018-GC05	GT0018-GC06
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1127393-089	EB1127393-090	EB1127393-091	EB1127393-092	EB1127393-093
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.4	9.3	9.4	9.6	9.6
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	0.6	1.2	1.8	0.6	0.6
Net Acid Production Potential	----	0.5	kg H2SO4/t	-201	-32.7	-2.5	-8.1	-41.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	361	287	290	260	269
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	202	33.9	4.3	8.7	42.0
ANC as CaCO3	----	0.1	% CaCO3	20.6	3.5	0.4	0.9	4.3
Fizz Rating	----	0	Fizz Unit	3	2	0	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.04	0.06	0.02	0.02

Analytical Results

Sub-Matrix: ROCK			Client sample ID	GT0009-GC11	GT0009-GC03	----	----	----
			Client sampling date / time	[20-DEC-2011]	[20-DEC-2011]	----	----	----
Compound	CAS Number	LOR	Unit	EB1127393-094	EB1127393-095	----	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.1	----	----	----
EA009: Nett Acid Production Potential								
Acid Production Potential (APP)	----	0.5	kg H2SO4/t	2.4	1.2	----	----	----
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.2	-34.0	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	336	573	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.6	35.2	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	0.7	3.6	----	----	----
Fizz Rating	----	0	Fizz Unit	0	2	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.08	0.04	----	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB1201048**	Page	: 1 of 16
Client	: **TERRENUS EARTH SCIENCES PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR IAN SWANE	Contact	: Customer Services
Address	: PO BOX 132 WILSTON QLD 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
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Telephone	: +61 07 3857 7009	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: Baralaba (Cockatoo Coal [CC])	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 13-JAN-2012
Sampler	: ----	Issue Date	: 27-JAN-2012
Site	: ----		
		No. of samples received	: 71
Quote number	: BN/103/11	No. of samples analysed	: 38

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Myles.Clark	Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG035S: LORs for soluble Hg have been raised due to sample matrix interferences.**

Analytical Results

Sub-Matrix: PULP			Client sample ID	GT0003-GC06 85.77 - 86.01	GT0006-GC04 52.22 - 52.53	GT0006-GC15 165.81 - 166.02	GT0007-GC07 35.29 - 35.54	GT0007-GC08 39.81 - 40.11
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-001	EB1201048-002	EB1201048-003	EB1201048-004	EB1201048-005
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.038**	**0.333**	<0.005	**1.72**	**0.372**

Analytical Results

Sub-Matrix: PULP			Client sample ID	GT0008-GC16 207.39 - 207.88	GT0008-GC10 207.94 - 208.21	GT0009-GC05 80.4 - 80.59	GT0010-GC08 54.27 - 54.57	GT0010-GC10 102.76 - 103
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-006	EB1201048-007	EB1201048-008	EB1201048-009	EB1201048-010
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.013**	**0.006**	**0.180**	**0.063**	**0.008**

Analytical Results

Sub-Matrix: PULP			Client sample ID	GT0012-GC09 87.38 - 87.58	GT0012-GC10 89.39 - 89.64	GT0012-GC14 159.9 - 160.07	ME01	ME02
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-011	EB1201048-012	EB1201048-013	EB1201048-047	EB1201048-048
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	----	----	----	9.4	8.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	----	576	227
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.561	0.112	0.359	----	----
ED007: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	14.5	3.8
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	8.5	3.8
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	0.6	0.5
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	5.6	2.6
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	29.2	10.6
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	545	174
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	218	109
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	327	65
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	160	140
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	450	110
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	<10	<10
Magnesium	7439-95-4	10	mg/kg	----	----	----	<10	<10
Sodium	7440-23-5	10	mg/kg	----	----	----	550	220
Potassium	7440-09-7	10	mg/kg	----	----	----	10	<10
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	----	----	----	1270	610
Potassium	7440-09-7	10	mg/kg	----	----	----	920	920
Calcium	7440-70-2	10	mg/kg	----	----	----	14800	690
Magnesium	7439-95-4	10	mg/kg	----	----	----	5910	1320
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	----	<1	<1
Antimony	7440-36-0	0.1	mg/kg	----	----	----	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	----	----	----	0.7	<0.1
Boron	7440-42-8	1	mg/kg	----	----	----	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	----	----	----	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	----	----	----	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	GT0012-GC09 87.38 - 87.58	GT0012-GC10 89.39 - 89.64	GT0012-GC14 159.9 - 160.07	ME01	ME02
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-011	EB1201048-012	EB1201048-013	EB1201048-047	EB1201048-048
EG005S : Soluble Metals by ICPAES - Continued								
Cobalt	7440-48-4	0.1	mg/kg	----	----	----	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	----	----	----	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	----	----	----	<1	<1
Lead	7439-92-1	0.1	mg/kg	----	----	----	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	----	----	----	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	----	----	----	<0.1	<0.1
Nickel	7440-02-0	0.1	mg/kg	----	----	----	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	----	----	----	**0.3**	<0.1
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	<0.1	<0.1
Zinc	7440-66-6	0.1	mg/kg	----	----	----	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	**9890**	**2880**
Antimony	7440-36-0	5	mg/kg	----	----	----	<5	<5
Arsenic	7440-38-2	5	mg/kg	----	----	----	**11**	<5
Boron	7440-42-8	50	mg/kg	----	----	----	<50	<50
Cadmium	7440-43-9	1	mg/kg	----	----	----	<1	<1
Chromium	7440-47-3	2	mg/kg	----	----	----	**6**	**2**
Cobalt	7440-48-4	2	mg/kg	----	----	----	**14**	<2
Copper	7440-50-8	5	mg/kg	----	----	----	**51**	**29**
Iron	7439-89-6	50	mg/kg	----	----	----	**23800**	**4440**
Lead	7439-92-1	5	mg/kg	----	----	----	**14**	**11**
Manganese	7439-96-5	5	mg/kg	----	----	----	**598**	**30**
Molybdenum	7439-98-7	2	mg/kg	----	----	----	<2	<2
Nickel	7440-02-0	2	mg/kg	----	----	----	**12**	<2
Selenium	7782-49-2	5	mg/kg	----	----	----	<5	<5
Vanadium	7440-62-2	5	mg/kg	----	----	----	**24**	**7**
Zinc	7440-66-6	5	mg/kg	----	----	----	**78**	**56**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	----	----	<0.0025	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	----	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME03	ME04	ME05	ME06	ME07
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-049	EB1201048-050	EB1201048-051	EB1201048-052	EB1201048-053
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.7	9.8	9.4	9.8	10.0
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	362	321	306	321	347
ED007: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	11.3	11.4	26.6	10.1	16.9
^ Exchangeable Magnesium	----	0.1	meq/100g	6.2	2.7	2.5	4.0	1.8
^ Exchangeable Potassium	----	0.1	meq/100g	0.8	0.8	0.4	0.8	0.6
^ Exchangeable Sodium	----	0.1	meq/100g	5.9	2.3	1.5	2.4	2.2
^ Cation Exchange Capacity	----	0.1	meq/100g	24.3	17.3	31.0	17.2	21.5
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	523	665	338	654	850
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	261	251	98	305	370
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	262	414	240	349	480
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	180	60	210	60	60
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	120	40	120	40	30
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	20	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	360	310	270	310	320
Potassium	7440-09-7	10	mg/kg	<10	40	30	30	30
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	1360	590	390	620	570
Potassium	7440-09-7	10	mg/kg	1080	1070	740	1110	900
Calcium	7440-70-2	10	mg/kg	8650	9140	68000	16500	14800
Magnesium	7439-95-4	10	mg/kg	4530	2390	5730	4820	3760
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	1	2	<1	1	2
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	1.8	0.8	0.5	0.3	0.4
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME03	ME04	ME05	ME06	ME07
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-049	EB1201048-050	EB1201048-051	EB1201048-052	EB1201048-053
EG005S : Soluble Metals by ICPAES - Continued								
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	0.7	0.3	<0.1	0.4	0.3
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	0.2	0.1	<0.1	<0.1	<0.1
Vanadium	7440-62-2	0.1	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8110	1550	4970	2200	1900
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	15	6	10	7	7
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	6	4	9	3	11
Cobalt	7440-48-4	2	mg/kg	25	3	8	9	18
Copper	7440-50-8	5	mg/kg	51	22	15	30	15
Iron	7439-89-6	50	mg/kg	15000	15600	20700	21400	29400
Lead	7439-92-1	5	mg/kg	14	20	15	22	15
Manganese	7439-96-5	5	mg/kg	326	393	550	622	913
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	21	2	6	8	18
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	19	8	16	8	15
Zinc	7440-66-6	5	mg/kg	98	51	45	52	50
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0025	<0.0025	<0.0005	<0.0025	<0.0025
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME08	ME09	ME10	ME11	ME12
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-054	EB1201048-055	EB1201048-056	EB1201048-057	EB1201048-058
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	10.0	9.9	9.8	10.1	9.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	382	363	283	541	371
ED007: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	11.3	14.9	8.1	22.3	8.2
^ Exchangeable Magnesium	----	0.1	meq/100g	2.3	5.0	3.4	3.8	2.9
^ Exchangeable Potassium	----	0.1	meq/100g	0.7	0.6	0.7	0.4	0.6
^ Exchangeable Sodium	----	0.1	meq/100g	3.3	4.1	6.6	6.9	9.3
^ Cation Exchange Capacity	----	0.1	meq/100g	17.7	24.6	18.8	33.4	21.0
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	894	785	567	1200	850
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	327	284	262	349	414
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	567	501	305	850	436
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	40	110	80	70	60
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	30	40	30	30	30
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	360	360	280	540	390
Potassium	7440-09-7	10	mg/kg	20	<10	<10	<10	<10
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	780	940	1500	1490	1930
Potassium	7440-09-7	10	mg/kg	1000	890	980	540	950
Calcium	7440-70-2	10	mg/kg	13200	14900	3730	35100	11300
Magnesium	7439-95-4	10	mg/kg	3740	4880	3160	9840	5150
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	2	2	2	2	2
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	0.8	0.9	0.8	0.7	0.6
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME08	ME09	ME10	ME11	ME12
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-054	EB1201048-055	EB1201048-056	EB1201048-057	EB1201048-058
EG005S : Soluble Metals by ICPAES - Continued								
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	**0.4**	**0.3**	**0.2**	<0.1	**0.1**
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	<0.1	**0.1**	<0.1	<0.1	**0.1**
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	**0.2**	**0.1**	**0.1**
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**1470**	**4290**	**8590**	**6340**	**8320**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**7**	**12**	**6**	**12**	**6**
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**5**	**5**	**6**	**11**	**6**
Cobalt	7440-48-4	2	mg/kg	**6**	**23**	**11**	**12**	**8**
Copper	7440-50-8	5	mg/kg	**26**	**32**	**54**	**19**	**59**
Iron	7439-89-6	50	mg/kg	**16400**	**28400**	**19500**	**57000**	**26200**
Lead	7439-92-1	5	mg/kg	**12**	**14**	**16**	**8**	**12**
Manganese	7439-96-5	5	mg/kg	**558**	**487**	**282**	**1330**	**454**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**5**	**19**	**12**	**12**	**12**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**8**	**16**	**21**	**38**	**24**
Zinc	7440-66-6	5	mg/kg	**65**	**69**	**81**	**54**	**74**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME13	ME14	ME15	ME16	ME17
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-059	EB1201048-060	EB1201048-061	EB1201048-062	EB1201048-063
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.4	10.2	10.0	9.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	347	390	548	429	262
ED007: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	16.8	9.9	18.7	21.9	15.2
^ Exchangeable Magnesium	----	0.1	meq/100g	9.1	7.2	1.6	0.6	4.7
^ Exchangeable Potassium	----	0.1	meq/100g	0.6	0.6	0.4	0.3	0.5
^ Exchangeable Sodium	----	0.1	meq/100g	2.8	4.2	6.1	3.7	2.1
^ Cation Exchange Capacity	----	0.1	meq/100g	29.3	21.8	26.8	26.5	22.5
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	654	469	1120	937	523
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	262	55	229	327	261
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	392	414	894	610	262
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	70	110	20	10	10
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	90	240	110	30	80
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	350	390	530	450	250
Potassium	7440-09-7	10	mg/kg	20	10	<10	<10	20
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	670	920	1360	840	470
Potassium	7440-09-7	10	mg/kg	920	900	670	880	760
Calcium	7440-70-2	10	mg/kg	59200	17000	20300	11700	13100
Magnesium	7439-95-4	10	mg/kg	15800	7040	3390	390	3200
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	1	<1	2
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	0.8	1.0	<0.1	<0.1	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME13	ME14	ME15	ME16	ME17
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-059	EB1201048-060	EB1201048-061	EB1201048-062	EB1201048-063
EG005S : Soluble Metals by ICPAES - Continued								
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	<0.1	0.1	<0.1	0.6	<0.1
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	0.1	0.1	<0.1	0.2	<0.1
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	0.1	<0.1
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4440	9710	1750	1290	2910
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	14	11	<5	<5	<5
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	4	7	4	<2	<2
Cobalt	7440-48-4	2	mg/kg	8	9	<2	<2	<2
Copper	7440-50-8	5	mg/kg	26	40	<5	34	<5
Iron	7439-89-6	50	mg/kg	38100	30300	8000	1700	7800
Lead	7439-92-1	5	mg/kg	9	11	28	11	29
Manganese	7439-96-5	5	mg/kg	1470	631	532	79	289
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	9	12	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	14	23	<5	<5	<5
Zinc	7440-66-6	5	mg/kg	60	73	47	38	28
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0025	<0.0025	<0.0025	<0.0005	<0.0025
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME18	ME19	ME20	ME21	ME22
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-064	EB1201048-065	EB1201048-066	EB1201048-067	EB1201048-068
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.8	9.6	9.8	9.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	269	209	166	296	394
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	523	371	349	567	927
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	196	131	131	240	556
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	327	240	218	327	371
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	30	50	30	20	110
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	60	20	40	20	50
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	260	200	160	280	380
Potassium	7440-09-7	10	mg/kg	10	<10	<10	<10	<10
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	1000	730	960	820	1570
Potassium	7440-09-7	10	mg/kg	1450	1160	1140	830	880
Calcium	7440-70-2	10	mg/kg	1230	1000	1090	14400	4360
Magnesium	7439-95-4	10	mg/kg	1270	740	1880	1970	860
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	2	2	2	1	1
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	0.8	0.8	1.6	<0.1	0.6
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	0.1	0.1	0.1	0.2	0.2
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	0.1	0.1	0.1	<0.1	0.1
Vanadium	7440-62-2	0.1	mg/kg	0.1	0.1	0.1	0.1	0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME18	ME19	ME20	ME21	ME22
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]
Compound	CAS Number	LOR	Unit	EB1201048-064	EB1201048-065	EB1201048-066	EB1201048-067	EB1201048-068
EG005S : Soluble Metals by ICPAES - Continued								
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3940**	**1690**	**4360**	**5810**	**3110**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	**7**	<5	<5
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**2**	<2	**4**	**5**	<2
Cobalt	7440-48-4	2	mg/kg	<2	<2	**2**	**6**	**2**
Copper	7440-50-8	5	mg/kg	**41**	**36**	**41**	**33**	**39**
Iron	7439-89-6	50	mg/kg	**4900**	**5950**	**6640**	**12000**	**3860**
Lead	7439-92-1	5	mg/kg	**19**	**14**	**18**	**19**	**13**
Manganese	7439-96-5	5	mg/kg	**33**	**96**	**53**	**188**	**61**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**4**	**3**	**8**	**8**	**4**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**7**	<5	**10**	**13**	**7**
Zinc	7440-66-6	5	mg/kg	**70**	**36**	**83**	**43**	**48**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME23	ME24	ME25	----	----
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	----	----
Compound	CAS Number	LOR	Unit	EB1201048-069	EB1201048-070	EB1201048-071	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.7	9.2	9.4	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	372	355	272	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	698	349	305	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	284	131	174	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	414	218	131	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	30	150	70	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	50	220	120	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	----	----
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	----	----
Sodium	7440-23-5	10	mg/kg	380	350	260	----	----
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	10	mg/kg	1670	1500	890	----	----
Potassium	7440-09-7	10	mg/kg	1050	1230	1200	----	----
Calcium	7440-70-2	10	mg/kg	7600	2090	1020	----	----
Magnesium	7439-95-4	10	mg/kg	7860	2190	1150	----	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	2	<1	2	----	----
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Arsenic	7440-38-2	0.1	mg/kg	<0.1	0.4	0.2	----	----
Boron	7440-42-8	1	mg/kg	<1	<1	<1	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Iron	7439-89-6	1	mg/kg	<1	<1	<1	----	----
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Molybdenum	7439-98-7	0.1	mg/kg	<0.1	0.2	0.4	----	----
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	0.2	<0.1	----	----
Vanadium	7440-62-2	0.1	mg/kg	0.2	0.3	<0.1	----	----

Analytical Results

Sub-Matrix: PULP			Client sample ID	ME23	ME24	ME25	----	----
			Client sampling date / time	[15-DEC-2011]	[15-DEC-2011]	[15-DEC-2011]	----	----
Compound	CAS Number	LOR	Unit	EB1201048-069	EB1201048-070	EB1201048-071	----	----
EG005S : Soluble Metals by ICPAES - Continued								
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4040	6440	2880	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	----	----
Arsenic	7440-38-2	5	mg/kg	5	<5	<5	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	5	5	2	----	----
Cobalt	7440-48-4	2	mg/kg	10	8	3	----	----
Copper	7440-50-8	5	mg/kg	48	59	49	----	----
Iron	7439-89-6	50	mg/kg	69800	13100	4460	----	----
Lead	7439-92-1	5	mg/kg	14	16	14	----	----
Manganese	7439-96-5	5	mg/kg	1360	48	44	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	4	----	----
Nickel	7440-02-0	2	mg/kg	14	10	3	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg	46	15	6	----	----
Zinc	7440-66-6	5	mg/kg	127	91	56	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0025	<0.0025	<0.0025	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1324288**	Page	: 1 of 13
Client	: **TERRENUS EARTH SCIENCES PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR IAN SWANE	Contact	: Customer Services
Address	: PO BOX 132 WILSTON QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: iswane@terrenus.com.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3857 7009	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: Baralaba Nth	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 04-OCT-2013
Sampler	: ----	Issue Date	: 21-OCT-2013
Site	: ----		
		No. of samples received	: 53
Quote number	: BN/526/13	No. of samples analysed	: 53

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Metals Production Chemist	Brisbane Acid Sulphate Soils
Andrew Epps	Metals Production Chemist	Brisbane Inorganics
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86047 016-GC01	86048 016-GC02	86049 016-GT03	86050 016-GT04	86101 102-GC01
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-001	EB1324288-002	EB1324288-003	EB1324288-004	EB1324288-005
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.6	9.0	9.1	7.3	8.2
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.5	-25.0	-20.2	<0.5	-10.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	286	342	360	558	445
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	12.4	26.5	21.7	3.8	13.0
ANC as CaCO3	----	0.1	% CaCO3	1.3	2.7	2.2	0.4	1.3
Fizz Rating	----	0	Fizz Unit	1	1	1	0	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.05	0.05	0.11	0.08
Sample Preparation Method								
Amount	----	0.01	kg	7.16	4.96	4.28	4.50	2.70

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86102 102-GC02	86103 102-GT02	86104 102-GC03	86105 185-GC01	86106 185-GC02
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-006	EB1324288-007	EB1324288-008	EB1324288-009	EB1324288-010
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.7	8.6	9.0	8.8	8.5
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-7.9	-1.8	-6.1	-20.9	-2.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	221	283	154	224	166
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	9.1	4.9	6.7	21.5	4.3
ANC as CaCO3	----	0.1	% CaCO3	0.9	0.5	0.7	2.2	0.4
Fizz Rating	----	0	Fizz Unit	0	0	0	1	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.10	0.02	0.02	0.05
Sample Preparation Method								
Amount	----	0.01	kg	5.18	6.62	5.68	4.64	5.24

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86107 185-GC03	89108 185-GC05	86109 185-GC06	86045 185R1-GT01	86046 185R1-GC02
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-011	EB1324288-012	EB1324288-013	EB1324288-014	EB1324288-015
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.5	9.5	8.1	8.9
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-16.8	-5.6	-5.1	-1.0	-6.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	290	153	200	172	92
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	17.4	5.6	5.7	3.2	6.4
ANC as CaCO3	----	0.1	% CaCO3	1.8	0.6	0.6	0.3	0.6
Fizz Rating	----	0	Fizz Unit	1	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	0.02	0.07	<0.01
Sample Preparation Method								
Amount	----	0.01	kg	3.68	2.28	4.82	4.42	2.50

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86110 281-GC01	86111 281-GT02	86112 281-GC02	86113 308-GC01	86114 308-GC02
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-016	EB1324288-017	EB1324288-018	EB1324288-019	EB1324288-020
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.5	9.2	8.9	8.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-23.1	-21.3	-17.0	-32.8	-1.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	329	207	248	197	277
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	31.1	22.2	17.6	33.4	4.6
ANC as CaCO3	----	0.1	% CaCO3	3.2	2.3	1.8	3.4	0.5
Fizz Rating	----	0	Fizz Unit	1	1	1	2	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.26	0.03	0.02	0.02	0.09
Sample Preparation Method								
Amount	----	0.01	kg	3.34	7.32	2.92	3.98	2.90

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86115 308-GT03	86116 308-GC03	86117 308-GC04	86118 352-GC01	86119 352-GC02
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-021	EB1324288-022	EB1324288-023	EB1324288-024	EB1324288-025
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.2	9.4	9.2	9.1	9.1
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-13.3	-40.3	-11.4	-8.0	-20.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	178	255	191	25	200
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	14.2	40.9	12.0	8.9	20.8
ANC as CaCO3	----	0.1	% CaCO3	1.4	4.2	1.2	0.9	2.1
Fizz Rating	----	0	Fizz Unit	1	2	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.02	0.02	0.03	0.02
Sample Preparation Method								
Amount	----	0.01	kg	6.56	5.46	2.90	4.28	4.76

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86120 571-GC01	86121 571-GC02	86122 571-GC03	86128	86002 GC29X-03
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-026	EB1324288-027	EB1324288-028	EB1324288-029	EB1324288-030
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.8	8.9	8.7	8.8	8.8
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-37.7	-10.1	-214	-103	-488
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	323	291	243	196	181
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	38.3	10.7	214	103	488
ANC as CaCO3	----	0.1	% CaCO3	3.9	1.1	21.8	10.5	49.8
Fizz Rating	----	0	Fizz Unit	2	1	3	3	5
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	<0.01	<0.01	<0.01
Sample Preparation Method								
Amount	----	0.01	kg	3.18	2.58	3.14	2.06	6.98

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86003	86129 GC-29X-06	86130	86004 GC29X-09	86005
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-031	EB1324288-032	EB1324288-033	EB1324288-034	EB1324288-035
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.1	9.0	9.5	9.6	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-28.3	-10.4	-51.2	-86.6	-52.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	186	223	296	344	299
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	28.3	13.5	51.8	87.2	52.7
ANC as CaCO3	----	0.1	% CaCO3	2.9	1.4	5.3	8.9	5.4
Fizz Rating	----	0	Fizz Unit	1	1	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	0.10	0.02	0.02	0.02
Sample Preparation Method								
Amount	----	0.01	kg	5.66	2.60	3.74	7.44	5.28

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86006	86007	86131 GC29X-12	86011 GC20C-03	86012 GC20C-08
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-036	EB1324288-037	EB1324288-038	EB1324288-039	EB1324288-040
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.5	9.4	8.1	9.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-63.4	-63.3	-16.8	-8.5	-53.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	328	340	174	45	288
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	64.0	63.3	19.0	8.5	54.2
ANC as CaCO3	----	0.1	% CaCO3	6.5	6.4	1.9	0.9	5.5
Fizz Rating	----	0	Fizz Unit	2	2	1	0	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	0.07	<0.01	0.02
Sample Preparation Method								
Amount	----	0.01	kg	6.14	6.84	3.60	5.22	5.88

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86013 GC20C-09	86015 GC20C-15	86014 GC20C-20	86016 GC20C-22	86017
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-041	EB1324288-042	EB1324288-043	EB1324288-044	EB1324288-045
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.1	9.4	9.3	9.4	9.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-16.1	-59.3	-13.5	-30.0	-80.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	129	294	134	334	302
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	16.7	62.1	13.5	31.5	80.8
ANC as CaCO3	----	0.1	% CaCO3	1.7	6.3	1.4	3.2	8.2
Fizz Rating	----	0	Fizz Unit	1	2	1	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.09	<0.01	0.05	0.02
Sample Preparation Method								
Amount	----	0.01	kg	6.30	2.38	8.06	0.60	0.70

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86018 GC20C-23	86019 GC20C-27	86123	86124	90513 GC29X-04
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1324288-046	EB1324288-047	EB1324288-048	EB1324288-049	EB1324288-050
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.5	8.8	8.7	7.8
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-91.1	-5.5	-170	-15.2	-3.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	341	155	209	138	291
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	91.4	6.1	170	15.8	13.2
ANC as CaCO3	----	0.1	% CaCO3	9.3	0.6	17.3	1.6	1.3
Fizz Rating	----	0	Fizz Unit	2	0	3	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.02	<0.01	0.02	0.32
Sample Preparation Method								
Amount	----	0.01	kg	5.26	4.76	----	----	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	90518 GC29X-05	90519 GC29X-10	90525 GC29X-11	----	----
			Client sampling date / time	[01-OCT-2013]	[01-OCT-2013]	[01-OCT-2013]	----	----
Compound	CAS Number	LOR	Unit	EB1324288-051	EB1324288-052	EB1324288-053	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.8	9.6	9.5	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.5	-26.6	-2.8	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	91	303	255	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	9.3	28.4	9.8	----	----
ANC as CaCO3	----	0.1	% CaCO3	0.9	2.9	1.0	----	----
Fizz Rating	----	0	Fizz Unit	1	1	1	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.19	0.06	0.23	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1326024**	Page	: 1 of 15
Client	: **TERRENUS EARTH SCIENCES PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR IAN SWANE	Contact	: Customer Services
Address	: PO BOX 132 WILSTON QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: iswane@terrenus.com.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3857 7009	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: Baralaba Nth	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 25-OCT-2013
Sampler	: ----	Issue Date	: 13-NOV-2013
Site	: ----		
		No. of samples received	: 63
Quote number	: BN/526/13	No. of samples analysed	: 63

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Metals Production Chemist	Brisbane Inorganics
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86037 GC17J-01	86038 GC17J-03	86039	86040 GC17J-04	86041 GC17J-05
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-001	EB1326024-002	EB1326024-003	EB1326024-004	EB1326024-005
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	7.3	8.7	8.7	8.5	7.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.2	-37.0	-35.9	-12.5	-12.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	53	180	181	214	128
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	2.2	37.0	35.9	12.5	23.1
ANC as CaCO3	----	0.1	% CaCO3	0.2	3.8	3.7	1.3	2.4
Fizz Rating	----	0	Fizz Unit	0	2	2	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	<0.01	0.35
Sample Preparation Method								
Amount	----	0.01	kg	2.20	0.48	0.38	0.44	0.36

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86042 GC17J-06	86043 GC17J-07	86044 GC17J-08	86167	86125
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-006	EB1326024-007	EB1326024-008	EB1326024-009	EB1326024-010
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.4	8.8	9.0	9.2	9.2
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-8.8	-17.4	-71.6	-29.8	-13.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	128	119	205	195	273
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	12.5	19.6	79.9	32.0	25.4
ANC as CaCO3	----	0.1	% CaCO3	1.3	2.0	8.1	3.3	2.6
Fizz Rating	----	0	Fizz Unit	1	1	2	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.12	0.07	0.27	0.07	0.40
Sample Preparation Method								
Amount	----	0.01	kg	0.62	0.48	0.48	4.40	5.90

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86126 GC17J-12	86127 GC17J-13	86138 GC17J-14	86132 GC17J-15	86133
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-011	EB1326024-012	EB1326024-013	EB1326024-014	EB1326024-015
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.2	9.4	9.4	9.5	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	9.5	-47.7	-90.4	-75.4	-35.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	666	258	231	296	264
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	15.3	49.2	91.3	75.7	37.1
ANC as CaCO3	----	0.1	% CaCO3	1.6	5.0	9.3	7.7	3.8
Fizz Rating	----	0	Fizz Unit	1	2	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.81	0.05	0.03	0.01	0.04
Sample Preparation Method								
Amount	----	0.01	kg	4.90	1.92	1.92	2.32	7.80

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86134	86135 GC17J-19	86136 GC17J-20	86137	86139
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-016	EB1326024-017	EB1326024-018	EB1326024-019	EB1326024-020
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.5	9.5	9.5	9.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-47.0	-47.2	-43.4	-32.6	-19.5
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	291	276	227	398	239
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	48.2	48.7	44.3	34.8	20.4
ANC as CaCO3	----	0.1	% CaCO3	4.9	5.0	4.5	3.5	2.1
Fizz Rating	----	0	Fizz Unit	2	2	2	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.05	0.03	0.07	0.03
Sample Preparation Method								
Amount	----	0.01	kg	4.60	7.32	5.88	2.16	5.42

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86140	86141 GC17J-21	86142 GC17J-25	86008 GC23P-01	86009 GC23P-02
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-021	EB1326024-022	EB1326024-023	EB1326024-024	EB1326024-025
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.4	9.3	9.5	8.9	8.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-145	-243	-30.4	-1.0	-2.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	362	328	295	88	112
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	146	244	31.3	1.0	2.9
ANC as CaCO3	----	0.1	% CaCO3	14.8	24.9	3.2	<0.1	0.3
Fizz Rating	----	0	Fizz Unit	3	3	2	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.03	0.03	<0.01	<0.01
Sample Preparation Method								
Amount	----	0.01	kg	6.64	6.74	5.52	7.02	1.30

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86010 GC23P-03	86021 GC23P-11	86022 GC23P-12	86023 GC23P-13	86024 GC23P-14
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-026	EB1326024-029	EB1326024-030	EB1326024-031	EB1326024-032
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.9	9.2	9.2	9.1	9.2
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.1	-47.8	-54.6	-54.5	-53.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	101	174	153	234	186
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	3.1	49.0	54.6	58.8	53.1
ANC as CaCO3	----	0.1	% CaCO3	0.3	5.0	5.6	6.0	5.4
Fizz Rating	----	0	Fizz Unit	0	2	2	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	0.04	<0.01	0.14	<0.01
Sample Preparation Method								
Amount	----	0.01	kg	3.06	0.88	1.06	0.76	0.82

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86025 GC23P-16	86026 GC23P-17	86027	86028	86029
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-033	EB1326024-034	EB1326024-035	EB1326024-036	EB1326024-037
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.6	9.5	9.5	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-45.5	-42.5	-17.3	-74.7	-54.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	184	250	266	284	252
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	45.5	42.5	21.9	80.2	54.1
ANC as CaCO3	----	0.1	% CaCO3	4.6	4.3	2.2	8.2	5.5
Fizz Rating	----	0	Fizz Unit	2	2	1	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	0.15	0.18	<0.01
Sample Preparation Method								
Amount	----	0.01	kg	2.12	7.34	7.64	4.32	6.22

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86030	86031	86032	86033	86034
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-038	EB1326024-039	EB1326024-040	EB1326024-041	EB1326024-042
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.5	9.5	9.6	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-41.1	-56.4	-48.9	-59.3	-11.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	261	278	270	301	192
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	41.1	56.4	48.9	59.3	11.6
ANC as CaCO3	----	0.1	% CaCO3	4.2	5.8	5.0	6.0	1.2
Fizz Rating	----	0	Fizz Unit	2	2	2	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	<0.01	0.01
Sample Preparation Method								
Amount	----	0.01	kg	5.84	4.88	5.26	6.46	4.54

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86035	86036 GC23P-22	86143 GC20C-07	86144 GC20C-14	86145
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-043	EB1326024-044	EB1326024-045	EB1326024-046	EB1326024-047
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.7	9.7	9.4	9.3	9.5
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.0	-7.0	-78.4	-21.0	-22.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	219	157	304	353	313
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.2	8.2	79.3	25.9	24.9
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.8	8.1	2.6	2.5
Fizz Rating	----	0	Fizz Unit	0	0	2	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.04	0.03	0.16	0.07
Sample Preparation Method								
Amount	----	0.01	kg	6.34	5.74	3.36	3.70	4.60

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86168 GC17J-09	86169 GC17J-11	86170 GC17J-16	86171 GC17J-18	86172 GC17J-22
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-048	EB1326024-049	EB1326024-050	EB1326024-051	EB1326024-052
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.9	7.8	8.3	9.6	9.8
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-127	16.4	31.5	-4.3	-127
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	317	652	453	289	377
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	157	21.2	13.2	15.0	137
ANC as CaCO3	----	0.1	% CaCO3	16.1	2.2	1.4	1.5	14.0
Fizz Rating	----	0	Fizz Unit	3	1	1	1	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.98	1.23	1.46	0.35	0.33
Sample Preparation Method								
Amount	----	0.01	kg	2.06	3.64	2.92	3.72	2.98

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86173 GC17J-24	86174 GC23P-06	86175 GC23P-09	86176 GC23P-18	86177 GC23P-21
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-053	EB1326024-054	EB1326024-055	EB1326024-056	EB1326024-057
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	8.5	7.4	7.2	9.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.4	3.2	26.7	-299	-139
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	117	266	201	83	318
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	24.0	4.1	4.5	305	143
ANC as CaCO3	----	0.1	% CaCO3	2.4	0.4	0.4	31.1	14.6
Fizz Rating	----	0	Fizz Unit	1	0	0	4	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.41	0.24	1.02	0.20	0.13
Sample Preparation Method								
Amount	----	0.01	kg	2.14	3.28	1.90	4.40	2.28

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	90528 GC20C-05	80531 GC20C-06	90532 GC20C-10	90535 GC20C-11	90538 GC20C-13
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]
Compound	CAS Number	LOR	Unit	EB1326024-058	EB1326024-059	EB1326024-060	EB1326024-061	EB1326024-062
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.0	8.6	9.4	7.9	8.2
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	5.2	11.8	-29.0	20.4	22.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	198	156	286	709	222
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.0	8.7	41.9	37.4	2.2
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.9	4.3	3.8	0.2
Fizz Rating	----	0	Fizz Unit	0	0	2	1	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.40	0.67	0.42	1.89	0.80
Sample Preparation Method								
Amount	----	0.01	kg	3.18	5.50	1.38	5.50	1.38

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86163 GC20C-18	90540 GC20C-24	90544 GC20C-26	----	----
			Client sampling date / time	[22-OCT-2013]	[22-OCT-2013]	[22-OCT-2013]	----	----
Compound	CAS Number	LOR	Unit	EB1326024-063	EB1326024-064	EB1326024-065	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.1	9.8	9.7	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	9.2	7.8	6.0	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	77	219	123	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.9	5.7	4.7	----	----
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.6	0.5	----	----
Fizz Rating	----	0	Fizz Unit	0	0	0	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.56	0.44	0.35	----	----
Sample Preparation Method								
Amount	----	0.01	kg	1.34	2.14	3.40	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1328277**	Page	: 1 of 29
Amendment	: **1**		
Client	: **TERRENUS EARTH SCIENCES PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR IAN SWANE	Contact	: Customer Services
Address	: PO BOX 132 WILSTON QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: iswane@terrenus.com.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3857 7009	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: Baralaba North	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 16-NOV-2013
Sampler	: ----	Issue Date	: 05-DEC-2013
Site	: ----		
		No. of samples received	: 57
Quote number	: BN/526/13	No. of samples analysed	: 57

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark**
- **EG005T(Total Metals by ICP-AES):Sample EB1328277 - 002 shows poor matrix spike recovery due to matrix interference. Confirmed by re-extraction and re-analysis.**
- **This report has been amended and re-released to allow the reporting of additional analytical data.**

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Andrew Epps	Metals Production Chemist	Brisbane Inorganics
Jiah Wallace	Physical Chemistry Section Supervisor	Brisbane Inorganics
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	86041 GC17J-05	86042 GC17J-06	86044 GC17J-08	86023 GC23P-13	86028
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-026	EB1328277-027	EB1328277-028	EB1328277-035	EB1328277-037
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.024**	**0.068**	**0.130**	**0.107**	**0.156**

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	86168 GC17J-09	86169 GC17J-11	86170 GC17J-16	86171 GC17J-18	86173 GC17J-24
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-040	EB1328277-041	EB1328277-042	EB1328277-043	EB1328277-045
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.686**	**1.00**	**1.46**	**0.214**	**0.007**

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	90532 GC20C-10	90538 GC20C-13	86163 GC20C-18	90540 GC20C-24	90544 GC20C-26
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-052	EB1328277-054	EB1328277-055	EB1328277-056	EB1328277-057
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.249**	**0.309**	**0.040**	**0.133**	**0.008**

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86047 016-GC01	86050 016-GT04	86103 102--GT02	86105 185-GC01	86107 185-GC03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-001	EB1328277-002	EB1328277-003	EB1328277-004	EB1328277-005
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	0.056	0.031	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	1.7	1.3	1.2	----	1.6
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	Very Dark Grey	Black	Black	Black
Texture	----	-	-	Rock	Rock	Rock	Rock	Rock
Emerson Class Number	----	-	-	8	8	8	8	8
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	5.5	3.8	3.2	10.6	10.7
Exchangeable Magnesium	----	0.1	meq/100g	5.7	4.3	3.7	7.8	4.3
Exchangeable Potassium	----	0.1	meq/100g	0.6	0.7	0.7	0.8	1.0
Exchangeable Sodium	----	0.1	meq/100g	1.8	0.6	0.8	1.1	2.0
Cation Exchange Capacity	----	0.1	meq/100g	13.6	9.5	8.4	20.3	17.9
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	444	68	256	----	1100
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	427	68	239	----	692
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	17	<1	17	----	410
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	160	960	400	----	80
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	190	120	90	----	<10
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	20	<10	----	<10
Magnesium	7439-95-4	10	mg/kg	<10	20	<10	----	<10
Sodium	7440-23-5	10	mg/kg	320	500	280	----	310
Potassium	7440-09-7	10	mg/kg	10	60	30	----	20
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	<1	----	2
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Arsenic	7440-38-2	0.1	mg/kg	1.5	<0.1	0.4	----	4.4
Barium	7440-39-3	1	mg/kg	<1	<1	<1	----	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	----	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86047 016-GC01	86050 016-GT04	86103 102--GT02	86105 185-GC01	86107 185-GC03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-001	EB1328277-002	EB1328277-003	EB1328277-004	EB1328277-005
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	----	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	<0.1	<0.1	<0.1	----	**0.3**
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Selenium	7782-49-2	0.1	mg/kg	**0.2**	**0.1**	**0.1**	----	**0.2**
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	----	**0.2**
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**9810**	**2340**	**1110**	----	**5440**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	----	<5
Arsenic	7440-38-2	5	mg/kg	**16**	**5**	<5	----	**15**
Barium	7440-39-3	10	mg/kg	**90**	**180**	**150**	----	**240**
Beryllium	7440-41-7	1	mg/kg	<1	**1**	<1	----	**1**
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	<1
Chromium	7440-47-3	2	mg/kg	**9**	<2	<2	----	**3**
Cobalt	7440-48-4	2	mg/kg	**10**	<2	<2	----	**11**
Copper	7440-50-8	5	mg/kg	**49**	**46**	**33**	----	**68**
Lead	7439-92-1	5	mg/kg	**19**	**31**	**20**	----	**28**
Manganese	7439-96-5	5	mg/kg	**305**	**35**	**34**	----	**80**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	----	<2
Nickel	7440-02-0	2	mg/kg	**22**	**3**	<2	----	**13**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	**22**	<5	<5	----	**10**
Zinc	7440-66-6	5	mg/kg	**104**	**55**	**56**	----	**99**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	----	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86047 016-GC01	86050 016-GT04	86103 102--GT02	86105 185-GC01	86107 185-GC03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-001	EB1328277-002	EB1328277-003	EB1328277-004	EB1328277-005
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	<0.1	**0.1**	<0.1	----	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86109 185-GC06	86046 185R1-GC02	86110 281-GC01	86113 308-GC01	86115 308-GT03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-006	EB1328277-007	EB1328277-008	EB1328277-009	EB1328277-010
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	0.184	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	1.4	----	<1.0	----	1.2
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	Black	Very Dark Grey	Black	Very Dark Grey
Texture	----	-	-	Rock	Rock	Rock	Rock	Rock
Emerson Class Number	----	-	-	8	8	8	8	8
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.7	6.1	9.6	9.7	4.1
Exchangeable Magnesium	----	0.1	meq/100g	1.9	5.2	2.4	6.9	2.5
Exchangeable Potassium	----	0.1	meq/100g	1.2	0.8	0.5	0.6	0.8
Exchangeable Sodium	----	0.1	meq/100g	1.9	1.3	0.3	1.1	0.9
Cation Exchange Capacity	----	0.1	meq/100g	7.7	13.4	12.8	18.2	8.4
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	854	----	495	----	700
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	581	----	222	----	461
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	273	----	273	----	239
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	180	----	480	----	100
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	<10	----	20	----	<10
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	----	10	----	<10
Magnesium	7439-95-4	10	mg/kg	<10	----	<10	----	<10
Sodium	7440-23-5	10	mg/kg	190	----	320	----	210
Potassium	7440-09-7	10	mg/kg	20	----	50	----	20
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	2	----	<1	----	2
Antimony	7440-36-0	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Arsenic	7440-38-2	0.1	mg/kg	2.9	----	0.4	----	0.9
Barium	7440-39-3	1	mg/kg	<1	----	<1	----	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Boron	7440-42-8	1	mg/kg	<1	----	<1	----	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86109 185-GC06	86046 185R1-GC02	86110 281-GC01	86113 308-GC01	86115 308-GT03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-006	EB1328277-007	EB1328277-008	EB1328277-009	EB1328277-010
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Iron	7439-89-6	1	mg/kg	<1	----	<1	----	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	**0.5**	----	**0.6**	----	**0.7**
Nickel	7440-02-0	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Selenium	7782-49-2	0.1	mg/kg	**0.4**	----	**0.2**	----	**0.2**
Vanadium	7440-62-2	0.1	mg/kg	**0.2**	----	<0.1	----	<0.1
Zinc	7440-66-6	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**1180**	----	**1150**	----	**930**
Antimony	7440-36-0	5	mg/kg	<5	----	<5	----	<5
Arsenic	7440-38-2	5	mg/kg	**5**	----	**11**	----	**6**
Barium	7440-39-3	10	mg/kg	**100**	----	**90**	----	**70**
Beryllium	7440-41-7	1	mg/kg	<1	----	<1	----	**1**
Boron	7440-42-8	50	mg/kg	<50	----	<50	----	<50
Cadmium	7440-43-9	1	mg/kg	<1	----	<1	----	<1
Chromium	7440-47-3	2	mg/kg	<2	----	<2	----	<2
Cobalt	7440-48-4	2	mg/kg	**7**	----	**12**	----	**5**
Copper	7440-50-8	5	mg/kg	**40**	----	**27**	----	**30**
Lead	7439-92-1	5	mg/kg	**18**	----	**19**	----	**20**
Manganese	7439-96-5	5	mg/kg	**9**	----	**134**	----	**2740**
Molybdenum	7439-98-7	2	mg/kg	<2	----	**3**	----	<2
Nickel	7440-02-0	2	mg/kg	**10**	----	**10**	----	**5**
Selenium	7782-49-2	5	mg/kg	<5	----	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	<5	----	<5	----	**27**
Zinc	7440-66-6	5	mg/kg	**138**	----	**70**	----	**44**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	----	<0.0005	----	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86109 185-GC06	86046 185R1-GC02	86110 281-GC01	86113 308-GC01	86115 308-GT03
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-006	EB1328277-007	EB1328277-008	EB1328277-009	EB1328277-010
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	**0.2**	----	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86118 352-GC01	86120 571-GC01	86002 GC29X-03	86129 GC29X-06	86006
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-011	EB1328277-012	EB1328277-013	EB1328277-014	EB1328277-015
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	----	0.059	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	----	2.1	1.1	1.5	1.7
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	Black	Very Dark Grey	Black	Black
Texture	----	-	-	Rock	Rock	Rock	Rock	Rock
Emerson Class Number	----	-	-	8	7	7	8	7
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.8	10.3	29.2	6.6	10.1
Exchangeable Magnesium	----	0.1	meq/100g	3.0	8.5	3.6	4.8	5.2
Exchangeable Potassium	----	0.1	meq/100g	0.7	0.6	0.2	0.6	0.6
Exchangeable Sodium	----	0.1	meq/100g	0.5	2.0	<0.1	0.3	2.1
Cation Exchange Capacity	----	0.1	meq/100g	7.1	21.3	33.0	12.3	18.0
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	564	478	444	820
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	462	410	342	462
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	102	68	102	358
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	170	30	130	180
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	160	<10	<10	20
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	<10	30	10	<10
Magnesium	7439-95-4	10	mg/kg	----	<10	20	<10	<10
Sodium	7440-23-5	10	mg/kg	----	350	120	210	390
Potassium	7440-09-7	10	mg/kg	----	10	20	20	10
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	<1	<1	<1	2
Antimony	7440-36-0	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	----	1.8	<0.1	2.1	10.2
Barium	7440-39-3	1	mg/kg	----	<1	<1	<1	<1
Beryllium	7440-41-7	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Boron	7440-42-8	1	mg/kg	----	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86118 352-GC01	86120 571-GC01	86002 GC29X-03	86129 GC29X-06	86006
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-011	EB1328277-012	EB1328277-013	EB1328277-014	EB1328277-015
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	----	<1	<1	<1	<1
Lead	7439-92-1	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	----	**0.1**	<0.1	**0.2**	**0.9**
Nickel	7440-02-0	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	----	**0.3**	<0.1	<0.1	**0.2**
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	<0.1	**0.1**	**0.2**
Zinc	7440-66-6	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**4560**	**11400**	**11200**	**7680**
Antimony	7440-36-0	5	mg/kg	----	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	----	**12**	**11**	**13**	**52**
Barium	7440-39-3	10	mg/kg	----	<10	**310**	**280**	**160**
Beryllium	7440-41-7	1	mg/kg	----	<1	<1	<1	<1
Boron	7440-42-8	50	mg/kg	----	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	----	**2**	**10**	**8**	**7**
Cobalt	7440-48-4	2	mg/kg	----	**7**	**7**	**7**	**50**
Copper	7440-50-8	5	mg/kg	----	**60**	**24**	**56**	**63**
Lead	7439-92-1	5	mg/kg	----	**18**	**7**	**24**	**28**
Manganese	7439-96-5	5	mg/kg	----	**272**	**3770**	**142**	**387**
Molybdenum	7439-98-7	2	mg/kg	----	<2	<2	<2	**2**
Nickel	7440-02-0	2	mg/kg	----	**11**	**10**	**15**	**50**
Selenium	7782-49-2	5	mg/kg	----	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	----	**8**	**37**	**24**	**21**
Zinc	7440-66-6	5	mg/kg	----	**107**	**47**	**101**	**92**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86118 352-GC01	86120 571-GC01	86002 GC29X-03	86129 GC29X-06	86006
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-011	EB1328277-012	EB1328277-013	EB1328277-014	EB1328277-015
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	----	**0.2**	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86131 GC29X-12	86011 GC20C-03	86015 GC20C-15	86016 GC20C-22	86018 GC20C-23
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-016	EB1328277-017	EB1328277-018	EB1328277-019	EB1328277-020
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	----	4.4	----	1.2	----
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	Yellowish Brown	Dark Grey	Very Dark Grey	Dark Grey
Texture	----	-	-	Rock	Rock	Rock	Rock	Sand
Emerson Class Number	----	-	-	8	7	7	8	2
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	5.2	10.3	11.4	6.1	9.4
Exchangeable Magnesium	----	0.1	meq/100g	3.1	10.0	3.2	3.2	4.2
Exchangeable Potassium	----	0.1	meq/100g	0.6	0.3	0.5	1.0	0.6
Exchangeable Sodium	----	0.1	meq/100g	3.3	1.4	0.5	0.8	0.6
Cation Exchange Capacity	----	0.1	meq/100g	12.2	22.0	15.6	11.2	14.7
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	222	----	802	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	222	----	444	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	<1	----	358	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	<10	----	140	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	<10	----	40	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	<10	----	<10	----
Magnesium	7439-95-4	10	mg/kg	----	<10	----	<10	----
Sodium	7440-23-5	10	mg/kg	----	40	----	330	----
Potassium	7440-09-7	10	mg/kg	----	<10	----	60	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	1	----	1	----
Antimony	7440-36-0	0.1	mg/kg	----	<0.1	----	<0.1	----
Arsenic	7440-38-2	0.1	mg/kg	----	0.1	----	0.7	----
Barium	7440-39-3	1	mg/kg	----	<1	----	<1	----
Beryllium	7440-41-7	0.1	mg/kg	----	<0.1	----	<0.1	----
Boron	7440-42-8	1	mg/kg	----	<1	----	<1	----
Cadmium	7440-43-9	0.1	mg/kg	----	<0.1	----	<0.1	----
Chromium	7440-47-3	0.1	mg/kg	----	<0.1	----	<0.1	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86131 GC29X-12	86011 GC20C-03	86015 GC20C-15	86016 GC20C-22	86018 GC20C-23
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-016	EB1328277-017	EB1328277-018	EB1328277-019	EB1328277-020
EG005S : Soluble Metals by ICPAES - Continued								
Cobalt	7440-48-4	0.1	mg/kg	----	<0.1	----	<0.1	----
Copper	7440-50-8	0.1	mg/kg	----	<0.1	----	<0.1	----
Iron	7439-89-6	1	mg/kg	----	1	----	<1	----
Lead	7439-92-1	0.1	mg/kg	----	<0.1	----	<0.1	----
Manganese	7439-96-5	0.1	mg/kg	----	<0.1	----	<0.1	----
Molybdenum	7439-98-7	0.1	mg/kg	----	<0.1	----	0.5	----
Nickel	7440-02-0	0.1	mg/kg	----	<0.1	----	<0.1	----
Selenium	7782-49-2	0.1	mg/kg	----	<0.1	----	0.2	----
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	----	0.2	----
Zinc	7440-66-6	0.1	mg/kg	----	<0.1	----	<0.1	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	6710	----	2890	----
Antimony	7440-36-0	5	mg/kg	----	<5	----	<5	----
Arsenic	7440-38-2	5	mg/kg	----	12	----	11	----
Barium	7440-39-3	10	mg/kg	----	50	----	300	----
Beryllium	7440-41-7	1	mg/kg	----	<1	----	1	----
Boron	7440-42-8	50	mg/kg	----	<50	----	<50	----
Cadmium	7440-43-9	1	mg/kg	----	<1	----	<1	----
Chromium	7440-47-3	2	mg/kg	----	5	----	2	----
Cobalt	7440-48-4	2	mg/kg	----	15	----	11	----
Copper	7440-50-8	5	mg/kg	----	35	----	61	----
Lead	7439-92-1	5	mg/kg	----	12	----	27	----
Manganese	7439-96-5	5	mg/kg	----	125	----	389	----
Molybdenum	7439-98-7	2	mg/kg	----	<2	----	<2	----
Nickel	7440-02-0	2	mg/kg	----	15	----	12	----
Selenium	7782-49-2	5	mg/kg	----	<5	----	<5	----
Vanadium	7440-62-2	5	mg/kg	----	13	----	11	----
Zinc	7440-66-6	5	mg/kg	----	58	----	87	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	<0.0005	----	<0.0005	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	<0.1	----	<0.1	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86124 GC20C-04	90513 GC29X-04	90518 GC29X-05	90525 GC29X-11	86037 GC17J-01
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-021	EB1328277-022	EB1328277-023	EB1328277-024	EB1328277-025
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	0.207	0.066	0.059	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	6.1	2.0	<1.0	<1.0	<1.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	----	----	----	L. Yellowish rown
Texture	----	-	-	Rock	----	----	----	Sand
Emerson Class Number	----	-	-	8	----	----	----	3
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	8.4	----	----	----	3.4
Exchangeable Magnesium	----	0.1	meq/100g	6.9	----	----	----	5.3
Exchangeable Potassium	----	0.1	meq/100g	0.4	----	----	----	0.2
Exchangeable Sodium	----	0.1	meq/100g	0.8	----	----	----	0.6
Cation Exchange Capacity	----	0.1	meq/100g	16.4	----	----	----	9.5
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	418	196	136	444	120
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	384	196	136	274	120
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	34	<1	<1	170	<1
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	80	570	60	200	<10
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	<10	10	10	20	30
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	20	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	20	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	160	260	80	300	40
Potassium	7440-09-7	10	mg/kg	10	20	<10	<10	<10
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	<1	1	<1
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	1.9	<0.1	0.4	0.1	<0.1
Barium	7440-39-3	1	mg/kg	<1	<1	<1	<1	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86124 GC20C-04	90513 GC29X-04	90518 GC29X-05	90525 GC29X-11	86037 GC17J-01
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-021	EB1328277-022	EB1328277-023	EB1328277-024	EB1328277-025
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	**0.5**	**0.4**	**0.6**	**0.2**	<0.1
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	**0.2**	**0.2**	**0.2**	**0.1**	<0.1
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	**0.1**	**0.2**	<0.1
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**12100**	**16000**	**6850**	**7020**	**1950**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**13**	**10**	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**30**	**130**	**50**	**690**	**100**
Beryllium	7440-41-7	1	mg/kg	**1**	<1	<1	<1	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**9**	**12**	**5**	**7**	<2
Cobalt	7440-48-4	2	mg/kg	**8**	**5**	**4**	**2**	**5**
Copper	7440-50-8	5	mg/kg	**72**	**60**	**52**	**45**	<5
Lead	7439-92-1	5	mg/kg	**22**	**19**	**16**	**12**	<5
Manganese	7439-96-5	5	mg/kg	**169**	**171**	**330**	**113**	**250**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**15**	**14**	**6**	**7**	**3**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**26**	**38**	**13**	**17**	**6**
Zinc	7440-66-6	5	mg/kg	**52**	**74**	**88**	**61**	**6**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86124 GC20C-04	90513 GC29X-04	90518 GC29X-05	90525 GC29X-11	86037 GC17J-01
			Client sampling date / time	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	01-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-021	EB1328277-022	EB1328277-023	EB1328277-024	EB1328277-025
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86125	86126 GC17J-12	86133	86136 GC17J-20	86140
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-029	EB1328277-030	EB1328277-031	EB1328277-032	EB1328277-033
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.325	0.580	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	<1.0	1.3	----	1.7
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black	----	Very Dark Grey	Black	Black
Texture	----	-	-	Rock	----	Rock	Rock	Rock
Emerson Class Number	----	-	-	8	----	8	8	8
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	20.8	----	9.7	8.8	15.0
Exchangeable Magnesium	----	0.1	meq/100g	5.1	----	3.4	4.3	4.6
Exchangeable Potassium	----	0.1	meq/100g	0.5	----	0.6	0.7	0.6
Exchangeable Sodium	----	0.1	meq/100g	0.5	----	0.6	2.3	0.9
Cation Exchange Capacity	----	0.1	meq/100g	26.9	----	14.3	16.1	21.0
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	598	342	888	----	1170
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	358	342	564	----	794
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	239	<1	324	----	376
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	250	1380	80	----	60
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	10	20	<10	----	20
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	160	<10	----	<10
Magnesium	7439-95-4	10	mg/kg	<10	70	<10	----	<10
Sodium	7440-23-5	10	mg/kg	270	430	280	----	440
Potassium	7440-09-7	10	mg/kg	20	70	40	----	30
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	2	----	1
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Arsenic	7440-38-2	0.1	mg/kg	2.9	<0.1	2.9	----	0.3
Barium	7440-39-3	1	mg/kg	<1	<1	<1	----	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	----	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86125	86126 GC17J-12	86133	86136 GC17J-20	86140
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-029	EB1328277-030	EB1328277-031	EB1328277-032	EB1328277-033
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	----	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	<0.1	**0.2**	**0.6**	----	**0.2**
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Selenium	7782-49-2	0.1	mg/kg	**0.3**	**0.1**	<0.1	----	<0.1
Vanadium	7440-62-2	0.1	mg/kg	**0.1**	<0.1	**0.2**	----	**0.1**
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**9370**	**2240**	**1280**	----	**8680**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	----	<5
Arsenic	7440-38-2	5	mg/kg	**14**	<5	**12**	----	**9**
Barium	7440-39-3	10	mg/kg	**100**	**220**	**80**	----	**300**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	----	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	<1
Chromium	7440-47-3	2	mg/kg	**8**	<2	**2**	----	**6**
Cobalt	7440-48-4	2	mg/kg	**5**	**2**	**11**	----	**13**
Copper	7440-50-8	5	mg/kg	**59**	**46**	**29**	----	**44**
Lead	7439-92-1	5	mg/kg	**16**	**24**	**18**	----	**16**
Manganese	7439-96-5	5	mg/kg	**323**	**288**	**1260**	----	**1860**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	----	<2
Nickel	7440-02-0	2	mg/kg	**15**	**3**	**10**	----	**15**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	**21**	**6**	**35**	----	**35**
Zinc	7440-66-6	5	mg/kg	**96**	**44**	**61**	----	**72**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	----	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86125	86126 GC17J-12	86133	86136 GC17J-20	86140
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-029	EB1328277-030	EB1328277-031	EB1328277-032	EB1328277-033
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86008 GC23P-01	86027	86032	86144 GC20C-14	86172 GC17J-22
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-034	EB1328277-036	EB1328277-038	EB1328277-039	EB1328277-044
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	0.144	----	0.150	0.164
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	1.2	1.1	<1.0	<1.0	<1.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	L. Yellowish Brown	Grey	Dark Grey	Black	----
Texture	----	-	-	Sand	Rock	Rock	Rock	----
Emerson Class Number	----	-	-	3	7	7	8	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	3.6	14.2	19.9	9.1	----
Exchangeable Magnesium	----	0.1	meq/100g	0.3	1.3	1.1	4.4	----
Exchangeable Potassium	----	0.1	meq/100g	<0.1	0.5	0.6	1.1	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	0.2	0.3	0.9	----
Cation Exchange Capacity	----	0.1	meq/100g	3.9	16.2	21.8	15.5	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	204	564	837	905	820
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	136	325	530	649	342
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	68	239	307	256	478
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	20	210	40	190	140
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	10	<10	<10	<10	20
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	20	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	50	240	240	340	430
Potassium	7440-09-7	10	mg/kg	20	80	90	50	10
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	<1	1	<1
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	<0.1	0.2	0.6	0.9	0.6
Barium	7440-39-3	1	mg/kg	<1	<1	<1	<1	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86008 GC23P-01	86027	86032	86144 GC20C-14	86172 GC17J-22
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-034	EB1328277-036	EB1328277-038	EB1328277-039	EB1328277-044
EG005S : Soluble Metals by ICPAES - Continued								
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	<0.1	<0.1	**0.2**	**0.1**	**0.6**
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	**0.1**
Vanadium	7440-62-2	0.1	mg/kg	<0.1	**0.2**	**0.1**	**0.2**	**0.3**
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**890**	**510**	**1210**	**3070**	**6700**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	**6**	<5	**12**
Barium	7440-39-3	10	mg/kg	**30**	**30**	**50**	**160**	**230**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	**1**	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	<2	<2	**3**	<2	**4**
Cobalt	7440-48-4	2	mg/kg	<2	**3**	**4**	**2**	**8**
Copper	7440-50-8	5	mg/kg	<5	**12**	**12**	**53**	**44**
Lead	7439-92-1	5	mg/kg	<5	**10**	**22**	**30**	**15**
Manganese	7439-96-5	5	mg/kg	**114**	**266**	**509**	**78**	**1520**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	<2	<2	**3**	**4**	**10**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	<5	<5	**6**	<5	**24**
Zinc	7440-66-6	5	mg/kg	<5	**38**	**44**	**86**	**48**
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86008 GC23P-01	86027	86032	86144 GC20C-14	86172 GC17J-22
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-034	EB1328277-036	EB1328277-038	EB1328277-039	EB1328277-044
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86174 GC23P-06	86175 GC23P-09	86176 GC23P-18	86177 GC23P-21	90528 GC20C-05
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-046	EB1328277-047	EB1328277-048	EB1328277-049	EB1328277-050
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.163	0.974	<0.005	<0.005	0.177
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	1.3	<1.0	<1.0	<1.0	<1.0
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	248	42	342	871	307
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	248	42	257	495	239
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<1	<1	85	376	68
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	390	600	20	20	210
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	80	90	20	<10	20
Magnesium	7439-95-4	10	mg/kg	40	60	<10	<10	10
Sodium	7440-23-5	10	mg/kg	60	50	80	330	180
Potassium	7440-09-7	10	mg/kg	100	40	10	<10	10
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	<1	<1	<1
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	7440-38-2	0.1	mg/kg	0.3	<0.1	<0.1	0.2	<0.1
Barium	7440-39-3	1	mg/kg	<1	<1	<1	<1	<1
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	7439-96-5	0.1	mg/kg	<0.1	0.7	<0.1	<0.1	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	1.2	<0.1	<0.1	0.2	0.3
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	7782-49-2	0.1	mg/kg	0.2	<0.1	<0.1	0.1	0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	86174 GC23P-06	86175 GC23P-09	86176 GC23P-18	86177 GC23P-21	90528 GC20C-05
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00	22-OCT-2013 15:00
Compound	CAS Number	LOR	Unit	EB1328277-046	EB1328277-047	EB1328277-048	EB1328277-049	EB1328277-050
EG005S : Soluble Metals by ICPAES - Continued								
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	0.8	0.2	0.1
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1310	690	840	3910	2250
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	9	<5	<5	<5
Barium	7440-39-3	10	mg/kg	60	30	70	120	20
Beryllium	7440-41-7	1	mg/kg	1	<1	1	<1	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	<2	<2	<2	3	<2
Cobalt	7440-48-4	2	mg/kg	<2	3	<2	2	<2
Copper	7440-50-8	5	mg/kg	42	32	24	44	39
Lead	7439-92-1	5	mg/kg	27	11	10	10	8
Manganese	7439-96-5	5	mg/kg	12	5	33	102	21
Molybdenum	7439-98-7	2	mg/kg	2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	2	4	<2	4	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	<5	<5	<5	10	<5
Zinc	7440-66-6	5	mg/kg	36	16	26	51	10
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	90531 GC20C-06	90535 GC20C-11	----	----	----
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1328277-051	EB1328277-053	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.392	1.15	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	<1.0	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	179	478	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	179	171	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<1	307	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	210	240	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	<10	20	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	----	----	----
Magnesium	7439-95-4	10	mg/kg	<10	<10	----	----	----
Sodium	7440-23-5	10	mg/kg	170	310	----	----	----
Potassium	7440-09-7	10	mg/kg	<10	10	----	----	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	<1	<1	----	----	----
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	----	----	----
Arsenic	7440-38-2	0.1	mg/kg	<0.1	<0.1	----	----	----
Barium	7440-39-3	1	mg/kg	<1	<1	----	----	----
Beryllium	7440-41-7	0.1	mg/kg	<0.1	<0.1	----	----	----
Boron	7440-42-8	1	mg/kg	<1	<1	----	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	----	----	----
Chromium	7440-47-3	0.1	mg/kg	<0.1	<0.1	----	----	----
Cobalt	7440-48-4	0.1	mg/kg	<0.1	<0.1	----	----	----
Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	----	----	----
Iron	7439-89-6	1	mg/kg	<1	<1	----	----	----
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	----	----	----
Manganese	7439-96-5	0.1	mg/kg	<0.1	<0.1	----	----	----
Molybdenum	7439-98-7	0.1	mg/kg	0.3	<0.1	----	----	----
Nickel	7440-02-0	0.1	mg/kg	<0.1	<0.1	----	----	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	----	----	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Client sample ID	90531 GC20C-06	90535 GC20C-11	----	----	----
			Client sampling date / time	22-OCT-2013 15:00	22-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1328277-051	EB1328277-053	----	----	----
EG005S : Soluble Metals by ICPAES - Continued								
Vanadium	7440-62-2	0.1	mg/kg	0.1	0.1	----	----	----
Zinc	7440-66-6	0.1	mg/kg	<0.1	<0.1	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7770	3920	----	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	----	----	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	----	----	----
Barium	7440-39-3	10	mg/kg	100	90	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	----	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	----	----
Chromium	7440-47-3	2	mg/kg	8	<2	----	----	----
Cobalt	7440-48-4	2	mg/kg	8	<2	----	----	----
Copper	7440-50-8	5	mg/kg	50	34	----	----	----
Lead	7439-92-1	5	mg/kg	12	12	----	----	----
Manganese	7439-96-5	5	mg/kg	84	1190	----	----	----
Molybdenum	7439-98-7	2	mg/kg	2	<2	----	----	----
Nickel	7440-02-0	2	mg/kg	7	2	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	----	----	----
Vanadium	7440-62-2	5	mg/kg	18	14	----	----	----
Zinc	7440-66-6	5	mg/kg	74	24	----	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1328300**	Page	: 1 of 3
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Project	: Baralaba Nth	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 18-NOV-2013
Sampler	: ----	Issue Date	: 28-NOV-2013
Site	: ----		
		No. of samples received	: 2
Quote number	: BN/526/13	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
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General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	86001 GC23P-04	86020 GC23P-05	----	----	----
			Client sampling date / time	12-NOV-2013 15:00	12-NOV-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1328300-001	EB1328300-002	----	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.6	9.1	----	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.7	-38.6	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	53	143	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	3.3	40.1	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	0.3	4.1	----	----	----
Fizz Rating	----	0	Fizz Unit	0	2	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	0.020	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.05	----	----	----

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EARTH SCIENCES

Appendix G. Water Management Plan

ENGENY WATER MANAGEMENT

BARALABA COAL COMPANY LIMITED

Wonbindi Coal Pty Ltd

Baralaba Mine Water Management Plan

2022 Annual Review

27 September 2022

M3600_016-REP-001-1

Job no. and Project Name: M3600_016 Baralaba Mine Water Management Plan – 2022 Annual Review
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	9/09/2022	Client Review	Amy Hersant	Tim Wallis	Emily Beck	Raymond Yau
1	27/09/2022	Final Issue	Amy Hersant	Tim Wallis	Emily Beck	Raymond Yau
Signatures						

DISCLAIMER

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1 INTRODUCTION

The Baralaba North Mine is an open cut coal mine located in the Bowen Basin, Central Queensland, approximately 3km from the township of Baralaba. It is approved to extract up to 4.1 million tonnes per annum (mtpa) of run-of-mine (ROM) coal.

The Baralaba North Mine includes two operating domains, Baralaba Central and Baralaba North. Baralaba Central remains in use for waste dumping to backfill mine voids, progressive rehabilitation, heavy equipment workshops, fuelling and servicing, and haul roads. Baralaba North is used for open cut coal mining, coal crushing, screening, and stockpiling, heavy equipment workshops, fuelling and servicing, and offices and amenities.

This Water Management Plan (WMP) covers the Baralaba North Mine, including Baralaba Central and Baralaba North (refer to Figure 1.1).

Activities on the land subject to the mineral resource authority are subject to the conditions of approval in the Baralaba North Mine environmental authority (EA) EPML00223213, and may occur within the following mining leases:

- Baralaba Central – ML 5605, ML 80157, and ML 700004.
- Baralaba North – ML 80169, ML 80170, and ML 80201.
- Anabranch Crossing – ML 80200.
- Other – ML 5580, ML 5581, and ML 5590.

1.1 PURPOSE AND SCOPE

This WMP has been prepared in accordance with the Department of Environment and Science (DES) Guideline - Preparation of Water Management Plans for Mining Activities (ESR/2016/3111)/ (EM324) and relevant Schedule C (Water) Conditions from the Baralaba North Mine EA (EPML00223213).

The purpose of this WMP is to examine and address issues relevant to the importation, generation, use, and management of water at the Baralaba North Mine in order to minimise the quantity of mine-affected water required to be released from site and prevent the uncontrolled release of mine affected water from the site.

The WMP includes the following:

- Environmental values associated with surface water and groundwater at the site.
- A study of potential sources of contamination at the site, including the potential for saline and acid rock drainage.
- Site water management infrastructure.
- Site water balance model.
- Potential impacts of mining on surface water and groundwater environmental values.
- Emergency and contingency planning for potential emergency scenarios.
- Roles and responsibilities for the WMP; and,
- Review and continual improvement process for the WMP.

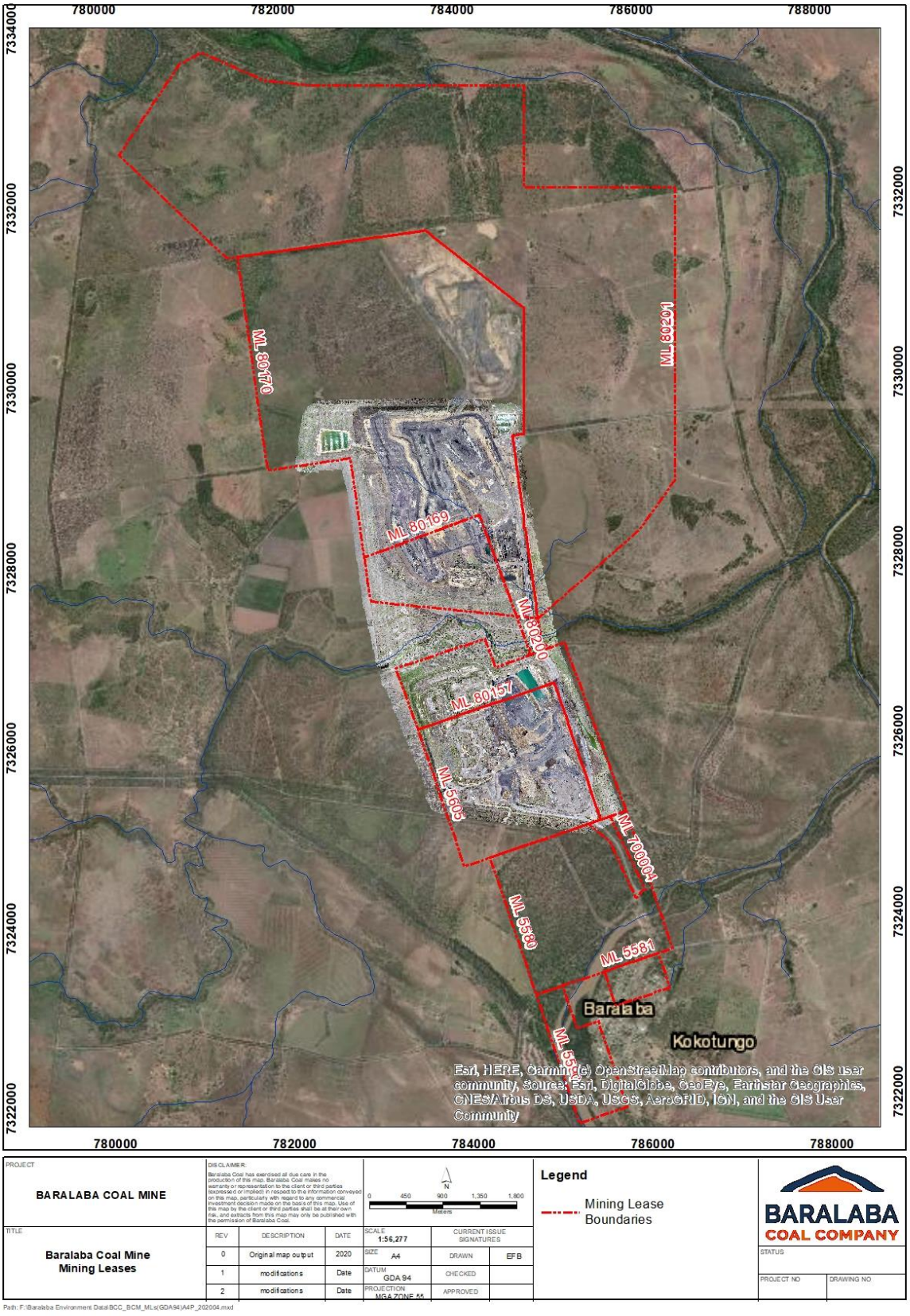

Figure 1.1: Baralaba North Mine Leases

2 RELEVANT ENVIRONMENTAL AUTHORITY CONDITIONS

This WMP has been prepared in accordance with the relevant Schedule C (Water) Conditions from the Baralaba North Mine EA (EPML00223213), as outlined in Table 2.1.

Table 2.1: Relevant EA Schedule C (Water) Conditions

- C27 A Water Management Plan must be developed by an appropriately qualified person and implemented prior to the commencement of activities to relinquishment.

- C28 The Water Management Plan must:
  - 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
  - Be developed in accordance with the administering authority's most recent version of the guideline for "Preparation of water management plans for mining activities (EM324)" or any updates that become available from time to time and include:
    - A study of the source of contaminants.
    - A water balance model for the site.
    - A water management system for the site.
    - Measures to manage and prevent saline drainage.
    - Measures to manage and prevent acid rock drainage.
    - Contingency procedures for emergencies; and,
    - A program for monitoring and review of the effectiveness of the Water Management Plan.

- C29 The Water Management Plan must be reviewed each calendar year and a report prepared by an appropriately qualified person. The report must:
  - Assess the plan against the requirements under condition C28.
  - Include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and,
  - Identify any amendments made to the water management plan following the review.

- C30 The holder of this environmental authority must attach to the review report required by condition C29, a written response to the report and recommended actions, detailing the actions taken or to be taken by the environmental authority holder on stated dates:
  - To ensure compliance with this environmental authority; and,
  - To prevent a recurrence of any non-compliance issues identified.

- C31 The review report required by condition C29 and the written response to the review report required by condition C30 must be submitted to the administering authority by 1 November each year.

- C32 A copy of the Water Management Plan must be provided to the administering authority on request.

3 ENVIRONMENTAL VALUES

3.1 SURFACE WATER

3.1.1 Description

The Baralaba North Mine is located in the Lower Dawson region of the Dawson River catchment, which is part of the larger Fitzroy Basin (refer to Figure 3.1). The Dawson River valley is relatively flat (average slope of less than 5%). Anabranches and ox bow lakes are common.

The Baralaba North Mine is located on the northern floodplain of the lower Dawson River. An anabranch of the Dawson River separates Baralaba North from Baralaba Central.

The Dawson River joins the Fitzroy River approximately 60km downstream of the Baralaba North Mine. The Fitzroy River subsequently flows through Rockhampton and into the Great Barrier Reef Marine Park.

3.1.2 Surrounding Environmental Values

In accordance with Section 9 of the *Environmental Protection Act 1994* (Qld) (EP Act), environmental values are defined as a:

a) quality or characteristic that is conducive to ecological health or public amenity or safety; or
b) another quality of the environment identified and declared to be an environmental value under an Environmental Protection Policy or Regulation (e.g. water suitable for swimming in or drinking).

The *Environmental Protection (Water) Policy 2009 Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment* (EHP, 2011) provides a list of environmental values for all waters within the Dawson River Sub-basin, including:

- Protection of aquatic ecosystem values.
- Suitability for drinking water supplies.
- Suitability for primary contact recreation.
- Suitability for secondary contact recreation.
- Suitability for visual recreation.
- Suitability for human consumers of wild or stocked fish, shellfish, or crustaceans.
- Protection of cultural and spiritual values.
- Suitability for crop irrigation.
- Suitability for aquaculture (e.g., red claw, barramundi).
- Suitability for stock watering; and,
- Suitability for industrial use.

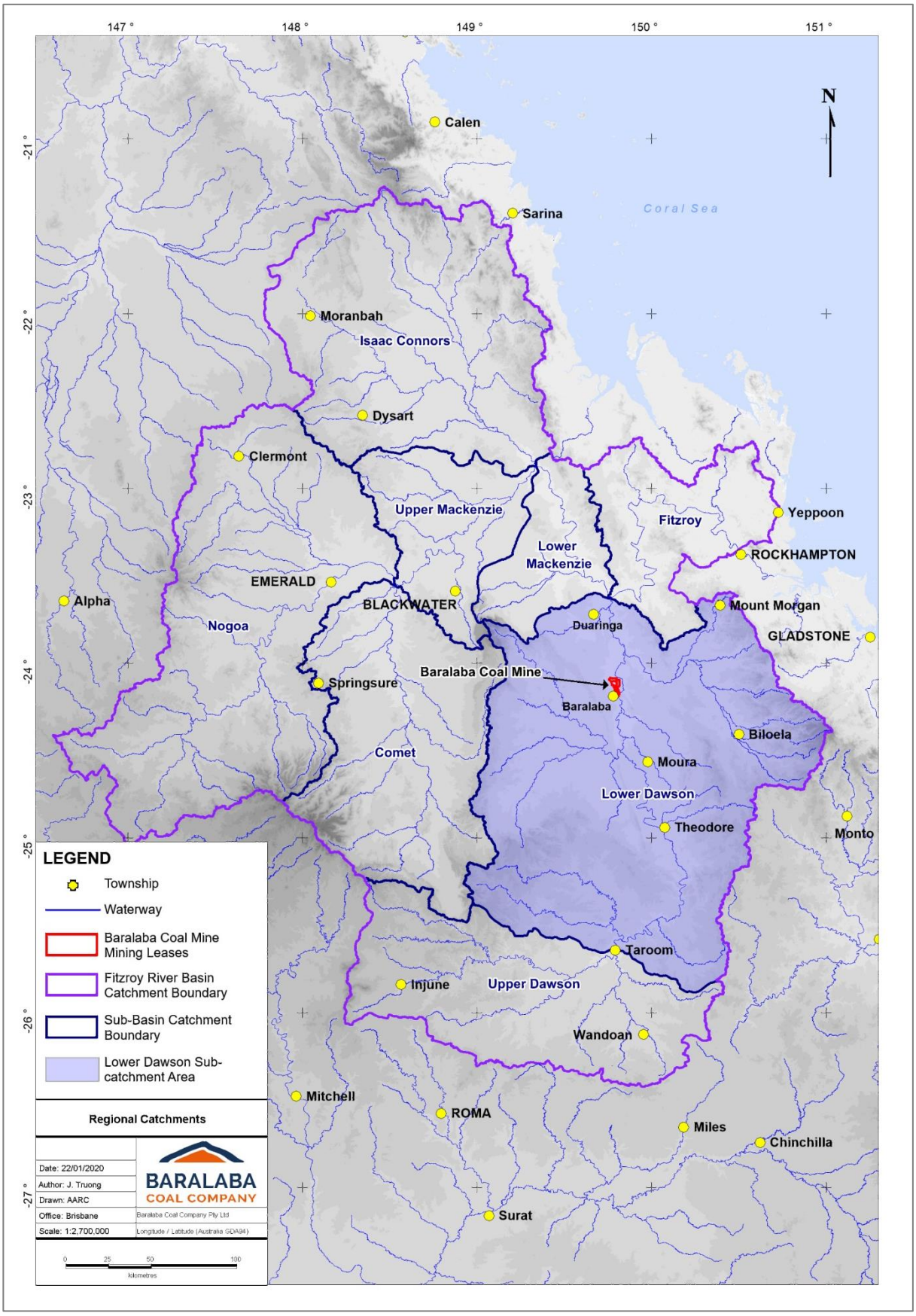

Figure 3.1: Fitzroy Basin

Environmental values that are relevant to the Baralaba North Mine's defined receiving environment are aquatic ecosystem values and suitability for stock watering. The receiving environment is not known to provide for any of the industrial, recreational, cultural, or spiritual environmental values.

i. Aquatic ecosystems

Aquatic flora and fauna in the vicinity of the Baralaba North Mine area have been surveyed and were found to be representative of the region.

No aquatic species of conservation significance are known or likely to occur within the Baralaba North Mine lease boundary. Furthermore, the Baralaba North Mine area is not known to support any important functions required for the maintenance of aquatic species of conservation significance in the receiving environment.

The surrounding aquatic environment both upstream and downstream of the Baralaba North Mine is monitored biannually in accordance with Receiving Environment Monitoring Program (REMP). Recent REMP monitoring did not identify any impacts from the Baralaba North Mine on the receiving aquatic environment.

ii. North-West Soak and High Ecological Significance (HES) Wetland

The North-West Soak (Eucalyptus tereticornis palustrine wetland) is located in the north-west corner of ML80201. It is potentially associated with a perched aquifer that is recharged by rainfall and the alluvial aquifer. The area is not a RAMSAR wetland but has been assessed as being an intact and functioning ecosystem. Condition A3 of the Baralaba North Mine EA (EPML00223213) excludes mining activities in or within 200m of the North-West Soak and HES Wetland Protection Area.

iii. Agricultural use

The Dawson River supports a variety of agriculture and irrigation activities. Water quality in the Dawson River is generally suitable for agricultural activities, although salinity levels have been reported to increase during periods of low flow. Surface water samples from monitoring sites within the Anabranch and the Dawson River in the immediate vicinity of the Baralaba North Mine generally recorded concentrations of dissolved metals below Australian and New Zealand Guidelines for Fresh and Marine Water Quality guideline levels (ANZECC, 2000) for agricultural use.

According to the Business Queensland water entitlement viewer, currently there are no water licenses attached to properties adjoining the Dawson River Anabranch. However, local landholders may have access to water allocations from the Anabranch, and it is known that local landholders allow livestock to access the Anabranch on an informal basis.

iv. Drinking water use

The Dawson River is heavily regulated. Five weirs are located upstream of the Baralaba North Mine, the nearest being the Neville Hewitt Weir. The Neville Hewitt Weir was constructed across the Dawson River in 1976. The impoundment formed by the Neville Hewitt Weir forms a permanent body of water that has a surface area of approximately 290ha at full supply. It forms part of the reticulated domestic water supply network for the township of Baralaba. The Neville Hewitt Weir is located upstream of the Baralaba North Mine and is considered to be outside of the potential impact area of the mine.

The Dawson River joins the Fitzroy River approximately 60km downstream of the Baralaba North Mine. The Fitzroy River provides drinking water for Rockhampton, which is located a further 180km downstream of the Baralaba North Mine.

3.1.3 Background Surface Water Quality

The *Environmental Protection (Water) Policy 2009 Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment* (EHP, 2011) provides water quality objectives (WQOs) to support and protect the environmental values of water within the Dawson River Sub-basin.

Background surface water quality data from the Anabranch and Dawson River was collected by WBM (2011a, 2011b & 2011c). The monitoring data indicates that the Dawson River is generally more saline and has higher concentrations of total suspended solids (TSS), aluminium, copper, and iron than the applicable WQO's. This has been attributed to elevated concentrations of these parameters at reference (upstream) monitoring sites and in the surrounding soil, and to releases from the Neville Hewitt

Weir. The data also indicates that water within the Anabranch is of poorer quality than water within the Dawson River due to the ephemeral nature of the Anabranch (WBM 2011c).

3.2 GROUNDWATER

3.2.1 Description

The Baralaba North Mine is underlain by two main aquifer types, Tertiary and Quaternary alluvial aquifers, and Permian coal seam aquifers. The Tertiary alluvium underlies most of the Baralaba North area, while the Quaternary alluvium is localised along the Dawson River anabranch and the Dawson River.

In 2021, the Baralaba Coal Mine groundwater monitoring network was expanded to include 13 additional bores. Monitoring data from these bores will inform future revisions of this Water Management Plan.

3.2.2 Background quality

Historically, groundwater underlying the Baralaba North Mine has been of poor supply and/or poor quality. Historical monitoring data shows limited seasonal fluctuation in groundwater levels due to the very low rates of recharge to the system. In regard to water quality, groundwater underlying the Baralaba North Mine has been determined to be saline and contains elevated concentrations of heavy metals. For these reasons' groundwater is considered to be unsuitable for domestic or agricultural use. This is supported by anecdotal evidence that surrounding landowners generally rely on surface water, rather than groundwater, for agriculture and irrigation.

i. Permian aquifer

Permian Coal Measures, comprising Kaloola Coal Measures overlain by late Permian Baralaba Coal Measures. The Baralaba Coal Measures contain the target coal seams within the project area, which are folded and faulted, but generally dip steeply to the west at angles of between 25° and 55° (SKM 2014). There are a total of 12 major coal seams, which range in thickness from 0.5 to 4.4m, with an average interburden thickness of 25m (AGE 2012).

Background groundwater monitoring data from the Permian aquifers was collected by AGE (2012) and SKM (2013). The data indicates that groundwater from the Permian aquifers is fresh to saline, with variable EC levels ranging between 490 – 24,460µS/cm. pH levels are neutral to slightly acidic, ranging from 6.31 – 7.9. Total metal concentrations were above the ANZECC (2000) guideline levels, therefore groundwater from the Permian aquifers is considered to be unsuitable for domestic and agricultural use.

A network of groundwater monitoring bores has been installed at the Baralaba North Mine to monitor potential impacts on groundwater during operations. Recent groundwater monitoring data from the Permian aquifer from 2018 – 2020 returned relatively stable EC levels, ranging between 94 – 1,090S/cm. pH levels were also relatively stable, ranging from 7.3 – 8.69.

ii. Alluvial aquifers

Unconsolidated alluvial deposits of Tertiary and Quaternary age are pervasive across the project area. The Tertiary sediments occur as isolated pockets across the project area, with the majority of alluvium of Quaternary age, which range in thickness from 13m to 20m (AGE 2012). Along the flood plains of the Dawson River and anabranch the Quaternary sediments comprise a 2-10m thick upper clayey layer and a 1-16m thick lower layer of sands and gravels.

Background groundwater monitoring data collected by AGE (2012) and SKM (2013) indicates that groundwater quality from the Quaternary alluvial aquifer is relatively fresh, with EC levels ranging between 300 –1,200µS/cm. The acidity of groundwater from both alluvial aquifers was within the ANZECC (2000) guideline range of 6.5 – 8.5, however concentrations of filtered metals, including manganese, nickel, and zinc, were above the ANZECC (2000) guidelines. Therefore, groundwater from the alluvial aquifers is also considered to be unsuitable for domestic and agricultural use.

Eleven alluvial groundwater bores have been installed at the Baralaba North Mine, however, due to the ephemeral nature of the alluvial aquifer only one bore was able to be sampled on a consistent basis between 2018 – 2020. Monitoring data from this bore between 2018 - 2020 returned relatively fresh EC levels between 636 – 738µS/cm. pH values were within the ANZECC (2000) guideline range, ranging from 6.89 – 8.37.

3.2.3 Water Users

The Baralaba North Mine is within the Dawson River Groundwater Management Unit which is a category 1 low-level resource that has no abstraction allocations, primarily due to its poor water quality. The area is not a declared sub-artesian groundwater area, meaning that bores may be drilled for irrigation and stock watering purposes without a licence from DNRME. Unregistered bores may be present in the vicinity of the Baralaba North Mine.

The township of Baralaba does not use groundwater as a drinking water source due to the poor water quality and unreliability of the supply.

The Baralaba North Mine utilises a portion of the groundwater ingress into the active pits for dust suppression.

4 CONTAMINANT SOURCES

Contaminant sources at the Baralaba North Mine include:

- Spoil.
- The ROM areas located on ML5605 and ML80170.
- Hydrocarbon and chemical usage and storage areas on ML5605 and ML80170; and,
- Blasting.

At present, coal is crushed and screened at the Baralaba North ROM, a process which does not generate tailings or rejects. There is currently no plan for a CHPP to be constructed at Baralaba North.

4.1 SPOIL

An investigation of the chemical and physical characteristics of overburden and spoil at Baralaba Central was completed in 2009. The investigation confirmed that the overburden is non-acid forming with very low total sulphur content (<0.1%) and a relatively high average excess acid neutralising capacity (average 82 kg H2SO4 per tonne).

There is no indication that potential contaminants are being leached from overburden into the water management system at Baralaba Central, or that there are high levels of potential contaminants in groundwater.

A geochemical assessment of spoil at Baralaba North was completed by Terrenus Earth Sciences (2012). The findings were as follows:

- Spoil at Baralaba North will generate alkaline, low to medium-salinity runoff/seepage following surface exposure.
- The sulfur concentration of spoil at Baralaba North is very low with 99% of samples classified as non-acid forming (NAF). Most samples were further classified as 'barren' with respect to sulfur.
- Total metal and metalloid concentrations in spoil samples were low and below the applied health-based investigation levels for soils.
- Multi-element results indicated that some spoil materials may produce leachate containing slightly elevated concentrations of soluble Mo and potentially Se, which is common for spoil materials at coal mines in the Bowen Basin.
- Spoil materials display moderate to high effective cation exchange capacity (eCEC) values which should not preclude direct revegetation. Most spoil materials were sodic to strongly sodic but have reasonably balanced exchangeable cation ratios with respect to exchangeable Ca:Mg:K ratios. Therefore, revegetation should be possible without the need for significant amelioration.

Overall, it was concluded that the spoil generated at Baralaba North will have a very high factor of safety with respect to potential acid generation and excess alkalinity and will generate low to medium salinity surface runoff and seepage.

4.2 COAL STORAGE

In anticipation of the construction of a CHPP, a geochemical assessment of potential coal reject material from the Baralaba North Mine was completed by Terrenus Earth Sciences (2012). The findings were as follows:

- Coal will generate alkaline, low-salinity runoff/seepage following surface exposure.
- The total sulfur concentration of most samples was very low (median sulfur content of 0.7%) although a small proportion of samples contained sufficient sulfidic (pyritic) material to potentially generate weak acidity.
- Coal is expected to be NAF and the magnitude of any acidity generated is expected to be very low.
- Total metal and metalloid concentrations in samples were low and below the applied health-based investigation levels for soils. However, coal materials may produce leachate containing slightly elevated soluble Mo, and potentially Se, concentrations which is common for coal materials at coal mines in the Bowen Basin.

In general, coal will only be stored at the Baralaba North Mine for a relatively short period of time compared to spoil, which will be stored at the site in perpetuity. Overall, the potential for contamination as a result of coal storage at the Baralaba North Mine is considered to be low. The management strategy for coal storage is based around directing seepage and runoff away from the ROM pads.

4.3 HYDROCARBON AND CHEMICAL STORAGE AND USE

As the Baralaba North Mine stores and consumes minimal quantities of hydrocarbons and chemicals, the risk of contamination of surface water or groundwater as a result of hydrocarbon and chemical storage and use at the Baralaba North Mine is considered to be low.

The bulk diesel fuel storage facilities at the Baralaba North Mine are double skinned tanks and are managed in accordance with the *Australian Standard (AS) 1940:2017 The storage and handling of flammable and combustible liquids* and Baralaba Coal's Environmental Management System. The volumes of Class C1 combustible liquids stored at the mine include:

- Up to 330,000L of diesel (in 3 x 110,000L self-bunded trans tanks).
- Up to 80,000L of oils and grease; and,
- Up to 40,000L of waste oil (storage for transfer off-site for recycling).

4.4 BLASTING

Standard blasting techniques are employed at the Baralaba North Mine such that the explosive residue remains in the coal product or is subsequently mined with the overburden and replaced in the mined pit. Therefore, surface water or groundwater contamination as a result of blasting activities at the Baralaba North Mine is considered to be low.

4.5 CONTAINMENT

The potential for contaminant transport via overland flow is managed in accordance with the Baralaba North Mine Erosion and Sediment Control Plan. Several sediment basins are in place along haul roads, light vehicle tracks and overburden dumps at the Baralaba North Mine to capture and treat runoff. Further, the flood levees around the southern perimeter of ML80169 and the northern perimeter of ML80157 prevent overland flow from Baralaba Central and Baralaba North from entering the Dawson River Anabranch.

Water that is collected in the active mining pits (i.e. rainfall, runoff, and groundwater inflows) is reused onsite for haul road dust suppression or coal sprays, or it is released off-site in accordance with the EA Schedule C (Water) Conditions.

4.6 SEWAGE TREATMENT

All effluent generated onsite is trucked offsite by a licensed contractor to Biloela. Therefore, the potential for surface water or groundwater contamination as a result of sewage treatment effluent is considered to be low.

5 WATER MANAGEMENT INFRASTRUCTURE

The water management system at the Baralaba North Mine aims to:

- Divert runoff from undisturbed areas around disturbed areas.
- Capture and treat runoff from disturbed areas.
- Pump excess water from the active mining pits into mine-affected water storages.
- Re-use mine-affected water for haul road dust suppression and coal spraying.
- Release excess mine-affected water to the Dawson River in accordance with the EA Schedule C (Water) Conditions.

Key mine-affected water management infrastructure at the Baralaba North Mine includes:

- Flood Protection Levees.
- Mine Dams.
- ROM Dams.
- Sediment Dams.
- Mine Pits; and,
- Pumps and Pipelines.

Key water management infrastructure at the Baralaba North Mine is shown in Figure 5.1 and Figure 5.2 and described in Sections 5.1 and 5.2. The catchments shown in Figure 5.1 are based on the LiDAR survey data provided by Baralaba on 29 June 2022. At the Baralaba North Mine, the water management system will be developed in stages as mining progresses.

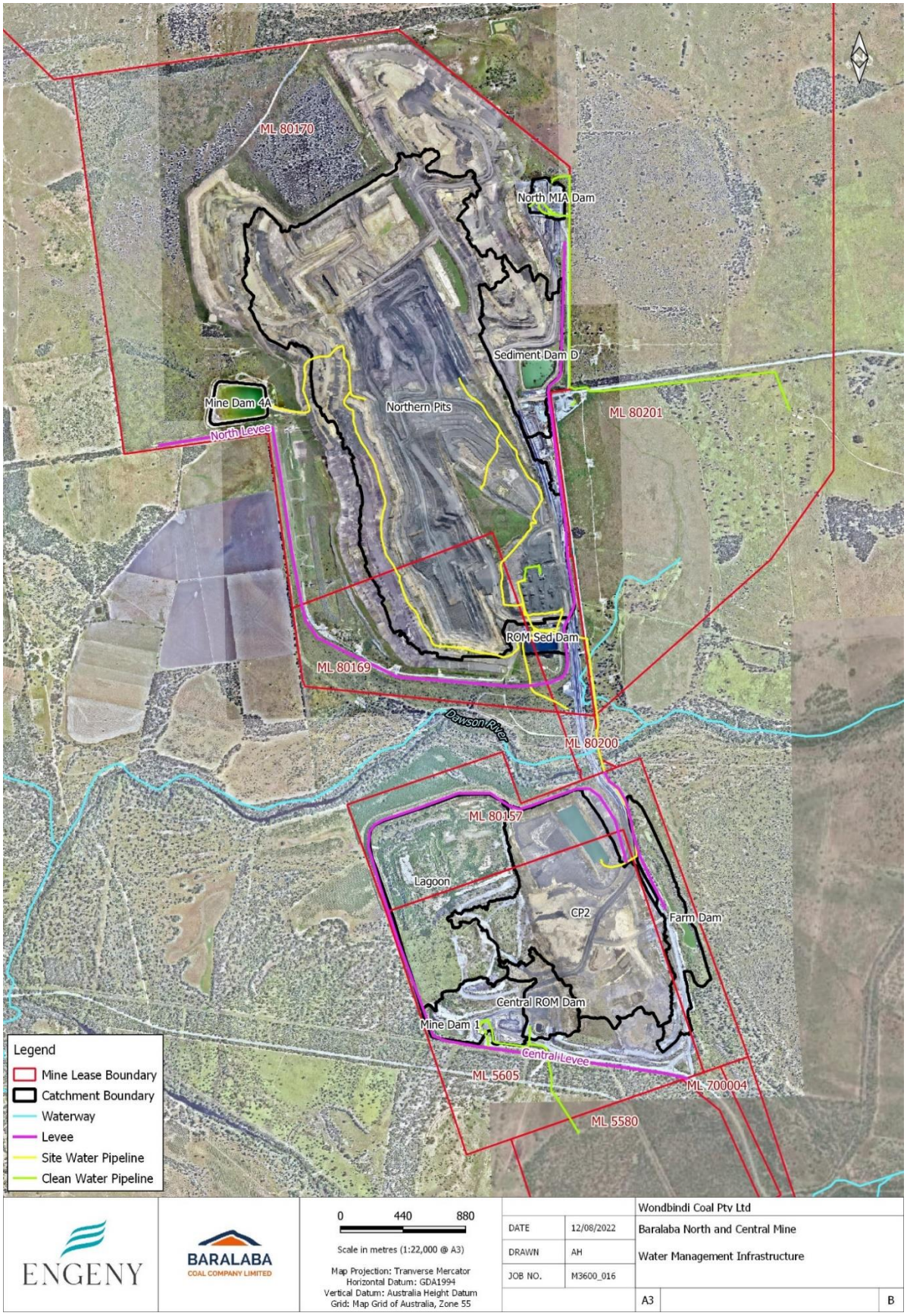

Figure 5.1: Baralaba Mine Water Management Infrastructure

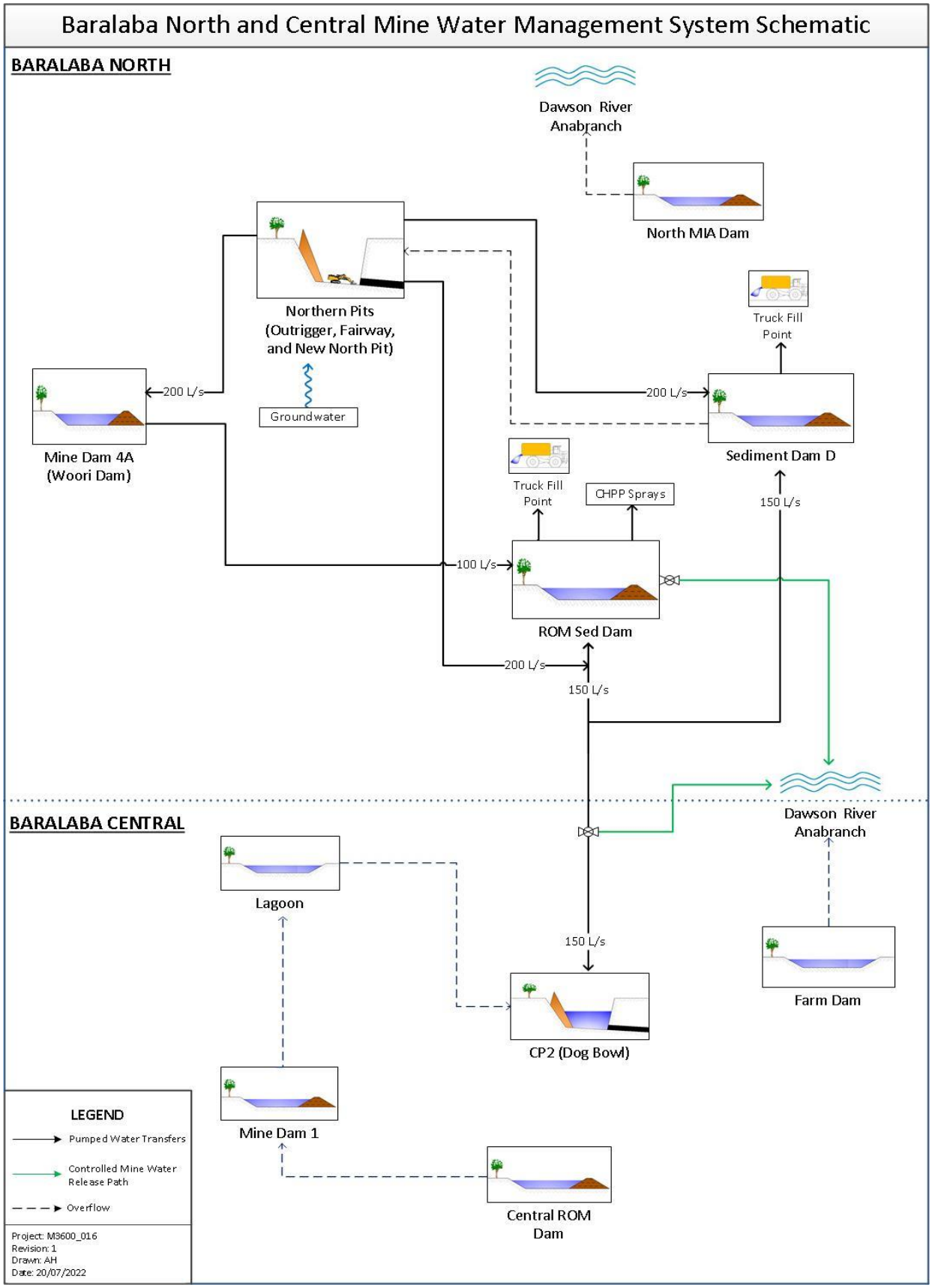

Figure 5.2: Water Management System Schematic

5.1 BARALABA CENTRAL

5.1.1 Central Levee

The current Baralaba Central flood levee was constructed to provide 1 in 1,000-year annual exceedance probability (AEP) flood protection and is considered a regulated structure onsite. It replaced the previous flood levee which only provided 1 in 100-year AEP flood protection. The practical impact of the flood levee is that there is no catchment outside of the mine workings that contributes runoff to the site water storage infrastructure. The area enclosed by the flood levee is approximately 234 ha and includes all areas disturbed by mining.

The Baralaba Central flood levee is a regulated structure under the EP Act. It has been built to a height of 90m AHD which is 0.5m above the 1 in 1,000-year AEP flood level of 89.5m AHD.

5.1.2 Mine Dam 1

Mine Dam 1 is located on the south-western boundary of Baralaba Central and has been identified as a regulated structure onsite for Dam Break. It captures runoff from the workshop laydown area and vehicle washdown bay. Mine Dam 1 has a total capacity of 178.6 ML and a catchment area of approximately 22-ha.

Water quality data for Mine Dam 1 from January 2021 is provided in Table 5.1. This data was presented in the 2021 WMP, however, more recent monitoring data is not available.

Table 5.1: Mine Dam 1 Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
06/01/2021	3,470	7.9	-	13.1

5.1.3 Central ROM Dam

The Central ROM Dam is a relatively small, non-regulated dam designed to capture runoff from the Central ROM pad. It has a capacity of approximately 22 ML and catchment area of 15-ha.

Water quality data for the Central ROM Dam from January 2021 is provided in Table 5.2. This data was presented in the 2021 WMP, however, more recent monitoring data is not available.

Table 5.2: Central ROM Dam Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
06/01/2021	24,800	8.16	-	5.7

5.1.4 Lagoon

The lagoon dam is an old borrow pit located at the north-west corner of Baralaba Central. Surface water collects in the lagoon during high rainfall events as a result of runoff from the eastern side of the waste dump. A secondary borrow pit alongside the lagoon also collects surface runoff. The lagoon has an estimated capacity of 55ML and catchment area of 84-ha. It has remained dry over the previous 12 months; therefore water quality data is not available.

5.1.5 Central Pit

The current volume of mine-affected water stored onsite is approximately 1.0 GL (based on monitoring data from May 2022), mostly stored in the legacy void Central Pit 2 (CP2). CP2 has a capacity of approximately 2.4 GL and catchment area of 113 ha.

After the 2010/2011 floodwaters were discharged from the site, an estimated 700ML of water remained in CP2. Since 2010/11, the volume of mine-affected water stored in CP2 has increased due to inflows of rainfall and runoff. The water quality in CP2 has declined over time, possibly due to groundwater ingress and evaporation. As shown in Table 5.3, the current EC of CP2 is approximately 11,700 µS/cm.

Table 5.3: CP2 Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
02/11/2021	12,786	8.11	26.7	11
15/12/2021	11,681	8.60	31.2	6

A water pipeline between Baralaba Central and Baralaba North allows water to be transferred from CP2 to the ROM Sed Dam and Sediment Dam D for dust suppression and coal spraying. A skid mounted pump is stationed in CP2 to facilitate pumping water out of CP2.

Central Pit 1 (CP1) was previously located alongside CP2. It was fully backfilled in early 2021 and the catchment now reports to CP2.

5.1.6 Farm Dam

The farm dam has a capacity of approximately 91ML and catchment area of 22-ha. It was the mine's primary supply of raw water when mining was occurring at Baralaba Central. Currently, water stored in this dam is not used in the operation, however it could be used for dust suppression or to support construction activities if required.

Water quality data for the Farm Dam from January 2021 is provided in Table 5.4. This data was presented in the 2021 WMP, however, more recent monitoring data is not available.

Table 5.4: Farm Dam Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
06/01/2021	3,460	9.41	-	37.2

5.2 BARALABA NORTH

5.2.1 North Levee

In 2014, a 1 in 1,000-year AEP flood protection levee, with 0.5m freeboard, was constructed around the Baralaba North area, and is considered a regulated structure onsite. It prevents runoff from Baralaba North entering the Dawson River Anabranch. It also prevents flooding of the active pits. To minimise the risk of uncontrolled releases from Baralaba North, during normal operations the release valves on the levee are closed. The valves may only be opened at the written direction of an authorised Baralaba Coal representative.

5.2.2 Mine Dam 4a

Mine Dam 4a has been constructed to store and evaporate mine-affected water that is collected in the active mining pits. Mine Dam 4a is a turkey's nest embankment dam with a storage capacity of 362.5ML (at dam crest height) but is operated below the Maximum Operating Level (MOL) of 295ML. Mine Dam 4a receives pumped inflows of groundwater and surface water from the active mining pits.

Water quality data for Mine Dam 4a from November 2021 is provided in Table 5.5, this was the only water quality testing completed in the 12 months to June 2022.

Table 5.5: Mine Dam 4a Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
02/11/2021	40,421	7.8	-	16.0

5.2.3 ROM Sediment Dam

The ROM Sed Dam acts as a temporary storage for mine-affected water pumped out of the active mining pits. Water from the ROM Sed Dam is either used for dust suppression or transferred to larger mine-affected water storages (i.e., CP2). The ROM Sed Dam has a capacity of approximately 50ML and catchment area of 7-ha.

Water quality data for the ROM Sed Dam for the past 12-months to June 2022 is provided in Table 5.6.

Table 5.6: ROM Sediment Dam Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
02/11/2021	13,305	8.22	25.7	16.0
15/12/2021	9,760	8.75	31.3	9.0

5.2.4 Sediment Dam D (Northern Sediment Dam)

Sediment Dam D has a capacity of 179 ML and catchment area of approximately 40 ha. Included within its catchment area is a large portion of the existing Baralaba North waste dump and associated haul roads. Sediment Dam D has transitioned to a MAW storage in early 2022 and will be used to supply 80% of the dust suppression demand on-site. It will also receive dewater from the Northern Pits as well as transfers from CP2. Sediment Dam D is not a regulated structure.

An amendment to the EA (EPML00223213) moved the location the MAW release point (RP N1), and will allow MAW releases from Sediment Dam D into the main branch of the Dawson River located around 3.5km to the east of the site. The amendment came into effect on the 16th of September 2022; however, releases will not occur during the 2022/2023 water year as the required infrastructure will not be in place during this period.

Water quality data for the Sediment Dam D for the past 12-months to June 2022 is provided in Table 5.7.

Table 5.7: Sediment Dam D Water Quality Data

Sample Date	EC (µS/cm)	pH	Temperature (ºC)	Turbidity (NTU)
02/11/2021	9,123	9.12	24.9	11.0
15/12/2021	7,676	9.9	31.7	15.0

5.2.5 North MIA Dam

The North MIA Dam has a capacity of approximately 6.7ML. The dam has recently been desilted, resulting in an additional 0.5m worth of storage capacity. The North MIA Dam has a catchment area of approximately 5-ha which encompasses the MIA workshops areas, offices, and amenities.

North MIA Dam has remained dry for the past 12-months; therefore, no water quality data is available.

5.2.6 Northern Pits

Although not technically a part of the water management system, the Northern Pits has been included as a component of the water management system due to their role in water containment and emergency planning.

The Northern Pits were joined in late 2021 when the land bridge that separated the Northern Pits (Fairway and Outrigger) and New Northern Pit was mined through, joining all three pits into one.

Water that is collected in the Northern Pits is dewatered to either Mine Dam 4a, ROM Sed Dam or Sediment Dam D depending on the available capacity in these storages. In the event of an above average wet season, extreme flood conditions, or if conditions do not allow for controlled releases of mine-affected water into the Dawson River, then the Northern Pits may be temporarily used to store water to minimise the risk of uncontrolled releases of mine-affected water.

5.2.7 Sediment Dams

In addition to the ROM Sediment Dam and Sediment Dam D described above, a number of sediment dams have been constructed within the Baralaba North area to capture runoff from haul roads, light vehicle tracks, overburden dumps and other disturbed areas. The Sediment Dams are understood to have been located and designed in accordance with the Baralaba North Sediment and Erosion Control Plan and will therefore generally be in accordance with the Best Practice Erosion and Sediment Control guideline (IECAA 2008).

The sizing of the sediment dams is based upon storm events with an average recurrence interval (ARI) of three months to one year (i.e. smaller, more frequent storm events that generate the majority of the annual volumetric runoff). The sizing method avoids storing large amounts of water in the dams for long periods of time which can lead to an accumulation of salt.

5.2.8 Clean Water Diversion Drains

A number of clean water diversion drains have been installed to divert runoff from undisturbed areas within the Baralaba North area around disturbed areas as mining progresses. For instance, a clean water diversion drain has been installed on the south-western side of the flood levee on ML80169. This drain directs overland flow from the western side of the flood levee towards the Dawson River Anabranch, thereby preventing a pond from forming against the flood levee.

5.3 CATCHMENT AREAS

Catchment areas reporting to dams at the Baralaba North Mine are quantified in Table 5.8 and mapped in Figure 5.3 and Figure 5.4. The catchment areas have been delineated using the latest site aerial and LiDAR survey flown in June 2022.

Table 5.8: Catchment Areas (in Hectares)

Storage	Natural	Hardstand	Spoil / Topsoil Stockpile	Pit	Cleared	Rehab	Coal Stockpile	Total
Mine Dam 1	0	10.2	10.3	0	0	1.4	0	**22.0**
Central ROM Dam	0	2.1	9.7	0	0	0	3.3	**15.1**
Lagoon	0	2.9	60.0	0	0	20.8	0	**83.8**
CP2	0	6.9	93.7	9.7	0	2.4	0	**112.6**
Farm Dam	4.5	11.3	7.2	0.0	0	1.9	0	**24.9**
Total (Baralaba Central)	**4.5**	**33.4**	**180.9**	**9.7**	**0.0**	**26.6**	**3.3**	**258.3**
Mine Dam 4a	0	8.2	0	0	0	0	0	**8.2**
ROM Sed Dam	0.6	5.1	0	0	0.4	0.6	0	**6.7**
North MIA Dam	0	4.8	0	0	0	0	0	**4.8**
Northern Pits (Fairway, Outrigger & New North Pit)	0	28.0	100.0	212.5	11.9	1.1	18.9	**372.6**
Sediment Dam D	0.4	16.7	17.9	0	0.9	3.2	0	**39.2**
Total (Baralaba North)	**1.0**	**62.9**	**118.0**	**212.5**	**13.2**	**4.9**	**18.9**	**431.5**
Total	**5.5**	**96.3**	**298.9**	**222.2**	**13.2**	**31.4**	**22.2**	**689.8**

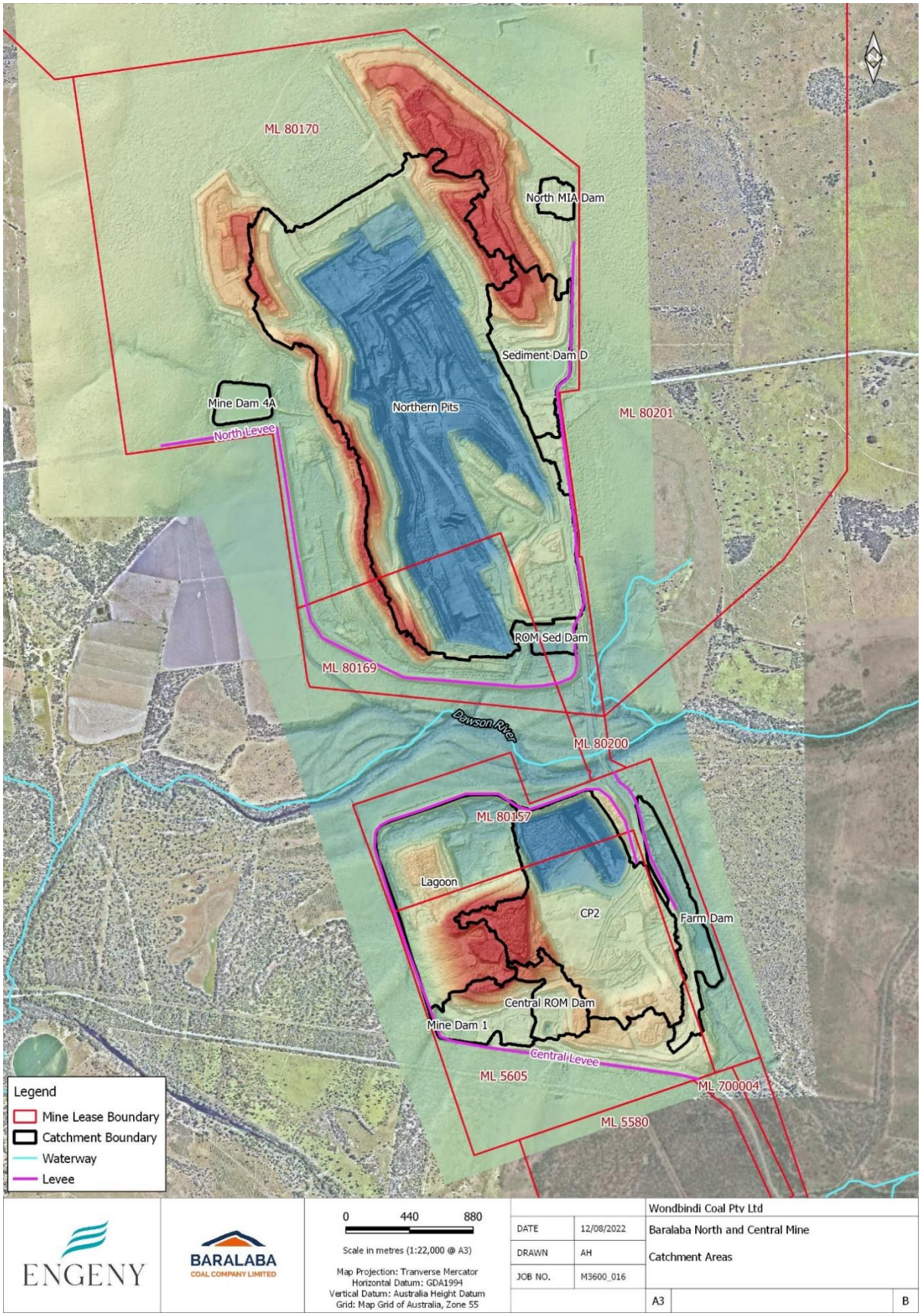

Figure 5.3: Baralaba Mine Catchment Areas

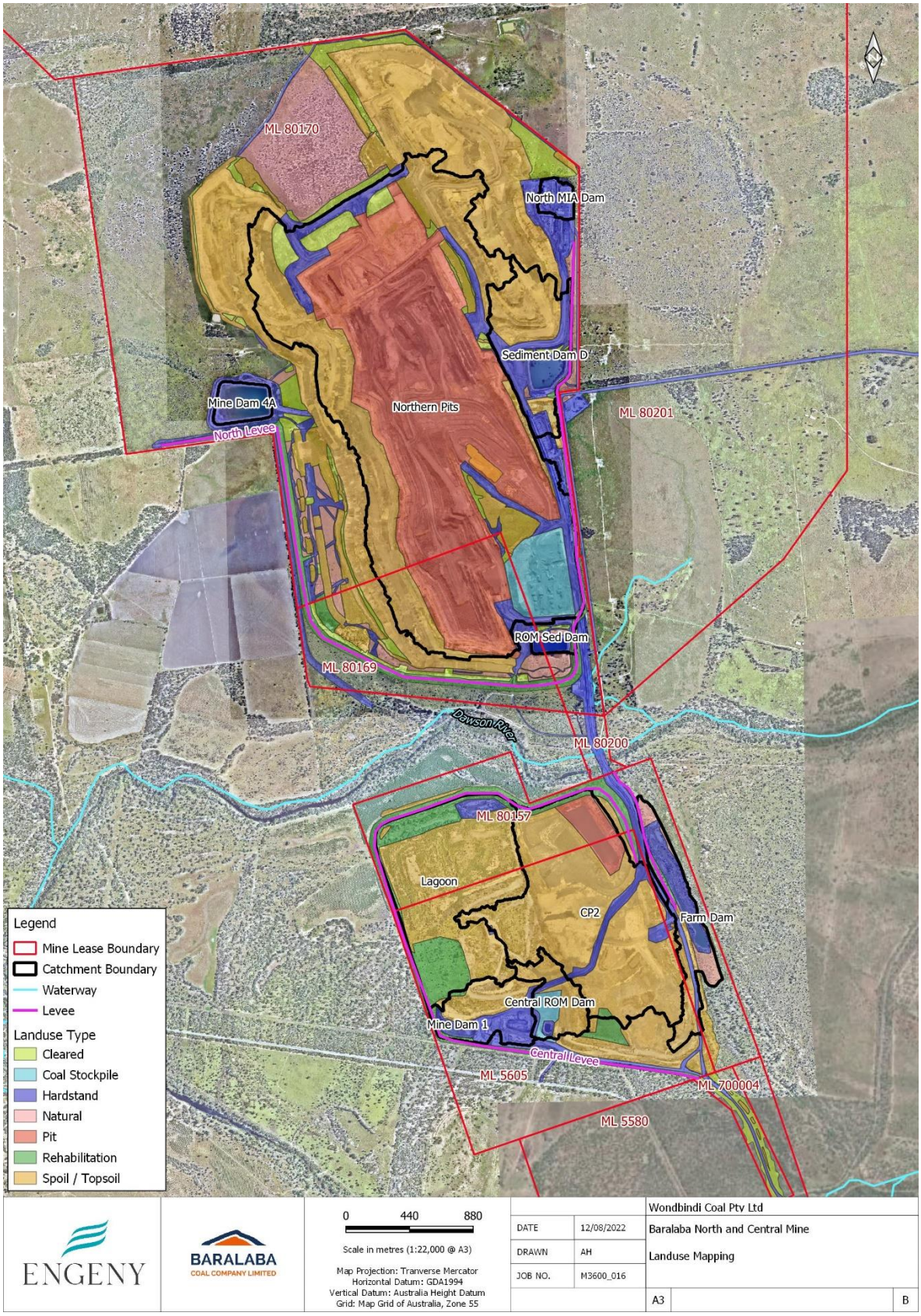

Figure 5.4: Baralaba Mine Land Use Breakdown

5.4 SUMMARY OF WATER MANAGEMENT INFRASTRUCTURE

Table 5.9 is a summary of existing water management infrastructure at the Baralaba North Mine.

Table 5.9: Summary of Water Management Infrastructure

Storage	Description & Purpose	Regulated Structure	Overflow Destination	Catchment Area (ha) [1]	Full Supply Volume (ML)	Current Volume (ML) [2]	Current EC (uS/cm) [3]
			Baralaba Central				
Mine Dam 1	Captures surface runoff from the workshop laydown area and vehicle washdown bay.	Y	Lagoon	22.0	178.6	6.6	3,470
Central ROM Dam	Captures surface runoff from the central ROM pad.	N	Mine Dam 1	15.1	22.0	5.6	24,800
Lagoon	Naturally occurring lagoon that captures surface runoff from its direct catchment.	N	CP2	83.8	54.7	0.0	0.0
CP2	Legacy mining pit that is the primary store of mine-affected water. Water from CP2 may be pumped to the ROM Sed Dam or Sediment Dam D via a pontoon mounted pump if supplies of water in Baralaba North for dust suppression and coal spraying are low.	N	Dawson River	112.6	2,417	827.0	11,681
Farm Dam	Captures surface runoff from its direct catchment.	N	Dawson River	24.9	91.4	40.5	3,460
			Baralaba North				
Mine Dam 4a	Used to store and evaporate mine-affected water that is dewatered from the Northern Pits.	N	Northern Pits	8.2	295.4	74.3	40,421
ROM Sed Dam	Captures surface water runoff from the Northern ROM pad. Supplies water for dust suppression and coal spraying.	N	Dawson River Anabranch (Pools behind Northern Levee)	6.7	50.0	49.6	9,760
Sediment Dam D	As of 2022, is a MAW storage storing dewater from Northern Pits. Also stores water pumped	N	Northern Pits	39.2	179.0	40.5	7,676

Storage	Description & Purpose	Regulated Structure	Overflow Destination	Catchment Area (ha) [1]	Full Supply Volume (ML)	Current Volume (ML) [2]	Current EC (uS/cm) [3]
	from direct transfer from CP2 and captures surface runoff from its direct catchment. Primary supply for dust suppression (supplying around 80% of the demand)						
North MIA Dam	Captures surface runoff from the MIA area.	N	Dawson River anabranch	4.8	6.7	0.0	0.0
Northern Pits (Fairway, Outrigger and New Northern Pit)	The three active mining pits Fairway, Outrigger and New Northern Pit joined to form one combined pit in late 2021. The Northern Pits are dewatered to Mine Dam 4a, ROM Sed Dam or Sediment Dam D depending on available capacity in these storages. Overflows from the Sediment Dam D and Mine Dam 4a are also directed into the Northern Pits.	N	Dawson River anabranch	372.6	75,303	0.0	0.0
TOTAL SITE (INCLUDING PITS)				**689.8**	**78,309[4]**	**1,004 [4]**	
TOTAL MINE-AFFECTED				**581.2 [5]**	**3,006 [6]**	**1,004**	

[1] Catchment areas delineated using the latest site aerial and LiDAR survey flown on 28/06/2022.

[2] Current volumes based on water volume monitoring data from May 2022.

[3] Current EC levels based on water quality monitoring data from the dates:

December 2021 – CP2, ROM Sed Dam, Sediment Dam D

November 2021 – Mine Dam 4a

January 2021 – Central ROM Dam, Mine Dam 1, Farm Dam (Same as 2021 WMP update. Monitoring data for these storages dated after the 2021 WMP update is not available)

[4] Includes the Northern Pits. Excludes the capacity of the clean water storages (i.e., Farm Dam and Lagoon).

[5] Catchment area reporting to mine-affected water storages. Excludes the Farm Dam and Lagoon catchments.

[6] Total mine-affected water storage capacity during normal operations. Excludes the storage capacity of the Farm Dam, Lagoon and Northern Pits. The Northern Pits could be used to store mine-affected water during high rainfall events.

5.5 REGULATED STRUCTURES

The design, operation, and management of regulated structures at the Baralaba North Mine is undertaken in accordance with the Baralaba Regulated Structures Operational Management Plan and relevant conditions from the Baralaba North Mine EA (EPML00223213).

Currently, the following structures are classified as regulated structures for Dam Break:

- Mine Dam 1.
- Baralaba Central Levee.
- Baralaba North Levee.

The operation and management of these regulated structures is further described in the Baralaba Regulated Structures Operational Management Plan.

6 SITE WATER BALANCE

6.1 WATER BALANCE MODEL DEVELOPMENT

The water balance model for the Baralaba North Mine has been developed using GoldSim software. GoldSim is an industry standard computer program for carrying out dynamic, probabilistic simulations of systems and processes (e.g., hydrological assessments of mine site water balance).

6.1.1 Purpose

The site water balance model provides the basis for:

- Forecasting the mine-affected water inventory during actual and predicted climate events.
- Assessing the compliance and operations risks associated with excess or shortfalls of mine-affected water on site.
- Assessing the risk of overflows from mine-affected water storages.
- Informing mine-affected water management strategies over the life of mine.

6.1.2 Description

The water balance model operates on a daily time step and simulates the quantity and quality of water stored in dams and pit, as well as waterways that have the potential to receive controlled releases of mine-affected water (i.e., the Dawson River). Key aspects of the site water balance model are:

- The model simulates the performance of the water management system using 133 years of historical rainfall data.
- The water balance model includes a coupled salt balance that estimates the TDS concentration within each storage and receiving waterway. Note that TDS is converted to EC within the model using a conversion factor of 1mg/L TDS = 1.49µS/cm EC in accordance with the Australian Drinking Water Guidelines (NHMRC, 2013).
- The model simulates the water management infrastructure shown in Figure 5.1 and Figure 5.2 as well as the various water inflows and outflows described in Sections 5.
- Stage/storage/area curves are used to relate volume to area and level for each storage.

The site water balance was revised in July 2022 to represent the current mine water management system and operational mining conditions at the Baralaba North Mine. Water inflows and outflows for the water balance model are further described below.

6.2 WATER INFLOWS

6.2.1 Rainfall

Long-term climate data for the Baralaba North Mine was obtained from the SILO climate database facility hosted by the Department of Environment and Science (DES). A SILO Data Drill climate series from January 1889 to July 2021 was obtained for a grid point at Baralaba Central. Rainfall data from the Baralaba Post Office Station was patched into the SILO Data Drill point climate series to increase the accuracy of the climate series between 01/08/1926 and 23/07/2013.

The climate data indicates that the Baralaba North Mine is characterised by a sub-tropical climate, dominated by a wet humid summer and dry winter. The variation in annual rainfall totals is presented in Figure 6.1. The median site rainfall is 673 mm.

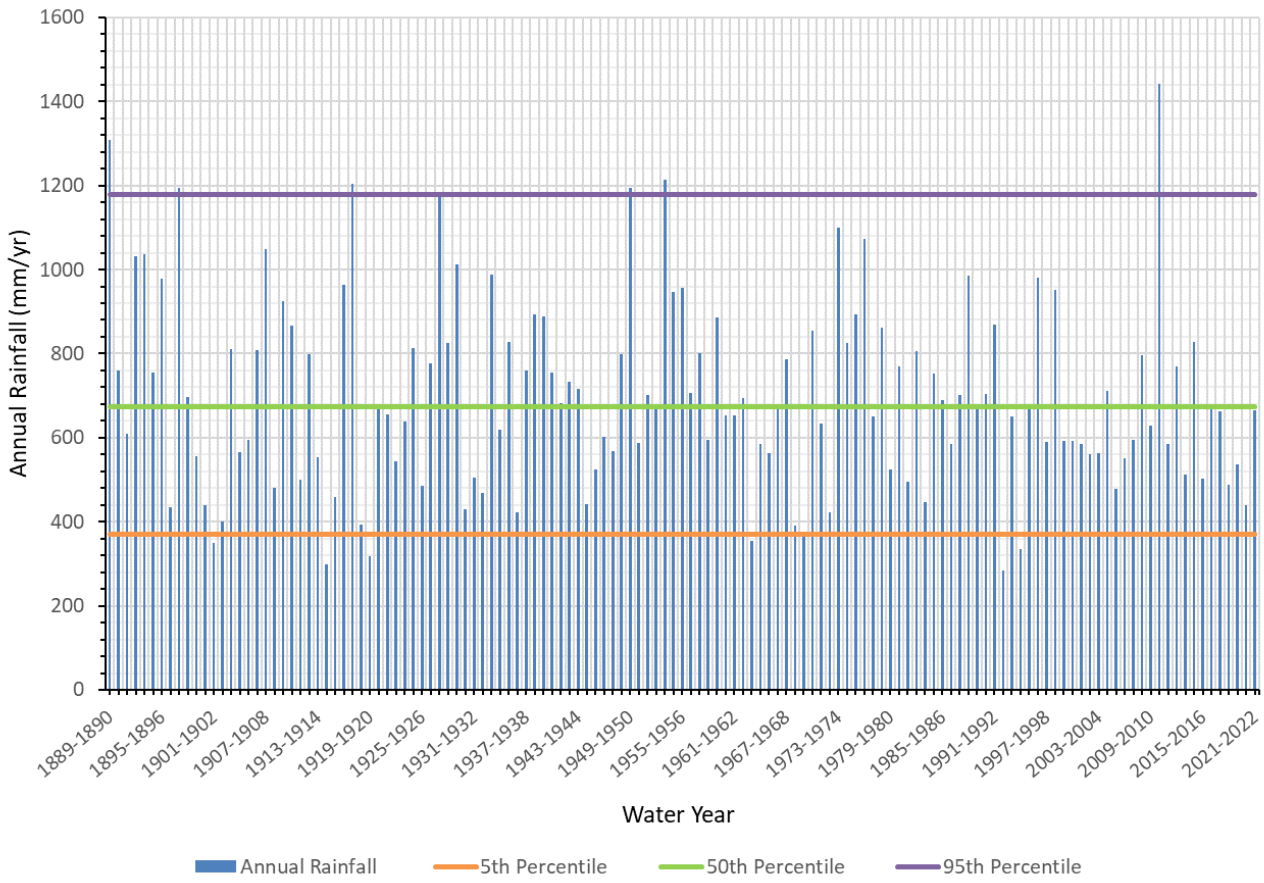

Figure 6.1: Annual Rainfall Totals

6.2.2 Catchment Runoff

Catchment runoff has been simulated within the site water balance model using the Australian Water Balance Model (AWBM). A schematic representation of the AWBM model is provided in Figure 6.2. The model represents the catchment using three surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated on a daily time step, independently of the other surface stores. At each time step, rainfall is added to each of the three surface stores and evapotranspiration is subtracted from each store. If the value of water in the store exceeds the capacity of the store, the excess water becomes runoff. Part of this runoff becomes recharge of the baseflow store if there is a baseflow component to the stream flow.

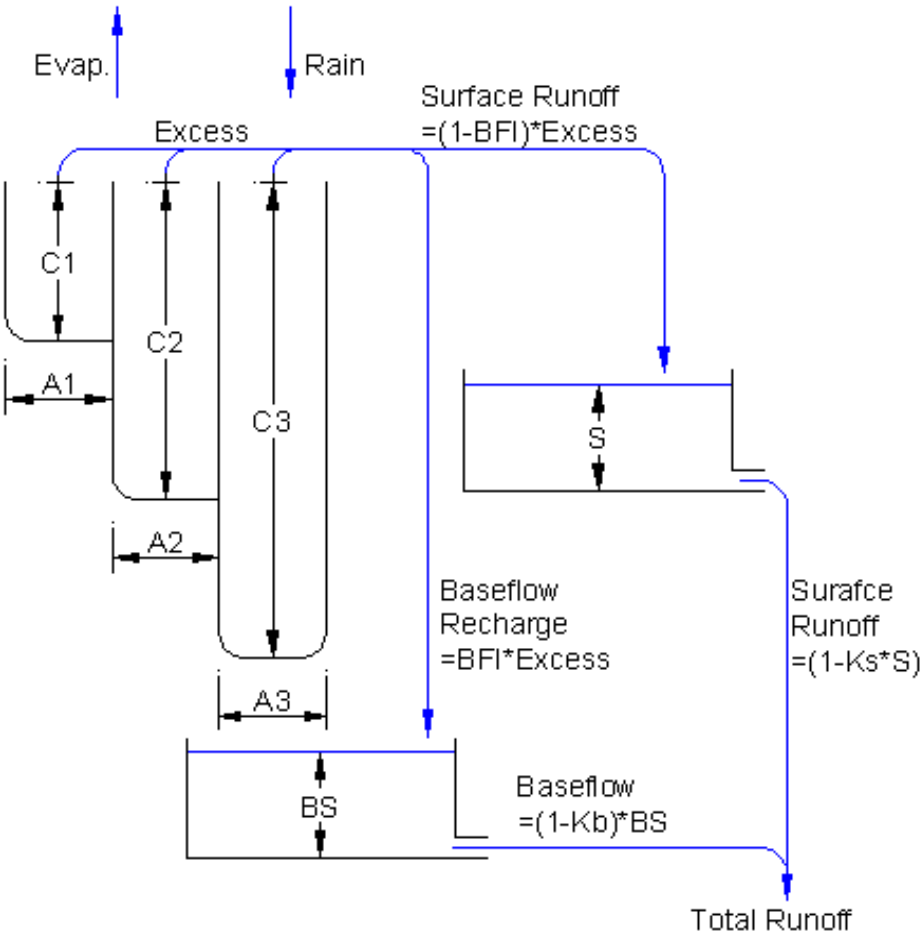

Figure 6.2: AWBM Schematic

AWBM catchment runoff parameters for various land use types have been adopted from the Baralaba North EIS (WRM, 2014). The parameters are summarised in Table 6.1.

Table 6.1: Adopted AWBM Runoff Parameters

Parameter	Natural	Spoil	Hardstand & Pits	Rehabilitated Spoil	Coal Stockpile	Cleared
C1 (mm)	60	40	12	40	12	24
C2 (mm)	90	140	38	140	38	76
C3 (mm)	180	240	0	240	0	0
A1	0.2	0.1	0.1	0.1	0.1	0.1
A2	0.4	0.4	0.9	0.4	0.9	0.9
A3	0.4	0.5	0	0.5	0	0
BFI	0	0.9	0	0.9	0	0
Kb	0	0.95	0	0.95	0	0

Parameter	Natural	Spoil	Hardstand & Pits	Rehabilitated Spoil	Coal Stockpile	Cleared
Ks	0	0	0	0	0	0
Long Term Volumetric Runoff Coefficient	8%	5.1%	24%	5.1%	24%	12.6%

Catchment runoff is therefore determined in the model by applying the parameters in Table 6.1 to the land use areas contained within each catchment. The overall site land use type breakdown and the proportion of the overall site MAW catchment area of each land use, is shown for both 2022 and 2023 in Table 6.2. The 2022 land use proportions were determined using the catchments delineated based on the May 2021 LiDAR, and the June 2022 land use spatial layer (Figure 5.4). The 2023 projected land use proportions were based on the current mine planning for 01/07/2023.

Table 6.2: Site Land Type Breakdown

Statistic	Natural	Spoil	Hardstand & Pits	Rehabilitated Spoil	Coal Stockpile	Cleared
2022 Actual						
Total Area (ha)	5.5	298.9	318.5	31.4	22.2	13.2
Proportion	1%	43%	46%	5%	3%	2%
2023 Projected						
Total Area (ha)	11.0	351.7	328.4	31.3	22.2	23.1
Proportion	2%	51%	48%	5%	3%	3%

6.2.3 Groundwater Inflows

A groundwater inflow rate of 0.6 ML/d to the active pits was adopted for the Baralaba North Continued Operation Project (BNCOP) Environmental Impact Statement (EIS) (WRM, 2013). From onsite anecdotal evidence and site inspections, this groundwater inflow rate is considered conservative. Water pumped out of the active pits should be monitored on a daily basis such that a more accurate estimate of the groundwater inflow rate can be incorporated into future revisions of the site water balance model.

6.2.4 Raw Water Supply

The Baralaba North Mine has access to two raw water allocations, totalling 450ML/yr (refer to Table 6.3). Raw water is used at both Baralaba Central and Baralaba North to supply ablution blocks, vehicle wash down bays and haul road dust suppression. Monitoring data for the raw water usage for the period 1/07/21 to 31/06/22 showed the Baralaba North Mine used 4.13 ML of these allocations.

Table 6.3: Raw Water Allocations

Allocation	Allocation Holder	Allocation Amount
Hewitts Weir	Wonbindi Coal Limited	400 ML
Broadmeadow Allocation	Cacatua Pastoral Pty Ltd	50 ML

6.2.5 Potable Water

A total of 2.08ML, or approximately 40kL/week, of potable water is imported to site by water trucks from the Baralaba Council water reticulation system. However, as this is not material to the water balance, it has not been included in this assessment.

6.3 WATER DEMANDS AND LOSSES

6.3.1 Evaporation

Daily lake evaporation rates for the Baralaba North Mine have been obtained from the same SILO Data Drill data described above in Section 6.2.1. Figure 6.3 shows the average daily evaporation per month from ponded water bodies at the Baralaba North Mine. Annually this equates to approximately 1,795 mm/yr, with daily evaporation rates varying from 2.5mm/day in June to 6.8mm/day in December.

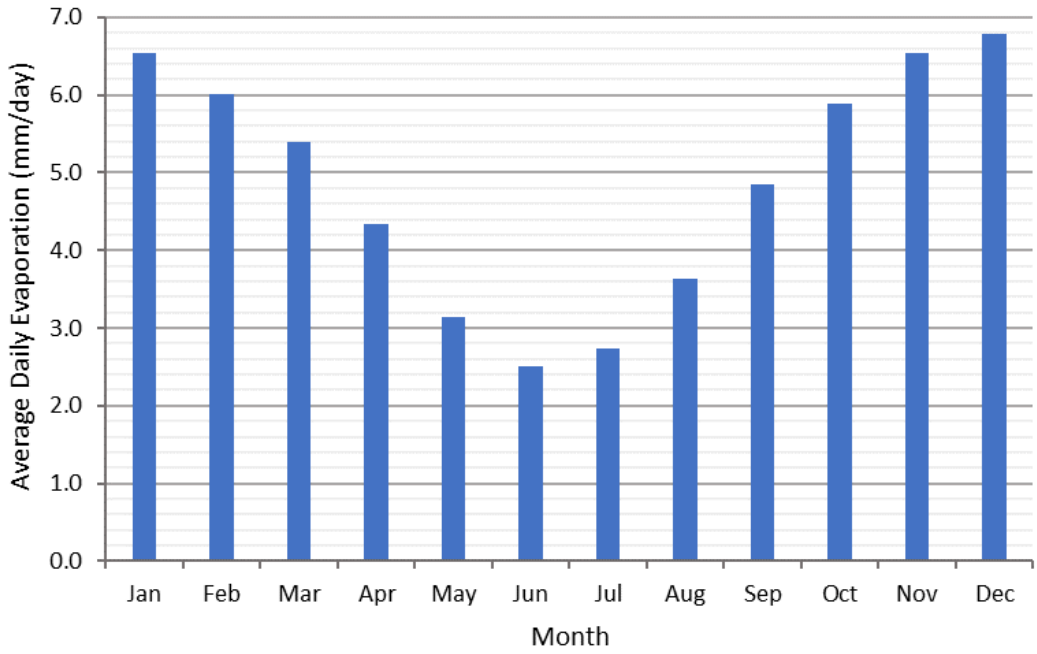

Figure 6.3: Annual Daily Evaporation

6.3.2 Seepage Losses

Seepage losses were not factored into the site water balance model as the risk of seepage at the Baralaba North Mine has been classified as low.

6.3.3 Operational Water Consumption

Water is consumed at the Baralaba North Mine for coal crushing and screening, dust suppression and haul road dust suppression. Estimated water consumption rates, based on data from the previous year of mining, are summarised in Table 6.4. Water consumption currently accounts for a net outflow from the system of 566ML/year.

The dust suppression demand is based on site records of water cart loads from July 2021 to June 2022. The coal spray estimate is based on tonnes of coal processed from July 2021 to June 2022 combined with the coal throughput and spraying rate.

Table 6.4: Baralaba Mine Water Consumption Summary

Consumption	Water Source	Net Consumption (ML/yr.)	Assumptions
CHP	ROM Sed Dam	69	Coal Spray Rate: 7.5 L/s CHF Throughput: 450 T/hr

Consumption	Water Source	Net Consumption (ML/yr.)	Assumptions
Dust Suppression	Sediment Dam D (80%) ROM Sed Dam (20%)	497	Truck Fill Factor: 90%
TOTAL		**566**	

6.3.4 Mine Water Release

Mine-affected water can be released from the water management system via a pipeline extending from Sediment Dam D to the Dawson River (RP N1). Mine-affected water can be released in a controlled manner to the Dawson River in accordance with the EA Schedule C (Water) Conditions. However, the current operating strategy is to operate the Baralaba North Mine as a zero-release site.

6.4 MODEL CALIBRATION

6.4.1 Approach

A preliminary water balance model calibration was undertaken using site monitored storage water levels/volumes, water usage and production data for the period July 2021 to June 2022 (1 year). The model results were compared against recorded inventory to determine the calibration accuracy. Key data inputs and assumptions for the calibration included:

- Storage water levels in the following key mine affected water storages.
  - Sediment Dam D.
  - ROM Sed Dam.
  - Mine Dam 4a.
  - Mine Dam 1.
  - Central ROM Dam.
  - CP2.
- Site recorded daily rainfall data.
- Monthly CHF water demand based on recorded monthly coal production and assumption that:
  - Coal Spray Rate: 7.5 L/s
  - CHF Throughput: 450 T/hr
- Daily dust suppression demand based on recorded daily number of water truck loads and assumption of 90% truck fill factor.
- Average daily groundwater inflow of 0.6 ML/day to the active pits. This volume was adopted for the Baralaba North Continued Operation Project (BNCOP) Environmental Impact Statement (EIS) (WRM, 2013) and was adopted for previous years of inventory forecast modelling.
- Catchment and land use areas are interpolated over the simulation period based on the inputs for the start and end of the simulation:
  - July 2021 areas adopted as documented in the 2021 WMP (Engeny, 2022).
  - June 2022 areas are delineated based on survey dated 31/05/2022.
- Daily lake evaporation, and evaporation has been adopted from the SILO data drill.

6.4.2 Calibration Results

Figure 6.4 shows the modelled total MAW inventory for the 1-yr period between 1st July 2021 to 30th June 2022. The purple diamonds are the total MAW inventory, recorded monthly, and the red line is the modelled inventory based on the conditions listed in Section 6.4.1. Modelled inventories for the Northern Pits, New North Pit, Lagoon and Farm Dam are not included in this result.

The green line in Figure 6.4 represents a sensitivity analysis of the modelled inventory with the added condition that all pump transfers from the Northern Pits are not operational until mid to late December 2021. This represents site-recorded monthly pump meter hours for the three pumps that dewater the Northern Pits, which stated no transfers occurred between July 2021 and December 2021. The exact date of the pump meter readings is not given; therefore, this sensitivity assumed these readings were recorded at the start of each month. This indicates transfers from the Northern Pits did not occur until approximately one month after the intense rainfall event on 11 November 2021.

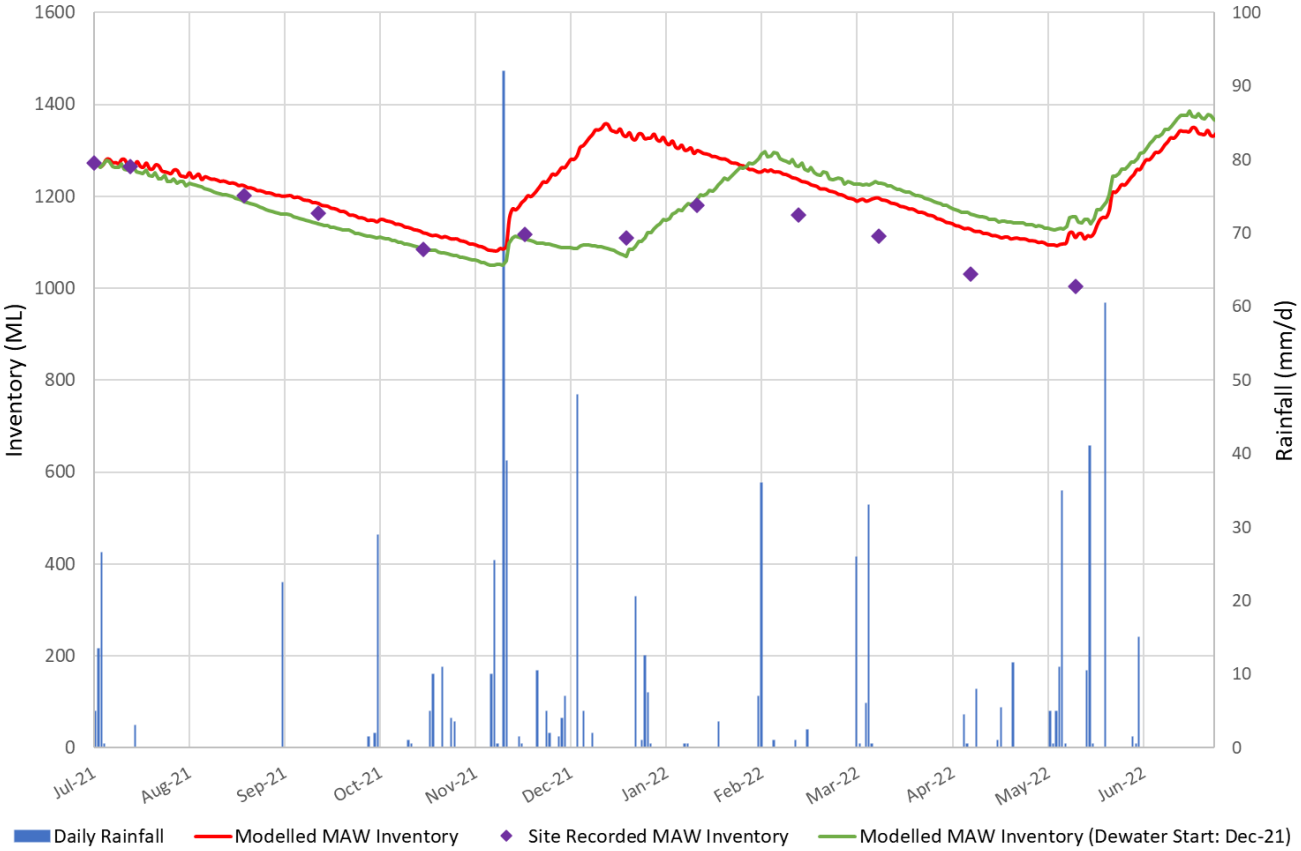

Figure 6.4: Water Balance Model Calibration – Total MAW Inventory

Overall, the review of the calibration results showed:

- Operating and pump transfer conditions within the WBM are based on fixed rules that do not always reflect the adaptive operation of the site water management system and this is generally reflected in the reduced fit after November 2021.
  - Pump transfers in the model are currently based on the inventory of the origin and destination storages, and the pump will start operating if the inventory in the origin storage is above the Dead Storage Volume (DSV) and if the inventory in the destination storage is below its Max Operating Volume. The pump will stop transferring when the origin storage reaches the DSV level and/or the destination storage exceeds its Max Operating Volume.
- The pump transfer conditions in the WBM for dewatering the Northern Pits operates based on this condition, with the DSV being 0 ML. This results in the following:
  - Transfers from Northern Pits in the WBM will begin when any amount of water is in the pit. This is seen in the difference between the modelled (red line) and sensitivity (green line) scenarios between July 2021 and December 2021. The modelled scenario MAW inventory (red line) had a larger volume over this period, resulting from the groundwater ingress into the pits (0.6 ML/day) being regularly pumped out and entering the MAW system. In comparison, as the sensitivity scenario (green line) has no active transfers from Northern Pits during these months, the results show better correlation

with the site-recorded inventory (up until 20th December 2021), showing that the fixed WBM dewatering rules from Northern Pits are not always representative of the on-site dewatering operations.

  - The assumption the pits are fully dewatered, is likely not an accurate representation of on-site dewatering and potentially explains why the modelled (red) and sensitivity (green) inventories from February 2022 to June 2022 are between 50-100 ML greater than the site-recorded inventory, despite the trend for both scenarios being similar.
  - Records of the Northern Pits inventory show 0 ML stored each month over the simulation period. This is considered unlikely, considering the large number of intense rainfall events that occurred over this period; however, there is currently insufficient site data to validate this result.

- AWBM parameters for rainfall and runoff appear to estimate runoff ingress to the WMS well. This is supported by the correlation between the sensitivity scenario and the site-recorded inventory between 1st July to 20th December, where pump transfers from the Northern pits are not operational, and all water entering the system is through direct rainfall and runoff.

In addition to the observations outlined above, it should be noted that there have been significant changes to catchment areas and operating conditions on-site within the calibration period. This includes the joining of Northern Pits (Fairway and Outrigger) with New North Pit, which occurred in late 2021; and the conversion of Sediment Dam D to a MAW storage (operational before July 2022). Both changes are not reflected in this calibration.

6.4.3 Recommendations for Further Improvements

Based on the above, the following recommendations and opportunities for future improvement are:

- Review of operating conditions within the model against what typically occurs on site, with a focus on the dewatering conditions for the Northern Pits.
- Site to increase frequency and accuracy of storage monitoring, including in pit storage.
- Site to record date of pump meter readings when dewatering commences/stops.
  - For Northern Pits: recording of the meter reading dates and inventory volumes on the same dates will assist with calculating daily groundwater ingress into the Northern Pits.

6.5 WATER BALANCE MODEL RESULTS

The water balance model for the Baralaba North Mine has been used to forecast the performance of the current water management system for one year, commencing on 1 July 2022. The following sections summarise key results from the water balance model.

6.5.1 Overview

Figure 6.5 shows the total mine-affected water inventory forecast from 1 July 2022 to 30 June 2023. The inventory includes all the mine-affected water storages shown inFigure 5.1 but excludes the clean water storages (Lagoon and Farm Dam).

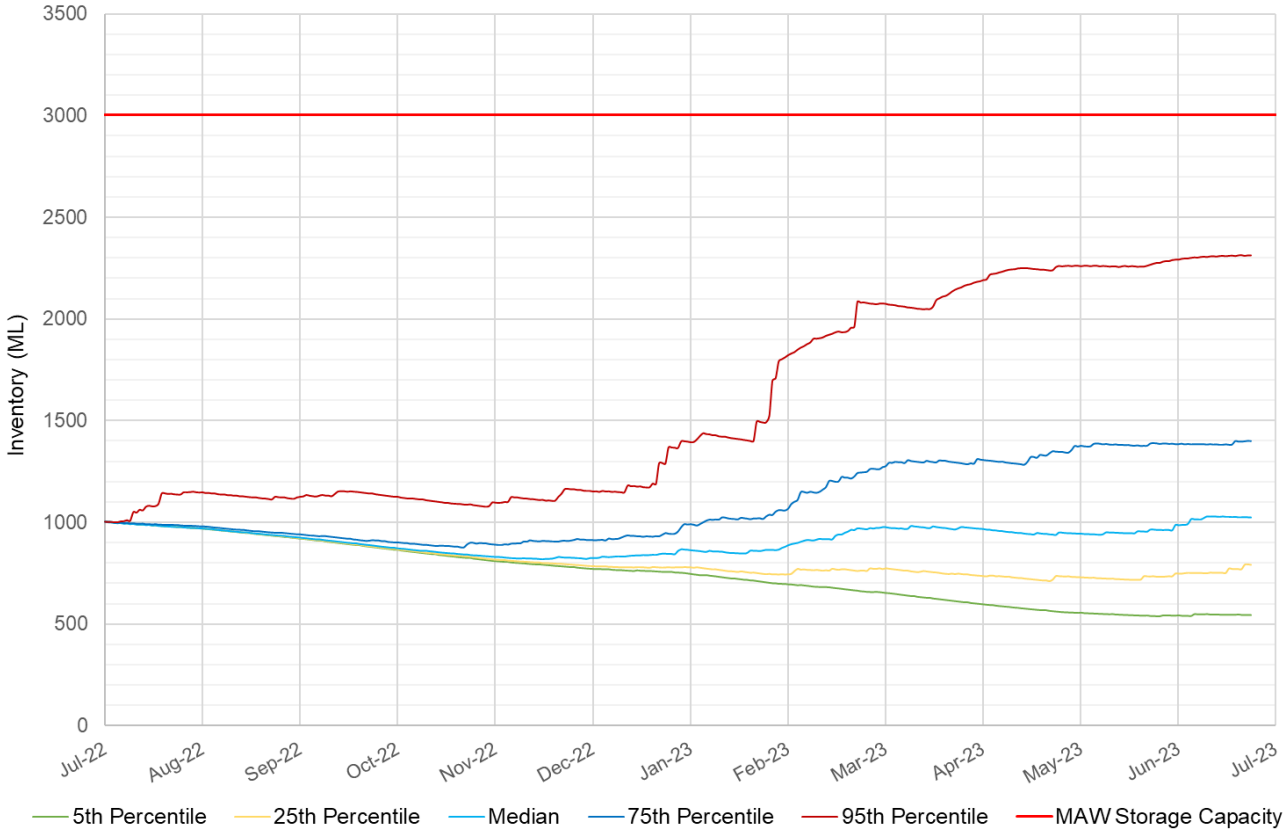

Figure 6.5: Mine Water Inventory Forecast

The initial mine water inventory is 1,004 ML, which is the recorded site water inventory on 16 May 2022. In the median, the total site mine-affected water inventory increases by approximately 22 ML. In the 95th percentile, the site accumulates 1,309 ML of mine-affected water, reaching a maximum volume of 2,313 ML. This is still below the maximum site MAW storage capacity of 3,004 ML.

6.5.2 System Inflow and Outflows

Median annual inflows and outflows to/from mine-affected water storages are shown in Figure 6.6 and Figure 6.7 respectively. On average, runoff is the largest proportion of annual inflows to the MAW Inventory, at approximately 52% of total inflows; while dust suppression is the largest proportion of outflows, making up approximately 59% of total outflows.

The model runs under the condition that Baralaba North and Central is a zero-release system, and therefore does not predict any controlled releases of mine-affected water into the Dawson River up to the 95th percentile.

Although the model predicts that 10 ML of internally draining overflows of mine affected water are coming from ROM Sed Dam over the simulation period. Overflows from this storage do not enter the Dawson River, instead ponding behind the North Levee in the south-east corner.

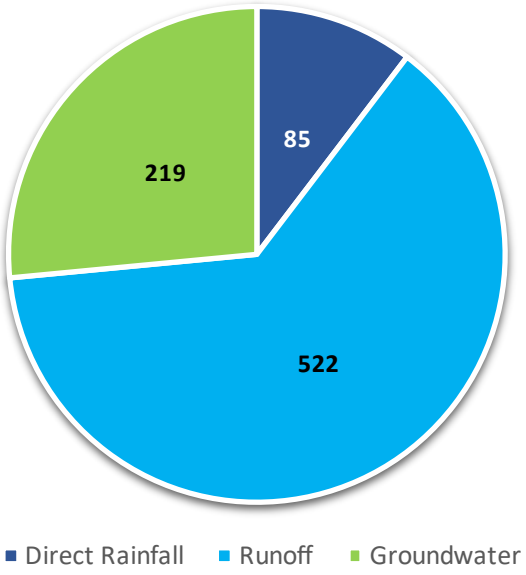

Figure 6.6: Median Annual Inflows (ML)

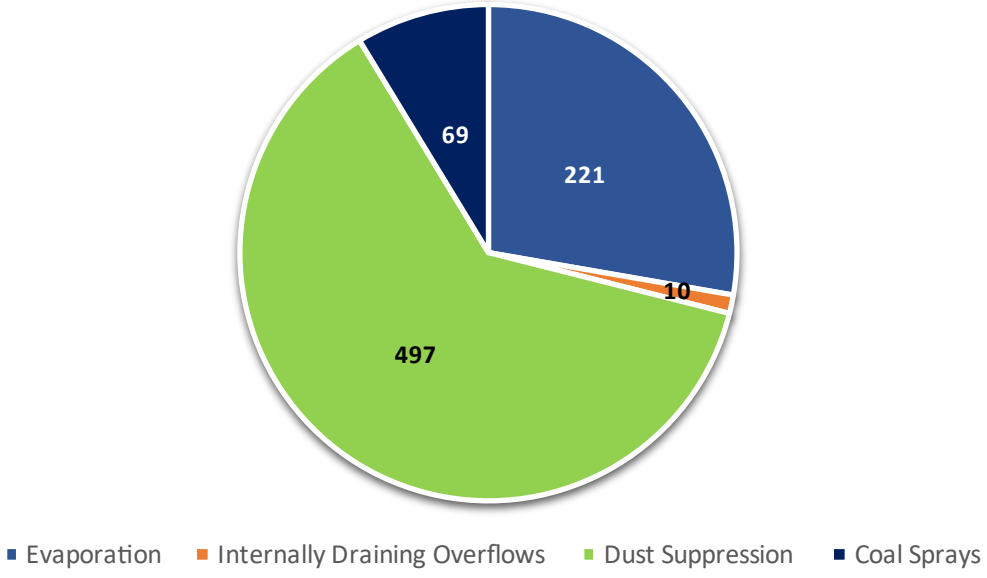

Figure 6.7: Annual Outflows Under Median Climate Conditions (ML)

7 POTENTIAL IMPACTS OF MINING OPERATIONS

In accordance with the **Department of Environment and Science (DES) Guideline – Preparation of Water Management Plans for Mining Activities (ESR/2016/3111)/(EM324)** the potential impacts resulting from mining operations are described below.

7.1 SURFACE WATER QUALITY

Surface water modelling completed by WRM (2012) predicts that downstream Dawson River salinity would increase by up to 25µS/cm during controlled releases of mine-affected water but would not exceed the WQO's for the Dawson River catchment. Therefore, controlled releases of mine-affected water from the Baralaba North Mine will have minimal impact on the receiving water salinity.

The EA release conditions include limits for contaminants other than EC, and it is possible that these conditions may prevent controlled releases from occurring in some circumstances. The concentration of potential contaminants in mine-affected water will be monitored and assessed prior to initiating controlled releases of mine-affected water.

7.2 SURFACE WATER FLOW

The 1 in 1,000 year AEP flood levee provides a barrier to surface runoff from the Baralaba North mine into the Dawson River anabranch. Therefore, surface water runoff from mining operations within Baralaba North will have minimal impact on the receiving water quality.

7.3 AQUIFER DRAWDOWN AND REGIONAL IMPACTS

Quaternary and Tertiary alluvial aquifers, as well as the underlying Permian coal seam aquifers, have been identified in the vicinity of the Baralaba North Mine (refer to Section 3.2). The alluvium is generally heterogeneous in composition. Consequently, the effects of groundwater drawdown will be variable across the aquifer. Historically, the alluvium has been dry or with minimal saturated thickness in localised areas. However, monitoring of groundwater bores indicated recharge of this aquifer had occurred following the 2010/2011 floods. It is anticipated that this aquifer will gradually return to historical levels. Any drawdown effects from mining operations are likely to be limited in extent.

The Permian coal seam aquifers are confined and based on the geology. The effects of groundwater drawdown are likely to be restricted to the north and south of the active pits. The groundwater within this aquifer is highly saline and, as a consequence, is not used for domestic or agricultural purposes. Therefore, any impacts from dewatering and associated drawdown are likely to be restricted to the mine itself.

Ongoing groundwater monitoring of existing bores will provide additional information on possible impacts of groundwater inflow.

7.4 GROUNDWATER QUALITY IMPACTS

The alluvial aquifer is not considered to be a beneficial groundwater resource due to poor water quality and unreliable supply. It is not hydraulically connected with the Anabranch or Dawson River. Therefore, potential impacts to alluvial groundwater are limited to seepage associated with mining operations in Baralaba North.

Spoil generated at Baralaba North will have a very high factor of safety with respect to potential acid generation, excess alkalinity and will generate low to medium salinity surface runoff and seepage. As spoil comprises over 99% of all mineral waste generated at Baralaba North, the management of mineral waste at the site is considered unlikely to pose any significant environmental issues.

Coal will generate alkaline, low-salinity runoff/seepage following surface exposure. It will not pose a significant risk of developing acid conditions. Further, the high excess alkalinity and low sulphur content of samples suggests that the magnitude of any localised acid generation, if it occurs, will be very small.

There is currently no coal rejects material created from the crushing and screening process at the ROM.

There are procedures in place to ensure appropriate management of hydrocarbon and chemical storage and spills at the Baralaba North Mine. Any spills of hydrocarbons or chemicals are likely to be small in scale and will be contained and remediated using on-site resources. Hydrocarbon and chemical storage and use at Baralaba North is not considered to pose a significant risk to groundwater quality.

7.5 IMPACTS TO MINING OPERATIONS FROM GROUNDWATER

Groundwater inflow into the active pits will potentially impact the mining operations if not managed appropriately. The mine-affected water storages are configured to receive water pumped from the active pits, making it available for release when compliant with the EA Schedule C (Water) Conditions. Carrying out additional groundwater studies will improve the estimate of the groundwater inflow rate. Management practices will be implemented to ensure that appropriate infrastructure is built to manage the quantity of water predicted, or improved measurement of pit dewatering operations could be adopted to improve the estimate of the groundwater inflow rate.

8 MONITORING AND MAINTENANCE

8.1 WATER MANAGEMENT INFRASTRUCTURE

Monitoring and maintenance of water management infrastructure, including flood levees, dams, the network of pumps and pipes, and diversion drains is part of the Baralaba North Mine environmental inspection program.

Internal monitoring will be undertaken on a quarterly basis, and pre- and post-significant rainfall events, to ensure that all water monitoring infrastructure is operating as intended and that there are no signs of loss of structural integrity. Monitoring checklists are required to be completed and filed in the records management system.

8.1.1 Regulated Structures

Monitoring and maintenance of regulated structures (including flood levees) will be undertaken in accordance with the EA Schedule G (Regulated Structures) conditions.

In addition to internal quarterly monitoring, and pre- and post-significant rainfall monitoring, each regulated structure (i.e. Mine Dam 1 and the two flood levees) will be inspected on an annual basis by a suitably qualified and experienced person in accordance with the definition in the EA.

Baralaba Coal Company will consider the recommendations from the annual inspection report and take action to ensure that each regulated structure can safely perform its intended function.

8.2 WATER QUALITY MONITORING

In situ EC and pH monitoring of water storage infrastructure is generally undertaken pre, post and during the wet season as required. Although the EC levels of mine-affected water stored on site is relatively high, water quality monitoring data from the past three years does not show an increase in EC above the estimated groundwater EC range.

The main source of salinity in the Baralaba North Mine water management system is groundwater inflows to the active pits. The 2010/2011 floods caused the alluvium aquifers underlying Baralaba North and Baralaba Central to recharge. Subsequent groundwater inflows into the active pits are estimated to be around 0.6ML/day. It should be noted that the inflow rate has not been updated since the most recent flood in late 2021.

Monitoring of EC levels in water storage infrastructure will continue for the life of the mine.

8.3 MONITORING DURING CONTROLLED RELEASES OF MINE AFFECTED WATER

Table 8.1 summarises the water quality monitoring that must occur prior to and during controlled releases of mine-affected water in accordance with the EA Schedule C (Water) conditions.

Table 8.1: Monitoring During Controlled Releases of Mine-Affected Water

Quality Characteristic	Location of Monitoring	Frequency
Flow	Gauging Station 1 (Dawson River within 2km upstream of Anabranch, and downstream of the Jerry Creek-Dawson River confluences)	Continuous (minimum daily)
EC, pH, turbidity, suspended solids, sulphate	RP N1, Dawson River – End-of-pipe location	Daily during release (the first sample must be within 2 hours of commencement of release)
Metals and metalloids	RP N1, Dawson River – End-of-pipe location	Commencement of release and thereafter weekly during release
Quantity of mine-affected water released	End-of-pipe location	-

9 EMERGENCY AND CONTINGENCY PLANNING

9.1 FLOOD

Emergency and contingency planning for a flood event is provided in the Golding Emergency and Contingency Response Plan (dated October 2021). Contingency measures include:

- The design and construction of flood levees has been certified by a RPEQ.
- Monitoring and maintenance of the flood levees occurs on a quarterly basis, and pre- and post- significant rainfall events. As regulated structures, the flood levees are also required to be inspected on an annual basis by a suitably qualified and experienced person in accordance with the definition in the EA.
- Monitoring and maintenance will ensure that no erosion, cracking or vertical or horizontal deformation has impacted on the integrity of the levees, and that the levees have been operated and maintained in accordance with the certified design plan.
- Site personnel are required to monitor river heights at Moura, Bindaree and Baralaba and will maintain preparedness levels relevant to the level of risk. These preparedness levels are based on Dawson River observations at Baralaba and are described in the Baralaba Coal Mine Emergency and Contingency Response Plan.

9.2 LOSS OF ELECTRICAL SUPPLY

There is minimal pumping equipment required to effectively operate the Baralaba North Mine. All pumps employed on-site are diesel powered, there are no critical pumps on site that would potentially cause a non-compliance incident without power as all the mine affected water storages are contained inside the Central Levee and North Levee embankments which drain internally. Apart from Baralaba Central workshop, all areas on site have power supplied by generator. Where electric pumps are used, generators can be quickly repositioned should the unit supplying the pumps fail.

9.3 INABILITY TO OBTAIN CRITICAL EQUIPMENT AND SPARE PARTS

There are no items of critical equipment required for the Baralaba North Mine water management system. Pump and pipe components are standard and are interchangeable. Maintenance and spare parts logistics will be managed on site by the Golding Contracting Maintenance Department.

9.4 INABILITY TO ACCESS CRITICAL CONTROL AND MONITORING POINTS

In a flood event, access will be managed by the on-scene commander in accordance with the Golding Emergency and Contingency Response Plan.

10 ADMINISTRATION

10.1 INCIDENT RESPONSE PROCEDURES

Any unauthorised discharge from water management infrastructure (e.g. dams and pipelines) shall be treated as an environmental incident. Environmental incidents will be investigated in accordance with Golding Incident Notification Recording, Investigation and Reporting Procedure, which are available to site personnel.

Site personnel must notify the Baralaba Coal Management Team upon becoming aware of an incident that has potential to cause material or serious environmental harm. This notification may be delivered verbally.

10.2 INCIDENT REPORTING

10.2.1 Internal

Site personnel are required to report on environmental incidents in accordance with the Golding Incident Notification Recording, Investigation and Reporting Procedure. Access to the records management system must be made available to Baralaba Coal Company personnel upon request.

10.2.2 Regulatory Authority

In accordance with Conditions A21 – A24 of the Baralaba North Mine EA, the General Manager Operations, or an approved Delegate, must notify DES (in writing) within 24 hours of becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably not expected to be in accordance, with the conditions of the EA.

Within 10 business days of the initial notification of the emergency or incident, or receipt of the monitoring results, whichever is the latter, further advice must be provided to DES. The advice must include:

- Results and interpretation of any samples taken and analyzed.
- Outcomes of any actions taken at the time to prevent or minimize unlawful environmental harm.
- Proposed actions to prevent a recurrence of the emergency or incident.

10.3 REVIEW

This WMP will be reviewed and updated on an annual basis. The review will consider:

- Quarterly and pre- and post-significant rainfall event inspections.
- Annual regulated structure inspection reports.
- Environmental incident reporting.
- Any unauthorised discharge from water management infrastructure.
- Water quality monitoring data.
- Any amendments to the EA, relevant legislation, policies, and guidelines.
- Any changes to mining activities or mining contractors at the site; and,
- New mining technologies/methods.

The performance of the water management system will be evaluated during the annual review of the WMP. Relevant performance criteria to be considered during the annual review are:

- Regulatory compliance as outlined in Section Chapter 1542295573, and,
- Continuous improvement.

10.4 TRAINING

The content of this WMP shall be included in the site familiarisation training for relevant personnel. Baralaba Coal Company shall ensure employees and contractors involved with monitoring, maintenance and operation of the water management infrastructure are appropriately trained.

10.5 ROLES AND RESPONSIBILITIES

Roles and responsibilities associated with the implementation of this WMP are outlined in Table 10.1.

Table 10.1: Roles and Responsibilities

Role	Responsibility
General Manager	Ensure the adequacy of contractors environmental management procedures. Regulatory authority reporting.
Senior Environment Officer	Investigate exceedance of water quality and contaminant trigger levels. Review water management plan as required (annually following wet season, and when changes are made). Arrange annual audit of Regulated Structures. Undertake Baralaba Coal Mine water management infrastructure inspections - quarterly and following significant rainfall.
Mining Contractor	Manage pumping and pipeline operation to distribute water around site and manage dam levels. Monitor water storage capacity. Facilitate investigation and resolution of incidents and complaints. Ensure mine water infrastructure is operated within certified design specifications. Monitoring and maintenance of mine water infrastructure. Implement emergency and contingency planning measures. Ensure relevant personnel are fully trained in the requirements of the Water Management Plan and associated procedures.

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12 QUALIFICATIONS

a) In preparing this document, including all relevant calculation, and modelling, Engeny Water Management (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.

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g) This Report does not provide legal advice.

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Appendix H. Site Water Balance and Surface Water Assessment

BARALABA NORTH CONTINUED OPERATIONS PROJECT, SITE WATER BALANCE AND SURFACE WATER ASSESSMENT

Cockatoo Coal Limited
April 2014

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REPORT TITLE: Baralaba North Continued Operations Project, Site Water Balance and Surface Water Assessment

CLIENT: Cockatoo Coal Limited

REPORT NUMBER: 0876-08-E3

Revision Number	Report Date	Description	Report Author	Reviewer
2	8 April 2014	Final Report	TB/DN	MB
3	11 April 2014	Revised Final Report	TB/DN	MB

For and on behalf of
WRM Water & Environment Pty Ltd

David Newton
Director

NOTE: This report has been prepared on the assumption that all information, data and reports provided to us by our client, on behalf of our client, or by third parties (e.g. government agencies) is complete and accurate and on the basis that such other assumptions we have identified (whether or not those assumptions have been identified in this advice) are correct. You must inform us if any of the assumptions are not complete or accurate. We retain ownership of all copyright in this report. Except where you obtain our prior written consent, this report may only be used by our client for the purpose for which it has been provided by us.

EXECUTIVE SUMMARY

WRM Water & Environment Pty Ltd (WRM) was commissioned by Cockatoo Coal Limited (CCL) to undertake a surface water impact assessment for the proposed Baralaba North Continued Operations Project (hereafter referred to as the BNCOP or the Project). The surface water impact assessment will form part of an Environmental Impact statement (EIS) for the Project under Sections 70 and 71 of the Environmental Protection Act 1994 (QLD). This report documents the methodology and results of the surface water impact assessment for the BNCOP.

The BNCOP provides for the continuation and expansion of open cut coal mining and the introduction of coal processing at the existing Baralaba Coal Mine, operated by CCL. The Baralaba Coal Mine is located in the lower Bowen Basin region of central Queensland, just north of the township of Baralaba.

The proposed strategy for the management of surface water at the BNCOP is based on the separation of water from different sources based on anticipated water quality. The adopted principles for management of water on the site are summarised as follows:

- unaffected surface water will be diverted around disturbed areas and released from site wherever possible, minimising the capture of clean surface runoff;
- sediment-laden runoff from the overburden emplacement areas will be captured in dedicated sediment dams to improve water quality, prior to off-site release or re-use in the mine water system;
- mine-affected water collected in-pit (groundwater inflow, surface runoff) and runoff from coal stockpiles and the CHPP could potentially have elevated salinity and will be captured and retained for use on-site and/or controlled off-site discharge;
- controlled discharge of excess water off site will be in accordance with the existing Environmental Authority for the Baralaba Coal Mine;
- water for on-site demands will be sourced preferentially from water collected and stored on-site. Externally sourced raw water will be used as a supplementary supply.

The potential impacts of the Project on surface water resources include:

- impacts on regional water availability due to the potential need to obtain water from external sources to meet operational water requirements of mining operations;
- adverse impacts on the quality of surface runoff draining from the disturbance area to the various receiving waters surrounding the Project;
- adverse impacts on environmental values in the Dawson River associated with controlled releases from the mine water management system;
- loss of catchment area draining to local drainage paths and wetlands due to capture of runoff within onsite storages and the open cut pit.

The impacts of the Project on surface water resources will be mitigated through the implementation of a mine site water management system to control the flow and storage of water of different qualities across the site. A surface water monitoring program will be implemented to continually assess environmental impacts and ensure that the site water management system is meeting its objectives.

The performance of the mine water management system has been investigated using a detailed site water balance model. The model simulated water inflows and outflows through the various stages of mine development for 110 different climate sequences (each referred to as a 'realisation') extracted from historical rainfall data.

Water collected on the site will be used as first priority to satisfy site demands, such as coal processing and dust suppression. Water will be drawn from off-site sources only when required to make up a shortfall in water available on the site.

CCL currently holds 500 ML of volumetric licence water allocation from the Dawson River. The water balance model results show that the existing water licence allocation of 500 ML should be sufficient to meet all site demands:

- for the first 5 years of operations,
- in more than 90% of modelled realisations for years 6, 7, 10, 11 and 12,
- in more than 75% of realisations for the remaining years.

If required, additional water licences would be sought and purchased by CCL over the life of the project to meet raw water demands. There is a 10% chance that the volume of external water supply required from Year 8 of the Project onwards will be in the range of 500 ML/yr to 700 ML/yr.

Water required from external sources will be obtained under appropriate Water Access Licences to ensure no adverse impacts on water availability for other licensed water users.

The results of the water balance modelling indicate that there is a low risk of the BNCOP water management system accumulating water over the 15 year mine life. The results show that the system recovers well after each wet season.

The model results show no uncontrolled spills of mine-affected water from the Mine Water Dam or Process Water Dam, consistent with the proposed operating strategy for the mine water system.

Controlled releases from the mine water system will occur when water quality and river flow meet the trigger levels in the Environmental Authority. The water balance model indicates that the minimum dilution ratio of controlled release discharges is 50 (river flow rate equals 50 times site discharge rate), with a median dilution ratio of greater than 190. Based on this level of dilution, the impacts of controlled releases on flow and water quality in the river should be almost undetectable.

The Project will temporarily reduce the catchment area draining to receiving watercourses due to capture of runoff from disturbed catchment areas within the mine water management system. The maximum captured catchment areas represent:

- less than 1% of the Saline Creek catchment;
- approximately 0.01% of the Dawson River catchment; and
- approximately 52% of the catchment draining to the wetland area to the north of the Project.

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. An area of approximately 2.9 km^2 will continue to drain to the mine final void. The changed topography following completion of the Project will have the following impacts on catchment areas:

- the catchment draining north to Saline Creek will increase by 0.27 km^2, an increase of less than 0.1%;
- the catchment draining to the northern wetland will be reduced by 4.1 km^2. This represents a reduction in catchment area of about 23%; and
- the catchment draining directly to the Dawson River and Dawson River Anabranch will be increased by 0.97km^2.

The reduction in catchment area draining to the wetland area north of the site will reduce catchment runoff inflows to the wetland by a similar proportion to the reduction in catchment area. However, the wetland also receives inflow from flood events in Saline Creek for relatively small events (less than 1 in 2 year annual exceedance probability) and inflows from the Dawson River during major river floods (1 in 50 annual exceedance probability and larger). Due to these flood inflows to the wetland, the impacts on total wetland inflows will be less than indicated by the proportional reduction in catchment area.

Water balance simulation of the final void shows that the water surface is expected to reach an equilibrium water level approximately 50 m below the overflow level. The lake will take approximately 400 years to reach the equilibrium level.

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Acronyms and Abbreviations

AEP	Annual Exceedance Probability
ANZECC	Australian and New Zealand Environment and Conservation Council
AMTD	Adopted Middle Thread Distance
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWBM	Australian Water Balance Model
BFI	Base flow index
BNCOP	Baralaba North Continued Operations Project
BOM	Bureau of Meteorology
BPESC	Best Practice Erosion and Sediment Control
CCL	Cockatoo Coal Limited
CDA	Co-Disposal Area
CSG	Coal Seam Gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CHPP	Coal Handling and Preparation Plant
DCEE	Department of Climate Change and Energy Efficiency
DEHP	Department of Environment and Heritage Protection
DEHP Manual	Manual for Assessing Consequence Categories and Hydraulic Performance of Structures Version 3.1 (DEHP, 2013)
DERM	Department of Environment and Resources Management
DEWS	Department of Energy and Water Supply
DNRM	Department of Natural Resources and Mines
DPI	Department of Primary Industries
DSA	Design Storage Allowance
DSITIA	Department of Science, Information Technology, Innovation and the Arts
EA	Environmental Authority
EC	Electrical Conductivity
EFO	Environmental Flow Objectives
EIS	Environmental Impact Statement
ESS	extreme storm storage
EM Plan	Environmental Management Plan
EP Act	Environmental Protection Act 1994
EP Regulation	Environmental Protection Regulation 2008
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPC	Exploration Permit for Coal
EPP	Environmental Protection Policy
EPP (Water)	Environmental Protection (Water) Policy 2009
EV	Environmental Value
GW	Groundwater
IECA	International Erosion Control Association
IESC	Independent Expert Scientific committee
IQQM	Integrated Quantity Quality Model
IWMS	Integrated Water Management System
Kb	Baseflow recession constant
Ks	Surface flow recession constant
MDL	Mineral Development Licence
MIA	Mine Infrastructure Area
ML	Mining Lease
MOV	Maximum Operating Volume
MRL	Mandatory Reporting Level
OPSIM	Operational Simulation
NTU	Nephelometric Turbidity Units
NWQMS	National Water Quality Management Strategy

PAR	population at risk
Project	Baralaba North Continued Operations Project
QLD	Queensland
QWQG	Queensland Water Quality Guidelines
ROM	Run-of Mine
ROP	Resource Operation Plan
Sed Dam	Sediment Dam
TDS	Total Dissolved Salts
TEP	transitional environmental program
TLO	train load out
TOR	Terms of Reference
TSS	Total Suspended Solids
WASO	Water Allocation Security Objective
Water Act	*Water Act 2000* (QLD)
WQG	Water Quality Guideline
WQO	Water Quality Objective
WRM	WRM Water and Environment Pty Ltd
WRP	Water Resource Plan
Yr	year

1 INTRODUCTION

WRM Water & Environment Pty Ltd (WRM) was commissioned by Cockatoo Coal Limited (CCL) to undertake a surface water impact assessment for the proposed Baralaba North Continued Operations Project (hereafter referred to as the BNCOP or the Project). The surface water impact assessment will form part of an Environmental Impact statement (EIS) for the Project under Sections 70 and 71 of the *Environmental Protection Act 1994* (QLD).

The BNCOP provides for the continuation and expansion of open cut coal mining and the introduction of coal processing at the existing Baralaba Coal Mine, operated by CCL. The Baralaba Coal Mine is located in the lower Bowen Basin region of central Queensland, just north of the township of Baralaba, as shown in Figure 1.1.

The proposed life of the BNCOP is 15 years, commencing in 2015 or upon receipt of all required approvals. The main activities associated with the development of the BNCOP would include:

- ROM coal production up to 4.1 Mtpa for an additional 15 years (commencing approximately 1 April 2015 or upon grant of all required approvals), including mining operations associated with:
  - continued development of the Baralaba North pit;
  - extension of the Baralaba North pit to the north within MDL416 / EPC 1047 (both tenements held by Wonbindi Coal Pty Ltd); and
  - spoil dump to the east of the Baralaba North pit within EPC 1237 (tenement held by Queensland Coking Coal Pty Ltd).
- exploration activities;
- progressive backfilling of mine voids with waste material behind the advancing open cut mining operations at the Baralaba North / Wonbindi North Mine and/or within the Baralaba Coal Mine final void;
- continued and expanded placement of waste material in out-of-pit emplacements adjacent to the pit extents;
- progressive development of new haul roads and internal roads;
- construction and operation of a CHPP at the Baralaba North / Wonbindi North Mine;
- disposal of CHPP rejects on-site within mine voids behind the advancing open cut mining operations and/or within the Baralaba Coal Mine final void;
- progressive development of sediment basins and storage dams, pumps, pipelines and other water management equipment and structures (including levees);
- continued development of soil stockpiles, laydown areas and borrow areas;
- use of upgraded administration and maintenance facilities at the Baralaba Coal Mine and establishment of new mine infrastructure areas in Baralaba North / Wonbindi North Mine;
- other associated minor infrastructure, plant, equipment and activities, including minor modifications and alterations to existing infrastructure as required to accommodate the increased throughput;

- continued road transport of product coal (using AB triple and AAB quad road-trains) along the "Middle Road" (a network of public roads including Theodore-Baralaba Road) to the product coal stockpiles and TLO facility located approximately 10 km east of Moura, or new product coal stockpiles and TLO facility (subject to separate approvals being in place); and
- use of existing/new product coal stockpiles and TLO facility for loading of product coal to trains for transport by rail and export via Gladstone.

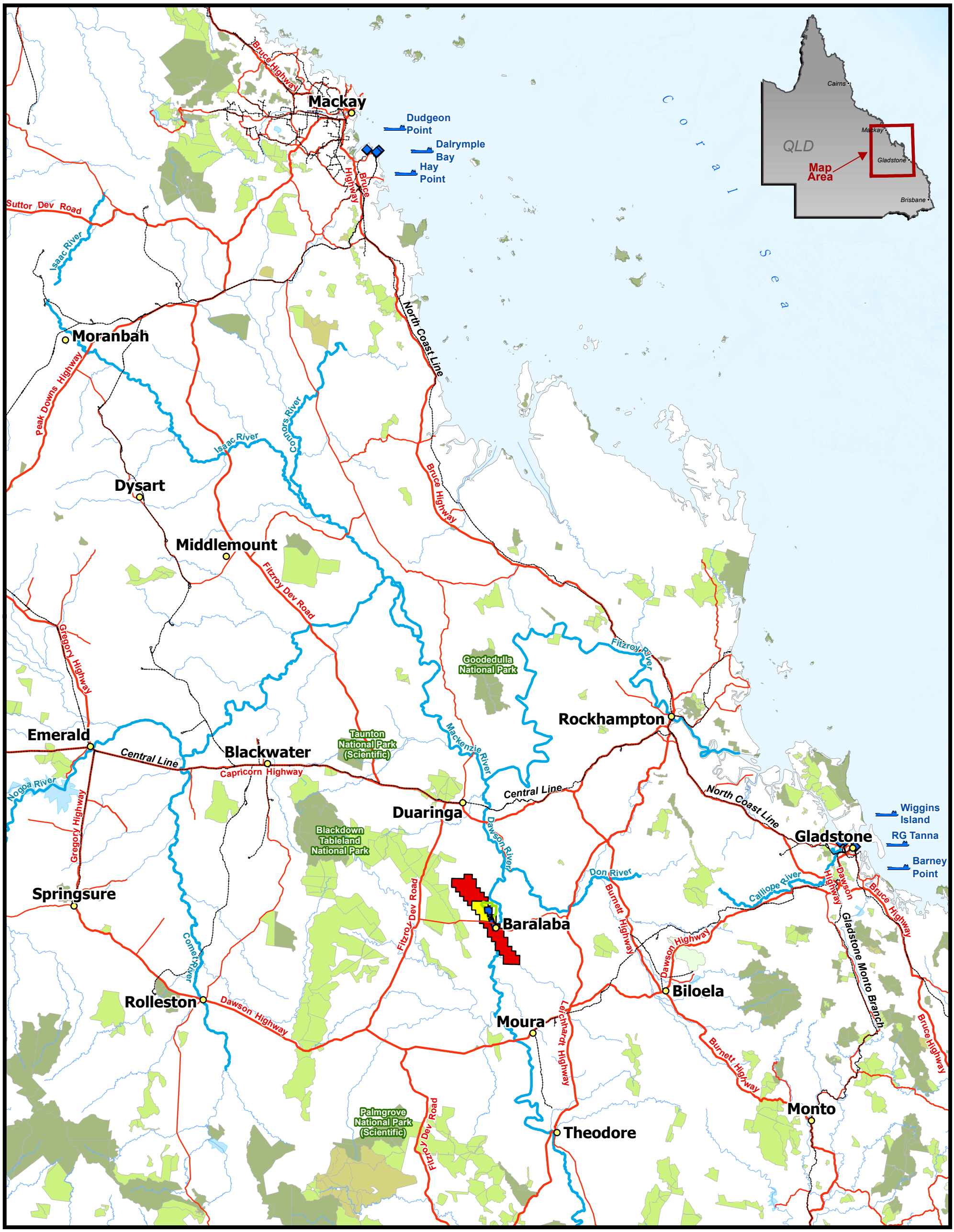
The general layout of infrastructure for the BNCOP is shown in Figure 1.2.

Based on the planned maximum production rate, approximately 50 million tonnes (Mt) of product coal would be produced during the 15 years of the BNCOP.

This report presents the methodology and findings of the surface water impact assessment for the BNCOP. The methodology for the assessment included development of a detailed site water balance model to identify appropriate sizes for mine site water storages and quantify the impacts of the Project on surface water resources.

The report is structured as follows:

- Section 2 provides excerpts from the Terms of Reference (TOR) for the EIS relevant to surface water resources and identifies where these are addressed in the surface water impact assessment report.
- Section 3 is an overview of legislation relevant to surface water impacts and management for the Project.
- Section 4 provides a description of the existing surface water environment in the vicinity of the Project.
- Section 5 presents an overview of the proposed strategy and infrastructure for management of surface water at the BNCOP.
- Section 6 provides details of the methodology and assumptions for the water balance model that has been used to quantify the performance of the proposed surface water management system for the Project.
- Section 7 provides information on the sizing of regulated dams for the Project.
- Section 8 presents details of the simulated performance of the mine water management system.
- Section 9 discusses the impacts of the Project, including potential cumulative impacts.
- Section 10 presents a summary of the mitigation and management measures that will be used to minimise the impacts of the Project on surface water resources.
- Section 11 presents a summary of findings of the surface water impact assessment.
- Section 12 is a list of references.



PROJECT

BARALABA NORTH CONTINUED OPERATIONS PROJECT

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Legend

Populated Place
Road
Rail
Watercourse
Cockatoo Coal ML
Cockatoo Coal MDL
Cockatoo Coal EPC
BNCOP Operational Land
Coal Terminal

Protected Areas
National Park
Forest Reserve
State Forest
Timber Reserve
Other

TITLE

Figure 1.1
Regional Location

REV	DESCRIPTION	DATE
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1	Logo Update	01/04/14
2	Figure Update	02/04/14

SCALE 1:1,500,000
SIZE A3
DATUM GDA 94
PROJECTION MGA Zone 55

CURRENT ISSUE SIGNATURES	
DRAWN	MJS
CHECKED	BJD
APPROVED	BJD

wrm water + environment

STATUS **FINAL**

PROJECT NO Baralaba Nth
DRAWING NO BBN-091-04-02-140402

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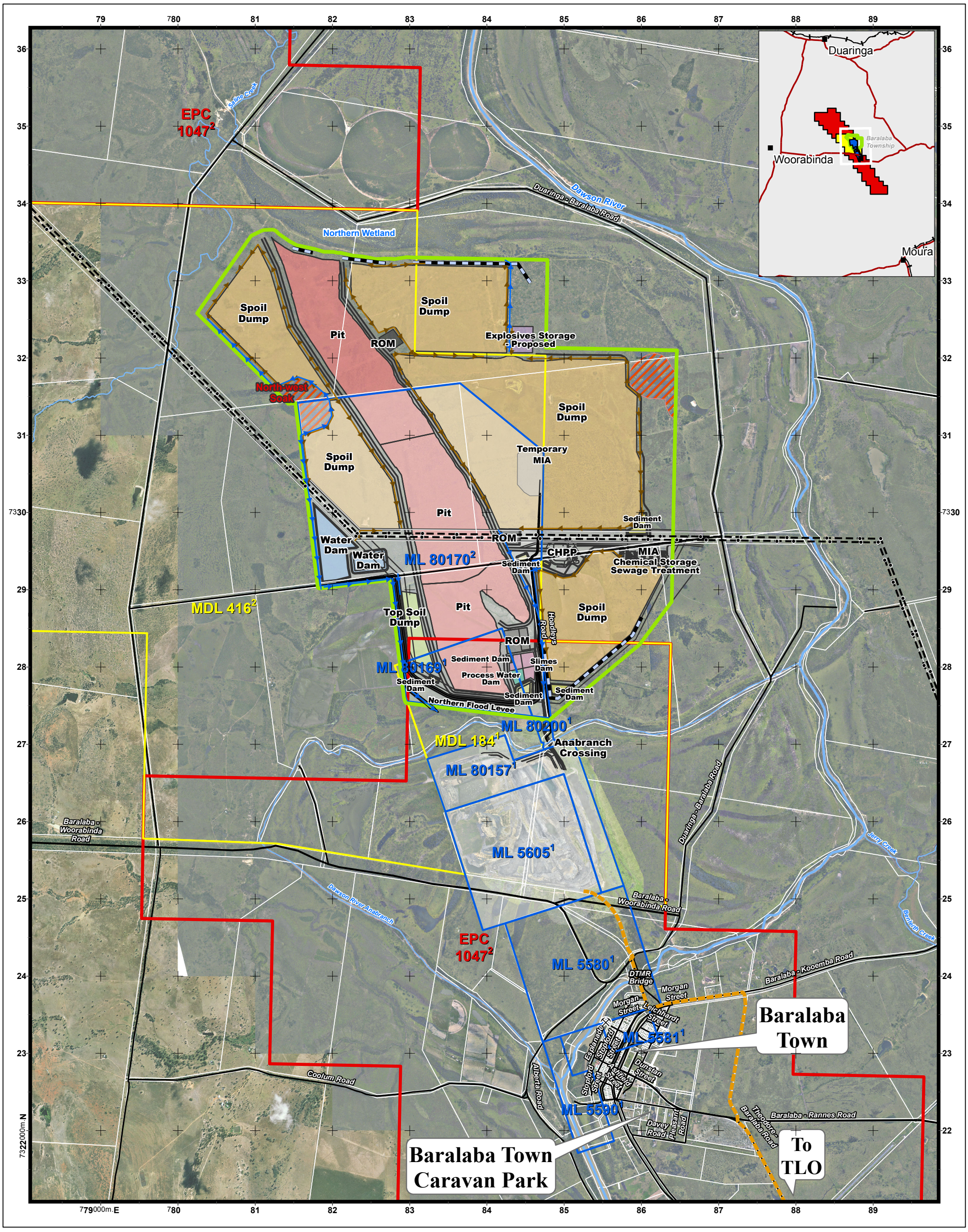

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	1	Data & Text Updates	01/04/14	DATUM GDA 94	CHECKED BJD
	2	Figure Update	02/04/14	PROJECTION MGA Zone 55	APPROVED BJD

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NOTE:
¹ : HELD BY BARALABA COAL PTY LTD
² : HELD BY WONBINDI COAL PTY LTD

Legend

- Road
- Watercourse
- Cadastre
- Cockatoo Coal ML
- Cockatoo Coal MDL
- Cockatoo Coal EPC
- Area of Exclusion of Mining Activities
- Product Road Transport Route
- Powerline & Power Pole
- BNCOP Operational Land
- Clean Water Drain
- Dirty Water Drain
- Proposed Flood/Erosion Protection Levee

wrm water + environment

STATUS: **FINAL**

PROJECT NO	DRAWING NO
Baralaba Nth	BBN-091-05-02-140402

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2 TERMS OF REFERENCE FOR EIS – SURFACE WATER

The site-specific Terms of Reference (TOR) seek information corresponding to the project assessment requirements of the EP Act. The EIS process applies to site-specific environmental authority (EA) applications for undertaking resource projects that meet any of the Department of Environment and Heritage Protection's (DEHP) EIS triggers in the guideline "Environmental impact statement – Triggers for environmental impact statements under the *Environmental Protection Act 1994* for mining, petroleum and gas activities".

This assessment, which forms part of the EIS, addresses the TOR concerning surface water. Table 2-1 lists the elements of the TOR relevant to this assessment and the sections of this report where those TOR are addressed.

Table 2-1 Final Terms of Reference for BNCOP – Surface Water Resources

Key Issue	Requirement	Report Section
Project description ▪ Climate	Describe the site's climate patterns that are relevant to the environmental assessment, with particular regard to discharges to water and air and the propagation of noise. Climate information should be presented in a statistical form including long-term averages and extreme values, as necessary.	Section 4.1
Assessment of critical matters ▪ Water quality	Detail the chemical and physical characteristics of surface waters and groundwater within the area that may be affected by the project.	Section 4.5
	Identify the quantity, quality and location of all potential discharges of water and waste water by the project, whether as point sources (such as controlled discharges from regulated dams) or diffuse sources (such as seepage from waste rock dumps or irrigation to land of treated sewage effluent).	Sections 6 & 8
	Assess the potential impacts of any discharges on the quality and quantity of receiving waters taking into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts.	Section 8.3
	Describe how the achievement of the objectives would be monitored and audited, and how corrective actions would be managed.	Section 10

Key Issue	Requirement	Report Section
▪ Water resources	Provide details of any proposed impoundment, extraction, discharge, injection, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the *Water Act 2000* (QLD).	Sections 6 & 8
	Detail any significant diversion or interception of overland flow. Include maps of suitable scale showing the location of diversions and other water-related infrastructure in relation to mining infrastructure.	Section 5
	Describe the options for supplying water to the project, and assess any potential consequential impacts in relation to the objectives of any water resource plan, resource operations plan and wild river declaration that may apply.	Section 6.7
	Develop hydrological models as necessary to describe the inputs, movements, exchanges and outputs of all significant quantities and resources of surface water and groundwater that may be affected by the project. The models should address the range of climatic conditions that may be experienced at the site, and adequately assess the potential impacts of the project on water resources. The models should include a site water balance. This should enable a description of the project's impacts at the local scale and in a regional context including proposed: • changes in flow regimes from diversions, water take and discharges; • alterations to riparian vegetation and bank and channel morphology; and • direct and indirect impacts arising from the development.	Section 6
▪ Independent Expert Scientific Committee	The National Partnership Agreement on Coal Seam Gas and Large Coal Mining, to which Queensland is a signatory, specifies that all coal seam gas and large coal mining proposals that are likely to have a significant impact on water resources are to be referred to the Independent Expert Scientific Committee (IESC) for advice. If relevant, the EIS must include a specific section responding to the information requirements contained in the IESC's Information Guidelines for Proposals Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources.	Section 3.4
▪ Flooding & regulated dams	List and describe all dams or levees proposed on the project site and undertake an assessment to determine the hazard category of each dam or levee (low, significant, or high), according to the criteria in the EHP Manual for Assessing Hazard Categories and Hydraulic Performance of Dams.	Section 7

Key Issue	Requirement	Report Section
Appendix 2: Matters of Environmental Significance ▪ Impacts on water resources	This section should include a description, including mapping, of surface and groundwater resources on the site pre-development and any impacts on these water resources including, but not limited to: 1. Changes to hydrology, such as changes to: • flow regimes; • recharge rates; • aquifer pressure or pressure relationships between aquifers; • groundwater table levels; • groundwater/surface water interaction; • river/floodplain connectivity; or • inter-aquifer connectivity.	Section 4
	2. Changes to water quality: • elevated levels of salts, trace elements and heavy metals; • changes in pH, • elevated levels of aluminium, barium, boron, cadmium, chromium, copper, iron, fluoride, lead, manganese, mercury and zinc; or • elevated nutrient levels.	Section 9
	3. Changes to ecosystem function and integrity resulting in: • areas of the water resource being destroyed or substantially modified in a way that may have an adverse effect on water-dependent ecosystems; • a substantial adverse change to the benefits or services provided by a water resource; • a substantial change in the biological diversity or species composition of a water resource or its ecological connectivity to other water resources; • the habitat or lifecycle of native species which are ecologically associated with the water resource or which are important determinants of the water resource's character being seriously affected; or • an invasive or pest species that is harmful to the ecosystem functioning or integrity of the water resource becoming established (or an existing invasive or pest species being spread) in the water resource.	Section 9
	This section should include an assessment of both short and long-term impacts to water resources and contain a cumulative impact assessment of surface and groundwater resources related to all known and proposed similar development in the region. Further, this section should identify other users of surface and groundwater resources and any impacts, both short and long-term that may occur as a result of the proposed action.	Section 9

Key Issue	Requirement	Report Section
▪ Avoidance, mitigation and offset measures	Describe any avoidance and mitigation measures proposed to reduce the impacts on the listed threatened species and ecological communities and water resources and include the following elements: • a description of proposed safeguards, avoidance and mitigation measures to deal with relevant impacts of the action including mitigation measures proposed to be taken by state governments, local governments or the proponent; • an assessment of the expected or predicted effectiveness of the mitigation measures; • an explanation of any statutory or policy basis for the mitigation measures, including a discussion on how the proposed approach is not inconsistent with relevant recovery plans and threat abatement plans for listed threatened species and communities. Describe any proposed offsets for residual impacts to listed threatened species and ecological communities and water resources as a result of the proposed action.	Section 10

3 REGULATORY FRAMEWORK

3.1 OVERVIEW

The following legislation, regulations, plans, policies and guidelines are relevant to this assessment:

- *Environmental Protection Act 1994* (QLD),
- Environmental Protection (Water) Policy 2009,
- Dawson River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011),
- Queensland Water Quality Guidelines (DEHP, 2009),
- National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000),
- Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (DEHP, 2013),
- Information guidelines for proposals relating to the development of coal seam gas and large coal mines where there is a significant impact of water resources (IESC, 2013),
- *Water Act 2000* (QLD),
- Water Resource (Fitzroy Basin) Plan 2011,
- Fitzroy Basin Resource Operations Plan 2013,
- Water Regulation 2002 (QLD),
- *Water Supply (Safety and Reliability) Act 2008* (QLD),
- Central Queensland Regional Water Supply Strategy.

The relevance of these documents to the Project is summarised in the following sections.

3.2 *ENVIRONMENTAL PROTECTION ACT (1994)* (QLD)

The EP Act protects Queensland's environment while allowing for development that improves the total quality of life, now and in the future, in a way that maintains ecological processes. Surface water management is regulated through these documents (and also the *Water Act 2000 (QLD)* (Water Act)).

The EA conditions regulate dams containing hazardous waste. Surface water discharges, and associated monitoring are also authorised and regulated through the EA conditions.

3.2.1 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP (Water)) is subordinate legislation under the EP Act. The EPP (Water) provides a framework for:

- identifying environmental values (EVs) and management goals for Queensland waters,
- stating the water quality guidelines and water quality objectives (WQOs) to enhance or protect the EVs.

The indicators and water quality guidelines for an EV are based on the following documents:

- site specific documents for the water,
- Queensland Water Quality Guidelines,
- Australian Water Quality Guidelines (produced under the National Water Quality Management Strategy and published by the Natural Resource Management Ministerial Council), and
- other relevant documents published by a recognised entity under the EPP (Water).

Under this policy, the EVs for a particular water are protected if the recorded values for all water quality indicators are consistent with the water quality guidelines stated for the indicators.

3.2.2 Dawson River Sub-basin Environmental Values and Water Quality Objectives 2011

The relevant document for the purpose of the Project is the "*Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment*", September 2011 (DEHP, 2011). The document is made pursuant to the provisions of the EPP Water. It contains EVs and WQOs for waters in the Dawson River Sub-basin (excluding Callide Creek catchment), and they are listed under schedule 1 of EPP Water.

This Project is located on the border between the Northern upland tributaries and Lower Dawson main channel – unregulated reaches (Plan WQ1309, DEHP 2011). The same EVs are listed for both of these areas:

- aquatic ecosystems
- irrigation
- farm supply
- stock water
- human consumer
- primary recreation
- secondary recreation
- visual recreation
- drinking water
- industrial use
- cultural and spiritual values.

The corresponding WQOs for the above EVs are provided in Table 3-1. Where different EVs have different WQOs, the lowest value has been used. The relevant EV providing the lowest WQO is identified in Table 3-1. WQOs are shown for physico-chemical parameters only.

Table 3-1 Water Quality Objectives, Lower Dawson Main Channel & Northern Upland Tributaries

Parameter	Objective	Relevant EV
ammonia N	20 µg/L	Aquatic ecosystem [a]
oxidised N	60 µg/L	Aquatic ecosystem [a]
organic N	420 µg/L	Aquatic ecosystem [a]
total nitrogen	500 µg/L	Aquatic ecosystem [a]
filterable reactive phosphorus (FRP)	20 µg/L	Aquatic ecosystem [a]
total phosphorus	50 µg/L	Aquatic ecosystem [a]
chlorophyll a	5.0 µg/L	Aquatic ecosystem [a]
dissolved oxygen	85%–110% saturation >80% <4mg/L at surface	Aquatic ecosystem [a] Primary recreation Drinking water
turbidity	50 NTU	Aquatic ecosystem [a]
suspended solids	10 mg/L	Aquatic ecosystem [a]
pH	6.5–8.5	Aquatic ecosystem [a]
conductivity (EC) baseflow	340 µS/cm	Aquatic ecosystem [a]
conductivity (EC) high flow	210 µS/cm	Aquatic ecosystem [a]
sulphate	25 mg/L	Aquatic ecosystem [a]
Total dissolved solids	2000 mg/L	Stock watering
colour	50 Hazen units	Drinking water
total hardness	150 mg/L as $CaCO_3$	Drinking water
sodium	30 mg/L	Drinking water
Aluminium	5 mg/L	Stock watering
Arsenic	2.0 mg/L (0.5 up to 5 mg/L)	Irrigation [b] Stock watering
Beryllium	0.5 mg/L	Irrigation [b]
Boron	5 mg/L	Stock watering
Cadmium	0.01 mg/L	Stock watering
Chromium	1 mg/L	Irrigation [b]
Cobalt	0.1 mg/L	Irrigation [b]
Copper	1 mg/L	Stock watering (cattle)
Fluoride	2 mg/L	Irrigation [b]
Iron	10 mg/L	Irrigation [b]
Lead	0.1 mg/L	Stock watering
Lithium	2.5 mg/L	Irrigation [b]
Manganese	10 mg/L	Irrigation [b]
Mercury	0.002 mg/L	Irrigation [b]
Molybdenum	0.05 mg/L	Irrigation [b]
Nickel	1 mg/L	Stock watering
Selenium	0.02 mg/L	Stock watering
Uranium	0.1 mg/L	Irrigation [b]
Vanadium	0.5 mg/L	Irrigation [b]
Zinc	5 mg/L	Irrigation [b]

[a] Moderately disturbed [b] Short-term trigger value

Figure 3.1 shows the location of wetlands identified under Plan WQ1309 (DEHP, 2011) in the vicinity of the Project. The performance requirements relating to wetlands are provided in the *Vegetation Management Act 1999 (QLD)*, aimed at maintaining water quality, bank stability, aquatic and terrestrial habitat.

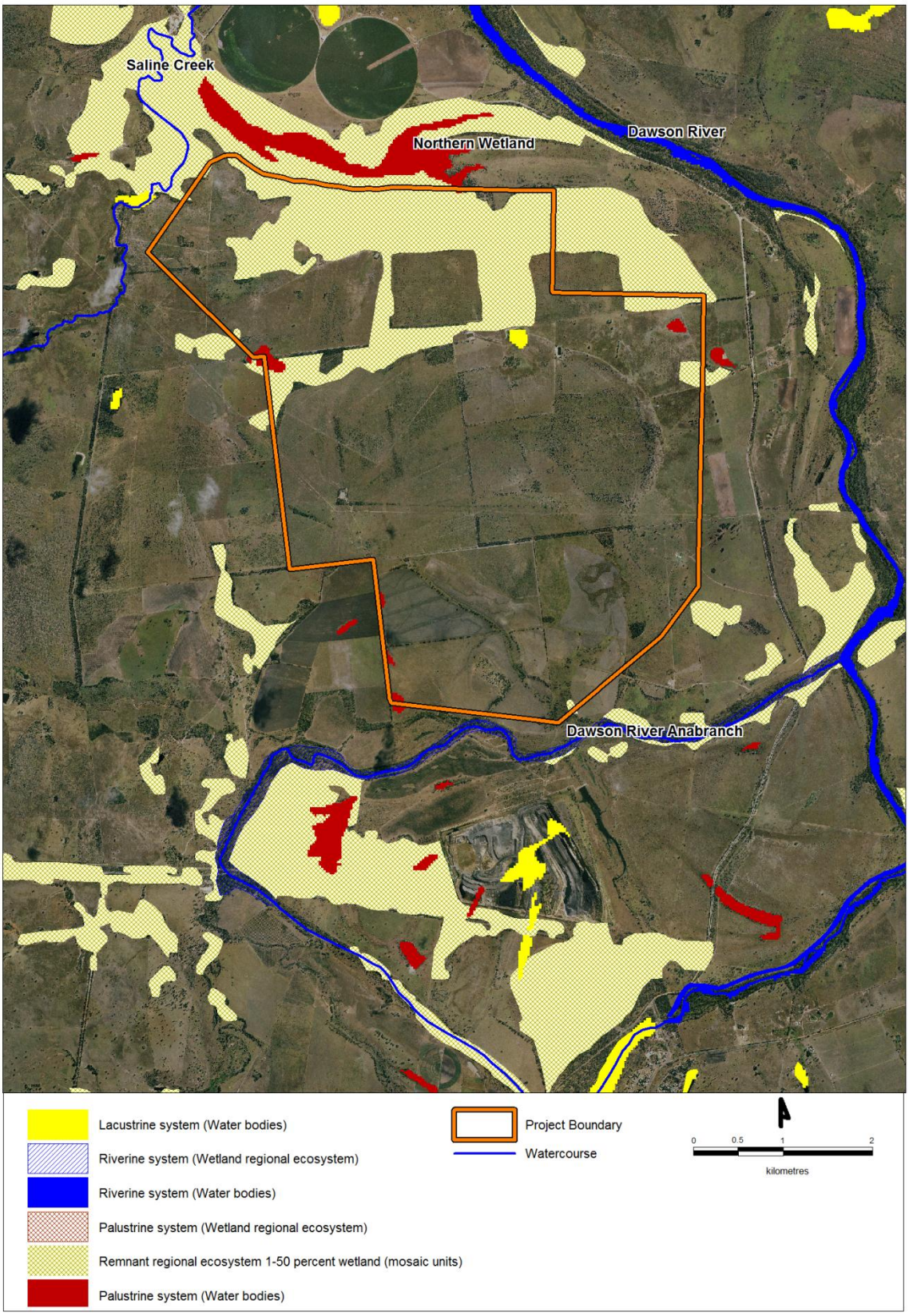

Figure 3.1 Location of wetlands

3.2.3 Queensland Water Quality Guidelines

The Queensland Water Quality Guidelines (QWQG) are intended to address the need identified in the ANZECC Guidelines by providing:

- guideline values (numbers) that are tailored to Queensland regions and water types; and
- a process/framework for deriving and applying more locally specific guidelines for waters in Queensland.

The guidelines include locally and regionally relevant guideline values for fresh, estuarine and marine waters.

3.2.4 National Water Quality Management Strategy and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The processes to identify EVs and to determine WQGs and WQOs are based on the National Water Quality Management Strategy (NWQMS) (ANZECC/ARMCANZ, 1994), Implementation Guidelines (ANZECC/ARMCANZ, 1998) and further outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). EVs and WQOs that are adopted by the Government for particular waters are included in Schedule 1 of the EPP Water.

The indicators and water quality guidelines relevant to the EVs are listed in the Queensland Water Quality Guidelines, Version 3 (DEHP, 2009) and ANZECC (2000). The ANZECC guidelines specify levels of protection corresponding to each of the following measures of the receiving water ecosystem condition:

- of high conservation value
- slightly to moderately disturbed
- highly disturbed.

3.3 CONSEQUENCE CATEGORIES AND HYDRAULIC PERFORMANCE OF STRUCTURES

All dams constructed as part of an environmentally relevant activity pursuant to the EP Act, such as those proposed for the Project, must have their consequence category assessed. DEHP developed a Manual for Assessing Consequences Categories and Hydraulic Performance of Structures (DEHP, 2013) to guide the determination of the consequence category of dams.

A dam is assigned a high, significant or low hazard category based on its potential impact on the environment, humans and stock or to cause general economic loss should the dam overflow or fail. A dam must be regulated by DEHP if the dam falls into the high or significant consequence category. Whilst all dams on site will be designed by a suitably qualified engineer and will have their consequence category reassessed on an annual basis, regulated dams require certified design plans to be submitted to DEHP and certified annual inspections and reports must be provided.

All regulated dams must as a minimum provide for a volume called a design storage allowance (DSA). DSA can be distributed across multiple regulated dams within an integrated water management system. A regulated dam must be designed and operated such that sufficient available storage is maintained to accommodate expected inputs and outputs during the year; and that the DSA storage volume is available at 1 November for the coming wet season.

Regulated dams must also provide sufficient capacity at all times to contain the runoff from a design storm event as specified in the manual. A mandatory reporting level (MRL) must be

estimated based on the lowest level required to contain the runoff volume. The MRL volume is measured with respect to the dam spillway level and must be marked in a clearly visible location.

3.4 INDEPENDENT EXPERT SCIENTIFIC COMMITTEE

The Queensland Government is a signatory to the National Partnership Agreement on Coal Seam Gas and Large Mining Development. This agreement is to create a more consistent national approach to strengthen the regulation of coal seam gas (CSG) and large coal mining development by ensuring that future decisions are informed by substantially improved science and independent expert advice.

The purpose of the 'Information guidelines for proposals relating to the development of coal seam gas and large coal mines where there is a significant impact of water resources', prepared by the Independent Expert Scientific Committee (IESC), is to provide a basis for the IESC's expectations for a risk based assessment on water resources (IESC, 2013). This document identifies the information needs for IESC advice including:

- proposal description
- background data and modelling
- water balance (regional and local)
- assessment of risk
- impacts of development
- assessment of cumulative impacts
- ongoing management and monitoring.

The Project was referred to the Department of the Environment and on 12 December 2013 it was advised that the Project is a controlled action requiring assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The IESC guidelines indicate that applying a water balance model is the most appropriate method for assessing potential changes in water resources. A detailed water balance model has been prepared for the project, as described in Section 6 of this report.

3.5 *WATER ACT 2000* (QLD)

In Queensland, the Water Act is the primary statutory document that establishes a framework for the planning, allocation and use of non-tidal water. The Water Act is largely administered by the Department of Natural Resources and Mines (DNRM) and the Department of Energy and Water Supply (DEWS).

The Water Act includes sustainable management of water and other resources, water resource planning, water security planning, demand management, establishment and operation of water authorities. All rights to the use, flow and control of all water in Queensland are vested in the State. Water cannot be legally taken or used unless it is authorised under a water entitlement (a water allocation or licence). The Water Act also prescribes the process for preparing Water Resource Plans (WRPs) and Resource Operation Plans (ROPs) for specific catchments within Queensland.

3.5.1 Water Resource (Fitzroy Basin) Plan 2011

Water Resource Plans (WRPs) are subordinate legislation to the Water Act. The Plans are developed and administered by DNRM. Under this process, WRPs are prepared to define a

balance between waterway health and community needs, and to set allocation and management objectives at a catchment scale.

The Water Resource (Fitzroy Basin) Plan 2011 (Fitzroy WRP) was revised in 2011, building upon the original Plan established in 1999. The Plan is valid for a period of ten years, after which it is reviewed. The Plan covers surface water, groundwater and overland flows.

For surface water and overland flow, the Fitzroy WRP sets two key objectives to assist in defining the balance between consumptive and environmental flows:

- Environmental Flow Objectives (EFOs) to protect or maintain waterway health, and
- Water Allocation Security Objectives (WASOs) to maintain water supplies (consumptive use).

The EFOs set out a series of mandatory and non-mandatory flow objectives for key locations in the Basin. The EFOs for the Fitzroy WRP cover a range of flow conditions including Seasonal Base Flow, a First Post-Winter Flow Event and Medium to High Flow Events.

The WASOs provide a level of security for supplemented and unsupplemented water entitlement holders. In the Dawson River, supplemented water is available as High Priority, Medium Priority and Medium Priority-A, i.e. it is supplied from a water storage. The difference between each priority level is reflected in their respective announced allocation whereby High Priority water is given priority of access over the others and is therefore more reliable. Unsupplemented water in the Dawson is accessed based on certain rules of take and is dependent upon run of river flows.

The key location of interest for this Project is the Fitzroy WRP's management Node 2, that is the Dawson River at Beckers (AMTD 71.0 km) defined in the Fitzroy WRP. Node 2 is located upstream of the Saline Creek and Dawson River confluence.

There is provision in the Fitzroy WRP for the taking of overland flow water to satisfy the requirements of an EA issued under the EP Act. This provision is likely to apply to surface water intercepted by the site water management system to protect downstream water quality.

There is some unallocated water as strategic reserve totalling 15,000 ML available for State purpose in the Isaac Connors, Fitzroy, Lower Mackenzie, Upper Mackenzie, Nogoa, Upper Dawson, Lower Dawson and Comet.

3.5.2 Fitzroy Basin Resource Operation Plan 2013

The Resource Operations Plan is a plan prepared under the provisions of the Water Act to implement a WRP for certain water in all or part of the plan area. The Fitzroy Basin Resource Operations Plan (Fitzroy ROP) was amended in December 2013 to provide the operational details on how the outcomes of the Fitzroy WRP can be achieved. While the WRP sets out the strategic goals for water resource management in the plan area, the Fitzroy ROP defines the rules which water allocations and licences may be granted.

Unsupplemented water is water taken under a water allocation or water licence that is not managed under a Resource Operations License (ROL) or Interim Resource Operations License (IROL). Unsupplemented water management relates to:

- taking water under high stream flow conditions (water harvesting) within the bounds of a water supply scheme; and
- taking water under any flow conditions outside of the bounds of a water supply scheme.

There is no proposal to take unsupplemented water for the project

3.6 *WATER SUPPLY (SAFETY AND RELIABILITY) ACT 2008* (QLD)

Administered by the DEWS, the *Water Supply (Safety and Reliability) Act 2008* provides for the safety and reliability of water supply. This is achieved primarily by:

- providing a regulatory framework for water and sewerage services in the State,
- providing a regulatory framework for recycled water and drinking water quality, primarily for protecting public health,
- the regulation of referable dams, and
- stating flood mitigation responsibilities.

Referable dams are legislated under the *Water Supply (Safety and Reliability) Act 2008*. The exact number and design details of referable dams for this project (if any) will not be finalised until the detailed design stage and during operations of the Project. An assessment of the population at risk (PAR) will be carried out for each dam (which does not contain hazardous waste) to determine if it meets the criteria for referable dams.

3.7 CENTRAL QUEENSLAND REGIONAL WATER SUPPLY STRATEGY

The Central Queensland Regional Water Supply Strategy ensures that supplies are equitably shared in a way that brings the broadest community benefit, including providing protection for the natural ecosystems at a regional level. The extent of the region covers the Fitzroy River basin, Water Park Creek, Calliope River and Boyne River. It was developed for the long term and is administered by DEWS .

The Strategy assessed current water availability and future demands, and identifies preferred options for the development of water supply infrastructure to meet future industrial, mining, agriculture and urban demands. The Strategy complements the existing water resource plan and resource operations plan for the Fitzroy River basin.

The additional water demand resulting from this development will be met within the proponent's allocation and internal water recycling measures, and hence there is no need to source allocations from new bulk supply infrastructure. The use of internal recycling of water is consistent with the Strategy.

4 EXISTING SURFACE WATER ENVIRONMENT

4.1 RAINFALL AND EVAPORATION

Table 4-1 shows summary details of Bureau of Meteorology (BOM) and DNRM rainfall recording stations with a significant period of record in the vicinity of the Project.

Table 4-1 BOM & DERM rainfall stations in the vicinity of the Project

Station No.	Station Name	Elevation	Lat. (°S)	Long. (°E)	Distance from Project	Opened	Closed
039004	Baralaba Post Office	100 m	24.18	149.81	5 km	1926	-
039143	Baralaba	83 m	24.18	149.81	5 km	1924	-*
130322A	Dawson River at Beckers	64 m	24.09	149.82	1 km	1964	-

Note: * Regular records cease in 1987.

Table 4-2 shows the long-term monthly rainfall averages for the period of record at the Baralaba Post Office. Table 4-2 also shows mean monthly evaporation recorded at the Brigalow Research Station which is located approximately 60 km south of the Project and at the Biloela DPI station, located approximately 65 km east of the Project. Table 4-3 shows the variability in monthly rainfall at the Baralaba Post Office station.

Mean annual Class A pan evaporation is approximately 3 times greater than mean annual rainfall. Figure 4.1 shows the annual distribution of monthly rainfall and evaporation. Both rainfall and evaporation are higher in the warmer months, with evaporation substantially exceeding rainfall in all months.

Table 4-2 Mean monthly rainfall and pan evaporation (mm/month)

Month	Rainfall	Pan Evaporation	
	Baralaba Post Office #039004 (Aug 1926- Jul 2013)	Brigalow Research Station #035149 (1968-2010)	Biloela DPI #039006 (1965-1996)
January	96.2	245	220
February	115.6	201	192
March	75.0	205	189
April	44.8	165	144
May	41.7	118	109
June	34.9	93	87
July	28.6	99	90
August	21.8	127	115
September	25.6	174	153
October	55.1	214	198
November	75.3	228	213
December	103.1	245	233
Total	**717.8**	**2,113**	**1,942**

Table 4-3 Monthly rainfall statistics for Baralaba Post Office (mm/month)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	96.2	115.6	73.5	44.8	41.7	34.9	28.6	21.8	25.6	55.1	75.3	103.1	713.7
Lowest	0	0	0	0	0	0	0	0	0	0	0	4	349.9
5th %ile	17.7	14	4.4	0.2	0	1.7	0	0	0	1.6	5.9	16.8	395
10th %ile	27.2	22.6	11.7	1.8	1.5	2	0	0	0	7.4	14.7	28.3	449.3
Median	78.2	87.5	57.2	25.4	25.4	24.3	15	12	12.2	46	77.2	81	688.3
90th %ile	174.2	231.7	140.8	97.4	87.4	78.5	85.7	59.1	64	116	130.2	198.9	953.2
95th %ile	223.7	292	221.4	126.6	125.8	89.8	114.4	66.1	91.6	135	166.7	293.3	1086.6
Highest	425.8	628.1	333.3	421.6	267.3	189.6	183.3	115.5	160.6	181.6	200.5	457.6	1348.6

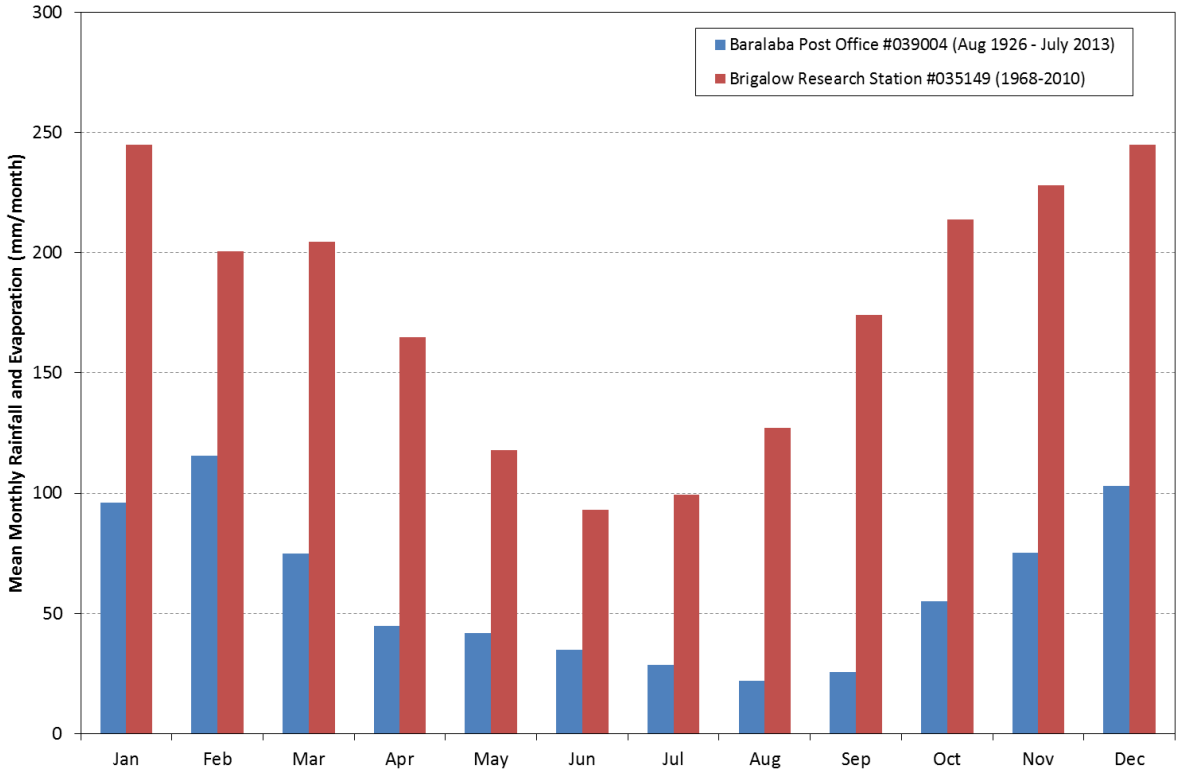

Figure 4.1 Distribution of monthly rainfall and pan evaporation

4.2 REGIONAL DRAINAGE NETWORK

4.2.1 Overview

The Project is located within the Fitzroy Basin, one of the largest seaward draining basins in Australia with a total catchment area of approximately 142,600 km^2. The major rivers and tributaries of the Fitzroy catchment include the Fitzroy, Dawson, Nogoa, Comet, Isaac and Mackenzie rivers. Drainage features in the vicinity of the Project are shown in Figure 4.2.

4.2.2 Dawson River

The Dawson River catchment is bordered by the Great Dividing Range to the south, the Auburn Range to the east, and the Carnarvon, Lynd, Expedition and Bigge Ranges to the west. The Dawson River flows north between the Dawson and Auburn Ranges to meet the Fitzroy River west of Rockhampton.

The Project is located in the lower Dawson River catchment, which has a catchment area of approximately 40,500 km^2 to Baralaba. The Lower Dawson River is regulated with several water supply storages including Theodore Weir, Orange Creek Weir, Moura Weir, Glebe Weir, Gyranda Weir and Neville Hewitt Weir (located adjacent to Baralaba) constructed as part of the Dawson Valley Water Supply Scheme. The Nathan Dam and Pipelines Project is currently under investigation and, if approved, will result in construction of a major water supply storage on the Dawson River upstream of the Nathan Gorge, about 150 km south of Baralaba. The dam will have a catchment area of approximately 23,000 km^2 and a capacity of approximately 888,000 ML. Construction is anticipated to be completed around 2020.

In the vicinity of the Project, the Dawson River is characterised by a 150 to 200 m wide main channel meandering along a lower terrace floodplain. The lower terrace consists of remnant river channels and is about 1.0 to 1.5 km wide. The lower terrace floodplain cuts through the greater Dawson River floodplain that varies between 4 km to 6 km wide at the Project location. Figure 4.3 shows a photograph of the Dawson River main channel near the bridge crossing downstream of Neville Hewitt weir, to the north of Baralaba.

The Dawson River adjacent to the Project is classified as an 8th order stream using the Strahler stream-classification method, using a 1:100,000 scale map.

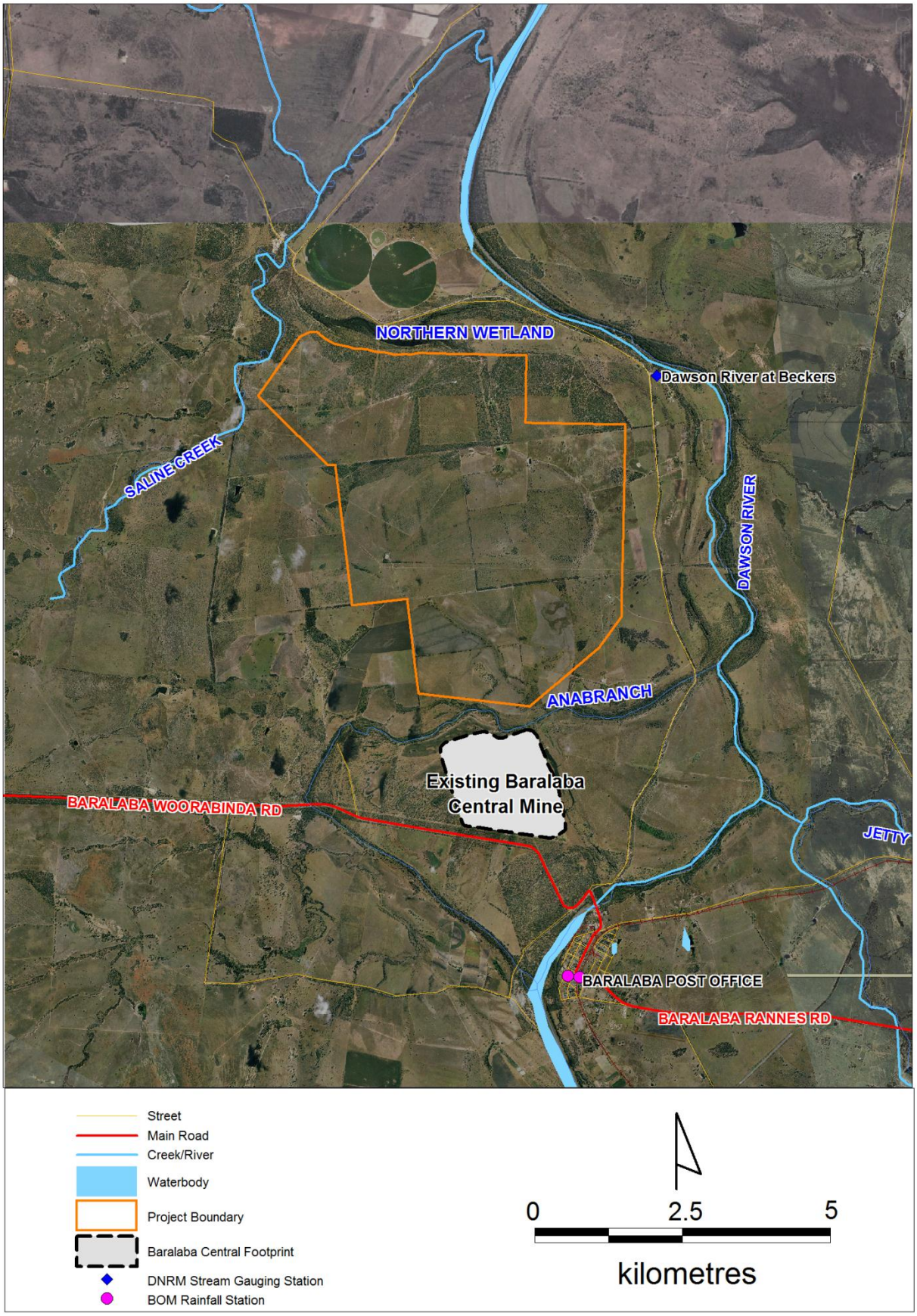

Figure 4.2 Drainage features near BNCOP

Figure 4.3 Photograph of Dawson River main channel downstream of Baralaba

4.3 LOCAL DRAINAGE NETWORK

The local drainage features in the vicinity of the Project are shown in Figure 4.2 and Figure 4.4. A minor ridge runs east-west across the Project area. Land on the southern side of the ridge flows south towards the Dawson River Anabranch (the Anabranch). A photograph of the Anabranch is shown in Figure 4.5. The Anabranch collects runoff from the local catchment on the southern side of the ridge, and also receives overflows from the Dawson River main channel during river floods.

Drainage across most of the project area is poorly defined, indicating large areas of shallow overland flow. Figure 4.6 shows a number of photographs of the general site topography.

Land to the north of the ridge on the site flows to a large wetland area (identified as “Northern Wetland” in Figure 4.4), which is also an anabranch of the Dawson River. Figure 4.7 shows photographs of the northern wetland area.

The north-western portion of the project boundary drains to Saline Creek. Saline Creek is a tributary of the Dawson River, the confluence of which lies approximately 5 km north of the project boundary. The catchment area of Saline Creek is approximately 50 km^2 to the project boundary and 300 km^2 to the confluence with the Dawson River. Figure 4.8 shows a photograph of the Saline Creek main channel near the north-west corner of the project boundary.

Adjacent to the Project, Saline Creek is classified as a 3rd and 4th order stream using the Strahler stream-classification method (using a 1:100,000 scale map). At its confluence with the Dawson River, Saline Creek is a 5th order stream.

The wetland area to the north of the project boundary and a number of other smaller wetlands in the vicinity of the project boundary are mapped by DEHP (see Figure 3.1).

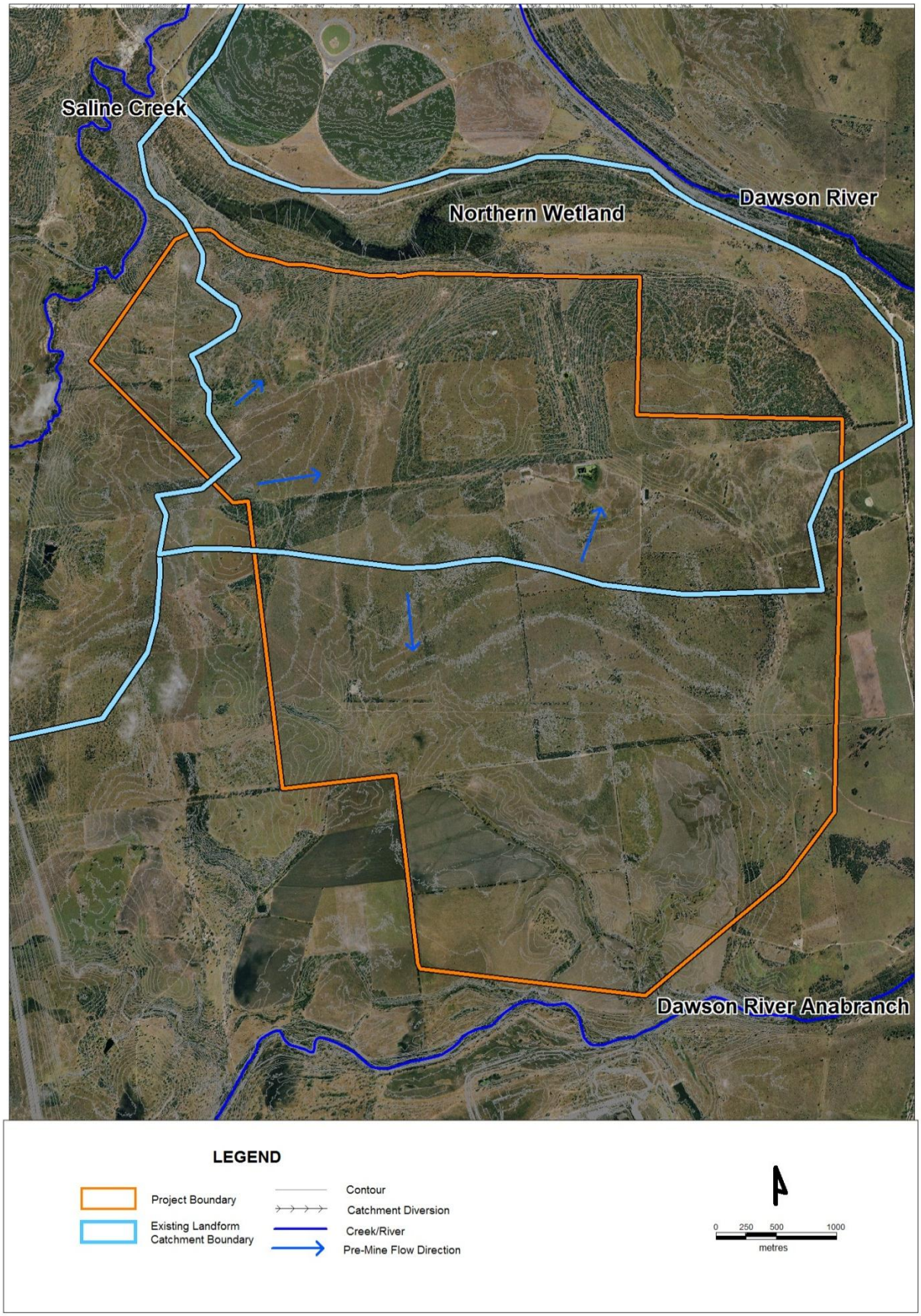

Figure 4.4 Pre-mine catchment boundaries

Figure 4.5 Photograph looking west along Dawson River Anabranch from Duaringa-Baralaba Road

Figure 4.6 Photographs showing general site topography

Figure 4.7 Photographs of northern wetland area

Figure 4.8 Photograph showing Saline Creek main channel

4.4 STREAMFLOW

The Queensland Government DNRM Beckers stream gauge (#130322A) is located on the Dawson River to the east of BNCOP, approximately 12.5 km downstream of Baralaba township and Neville Hewitt Weir. A summary of the station details is provided in Table 4-4. Dawson River at Beckers has historical streamflow data from June 1964, and historical water quality data (electrical conductivity) from August 1993 to current.

Table 4-4 DNRM streamflow station in the vicinity of the Project

Station No.	Station Name	Catchment Area (km²)	Opened	Closed
130322A	Dawson River at Beckers	40,500	June 1964	-

Figure 4.9 shows the recorded flow frequency relationship for streamflow recorded (Aug 1964 – 2013) at Dawson River at Beckers (#130322A). The flow frequency relationship for the recorded streamflow for the period prior to and post construction of the Neville Hewitt Weir is also shown. The Neville Hewitt Weir is located to the immediate north of the Baralaba township and was constructed in 1976. Under current catchment conditions (since the construction of the Neville Hewitt Weir), the Dawson River has a median (50th percentile) flow rate of approximately 0.16 m^3/s (14 ML/d). Flow in the river is very low (less than 0.01 m^3/s) approximately 40% of the time and is less than 0.001 m^3/s more than 30% of the time.

Median monthly flow at Beckers is summarised in Figure 4.10. River flow is strongly seasonal with a median flow in February more than 3 times larger than any other month.

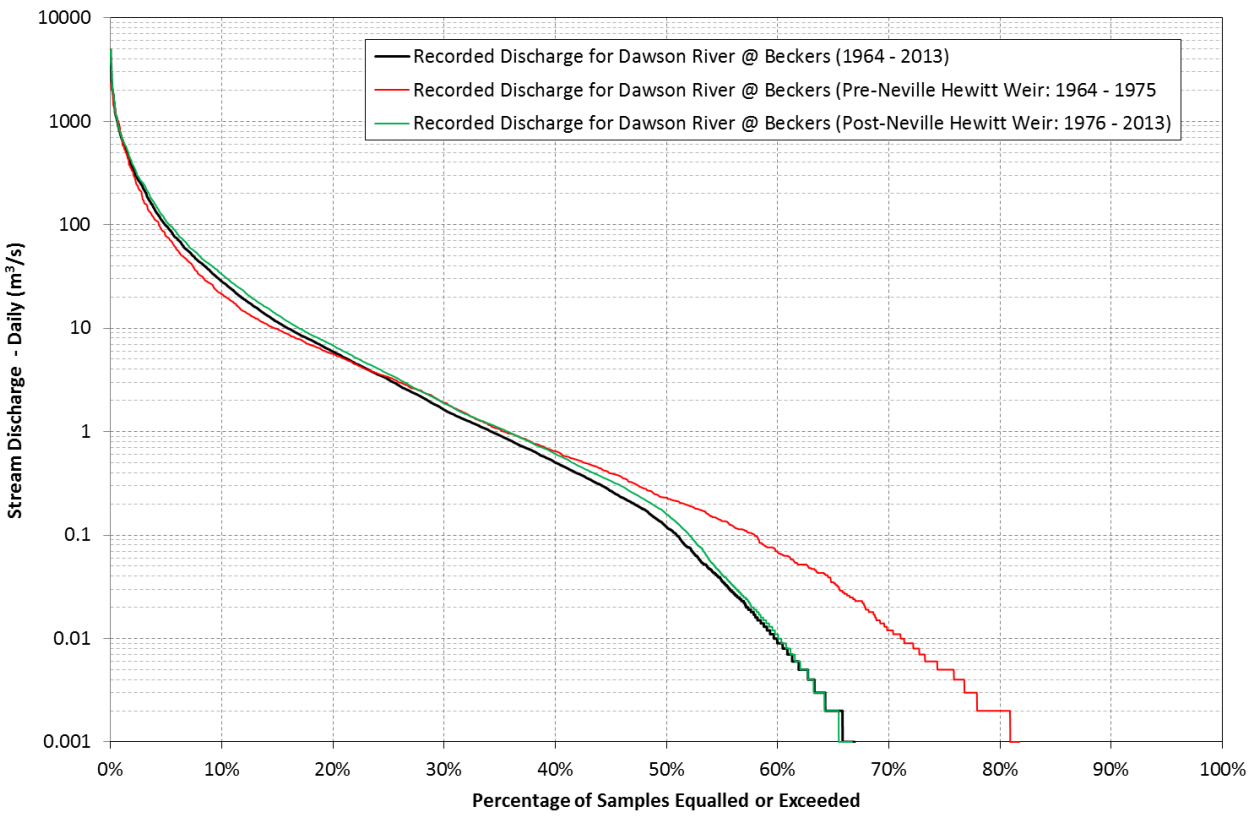

Figure 4.9 Dawson River at Beckers (#130322A) flow frequency relationship

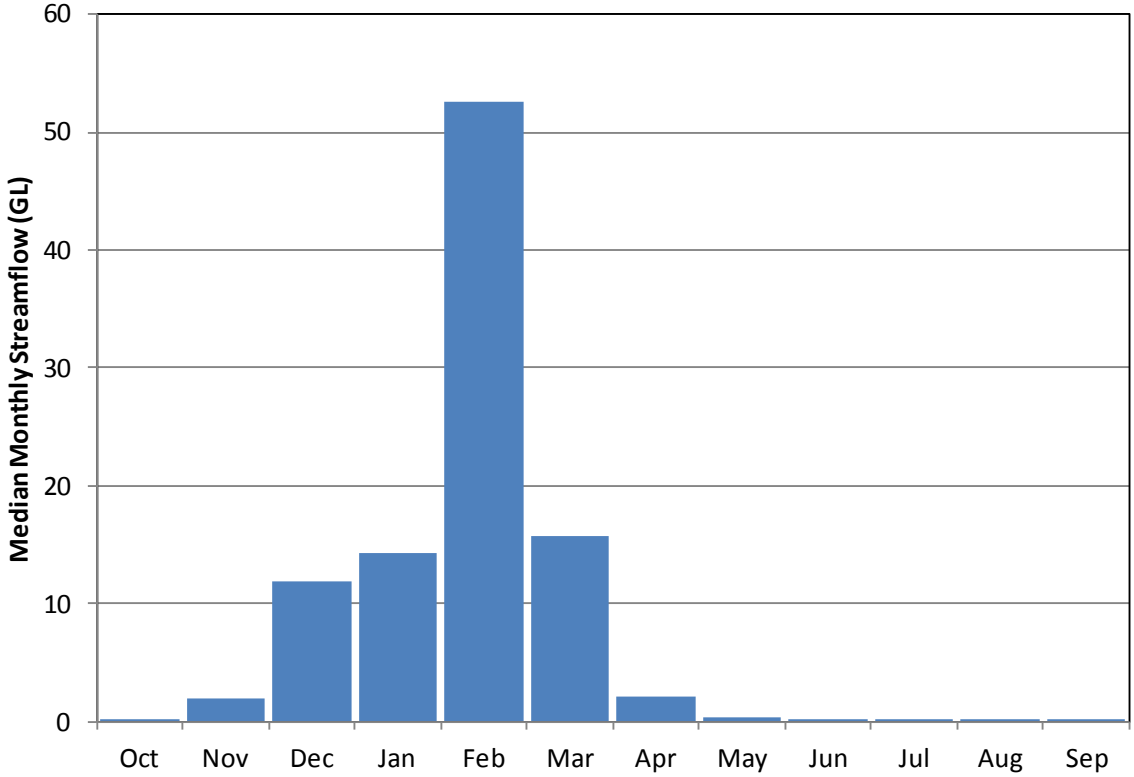

Figure 4.10 Median monthly flow, Dawson River at Beckers (#130322A)

4.5 WATER QUALITY

4.5.1 Baseline Water Quality Monitoring

The results of the CCL water quality monitoring program are provided in Appendix A. The sampling locations are shown in Figure 4.11. Most of the data collected under the CCL water quality monitoring program has been collected since 2011, with limited sampling back to 2009. The Saline Creek monitoring sites were sampled as part of the Aquatic Assessment, however although sampling was attempted throughout 2013, there was no flow and hence no sampling from late May 2013 through to mid-November 2013.

From February to August 2011, the Baralaba Coal Mine released water from the mine to the river under a transitional environmental program (TEP) in the aftermath of major flooding in December 2010. To provide a more realistic representation of background water quality, water quality data for sites downstream of the release point has not been included in the data summarised in Appendix A during the TEP period (8 February 2011 to 17 August 2011). Further discussion on the impacts of the temporary releases is provided in the following section.

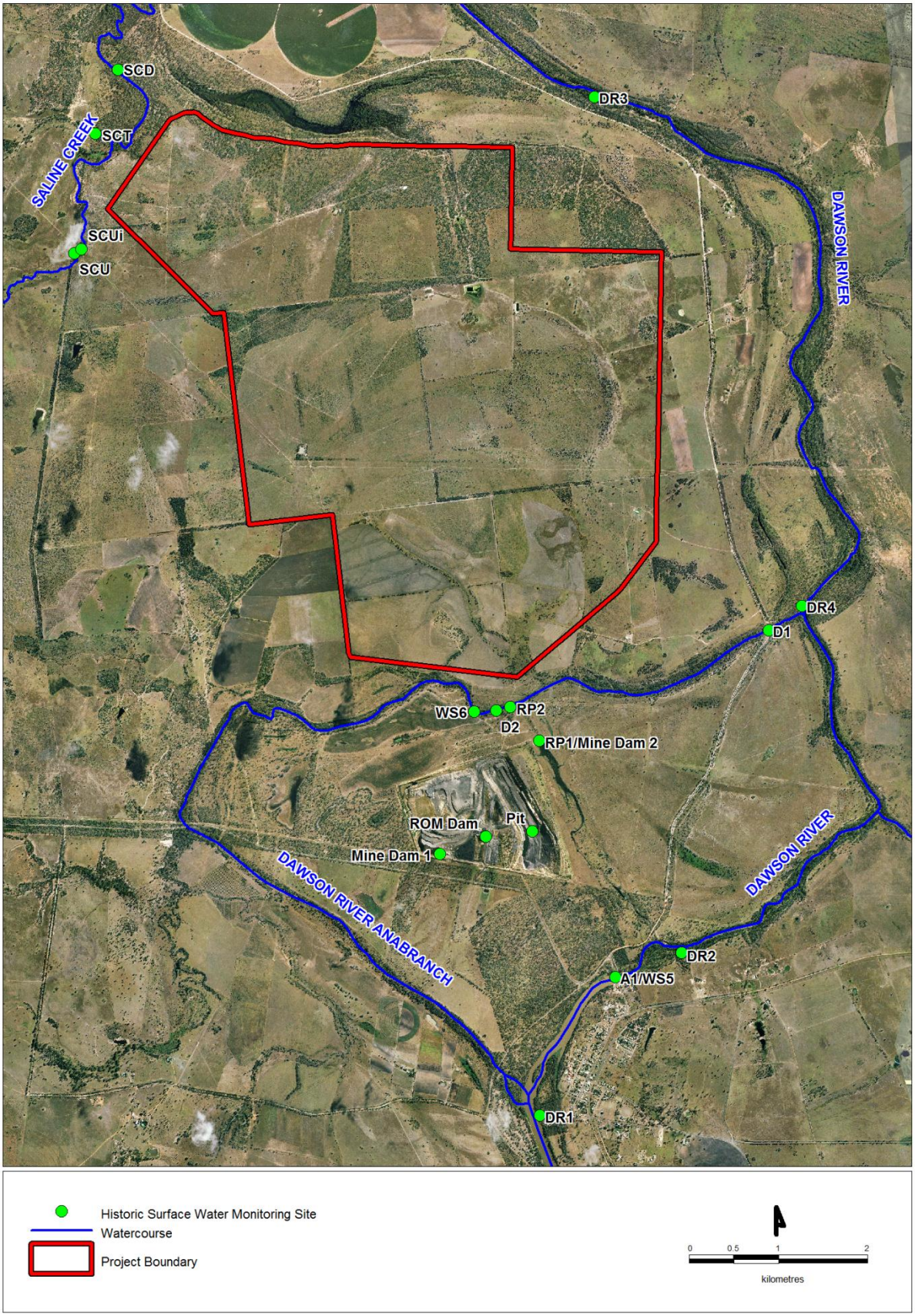

Figure 4.11 Historic water quality sampling locations

4.5.2 Regional Water Quality

Historical water quality data for the Beckers gauge is shown in Table 4-5 (note that this data is from DERM's summary table and only has a limited number of samples). The data indicates that water quality at Beckers meets the water quality objectives (see Table 3-1) for:

- EC
- pH
- hardness
- TDS
- dissolved oxygen
- sodium
- sulphate
- aluminium
- arsenic
- boron
- copper
- fluoride
- manganese
- zinc.

Water quality objectives are not achieved for:

- all species of nitrogen and phosphorous
- chlorophyll-a
- total suspended solids
- turbidity.

Figure 4.12 shows a time history of recorded EC data collected by DNRM for the Dawson River at Beckers. The data covers the period from 1994 to early 2014. The time series plot indicates that after early 2011, EC appears to have increased. Analysis of the data indicates:

- a median EC of 198 µS/cm and 80th percentile of 244 µS/cm from 1994 to 2010,
- a median EC of 363 µS/cm and 80th percentile of 539 µS/cm from 2011 to 2014.

Figure 4.13 compares recorded EC values for the Dawson River at Beckers with the results of CCL's water quality monitoring program at a location upstream (A1) and downstream (DR3) of the release point from the Baralaba Coal Mine (see Figure 4.11 for sampling locations). Figure 4.13 also shows Dawson River discharges over the corresponding period.

Figure 4.13 shows that the CCL recorded EC at DR3, downstream of the release point, generally corresponds well to the EC recorded by DNRM at Beckers. Figure 4.13 also shows that the upstream EC, recorded at sampling location A1, is elevated, particularly during the first part of 2011 when TEP releases were being made from Baralaba Coal Mine. The difference between upstream and downstream EC is generally of the order of 100 µS/cm or less. This indicates that a significant portion of the elevated EC observed since 2011 is attributed to other activities within the catchment upstream of Baralaba.

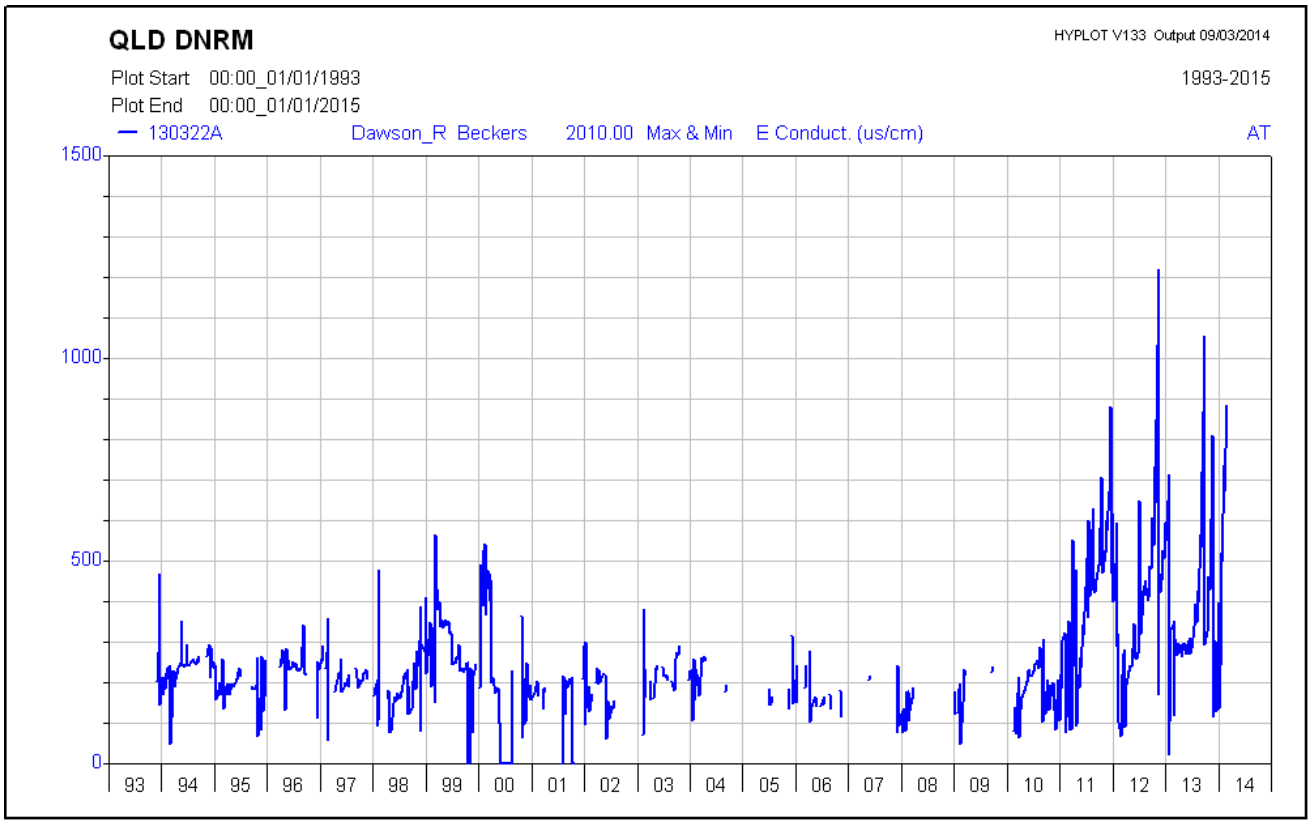

Figure 4.12 Time history of EC, Dawson River at Beckers

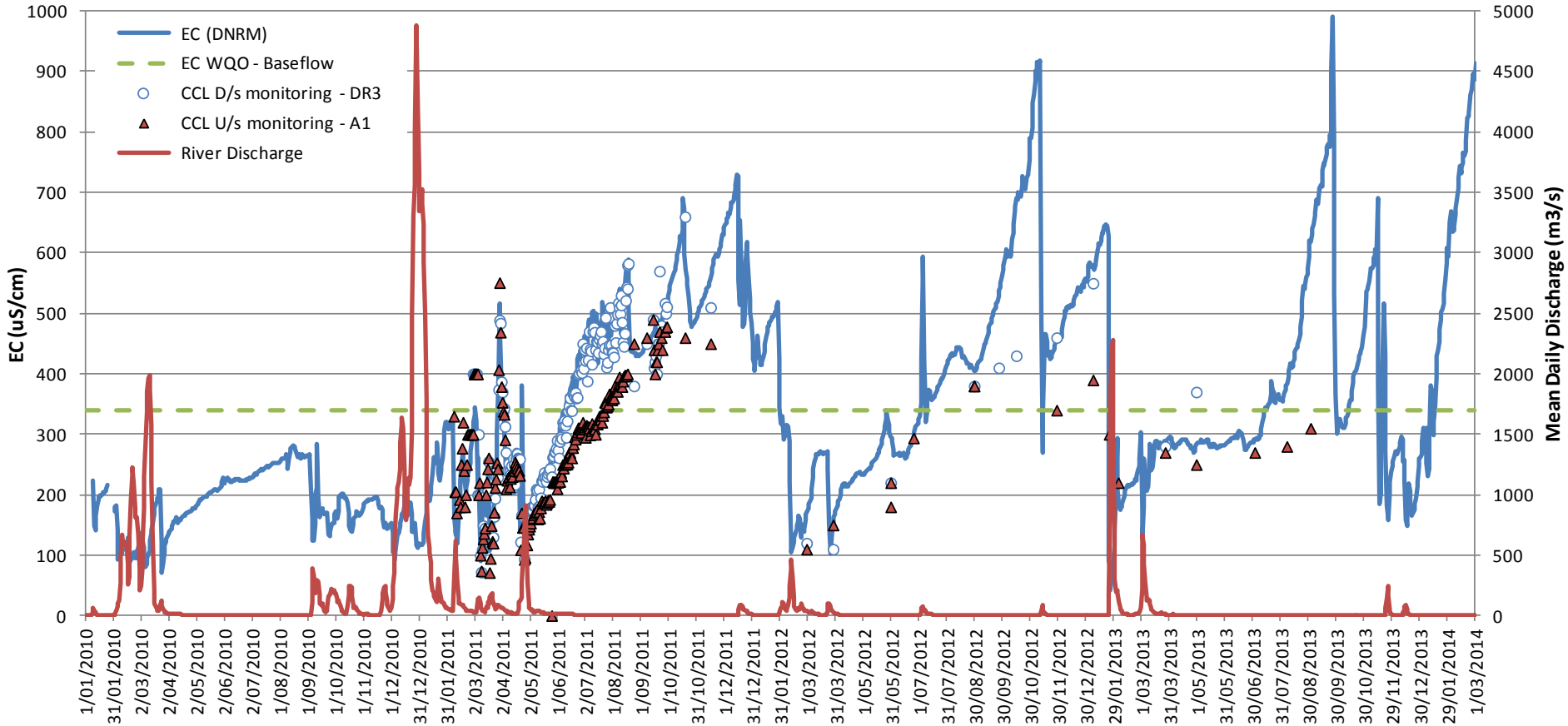

Figure 4.13 Time series of Dawson River EC upstream & downstream of Baralaba Coal Mine since 2011

Table 4-5 DNRM historical water quality data – Dawson River at Beckers

Start Date	End Date		N	Min	10%ile	50%ile	90%ile	Maximum	Mean	STD
26/11/1964	15/07/2009	Conductivity @ 25C (uS/cm)	123	70	128	192	272	790	201	77
01/06/1984	14/09/2010	Conductivity @ 25C FLD	88	86	129	185	269	1732	210	172
01/06/1984	15/07/2009	Turbidity (NTU)	80	1	14	100	531	1120	196	247
03/05/1995	14/09/2010	Turbidity (NTU) FLD	54	19	45	161	788	1430	293	326
22/09/1994	30/03/1995	Transparency (secchi depth) (Metres) FLD	3	0.07	-	-	-	0.65	0.45	0.33
01/06/1984	15/07/2009	Colour True (Hazen units)	73	2	7	21	82	300	40	52
24/10/1994	05/08/2008	Air Temperature () FLD	12	20.30	21.09	25.60	34.92	35.00	27.19	5.89
08/06/1971	14/09/2010	Water Temperature FLD	105	13.00	17.56	26.00	30.00	33.50	24.72	5.00
26/11/1964	15/07/2009	pH (pH units)	123	6.80	7.00	7.60	7.95	8.20	7.54	0.34
10/07/1990	14/09/2010	pH (pH units) FLD	72	6.50	7.00	7.40	8.07	8.50	7.46	0.41
26/11/1964	15/07/2009	Total Alkalinity as CaCO3 (mg/L)	123	24	45	71	95	120	71	20
04/07/1995	08/10/2001	Total Alkalinity as CaCO3 FLD	7	14	-	-	-	89	68	26
30/04/1996	30/04/1996	Phenolphthalein Alk. as CaCO3 FLD	1	0	-	-	-	0	0	0
09/06/1965	15/07/2009	Hydroxide as OH (mg/L)	92	0.00	0.00	0	0.01	0.02	0.00	0.01
11/12/1970	15/07/2009	Carbonate as CO3 (mg/L)	108	0.00	0.00	0.17	0.40	1.00	0.21	0.20
26/11/1964	15/07/2009	Bicarbonate as HCO3 (mg/L)	123	29	55	87	116	146	86	24
26/11/1964	15/07/2009	Hardness as CaCO3 (mg/L)	123	12	33	53	77	142	54	18
26/11/1964	15/07/2009	Hydrogen as H (mg/L)	96	0.00	0.00	0.00	0.00	0.10	0.00	0.01
26/11/1964	15/07/2009	Total Diss. Solids (mg/L)	118	0	0	111	145	274	104	48
26/11/1964	15/07/2009	Total Diss. Ions (mg/L)	123	64.0	95.1	148.7	208.0	491.3	151.4	52.3
09/04/1973	15/07/2009	Total Suspended Solids	96	2	12	50	352	682	108	149
03/12/2007	18/01/2008	Total Suspended Solids	19	119	145	397	615	844	405	198
26/11/1964	15/07/2009	Calcium as Ca soluble (mg/L)	123	3	8	13	19	32	13	5
26/11/1964	15/07/2009	Chloride as Cl (mg/L)	123	7	9	15	29	172	18	17
26/11/1964	15/07/2009	Magnesium as Mg soluble (mg/L)	123	1	3	5	7	15	5	2
03/12/2007	18/01/2008	Total Nitrogen – suspended (mg/L)	19	0.03	0.33	0.60	0.76	1.08	0.57	0.22
26/11/1964	15/07/2009	Nitrate as NO3(mg/L)	85	0.0	0.5	1.5	2.9	5.5	1.6	1.1
01/06/2001	01/06/2001	Nitrate + nitrite as N – total (mg/L)	1	1	-	-	-	1	1	0
01/12/1994	01/12/1994	Kjeldahl Nitrogen (mg/L)	1	0.64	-	-	-	0.64	0.64	0.00
03/12/2007	18/01/2008	Kjeldahl Nitrogen (mg/L)	19	0.61	0.86	1.06	1.21	1.49	1.03	0.19
16/11/1998	15/07/2009	Total Nitrogen (mg/L)	26	0.41	0.50	0.92	1.34	1.97	0.94	0.38
03/12/2007	18/01/2008	Total Nitrogen (mg/L)	19	0.71	0.97	1.33	1.64	1.75	1.29	0.27
24/10/1993	09/03/1999	Organic Nitrogen (mg/L)	34	0.40	0.58	0.91	1.38	1.90	0.92	0.34
24/10/1993	15/07/2009	Nitrate+nitrite as N soluble (FieldFilt)	58	0.00	0.00	0.21	0.56	4.40	0.33	0.66
03/12/2007	18/01/2008	Nitrate+nitrite as N soluble (FieldFilt)	19	0.10	0.11	0.26	0.35	0.44	0.26	0.10
24/10/1993	15/07/2009	Ammonia as N – soluble (Field Filtered)	58	0.002	0.006	0.023	0.062	0.580	0.038	0.076
03/12/2007	18/01/2008	Ammonia as N – soluble (Field filtered)	19	0.004	0.012	0.033	0.049	0.056	0.032	0.015
03/12/2007	18/01/2008	Kjeldahl Nitrogen – dissolved (mg/L)	19	0.38	0.39	0.47	0.54	0.58	0.47	0.06
09/02/1995	14/09/2010	Oxygen (Dissolved) (mg/L)FLD	53	2.9	4.1	6.8	8.6	12.5	6.5	1.9
03/12/2007	18/01/2008	Total Dissolved Nitrogen (Field– Filter)	19	0.613	0.642	0.705	0.790	0.977	0.720	0.087
03/12/2007	18/01/2008	Organic Nitrogen – dissolved (mg/L)	19	0.34	0.38	0.44	0.50	0.53	0.43	0.05
03/12/2007	18/01/2008	Total Kjeldahl Phosphorus as P (mg/L)	19	0.21	0.27	0.43	0.59	0.64	0.44	0.13
24/10/1993	15/07/2009	Total Phosphorus as P (mg/L)	61	0.032	0.059	0.240	0.490	0.720	0.261	0.175
24/10/1993	15/07/2009	Total React P (Ortho P) – soluble (FldF)	58	0.002	0.012	0.064	0.170	0.720	0.090	0.105
03/12/2007	18/01/2008	Total React P (Ortho P) – soluble (FldF)	19	0.100	0.108	0.125	0.241	0.246	0.152	0.051
03/12/2007	18/01/2008	Total Phosphorus– dissolved (Field–filt)	19	0.09	0.10	0.13	0.26	0.27	0.15	0.06
03/12/2007	18/01/2008	Organic Phospherous – dissolved	19	0.01	0.01	0.01	0.02	0.03	0.01	0.01
03/12/2007	18/01/2008	Total Phospherous –suspended	19	0.09	0.15	0.29	0.42	0.48	0.29	0.11
09/04/1973	15/07/2009	Potassium as K (mg/L)	97	2.4	4.6	6.0	7.4	9.0	6.0	1.2
26/11/1964	15/07/2009	Sodium as Na (mg/L)	123	6.9	12.0	17.0	28.8	110.0	19.4	11.0
26/11/1964	15/07/2009	Sulphate as SO4 (mg/L)	101	1	2	3	7	37	4	5
19/03/1990	15/07/2009	Aluminium as Al soluble (mg/L)	65	0.0	0.0	0.1	0.3	1.4	0.1	0.3
18/11/2002	18/11/2002	Arsenic as As – total (Micrograms/Litre)	1	0	-	-	-	0	0	0
09/04/1973	15/07/2009	Boron as B (mg/L)	75	0.0	0.0	0.0	0.1	0.2	0.0	0.0
19/03/1990	15/07/2009	Copper as Cu soluble mg/L	65	0.00	0.00	0.03	0.05	0.07	0.03	0.02
26/11/1964	15/07/2009	Flouride as F (mg/L)	118	0.07	0.10	0.14	0.30	1.35	0.20	0.18
23/11/1969	15/07/2009	Iron as Fe soluble (mg/L)	84	0.0	0.0	0.1	0.7	4.2	0.3	0.8
23/08/1984	15/07/2009	Manganese as Mn soluble (mg/L)	62	0.00	0.00	0.01	0.03	0.09	0.01	0.01
09/04/1973	15/07/2009	Silica as SiO2 soluble (mg/L)	97	2	9	13	17	39	13	5
19/03/1990	15/07/2009	Zinc as Zn soluble (mg/L)	61	0.00	0.00	0.01	0.05	0.21	0.02	0.03
01/09/1994	13/07/1999	Chlorophyll–a (ug/L)	32	0	1	6	19	130	11	23

4.7 WATER SUPPLY SYSTEM

The Dawson Valley Water Supply Scheme, operated by SunWater, is divided into the:

- upper Dawson sub-scheme and
- lower Dawson sub-scheme.

The extent of the upper Dawson sub-scheme is from the upstream limit of Glebe Weir (AMTD 356. 5 km) to the effective upstream limit of Neville Hewitt Weir (AMTD 113 km). The lower Dawson sub-scheme extends from the effective upstream limit of Neville Hewitt Weir (AMTD 113 km) to the downstream limit of Boolburra waterhole (AMTD 18. 37 km), which is near Duaringa. The Project is located within the lower Dawson sub-scheme.

The Scheme provides water for irrigation, urban water supply for the towns of Theodore, Moura, Baralaba and Duaringa, as well as supplying water to industry including coal mines, an ammonium nitrate plant and a gold mining venture (Sunwater, 2014).

Water authorities for the Dawson Valley Water Supply Scheme are separated into two types of entitlement:

- supplemented water entitlements are supplied with water from water storages; further divided into (DNRM, 2013):
  - High priority 5,579 ML
  - Medium priority 36,792 ML
  - Medium priority A 19,456 ML
- unsupplemented water entitlements access river flow on an opportunistic basis.

A summary of the key water storages in the Scheme is shown in Table 4-6.

Table 4-6 Dawson Valley Water Supply Scheme – major storages

Storage	Capacity (ML)	Constructed
Theodore Weir	4,760	1930
Orange Creek Weir	6,140	1932
Moura Weir	7,700	1946
Moura Offstream Storage	2,820	1998
Glebe Weir	17,700	1971
Neville Hewitt Weir	11,300	1976
Gyranda Weir	16,500	1987
Total	66,920	

5 PROPOSED WATER MANAGEMENT STRATEGY AND INFRASTRUCTURE

The proposed strategy for the management of surface water at the BNCOP is based on the separation of water from different sources based on anticipated water quality. The adopted principles for management of water on the site are summarised as follows:

- unaffected surface water will be diverted around disturbed areas and released from site wherever possible, minimising the capture of clean surface runoff;
- sediment-laden runoff from the overburden emplacement areas will be captured in dedicated sediment dams to improve water quality, prior to off-site release or re-use in the mine water system for water supply considerations;
- mine-affected water collected in-pit (groundwater inflow, surface runoff) and runoff from coal stockpiles and the CHPP could potentially have elevated salinity and will be captured and retained for use on-site and/or controlled off-site discharge;
- controlled discharge of excess water off site will be in accordance with the EA permit;
- water for on-site demands will be sourced preferentially from dedicated on-site mine-affected water storages. Water in these storages will be from on-site runoff and, groundwater seepage. Externally sourced raw water will be used as a supplementary supply;
- existing surface water drainage patterns will be maintained where practical to do so; and
- overburden dumps will be rehabilitated as soon as practical to minimise potential for release of sediment-laden surface runoff.

Further details of the mine site water management strategy are provided in Section 6.

A conceptual water management system layout for the BNCOP has been developed based on the water management principles described above. Figure 5.1 to Figure 5.5 show indicative locations of the key features of the mine, including infrastructure related to the management of water on the Project site for five different stages of mining (Years 3, 7, 8, 11 and 15). The main components of water-related infrastructure include:

- sediment dams to collect and treat runoff from overburden emplacement areas;
- dirty water drains to divert sediment-laden runoff from overburden emplacement areas to sediment dams;
- clean water drains to divert runoff from undisturbed catchments around areas disturbed by mining; and
- a dirty water system (including Mine Water Dam and Process Water Dam) to store water pumped out of the pit and to collect runoff from the CHPP and coal stockpile area, as well as decant water from the slimes dam area (only if required). A Slimes Dam would be required to accommodate slimes generated from the CHPP when space is unavailable for co-disposal or the capacity of the belt press filters is exceeded. The Slimes Dam would be resized and relocated over the life of the BNCOP as required. The water balance modelling has been undertaken assuming the belt press filters are utilised for the life of the mine. Notwithstanding, an indicative location for the Slimes Dam is shown on the mine layouts.

Details of proposed mine site storages, including indicative storage sizes and pumping rules are provided in Section 6.

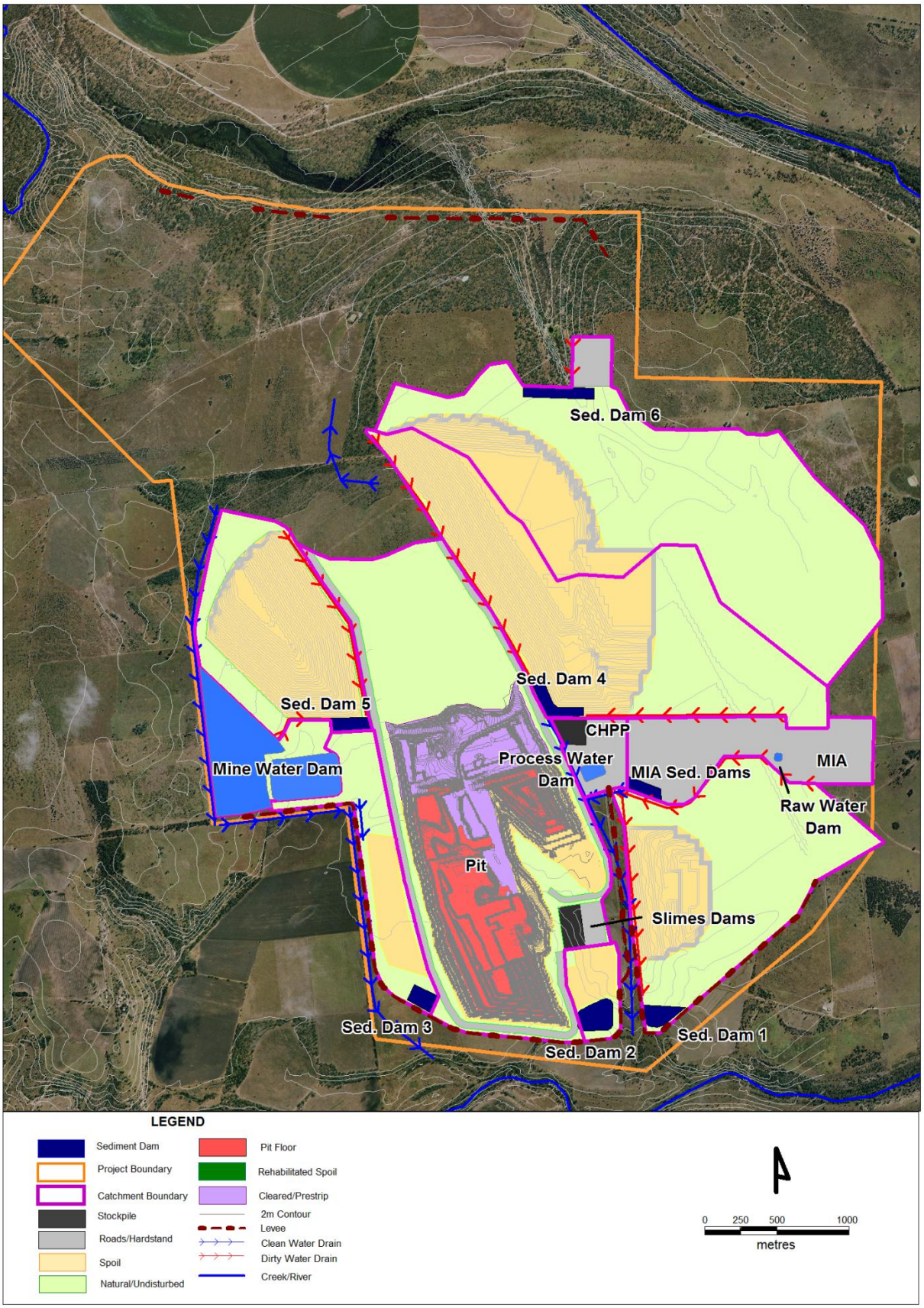

Figure 5.1 Year 3 mine plan

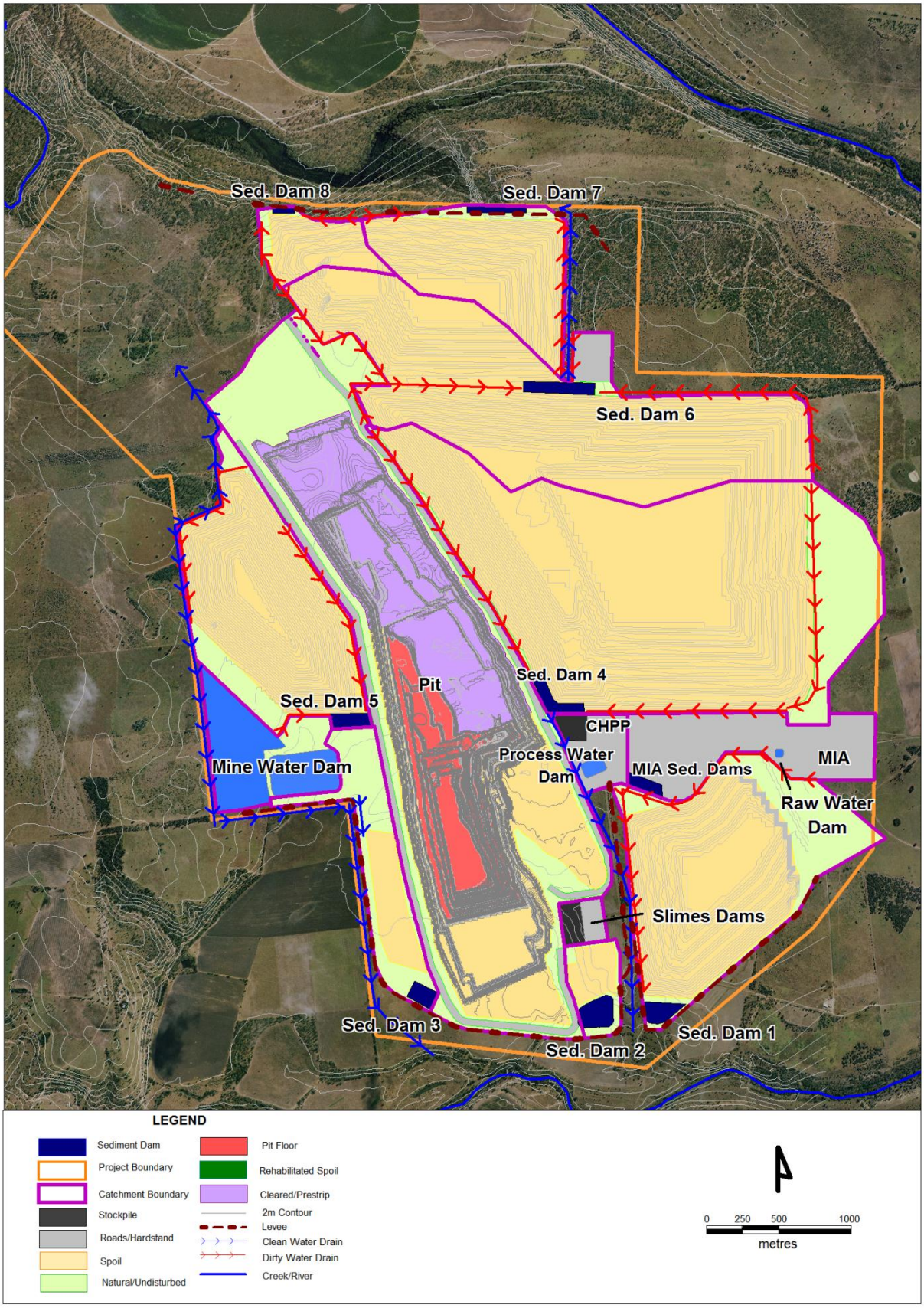

Figure 5.2 Year 7 mine plan

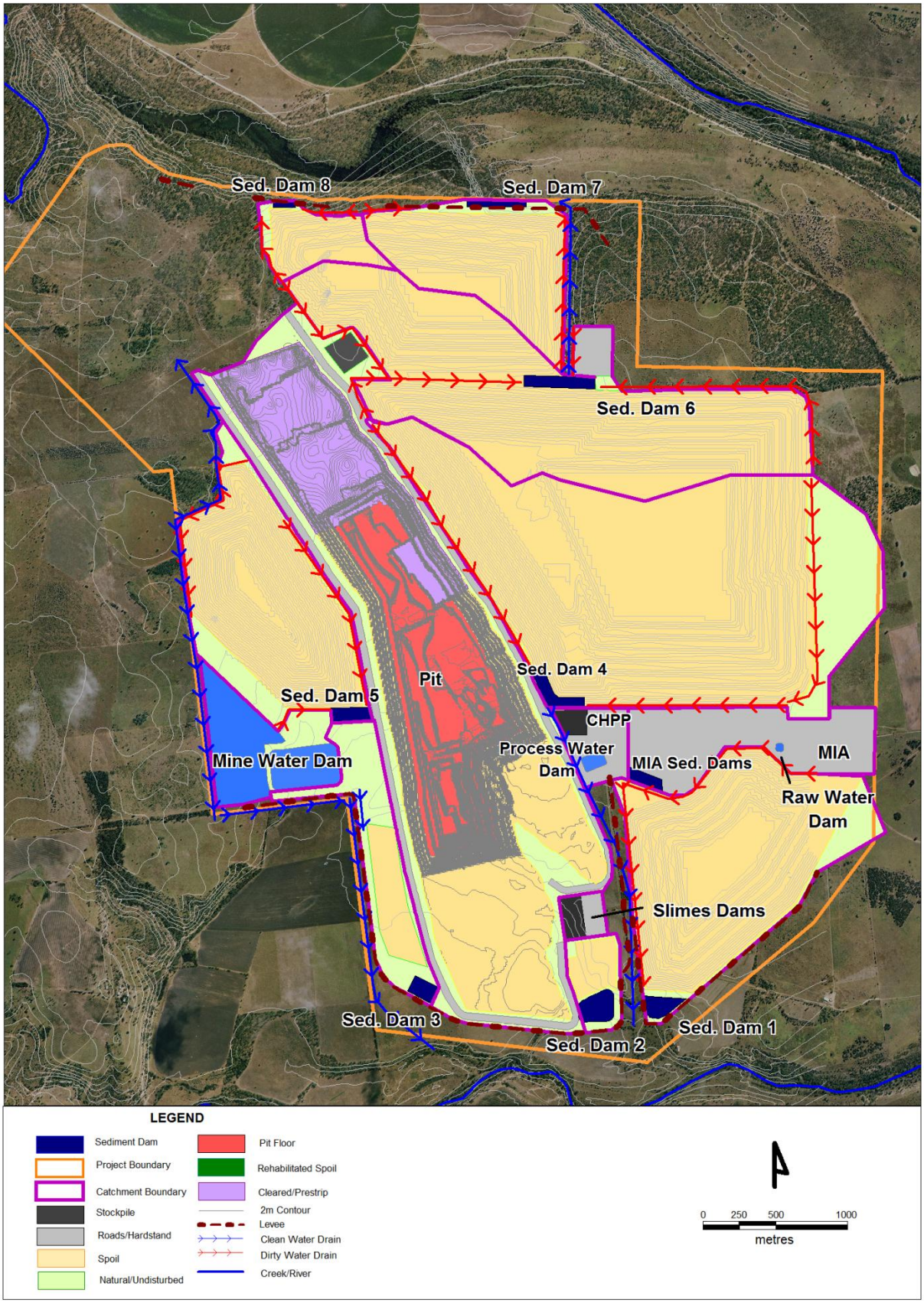

Figure 5.3 Year 8 mine plan

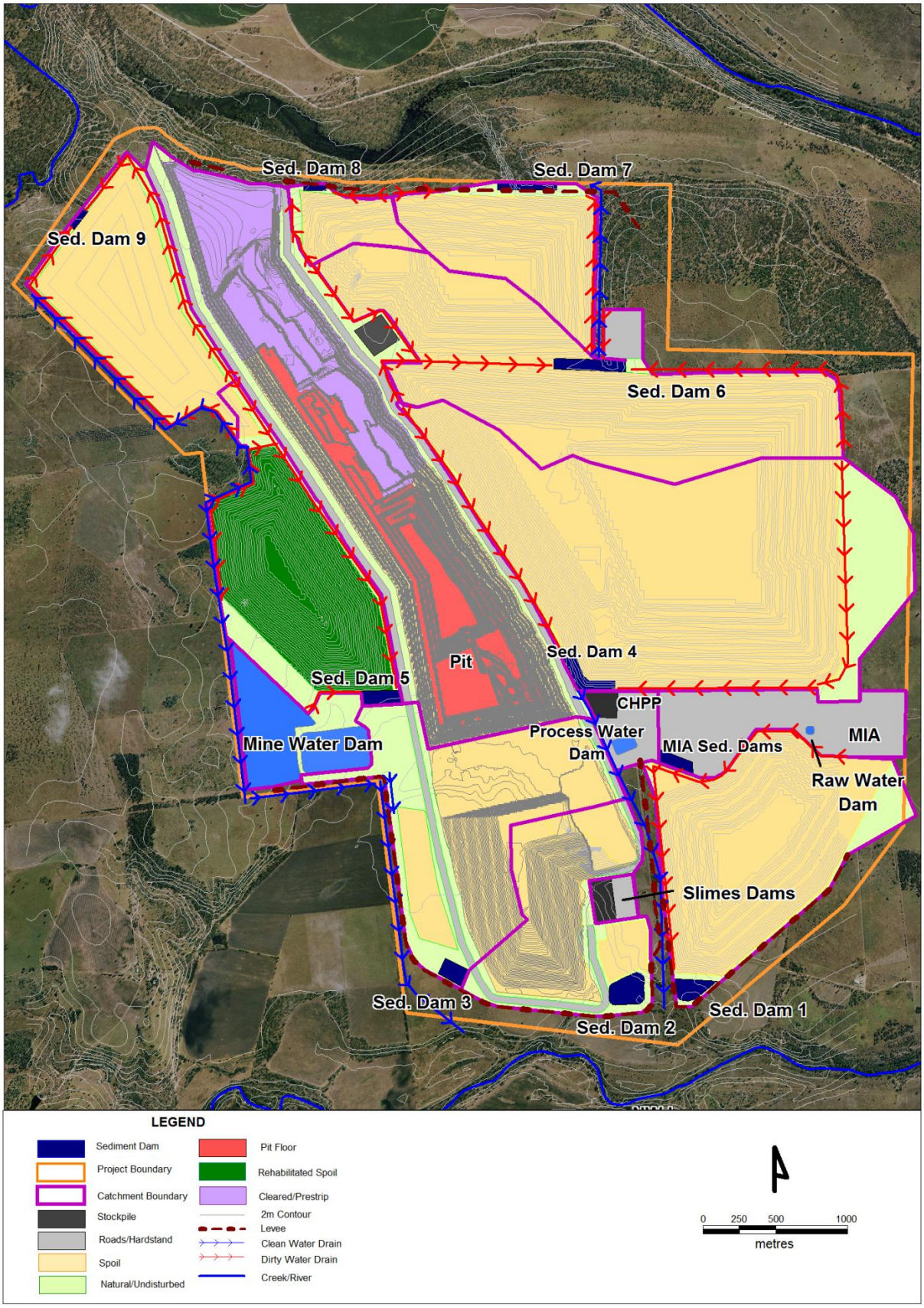

Figure 5.4 Year 11 mine plan

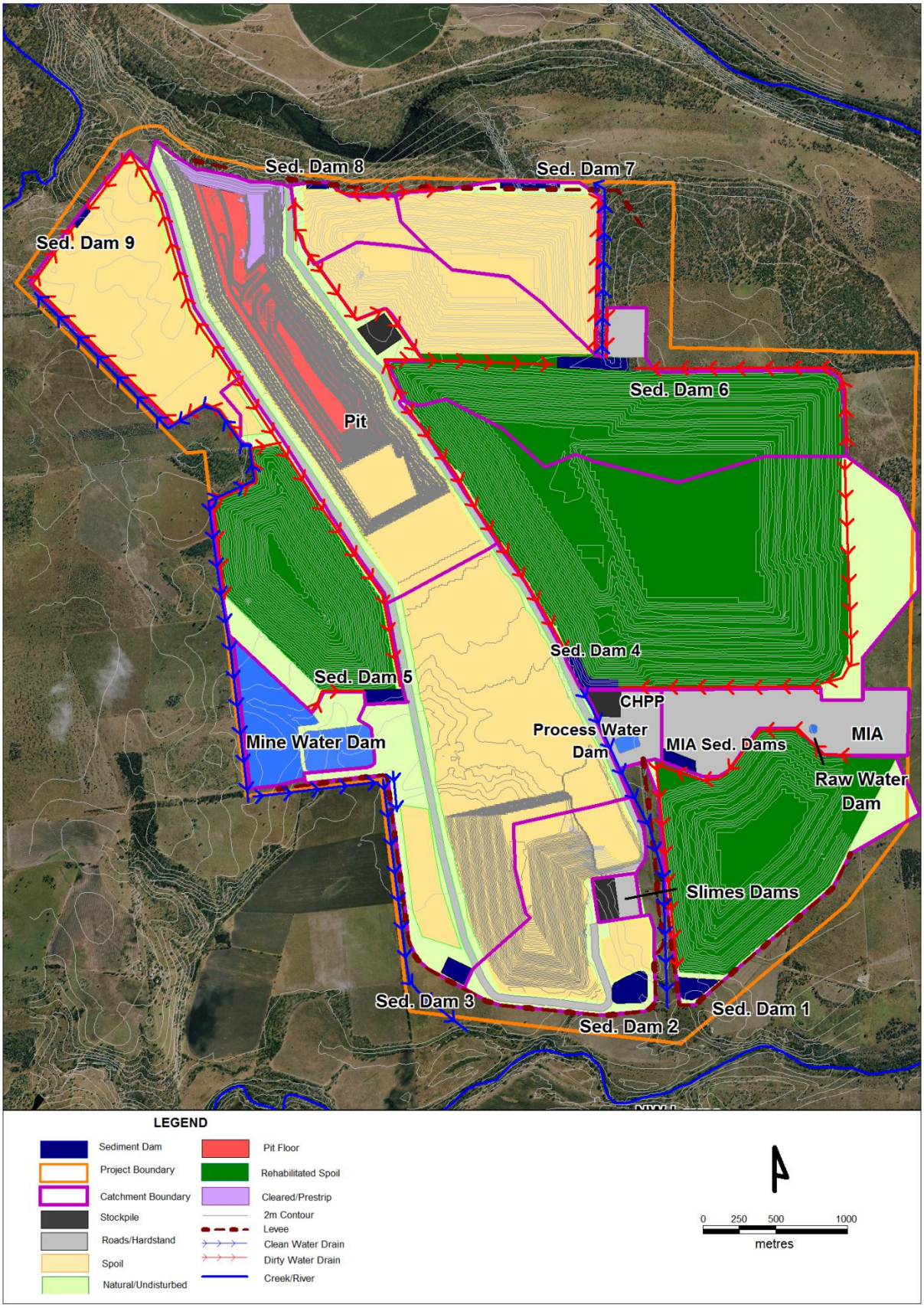

Figure 5.5 Year 15 mine plan

6 WATER BALANCE MODEL CONFIGURATION

6.1 OVERVIEW

The Operational Simulation (OPSIM) (Water Solutions Pty Ltd, 2012) model was used to assess the dynamics of the mine water balance under varying rainfall and catchment conditions throughout the progression of the Project. The OPSIM model dynamically simulates the operation of the water management system and keeps complete account of all site water volumes and representative water quality (salinity) on a daily time-step.

The model has been configured to simulate the operations of all major components of the water management system. The simulated inflows and outflows in the model are given in Table 6-1.

Table 6-1 Simulated Inflows to and outflows from the mine water management system

Inflows	Outflows
Direct rainfall on water surface of storages	Evaporation from water surface of storages
Catchment runoff	CHPP demand
Pit dewatering	Dust suppression demand
Raw water supply	Controlled releases to the Dawson River
Groundwater inflows	Washdown demand
	Off-site spills from storages

6.2 CLIMATE DATA

In order to extend the rainfall dataset for the water balance calculations, a synthetic rainfall dataset was also obtained for a location near the Project from the Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA) Data Drill service (Jeffrey et al. 2001). The Data Drill accesses grids of data "derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic. There are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia" (DSITIA, 2013). The key advantage of adopting the Data Drill data is that it has been adjusted to remove accumulated totals over multiple days and to fill periods of missing data using rainfall from nearby stations.

A comparison of mean monthly rainfall for Data Drill and the Baralaba Post Office gauge over the period Aug 1926 – July 2013 (the period of coincident rainfall) is presented in Table 6-2, which shows that the recorded and simulated rainfall data sets are comparable within a few percent.

Table 6-2 Mean monthly rainfall (Aug 1926 – July 2013)

Month	Baralaba Post Office	Data Drill
Jan	96.2	95.4
Feb	115.6	112.0
Mar	75.0	72.4
Apr	44.8	43.2
May	41.7	41.1
Jun	34.9	34.8
Jul	28.6	28.2
Aug	21.8	21.1
Sep	25.6	24.9
Oct	55.1	51.5
Nov	75.3	73.5
Dec	103.1	101.6
Total	**717.8**	**699.7**

Table 6-3 shows mean monthly evaporation recorded at the Brigalow Research Station which is located approximately 60km south of the Project. Table 6-3 also shows interpolated pan evaporation and Morton's Lake evaporation obtained from the Data Drill service for the Project area.

For water balance modelling, Morton's lake evaporation was used to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the rainfall runoff model was estimated using Morton's lake evaporation with an evapotranspiration factor of 0.98 selected to match Morton's wet environment areal evapotranspiration.

Table 6-3 Mean monthly evaporation (mm/month)

Month	Brigalow Research Station #035149 (1968-2010)	SILO Data Drill (Jan 1889 – July 2013)	
		Pan Evaporation	Morton's Lake Evaporation
Jan	245	235	206
Feb	201	192	172
Mar	205	197	171
Apr	165	156	133
May	118	118	99
Jun	93	94	77
Jul	99	102	86
Aug	127	129	113
Sep	174	171	147
Oct	214	211	184
Nov	228	225	198
Dec	245	240	212
Total (mm/y)	**2,113**	**2,069**	**1,798**

6.3 CONCEPTUAL WATER MANAGEMENT SYSTEM CONFIGURATION AND SCHEMATIC

A conceptual water management system layout for the BNCOP has been developed based on the water management principles described in Section 5 and shown in Figure 5.1 to Figure 5.5 . A conceptual plan for the modelled BNCOP water management system configuration is shown in Figure 6.1.

Note that the Baralaba Coal Mine operations are not included in the site water balance model. It is assumed that the BNCOP project operates independently of Baralaba Coal Mine with no water connection between the two sites. It is also assumed that no controlled releases will occur from the Baralaba Coal Mine, with all release opportunities under the Environmental Authority available to BNCOP.

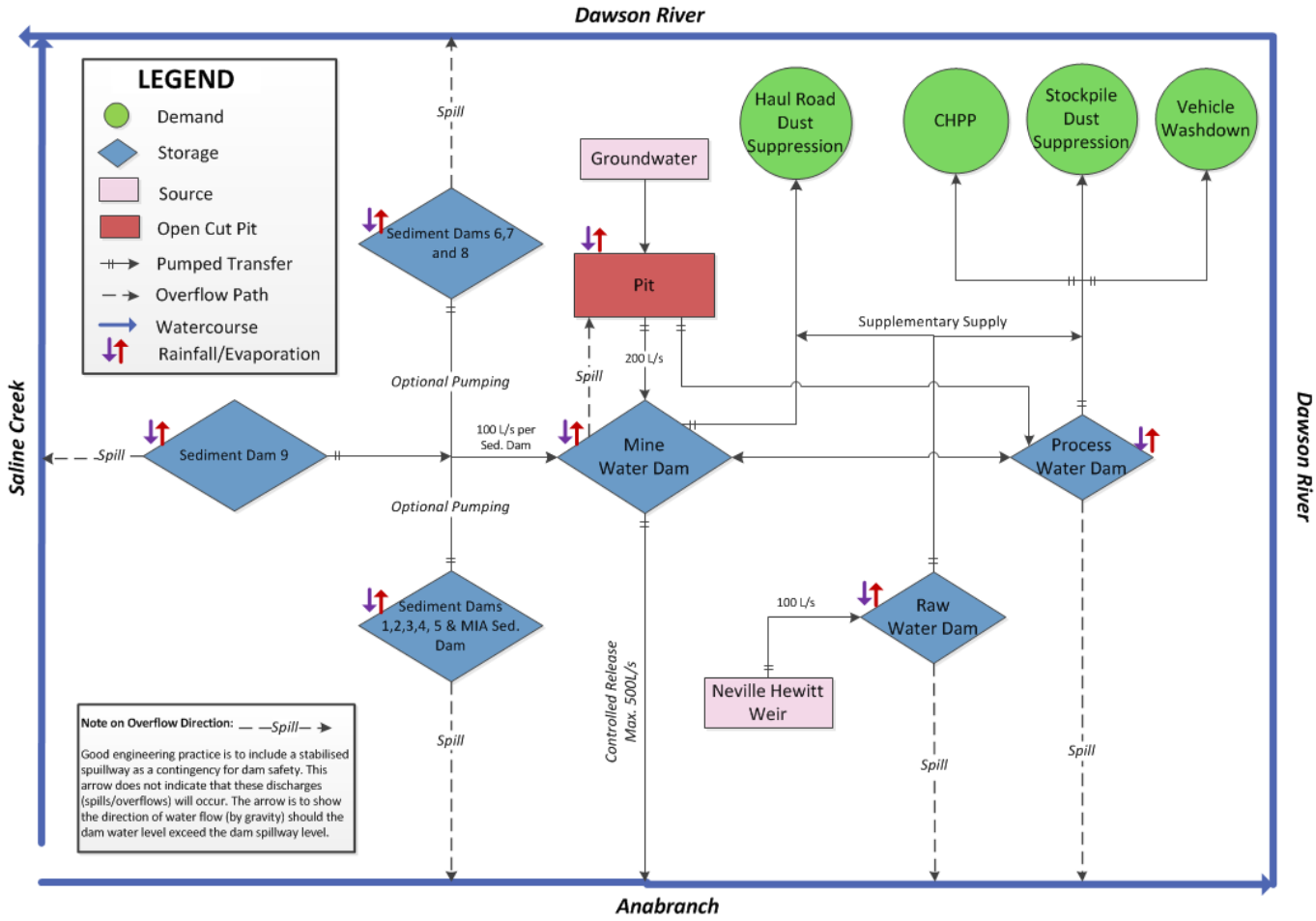

Figure 6.1 Water management system schematic

6.4 SIMULATION METHODOLOGY

6.4.1 Modelled Staging of Mine Plan

Mine plans for the Project have been provided for each of the 15 years of operation. Five representative years have been selected to reflect the mine progression, as shown in Figure 5.1 to Figure 5.5. The operational rules and physical layout for each representative stage of mine progression are applied to a range of years as shown in Table 6-4.

Table 6-4 Application of representative mine stages to full mine life

Representative Mine Stage	Equivalent Mine Plan	Applied Range to Mine Life
Stage 1	Year 3	Year 1 – Year 4
Stage 2	Year 7	Year 5 – Year 7
Stage 3	Year 8	Year 8 – Year 9
Stage 4	Year 11	Year 10 – Year 12
Stage 5	Year 15	Year 13 – Year 15

6.4.2 Simulation Methodology

The simulation used the 'forecast' simulation type in the OPSIM model. The model run duration is 15 years as per the mine plans, incorporating five different representative stages of mine life as described above. Although the catchment areas will continuously change as the Project progresses, the adopted approach of modelling discrete stages provides a reasonable representation of site conditions over the 15 year period.

The forecast simulation allows the model configuration to change over the modelled 15 year mine life by linking the representative stages shown in Table 6-4, reflecting variations in the water management system over time such as catchments, ROM coal production and groundwater seepage.

The changes in the physical layout and site catchment areas are shown in the mine stage plans in Figure 5.1 to Figure 5.5. The operational rules at each modelled stage are summarised in Table 6-5.

To assess the effects of varying climatic conditions, the forecast model is run for 110 realisations (with each realisation corresponding to the 15 year mine life), using 124 years of simulated climatic and streamflow data available from January 1889 to December 2012. A different rainfall input sequence is applied to each realisation. The first realisation adopts climatic data from 1889 to 1903, the second from 1890 to 1904 and so on through the 124 years of simulated climatic and streamflow data. A percentile analysis of the resultant 110 realisations can then be undertaken at user-defined confidence intervals to assess the behaviour of the various storages over extended dry and wet periods, reflecting the full range of climatic conditions experienced in the last 124 years.

Table 6-5 Water management system operating rules

Item	Name	Operating Rules
1	**External Water Supply**	
1.1	Neville Hewitt Weir	Supplies to Raw Water Dam as required (100 L/s).
2	**Water Demands**	
2.1	CHPP	Primary supply from Process Water Dam. Secondary supply from Raw Water Dam.
2.2	Haul Road Dust Suppression	Primary supply from Mine Water Dam. Secondary supply from Raw Water Dam.
2.3	Stockpile Dust Suppression	Primary supply from Process Water Dam. Secondary supply from Raw Water Dam.
2.4	Vehicle Wash-down	Primary supply from Process Water Dam. Secondary supply from Raw Water Dam.
3	**Active Mining Areas**	
3.1	Pit	Continuous dewatering primarily directed to Process Water Dam (until maximum operating level is reached) - 100L/s. Continuous dewatering is directed to the Mine Water Dam (up to its maximum operating volume of 1,100ML) when Process Water Dam is at its maximum operating level - 200L/s. Receives groundwater inflows. Receives storage overflows from Mine Water Dam.
4	**Water Storages**	
4.1	Mine Water Dam	Supplies water to Process Water Dam to meet demands (100 L/s). Supplies haul road dust suppression demand. Receives dewatering from pit (up to its maximum operating volume of 1,100 ML) when Process Water Dam is at maximum operating level. Controlled release to Dawson River Anabranch when inventory is above trigger volume of 400 ML and release conditions are satisfied. Receives pumped transfers from sediment dams as required. Overflows to Pit.[a]
4.2	Raw Water Dam	Receives inflows from Neville Hewitt Weir (100 L/s). Supplementary water source for Vehicle Wash-down, dust suppression and CHPP. Overflows to Anabranch.[a] Turkey's nest dam.
4.3	Process Water Dam	Supplies water to CHPP. Supplies water for vehicle wash-down and stockpile dust suppression. Receives runoff from the coal stockpile and CHPP. Receives pumped transfers from the active pit (100L/s) – primary source. Receives pumped transfers from the Mine Water Dam (100L/s) – secondary source. Transfers back to Mine Water Dam when high alarm level is reached, to prevent uncontrolled spills. Overflows to Anabranch.[a]

Item	Name	Operating Rules
4.4	Sediment Dams 1, 2, 3, 4, 5 & MIA sed. dam	Dewatered to Mine Water Dam (100 L/s) – subject to water supply requirements.[b] Overflows to Anabranch.
4.5	Sediment Dams 6, 7 & 8	Dewatered to Mine Water Dam (100 L/s) – subject to water supply requirements.[b] Overflows to Dawson River.
4.6	Sediment Dam 9	Dewatered to Mine Water Dam (100 L/s) – subject to water supply requirements.[b] Overflows to Saline Creek.
5	Receiving Waters	
5.1	Anabranch	Receives storage overflows from Raw Water Dam, Process Water Dam and Sediment Dams 1, 2, 3, 4, 5 & MIA Sed. Dam. Receives controlled releases from Mine Water Dam when its inventory is above trigger volume of 400ML and release conditions are satisfied.
5.2	Dawson River	Receives storage overflows from Sediment Dams 6, 7 & 8.
5.3	Saline Creek	Receives storage overflows from Sediment Dam 9.
6	General	
6.1	Climate	All storages and pits receive direct rainfall, local catchment runoff and lose water through evaporation.

[a] Modelled results show no spills for any of the modelled realisations – refer to Section 8.3.7.
[b] Sediment dams are dewatered to the Mine Water Dam when it is below an inventory trigger of 555 ML. When the Mine Water Dam inventory exceeds this volume, dewatering of the sediment dams into the Mine Water Dam ceases. Sediment dams are operated in accordance with Best Practice Erosion and Sediment Control Guideline (BPESC) guideline.

6.5 CONTROLLED RELEASES

6.5.1 Controlled Discharge Release Criteria

The controlled release strategy for BNCOP, specified in the EA permit (Permit Number EMPL00617113), is incorporated in the water balance modelling operational rules. Table C1 of the permit specifies the release point (RPN2), sources and receiving waters. The location of RPN2 is shown in Figure 10.1. Table C4 of the permit specifies the EC and flow criteria for controlled discharges, which are summarised in Table 6-6. The model assumes all flow releases are made at the maximum release rate of 0.5 m^3/s.

Table 6-6 Controlled release rules

Receiving Water Flow Criteria for Discharge	End-of-pipe Electrical Conductivity for Release
Low Flow <5 m^3/s for a period of 28 days after natural flow events that exceed 5 m^3/s	Electrical conductivity: < 340 µS/cm
Medium Flow > 5 m^3/s	Electrical conductivity: < 500 µS/cm
> 24 m^3/s	Electrical conductivity: < 1,500 µS/cm
> 53 m^3/s	Electrical conductivity: < 3,000 µS/cm
> 92 m^3/s	Electrical conductivity: < 5,000 µS/cm
High Flow > 140 m^3/s	Electrical conductivity: < 7,500 µS/cm
> 190 m^3/s	Electrical conductivity: < 10,000 µS/cm

Note: Release rate = 0.5 m^3/s

6.5.2 Simulated Dawson River Streamflow

Release of water from the mine water management system is dependent upon streamflow in the Dawson River. Hence, a long term simulation of the mine water management system requires a long term river streamflow sequence. A synthetic streamflow dataset for the Dawson River at Beckers (representing existing infrastructure) was obtained from the Dawson River IQQM model (DSITIA, 2013) for the period 1889 to 2012.

Figure 6.2 shows the recorded flow frequency relationship for streamflow recorded (Aug 1964 – 2013) and simulated (1889 – 2012) at Dawson River at Beckers (#130322A). The flow frequency relationship for the recorded streamflow for the period prior to and post construction of the Neville Hewitt Weir is also shown.

Under the flow release rules specified in Section 6.5.1, releases can only be made when the flow in the Dawson River is at least 5 m^3/s. Figure 6.2 shows that above 5 m^3/s, the flow frequency relationship of the long term simulated flow sequence for the Dawson River is comparable to the recorded data, hence the synthetic data set is considered acceptable for use in the modelling of controlled releases from BNCOP.

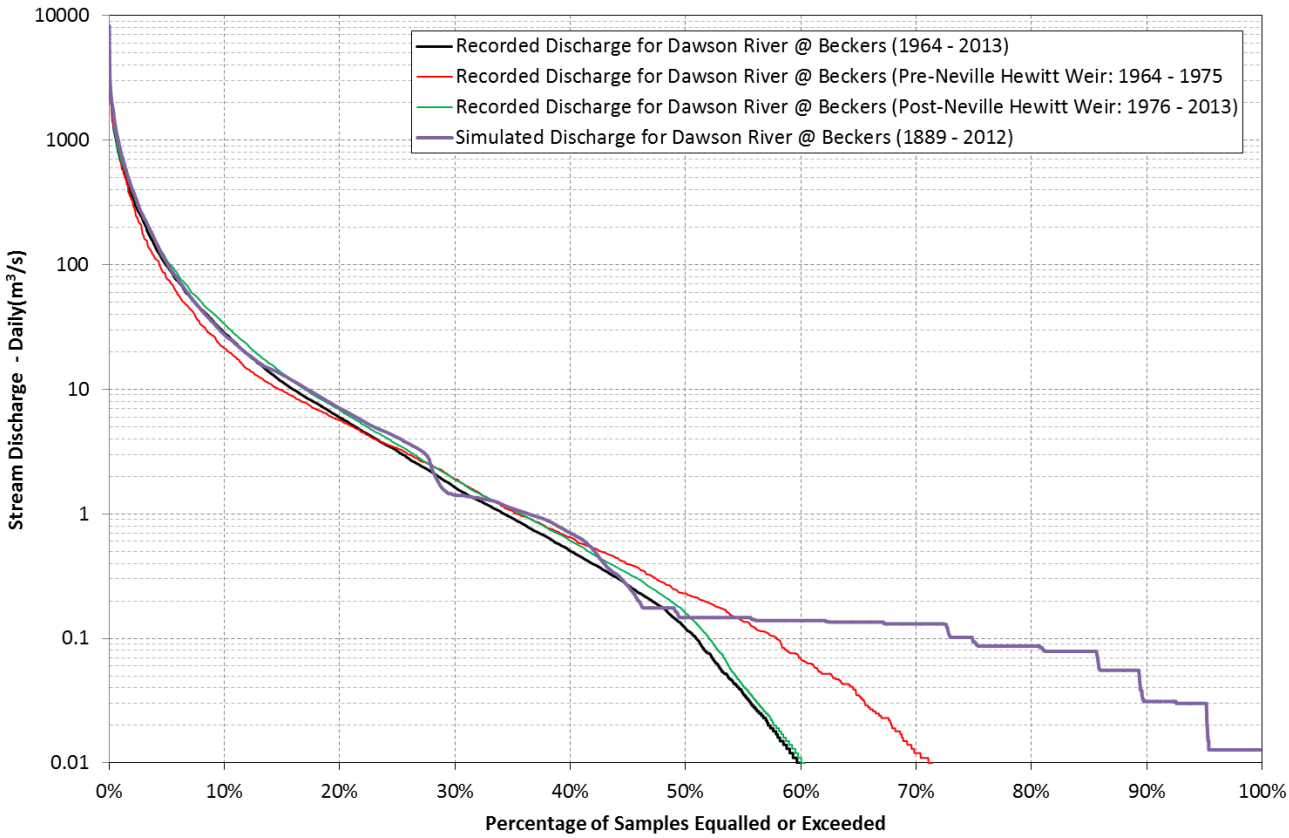

Figure 6.2 Dawson River at Beckers (#130322A) flow frequency relationship

6.5.3 Simulated Dawson River Water Quality

Historical salinity data (electrical conductivity) for the Beckers gauge is available for the period August 1993 to current. To extend the salinity dataset (to complement the long term simulated streamflow at the Beckers gauge), a long term synthetic salinity data set for the Dawson River at Beckers has been obtained from the IQQM model for the period 1889 to 2012 (DSITIA, 2013). Figure 6.3 shows the cumulative salt load for the recorded historical data set and for the simulated IQQM data set for the common period of record. The analysis assumed that, for the recorded salinity data set, the correlation between electrical conductivity and TDS was TDS = 0.68 x EC. Where the recorded data set had periods of missing data, the same periods were removed from the simulated data set.

Figure 6.3 shows that the IQQM simulation of the Dawson River overestimates the salt load at the Beckers gauge. Applying a constant scaling factor of 0.8 to the simulated salinity data set provides a good fit with the recorded salinity data set over the common period of record, as shown in Figure 6.4. This scaling factor of 0.8 has been applied to the full IQQM salinity data set for Dawson River salinity to obtain a suitable long term salinity data set for use in the OPSIM model.

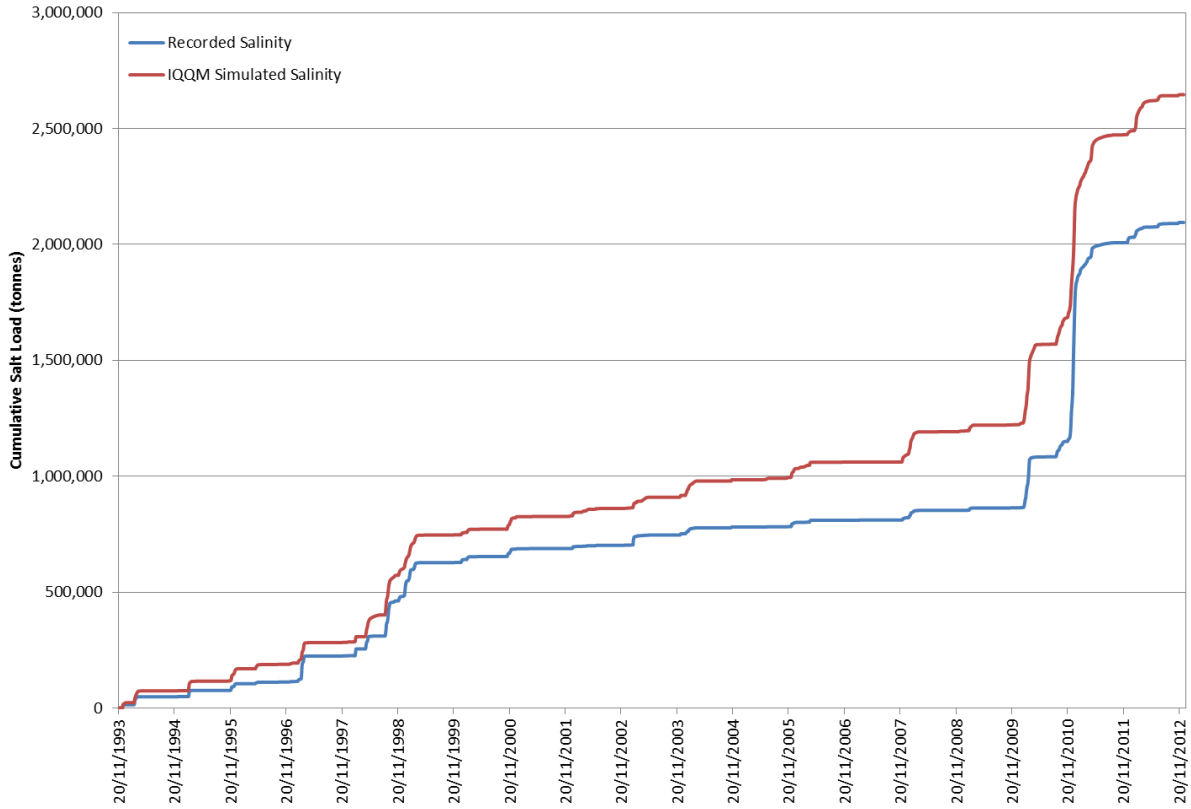

Figure 6.3 Comparison of recorded and simulated salt load at the Beckers stream gauge (#130322A)

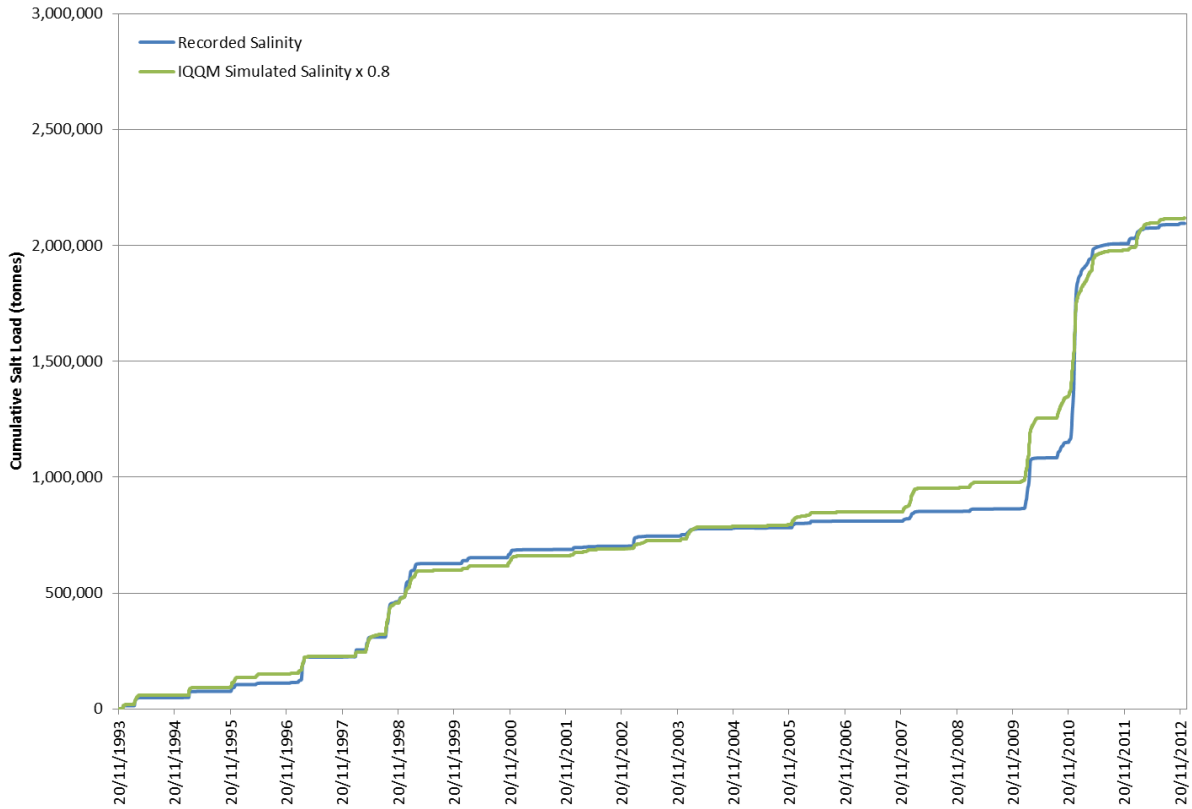

Figure 6.4 Comparison of recorded and scaled salt load at the Beckers stream gauge (#130322A)

6.6 SITE WATER DEMANDS

6.6.1 Overview

Project site demands include:

- Coal Handling and Preparation Plant (CHPP);
- haul road dust suppression;
- stockpile dust suppression; and
- vehicle washdown.

6.6.2 Coal Handling and Preparation Plant (CHPP)

Total daily process water demand for the Project (inclusive of recycle) has been estimated at 1.4 ML/d, or 511 ML/yr (BECA, 2013). The average net water demand for the Project (exclusive of recycle) over the 15 year mine life has been estimated at 211 ML/yr (Cockatoo Coal, 2013). These CHPP demand estimates equate to a recycle rate for the CHPP of approximately 60%.

Using the predicted annual production schedule, it was calculated that a net CHPP water demand of 132 L/tonne of processed ROM coal was required to achieve an average demand rate over the life of the Project of 211 ML/yr (as per the Supplementary Bankable Feasibility Study (CCL, 2013)). Table 6-7 shows the production schedule and the net CHPP makeup requirement for the representative mine stages. The adopted CHPP makeup rates for water balance modelling are the average for each representative stage, as shown in Table 6-7 and Figure 6.5. CHPP demand is sourced from the Process Water Dam as first priority, and the Raw Water Dam to meet any deficit in supply.

Table 6-7 CHPP water demands

Years of Mine Life	ROM Coal Mined (Mtpa)	ROM Coal Bypass (Mtpa)	ROM Coal Processed (Mtpa)	Net CHPP Makeup Requirement (ML/yr)	Representative Mine Stage	Average CHPP Demand for each Representative Mine Stage (ML/yr)
1	1.1	0.7	0.5	59	Year 3	103
2	3.1	2.4	0.7	96		
3	3.6	2.4	1.2	158		
4	4.1	3.3	0.8	100		
5	3.9	3.3	0.5	71	Year 7	136
6	3.4	2.2	1.1	147		
7	3.6	2.1	1.5	191		
8	4.1	2.7	1.4	185	Year 8	218
9	4.0	2.1	1.9	251		
10	3.9	2.0	1.9	250	Year 11	297
11	3.6	1.2	2.4	313		
12	4.0	1.5	2.5	329		
13	4.1	1.4	2.6	345	Year 15	339
14	2.1	0.4	1.7	226		
15	3.8	0.4	3.4	446		

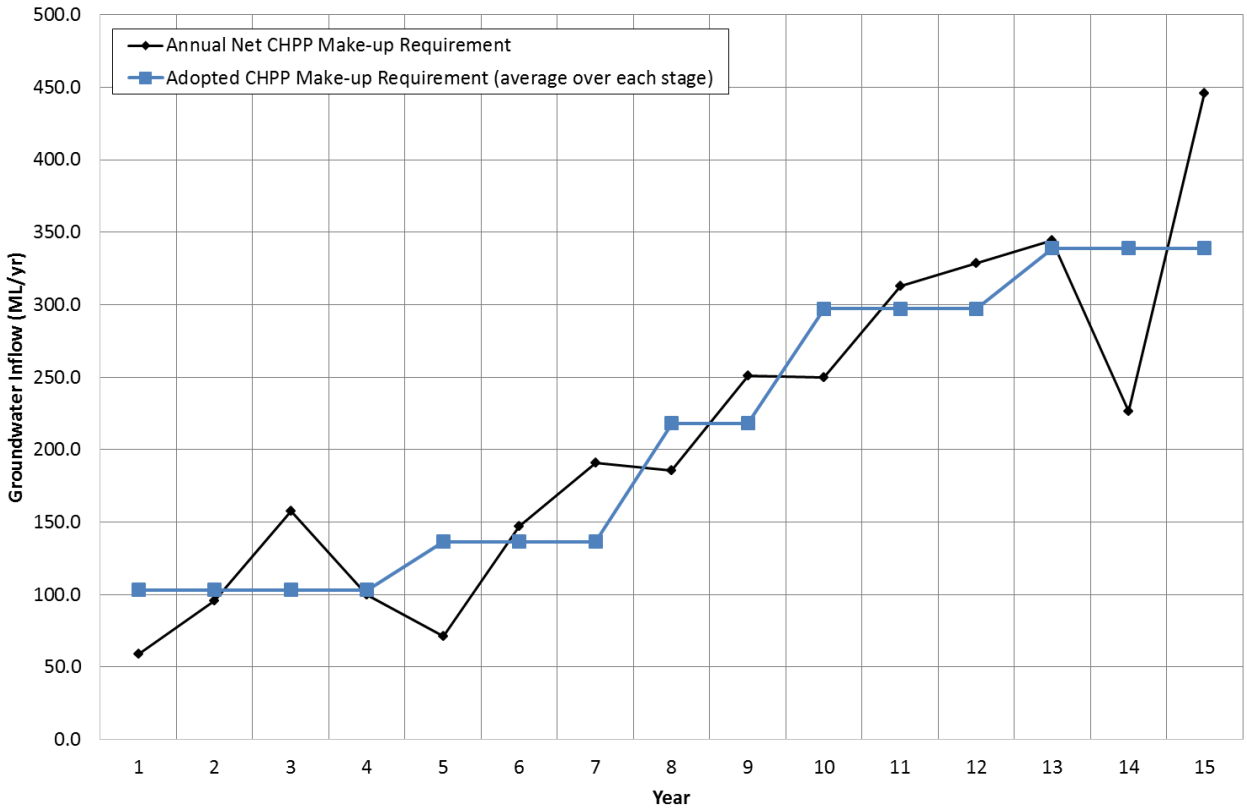

Figure 6.5 Adopted CHPP make-up requirement

6.6.3 Dust Suppression

Dust suppression watering rates need to be sufficient to replace evaporative losses. The evapotranspiration rate in the project area is approximately 1,770 mm/yr (based on a long term average of SILO Data Drill Morton's Wet evapotranspiration for the site), which equates to 4.8 mm/d. It is proposed to adopt a maximum dust suppression watering rate (for a dry day) of 4.8 mm/d for water balance modelling.

A daily time series of dust suppression water requirements was developed for water balance modelling, assuming that:

- on days on which the rainfall depth is greater than 5 mm/d, no dust suppression will be required;
- when daily rainfall is less than 5mm/d, the maximum rate of 4.8 mm/d is interpolated linearly with rainfall; and
- when there is no daily rainfall, the maximum dust suppression watering rate of 4.8 mm/d is applied.

Dust suppression watering rates were calculated based on the SILO Data Drill daily rainfall time series. The resultant long term average daily dust suppression watering rate of the adopted dataset (including rainfall days) is 4.1 mm/d.

This method allows for seasonal variation in dust suppression water application rates based on rainfall variability. Since the adopted dust suppression time series is linked to the daily rainfall, the impact on dust suppression water demand during wet and dry periods in the climate record is incorporated in the water balance assessment.

Dust suppression demand has been calculated for internal heavy vehicle haul roads, light vehicle hauls roads and coal stockpiles, based on the following:

- The dust suppression requirement for internal heavy vehicle haul roads and for product haul roads was calculated based on the haul road lengths shown in Table 6-8 and watered road widths of 20 m and 9 m, respectively;
- The dust suppression requirement for coal stockpiles was calculated based on the areas shown in the provided mine plans.

Note that CCL has made the commitment to seal Middle Road, hence dust suppression will not be required.

The resultant average of the adopted daily time series dust suppression demand is presented in Table 6-8. Dust suppression is sourced from the Mine Water Dam as a priority, and the Raw Water Dam to meet any deficit in supply.

Table 6-8 Estimated haul road & stockpile dust suppression requirements

Mining Stage	Haul Roads					Coal Stockpiles		
	Road Length (km)		Total Area (ha)	Max. Total Daily Dust Suppression (ML/d)[a]	Yearly Average Total Dust Suppression (ML/yr)[b]	Area (ha)	Max. Total Daily Dust Suppression (ML/d)[a]	Yearly Average Total Dust Suppression (ML/yr)[b]
	Heavy Vehicle	Product Haul						
3	15.7	13.7	43.7	2.1	657	12.7	0.6	191
7	27.0	13.7	66.3	3.2	997	12.7	0.6	191
8	27.0	13.7	66.3	3.2	997	17.3	0.8	260
11	23.6	13.7	59.5	2.9	894	17.3	0.8	260
15	23.6	13.7	59.5	2.9	894	17.3	0.8	260

[a] For a non-rainfall (0mm) day.
[b] Based on long-term average including rainfall days.

6.6.4 Vehicle Washdown

Vehicle washdown has been estimated conservatively (high) to be approximately 30 kL/d (11 ML/yr) from the Process Water Dam as a priority, and from the Raw Water Dam to meet any deficit in supply (CCL, 2013).

6.6.5 Demand summary

A summary of the Project site water demands is shown in Table 6-9.

Table 6-9 Summary of site demands – net usage

Mining Stage (Year)	Haul Road Dust Suppression (ML/yr)	Stockpile Dust Suppression (ML/yr)	CHPP Net Demand (ML/yr)	Net Vehicle Washdown (ML/yr)	Total Site Demand (ML/yr)
3	657	191	103	11	**962**
7	997	191	136	11	**1,335**
8	997	260	218	11	**1,486**
11	894	260	297	11	**1,462**
15	894	260	339	11	**1,504**

6.7 SITE WATER SOURCES

6.7.1 Pit Groundwater Inflows

Estimates of annual groundwater inflow volumes to the open cut pit for the life of the Project were provided by groundwater consultants HydroSimulations (2014) and are shown in Figure 6.6 . The adopted groundwater inflow rates for water balance modelling are the average for each representative stage, as shown in Table 6-10. Evaporation of groundwater from the open cut pit walls was taken into account with an assumed loss of 0.1 ML/d (36.5 ML/yr), as shown in Figure 6.6 and in Table 6-10. Open water evaporation from water accumulating in the open cut pit is accounted for in the OPSIM model.

Table 6-10 Adopted groundwater inflows

Years of Mine Life	Total Groundwater Intercepted ML/yr	Representative Mine Stage	Average groundwater intercepted for each Representative Mine Stage ML/yr	Average groundwater inflow (accounting for evaporation from open cut pit walls) ML/yr
1	1,094	Year 3	917	881
2	674			
3	846			
4	1,056			
5	1,110	Year 7	1,003	967
6	1,010			
7	890			
8	881	Year 8	966	929
9	1,051			
10	958	Year 11	1,053	1,016
11	1,344			
12	856			
13	1,001	Year 15	899	863
14	933			
15	764			

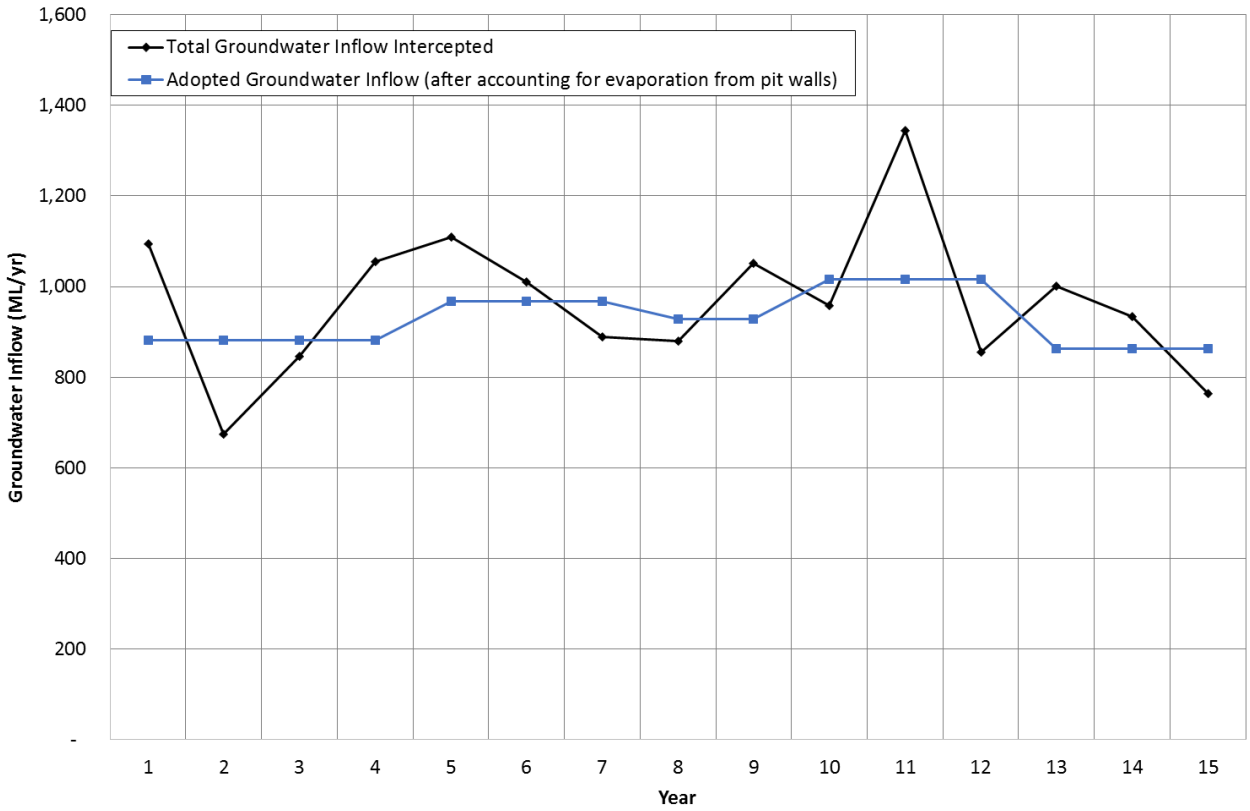

Figure 6.6 Groundwater inflows

6.7.2 Catchment Runoff

Catchment Yield Parameters

The OPSIM model uses the Australian Water Balance Model (AWBM) (Boughton WC, 1993) to estimate runoff from rainfall. The AWBM is a saturated overland flow model which allows for variable source areas of surface runoff.

The AWBM uses a group of connected conceptual storages (three surface water storages and one ground water storage) to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation. Simulated surface runoff occurs when the storages fill and overflow. The model uses daily rainfalls and estimates of catchment evapotranspiration to calculate daily values of runoff using a daily water balance of soil moisture. The model has a baseflow component which simulates the recharge and discharge of a shallow subsurface store. Runoff depth calculated by the AWBM model is converted into runoff volume by multiplying by the contributing catchment area.

The model parameters define the storage depths (C1, C2 and C3), the proportion of the catchment draining to each of the storages (A1, A2 and A3), and the rate of flux between them (K_b, K_s and BFI) (Boughton and Chiew, 2003). Catchments across the site have been characterised into the following land use types, adopted from previous surface water investigations (WRM, 2013):

- natural / undisturbed
- roads / industrial / hardstand
- spoil
- mining Pit

- rehabilitated spoil
- cleared/prestrip
- stockpile

The model parameters shown in Table 6-11 are based on previous work undertaken for Baralaba Coal Mine (WRM, 2013) which included calibration to recorded site data. An additional land use type was added to reflect pre-strip areas which were assumed to produce a volume of runoff between natural and industrial/hardstand.

Table 6-11 Adopted AWBM parameters for various catchment types

Parameter	Natural/ Undisturbed	Roads/ Industrial/ Hardstand	Spoil	Mining Pit	Rehabilitated Spoil	Cleared/ Prestrip	Stockpile
A1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
A2	0.4	0.9	0.4	0.9	0.4	0.9	0.9
A3	0.4	0	0.5	0	0.5	0	0
C1	60	12	40	12	40	24	12
C2	90	38	140	38	140	76	38
C3	180	0	240	0	240	0	0
BFI	0	0	0.9	0	0.9	0	0
K_b	0	0	0.95	0	0.95	0	0
K_s	0	0	0	0	0	0	0
Long Term Volumetric Runoff Coefficient	8%	24%	5.1%	24%	5.1%	12.6%	24%

Catchment Areas

Adopted catchment areas draining to the open cut pit and the various storages represented in the mine site water balance are shown in Figures 6.1 to 6.5 and provided in Table 6-12. Note that recharge through spoil dumped in-pit has been excluded from the water balance model, as this component is already accounted for in the groundwater modelling (i.e. it is included in the adopted groundwater inflows). This only affects the pit, Sediment Dam 2 and Sediment Dam 3 catchments.

Table 6-12 Catchment areas and land types

Storage	Contributing Catchment							
	Natural/ Undisturbed	Roads/ Industrial/ Hardstand	Spoil	Mining Pit	Rehabilitated Spoil	Cleared/ Prestrip	Stockpile	Total
Year 3								
Mine Water Dam	9.3	45.6						54.9
Pit (surface + baseflow)	142.0	42.4		88.4		66.0	4.5	343.2
Pit (surface only)			54.5					54.5
Process Water Dam		17.9					3.6	21.6
MIA Sed Dams		73.6						73.6
Sed Dam 1	142.1		46.7					188.8
Sed Dam 2	10.6		10.8					21.4
Sed Dam 3	40.8		20.3					61.1
Sed Dam 4	100.6		146.4					246.9
Sed Dam 5	38.5		89.0					127.4
Sed Dam 6	264.8	9.2	71.8					345.8
Year 7								
Mine Water Dam	9.2	50.2					4.5	63.9
Pit [a]	114.1	50.8		79.9		153.9		398.7
Pit [b]			135.8					1.35.8
Process Water Dam		17.9					3.7	21.6
MIA Sed Dams		73.6						73.6
Sed Dam 1	54.1		134.7					188.8
Sed Dam 2	10.7		10.8					21.4
Sed Dam 3	40.8		20.3					61.1
Sed Dam 4	64.1		362.5					426.6
Sed Dam 5	30.1		122.6					152.7
Sed Dam 6	9.2		269.6					278.8
Sed Dam 7	8.8		85.7					94.5
Sed Dam 8	4.2		26.6					30.8
Year 8								
Mine Water Dam	9.2	50.2					4.5	63.9
Pit [a]	73.9	53.3		122.4		105.0	4.6	359.1
Pit [b]			178.8					178.8
Process Water Dam		17.9					3.7	21.6
MIA Sed Dams		73.6						73.6
Sed Dam 1	25.7		169.2					194.8
Sed Dam 2	10.7		10.8					21.4
Sed Dam 3	40.8		20.3					61.1

Storage	Contributing Catchment							
	Natural/ Undisturbed	Roads/ Industrial/ Hardstand	Spoil	Mining Pit	Rehabilitated Spoil	Cleared/ Prestrip	Stockpile	Total
Sed Dam 4	64.1		362.5					426.6
Sed Dam 5	30.1		122.6					152.7
Sed Dam 6	1.6	9.2	269.6					280.3
Sed Dam 7	8.8		85.7					94.5
Sed Dam 8	4.2		26.6					30.8
Year 11								
Mine Water Dam	9.2	50.2					4.5	63.9
Pit [a]	51.8	40.5		108.9		126.0	4.6	330.9
Pit [b]			76.9					76.9
Process Water Dam		17.9					3.7	21.6
MIA Sed Dams		73.6						73.6
Sed Dam 1	25.7		169.2					194.8
Sed Dam 2 [a]	24.2	11.4	20.9					56.4
Sed Dam 2 [b]			71.0					71.0
Sed Dam 3 [a]	50.8	11.9	20.2					82.9
Sed Dam 3 [b]			103.0					103.0
Sed Dam 4	64.1		362.5					426.6
Sed Dam 5	31.2		4.0		122.6			157.8
Sed Dam 6	1.6	9.2	269.6					280.3
Sed Dam 7	8.8		85.7					94.5
Sed Dam 8	4.2		26.6					30.8
Sed Dam 9	20.6		110.7					131.3
Year 15								
Mine Water Dam	9.2	50.2					4.5	63.9
Pit	42.5	30.6	118.6	70.1		20.0	4.6	286.5
Process Water Dam		17.9					3.7	21.6
MIA Sed Dams		73.6						73.6
Sed Dam 1	25.7				169.2			194.8
Sed Dam 2 [a]	24.2	11.4	20.9					56.5
Sed Dam 2 [b]			71.0					71.0
Sed Dam 3 [a]	60.6	21.8	20.3					102.8
Sed Dam 3 [b]			206.9					206.9
Sed Dam 4	64.1				362.5			426.6
Sed Dam 5	31.2		4.0		122.6			157.8
Sed Dam 6		9.2	83.5		186.0			278.8
Sed Dam 7	8.8		85.7					94.5
Sed Dam 8	4.2		26.6					30.8
Sed Dam 9	20.6		110.7					131.3

[a] = Surface + Baseflow.

[b] = Surface runoff only.

6.7.3 External Water Supply

Water supply required to meet minesite demands that cannot be met by water captured and stored on site will be sourced externally from the Dawson River in accordance with relevant licence conditions.

CCL currently holds 400 ML (medium priority – Zone M), 50 ML (high priority – Zone D) and 50 ML (medium security – Zone D) of volumetric licence water allocation from the Dawson River under the Water Act. This water allocation is accessed in accordance with the relevant conditions of the *Water Resource Plan (Fitzroy Basin) Plan 2011* and *Fitzroy Basin Resource Operations Plan 2011*, respectively.

6.8 ADOPTED SALINITY PARAMETERS

Water quality as salinity (total dissolved solids – TDS) is modelled in the water balance as a catchment salts generation rate. Salts generation rates for the various land use types have been adopted from previous work undertaken for the Baralaba Coal Mine (WRM, 2013), supplemented by analysis of updated water quality data. Table 6-13 shows the adopted salts generation rates, as well as the adopted open cut pit groundwater inflow salt concentration and raw water supply salt concentration.

Table 6-13 Adopted catchment salts generation rates for various catchment types

Catchment Type	Catchment Salts Generation Rate (mg/L)	Source
Natural/Undisturbed	250	Based on average EC of a number of monitoring locations on Dawson River and Anabranch. Multiplied by 0.68 to convert to TDS.
Roads/Industrial/Hardstand	1,000	Based on Baralaba Central report (WRM, July 2013).
Spoil	270	Based on 90th percentile EC from static geochemistry test (Terrenus, 2014). Multiplied by 0.68 to convert to TDS.
Mining Pit	1,000	Based on Baralaba Central report (WRM, 2013).
Rehabilitated spoil	270	Assumed same as spoil.
Cleared/Prestrip	270	Assumed same as spoil.
Stockpile	2,500	Based on Baralaba Central report (WRM, 2013).
Groundwater inflows	7,500	Represents concentration with approximately 45% probability of exceedance per advice from (HydroSimulations, 2014).
Raw water inflows	163	Average EC at Beckers from 1993 to current. Multiplied by 0.68 to convert to TDS.

6.9 STORAGE CAPACITIES

The following maximum storage capacities have been adopted for the water balance modelling.

- Mine Water Dam – 1,200 ML (maximum operating level of 1,100ML)
- Raw Water Dam – 10 ML
- Process Water Dam – 47 ML (maximum operating level of 21 ML)

An assessment of the required Design Storage Allowance has been undertaken based on the method of Operational Simulation (see Section 7).

Approximate pit capacities have been estimated from the contour information supplied with the mine plans, and are as follows:

- Year 3 – 50,000 ML
- Year 7 – 101,000 ML
- Year 8 – 97,000 ML
- Year 11 –111,000 ML
- Year 15 –71,000 ML

Note that all storages have been assumed empty at start of the water balance simulation.

6.10 SEDIMENT DAMS

6.10.1 Sizing

Conceptual sediment dam locations have been proposed based on the current mine plans and are shown in Figure 5.1 to Figure 5.5. The locations and sizes of the sediment dams are conceptual for inclusion in the water balance modelling and will be refined and confirmed through detailed design.

Sizing of the proposed sediment basins has been undertaken in accordance with the Best Practice Erosion and Sediment Control (BPESC) guideline (IECA, 2008). The BPESC document provides guidance on sediment basin sizing, design and operation.

Sizing of sediment dams using the BPESC guideline is based on storm events with an average recurrence interval (ARI) of 3 months to 1 year. That is, it is targeted towards treating the smaller, more frequent events which comprise the bulk of the annual volumetric runoff. However, it also provides sediment trapping benefits during larger, less frequent storms through removal of coarse sediments passing through the basin.

6.10.2 Concept Sizing Details

A summary of the assumptions and parameters adopted for the concept sizing of the sediment basins is as follows:

- the catchment area used to size each sediment dam is the maximum area draining to a given dam at any time during the mine life
- Type D Basin (for dispersive soils)
- design rainfall – 85%, 5 day rainfall depth (for sensitive receiving waters)
- volumetric runoff co-efficient C_v – 0.57 (based on Table B7 [IECA, 2008], Group D Clay soils)

- maximum 5m storage depth

Based on the parameters outlined above, conceptual volumes for the sediment dams are presented in Table 6-14.

Table 6-14 Sediment dam concept sizing

Dam	Volume (ML)	Surface Area (ha)
Sediment Dam 1	51.8	1.2
Sediment Dam 2	33.7	0.8
Sediment Dam 3	82.4	1.9
Sediment Dam 4	113.5	2.6
Sediment Dam 5	42.0	1.0
Sediment Dam 6	92.0	2.1
Sediment Dam 7	25.1	0.6
Sediment Dam 8	17.0	0.4
Sediment Dam 9	35.1	0.8
MIA Sediment Dams [a]	19.6	0.4

[a] May be provided in a number of smaller sediment dams

6.10.3 Sediment Dam Collection System – Operating Rules

The operating rules for the sediment dam collection system will include the option to release water off site, or to pump captured water back into the mine water management system if site water supplies are running low. A nominal cease-to-pump trigger volume of 555 ML (based on the DSA assessment – Section 7.4) in the Mine Water Dam has been selected. This means that water from the sediment dams would not continue to be transferred into the Mine Water Dam when there is a substantial amount of water already being stored on site, ensuring sufficient storage space remains available for dewatering the pit.

7 REGULATED DAMS SIZING

7.1 PRELIMINARY HAZARD CATEGORY

A preliminary assessment of the Consequence Category of the proposed dams has been undertaken in accordance with the failure to contain criteria in the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures Version 3.1 (DEHP, 2013) (DEHP Manual). Note that the TOR references the superseded DEHP Manual, however the following assessment has been undertaken in accordance with the current DEHP Manual.
All dams with a 'Significant" Consequence Category or greater are deemed "regulated dams". Any dams likely to contain contaminants that could cause material or serious environmental harm must be designed to avoid contamination of waters and land by effective containment.

Water captured in the mine-affected water management system has the potential to come into contact with runoff from acid-forming material, and may contain elevated metal concentrations. In addition, the groundwater quality may exceed the minimum hazard category salinity threshold based on contaminant concentration and volume given in the DEHP Manual.

Given the above, the Mine Water Dam and Process Water Dam have been classified as "Regulated" storages (or having a Significant Consequence Category).

7.2 HYDRAULIC PERFORMANCE CRITERIA

All regulated dams that are classified as a "significant" or "high" consequence category for the "failure to contain – overtopping" scenario must address the requirements for DSA, extreme storm storage (ESS) allowance and a mandatory reporting level (MRL).

The regulated dams at BNCOP must be designed and operated such that sufficient available storage is maintained to accommodate expected inputs and outputs during the year, and the DSA is provided at the 1st of November each year for the coming wet season "in order to prevent a discharge from that dam up to a specified AEP". The DEHP Manual states that the MRL "is a level at which the dam has a remaining available volume equivalent to the ESS allowance" and "all reasonable efforts must be made to ensure the ESS is provided for at all times".

The DEHP Manual states that "for sites with interconnected regulated dams functioning as an integrated containment system, the DSA and/or ESS volume calculated for the entire containment system catchment may be shared across a number of regulated dams".

The DSA and ESS volumes will be shared between the regulated dams using an Integrated Water Management System (IWMS) as described in the DEHP Manual. The majority of the DSA storage volume will be available within the Mine Water Dam. Water from the Process Water Dam will be pumped to the Mine Water Dam via fixed pumping infrastructure above an alarm level. Where an integrated containment system approach is taken, system resilience must by demonstrated, which would include preparing a system design plan for the integrated system. The design plan must include 'as constructed' plans, operational rules for each dam and the

system as a whole, standards of serviceability and accessibility of water transfer equipment or structures.

The DEHP Manual specifies the hydrological design criteria for adequate containment storage of a “Significant” consequence dam of 1 in 20 AEP (5% AEP).

For comparison purposes, the DSA has been calculated using both the method of deciles and the method of operational simulation for performance based containment.

7.3 METHOD OF DECILES DSA & MRL ASSESSMENT

Table 7-1 shows the design storage allowance (DSA) and mandatory reporting level (MRL) volumes for each of the mine water dams using the method of deciles as described in the DEHP Manual. The DSA volume was calculated using the 1:20 AEP four-month wet season rainfall depth from the SILO Data Drill for the project site (727mm). The majority of the pit capacity was not included in DSA calculations as it is not a permanent water storage, however CCL have advised that up to 1,500 ML of water can be stored in-pit without causing a disruption to mining. ESS and MRL volumes were deemed to not apply to the pit as it is not a water storage at risk of spilling to receiving waters (total pit capacity >50,000 ML). Normal operation would see the pit dewatered to the Mine Water Dam and only when the Mine Water Dam is full will water be retained in pit to prevent uncontrolled spills. Investigations will be undertaken during detailed design to ensure the suitability of storing excess water in-pit.

Note that the daily net process inflow is a negative value and is therefore not taken into account in the DSA calculation using the method of deciles.

The MRL volume was calculated using the 1:10 AEP 72 hour design rainfall intensity of 2.88 mm/h (total rainfall depth of 207mm) obtained from Australian Rainfall and Runoff (Pilgrim, 1998).

Table 7-1 Method of deciles DSA volume and ESS/MRL volume

Storage	Catchment Area (ha)	Storage Capacity (ML)	DSA Volume (ML)	ESS/MRL Volume (ML)
Pit (max. Year 8)	537.9	1,500	3,911	-
Mine Water Dam	63.9	1,200	465	132
Process Water Dam	21.6	46	157	45
Total	623.4	2,746	4,352	177

The total DSA volume far exceeds the storage capacity of the system if the pit catchment is included in the method of deciles.

Note that the MRL calculations show the ESS volume for the Process Water Dam is equivalent to almost its entire capacity. This MRL volume will be accounted for in the Mine Water Dam as part of sharing the required DSA and ESS volumes across the integrated system. The MRL volume for the total integrated system is significantly less than the combined storage capacity of the contained water storages.

7.4 METHOD OF OPERATIONAL SIMULATION

The Project's integrated system DSA has been estimated using the method of Operational Simulation for Performance Based Containment. The OPSIM model was used for this calculation. The modelled operational rules and mine configuration for Stage 2 (years 5 – 7) was found to produce the largest increases in the stored water volume over all historical climate sequences. A 1-year forecast simulation of Stage 2 was undertaken, starting from the 1st November. An iterative process was undertaken to determine the starting inventory level that would result in a 1:20 year AEP spill frequency (assuming was no restriction on pit dewatering other than its pump capacity of 200 L/s). Note that runoff collected in sediment dams was only pumped back into the Mine Water Dam up to this starting inventory level.

Using the operational simulation method, the total site DSA volume was calculated to be 430ML. As there is no site specific data available for calibration of the BNCOP water balance model, the Dams Manual states that a design simulation margin of 50% must be added to the calculated DSA volume which results in a total DSA volume of 645ML. To ensure the DSA is available in the Mine Water Dam, the inventory must be returned to 555 ML by the 1st Nov each year.

The DSA volume of 645 ML calculated with the method of operational simulation compares with a DSA volume of 4,352 ML using the method of deciles. The method of deciles is considered conservative, with the operational simulation providing a more accurate representation of DSA requirements as it includes the historical rainfall record, a more realistic rainfall-runoff representation and predicted site processes.

The DSA volume calculated is contingent on the controlled releases operating as specified in the EA permit (Permit Number EMPL00617113). If the actual controlled release capabilities of the system are not consistent with the assumptions used in the model, than it is likely a significantly larger DSA volume will be required. Note that water quality parameters other than salinity could limit release.

This DSA volume was incorporated back into the full 15 year operational simulation forecast, as an operational rule for the Mine Water Dam. Note that this assessment included a maximum operating volume in the Mine Water Dam (1,100 ML) which restricted pit dewatering. The results of the operational water balance show that the adopted sizes and operating levels are adequate in providing full containment (i.e. no spill) of mine-affected water (see Section 8.3.7) under historical climate conditions, when operated as specified. There is a less than 5% chance of the Mine Water Dam inventory exceeding 555 ML (i.e. not meeting the DSA volume of 645 ML) on the 1st November of each year of mine life, as shown in Figure 7.1.

Once the mine is operational and better estimates of groundwater inflows, catchment runoff parameters and demands are available, the calculated DSA volume will be reviewed.

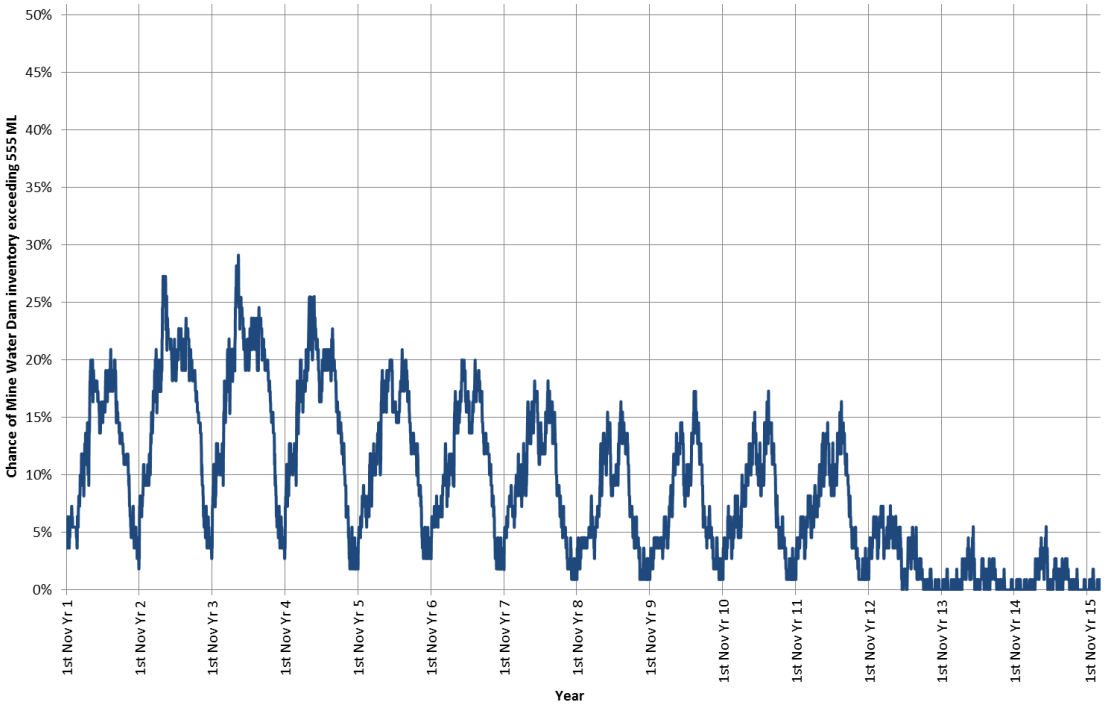

Figure 7.1 Forecast risk of exceeding a Mine Water Dam inventory of 555 ML

8 WATER MANAGEMENT SYSTEM PERFORMANCE ASSESSMENT

8.1 OVERVIEW

Key surface water issues for the Project include:

- potential for uncontrolled spills from the mine water dams;
- potential to impact on production due to in-pit water accumulation; and
- potential for inadequate supplementary water supply from the Dawson River to meet mine-site demands for production and dust suppression.

The impacts of the Project on Dawson River flooding have been assessed separately in the BNCOP Flood Study prepared by Water Solutions (2014).

An assessment of the impacts of the Project's mine water management system has been undertaken using the water balance model, against the following key performance indicators:

- mine water inventory – the risk of accumulation (or reduction) of the overall mine water inventory at the project, and the associated volumes;
- external raw water requirements – the risk of requiring imported external water to supplement on-site mine water supplies and the reliability of raw water supply;
- uncontrolled spillway discharges – the risk of uncontrolled discharges from the site storages to receiving waters; and
- overall site water balance.

A schematic layout of the water balance model, operational guidelines and controls applied to the model are provided in Section 6.

8.2 INTERPRETATION OF RESULTS

The modelling methodology of a forecast simulation is described in Section 6.4. In interpreting the results of the water balance assessment, it should be noted that the results provide a statistical analysis of the water management system's performance over the 15 years of mine life, based on 110 realisations with different climatic sequences. The 50th percentile probability represents the median results, the 10th percentile represent 10% exceedance (i.e. wet conditions) and the 90th percentile results represent 90% exceedance (i.e. dry conditions). There is an 80% chance that the result will fall within the 10th and 90th percentiles and a 98% chance the result will fall between the 1st and 99th percentiles. Importantly, note that a percentile trace shows the percentile chance of a particular value on each day, and ***does not*** represent continuous results from a single model realisation e.g. the 50th percentile trace does not represent the model time series for median climatic conditions.

A single realisation can also be selected from the 110 modelled realisations in order to show the water management system's actual performance (not a statistical representation) for a particular climate sequence.

8.3 WATER BALANCE MODEL RESULTS

8.3.1 Overall Water Balance

A water balance for one of the 110 modelled realisations is presented in Table 8-1, averaged over each stage of modelled mine life (stages are defined in Section 6.4). The water balance results provided are those for the single realisation with median inflows (including direct rainfall, catchment runoff and groundwater) over the life of the Project. The results for this single realisation are presented in Table 8-1 to show inflows, outflows and overall water balance for each of the mine stages for a representative climate sequence. It should be recognised that the following items are subject to climatic variability:

- rainfall runoff;
- evaporation;
- imported water requirement; and
- site releases/spills.

The results for a single realisation with median inflows show that over the life of the project:

- external raw water supply is required in every stage of mine life, with the greatest amount required in stages 1 and 3;
- the largest demand from the water management system is due to haul road dust suppression;
- total mine water demand (including CHPP make-up, dust suppression and vehicle wash-down) supplied from either raw or recycled water ranges between approximately 947 ML/yr and 1,508 ML/yr, with the highest demand in Stage 3;
- no overflows from the Process Water Dam or Mine Water Dam occurred in the simulation period;
- the combined spill volume from the sediment dams is highest in the first stage (597 ML/yr), which corresponds to the stage with the highest rainfall yield, and ranges between 13 ML/yr and 68 ML/yr for the remaining stages.

Note that the results presented in Table 8-1 are for a single realisation and will include wet and dry periods distributed throughout the mine life. Rainfall yield for each stage is affected by the variation in climatic conditions within the adopted climate sequence. For example, the high runoff yield indicated for Stage 1 likely reflects a wet period at the commencement of the selected realisation.

Table 8-1 Water balance for realisation with median runoff inflows

	Volume (ML/yr)				
Stage	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Applied Period of Mine Life	Annual Average for Yr1 –Yr4	Annual Average for Yr5 – Yr7	Annual Average for Yr8 – Yr9	Annual Average for Yr10 – Yr12	Annual Average for Yr13 – Yr15
Water Inputs					
Rainfall Yield (Direct Rainfall + Catchment Runoff)	2,201	558	1,629	544	650
Groundwater Inflow	881	967	929	1,016	863
Raw Water	14	36	481	245	358
Total	**3,096**	**1,562**	**3,039**	**1,805**	**1,870**
Water Outputs					
Evaporation	532	447	330	309	339
Stockpile Dust Suppression	186	192	258	251	250
Haul Road Dust Suppression	647	1,017	1,021	893	889
Vehicle Wash-down Demand	11	11	11	11	11
Sediment Dam Spills	597	13	68	13	15
Mine Water Dam Spills	0	0	0	0	0
Process Water Dam Spills	0	0	0	0	0
CHPP Make-up Water	103	136	218	297	339
Off-site Controlled Releases	811	14	1,112	0	61
Total	**2,887**	**1,831**	**3,018**	**1,775**	**1,904**
Net Change in Onsite Storage	**209**	**-269**	**21**	**31**	**-33**

Note: totals may have minor discrepancies due to rounding

8.3.2 Pit Storage Characteristics

An assessment of pit inventory characteristics has been undertaken to determine the likelihood of water inundating the pit, which could impact production. CCL have advised that up to 1,500 ML of water can be stored in-pit without causing a disruption to mining. A forecast assessment has been used.

Figure 8.1 shows the predicted probability of the modelled in-pit storage volume. A build-up of water in the active pits generally occurs when the out-of-pit storages are too full to accept additional pit water, or the catchment runoff draining to the pit is greater than the dewatering pump capacity. The assessment of the in-pit inventory shows that:

- at any point in time during the mine life, there is at least a 50% chance that the active pit will essentially be completely dewatered;
- there is a 10% chance that the in-pit storage will reach at least 184 ML in years 5 and 6;
- there is a 1% chance in each of years 5, 6 and 7 (the second modelled stage) that the in-pit storage will reach at least 900 ML; and

- the in-pit inventory is not at risk of accumulating over the life of the mine (i.e. over multiple wet seasons), rather the system is able to recover prior to each subsequent wet season.

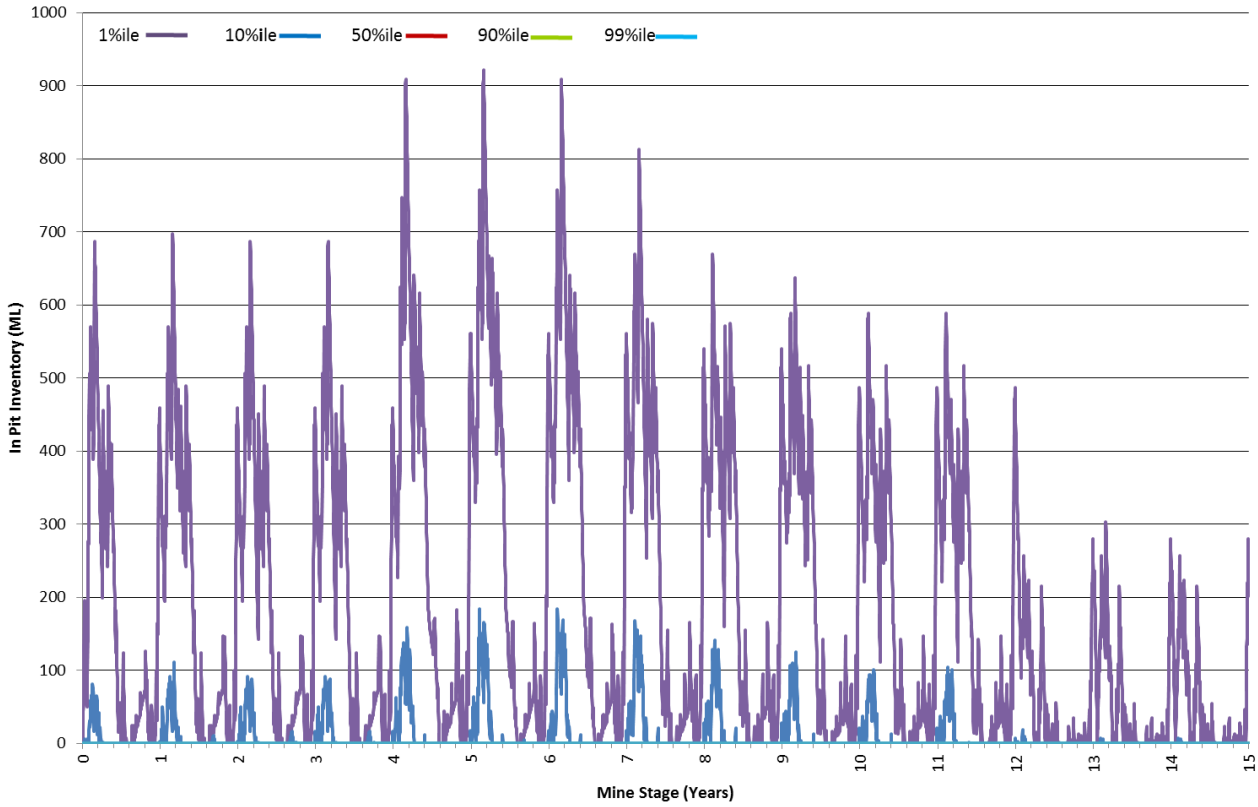

Figure 8.1 Forecast in-pit inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile

8.3.3 Out-of-Pit Storage Characteristics

A forecast assessment has been undertaken to estimate the future out-of-pit water inventory. The out-of-pit water storages included in the analysis are the:

- Mine Water Dam;
- Process Water Dam; and
- sediment dams (including Sediment Dams 1 – 9 and the MIA sediment dam).

Figure 8.2 and Figure 8.3 show the predicted probability of the modelled total out-of-pit storage inventory and Mine Water Dam inventory, respectively. The Mine Water Dam is the primary out-of-pit storage and has a capacity of 1,200 ML. The maximum operating volume (MOV) of the Mine Water Dam is the volume at which dewatering from the pit into the Mine Water Dam ceases, and is set at 1,100 ML. The MOV is selected to provide sufficient storage to accommodate unexpected rainfall events without spills occurring from the Mine Water Dam. Sediment dams are dewatered to the Mine Water Dam to provided additional supply for on-site use only when the Mine Water Dam is less than a trigger volume of 555 ML. Controlled releases to the Dawson River occur only when the Mine Water Dam is above a trigger volume of 400 ML, to ensure water is not being released when there is not a surplus on-site.

The results show that:

- consistent with the in-pit inventory results, the water management system is not at risk of accumulating water over the life of the mine and is able to recover prior to each subsequent wet season;
- for the total out-of-pit inventory (Figure 8.2):
  - in Year 4 there is a 90% chance that the combined out-of-pit inventory will reach at least 140 ML;
  - in each year of operation, there is a 50% chance that the inventory will reach between 200 ML – 400 ML (approximately);
  - in each of years 3 to 8, there is a 10% chance that inventory will reach at least 1,000 ML;
  - in each of years 5 to 12 (i.e. stages 2, 3 and 4), there is a 1% chance of the inventory reaching at least 1,400 ML (approximately);
- for the Mine Water Dam inventory (Figure 8.3):
  - in each year of operation, there is a 50% chance that the inventory will reach between 200 ML – 400 ML (approximately);
  - in each of the years between Year 1 and Year 13, there is a 10% chance that the inventory will reach a volume at or above 555 ML (the level at which sediment dam dewatering to the Mine Water Dam ceases); and
  - in each of years 5 to 7 (Stage 2), there is a 1% chance that the inventory will reach 1,090 ML, just below the MOV (the level at which pit dewatering to the Mine Water Dam ceases).

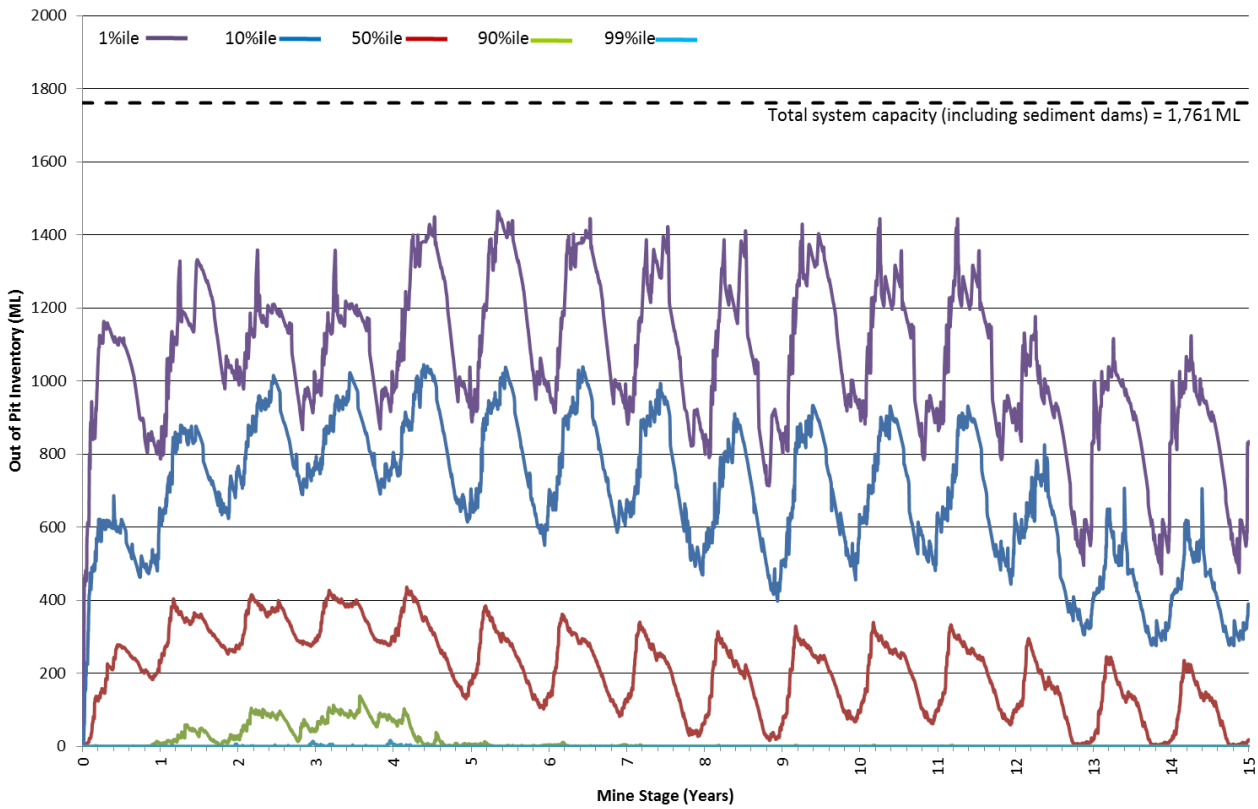

Figure 8.2 Forecast out-of-pit inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile

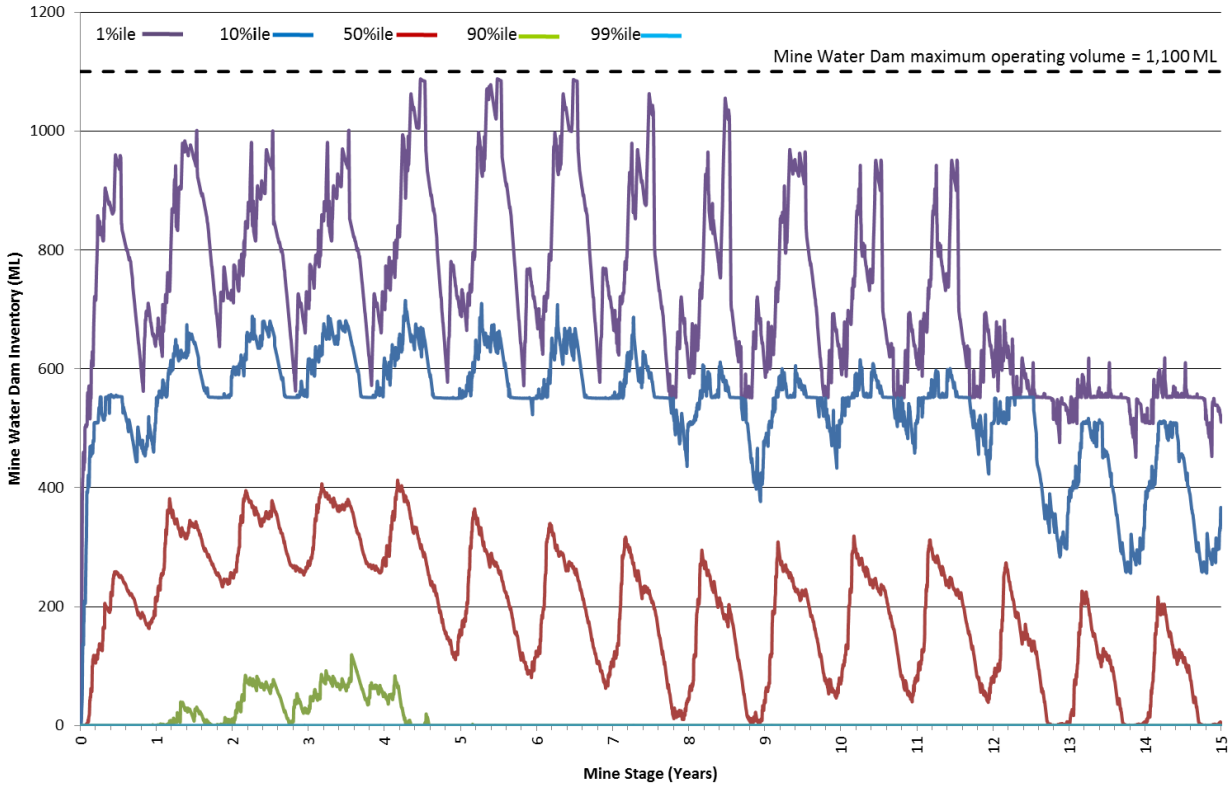

Figure 8.3 Forecast Mine Water Dam inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile

8.3.4 Controlled Releases to Dawson River

Controlled releases to the Dawson River are allowed when the Mine Water Dam reaches a trigger volume of 400 ML (subject to water quality release conditions). This ensures that water is not being released at times when there the on-site inventory is low and water retention is a key objective.

The potential for controlled releases from the Project has been assessed using a forecast assessment simulation. The predicted probability of the annual controlled discharge volume is provided in Figure 8.4. The results show that:

- in each of years 9, 13, 14 and 15, there is at least 50% chance that there will be no controlled releases made to the Dawson River;
- in each of years 1 - 8 and years 10 – 12, there is at least a 50% chance that the controlled releases will be less than 125 ML;
- in each year, there is a 10% chance that controlled releases will total at least 1,000 ML/yr – 1,270 ML/yr;
- in each of years 5 – 12, there is a 1% chance that controlled releases will total at least 3,000 ML/yr – 3,170 ML/yr; and
- in Year 13 there is a 1% chance that controlled releases will total at least 2,280 ML/yr.

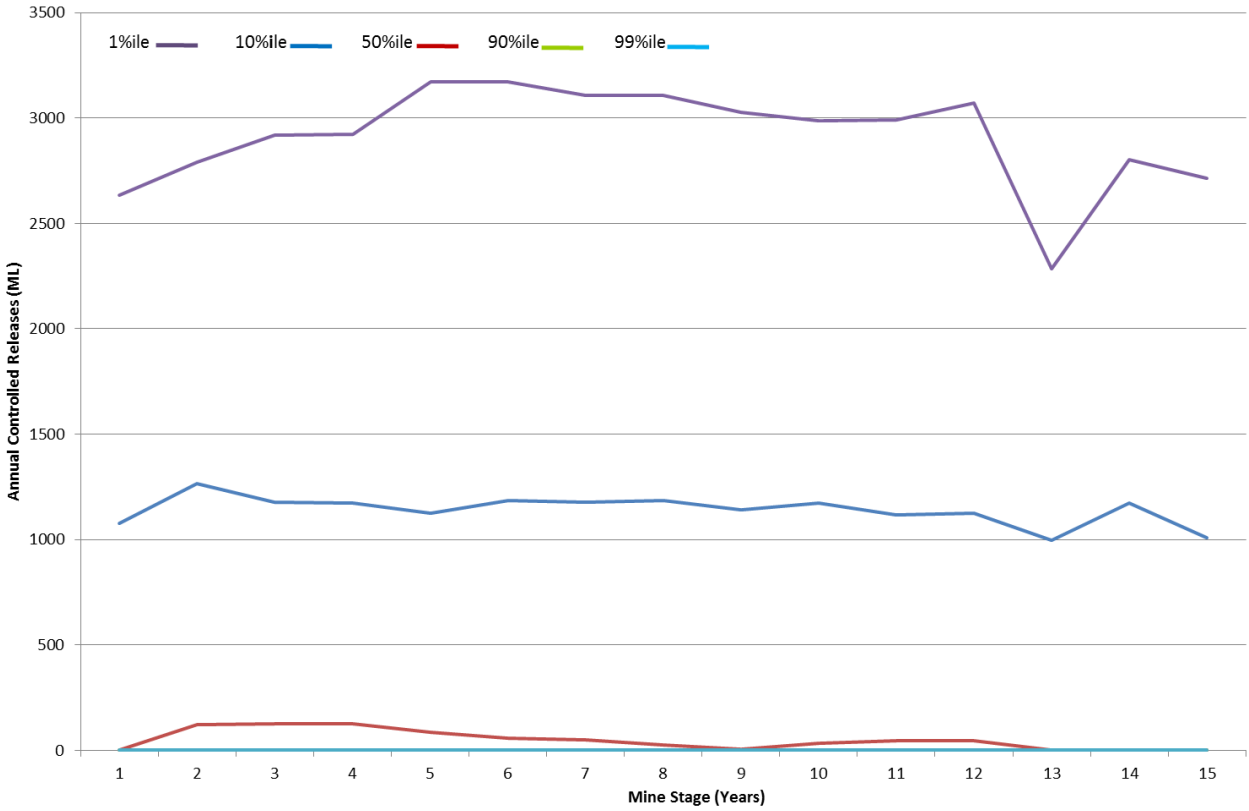

Figure 8.4 Forecast annual controlled releases to Dawson River, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile conditions

Table 8-2 shows the target dilution ratio for each of the release categories detailed in Section 6.5, where the dilution ratio is the daily volume of the Dawson River divided by the volume of controlled release for controlled releases to the Dawson River. Figure 8.5 shows a ranked plot of the minimum modelled (from 110 modelled realisations) daily dilution ratio on release days within each release category. Note that no controlled releases occur in the model for release category 1 and 2, due to the salinity in the Mine Water Dam exceeding the end-of-pipe salinity limits. The results show that:

- the minimum modelled dilution ratio that occurred from all release categories throughout all modelled realisations was 48;
- the minimum modelled dilution ratio that occurred within each release category was not less than the target dilution ratio under the controlled release rules;
- 50% of release days exceeded a minimum dilution ratio of:
  - 79 for release category 3;
  - 148 for release category 4;
  - 234 for release category 5;
  - 336 for release category 6; and
  - 749 for release category 7.

Theoretically, the dilution ratio could be 10 or lower, because releases can be made at 0.5 m^3/s when the river flow is 5 m^3/s, or potentially even lower (see Section 6.5.1). However, releases are usually required under wet conditions, when the corresponding river flow is likely to be much higher than the minimum flow for releases. In addition, the water quality of water stored on site often prohibits releases when the river flow rate is relatively low.

Table 8-2 Controlled release rules summary

Release Category #		Receiving Water Flow Criteria for Discharge (m^3/s)	Target Dilution Ratio [a]	End-of-pipe Salinity Limit for Release	
				µS/cm	mg/L
1	Low Flow	>5 [b]	10	<340	<231
2	Medium Flow	>5	10	<500	<340
3	Medium Flow	>24	48	<1500	<1020
4	Medium Flow	>53	106	<3000	<2040
5	Medium Flow	>92	184	<5000	<3400
6	High Flow	>140	280	<7500	<5100
7	High Flow	>190	380	<10000	<6800

a: Maximum release rate = 0.5 m^3/s
b: for a period of 28 days after natural flow events that exceed 5 m^3/s

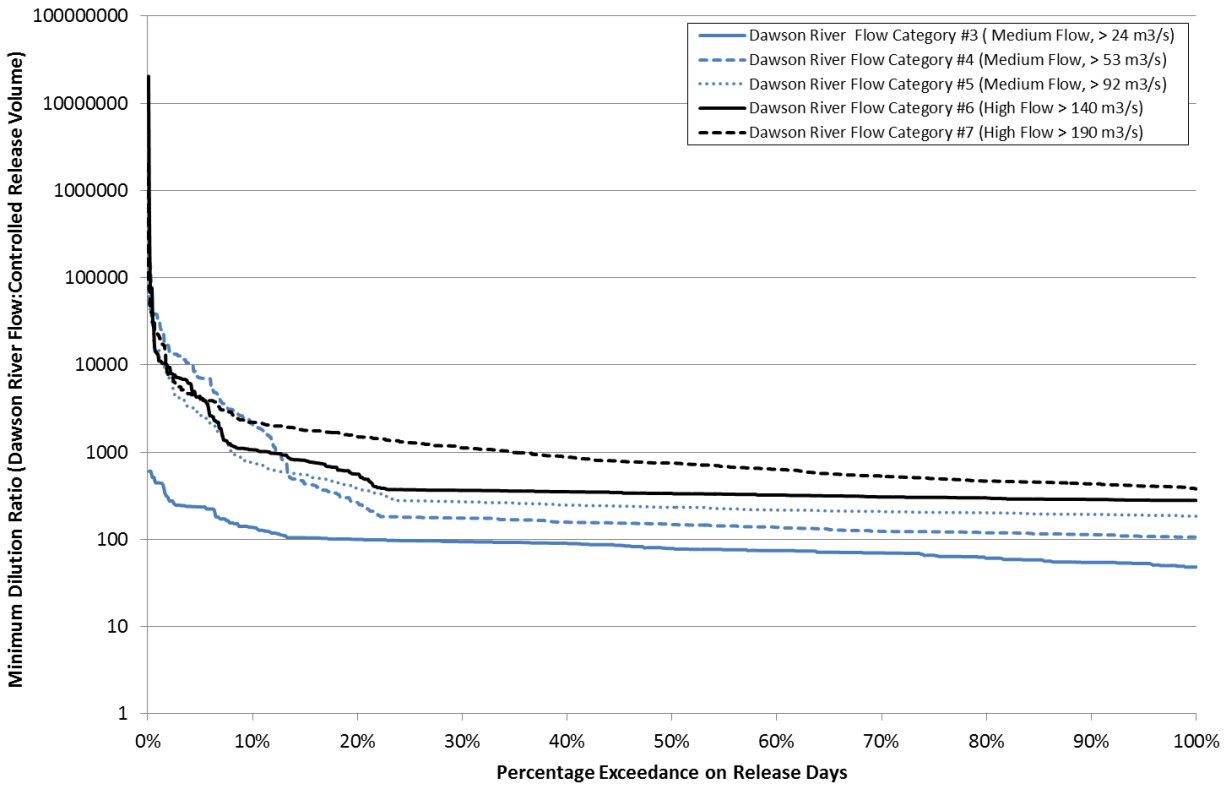

Figure 8.5 Ranked plot of minimum dilution ratio on release days

Figure 8.6 shows a ranked plot of the maximum modelled (from 110 modelled realisations) daily controlled release salinity on release days within each release category. The results show that:

- the maximum modelled daily release salinity that occurred within each release category was not more than the end-of-pipe salinity limit (shown in Table 8-2) under the controlled release rules;
- 100% of release days in all release categories exceeded a maximum modelled release salinity of around 540-590 mg/L;
- 50% of release days had a maximum modelled release salinity less than:
  - 820 mg/L for release category 3;

- 1,360 mg/L for release category 4;
- 2,040 mg/L for release category 5;
- 2,280 mg/L for release category 6; and
- 2,720 mg/L for release category 7.

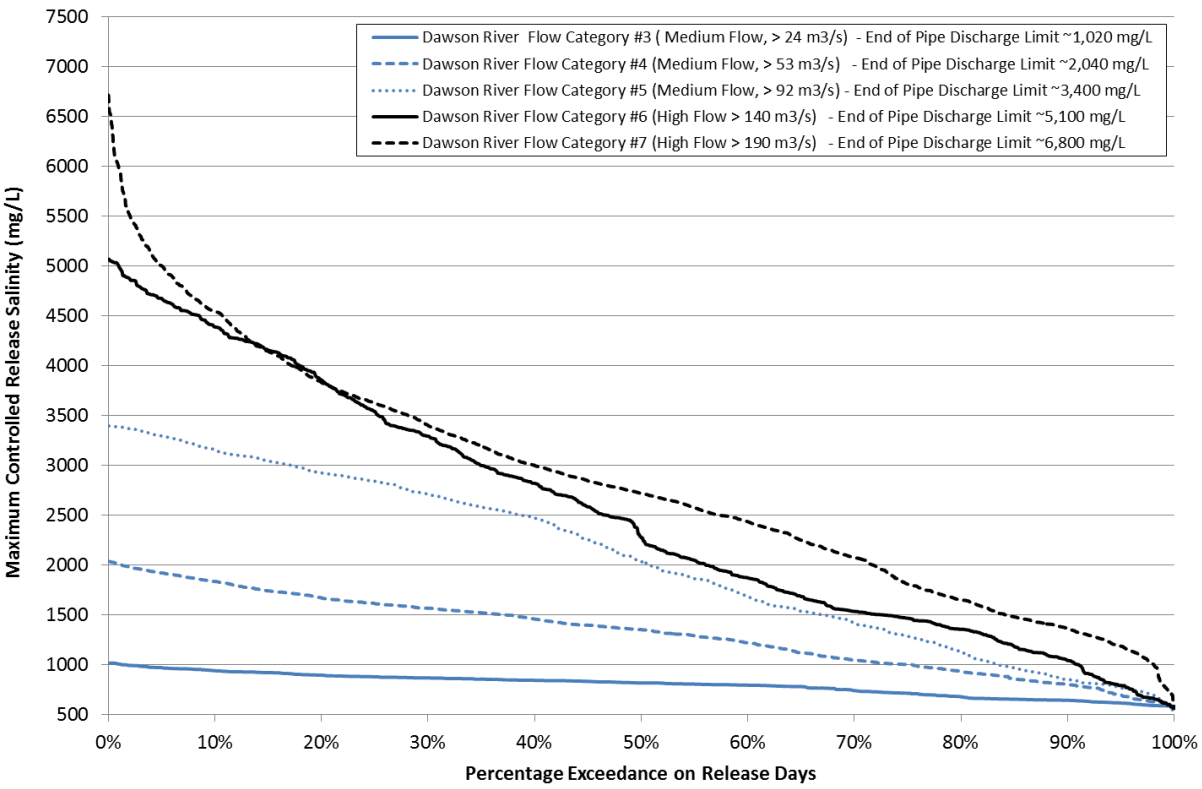

Figure 8.6 Ranked plot of maximum discharge salinity on release days

Additional flexibility could be gained by storing the water retained from sediment dams separately to allow for mixing with mine affected water as required. Consistent with current best practice in mine water management, CCL has committed to further investigate the potential options and proposed approach for separation of different water quality source waters on-site as part of the detailed design of the water management system, and refine as necessary during the life of the BNCOP. The investigation would be undertaken if the controlled release rules were to significantly restrict opportunities to discharge to the Dawson River.

8.3.5 Off-Site Water Requirements

For the purposes of current investigations, the term "site raw water requirements" represents the amount of imported raw water from the Dawson River that is required to sustain the nominated design production rate and associated operational demands for the Project. The simulation of the water management system assumes that any shortfall in water captured on-site is made up from imported raw water – that is, during dry periods imported raw water is used to ensure that all operational demands are met.

This potential requirement for raw water supply has been assessed using a forecast assessment simulation. The predicted probability of annual raw water demand is provided in Figure 8.7. The results show that:

- the highest risk for requiring off-site raw water occurs in the last representative mine stage, which includes years 13, 14 and 15;

- the lowest risk for requiring off-site raw water occurs in the first representative mine stage, which includes years 1, 2, 3 and 4;
- there is a 50% chance that:
  - in each of the last three years, a total volume of about 250-300 ML/yr of off-site supplies will be required to supply operational demand;
  - in each of the first seven years, a total volume of less than about 50 ML/yr of off-site supplies will be required to supply operational demand;
- there is a 10% chance (90th percentile results) that in each of the last three years, at least 700 ML/yr is required;
- there is a 1% chance (99th percentile results) that:
  - in each of the last three years, at least 850 ML/yr is required;
  - in each of the first four years at least 220-340 ML/yr is required; and
- There is a less than 1% chance in each year of Stage 1 (years 1 - 4) and a less than 10% chance in each year of Stage 2 (years 5 -7) and Stage 4 (years 10 – 12) that more than 500 ML will be required to meet demands.

Note that the higher risk of requiring off-site water in Year 1 compared to Year 2 – Year 4 is because the storages are modelled as initially being dry, hence a higher demand is required to fill these storages to their operating levels in the first few days of the simulation.

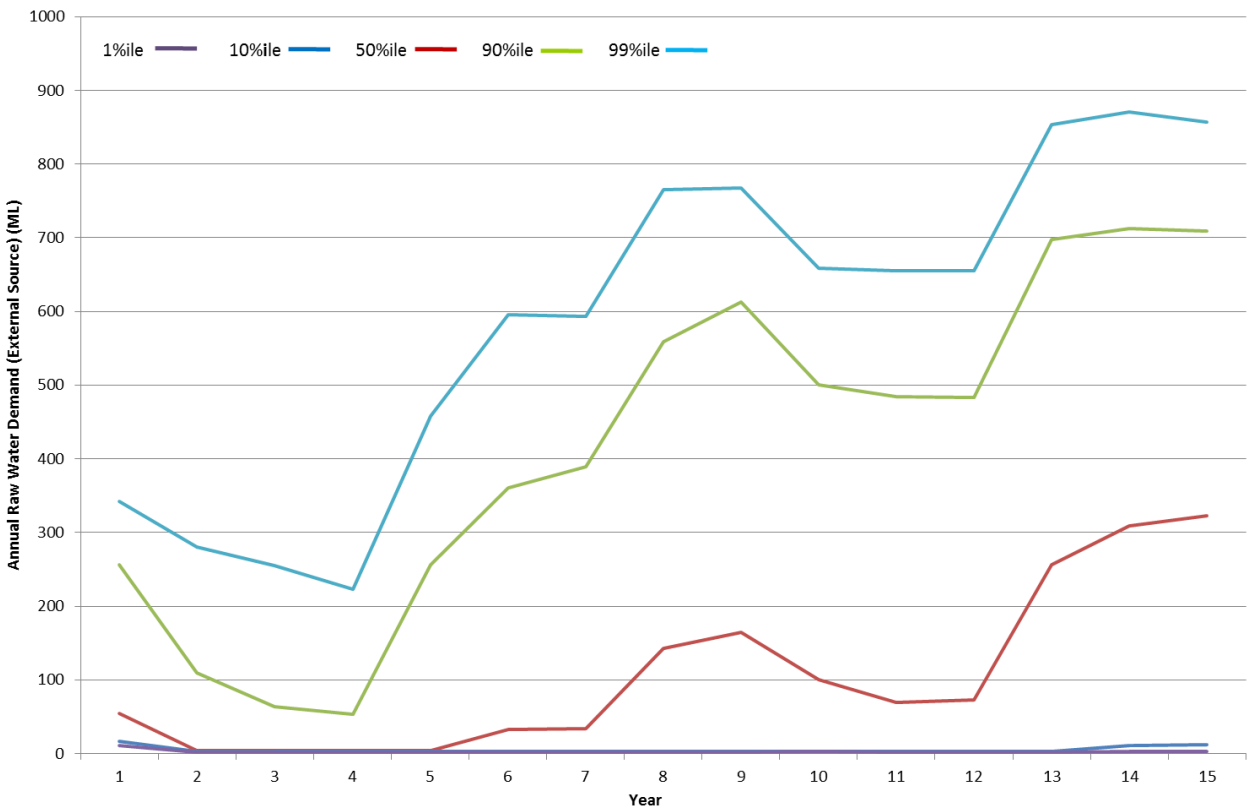

Figure 8.7 Forecast annual raw water demand, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile conditions

8.3.6 Water Supply Reliability

The water management system's reliability in meeting mine site demands (including CHPP make-up, vehicle washdown and dust suppression) has been assessed using a forecast assessment. The predicted annual water supply reliability is shown in Figure 8.8. CCL currently holds 500 ML/yr of volumetric licence water allocation from the Dawson River (see Section 6.7.3). For the purpose of this analysis, the supply reliability was calculated assuming 500 ML/yr of licences are available for use by the Project. The supply reliability was calculated for each year of mine life as the percentage of realisations (out of 110) where the annual raw water demand for that year was less than 500 ML. The results show that shows that:

- during Stage 1 (years 1 - 4), the existing licences will be sufficient to meet all site demands;
- during Stage 2 (years 5 -7) and Stage 4 (years 10 - 12), there is a greater than 90% chance in each of these years that the existing licences will meet demands (i.e. a 5% chance in Stage 2 and an 8-10% chance in Stage 4 that more than 500 ML/yr in licences will be needed);
- during Stage 3 (years 8 – 9) and Stage 5 (years 13 – 15) there is a less than 90% chance that the existing licences will meet demands;
  - in Stage 3 there is a greater than 83% chance in each year that the existing licences will meet demands; and
  - in Stage 5 there is greater than 75% chance in each year that the existing licences will meet demands.

If required, additional water licences would be sought and purchased by CCL over the life of the project to meet raw water demands.

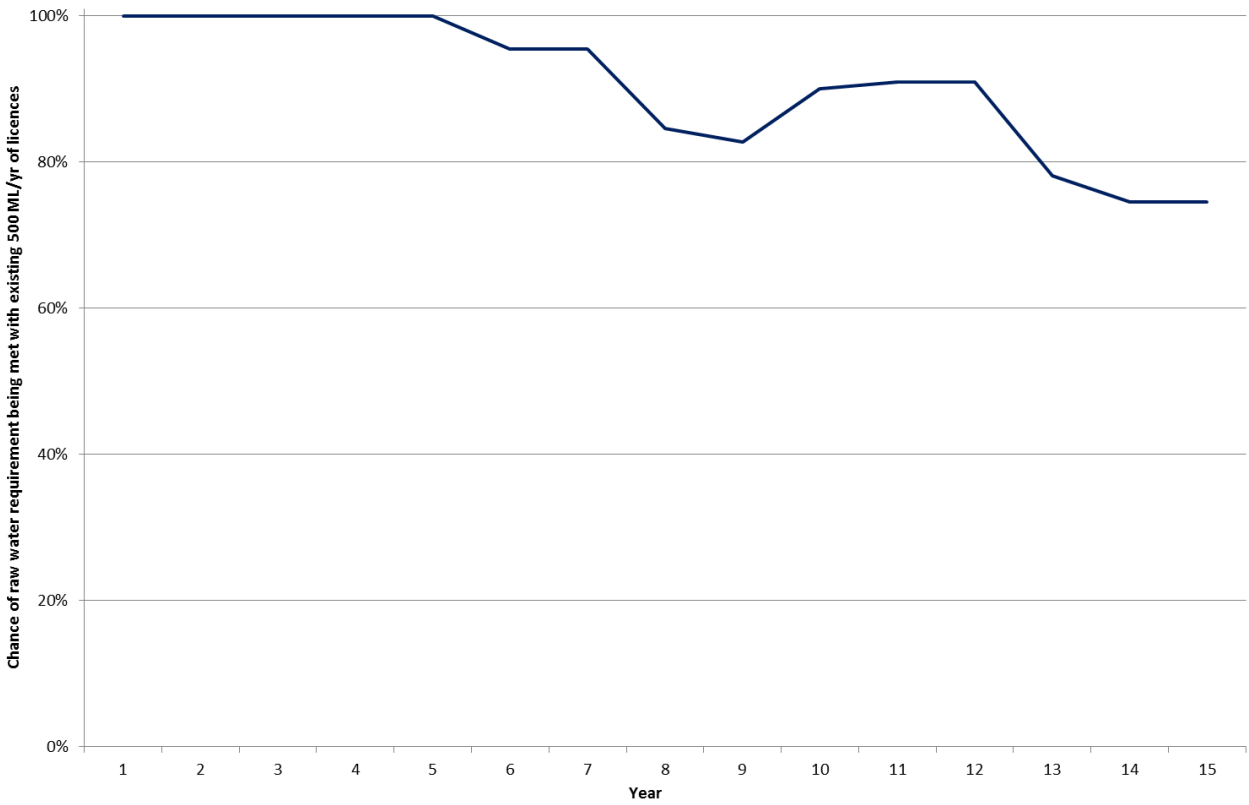

Figure 8.8 Forecast annual water supply reliability

8.3.7 Uncontrolled Off-Site Discharges

Expected discharges from the Project have been assessed on the basis of simulated spillway overflows from key site storages to receiving waters. The assessment includes storages which have the ability to discharge via a spillway into the receiving waters, including the Mine Water Dam, Process Water Dam, active pit and sediment dams.

The model of the water management system has been configured to ensure mine affected water is contained within the mine water management system. Hence, the modelled results show no spills of mine affected water from the Mine Water Dam, Process Water Dam or from the active pit for any of the modelled realisations.

Sediment dams are dewatered to the Mine Water Dam when it is below 555 ML. When the Mine Water Dam inventory exceeds this volume, sediment dams are allowed to discharge off site. Note that sizing of the proposed sediment dams is in accordance with the Best Practice Erosion and Sediment Control (BPESC) guideline (IECA, 2008) (see Section 6.10).

The potential for spills from the sediment dams has been assessed using a forecast assessment simulation. The predicted probability of the annual combined sediment dam discharge volume is provided in Figure 8.9. The results show that:

- in each year, there is at least 50% chance that there will be no sediment dam overflows;
- in each of years 2, 3, 4 and 10, there is a 10% chance that combined sediment dam overflow volume will be at least 550 ML/yr – 600 ML/yr;
- in each of years 1, 5 – 9 and 11 – 15, there is a 10% chance that combined sediment dam overflow volume will be at least 300 ML/yr – 450 ML/yr; and
- in each of years 5 and 10, there is a 1% chance that combined sediment dam overflow volume will be at least 2,070 ML/yr – 2,100 ML/yr.

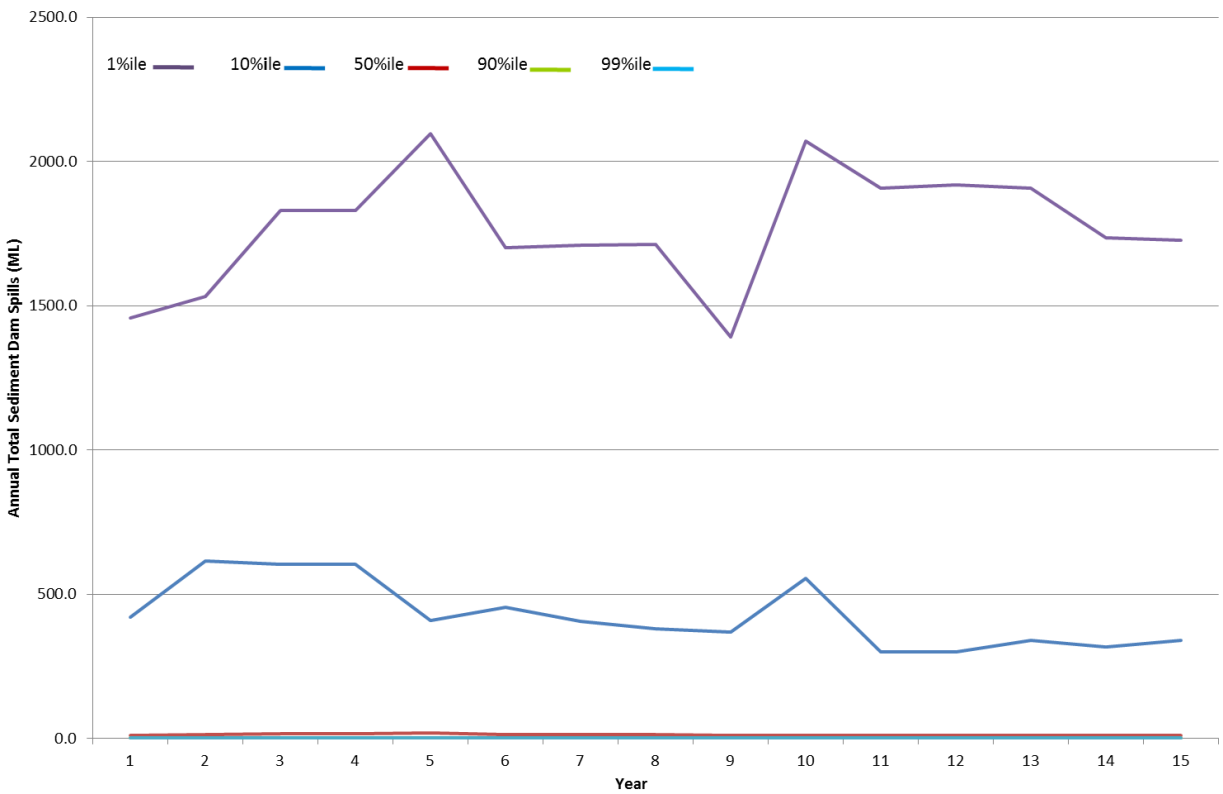

Figure 8.9 Forecast annual combined sediment dam spills, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) percentile conditions

Table 8-3 shows the predicted spills from the individual sediment dams over the full period of operation for the median result as well as the 90th and 10th percentile confidence limits of the estimate. Note that sediment dams 7 and 8 are not present until the second stage of the modelled mine life and hence are only active for 11 years and Sediment Dam 9 is not present until the fourth stage and hence is only active for 6 years. The results show that:

- the larger sediment dams have a higher risk of spilling than the smaller sediment dams. For example, Sediment Dam 8 has the smallest capacity at 17 ML (see Section 6.10.2) and shows the lowest risk of spilling. Sediment Dam 4, in contrast, has the largest capacity and the largest risk of spilling. This is because the dewatering from each sediment dam to the Mine Water Dam is given equal priority at all times and is the same rate as from all other sediment dams. The smaller capacity sediment dams are dewatered to a proportionally lower volume than the larger sediment dams;
- the median average annual number of spill days is less than 10 days for all sediment dams, except for Sediment Dam 4;
- the 10th percentile average annual number of spill days is less than 10 days for sediment dams 2, 3, 8 and 9 and the MIA sediment dam; and
- the 10th percentile average annual number of spill days is less than 20 days for sediment dams 1, 5, 6 and 7.

Table 8-3 Predicted spills from sediment dams

Sediment Dam	Years of Operation	Simulation	Average Annual Spill Volume (ML/yr)	Average Annual Spill Days (days/yr)
1	15	10%ile	42.5	16.4
		50%ile	20.4	8.7
		90%ile	2.6	1.1
2	15	10%ile	4.7	3.4
		50%ile	1.2	0.1
		90%ile	0.0	0.0
3	15	10%ile	9.7	0.7
		50%ile	1.6	0.2
		90%ile	0.0	0.0
4	15	10%ile	79.3	21.2
		50%ile	38.8	11.2
		90%ile	7.8	1.6
5	15	10%ile	23.4	15.2
		50%ile	10.6	8.9
		90%ile	0.0	0.0
6	15	10%ile	69.8	13.5
		50%ile	27.2	7.4
		90%ile	2.1	0.6
7	11	10%ile	14.6	16.6
		50%ile	2.3	6.4
		90%ile	0.0	0.0
8	11	10%ile	1.9	1.6
		50%ile	0.0	0.0
		90%ile	0.0	0.0
9	6	10%ile	9.4	9.0
		50%ile	0.1	0.1
		90%ile	0.0	0.0
MIA Sed Dams	15	10%ile	62.4	3.9
		50%ile	41.8	2.8
		90%ile	23.7	1.9

Quality of Sediment Dam Discharges

Table 8-4 shows the salinity concentration of sediment dam overflows, averaged over the full 110 modelled realisations for each mine stage. The modelling results show that the average salinity of discharges is relatively consistent between each sediment dam, and also between each modelled stage. The salinity of releases from a sediment dam is dependent on the quality of surface runoff from its catchment. The MIA sediment dam captures a catchment classified entirely as hardstand, hence the modelled salinity concentration of spills from this dam is

higher. In reality, the MIA sediment dams could be pumped preferentially into the Mine Water Dam to reduce the risk of spills. During detailed design of the mine infrastructure area and associated water management system, CCL has committed to consider adopting a more stringent sediment dam design criteria and/or altering the operating rules (e.g. pump all collected runoff to the Mine Water Dam) to reduce the risk of potential overflows from sediment dams containing runoff from the mine infrastructure area.

Under relatively dry conditions, water would be collected from sediment dams for use in site operations. Sediment dams are more likely to overflow during wet periods when significant dilution with undisturbed catchment runoff would occur. There is the potential for some localised minor salinity impacts however this would be infrequent and the impact would reduce further downstream with more catchment contributing runoff, resulting in greater dilution.

Although sediment dams have been designed in accordance with the Best Practice Erosion and Sediment Control (BPESC) guideline (IECA, 2008), discharge from sediment dams will still need to meet the EA conditions. Water stored in sediment dams will be monitored, and if data indicates a potential exceedance of EA conditions during release then water will be pumped back to the Mine Water Dam.

Table 8-4 Salinity concentration of sediment dam overflows

	Average Salinity Concentration (mg/L)				
Stage	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Applied Period of Mine Life	Annual Average for Yr1 –Yr4	Annual Average for Yr5 – Yr7	Annual Average for Yr8 – Yr9	Annual Average for Yr10 – Yr12	Annual Average for Yr13 – Yr15
Sediment Dam 1	251	263	271	268	267
Sediment Dam 2	243	241	241	507	500
Sediment Dam 3	244	245	244	415	465
Sediment Dam 4	256	269	267	268	266
Sediment Dam 5	259	266	267	265	262
Sediment Dam 6	290	330	327	324	321
Sediment Dam 7	-	270	271	270	267
Sediment Dam 8	-	263	265	259	256
Sediment Dam 9	-	-	-	267	264
MIA Sediment Dam	1,000	1,000	1,000	1,000	999

8.3.8 Mine Water Dam Salinity

Figure 8.10 shows a plot of the simulated water inventory volume and salinity for the Mine Water Dam for a single realisation. Figure 8.11 shows a statistical representation of forecast results. There is at least a 50% chance at any point in time that the salinity of the Mine Water Dam will be below about 7,000 mg/L.

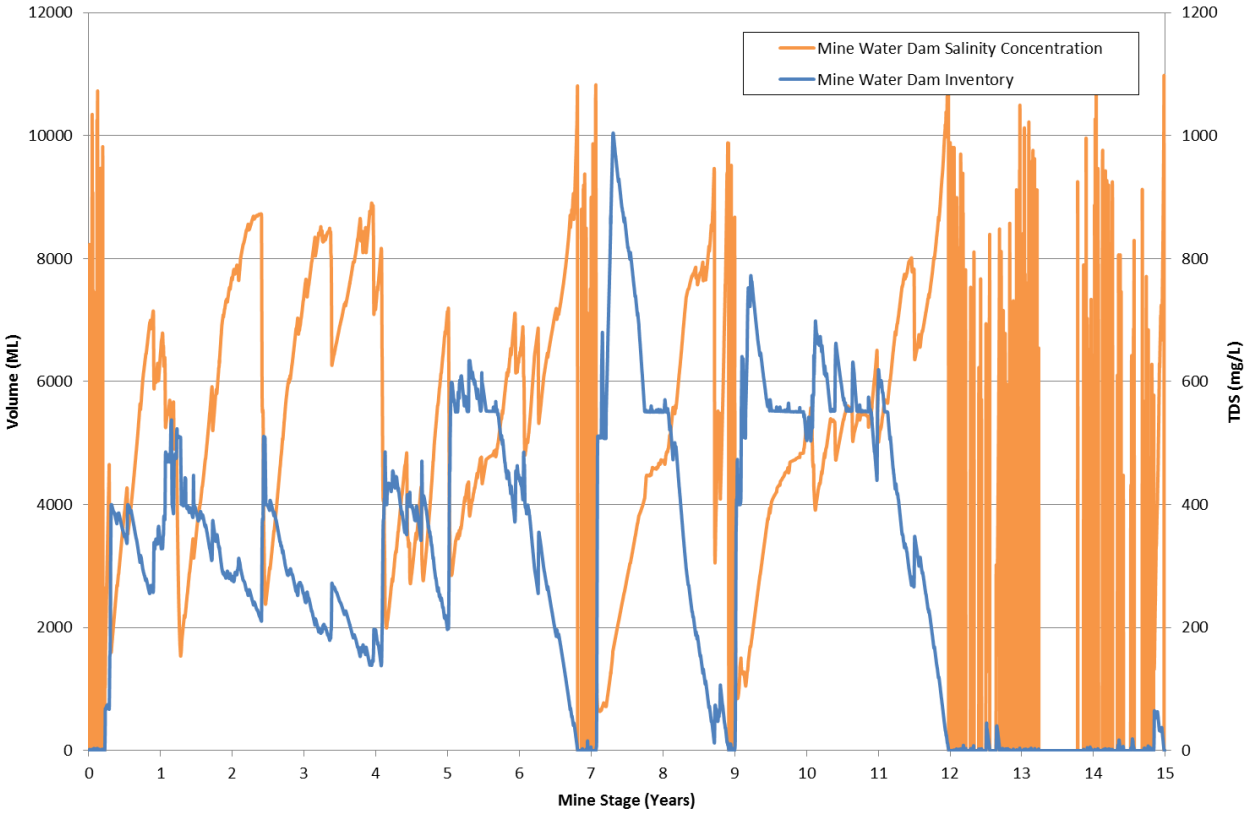

Figure 8.10 Mine Water Dam inventory and salinity– single representative realisation

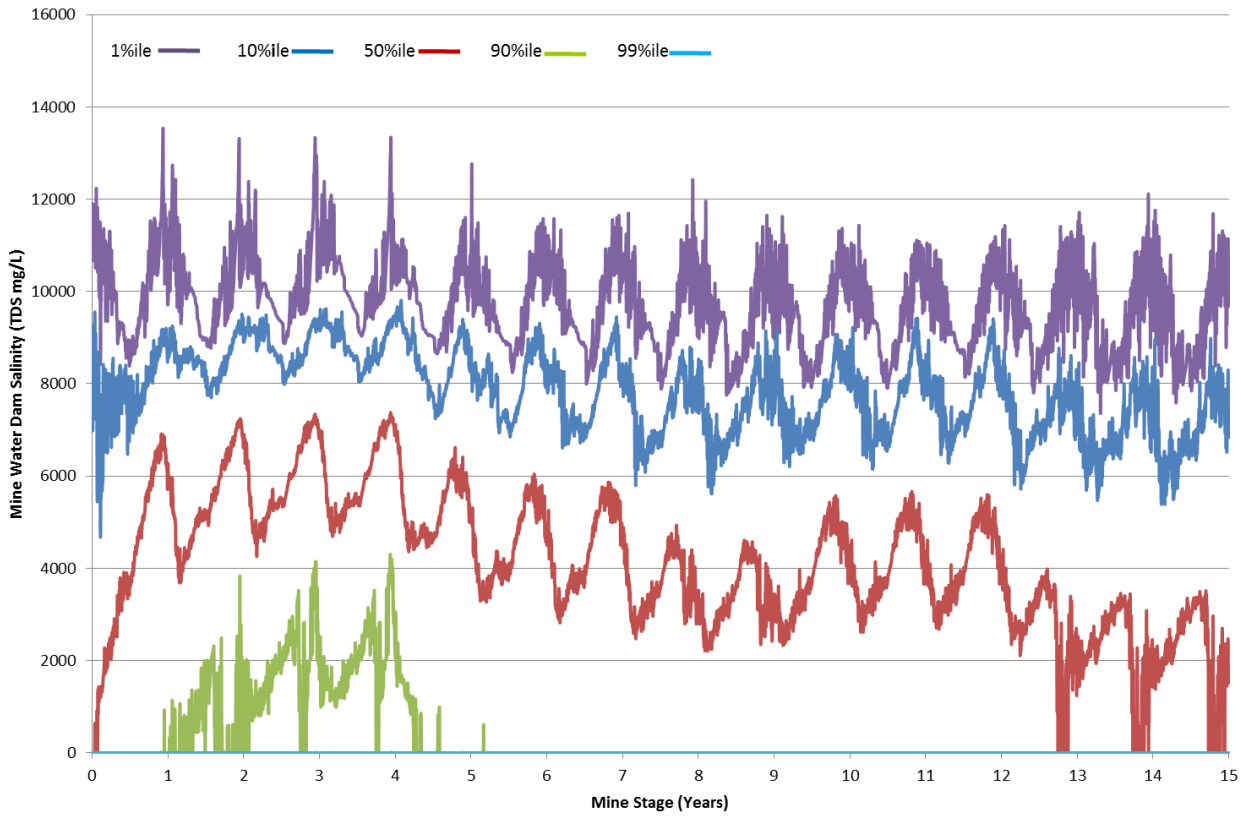

Figure 8.11 Forecast Mine Water Dam salinity concentration

8.3.9 Water Balance Model Results Summary

The risk of requiring externally sourced raw water is relatively consistent for the first twelve years of mine life, with the highest risk occurring in the last three years of mine life. CCL currently holds 500 ML of volumetric licence water allocation from the Dawson River.

The existing water licence allocation of 500 ML would meet all site demands:

- for the first 5 years of operations,
- in more than 90% of modelled realisations for years 6, 7, 10, 11 and 12,
- in more than 75% of realisations for the remaining years.

If required, additional water licences would be sought and purchased by CCL over the life of the project to meet raw water demands.

The results of the water balance modelling indicate that under the current model assumptions and configuration, there is a low risk of the BNCOP water management system accumulating water over the 15 year mine life. The results show that the system recovers well after each wet season.

The model results show no uncontrolled spills of mine-affected water from the Mine Water Dam or Process Water Dam occur.

8.4 ADAPTIVE MANAGEMENT OF MINE WATER BALANCE

The model results presented above represent the application of the adopted mine water management system rules over the mine life, regardless of climatic conditions. In reality, there are numerous options for adaptive management of the mine water management system to accommodate climatic conditions. For example, temporary adjustments to pumping arrangements could be made to accommodate very wet or dry periods. These alternative management approaches would be used to reduce the risks to the project associated with climatic variability.

8.5 FINAL VOID STORAGE BEHAVIOUR

8.5.1 Overview

The BNCOP final void water levels have been modelled as part of the BNCOP groundwater assessment (HydroSimulations, 2014). The OPSIM water balance model was reconfigured to simulate the final void behaviour to assess the long term accumulation of water and salts in the BNCOP final void.

8.5.2 Groundwater Behaviour

Figure 8.12 shows the relationship between the final void lake level and groundwater inflow rate developed by HydroSimulations (2014). Groundwater inflows from the surrounding un-mined geological units decline as lake stage increases. However, inflows from the in-pit spoil dump (i.e. the area to the south of the final void) actually increase as lake stage increases. This increase is not due to a change in hydraulic gradient between the lake and spoil dump (the gradient remains fairly constant), but rather an increase in the saturated cross-sectional area through which water can be transmitted (i.e. while lake stage is increasing, the heads in the spoil dump are also increasing).

For the purposes of modelling the recovery of the final void lake level, the combined relationship of these two inflow components is required, shown in Figure 8.12. The combined inflow rate from the surrounding un-mined geological units and from the in-pit spoil dump to the south decreases from about 1.5 ML/d at the base of the void to around 1.1 ML/d when the water level reaches about -40 mAHD. Above this void lake level, the groundwater inflow rate remains relatively constant at about 1.1 ML/d.

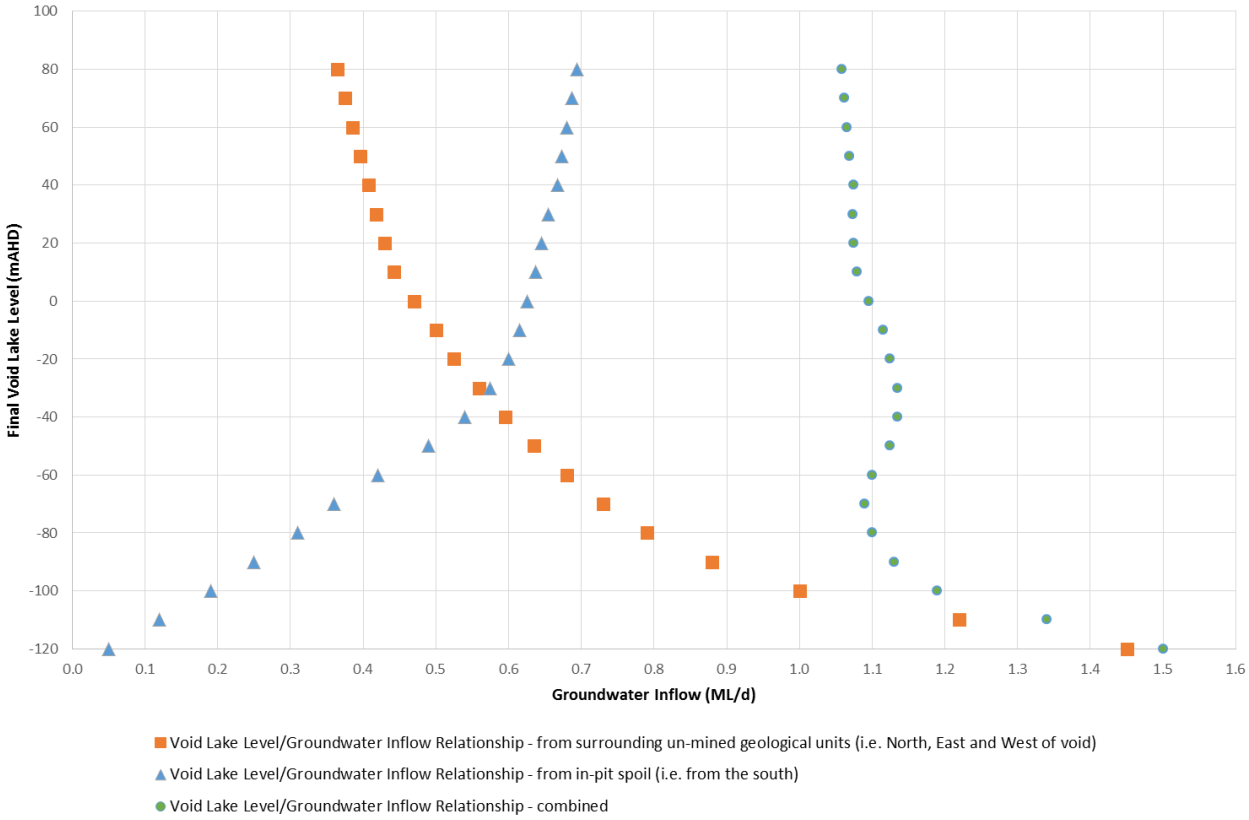

Figure 8.12 Adopted long term gross groundwater and seepage inflows and outflows to the final void

8.5.3 OPSIM Model Configuration

The final void configuration and contributing catchment area are shown in Figure 8.13. Following mine closure, there are no further operational demands and all infrastructure and mine water storages are rehabilitated. The water balance and final equilibrium water level of the final void is dependent on the rainfall and runoff entering the void, evaporation loss from the void, and the inflow or outflow of groundwater. It has been assumed that permanent drainage of spoil dumps would be installed to minimise capture of surface runoff in the final void. Appropriate engineering design of final landform drainage will be undertaken to ensure a long term stable drainage system.

The OPSIM model was run as a static simulation using the SILO Data Drill rainfall and evaporation data sequences from 1889 to 2012. A constant groundwater inflow rate of 1.1 ML/d, based on the information provided by HydroSimulations in Section 8.5.2 above, was applied to the simulation. Although the groundwater inflow rate is predicted to be higher initially (i.e. up to 1.5 ML/d when the lake level is near the bottom of the void), this will only impact a short period at the beginning of the void lake level's recovery. Once the void lake level has reached 30 to 40 m (i.e. -90 to -80 mAHD), the groundwater inflow rate has decreased to about 1.1 ML/d. The representative salinity parameter applied to the groundwater inflows was 7,500 mg/L, as per Section 6.8.

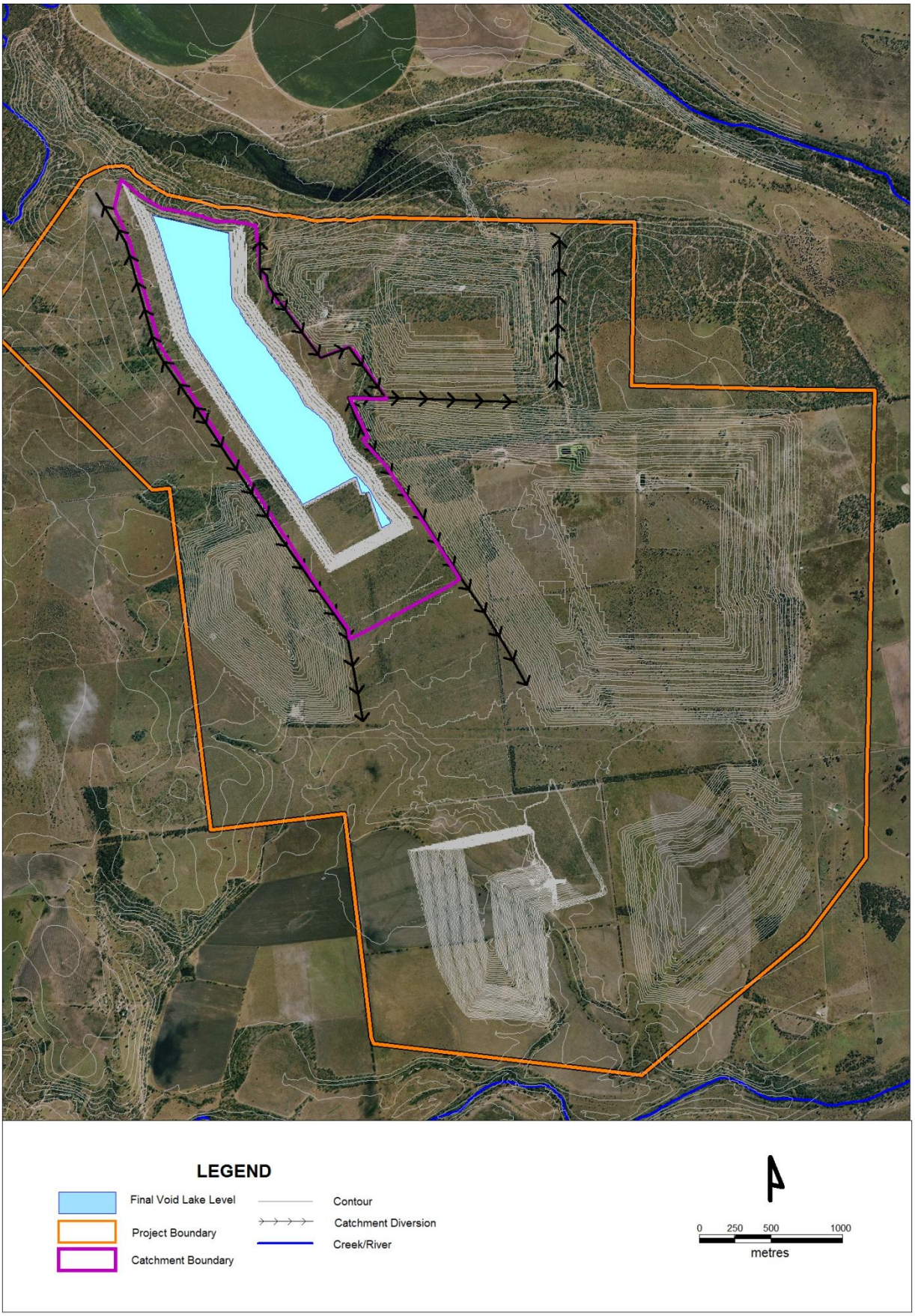

Figure 8.13 Conceptual final landform

8.5.4 OPSIM Model Results

The predicted void lake level and salt concentration, represented as total dissolved solids (TDS), in the final void is shown in Figure 8.14 and Figure 8.15, respectively. The void lake level as predicted in the groundwater model by HydroSimulations is also shown in Figure 8.14 for comparison. The results of the assessment are summarised as follows:

- the final void will reach an equilibrium water level of approximately 20 mAHD (i.e. 140m above the void base) after about 400 years. This result is generally consistent with the results produced by HydroSimulations (2014).
- the freeboard between the final water level surface and the void spill height is approximately 50 m. Hence, the final void is unlikely to fill (nor spill), as a rainfall event causing enough catchment runoff to fill the void is unlikely.
- the salinity in the final void would gradually increase due to the salinity of groundwater inflows, with TDS concentrations reaching 30,000 mg/L towards the end of the simulation period (500 years). It is likely that TDS concentrations would continue to increase over time as water evaporates and salt mass increases.

The difference in the recovery rate between the surface water model and the groundwater model is related to the different temporal and spatial resolution used in each of the models. The OPSIM surface water model is run on a daily time-step, hence storm events are included. During these events, the pit lake recovers faster than the groundwater model which uses annual average rainfall rates. The use of average annual rainfall effectively eliminates individual storm events and enhances the effect of evaporation, causing a slower recovery. The groundwater model also has a coarser representation of the final void bathymetry compared to the OPSIM surface water model. Allowing for these differences in the simulation methodology and assumptions, the surface and groundwater model results are considered to be in reasonable agreement.

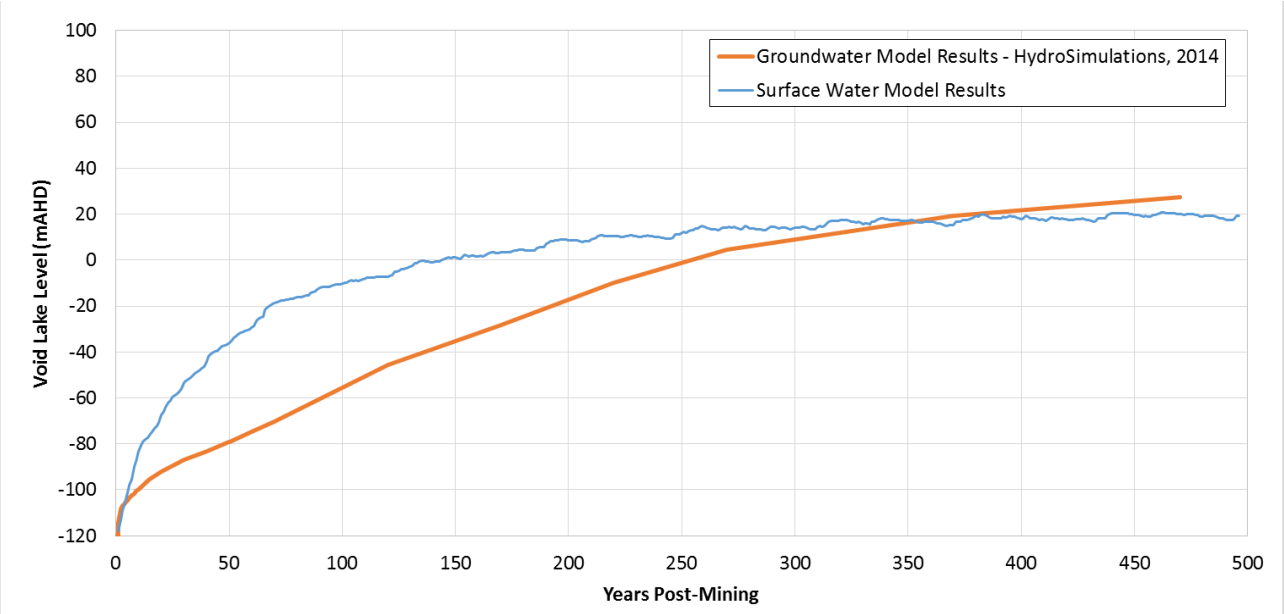

Figure 8.14 Final void lake level

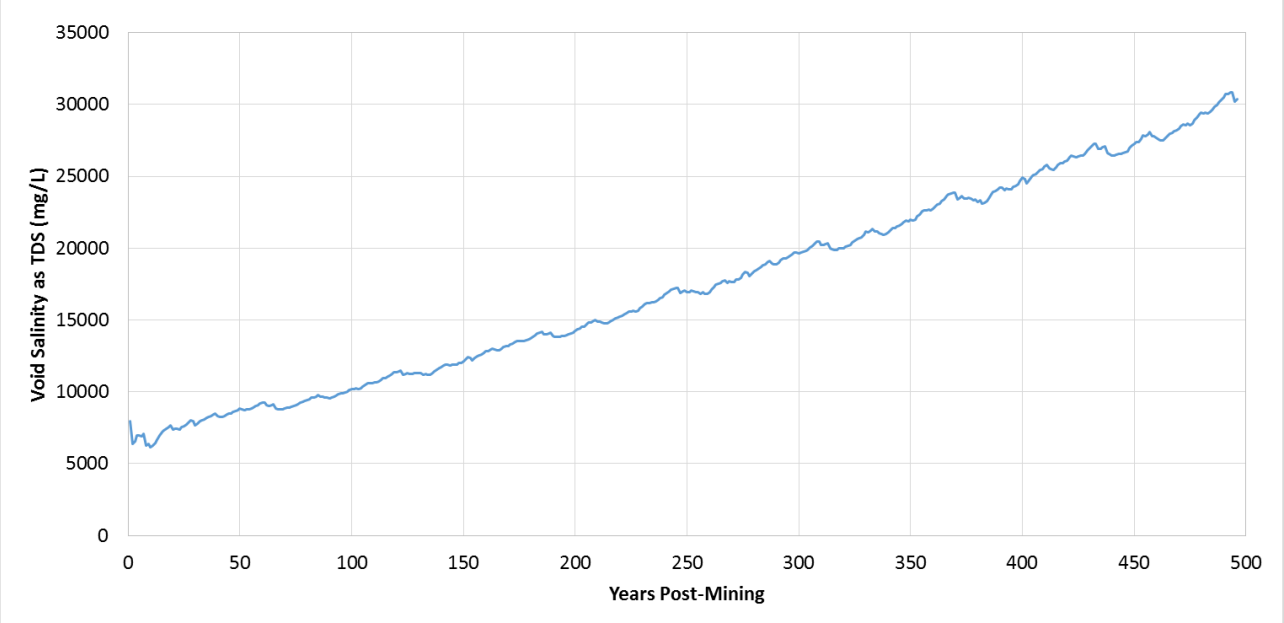

Figure 8.15 Final void total dissolved solids concentration

8.6 WATER BALANCE MODEL SENSITIVITY TO CLIMATE CHANGE

8.6.1 Overview

An assessment of the effect of climate change on the water balance model results was undertaken using the OPSIM model.

Projections of Australia's future climate were obtained from the "Climate Change in Australia" service (DCEE, 2013), developed by CSIRO and the Bureau of Meteorology through the Australian Climate Change Science Program. An explanation on the available climate change projections by the Climate Change in Australia service is provided below:

> "Projections are given relative to the period 1980-1999 (referred to as the 1990 baseline for convenience). The projections give an estimate of the average climate around 2030, 2050 and 2070, taking into account consistency among climate models. Individual years will show variation from this average. The 50th percentile (the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (lowest 10% and highest 10% of the spread of model results) provide a range of uncertainty. Emissions scenarios are from the IPCC Special Report on Emission Scenarios. Low emissions is the B1 scenario, medium is A1B and high is A1FI."

Climate change projections were chosen based on the medium emissions scenario for 2030 for the 10th and 90th percentile estimates to provide an indication of variation in potential climate change.

Table 8-5 shows the range of projected change in rainfall and evaporation provided by the Climate Change in Australia service for the relevant area. The adopted projected percentage changes, shown in Table 8-5 were applied to the daily time series of rainfall and evaporation used in the water balance model, whilst all other inputs and operating rules remained unchanged. Scenario 1 represents conditions that are 15% drier than current and 3% greater evaporation rates and Scenario 2 represents conditions that are 7.5% wetter than current and 6% greater evaporation rates. Scenario 1 and Scenario 2 (for both the operational model and the final void model) were compared to the modelling results presented in Section 8.3 and Section 8.5, which will be referred to as the base case.

Table 8-5 Climate change projection for 2030, medium emission scenario

Scenario Name	Climate Change Projection Estimate	Rainfall		Evaporation	
		Projected Range	Adopted	Projected Range	Adopted
Scenario 1	10%ile	-20% to -10%	-15%	2% to 4%	3%
Scenario 2	90%ile	5% to 10%	7.5%	4% to 8%	6%

8.6.2 Scenario 1

The results of the forecast water balance simulation for Scenario 1 (10% drier conditions) are summarised as follows for the operational simulation:

- the volume of water held on site is reduced:
  - at any point in time prior over the mine life, there is at least a 50% chance that the Mine Water Dam will be less than 260 ML, compared to 400 ML for the base case;
  - at any point in time prior over the mine life, there is at least a 90% chance (10% exceedance results trace) that the Mine Water Dam will be *less than* 553 ML, compared to 715 ML for the base case;

  - at any point in time prior over the mine life, there is at least a 99% chance (1% exceedance results trace) that the Mine Water Dam will be *less than* 910 ML, compared to 1,087 ML for the base case;
- there are no modelled spills from the Mine Water Dam or Process Water Dam.
- the risk of water accumulating in the active mining area is reduced. This is due to less inflow to the active mining area from direct rainfall and runoff, and also due to the Dirty Mine Water Dam reaching the maximum operating volume (MOV) (set to prevent spills) less often, resulting in more available storage space for dewatering to occur when it is required:
  - the in-pit inventory is not at risk of accumulating over the life of the mine (i.e. over multiple wet seasons), rather the system is able to recover prior to each subsequent wet season.
  - at any point in time during the mine life, there remains at least a 50% chance that the active pit will essentially be completely dewatered;
  - there is a 10% chance that the in-pit storage will reach at least 80ML in years 5 and 6, compared to 184 ML for the base case;
  - there is a 1% chance in each of years 5, 6 and 7 (the second modelled stage) that the in-pit storage will reach at least 530 ML to 590 ML, compared to 900ML in the base case; and
- the volume of controlled releases is reduced:
  - In each year, there is at least a 50% chance that there would be no controlled releases;
  - The 10% exceedance results trace varied between 500 ML/yr and 900 ML/yr, compared to 1,000 ML/yr – 1,270 ML/yr for the base case;
  - The 1% exceedance results trace varied between 1,780 ML/yr and 2,500 ML/yr, compared to 2,280 ML/yr – 3,170 ML/yr for the base case;
- the risk of requiring off-site water increases in order to supplement the reduced volumes of water available on-site is increased;
- the water supply reliability is reduced as a result of requiring a greater volume of off-site water supplies.
  - there is only a greater than 90% chance that the raw water demand can be met with the existing 500 ML/yr of licences in the first 5 years of operation. The reliability is about 87% in Year 6 and Year 7, is 80% or below in years 8 to 12, and is about 50% in years 13 – 15.
- the risk of sediment dams spilling is reduced, as there is more available storage space in the Mine Water Storage.

The results of the forecast water balance simulation for Scenario 1 (10% drier conditions) are summarised as follows for the final void behaviour assessment:

- the final void will reach an equilibrium water level of approximately 0 mAHD (i.e. 120m above the void base) after about 400 years, compared to reaching an equilibrium water level of approximately 20 mAHD for the base case climate scenario (see section 8.5)
- the salinity in the final void would gradually increase, with TDS concentrations reaching 40,000 mg/L towards the end of the simulation period (500 years), compared to 30,000 mg/L for the base case climate scenario.

8.6.3 Scenario 2

The results of the forecast water balance simulation for Scenario 2 (wetter conditions) are summarised as follows for the operational simulation:

- the effect of the increase in rainfall is largely offset by the increase in evaporation. The combined effect of these two changes has resulted in an overall increase of water captured on-site:
  - The volume of water held on site is slightly higher, resulting in an increased risk of reaching the MOV of the Mine Water Dam;
- there are no modelled spills from the Mine Water Dam;
- under this scenario there is a slight risk of spills occurring from the Process Water Dam. The results show that there is at least a 99% chance (1% exceedance results trace) that the annual spill volume from the Process Water Dam will be *less than* 3 ML. In reality the normal operating volume of this dam could be reduced or the pump rate back to the Mine Water Dam could be increased to prevent the very small risk of this dam spilling from occurring.
- the risk of water accumulating in the active mining area is slightly increased:
  - Over the majority of mine life, there remains a 50% chance that the active pit will be completely dewatered at any point in time;
  - there is a 10% chance that the in-pit storage will reach at least 220ML in years 5 and 6, compared to 184 ML for the base case;
  - there is a 1% chance in each of years 5, 6 and 7 (the second modelled stage) that the in-pit storage will reach at least 1,050 ML, compared to 900ML in the base case; and
- the volume of controlled releases is increased;
- the risk of requiring off-site water decreases slightly, as there is more water captured on-site which is preferentially used to meet site demands. The risk profile barely changes when compared to the base case;
- the water supply reliability is slightly improved as a result of requiring less volume of off-site water supplies; and
- the risk of sediment dams spilling is increased, as the Mine Water Dam is at or above its cease to pump trigger volume for sediment dams more frequently.

The results of the forecast water balance simulation for Scenario 2 (wetter conditions) for the final void behaviour assessment shows that the equilibrium water level and the salinity in the final void towards the end of the simulation period (500 years) are virtually unchanged compared to the base case climate scenario (see section 8.5). This is because the effect of the increase in rainfall is largely offset by the increase in evaporation.

8.6.4 Summary of Climate Change Impacts

Scenario 1 (drier conditions) resulted in a lower risk of water accumulating in the active mining area and an increased risk of requiring off-site water supplies.

Scenario 2 (wetter conditions) resulted in a slight increase in risk of water accumulating in the active mining area. However in both scenarios, the water management system continued to operate to meet the system objectives.

It is important to note that the projected changes to rainfall and evaporation were for 2030, which is towards the end of the BNCOP mine life. These projected changes were applied to the water balance model of the full mine life, however, which would result in a conservatively high estimate of the impacts of the projected changes.

9 IMPACT ASSESSMENT

9.1 POTENTIAL IMPACTS

The potential impacts of the Project on surface water resources include:

- impacts on regional water availability due to the potential need to obtain water from external sources to meet operational water requirements of mining operations;
- adverse impacts on the quality of surface runoff draining from the disturbance area to the various receiving waters surrounding the Project;
- adverse impacts on environmental values in the Dawson River associated with controlled releases from the mine water management system;
- loss of catchment area draining to local drainage paths and wetlands due to capture of runoff within onsite storages and the open cut pit.

An assessment of each of these potential impacts of the Project is provided in the following sections. Potential impacts of the Project on flood levels and flood velocities in the Dawson River and its tributaries are addressed in a separate flood study report (Water Solutions, 2014).

9.2 MINE SITE WATER REQUIREMENTS

A significant proportion of mine site water requirements will be sourced from water collected on the site, including rainfall runoff and groundwater inflows to the open cut pit which will be stored in the Mine Water Dam for recycling.

The results of the water balance modelling (see Section 8.3.6) show that the existing water licence allocation of 500 ML will meet all site demands:

- for the first 5 years of operations,
- in more than 90% of modelled realisations for years 6, 7, 10, 11 and 12,
- in more than 75% of realisations for the remaining years.

If required, additional water licences would be sought and purchased by CCL over the life of the project to meet raw water demands. As all off-site water supplies for the project would be obtained from licensed sources, there will be no adverse impact on other licensed users who will still have access to their entitlement (subject to climatic conditions and the operation of the water supply scheme).

9.3 UNCONTROLLED OFFSITE RELEASES

The results of the water balance modelling indicate that under the current model assumptions and configuration, there is a low risk of the BNCOP water management system accumulating water over the 15 year mine life. The results show that the system recovers well after each wet season.

The model results show no uncontrolled spills of mine-affected water from the Mine Water Dam or Process Water Dam occur.

Some overflow of treated water from sediment dams may occur during wet periods that exceed the design standard of the sediment control system (see Section 8.3.7). Available geochemical information indicates that the runoff draining to most of the sediment dams should have low salinity. Overflows would only occur during significant rainfall events which will also generate runoff from surrounding undisturbed catchments. Hence, it is unlikely that sediment dam overflows will have a measurable impact on receiving water quality.

9.4 CONTROLLED RELEASES – INCLUDING CUMULATIVE IMPACTS

The potential impacts on Dawson River water quality of controlled releases from the BNCOP (in accordance with the controlled release strategy specified in the existing EA EMPL00617113) were assessed using the OPSIM model. The results of the water balance model (see Section 8.3.4) show that the adopted release rules will ensure a minimum dilution ratio in the Dawson River of 48, with typical values of 100 or greater.

Water quality impacts immediately downstream of the release point in the Anabranch will be greater than in the river because average dilution is likely to be significantly lower than in the river. The water quality impacts on the Anabranch will be similar to the impacts of the current Baralaba Coal Mine.

A comparison of the available water quality data (provided in Appendix A) for river and on-site locations at the existing Baralaba Coal Mine shows that water quality parameters besides salinity within the mine water system are comparable to values in the river. However, the following water quality parameters have higher concentrations on-site than in the river:

- sulphate
- chloride
- calcium
- magnesium
- nitrate
- hardness
- molybdenum
- selenium.

The significant dilution of controlled discharges, combined with the proposed management strategies and monitoring recommended in the BNCOP geochemistry assessment (Appendix E of the EIS) (Terrenus, 2014), will ensure that the risks of mine-affected water impacting downstream water quality are low.

The impacts of controlled releases on river flow volumes will be very small, due to the significant dilution of controlled discharges. For example, for a dilution ratio of 50, the controlled release would increase river flow by 2%. Most of the time, the dilution ratio is much larger (see Section 8.3.4). Hence, controlled releases will have no measurable impact on Dawson River flows.

The cumulative impacts associated with contemporary development of the potential Baralaba South Project were also assessed. The Baralaba South Project, located to the south of Baralaba, is under consideration at present and has not yet been fully designed or submitted for approval. Hence, it was necessary to make a number of assumptions to allow the potential impacts of discharges to be assessed.

To simulate the impacts of the Baralaba South Project, the OPSIM water balance model was reconfigured to include a representation of the contribution of controlled releases from the potential Baralaba South Project. A number of conservative assumptions were made to provide a worst case estimate for cumulative impacts. The potential development of the Baralaba South Project was assumed to have:

- the same release conditions as BNCOP (see Section 6.5);
- an unlimited supply of "stored" water onsite in order to maximise utilisation of any release opportunities. In reality, the releases would be limited by how much water onsite was actually available for release at a given time (providing the water was compliant with the water quality release criteria); and
- a constant salinity concentration for the "stored" water.

Note that the salinity concentration of controlled releases from BNCOP varies daily, based on the daily water balance of the mine life and the salinity in the Dawson River also varies daily, based on the IQQM data.

The salinity concentration of the modelled releases from BNCOP was assessed to provide a basis for selecting an appropriate constant salinity parameter to apply to the potential Baralaba South Project. Two options for the controlled releases from the potential Baralaba South Project were assessed:

- the first scenario adopted a salinity concentration of 2,000 mg/L (based on the average controlled release salinity from BNCOP from all modelled realisations);
- the second scenario adopted a salinity concentration of 5,000 mg/L (based on the 99th percentile controlled release salinity from BNCOP from all modelled realisations).

Figure 9.1 shows a ranked plot of the salinity concentration in the Dawson River at Beckers over the 15 year mine life for a representative realisation (i.e. climatic sequence) for four scenarios:

- the Dawson River with no mine releases;
- the Dawson River plus controlled releases from BNCOP (varying salinity); and
- the Dawson River plus controlled releases from BNCOP (varying salinity) and from Baralaba South for two scenarios:
  - releases at a constant salinity of 2,000 mg/L; and
  - releases at a constant salinity of 5,000 mg/L.

The results of the cumulative impacts assessment show that there is negligible impact on the downstream water quality through controlled releases by BNCOP alone, or in combination with the potential Baralaba South Project.

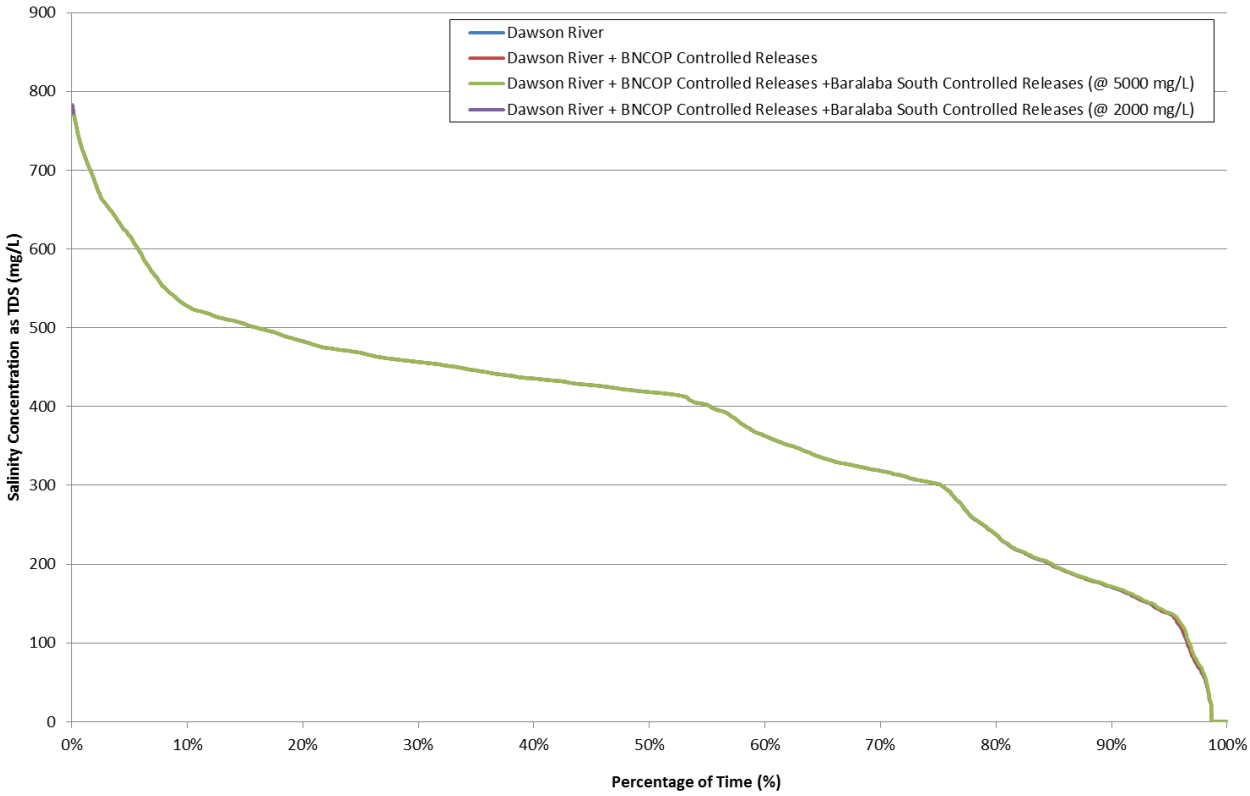

Figure 9.1 Distribution of Dawson River salinity on release days

9.5 LOSS OF CATCHMENT

9.5.1 During Active Mining Operations

During active mining operations, the mine water management system will capture runoff from areas that would have previously flowed to the receiving waters of Saline Creek, the Dawson River Anabranch and northern wetland area. The captured catchment area will change as the Project develops.

Table 9-1 shows the catchment area captured within the mine water management system for various stages of mine development. The catchment areas shown in Table 9-1 are the catchment areas captured assuming that no water overflows or is released from sediment dams. Hence, the maximum captured catchment areas represent:

- less than 1% of the Saline Creek catchment;
- approximately 0.01% of the Dawson River catchment to the Beckers stream gauge; and
- approximately 52% of the northern wetland catchment.

Table 9-1 Catchment area captured within the mine water management system

Catchment	Total Catchment Area (km²)	Mine Captured Catchment Area (km²)				
		Year 3	Year 7	Year 8	Year 11	Year 15
Saline Creek	292	0.0	0.0	0.0	1.0	1.0
Northern Wetland	17.5	3.7	7.7	7.8	9.2	9.2
Dawson River (including anabranch)	40,500	1.2	1.2	1.2	1.2	1.2

9.5.2 Final Landform

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. It has been assumed that permanent drainage of overburden emplacement areas will be installed to minimise capture of surface runoff in the final void. An area of approximately 2.86 km² will continue to drain to the mine final void.

The catchment boundaries of the final landform are shown in Figure 9.2. The net change in catchment area draining from the site is summarised in Table 9-2. The changed topography as a result of the Project will have the following impacts on catchment areas:

- the catchment draining north to Saline Creek will increase by 0.27 km², an increase of less than 0.1%;
- the catchment draining to the northern wetland will reduced by 4.1 km². This represents a reduction in catchment area of about 23%; and
- the catchment draining directly to the Dawson River and Dawson River Anabranch will be increased by 0.97km²; and, in practical terms, will have no measureable impact on river flows.

Table 9-2 Change in catchment area, final landform

Receiving Watercourse	Change in Catchment Area (km²)
Saline Creek	+0.27
Northern Wetland	-4.10
Dawson River (to Beckers Stream Gauge)	+0.97
Final Void	+2.86

The reduction in catchment area draining to the wetland area north of the site will reduce catchment runoff inflows to the wetland by a similar proportion to the reduction in catchment area. However, the wetland also receives inflow from flood events in Saline Creek relatively small events (less than 1 in 2 year annual exceedance probability) year and inflows from the Dawson River during major river floods (1 in 50 and larger). Due to these flood inflows to the wetland, the impacts on total wetland inflows will be less than indicted by the proportional reduction in catchment area. An assessment of the frequency of flood inundation of the wetland is provided in Section 9.6.

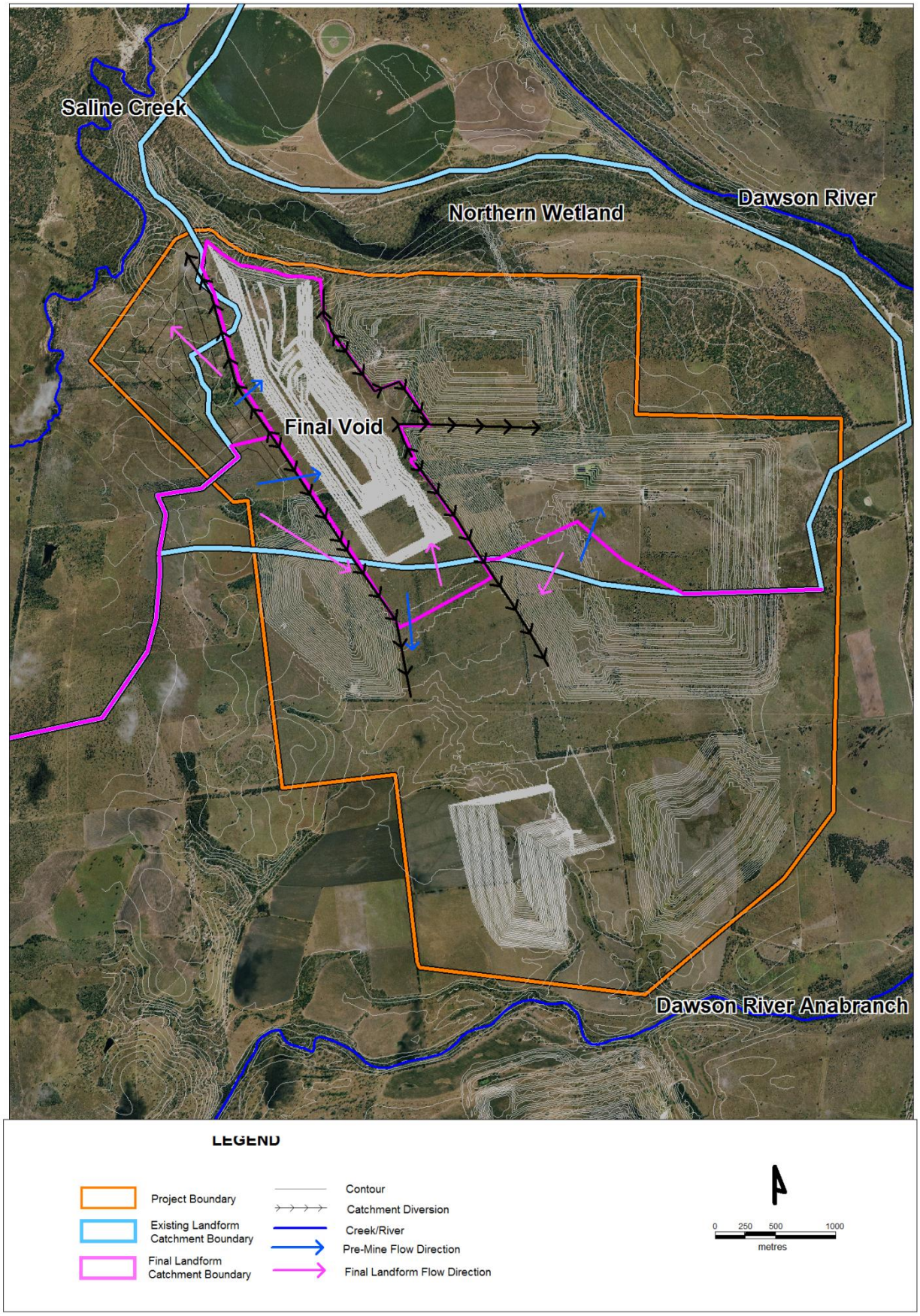

Figure 9.2 Final landform catchment boundaries

9.6 FLOOD INUNDATION FREQUENCY OF NORTHERN WETLAND

Flood modelling of the Dawson River and Saline Creek (Water Solutions 2014) indicates that the Northern Wetland is periodically inundated by flooding from Saline Creek and the Dawson River. The results of the Water Solutions flood study for the 1 in 20, 1 in 50 and 1 in 100 year AEP flood events show that the Dawson River overflows the western river bank to directly inundate the Northern Wetland for the 1 in 50 and 1 in 100 year AEP flood events. The wetland is affected by Saline Creek flooding for the 1 in 20 AEP event.

A simplified hydraulic assessment was undertaken to estimate the likely frequency of flooding of the Northern Wetland by Saline Creek for events less than the 1 in 20 AEP event. A representative cross-section of Saline Creek adjacent to the overflow point into the Northern Wetland (see Figure 9.3) was extracted from digital elevation data. A rating curve for this cross-section was developed to match peak flood levels and discharges from the flood study.

Approximate Saline Creek discharges for design events less than 1 in 20 AEP were obtained by scaling the 1 in 20 discharge in proportion to design rainfall intensity. On this basis the estimated 1 in 2 AEP discharge was about 100 m^3/s (compared to a 1 in 20 AEP discharge of 200 m^3/s).

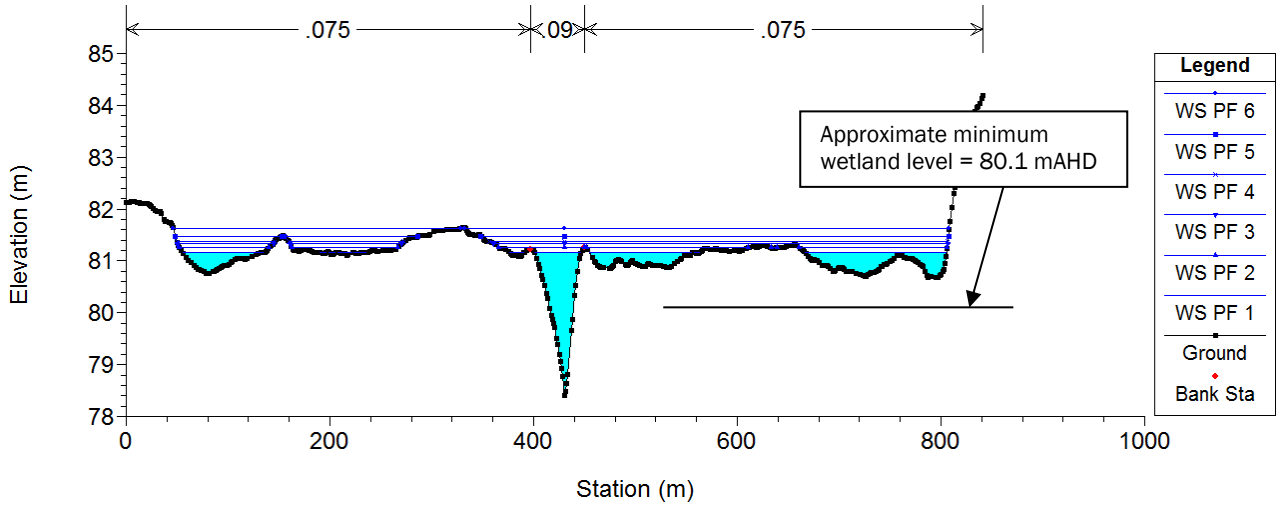

Figure 9.3 Cross section of Saline Creek

The topography in the vicinity of the overflow point from Saline Creek into the Northern Wetland is shown in Figure 9.4. The minimum wetland level is about 80.1 mAHD. Comparison with Figure 9.3 shows that this is lower than the bank level of Saline Creek, which is over 81 mAHD. Hence, any event that causes overbank flow in Saline Creek will result in overflow into the Northern Wetland.

From the estimated rating curve for Saline Creek, the 1 in 2 AEP flood level in Saline Creek near the overflow point to the Northern Wetland is approximately 81.3 mAHD, which is more than a metre higher than the minimum wetland level. Hence, water from Saline Creek is likely to overflow into the wetland during a 1 in 2 year AEP event. This indicates that there is a better than 50% chance each year that the Northern Wetland will experience flood inflows from Saline Creek.

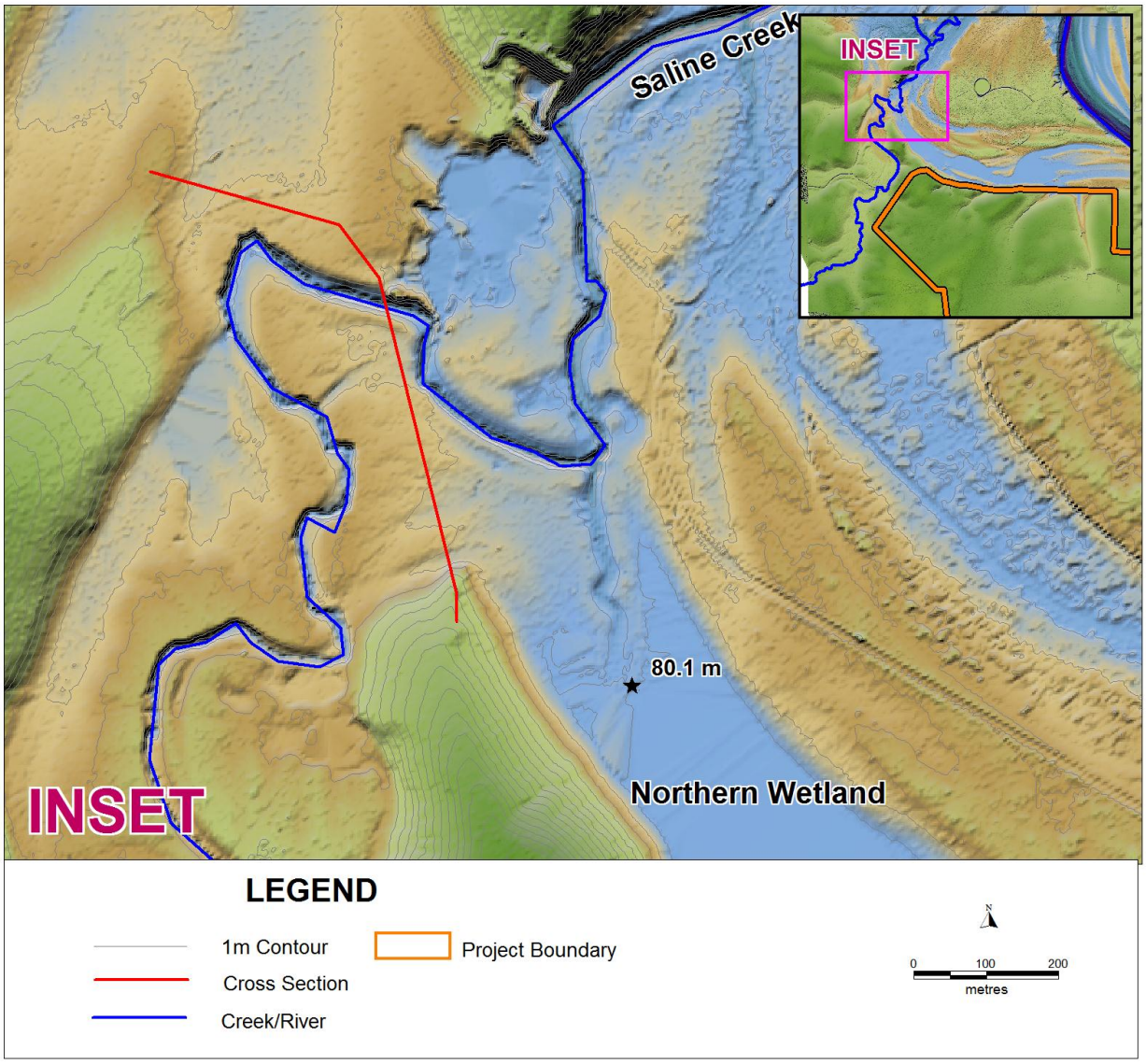

Figure 9.4 Topography of Saline Creek in the vicinity of the Northern Wetland

10 MITIGATION AND MANAGEMENT MEASURES

10.1 OVERVIEW

The impacts of the Project on surface water resources will be mitigated through the implementation of the following measures:

- a mine site water management system to control the flow and storage of water of different qualities across the site;
- a sediment control plan to reduce sediment loads from disturbed area runoff; and
- a surface water monitoring program to continually assess environmental impacts and ensure that the site water management system is meeting its objectives of minimal impact on receiving waters.

An overview of each of these management measures is provided in the following sections. Further detail on the proposed mitigation and management measures will be provided in the water management plan for the approved Project.

10.2 MINE WATER MANAGEMENT SYSTEM

A key objective of the mine water management system will be to minimise the risk of uncontrolled releases from mine site storages. To achieve this objective, operation of the mine water management system will be based on the following principles:

- diversion of clean surface water runoff away from areas disturbed by mining activities;
- operation of the mine water management system to ensure no uncontrolled releases of mine water from the site;
- collection of potentially sediment-affected runoff in sediment dams for treatment prior to release from site or reuse in the mine water management system;
- transfer of groundwater and seepage inflows to the open cut pits to the mine water system for reuse as a water supply;
- collection of contaminated water from industrial areas for treatment in an oil and grease separator prior to recycling in the mine water management system; and
- minimisation of fresh water usage by recycling water from the mine water system before taking additional water from external sources.

Details of the operation of the mine water management system are provided in Section 6.

An important component of the mine water management system will be to ensure that contingency measures are in place to accommodate either a surplus or deficit of water on site. Appropriate water licences will be obtained to meet the potential shortfall in water during dry conditions. Mine operations will also be planned to ensure that mining can continue during extended wet periods when water may accumulate in the open cut mining areas.

The site water management plan will detail reporting and action procedures to identify any lack of compliance with objectives and a process for implementing corrective actions.

10.3 SEDIMENT AND EROSION CONTROL PLAN

A sediment and erosion control plan will be developed as part of detailed design for the Project. The design of sediment control measures will be based on the principle of ensuring that runoff from disturbed areas is separated from clean area runoff and collected in sediment dams for treatment.

Sizing of the proposed sediment basins will be undertaken in accordance with the Best Practice Erosion and Sediment Control (BPESC) guideline (IECA, 2008). The BPESC document provides guidance on sediment basin sizing, design and operation. Sizing of sediment dams using the BPESC guideline is based on storm events with an average recurrence interval (ARI) of 3 months to 1 year. That is, it is targeted towards treating the smaller, more frequent events which comprise the bulk of the annual volumetric runoff. However, it also provides sediment trapping benefits during larger, less frequent storms through removal of coarse sediments passing through the basin.

Locations of proposed major sediment dams to collect and treat runoff from overburden emplacement areas are shown in Figure 5.1 to Figure 5.5. Additional minor sediment traps may also be required at other locations across the site.

10.4 SURFACE WATER MONITORING PROGRAM

Monitoring of surface water quality both within and external to the mine site will form a key component of the surface water management system. Monitoring of upstream, onsite and downstream water quality will assist in demonstrating that the site water management system is effective in meeting its objective of minimal impact on receiving water quality and will allow for early detection of any impacts and appropriate corrective action.

The surface water monitoring protocols will:

- ensure compliance with the BNCOP Environmental Authority;
- provide valuable information on the performance of the water management system; and
- facilitate adaptive management of water resources on the site.

The Proponent has previously monitored a number of surface water locations in the BNCOP vicinity (as detailed in Section 4.5.1). The Surface Water Monitoring Program will include the continued monitoring of a number of these sites to monitor surface water flows and quality upstream and downstream of the mine. The following changes will be required to the monitoring program to accommodate the BNCOP:

- addition of sampling locations along Saline Creek, upstream and downstream of mine disturbance within the Saline Creek catchment;
- addition of new mine site storages for the BNCOP;
- monitoring of controlled release and uncontrolled discharge rates and daily volumes;
- monitoring of water levels in key storages and transfer volumes between storages within the mine site to provide a basis for validating the water balance modelling and, if necessary, updating the modelling to reflect operating experience.

Figure 10.1 shows proposed stream monitoring locations. Details of the proposed monitoring locations, including sample collection frequency and key water quality parameters to be monitored, are shown in Table 10-1. Table 10-1 also shows the proposed water quality monitoring program for water storages on site.

Where more than 25 mm of rainfall is recorded in 24 hours, an inspection of the site water management system, in particular, sediment control infrastructure, will be undertaken.
The post-event inspection will include field-based assessment of water quality for any sediment dam overflows. Daily rainfall and dam volumes will also be recorded at the sites to assist in identifying significant rainfall events.

Note the continued monitoring of release points and on-site storages related to Baralaba Coal Mine are not included in the monitoring program for BNCOP.

Table 10-1 Surface water monitoring program

Location		Coordinates		Parameters	Frequency
		Easting	Northing		
Saline Creek	SCU	779872	7332083	Suite 2	Monthly or when daily rainfall > 25 mm
	SCT	780110	7333423		
	SCD	780362	7334138		
Dawson River Anabranch	D1	787655	7327854	Suite 1 Suite 2	Daily during Controlled Releases Monthly Weekly during Controlled Releases
	D2	784600	7326959		
	Anabranch Gauging Station	784600	7326959	Flow Rates	Continuous during Controlled Releases
BNCOP Discharge Point	RPN2	784727	7327357	Suite 1 Suite 2	Daily during Controlled Releases Upon commencement of Controlled Release and weekly thereafter.
Dawson River Upstream	A1	785939	7323969	Suite 1 Suite 2	Daily during Controlled Releases Monthly Weekly during Controlled Releases
	DR1	785364	7321567		
	Neville Hewitt Weir	785923	732916	Flow Rates	Daily
	Stream Gauge	788121	7327857	Flow Rates	Daily
Dawson River Downstream	DR4	788200	7328272	Suite 1 Suite 2	Daily during Controlled Releases Monthly Weekly during Controlled Releases
	DR3	785706	7333836		
	Beckers	786929	7333203	Flow Rates	Daily
BNCOP Mine Site	MD 4a	TBA	TBA	Suite 2	Monthly
	MD 4b	TBA	TBA		
	Process Water Dam	TBA	TBA		
	Sediment Dams	TBA	TBA	Suite 2	Monthly until baseline established, then quarterly

Suite 1= pH, EC, TSS, TDS, Turbidity, Sulphate
Suite 2 = Suite 1 + Major Anions, Major Anions, Alkalinity, Metals

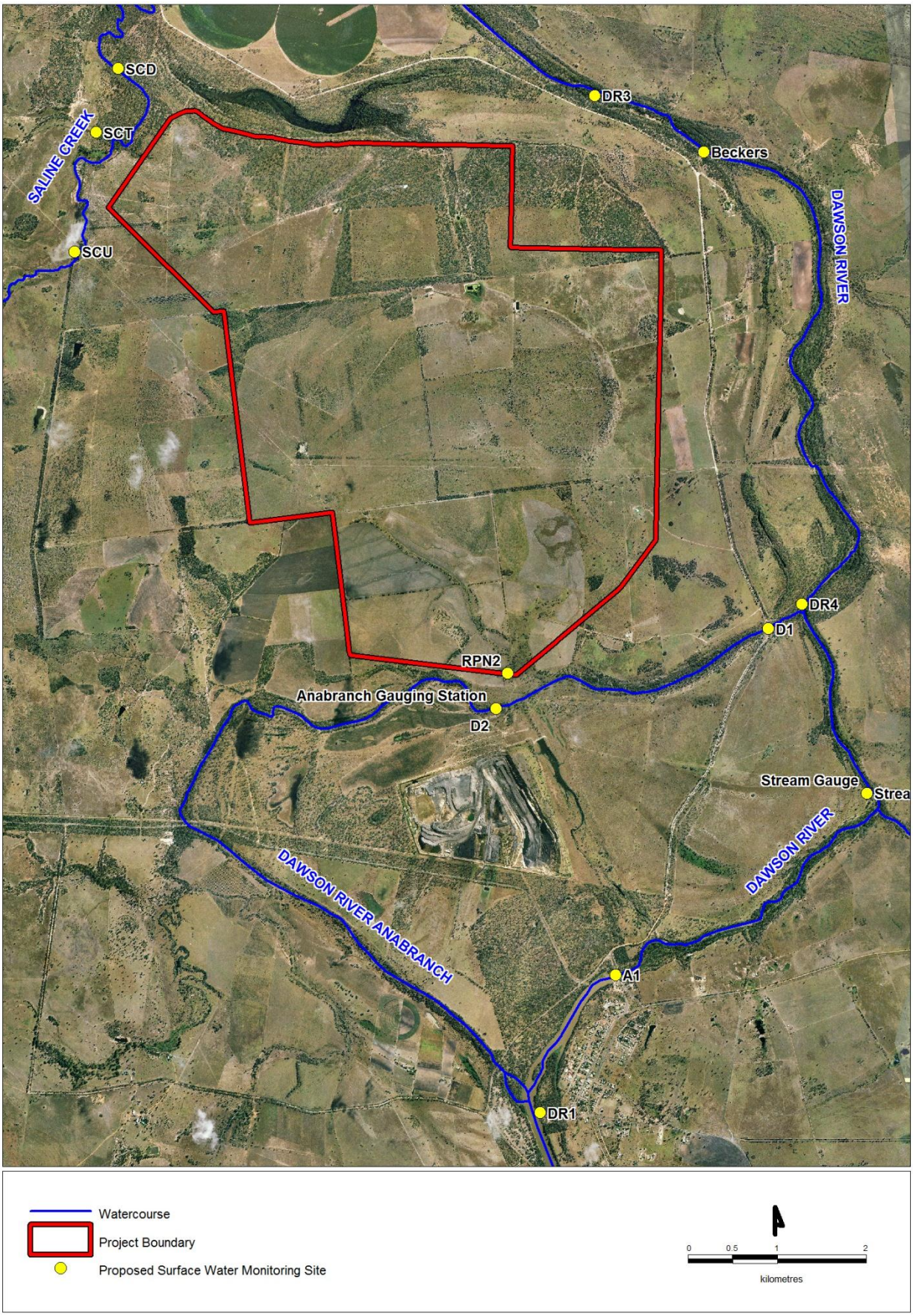

Figure 10.1 Proposed water monitoring locations

11 SUMMARY OF FINDINGS

The impacts of the Project on surface water resources will be mitigated through the implementation of a mine site water management system to control the flow and storage of water of different qualities across the site. A surface water monitoring program will be implemented to continually assess environmental impacts and ensure that the site water management system is meeting its objectives.

The performance of the mine water management system has been investigated using a detailed site water balance model. The model simulated water inflows and outflows through the various stages of mine development for 110 different climate sequences (each referred to as a 'realisation') extracted from historical rainfall data.

Water collected on the site will be used as first priority to satisfy site demands, such as coal processing and dust suppression. Water will be drawn from off-site sources only when required to make up a shortfall in water available on the site.

CCL currently holds 500 ML of volumetric licence water allocation from the Dawson River. The water balance model results show that the existing water licence allocation of 500 ML should be sufficient to meet all site demands:

- for the first 5 years of operations,
- in more than 90% of modelled realisations for years 6, 7, 10, 11 and 12,
- in more than 75% of realisations for the remaining years.

If required, additional water licences would be sought and purchased by CCL over the life of the project to meet raw water demands. There is a 10% chance that the volume of external water supply required from Year 8 of the Project onwards will be in the range of 500 ML/yr to 700 ML/yr.

Water required from external sources will be obtained under appropriate Water Access Licences to ensure no adverse impacts on water availability for other licensed water users.

The results of the water balance modelling indicate that there is a low risk of the BNCOP water management system accumulating water over the 15 year mine life. The results show that the system recovers well after each wet season.

The model results show no uncontrolled spills of mine-affected water from the Mine Water Dam or Process Water Dam, consistent with the proposed operating strategy for the mine water system.

Controlled releases from the mine water system will occur when water quality and river flow meet the trigger levels in the Environmental Authority. The water balance model indicates that the minimum dilution ratio of controlled release discharges is 50 (river flow rate equals 50 times site discharge rate), with a median dilution ratio of greater than 190. Based on this level of dilution, the impacts of controlled releases on flow and water quality in the river should be almost undetectable.

The Project will temporarily reduce the catchment area draining to receiving watercourses due to capture of runoff from disturbed catchment areas within the mine water management system. The maximum captured catchment areas represent:

- less than 1% of the Saline Creek catchment;
- approximately 0.01% of the Dawson River catchment; and
- approximately 52% of the catchment draining to the wetland area to the north of the Project.

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. An area of approximately 2.9 km^2 will continue to drain to the mine final void. The changed topography following completion of the Project will have the following impacts on catchment areas:

- the catchment draining north to Saline Creek will increase by 0.27 km^2, an increase of less than 0.1%;
- the catchment draining to the northern wetland will be reduced by 4.1 km^2. This represents a reduction in catchment area of about 23%; and
- the catchment draining directly to the Dawson River and Dawson River Anabranch will be increased by 0.97km^2.

The reduction in catchment area draining to the wetland area north of the site will reduce catchment runoff inflows to the wetland by a similar proportion to the reduction in catchment area. However, the wetland also receives inflow from flood events in Saline Creek for relatively small events (less than 1 in 2 year annual exceedance probability) and inflows from the Dawson River during major river floods (1 in 50 annual exceedance probability and larger). Due to these flood inflows to the wetland, the impacts on total wetland inflows will be less than indicated by the proportional reduction in catchment area.

Water balance simulation of the final void shows that the water surface is expected to reach an equilibrium water level approximately 50 m below the overflow level. The lake will take approximately 400 years to reach the equilibrium level.

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APPENDIX A

Water Quality Monitoring Results

Water Quality Parameter		Sampling Site: Dawson River Upstream				Anabranch U/S		Anabranch D/S	Dawson River Downstream		Saline Creek				Site Dams				Release Points	
		A1	WS5	DR1	DR2	WS6	D2	D1	DR3	DR4	SCT	SCD	SCU	SCUi	Mine Dam #1	Mine Dam #2 Farm Dam	Pit	ROM Dam	RP1	RP2
pH	N	219	10	15	2	9	13	16	28	3	2	1	1	1	12	11	12	11	201	70
(pH units)	20%ile	6.92	7.72	7.48	6.90	7.30	7.24	7.4	7.20	7.54	5.94	7.05	6.50	6.22	7.54	8.20	7.92	8.00	7.01	6.97
	Median	7.78	8.35	8.00	7.05	7.60	7.50	7.7	7.85	7.6	6.22	7.05	6.50	6.22	7.85	8.60	8.00	8.10	7.88	7.64
	80%ile	8.10	9.52	8.34	7.20	7.64	7.72	7.9	8.16	7.6	6.50	7.05	6.50	6.22	8.10	8.90	8.10	8.30	8.28	7.86
Conductivity	N	219	10	15	2	9	13	16	28	3	2	1	1	1	12	11	12	11	203	71
(µS/cm)	20%ile	187	168	244	152	158	238	310	380	310	432	382	112	74	2,600	360	7,020	4,500	403	368
	Median	270	185	280	170	200	310	2,235	450	340	470	382	112	74	7,700	3,910	7,290	8,000	620	423
	80%ile	369	308	360	188	532	382	2,440	511	406	507	382	112	74	16,280	7,380	7,740	8,800	1,459	476
Total Suspended Solids	N	237	8	17	2	5	15	21	35	3	2	1	1	1	14	13	14	11	188	72
(mg/L)	20%ile	6	13	5	160	32	5	13	9	5	24	11	45	20	7	14	7	10	12	21
	Median	20	20	8	160	98	7	16	13	5	27	11	45	20	14	33	11	18	28	46
	80%ile	55	61	29	160	206	30	28	56	7	30	11	45	20	29	300	15	24	91	97
Total Dissolved Solids	N	60	0	15	0	0	16	16	23	3	0	0	0	0	15	14	15	10	32	5
(mg/L)	20%ile	150	-	183	-	-	154	134	202	208	-	-	-	-	1,650	285	4,136	5,322	42	275
	Median	207	-	211	-	-	209	277	232	213	-	-	-	-	4,290	2,095	4,990	5,775	300	290
	80%ile	248	-	227	-	-	315	1,300	267	244	-	-	-	-	9,560	3,936	5,442	5,878	502	322
Sulphate	N	230	9	18	2	9	16	22	36	3	2	1	1	1	15	14	15	11	184	72
(mg/L)	20%ile	5	2	4	5	1	1	2	5	4	6	11	7	5	356	5	568	540	20	15
	Median	6	3	4	5	1	1	87	5	4	8	11	7	5	810	117	640	650	65	42
	80%ile	12	10	5	5	2	2	94	5	5	9	11	7	5	1880	462	690	700	140	67
Turbidity	N	234	9	12	0	9	12	18	32	3	2	1	1	1	11	10	11	10	189	72
(NTU)	20%ile	17	7	6	-	15	4	11	9	8	67	39	19	34	2	9	2	4	23	150
	Median	60	14	20	-	25	5	15	15	13	67	39	19	34	4	28	4	8	65	300
	80%ile	150	154	67	-	166	13	20	47	26	68	39	19	34	13	152	7	11	304	500
Chloride	N	32	7	3	2	8	2	4	9	0	0	0	0	0	2	2	2	2	23	6
(mg/L)	20%ile	25	13	12	12	10	9	12	24	-	-	-	-	-	1,632	1,320	1,660	956	48	48
	Median	40	19	18	15	12	9	262	78	-	-	-	-	-	2,745	1,650	1,750	1,010	100	56
	80%ile	71	22	26	17	16	9	522	86	-	-	-	-	-	3,858	1,980	1,840	1,064	214	64
Calcium	N	31	7	3	2	8	2	4	9	0	1	1	1	0	2	2	2	2	22	6
(mg/L)	20%ile	12	10	12	12	13	13	17	11	-	9	9	5	-	188	76	214	130	11	9
	Median	16	13	13	13	13	13	45	16	-	9	9	5	-	305	93	220	130	19	11
	80%ile	20	17	15	14	17	13	79	23	-	9	9	5	-	422	109	226	130	43	12
Magnesium	N	29	7	3	2	8	2	4	8	0	2	1	1	1	2	2	2	2	19	6
(mg/L)	20%ile	4.3	5.0	4.0	4.0	4.9	4.3	6.0	3.9	-	12.1	10.6	3.6	2.5	147.2	58.0	146.0	112.0	5.6	5.3
	Median	5.9	5.3	4.8	4.9	5.8	4.4	27.7	7.9	-	13.7	10.6	3.6	2.5	249.5	77.5	155.0	115.0	8.8	5.8
	80%ile	9.7	6.6	5.8	5.7	10.8	4.5	53.0	12.2	-	15.2	10.6	3.6	2.5	351.8	97.0	164.0	118.0	16.4	6.3
Sodium	N	27	7	2	2	8	0	2	4	0	2	1	1	1	0	0	0	1	23	6
(mg/L)	20%ile	19	15	14	12	12	-	356	47	-	51	43	10	8	-	-	-	680	72	56
	Median	31	19	15	14	16	-	380	51	-	61	43	10	8	-	-	-	680	100	71
	80%ile	44	22	16	16	23	-	404	54	-	70	43	10	8	-	-	-	680	212	76
Ammonia As N	N	45	2	16	1	8	15	10	19	3	2	1	1	1	14	13	14	11	26	7
(mg/L)	20%ile	0.010	0.074	0.006	0.120	0.418	0.006	0.015	0.008	0.006	0.117	0.017	0.239	0.181	0.006	0.006	0.038	0.090	0.010	0.010
	Median	0.030	0.140	0.026	0.120	1.000	0.029	0.030	0.020	0.006	0.143	0.017	0.239	0.181	0.016	0.008	0.150	0.120	0.030	0.020
	80%ile	0.070	0.206	0.050	0.120	1.000	0.052	0.076	0.048	0.008	0.169	0.017	0.239	0.181	0.218	0.112	1.008	0.430	0.060	0.056
Nitrate as N	N	45	5	15	0	0	15	9	17	3	2	1	1	1	14	13	14	11	26	7
(mg/L)	20%ile	0.02	0.08	0.01	-	-	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	7.30	4.10	0.61	0.89
	Median	0.05	0.20	0.01	-	-	0.06	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	17.50	7.70	1.00	0.95
	80%ile	0.20	0.20	0.04	-	-	0.11	0.02	0.18	0.03	0.01	0.01	0.01	0.01	0.05	0.15	20.00	19.00	1.40	1.20
Nitrite as N	N	40	3	15	1	8	15	8	18	3	2	1	1	1	14	13	14	11	23	6
(mg/L)	20%ile	0.01	0.20	0.00	0.14	0.05	0.01	0.00	0.00	0.00	0.01	0.01	0.17	0.01	0.00	0.00	0.09	0.06	0.02	0.02
	Median	0.02	0.30	0.00	0.14	0.10	0.01	0.00	0.01	0.00	0.02	0.01	0.17	0.01	0.00	0.00	0.12	0.13	0.02	0.03
	80%ile	0.03	0.72	0.01	0.14	0.10	0.02	0.01	0.02	0.00	0.02	0.01	0.17	0.01	0.01	0.01	0.18	0.18	0.02	0.03
Total Fluoride	N	43	1	15	1	6	13	7	16	2	2	1	1	1	12	11	12	9	26	7
(mg/L)	20%ile	0.02	0.15	0.10	0.02	0.50	0.10	0.10	0.05	0.10	0.18	0.09	0.05	0.08	0.10	0.10	0.10	0.10	0.02	0.02
	Median	0.04	0.15	0.10	0.02	0.50	0.10	0.10	0.10	0.10	0.25	0.09	0.05	0.08	0.11	0.29	0.10	0.10	0.03	0.02
	80%ile	0.10	0.15	0.10	0.02	0.50	0.10	0.10	0.20	0.10	0.31	0.09	0.05	0.08	0.84	0.30	0.20	0.10	0.10	0.02
Hardness	N	31	7	1	1	8	1	3	8	0	2	1	1	1	1	1	1	2	23	6
(mg/L)	20%ile	47	47	42	42	52	50	192	41	-	68	66	28	13	600	350	1100	786	54	47
	Median	59	54	42	42	55	50	380	92	-	69	66	28	13	600	350	1100	795	93	52
	80%ile	89	69	42	42	57	50	434	100	-	70	66	28	13	600	350	1100	804	218	54
Carbonate	N	26	1	1	0	0	2	2	9	0	0	0	0	0	2	2	2	2	21	6
(mg/L)	20%ile	10	75	5	-	-	6	6	10	-	-	-	-	-	6	6	6	10	10	10
	Median	10	75	5	-	-	8	8	10	-	-	-	-	-	8	8	8	10	10	10
	80%ile	10	75	5	-	-	9	9	10	-	-	-	-	-	9	9	9	10	32	10
Filtered Metals																				
Aluminium	N	46	7	16	1	7	15	8	17	3	2	1	1	1	14	13	14	11	24	7
(µg/L)	20%ile	50	67	12	490	21	2	5	5	36	101	65	87	39	2	2	2	2	50	184
	Median	100	730	38	490	110	7	10	50	83	112	65	87	39	5	9	14	3	70	510
	80%ile	480	1760	140	490	746	37	38	63	105	123	65	87	39	36	54	29	25	358	1150
Antimony	N	29	7	2	1	8	2	2	9	0	0	0	0	0	2	2	2	2	21	6
(µg/L)	20%ile	5	5	2	5	5	2	2	5	-	-	-	-	-	2	2	5	6	5	5
	Median	5	5	3	5	5	3	3	5	-	-	-	-	-	3	3	5	7	5	5
	80%ile	5	5	4	5	5	4	4	5	-	-	-	-	-	4	4	5	7	5	5
Arsenic	N	46	7	16	1	1	15	10	19	3	2	1	1	1	14	13	14	11	26	7
(µg/L)	20%ile	1	5	1	1	1	1	1	1	1	1	1	1	1	1	2	8	3	2	2
	Median	1	5	1	1	1	1	2	2	1	1	1	1	1	1	3	10	5	3	3
	80%ile	1	5	1	1	1	2	3	2	1	1	1	1	1	2	5	14	8	3	5
Beryllium	N	29	7	2	1	8	2	2	9	0	0	0	0	0	2	2	2	2	21	6
(µg/L)	20%ile	1	2	1	1	3	1	1	1	-	-	-	-	-	1	1	1	1	1	1
	Median	1	5	1	1	5	1	1	1	-	-	-	-	-	1	1	1	1	1	1
	80%ile	1	5	1	1	5	1	1	1	-	-	-	-	-	1	1	1	1	1	1
Boron	N	40	7	9	1	8	9	7	13	3	2	1	1	1	8	8	8	9	25	7
(µg/L)	20%ile	45	36	37	50	30	44	42	39	43	142	133	96	55	24	38	86	90	50	50
	Median	50	38	38	50	35	47	45	50	44	164	133	96	55	48	47	95	120	50	50
	80%ile	50	48	47	50	46	49	66	56	47	186	133	96	55	75	62	116	174	62	50

	Water Quality Parameter		Sampling Site: Dawson River Upstream				Anabranch U/S		Anabranch D/S	Dawson River Downstream		Saline Creek				Site Dams				Release Points	
			A1	WS5	DR1	DR2	WS6	D2	D1	DR3	DR4	SCT	SCD	SCU	SCUi	Mine Dam #1	Mine Dam #2 Farm Dam	Pit	ROM Dam	RP1	RP2
Filtered Metals	**Cadmium**	N	45	3	16	1	8	15	8	19	3	2	1	1	1	14	13	14	11	23	7
	(µg/L)	20%ile	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
		Median	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.2
		80%ile	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
	Chromium	N	46	7	16	1	8	15	8	19	3	2	1	1	1	14	13	14	11	24	7
	(µg/L)	20%ile	1	5	2	1	5	2	1	1	2	1	1	1	1	2	2	2	1	1	1
		Median	1	5	2	1	5	2	2	2	2	1	1	1	1	3	2	3	2	1	1
		80%ile	2	5	2	1	5	2	2	2	2	1	1	1	1	6	4	5	4	1	2
	Cobalt	N	46	7	16	1	8	15	9	19	3	2	1	1	1	14	13	14	11	25	7
	(µg/L)	20%ile	1	3	1	1	3	1	1	1	1	1	1	2	1	1	1	2	1	1	1
		Median	1	5	1	1	5	1	1	1	1	1	1	2	1	1	1	4	2	1	1
		80%ile	1	5	1	1	5	1	1	1	1	1	1	2	1	2	3	10	5	1	1
	Copper	N	49	7	16	1	1	15	10	19	3	2	1	1	1	14	13	14	11	26	7
	(µg/L)	20%ile	1	3	1	2	3	1	1	1	1	2	2	1	1	1	1	1	1	2	3
		Median	2	5	1	2	3	1	1	1	1	2	2	1	1	2	1	2	2	3	4
		80%ile	2	5	2	2	3	1	2	2	1	2	2	1	1	5	3	3	3	3	5
	Iron	N	48	6	16	1	6	15	10	19	3	2	1	1	1	14	13	14	11	26	7
	(µg/L)	20%ile	114	100	81	350	0	43	131	62	45	838	5	4030	498	10	9	12	5	120	318
		Median	220	350	145	350	300	240	210	150	88	1447	5	4030	498	580	150	970	280	275	400
		80%ile	506	1200	190	350	1000	362	312	228	125	2055	5	4030	498	2340	540	1480	1300	620	880
	Lead	N	46	3	16	1	8	15	8	19	3	2	1	1	1	14	13	14	11	23	7
	(µg/L)	20%ile	1	1	1	1	3	1	1	1	1	0	0	1	0	1	1	1	1	1	1
		Median	1	1	1	1	5	1	1	1	1	1	0	1	0	1	1	1	1	1	1
		80%ile	1	3	1	1	5	1	1	1	1	1	0	1	0	1	1	1	1	1	2
	Manganese	N	47	7	16	1	8	15	10	18	3	2	1	1	1	14	13	14	11	25	7
	(µg/L)	20%ile	2	5	1	5	3	1	4	1	44	228	143	292	124	3	1	11	3	5	5
		Median	5	6	2	5	21	3	55	5	96	285	143	292	124	37	1	36	22	6	5
		80%ile	5	9	3	5	112	44	144	34	98	342	143	292	124	126	143	104	120	85	6
	Mercury	N	44	7	15	1	8	14	7	18	3	2	1	1	1	13	12	13	11	24	7
	(µg/L)	20%ile	0.1	0.1	0.5	0.1	0.1	0.5	0.5	0.1	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.1	0.1	0.1
		Median	0.1	0.1	0.5	0.1	0.1	0.5	0.5	0.3	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1
		80%ile	0.5	0.1	0.5	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1
	Molybdenum	N	46	7	16	1	8	15	10	19	3	2	1	1	1	14	13	14	11	26	7
	(µg/L)	20%ile	2	5	1	5	3	1	1	2	2	0	0	0	0	9	2	43	20	6	5
		Median	5	5	2	5	5	2	2	5	2	0	0	0	0	38	12	53	29	11	6
		80%ile	5	5	2	5	5	2	6	5	2	0	0	0	0	87	22	60	54	18	7
	Nickel	N	47	3	16	1	2	15	10	19	3	2	1	1	1	14	13	14	11	26	7
	(µg/L)	20%ile	1	3	1	1	3	1	2	1	1	2	2	2	1	2	2	14	6	2	2
		Median	1	4	1	1	3	1	2	1	1	2	2	2	1	7	2	24	12	3	2
		80%ile	2	5	2	1	3	2	4	2	2	3	2	2	1	26	7	32	27	4	3
	Selenium	N	46	7	16	1	8	15	10	17	3	2	1	1	1	14	13	14	11	26	7
	(µg/L)	20%ile	1	5	2	1	5	2	3	1	3	1	1	1	1	6	5	15	6	3	4
		Median	1	5	5	1	5	5	5	5	5	1	1	1	1	10	5	26	16	4	4
		80%ile	5	5	5	1	5	5	5	5	5	1	1	1	1	30	27	39	43	5	5
	Uranium	N	46	7	16	1	8	15	8	19	3	2	1	1	1	14	13	14	11	25	7
	(µg/L)	20%ile	1	1	1	100	2	1	1	1	1	0	0	0	0	3	1	11	11	5	100
		Median	5	5	1	100	5	1	1	1	1	0	0	0	0	6	1	14	13	5	100
		80%ile	100	5	1	100	5	1	1	5	1	1	0	0	0	8	2	16	14	100	100
	Vanadium	N	46	7	16	1	8	15	8	19	3	2	1	1	1	14	13	14	11	25	7
	(µg/L)	20%ile	3	5	3	5	5	1	1	3	1	1	0	0	4	1	3	1	1	5	5
		Median	5	6	4	5	5	1	2	5	2	2	0	0	4	1	5	1	1	5	6
		80%ile	5	7	5	5	5	2	4	5	2	3	0	0	4	2	12	2	5	6	8
	Zinc	N	47	7	16	1	4	15	10	18	3	2	1	1	1	14	13	14	11	25	7
	(µg/L)	20%ile	1	5	2	3	6	2	2	1	2	4	3	9	13	2	2	2	2	2	4
		Median	2	5	2	3	7	2	2	2	2	8	3	9	13	4	2	6	2	4	4
		80%ile	5	5	2	3	24	4	5	7	4	12	3	9	13	7	3	18	8	5	5
	Silver	N	12	0	14	0	0	13	6	9	3	2	1	1	1	12	11	12	9	0	0
	(µg/L)	20%ile	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-
		Median	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-
		80%ile	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-
Total Metals	**Aluminium**	N	51	6	17	1	8	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	520	330	238	8,500	198	59	170	336	366	175	170	99	58	21	272	26	28	340	2,400
		Median	1,300	845	1,300	8,500	530	95	260	790	570	212	170	99	58	57	720	37	90	675	8,400
		80%ile	2,800	6,700	3,740	8,500	1,046	160	510	3,040	1,008	248	170	99	58	238	5,580	152	150	3,200	9,260
	Antimony	N	30	0	3	1	0	3	3	10	0	0	1	0	0	3	3	3	2	21	6
	(µg/L)	20%ile	5	-	1	5	-	1	1	4	-	-	1	-	-	2	3	4	5	5	5
		Median	5	-	1	5	-	1	1	5	-	-	1	-	-	3	5	5	6	5	5
		80%ile	5	-	3	5	-	3	3	5	-	-	1	-	-	4	5	6	7	5	5
	Arsenic	N	48	6	17	1	0	16	11	19	3	2	0	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	1	5	1	2	-	1	1	1	1	1	-	2	2	1	3	8	3	3	3
		Median	1	5	1	2	-	2	2	2	1	1	-	2	2	1	4	10	5	3	5
		80%ile	2	6	2	2	-	2	3	3	1	1	-	2	2	3	6	15	8	3	6
	Beryllium	N	30	6	3	1	8	3	3	10	0	0	0	0	0	3	3	3	2	21	6
	(µg/L)	20%ile	1	1	1	1	3	1	1	1	-	-	-	-	-	1	1	1	1	1	1
		Median	1	5	1	1	5	1	1	1	-	-	-	-	-	1	1	1	1	1	1
		80%ile	1	5	1	1	5	1	1	1	-	-	-	-	-	1	3	1	1	1	1
	Boron	N	42	6	10	1	8	10	8	13	3	2	1	1	1	9	9	9	9	25	7
	(µg/L)	20%ile	46	37	40	50	32	44	40	43	45	162	139	97	58	37	42	94	110	50	50
		Median	50	41	45	50	37	50	50	50	47	176	139	97	58	60	50	100	140	50	50
		80%ile	50	50	48	50	41	53	63	60	51	190	139	97	58	102	69	144	188	70	50
	Cadmium	N	47	2	17	1	8	16	9	19	3	0	1	0	0	15	14	15	11	23	7
	(µg/L)	20%ile	0.1	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.1	-	0.1	-	-	0.1	0.1	0.1	0.1	0.2	0.2
		Median	0.2	0.4	0.1	0.2	0.2	0.1	0.1	0.1	0.1	-	0.1	-	-	0.1	0.1	0.2	0.2	0.2	0.2
		80%ile	0.2	0.4	0.2	0.2	0.4	0.1	0.1	0.2	0.1	-	0.1	-	-	0.3	0.2	0.3	0.5	0.2	0.2

	Water Quality Parameter		Sampling Site: Dawson River Upstream				Anabranch U/S		Anabranch D/S	Dawson River Downstream		Saline Creek				Site Dams				Release Points	
			A1	WS5	DR1	DR2	WS6	D2	D1	DR3	DR4	SCT	SCD	SCU	SCUi	Mine Dam #1	Mine Dam #2 Farm Dam	Pit	ROM Dam	RP1	RP2
Total Metals	**Chromium**	N	48	2	17	1	2	16	9	19	3	1	1	1	0	15	14	15	11	24	7
	(µg/L)	20%ile	1	4	2	5	9	1	1	1	2	2	2	1	-	2	2	1	1	1	3
		Median	2	5	2	5	10	2	2	2	2	2	2	1	-	2	3	2	2	1	7
		80%ile	4	5	3	5	10	2	2	3	2	2	2	1	-	4	6	4	3	3	9
	Cobalt	N	48	2	17	1	0	16	10	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	1	3	1	3	-	1	1	1	1	2	1	3	1	1	1	3	1	1	1
		Median	1	4	1	3	-	1	1	1	1	2	1	3	1	1	2	4	3	1	3
		80%ile	1	4	1	3	-	1	1	2	1	3	1	3	1	3	6	9	7	2	5
	Copper	N	50	6	17	1	3	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	1	5	1	6	7	1	1	1	1	2	3	1	2	1	1	2	2	3	6
		Median	2	5	2	6	7	1	1	3	1	3	3	1	2	4	3	3	3	5	10
		80%ile	5	6	5	6	8	3	5	5	2	3	3	1	2	8	7	5	5	6	13
	Iron	N	51	6	17	1	8	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	750	100	362	7,700	202	400	360	512	556	3,000	1,700	6,180	805	144	416	69	26	720	1,800
		Median	1,700	425	1,100	7,700	800	545	580	880	880	3,420	1,700	6,180	805	970	1,090	1,000	350	1,060	3,700
		80%ile	3,300	500	3,820	7,700	1,320	1,100	1,500	3,980	1,312	3,840	1,700	6,180	805	2,300	4,600	1,960	2,000	2,000	9,600
	Lead	N	48	6	16	1	0	16	9	19	3	2	1	1	1	15	14	15	11	24	7
	(µg/L)	20%ile	1	5	1	4	-	1	1	1	1	1	0	1	1	1	1	1	1	1	2
		Median	1	5	1	4	-	1	1	1	1	1	0	1	1	1	1	1	1	1	5
		80%ile	2	5	1	4	-	1	1	1	1	1	0	1	1	1	1	1	1	2	6
	Manganese	N	51	6	17	1	8	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	18	44	11	13	186	52	26	58	76	323	145	378	130	29	94	27	6	25	25
		Median	38	78	19	13	285	97	150	97	120	492	145	378	130	43	160	67	65	83	100
		80%ile	69	83	37	13	341	140	300	166	126	660	145	378	130	168	752	122	240	160	110
	Mercury	N	45	6	15	1	8	14	7	17	3	2	1	1	1	13	12	13	10	24	7
	(µg/L)	20%ile	0.1	0.1	0.5	0.1	0.1	0.5	0.5	0.1	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.1	0.1	0.1
		Median	0.1	0.1	0.5	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1
		80%ile	0.5	0.1	0.5	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.1
	Molybdenum	N	48	2	17	1	8	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	2	5	1	5	5	1	1	2	2	0	0	0	0	11	2	47	22	8	6
		Median	5	6	2	5	5	2	2	2	2	0	0	0	0	37	16	54	32	13	8
		80%ile	5	7	2	5	5	2	5	5	2	0	0	0	0	85	24	59	54	20	9
	Nickel	N	50	3	17	1	2	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	2	5	1	5	5	1	2	2	1	3	2	2	2	2	3	15	7	3	3
		Median	3	6	2	5	6	2	2	3	1	3	2	2	2	8	4	25	13	4	7
		80%ile	4	7	3	5	7	3	5	5	2	3	2	2	2	27	14	34	28	7	10
	Selenium	N	48	4	17	1	8	16	11	18	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	1	3	2	1	5	2	2	1	3	11	56	39	1	6	5	16	6	4	4
		Median	1	6	5	1	5	5	3	3	5	25	56	39	1	13	11	26	19	5	5
		80%ile	2	6	5	1	5	7	5	5	5	40	56	39	1	59	53	62	51	5	5
	Uranium	N	48	1	17	1	8	16	9	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	1	1	1	100	2	1	1	1	1	0	0	0	0	3	1	12	12	5	100
		Median	5	1	1	100	5	1	1	1	1	0	0	0	0	7	2	14	13	6	100
		80%ile	100	1	1	100	5	1	1	5	1	1	0	0	0	9	5	18	15	100	100
	Vanadium	N	48	6	17	1	2	16	9	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	5	5	4	16	12	1	2	5	2	1	0	0	5	1	4	1	1	5	10
		Median	6	8	5	16	15	1	2	5	3	2	0	0	5	1	8	1	1	7	21
		80%ile	10	15	10	16	17	1	4	11	4	3	0	0	5	2	21	2	5	11	27
	Zinc	N	50	6	17	1	8	16	11	19	3	2	1	1	1	15	14	15	11	26	7
	(µg/L)	20%ile	3	6	2	36	11	2	2	2	2	9	6	11	15	2	2	4	2	4	19
		Median	7	17	3	36	15	5	4	9	3	13	6	11	15	6	7	7	6	14	28
		80%ile	16	49	7	36	17	10	11	21	4	17	6	11	15	18	19	25	22	24	34
	Total Silver	N	13	0	15	0	0	14	7	10	3	2	1	1	1	13	12	13	9	0	0
	(µg/L)	20%ile	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-
		Median	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-
		80%ile	1	-	1	-	-	1	1	1	1	0	0	0	0	1	1	1	1	-	-

N=Number of samples
Note: Analytes analysed in a concentration below the detection limit were replaced with the detection limit.

Appendix I. Geotechnical Reference Report Volume 1 Main Report

BARALABA COAL COMPANY PTY LTD
GOLDING CONTRACTORS PTY LTD

BARALABA COAL PROJECT

GEOTECHNICAL REFERENCE REPORT Volume 1 Main Report

Report Number 41007-1-2

Issued for and on behalf of
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SHERWOOD GEOTECHNICAL AND RESEARCH SERVICES

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EXECUTIVE SUMMARY

Baralaba North mine geotechnical conditions comprise folded and, in some places, faulted Permian coal measures rocks overlain by older and modern Dawson River alluvium. Rock mass strength is relatively high despite the complex structural geology, as evidenced by the generally stable performance of excavated slopes to date. Two classes of spoil materials are recognised: spoil comprising only fresh Permian rock, and spoil comprising any mix of fresh and weathered Permian rock and alluvium.

This Geotechnical Reference Report (GRR) is provided in two volumes. Volume 1 (main report) is based on geotechnical investigations and assessment of operational conditions based on inspections and proven slope performance. It comprises an introduction and background, an overview of geology, geotechnical conditions, groundwater, and hydrogeology, and an overview of Baralaba mine geotechnical history.

The intent of geotechnical design and the basis for design are reviewed, together with geotechnical hazards, identified instability mechanisms, and information on the scale of mechanisms and extent of instability impacts.

Geotechnical model information is provided in outline, with additional sources of information referenced. The geotechnical model and domains are described, together with geological information, various survey and mining records, soil and rock materials, rock mass structure, and rock mass shear strength. Little is known of the insitu stress state, other than it does not appear to have had any significant impact on slope performance. Groundwater models are described, and information provided on mine wastes, stockpiled mining products, and applied loadings.

Design recommendations and guidelines are provided in summary form, together with a list of geotechnical design parameters for all materials. Excavated and dumped slope design checks are described. Rockfall hazard and slope instability runout estimates are discussed. Water management structures are outside the scope of this GRR and details must be sourced separately from others.

Volume 2 (appendices) is provided separately as electronic file folders only.

1. INTRODUCTION AND BACKGROUND

1.1 Context

Coal has been mined at Baralaba for more than a century. The current open cut operation commenced in 2005 at Baralaba Central, where coal recovery was completed in 2014, and Baralaba North commenced in 2013. Originally, product coal was supplied to the Queensland Government and the Mount Morgan mining and smelting operations. Since 2005, a low volatile PCI product has been supplied to the export market.

The current mining operations are located on the west bank of the Dawson River, with Baralaba Central and Baralaba North separated by a major east-west oriented river anabranch channel. Coal is recovered from the late Permian Baralaba Coal Measures of the southeast sector of the Bowen Basin. Another potential mining area, Baralaba South, is located south of Baralaba township on the east bank of the Dawson River. **Figure 1-1** is an overall view of the Baralaba mining project area, excluding Baralaba South, while **Figure 1-2** shows more detail for the current mining operations in Baralaba North.

Flood exclusion is provided by a levee system. In February 2011 the levee breached, resulting in flooding of the Baralaba Central pit CP01. The immediately adjacent “Dog Bowl” CP02 was mined to provide an alternative coal source while CP01 was dewatered. CP01 was subsequently completed as CP03. The CP02 void is used as a water storage while planned backfilling of CP03 is completed with spoil hauled from Baralaba North.

Baralaba North was developed initially along the southern side of a regional powerline corridor. The east-side synclinal feature, termed the Outrigger mining area, was mined in a northward progression followed by southward development of the main west-side synclinal feature, termed the Fairway mining area. Mining development to the north of the powerline corridor commenced in mid-2020, and the powerline will be relocated by mid-2021 allowing the northern extension to be linked to the Outrigger-Fairway area.

Pit slope design for Baralaba Central evolved from original contractor-based profiles based on operational experience with other Bowen Basin mines, particularly at Dawson. Excavated slope and dump slope designs were modified as the mining path advanced and deepened, and these designs were based on advice from a range of geotechnical consultants. Only a limited amount of historical geotechnical information is currently available.

SGRS notes that Geotechnical Reference Reports (GRRs) or equivalents are becoming a normal aspect of minesite geotechnical hazard management for the Australian black coal open cut mining industry. A GRR provides the means for centralising and maximising accessibility to acceptable geotechnical information and slope design recommendations for excavations and dumps. Most sites have principal hazard management plans for geotechnical hazards, and GRRs are normally referenced specifically in such plans. The format of this report is based on SGRS experience with GRR preparation for such purposes.

1.2 GRR Version History Updating and Review

This GRR is the first version for Baralaba North mine. As additional geotechnical information accumulates or design recommendations change, or whenever there are changes warranted by review requirements of the mine’s safety and health management processes, the GRR should be updated.

1.3 Format and Contents

This GRR provides reference information for developing design-level risk controls for identified geotechnical hazards as follows:

- Geological and Geotechnical Conditions (**Section 2**)
- Overview of Baralaba North Mine Geotechnical History (**Section 3**)
- Design Controls and Acceptance Criteria (**Section 4**)
- Geotechnical Hazards and Potential Instability Mechanisms (**Section 5**)
- Geotechnical Model Information (**Section 6**)
- Design Recommendations and Guidelines (**Section 7**)
- Slope Stability and Rockfall Hazard Runout Estimates (**Section 8**)
- Water Management (**Section 9**)
- References (**Section 10**).

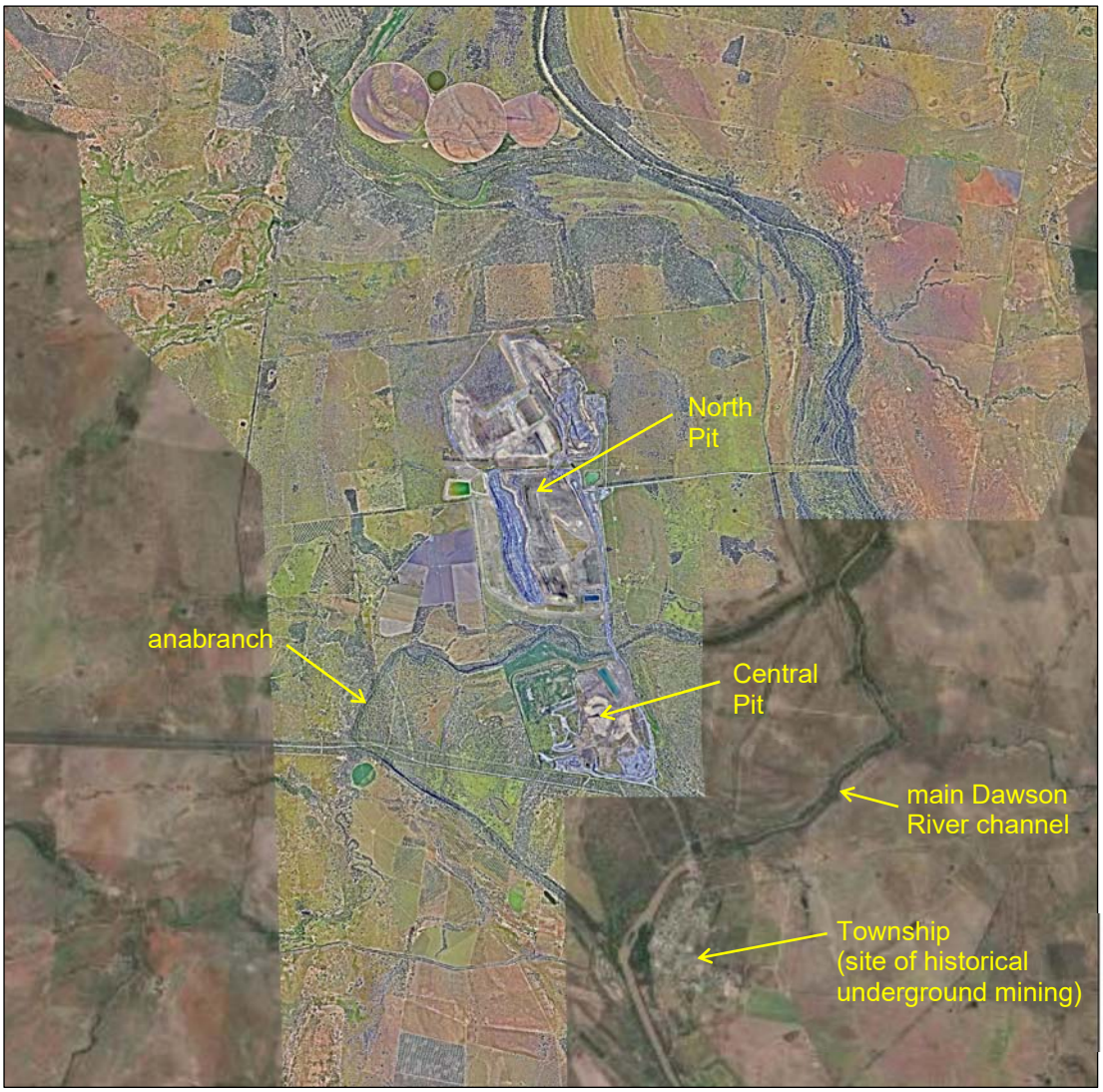

Figure 1-1 Overall plan of Baralaba Mine area (image provided by Golding)

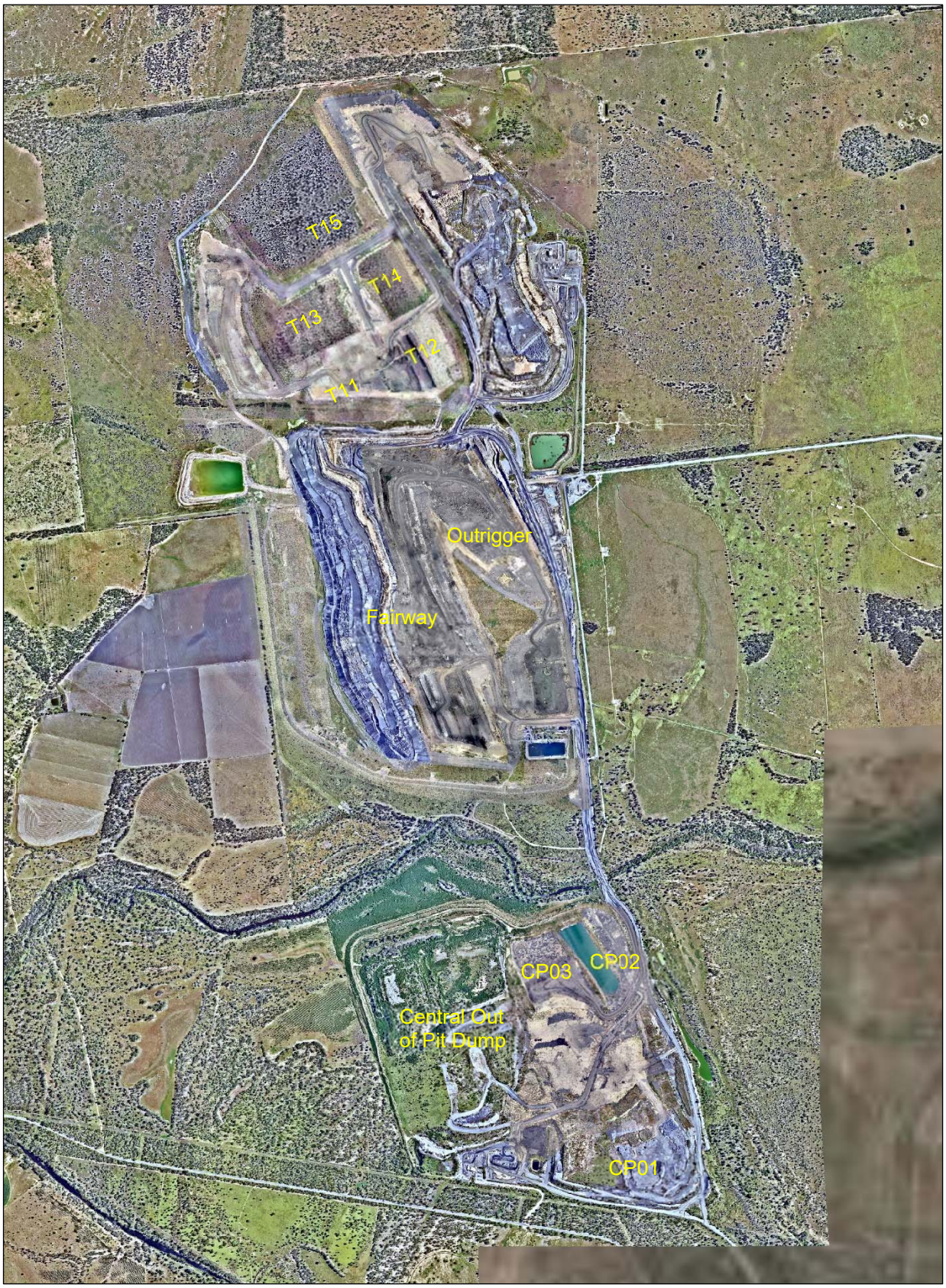

Figure 1-2 Detailed view of current Baralaba mining area (image provided by Golding)

2. GEOLOGICAL AND GEOTECHNICAL CONDITIONS

2.1 Geology

Baralaba North is located on the northwards-draining floodplain of the Dawson River. A cover sequence of Recent, Quaternary, and possibly Neogene alluvial floodplain sediments unconformably overlies weathered and fresh late-Permian Baralaba Coal Measures within the east limb of the southeast sector of the Bowen Basin.

The cover alluvium has a thickness of up to 16 m comprising predominantly clay with variable but generally low proportions of gravel, silt, and clay. Near-surface alluvium is typically a silty clay of high plasticity, forming a self-mulching, cracking “black soil” layer underlain by more leached alluvium with a sodic horizon. The Dawson River drainage system includes tributary channels and an anabranch forming the separation between the Central and North pits. All drainage channels have cut through the cover alluvium to a floor in weathered Permian rock.

Deposition of the Permian alluvial floodplain sediments and peat mires contributed to a sequence of sandstones, siltstones, and occasional claystones which are generally more carbonaceous in the stratigraphically lower part. There are several tuffaceous intervals particularly in the stratigraphically lower part. Burial and subsequent uplift/erosion have resulted in multiple seams of semi-anthracite rank.

The coal measures rocks are structurally deformed into a sequence of gently northwest-plunging chevron-style folds (**Figure 2-1**) where uplift and erosion have preserved larger-scale synclines with more localised smaller-scale anticlines. Folded strata, dipping generally at 30° to 50° but in places at up to 80°, have also been structurally displaced by primarily steep-dipping reverse faults with some dextral strike-slip offsets. The geological timing of the structural deformations is likely to comprise multiple episodes consistent with the documented history of Bowen Basin evolution (Ref.1).

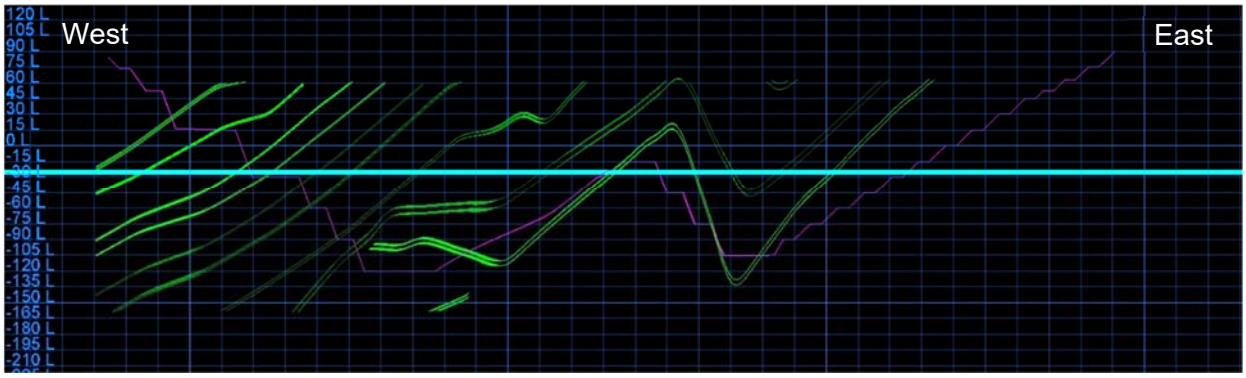

Figure 2-1 Cross section of Baralaba North seam structure viewed towards north

Coal seam nomenclature and associations, including typical seam and interburden thicknesses, are listed in **Figure 2-2**. The Coolum seam is the most economically significant. Underlying the Sub-Dirty seam is the Kaloola sequence of generally thinly-bedded carbonaceous bands and tuffs. Within the current mining operation, the Doubtful ply sequence provides the uppermost fresh coal. The prominent tuffaceous member underlying the Dirty seam is likely to be the Yarrabee Tuff equivalent, based on recent regional correlation of late Permian Bowen Basin stratigraphic sequences (Ref.2).

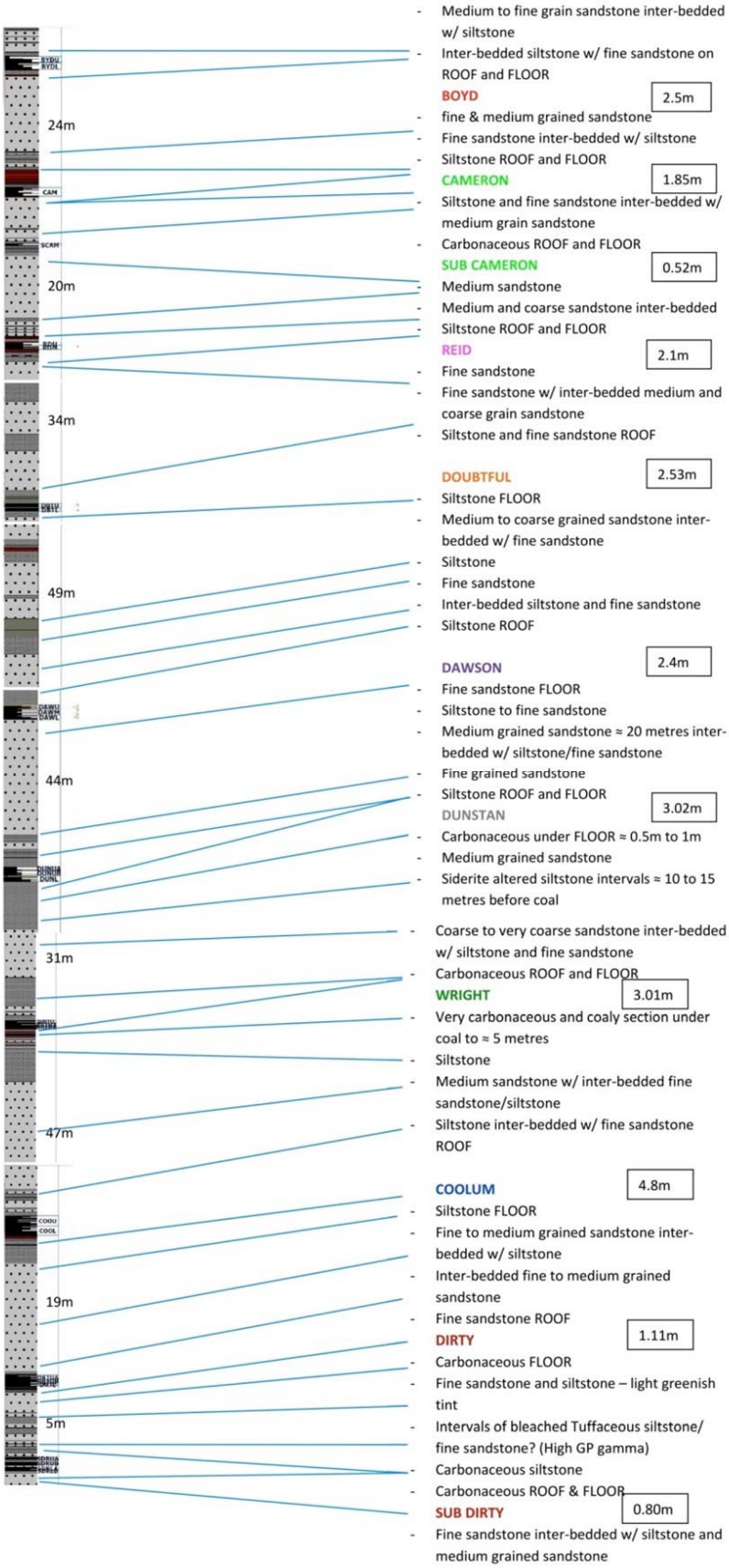

Figure 2-2 Baralaba Coal Measures seam associations (after Ref. A1)

2.2 Geotechnical Conditions

From a geotechnical perspective the cover alluvium and some of the uppermost weathered Permian is essentially a free-dig zone. For out-of-pit spoil dumping, it is necessary to remove the cracking blacksoil surface layer down to a tight horizon, typically at a depth of 0.5 m to 1.0 m, to achieve a suitable dump foundation.

Permian strata are typically structured with two sets of stress-relief joints, approximately mutually orthogonal to bedding, but other orientations of joints and small faults reflect the effects of folding and faulting. Highly-structured ground is difficult to drill and blast efficiently due to groundwater flow and the localised effects of joints and faults on backbreak. Despite this, presplit blasting has been generally effective in limiting propagation of damage into blasted rock batters and has resulted in improved trimming of faces to design.

Pits are typically mined in terraces, with “highwalls” on the west margins and “footwalls” on the east margins. Footwalls are typically sub-parallel to dipping strata and expose the more carbonaceous lower part of the stratigraphic sequence. Highwalls typically form the west side of excavations where the seam structure continues to dip westwards, so highwalls are therefore excavated through the seam sequence. North pit highwalls are typically presplit, with vertical intervals of 30 m between benches. Central pit highwalls were presplit with vertical intervals of up to 45 m.

Footwalls present potential slab or planar instability hazards because of relatively weak bedding partings and occasional across-bedding structures compounded by relatively low breakout strength and potentially significant groundwater pressures within bedding partings. In theory the footwall could be excavated by following the floor of the lowest coal seam. In practice, from Central and North pit experiences, the vertical height of footwall batters should be limited to reduce the likelihood of slabbing or planar instability to an acceptably low level. As a result, footwalls are underbenched with vertical intervals between benches of 15 m.

Run-of-mine coal processing comprises sizing and stockpile blending. This demands minimal contamination during coal exposure and recovery, including constraints on blasting and excavator operations. Coal is typically recovered in flitches, with vertical separations between terraces of typically 3 flitches or 15 m for currently utilised equipment.

Both highwalls and footwalls are relatively straightforward for mining except where complexity is introduced by larger-scale fault structures that intersect the plunging folds. This results in zones where the bedding structure is both faulted and steeply dipping out of highwalls, and zones where the trace of coal seams forms very tight folded structures on terrace outcrops. Complex geology zones present planning and operational challenges. Fortunately, despite the closely-spaced defects and multiple defect orientations, the rock mass remains relatively interlocked and can be mined successfully to plan provided that batter and crest are not overdug in loose ground which may behave similarly to blasted ground.

2.3 Groundwater and Geohydrology

Details of feasibility studies are provided separately in Appendix C and Appendix D. Groundwater pressure conditions are dominated at shallow depths by relatively rapid responses of the Quaternary and Recent Dawson River floodplain alluvium, and at depth by relatively slow responses due to material and geometric anisotropy of the highly structured Permian rock mass.

3. OVERVIEW OF BARALABA MINE GEOTECHNICAL HISTORY

Coal was first reported from an outcrop on the bank of the Dawson River in 1899. The Baralaba State Coal Mine commenced operations in 1916 and supplied the Dawson-Rannes railway. The Mt Morgan Gold Mining Company commenced the Baralaba Mine in 1921. The two mining operations were merged but in 1928 the Baralaba State Coal Mine was closed following flooding. Underground and open cut mining operations at Baralaba Mine continued until 1969.

In 2005 Peabody recommenced open cut truck-excavator mining with development of Baralaba Central CP01 to the north of the Dawson River. Cockatoo Coal took over Peabody's interests and managed mining from 2008 until 2015. After recommencement in 2017 under a revised governance structure, mining has continued as a contract operation. There are plans to commence mining at Baralaba South, to the south of the township on the east bank of the Dawson River.

Since 2005 mining operations have involved excavator-truck terracing methods in folded, generally steep-dipping strata transected by faults. Coal is recovered by selective excavation as there is no coal washery and post-processing is limited to sizing, screening, and stockpiling. Product coal is trucked to a rail loadout near Moura and then railed to Gladstone.

From 2005 to 2011 there were no recorded significant geotechnical incidents, other than minor slab detachments on the eastern footwall side of CP01. A major regional flooding event in February 2011 resulted in the anabranch levee being breached at the northwest corner of CP01, flooding the pit.

A separate steep synclinal deposit immediately to the east of CP01 was excavated following the 2011 flooding. This satellite area was designated CP02 and is informally known as the "Dog Bowl". More significant slab and face instability was experienced in CP02 because of the combination of steep dip (both limbs of the syncline dipped at 60° or greater), stress relief delamination along floor bands, and occasional localised across-bedding structures large enough to trigger face slab detachments. Passive reinforcement was introduced in the form of rows of grouted rebar, with mixed success. Exposure of rebars in the current CP02 faces indicates that degradation and erosion has caused an average loss of between 1m and 2m from the as-mined faces. Geotechnical history of this period is reflected in several reports by Geotechnical Consulting Services and Pells Sullivan Meynink (PSM) that are provided in **Volume 2**, **Appendices A, B**.

With completion of CP02 it was possible to complete dewatering of CP01 and recommence mining as CP03. Initial out-of-pit dumping was followed by progressive backfilling of CP01/CP03 from the south endwall. A cutback of the west highwall enabled the pit to be deepened, but the deepening triggered zones of instability along the east footwall of the barren zone. By this stage PSM was conducting quarterly inspections and undertaking geotechnical investigations to provide design recommendations for Baralaba North (**Volume 2**, **Appendix B**) and also Baralaba South (not referenced in this GRR).

The PSM geotechnical investigations formalised the recognition of weak bedding-parallel tuffaceous strata particularly in the stratigraphic interval underlying the Dirty seam. These weak bands result in a stability limitation on footwall bench height that is related to bedding dip, groundwater pressure, and across-bedding breakout strength. Introduction of footwall benching enabled CP03 to be deepened until floor heave instability developed.

Baralaba North pit development commenced in the Outrigger zone, a northwards-plunging synclinal structure. An initial out-of-pit spoil dump was developed on the east side of the Outrigger shell and on the north side of a powerline easement. Slabbing instability was experienced in the weathered zone of the Outrigger footwall, and coal recovery from the V-shaped southern endwall triggered localised south endwall instability. Terrace mining extended northward following the plunge of the Outrigger syncline, with the mined-out void progressively backfilled to include a haulage ramp.

The west side of the Outrigger shell progressively steepened to a near-vertical condition as it approached the initial north endwall but remained stable with minimal spalling until it was intersected and overprinted by multiple faults at the intersection of the Fairway shell and the Outrigger syncline. To control rockfall risks, Outrigger bench heights were limited to 10 m within this complex geology zone and temporary windrows were placed at dig face toes at all times except when diggers were working face-on.

Initially the Baralaba North shells were limited on the north side by the powerline, and the northern endwall was developed westwards to commence the south-advancing terraces for the Fairway zone. The northern endwall presented geotechnical stability challenges where it intersected the complex geology zone. Despite the highly fractured and kinked folding in the complex zone, it proved to be possible to excavate safely by digging to design, leaving relatively loose and normally trimmable material in place, and where possible by maintaining catch benches to retain inevitable dribbling and spalling material.

Fairway terraces were developed initially through relatively simple synclinal geometry where the bedding structure was still dipping westwards along the west or “highwall” side. A complex geology zone intersects the middle of the Fairway shell where the seam subcrops are displaced westwards by intersection with a plunging asymmetrical anticline-syncline pair. Adequate wall stability for the complex zone was demonstrated through a combination of defect mapping, piezometer measurements of groundwater pressure distribution, and a mining methodology based on 30 m batters presplit at initially 65° and later 70° with careful trimming to design profile with avoidance of overdigging in highly fractured and locally folded ground.

Development of the initial Outrigger and Fairway zones supplied spoil for backfilling the Baralaba Central CP03 void, for ramp regrading within the Outrigger void, and for construction of the out-of-pit Noise Bund to the west side of the Fairway shell. Remnant water within the CP03 void included a mud base, and high-face backfill dumping with dozer-pushing to form a concave-advancing face became the preferred method for controlling stability. Large-scale face slumping developed when the concave shape was lost, and this was stabilised by advancing wing dumps along the east and west margins. Further control was provided by eliminating ponded water from the CP03 void.

The Fairway Noise Bund reaches a height of about 60 m above natural surface and comprises two 30 m lifts separated by a residual 10 m bench. Localised instability developed in locations where the dump foundation comprised a former surface drainage feature with deeper clay-rich alluvium, and where the upper lift was over-dumped, eliminating the remnant bench and over-steepening the dump slope profile.

Prestripping to the north of the powerline commenced in mid-2020 and relocation of the powerline by mid-2021 enabled terraces to be advanced northwards from the Fairway and Outrigger voids. Geological conditions will vary from a single syncline to multiple intersecting folds with localised faults similar to what has previously been experienced in the initial northern Outrigger-Fairway endwall and both the eastern (footwall) and western (highwall) sides of the Fairway zone. Geotechnical and operational learnings from the Fairway and Outrigger zones are expected to provide an adequate basis for northwards pit development.

4. DESIGN CONTROLS AND ACCEPTANCE CRITERIA

4.1 Design Intent

The design intent is to provide an outcome (eg a slope profile or a working area) where the risks of undesirable consequences, such as instability of the slope profile resulting in injury or death, lost production, environmental harm, and reputational damage, are controlled to an acceptably low level. The intended outcome is that the design is acceptably safe and stable as described in relevant law, regulation, and corporate policy.

4.2 Identified Hazards

Geotechnical hazards are formally determined and described by a broad-brush risk assessment and principal hazard management plan. However, in general terms the identified geotechnical hazards will include:

- rockfall impacting personnel or equipment
- instability of excavated highwalls, endwalls, and lowwalls;
- instability of tipheads
- instability of waste dumps
- bench collapse under machine loading
- inpit floor heave
- trench wall collapse
- inundation resulting from inrush of uncontained stored water or other fluidised material.

4.3 Design-Level and Operational-Level Risk Controls

Risk controls for the identified hazards must be listed in any geotechnical principal hazard management plan together with the processes by which the controls are implemented and monitored. Design-level controls are developed based on site knowledge, experience, and assessment by appropriately qualified and experienced persons. Operational-level controls typically range from checks for conformance with design parameters, compliance with standard operating procedures, and adequacy of training, to observation-based trigger action response Plans (TARPs).

Many of the principles embedded in TARPs are based on awareness of geotechnical hazards and how they are manifested. While the GRR may include descriptions of and references to geotechnical principles, the primary purpose of the GRR is to provide the geotechnical knowledge base for determination of design-level risk controls.

4.4 Development of Design-Level Risk Controls

Design-level risk controls are applied to create a ground condition where the consequences of instability or excessive ground movement are understood, and where the likelihoods are acceptably low, resulting in an acceptable level of risk. The meaning of acceptable level of risk is provided in the Queensland Coal Mining Safety and Health Act and Regulations.

Design to achieve an acceptable level of risk may be based on established satisfactory ground behaviour, having regard to the efficient operation of equipment and the demonstrated levels of skill and care by equipment operators. Design may also be based on geotechnical analysis, mostly regarding slope stability. To a lesser extent in practice, geotechnical design may be based on achieving acceptable levels of deformation of slopes or of ground supporting mining equipment, and long-term safety and stability of post-mining landforms.

Limit equilibrium analysis is the primary tool for slope stability design. Routine slope stability analysis is computerised and carried out in 2D. 3D analysis methods are also available but are currently more restrictive in terms of the assumptions that underpin the analysis methodologies. A person carrying out either 2D or 3D analysis is required to have an acceptable level of knowledge of the methodologies and acceptable level of experience in applying the methodologies.

Slope stress-deformation analysis may also be undertaken, most readily in 2D but also in 3D if justifiable, using computerised modelling techniques. Both slope stability analysis and stress-deformation modelling require information on slope geometry and geology, material strength and stiffness parameters, and groundwater pressure distributions.

4.5 Acceptance Criteria for Design-Level Risk Controls

The outcome of limit equilibrium slope stability analysis is a Factor of Safety (FOS) which is the single factor by which the strengths of all the materials in the modelled slope must be reduced so that the slope is just in a state of collapse (ie the effects of destabilising forces are just balanced by the effects of stabilising forces). Stable slopes have computed FOS outcomes greater than 1.0, while unstable slopes have computed FOS outcomes of 1.0 or less.

Alternative methodologies based on probabilistic techniques may also be used to generate a so-called “probability of failure” (POF) which is in reality the calculated likelihood that the FOS is 1.0 or less based on a distribution of outcomes resulting from variability of inputs. Probabilistic techniques may be limited in practice by lack of knowledge of statistics for material parameters, and also by lack of statistical treatment of both geometric and groundwater pressure variations.

Stress-deformation numerical modelling can be used to determine a Strength Reduction Factor (SRF) which is similar, but not exactly equivalent, to the slope stability analysis Factor of Safety (FOS). Reliable SRF calculation requires simulation of the sequence of excavation and dumping, starting from the pre-mining initial stress state. As an acceptance criterion, SRF should be treated as a direct substitution for FOS. However, reliance on SRF implies that the stress-deformation modelling has been undertaken to an appropriate level of competence using acceptable parameters.

There is a substantial geotechnical literature regarding the choice of an acceptance criterion for FOS. It is essential to understand that FOS is not an intrinsic property of a slope, but the outcome of a calculation based on a geotechnical model. The following overview of FOS and POF acceptance criteria is based upon Table 1.1 and Section 1.4.4 of Ref.3. Extensive information applicable to open pit geotechnical design may be found in the full set of LOP Guideline texts, Refs.3, 4, 5, 6, 7)

For routine pit slope design purposes, a minimum computed FOS of 1.20 is generally regarded as acceptable because the effects of associated uncertainties in slope geometry, material strengths, groundwater pressures, and analysis methodology lead to an acceptably low likelihood of instability. There is no precise relationship between FOS value and the likelihood

of instability or the likelihood of unacceptable deformation. The choice of FOS criterion for a slope design is therefore a matter for geotechnical engineering judgement. Within the context of Baralaba Mine operations, slope designs based on the FOS ≥ 1.20 criterion have been proven to have an acceptably low likelihood of instability provided that appropriate parameters and methodologies have been used in the design process.

There is usually some uncertainty and variability in input parameters for slope stability analysis, so the computed FOS value is often expressed as a range based on different combinations of geometry, strength, and groundwater pressure parameters. Calculated POF outcomes will generally not be equivalent to the likelihood of instability as evaluated by qualitative risk assessment. It is therefore not appropriate to substitute a computed POF criterion for a FOS criterion or a likelihood parameter in a risk assessment. Computed POF may be helpful for checking the sensitivity of designs to uncertainties in input parameters.

Apart from prediction of movements and stress distributions, stress-deformation modelling can be used to calculate a single Strength Reduction Factor (SRF) that accounts for the modelled stress distribution within a slope resulting from the sequence of slope construction and accounting for differences in deformability as well as differences in strength. The SRF is a close analogue to a stability analysis FOS, and an equivalent acceptance criterion may be applied to SRF outcomes as to FOS outcomes.

Operational slope design for Baralaba Mine is carried out using a general acceptance criterion of FOS ≥ 1.20. Alternative criteria may be applied for specific purposes or reasons, but if so, the details shall be provided in the design documentation together with the reasoning by which the alternative criteria were selected.

Less routine operational slope designs arise where there is long-term exposure of critical infrastructure such as haulroads, levees, power transmission structures, or industrial facilities. Depending on considerations ranging from prior operational experience for equivalent geotechnical conditions to levels of uncertainty in parameters and conditions, it may be appropriate to adopt a higher FOS value as an acceptance criterion.

Acceptance criteria for post-mining landforms will include consideration of slope stability and safety. It will not necessarily be appropriate to utilise geotechnical stability analysis in the routine way due to the much longer time-frames being considered and greater uncertainty about regarding very long-term strength and groundwater flow parameters. It may also be necessary to demonstrate an understanding of long-term ground movement behaviour for geotechnically stable slopes. Any documentation of stability for post-mining landforms shall therefore require a statement about how stability and safety were assessed, and the justification for any acceptance criterion that is adopted for such purpose.

5. GEOTECHNICAL HAZARDS AND POTENTIAL INSTABILITY MECHANISMS

5.1 Geotechnical Hazards

For development of a geotechnical principal hazard management plan, site management must undertake the process outlined in relevant statutory requirements. Following is a summary of the generic hazards that were identified in the Baralaba Mine operational risk assessment upon which the Geotechnical principal hazard management plan was developed:

Highwall/endwall failure onto pedestrians resulting in injury

Highwall/endwall failure onto mobile equipment resulting in equipment damage

Highwall/endwall failure onto mobile equipment resulting in injury

Lowwall failure onto pedestrians resulting in injury

Lowwall failure onto mobile equipment resulting in equipment damage

Lowwall failure onto mobile equipment resulting in injury

Dump slumping whilst discharging loads resulting in injury

Coal face failure during coal mining resulting in injury to operator.

For the purposes of geotechnical risk management, the following list of generic hazards and explanatory notes have been utilised in the geotechnical assessments upon which the design recommendations in this reference report are based:

Rockfall Impacting Personnel or Equipment

Rockfalls may occur wherever support is removed by erosion, vibration, or strength loss allowing loose material on excavated slopes and dumped slopes to move.

Instability of Excavated Highwalls, Endwalls, and Lowwalls

Excavated slope instability may develop where the materials forming part or all of a slope profile are not strong enough to resist gravitational and other dynamic effects such as machine weight or vibration loadings. Groundwater pressure interacts with materials to influence the effective strength that can be mobilised. Material strength may be mobilised through the rock or soil mass, or along rock mass defects, and critical conditions require geotechnical assessment.

Instability of Tipheads

Critical loading of tipheads involves the dynamic action of a loaded truck approaching and stopping at the dump point and requires specific controls that have the capability to virtually eliminate tiphead instability risks.

Instability of Waste Dumps

Waste dump instability may develop where the materials forming the dump profile, potentially including the insitu foundation materials below the dump, are not strong enough to resist gravitational and other dynamic effects such as machine weight or vibration loadings. Groundwater pressure interacts with dump materials, and potentially also any weak layers within the dump foundation, to influence the effective strength that can be mobilised. Pit floor mud that is incorporated into a dump may also contribute to instability.

Bench Collapse under Machine Loading

Bench collapse under machine loading may occur where the machine is positioned close enough to the crest to cause stresses in the ground behind the batter that are greater than the available material strength. Groundwater pressures, dynamic load effects, and the 3D distribution of machine loading may contribute to stress conditions resulting in instability. Consequences of bench collapse include the dynamic effects on the movement and eventual arrest of the machine and any occupants.

Inpit Floor Heave

Floor heave arises where there are stresses within the floor, including the effects of adjacent excavated slopes or dumped slopes, that cannot be resisted by the available strength of the floor materials. The floor materials will most likely include low-strength bedding-parallel or across-bedding defects, but the breakout strength of intact rock layers may also be implicated. Contributing factors may include groundwater pressures and high stresses that may develop within the floor as a consequence of mining induced stress relief or slope loading.

Trench Wall Collapse

Trenches may be dug for investigation purposes but may be subject to wall collapse if the gravitational loading of unsupported wall height exceeds the available strength of the wall materials. Contributing factors may include unavoidable loosening of the wall materials by the excavation process, groundwater pressures, and presence of weak materials or structures.

Inundation from Inrush of Uncontained Stored Water or Other Fluidised Material

Loss of containment may develop where there is inadequate structural or geotechnical strength, or where there are storage overtopping or leakage paths that result in erosion including seepage piping erosion. Certification of adequacy for stored water or flood exclusion levees at Baralaba Mine is undertaken separately from mine geotechnical assessment.

5.2 Identified Mechanisms

Mechanisms of instability, collapse, or heave will depend on the distribution of materials and geometric configuration of the slope or excavation. Identification of potential mechanisms is not prescriptive, requiring geotechnical hazard awareness with participation and confirmation by persons with suitable and recognised training and experience. In Queensland, any person making an instability identification should be suitably qualified and experienced. Any geotechnical oversight requiring engineering certification must be undertaken by a Registered Professional Engineer of Queensland (RPEQ).

5.3 Scale of Mechanisms and Extent of Instability Impacts

The scale of potential mechanisms is dependent on materials and slope conditions and requires assessment by an appropriately qualified and experienced person, typically an external geotechnical specialist. Because of the slope configurations and materials present at Baralaba Mine, observations of mechanism scale and extent of impacts may also require participation of mine personnel. This particularly apples to recording the extent of rockfall movement prior to clean-up, as such observations are of great assistance in calibration of rockfall mechanism models and runout predictions.

6. GEOTECHNICAL MODEL INFORMATION

6.1 Information Sources

Available information on which this report is based consists of geological, hydrogeological, and geotechnical investigations and inspection reports. **Section 10** (References) lists prior information from several sources:

- Geotechnical Consulting Services (**Appendix A**)
- Pells Sullivan Meynink (**Appendix B**)
- Sinclair Knight Merz (**Appendix C**)
- JBT Consulting (**Appendix D**)
- Sherwood Geotechnical and Research Services Assessment Reports (**Appendix E**)
- Sherwood Geotechnical and Research Services Inspection Reports (**Appendix F**).

Volume 2 of this GRR is provided as electronic file folders only, and consists of full details of all Appendices.

6.2 Geotechnical Model and Domains

A geotechnical behaviour model comprises several components which together form the body of information on which geotechnical design and risk management are based:

- geological information and modelling;
- topographic survey and prior mining records;
- soil and rock materials;
- rock mass structure;
- insitu stress state;
- groundwater models;
- mining waste materials;
- mining product stockpiles;
- applied loadings.

Relevant information regarding any of the above components may change with the progression of mining or with the acquisition and interpretation of new data.

For the geological conditions at Baralaba, the geotechnical behaviour model can be conveniently subdivided into the following domains:

(1) Excavated highwalls or endwalls in simple geology, where seam structure is either dipping into the face or has no component of significant structure dipping out of the face;

(2) Excavated highwalls or endwalls in complex geology, where seam structure is disrupted by folding and/or faulting that may include changes over short distances and may also include bedding or other structures that dip out of the face;

(3) Excavated footwalls in either simple or complex geometry, where faces are essentially parallel to seam structure but may include benches;

(4) Spoil dumps formed by routine truck paddock dumping or tiphead dumping;

(5) High-face spoil dumps where tiphead dumping cannot be routinely undertaken because of additional instability risk controls.

6.3 Geological Information and Modelling

The geological model for Baralaba North is prepared and maintained by Baralaba Coal. Current and historical geological information and models are provided for mine planning and technical assessment purposes.

6.4 Topographic Survey and Prior Mining Records

Topographic survey and coal measurement are carried out by the mine operator as required for mine planning operations and reconciliation processes. Records of prior surveys and measurements are retained and available for assessment as required.

6.5 Soil and Rock Materials

The geological sequence at Baralaba comprises Recent and Quaternary alluvium overlying weathered and fresh Permian coal measures rocks. Basement rocks below the Permian coal measures sequence are not encountered in mine activities.

Recent alluvium is soil-like and includes surface floodplain clays, silts, sands and gravelly sands with a surface of self-mulching cracking clayey silt. Quaternary alluvium is generally tighter, more stratified and prone to dispersive erosion due to ageing and densification (**Figure 6-1**).

Figure 6-1 Recent (darker) and Quaternary (lighter) alluvium overlying weathered late Permian Baralaba Coal Measures rocks, Fairway-Outrigger north endwall, January 2019

Weathered Permian (**Figure 6-1**) ranges from hard soil-like material to very low and low-strength rock. The depth of free-digging within the weathered zone varies with local lithology and is sometimes limited by old duricrust layers but is typically 15 m or greater.

Coal measures rocks comprise multiple coal seams of relatively low ash content and semi-anthracite rank. Non-coal rocks comprise alluvial floodplain sequences of siltstones, sandstones, claystones, and tuffaceous layers which may include polished and clay-like interfaces and bands. Rock material characteristic strengths for fresh coal measures vary from low to very high with typical UCS values ranging from 10 MPa to 35 MPa and averaging about 28 MPa (Ref. B1). UCS values vary systematically with lithology and stratigraphy, but not to the extent that warrants contrasting layers to be explicitly recognised.

Figure 6-2 Baralaba Coal Measures rocks exposed on Outrigger west sidewall: note pale Yarrabee Tuff underlying Dirty seam coal and steep structure dip (March 2019)

6.6 Rock Mass Structure

Large-scale structure is dominated by chevron-style folding with relatively straight limbs and localised bends. The broad-scale syncline that defines the mine resource plunges gently to the NNW, following the trend of the regional-scale Taroom trough. At intervals, smaller-scale folding interrupts the broader syncline with tight anticline-syncline pairs that also plunge gently to the NW at an oblique angle to the broader structure. Interactions between the different fold scales may include faults and kinked bands, as well as compressed or buckled bedding within the fold hinges.

Signature effects of folding that influence rock mass behaviour at the scale of mining operations are seam structure that dips moderately either westwards or eastwards, with the general trend deepening to the west and north. Flexural shear along bedding partings is inevitable within the synclinal and anticlinal bend zones, together with conjugate small-scale low angle across-bedding shears.

Figure 6-3 is a general view of the Fairway (west) highwall showing simple bedding structure dipping into the wall towards the west, while **Figure 6-4** shows a general view of the Fairway (east) footwall with simple bedding structure dipping towards the west.

Figure 6-3 Fairway west highwall in blocky rock with simple bedded structure dipping westward into the face (1 April 2021)

Figure 6-4 Fairway east footwall in blocky rock with simple bedded structure dipping westward to form batter faces between benches (1 April 2021)

Figure 6-5 is a south-looking view of the mid-pit asymmetrical anticline-syncline pair that is exposed in this area of the Fairway zone, while **Figure 6-6** shows the intersection of this anticline-syncline pair on the Fairway highwall, with local-scale faults to accommodate the shear deformations where the tighter fold plunges at an oblique angle to the broader syncline.

Figure 6-5 Fairway mid-pit asymmetrical anticline-syncline pair viewed towards south

Figure 6-6 Fairway mid-pit asymmetrical anticline-syncline pair viewed towards southwest showing intersection with highwall

A larger-scale anticline-syncline pair forms the Fairway and Outrigger sections of the pit shell, with the. Intersection of the Outrigger and Fairway synclines

Figure 6-7 is a stereoplot of all North Pit defects obtained from face mapping to March 2021. This structure appears complex but is an overlay of relatively simple conjugate patterns resulting from the effects of overburden stress reduction on pre-existing folded bedded rock. The combination of rock material strength and complex bedded structure results in a relatively fractured but highly interlocked, blocky rock mass.

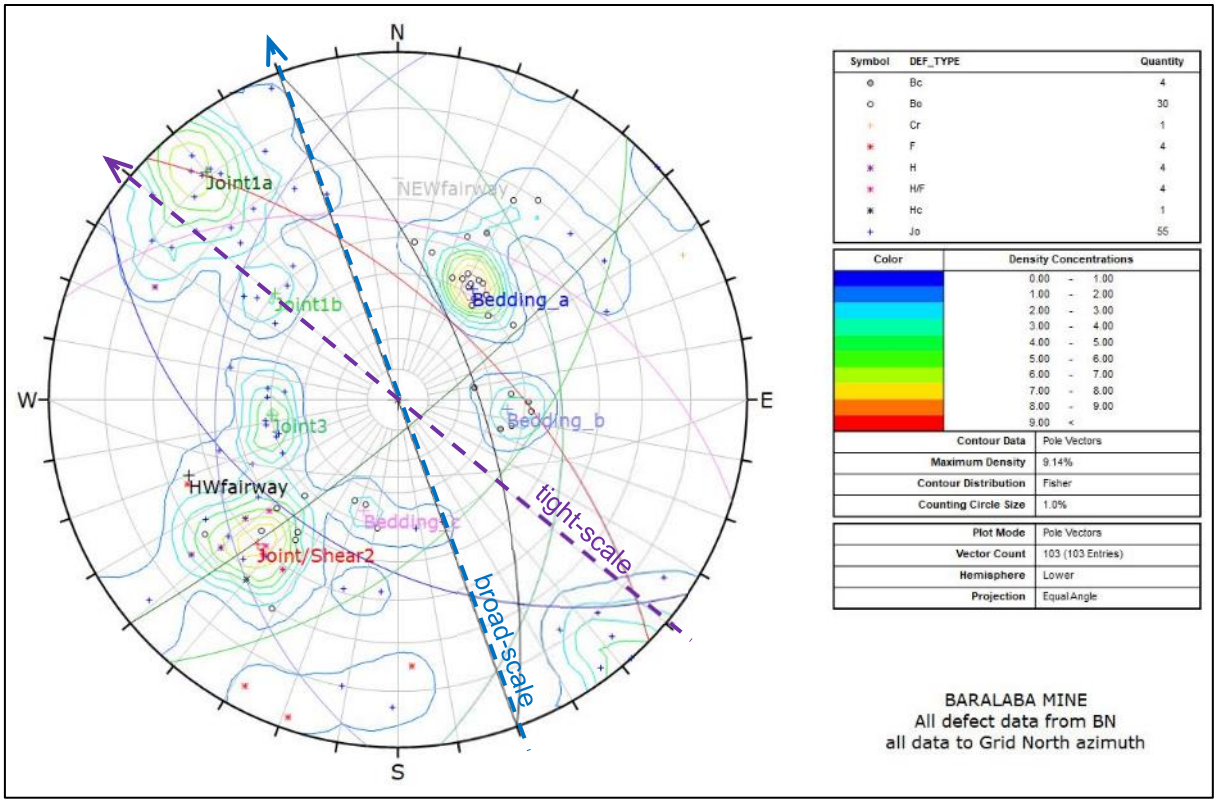

Figure 6-7 Stereoplot of all North Pit face-mapped defects showing conjugate sets and offset between broad-scale syncline plunge and tight-scale anticline-syncline pairs

Larger-scale faults have been relatively uncommon to date. Based on Central Pit experience, such faults may result in bench-scale rockfall hazards but do not cause significant geotechnical issues for slope profile stability.

6.7 Rock Mass Shear Strength

PSM (Ref. B1) carried out a detailed evaluation of rock mass shear strength based on the Generalised Hoek-Brown model with rock material UCS and detailed borehole scanner data to interpret strength parameters. These rock mass strengths were reviewed by SGRS (Ref. E1) as being too low for the observed conditions in Central Pit. Subsequently PSM carried out a further justification of their interpretation (Ref. B2) which was not considered to be reasonable by SGRS.

Since that time SGRS has utilised a simpler Mohr-Coulomb strength model with parameters adopted based on Bowen Basin experience and precedence. If anything, based on Fairway and outrigger observations to date, the SGRS parameters are possibly conservative (ie lower)

than the actual strengths. The SGRS parameters have been adopted for all the North Pit stability and stress-deformation modelling that forms the basis for the design recommendations described in **Section 7**.

The Baralaba Coal Measures are stratigraphically equivalent to the Blackwater Group of the central Bowen Basin, which comprise the Rangal Coal Measures overlying the Fort Cooper Coal Measures and separated by the Yarrabee Tuff marker bed. Although not proven by zircon dating, it is likely that the pale tuffaceous band underlying the Dirty seam is the Yarrabee Tuff. Underlying this sequence is the Sub-Dirty seam and a thick succession of tuffaceous claystones and carbonaceous beds comprising the Kaloola member. As this sequence typically forms the exposed synclinal footwalls at Baralaba, multiple levels of weak bedding-parallel surfaces should be expected.

Footwall instability arises through slab sliding with breakout either through rock mass or along accommodation shears at a low angle to bedding. Footwall stability relies upon underbenching to reduce toe loadings by creating benches at intervals determined through stability assessment. The original PSM recommendation (Refs. B1, B2) of 10 m wide benches at 15 m vertical intervals was confirmed by SGRS (Ref. E1) and implemented at Baralaba North in the Outrigger and Fairway zones. This design has been effective in reducing the incidence of bench slab instability to acceptably low levels with manageable amounts of movement and rockfall.

As mining progresses northward the design pit shell becomes potentially deeper than the sections covered by the PSM reports. SGRS carried out additional assessment to confirm underbench design recommendations for a deeper footwall as described in **Section 7**.

6.8 Insitu Stress State

There is no record of insitu stress measurements at Baralaba. Insitu stresses may be inferred from published Australia-wide measurements (Ref.8). Alternatively, virgin stress conditions could be assumed based on regional experience with a typical maximum horizontal stress between 1.0- and 2.0-times vertical overburden stress. The likely orientation of the maximum horizontal stress for this part of Queensland is likely to be roughly NE-SW.

For stress-deformation modelling at Baralaba, it is essential to include initial stages for setting the nominal stress conditions to account for effects of bedding structure. Notionally this could be readily done using an initial state corresponding to deeper burial followed by an unloading stage to current natural ground. This would simulate the effect that the folded structure with weak bedding-parallel surfaces may have on initial stress conditions locally within the rock mass prior to modelling the effects of mining-induced stress changes.

6.9 Groundwater Models

Extensive groundwater investigations were undertaken for the Baralaba North expansion study, and in particular to determine the effects of future regional flooding with the aim of maintaining integrity of the levee system to prevent future flooding of the pit. Details are provided in **Volume 2**, **Appendix C**.

During these feasibility studies a number of observation bores and piezometers were installed. Some of these are located outside of the mine footprint and remain in service. Piezometer data are recorded on loggers which are downloaded from time to time. None of the remaining

piezometers are close enough to mining voids to provide geotechnically useful evidence of mining-induced groundwater pressure drawdown.

Geotechnical Groundwater Information from Piezometer Data

Groundwater models for pit slope geotechnical design purposes are generally simplified to be based on assumed or measured groundwater phreatic surfaces. For rock slopes, the drawdown of the phreatic surface caused by mining activity is usually a matter for geotechnical judgement based on prior experience in similar conditions. For spoil slopes, the location of the phreatic surface is a matter of geotechnical judgement based on prior industry experience and research findings (Ref.9).

Groundwater pressure may be:

(a) **Unconfined**, where the groundwater flow and pressure are locally controlled only by the depth at which water pressure is equal to atmospheric pressure (the groundwater table), or

(b) **Confined**, where the groundwater flow and pressure are locally controlled by relative permeabilities of materials and water pressure or flow conditions at distant boundaries.

Unconfined groundwater conditions can be described in terms of the groundwater table (phreatic surface) where the water pressure is atmospheric. When unconfined groundwater is flowing laterally, the groundwater table will not be at a constant level and groundwater will flow in the direction of reducing groundwater table level.

At Baralaba the seasonally dependent regional groundwater table is typically located close to the base of weathering for the Permian rock units. Perched or transient groundwater may also rise within the Quaternary and Recent alluvium and may be treated as unconfined.

Mining excavations cause the groundwater table to be lowered within a zone of influence that, as a rule of thumb, may extend laterally for a distance of 1 – 3 times the pit depth. Lateral flows are induced because the pit acts as a drain, and dewatering pumps are required to manage water levels within operating areas resulting from a combination of seepage inflow and rainfall runoff. The distribution of groundwater pressures within the zone of influence will depend on rock mass structure and rock materials, both of which contribute to anisotropic and lithologically variable hydraulic conductivity that has both geometric and material elements. While a phreatic surface will still develop, much of the groundwater flow will be confined and this will have a controlling effect on pore pressure distribution.

For all pit slopes, significant uncertainties in groundwater pressures arise wherever there is reliance on simplifying assumptions involving groundwater phreatic surfaces. The impacts of such uncertainties should be addressed as part of geotechnical assessment processes. Uncertainties can be significantly reduced if piezometer data are available and utilised.

The Fairway excavations during 2019 revealed zones of complex geology for which stability assessments identified marginally acceptable conditions resulting from significant uncertainty regarding groundwater pressure distributions (Ref. F4). Piezometers were installed in December 2019 at the crest and +30mRL bench levels at the dogleg corner shown in **Figure 6-6**. Piezometer data enabled detailed groundwater pressure modelling that took account of anisotropic hydraulic conductivities in both geometric (folding) and stratigraphic (across-bedding versus along-bedding) senses. This model provided for updated assessment that determined stability to be acceptable (Ref. E4).

Data logging from the two Fairway highwall piezometers will continue until completion of excavation and for some period during backfilling to enable updating of the hydraulic

conductivity parameters and refinement of the modelling procedure. The current modelling procedure has been applied to the deeper progression of mining towards the north.

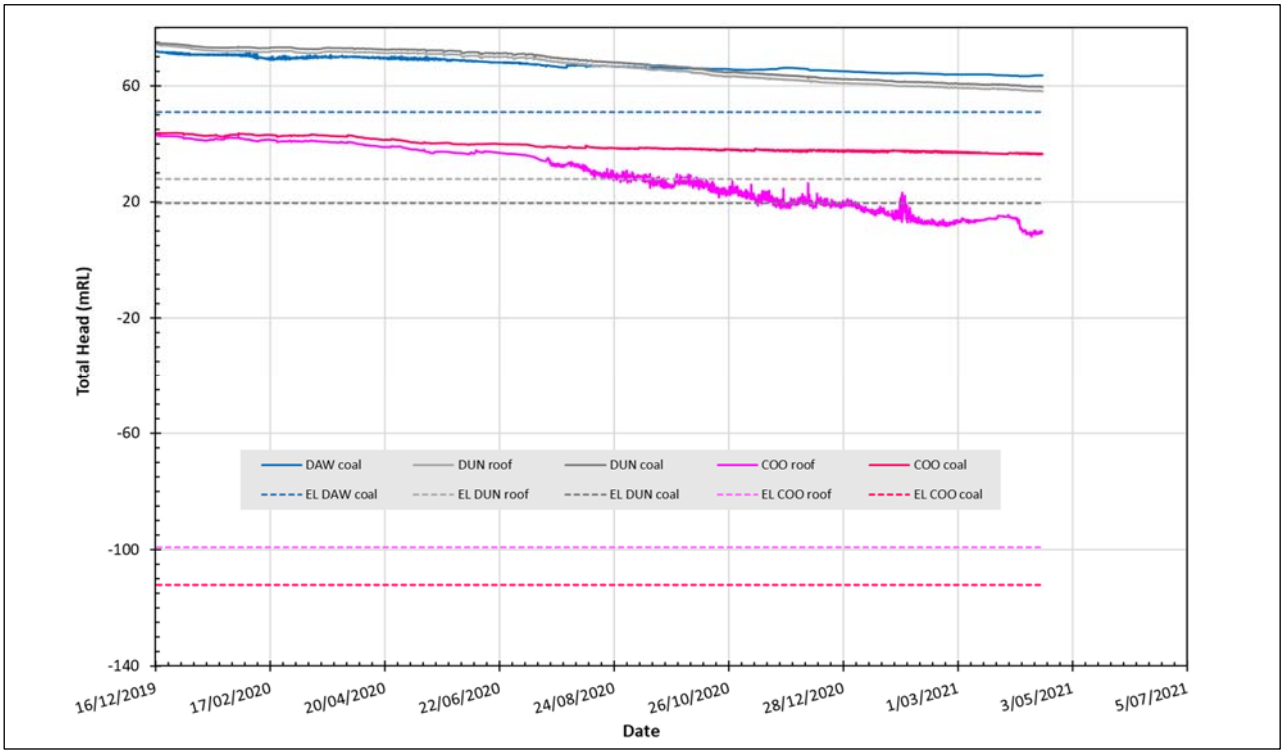

Figure 6-8 Fairway highwall crest piezometer Total Head history to April 2021 with enhanced drawdown effect in Coolum seam roof relative to seam

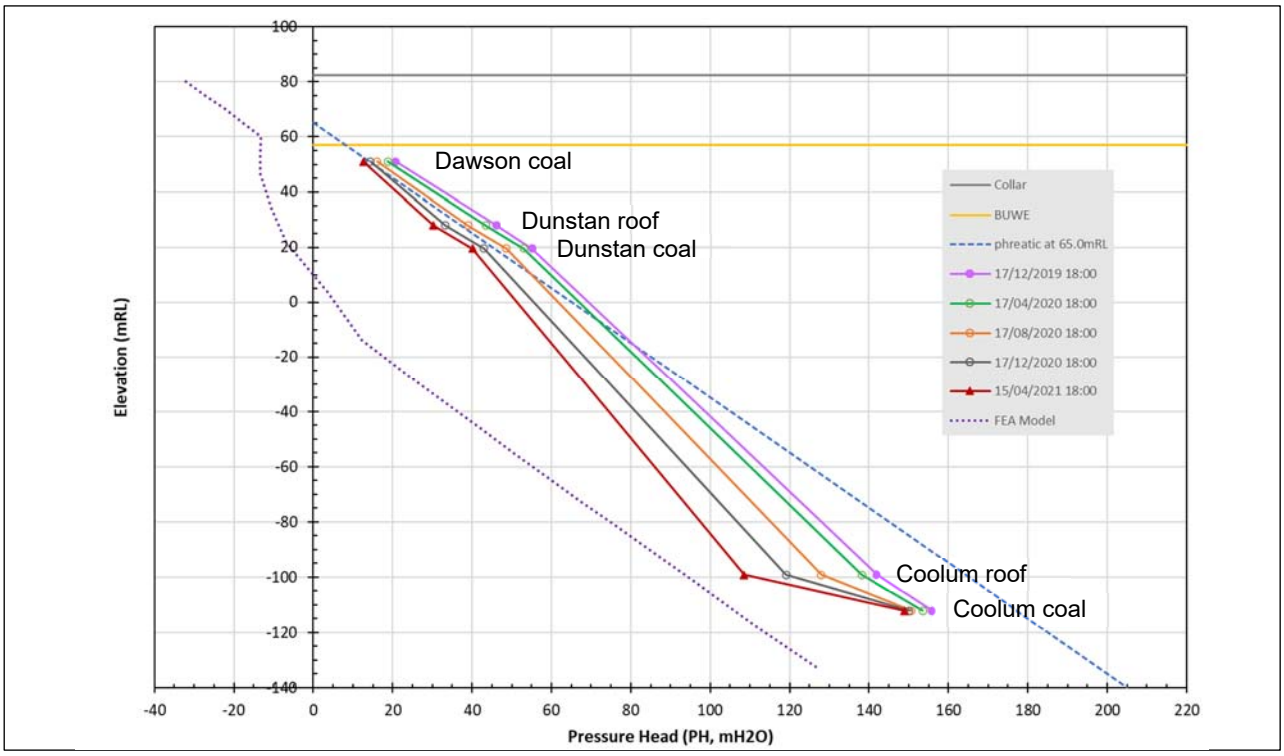

Figure 6-9 Fairway highwall crest piezometer Pressure Head – Elevation profile at 4-month intervals to April 2021 showing greatest drawdown at Coolum seam roof level

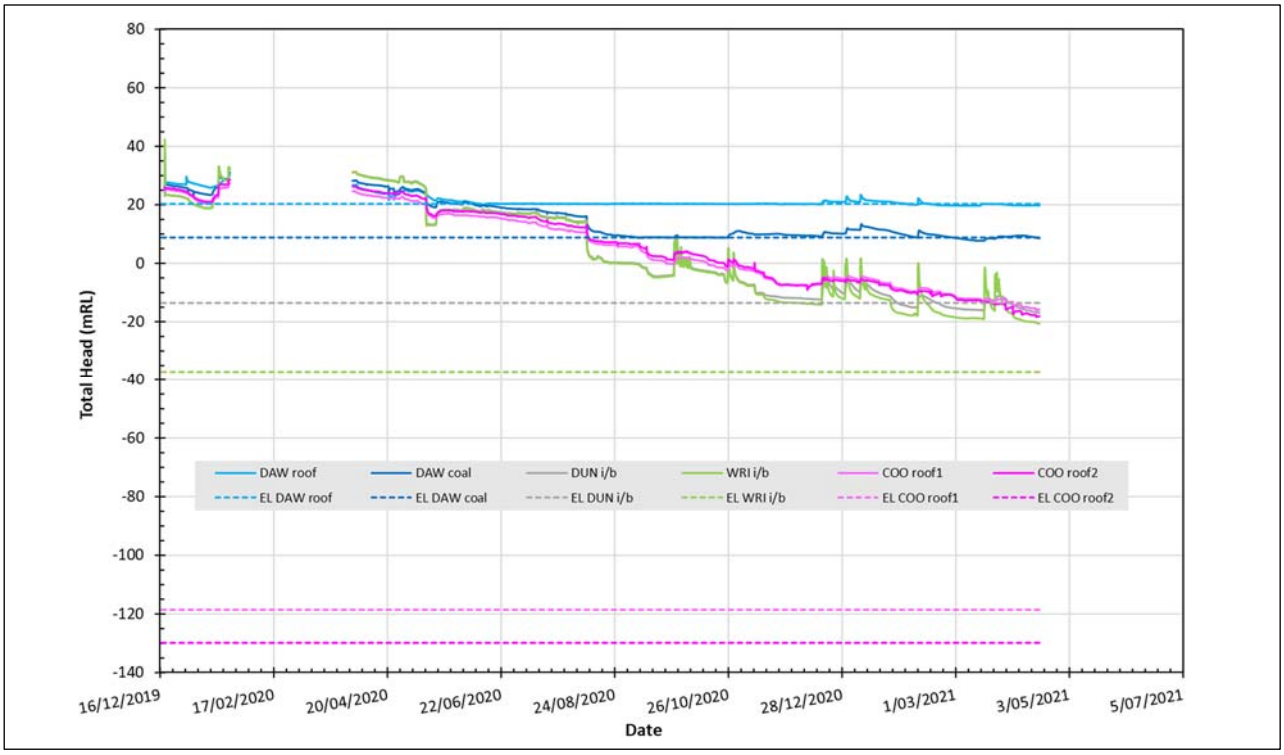

Figure 6-10 Fairway highwall bench piezometer Total Head history to April 2021 with drawdown to dry in Dawson roof and seam and Dunstan interburden and enhanced drawdown in Wright interburden relative to Coolum seam roof

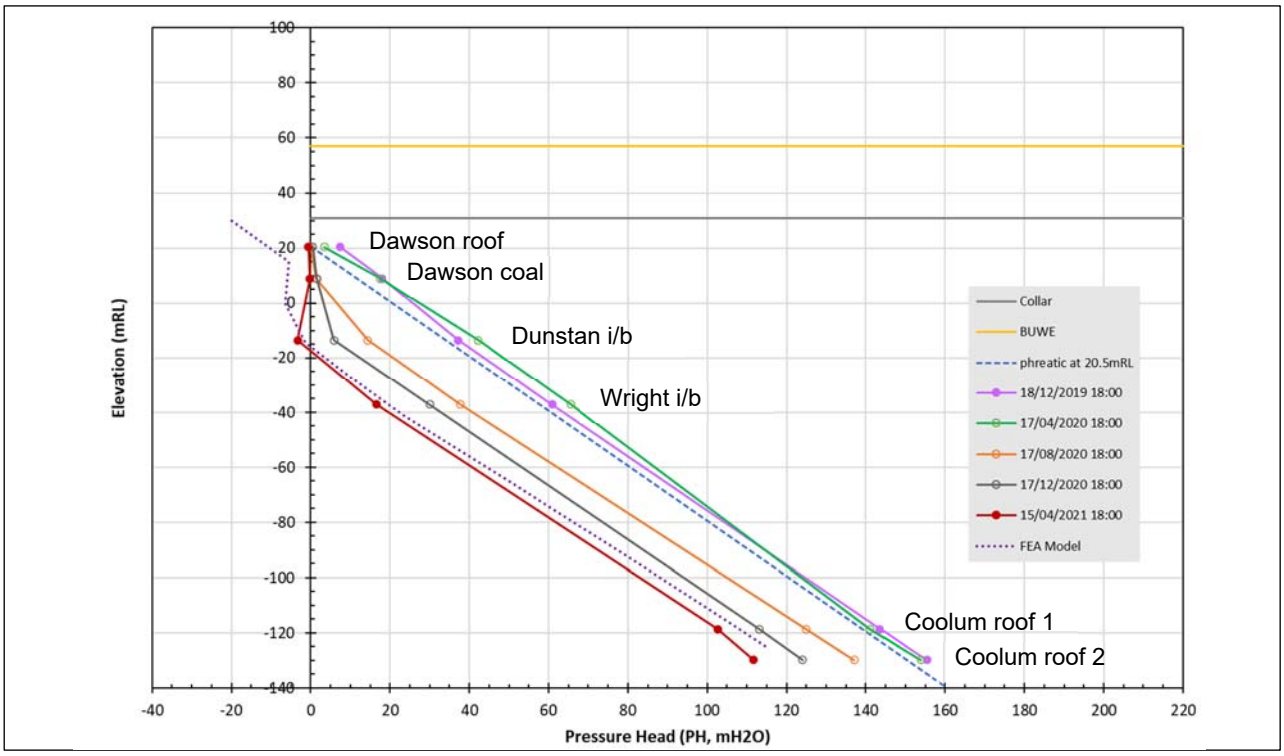

Figure 6-11 Fairway highwall bench piezometer Pressure Head – Elevation profile at 4-month intervals to April 2021 showing drawdown close to FEA Model predicted levels

Groundwater Pressure Models for Excavated Slopes

Groundwater conditions within excavated slopes are typically confined to an extent depending on the slope profile and geological conditions. For routine geotechnical analysis it may be adequate to represent groundwater pressure conditions by adopting an assumed phreatic surface location that is adopted on the basis of experience. When doing so, the groundwater pressures within materials below the phreatic surface may be modified using Hu parameters appropriate to the materials and slope conditions. Guidance regarding Hu parameter values is best obtained from groundwater pressure modelling, particularly in the structured rock mass at Baralaba. Obviously, all model assumptions are most reliable when guided by groundwater pressure measurements using piezometers or standing water levels in boreholes.

Alternatively, groundwater pressure distribution and phreatic surface location may be modelled using hydraulic conductivity parameters that are appropriate for various materials. Guidance regarding permeability parameter values is provided in **Section 7**. Such modelling also requires appropriate representation of the pressure and/or flow boundary conditions that control the groundwater pressures and flows in the region of greatest interest. In practice, this requires that the flow boundary conditions be either quite complex and uncertain, or that flow boundary conditions are applied at a suitably distant location so that the choice of location does not significantly affect the model outcomes in the region of greatest interest.

Groundwater Pressure Models for Waste Dumps and Stockpiles

Groundwater conditions within dumped spoil slopes are most likely to be unconfined. Conditions for design are based on the recommendations within (ACARP C20019). Guidance regarding spoil and stockpile permeability parameter values is provided in **Section 7**.

Perched groundwater tables may develop when spoil is dumped over an older running surface that has been compacted by grading and trafficking. Piezometric surfaces are likely to be within a meter or so of the less permeable base layer, and temporary unless dump settlement results in ponding of water against the toeline of a subsequent dump lift. Under such conditions a potential rill-wedge instability mechanism may develop due to the deformation and strength loss associated with basal ponding of a single dump lift.

When water is ponded within voids, the transient response time is typically faster than the rate of water level change and therefore the zone of saturation within the dump should be assumed to correspond to the void water level. Potential instability may result when relatively rapid drawdown of void water levels causes a transient pressure lag effect within the saturated spoil.

6.10 Mining Waste Materials

Spoil Materials

The geotechnical behaviour of the alluvium cover and Permian sedimentary rock spoil materials, whether weathered or fresh, is relatively well understood and predictable. Appropriate information is readily available for design purposes, and standard operating procedures for dumps are appropriate. For design purposes, Permian fresh rock spoil is considered to be equivalent to BMA Coal Category 3 (Ref.9). Alluvium and weathered Permian rock spoil are typically weak and water-sensitive and are considered to be equivalent to an average of BMA Coal Categories 1 and 2 (Ref.9). Strength parameters for all materials are listed in utilised for dump design recommendations.

Recent and Quaternary alluvium material are typically highly variable and almost always result in water-sensitive spoils with generally poor geotechnical performance in dumps unless tiphead heights are limited and drainage conditions are well maintained. Appropriate assessments should always be carried out in advance for new mining areas in order to minimise the likelihoods of geotechnical instability hazards developing when these materials are dumped.

Coal Handling Plant Wastes

Selective mining practices are used to recover raw coal which is stockpiled at the ROM. Processing is limited to crushing and sizing so there are minimal wastes. Raw coal which fails to meet product specifications is unusual, but if identified is encapsulated in waste dumps.

6.11 Mining Product Stockpiles

ROM and product stockpiles are of modest height. Nevertheless, strict operating procedures apply to all stockpiles to minimise the risks rising from reclaim face collapse. Sudden collapse, including flowsliding in extreme conditions, can develop if stockpile faces are steeply cut to excessive heights. This behaviour arises from the temporary apparent strength gain caused by desaturation and localised suction development.

6.12 Applied Loadings

Two categories of loadings are considered: static loads due to the weight and size of structures or stationary machines, and dynamic loads resulting from earthquakes, blasting, and machine vibrations or load cycling.

Static Load Action Effects

Self-weight gravitational loading is always present and is the predominant load effect for pit slopes and stockpiles. Rigorous assessment of static load action effects in 2D is relatively straightforward and readily undertaken. Applied loadings arising from the weight and contact footprint of machines are inherently 3D, and appropriate treatment is required for meaningful application to equivalent 2D analysis.

Dynamic Load Action Effects Generally

Rigorous modelling of dynamic loadings is impractical because of 3D and time-dependent complexities and uncertainties. However, there are significant differences between earthquake load actions and blasting or vibrating machinery load actions, and these are relevant to geotechnical stability assessment and hazard management.

Earthquake Load Action Effects

Earthquake loading can only be approximately predicted in the absence of a site-specific seismicity assessment. Consideration of relevant regional seismicity information and the current Australian Standard earthquake loading code (Ref.10) resulted in peak lateral ground acceleration levels (pga, or a_h) being estimated for Baralaba at various levels of Annual Probability of Exceedance (AEP) as:

AEP 1/2500	(0.04% AEP)	a_h = 0.153 g
AEP 1/500	(0.2% AEP)	a_h = 0.085 g
AEP 1/100	(1% AEP)	a_h = 0.0425 g

Unless the earthquake is located at very close range (within a few kilometres) and very shallow depth (one kilometre or less), the felt effect results from transit of a combination of compressional and shear waves that effect all parts of the loaded area simultaneously. Loading action effects are simulated by cyclic application of acceleration to the mass of the loaded body.

The predominant frequency of earthquake waves is relatively low, so a peak lateral ground acceleration of 0.085 g corresponds approximately to a peak particle velocity ppv = 40 mms^{-1} to 100 mms^{-1}. An earthquake of such magnitude probably has a duration of significant shaking of between 10 and 25 seconds. The combined effect of movement magnitude and duration might be sufficient to dislodge small already loose rocks on pit slopes but is unlikely to cause ground cracking or to dislodge blocks of material with masses larger than 500 kg unless these were already precariously loose.

The effect of earthquake loading on pit slope stability is geometry-dependent. For routine slope design purposes, pseudo-static screening stability analyses provide an appropriate starting-point. For a 0.2% AEP event, modelled as a_h = 0.085 g with a_v = -0.0085 g (simultaneously upwards), a slope with a routine static minimum FOS of 1.20 will almost always result in a pseudo-static FOS (PSFOS) analysis outcome of PSFOS ≥ 1.00 meaning that earthquake-induced slope displacements are likely to be insignificantly small. For PSFOS values of 1.00 to 0.80, some cracking is to be expected but earthquake-induced displacements are likely to be small and not compromise the safe functioning of the slope. However, PSFOS values of 0.80 or less will correspond to significant movement and damage that may compromise the continued safe functioning of the slope.

Based on the above, more detailed assessment of earthquake loading effects should be carried out whenever a PSFOS ≤ 0.95 is obtained. The simplest approach is to undertake a Newmark analysis of induced movement, which requires an input accelerogram. This may be a historical record from a local seismic monitoring station that is scaled to the design-level pga, or a "similar" accelerogram from elsewhere that is similarly scaled. Geoscience Australia coordinates a network of monitoring stations from which records can be obtained upon request.

The most "realistic" assessment of earthquake loading effects requires 2D or 3D stress-deformation modelling to which an input accelerogram is applied typically at the base of the modelled section. This level of analysis requires substantial resources and time and is considered impractical for general application to a relatively low seismicity-risk locality such as Baralaba.

Baralaba slope stability assessments including earthquake loading have, to date, been carried out using the pseudo-static screening approach. This is considered to be appropriate and adequate because of the historical relatively low seismicity-risk for the Baralaba locality.

Blasting Load Action Effects

Blast-induced ground motions are typically of much higher frequency, attenuate rapidly with distance, and may include more complex surface motions. Baralaba mine, like all similar-scale black coal mines, carries out regular blasting activities and therefore has an observational history of the impacts of blasting on slope performance. There have never been any reports of significant rockfall or slope instability arising from mine blasting.

The attenuation of blast-induced ground motion is frequency dependent, so that lower-frequency motion is felt further away than higher-frequency motion. At close range, blast-induced vibrations can be of sufficient magnitude to cause reflective cracking (where a compressive wave reflects off a free-surface such as a pit slope or pit crest) or shear

displacement (where local shear-stress close to the ground surface exceeds the local shear strength). Crest cracking, local shear-stress rupture, and post-blast cracking near crests is observed from time to time and usually results in adjustments to blasts designs to limit recurrences.

SGRS understand that vibration monitoring is regularly undertaken for documentation of blast-induced motions relative to regulated limits at lease boundaries. In principle, the standard outputs from blast monitors could be analysed to provide site-specific ground motion data for undertaking slope stability assessments. In practice, no such requirement has been identified to date.

Machine Vibration Load Action Effects

Heavy equipment engines, dozer track-slap, and excavator- or shovel-loading of trucks create localised dynamic loads of variable frequency and duration. When machine vibrations transmit sufficient energy to nearby loosened, usually oversteepened excavated faces, it is possible for single shock loads or resonant vibrations to dislodge material. These effects of machine loading are only significant when a quasi-stable face already exists at relatively close range, which probably explains why it is often discussed by operators in the context of rockfall hazard identification and risk assessment. With appropriate standard operating procedures and work practices, such effects are not significant for slope design purposes.

Low-frequency repeated loads such as dozer-trafficking of stockpiles or water-bearing palaeochannel sands may trigger cyclic softening or liquefaction of susceptible materials. Similar effects may occur during the loading and filling cycles for excavators or shovels, due to the cyclic load changes on their tracks during filling, swinging, and emptying. These actions have resulted in sinkage of equipment when working on wet susceptible palaeochannel materials. The appropriate treatment is to improve drainage or to work the machines on non-susceptible materials.

Measurement and Interpretation of Seismic Data

Blast vibration monitors are used routinely for open cut coal mining, and in principle their data could be analysed in further detail to provide information on blast load action effects that could be used for rockfall and slope stability assessment purposes. Operational experience at Baralaba has not identified a requirement for such assessment.

For earthquake monitoring purposes, strong-motion monitors must be deployed and regularly serviced. Alternatively, Geoscience Australia maintains a regional-scale network of strong-motion monitoring stations. Historical records from regional earthquakes may be obtained from Geoscience Australia and a site-specific seismicity assessment can be obtained from a commercial service provider.

6.13 Ongoing Information Gathering

Baralaba Coal directly manages exploration activities and geological modelling. When exploration is planned, or when geotechnical circumstances are identified, detailed proposals are prepared and negotiated with Baralaba Coal.

Ground conditions are reviewed during geotechnical site inspections, and this may identify grounds for sampling and geotechnical testing or include recommendations for additional investigations. **Appendix F** includes all site inspection reports issued since the resumption of mining in Baralaba North in 2018.

7. DESIGN RECOMMENDATIONS AND GUIDELINES

7.1 Prior Mining Geotechnical Performance History

Geotechnical design recommendations are based on consideration of prior mining performance together with geotechnical analysis of stability and potential ground movement. An introduction to prior mining geotechnical performance history is provided in **Section 2** and **Section 3**, and details are documented or referenced in various reports by:

- Geotechnical Consulting Services (**Appendix A**)
- Pells Sullivan Meynink (**Appendix B**)
- Sinclair Knight Merz (**Appendix C**)
- JBT Consulting (**Appendix D**)
- Sherwood Geotechnical and Research Services Assessment Reports (**Appendix E**)
- Sherwood Geotechnical and Research Services Inspection Reports (**Appendix F**).

7.2 Slope Design Guidelines

North Pit Updated Shell Design Recommendations (December 2020)

North Pit shell slope design recommendations to date have been based on 2015 geotechnical investigations and reporting (Refs.B1, B2, E1) that have been reviewed and modified since resumption of mining activities in 2018. Fairway terraces T01 -T09 have provided updated experience with mining through both “simple” and “complex” geology zones, in both highwall (west) and footwall (east) sideslopes.

The following slope profile designs are recommended:

<u>Excavated Highwalls</u>

Alluvials: effective slope angle of 45° from ground surface to base of alluvials (if dug steeper, use a windrow to demarcate “toe” at 45° projection from crest), 10 m bench width at toe level.

Weathered Coal Measures Rock Mass: non-presplit trimmed slope angle of 65°, alternatively a 45° softwall which may be flitch-benched rather than a single batter, 10 m bench at base of weathering or lower to suit horizon selection, maximum unbenched batter height 30 m to 35 m.

Fresh Coal Measures Rock Mass: presplit slope angle of 70°, maximum unbenched batter height 45 m to 50 m, bench width minimum 15 m or to suit drill tailroom. *It is noted that presplit slope angles of 65° were earlier utilised in North Pit and then successfully changed to 70°. Presplit angles of 70° were successfully implemented in the final CP03 highwall and north endwall.*

<u>Excavated Footwalls</u>

Alluvials: as for highwalls.

Weathered Coal Measures Rock Mass: batters to follow bedding dip, maximum batter height 15 m, or less to suit horizon selection, minimum 10 m bench widths.

Fresh Coal Measures Rock Mass: batters to follow bedding dip, maximum batter height 20 m or less to suit horizon selection, minimum 10 m bench widths for dip ≤ 60°, 15 m bench widths for dip > 60°.

Excavated Pillar or Plug at Old Powerline Corridor

A rock pillar or plug crest at -30 mRL with a minimum crest width of 20 m is required at the boundary between previous Outrigger and Fairway mine voids and the northwards continuation of mining in T11 (Ref.F5). Where the T11 excavation level is below -30 mRL on the north face of this pillar, the excavated profile is as for excavated final endwalls.

Excavated Final Endwalls

As for highwalls.

Excavated Advancing Terrace Walls

As for highwalls but consider softwalls as an alternative.

NOTE: The above recommendations cover both “simple” and “complex” geology. “Simple” geology refers to a single syncline limb or syncline-anticline pair, plunging to the north-northwest, with bedding dip westwards into the (west-side) highwall and bedding dip westwards out of the (east-side) footwall. “Complex” geology refers to more complex bedding intersections resulting from additional syncline-anticline structures and/or structure offsets formed by modelled faults.

Dumped Spoil Slopes

Recommended tip-head dump slope profiles consist of lift heights not exceeding 30 m for fresh Permian rock spoil, and not exceeding 20 m for any mix of weathered Permian rock spoil and other materials. Each lift must be separated by a minimum bench width of 10 m.

High-face dumping may be undertaken where tip-head heights exceed 30 m for fresh Permian rock spoil, or alternatively exceed 20 m for any mix of weathered Permian rock spoil and other materials. Additional risk controls such as short-dumping and dozing or specific geotechnical assessment recommendations shall be implemented for each high-face dump situation depending on circumstances.

North Pit Fairway South Endwall Slope Profile

The prestrip levels of the Fairway South Endwall were dug when the previous recommendations (Ref.E1) were in place, and called for the south endwall to be designed with a 45° interramp angle, either as a softwall or a stepped sequence of 15m high batters with 65° non-presplit faces. Based on current Fairway experience, it is now recommended that the South Endwall be completed to the same slope profile as currently adopted for the Fairway highwall.

Future North Pit Piezometer Installations

The Fairway west highwall piezometer installation has provided critical groundwater press data that confirmed the acceptability of the design highwall profile through a “complex” geology zone.

Continuation of northward mining into T11 and beyond will encounter intersecting anticline-syncline pairs forming zones of complex geology, and where groundwater pressure conditions cannot be relied-upon to be similar to those measured in the Fairway west highwall. Recommendations have been provided for future mining to include allowances for up to three piezometers within the future west highwall (one at crest and one at an intermediate bench) and east footwall (one at an intermediate bench level) to confirm design models and facilitate changes to design to maintain acceptably low likelihoods of instability where complex geology intersects with the pit shell.

7.3 Pit Slope Geotechnical Parameters

Shear strength and hydraulic conductivity parameters have been adopted based on a combination of earlier feasibility study reports (Refs. B1-B7, C1-C2, D1-D2, E1) and more recent slope stability assessments (Refs. E2-E8). Reference parameters are listed in **Table 1**. Stress-deformation modelling has been less widely undertaken (Refs. E1, E4) and parameters are largely derived from previous SGRS assessments for similar materials at other sites. Reference parameters are listed in **Table 2**.

7.4 Excavated Slope Design Checks

Design checks have been carried out for the northward progression of North Pit to confirm that earlier assessments and ongoing operational experience are likely to remain valid as the pit deepens with progression northwards.

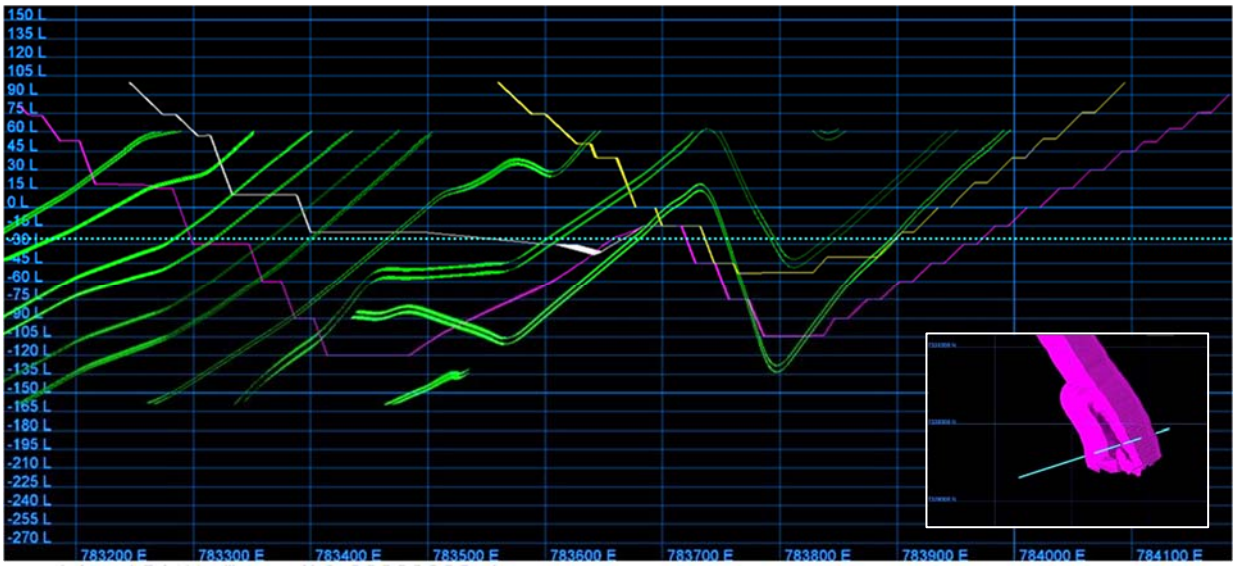

Figure 7-1 North Pit T11 geological model section with potential pit shells superimposed

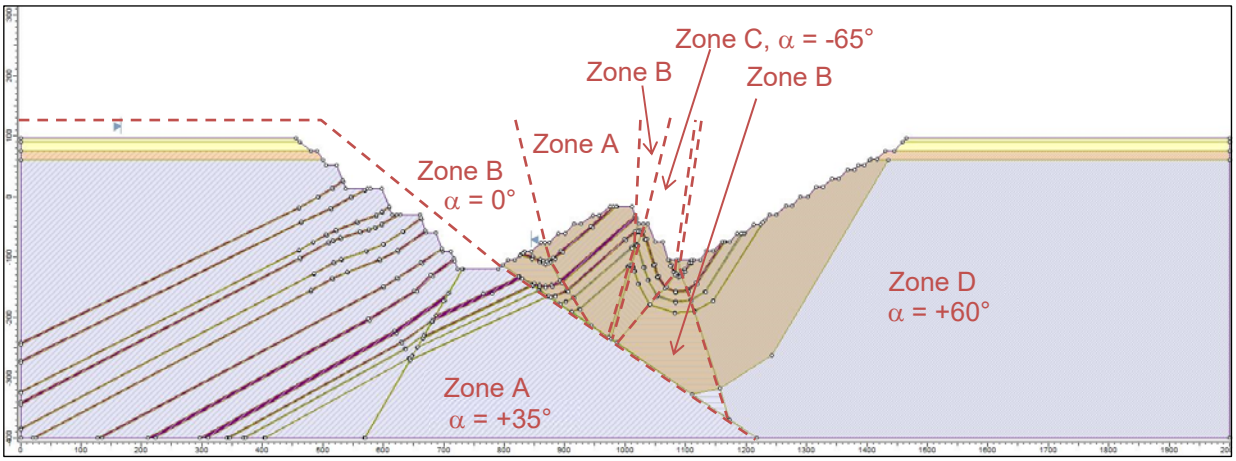

Figure 7-2 North Pit T11 geological model section remodelled for slope stability assessment, showing zones for groundwater flow modelling

Figure 7-1 shows a provided example of a potential pit shell section within the T11 area. In order to construct a suitable analytical model from this example section, various assumptions were required regarding the presence of faults, the possible nature of fault displacements, and nature of seam structure where it was not included in the geological model provided. The adopted analytical model section is shown in **Figure 7-2**.

Slope stability modelling was carried out to confirm general conditions for stability. Rigorous analysis of multiple section geometries was not considered to provide worthwhile incremental benefits because of the high likelihood of variability as had previously been experienced in the Fairway and Outrigger excavations. Modelling of groundwater flow required subdivision of the model geometry into several zones (**Figure 7-2**) to approximately follow the seam structure orientation and thereby include the effects of both geometric and material flow anisotropy. For the general highwall, potential arc mechanisms were analysed to determine the effect of rock mass shear strength on stability, which was confirmed to be acceptable (**Figure 7-3**) based on a minimum computed Factor of Safety (FOS) greater than 1.20. The modelled pit floor was at -120mRL, implying that mining could potentially continue northward to even greater depths if considered economical.

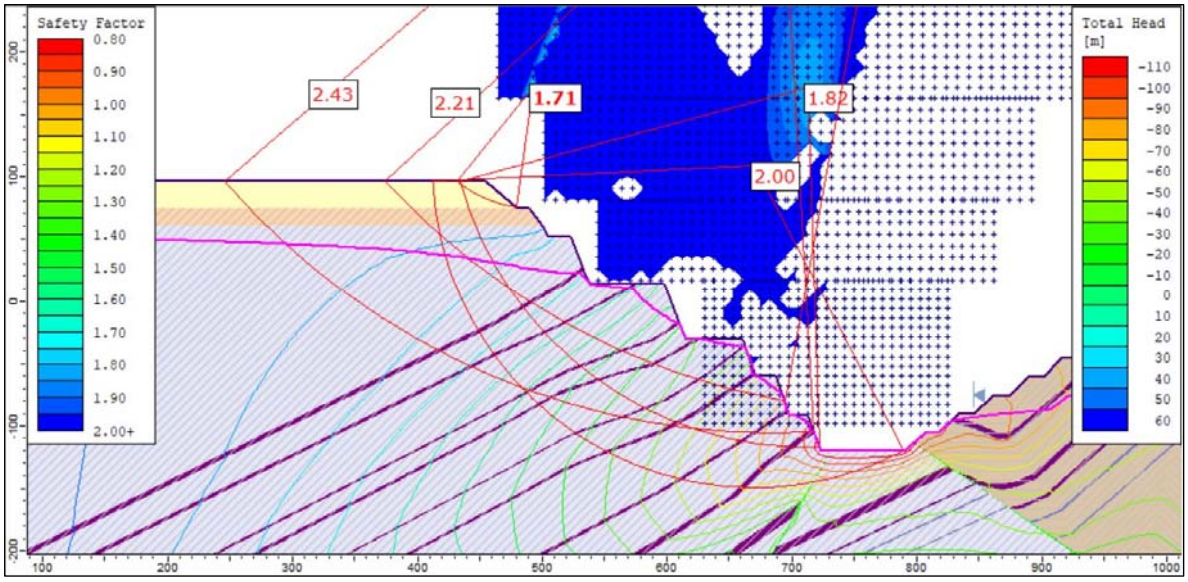

Figure 7-3 General North Pit highwall section with FOS ≥ 1.70 for potential rock mass strength-controlled instability

The general section potentially includes an anticline-syncline pair, resulting in a footwall condition with different rock mass structure to what has been experienced previously in the Outrigger and Fairway mining areas, and which potentially includes the Yarrabee Tuff bed underlying the Dirty seam. This modelled condition is shown in **Figure 7-4**.

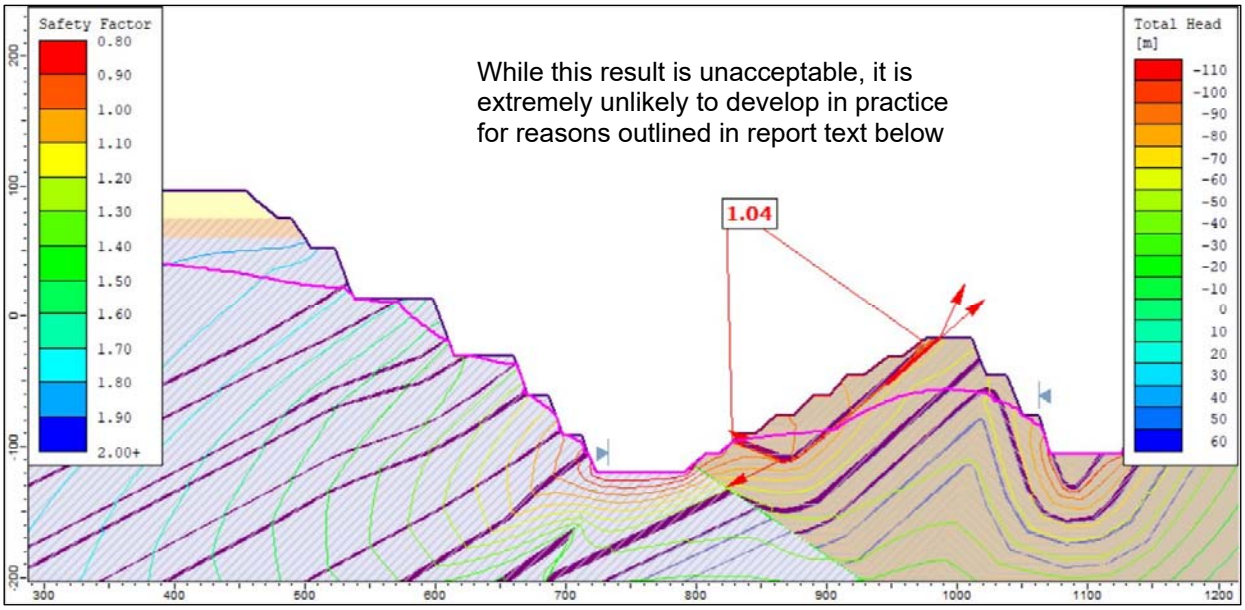

Figure 7-4 General North Pit in-pit anticline-syncline pair with FOS = 1.04 for potential block sliding on weak bedding-parallel surface with low rock mass breakout strength

For modelling purposes the worst-case breakout strength together with the weak bedding-parallel strength, as determined by PSM (Refs. B1, B2) was applied and resulted in an unacceptably low FOS outcome of 1.04. The **Figure 7-4** case is believed to be an extremely unlikely worst-case outcome, as previous observations of the Outrigger footwall (Ref. E2) found stable ground conditions despite similarly unacceptable calculation outcomes. Similar but deeper-seated conditions (**Figure 7-5**) were acceptably stable with a minimum computed FOS outcome of 1.48. On the shorter and more steeply dipping east-facing anticline slope, worst-case stability conditions were acceptable (**Figure 7-6**) with a minimum computed FOS outcome of 2.38.

The east footwall presents a significant unknown for geotechnical stability design in terms of unprecedented height of exposure of the Kaloola member. There is little geological and no geotechnical information in this part of the deposit because of the absence of coal resources. Design for current conditions is based on the requirement for underbenching, but this may prove to be unnecessarily conservative. Based on the worst-case assumptions about strength conditions, the critical condition for overall slope profile stability is for sliding along one of the known Kaloola carbonaceous intervals with a tuffaceous claystone. The minimum computed FOS outcome was 1.66 (**Figure 7-7**), suggesting some opportunity for steepening the slope profile while maintaining adequate stability.

However, any such footwall opportunity relies on further understanding the impacts of geological uncertainties on bench-scale and multiple-bench footwall stability. Based on current information and experience it is premature to consider steepening the east footwall slope. As mining progresses deeper in T11 there will be opportunities to assess the materials that are exposed, including future strength testing if considered worthwhile.

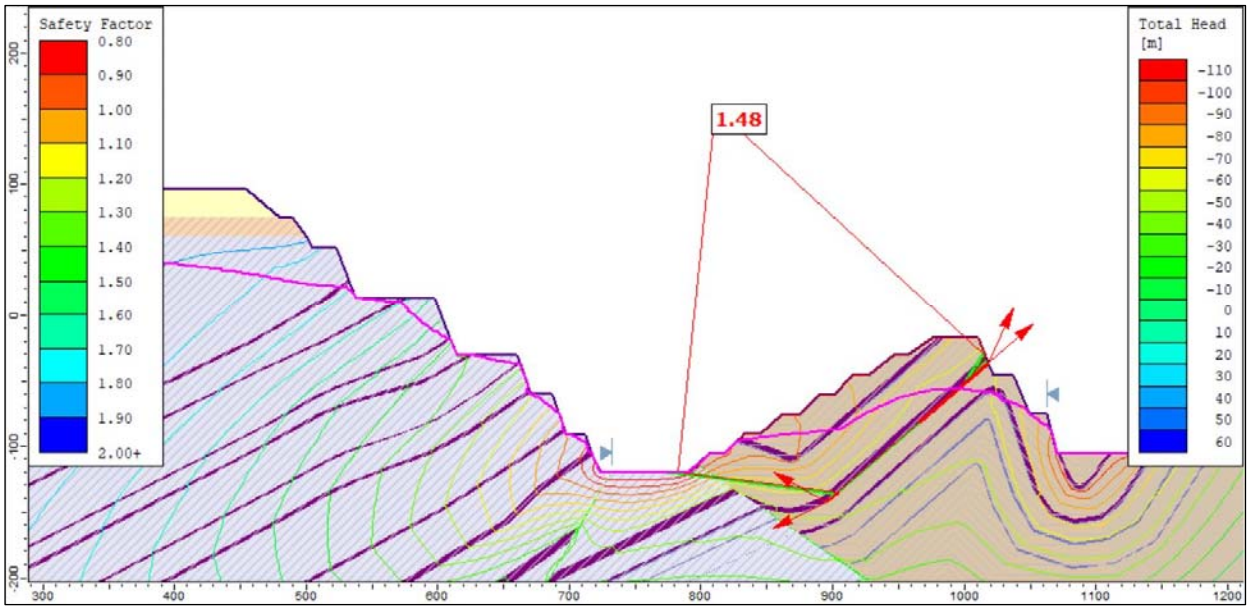

Figure 7-5 General North Pit in-pit anticline-syncline pair with FOS = 1.48 for potential deep-seated block sliding on weak bedding-parallel surface with low rock mass breakout strength and moderate seam structure dip

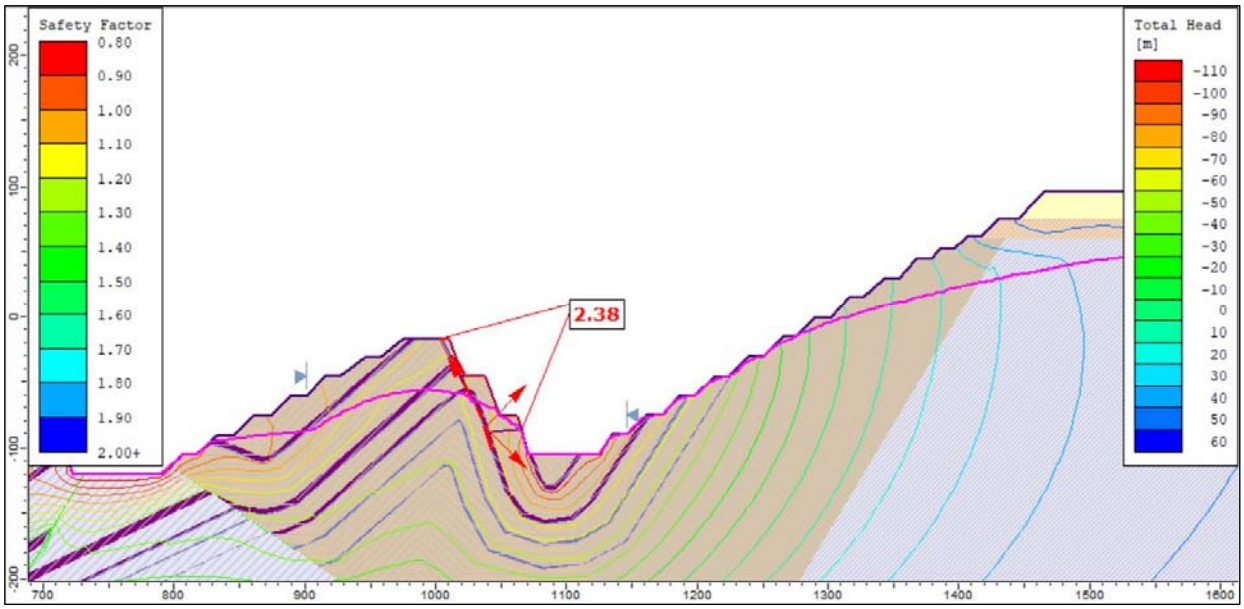

Figure 7-6 General North Pit in-pit anticline-syncline pair with FOS = 1.48 for potential deep-seated block sliding on weak bedding-parallel surface with low rock mass breakout strength and high seam structure dip

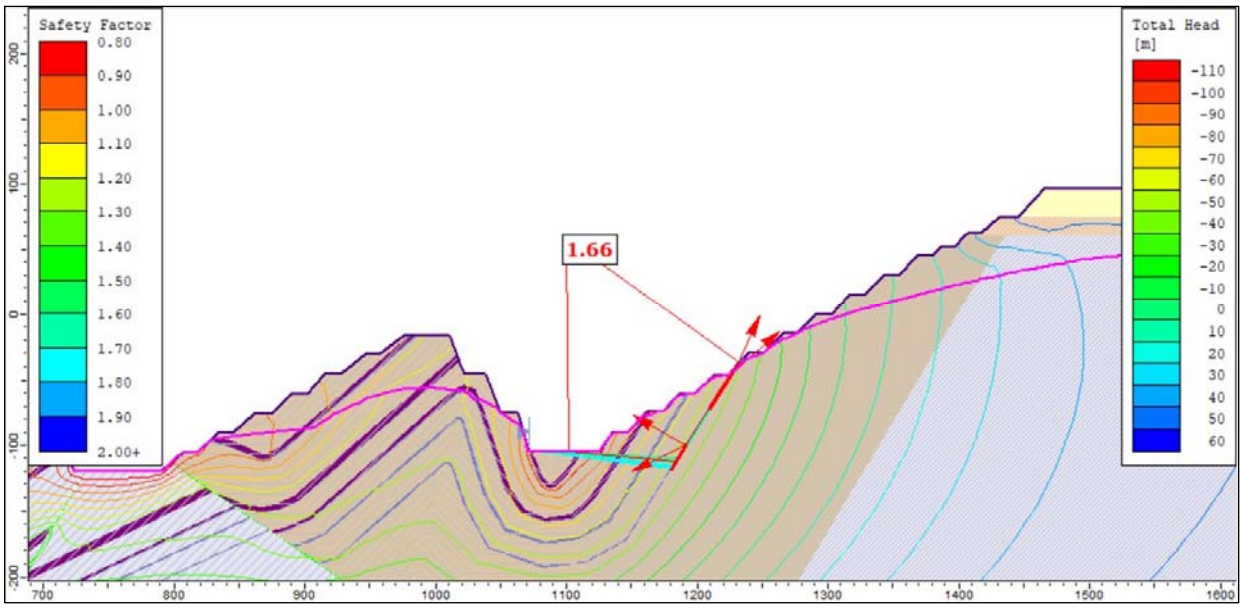

Figure 7-7 General North Pit east footwall profile with FOS = 1.66 for potential deep-seated block sliding on weak bedding-parallel surface with low rock mass breakout strength and moderate seam structure dip

Underbenching for footwall stabilisation was reviewed in detail (Refs. B1, B2, E1) where the relationships between footwall bedding dip and underbench height and width were reviewed. **Figure 7-8** is a summary of information in Ref. B1 and shows overall footwall angle (toe-crest angle) versus bench height for bench widths of 10 m for four different assumptions regarding ground conditions:

- simple geology, aggressive (A);
- simple geology, recommended (B);
- complex geology, aggressive (A);
- complex geology, aggressive (B).

Bench heights of 15 m were adopted for the Outrigger and Fairway footwalls and were generally successful in limiting single bench slabbing instability to very low likelihood levels. In practice, occasional 30 m bench heights resulted either from design issues or from localised bench instability. Based on this experience, and assuming similar geotechnical conditions progressing northwards, **Figure 7-8** also shows the effect of recommending a northward design 20 m bench height and the effect of a localised 40 m bench height resulting from losing a single bench.

Further evaluation of the impacts of variable geology on footwall breakout stability conditions for a 20m bench height was carried out for a simplified 45° seam structure dip and both 5 m (model: **Figure 7-9**) and 10 m (model, **Figure 7-10**) bench widths.

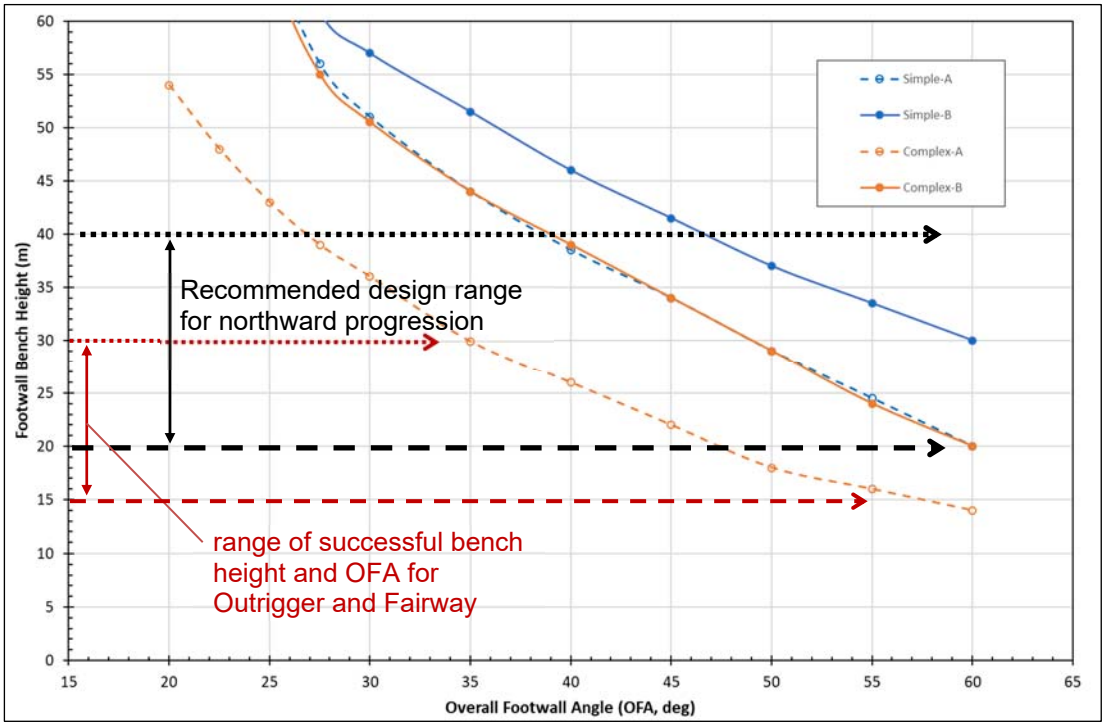

Figure 7-8 PSM feasibility study underbenching recommendations for stable footwall bench heights at different overall footwall angles (after Ref.B1 Figs. 63,63)

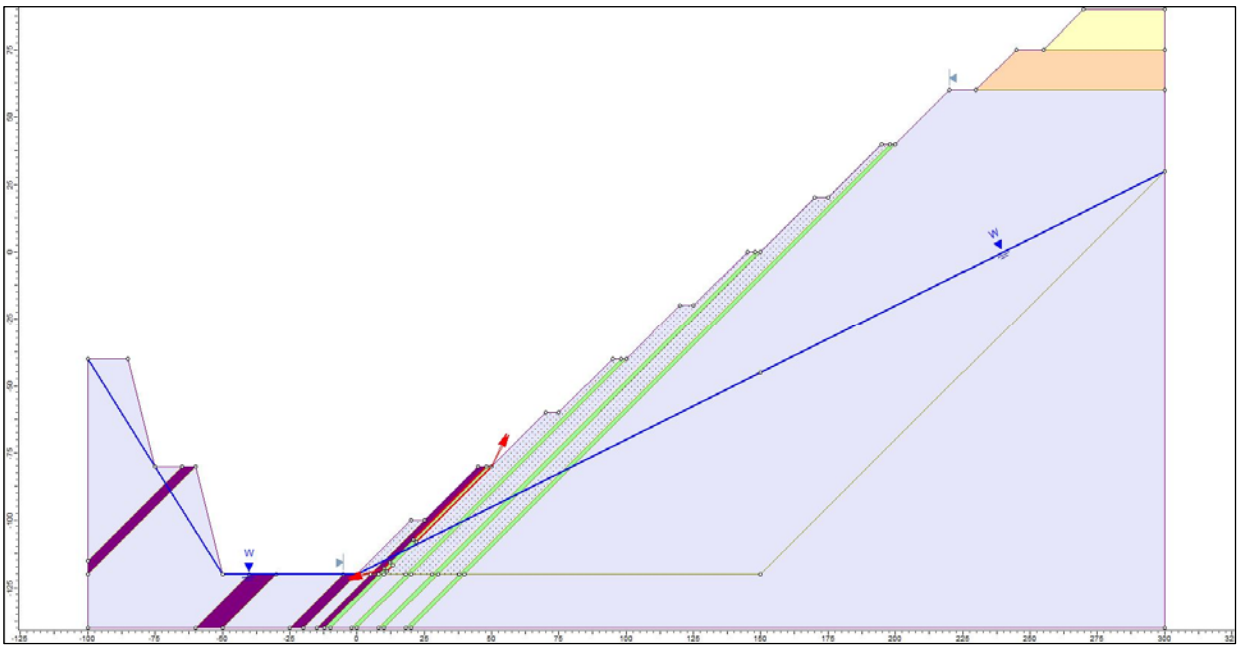

Figure 7-9 Example underbenched footwall stability model with 5 m bench widths and 20 m bench heights, for most favourable groundwater pressure Case A

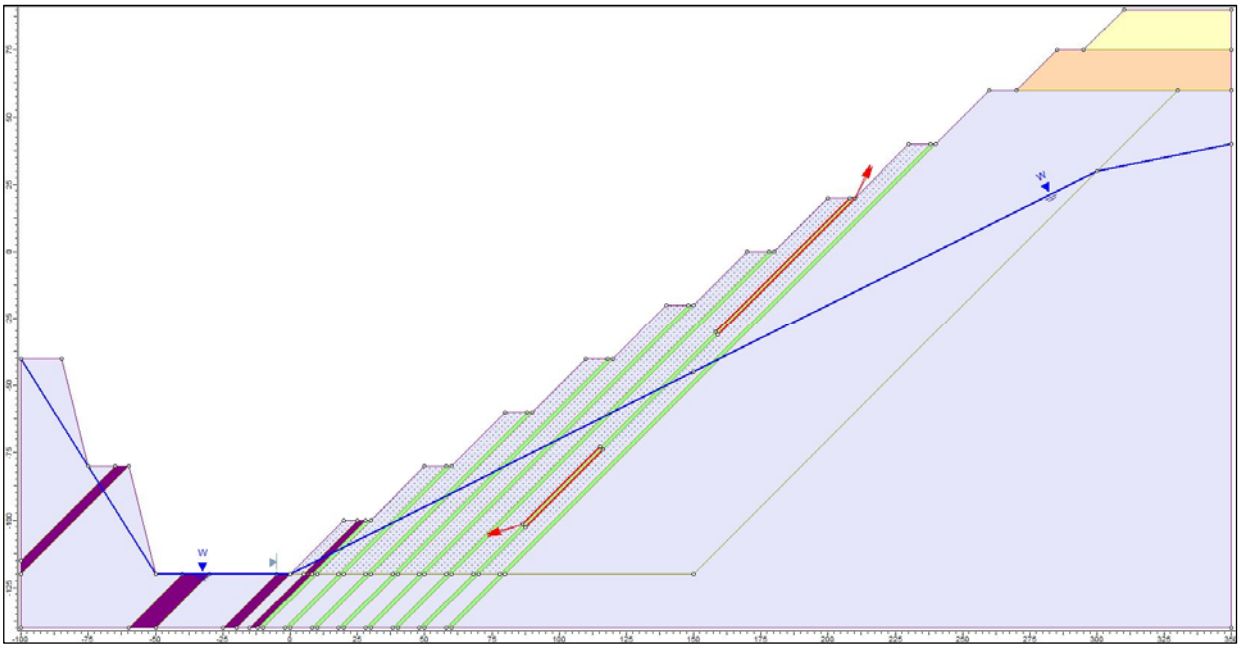

Figure 7-10 Example underbenched footwall stability model with 10 m bench widths and 20 m bench heights, for least favourable groundwater pressure Case C

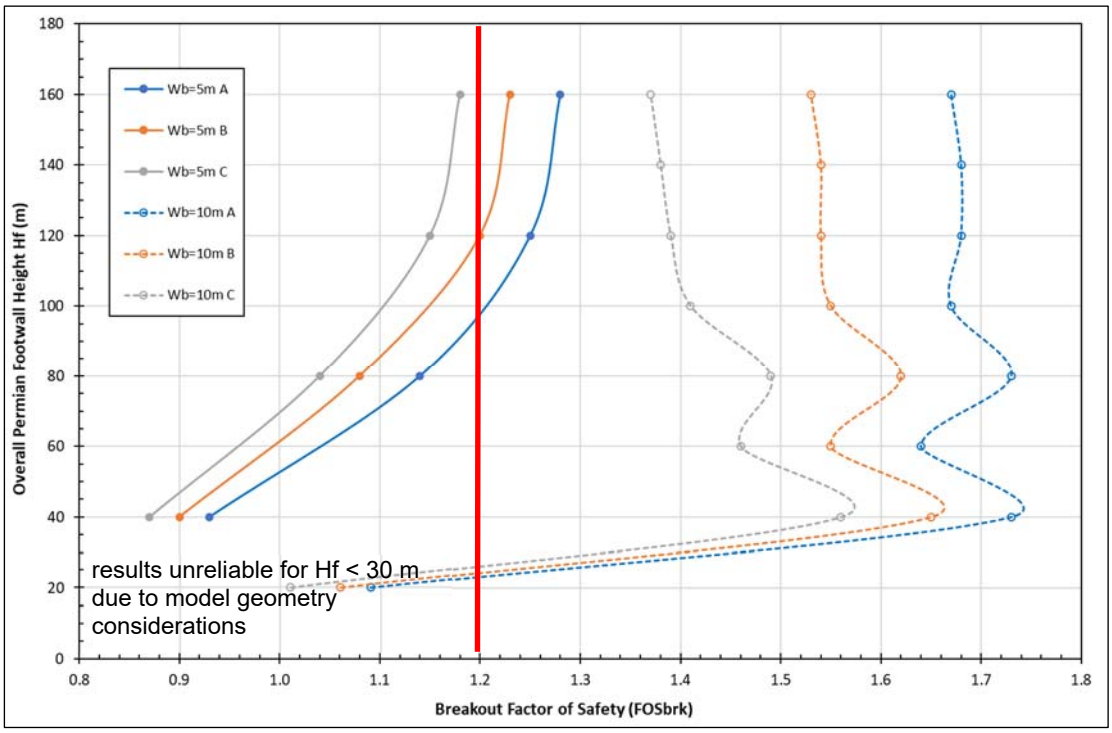

Figure 7-11 Model footwall stability outcomes for 5 m and 10 m bench widths, with 20 m bench height and variable groundwater conditions A (best), B (median), C (worst)

The underbenching recommendations of **Figure 7-8** should be compared with the breakout stability outcomes shown in **Figure 7-11**. At a Permian footwall height of up to 160 m, 10 m bench widths should provide adequate stability for 45° seam structure dip which is approximately equivalent to a 34.5° overall footwall angle. There is limited scope for adequate footwall stability at dips steeper than 45°, and abundant scope for footwall stability at dips flatter

than 45°. Based on a combination of observations, experience, and the above analyses, it is recommended that footwall underbenching be based on 15 m – 20 m heights and 10 m widths.

7.5 Dumped Slope Design Checks

Dump slope profile recommendations in Section 7.2 above are based on adopted spoil shear strength parameters. Since 2018, progressive backfilling of the CP03 void (high-face dumping) and construction of the North Noise Bund (ex-pit tiphead and paddock dumping) have provided evidence that these strengths are realistic. Stability analyses for the North Noise Bund adjacent to the Fairway void were carried out in 2019 after slumping was observed, with the worst-case shear strength for wetted topsoil determined by backanalysis.

Two classes of spoil material have been recognised. For the weaker (Cat.1.5) weathered and mixed-source spoil, truck dump-point stability limits the tip-head height to 20 m. The maximum acceptably stable tip-head height for fresh Permian rock spoil is 30 m. An offset bench width of 10 m is required between lifts to control rolling rocks during tip development.

Stability analyses were carried out for both spoil types and for an overall 60 m dump height comprising 2 x 30 m lifts separated by a 10 m bench. The critical mechanism for potential inpit dump instability would pass through saturated basal spoil because of the fresh rock comprising the foundation. For ex-pit dumping the foundation would comprise either dry or wetted topsoil and the critical mechanism would more likely pass along the topsoil layer.

Figure 7-12 shows the critical potential instability mechanism for spoil base sliding with a minimum computed FOS = 1.33. If a dry topsoil layer formed the foundation (**Figure 7-13**), the minimum computed FOS = 1.32. If a wetted topsoil layer formed the foundation (**Figure 7-14**), the minimum computed FOS = 0.90. Corresponding FOS outcomes for the fresh Permian rock spoil were 1.76, 1.48, and 1.00.

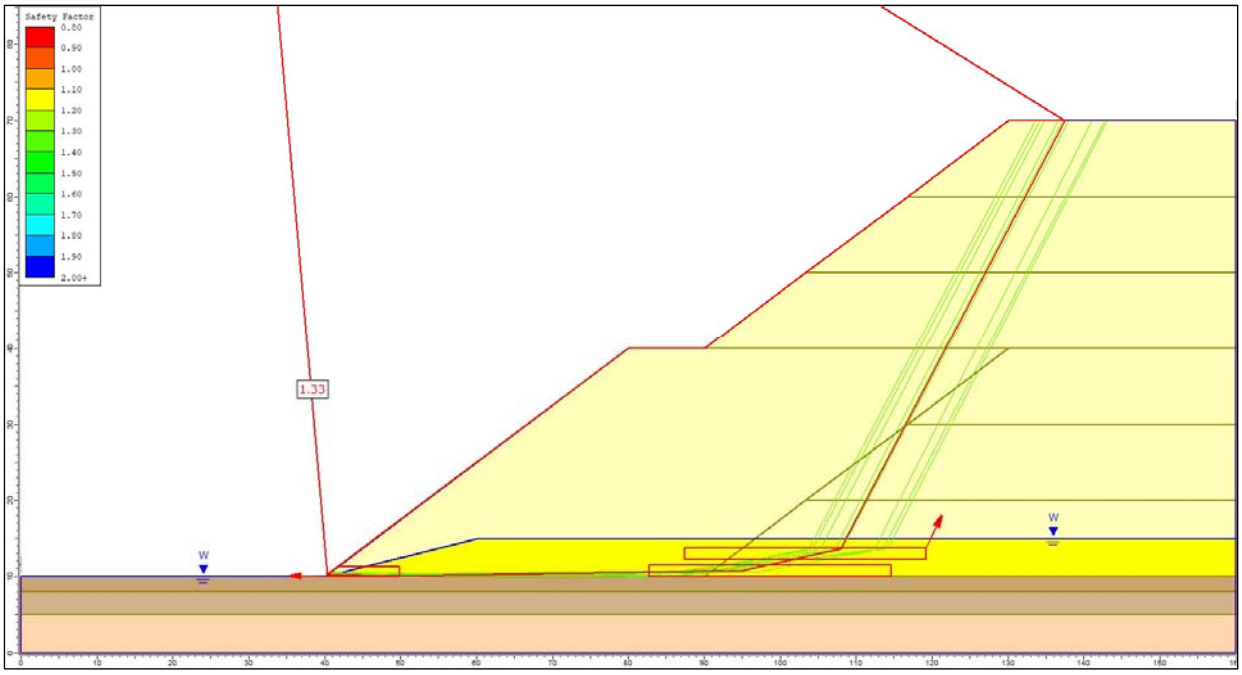

Figure 7-12 60 m dump height, 2 x 30 m lifts, worst-case spoil, spoil base sliding, FOS = 1.33 (not shown: 1.76 for best-case spoil)

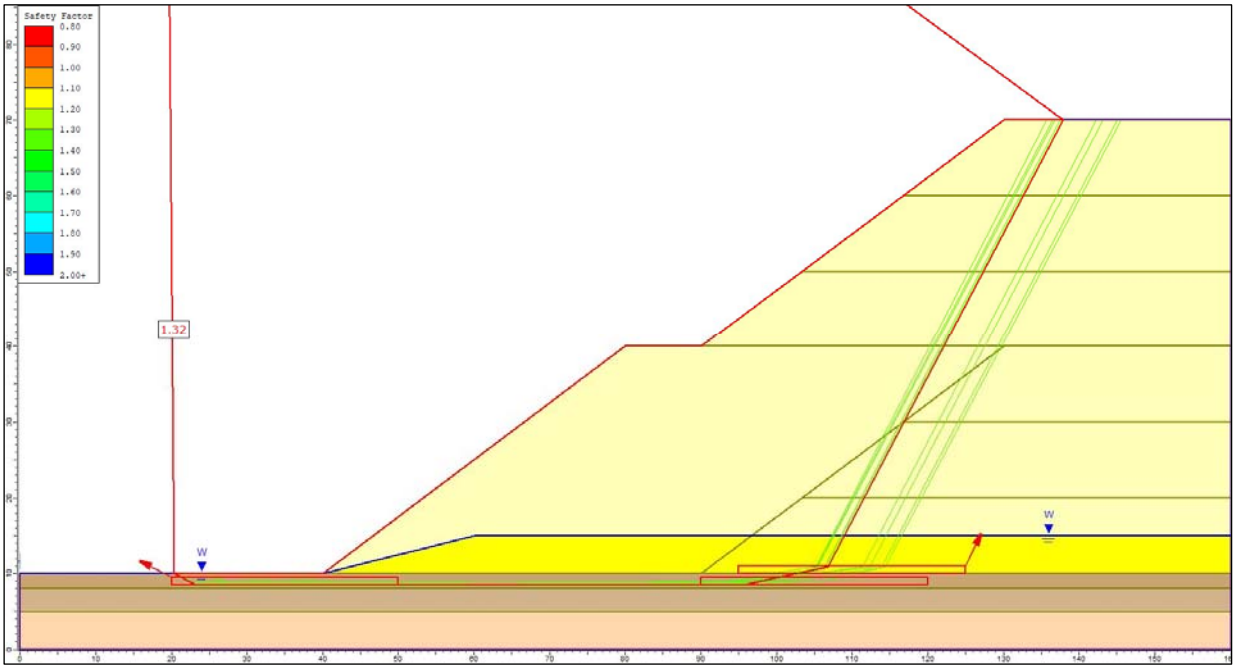

Figure 7-13 60 m dump height, 2 x 30 m lifts, worst-case spoil, dry topsoil base sliding, FOS = 1.32 (not shown: 1.48 for best-case spoil)

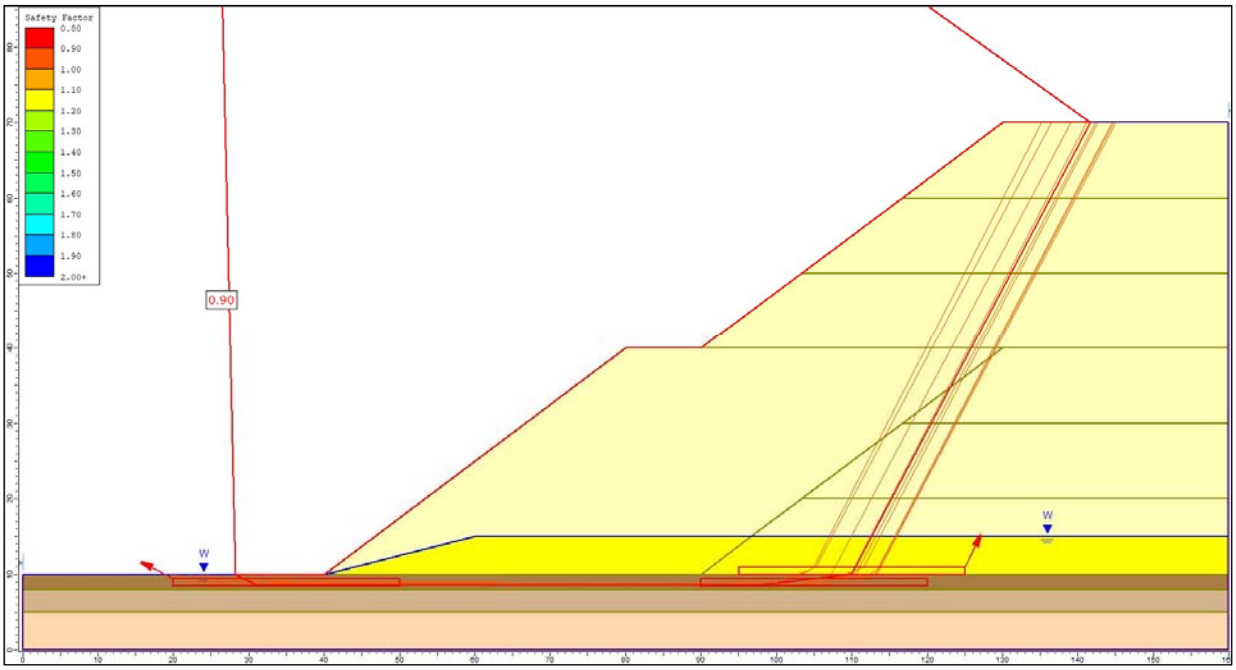

Figure 7-14 60 m dump height, 2 x 30 m lifts, worst-case spoil, wet topsoil base sliding, FOS = 0.90 (not shown: 1.00 for best-case spoil)

Based on these analysis outcomes, it can be concluded that the recommended dump design profiles for the two spoil types will provide adequate dump-point and dump slope profile stability except for the case of ex-pit dumping without adequate cleanup of topsoil, resulting in a wet topsoil foundation.

The recommended minimum topsoil foundation treatment is to cut the ground surface down by grading or dozing to a hard horizon, typically at a minimum depth of 500 mm or greater below the natural self-mulching “blacksoil” surface level. In areas where the foundation comprises more clayey palaeochannel infill, deeper treatment may be required to reach a hard foundation level.

Table 1 Shear Strength and Hydraulic Conductivity Parameters (for Stress-Deformation, see Table 2)

Material	γ (kNm^{-3})	c' (kPa)	ϕ' (deg)	t (kPa)	Ks (ms^{-1})	K2/K1	α (deg)	Comments
Alluvium (General)	18	26	26°	2	6 x 10^{-4}	0.25	0°	for broad-scale modelling
Alluvium (Recent)	18	10	26°	2	6 x 10^{-4}	0.25	0°	more detailed ex-pit dump modelling
Alluvium (Quat.)	20	30	26°	2	6 x 10^{-4}	0.25	0°	more detailed ex-pit dump modelling
Topsoil (dry)	18	10	20°	2	6 x 10^{-5}	0.25	0°	more detailed ex-pit dump modelling
Topsoil (wetted)	18	0	11.5°	2	6 x 10^{-5}	0.25	0°	more detailed ex-pit dump modelling
Faults	25	5	22°	2	6 x 10^{-9}	0.25	varies	K1 follows fault orientation
DW_CM_Rock	23	115	32°	10	6 x 10^{-9}	0.50	varies	K1 follows seam structure orientation
DW_Coal	15	5	30°	2	6 x 10^{-9}	1.00	varies	K1 follows seam structure orientation
FR_CM_Rock	25	450	42°	25	6 x 10^{-10}	0.50	varies	K1 follows seam structure orientation
FR_Coal	13	100	35°	10	6 x 10^{-8}	1.00	varies	K1 follows seam structure orientation
Footwall Bedding	25	0	19°	2	6 x 10^{-8}	1.00	varies	K1 follows seam structure orientation
Bedding Shear	25	0	15°	2	6 x 10^{-10}	0.50	varies	K1 follows seam structure orientation
Footwall Breakout	25	250	28.5°	10	6 x 10^{-10}	0.50	varies	K1 follows seam structure orientation
Spoil FR-CM Uns.	19	50	30°	5	6 x 10^{-7}	33.33	0°	fresh rock source, mainly sandstone
Spoil FR-CM Sat.	21	20	25°	2	2 x 10^{-5}	1.00	0°	fresh rock source, mainly sandstone
Spoil General Uns.	19	30	28°	5	6 x 10^{-7}	33.33	0°	fresh rock source, general lithologies
Spoil General Sat.	21	15	23°	2	2 x 10^{-5}	1.00	0°	fresh rock source, general lithologies
Spoil Freedig Uns.	19	25	26.5°	5	6 x 10^{-7}	33.33	0°	Alluvium and DW rock sources
Spoil Freedig Sat.	21	7.5	20.5°	2	2 x 10^{-5}	1.00	0°	Alluvium and DW rock sources

Table 2 Stress-Deformation Parameters (for Hydraulic Conductivity, see Table 1)

Material	γ (kNm^{-3})	c' (kPa)	ϕ' (deg)	t (kPa)	E (MPa)	ν	α (deg)	Comments
Alluvium (General)	18	26	26°	2	50	0.25	0°	for broad-scale modelling
Alluvium (Recent)	18	10	26°	2	50	0.25	0°	more detailed ex-pit dump modelling
Alluvium (Quat.)	20	30	26°	2	50	0.25	0°	more detailed ex-pit dump modelling
Topsoil (dry)	18	10	20°	2	40	0.25	0°	more detailed ex-pit dump modelling
Topsoil (wetted)	18	0	11.5°	2	20	0.25	0°	more detailed ex-pit dump modelling
Faults	25	5	22°	2	2000	0.25	varies	varies with fault orientation, Table 1
DW_CM_Rock	23	115	32°	10	2000	0.25	varies	varies with seam structure, Table 1
DW_Coal	15	5	30°	2	1000	0.25	varies	varies with seam structure, Table 1
FR_CM_Rock	25	450	42°	25	5000	0.25	varies	varies with seam structure, Table 1
FR_Coal	13	100	35°	10	2500	0.25	varies	varies with seam structure, Table 1
Footwall Bedding	25	0	19°	2	2000	0.25	varies	varies with seam structure, Table 1
Bedding Shear	25	0	15°	2	2000	0.25	varies	varies with seam structure, Table 1
Footwall Breakout	25	250	28.5°	10	5000	0.25	varies	varies with seam structure, Table 1
Spoil FR-CM Uns.	19	50	30°	5	50	0.25	0°	fresh rock source, mainly sandstone
Spoil FR-CM Sat.	21	20	25°	2	25	0.25	0°	fresh rock source, mainly sandstone
Spoil General Uns.	19	30	28°	5	40	0.25	0°	fresh rock source, general lithologies
Spoil General Sat.	21	15	23°	2	20	0.25	0°	fresh rock source, general lithologies
Spoil Freedig Uns.	19	25	26.5°	5	30	0.25	0°	Alluvium and DW rock sources
Spoil Freedig Sat.	21	7.5	20.5°	2	15	0.25	0°	Alluvium and DW rock sources

8. ROCKFALL HAZARD AND SLOPE INSTABILITY RUNOUT ESTIMATES

8.1 Consequences of Rockfall and Slope Instability

Rockfall and slope instability hazards are an implicit feature of both excavated and dumped slopes. Rockfall hazards cannot be eliminated because of the ongoing effects of degradation, weathering, stress changes, and erosion over time. Rockfall risks must therefore be minimised wherever possible by both design-level and operational controls which must remain effective for all stages of the mining process. Slope instability hazards can be effectively managed by design-level risk controls, but likelihoods of instability cannot be eliminated due to residual uncertainty in geotechnical models and operational factors.

The following information provides a basis for consideration of design-level rockfall risk controls. Operational risk controls take the following forms:

(1) Compliance with design, with the intent to minimise the size and frequency of rockfalls and reduce the likelihood of instability to an acceptably low level;

(2) Rockfall mitigation treatments, with the intent to minimise falling rocks and to trap rocks that do fall into zones where risks to personnel and equipment are acceptably low;

(3) Restricted access directions from the Open Cut Examiner;

(4) Exclusion zones, with the intent to minimise exposure to rockfalls or unstable slopes;

(5) Regular inspections by appropriately qualified and experienced persons to confirm that the above controls are effective and to detect abnormal conditions requiring additional risk management action.

The intent of general slope exclusion zones is to provide sufficient physical separation between potential rockfall trajectories and targets to reduce the likelihood of a rockfall contact incident to an acceptably low level. Currently at Baralaba Mine there are generally applied exclusion zones documented in mine procedures.

For individual rockfalls, the trajectory of movement will depend on the movement pathway and material characteristics. Within limitations, trajectories of falling material may be predicted using analytical tools.

Consequences of larger-scale slope failure processes depend on the nature and scale of the failure process. Slope instability is gravitationally driven and will always result in loss of material from higher parts of the slope profile and accumulation of material at and beyond the slope toe. The debris runout distance beyond the pre-failure slope toeline will be dependent on slope geometry and dynamic processes.

8.2 Rockfall Trajectory Estimation

The 10 m standoff that is commonly adopted in the coal mining industry to restrict unprotected access has its origins in decades-old industry experience that most rocks falling down a highwall batter will strike and land within 8 m to 10 m of the slope toeline.

To date, movement trajectories for Baralaba Mine have not been specifically modelled. If a future requirement is identified, special-purpose software will be utilised (for example, Ref.11) or

otherwise predictions will be made based on site observations. The adopted standard standoff distance of 10 m is based on experience to date of appropriately qualified and experienced personnel. For specific situations, an alternative standoff distance may be recommended by an appropriately qualified and experienced person for application both to multi-benched excavated slope profile toelines and to dumped slope toelines.

8.3 Slope Instability Runout Estimation

Prediction of slope failure runout distance cannot be over-simplified because of the complex interactions of the factors involved. Landslide researchers have for a long time period compiled runout data for unstable slopes over a very wide range of scales, from which has emerged the concept of a runout ratio H/L where H is the overall toe-crest height of the slope and L is the horizontal distance from the crest position to the toe position after unstable movement has occurred. **Figure 8-1** illustrates the runout ratio (also known as fahrböschung) and also the concept of a fan angle for the failed debris.

Runout data from a large number of open pit slopes, but predominantly metalliferous mines, has been reviewed (Refs.12,13) for the purpose of estimating runout. The following guidance applies:

(1) irrespective of any technical assessment of runout, a restricted access direction from the Open Cut Examiner shall always apply;

(2) the Open Cut Examiner may take into account any site-specific runout advice from a suitably qualified and experienced geotechnical specialist;

(3) debris from a failed mass will come to rest at a fan angle that is less than or equal to the dump rill angle, in other words at an angle less than 37°;

(4) material will be lost from higher up, and accumulate lower down, so the effective post-failure runout ratio H/L will always be less than the pre-failure overall slope angle;

(5) mobility of failure debris is usually underestimated. Mobility increases as the volume of failed material increases, and mobility also increases as the proportion of weathered material increases;

(6) initial estimates of the effective post-failure runout ratio (H/L) for a single batter-scale instability may be made based on **Figure 8-2** which shows a general trendline but also illustrates scatter associated with unstable volume and slope scale;

(7) initial estimates of the effective post-failure runout ratio (H/L) for instability of a general multi-batter slope profile of variable overall slope angle may be made based on **Figure 8-3**. Further elaboration based on subdivision into weathered-weak and unweathered-fresh strong rock is provided in **Figure 8-5**. For the different trends applying to the two classes of rock materials, **Figure 8-5** and **Figure 8-6** provide guidance about refining the selection of H/L to incorporate the likelihood of the H/L ratio being exceeded.

The above guidance information has not been rigorously verified for coal measures rock masses but is a reasonable starting-point for runout assessment. It is recommended that the published information be interpreted with the assistance of a suitably qualified and experienced geotechnical specialist. Ref.11 is an example of software suitable for application to Baralaba pit slope conditions.

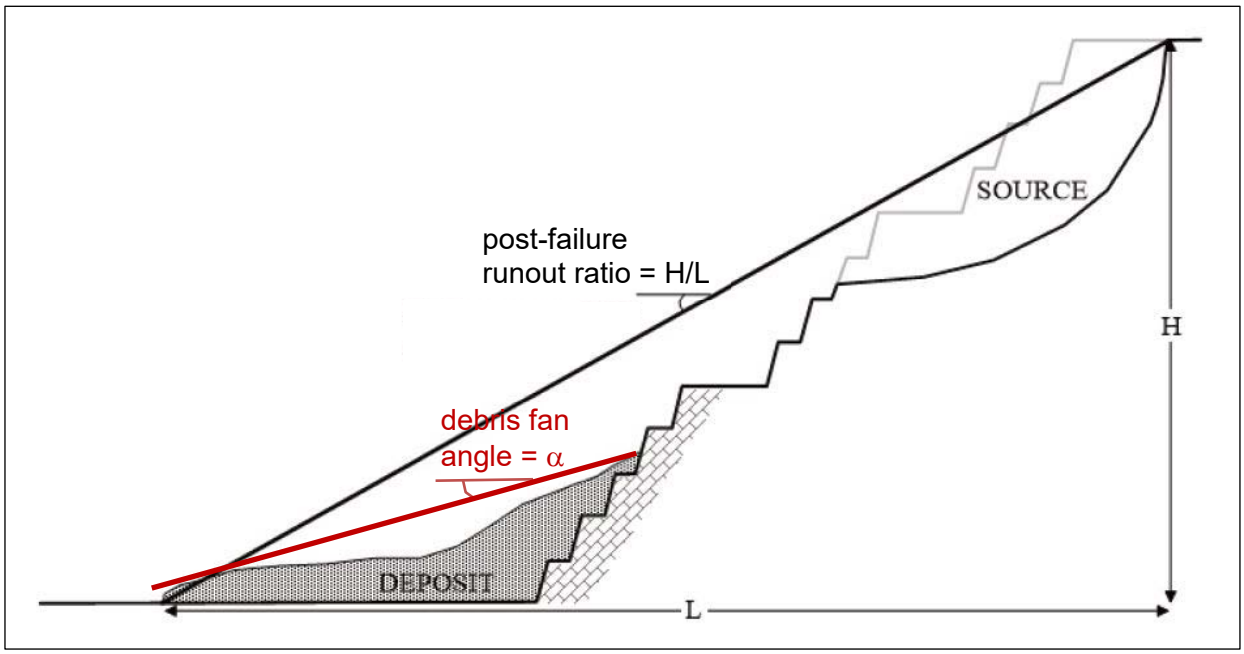

Figure 8-1 Definition of slope failure debris runout terms (after Ref.14)

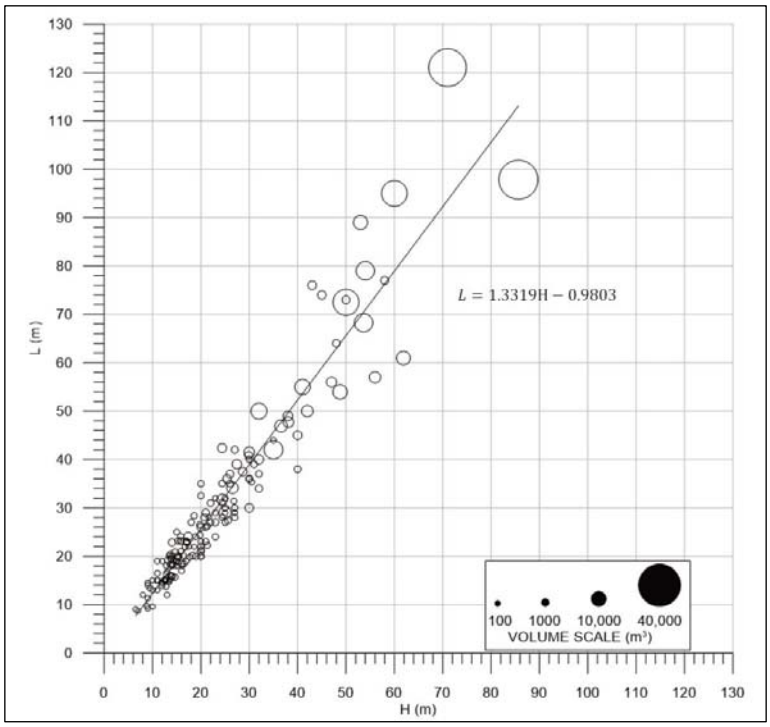

Figure 8-2 Single-bench(batter failure) debris runout relationship (Ref.13)

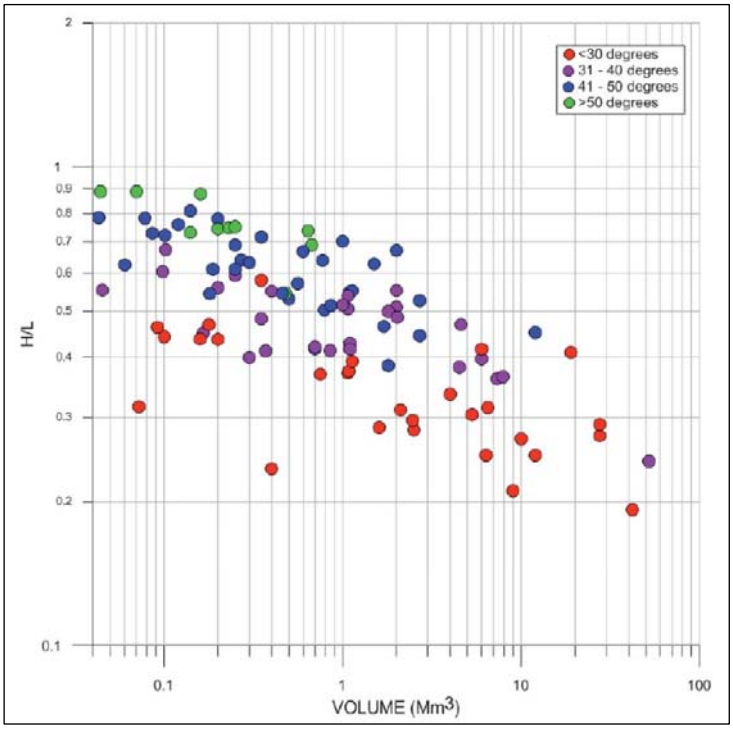

Figure 8-3 Slope profile post-failure runout ratio variation with mobility index (pre-failure overall slope angle (Ref.13)

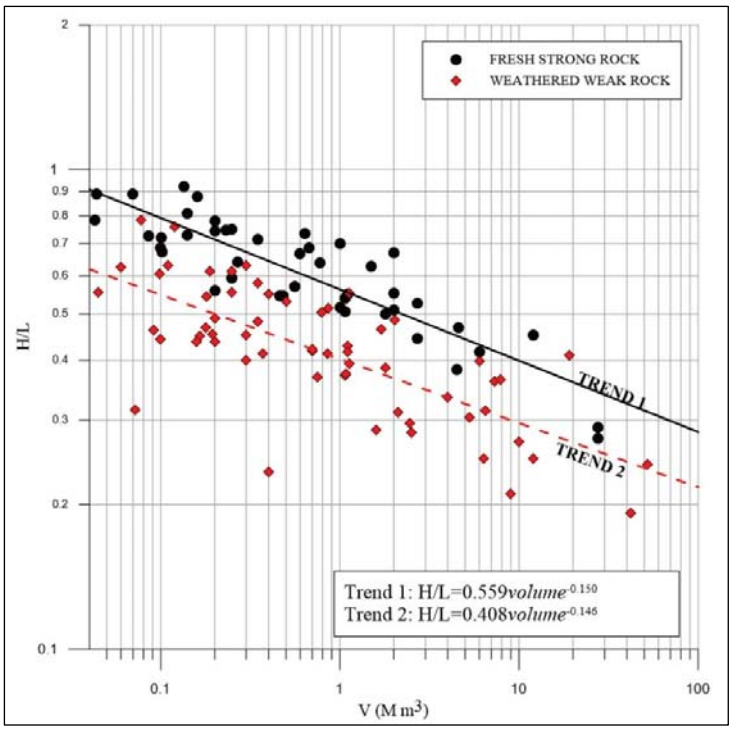

Figure 8-4 Slope profile post-failure runout ratio variation with mobility trend (rock mass strength class) (Ref.13)

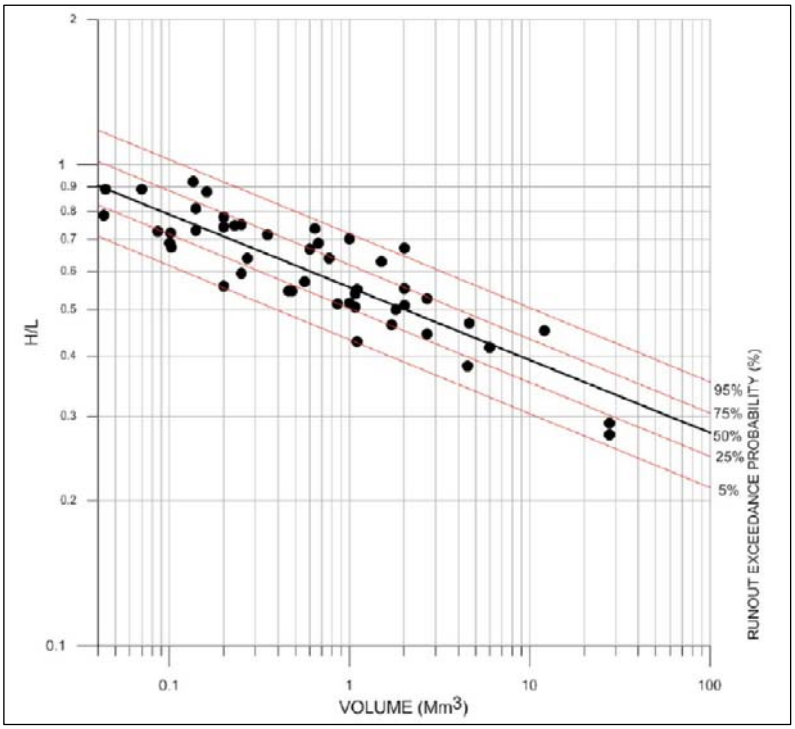

Figure 8-5 Exceedance probability for slope profile post-failure runout ratio variation with mobility trend (Trend 1, fresh strong rock mass) (Ref.12)

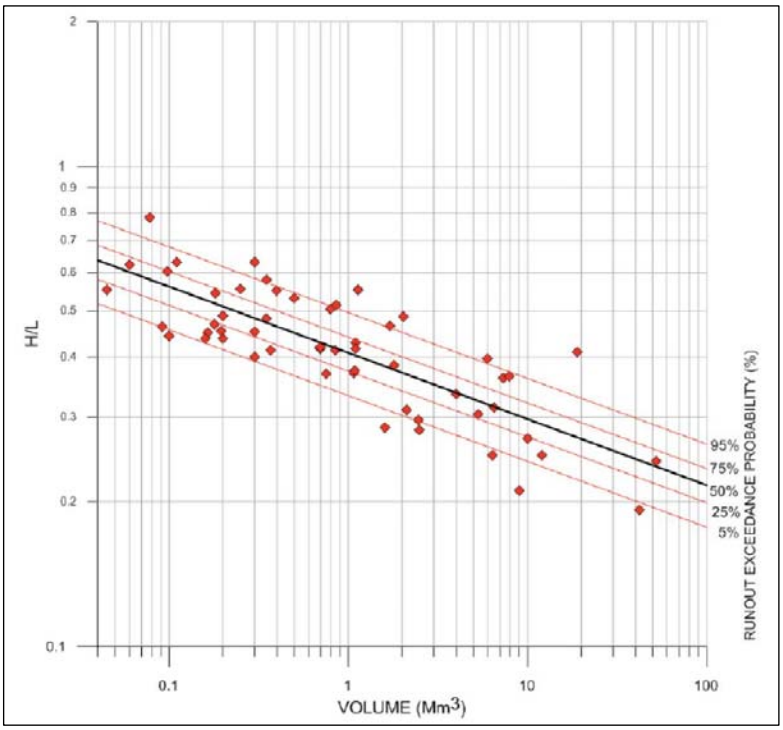

Figure 8-6 Exceedance probability for slope profile post-failure runout ratio variation with mobility trend (Trend 2, weathered weaker rock mass) (Ref.14)

9. WATER MANAGEMENT

The mine water management system is designed to exclude and divert runoff from non-disturbed areas, and to capture and transfer runoff from disturbed areas to mine water storages within the mine lease.

Flooding of the BC01 workings in early 2011 had a significant impact on mining operations and recovery took some time. The flood exclusion system was strengthened and is routinely inspected.

Since 2011, mine water management has been undertaken by the mine owner or owner-engaged subcontractors. To date, design and management of the water management system for Baralaba Mine has not influenced the geotechnical behaviour or performance of the pit slopes. Mine geotechnical activities have not been required to specifically address mine water management issues.

10. REFERENCES

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see following pages for VOLUME 2 (Appendices) References

VOLUME 2 (APPENDICES)

Appendix A Geotechnical Consulting Services Reports

(A 1) Geotechnical Consulting Services Pty Ltd. Geotechnical Inspection, 3 May 2012. Report to Baralaba Coal, 8 May 2012.

(A 2) Geotechnical Consulting Services Pty Ltd. Footwall Failure Modes. Report to Baralaba Coal, 26 October 2012.

(A 3) Geotechnical Consulting Services Pty Ltd. Geotechnical Inspection, 23 October 2012. Report to Baralaba Coal, 19 December 2012.

(A 4) Geotechnical Consulting Services Pty Ltd. In-Pit Dump Stability. Report to Baralaba Coal, 2 January 2013.

(A 5) Geotechnical Consulting Services Pty Ltd. Baralaba. Email to Sherwood Geotechnical and Research Services, 8 August 2014.

Appendix B Pells Sullivan Meynink Reports

(B 1) Pells Sullivan Meynink. Baralaba Expansion Project, Baralaba North Operation: Geotechnical Feasibility Investigation. Report to Cockatoo Coal Limited, Ref. PSM1673-023R, 13 April 2012.

(B 2) Pells Sullivan Meynink. Baralaba Expansion Project, Baralaba North Operation: Addendum to Geotechnical Feasibility Report. Report to Cockatoo Coal Limited, Ref. PSM1673-079R, 13 April 2015.

(B 3) Pells Sullivan Meynink. Baralaba Expansion Project, Baralaba Central Operation Geotechnical Assessment of Proposed Cutback. Report to Cockatoo Coal Limited, Ref. PSM1673-053L, 11 March 2013.

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(B 10) Pells Sullivan Meynink. PSM Site Visit: Baralaba Central and North Pits. Report to Cockatoo Coal Limited, Ref. PSM1673-076L, 20 August 2014.

Appendix C EIS Appendix D Groundwater Reports

(C 1) Hydro Simulations. Baralaba North Continued Operations (BNCOP) Groundwater Modelling and Assessment. Report to Cockatoo Coal Limited, Ref. HC2014/002, April 2014.

(C 2) Sinclair Knight Merz. Baralaba North Continued Operations EIS Groundwater Studies Preliminary Conceptual Groundwater Model. Report to Cockatoo Coal Limited, Ref. QE06728_200-FG-RP-0001, drafts 10 February 2014 and 11 July 2013.

(C 3) Sinclair Knight Merz. Baralaba North Mine Water Management Support Groundwater Field Installation Draft Report. Report to Cockatoo Coal Limited, Ref. QE99082_300-FG-RP-0001, 22 February 2013.

Appendix D JBT Groundwater Reports

(D 1) JBT Consulting Pty Ltd. Groundwater Seepage Modelling Preliminary Results. Presentation to Cockatoo Coal Limited, 29 November 2012.

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(D 3) JBT Consulting Pty Ltd. Baralaba North – Options for Ongoing Groundwater Data Collection. Report to Cockatoo Coal Limited, Ref. JBT01-029-003, 19 December 2012

Appendix E SGRS Geotechnical Assessment Reports (to 30 April 2021)

(E 1) Sherwood Geotechnical and Research Services. Baralaba Mine Pit Slope Design Geotechnical Review. Report to Cockatoo Coal Limited, Ref. 35015-1-1, 31 July 2015.

(E 2) Sherwood Geotechnical and Research Services. BN Outrigger Pit East Sidewall Stability Assessment 30m Bench Height Dirty Seam Underburden. Memo to Golding Contractors Pty Ltd, Ref. 39007 / 8489-1, 11 September 2018.

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(E 8) Sherwood Geotechnical and Research Services. BN Noise Bund Instability Mitigation Recommendations. Memo to Golding Contractors Pty Ltd, Ref. 40007 / 4278-1, 11 May 2020.

Appendix F SGRS Geotechnical Site Inspection Reports (to 30 April 2021)

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(F 2) Sherwood Geotechnical and Research Services. Geotechnical Site Inspection 29-30 August 2018 Report. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 39007 / 8475-2, 12 September 2018.

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(F 4) Sherwood Geotechnical and Research Services. Fairway Pit Slope Stability Assessment Update April 2019. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 39007 / 3179-1, 2 May 2019 (includes Site Inspection 6 March 2019).

(F 5) Sherwood Geotechnical and Research Services. Baralaba Mine Geotechnical Site Inspection 10 July 2019 Report. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 40007 / 3396-2, 19 August 2019.

(F 6) Sherwood Geotechnical and Research Services. Geotechnical Site Inspection 17 September 2019 Summary Report. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 40007 / 3472-1, 18 September 2019.

(F 7) Sherwood Geotechnical and Research Services. Geotechnical Site Inspection 16-17 December 2019 Report. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 40007 / 4007-2, 10 January 2020.

(F 8) Sherwood Geotechnical and Research Services. Geotechnical Site Inspection 31 July 2020 Report. Memo to Golding Contractors Pty Ltd Baralaba Coal Mine, Ref. 41007 / 4493-2, 28 August 2020.

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Risk Description					Risk Evaluation					Risk Rating						
						Consequence										
Risk Scenario/Threat Title	Causes (Triggers / Indicators)	Impacts (Consequences)	Existing Controls	Control Effectiveness	Likelihood	Health	Safety	Environment	Compliance	Health	Safety	Environment	Compliance	Final Risk Rating	Management Effectiveness	Contingent Risk Management Approach
Residual Void																
Safe																
Must be safe to humans, stock and wildlife	Accessibility to pit walls	Potential to fall into the void resulting in safety hazard for personnel, stock and wildlife	Exclusion fencing and suitable signage at an FOS distance >1.2 to be established around the highwall, low wall, and end walls. 15% or less gradient for base of tertiary surrounding void walls to enable exit for cattle/wildlife if access was gained.		1		4				H			H		
Stable - geotechnical risk																
Pit wall collapse	Excessive slope steepness, physical material properties, poor drainage, adverse rainfall event	Localised land impacts, increase in void catchment area/change in water balance, and potential to increase flooding risks.	Construction of landforms to be in accordance with engineered designed (e.g. appropriate construction material, compaction, etc.) 0-9°(0-15%) to the base of tertiary 9 - 70° (15-274%) below the base of tertiary. Must have a safety factor ≥1.2 Inspection by suitably qualified personnel to ensure structural integrity. Certification by a suitably qualified and experienced person that the residual void is outside of the 1:1000 annual exceedance probability (AEP) floodplain.		1			2				L		L		
Extreme erosion potential from batters or exposed faces (tertiary)	Erosional instability resulting from improper drainage at the top of the void.	Localised land impacts, increase in void catchment area/change in water balance	Construction of landforms to be in accordance with engineered designed (e.g. slope design).		3			2				M		M		
Non-polluting - geochemical risk																
Release of void water to the environment	Pit overtopping, connection from floodwaters, groundwater table rises and connects to permian aquifers causing saline pollution.	Groundwater impacts (incl. GDEs), downstream water quality impacts,	Long term groundwater modelling and final void water balance confirms the final void will remain as a sink in perpetuity. Void is located outside PMF elevation level. Final void design minimises void size and catchment area.		1			2				L		L		
Elevated Landforms (Grazing PMLU) **Safe**																
Rehabilitation landform results in safety hazards exceeding those	Inadequate surface preparation, localised settlement, erosion gullies.	Safety hazard for personnel, stock and wildlife	Surface preparation measures (initial), monitoring, maintenance controls (pre-closure)		3		3				H			H		Rehabilitation area safety assessment done early monitoring phase, approximately year 2 and/or year 5, undertake repairs and maintenance as required
Stable - geotechnical risk																
Sink holes and ground subsidence	Not constructed to design, adverse rainfall event	Localised land impacts and downstream water quality	Surface preparation measures (initial), monitoring, maintenance controls (pre-closure)		2		2				L			L		Rehabilitation area monitoring and assessment, undertake repairs and maintenance as required
Stable - erosional risk																
Initial/ongoing gully, pipe and/or sheet erosion of rehabilitated area	Rehabilitation failure/ vegetation disease/loss, climatic events, other	Localised land impacts and downstream water quality	Landform design moderating slope, adequate/effective subsoil and topsoil amelioration, prompt revegetation establishment.		3			2				M		M		
Non-polluting																
Highly saline or sediment-laden run-off or seepage from rehabilitated areas	Rehabilitation failure/ vegetation disease/loss, climatic events, other	Localised land impacts, downstream water quality and drainage system impacts	Sequencing of rehabilitation upslope so that new rehabilitation drains to established areas. Regular water quality monitoring pH: 6.5-8.5 (median) EC: 500 micrograms/cm (median) or less Sulfate: 250 mg/L (median) or less		3			3				H		H		Where water quality criteria are not being met, undertake investigation to determine cause and mitigate
Sustainable - PMLU																

Risk Description					Risk Evaluation					Risk Rating						
						Consequence										
Risk Scenario/Threat Title	Causes (Triggers / Indicators)	Impacts (Consequences)	Existing Controls	Control Effectiveness	Likelihood	Health	Safety	Environment	Compliance	Health	Safety	Environment	Compliance	Final Risk Rating	Management Effectiveness	Contingent Risk Management Approach
Unable to achieve characteristics to classify as Land suitability Class IV	Weather, poor soil characteristics, poor management practices impacting germination, vegetation establishment and PMLU density/diversity metrics	Failure to achieve rehabilitation completion criteria targets	Management and maintenance activities, rehabilitation performance monitoring		2			3				M		M		Rehabilitation area monitoring and assessment, undertake repairs and improvement works as required
Pests and weeds	Poor local, regional or site property management practices.	Increased risk of not achieving designated PMLU	Pest and weed management practices, monitoring programs to allow early detection and management		2			2				L		L		Intensify monitoring and management measures as appropriate
Infrastructure (Grazing PMLU)																
Safe																
Infrastructure not suitably decomissioned to a safe landform	Inadequate removal of equipment, remediation of foundations and contaminated areas, surface preparation Failure to meet Grazing Land Suitability Class 4	Safety hazard for personnel, stock and wildlife	Decomissioning management, adequate contaminated land investigations, surface preparation measures (initial), monitoring, maintenance controls (pre-closure)		2		2				L			L		Rehabilitation area safety assessment done early monitoring phase, approximately year 2 and/or year 5, undertake repairs and maintenance as required
Stable - geotechnical risk																
Not applicable																
Stable - erosional risk																
Gully and rill erosion	Not constructed to design, adverse rainfall event	Localised land impacts and downstream water quality	Surface preparation measures (initial), monitoring, maintenance controls (pre-closure)		1			2				L		L		Rehabilitation area monitoring and assessment, undertake repairs and maintenance as required
Non-polluting																
Contaminated soils and/or run-off	Inadequate decommissioning works, improper contaminated land clean up	Localised land impacts and downstream water quality impacts	Contaminated land assessment, existing onsite spill management. Hazardous materials are stored onsite in accordance with AS1940		1			2				L		L		
Sustainable - PMLU																
Unable to achieve characteristics to classify as Land suitability Class IV	Weather, poor soil characteristics, poor management practices impacting germination, vegetation establishment and PMLU density/diversity metrics	Failure to achieve rehabilitation completion criteria targets	Management and maintenance activities, rehabilitation performance monitoring		2			3				M		M		Rehabilitation area monitoring and assessment, undertake repairs and improvement works as required
Pests and weeds	Poor local, regional or site property management practices.	Increased risk of not achieving designated PMLU	Pest and weed management practices, monitoring programs to allow early detection and management		2			2				L		L		Intensify monitoring and management measures as appropriate
Nature Conservation Area within ML700004																
Safe																
Rehabilitation landform results in safety hazards exceeding those found in the surrounding unmined areas	Inadequate surface preparation, localised settlement, erosion.	Increased risk of not achieving designated PMLU	Surface preparation measures (initial), monitoring, maintenance controls (pre-closure)		1			2				L		L		
Stable - geotechnical risk																
Not applicable																
Stable - erosional risk																
Initial/ongoing gully, pipe and/or sheet erosion of rehabilitated area	Rehabilitation failure/ vegetation disease/loss, climatic events, other	Localised land impacts and downstream water quality impacts Increased risk of not achieving designated PMLU	Adequate/effective subsoil and topsoil amelioration, prompt revegetation establishment. Revegetation monitoring and management as required		2			2				L		L		
Non-polluting																
Sediment-laden run-off draining into adjacent remnant vegetation	Rehabilitation failure/ vegetation disease/loss, climatic events, other	Sedimentation in adjacent remnant vegetation	Adequate/effective subsoil and topsoil amelioration, prompt revegetation establishment. Revegetation monitoring and management as required		1			2				L		L		
Sustainable - PMLU																

Risk Description					Risk Evaluation					Risk Rating						
						Consequence										
Risk Scenario/Threat Title	**Causes (Triggers / Indicators)**	**Impacts (Consequences)**	**Existing Controls**	**Control Effectiveness**	**Likelihood**	**Health**	**Safety**	**Environment**	**Compliance**	**Health**	**Safety**	**Environment**	**Compliance**	**Final Risk Rating**	**Management Effectiveness**	**Contingent Risk Management Approach**
Monitoring indicates that rehabilitation milestone criteria will not be met within suggested timeframe	Weather, poor soil characteristics, poor management practices impacting germination, vegetation establishment and PMLU density/diversity metrics, and shortage of topsoil resources	Not achieving sustainable post-mining land use	Ongoing grazing management, soil amelioration, frequent early monitoring of vegetation progress		2			3				M		M		Where vegetation is failing to establish, conduct soil investigation and ameliorate soil if needed, revegetate using tube stock for better likelihood of successful establishment.
Pests and weeds	Poor local, regional or site property management practices.	Increased risk of not achieving designated PMLU	Pest and weed management practices, monitoring programs to allow early detection and management		2			2				L		L		Intensify monitoring and management measures as appropriate
End of record																

Appendix J. Baralaba Rehabilitation Risk Assessment PRCP

Appendix K. Retained infrastructure agreement

Agreement between the Environmental Authority Holders of EPML00223213 and Underlying Landowner regarding infrastructure to be retained at the end of the tenure for the Baralaba Coal Mine

Parties:
Environmental Authority Holders (EPML00223213)
Wonbindi Coal Pty Limited (ABN 62 114 668 941) and Baralaba Coal Pty Ltd (ABN 50 009 805 029)

Landowner
Wonbindi Coal Pty Limited (ABN 62 114 668 941)

Recitals

- Wonbindi Coal Pty Ltd and Baralaba Coal Pty Ltd (Environmental Authority Holders) operate the Baralaba Coal Mine under the Environmental Authority (EA) EPML00223213. This EA authorises environmentally relevant activities inclusive of Schedule 3 13: Mining black coal within mining leases (ML) 5605, ML5580, ML5581, ML5590, ML80157, ML80169, ML80170, ML80200, ML80201, and ML700004
- Wonbindi Coal Pty Limited (Landowner) is the registered underlying landowner for the following formal land descriptions which are subject to this written agreement:
    - Lot 11 on KM46 (Dawson Dell)
    - Lot 13 on KM182 (Coominglah)
    - Lot 7 on KM44 (Willeroo)
- The infrastructure in which this written agreement relates is shown in Attachment A.
- Land title searches have been supplied in Attachment B, C and D for reference.
- The Landowner will utilise the specified infrastructure in the ongoing management and use of the land post-mining and requests that it be retained in-place at the end of the tenure.

The underlying Landowner and EA Holders agree that the following infrastructure as described below, and depicted in Attached A, is to be retained after the mining tenure.

- All above ground pipelines will be retained for the purpose of grazing operations;
- All access tracks, roads and haul roads, which do not intersect the realignment of the Hoadley's Road Easement;
- The 2nd North MIA Temporary Workshop will be retained for the purpose of grazing operations;
- The following dams; North Sediment Dam, MIA North Dam, minor sediment dams and retention basins.
- The following laydown yards; Build Pad, North Mine Infrastructure Areas, North HV Park Up LY and North Mag and Reload Laydown Yard,

- All existing fencing and security installations

The EA Holders under its obligations and general environmental duty under the *Environmental Protection Act 1994* to not carry out any activity that causes or is likely to cause harm unless all reasonable and practicable measures to prevent or minimise harm are taken. To that end the infrastructure listed above will be rehabilitated and/or maintained sufficiently so that structures do not pose harm to future agricultural undertakings within the underlying land or receiving environment.

Executed by Wonbindi Coal Pty Limited

In accordance with section 127 (1) of the Corporations Act 2001

Michael Jones

Full Name: Michael Jones
Position: CEO

Executed by Baralaba Coal Pty Ltd

In accordance with section 127 (1) of the Corporations Act 2001

Full Name: Darren Madgwick
Position: CFO

Retained Infrastructure
- AGPip-DogBowl-ROMdam
- AGPip-NthPit-SedDam
- Pip-Clear-Water
- 2nd Nth MIA TempWork
- Build Pad LY
- HR North
- MIA North Dam
- Mine Access Road
- North Access Track
- North Mag and Reload
- North Sediment Dam
- Nth HV Park Up & LY
- Nth Reload Concrete
- NthEastDumpSedDam
- Sediment Basins
- Mining Lease Boundary

Underlying Landholder
- Wonbindi Coal Pty Ltd

Retained Infrastructure Wonbindi Coal Pty Ltd

Baralaba North Mine

Client	Wonbindi Coal Pty Ltd
Author	E.Moo
Date	28/04/2025
Revision	3
Map Projection	GDA2020 / MGA zone 55

0 200 400 m

Data Source: QSpatial

Scale: 1:30,000
(160 mm x 240 mm)

Q:\Baralaba Coal\GIS\Workspaces\BARN_RetainedInfrastructure.qgz

aarc ENVIRONMENTAL SOLUTIONS

BARALABA
COAL COMPANY

Agreement between the Environmental Authority Holders of EPML00223213 and Underlying Landowner regarding infrastructure to be retained at the end of the tenure for the Baralaba Coal Mine

Parties:
Environmental Authority Holders (EPML00223213)
Wonbindi Coal Pty Limited (ABN 62 114 668 941) and Baralaba Coal Pty Ltd (ABN 50 009 805 029)

Landowner
Baralaba Coal Pty Ltd (ABN 50 009 805 029)

Recitals

- Wonbindi Coal Pty Ltd and Baralaba Coal Pty Ltd (Environmental Authority Holders) operate the Baralaba Coal Mine under the Environmental Authority (EA) EPML00223213. This EA authorises environmentally relevant activities inclusive of Schedule 3 13: Mining black coal within mining leases (ML) 5605, ML5580, ML5581, ML5590, ML80157, ML80169, ML80170, ML80200, ML80201, and ML700004
- Baralaba Coal Pty Ltd (Landowner) is the registered underlying landowner for the following formal land descriptions, which are subject to this written agreement:
    - Lot 2 on RP618842
    - Lot 1 on RP618842
    - Lot 8 on SP256221
    - Lot 12 on SP256221
    - Lot 1 on SP235019
- The infrastructure in which this written agreement relates is shown in Attachment A.
- Land title searches have been supplied in Attachment B, C and D for reference.
- The Landowner will utilise the specified infrastructure in the ongoing management and use of the land post-mining and requests that it be retained in-place at the end of the tenure.

The underlying Landowner and EA Holders agree that the following infrastructure as described below, and depicted in Attached A, is to be retained after the mining tenure.

- All above ground pipelines will be retained for the purpose of grazing operations.
- All access tracks, roads and haul roads which do not intersect the realignment of the Hoadley's Road Easement or the ML700004 Haul Road.
- The Central Heavy Vehicle Workshop will be retained for the purpose of grazing operations;

- The following laydown yards; Central Mine Infrastructure Area; Central run of mine (ROM) Pad; North ROM.
- The following dams; Lagoon Dam, Farm Dam, Mine Dam 1, Central ROM Dam, Mine Dam 4a, and clean water drains, minor sediment dams and retention basins; and
- All existing fencing and security installations.

The EA Holders under its obligations and general environmental duty under the *Environmental Protection Act 1994* to not carry out any activity that causes or is likely to cause harm unless all reasonable and practicable measures to prevent or minimise harm are taken. To that end the infrastructure listed above will be rehabilitated and/or maintained sufficiently so that structures do not pose harm to future agricultural undertakings within the underlying land or receiving environment.

Executed by Wonbindi Coal Pty Limited

In accordance with section 127 (1) of the Corporations Act 2001

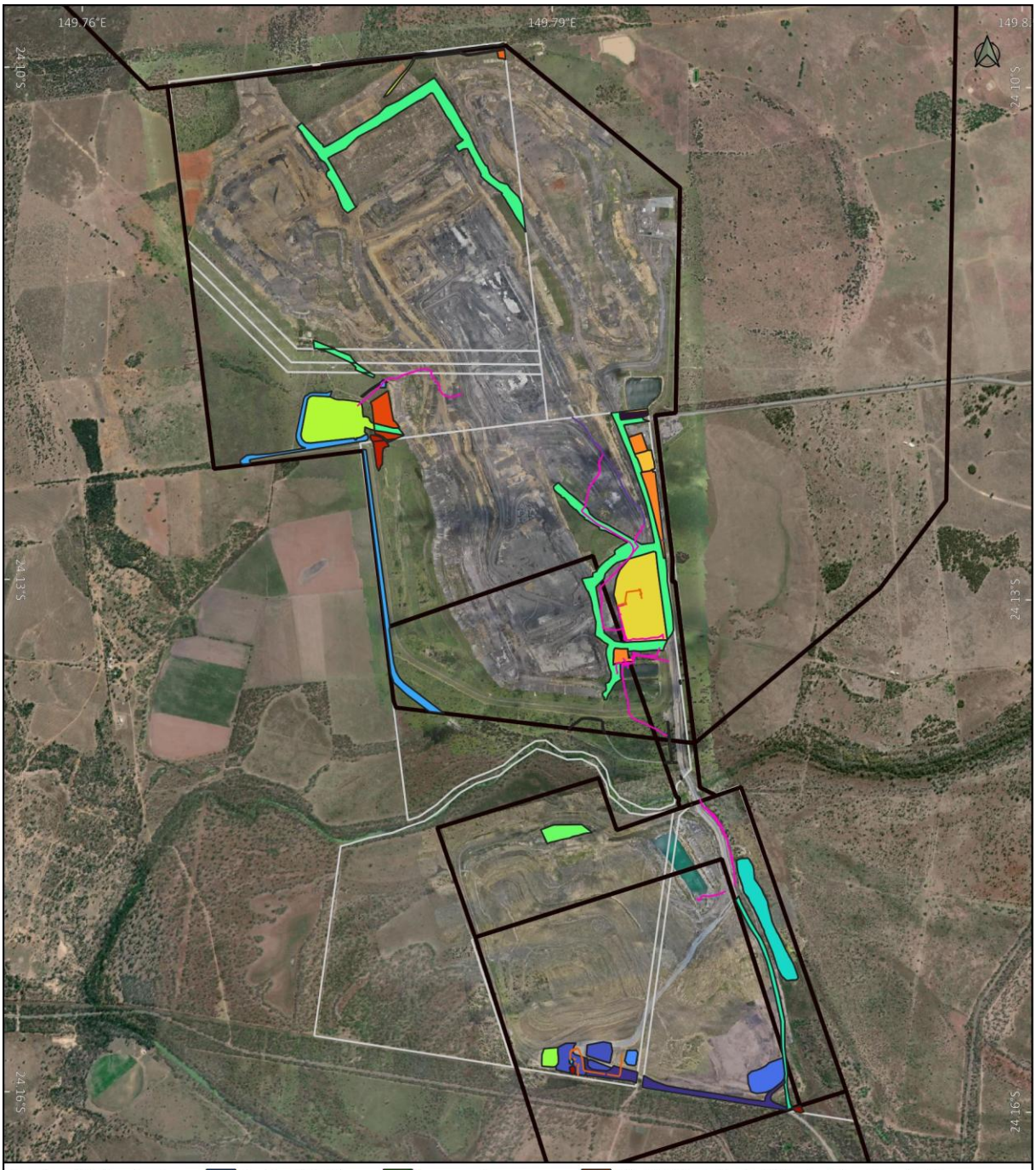
Michael Jones

Full Name: Michael Jones
Position: CEO

Executed by Baralaba Coal Pty Ltd

In accordance with section 127 (1) of the Corporations Act 2001

Full Name: Darren Madgwick
Position: CFO



Retained Infrastructure
- 100mm Pip AG
- 150mm Pip AG
- 315mm Pip AG
- Build Pad LY
- Central Access Track
- Central MIA
- Central ROM
- Central ROM Dam
- Clean Water Drain
- Central Workshop
- Farm Dam
- HR Central
- HR North
- Lagoon Dam
- Mine Dam 1
- Mine Dam 4a
- North Access Track
- North ROM
- North ROM Pad
- North Sediment Dam
- Nth HV Park Up & LY
- NthEastDump SedDam
- NthSedBasin 1
- NthSedBasin 2
- NthSedBasin 3
- Sediment Basins

Underlying Landholder
- Baralaba Coal Pty Ltd
- Mining Lease Boundary

Retained Infrastructure Barlalaba Coal Pty Ltd

Baralaba North Mine

Client	Wonbindi Coal Pty Ltd
Author	E.Moo
Date	28/04/2025
Revision	2
Map Projection	GDA2020 / MGA zone 55

0 300 600 m

Scale: 1:40,000 (160 mm x 240 mm)

Data Source: Q:\Baralaba Coal\GIS\Workspaces\BARN_RetainedInfrastructure.qgz

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