Appendix D Technical Reports and Information

Appendix D1	Microbat Call Identification Report (Balance Environmental 2015)
Appendix D2	Summary of Surface Water Quality Data for Mackenzie River
Appendix D3	Jellinbah Coal Mine REMP Design Report (AARC 2019b)
Appendix D4	Local Surface Water Quality Extended Dataset
Appendix D5	Central North Pit Final Void Hydrology Study (Engeny 2019b)
Appendix D6	Jellinbah Central North Extension Flood Assessment (WRM 2019)
Appendix D7	Conceptual and Numerical Groundwater Modelling (JBT 2019)
Appendix D8	Jellinbah Stage 3 Levee - Consequence Assessment Report (Parsons Brinckerhoff 2015)

Microbat Call Identification Report

Prepared for ("Client"):	AustralAsian Resource Consultants
Survey location/project name:	Jellinbah Central North
Survey dates:	16-19 February 2015
Client project reference:	
Job no.:	AARC1502
Report date:	13 March 2015

Methods

Data receipt and post-processing

Bat call data were recorded at two sites, for three nights per site, using a Song Meter SM2BAT detector (Wildlife Acoustics, USA) and an Anabat detector (Titley Scientific, Brisbane).

Data received for analysis included the following:

Site	Detector	Recording dates	Data received	Anabat sequence files generated from data
FA1	Anabat	Nights of 16, 17, 18 Feb. 2015	Anabat data (.DAT) file @ 917MB	49,133
FA2	Song Meter	Nights of 16, 17, 18 Feb. 2015	70 compressed audio (WAC) files	10,707

All Song Meter WAC files were post-processed with Wildlife Acoustics' *Kaleidoscope Version 2.2.1* to generate call sequence files in Anabat zero-crossing analysis (ZCA) format. *CFCread Version 4.4s* (Corben 2014a) was used to extract sequence files from the Anabat DAT files.

Bat call identification

All ZCA sequence files were analysed using *AnalookW* (Corben 2014b), with species identification achieved manually by comparing the *AnalookW* call sonograms with those of regionally-relevant reference calls and with published call descriptions (e.g. Reinhold *et al.* 2001; Milne 2002; Pennay *et al*. 2004).

Species' identification was also guided by considering their probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online) and/or the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows van Dyck *et al.* (2013).

Results & Discussion

The majority of the sequence files generated from the Anabat data contained only background noise, suggesting that the sensitivity setting was too low during deployment. Only 78 of the 49,133 sequence files contained bat call sequences of sufficient quality to allow an attempt at species identification. All of these 78 files contained substantial noise and mostly only weak bat call recordings, which made species identification difficult.

No bat calls were recorded by the Song Meter. Every Anabat file extracted from the WAC data contained just a short (0.5-2.0 second) pure-tone signal at approximately 63 kHz. No other noise was noted in any of the files viewed and there was no evidence of any bat calls or even bat-like signals..

The Anabat data yielded reliable species identification for the following species, recorded at FA1:

- *Chalinolobus gouldii*;
- *Chalinolobus picatus*;
- *Vespadelus baverstocki*; and
- *Saccolaimus flaviventris*.

Several other species may also have been present but very low call quality, along with potential confusion with some of the species listed above, meant that it was not possible to obtain a reliable diagnosis to species. These unconfirmed species included:

- *Scotorepens balstoni* (potentially confused with poor calls of *C. gouldii*);
- either *Chalinolobus morio* or *Vespadelus troughtoni* (single weak call with characteristic frequency around 52 kHz); and
- *Chaerephon jobensis* (potentially confused with weak/poor calls from *S. flaviventris*).

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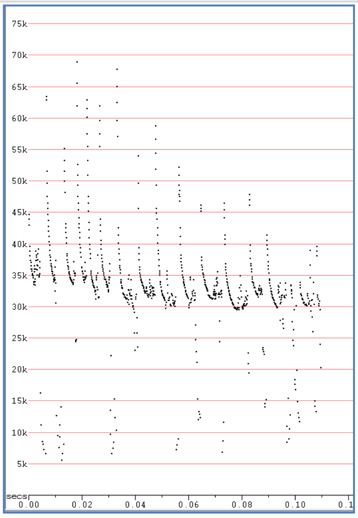
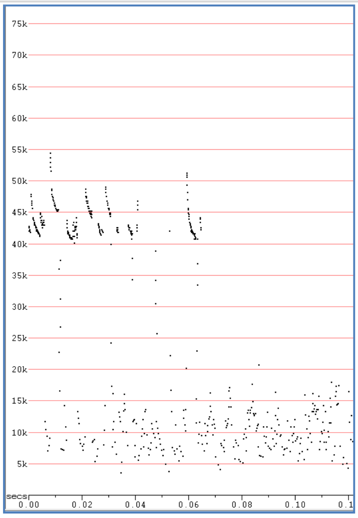
van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to The Mammals of Australia*. New Holland; Sydney.

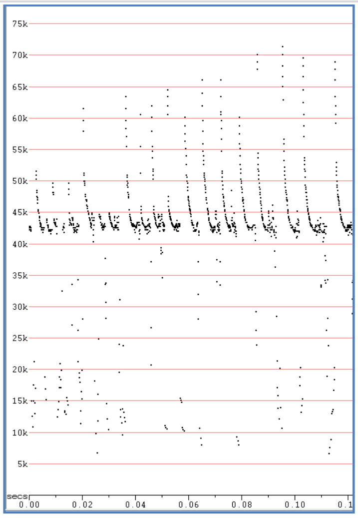
Appendix 1 Representative call sequences recorded at Jellinbah, 16-19 February 2015.
x-axis: time (sec) with time between pulses removed. y-axis: frequency (kHz)



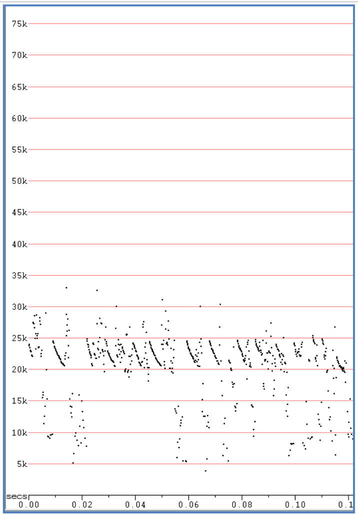
Chalinolobus gouldii



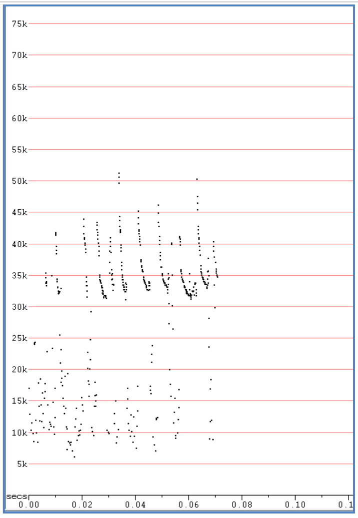
Chalinolobus picatus



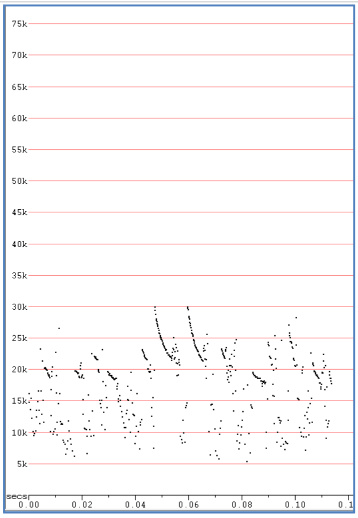
Vespadelus baverstocki



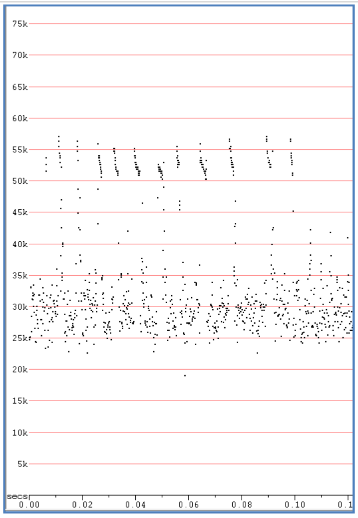
Saccolaimus flaviventris



Scotorepens balstoni or *C. gouldii*



Chaer. jobensis or *S. flaviventris*



Chal. morio or *Vesp. troughtoni*

Appendix D2 Summary of Water Quality Data for Mackenzie River

Parameter	ANZECC Aquatic	ANZECC Stock	ANZECC Irrigation	EPP (Water) WQOs Aquatic	EPP (Water) WQOs Livestock	EPP (Water) WQOs Irrigation	Mackenzie River					
							MR at Bingegang			MR at Rileys Crossing		
							Count	Med	80th	Count	Med	80th
pH	6.5-7.5	6.5-8.5	6-9	6.5-8.5	-	-	90	7.7	8	14	8.28	8.386
Turbidity (NTU)	25	-	-	50	-	-	39	61	100	14	14.5	207.4
Ammonia as N - soluble (mg/L)	0.01	-	-	0.06	-	-	16	0.0085	0.013	13	0.01	0.154
Nitrate + nitrite as N - soluble (mg/L)	-	-	-	-	-	-	16	0.033	0.24	14	0.092	0.136
Nitrate (mg/L)	0.015	400	-		-	-	53	1	2	14	0.65	1
Bicarbonate as HCO_3 (mg/L)	-	-	-	-	-	-	90	93	132.56	14	169.5	228.4
Hardness as $CaCO_3$ (mg/L)	-	-	60	-	-	-	90	63	91	14	156	227.4
Calcium as Ca soluble (mg/L)	-	1000	<60	-	-	-	90	15	20.66	14	31.5	41.6
Carbonate as CO_3 (mg/L)	-	-	-	-	-	-	69	0.3	0.84	14	1.95	
Boron (mg/L)	0.37	5	0.5	0.37	5	0.5 (LTV)	23	0.03	0.1	14	0.05	0.06
Chloride (mg/L)	0.02	-	175	-	-	-	90	10.58	15.2	14	84.5	164
Conductivity (µS/cm)	350	2,985^ 5,970*	1,300	720 (baseflow) 250 (high flow)	2,985	-	90	189	262	14	587.5	921
Fluoride (mg/L)	-	2	1	-	-	2 (STV) 1 (LTV)	90	0.205	0.3	14	0.21	0.274
Iron as Fe soluble (mg/L)	-	n/a	0.2	-	-	0.2 (LTV) 10 (STV)	35	0.17	2.5	14	0.01	0.042
Magnesium (mg/L)	-	n/a	0.2	-	-	-	90	6.45	9.62	14	19	30
Potassium (mg/L)	-	-	-	-	-	-	75	4	5.22	14	6.05	6.74
Silica as SiO_2 soluble (mg/L)	-	-	-	-	-	-	75	14.2	16.04	14	14	18
Sodium (mg/L)	-	-	115	-	30	-	90	13	18.3	14	56.5	99
Sulphate (mg/L)	-	1,000	-	25	1000	-	53	4.9	7.284	14	17.2	27.4
TDS (mg/L)	-	2,000	-	-	-	-	79	119.42	452.4	14	312	490.2
TN (mg/L)	0.25	-	5	0.5	-	-	3	0.5189	0.59072	14	0.4233	1.32
TP (mg/L)	0.03	-	0.05	0.05	-	-	25	0.09	0.17724	14	0.11	0.152
TSS (mg/L)	-	-	-	55	-	-	73	46	216.4	14	19.5	208

*Guideline value based on lowest concentration for reluctance of beef cattle to drink water. TDS was converted to EC using a conversion factor of 0.67 as recommended in ANZECC/ARMCANZ

^Guideline value based on lowest concentration for reluctance of poultry to drink water. TDS was converted to EC using a conversion factor of 0.67 as recommended in ANZECC/ARMCANZ

XX Indicates an exceedance of ANZECC (2000) water quality trigger values for the protection of aquatic ecosystems or livestock drinking water.

Indicates an exceedance of ANZECC (2000) water quality trigger values for the protection of irrigation water.

Indicates an exceedance of the relevant EPP (Water) WQO (i.e. the protection of aquatic ecosystems, or livestock drinking water)

JELLINBAH COAL MINE
RECEIVING ENVIRONMENT MONITORING PROGRAM

PREPARED FOR

JELLINBAH MINING PTY LTD

OCTOBER 2019

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LIST OF APPENDICES

Appendix A Trigger Action Response Plan .... A

LIST OF ABBREVIATIONS

%	percent
°C	degrees Celsius
AARC	AARC Environmental Solutions Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
COC	Chain of Custody
CPP	coal processing plant
DO	dissolved oxygen
EA	Environmental Authority
EC	electrical conductivity
EHP	Department of Environment and Heritage Protection
EPP (Water)	*Environmental Protection Policy (Water) 2009*
EV	Environmental Value
FRP	filterable reactive phosphorus
ISQG	Interim Sediment Quality Guidelines
Jellinbah	Jellinbah Mining Pty Ltd
km	kilometre(s)
km^2	square kilometre(s)
LOR	limit of reporting
m	metre(s)
mm	millimetre(s)
ML	Mining Lease
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per litre
Mtpa	Million tonnes per annum

mV	millivolt(s)
N	nitrogen
NATA	National Association of Testing Authorities
No.	number
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
PET	Plectoptera, Ephemoptera and Trichoptera
QC/QA	Quality control / quality assurance
REMP	Receiving Environment Monitoring Program
ROM	run-of-mine
RPD	Relative Performance Differences
SIGNAL	Stream Invertebrate Grade Number – Average Level
TARP	Trigger Action Response Plan
TDS	total dissolved solids
WQO	Water Quality Objective
µg/L	microgram(s) per Litre
µm	micrometre(s)
µS/cm	microSiemen(s) per centimetre

1.0 INTRODUCTION

The Jellinbah Coal Mine (the Project) is an open-cut coal operation, mining shallow, low stripping ratio coal reserves and producing approximately 4.5 – 5.0 million tonnes per annum (Mtpa) of pulverised coal injection and a minor amount of thermal coal, primarily for export. The Project is authorised by Environmental Authority (EA) EPML00516813 and operated by Jellinbah Mining Pty Ltd on behalf of the Jellinbah East Joint Venture. The participants of the Jellinbah East Joint Venture are: Jellinbah Group Pty Ltd, Tremell Pty Ltd, Marubeni Coal Pty Ltd and Sojitz Coal Resources Pty Ltd.

1.1 PURPOSE

The Project's EA requires a Receiving Environment Monitoring Program (REMP) to be developed and implemented. This REMP forms an update of the previous REMP prepared by Ison Environmental Planners in 2010.

This updated REMP has been developed in accordance with the *Receiving Environment Monitoring Program Guideline* (Department of Environment and Heritage Protection (EHP) 2014) to fulfil condition C21 of the EA:

C21 The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. For the purposes of the REMP, the receiving environment is the waters of the Mackenzie River and connected or surrounding waterways within 5 kilometres (km) downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water.

1.1.1 Aims and Objectives

This REMP aims to quantify the potential impacts of the operation of the Jellinbah Mine on the receiving environment. To achieve this, REMP monitoring is conducted on a regular basis (i.e. annually) to provide a comprehensive understanding of business-as-usual impacts. In addition, monitoring of the receiving environment is conducted during controlled and uncontrolled releases to determine the potential impacts associated with release events.

1.2 SCOPE

Condition C22 of the EA sets out the required content of the REMP. The REMP encompasses waters within 5 km downstream of each release point.

C22 The REMP must:

a) Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality);

b) Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected;

c) Include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in Table C8);

d) Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the Queensland Water Quality Guidelines 2009. This should include monitoring during periods of natural flow irrespective of mine or other discharges;

e) Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in Tables C2 and C3);

f) Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, BATLEY and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments);

g) Include, where appropriate, monitoring of macroinvertebrates in accordance with the AusRivas methodology,

h) Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents;

i) Describe sampling and analysis methods and quality assurance and control; and

j) Incorporate stream flow and hydrological information in the interpretations of water quality and biological data.

2.0 PROJECT DESCRIPTION

2.1 LOCATION

The Jellinbah Coal Mine is located in the Bowen Basin in central Queensland. Current operations areas are located approximately 24 km north-northeast of Blackwater and 190 km west of Rockhampton, within the Central Highlands Regional Council area. The Mackenzie North operational area, located north of the Mackenzie River, is situated within the Isaac Regional Council area.

The regional location of the Project is shown in Figure 1.

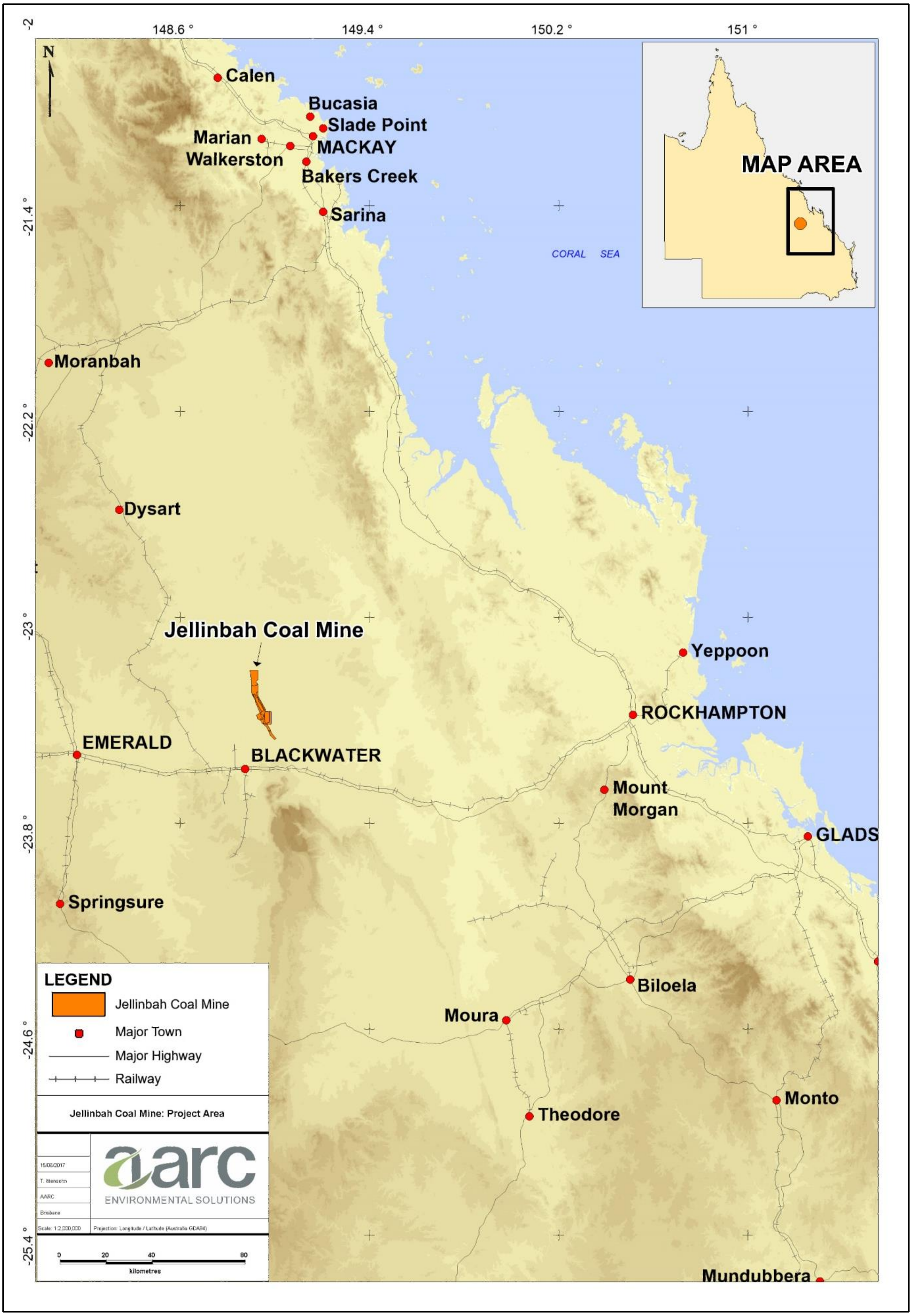

Figure 1 Regional Location of the Project

2.2 TENEMENTS

The Project encompasses 17 approved Mining Leases (MLs) comprising the following approved areas:

- Mackenzie North (operational);
- Jellinbah Plains (operational);
- Central North and Central North Extension (approved);
- Jellinbah Central (operational); and
- Jellinbah South (not currently operational).

Figure 2 illustrates the mining areas of the Jellinbah Coal Mine.

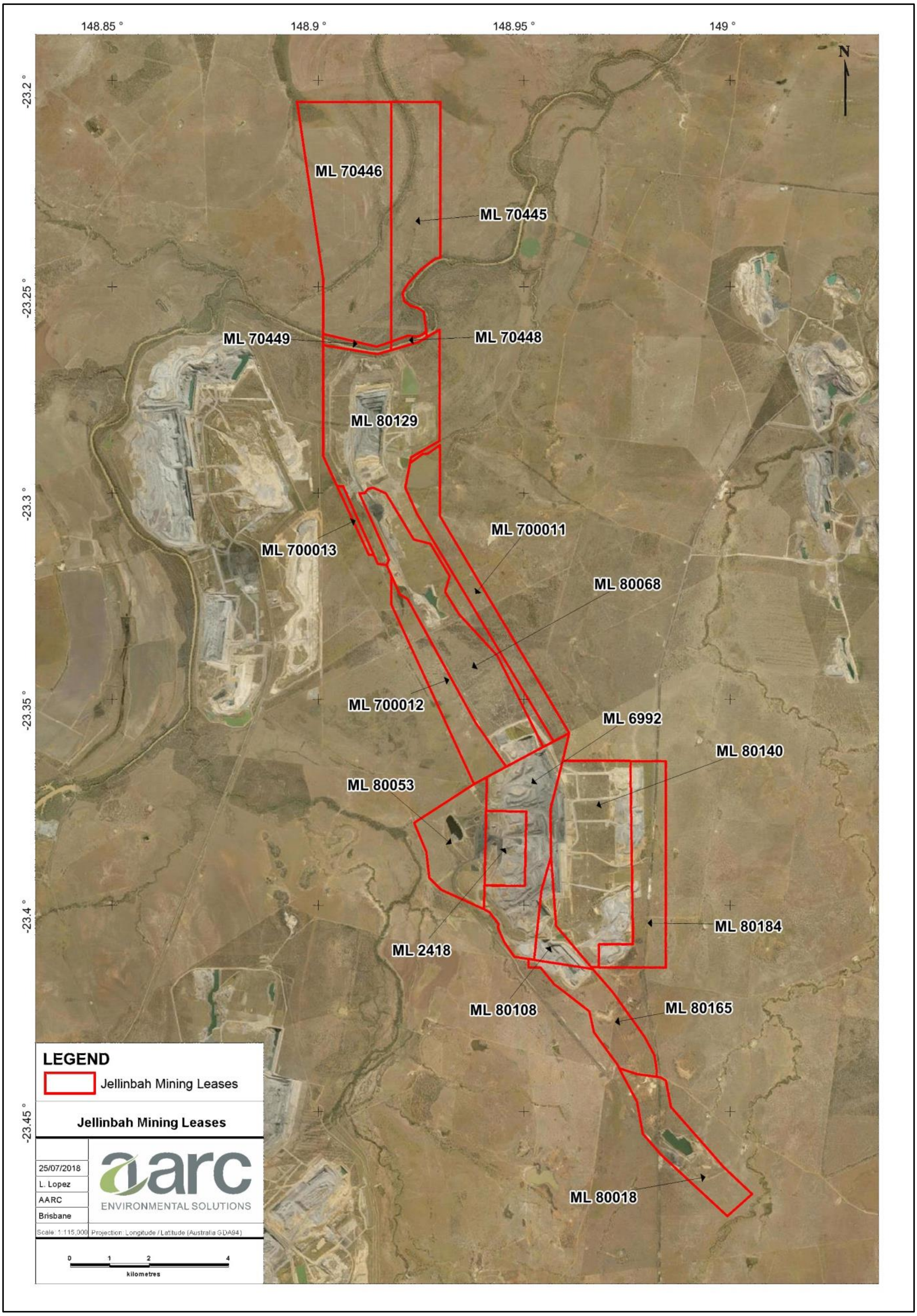

Figure 2 Jellinbah Coal Mine Tenements

2.3 ACTIVITIES

The principal activities undertaken at the Jellinbah Coal Mine are:

- Mining of a high-grade coal;
- Continuous assessment of the coal resource by exploration;
- Clearing of any remaining vegetation in advance of mining;
- Selective stripping of available topsoil under supervision to be immediately reused or stockpiled for future use in the rehabilitation program;
- Drilling and blasting of overburden to provide access to coal resources;
- Operation of a conventional open-cut truck and excavator mine to maintain production to meet market demands;
- Overburden used to form bunds, haul roads and hardstands or transported to out-of-pit spoil dumps located clear of the coal resource but within the boundary of the MLs or placed in the previous mining strip to backfill mined-out areas;
- Reshaping of spoil dumps, replacement of topsoil and revegetation of the mined out and backfilled area;
- Crushing and screening of run-of-mine (ROM) coal;
- Coal washing (if required) at the coal processing plant (CPP), located on ML 80053;
- Disposal of CPP rejects together with overburden (coarse rejects) and tailings (fine rejects) within existing mining voids;
- Transport of crushed and washed coal by private road to the existing rail loading area for rail transport to Gladstone;
- Operation of water management infrastructure such as regulated dams, sediment ponds, drains and bunds;
- Ongoing maintenance of levee banks at Jellinbah Plains and Mackenzie North to protect mining operations from flooding of the Mackenzie River;
- Utilisation of existing infrastructure facilities, including offices, power and water; and
- Continued direct and contract employment of operating workers and support personnel with flow-on employment through the provision of associated goods and services.

3.0 DESCRIPTION OF THE RECEIVING ENVIRONMENT

For the purposes of the REMP, the receiving environment is defined as the waters of the Mackenzie River and connected or surrounding waterways within 5 km downstream of a release point.

3.1 SURFACE WATER

The Project is located within the catchment of Blackwater Creek and the Mackenzie River, approximately 20 km downstream from Bedford Weir and 30 km upstream of the Bingegang Weir. Blackwater Creek runs parallel to the western boundaries of the Jellinbah Central area. The Mackenzie River traverses the Jellinbah Coal Mine between the Mackenzie North area and the mining operations at Jellinbah Plains and Jellinbah Central. The Mackenzie North area is located on the northern alluvial plain of the Mackenzie River. Flow distributions on the plain are complex and vary depending on the magnitude of stream flow in the river.

The Mackenzie River is a major tributary of the Fitzroy River which flows to the Coral Sea at Rockhampton. The total catchment area of Mackenzie River to the Bingegang Weir (30 km downstream of the Jellinbah Coal Mine) is approximately 50,960 square kilometres (km^2) and incorporates the Comet and Nogoa River sub-catchments (WRM 2013).

Watercourses within the region are ephemeral, with the exception of the Mackenzie River, which carries controlled releases from Fairbairn Dam, along the Nogoa River, upstream of Jellinbah Coal Mine.

Surface water features in the vicinity of the Project site are shown in Figure 3.

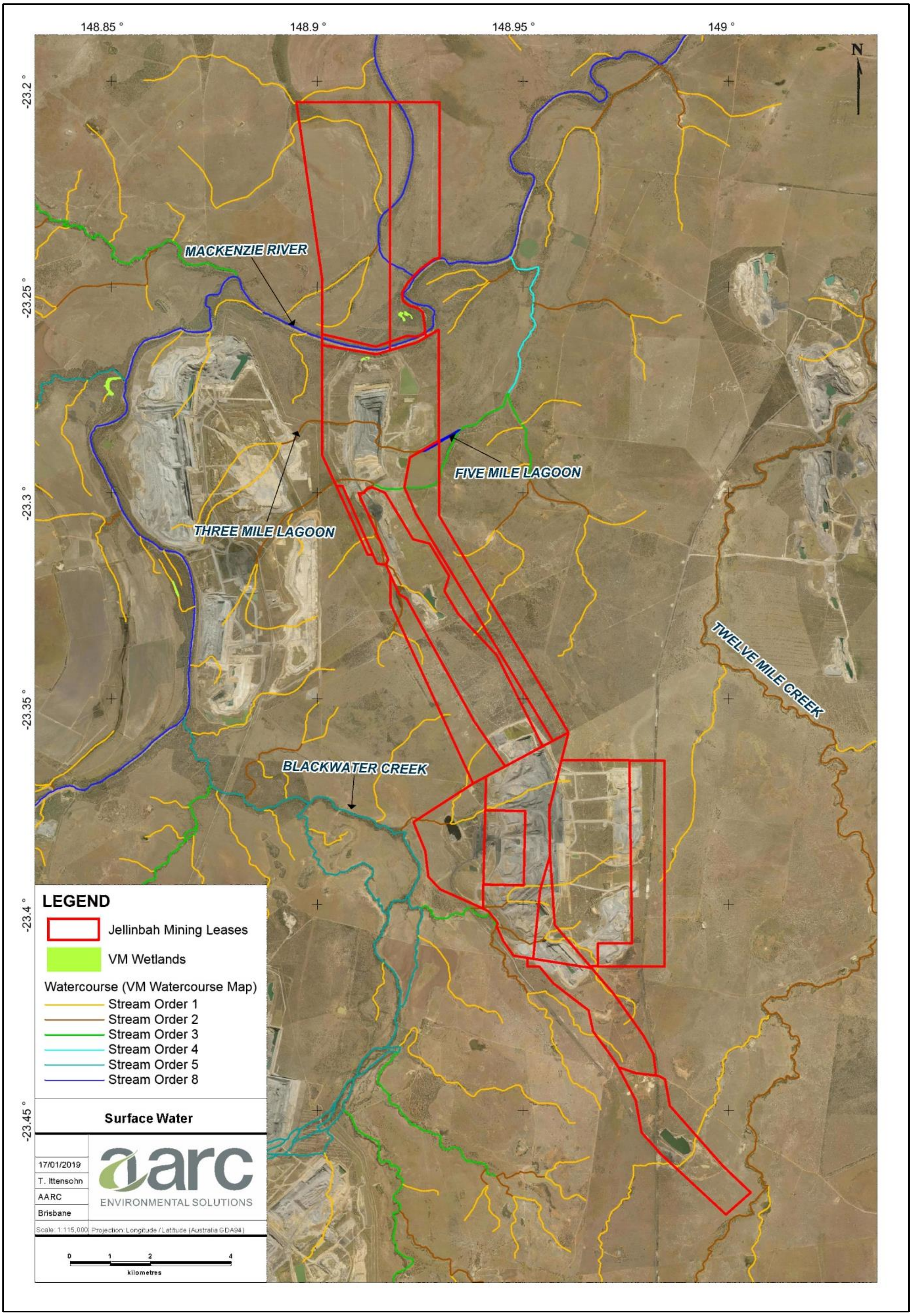

Figure 3 Surface Water Features

3.2 CURRENT LAND AND WATER USES

Surface waters in the region are of environmental value to the surrounding grazing industry, existing mining operations, the local community and native flora and fauna. Catchment to the Mackenzie River is harvested for a range of uses, including irrigation, urban, industrial and domestic water supplies (AARC 2013).

Drinking water supplies are obtained from Fairbairn Dam, located upstream of the Project, on the Nogoa River. Immediately upstream of the Project site the Bedford Weir regulates flow of the Mackenzie River through the proposed site, as well as, providing a source of water for industrial, and agricultural uses.

Releases are made from Fairbairn Dam to deliver supplies to downstream riparian water users and to maintain supplies from Bedford and Bingegang Weirs to various towns, mines and irrigators. Water captured in the Bingegang Weir, located downstream of the Project, is used to supply the towns of Middlemount and Dysart (WRM 2013). Semi-permanent pools exist in Blackwater Creek and the Mackenzie River, as well as Three and Five Mile Lagoons, which are located adjacent to the Jellinbah Plains operation.

Land use is typically rural with substantial areas cleared for predominately low-intensity cattle grazing. Beyond the towns of Clermont, Emerald, Springsure and Blackwater, the catchment is sparsely populated. Two coal mines are located in close proximity to the Jellinbah Coal Mine: Curragh North (immediately upstream) and Yarrabee (immediately downstream).

3.3 ENVIRONMENTAL PROTECTION (WATER) POLICY 2009

The *Environmental Protection (Water) Policy 2009* (EPP (Water)) is subordinate legislation under the *Environmental Protection Act 1994*. The EPP (Water) provides a framework for:

1. Identifying environmental values (EVs) for Queensland waters, and determining water quality objectives (WQOs) to protect or enhance those EVs; and

2. Including the identified EVs and WQOs under Schedule 1 of the EPP (Water).

The EPP (Water) is relevant to the Project with regard to the protection of EVs occurring within the receiving environment of the Project site. The EVs and WQOs for waters occurring in the vicinity of the Project site are provided in the document: *Environmental Protection (Water) Policy 2009*; *Mackenzie Sub-basin Environmental Values and Water Quality Objectives*.

3.3.1 Environmental Values

EVs are defined as “particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits” (EHP 2010).

The EVs and WQOs stated within this document have been developed in accordance with the EPP (Water) and the relevant supporting documents. The Project is situated within the Mackenzie River Sub-basin, and as such is subject to the EVs and WQOs outlined in the *Mackenzie River Sub-basin Environmental Values and Water Quality Objectives* document (as stipulated in Schedule 1 of the EPP (Water)).

EVs applicable to the Jellinbah Coal Mine, as defined in the *Mackenzie River Sub-basin Environmental Values and Water Quality Objectives*, include:

- Protection of aquatic ecosystems;
- Suitability for crop irrigation;
- Suitability for aquaculture (Isaac western upland tributaries only);
- Suitability for farm supply and use;
- Suitability for stock water;
- Suitability for human consumption of aquatic foods;
- Suitability for primary contact recreation;
- Suitability for secondary contact recreation;
- Suitability for visual recreation
- Suitability for drinking water supply;
- Suitability for industrial use; and
- Protection of cultural and/or spiritual values.

The *EPP (Water) Central Queensland Mapping (WQ1304 – Mackenzie River Sub-basin)* identifies several watercourses (rivers / creeks) and lakes / reservoirs on and surrounding the Project site. Of greatest significance to the Project are the Mackenzie River, Blackwater Creek, Three Mile Lagoon and Five Mile Lagoon. Associated values include aquatic ecosystems and stock water supply. The nearest downstream source of human consumption is the Bingegang Weir located 30 km downstream.

3.3.2 Water Quality Objectives

The EPP (Water) provides WQOs to support and protect the different EVs identified for waters within the Mackenzie River catchments. WQOs are provided in two main parts:

a) For the purposes of protecting the aquatic ecosystem EV; and

b) For EVs other than aquatic ecosystems ('human use EVs').

REMP monitoring data will be compared with the WQOs outlined in the EPP (Water) for the protection of the aquatic ecosystem EV, in particular the WQOs for moderately disturbed aquatic ecosystems in Mackenzie River Sub-basin waters. All WQOs relevant to the REMP are outlined in Table 1. It is important to note that the primary EVs associated with the Project site are aquatic ecosystems and stock watering suitability, and this will be reflected in the WQOs used to assess REMP monitoring results. WQOs for the protection of moderately disturbed freshwater lakes / reservoirs have been included in Table 1 due to two of the REMP monitoring sites being located within lagoons (Three and Five Mile Lagoon).

The *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 2000) provide widely recognised guidelines for a range of EVs, including aquatic ecosystems, stock watering and human consumption. The ANZECC guidelines also contain Interim Sediment Quality Guidelines for assessing metal levels in stream sediments. The ANZECC livestock drinking water guidelines are relevant for the Project area, and are shown in Table 1. Table 1 also includes contaminant trigger levels and trigger investigation levels defined within the Project's EA.

The Interim Sediment Quality Guidelines (ISQG), applicable to the stream sediment monitoring carried out as part of the REMP, are provided in Table 2. EPP (Water) WQOs applicable to macro-invertebrates are provided in Table 3.

Table 1 Water Quality Objectives, Trigger Levels and Contaminant Limits – Surface Water

Quality Characteristic	EA Trigger Levels			ANZECC (2000)		EPP (Water) WQOs	
	Release Contaminant Trigger Investigation Level	Receiving Waters Contaminant Trigger Level		Livestock Drinking Water [2]	Aquatic Ecosystems	Moderately Disturbed Aquatic Ecosystems [4]	Freshwater Lakes / Reservoirs [5]
		Blackwater Ck.	Mackenzie R.				
pH	-	6.5 – 9	6.5 – 8.5	-	6 – 7.5	6.5 – 8.5	6.5 – 8
Electrical conductivity (EC)	-	1,000 µS/cm	400 µS/cm	-	20 – 250 µS/cm	Base flow: 310 µS/cm High flow: 210 µS/cm	No / base flow: 250 µS/cm
Total dissolved solids (TDS)	-	-	-	4,000 mg/L	-	-	-
Turbidity	-	Low flow: 1,885 NTU * High Flow: 2,991 NTU *	-	-	2 to 15 NTU	50 NTU	1 – 20 NTU
Suspended solids	-	690 mg/L	690 mg/L	-		110 mg/L	-
Sulphate	-	250 mg/L	250 mg/L	1,000 mg/L		10 mg/L	-
Dissolved oxygen (DO)	-	-	-	-	90 – 120%	85 – 110%	90 – 110%
Ammonia N	900 µg/L	-	-	-	900 µg/L	20 µg/L	10 µg/L
Oxidised N	-	-	-	-	30 µg/L	60 µg/L	10 µg/L
Organic N	-	-	-	-	-	420 µg/L	330 µg/L
Total N	-	-	-	-	150 µg/L	775 µg/L	350 µg/L
Filterable reactive phosphorus (FRP)	-	-	-	-	5 µg/L	20 µg/L	5 µg/L
Total P	-	-	-	-	10 µg/L	160 µg/L	10 µg/L
Chlorophyll a	-	-	-	-	-	5 µg/L	5 µg/L
Calcium	-	-	-	1,000 mg/L	-	-	-
Sodium	180,000 µg/L	180,000 µg/L	180,000 µg/L	-	-	-	-
Nitrate	1,100 µg/L	-	-	400 mg/L	-	-	-
Aluminium	55 µg/L	-	-	5 mg/L	55 µg/L	-	-
Arsenic	13 µg/L	-	-	0.5 – 5 mg/L	13 µg/L	-	-
Boron	370 µg/L	-	-	5 mg/L	370 µg/L	-	-
Cadmium	0.2 µg/L	-	-	0.01 mg/L	0.2 µg/L	-	-

Quality Characteristic	EA Trigger Levels			ANZECC (2000)		EPP (Water) WQOs	
	Release Contaminant Trigger Investigation Level	Receiving Waters Contaminant Trigger Level		Livestock Drinking Water [2]	Aquatic Ecosystems	Moderately Disturbed Aquatic Ecosystems [4]	Freshwater Lakes / Reservoirs [5]
		Blackwater Ck.	Mackenzie R.				
Chromium	1 µg/L	-	-	1 mg/L	1 µg/L	-	-
Cobalt	90 µg/L	-	-	1 mg/L	-	-	-
Copper	2 µg/L	-	-	1 mg/L (cattle)	1.4 µg/L	-	-
Iron	300 µg/L	-	-	#	-	-	-
Lead	4 µg/L	-	-	0.1 mg/L	3.4 µg/L	-	-
Manganese	1,900 µg/L	-	-	#	1,900 µg/L	-	-
Mercury	0.2 µg/L	-	-	0.002 mg/L	0.6 µg/L	-	-
Molybdenum	34 µg/L	-	-	0.15 mg/L	-	-	-
Nickel	11 µg/L	-	-	1 mg/L	11 µg/L	-	-
Selenium	10 µg/L	-	-	0.02 mg/L	-	-	-
Silver	1 µg/L	-	-	-	0.05 µg/L	-	-
Uranium	1 µg/L	-	-	0.2 mg/L	-	-	-
Vanadium	10 µg/L	-	-	-	-	-	-
Zinc	8 µg/L	-	-	20 mg/L	8 µg/L	-	-
Fluoride	2,000 µg/L	-	-	2 mg/L	-	-	-
Petroleum hydrocarbons (C6-C9)	20 µg/L	-	-	-	-	-	-
Petroleum hydrocarbons (C10-C36)	100 µg/L	-	-	-	-	-	-

Note: 1. Total (unfiltered) measurements must be taken and analysed. 2. Recommended water quality trigger values (low risk) for heavy metal and metalloids in livestock drinking water (ANZECC). 3. 95% species protection in slightly-moderately disturbed ecosystems. 4. Water quality objectives to protect moderately disturbed aquatic ecosystems in the Mackenzie River Sub-basin (EPP Water). 5. Water quality objectives to protect moderately disturbed freshwater lakes / reservoirs (EPP Water). # Not sufficiently toxic. * For the purpose of measuring turbidity in Blackwater Creek, low flow is defined as <2 m^3/s and high flow is defined as >2 m^3/s.

Table 2 Sediment Quality Guidelines

Contaminant (mg/kg dry wt)	ANZECC (2000)	
	ISQG (Low) Trigger Level	ISQG (High) Trigger Level
Antimony	2	25
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1
Nickel	21	52
Silver	1	3.7
Zinc	200	410

Table 3 Water Quality Objectives – Macro-Invertebrates

Indicator	EPP (Water) WQOs	
	Composite	Edge Habitat
Taxa richness	12 – 21	23 – 33
PET taxa richness	2 – 5	2 – 5
SIGNAL index	3.33 – 3.85	3.31 – 4.2
% tolerant taxa	25 – 50%	44 – 56%

4.0 MINE RELEASE

Jellinbah Coal Mine currently has four operational release points, two of which release to Blackwater Creek and two of which release to the Mackenzie River. An additional release point is approved for the Mackenzie River: RP4 at Mackenzie North. Release point locations are provided in Table 4.

Mine affected water streams at the Jellinbah mine include:

- Groundwater;
- Water that accumulates in a pit;
- Water that has come into contact with coal stockpiles, processing areas, ROM pads;
- Process water; and
- Water in the tailings.

The REMP has been designed in accordance with the water release conditions whereby REMP site locations have been determined relative to the EA release and monitoring points.

Table 4 Current Release Points at the Jellinbah Coal Mine

Release Point	Location	Easting	Northing	Status
Blackwater Creek				
RP1	Jellinbah Central	697440	7413330	Existing
RP2	Jellinbah Central	697985	7410730	Existing
Mackenzie River				
RP3	Jellinbah Plains	7410730	7425570	Existing
RP4	Mackenzie North	696360	7428060	Approved
RP5	Jellinbah Plains	696387	7425862	Existing

5.0 RECEIVING ENVIRONMENT MONITORING PROGRAM

5.1 LOCATIONS

The REMP monitoring sites have been developed to incorporate all sampling procedures at each site location. The upstream background monitoring sites are used as reference sites and are not subject to the release of mine affected water from the Project. Impact sites are those located downstream of the release points and within the receiving environment. REMP monitoring at the Project site includes three upstream (background) and four downstream (impact) monitoring locations.

The locations of these receiving water monitoring sites are provided below in Table 5 and shown in Figure 4 (Mackenzie River) and Figure 5 (Blackwater Creek). The locations of release points are also depicted on Figure 4 and Figure 5.

Table 5 Receiving Water Monitoring Locations

Monitoring Points*	Receiving Waters Location Description*	Easting (MGA GDA94 Zone 55)	Northing (MGA GDA94, Zone 55)
Upstream Background Monitoring Points			
MP2	Blackwater Creek 1360 m upstream of RP2	695630	7410000
MP4	Upstream Mackenzie River	694535	7426000
Three Mile Lagoon (US3) (extra point)	Upstream Three Mile Lagoon	694443	7423876
Downstream Monitoring Points			
MP1	Blackwater Creek 1500 m downstream of RP1	694760	7413420
MP3	Downstream Mackenzie River	696930	7425950
Five Mile Lagoon (DS5) (extra point)	Downstream Five Mile Lagoon	696694	7423071
MP5	Downstream Mackenzie River (as required when operations commence)	697450	7428244

*MP = Monitoring Point, US = Upstream, DS – Downstream, RP = Release Point

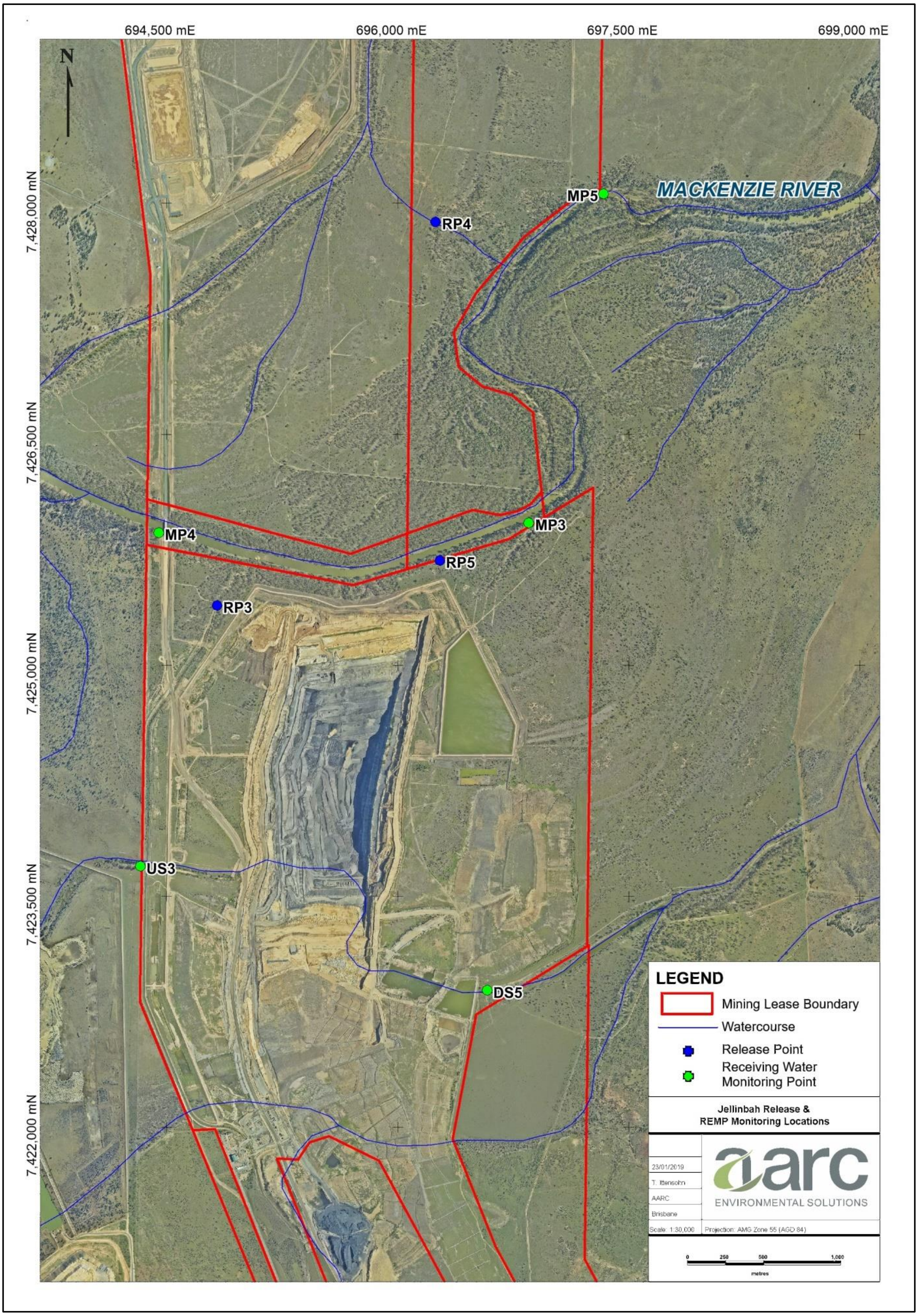

Figure 4 Release Points and Receiving Environment Monitoring Points – Mackenzie River

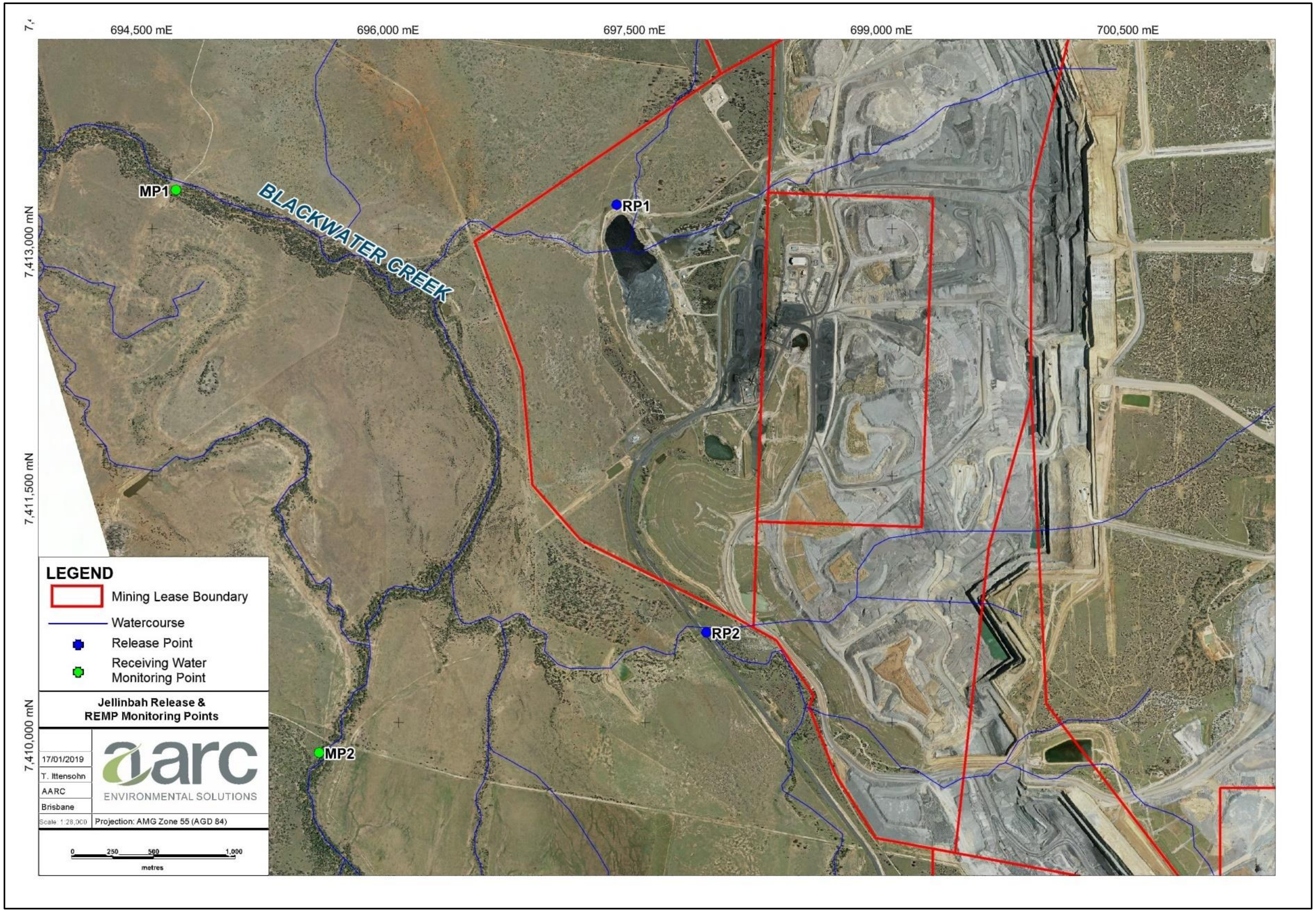

Figure 5 Release Points and Receiving Environment Monitoring Points – Blackwater Creek

5.1 TIMING AND FREQUENCY

Monitoring of the receiving environment occurs on a regular and event basis. Regular monitoring of surface water, stream sediments and macro-invertebrates is undertaken on an annual basis in March at all locations in Table 5, including Three and Five Mile Lagoons.

Additional surface water monitoring is undertaken on a daily basis during a release event only.

5.2 INDICATORS

Indicators for surface water, stream sediment and macro-invertebrates are adopted from a range of sources, including the Project's EA, ANZECC (2000) and EPP (Water) to ensure potential impacts to EVs are adequately assessed. Indicators for surface water, stream sediment and macro-invertebrates are listed in Table 6, Table 7 and Table 8, respectively.

Table 6 Surface Water Indicators

Quality Characteristics	Units	Limit of Reporting	Method
pH	pH units	-	Field
Temperature	°C	-	Field
DO	%	-	Field
EC	µS/cm	-	Field
TDS	mg/L	-	Field
Oxidation reduction potential (ORP)	mV	-	Field
Turbidity	NTU	-	Field
Suspended solids	mg/L	5	Laboratory
Calcium	mg/L	1	Laboratory
Magnesium	mg/L	1	Laboratory
Sodium	mg/L	1	Laboratory
Potassium	mg/L	1	Laboratory
Ammonia as N	mg/L	0.01	Laboratory
Nitrate as N	mg/L	0.01	Laboratory
Oxidised N	mg/L	0.01	Laboratory
Organic N	mg/L	0.1	Laboratory
Total N	mg/L	0.1	Laboratory
FRP	mg/L	0.01	Laboratory
Total P	mg/L	0.01	Laboratory
Sulphate as SO4-	mg/L	1	Laboratory
Chloride	mg/L	1	Laboratory
Fluoride	mg/L	0.1	Laboratory
Hydroxide Alkalinity (as $CaCO_3$)	mg/L	1	Laboratory
Carbonate Alkalinity (as $CaCO_3$)	mg/L	1	Laboratory

Quality Characteristics	Units	Limit of Reporting	Method
Bicarbonate Alkalinity (as $CaCO_3$)	mg/L	1	Laboratory
Total Alkalinity (as $CaCO_3$)	mg/L	1	Laboratory
Aluminium	mg/L	0.01	Laboratory – dissolved & total
Arsenic	mg/L	0.001	Laboratory – dissolved & total
Barium	mg/L	0.001	Laboratory – dissolved & total
Beryllium	mg/L	0.001	Laboratory – dissolved & total
Boron	mg/L	0.05	Laboratory – dissolved & total
Cadmium	mg/L	0.0001	Laboratory – dissolved & total
Chromium	mg/L	0.001	Laboratory – dissolved & total
Cobalt	mg/L	0.001	Laboratory – dissolved & total
Copper	mg/L	0.001	Laboratory – dissolved & total
Iron	mg/L	0.05	Laboratory – dissolved & total
Lead	mg/L	0.001	Laboratory – dissolved & total
Manganese	mg/L	0.001	Laboratory – dissolved & total
Molybdenum	mg/L	0.001	Laboratory – dissolved & total
Nickel	mg/L	0.001	Laboratory – dissolved & total
Selenium	mg/L	0.01	Laboratory – dissolved & total
Silver	mg/L	0.001	Laboratory – dissolved & total
Uranium	mg/L	0.001	Laboratory – dissolved & total
Vanadium	mg/L	0.01	Laboratory – dissolved & total
Zinc	mg/L	0.005	Laboratory – dissolved & total
Mercury	mg/L	0.0001	Laboratory – dissolved & total
Petroleum Hydrocarbon (C6 – C9)	µg/L	20	Laboratory
Petroleum Hydrocarbon (C10 – C36)	µg/L	50	Laboratory

Table 7 Stream Sediment Indicators

Quality Characteristics	Units	Limit of Reporting	Method
Moisture Content (dried @ 103°C)	%	1	Laboratory
Aluminium	mg/kg	50	Laboratory
Arsenic	mg/kg	5	Laboratory
Barium	mg/kg	10	Laboratory
Beryllium	mg/kg	1	Laboratory
Boron	mg/kg	50	Laboratory
Cadmium	mg/kg	1	Laboratory
Chromium	mg/kg	2	Laboratory
Cobalt	mg/kg	2	Laboratory

Quality Characteristics	Units	Limit of Reporting	Method
Copper	mg/kg	5	Laboratory
Iron	mg/kg	50	Laboratory
Lead	mg/kg	5	Laboratory
Manganese	mg/kg	5	Laboratory
Molybdenum	mg/kg	2	Laboratory
Nickel	mg/kg	2	Laboratory
Selenium	mg/kg	5	Laboratory
Silver	mg/kg	2	Laboratory
Vanadium	mg/kg	5	Laboratory
Zinc	mg/kg	5	Laboratory
Uranium	mg/kg	0.1	Laboratory
Mercury	mg/kg	0.1	Laboratory

Table 8 Macro-Invertebrates Indicators

Quality Characteristics	Units	Method
Total abundance	No.	Laboratory
Taxa richness	No.	Laboratory
SIGNAL 2 Score	-	Laboratory
PET taxa richness	No.	Laboratory

5.3 METHODOLOGY

5.3.1 Surface Water Monitoring

Samples are collected from each monitoring location (provided that water is present at the time) and field readings of oxygen saturation, temperature, EC, pH and TDS are recorded. Samples are immediately refrigerated and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis. The results of the downstream water tests are compared to upstream water quality, the relevant EA trigger and trigger investigation levels, trigger levels for 95% species protection under the ANZECC aquatic ecosystems guideline, and the EPP (Water) WQOs to protect moderately disturbed aquatic ecosystems in the Mackenzie River Sub-basin.

5.3.2 Stream Sediment Monitoring

Samples are taken at each of the sites outlined in Table 5 in accordance with the most recent version of *AS5667.1 Guidance on Sampling of Bottom Sediments*. Samples are sealed in sterilised glass jars and sent to a NATA accredited laboratory for analysis of trace metals. The results of the receiving environment are compared with upstream sites and the trigger levels set out in the EA.

5.3.3 Biological Monitoring

Biological monitoring is used to assess the ecological health of any given ecosystem and has the potential to provide a more direct indication of ecosystem health than episodic sampling of water quality. Biological monitoring uses surveys and other direct measurements of organisms and/or communities that are used to provide data on biological or ecological changes that result from changes in water quality, physical habitat (such as sedimentation, hydrological changes) and biological interactions (including the introduction of exotic weed species).

Biological monitoring is generally concerned with obtaining an assessment of the current condition of a watercourse relative to its natural (or baseline) condition. The condition of a site can then be described in terms of the amount of change over time, compared to an undisturbed reference site. Wherever possible the biological indicators at the impacted site are compared with the same biological indicators at a reference site to provide an assessment of change in condition.

5.3.3.1 Macro-Invertebrate Monitoring

Macro-invertebrates are invertebrates that can be seen with the naked eye. The types and numbers of macro-invertebrates found in a river or creek can be used as biological indicators (bio-indicators) of the health of that environment for the following reasons:

1) They are generally sensitive to the cumulative impacts of a wide range of disturbances and pollutants;

2) They are abundant in freshwater systems;

3) They are relatively easy to identify; and

4) They are easy to collect (Chessman 2003).

The monitoring of macro-invertebrates is undertaken in accordance with the AusRivas methodology and samples are taken at each site where water is present.

Macro-invertebrates are collected using a D-frame pond net (350 millimetres (mm) x 250 mm with 250 micrometre (µm) mesh) and employing a kick-sampling method (the substrate in the waterbody is disturbed and the net passed through the resulting plume to obtain benthos- and water column-dwelling macro-invertebrates). At each site a representative sweep is taken across various sections of edge habitat along a 100 metres (m) length of stream (where possible).

Macro-invertebrates are placed in a white sorting tub and 'live-picked' using a pipette and tweezers for a period of 20 minutes. Macro-invertebrates are placed in a vial containing 70% methylated spirits and sent to a NATA accredited laboratory for identification to family or sub-family level. Data are plotted on a Stream Invertebrate Grade Number – Average Level (SIGNAL) bi-plot for interpretation of the health of the waterbody.

The SIGNAL Index was developed by the National River Health Program as a tool for the bio-assessment of water pollution and considers the taxonomic composition of the invertebrate assemblage to determine river health. Each macro-invertebrate is given a grade number between one and ten based on their sensitivity to various pollutants (Chessman 2003), with a lower number indicating a higher tolerance to a range of conditions. The SIGNAL Index value is calculated by averaging the pollution sensitivity grade numbers of the families present at each site. Refer to Chessman (2003) for families excluded from SIGNAL scoring results.

Once plotted on a bi-plot, the SIGNAL Index and the number of invertebrate families found in a stream used together can provide an indication of the types of pollution and other physical and chemical factors that affect macro-invertebrate communities (Chessman 2003), depending on their position within the graph (refer to Figure 6).

Quadrant 3 Often indicating toxic pollution or harsh physical environments	**Quadrant 1** Indicates favourable habitat or chemically dilute water
Quadrant 4 Usually indicating urban, industrial, or agricultural pollution	**Quadrant 2** Often indicating high salinity or nutrient levels (may be natural)

Figure 6 Bi-plot Interpretation

5.4 DATA INTERPRETATION AND REPORTING

Field and laboratory data will be entered into a central database and compared with previous years' REMP results. In accordance with condition C23 of the EA, a REMP Findings Report will be prepared on an annual basis. This report will include an assessment of:

- Background reference water quality;
- The condition of downstream water quality compared against WQOs; and
- The suitability of current discharge limits to protect downstream EVs.

Assessment of water quality, stream sediment and macro-invertebrate data will be in accordance with relevant guidelines, including the *Queensland Monitoring and Sampling Manual 2009* (EHP 2010) and ANZECC (2000).

5.4.1 Investigation Requirements

<u>REMP</u>

The Trigger Action Response Plan (TARP) developed for the Jellinbah REMP outlines actions and measures to take in the event that downstream (impact site) water quality results collected as part of the REMP exceed any of the EA trigger levels outlined in Table 1.

<u>Release Event</u>

Note that the following investigation requirement only applies to an exceedance during a release event.

In accordance with condition C20 of the EA, where a result at a downstream monitoring location (excluding Five Mile Lagoon) exceeds both the Receiving Waters Contaminant Trigger Levels and the corresponding upstream result, an investigation into environmental harm must be conducted. The investigation must include actions taken to prevent environmental harm and be submitted with the Project's Annual Return.

C20 If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in Table C7 during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and:

a) Where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or

b) Where the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining:

i) Details of the investigations carried out; and

ii) Actions taken to prevent environmental harm.

Note: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with C20 b) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.

5.5 QUALITY ASSURANCE AND QUALITY CONTROL

5.5.1 Data Collection and Sampling

Field work conducted for the purposes of this REMP will be undertaken by a suitably qualified and experienced person. Data collection will be conducted in a professional manner with the highest attention paid to quality assurance and quality control procedures.

A number of quality control / quality assurance (QC/QA) procedures shall be adopted during the collection and analysis of REMP samples to ensure the reliability of monitoring results. All field testing and sample collection will be completed using best practice techniques and in accordance with instrument manufacturer's instructions (where applicable) and the most recent applicable guidelines and procedures. All equipment will be calibrated prior to each sampling event (or more regularly if recommended by the manufacturer).

At each REMP site, water quality measurements and water samples shall be collected prior to any other sampling to reduce sample contamination and bias of in-situ turbidity readings. Care shall be taken to prevent disturbance to the stream bed or banks when undertaking these tasks.

Prior to the collection of field filtered samples, the sampling syringe shall be rinsed twice using sampling water collected in a sample container. The entire inside surface of the syringe is to come in contact with the sample. The syringe shall then be refilled and a filter attached. The first 2 ml of the sample shall be discarded through the filter as a filter rinse, before filling the sample bottle via the filter.

For the macro-invertebrate monitoring, the nets and sorting tubs shall be thoroughly rinsed prior to sampling at each REMP site to prevent sample contamination.

5.5.2 Laboratory Analysis

All samples and specimens requiring laboratory analysis will be sent to a NATA laboratory. All NATA laboratories conduct analysis with the highest quality assurance procedures to ensure the accuracy of results.

In accordance with those requirements, the analysing laboratory will also be responsible for undertaking a range of QC/QA checks, (e.g. evaluation of sample preservation and holding times, relative performance differences (RPD) on duplicate samples, etc). The result of these QC/QA checks will be provided with the raw quality data in the report appendices.

All label information on each sampling bottle shall be completed while at the REMP site and checked during the completion of the Chain of Custody (COC) forms prior to sample dispatch. Sampling bottles containing dissolved water shall be appropriately demarcated as field filtered.

Each sample shall be clearly labelled, with sample details to be recorded on the sample jar in permanent marker. These details will then be recorded on the COC forms prior to the samples being dispatched. This process ensures samples can be readily tracked when sent to the laboratory for processing.

The COC's for each batch of samples are to be included in the coolers.

Cooler lids shall be taped with the security tape to ensure that any tampering is evident.

Data received from the laboratories shall be reviewed immediately following receipt to identify any anomalies that may require samples to be re-tested.

5.5.3 Data Interpretation

The interpretation of all results required under this REMP will be conducted in a professional manner by a suitably qualified and experienced person to ensure accuracy of interpretation and quality assurance.

6.0 REFERENCES

AARC Environmental Solutions Pty Ltd (AARC) 2013, *Mackenzie North Project: Aquatic Ecology Report*, report prepared for Jellinbah Resources Pty Ltd, July 2013.

Australian & New Zealand Environment & Conservation Council 2000, *Australian Water Quality Guidelines for Fresh and Marine Waters*, October 2000.

Chessman, B. 2003, SIGNAL 2 – *A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers*, Monitoring River Health Initiative Technical Report no 31, Commonwealth of Australia, Canberra.

Department of Environment and Heritage Protection (EHP) 2010, *Monitoring and Sampling Manual 2009 – Environmental Water (Protection) Policy 2009, Version 2*, State of Queensland, July 2013.

Department of Environment and Heritage Protection (EHP) 2011, *Environmental Protection (Water) Policy 2009 Mackenzie River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Mackenzie River Sub-basin*, State of Queensland, September 2011.

Department of Environment and Heritage Protection (EHP) 2014, *Receiving Environment Monitoring Program Guideline*, State of Queensland, May 2014.

Department of the Environment and Heritage 2003, *SIGNAL 2.iv – A scoring system for macroinvertebrates ('water bugs') in Australian rivers – user manual*, Australian Government.

Ison Environmental Planners 2010, *Receiving Environmental Monitoring Program – Jellinbah Coal Project*, report prepared for Jellinbah Mining Pty Ltd, October 2010.

Standards Australia 1999, *AS/NZS 5667.12:1999 Water Quality – Sampling. Part 12: Guidance on sampling of bottom sediments*, Standards Australia and Standards New Zealand, Homebush, NSW.

WRM Water & Environment 2013, *Mackenzie North Project: Surface Water Impact Assessment*, report prepared for Jellinbah Resources Pty Ltd, July 2013.

Appendix A Trigger Action Response Plan

<table>
<tr><th rowspan="2">Trigger Conditions</th><th>Level 1 Response</th><th>Level 2 Response</th><th>Level 3 Response</th></tr>
<tr><td>Reference Value (Upstream) > Impact Value (Downstream)</td><td>Impact Value (Downstream) > Reference Value (Upstream)</td><td>Impact Value (Downstream) > Reference Value (Upstream); and

First response determined significant or ongoing potential for environmental harm to occur</td></tr>
<tr><th colspan="4">Actions</th></tr>
<tr><td>First Response/Immediate Actions</td><td rowspan="3">No further action required</td><td colspan="2">1. Visually inspect relevant section of the waterway;
2. If applicable, identify the potential source of contaminants and stop the source (e.g. turn off pump);
3. If applicable, contain the spread of contaminants by implementing immediate mitigation measures (e.g. absorbent pads, or install sumps); and
4. Assess the potential for significant or ongoing environmental harm to occur.</td></tr>
<tr><td>Potential for Environmental Harm</td><td>No significant or ongoing potential for environmental harm to occur</td><td>Significant or ongoing potential for environmental harm to occur</td></tr>
<tr><td>Immediate Notification Requirements</td><td>No immediate notification requirements</td><td>In accordance with conditions A11 and A12 of the Jellinbah EA, administering authority must be notified of the incident by telephone or email. Details must be provided including the cause of incident, the potential for environmental harm and immediate actions taken etc. (see Jellinbah EA for further details and requirements)</td></tr>
</table>

A

Monitoring, Investigation and Reporting		If necessary, continue monitoring to ensure no significant or ongoing potential for environmental harm. Conduct a follow-up investigation/report if required.	Continue monitoring to ensure no additional potential for significant or ongoing environmental harm occurs. In accordance with condition A14 of the Jellinbah EA, results of any additional environmental monitoring conducted in response to a reported incident must be provided to the administering authority, as soon as practicable (but not more than **6 weeks** following the incident). See Jellinbah EA for further details. Conduct an investigation to identify the cause of environmental harm: • Review historical REMP data; • If available, review real-time monitoring gauge data; • If required, undertake additional site inspection; • Assess success of immediate mitigation measures; and • If required, recommend long-term mitigation and remediation measures to prevent a recurrence of contamination. In accordance with condition A13 of the Jellinbah EA, not more than

B

			14 days following the initial notification of an incident, written advice must be provided outlining the following: • Proposed actions to prevent a recurrence of the incident; and • Outcomes of actions taken at the time to prevent or minimise environmental harm.
Implement Long-term Mitigation Measures		No implementation of long-term mitigation measures necessary	Implement long-term mitigation measures to prevent the recurrence of environmental harm. Examples of long-term mitigation measures include: • Install new water management infrastructure; • Upgrade pipelines; • Modify or reshape drains; and/or • Review and update Water Management Plan.

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Appendix D4 Local Surface Water Quality Extended Dataset

Table D4-1 REMP Stream Water Quality Data – Dissolved Metals (2014-2018)

Dissolved Metals																					
Sampling Site	**Sampling Period**	**Parameter** **Aluminium**	**Arsenic**	**Barium**	**Beryllium**	**Boron**	**Cadmium**	**Chromium**	**Cobalt**	**Copper**	**Iron**	**Lead**	**Manganese**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Uranium**	**Vanadium**	**Zinc**	**Mercury**
Unit		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
LOR		**0.01**	**0.001**	**0.001**	**0.001**	**0.05**	**0.0001**	**0.001**	**0.001**	**0.001**	**0.05**	**0.001**	**0.001**	**0.001**	**0.001**	**0.01**	**0.001**	**0.001**	**0.01**	**0.005**	**0.0001**
Trigger level (95%)		**0.055**	**0.013**	**-**	**-**	**0.37**	**0.0002**	**0.001**	**-**	**0.0014**	**N/A**	**0.0034**	**1.9**	**-**	**0.011**	**0.018**	**0.00005**	**-**	**-**	**0.008**	**0.0006**
Trigger level (EA)		**0.055**	**0.013**	**-**	**-**	**0.37**	**0.0002**	**0.001**	**0.09**	**0.002**	**0.3**	**0.004**	**1.9**	**0.034**	**0.011**	**0.01**	**0.001**	**0.001**	**0.01**	**0.008**	**0.0002**
MP1 (Impact)	**Sep-14**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.02	0.002	0.149	0.001	0.18	0.0001	0.001	0.001	0.003	0.05	0.001	0.226	0.002	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.04	0.001	0.101	0.001	0.09	0.0001	0.001	0.001	0.004	0.05	0.001	0.003	0.003	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-17	1.62	0.004	0.269	0.001	0.16	0.0001	0.001	0.002	0.006	1.49	0.002	1	0.003	0.005	0.01	0.001	0.001	0.01	0.025	0.0001
	Apr-18	0.01	0.001	0.161	0.001	0.12	0.0001	0.001	0.001	0.002	0.05	0.001	0.085	0.004	0.001	0.01	0.001	0.001	0.01	0.008	0.0001
MP2S (Ref)	**Sep-14**	0.01	0.001	0.116	0.001	0.11	0.0001	0.001	0.001	0.003	0.05	0.001	0.002	0.002	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-15	0.01	0.001	0.386	0.001	0.09	0.0001	0.001	0.001	0.002	0.05	0.001	0.144	0.003	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.03	0.002	0.151	0.001	0.06	0.0001	0.001	0.001	0.002	0.05	0.001	0.019	0.002	0.002	0.01	0.001	0.001	0.01	0.007	0.0001
	Mar-17	0.36	0.003	0.162	0.001	0.1	0.0001	0.001	0.001	0.001	0.39	0.001	0.206	0.001	0.002	0.01	0.001	0.001	0.01	0.013	0.0001
	Apr-18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MP3 (Impact)	**Sep-14**	0.01	0.001	0.078	0.001	0.06	0.0001	0.001	0.001	0.002	0.05	0.001	0.008	0.001	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-15	0.01	0.001	0.033	0.001	0.05	0.0001	0.001	0.001	0.002	0.05	0.001	0.002	0.001	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.45	0.002	0.057	0.001	0.05	0.0001	0.001	0.002	0.005	0.37	0.001	0.118	0.001	0.004	0.01	0.001	0.001	0.01	0.01	0.0001
	Mar-17	0.95	0.001	0.154	0.001	0.05	0.0001	0.001	0.001	0.004	0.54	0.001	0.014	0.001	0.003	0.01	0.001	0.001	0.01	0.019	0.0001
	Apr-18	0.02	0.002	0.042	0.001	0.05	0.0001	0.001	0.001	0.003	0.05	0.001	0.012	0.001	0.001	0.01	0.001	0.001	0.01	0.008	0.0001
MP4 (Ref)	**Sep-14**	0.01	0.001	0.08	0.001	0.05	0.0001	0.001	0.001	0.002	0.05	0.001	0.004	0.001	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-15	0.01	0.001	0.04	0.001	0.05	0.0001	0.001	0.001	0.002	0.05	0.001	0.062	0.001	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.04	0.002	0.051	0.001	0.05	0.0001	0.001	0.001	0.002	0.06	0.001	0.037	0.001	0.003	0.01	0.001	0.001	0.01	0.005	0.0001

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Dissolved Metals																					
Sampling Site	Sampling Period	Parameter Aluminium	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Uranium	Vanadium	Zinc	Mercury
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR		0.01	0.001	0.001	0.001	0.05	0.0001	0.001	0.001	0.001	0.05	0.001	0.001	0.001	0.001	0.01	0.001	0.001	0.01	0.005	0.0001
Trigger level (95%)		0.055	0.013	-	-	0.37	0.0002	0.001	-	0.0014	N/A	0.0034	1.9	-	0.011	0.018	0.00005	-	-	0.008	0.0006
Trigger level (EA)		0.055	0.013	-	-	0.37	0.0002	0.001	0.09	0.002	0.3	0.004	1.9	0.034	0.011	0.01	0.001	0.001	0.01	0.008	0.0002
	Mar-17	0.27	0.002		0.001	0.05	0.0001	0.001	0.001	0.003	0.17	0.001	0.007	0.001	0.002	0.01	0.001	0.001	0.01	0.014	0.0001
	Apr-18	0.01	0.002	0.045	0.001	0.05	0.0001	0.001	0.001	0.002	0.05	0.001	0.004	0.001	0.001	0.01	0.001	0.001	0.01	0.005	0.0001
MP5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	0.02	0.002	0.04	0.001	0.05	0.0001	0.001	0.001	0.003	0.05	0.001	0.003	0.001	0.001	0.01	0.001	0.001	0.01	0.009	0.0001
DS5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.01	0.004	0.041	0.001	0.1	0.0001	0.001	0.001	0.001	0.1	0.001	0.168	0.001	0.004	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.18	0.004	0.014	0.001	0.05	0.0001	0.001	0.001	0.002	0.2	0.001	0.057	0.001	0.002	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-17	1.33	0.016		0.001	0.14	0.0001	0.001	0.001	0.004	1.19	0.001	0.1	0.003	0.005	0.01	0.001	0.001	0.01	0.005	0.0001
	Apr-18	0.01	0.003	0.033	0.001	0.09	0.0001	0.001	0.001	0.001	0.05	0.001	0.018	0.001	0.001	0.01	0.001	0.001	0.01	0.005	0.0001
US3 (Ref)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.01	0.002	0.07	0.001	0.09	0.0001	0.001	0.001	0.001	0.13	0.001	0.07	0.001	0.001	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	0.06	0.004	0.044	0.001	0.05	0.0001	0.001	0.001	0.002	0.07	0.001	0.001	0.002	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	0.01	0.004	0.065	0.001	0.11	0.0001	0.001	0.001	0.001	0.08	0.001	0.131	0.002	0.001	0.01	0.001	0.001	0.01	0.007	0.0001

Appendix D4 Local Surface Water Quality Extended Dataset

Table D4-2 REMP Stream Water Quality Data – Total Metals (2014-2018)

Total metals																					
Sampling Site	**Sampling Period**	**Parameter**																			
		Aluminium	**Arsenic**	**Barium**	**Beryllium**	**Boron**	**Cadmium**	**Chromium**	**Cobalt**	**Copper**	**Iron**	**Lead**	**Manganese**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Uranium**	**Vanadium**	**Zinc**	**Mercury**
Unit		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
LOR		**0.01**	**0.001**	**0.001**	**0.001**	**0.05**	**0.0001**	**0.001**	**0.001**	**0.001**	**0.05**	**0.001**	**0.001**	**0.001**	**0.001**	**0.01**	**0.001**	**0.001**	**0.01**	**0.005**	**0.0001**
Contaminant level (livestock drinking water)		**5**	**0.5 up to 5**	**-**	**-**	**5**	**0.01**	**1**	**1**	**1 (cattle)**	**Not sufficiently toxic**	**0.1**	**Not sufficiently toxic**	**0.15**	**1**	**0.02**	**-**	**0.2**	**-**	**20**	**0.002**
MP1 (Impact)	**Sep-14**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	10.4	0.005	0.271	0.001	0.17	0.0001	0.011	0.006	0.01	11.8	0.006	0.63	0.002	0.012	0.01	0.001	0.001	0.03	0.03	0.0001
	Mar-16	4.74	0.014	0.137	0.001	0.11	0.0001	0.005	0.002	0.024	4.94	0.003	0.125	0.004	0.008	0.01	0.001	0.001	0.01	0.015	0.0001
	Mar-17	16.2	0.009	0.427	0.001	0.17	0.0001	0.017	0.012	0.02	18.8	0.013	1.73	0.004	0.024	0.01	0.001	0.001	0.04	0.046	0.0001
	Apr-18	1.62	0.002	0.218	0.001	0.13	0.0001	0.002	0.002	0.005	1.81	0.001	0.176	0.004	0.004	0.01	0.001	0.001	0.01	0.015	0.0001
MP2S (Ref)	**Sep-14**	1.83	0.002	0.148	0.001	0.12	0.0001	0.002	0.001	0.004	1.8	0.001	0.076	0.001	0.004	0.01	0.001	0.001	0.01	0.006	0.0001
	Mar-15	0.25	0.001	0.424	0.001	0.12	0.0001	0.001	0.001	0.002	0.22	0.001	0.234	0.005	0.002	0.01	0.001	0.001	0.01	0.019	0.0001
	Mar-16	1.08	0.003	0.189	0.001	0.05	0.0001	0.001	0.001	0.003	1.2	0.001	0.282	0.001	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-17	2.82	0.005	0.161	0.001	0.1	0.0001	0.002	0.002	0.004	3.45	0.002	0.594	0.001	0.005	0.01	0.001	0.001	0.01	0.01	0.0001
	Apr-18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MP3 (Impact)	**Sep-14**	0.19	0.001	0.088	0.001	0.05	0.0001	0.001	0.001	0.004	0.21	0.001	0.02	0.001	0.003	0.01	0.001	0.001	0.01	0.033	0.0001
	Mar-15	7.19	0.002	0.071	0.001	0.05	0.0001	0.012	0.002	0.007	7.74	0.002	0.086	0.001	0.012	0.01	0.001	0.001	0.02	0.015	0.0001
	Mar-16	5.14	0.002	0.08	0.001	0.05	0.0001	0.008	0.002	0.006	4.97	0.001	0.105	0.001	0.011	0.01	0.001	0.001	0.02	0.01	0.0001
	Mar-17	4.91	0.002	0.142	0.001	0.05	0.0001	0.004	0.002	0.007	4.53	0.002	0.099	0.001	0.007	0.01	0.001	0.001	0.01	0.014	0.0001
	Apr-18	2.74	0.002	0.071	0.001	0.06	0.0001	0.004	0.001	0.005	2.92	0.001	0.048	0.001	0.007	0.01	0.001	0.001	0.02	0.014	0.0001
MP4 (Ref)	**Sep-14**	0.29	0.001	0.092	0.001	0.06	0.0001	0.001	0.001	0.002	0.32	0.001	0.028	0.001	0.002	0.01	0.001	0.001	0.01	0.007	0.0001
	Mar-15	0.01	0.001	0.04	0.001	0.05	0.0001	0.001	0.001	0.002	0.05	0.001	0.061	0.001	0.003	0.01	0.001	0.001	0.01	0.005	0.0001
	Mar-16	3.62	0.002	0.071	0.001	0.05	0.0001	0.006	0.002	0.006	3.56	0.001	0.1	0.001	0.008	0.01	0.001	0.001	0.02	0.008	0.0001

Appendix D4 Local Surface Water Quality Extended Dataset

Total metals																					
Sampling Site	**Sampling Period**	**Parameter** **Aluminium**	**Arsenic**	**Barium**	**Beryllium**	**Boron**	**Cadmium**	**Chromium**	**Cobalt**	**Copper**	**Iron**	**Lead**	**Manganese**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Uranium**	**Vanadium**	**Zinc**	**Mercury**
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR		0.01	0.001	0.001	0.001	0.05	0.0001	0.001	0.001	0.001	0.05	0.001	0.001	0.001	0.001	0.01	0.001	0.001	0.01	0.005	0.0001
Contaminant level (livestock drinking water)		5	0.5 up to 5	-	-	5	0.01	1	1	1 (cattle)	Not sufficiently toxic	0.1	Not sufficiently toxic	0.15	1	0.02	-	0.2	-	20	0.002
	Mar-17	3	0.002	0.102	0.001	0.05	0.0001	0.002	0.001	0.005	2.64	0.001	0.082	0.001	0.004	0.01	0.001	0.001	0.01	0.008	0.0001
	Apr-18	1.74	0.002	0.074	0.001	0.06	0.0001	0.002	0.001	0.004	1.86	0.001	0.048	0.001	0.006	0.01	0.001	0.001	0.01	0.022	0.0001
MP5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	1.98	0.002	0.064	0.001	0.06	0.0001	0.002	0.001	0.005	2.07	0.001	0.03	0.001	0.005	0.01	0.001	0.001	0.01	0.009	0.0001
DS5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	6.47	0.006	0.092	0.001	0.08	0.0001	0.008	0.004	0.008	8.13	0.003	0.236	0.001	0.012	0.01	0.001	0.001	0.02	0.019	0.0001
	Mar-16	1.7	0.005	0.022	0.001	0.05	0.0001	0.002	0.001	0.003	2.38	0.001	0.094	0.001	0.004	0.01	0.001	0.001	0.01	0.006	0.0001
	Mar-17	2.06	0.019	0.009	0.001	0.14	0.0001	0.003	0.002	0.004	2.85	0.001	0.22	0.003	0.006	0.01	0.001	0.001	0.01	0.007	0.0001
	Apr-18	0.78	0.004	0.047	0.001	0.1	0.0001	0.001	0.001	0.003	0.99	0.001	0.07	0.002	0.005	0.01	0.001	0.001	0.01	0.009	0.0001
US3 (Ref)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.04	0.002	0.073	0.001	0.06	0.0001	0.001	0.001	0.001	0.55	0.001	0.065	0.001	0.001	0.01	0.001	0.001	0.01	0.007	0.0001
	Mar-16	1.93	0.007	0.058	0.001	0.05	0.0001	0.003	0.002	0.003	2.65	0.001	0.211	0.002	0.006	0.01	0.001	0.001	0.01	0.006	0.0001
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	0.1	0.003	0.08	0.001	0.12	0.0001	0.001	0.001	0.001	0.45	0.001	0.139	0.002	0.003	0.01	0.001	0.001	0.01	0.005	0.0001

Appendix D4 Local Surface Water Quality Extended Dataset

Table D4-3 REMP Stream Water Quality Data – Major Cations and Anions (2014-2018)

Sampling Site	Sampling Period	Major Cations and Anions													
		Ammonia as N	Nitrate as N	Oxidised nitrogen	Sulfate as SO4-	Chloride	Fluoride	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Calcium	Magnesium	Sodium	Potassium
LOR		0.01	0.01	0.01	1	1	0.1	1	1	1	1	1	1	1	1
Trigger level (EA)		0.9	1.1	-	250	-	2	-	-	-	-	-	-	180	-
EPP Criteria		0.02	-	0.06	10	-	-	-	-	-	-	-	-	-	-
MP1 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.07	0.06	0.06	41	426	0.9	1	1	190	190	24	14	301	9
	Mar-16	0.03	0.04	0.04	72	270	0.4	1	1	111	111	19	12	197	5
	Mar-17	0.32	0.32	n/a	148	39	n/a	1	1	208	208	26	15	143	12
	Apr-18	0.03	0.01	n/a	92	369	0.4	1	1	152	152	31	19	250	8
MP2 (Ref)	Sep-14	0.09	0.03	0.03	22	96	n/a	n/a	1	199	199	27	15	99	10
	Mar-15	0.02	0.01	0.01	316	589	0.7	1	7	108	115	104	45	329	14
	Mar-16	0.02	0.04	0.04	46	146	0.3	1	1	170	170	35	14	111	9
	Mar-17	0.04	0.01	n/a	65	17	n/a	1	1	135	135	25	9	62	8
	Apr-18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MP3 (Impact)	Sep-14	0.1	0.01	0.01	19	116	n/a	1	1	141	141	30	20	74	6
	Mar-15	0.03	0.3	0.3	7	23	0.5	1	1	76	76	15	8	20	5
	Mar-16	0.06	0.24	0.24	12	30	0.1	1	1	93	93	20	9	29	5
	Mar-17	0.03	0.07	n/a	43	9	n/a	1	1	90	90	18	10	36	6
	Apr-18	0.04	0.21	n/a	7	22	0.2	1	1	93	93	16	8	23	6
MP4 (Ref)	Sep-14	0.06	0.01	0.01	24	119	n/a	1	1	142	142	30	20	74	6
	Mar-15	0.04	0.3	0.3	7	24	0.6	1	1	78	78	16	8	21	5
	Mar-16	0.05	0.2	0.2	12	35	0.1	1	1	93	93	18	9	30	5
	Mar-17	0.03	0.03	n/a	67	11	n/a	1	1	122	122	23	15	49	6
	Apr-18	0.01	0.19	n/a	7	24	0.2	1	1	93	93	16	8	24	6
MP5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Appendix D4 Local Surface Water Quality Extended Dataset

Sampling Site	Sampling Period	Major Cations and Anions													
		Ammonia as N	Nitrate as N	Oxidised nitrogen	Sulfate as SO4-	Chloride	Fluoride	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Calcium	Magnesium	Sodium	Potassium
LOR		0.01	0.01	0.01	1	1	0.1	1	1	1	1	1	1	1	1
Trigger level (EA)		0.9	1.1	-	250	-	2	-	-	-	-	-	-	180	-
EPP Criteria		0.02	-	0.06	10	-	-	-	-	-	-	-	-	-	-
	Mar-15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	0.01	0.09	n/a	7	21	0.2	1	1	91	91	16	8	22	6
DS5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.08	0.01	0.01	13	32	0.8	1	1	188	188	20	8	66	10
	Mar-16	0.03	0.01	0.01	12	38	0.2	1	1	88	88	14	7	39	5
	Mar-17	0.03	0.01	n/a	246	4	n/a	1	84	119	203	13	8	209	14
	Apr-18	0.04	0.01	n/a	2	46	0.3	1	1	162	162	23	11	56	8
US3 (Ref)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	0.02	0.02	0.02	1	280	0.8	1	1	170	170	40	18	161	8
	Mar-16	0.06	0.01	0.01	4	13	0.2	1	1	143	143	21	10	30	5
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	0.04	0.01	n/a	1	88	0.3	1	1	291	291	35	22	95	17

Appendix D4 Local Surface Water Quality Extended Dataset

Table D4-4 REMP Stream Water Quality Data – Physico-chemical (2014-2018)

Parameter	Sampling Period	Field pH		Field Temp (°C)	Field DO (%)	Field EC (µ S/cm)		Field TDS (mg/L)	Field ORP (mV)	Turbidity (NTU)	Suspended Solids (mg/L)	Petroleum Hydrocarbon (µg/L)	
Trigger Level (EA)		Blackwater Creek < 6.5 or > 9	Mackenzie River < 6.5 or > 8.5	-	-	Blackwater Creek > 1000	Mackenzie River > 400	-	-	N/A	690	C6-C9 Fraction	C10 – C36 Fraction
EPP Criteria		6.5–8.5		-	85–110	Base flow < 310	High flow < 210	-	-	50	110*	LOR: 20 Trigger Level (EA): 20	LOR: 50 Trigger Level (EA): 100
MP1 (Impact)	Sep-14	n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	7.92		30.7	56	1782		1157	-2.3	519	66	<20	<50
	Mar-16	7.95		25.3	49.31	1178		1172	57.6	337	76	<20	<50
	Mar-17	8.2		28.4	2.9	908			120.5	838	142	<20	<50
	Apr-18	7.9		21.1		1550		1012.8		90	24	<20	<50
MP2 (Ref)	Sep-14	8.23		16.3	66.9	312		203.8	59.6	95	57	<20	<50
	Mar-15	8.72		30	171.5	2637		1716	31.9	22	22	<20	<50
	Mar-16	8.22		26.9	56.04	875		845	44.2	70.4	44	<20	150
	Mar-17	8.4		29.1	4.6	505			93.2	150	57	<20	<50
	Apr-18	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	<20	<50
MP3 (Impact)	Sep-14		8.05	22.7	105.5		270.5	174.2	37.4	15	16	<20	<50
	Mar-15		7.66	27.3	46.3		258	167.7	21.3	256	62	<20	<50
	Mar-16		7.81	29.7	45.23		325.7	299	22.7	155	45	<20	<50
	Mar-17		8.1	31.9	9.89		370		185	242	106	<20	<50
	Apr-18		7.98	23.6			265	176.4		90	22	<20	<50
MP4 (Ref)	Sep-14		n/a	21.4	113		340	218.4	107.3	11	12	<20	<50
	Mar-15		7.74	29.5	55.8		261.4	169.7	23.1	254	164	<20	<50
	Mar-16		7.55	28.8	46.07		335.2	312.7	34.5	304	44	<20	<50
	Mar-17		8.26	28.5	3.9		482		159.1	120	66	<20	<50
	Apr-18		8.07	23.1			279	184		90	24	<20	n/a
MP5 (Impact)	Sep-14		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a

Appendix D4 Local Surface Water Quality Extended Dataset

Parameter	Sampling Period	Field pH		Field Temp (°C)	Field DO (%)	Field EC (µ S/cm)		Field TDS (mg/L)	Field ORP (mV)	Turbidity (NTU)	Suspended Solids (mg/L)	Petroleum Hydrocarbon (µg/L)	
Trigger Level (EA)		Blackwater Creek < 6.5 or > 9	Mackenzie River < 6.5 or > 8.5	-	-	Blackwater Creek > 1000	Mackenzie River > 400	-	-	N/A	690	C6-C9 Fraction	C10 – C36 Fraction
EPP Criteria		6.5–8.5		-	85–110	Base flow < 310	High flow < 210	-	-	50	110*	LOR: 20 Trigger Level (EA): 20	LOR: 50 Trigger Level (EA): 100
	Mar-16		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-17		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18		8.01	23			266	176.25		90	14	<20	<50
DS5 (Impact)	Sep-14	n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	7.15		27.3	1.2	505		325	-138.5	224	321	<20	<50
	Mar-16	8.74		32.3	116.06	370.7		324	37.5	64.2	21	<20	<50
	Mar-17	9.95		28	10.6	1095			104.8	84	50	<20	390
	Apr-18	7.97		23.7		473		312.3		90	24	<20	<50
US3 (Ref)	Sep-14	n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	7.09		26.2	6.7	1186		773.5	-39.5	33.3	n/a	<20	<50
	Mar-16	7.29		24	26.85	311.5		318.1	33.5	110	21	<20	<50
	Mar-17	n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	7.64		22.9		804		533.13		90	13	<20	140

^ XX Indicates an exceedance of ANZECC (2000) water quality trigger values for the protection of aquatic ecosystems or livestock drinking water.
Indicates an exceedance of the relevant EPP (Water) WQO (i.e. the protection of aquatic ecosystems, or livestock drinking water)

.

Table D4-5 REMP Stream Water Quality Data – Petroleum Hydrocarbon (2014-2018)

Sampling Site	Sampling Period	Total Abundance	Taxa Richness	SIGNAL 2 Score	PET Taxa	% tolerant taxa	SIGNAL Count
EPP WQO (Composite)		-	12 – 21	3.33 – 3.85	2 – 5	25 - 50 %	-
MP1 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	59	14	3.2	1	58.33	12
	Mar-16	32	11	3.12	3	11.11	9
	Mar-17	13	3	1.67	0	100	2
	Apr-18	50	14	3.13	0	50	12
MP2 (Ref)	Sep-14	8	8	2.9	1	42.86	7
	Mar-15	19	12	3.15	0	60	10
	Mar-16	9	6	2.83	0	66.67	6
	Mar-17	45	13	2.9	0	83.33	12
	Apr-18	n/a	n/a	n/a	n/a	n/a	n/a
MP3 (Impact)	Sep-14	11	11	3.7	2	37.5	8
	Mar-15	15	9	2.89	0	57.14	7
	Mar-16	23	11	2.71	1	50	10
	Mar-17	27	10	1.94	0	100	8
	Apr-18	25	12	2.67	0	54.55	11
MP4 (Ref)	Sep-14	10	10	2.8	1	50	8
	Mar-15	7	6	3	0	50	6
	Mar-16	21	8	3.45	1	50	8
	Mar-17	28	9	1.57	0	100	7
	Apr-18	19	11	3.45	1	40	10
MP5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-16	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	65	19	3.33	1	43.75	16
DS5 (Impact)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	86	12	3.09	0	66.67	9
	Mar-16	89	13	2.48	1	63.64	11
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	64	18	2.57	1	66.67	15
US3 (Ref)	Sep-14	n/a	n/a	n/a	n/a	n/a	n/a
	Mar-15	137	20	2.34	0	58.82	17
	Mar-16	57	9	2.53	1	62.5	8
	Mar-17	n/a	n/a	n/a	n/a	n/a	n/a
	Apr-18	245	26	2.6	1	0	23

indicates an exceedance of the relevant EPP WQO

JELLINBAH RESOURCES

Central North Pit Final Void Hydrology Study

Central North Extension Assessment




October 2019

M61000_022-REP-001

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M61000_002 CENTRAL NORTH PIT FINAL VOID HYDROLOGY STUDY						
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REV	DESCRIPTION	AUTHOR	REVIEWER	PROJECT MANAGER	PROJECT DIRECTOR	DATE
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1. INTRODUCTION

1.1 Background

Jellinbah Mine is an open-cut coal operation located approximately 25 km north of the township of Blackwater in central Queensland. Mining activities at Jellinbah Coal Mine are approved under Environmental Authority (EA) EPML00516813 (DEHP, 2017).

The Jellinbah Central North Extension (CNE) is a proposed expansion of the existing Jellinbah Central North (CN) open-cut coal mine which include three (3) additional mining leases. The proposed extension will extend the operational life of the mine by 20 years and contribute 1 Mt per annum (Mtpa) run-of-mine (ROM) coal. The current approved operating protocols will be unchanged.

The Australian Government Department of the Environment and Energy has requested the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) to provide advice on the Jellinbah Coal Mine CNE.

Engeny Water Management (Engeny) was commissioned to assist Jellinbah Resources respond to queries raised by IESC associated with surface water and final voids.

1.2 Project Questions and Summary of Response

The key objective of the current assessment is to provide responses to the IESC information request (IESC, 2019). The IESC's relevant questions to the CNE final void and summary of responses and reference to further discussion in the report is provided in Table 1.1.

Table 1.1 IESC Advices and Responses

Advice No.	IESC Advice	Response & Reference
13	The proposed mine plan will result in an extension of an existing approved void (the Central North void) in the project area whose water is predicted to continue to increase in salinity until saturation is reached and salts precipitate. This void will pose multiple and ongoing risks to the environment. It will also not support fringing vegetation or aquatic biota typical of natural freshwater floodplain wetlands. Consideration should also be given to how this higher density saline water may affect groundwater flow (i.e. the void may no longer behave as a groundwater sink due to the density contrast between void water and underlying groundwater) and quality. The IESC suggests	The estimated water levels in the Central North final void including the proposed extension and the interconnected Central final void will be significantly lower than the spill level to receiving environment for all scenarios investigated including the climate change scenarios. In addition, while the final voids water quality (i.e. salinity) is expected to increase due to lower predicted water levels in the climate change scenarios, the estimated final void water level is significantly lower than the spill

Advice No.	IESC Advice	Response & Reference
	modelling of final void water quality should also be conducted with consideration of future climatic regimes as discussed in Paragraph 9.	level to receiving environment (i.e. final voids will act as sinks).
16a	Given the proximity and number of mining operations near the project area, cumulative impacts are highly likely. These cumulative impacts may include: a. pulses of potentially hypersaline water from one or more final voids that may be released to the floodplain or groundwater systems during a large flood event;	A flood modelling was undertaken by WRM indicating that the final voids are located outside the 1:1000 AEP flood extent. While the estimated water quality in Central North, CNE and Central North final voids will be hypersaline, the current assessment indicated that the final voids will remain as a sink and equilibrium water level in these voids will be significantly lower than the spill level to the receiving environment. In addition, likelihood of a saline pulse to groundwater occurring as a reasonable to flooding is very small.
29	The IESC notes that while the proposed project will result in the modification of a single approved void in the Jellinbah Central mine, the other mines in the broader Jellinbah operation will result in a further six final voids. All seven of these voids will have a lasting cumulative impact. The final voids pose long-term risks to biota from deteriorating water quality, especially increasing salinity. The proponent should work collaboratively with other operators to provide a mitigation plan for minimising impacts on wildlife and outline how these strategies will be monitored to assess their success.	The current assessment indicated that the estimated water levels at Central North void with proposed extension and Central North final voids will be significantly lower than the spill level to the receiving environment. The other final voids in Jellinbah Mine have been assessed previously (Engeny, 2018). Modelling results indicated that all final voids will remain well below the spill level and do not pose a risk of uncontrolled overflow to the receiving environment. In addition, none of the final voids in Jellinbah Mine will present a seepage risk to groundwater system as discussed in Jellinbah Final Void Hydrology Study (Engeny, 2018).
31	Both the Mackenzie North and Plains voids were modelled, with the results showing that final void water will be below the base of the alluvium (AARC 2018, p. 8). The modelling, however, does not examine the effects of extreme events nor the changes in contributing catchment areas arising from mining activities. It may be possible for water levels in both the Mackenzie North and Jellinbah Plains voids to rise above the base of the alluvium providing a connection between the void and the surrounding	Both Mackenzie North and Plans final void assessment were undertaken previously by Engeny (2018). These two final voids are not related to proposed actions for Central North Extension. The Central North void including the proposed extension is located 10 km south of Mackenzie River. The final void assessment (Engeny,2018) indicate that all final voids in

Advice No.	IESC Advice	Response & Reference
	environment. The saline void water could then discharge into aquifers or the surrounding surface environment via the alluvium. Given the proponent has stated the final voids will be a contaminated saline water sink, this has the potential to impact on the receiving environments and downstream ecosystems. The proponent should examine the effects of successive high-rainfall years on void water levels to ensure that discharge from final voids to the environment cannot occur through the alluvium.	Jellinbah Mine will remain as sink to groundwater and will not spill to receiving environment. The long-term climate data used in this assessment include several historical extreme events such as 2011 flooding event (Figure 3 1). The water balance model results indicated no discharge from CNE final void to receiving environment for all extreme events as discussed in Section 4.1. The impacts of climate change have been assessed in Section 4.2 which show no overflow to receiving environment from Central North including proposed extension and Central final voids. It should be noted that the proposed extension to Central North final void will cause a small increase in void equilibrium water level (~0.14m) and negligible change in water quality (i.e. salinity).

2. FINAL VOID DESIGNS

2.1 Final Landform Arrangements

Figure 2.1 and Figure 2.2 present the adopted final landform catchments and surfaces for Central North void with and without the extension based on existing topography and provided final void surfaces from Minserve (2018). Final landform drains were incorporated to divert external catchments where possible to reduce the volume of runoff reporting to the voids.

Potential seepage paths through backfilled spoil, from Central North to Central, were identified. These connections were simulated to quantify effect and magnitude.

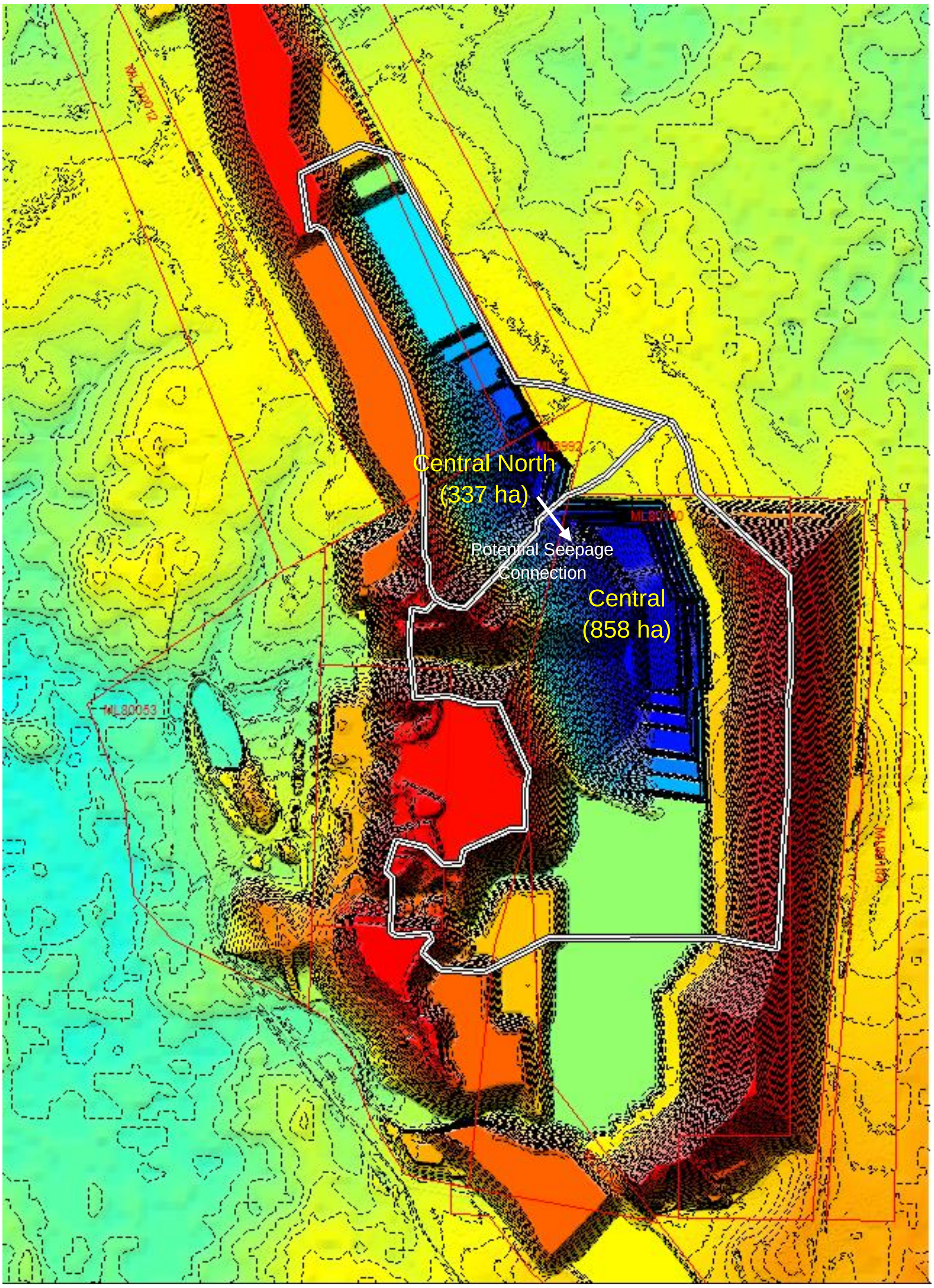

Figure 2.1 Central North without Extension Final Void Arrangements

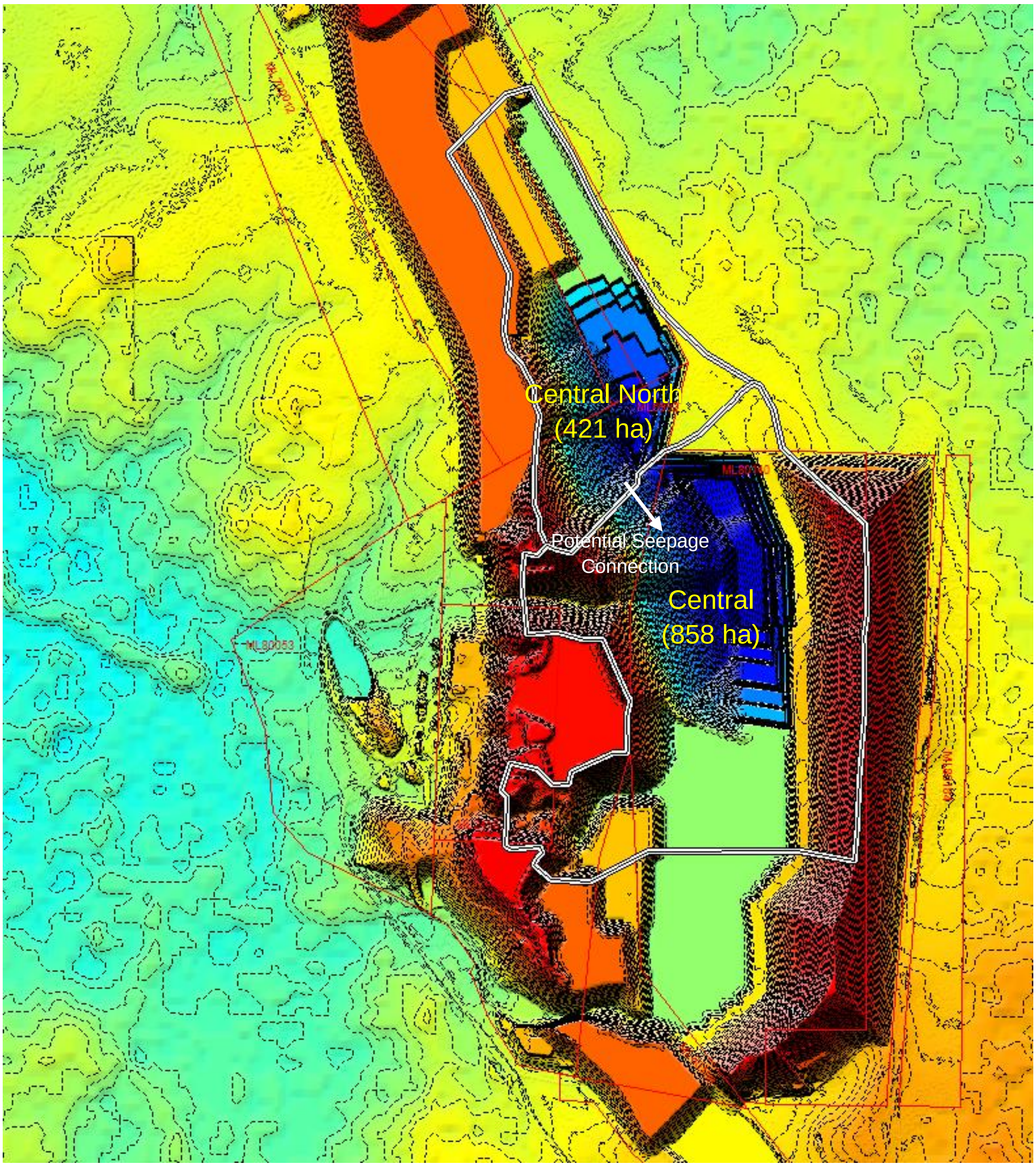

Figure 2.2 Central North with Extension Final Void Arrangements

3. WATER BALANCE MODELLING APPROACH

3.1 Overview

The post-closure water and salt balance of the Jellinbah Mine was simulated using the GoldSim software. GoldSim is a general-purpose software package for simulating complex systems in engineering, science and business. All inputs and assumptions are outlined in the subsequent sections.

The water balance model of the final voids utilises a daily time step, and simulates rainfall, runoff, evaporation, groundwater ingress, overflows (where applicable) and the long-term void lake water quality changes as a result of these flows.

3.2 Final Surfaces

The Central North final void with and without concept design landforms were provided by Jellinbah Mine. These designs were used to develop storage curves and catchments for the final voids.

3.3 Climate Data

Jellinbah Mine has a sub-tropical climate, dominated by a wet humid summer and dry winter. Long-term climate for Jellinbah Mine was obtained from the SILO climate database facility hosted by the Department of Science, Information Technology, and Innovation (DSITI). A SILO Patched Point Data climate series was obtained for the New Caledonia Station (35132), which is located about 5 km from Jellinbah Mine. This site is considered to be representative of Jellinbah Mine site rainfall and the data set ranges back to January 1889. Table 3.1 presents a summary of this data.

Table 3.1 Average Climate Data Statistics for New Caledonia Station (BoM, 2018)

Month	Mean Rainfall (mm)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Morton's Lake Evap. (mm)
Jan	95.0	33.7	21.6	205
Feb	83.7	32.9	21.4	171
Mar	59.5	31.9	20.1	172
Apr	30.3	29.4	16.5	133
May	30.5	26.1	12.3	101
June	30.5	23.3	9.4	79
July	25.2	23.0	7.8	88

Month	Mean Rainfall (mm)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Morton's Lake Evap. (mm)
Aug	18.0	25.0	9.4	116
Sept	22.7	28.2	12.8	150
Oct	40.1	30.8	16.5	187
Nov	55.2	32.4	18.9	199
Dec	86.5	33.7	20.7	212
Annual	**577.2**	**-**	**-**	**1812**

The long-term climate data used in this assessment include several historical extreme events such as 2011 flooding event (Figure 3.1).

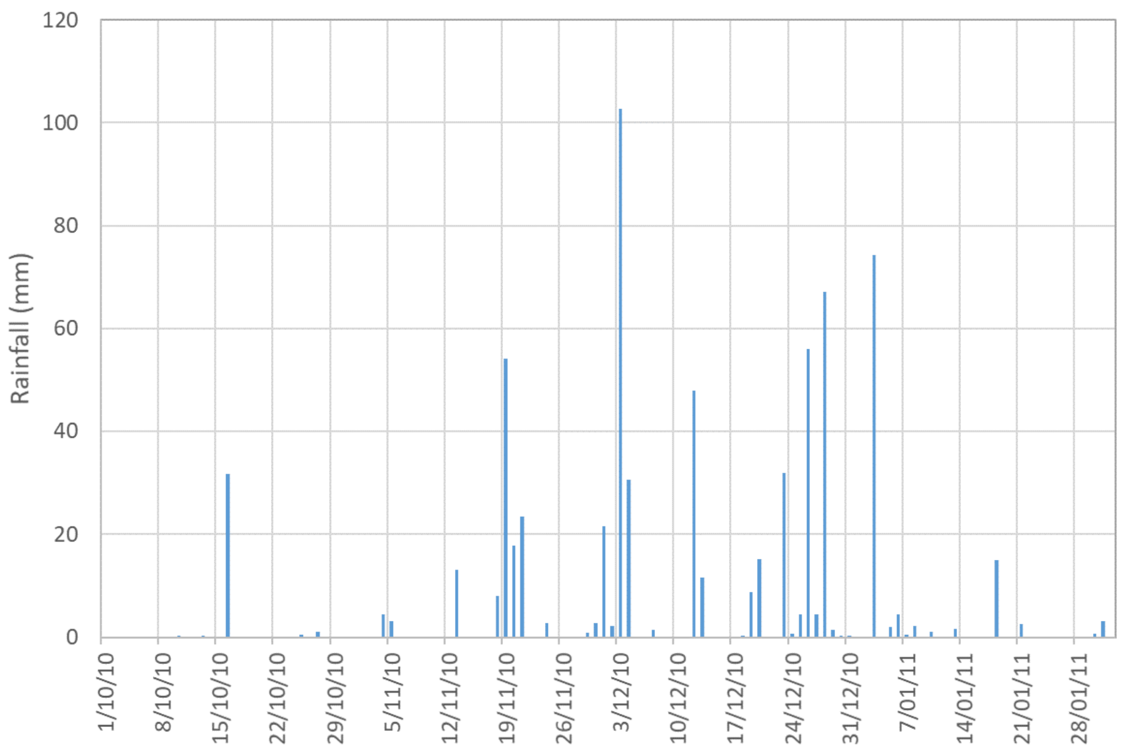

Figure 3.1 Recorded Rainfall Depths for the 2011 Flood Event

Morton's lake evaporation represents a theoretical calculation of lake evaporation based on other observed climate parameters. Morton's lake evaporation was used to calculate the evaporation rate from the void lakes.

Corrections to the lake evaporation rates were applied in the final void water balance model to reflect the reduction to the freshwater evaporation rate that occurs for a saline water body. The evaporation reduction relationship proposed by Grayson, et al. (1996) was utilised as follows:

- Evaporation reduction factor = $1/[1+\text{TDS (mg/L)}/10^6]$

This equation predicts a relatively small evaporation correction for salinity of approximately 1% reduction per 10,000 mg/L total dissolved solids (TDS) for TDS values up to 50,000 mg/L (i.e. 5% reduction for 50,000 mg/L TDS).

3.4 Catchment Runoff

Catchment runoff has been simulated using the Australian Water Balance Model (AWBM). A schematic representation of the AWBM model is provided in Figure 3.2. The model represents the catchment using three surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated independently of the others. The model calculates the water balance of each partial area at daily time steps. 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.

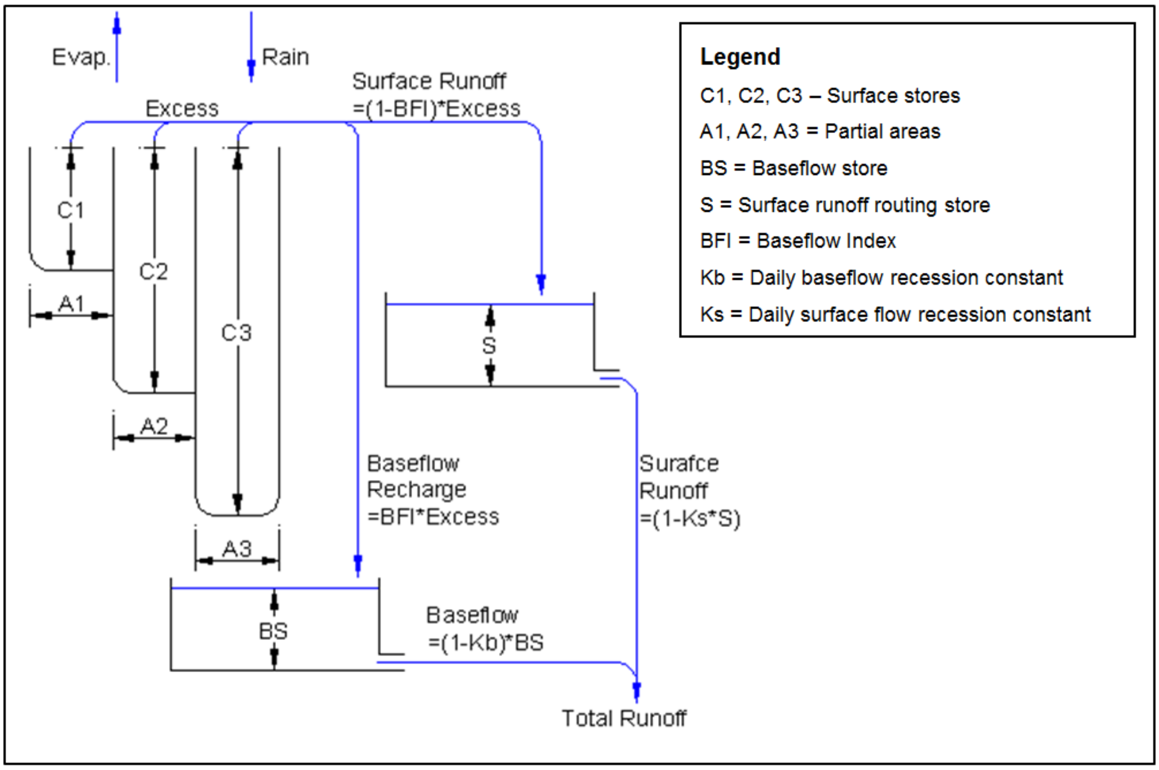

Figure 3.2 AWBM Schematic

The adopted AWBM parameters are shown in Table 3.2. These parameters are consistent with those adopted for the Jellinbah Mine water balance models. Pit and rehabilitated spoil AWBM land use catchment runoff parameters were adopted from parameters developed for similar sites in the Bowen Basin. AWBM natural land use catchment runoff parameters have been adopted from parameters calibrated to the streamflow gauging station at Blackwater Creek at Curragh (130108).

Table 3.2 Adopted AWBM Runoff Parameters

Land Use	C1 (mm)	C2 (mm)	C3 (mm)	A1	A2	A3	BFI	Kb	Ks
Natural	25.	95	230	0.134	0.433	0.433	0.03	0.98	0.50
Rehab Spoil	11	60	130	0.134	0.433	0.433	0.00	0.60	0.00
Pit	10	25	50	0.134	0.433	0.433	0.10	0.60	0.10

Blackwater Creek gauging station was considered the most suitable gauge as it has a similar catchment landuse, a long streamflow record and an accurate flow control structure. Blackwater Creek at Curragh (Station Number 130108) gauging station commenced in August 1972 and closed in May 2009. The results of the calibration are shown in Figure 3.3 and Figure 3.4.

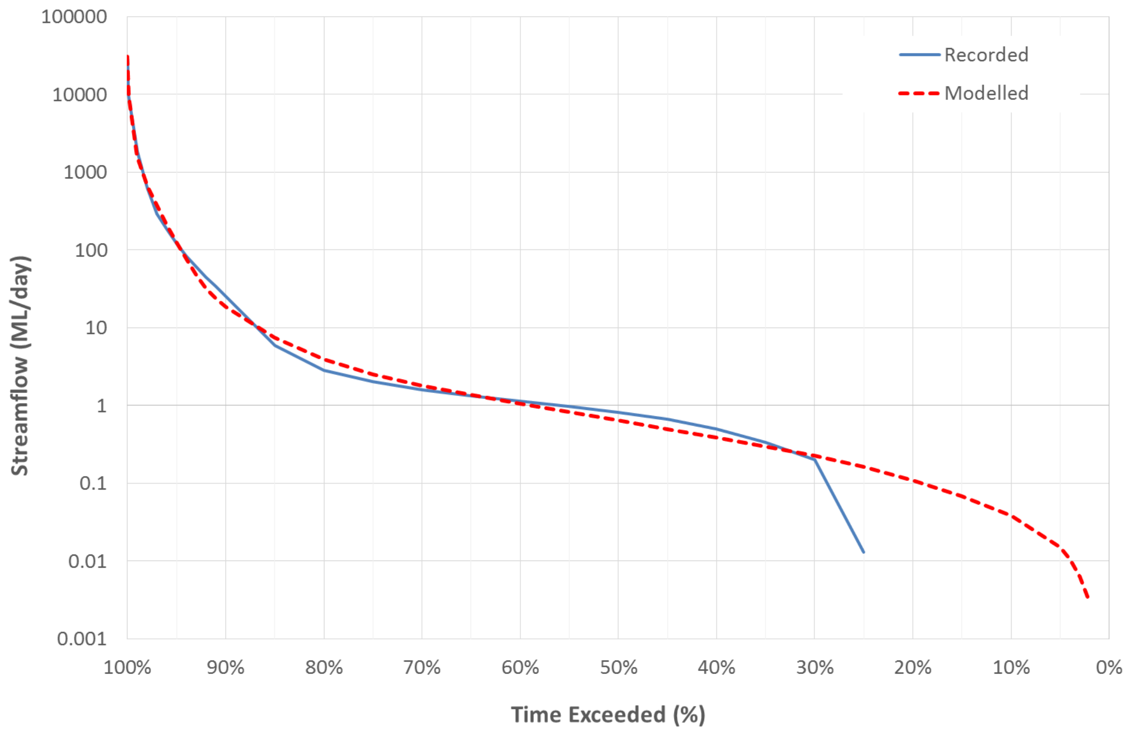

Figure 3.3 Modelled Flow Duration Curve for Blackwater Creek at Curragh

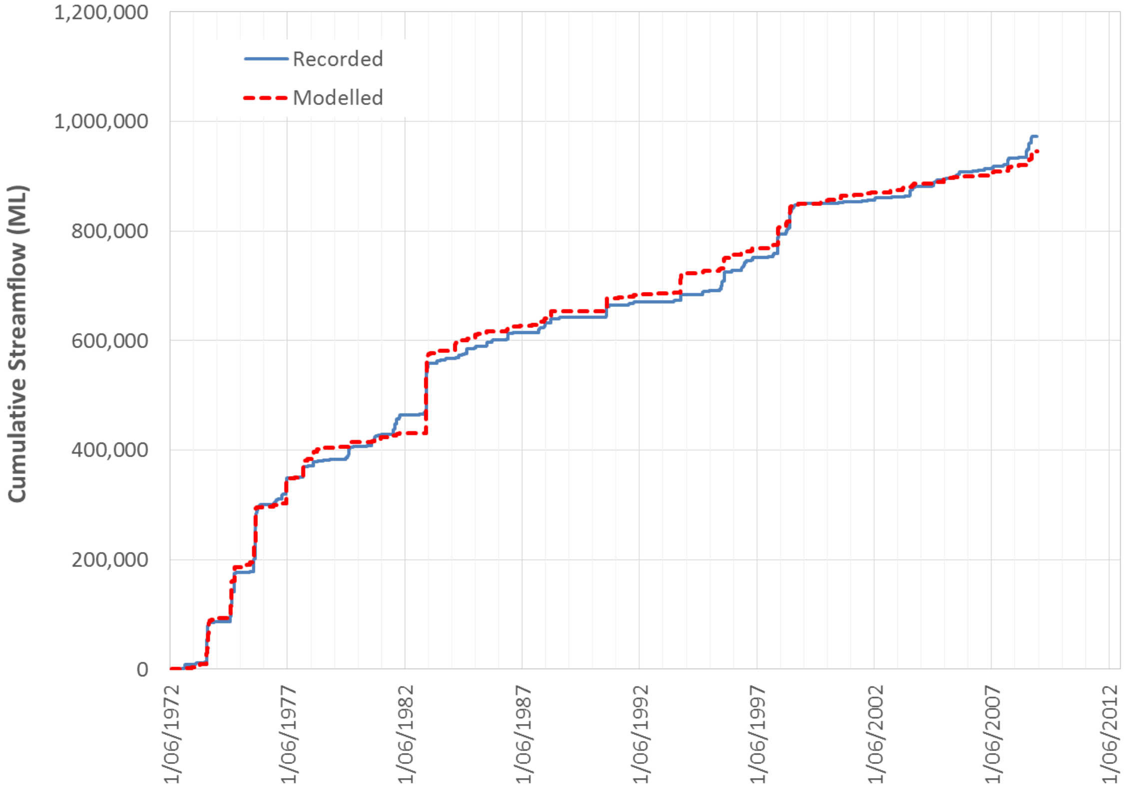

Figure 3.4 Modelled Cumulative Streamflows for Blackwater Creek at Curragh

3.5 Groundwater Interactions

Long-term estimated groundwater inflow rates for Central North were provided by JBT Consulting (2018) and are summarised in Table 3.3.

Table 3.3 Groundwater Inflow Estimates from JBT Consulting

Jellinbah Mine Void	Inflow from Alluvium	Inflow from Permian Coal Measures
Central North	-	0.3 ML/day
Central	-	0.3 ML/day

3.6 Inter-void Seepage

Potential seepage connections were identified through backfilled spoil, which has a higher hydraulic conductivity than in-situ material, from Central North to Central as indicated in Figure 2.1.

Darcy's law was used to develop seepage flow rate (Q) estimates, using the cross-sectional area to flow A, the difference in hydraulic head Δh, the seepage path length L and hydraulic conductivity K.

$$Q = \frac{KA\Delta h}{L}$$

A horizontal hydraulic conductivity of 1 m/day was adopted by AGE for numerical groundwater modelling (AGE, 2013). This value is significantly higher than other observed spoil values at similar sites but was adopted to provide an upper estimate of seepage potential.

Water balance modelling was conducted with and without allowing for seepage. The results presented show the highest final void levels between these simulations i.e. seepage was modelled for the receiving void results (i.e. Central) and excluded for the source void results (i.e. Central North).

3.7 Water Quality

3.7.1 Inputs

The final void water balance model includes a salt balance for the void lakes. Table 3.4 presents a summary of the water quality (salinity) parameters adopted for the final void water balance model.

Table 3.4 Water Quality Input Summary

Input	Value	Source
Runoff – Rehabilitated Spoil	1,000 µS/cm	Based on water quality monitoring data for South West Dam (primarily rehabilitated catchment). Similar to nearby mine sites.
Runoff – Natural Catchments	(300 x Runoff(mm) $^{-0.19}$) µS/cm, with maximum of 450µS/cm	Parameters from nearby coal mine sites
Direct Rainfall	4 mg/L	Based on latitude and distance from coast, Salinity Management Handbook (DNR, 1997)
Groundwater Inflow	450 mg/L – Alluvial 17,150 mg/L - Permian coal measures	Averages of ranges presented in the Groundwater Impact Assessment by AGE (2006)

3.7.2 Salinity EC Conversion

The water balance model calculates the TDS for each of the water storages and receiving waterways using a salt mass balance approach. As regulatory compliance and the majority of monitoring is measured using EC, a conversion was required. A TDS–EC conversion factor of 0.67 was adopted for the hydrology assessment.

3.7.3 Runoff Salinity

Runoff ECs presented are based on assessments of measured site water quality data and calibrations. The water quality of the runoff from rehabilitated spoil would be expected to improve over time, as the salts leach out of the surface spoil layers. A constant rehabilitated spoil runoff EC value was conservatively adopted for the post-closure void hydrology predictions.

Runoff entering the final voids was assumed to be completely mixed with the existing stored water. This does not account for the potential stratification of water quality within voids with high depth to surface area ratio in which partial mixing with different layers may occur during the colder months (ACARP, 2017). Assuming complete mixing of the void lake contents will provide an average salinity in the void lake over the simulation period.

3.7.4 Groundwater Quality

The *Groundwater Impact Assessment for Mackenzie South* conducted by AGE in 2006 included an assessment of groundwater samples from monitoring bores installed and monitored by ERM. Groundwater samples collected from the coal seams indicate variable but overall saline water quality, with TDS ranging from 9000 to 25,300 mg/L (AGE, 2006). The water is slightly alkaline with a pH ranging from 7.1 to 7.6 and the predominant ions are sodium and chloride.

The samples of groundwater from the alluvial aquifer at Plains had TDS concentrations of 368 – 536 mg/L. This range is consistent with observed water quality from the dewatering bores at Plains Pit. The average values of these ranges were used in the water balance model. The key input is the adopted alluvial TDS of 450 mg/L, as the inflows from the coal seams are an order of magnitude smaller.

3.8 Model Assumptions

The following key assumptions were applied in the water balance modelling:

- Water losses associated with the saturation of the spoil in the backfilled voids (typically during first filling conditions) was excluded. The model results are indicative of void lake behaviour after the backfill material becomes saturated.
- The void lakes are fully mixed (i.e. no stratification). Water quality results indicate the average salt concentration of the entire void lake.
- Rehabilitated spoil runoff salinities are set as constant values based on expected runoff qualities immediately after rehabilitation. Improved runoff quality over time has not been simulated and accordingly the predicted long-term salinities of the void lakes are likely to be upper limiting values.

- All spoil stockpiles, backfilled areas and regraded pit walls were assumed to be rehabilitated spoil. Only steeper in-situ high-wall areas were modelled as ‘pit’ land-use, with higher runoff parameters.

4. FINAL VOID HYDROLOGY RESULTS

4.1 Fina Void Assessment

The GoldSim model was simulated by looping the 129 years of available SILO climate data, until the volume of each void was observed to reach an equilibrium state. The climate data includes extreme events such as the 2011 flood event. The following assumption have been made which results in highest void level

- Central North final void: adopted maximum catchment, assumes no seepage to Central
- Central final void: adopted maximum catchment, assumes seepage from Central North

Table 4.1 summarises the Central North and the Central final void water balance results. Final landform arrangements and void equilibrium levels for each void were developed by Minserve and included in Appendix A. The forecast void lake levels and salinities for each final void are presented in Figure 4.1 to Figure 4.4. No final voids pose an overtopping risk; all final void equilibrium volumes are under 25% total void capacity.

All the final voids are expected to act as ‘sinks’ and will not contribute to sustained baseflow recharge.

Modelling results indicate that the proposed extension to Central North final void will cause a small increase in void equilibrium water level (~0.14m) and negligible change in water quality (i.e. salinity).

The salinity of the final voids will continue to slowly increase over time due to the ongoing concentration from evaporation without significant freshwater inflows flushing from rainfall runoff. Stratification is expected to result in lower solute concentrations in the surface layer of the lakes and higher solute concentrations in the deeper layer of the lakes compared to the average concentrations presented fully mixed lake conditions.

Table 4.1 Final Void Lake Results Summary

Final Void	Catchment Scenario	Bottom of Pit (m AHD)	Void Spill Elevation (m AHD)	Time to Equilibrium (years)	Void Equilibrium Water Level (m AHD)	Max Level post equilibrium (m AHD)	Void Equilibrium Lake Area (ha)	Equilibrium Volume (GL, % of total volume)	Void EC after 100 years (µS/cm)	Void EC after 400 years (µS/cm)
Central-North[1]	Without CNE	-7.1	140[3]	30	45.3[3]	45.3[3]	16.0	3.2	18,280	25,430
	With CNE			30	45.3[3]	45.3[3]	21.3	4.1	19,900	28,730
Central[2]	Without CNE	-60.2	140	90	2.68	10.09	69.5	22.3	26,690	106,790
	With CNE			90	2.82	10.15	69.6	22.4	26,410	106,920

1. No seepage to Central assumed (results in largest area and volume).

2. Seepage from Central-North included (results in largest area and volume).

3. Spills to Central first at 45.3 m AHD. Both voids would then overflow to the environment at 140 m AHD.

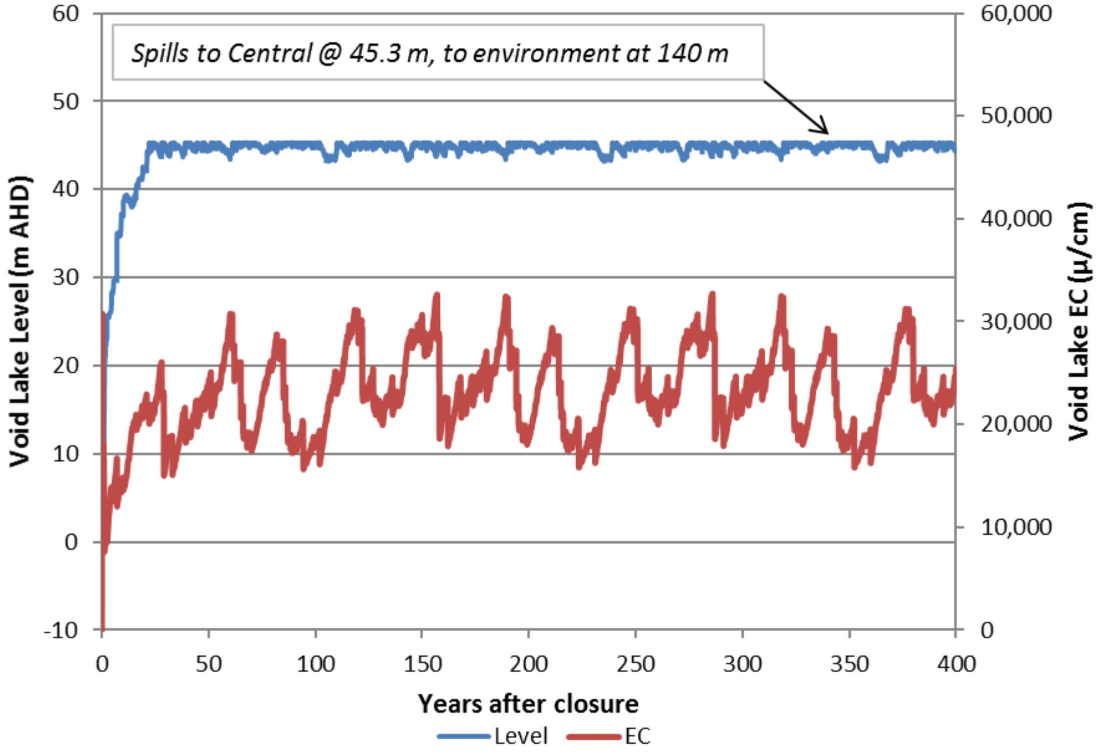

Figure 4.1 Central North without Extension

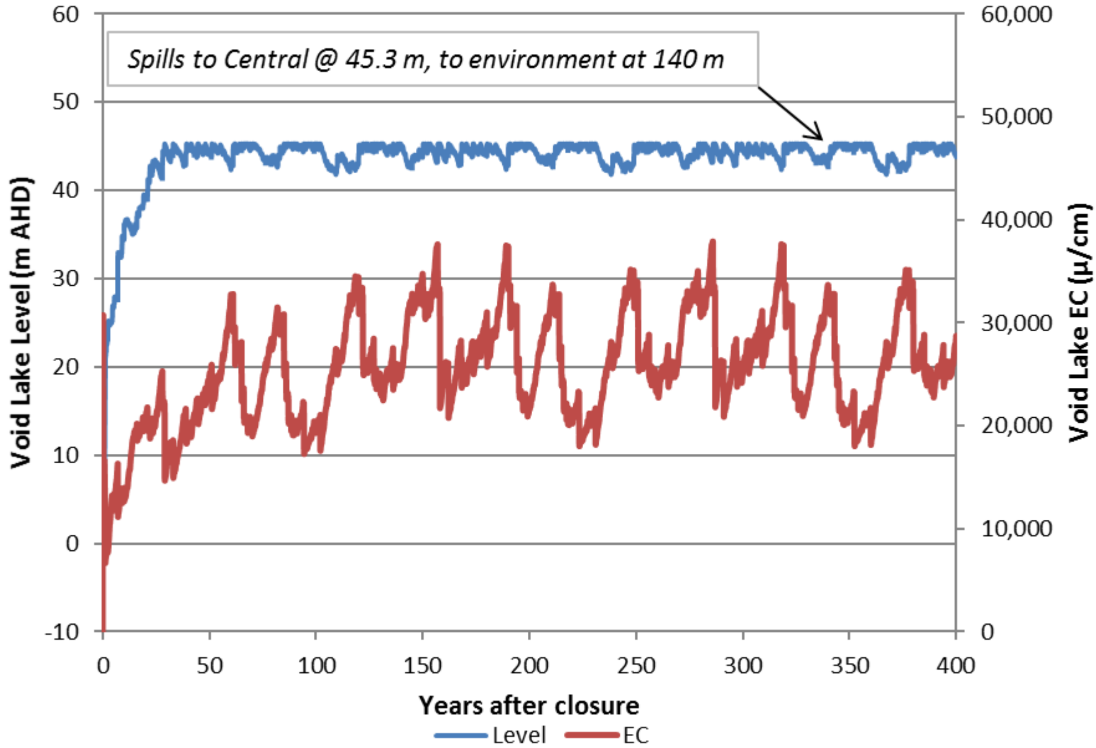

Figure 4.2 Central North with Extension

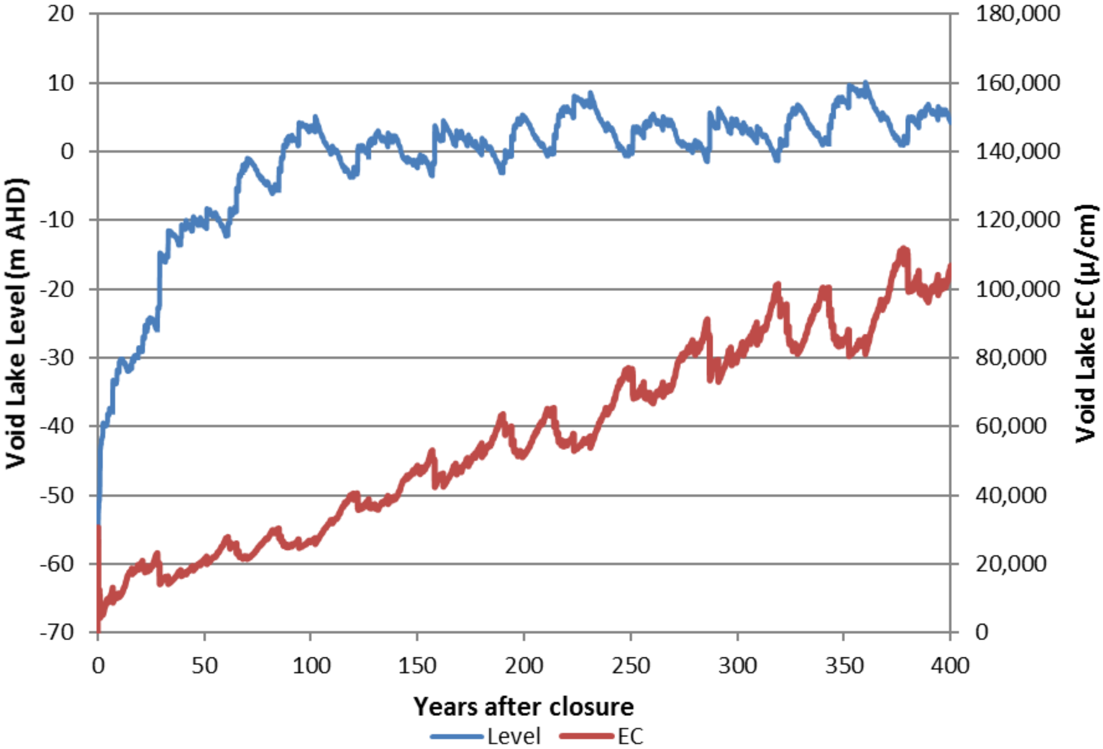

Figure 4.3 Central without Central North Extension

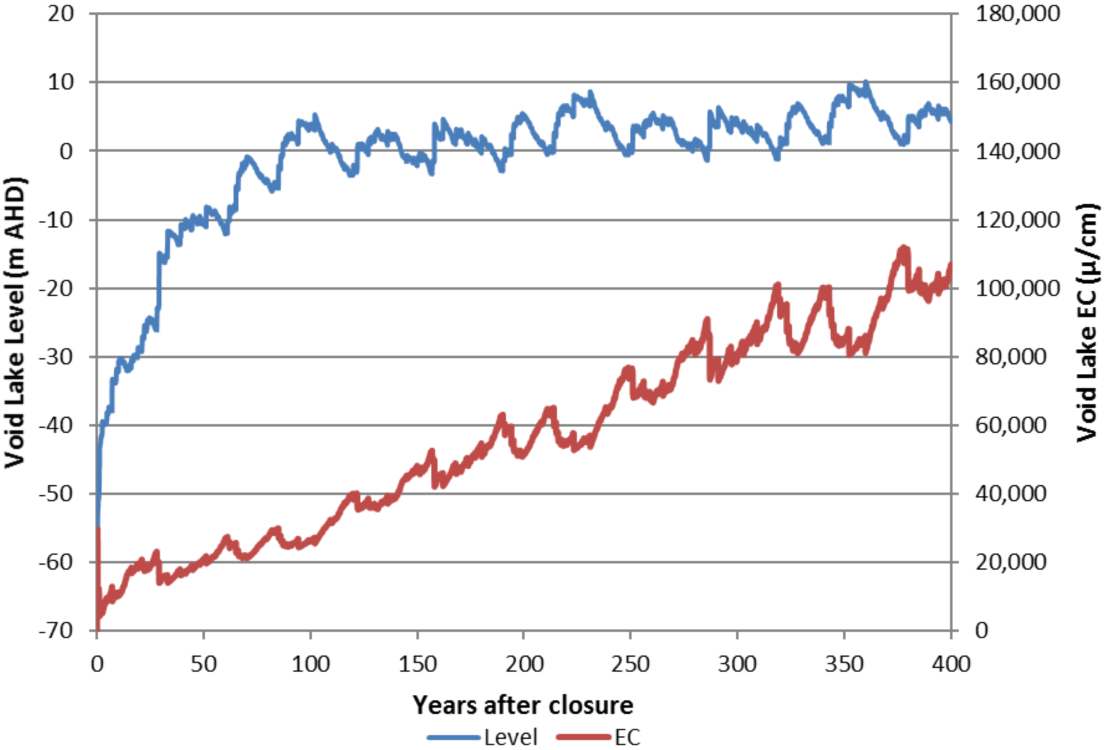

Figure 4.4 Central with Central North Extension

4.2 Climate Change Sensitivity Analysis

A climate change sensitivity was undertaken to understand the impact of climate change on final void level and salinity estimates derived from water balance model simulation. The model climate data inputs were adjusted using the methodologies outlined in "Climate Change in Australia Technical Report" (CSIRO, 2015) to undertake the sensitivity assessment. The CSIRO report provides projections of future climate variables as a result of climate response to several greenhouses gas and aerosol emission scenarios (Representative Concentration Pathways).

Climate projections for Jellinbah Mine were obtained using the projection builder tool (Whetton et. al, 2012) provided on the Climate Change Australia website which was developed using the climate model evaluations detailed in the CSIRO report. Projections were obtained for the "Best and "worst" case scenarios which are based on the following:

- Best Case – higher rainfall and lower evaporation, reducing void water level and
- Worst Case – lower rainfall and higher evaporation, increasing voids water level.

Projections are also provided for the "Maximum Consensus" which is the climate future projected by at least 33% of the climate models and which comprises at least 10% more models than any other. The "Maximum Consensus" is considered the most representative forecast of all the climate models.

Projected changes to annual rainfall and evapotranspiration were obtained for the following most conservative climate change scenario:

- 2090 projection year – furthest available estimated data
- Representative Concentration Pathway 8.5 (RCP8.5) – represents no intervention to reducing greenhouse gas and aerosol emissions.

The climate change sensitivity parameters are provided in Table 4.2. The predicted change in evapotranspiration has increased for all climate change scenarios.

Table 4.2 Climate Change Sensitivity Parameters

Scenario	Change in Annual Rainfall	Change in Annual Evapotranspiration	Model and Consensus
Best Case	-34%	14.5%	Model – GFDL-ESM2M Consensus - Low
Worst Case	19.1%	8.3%	Model – NorESM1-M Consensus - Moderate

Scenario	Change in Annual Rainfall	Change in Annual Evapotranspiration	Model and Consensus
Maximum Consensus	-15.4%	15.2%	Model – GFDL-ESM2M Consensus - Moderate

The Jellinbah Mine final void simulation model daily climate inputs were adjusted using the values in Table 4.2 to assess the impact of the “best” case, “Worst” case and “Maximum consensus” climate change scenarios on the final void water level results. The climate change sensitivity assessment was undertaken on CNE with seepage into Central Void scenario. The climate change sensitivity assessment results are shown in Figure 4.5 and Figure 4.6. The climate change sensitivity assessment indicates:

- Under the “Best” and “Worst” case scenarios the Central North void water level varies from -30 to 28 mAHD respectively. This shows the final void level is highly sensitive to climate change impacts to rainfall and evaporation depths. The estimated final void salinity for climate change scenarios increases where lower water level was predicted. In all scenarios, the final void water level was significantly below the spill level to environment (i.e. RL 140 mAHD).

- The “Maximum Consensus” climate projection shows a reduction in the final void water level from 10 m AHD to -16 mAHD. This shows the majority of the climate model projections of future climate variables will produce reduction to the estimated final void water level.

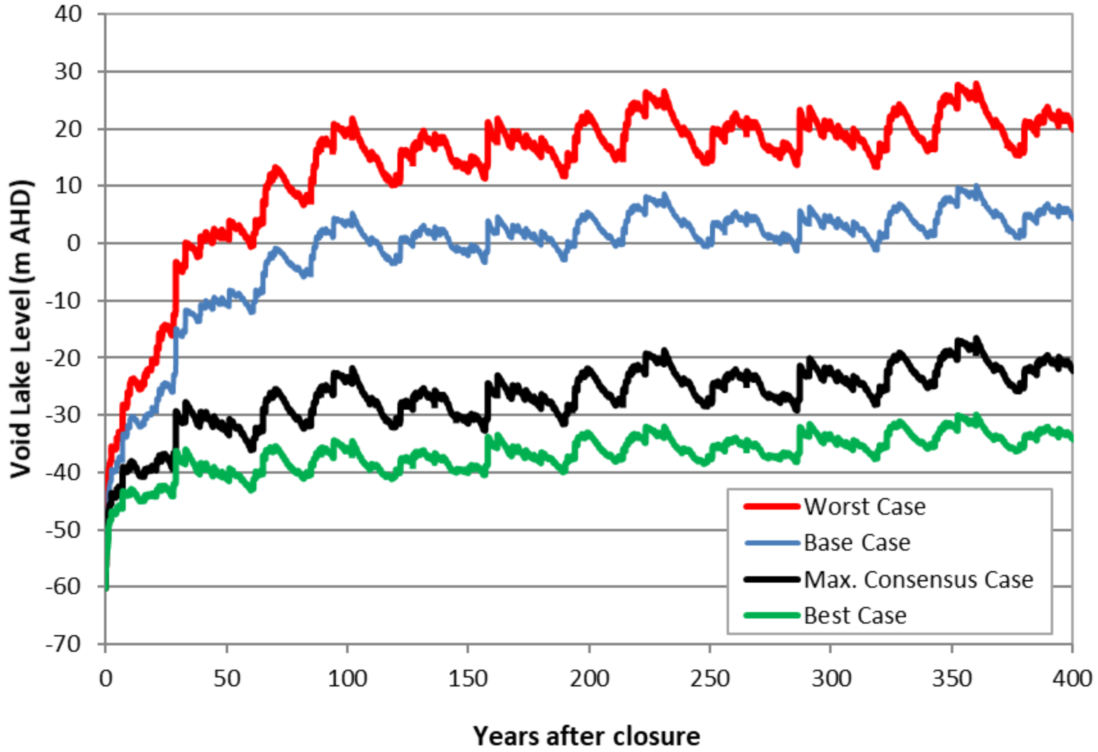

Figure 4.5 Final Void Level Climate Change Sensitivity Assessment

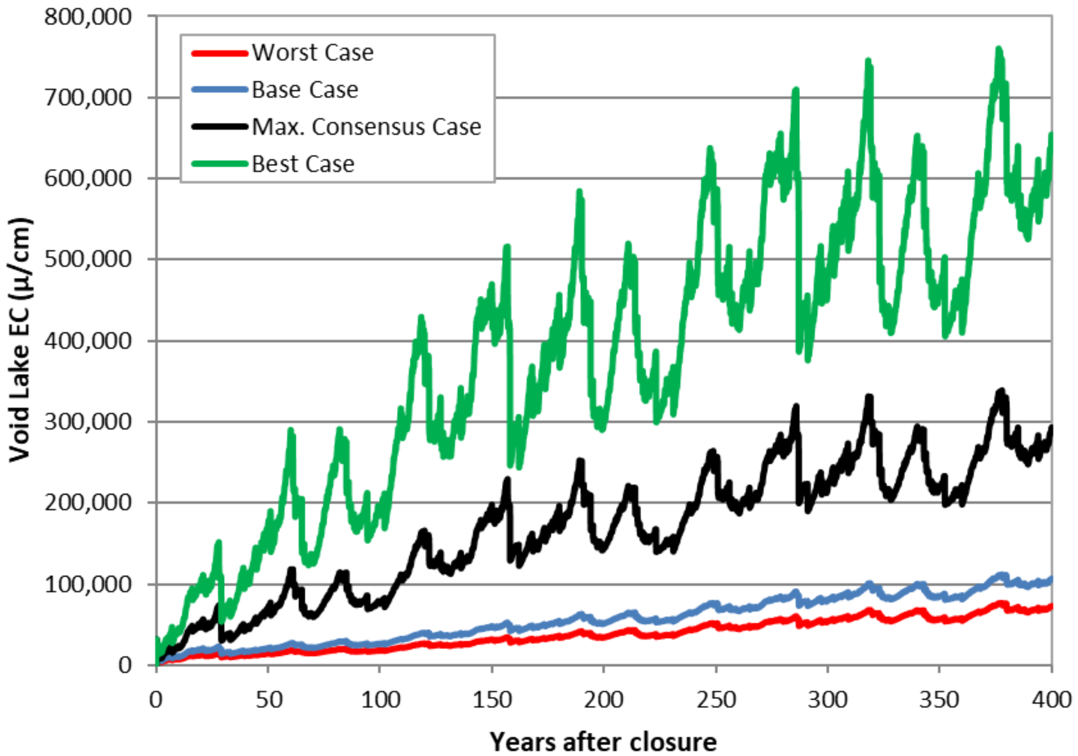

Figure 4.6 Final Void Salinity Climate Change Sensitivity Assessment

5. CONCLUSION

Long-term water balance models were developed for Central and Central North void with and without the proposed extension using 129 years of historical climate data and final void surfaces provided. The modelling results indicate:

- The Central North Voids with and without the proposed extension remain well below spill level (RL 140 m AHD) and do not pose a risk of uncontrolled overflows to the receiving environment.
- In addition, none of these final voids present a seepage risk to groundwater systems, based on the water balance results and the assessment by JBT Consulting (2018), and will remain as groundwater sinks.
- Seepage from Central North to Central may be significant. Worst case scenario results were presented with regard to seepage and void volumes remain well below void capacity.
- The predicted water level for Central void and Central North void with extension is significantly below the spill level of RL140 m AHD into the receiving environment.
- The proposed extension to Central North final void will cause a small increase in void equilibrium water level (~0.14m) and negligible change in water quality (i.e. salinity).
- The impacts of climate change have been assessed which show no overflow to receiving environment from the Central North with proposed extension and Central final voids.

6. 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:

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   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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g. This report does not provide legal advice.

7. REFERENCES

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APPENDIX A

Final Landform Figures

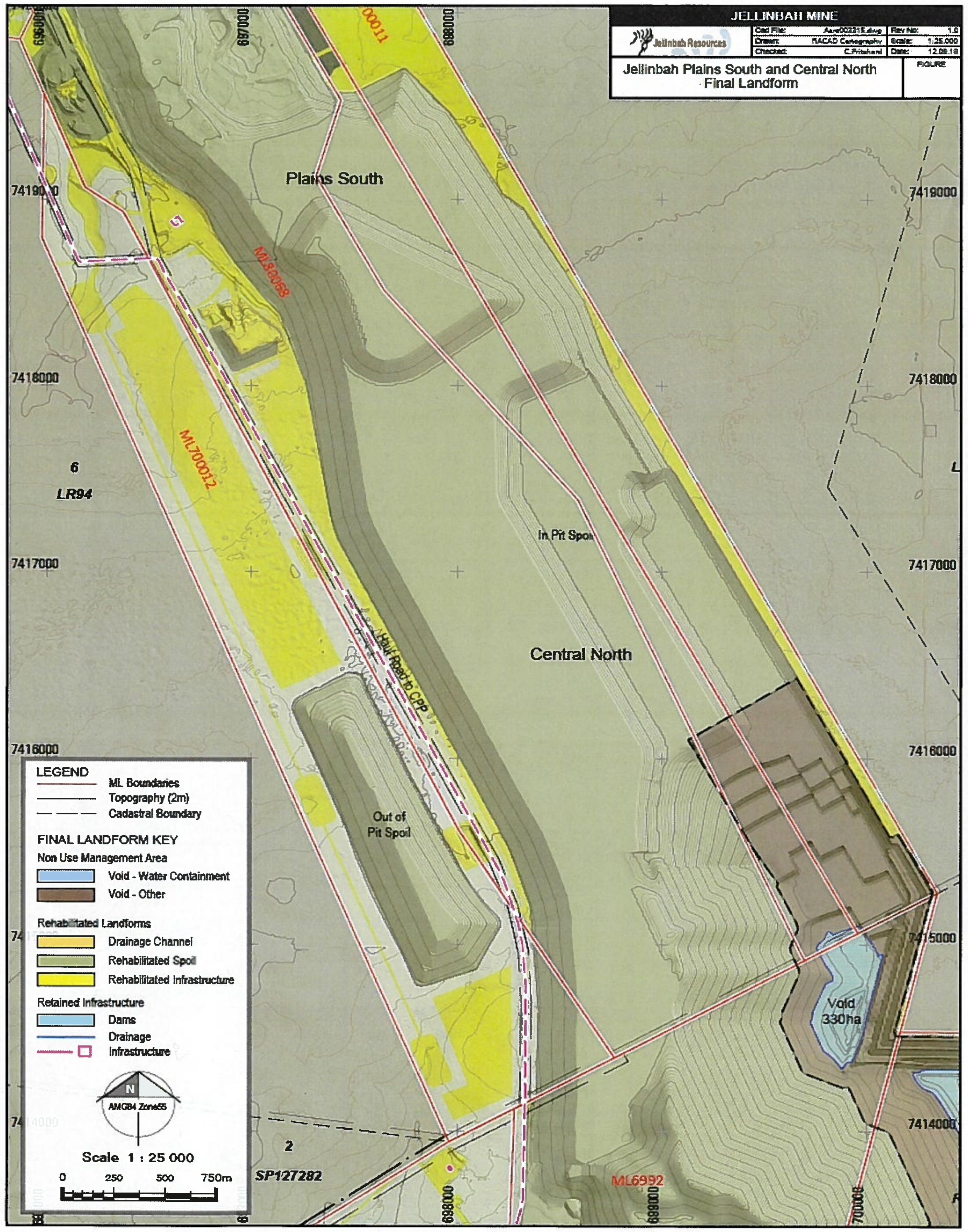

Figure A1: Jellinbah Central North Final Landform with Extension

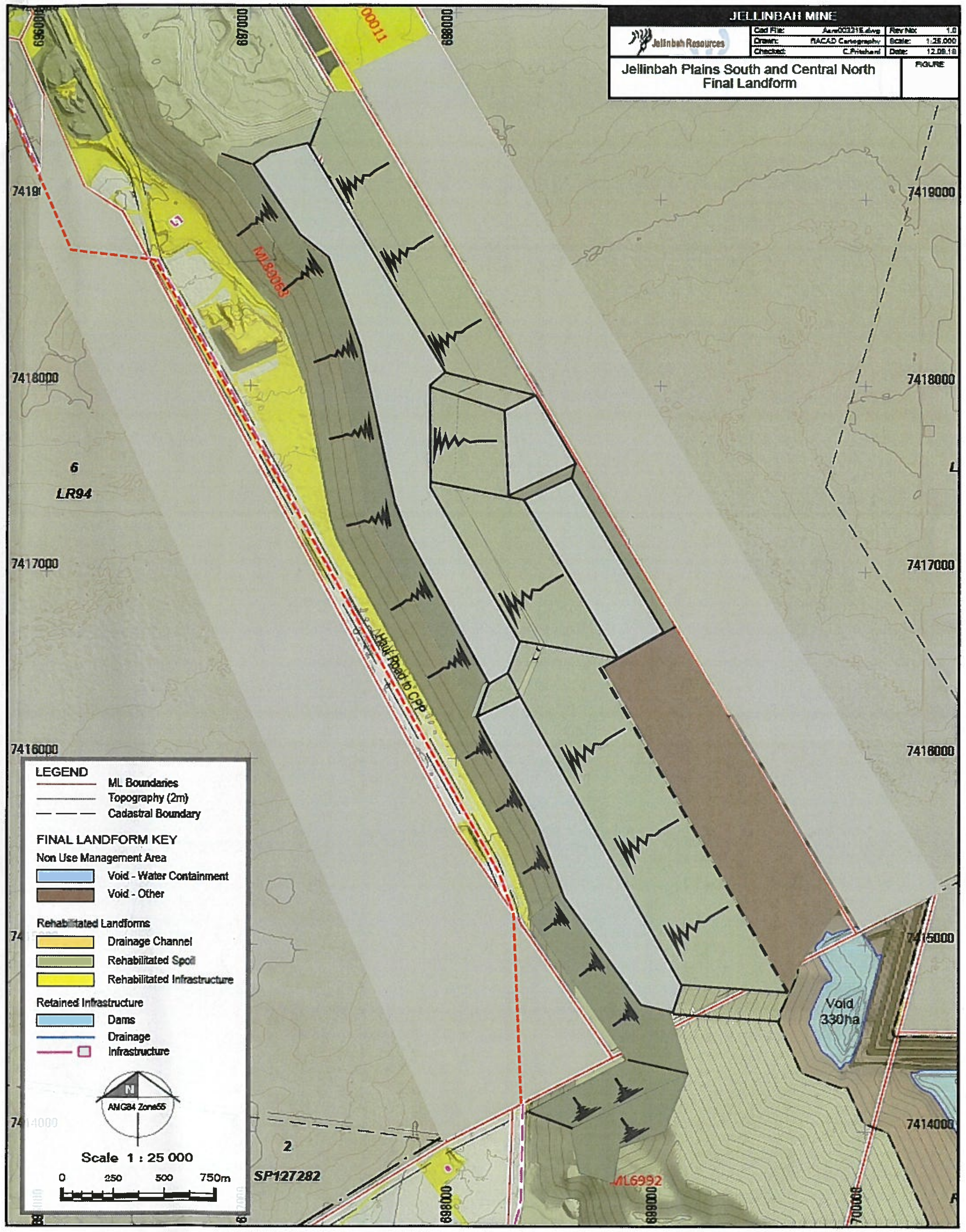

Figure A2: Jellinbah Central North Final Landform without Extension

Jellinbah Central North Extension

Flood assessment

Jellinbah Resources

0684-12-B1, 25 October 2019

For and on behalf of WRM Water & Environment Pty Ltd
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1 Introduction

1.1 BACKGROUND

The Jellinbah Coal Mine and proposed Central North Extension (CNE) are located in the Bowen Basin in central Queensland. The operational area of the current mine is located approximately 24 km north-northeast of Blackwater and 190 km west of Rockhampton.

The mine encompasses two operating mine areas – Jellinbah Central, operated by Jellinbah Group, and Jellinbah Plains, a contractor-run operation.

The purpose of the CNE Project is to extend mining activities at Jellinbah for current resource areas and expand the area available for dumping of spoil into three new MLs: ML 700011, ML 700012, and ML 700013. No changes to the currently approved mining methods or production rates are proposed as part of the Project. The CNE is anticipated to augment production in future years, extending the mine's overall production life.

An EA Amendment Application (Major Amendment) was submitted to the Queensland Department of Environment and Heritage Protection (EHP) in August 2015, in accordance with the requirements of the Queensland Environmental Protection Act 1994 (EP Act). Following a public notice period, EHP approved the EA amendment application on 10th January 2017. Specific conditions were amended for management and mitigation of impacts on both State and Commonwealth environmental values.

As no changes to the existing Jellinbah levee designs are proposed as part of the Central North Extension, full details of flood conditions in the nearby waterways were not included in the original submission.

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) provides independent, expert, scientific advice to the Australian and state government regulators on the potential impacts of coal seam gas and large coal mining proposals on water resources. The IESC was requested by the Australian Government Department of the Environment and Energy to provide advice on the CNE. The IESC raised a number of queries regarding the potential flood-related impacts associated with the Jellinbah Central North Extension Project (CNE). In particular, the IESC requested further information on flooding in Blackwater Creek, the Mackenzie River and Twelve Mile Creek.

Jellinbah Resources engaged WRM to prepare a brief report drawing on previous investigations to help address the IESC's additional information requests. WRM has previously undertaken flood studies for a number of projects in the immediate vicinity of the CNE, including:

- Jellinbah Resources' Mackenzie North Project;
- Jellinbah Resources' Southern Levee Extension;
- Yancoal's Wilpeena Project; and
- Wesfarmers' (now Coronado's) Curragh North Extension Project.

1.2 SCOPE OF THIS REPORT

WRM was engaged to provide further information to assist in responding to the following information requested by the IESC:

1. Further information is required on the construction and location of the levee. Design assumptions regarding flood risk should also be provided so an assessment can be made on the levee's ability to minimise environmental impacts during flood events.

2. No historical flood data has been provided and no explanation has been given on the methods used to derive the 1:1,000 AEP flood.

3. Models of the surface water regime and floods for both the Mackenzie River and Blackwater Creek should be produced. These models should identify:

   a) Peak flows and water depths as a function of AEP;

   b) Volume, duration, frequency and seasonality of inflows;

   c) Wetting and drying cycles over multiple years (responses to different climatic conditions); and

   d) The interaction between the pits/final voids and the flood extent of the Mackenzie River and Blackwater Creek.

   Note that queries in 3b) and 3c) regarding the seasonality of inflows and multi-year wetting and drying cycles are not specifically addressed in this report as they are not relevant to flood behaviour in rare to extreme riverine flood events.

2 Location of the existing levee

The alignment of the existing Jellinbah flood levee in relation to the Mackenzie River floodplain and the lease boundaries of the proposed Central North Extension Project is shown in Figure 2.1.

The levee extends around the western, northern and eastern sides of the mining area. An out-of-pit overburden stockpile has been placed over part of the levee's eastern extent.

No new open-cut mining areas are proposed within the Mackenzie River floodplain, and therefore, no changes to the existing levees are proposed as part of the Central North Extension Project.

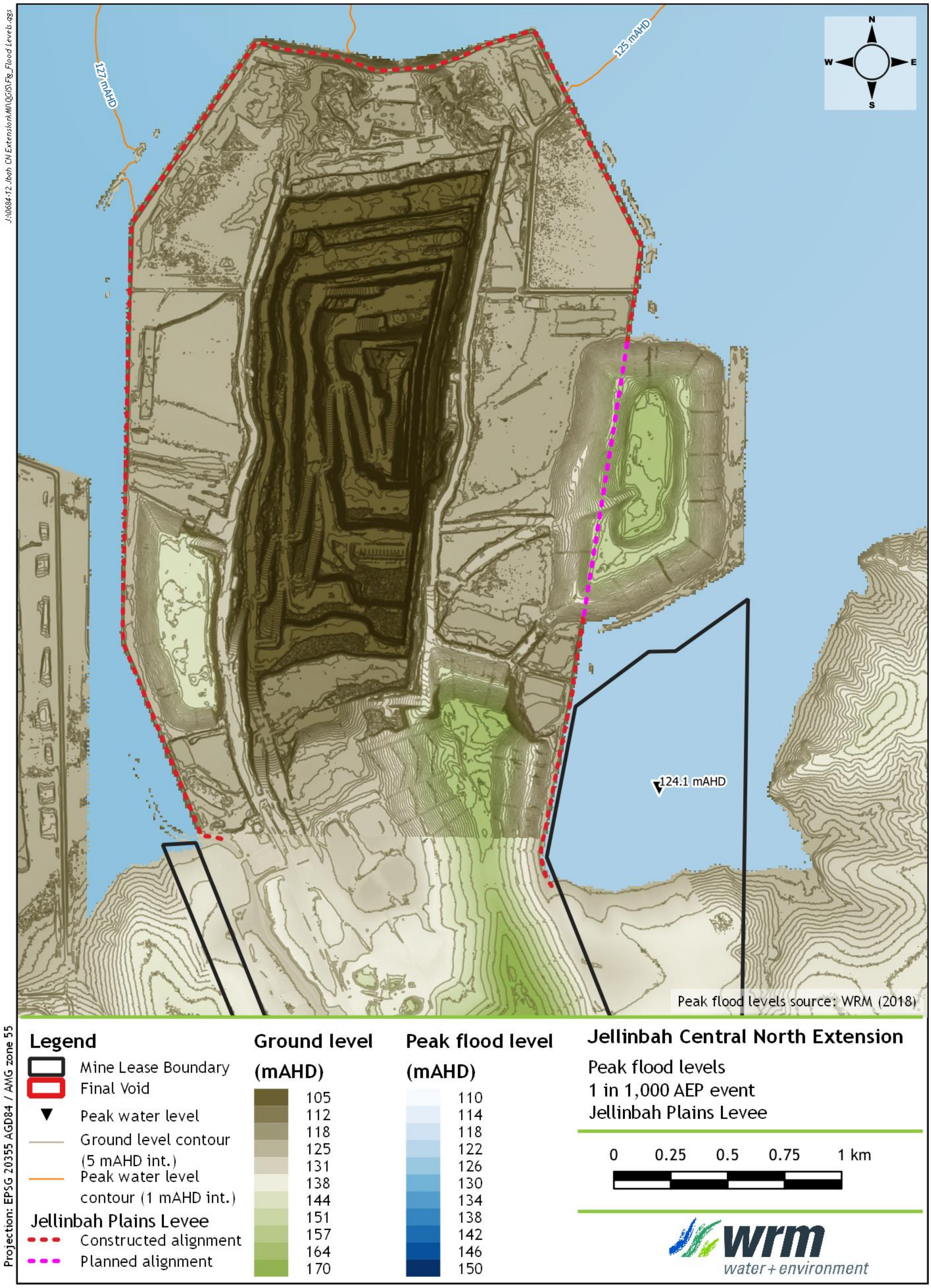

Figure 2.1 – Existing Jellinbah levee

3 Mackenzie River and Blackwater Creek flooding

3.1 DESIGN 1 IN 1,000 AEP FLOOD LEVELS AT JELLINBAH

The impacts of the Jellinbah levees on flooding were assessed as part of impact assessments undertaken in 2006.

The existing levee designs were developed based on investigations undertaken by WRM in June 2015 to estimate design 1 in 1,000 AEP peak flood levels for the Plains Area (Mackenzie South) Stage 3 Levee.

Flood conditions were assessed based on detailed hydrologic and hydraulic analysis of the nearby Mackenzie River using flood models previously developed by WRM for other nearby projects, in particular, Wesfarmers' Curragh North Pit V Expansion Project (WRM, 2010 and WRM, 2012) and Jellinbah Resources' Mackenzie North Project (WRM, 2013b). For those studies, a hydrological model of the Mackenzie River and its tributaries was developed and calibrated to historical flood events.

The hydraulic model used in previous studies was subsequently revised to use the TUFLOW GPU Solver. This enabled the model grid size to be reduced (improving representation of the channel and adjacent floodplain). The refined model was recalibrated to historical water level and flow data. Details of the hydraulic model calibration results are provided in the *Jellinbah Plains Stage 3 Levee Design Flood Levels Report* (WRM, 2015), which is attached as Appendix A.

The *Mackenzie North Project Flood Impact Assessment Report* (WRM, 2013a), which outlines the hydrological modelling methodology adopted for design of the Plains Stage 3 Levee is provided as Appendix B. The Mackenzie River hydraulic model was further revised in 2018 (using more recently obtained survey data) for detailed design of the Mackenzie North levee (WRM, 2018). That study yielded flood model results which were consistent with the Jellinbah Plains Stage 3 levee design report. The hydraulic models for both studies included all currently approved works within the Mackenzie River and Blackwater Creek floodplains.

Figure 3.1 shows the estimated extent of flooding in the 1 in 1,000 AEP event based on the results of the most recent study (WRM, 2018). The results show the northern part of the CNE lease areas is affected by Mackenzie River flooding in the 1 in 1,000 AEP flood, but flooding in Blackwater Creek (which is strongly affected by Mackenzie River backwater) does not extend onto the lease area.

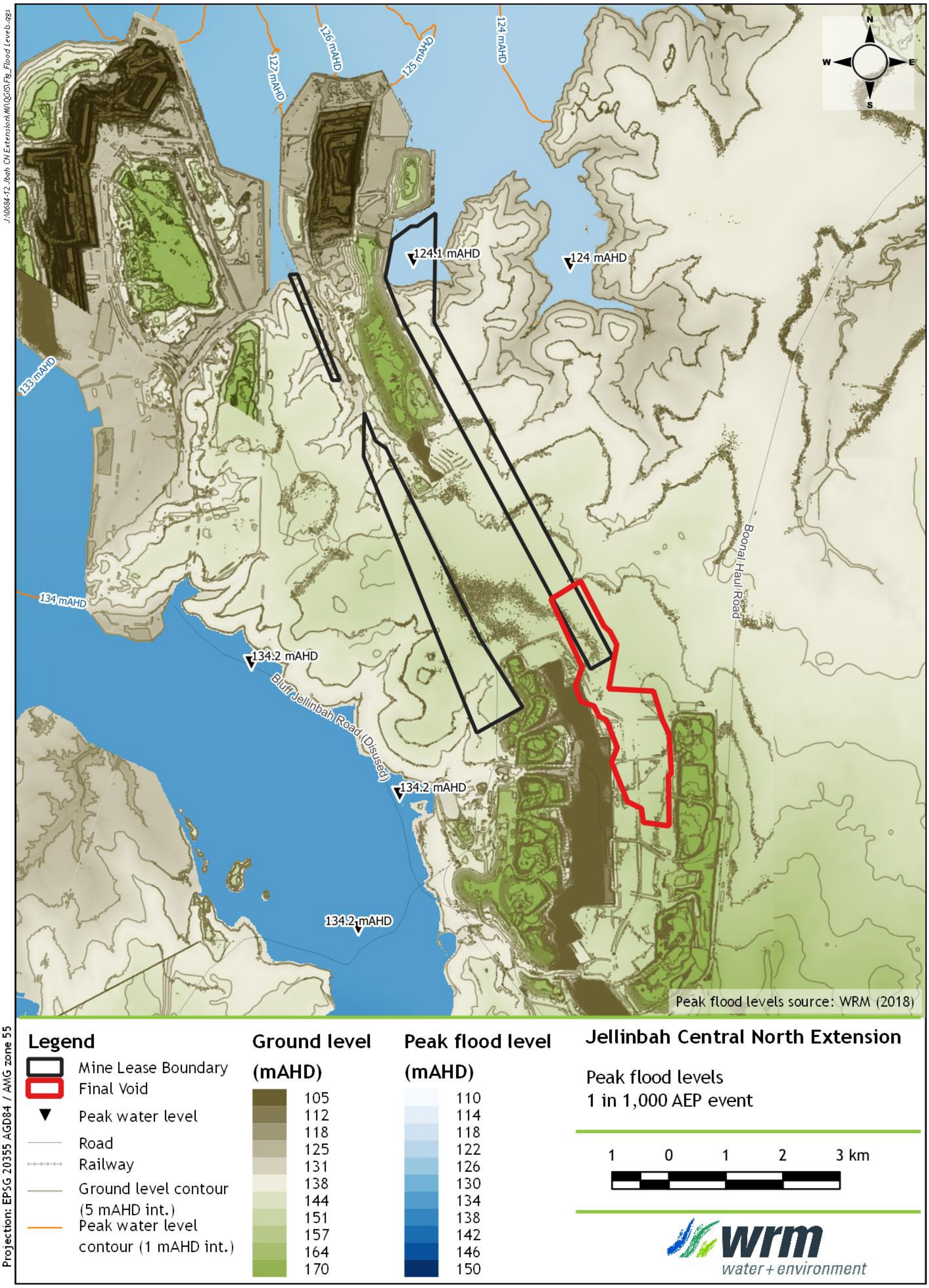

Figure 3.1 – Extent of flooding near CNE – 1 in 1,000 AEP flood

3.2 FLOOD LEVELS IN PROBABLE MAXIMUM FLOOD AT JELLINBAH

Modelling of the Probable Maximum Flood (PMF) in the vicinity of the project was undertaken as part of the *Curragh North Pit U Flood Assessment* (WRM, 2010). The results of that study were used to prepare the flood map in Figure 3.2, which shows that the PMF in Blackwater Creek would not impact the CNE. Note that the flood model prepared for that study did not extend up Blackwater Creek beyond the project area, and development near the confluence of the Mackenzie River and Blackwater Creek associated with Curragh Extension Project were not included (as the WRM 2010 study pre-dated that proposal). However, as PMF flooding is dominated by the effects of Mackenzie River backwater, the impact of these simplifications on flood level estimates near the CNE is likely to be minimal.

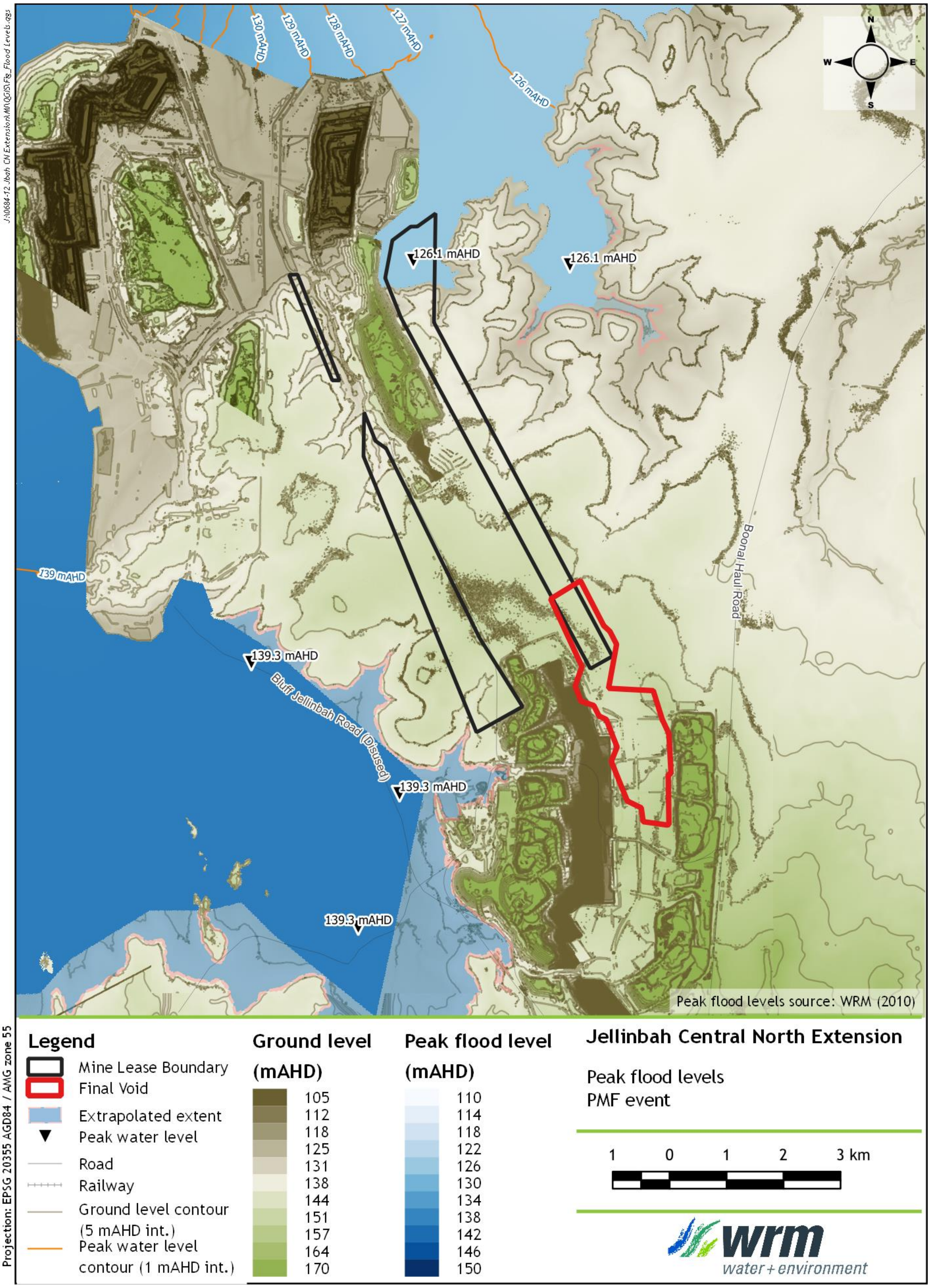

Figure 3.2 – Extent of flooding near CNE – probable maximum flood

4 Twelve Mile Creek flooding

As shown in Figure 4.1, at its nearest point, Twelve Mile Creek is located approximately 4 km to the northeast of the CNE project.

Detailed ground level survey data is unavailable for this reach of Twelve Mile Creek. However, some detailed Light Detection and Ranging (LiDAR) data is available nearby, downstream of the location shown in in Figure 4.1. At this point, Twelve Mile Creek has a catchment of approximately 255 km^2.

For the purpose of this report, the potential for Twelve Mile Creek flooding to impact the project was assessed by:

- Estimating the Twelve Mile Creek catchment to this location based on data from the Shuttle Radar Topography Mission (SRTM);
- Estimating the peak 1 in 100 AEP discharge (616 m^3/s) using the Regional Flood Frequency Estimation Model (RFFE) (Ball et al, 2019);
- Estimating the peak 1 in 100 AEP flood depth and width (approximately 1,000 m) by estimating the corresponding normal depth at the location where LiDAR data was available.
- Extrapolating the width and depth of flooding upstream, assuming the flow depth and width are similar to the above location.

The results presented in Figure 4.1 show that the CNE is located well away from the estimated extent of flooding in Twelve Mile Creek.

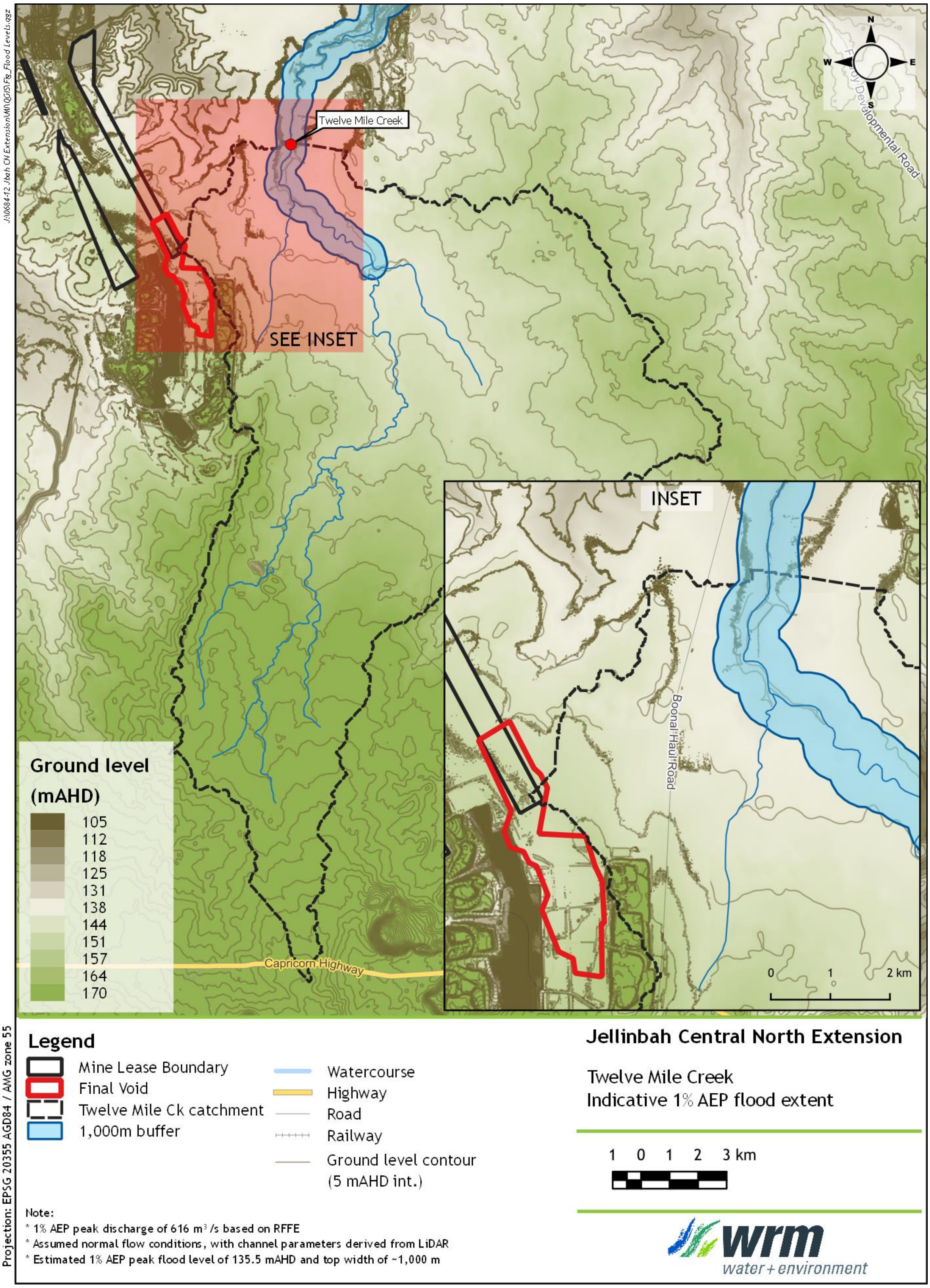

Figure 4.1 - Indicative flood extent - Twelve Mile Creek

5 Findings

As no changes to the existing Jellinbah levee designs are proposed as part of the Central North Extension, full details of flood conditions in the nearby waterways were not included in the original CNE submission.

No modifications to the existing Jellinbah levees are proposed as part of the proposed CNE Project. Details of the basis of the existing Jellinbah levee designs are provided in the previous studies appended to this report. The impacts of the existing levees were assessed as part of the original impact assessment studies in 2006.

Extensive analysis of historical flood behaviour was undertaken for previous flood studies of the Mackenzie River and Blackwater Creek in the vicinity of the CNE. Relevant information from these studies have been extracted and appended to this report. In addition, a simplified assessment of the potential extent of flooding in the nearby reaches of Twelve Mile Creek was undertaken to demonstrate that the CNE would not be impacted by flooding in Twelve Mile Creek.

Based on the information presented in the previous sections:

- The northern portions of the proposed CNE lease areas would be impacted by Mackenzie River flooding in the 1 in 1,000 AEP flood event.
- Flooding in Blackwater Creek in very large floods (which is dominated by Mackenzie River backwater flooding) would not extend onto the CNE lease area in all flood events, up to and including the PMF.
- The proposed Jellinbah final void would not be impacted by flooding in the Mackenzie River, Blackwater Creek or Twelve Mile Creek.
- The CNE lease area would not be impacted by flooding in Twelve Mile Creek.

6 Summary of responses

DOE Advice	IESC Advice	Ref	Response
5	Further information is required on the construction and location of the levee. Design assumptions regarding flood risk should also be provided so an assessment can be made on the levee's ability to minimise environmental impacts during flood events.	NA	Refer Section 2 for details of the existing levee. No changes are proposed to the existing levee - as no additional open cut mining operations are proposed within the Mackenzie River floodplain. The flood study prepared for the design (referenced in the *Jellinbah Stage 3 Levee Consequence Assessment Report)* is provided as Appendix A.
6	No historical flood data has been provided and no explanation has been given on the methods used to derive 1:1,000 AEP flood.	PD: Sec 5.4 & Table 24	Refer section 3.1 of this report and Appendix B - which includes details of the flood modelling methodology for the 1:1,000 AEP design flood as well as historical flood data.
6a-6d	Models of the surface water regime and floods for both the Mackenzie River and Blackwater Creek should be produced. These models should identify: a) Peak flows and water depths as a function of AEP; b) Volume, duration, frequency and seasonality of inflows; c) Wetting and drying cycles over multiple years (responses to different climatic conditions); and d) The interaction between the pits/final voids and the flood extent of the Mackenzie River and Blackwater Creek		The flood modelling previously undertaken for Blackwater Creek and the Mackenzie River is described in Section 3 and the Appendices. Details include: • Peak flows and water depths for a range of AEPs to the PMF. • Description of the frequency of flooding and the volume and duration of design and historical flood hydrographs. • The pit/final void location – which is outside the extent of the PMF for the Mackenzie River and Blackwater Creek. The extent of Twelve Mile Creek flooding is also indicated in Section 4. Multi-year wetting and drying cycles are not relevant to the design of the flood protection system for large floods.

7 References

Ball et al, 2019	*Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia, Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019
WRM, 2010	*'Curragh North Pit U Flood Assessment', Report prepared by WRM Water & Environment Pty Ltd for Hansen Bailey, Ref. 0584-01-F[Rev 4], 24 June 2010*
WRM, 2012	*Revised Mackenzie River Design Flood Discharges and Flood Levels for Wesfarmers Curragh Pty Ltd 0584-02-H*, WRM Water & Environment Pty Ltd, 30 August 2012
WRM, 2013a	*Revised Mackenzie River Design Flood Discharges and Flood Levels for Jellinbah Resources Pty Ltd 0684-01-H[Rev2]*, WRM Water & Environment Pty Ltd, 30 May 2013
WRM, 2013b	*Mackenzie North Project Flood Impact Assessment for Jellinbah Resources Pty Ltd 0684-01-J*, WRM Water & Environment Pty Ltd, 10 July 2013
WRM, 2015	*Jellinbah Plains Stage 3 Levee Design Flood Levels, Jellinbah Resources, 0684-04-C1, WRM Water & Environment Pty Ltd, 9 June 2015*
WRM, 2018	*Jellinbah Mackenzie North Pit Flood study for northern levee design*, 0684-08-C1, WRM Water & Environment Pty Ltd, 11 May 2018

Appendix A Jellinbah Plains Stage 3 Levee Design Flood Levels Report

wrm water + environment

Jellinbah Plains Stage 3 Levee Design Flood Levels

Jellinbah Resources

0684-04-C1, 9 June 2015

For and on behalf of WRM Water & Environment Pty Ltd
Level 9, 135 Wickham Tce, Spring Hill
PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200

Michael Batchelor
Director

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1 Introduction

WRM Water & Environment Pty Ltd was engaged by Jellinbah Resources Pty Ltd to estimate 1 in 1000 AEP peak flood levels for use in the detailed design of the proposed Plains Area (Mackenzie South) Stage 3 Levee.

Detailed hydrologic and hydraulic analysis of the nearby Mackenzie River was undertaken using flood models previously developed by WRM for other nearby projects, in particular, Wesfarmers' Curragh North Pit V Expansion Project and Jellinbah Resources' Mackenzie North Project.

During recent flood investigations for Wesfarmers, WRM has further refined the hydraulic model using the new TUFLOW GPU Solver. This has enabled the model grid sized to be further reduced (improving representation of the channel and adjacent floodplain), while reducing the run time by a factor of 30.

The above changes affect the modelled flood behaviour, and so as part of the present study, the refined model was recalibrated to historical water level and flow data.

This report outlines the modelling methodology and adopted design flood conditions for use in detailed design of the Plains Area (Mackenzie South) Stage 3 Levee. The results presented herein should not be used for any other purpose without seeking advice from WRM Water & Environment regarding its applicability.

2 Proposed infrastructure

The hydraulic model includes the existing and proposed developments shown in Figure 2.1 and listed below:

- Existing Curragh North Levee (excluding Pit V extension): as represented in previous revisions of the model.
- Approved Curragh Pit V Levee: The original modelling undertaken for the Pit V extension flood studies adopted the alignment shown in Figure 2.1. In practice Wesfarmers has opted to construct the levee on an alignment which will cause a lesser impact on nearby flood levels. The hydraulic modelling is based on the as-built alignment. However, the impact of the alignment shown in Figure 2.1 has also been assessed, to ensure that local conditions are not worsened (the results are provided in Appendix B).
- Approved Mackenzie North Levee: The site of the proposed Mackenzie North operation is located on the northern floodplain of the Mackenzie River. The proposed mine may also require the construction a diversion of the Mackenzie River anabranch. For the purposes of this study, the diversion has been included. The project also includes the construction a haul road and associated bridge crossings which have been included in the hydraulic model.
- Proposed Plains Area Stage 3 levee (alignment provided by Jellinbah Resources on 8 April 2015).
- Conveyor and access road crossing Blackwater Creek and minor tributaries. Detailed design plans for these structures were obtained from Parsons Brinckerhoff as part of work undertaken for Wesfarmers Curragh.
- Various farming levees and earthen structures located on the Mackenzie River floodplain (the Bedford Property). These structures would overtopped in large floods. The model representation of these structures was refined further as part of the present study due to the reduced grid size and differences between the TUFLOW “Classic” and GPU solvers. However, they are based on the original survey data obtained for previous flood modelling, and will not reflect any recent changes to the topography.

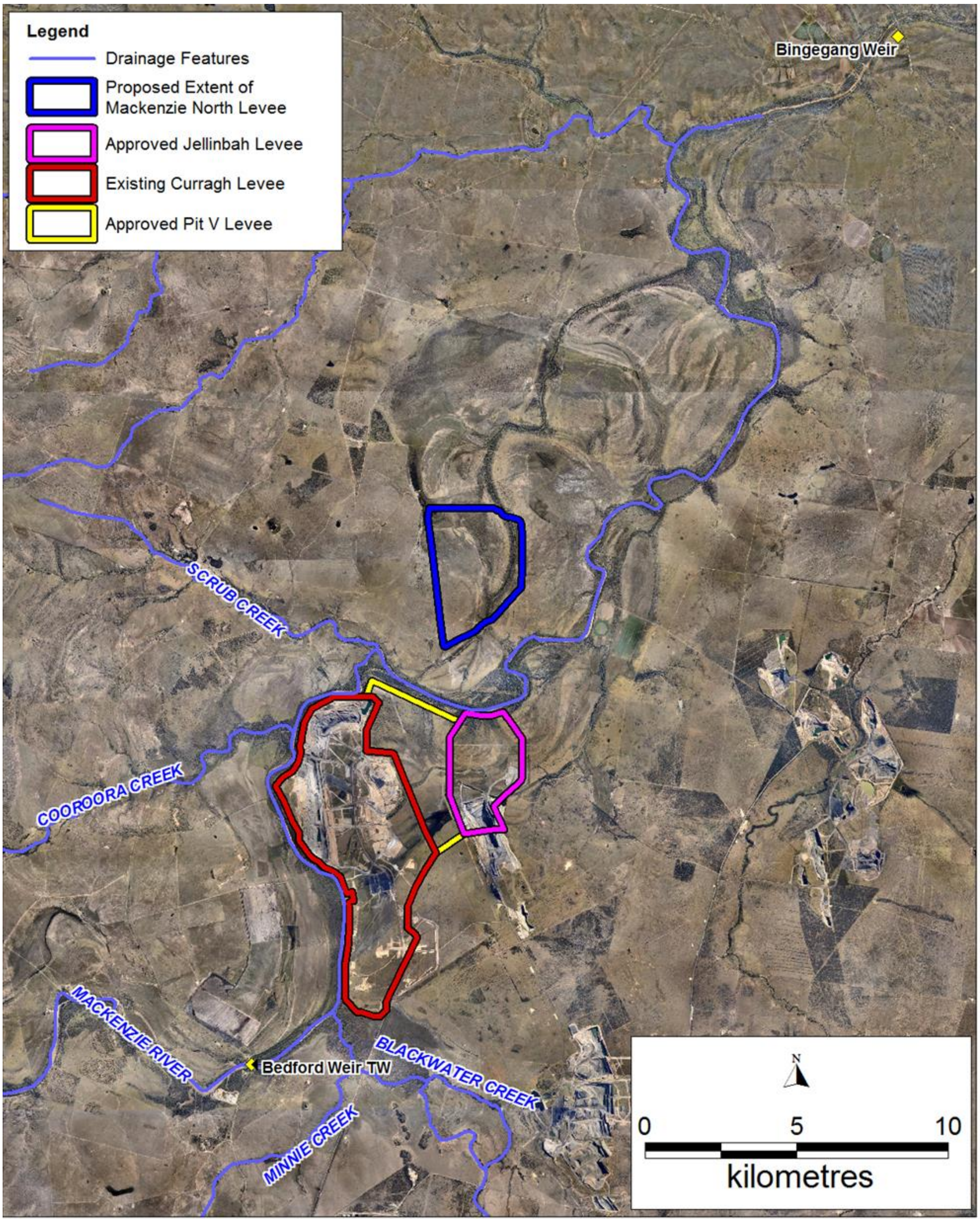

Figure 2.1 Floodplain infrastructure in the vicinity of the project

3 Hydraulic model setup

This investigation used the hydraulic model developed previously for the analysis of Wesfarmers' Curragh North Pit V Project and the Jellinbah Mackenzie North project.

The Mackenzie River is a complex system and, as such, the TUFLOW 2D hydrodynamic model (WBM, 2008) was used. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically calculates breakout points and flow directions within the study area.

The models were initially developed and simulated using the TUFLOW "Classic" Solver however simulation times proved to be prolonged and ultimately impractical. As such, the new TUFLOW GPU Solver was used to simulate the local and regional model resulting in significantly shorter simulation times and reduced tailwater instabilities at downstream boundaries.

3.1 TERRAIN DATA

Topographic data used for the previous hydraulic investigations was provided by Atlass (Airborne Topographic Laser Survey Systems) Australia Pty Ltd via Wesfarmers Curragh Pty Ltd. The ground surface model was obtained by LiDAR capture on 07 July 2009. The data was adjusted by Atlass to fit local ground control data supplied by Wesfarmers Curragh Pty Ltd consisting of 8 horizontal control points and 282 vertical control points. A thinned LiDAR DTM data set was provided over the model area to the north of the existing Curragh Mine. Based on a sample of 227 control points the vertical RMS error of the DTM is quoted as 0.06m and horizontal accuracy is 0.50 m.

The model area was extended downstream of the previous model boundary and the DTM was supplemented with additional data obtained by AAMHatch on 29 September, 2005. Additional topographic data, obtained by Peabody Energy covering the area of MDL162 tenement only, was also obtained, however metadata for this additional data-set was not available at the time of writing. The topographic data was converted into a digital terrain model (DTM) for use in the hydraulic modelling and mapping tasks.

Note that while it is not anticipated the nearby floodplain topography has changed significantly over the past 10 years outside of the active areas, if there have been changes, this would potentially affect design flood levels in the project area.

Previous TUFLOW models developed for the Mackenzie River utilised a 15 m grid. A 10 m grid has been used in this investigation. The finer grid allows for a better representation of creek and river geomorphology and has resulted in a slight difference in water levels and depths when compared to previous model results.

3.2 DESIGN INFLOWS

Design inflows for the Mackenzie River were extracted from the hydraulic model developed for previous investigations. The Mackenzie River design 1 in 1000 AEP flow hydrograph was extracted from the Mackenzie River URBS model. The peak design discharge was 17,200m^3/s.

3.3 TAILWATER CONDITIONS

The downstream boundary is located approximately 28.6 km downstream of the confluence of Blackwater Creek and the Mackenzie River. A HT (water level) Boundary was used as the downstream boundary. As outlined in the TUFLOW GPU model release notes, using this type of boundary and applying a level that is below the lowest ground elevation along the boundary results in the model being forced to adopt normal flow conditions and water is able to exit the model.

4 Hydraulic model results

The hydraulic model was used to estimate design flood levels in the vicinity of the proposed works. The results are shown in the longitudinal profile along the proposed levee in Figure 4.1.

Maps of flood depth and flood velocity are provided in Figure 4.2 and Figure 4.3, and design flood levels along the levee are tabulated in Table 4.1. The section line for Figure 4.1 and Table 4.1 is shown in Figure 4.4.

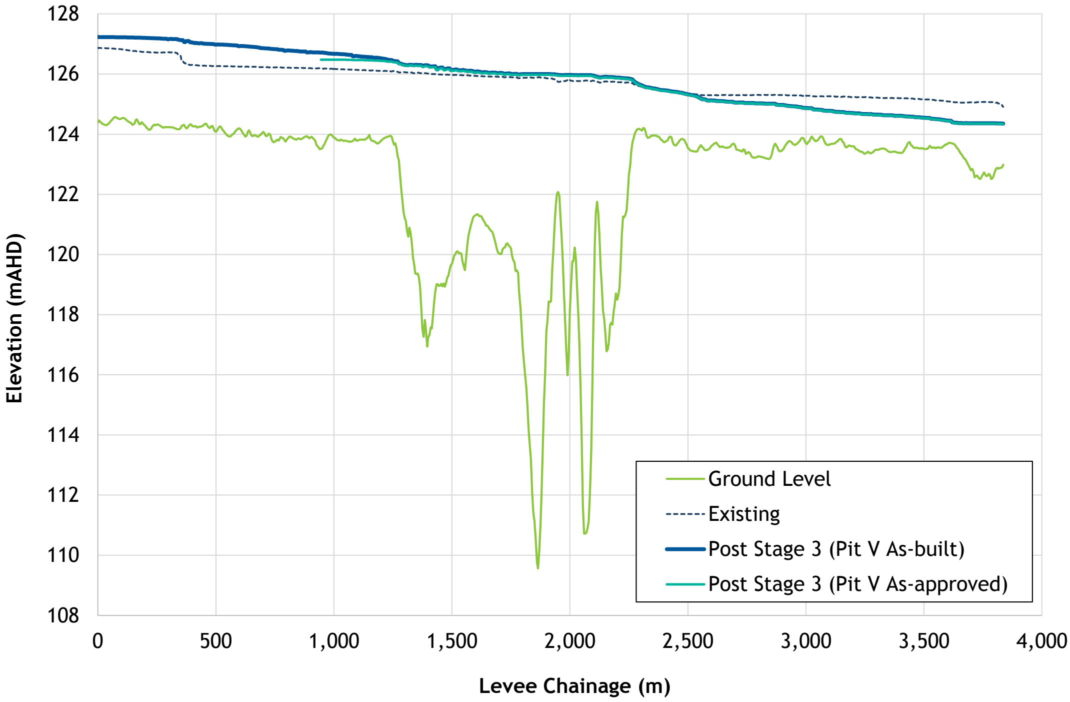

Figure 4.1 Longitudinal profile along Plains Area levee - post Stage 3

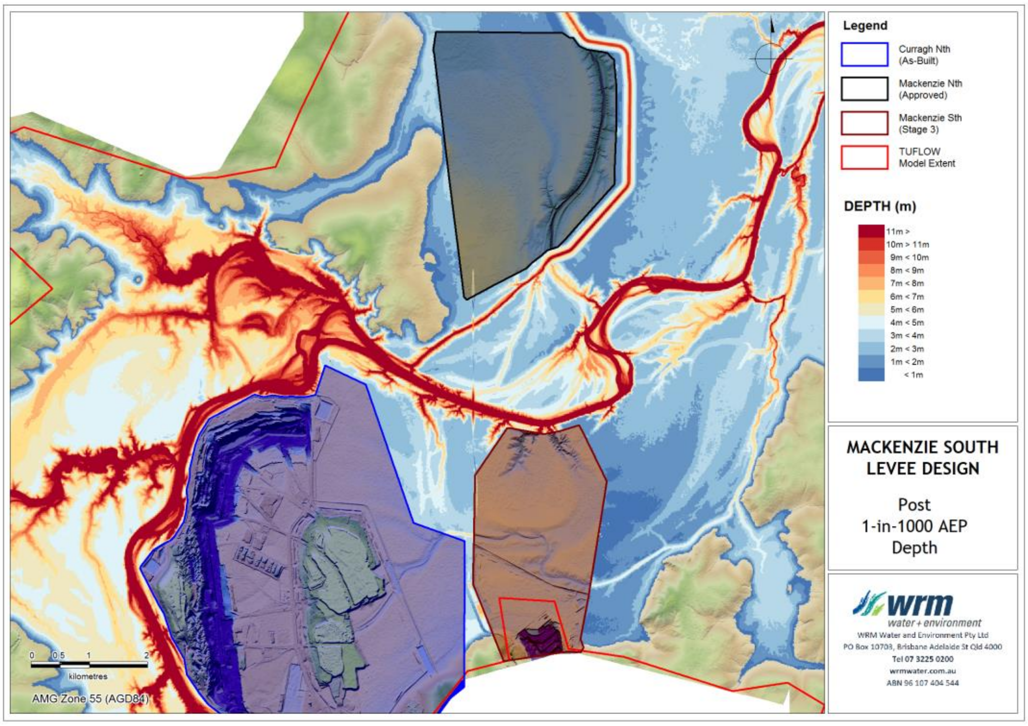

Figure 4.2 Peak 1 in 1,000 AEP design flood depths near the Stage 3 Levee

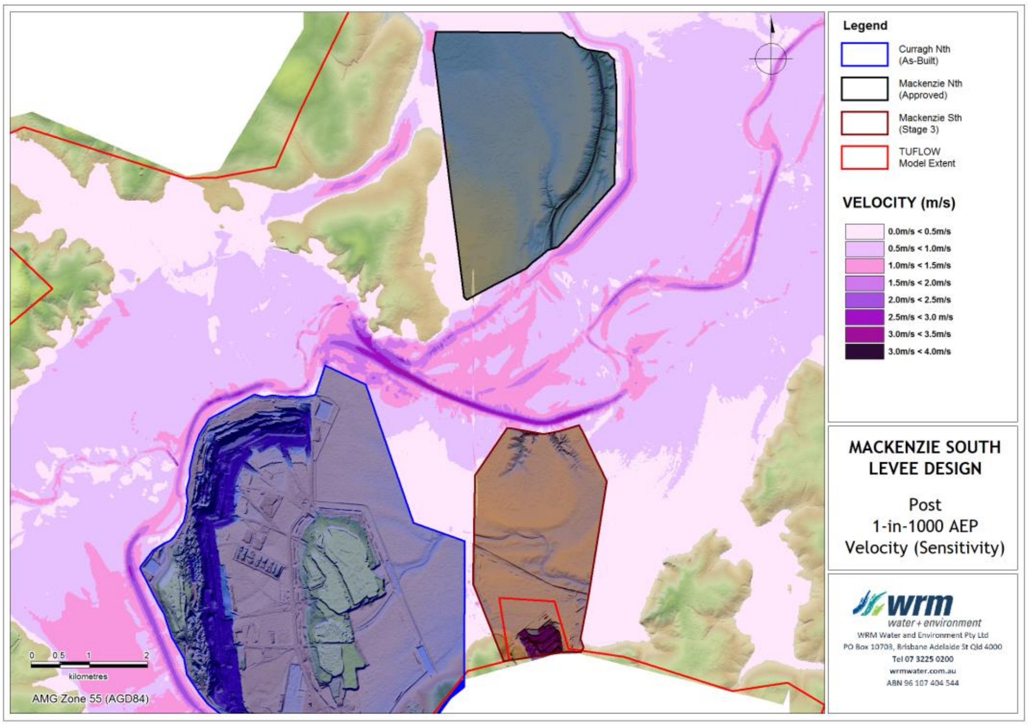

Figure 4.3 Peak 1 in 1,000 AEP design flood velocities near the Stage 3 Levee

Table 4.1 – Design 1 in 1,000 AEP design flood levels along Stage 3 levee

Section Chainage	Ground Level (m AHD)	Design Flood Level (m AHD)	Design Flood Level incl Freeboard (m AHD)
-	124.40	127.23	127.73
100	124.53	127.22	127.72
200	124.28	127.21	127.71
300	124.24	127.16	127.66
400	124.27	127.05	127.55
500	124.08	126.98	127.48
600	124.19	126.93	127.43
700	124.08	126.86	127.36
800	123.82	126.78	127.28
900	123.89	126.73	127.23
1,000	123.89	126.67	127.17
1,100	123.79	126.59	127.09
1,200	123.79	126.52	127.02
1,300	121.21	126.30	126.80
1,400	117.25	126.29	126.79
1,500	119.69	126.13	126.63
1,600	121.31	126.07	126.57
1,700	120.04	126.03	126.53
1,800	116.89	126.00	126.50
1,900	117.47	126.00	126.50
2,000	118.13	125.97	126.47
2,100	118.02	125.95	126.45
2,200	118.50	125.88	126.38
2,300	124.15	125.63	126.13
2,400	123.74	125.46	125.96
2,500	123.54	125.32	125.82
2,600	123.62	125.13	125.63
2,700	123.62	125.06	125.56
2,800	123.26	125.03	125.53
2,900	123.47	124.97	125.47
3,000	123.70	124.87	125.37
3,100	123.65	124.78	125.28
3,200	123.60	124.70	125.20

3,300	123.49	124.65	125.15
3,400	123.38	124.61	125.11
3,500	123.51	124.55	125.05
3,600	123.69	124.45	124.95
3,700	122.80	124.37	124.87
3,800	122.74	124.36	124.86
3,836	122.99	124.35	124.85

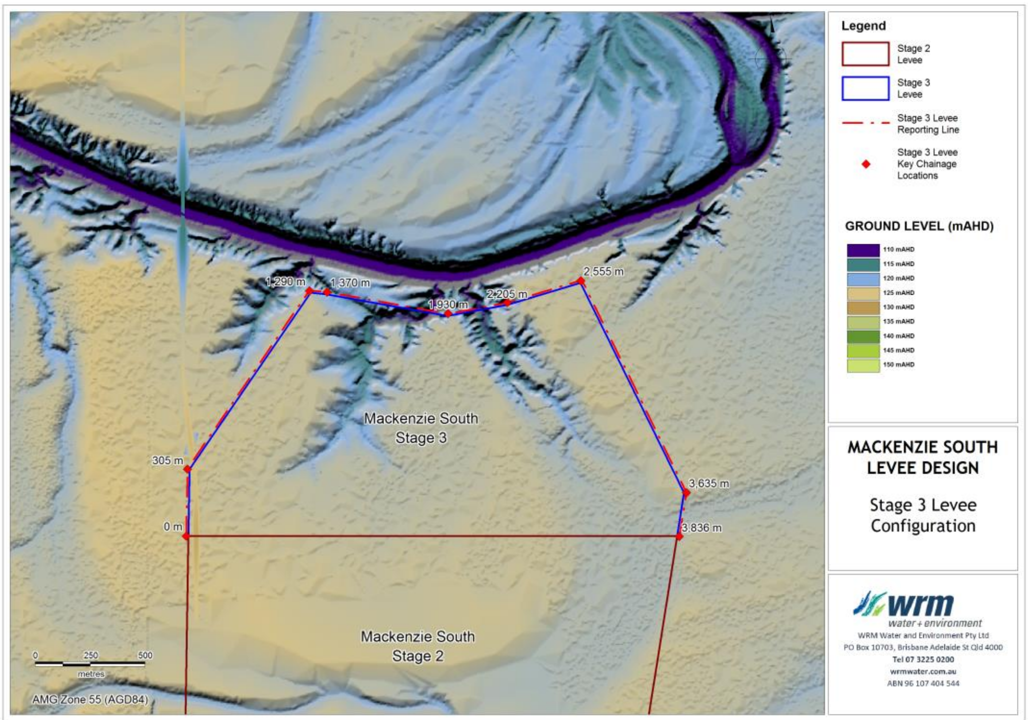

Figure 4.4 Reporting points for design flood levels

5 References

WRM, 2012	*Revised Mackenzie River Design Flood Discharges and Flood Levels for Wesfarmers Curragh Pty Ltd 0584-02-H,* WRM Water & Environment Pty Ltd, 30 August 2012
WRM, 2013	*Revised Mackenzie River Design Flood Discharges and Flood Levels for Jellinbah Resources Pty Ltd 0684-01-H[Rev2],* WRM Water & Environment Pty Ltd, 30 May 2013
WRM, 2013	*Mackenzie North Project Flood Impact Assessment for Jellinbah Resources Pty Ltd 0684-01-J,* WRM Water & Environment Pty Ltd, 10 July 2013

Appendix A **Model calibration**

A1 Adopted Manning's 'n' values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types were mapped, and an appropriate roughness value assigned to each region.

Vegetation mapping was undertaken using an orthophotograph of the area captured in July 2009 (provided by Wesfarmers Curragh Pty Ltd). In areas outside the extent of the photograph, Google Earth imagery was used.

The Manning's 'n' values were selected during model calibration to the January 2011 event, and were applied to all model scenarios. The calibration was revisited as part of the present study due to the change to the GPU solver and refinement of the model grid.

The Manning's 'n' values used in the hydraulic models for this investigation are outlined in Table A.1. Figure A.1 and

Figure A.2 show photographs of the Mackenzie River and Anabranch channel, respectively.

Figure A.3 shows the location of the various areas of roughness adopted for the hydraulic modelling task. Note that the mapping of roughness has been refined for the present study.

Table A.1 – Adopted Manning's 'n' values

Location	Adopted Manning's 'n'
Floodplain	0.062
River Channel	0.045
Trees on banks and overbanks	0.090

Figure A.4 and Figure A.5 show the results of the calibration to water levels recorded in 2011 at Bedford Weir Tailwater, and at three pints along the Curragh North levee, where water levels were surveyed during the event.

Figure A.1 – Photograph showing the Mackenzie River channel and overbank vegetation

Figure A.2 – Photograph showing the Anabranch channel and overbank vegetation

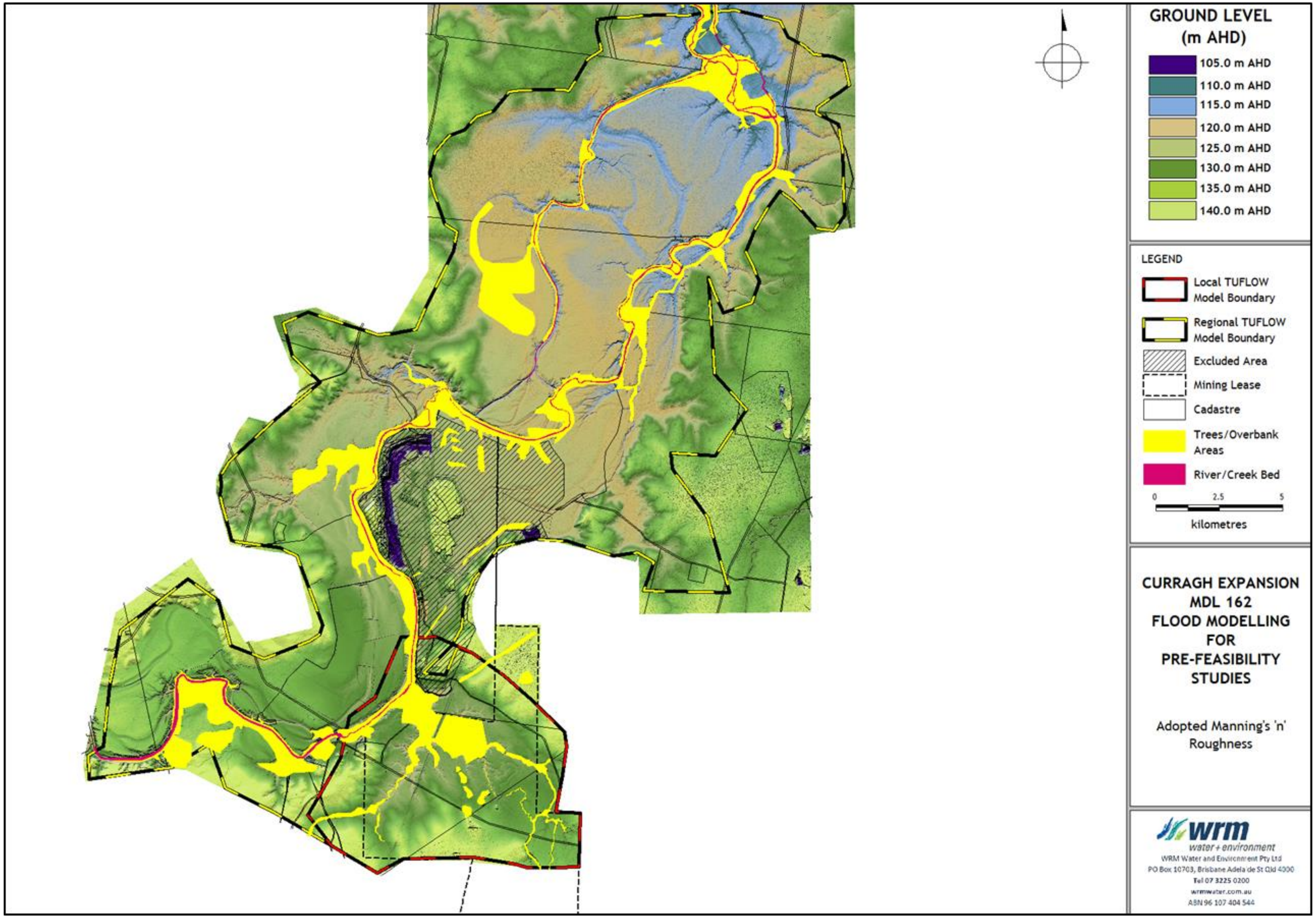

Figure A.3 – Adopted roughness mapping

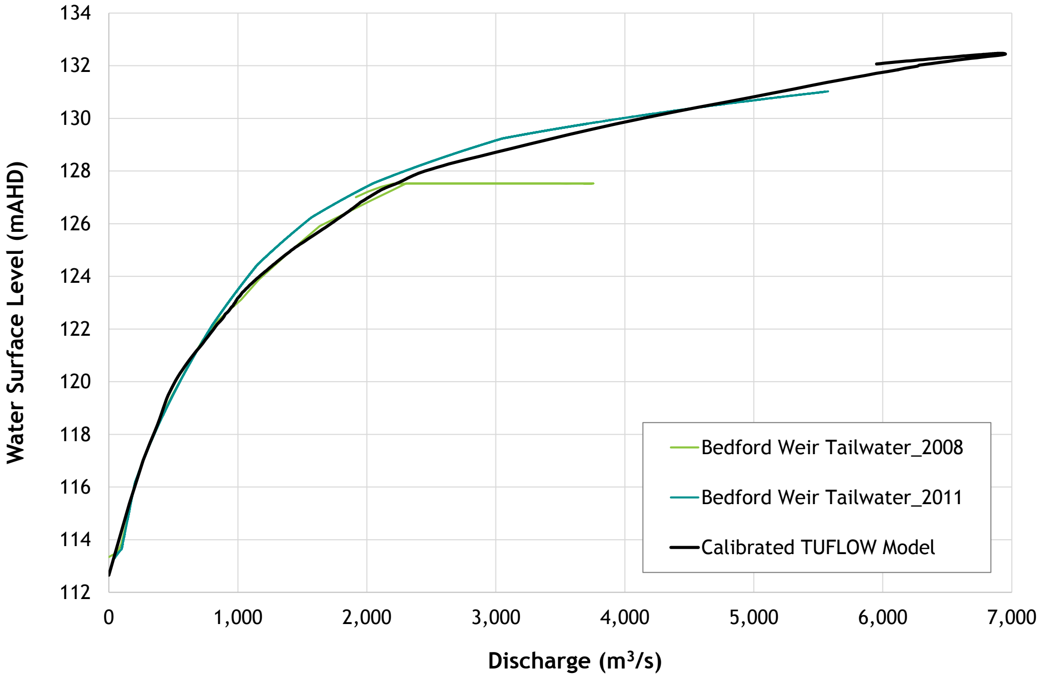

Figure A.4 - TUFLOW model 2011 Event calibration to Bedford Weir tailwater rating curves

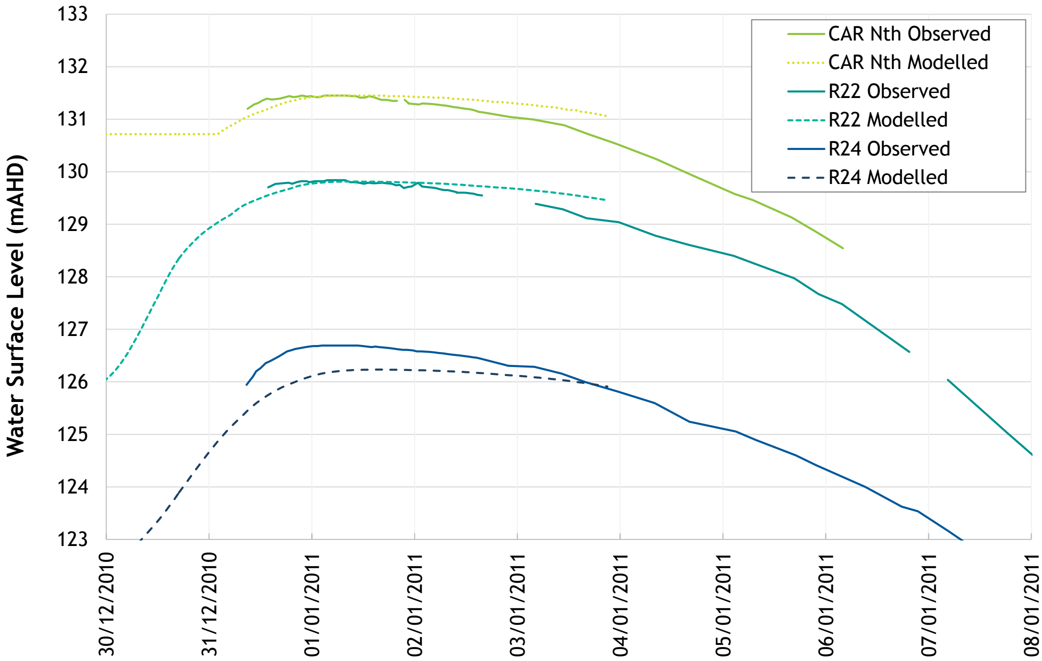

Figure A.5 - TUFLOW model 2011 event calibration to surveyed water levels along Curragh North Levee

Appendix B Sensitivity Analysis

Sensitivity analysis was carried out to assess the potential impact of changes to the nearby infrastructure on design flood conditions. The following potential changes were assessed:

- Impact of Mackenzie River bridge structure loss assumptions;
- Impact of construction of Pit V levee to as-build alignment instead of as approved.

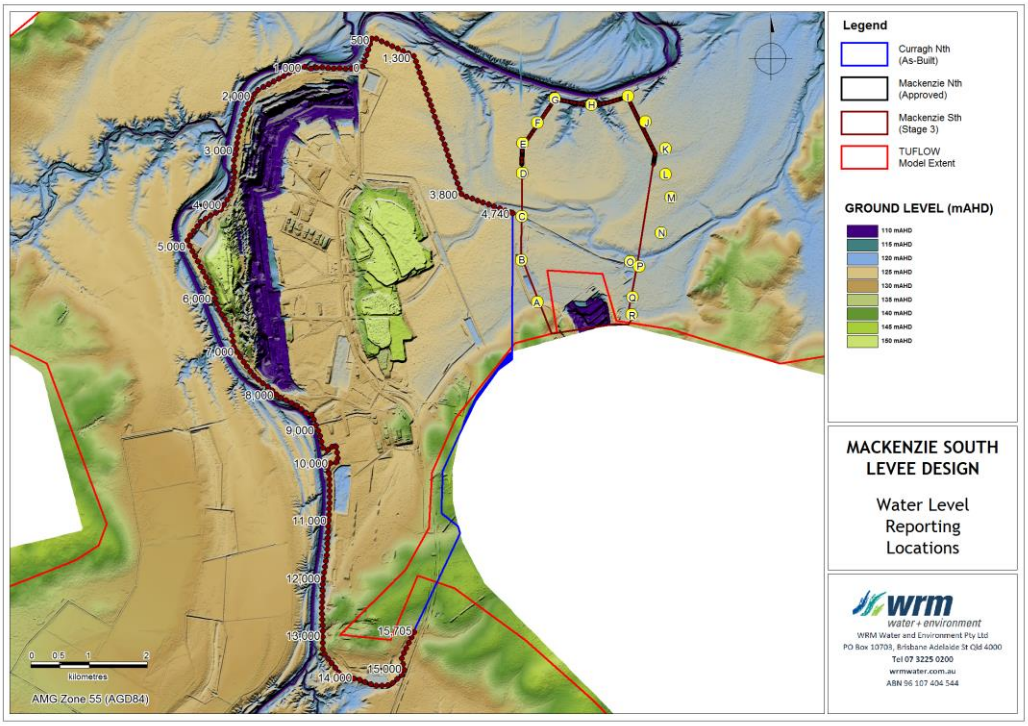

Figure B.1 – Locations of key reporting points for sensitivity analysis

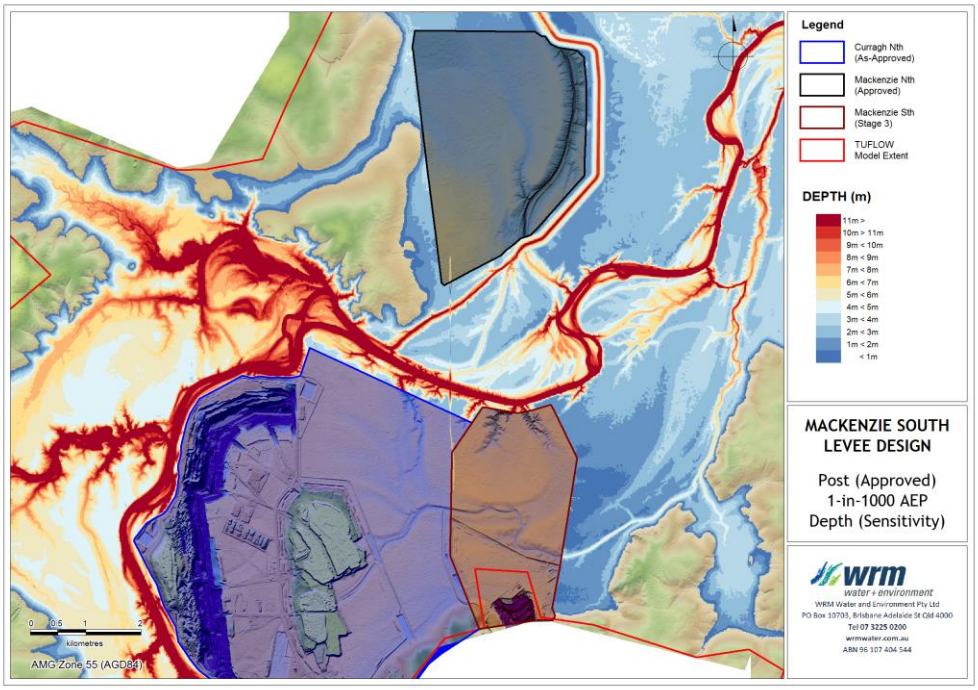

Figure B.2 – Curragh North Pit V as approved (high bridge loss) – flood depth

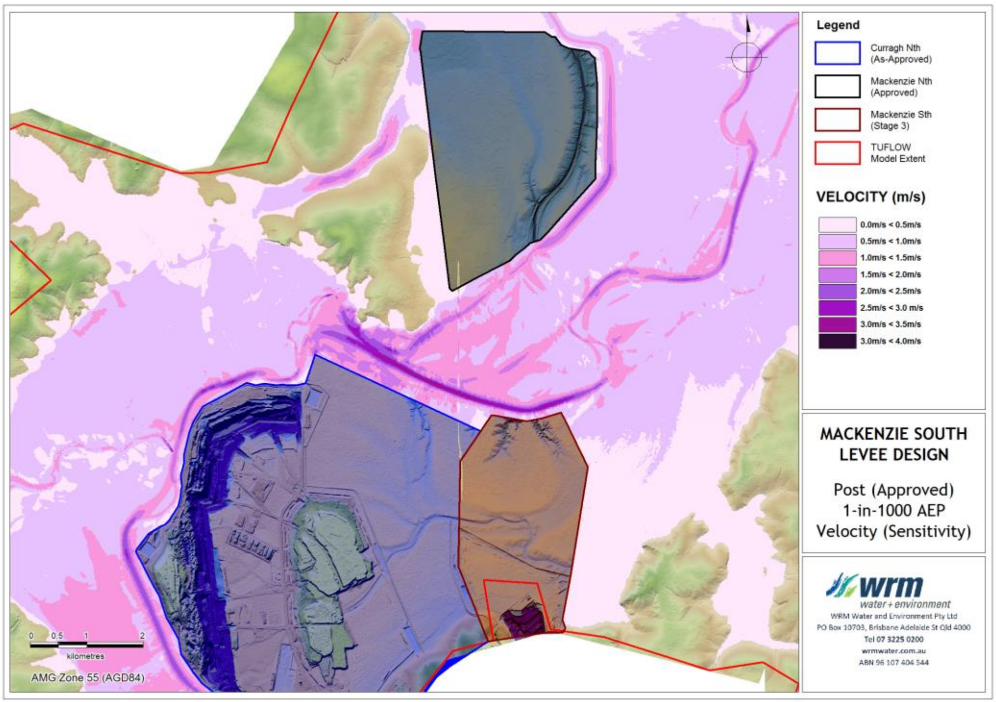

Figure B.3 – Curragh North Pit V as approved (high bridge loss) – flood velocity

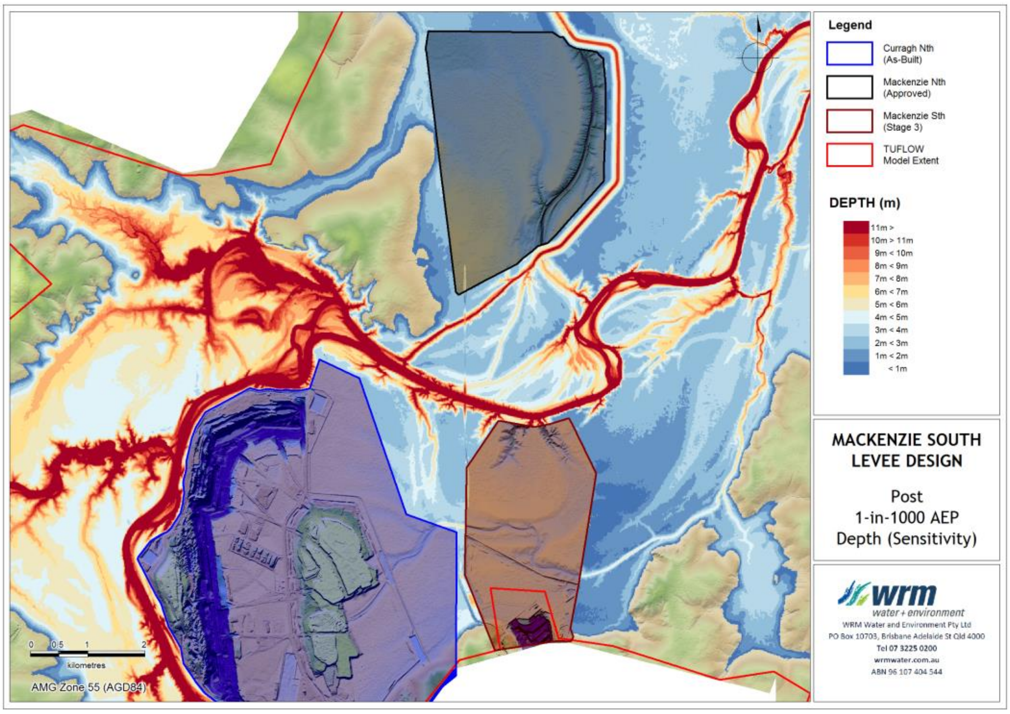

Figure B.4 – Curragh North Pit V as constructed (low bridge loss) – Flood Depth

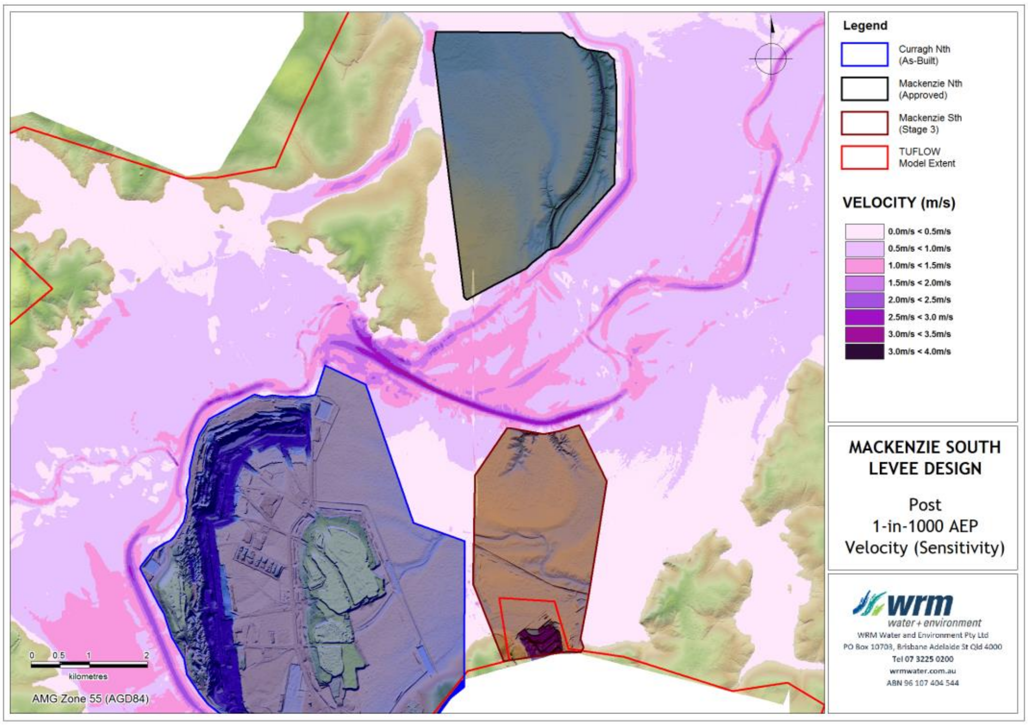

Figure B.5 – Curragh North Pit V as constructed (low bridge loss) – flood velocity

Table B.1 – Sensitivity analysis and comparison with previous modelling

			Water Surface Level (mAHD)					
			CPU Model 15m Grid		GPU Model/10m Grid/Recalibrated			
			0584-02-H	0684-01-H[Rev2]				
Curragh Pit V			As built	As built	As built	As built	As approved	As approved
Mackenzie South			Stage 3 As Approved	Stage 3 As Approved	Stage 3 As Proposed	Stage 3 As Proposed	Stage 3 As Proposed	Stage 3 As Proposed
Mackenzie North			No	No	Yes	Yes	Yes	Yes
Mackenzie North Haul Road			N/A	N/A	10m Opening	Bridge Removed	10m Opening	Bridge Removed
			Q1000_Previous Model	Q1000_Previous Model	Q1000_Post_Exist	Q1000_Post_Exist _Sensitivity	Q1000_Post_Approved	Q1000_Post_Approved _Sensitivity
A	694,773	7,422,075	126.93	126.93	127.28	127.22	-	-
B	694,499	7,422,798	126.93	126.93	127.27	127.21	-	-
C	694,507	7,423,543	126.93	126.93	127.26	127.19	-	-
D	694,516	7,424,284		126.92	127.24	127.18	-	-
E	694,525	7,424,789		126.80	127.16	127.11	-	-
F	694,777	7,425,144		126.51	126.78	126.74	-	-
G	695,068	7,425,555		126.04	126.34	126.37	126.32	126.36
H	695,697	7,425,448		125.66	126.00	126.02	125.97	126.01
I	696,322	7,425,593		124.92	125.19	125.20	125.18	125.19
J	696,622	7,425,161		124.48	124.79	124.80	124.78	124.79
K	696,960	7,424,699		123.99	124.40	124.40	124.38	124.39
L	696,960	7,424,262		123.90	124.29	124.30	124.28	124.29
M	697,054	7,423,868		123.48	124.13	124.14	124.12	124.12
N	696,887	7,423,256		123.41	124.10	124.10	124.09	124.09
O	696,361	7,422,773		123.41	-	-	-	-
P	696,515	7,422,691		123.41	124.10	124.11	124.09	124.09
Q	696,395	7,422,161		123.41	124.10	124.11	124.09	124.10
R	696,386	7,421,861		123.41	124.12	124.12	124.10	124.11

Appendix B Mackenzie North Project Flood Impact Assessment Report

MACKENZIE NORTH PROJECT FLOOD IMPACT ASSESSMENT

Jellinbah Resources Pty Ltd
July 2013

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CLIENT: Jellinbah Resources Pty Ltd
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For and on behalf of
WRM Water & Environment Pty Ltd

Michael Batchelor
Director

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1 INTRODUCTION

WRM Water & Environment Pty Ltd was engaged by Jellinbah Resources Pty Ltd to undertake an impact assessment of the proposed Mackenzie North Project.

WRM has previously undertaken hydrologic and hydraulic modelling of the Mackenzie River in the vicinity of the Jellinbah mine to estimate design flood discharges and flood levels for Wesfarmers' Curragh North Pit U Expansion Project and the Jellinbah Mackenzie North Project. The models and data used for these assessments were made available by Wesfarmers for this impact assessment.

The proposed mine area extends onto the Mackenzie River floodplain and will require the construction of a flood levee, haul road and bridge crossings.

The proposed mine may also require the construction of an anabranch diversion subject to determination from the Department of Natural Resources and Mines (DNRM) as to the status of the anabranch (i.e.: "overflow" or "water course"). For the purposes of this study, the diversion has been included.

The location of the project is shown in Figure 1.1.

Detailed hydrologic and hydraulic modelling was carried out for the Mackenzie River and floodplain in the vicinity of the proposed disturbance area. The modelling results define existing flood conditions in the Mackenzie River floodplain areas as well as conditions following the development of the Mackenzie North Project, and the approved structures for Jellinbah's Mackenzie South Pit and Wesfarmers' Curragh North Pit V.

This report details the modelling methodology and modelling results. Hydrologic modelling data and results are shown in Appendix A and Appendix B. Figures showing the hydraulic modelling results for both the existing and post-developed conditions are shown in Appendix C and Appendix D, respectively.

The results presented herein should not be used for any other purpose without seeking advice from WRM Water & Environment regarding its applicability.

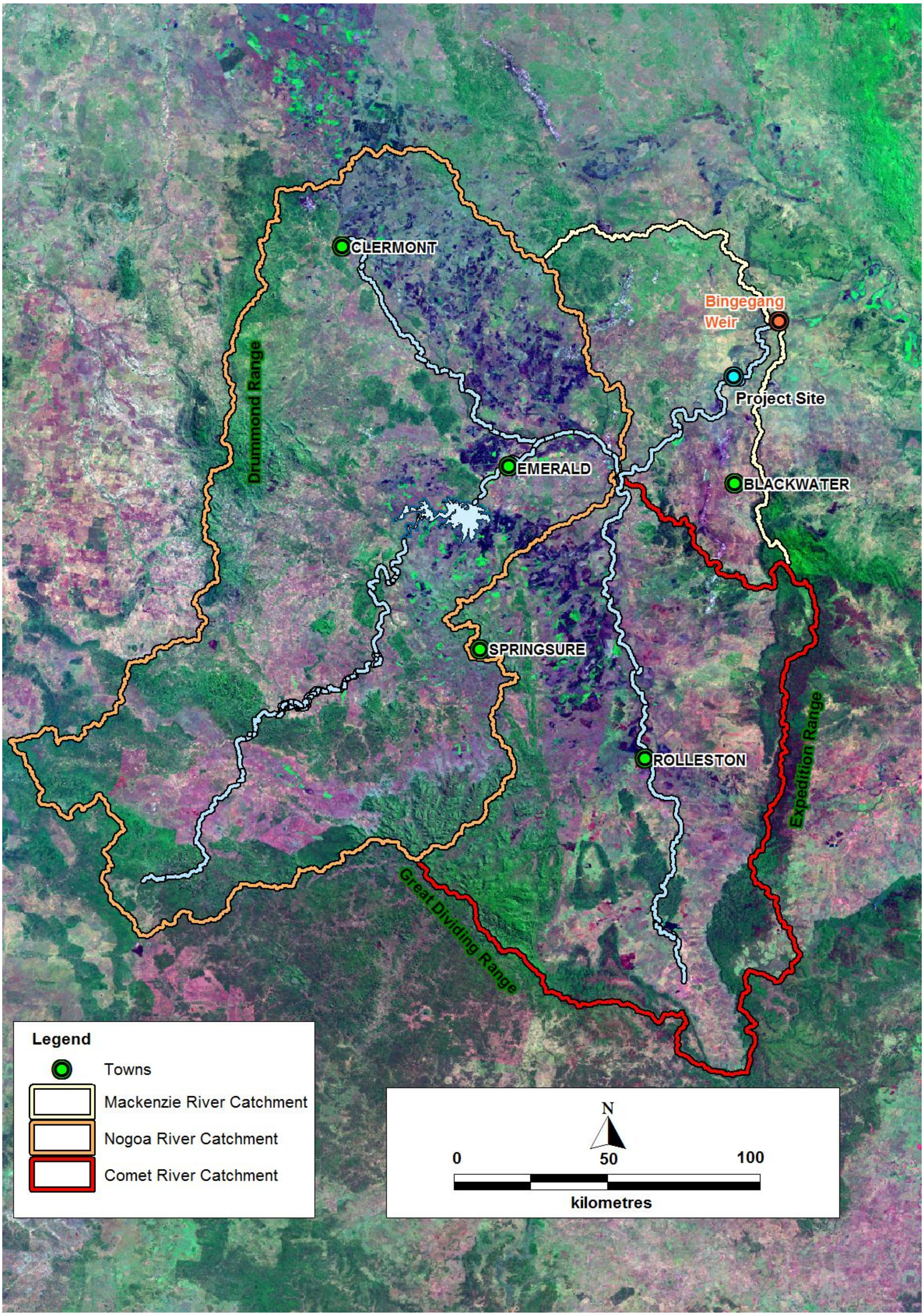


Figure 1.1 Mackenzie North Project Locality and Mackenzie River Catchment

2 BACKGROUND INFORMATION

2.1 PROPOSED MACKENZIE NORTH INFRASTRUCTURE

The proposed Mackenzie North project is located on the northern floodplain of the Mackenzie River. The proposed project includes the construction of a levee which will protect the proposed workings from flooding in the Mackenzie River floodplain. The proposed levee is located on the opposite bank and to the north of the approved Jellinbah levee as shown in Figure 2.1. A number of existing projects are located in the nearby vicinity, including the existing Wesfarmers Curragh Project. Both the existing Jellinbah and Curragh operations have approval to extend levees into the Mackenzie River floodplain to the south of the proposed project. The extent of these existing projects is shown in Figure 2.1.

2.2 DRAINAGE CHARACTERISTICS

The Mackenzie River is a major tributary of the Fitzroy River which flows to the Coral Sea at Rockhampton. Figure 1.1 shows the drainage network of the Mackenzie River catchment and its major tributaries, the Nogoa River (including Theresa Creek) and the Comet River. The catchments are bordered by the Expedition Range to the east, the Great Dividing Range to the south, the Drummond Range to the west and the Peak Range to the north.

The total catchment area of Mackenzie River to the Bingegang Weir (as shown in Figure 1.1) is approximately 50,960 km^2. The catchment areas of the tributaries at the upstream end of the Mackenzie River are approximately:

- Nogoa River - 28,550 km^2 (of which 8,610 km^2 is contributed by Theresa Creek)
- Comet River - 16,510 km^2

Outside of the towns of Clermont, Emerald, Springsure and Blackwater, the catchment is sparsely populated. Land use is typically rural with substantial areas cleared for grazing. Fairbairn Dam was constructed on the Nogoa River 40 km upstream of the Theresa Creek confluence in 1973, and supplies large areas of irrigated crops associated with the Emerald Irrigation Area. The dam stores 1,300 GL when full and has a catchment area of 16,500 km^2. It has significantly changed the flow regime in the downstream reaches of the Nogoa and Mackenzie Rivers. Releases are made from the dam to deliver supplies to downstream riparian water users and to maintain supplies from Bedford and Bingegang Weirs to various towns, mines and irrigators.

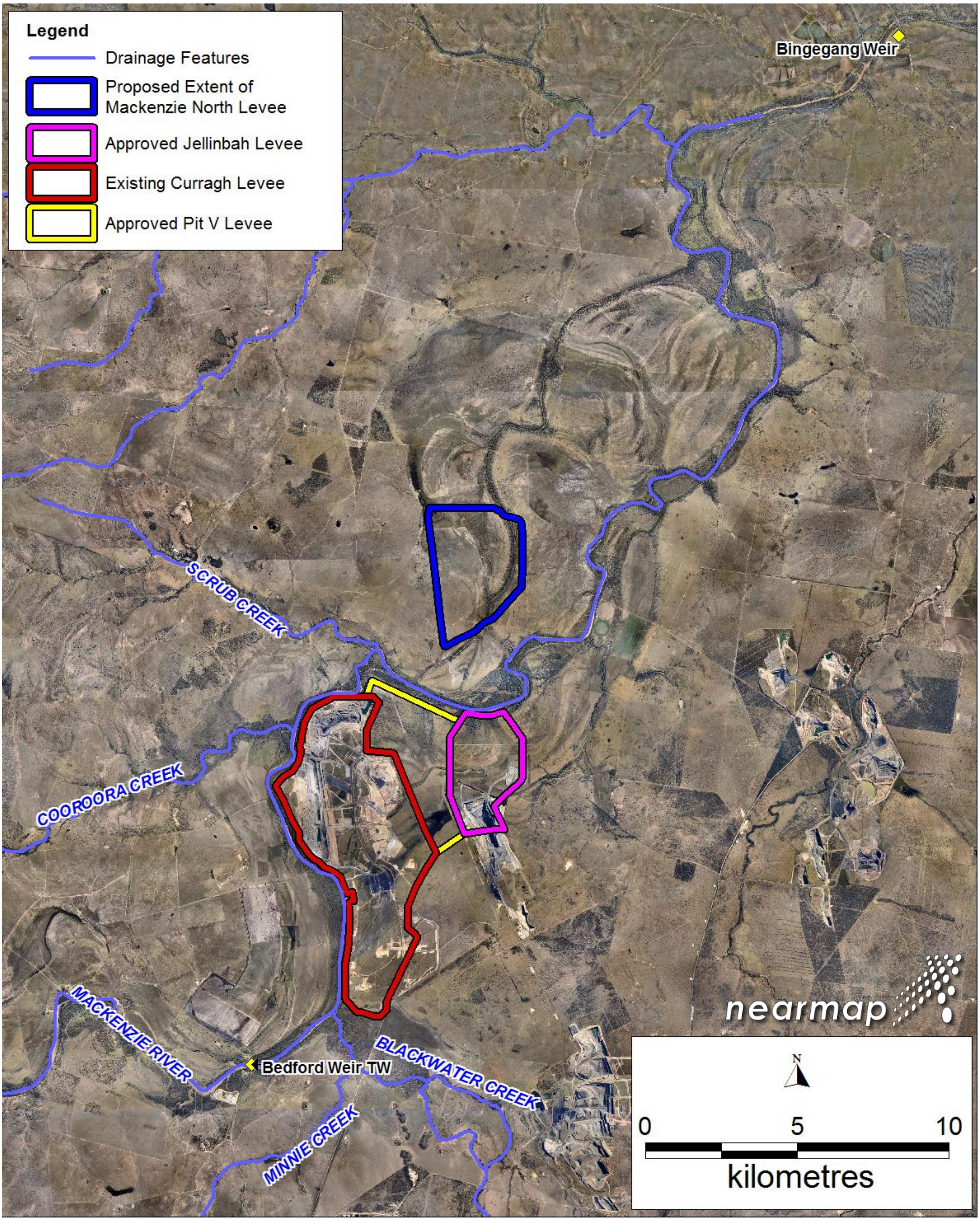


Figure 2.1 Existing and approved floodplain infrastructure in the vicinity of the proposed Mackenzie North Project

The main channel of the Mackenzie River in the Project area has a base width of up to 50m and is about 20m deep. Figure 2.2 shows the Mackenzie River channel to the south of the project site.

As shown in Figure 2.1, Scrub Creek, a minor tributary, joins the Mackenzie River to the south-west of the proposed Mackenzie North levee. Blackwater Creek and Cooroora Creek join the Mackenzie River upstream of the site. The catchment areas of these minor tributaries are approximately:

- Blackwater Creek – 1,022 km^2
- Cooroora Creek - 625 km^2
- Scrub Creek - 78 km^2

Figure 2.2 Mackenzie River Channel to the south of the proposed Mackenzie North Project

3 ESTIMATION OF DESIGN DISCHARGES

3.1 METHODOLOGY

Design flood discharges in the vicinity of the Project site were estimated using an URBS (Carroll, 2004) hydrologic model of the Mackenzie River catchment. URBS is a runoff-routing computer model that uses a network of conceptual storages to represent the routing of rainfall excess through a catchment. URBS is used extensively throughout Australia by the Bureau of Meteorology for flood forecasting on major river systems.

For this study, the URBS model was used in the “split mode” which enables the simulation of separate catchment and channel routing. Adopted rainfall losses are subtracted from the total rainfall hyetograph to obtain rainfall excess. Rainfall excess is routed through a conceptual storage representing each sub-catchment of the model before being added to the creek or river channel. Routing through the creek or river system uses the Muskingum method.

The URBS model was calibrated against recorded stream flows within the catchment for the following historical flood events:

- February 1978;
- May 1983;
- April 1990;
- March 1994;
- January 2008; and
- January 2011.

The calibrated model was then used to estimate design flood discharges. Estimated design discharges were checked against the results of flood frequency analysis of an annual series of peak flows from a number of stream gauging stations within the catchment.

3.2 MODEL CONFIGURATION

The adopted URBS model of the Mackenzie River catchment is based on an URBS model developed by Sunwater. The Sunwater model consists of four linked models, the details of which are shown in Table 3.1. Note that the Nogoa, Theresa and Comet models discharge into the Mackenzie model. The extents and catchment subdivisions of the four models are shown in Figure 3.1.

Catchment subdivisions for the Sunwater model were determined using the CatchmentSIM program (Ryan, 2004), and a Digital Elevation Model derived from the NASA Shuttle Radar Topographic Mission (SRTM) data.

Only minor changes were made to the Sunwater models for use in this study. All catchment areas were the same as the Sunwater models. The only change to the model configuration was the addition of a storage representing Lake Nuga Nuga in the upper reaches of the Comet River catchment. In the absence of detailed survey data, the adopted storage for Lake Nuga Nuga was approximated based on an estimate of the lake surface area and an assumed flow width for overflows from the lake. The addition of this storage improved the model representation of recorded flows in the upper Comet River catchment.

Table 3.1 Configuration of Mackenzie River URBS Models

Model	No. of Sub-catchments	Catchment Area (km^2)	Downstream Boundary
Nogoa River	105	16,167	Fairbairn Dam Outflow
Theresa Creek	59	8,448	Gregory Highway
Comet River	106	16,136	Comet Weir
Mackenzie River	76	9,762	Bingegang Weir
Total	**346**	**50,513**	**Bingegang Weir**

3.3 AVAILABLE DATA

3.3.1 General

Available data for the calibration of the URBS model consisted of:

- Recorded rainfalls (daily and pluviometer records).
- Recorded water levels at stream gauging stations within the catchment, and
- Rating curves to convert recorded water levels to discharges at the stream gauges.

3.3.2 Rainfall Data

Table A1 (Appendix A) provides details of the available rainfall stations in the vicinity of the Mackenzie River catchment. The available rainfall data provides reasonable coverage of the catchment. However, the pluviometer network for the earlier calibration events is relatively limited. The location of the rainfall stations in the vicinity of the Mackenzie River catchment is shown in Figure 3.1.

3.3.3 Streamflow Data

Recorded water level data and rating curves were obtained from the Department of Environment and Heritage Protection (DEHP) and Sunwater (see Table 3.2). Rainfall data was obtained from the Bureau of Meteorology and DEHP. Due to equipment malfunctions or other recording errors, data was not available at all rainfall and streamflow monitoring sites for all events.

Details of stream gauging stations in the catchment are provided in Table A2 in Appendix A and show the streamflow data available for the various calibration events at key stations. The locations of the key streamflow gauges used in the calibration are shown in Figure 3.1. Note that the URBS model was not calibrated to every streamflow gauge within the catchment because many of these gauges command small catchment areas that will have a negligible impact on the overall model performance.

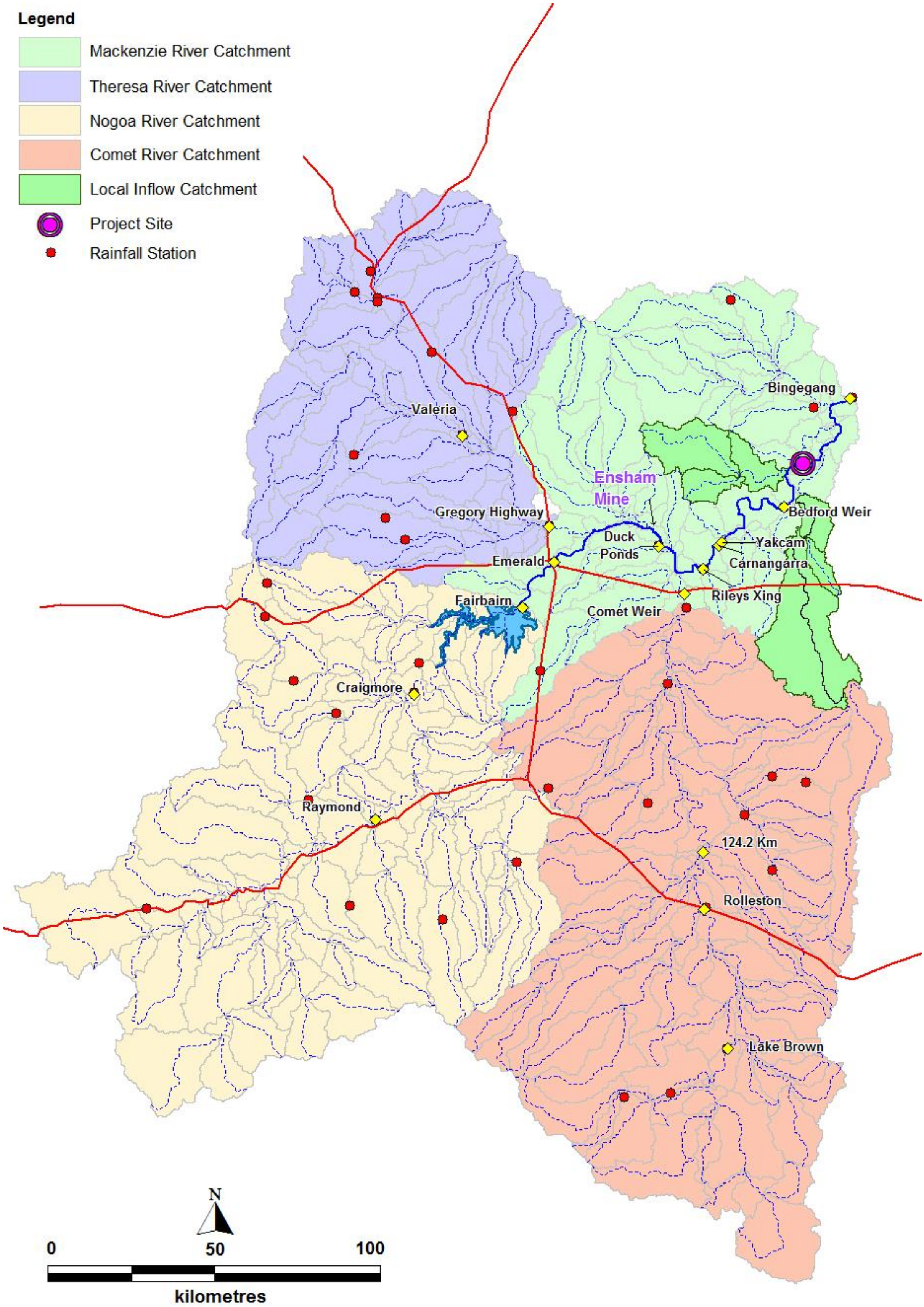


Figure 3.1 URBS Model Configuration

Table 3.2 Streamflow Data Availability for Calibration Events

URBS Model	Station No.	Station Name	AMTD (km)	1978 Flood	1983 Flood	1990 Flood	1994 Flood	2008 Flood	2011 Flood
Nogoa	130202A	Raymond	815.1	✓	✓	×	×	✓	×
	130209A	Craigmore	755.7	✓	✓	✓	×	✓	×
	-	Inflow		✓	✓	✓	✓	✓	×
	130216A	Fairbairn	685.6	✓	✓	✓	✓	✓	✓
Theresa	130210A	Valeria	51.5	✓	✓	✓	✓	✓	×
	130206A	Gregory Highway	14.5	✓	✓	✓	✓	✓	✓
Comet	130502B	Lake Brown	199.2	×	×	×	×	✓	×
	130901	Rolleston		✓	✓	×	×	✓	×
	130506A	The Lake	124.2	×	×	✓	×	✓	✓
	130504A	Comet Weir Inflow	17.2	✓	✓	✓	✓	×	✓
	130504B	Comet Weir	10.8	×	×	×	×	✓	✓
Mackenzie	130201B	Emerald	665.8	✓	✓	×	×	✓	✓
	130219A	Duckponds	625.4	×	×	×	×	✓	✓
	130113A	Rileys Crossing	601.4	×	×	×	×	✓	✓
	130103A	Carnangarra	585.8	✓	✓	✓	✓	×	×
	130920	Yakcam		P	P	P	P	✓	✓
	130104A	Bedford Weir HW	548.8	×	×	×	×	✓	✓
	130111A	Bedford Weir TW	548.7	×	×	×	×	×	✓
	130106A	Bingegang Weir HW	489.2	✓	✓	✓	P	✓	✓
	130110A	Bingegang Weir TW	489.1	×	×	×	P	×	×

× Data unavailable or incomplete
✓ Hydrograph available
P Peak water level only available

Recorded peak water levels at key stream gauges for the 6 calibration events are shown in Table 3.3. Note that recorded peak water levels in the lower Comet River are not shown. These levels are potentially affected by backwater effects from the Mackenzie River during large flood events. The following observations are taken from Table 3.1:

- The 2011 flood event produced the largest recorded outflow from Fairbairn Dam. The peak dam water level was more than 1 m higher than the previous maximum in the 2008 flood.
- The 2011 flood in Theresa Creek had a smaller peak discharge than most of the other events used in model calibration.
- The 2011 flood in the Comet River had a significantly larger peak discharge than the 2008 and 1978 flood events.
- Peak flood levels for the 2011 flood in the Mackenzie River were much higher than the 2008 flood and were very similar to the 1978 flood.

Table 3.3 Recorded Peak Water Levels for Calibration Events at Key Stream Gauges

System	Station No.	Station Name	Recorded Peak Water Level (m) 1978 Flood	1983 Flood	1990 Flood	1994 Flood	2008 Flood	2011 Flood
Nogoa	130216A	Fairbairn	207.02	206.67	206.64	199.94[a]	208.67	209.70
Theresa	130206A	Gregory Highway	11.02	10.42	2.37	9.84	10.81	9.57
Comet	130506A	The Lake	12.64	13.56	10.30	×	13.74	17.28
	130504A	Comet Weir Inflow	11.96	10.88	9.96	10.06	×	×
	130504B	Comet Weir	×	×	×	×	10.33	13.98
Mackenzie	130219A	Duckponds	×	×	×	11.01	14.51	15.03
	130113A	Rileys Crossing	×	×	×	×	20.44	22.78
	130103A	Carnangarra	21.50	18.95	16.00	15.86	19.57[b]	×
	130920	Yakcam	23.15	20.12	16.70	16.00	20.55	23.05
	130104A	Bedford Weir HW	×	×	×	×	130.58	132.23
	130111A	Bedford Weir TW	×	×	×	×	×	21.69[d]
	130106A	Bingegang Weir HW	17.41	15.88	11.85	11.11	16.13[c]	17.45[c]
	130110A	Bingegang Weir TW	×	×	×	12.05	×	×

Shaded values are the largest of the 5 calibration events
× No peak level available
[a] Below dam spillway level
[b] Inferred from peak stage relationship with Yakcam
[c] Bingegang Weir raised in 1998
[d] Peak level unreliable

3.4 REVIEW OF STREAM GAUGE RATING CURVES

3.4.1 Overview

Stream gauge rating curves for key stations provided by DEHP and Sunwater were reviewed for consistency and checked against stream gaugings undertaken during the January 2008 flood. A summary of the gaugings at relevant locations for the 2008 flood is provided in Table 3.4

Table 3.4 Stream Gaugings for Mackenzie River Catchment, January 2008 Flood

Station No.	Station Name	Date & Time	Mean Gauge Height (m)	Gauged Discharge (m^3/s)
130110A	Bingegang TW	25/01/2008 10:50	17.01	3710
		29/01/2008 10:10	15.61	2680
130111A	Bedford TW	27/01/2008 9:45	17.72	3070
		28/01/2008 15:15	17.15	2100
130113A	Rileys Crossing	21/01/2008 9:55	19.70	3340
		22/01/2008 9:45	20.16	3643
		23/01/2008 9:30	20.44	3854
		28/01/2008 11:10	16.81	1773
		31/01/2008 11:15	11.99	668
130201B	Emerald	22/01/2008 14:25	15.30	3146
		27/01/2008 14:30	11.48	832
130206A	Gregory Highway	19/01/2008 11:58	10.64	3840
130504B	Comet Weir	21/01/2008 16:10	9.32	421 [a]
		27/01/2008 12:50	8.64	521 [a]

[a] Affected by backwater

The results of the rating curve review indicated that adopted rating curves at most stations appeared reasonable and were in good agreement with the 2008 gaugings. However, significant issues with the rating curve at high flows were found at the following gauges:

- Theresa Creek at Gregory Highway,
- Mackenzie River at Carnangarra, and
- Mackenzie River at Bingegang Weir.

Further details of the review of the rating curves at these gauges are provided in the following sections.

3.4.2 Theresa Creek at Gregory Highway

Figure 3.2 compares the original Theresa Creek rating curve and DEHP's revision based on the January 2008 streamflow gauging. The rating curve results in a much larger estimated peak flow for the January 2008 flood at this location. It is understood that the rating curve for this station is the subject of ongoing review and has not yet been finalised. The rating curve, as presented in Figure 3.2 was adopted for this study.

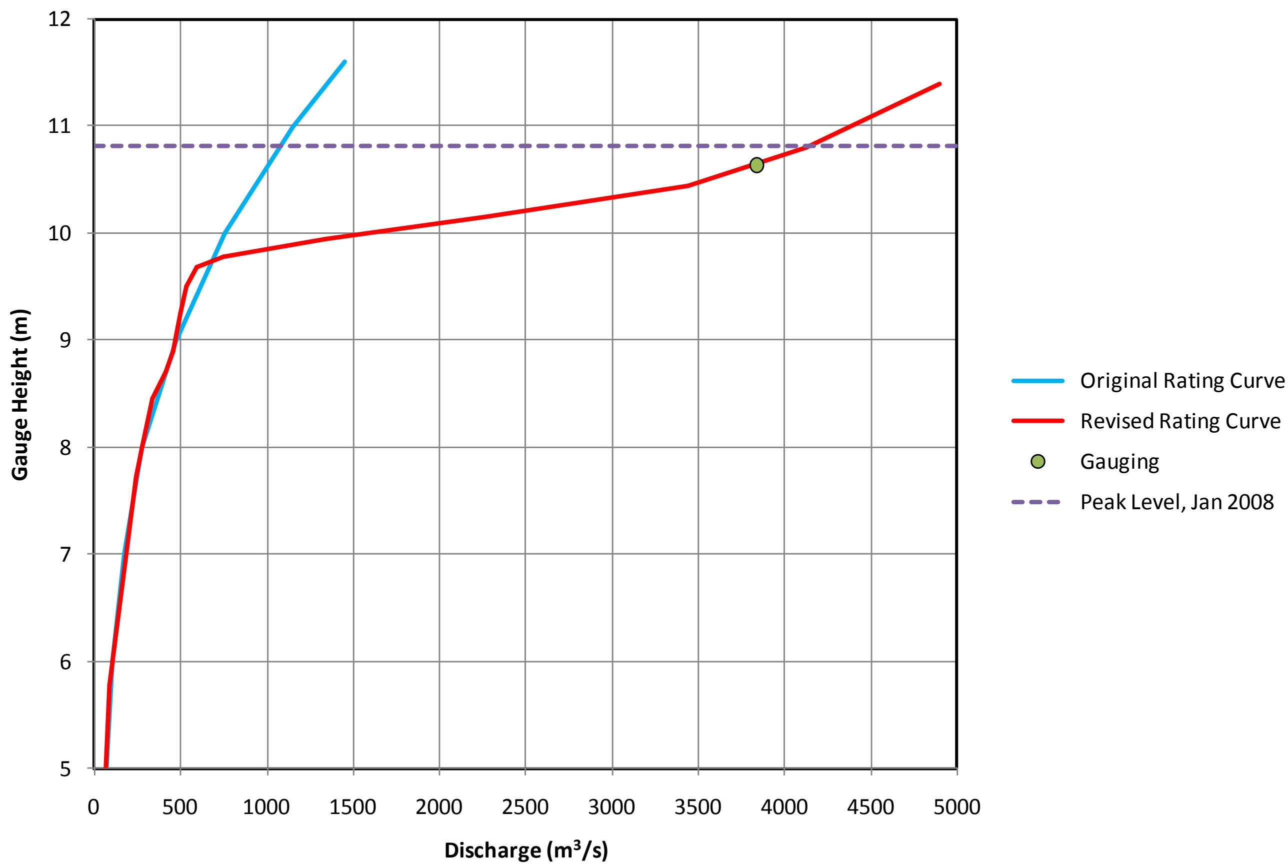


Figure 3.2 Comparison of Rating Curves with Gauged Streamflow, Theresa Creek at Gregory Highway

3.4.3 Mackenzie River at Carnangarra and Bingegang Weir

The rating curve at Carnangarra is important for the current study because this gauge is the only location near the Mackenzie North project site for which recorded stream height data is available for 4 of the 5 calibration events (see Table 3.2).

For the 1978 flood, the recorded peak water level at Carnangarra was 21.50 m. The DEHP rating curve for this gauge yields a corresponding peak flow of 3940 m^3/s.

No data is available at Carnangarra for the 2008 flood. However, data is available for the Yakcam gauge, which is a short distance downstream (see Figure 3.1). Based on the recorded peak stage of 20.55 m at Yakcam, and a line of best fit between the peak stages recorded at Yakcam and Carnangarra for 9 flood events between 1978 and 1998 (see Figure 3.3), we can infer a peak stage of 19.57 m at Carnangarra for the 2008 flood.

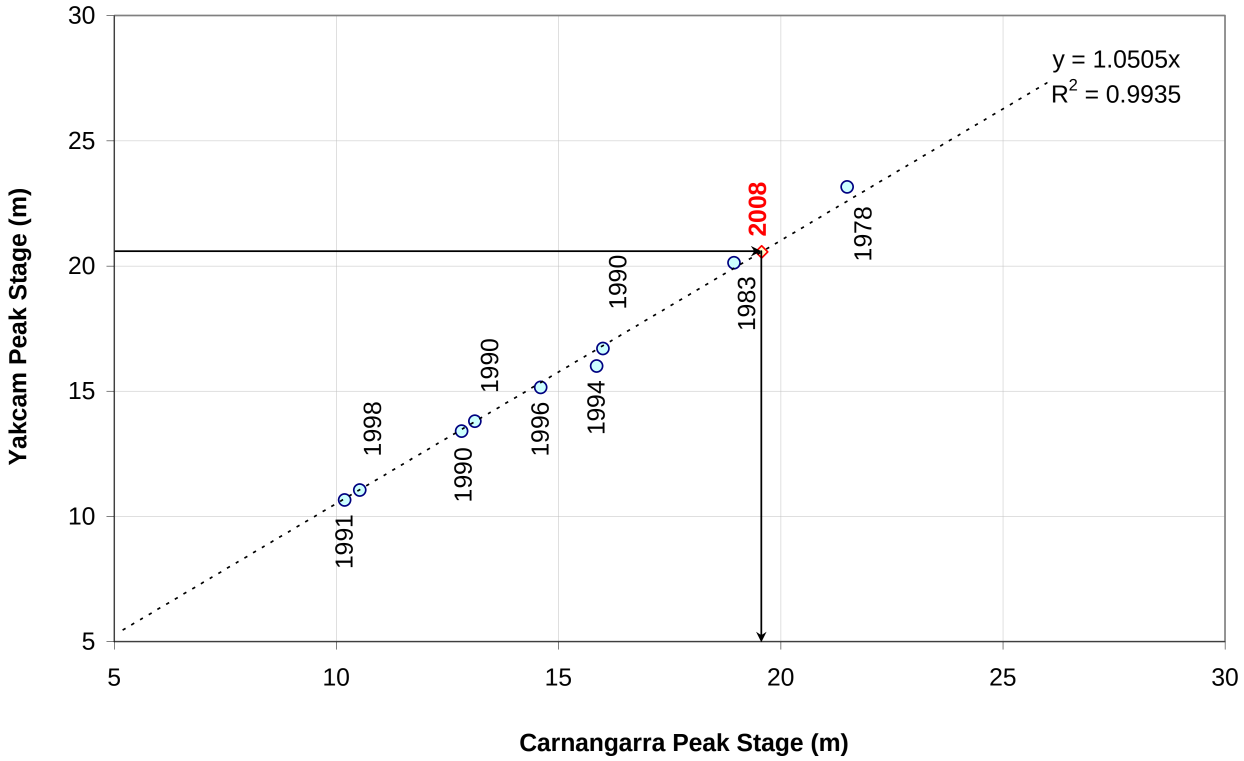


Figure 3.3 Peak Stage Relationship, Mackenzie River at Yakcam and Carnangarra

A stream gauging very close to the peak of the 2008 flood at Rileys Crossing yielded a gauged discharge was 3854 m³/s. As Rileys Crossing is only 15.6 km upstream of Carnangarra, and there are no significant tributaries between, the Rileys Crossing gauged discharge should be a reasonable estimate of the peak discharge at Carnangarra.

Figure 3.4 shows there is a significant discrepancy between the above inferred peak 2008 flood conditions and DEHP's rating curve at Carnangarra. The DEHP rating curve also implies the peak 1978 flood discharge was only about 100 m³/s higher than the peak discharge measured at Riley's Crossing in 2008. This is very unlikely, as the peak water level measured at Yakcam in 1978 was 2.6 m higher than in 2008.

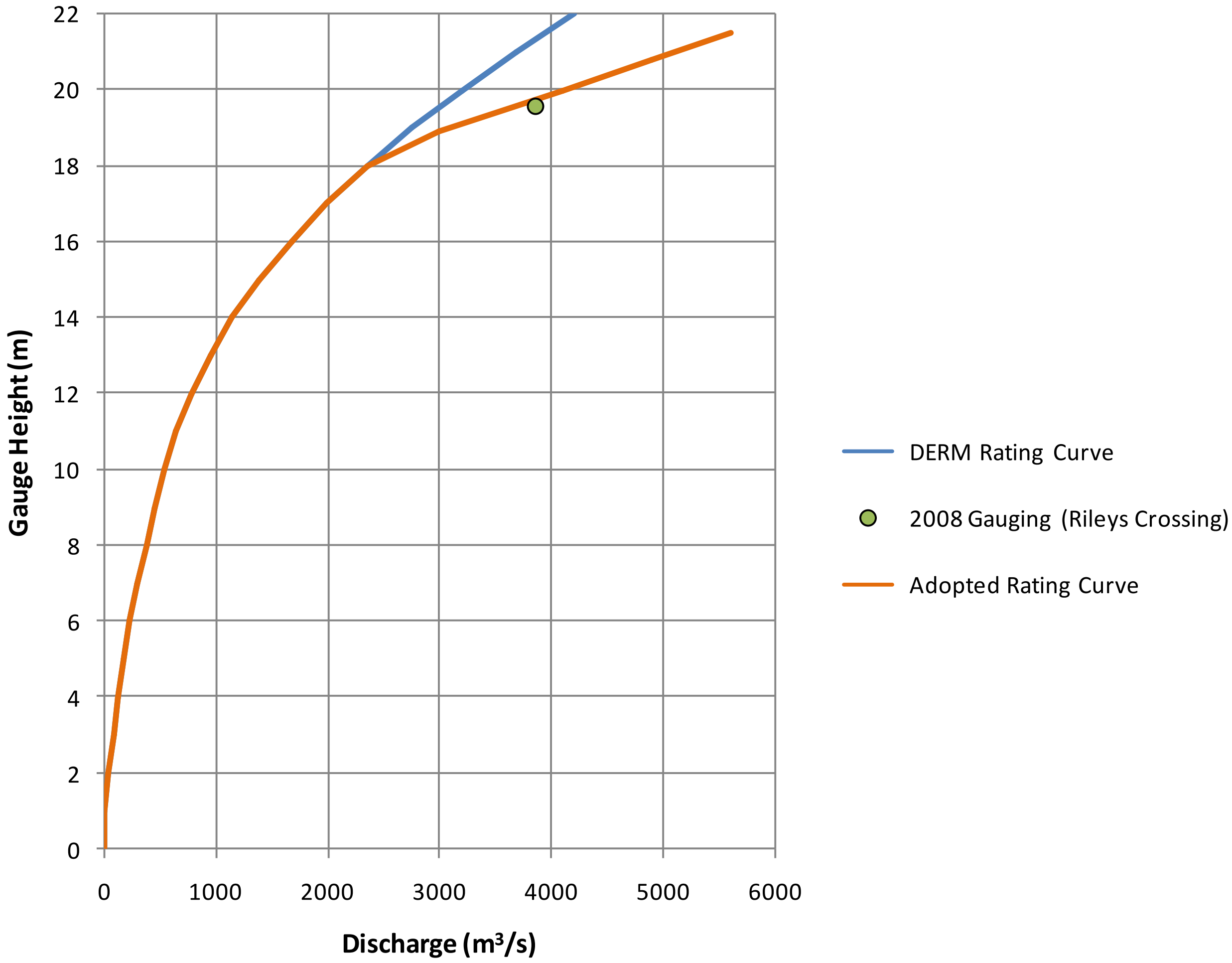


Figure 3.4 Adopted Rating Curve, Mackenzie River at Carnangarra

The DEHP rating curve at Bingegang Weir Headwater indicates a peak flow of 7770 m^3/s for the 1978 event. The catchment area at Bingegang Weir (50,500 km^2) is about 12% greater than at Carnangarra (44,900 km^2). Hence, it seems unlikely that the peak flood discharge at Bingegang Weir would be almost double the peak discharge at Carnangarra.

Table 3.5 shows flood volumes for the 1978 event based on recorded flood heights and the DEHP rating curves at Carnangarra and Bingegang. Modelled flow volume has been used for the Comet River because the gauge is affected by backwater from the Mackenzie River.

The DEHP rating curves indicate a flood volume at Carnangarra which is lower than the sum of the inflow volumes at the upstream gauging stations and a volume at Bingegang Weir that is 70% higher than the volume at Carnangarra. Hence, the available information indicates that:

- the DEHP rating curve for Carnangarra underestimates peak flow and flood volume, and
- the DEHP rating curve for Bingegang overestimates peak flow and flood volume at Bingegang Weir.

For this reason, the following method was adopted to derive modified rating curves for Carnangarra and Bingegang Weir:

- The URBS model was initially calibrated to the 2008 event and then run for the 1978 event with the following inflows;
  - Fairbairn Dam and Gregory Highway inflows were set to the recorded inflow hydrograph (based on the Gregory highway rating curve).
  - URBS modelled inflow was adopted for the Comet River to eliminate backwater effects on the recorded hydrograph.
- The estimated peak discharge at Carnangarra from the URBS model was adopted as an estimate of the actual 1978 peak discharge at Carnangarra.
- The Carnangarra rating curve was modified to fit to the gauged 2008 peak flow (at Riley's Crossing) and the estimated 1978 peak flow.
- The URBS model was run with the Carnangarra hydrograph based on the recorded flood heights and the modified Carnangarra rating curve.
- The estimated peak discharge at Bingegang Weir from the URBS model was adopted as an estimate of the actual 1978 peak discharge at Bingegang.
- The Bingegang 1978 rating curve (prior to raising of the weir) was modified to fit to the estimated 1978 peak flow.

Figure 3.5 and Figure 3.6 show the recorded and predicted 1978 flood hydrographs at Carnangarra and Bingegang Weir respectively with upstream inflows set to recorded inflow hydrographs as described above.

Figure 3.7 shows the adopted rating curve for Mackenzie River at Bingegang Weir Headwater. The peak flow for the 1978 event using the modified rating curve is 5550 m^3/s. The 1978 flood volumes based on the modified rating curves for Carnangarra and Bingegang (shown in Table 3.5) are more consistent with expected values.

Table 3.5 Flood Volumes From Recorded Flood Heights, 1978 Flood Event

System	Station No.	Station Name	Proportion of catchment to Bingegang	Flood Volume from DEHP Rating Curves (GL)	Flood Volume from Modified Rating Curves (GL)
Nogoa	130216A	Fairbairn	32%	640	
Theresa	130206A	Gregory Highway	17%	1040 [a]	
Comet	130504A	Comet	32%	410 [b]	
		Sum of Inflows	81%	2090	2090
Mackenzie	130103A	Carnangarra	89%	1960 [c]	2380
	130106A	Bingegang Weir HW	100%	3330 [d]	2865

[a] Based on rating curve at Gregory Highway (see Section 3.4.2).
[b] Based on modelled flow volume due to backwater effects on recorded volume.
[c] Based on DEHP rating curve for Carnangarra.
[d] Based on DEHP rating curve for Bingegang Weir prior to weir raising in 1998.

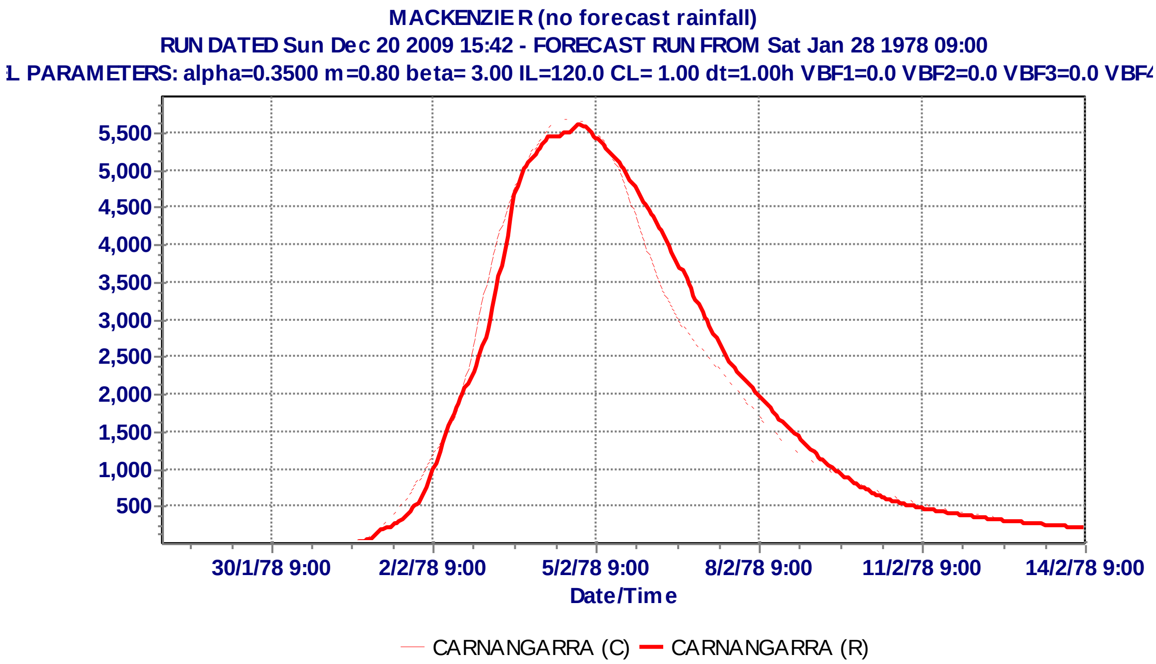


Figure 3.5 Comparison of Calculated (C) and Recorded (R) 1978 Discharge Hydrographs at Carnangarra with Recorded Upstream Inflows and Modified Carnangarra Rating Curve

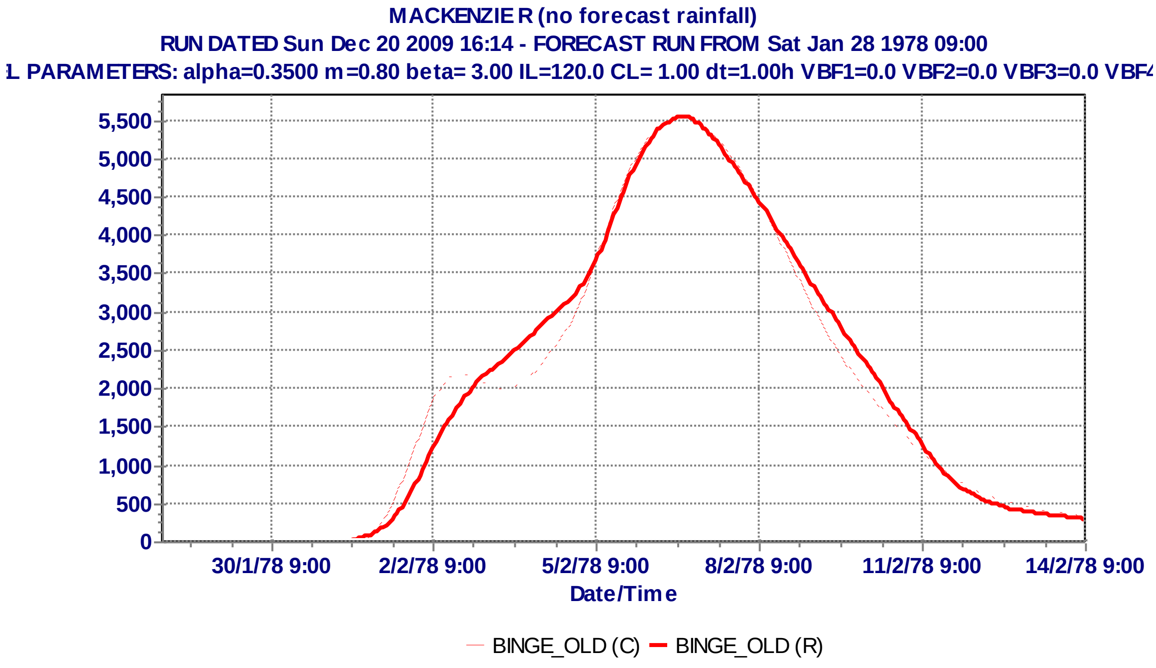


Figure 3.6 Comparison of Calculated (C) and Recorded (R) 1978 Discharge Hydrographs at Bingegang with Recorded Upstream Inflows and Modified Bingegang Rating Curve

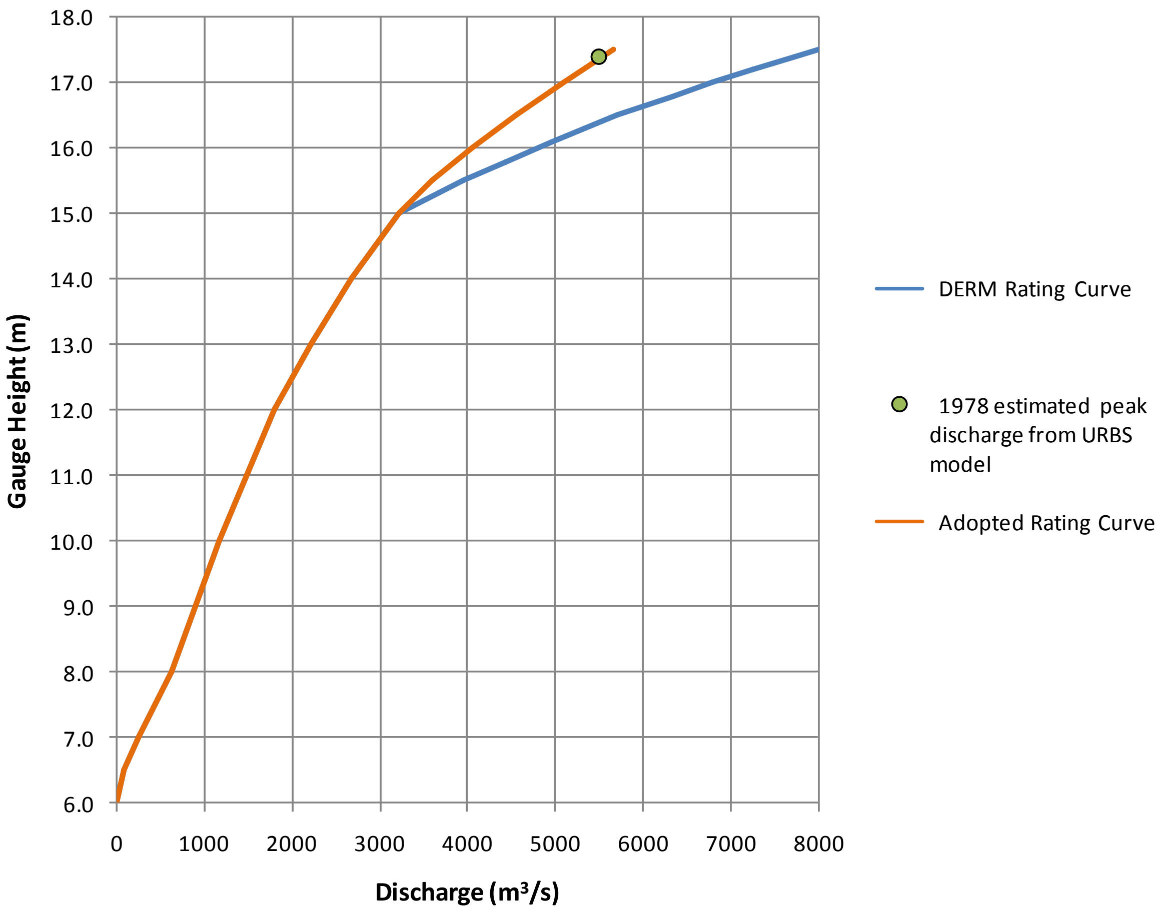


Figure 3.7 Adopted Rating Curve, Mackenzie River at Bingegang Weir Headwater

3.5 URBS MODEL CALIBRATION

3.5.1 Overview

The URBS model was calibrated against recorded stream flows within the catchment for the following historical flood events:

- February 1978,
- May 1983,
- April 1990,
- March 1994,
- January 2008, and
- January 2011.

Calibration of the URBS model was achieved by:

- Adjusting the selected initial and continuing loss rates for each of the four component URBS models for each of the calibration events,
- Adjusting the channel and catchment routing parameters (“alpha” and “beta”) for each of the component URBS models.
- Adjusting a small number of channel routing parameters using reach length factors, and
- Adding or modifying conceptual storage within the models.

3.5.2 Flood Losses to Ensham Open Cut Pits

Of all of the historical events, the 2008 flood had the best quality and quantity of recorded rainfall and streamflow data. However, for this event, flood behaviour at the Project site was affected by flooding of open cut mining pits at the Ensham mine, located about 80 km upstream of the Mackenzie North project site. The timing and rate of inflows to the pits is unknown. However, based on the surface area of the pits (see Figure 3.8) and an assumed depth, the flood volume that flowed in to the pits is estimated to be of the order of 100 to 200 GL. Flood water losses into the Ensham pits were modelled as follows:

- 20% of flow above 2200 m^3/s downstream of the Duckponds gauge was diverted into the pits,
- the first 120 GL of the diverted flow plus 10% of the diverted flow is lost from the model,
- The rest of the diverted flow was routed through a conceptual storage, representing temporary flood storage available in the open cut pits.

Using this approach, the simulated loss of flood volume for the 2008 flood was 170 GL. This represents about 6% of the recorded 2008 flood volume at Bedford Weir. The results of the URBS model, with and without the loss of flow at Ensham, indicate that the peak flood discharge at Bedford Weir would have been about 600 m^3/s higher if flood water had not entered the Ensham pits. The flow loss and conceptual storage were not included in the model for the other 4 calibration events.

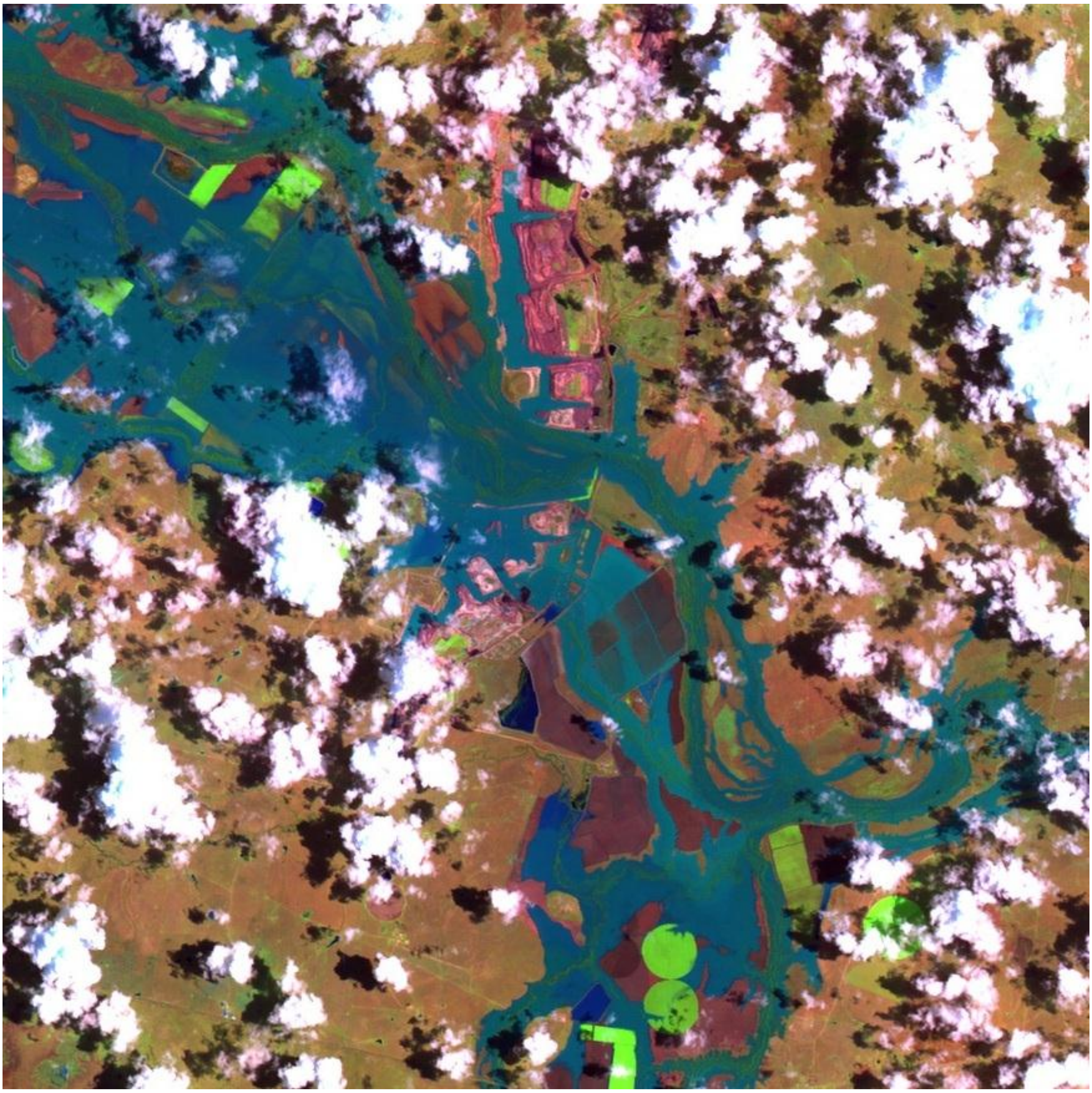


Figure 3.8 Ensham Mine in Landsat-5 TM image acquired on 21 January 2008 (Source: Australian Government, Geoscience Australia)

3.5.3 Recorded Rainfalls

Estimates of total event rainfall for each sub-catchment of the URBS models were prepared by weighting recorded data (both daily and pluviograph stations) based on the square of the inverse distance from the centroid of each sub-catchment to the nearest four rainfall stations, using the method described by Malone (2000). The hyetograph for each sub-catchment was then obtained by applying the temporal rainfall distribution derived from the nearest pluviograph station. Note that some of the earlier calibration events had relatively limited coverage by pluviograph stations, resulting in substantial reliance on daily rainfalls in some areas of the catchment.

3.5.4 Initial Water Levels in Fairbairn Dam

Fairbairn Dam has a significant impact on flood behaviour in the Mackenzie River system through the removal of flood volume to fill the dam (if the dam is at a low level at the commencement of a major rainfall event) and the attenuation of flows through the dam spillway.

Figure 3.9 shows the relationship between water level, storage in Fairbairn Dam and spillway discharge, obtained from Sunwater. The adopted dam storage capacity at spillway level is approximately 1300 GL. Table 3.6 shows the adopted (as recorded) starting water level in Fairbairn Dam for each of the calibration events based.

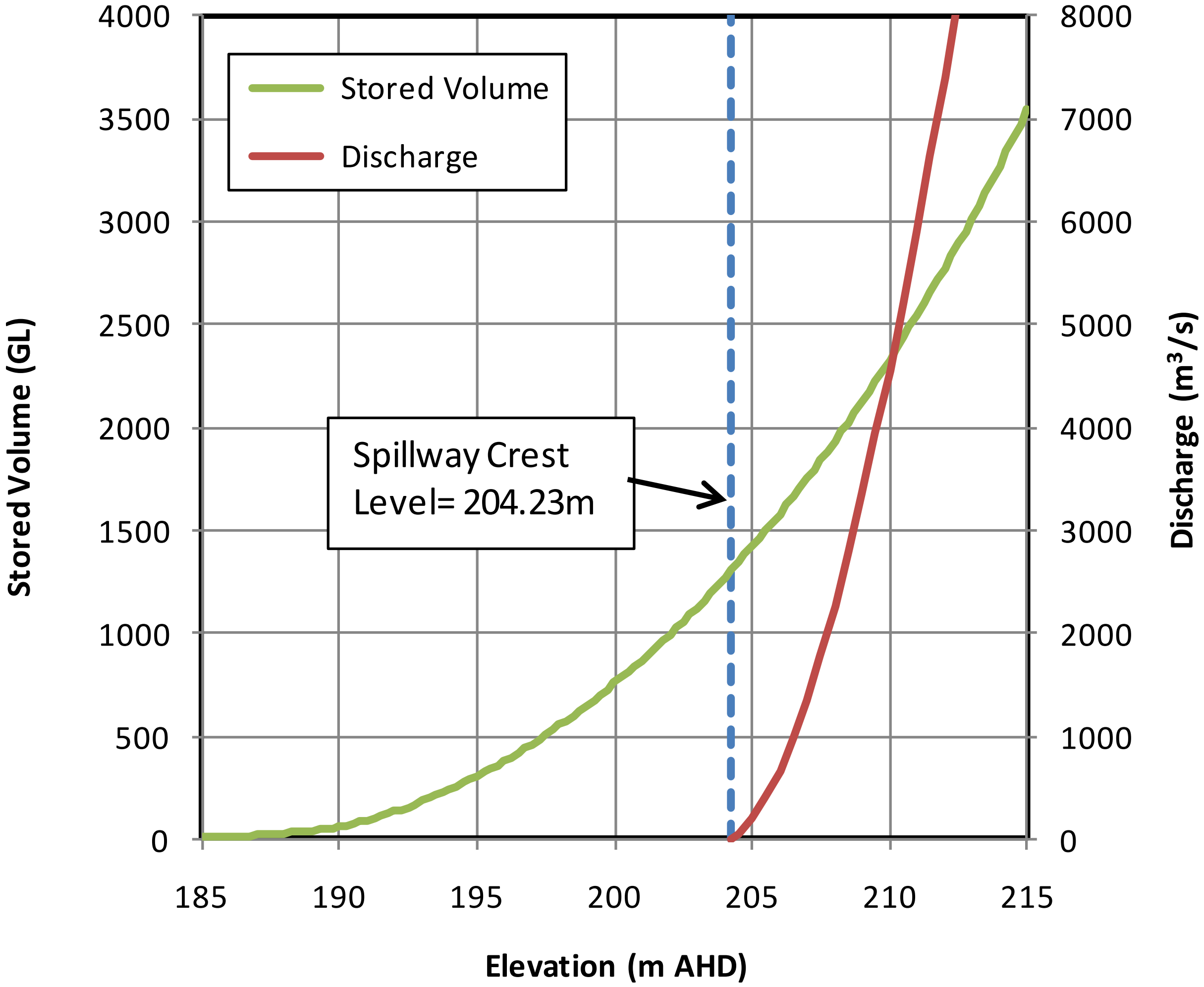


Figure 3.9 Adopted Storage and Spillway Discharge Curves for Fairbairn Dam

Table 3.6 Adopted Fairbairn Dam Starting Water Levels for Calibration Events

Event	Adopted Starting Water Level (mRL)
1978	203.41
1983	202.27
1990	203.50
1994	197.73
2008	197.06

Note: Peak level in 1994 event was below spillway crest

3.5.5 Adopted URBS Model Parameters

Table 3.7 shows the adopted model parameters for each of the four URBS models for the five calibration events. The same alpha and beta parameters were adopted for all events for each model. Initial and continuing losses were varied between events.

Table 3.7 Adopted URBS Model Parameters for Calibration Events

			1978		1983		1990		1994		2008		2011	
System	Alpha	Beta	IL[a]	CL[b]	IL	CL	IL	CL	IL	CL	IL	CL	IL	CL
Nogoa	0.33	2.5	100	1.2	75	3.3	0	2.7	75	2.6	75	2.2	20	4.2
Theresa	0.27	3.0	160	0.4	140	1.2	30	0.8	130	1.2	95	3.0	30	3.5
Mackenzie	0.35	3.0	120	1.0	50	1.5	100	4.0	50	1.5	100	4.0	60	1.5
Comet	0.45	3.5	10	3.5	50	2.5	0	1.0	80	1.5	15	2.5	60	2.2

[a] IL = Initial Loss, mm
[b] CL = Continuing Loss Rate, mm/hr

3.6 URBS MODEL CALIBRATION RESULTS

Figures 3.10 to 3.23 show a comparison of calculated and recorded flood discharge hydrographs for the January 2011 event for the 4 linked URBS models. The models provide a good representation of the hydrograph shape and peak discharge for the 1978, 2008 and 2011 calibration events. The fit to the 1983 and 1994 events is not as good. The fit to the 1990 event is reasonable, although the recorded data is incomplete for this event.

A comparison of calculated and recorded flood discharge hydrographs at other key stations for the remaining calibration events is provided in Appendix B. Overall, the URBS model is considered to provide a good representation of the hydrologic response of the Mackenzie River catchment. For some events, recorded rainfalls do not correspond well to the shape of the recorded hydrograph. This limits the goodness of fit that is able to be obtained at downstream gauging stations. For the largest flood event (2011), the model fit to recorded data is generally very good.

3.6.1 Nogoa river

Figure 3.10 and Figure 3.11 show a comparison of calculated and recorded flood hydrographs for the Nogoa River at Craigmore (catchment area = 13,870 km²) and Fairbairn Dam (dam outflow, catchment area = 16,170 km²). The timing and shape of the recorded hydrograph are reproduced well by the URBS model. The calculated hydrograph at Craigmore has a significantly higher peak discharge than the recorded hydrograph. However, the accuracy of the rating curve at Craigmore near the hydrograph peak is doubtful. The calculated hydrograph compares very well to the recorded hydrograph at Fairbairn Dam outflow.

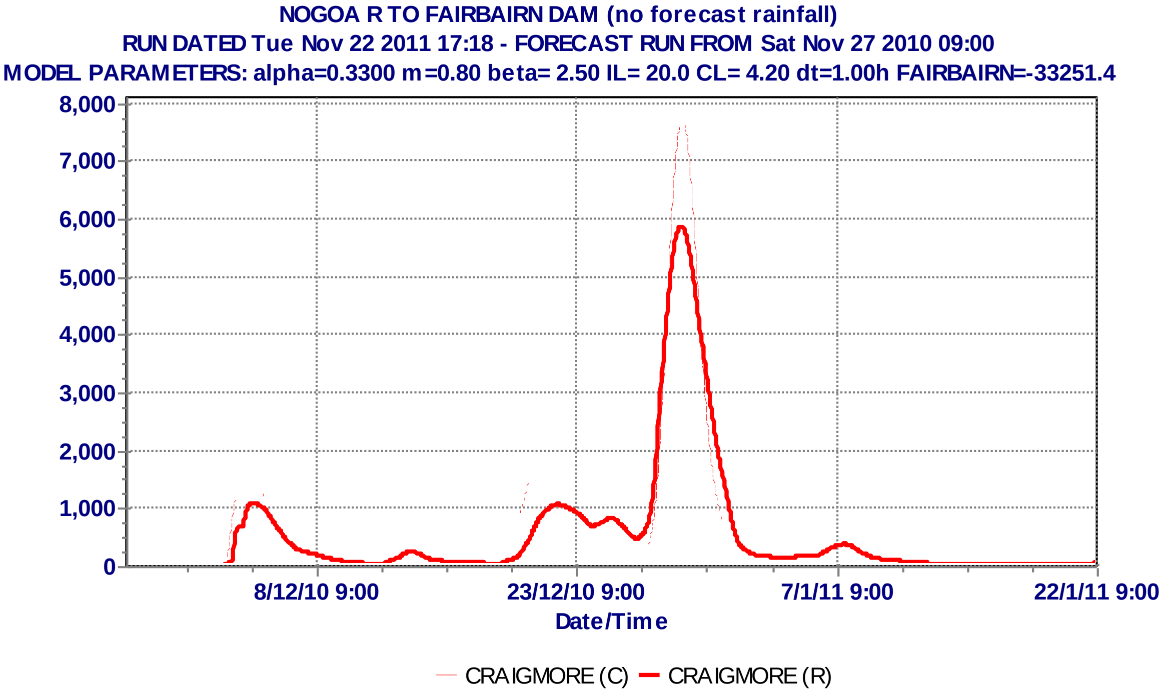
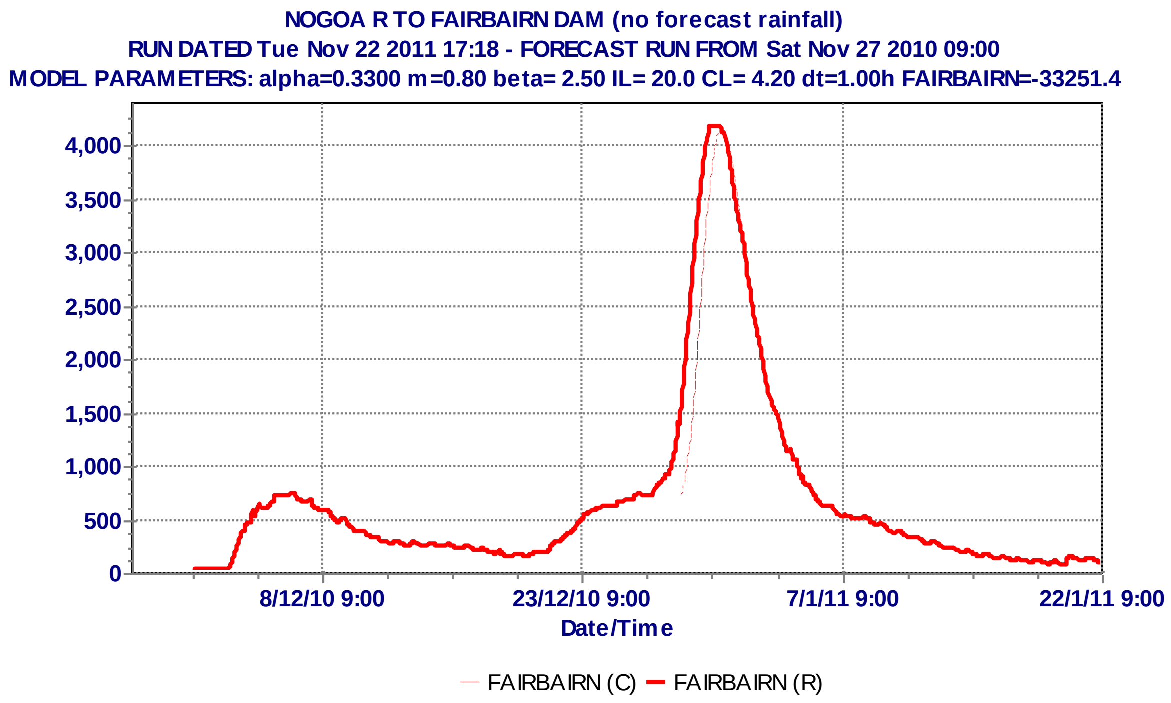


Figure 3.10 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Nogoa River at Craigmore (130209A)



Nogoa

Figure 3.11 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Nogoa River at Fairbairn Dam Outflow (130216A)

3.6.2 Theresa Creek

Figure 3.12 and Figure 3.13 show a comparison of calculated and recorded flood hydrographs for Theresa Creek at Valeria (catchment area = 4,426 km^2) and Gregory Highway (catchment area = 8,448 km^2). The calculated hydrographs provide a reasonable representation of the timing of discharge but generally overestimate the smaller discharge peaks and underestimate the main discharge peak at Gregory Highway. It is likely that the poor fit to some runoff peaks is due to the relatively coarse representation of rainfall across the catchment (11 gauges across 8,448 km^2), rather than the unsuitability of the URBS model routing parameters. At Valeria, some peak discharges are significantly overestimated and the others are significantly underestimated. The adopted URBS model routing parameters for the Theresa Creek catchment have been demonstrated to provide a good fit to recorded hydrographs for the largest recorded flood events at Gregory Highway (1978 and 2008 flood events).

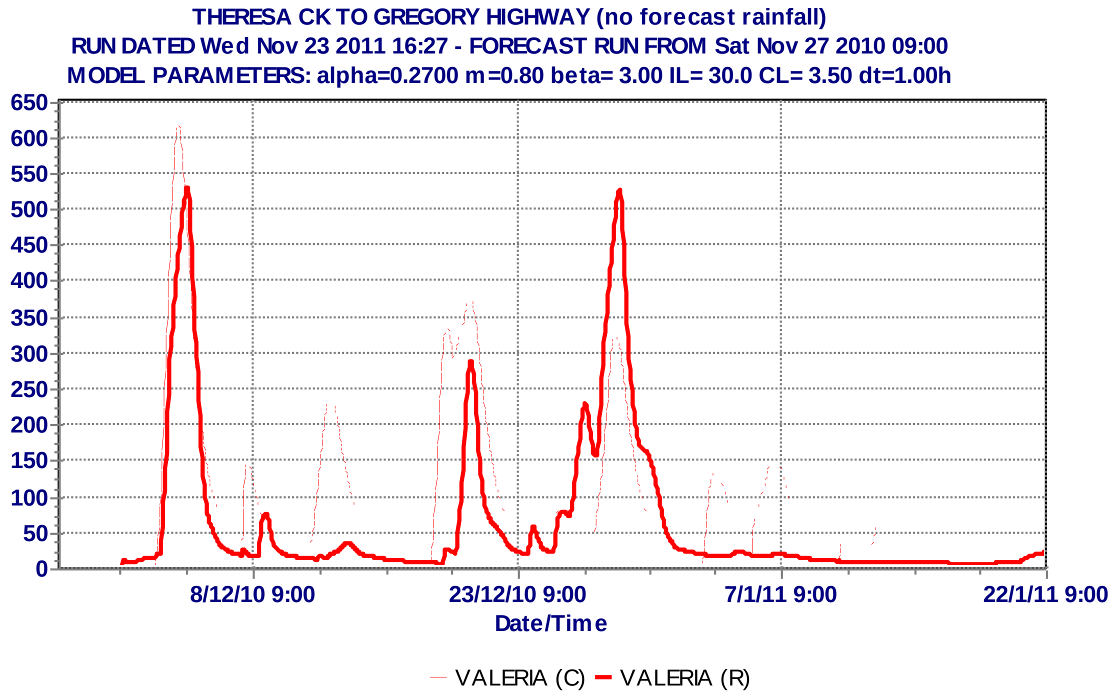


Figure 3.12 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Theresa Creek at Valeria (130210A)

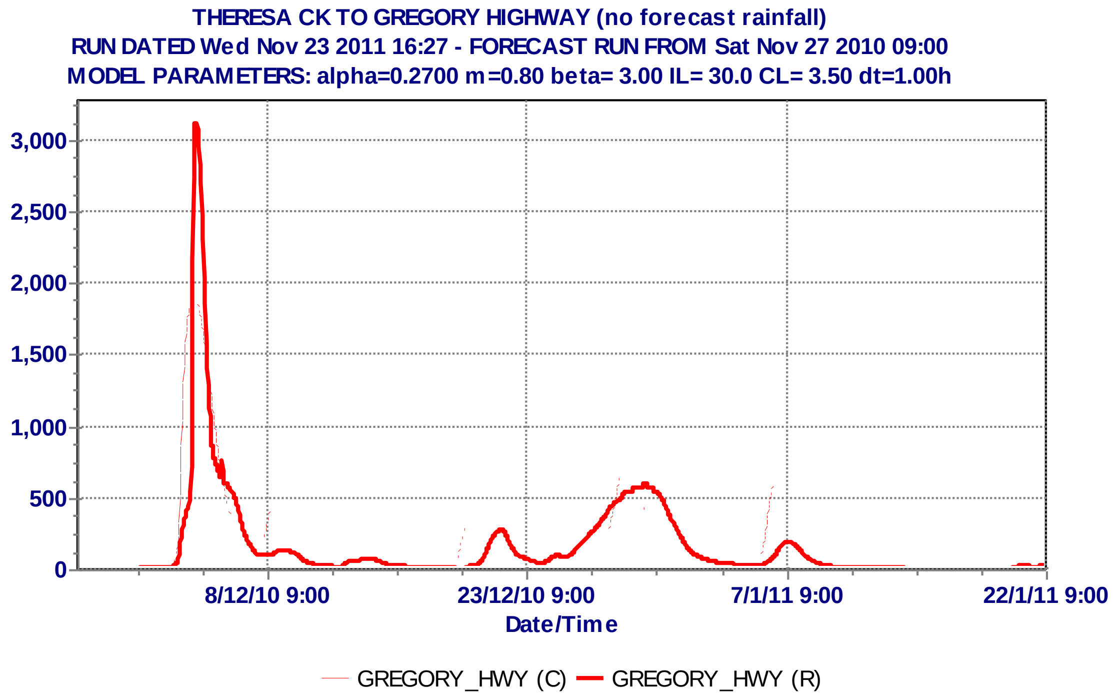


Figure 3.13 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Theresa Creek at Gregory Highway (130206A)

3.6.3 Mackenzie River

Figure 3.14 to Figure 3.17 show a comparison of calculated and recorded flood hydrographs for the Mackenzie River at Duckponds (catchment area = 27,130 km^2), Rileys Crossing (catchment area = 45,040 km^2) and Bedford Weir Headwater (catchment area = 46,847 km^2). Note that all of these results are based on matching the recorded hydrograph at Gregory Highway (Theresa Creek), Fairbairn Dam (Nogoa River) and Comet Weir (Comet River). Using recorded (matched) inflows to the Mackenzie sub-model enables the verification of the Mackenzie sub-model routing parameters because the effect of any inaccuracies in the modelled upstream inflows is removed from the routing parameter estimation. The recorded hydrographs for Duckponds and Rileys Crossing are based on the current DEHP rating curves for these stations.

Due to the unavailability of data for the 2011 event at the Bedford Weir, the rating curve for the Bedford Weir Headwater was extrapolated in 2011 from the calibrated TUFLOW model developed for previous investigations. Figure 3.14 shows a comparison of the rating curve at Bedford Weir Tailwater from the recalibrated TUFLOW model with recorded tailwater levels and stream gaugings for the 2008 flood event. The estimated peak discharge for the 2011 flood (7,000 m^3/s) was obtained by matching recorded and predicted peak flood levels.

Figures 4.7, 4.8 and 4.9 show good agreement between the timing, shape and peak discharge of the calculated and recorded flood hydrographs, indicating that the URBS model provides a realistic representation of flood routing behaviour in the Mackenzie River system.

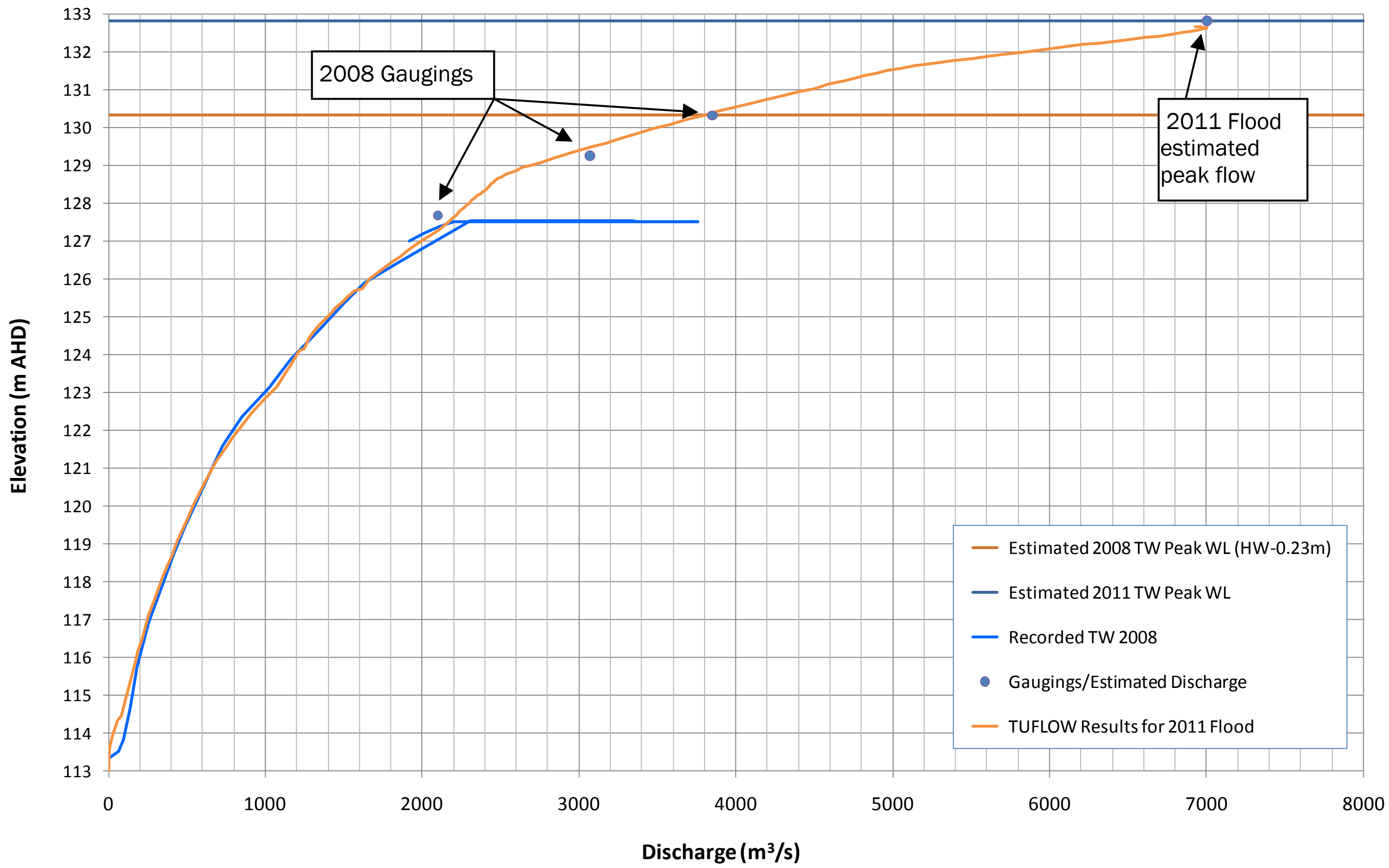


Figure 3.14 Comparison of Modelled Bedford Weir TW Rating Curve with Recorded Data

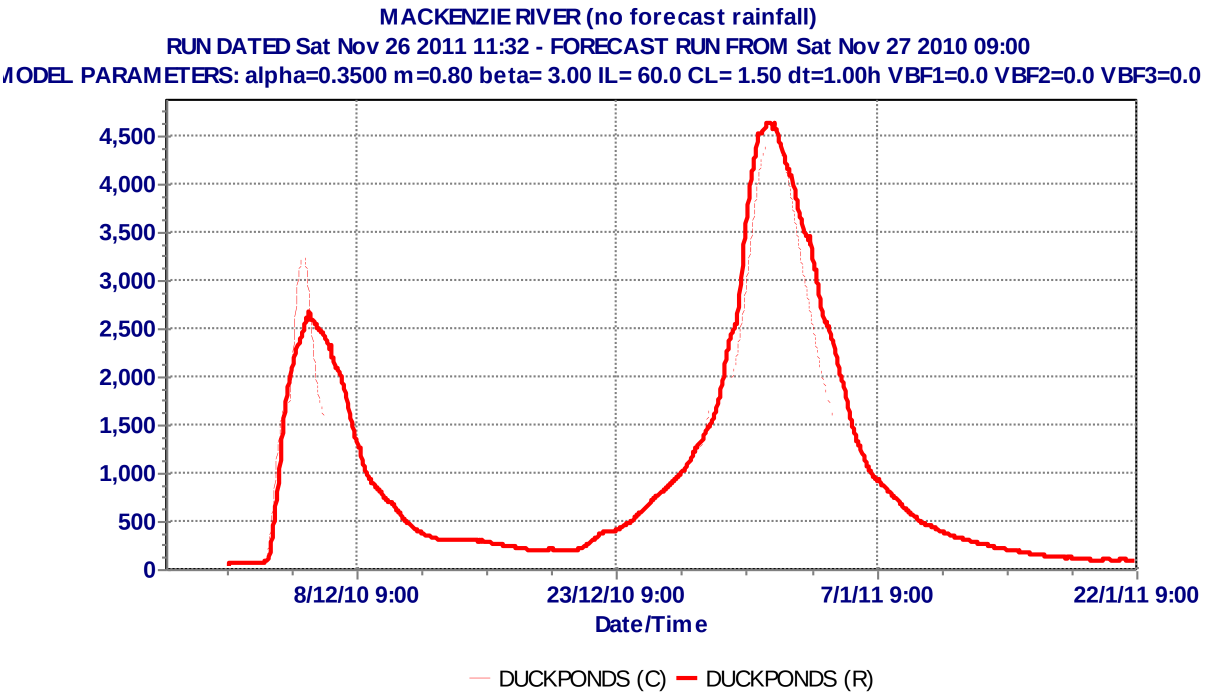


Figure 3.15 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Mackenzie River at Duckponds (130219A) with Matched Hydrographs at Gregory Highway, Fairbairn Dam and Comet Weir

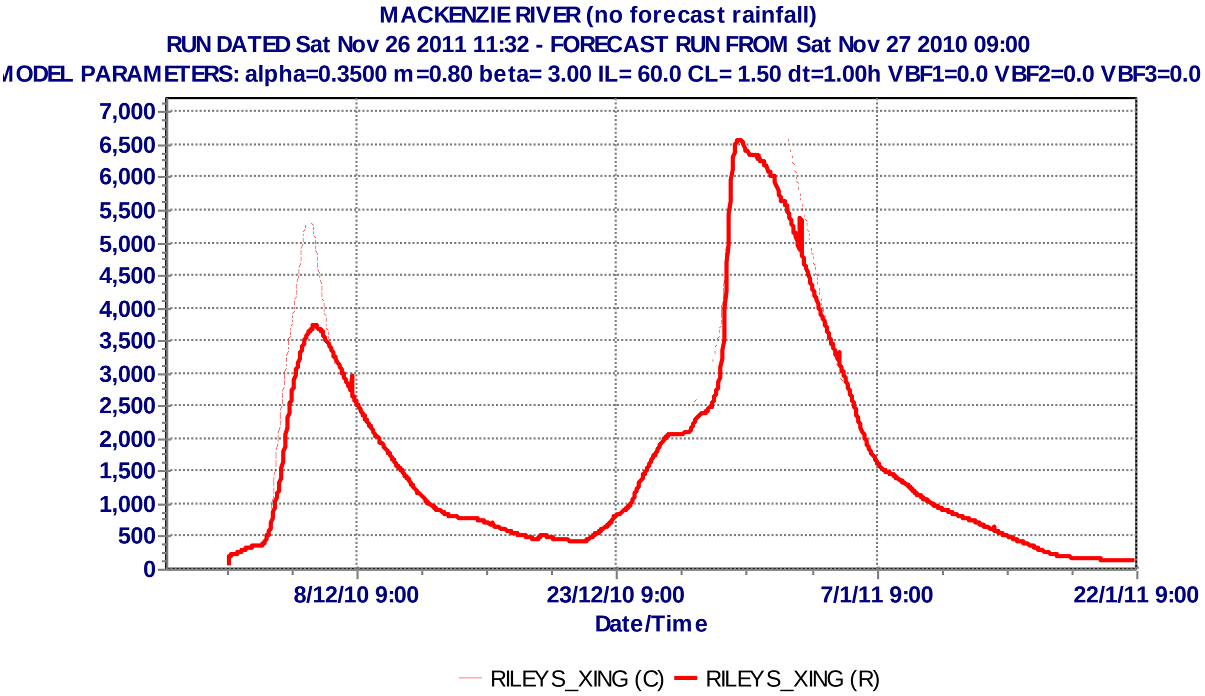


Figure 3.16 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Mackenzie River at Rileys Crossing (130113A) with Matched Hydrographs at Gregory Highway, Fairbairn Dam and Comet Weir

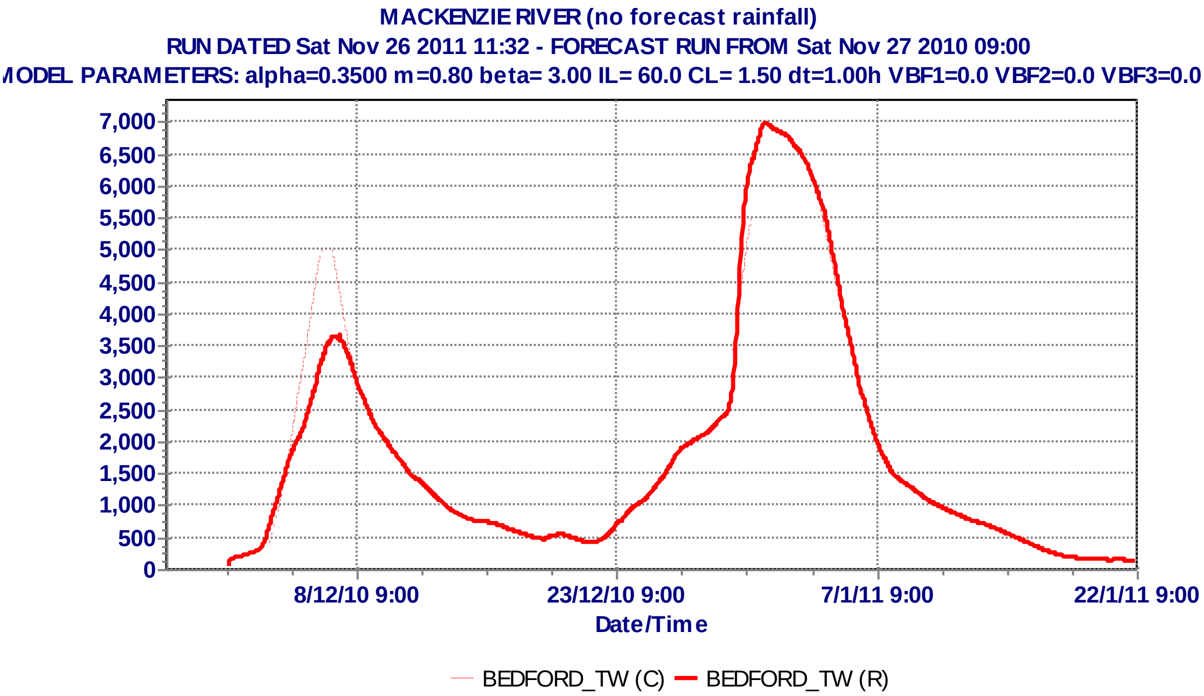


Figure 3.17 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Mackenzie River at Bedford Weir Headwater (130104A) with Matched Hydrographs at Gregory Highway, Fairbairn Dam and Comet Weir

3.6.4 Comet River

Figure 3.18 to Figure 3.24 show a comparison of recorded and calculated hydrographs at four gauging stations along the Comet River, with no matched hydrographs upstream. The timing of the calculated major flood peak is reasonable with the recorded peak, but the magnitude of the calculated peak is significantly lower than the recorded peak. It is likely that the relatively sparse distribution of rainfall gauges over the Comet River catchment (see Figure 3.1) limits the goodness of fit to the recorded hydrograph because the rainfall gauges do not provided a good representation of rainfall across the catchment.

Figure 3.18 to Figure 3.24 show similar results for the lower three stream gauges with the upstream hydrograph matched to the recorded hydrograph. The results show that the fit to the recorded hydrographs is satisfactory, particularly at Comet Weir where the recorded and calculated hydrographs are in very close agreement.

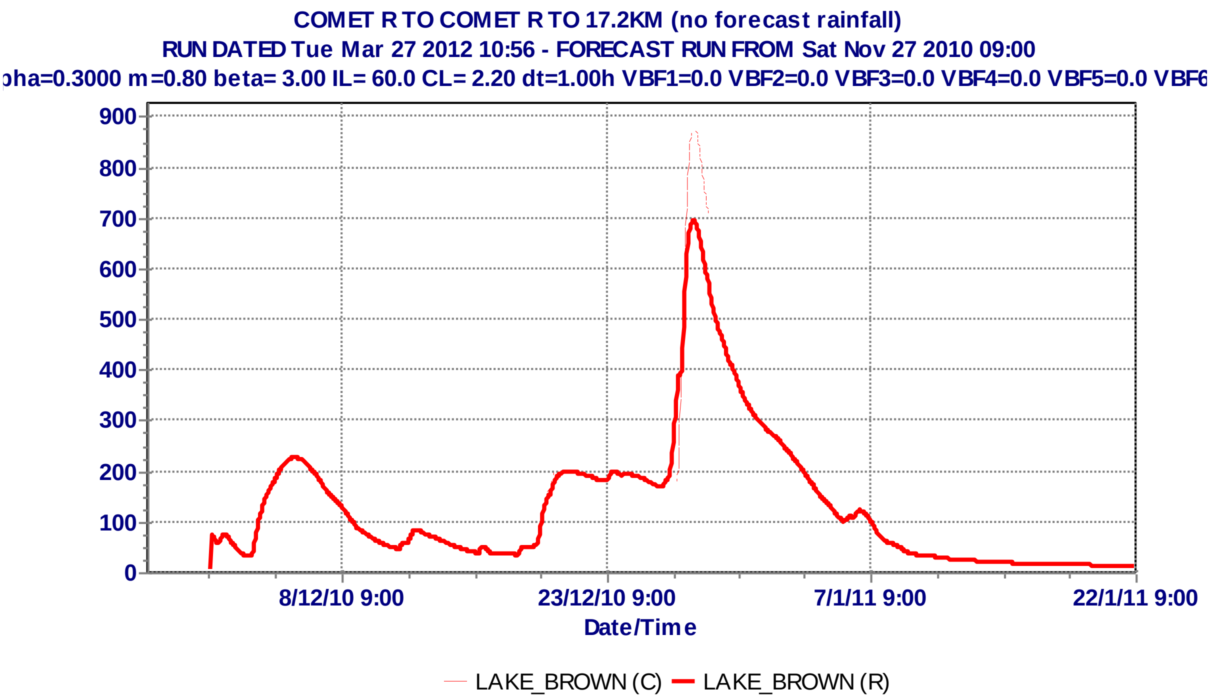


Figure 3.18 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at Lake Brown (130502B) –Calibration Parameters

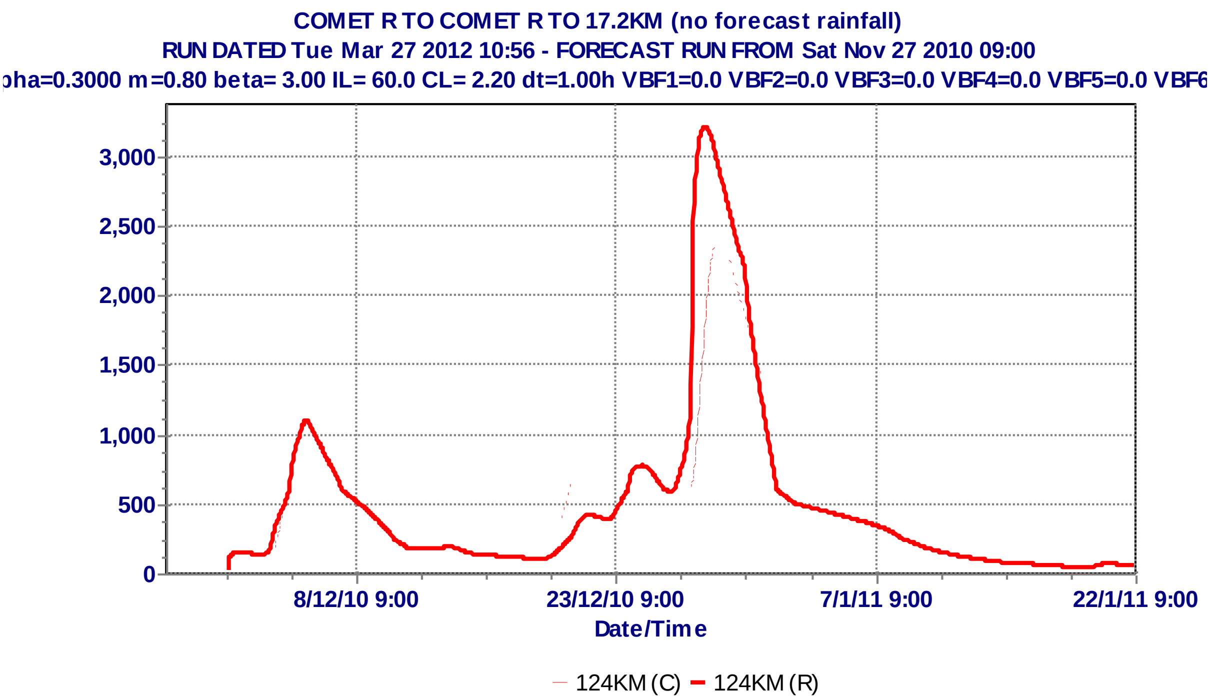


Figure 3.19 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at The Lake (AMTD=124km, 130506A) –Calibration Parameters

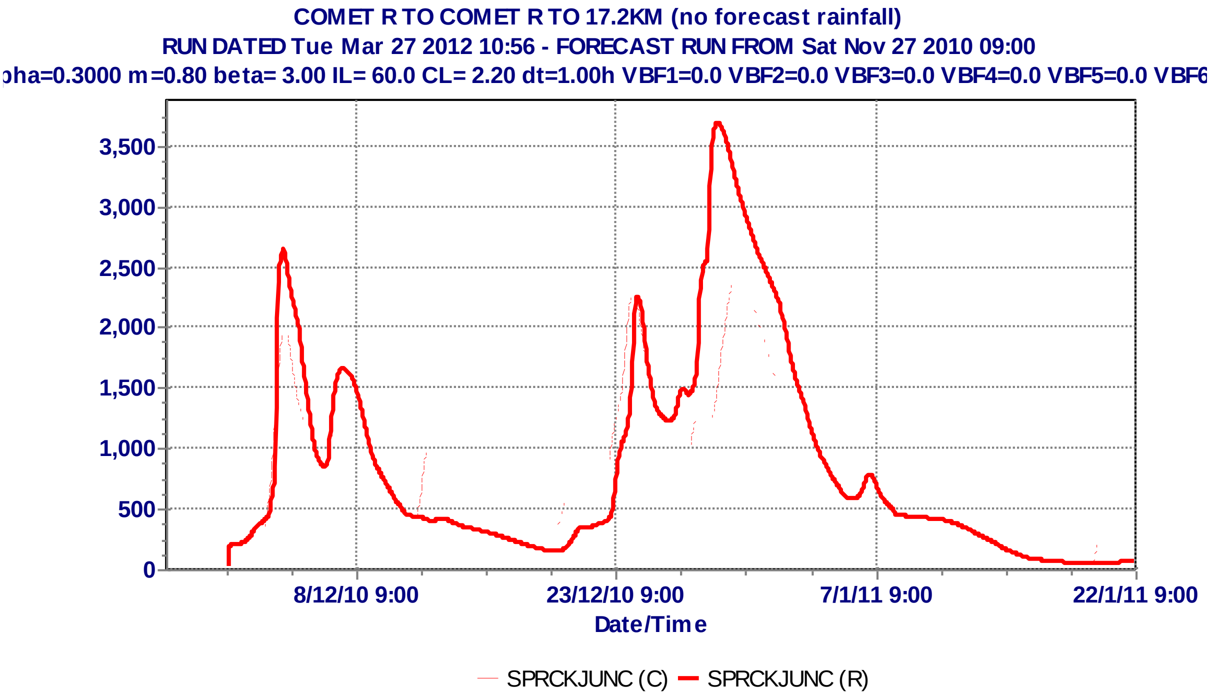


Figure 3.20 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at Springsure Creek Junction (130510A) –Calibration Parameters

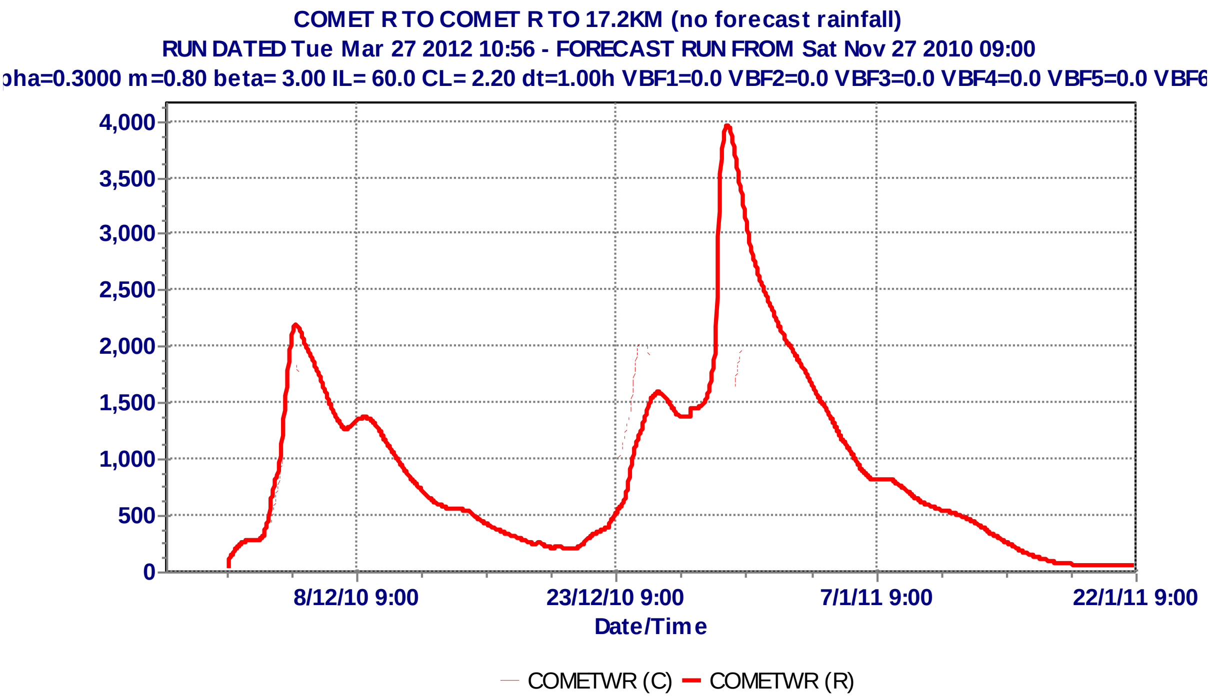


Figure 3.21 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at Comet Weir (130504B) – Calibration Parameters

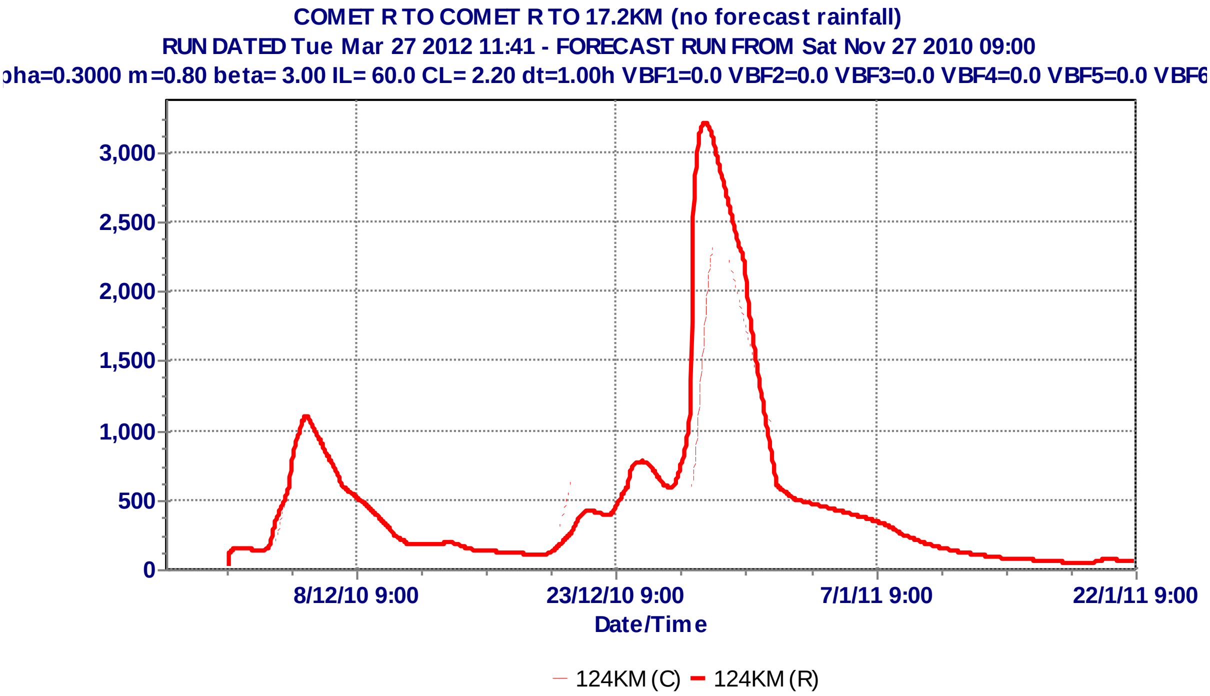


Figure 3.22 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at The Lake (AMTD=124km, 130506A) – Calibration with Matched Hydrograph at Lake Brown

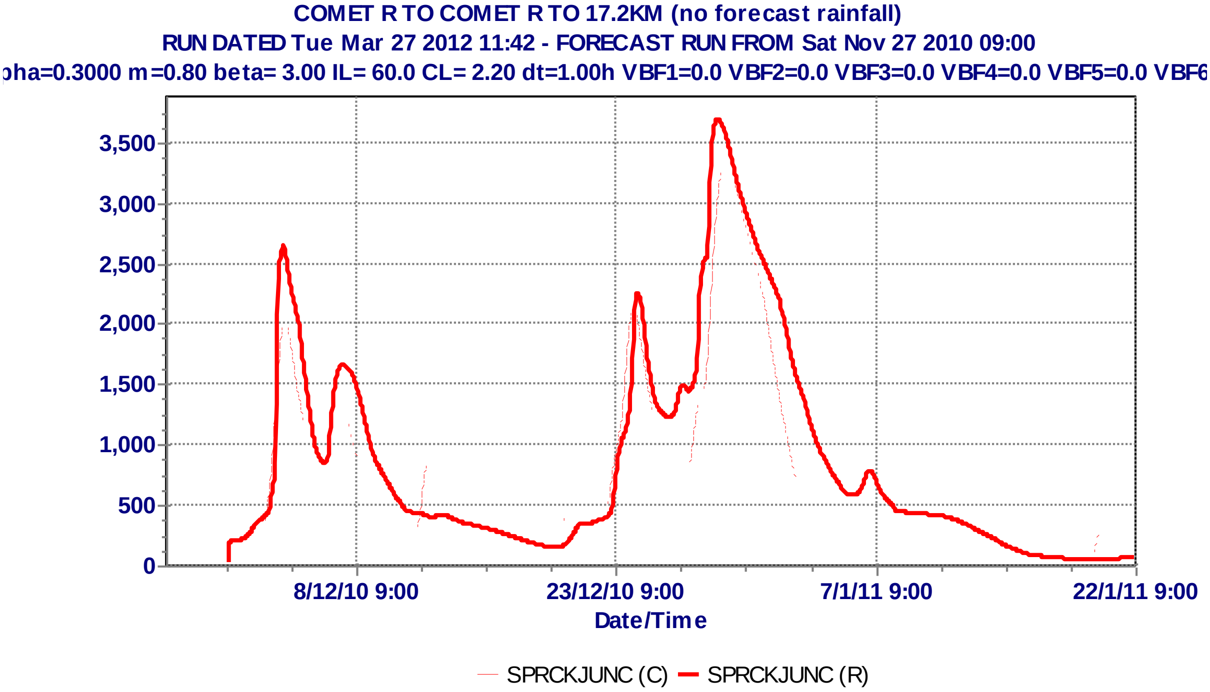


Figure 3.23 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at Springsure Creek Junction (130510A) – Calibration with Matched Hydrograph at The Lake

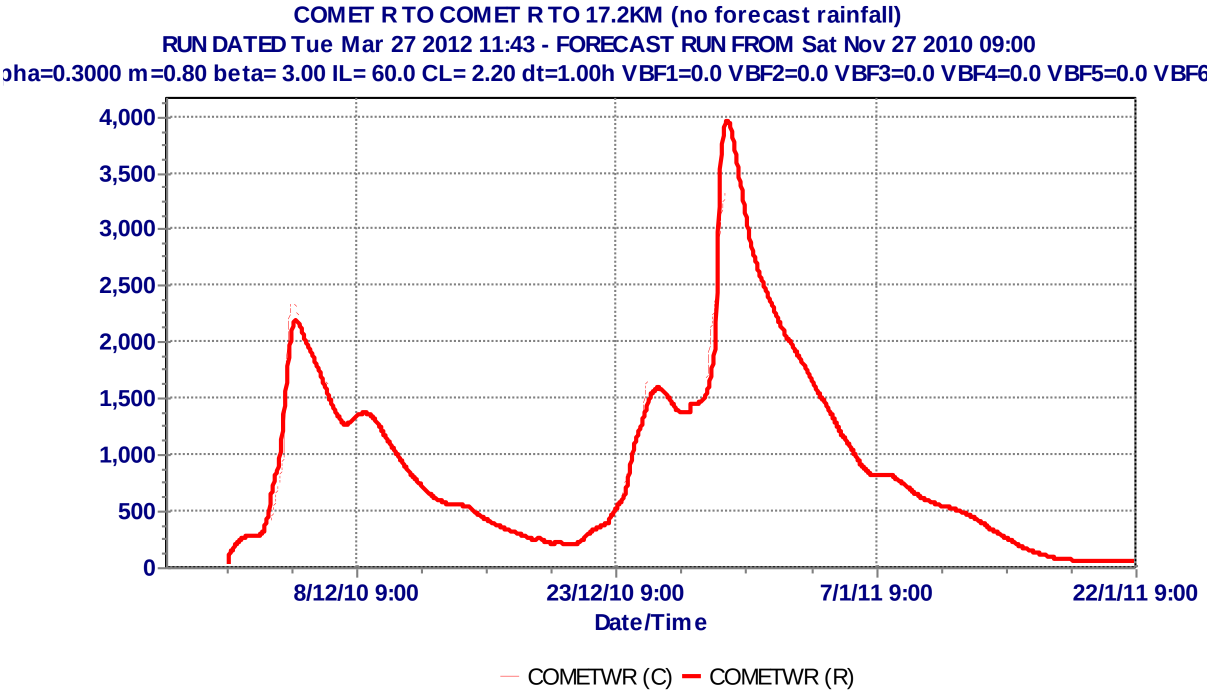


Figure 3.24 Comparison of Calculated (C) and Recorded (R) 2010/11 Discharge Hydrographs, Comet River at Comet Weir (130504B) – Calibration with Matched Hydrograph at Springsure Creek Junction

3.7 FLOOD FREQUENCY ANALYSIS

Flood frequency analysis was used to obtain estimates of design flood discharges at five locations along the Nogoa/Mackenzie River system. The methodology recommended in Book 4, Section 2 of Australian Rainfall and Runoff (ARR, 1999) was used to fit a Log-Pearson Type III distribution to an annual series of recorded peak flood discharges for the various stream gauges. Low-flow outliers were removed where this improved the fit between the fitted distribution and recorded floods or reduced the skew of the fitted distribution.

Due to the significant impact of Fairbairn Dam on the flood response of the Mackenzie River, separate analyses were undertaken for pre and post- dam periods. Table 3.8 shows the adopted locations and periods of record used for the flood frequency analysis. Note that the available period of record at the various stations is of the order of 30 to 50 years. Since this period of record is relatively short, estimates of design floods obtained from flood frequency analysis will be subject to significant uncertainty. However, flood frequency estimates are useful in obtaining an alternative estimate of the likely magnitude of design peak discharges for comparison with the runoff-routing model results.

Adopted peak annual discharges for each of the five locations are provided in Table 3.9. Note that the modified rating curves for Carnangarra and Bingegang Weir were used to obtain annual peak flood discharges (see Section 3.4).

Table 3.8 Adopted Stations for Flood Frequency Analysis

System	Station No.	Station Name	Pre/Post Dam	Period of Record	No. Years Data
Nogoa	130201A/B	Emerald	Pre	1920 - 1962	43
Comet	130501A	Comet Weir	NA	1920 - 1973	54
Mackenzie	130101A	St Aubins	Pre	1921 - 1959	39
	130103A	Carnangarra	Post	1974 - 1999	26
	130106A	Bingegang Weir HW	Post	1974 - 2002	29

Table 3.9 Adopted Discharges for Flood Frequency Analysis

Emerald		Comet Weir		St Aubins		Carnangarra		Bingegang	
Year	Peak Q (m^3/s)	Year	Peak Q (m^3/s)	Year	Peak Q (m^3/s)	Year	Peak Q (m^3/s)	Year	Peak Q (m^3/s)
1920	10	1920	1	1921	726	1974	2415	1974	2340
1921	244	1921	731	1922	6558	1975	1420	1975	1324
1922	1928	1922	1367	1923	384	1976	2435	1976	2566
1923	157	1923	36	1924	1044	1977	1216	1977	1271
1924	821	1924	256	1925	579	1978	5600	1978	5550
1925	327	1925	102	1926	185	1979	127	1979	110
1926	95	1926	67	1927	651	1980	102	1980	255
1927	365	1927	97	1928	3822	1981	278	1981	319
1928	1308	1928	1478	1929	417	1982	187	1982	370
1929	207	1929	170	1930	862	1983	3050	1983	3940
1930	244	1930	280	1931	12	1984	1431	1984	1511
1931	15	1931	1	1932	679	1985	337	1985	178
1932	250	1932	218	1933	2773	1986	243	1986	217
1933	1271	1933	337	1934	1622	1987	408	1987	473
1934	630	1934	305	1935	345	1988	368	1988	315
1935	170	1935	36	1936	1176	1989	532	1989	519
1936	634	1936	213	1937	2250	1990	1676	1990	1733
1937	1382	1937	261	1938	258	1991	970	1991	2150
1938	61	1938	92	1939	756	1992	224	1992	207
1939	299	1939	202	1940	2151	1993	136	1993	139
1940	660	1940	470	1941	1491	1994	1635	1994	1510
1941	721	1941	199	1942	156	1995	107	1995	215
1942	177	1942	142	1943	1685	1996	1287	1996	1355
1943	599	1943	577	1944	317	1997	187	1997	173
1944	74	1944	28	1945	105	1998	100	1998	649
1945	255	1945	20	1946	938	1999	739	1999	730
1946	264	1946	244	1947	1131			2000	163
1947	517	1947	252	1948	75			2001	706
1948	35	1948	19	1949	3661			2002	597
1949	1015	1949	1072	1950	3966				
1950	1894	1950	1337	1951	5888				
1951	4423	1951	1972	1952	561				
1952	547	1952	82	1953	1491				
1953	374	1953	143	1954	7212				
1954	2640	1954	2695	1955	3925				
1955	2020	1955	1218	1956	5792				
1956	2780	1956	2370	1957	6368				
1957	2783	1957	1513	1958	801				
1958	557	1958	48	1959	4327				
1959	868	1959	917						
1960	209	1960	157						
1961	615	1961	373						
1962	653	1962	204						
		1963	1176						
		1964	22						
		1965	29						
		1966	255						
		1967	98						
		1968	291						
		1969	17						
		1970	2						
		1971	255						
		1972	472						
		1973	204						

Table 3.10 Flood Frequency Analysis Results

Location	Estimated Design Discharge from FFA (m³/s)			
	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Emerald	2,000	2,800	3,900	4,900
Comet Weir	1,200	1,900	3,300	4,700
St Aubins	5,000	7,300	11,000	14,400
Carnangarra	2,600	4,000	6,600	9,300
Bingegang Weir HW	2,600	4,000	6,600	9,300

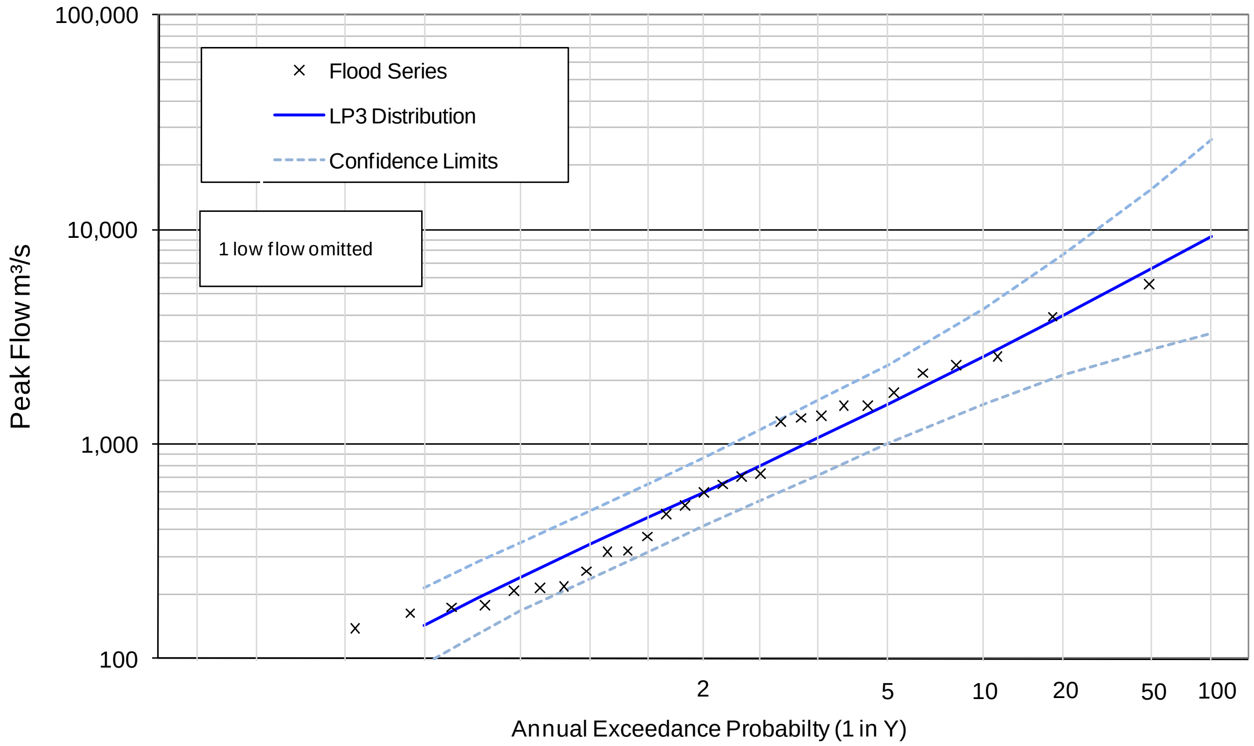


Figure 3.25 Flood Frequency Plot, Nogoa River at Emerald, Pre-Dam

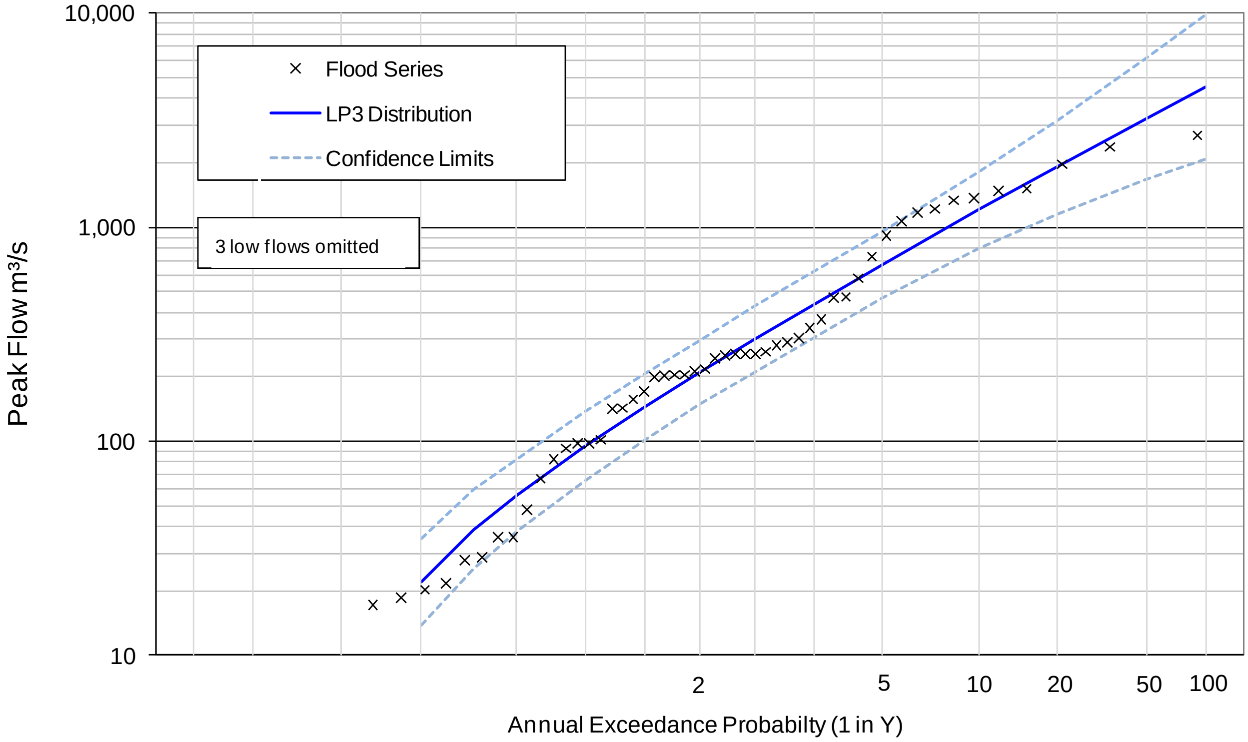


Figure 3.26 Flood Frequency Plot, Comet River at Comet Weir

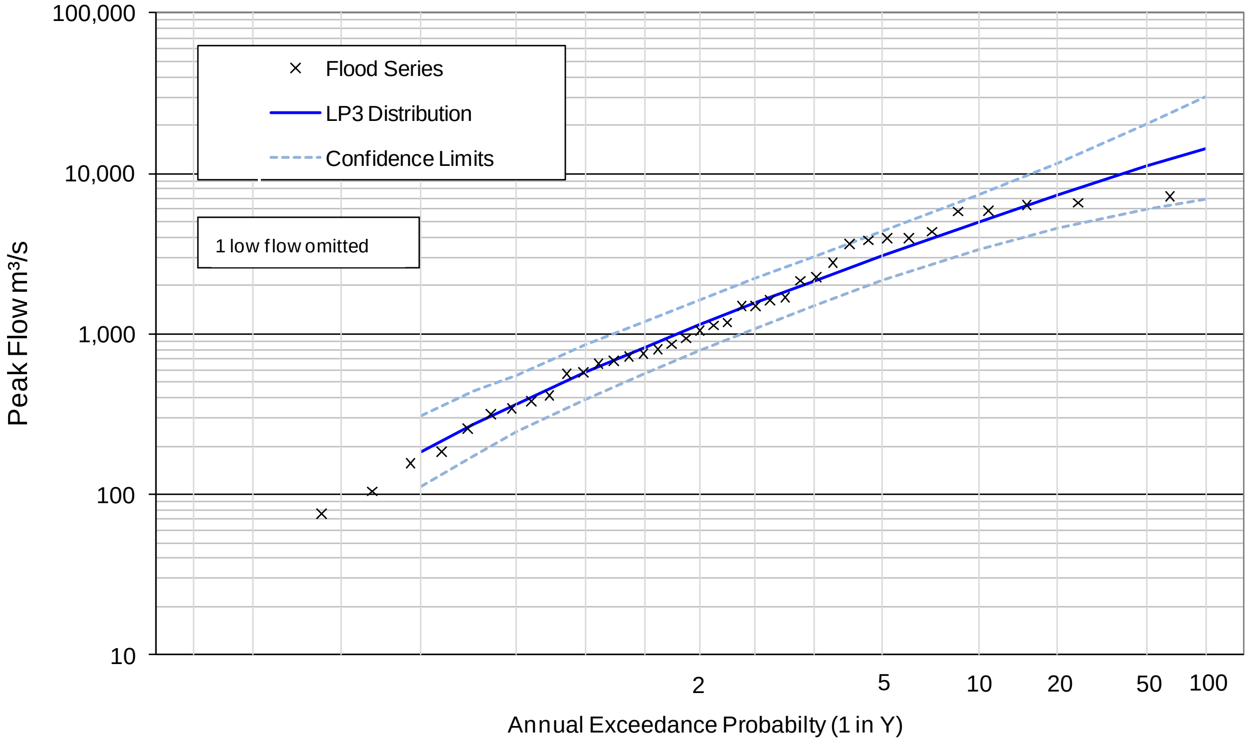


Figure 3.27 Flood Frequency Plot, Mackenzie River at St Aubins, Pre-Dam

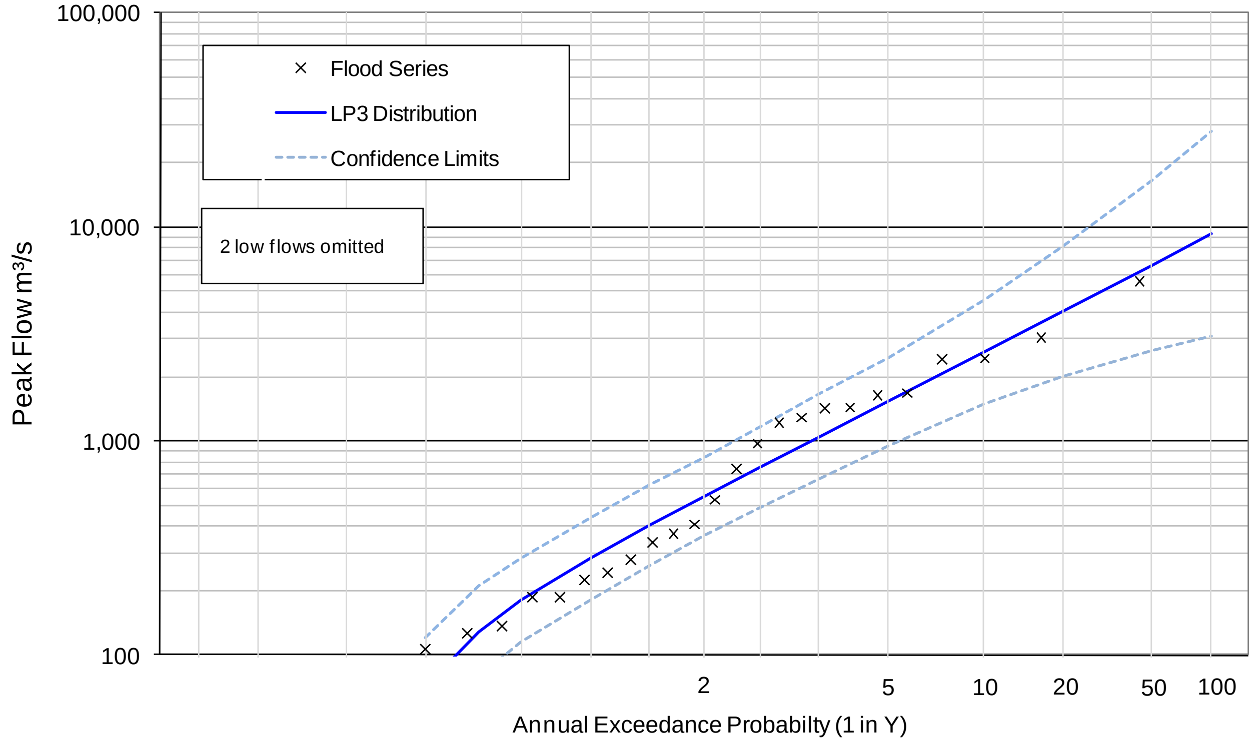


Figure 3.28 Flood Frequency Plot, Mackenzie River at Carnangarra, Post-Dam

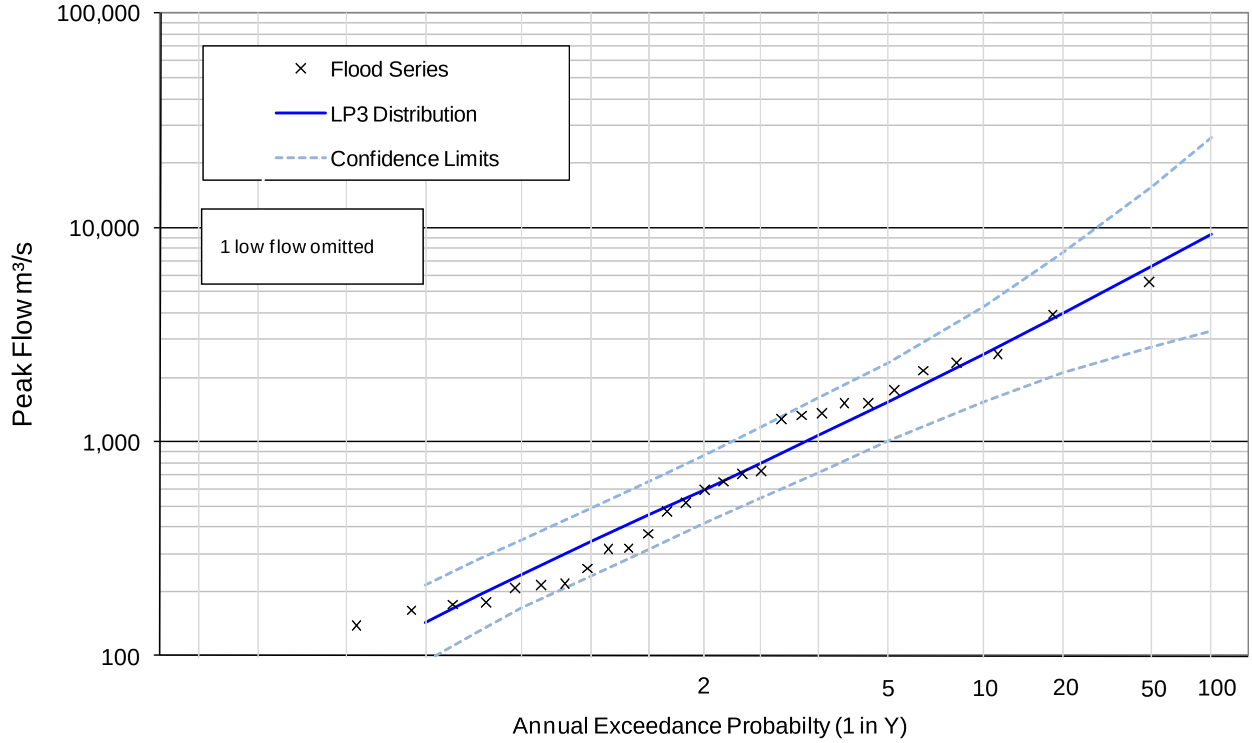


Figure 3.29 Flood Frequency Plot, Mackenzie River at Bingegang Weir, Post-Dam

3.8 DESIGN RAINFALLS AND TEMPORAL PATTERNS

Design rainfalls for the Mackenzie River catchment are available from the following sources:

- Australian Rainfall & Runoff (ARR, 1999), and
- CRCFORGE method developed as part of the Queensland Government's Extreme Rainfall Estimation Project (Hargraves, 2004).

Design rainfalls from Australian Rainfall & Runoff are based on daily and sub-daily recorded rainfalls. However, the latest data used to derive the design rainfalls is from the mid-1980s. The CRCFORGE rainfalls are based on daily data only, but the rainfall data set includes an additional 20 years of data compared to ARR 1999. Since the Mackenzie River catchment has a response time of the order of several days, any inaccuracies associated with not using sub-daily data are expected to be small. To make use of the most recent available data for the study area, the CRCFORGE design rainfall estimates were adopted for the estimation of design discharges in this study. The CRCFORGE method also has the advantage of providing rainfall estimates up to 2,000 year ARI.

Estimates of the Probable Maximum Precipitation (PMP) over the Mackenzie River catchment were obtained using the Generalised Tropical Storm Method (GTSMR) (BOM, 2003).

Design rainfalls were estimated at 8 locations across the study catchment using the "Rainfall" utility (Hargraves, 2004). The 8 rainfall locations were selected to provide a general representation of potential rainfall variability across the catchment. Adopted 72 hour design rainfalls at the 8 rainfall locations for the 20, 50, 100 and 1,000 year ARI events are shown in Table 3.11.

Table 3.11 72 Hour Design Rainfall Depths (No Areal Reduction Factor)

	72 Hour Design Rainfall Depth (mm)				
Location	**20 Year ARI**	**50 Year ARI**	**100 Year ARI**	**1,000 Year ARI**	**PMP [a]**
Upper Nogoa	211	254	286	393	785
Mid Nogoa	235	282	316	433	770
Emerald	228	273	307	427	770
Retreat Ck	246	294	330	454	770
Theresa Ck	223	267	301	420	770
Upper Comet	249	299	335	459	886
Lower Comet	217	260	293	412	770
Mackenzie	224	271	306	431	809

[a] Catchment area is included in PMP estimate

Design storm temporal patterns from ARR (1999) for Zone 3 were adopted for storms up to 72 hours duration. ARR does not provide storm temporal patterns for longer durations. For 96 and 120 hour duration design events, extreme event temporal patterns (derived using the "average variability method") from the GTSMR (BOM, 2003) were adopted. The GTSMR temporal patterns were adopted for all durations for the 1,000 year ARI and PMP rainfalls.

3.9 AREAL REDUCTION FACTORS

Design rainfalls derived from statistical analysis of point rainfalls are likely to overestimate the average rainfall that can persist over a large area. An estimate of design rainfall over a given area is obtained by applying an areal reduction factor (ARF) to point rainfall estimates. Hargraves (2004) provides estimated areal reduction factors based on storm duration and catchment area. Table 3.12 shows the adopted ARFs for the Nogoa River to Emerald (16,500 km^2) and the Mackenzie River to Bedford Weir (45,000 km^2) for events up to 1,000 Year ARI. The Bedford ARFs were used to derive estimates of design discharge at Bedford. The Emerald ARFs were used when comparing design discharges at Emerald from the URBS model with values obtained from flood frequency analysis. Since catchment area is included in the methodology for the estimation of PMP, no other ARFs were applied to estimated PMP depths.

Table 3.12 Adopted Areal Reduction Factors for Design Rainfalls up to 1000 Year ARI

Storm Duration (Hours)	Emerald ARF	Bedford ARF
24	0.75	0.69
36	0.79	0.74
48	0.82	0.77
72	0.85	0.81
96	0.87	0.84
120	0.89	0.85

3.10 DESIGN DISCHARGES

3.10.1 General

The calibrated URBS model (without losses for inflows to the Ensham mine pits) was used to estimate design flood discharges in the Mackenzie River catchment based on the design rainfalls and areal reduction factors presented in Section 3.9. The URBS model was run for a range of design storm durations from 24 hours to 120 hours. The 72 hour storm duration created the highest peak discharge in the vicinity of the Mackenzie North project.

Design discharges were estimated assuming Fairbairn Dam was full at the commencement of the event. This assumption provides a conservative (high) estimate of design flood discharges at the project site. A separate estimate of design discharges without Fairbairn Dam was also made by removing the dam from the model to represent pre-Fairbairn Dam conditions.

3.10.2 Adopted Rainfall Losses

Table 3.13 shows the initial and continuing rainfall losses adopted for design events. Losses were initially selected based on representative values derived from the model calibration. These values were then adjusted to achieve better correlation with the flood frequency analysis results. For the Nogoa, Theresa and Mackenzie systems, consistent losses were adopted for the 20, 50 and 100 year ARI events. For the Comet River, the initial loss was varied between the different design event magnitudes. For the extreme events (1,000 year ARI and PMF), the same continuing loss rates used for the smaller events in each system were adopted, with initial losses set to zero.

Table 3.13 Adopted URBS Model Rainfall Losses for Design Events

	20 Year ARI		50 Year ARI		100 Year ARI		1,000 Year ARI		PMF	
System	IL[a]	CL[b]	IL	CL	IL	CL	IL	CL	IL	CL
Nogoa	50	2.4	50	2.4	50	2.4	0	2.4	0	2.4
Theresa	10	1.0	10	1.0	10	1.0	0	1.0	0	1.0
Mackenzie	10	1.0	10	1.0	10	1.0	0	1.0	0	1.0
Comet	50	2.0	30	2.0	10	2.0	0	2.0	0	2.0

[a] IL = Initial Loss, mm
[b] CL = Continuing Loss Rate, mm/hr

Table 3.14 shows the estimated design discharges at various locations along the river system, with and without Fairbairn Dam. Table 3.14 also compares the URBS model discharges to the results of the flood frequency analysis (FFA) for events up to 100 years ARI.

The comparison between the URBS model discharges and the FFA results is very good at most locations. Without Fairbairn Dam, the URBS model discharges at Bedford Weir are 10% to 20% lower than the FFA results. The FFA results at this location are based on data at the St Aubins gauge, which ceased operation in 1959. The quality of the rating curve at this location for high flows is unknown.

Figure 3.30 compares the URBS model design discharge estimates to the fitted flood frequency distribution at Carnangarra (representative of flows at Bedford Weir). At Bedford Weir with Fairbairn Dam in place, the URBS design discharges are higher than the FFA estimates for the 20 and 50 year ARI events. This would be expected because the FFA results account for the effects of different starting water levels in Fairbairn Dam for each flood event. For the 100 year ARI event at this location, the URBS model discharge is about 5% lower than the corresponding FFA discharge estimate. The FFA estimate of 100 year ARI peak discharge is based on less than 30 years of recorded flood data and is hence subject to substantial uncertainty.

Table 3.14 Design Discharges, 20, 50, 100 & 1,000 Year ARI Design Floods and PMF

Event ARI	Source of Discharge Estimate	Peak Discharge (m³/s) without Fairbairn Dam			Peak Discharge (m³/s) with Fairbairn Dam	
		Nogoa R @ Emerald	Comet R @ Comet	Mackenzie R @ Bedford [a]	Mackenzie R @ Bedford [b]	Mackenzie R @ Bingegang
20 Year	URBS	2,790	2,140	**6,700**	**5,300**	5,400
	FFA	*2,800*	*1,900*	*7,300*	*4,000*	*4,000*
50 Year	URBS	3,900	3,340	**9,200**	**7,110**	7,200
	FFA	*3,900*	*3,200*	*11,000*	*6,600*	*6,600*
100 Year	URBS	5,040	4,540	**11,700**	**8,860**	8,940
	FFA	*4,900*	*4,500*	*14,400*	*9,300*	*9,300*
1,000 Year	URBS			**20,700**	**17,200**	
PMF	URBS	30,400	21,000	**59,000**	**49,900**	

[a] FFA based on Mackenzie River at St Aubins [b] FFA based on Mackenzie River at Carnangarra
[c] PB, 2004

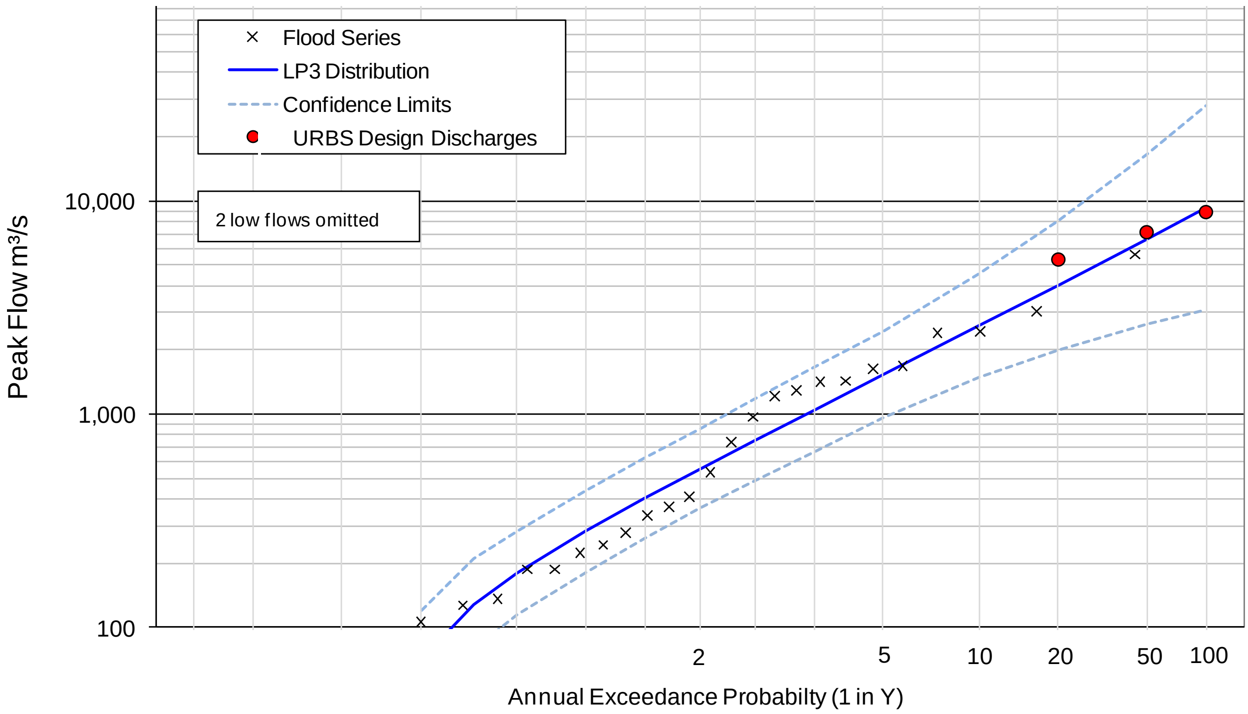


Figure 3.30 Comparison of URBS and Flood Frequency Analysis at Bedford Weir, Post-Dam

4 HYDRAULIC MODELLING METHODOLOGY

4.1 OVERVIEW

This investigation used the hydraulic model developed previously for the analysis of Wesfarmers' Curragh North Pit V Project and the Jellinbah Mackenzie North project. The Mackenzie River is a complex system and, as such, the TUFLOW 2D hydrodynamic model (WBM, 2008) was used to simulate the 50, 100 and 1,000 year average recurrence interval (ARI) design events for existing and post-developed conditions. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically calculates breakout points and flow directions within the study area.

The model was modified to focus on the potential requirements of the Mackenzie North Project. The downstream boundary of the previous model was located only 1.7 km downstream of the project area and, as such, the model boundary effects extended into the project area. The model developed for this investigation was extended a suitable distance downstream of the disturbance area in order to eliminate the likelihood of downstream boundary effects impacting on the model results.

4.1.1 Available Data

A digital terrain model (DTM) used for the previous hydraulic investigations was provided by Atlass (Airborne Topographic Laser Survey Systems) Australia Pty Ltd via Wesfarmers Curragh Pty Ltd. The ground surface model was obtained by LiDAR capture on 07 July 2009. The data was adjusted by Atlass to fit local ground control data supplied by Wesfarmers Curragh Pty Ltd consisting of 8 horizontal control points and 282 vertical control points. A thinned LiDAR DTM data set was provided over the whole model area. Based on a sample of 227 control points the vertical RMS error of the DTM is quoted as 0.06m and horizontal accuracy is 0.50m.

The model area was extended downstream of the previous model boundary and the DTM was supplemented with additional data obtained for Jellinbah Resources by AAMHatch on 29 September, 2005. The extent of the hydraulic model is shown in Figure 4.1. Two levels of accuracy were provided. With areas close to the project site, the processed data has a vertical accuracy of less than 0.1 m. Further downstream from the project site the processed ground level data has a vertical accuracy of less than 0.3 m. The processed data was compared to 166 test points, obtained by field survey, and was found to have a standard error (RMS) of 0.07 m.

4.1.2 Design Inflows

Design inflows for the Mackenzie River were extracted from the hydraulic model developed for previous investigations. Inflows for this previous model were obtained from the hydrologic analysis outlined in Section 3. The adoption of these extracted inflows was undertaken in order to ensure consistency with the previous modelling and so the extended model results could be validated against the original results.

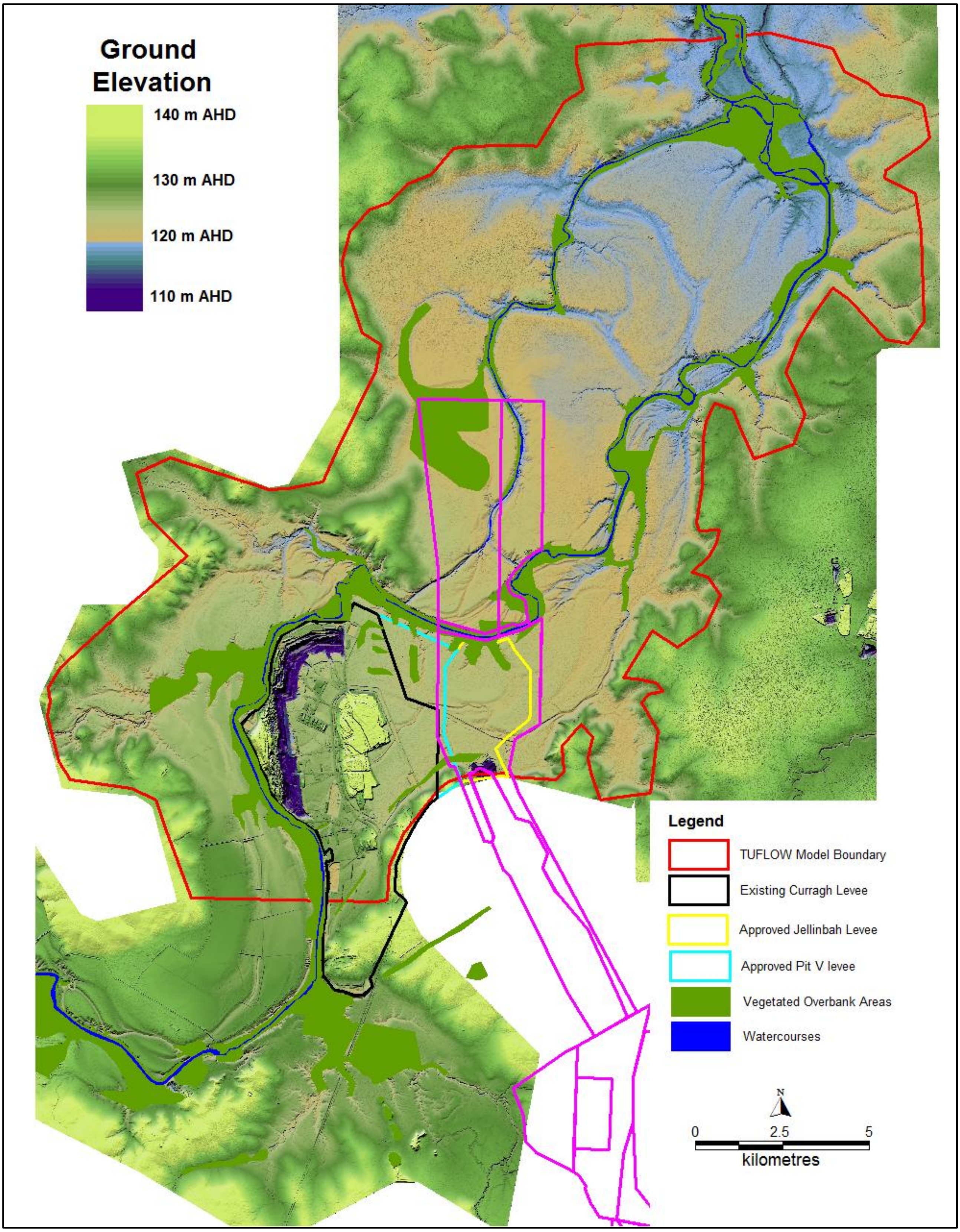


Figure 4.1 Approved Hydraulic Model Overview

4.1.3 Adopted Manning's 'n' Values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types were mapped, and an appropriate roughness value assigned to each region.

Vegetation mapping was undertaken using an orthophotograph of the area captured in July 2009 (provided by Wesfarmers Curragh Pty Ltd). In areas outside the extent of the photograph, Google Earth imagery was used. The Manning's 'n' values were selected during model calibration to the January 2011 event, and were applied to all model scenarios. The Manning's 'n' values used in the hydraulic models for this investigation are outlined in Table 4.1. Figure 4.1 shows the location of the various areas of roughness adopted for the hydraulic modelling task.

Table 4.1 Adopted Manning's 'n' values

Location	Adopted Manning's 'n'
Floodplain	0.060
River Channel	0.045
Overbank Areas (Trees)	0.130

Figure 2.2 and Figure 4.2show photographs of the Mackenzie River and Anabranch channel, respectively.

Figure 4.2 Photograph showing the Anabranch channel and overbank vegetation

4.1.4 Tailwater Conditions

The downstream boundary of the TUFLOW model was set well downstream of the proposed Mackenzie North project site to minimise its influence on flood behaviour predicted for lease areas. The downstream boundary condition used for the hydraulic model was a Normal Depth of 0.008 m/m and was determined based on the flood slope estimated from previous investigations. The adopted normal depth slope is representative of the flood gradients found in downstream sections of the modelling area. The model results in the area of interest are insensitive to the adopted downstream boundary condition; with little to no variation in water surface levels for a range of flood slopes.

4.2 MODEL CONFIGURATION – APPROVED CONDITIONS

Figure 4.1 shows the locations of the Approved Conditions TUFLOW model for the Mackenzie River in the vicinity of the proposed Mackenzie North project. The Approved Conditions TUFLOW model includes the approved Jellinbah and approved Curragh Pit V levee designs as well as the existing Curragh levee.

4.3 MODEL CONFIGURATION – ULTIMATE MACKENZIE NORTH PIT CONDITIONS

The Ultimate Mackenzie North Pit TUFLOW model was constructed using the Approved Conditions model DTM and includes all works in the Approved Conditions Model. The proposed Mackenzie North project includes a mine area located on the northern floodplain opposite the Jellinbah mine site. In order to prevent inundation of the proposed Mackenzie North project from Mackenzie River floodwaters, it is proposed a levee be constructed around the proposed site to provide 1,000 year ARI flood immunity.

An anabranch of the Mackenzie River is located within the Mackenzie North lease area. Note that the requirement to divert the anabranch is subject to determination from DNRM as to the status of the anabranch (i.e.: “overflow” or “water course”). For the purposes of this study, the diversion has been included. A diversion channel has been modelled to redirect flows around the proposed site. This new diversion channel geometry was designed to approximately replicate the existing anabranch and is approximately 275 m wide (at the top of bank) and 5.0 km long (see Figure 4.2). The main channel of the existing anabranch is approximately 4.1 km long. A ‘low-flow’ channel, 90 m top width, is located in the centre of the diversion channel to convey smaller flows. Figure 4.3 shows a cross-sectional comparison of the existing anabranch and the proposed diversion.

The proposed levee is offset from the top of the diversion channel bank by approximately 100m. The channel is aligned along the eastern levee and re-joins the anabranch channel to the north of the proposed development. The levee was modelled in TUFLOW as a solid obstruction and was represented, conservatively, as a vertical wall at the toe of the proposed levee.

The adopted configuration of the site was developed based on the initial modelling to limit the upstream impacts. The location was chosen by undertaking several model iterations in order to manage impacts at the Curragh North levee. The initial model runs included an option which maximised the development area, however the protrusion of the levee into areas of significant flow resulted in large increases in upstream water levels.

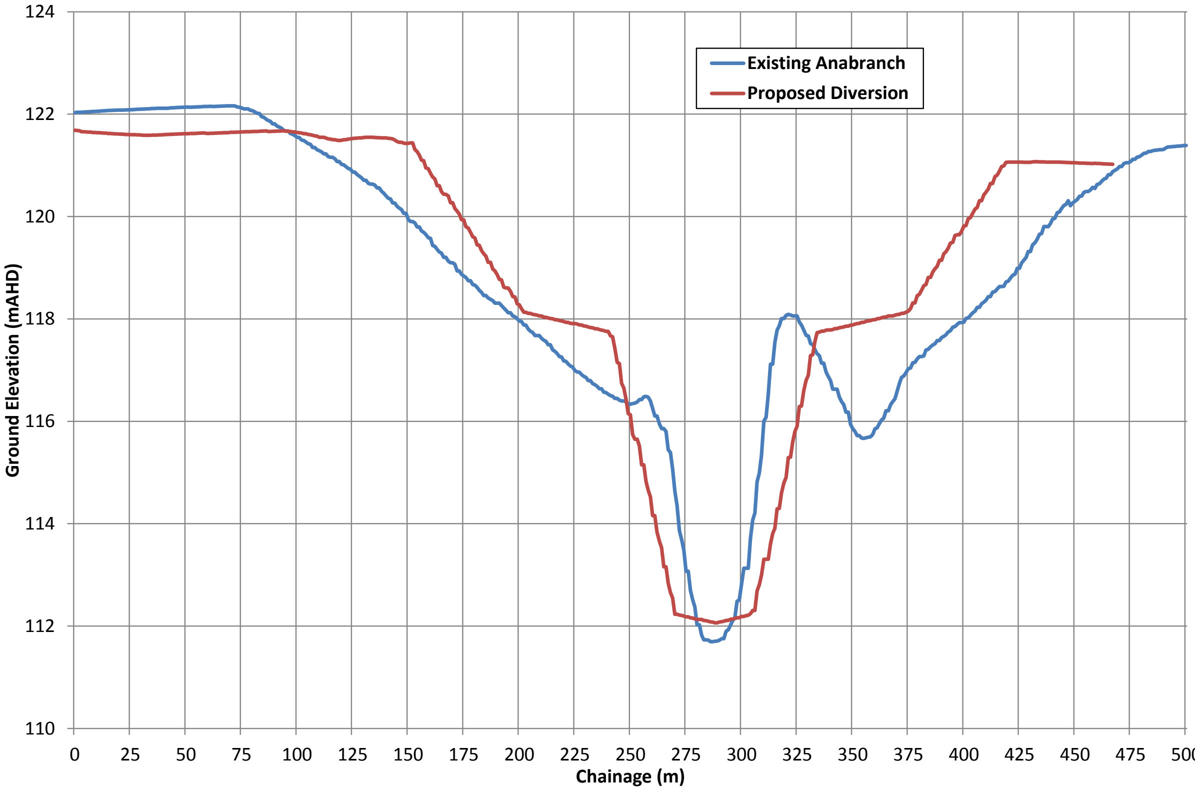


Figure 4.3 Comparison of Existing Anabranch and New Diversion Cross Sections

A haul road is proposed to link the existing Jellinbah mine with the Mackenzie North project. The preliminary haul road embankment design prepared by Parsons Brinckerhoff (see Appendix C) was included in the model. The haul road includes a low level crossing of the Anabranch and a bridge structure which traverses the Mackenzie River. The configuration of the haul road crossings was based on previous modelling undertaken for the Mackenzie North Project. The Mackenzie River haul road bridge was modelled as a layered flow constriction. The Anabranch culvert crossing was modelled as a 1D Network consisting of three (3) 2.1 m diameter reinforced concrete pipes.

Preliminary plans showing the configuration of the proposed Anabranch culvert and Mackenzie River Bridge are located in Appendix C.

Figure 4.4 shows the proposed post-developed topographic features in the vicinity of the Mackenzie North mine site.

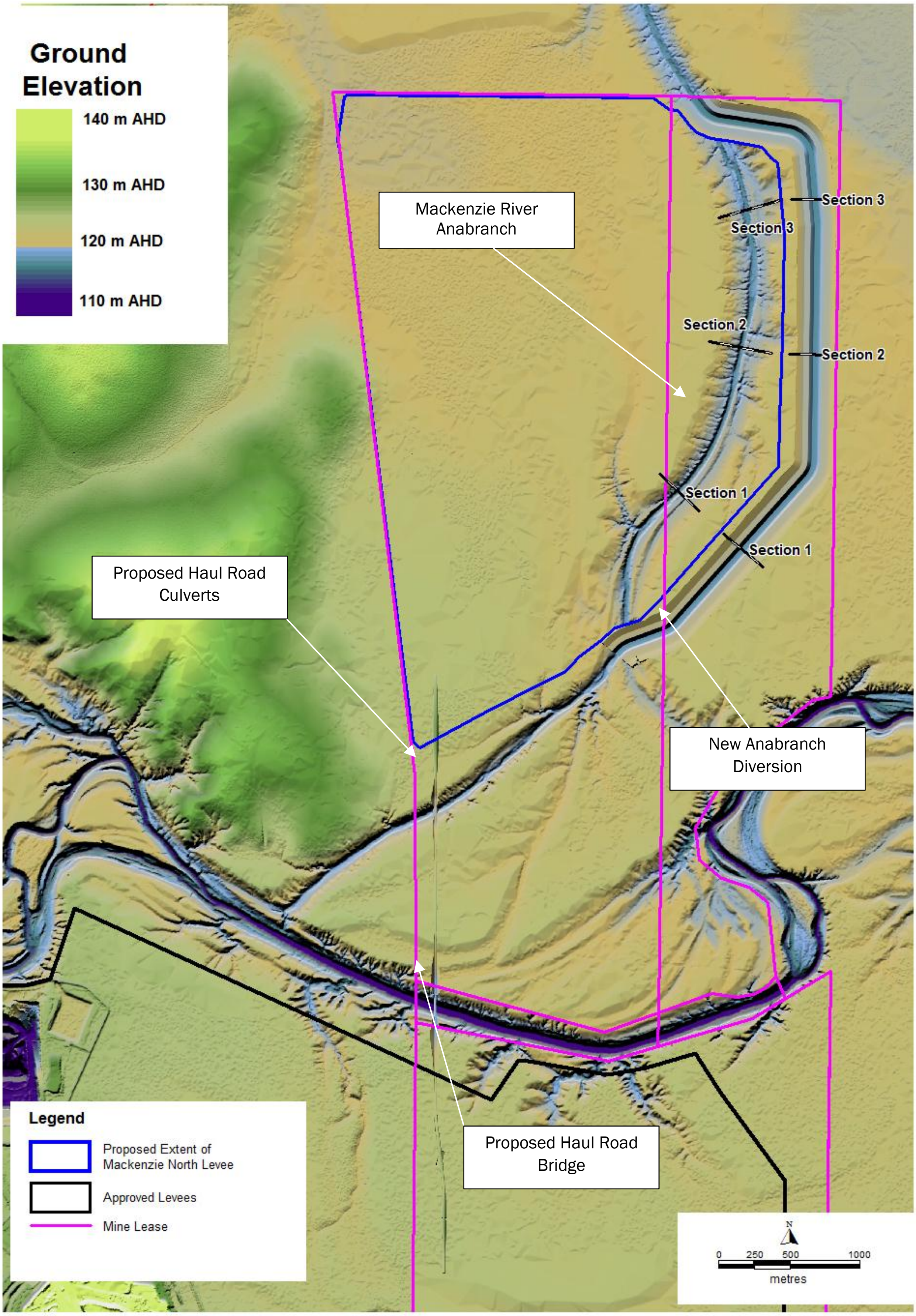


Figure 4.4 Post-Developed Conditions – Proposed Diversion Works

5 HYDRAULIC MODEL RESULTS

The TUFLOW model was used to determine design flood levels, depths, extents and velocities on the floodplain in the vicinity of the Mackenzie North Project for the 50, 100 and 1000 year ARI design floods for the Approved and Ultimate Mackenzie North Pit conditions.

The results of the Approved and Ultimate Mackenzie North Pit models were used to assess the impact of the proposed project on approved conditions. These impacts are detailed in the following sections.

5.1 APPROVED CONDITIONS MODEL RESULTS

Plans showing the flood depth, extent and velocity for the Approved conditions Mackenzie River model are presented in Appendix D. As the results indicate, there is widespread inundation of the Mackenzie River floodplain in the vicinity of the Mackenzie North project site for all of the modelled design events. Overbank flooding is generally shallow (less than 1.0 m) for the 50 year ARI design event with increasing depths for the 100 and 1,000 year ARI design events.

Stream velocities are significant (point velocities greater than 3.0 m/s) in the Mackenzie River and anabranch channel for all modelled design events. The velocity in the overbank areas is lower (point velocities less than 1.0 m/s).

Mackenzie River floodwater overflows into the anabranch when water levels reach approximately 114.1 mAHD at the downstream extent of the anabranch. As shown in Figure 4.3, once water levels reach approximately 122 mAHD in the anabranch (and Mackenzie River main channel), widespread breakouts occur.

5.2 ULTIMATE MACKENZIE NORTH PIT MODEL RESULTS

Plans showing the flood depth, extent, velocity and afflux (increase in water level) for the existing conditions Mackenzie River model are presented in Appendix E. As with the existing condition model results, high depths and velocities are generally restricted to the Mackenzie River and Anabranch channels Figure 5.1 and Figure 5.2 show the extent and velocity of flooding in the 1,000 year ARI flood event.

Point velocities in the proposed diversion range from approximately 1.5 m/s to 2.8 m/s, while overbank flooding is typically shallow, and at lower velocities.

In large flood events, flow may occur over a low saddle to the west of the project area. The alignment of the north-western section of the levee was adjusted to prevent constriction of flows and resultant high velocities through this area.

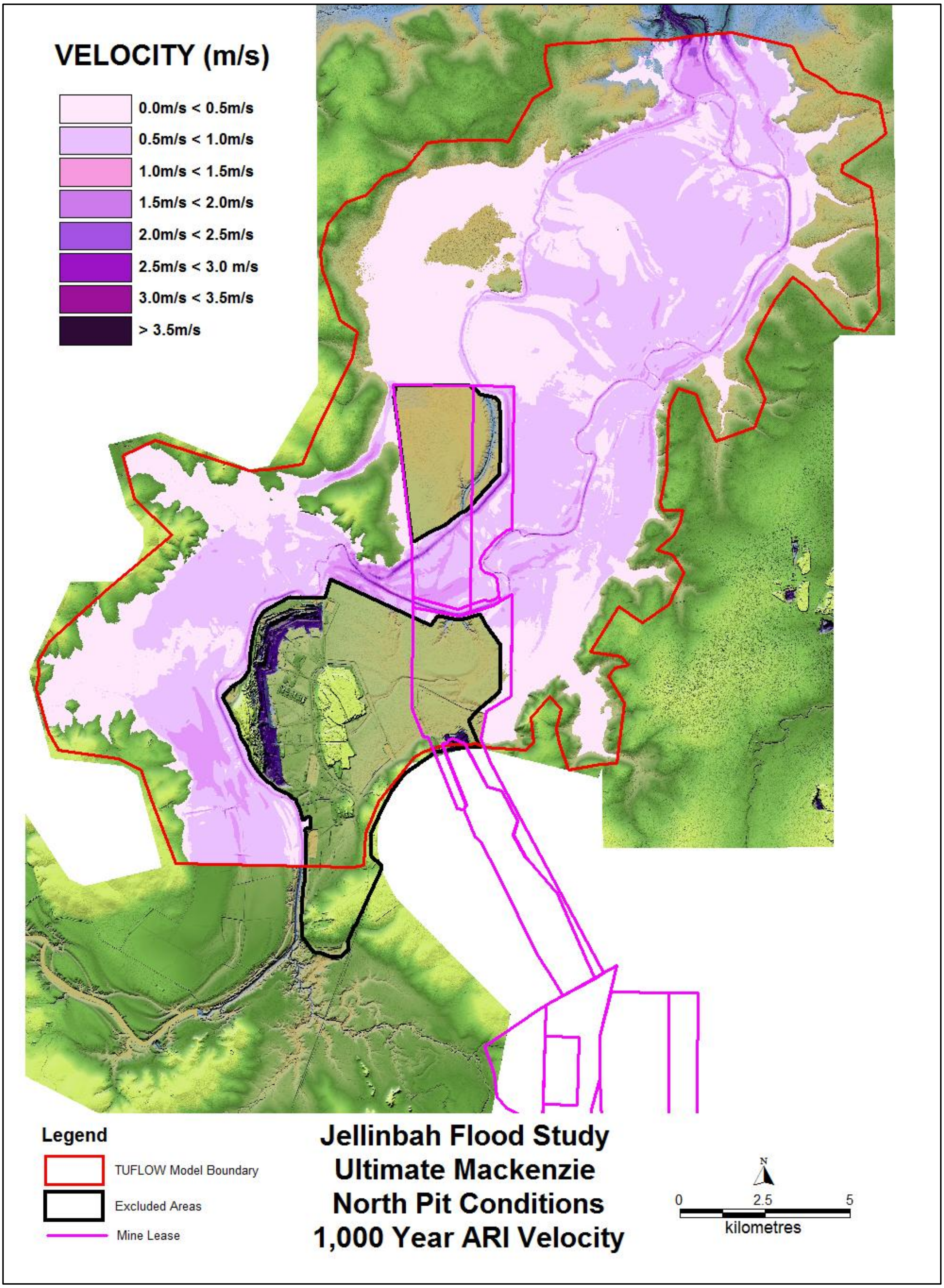


Figure 5.1 1,000 Year ARI Design Event Ultimate Mackenzie North Pit Project Velocity

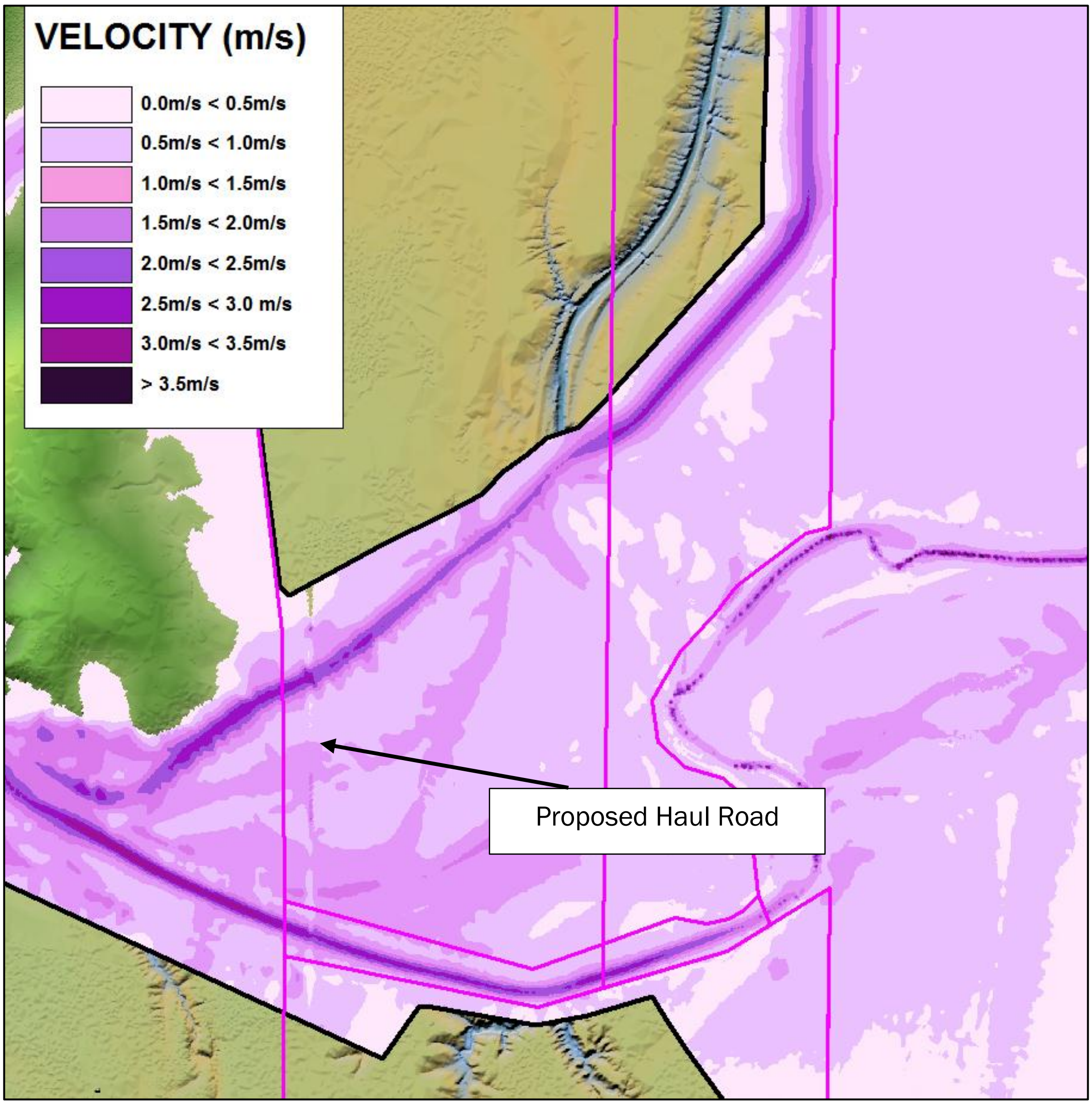


Figure 5.2 1,000 Year ARI Design Event Velocity in Vicinity of Proposed Diversion and Haul Road

Figure 5.3 shows the impact of the project (difference between the Approved and Ultimate Mackenzie North conditions) on flood depth for the 1,000 year ARI design flood. The figure shows the levee and haul road would result in moderate increases in flood level, most notably to the south of the project immediately upstream of the proposed haul road (at the Curragh lease boundary) where water levels are predicted to increase by approximately 0.12 m.

An increase in water level of approximately 0.31 m is indicated immediately to the east of the haul road. There is also an increase in water level of 1.54 m to the immediate west of the Mackenzie North project area. This is due to blockage of flow in this location, and inundation of areas not previously flooded.

The impacts of the proposed development reduce upstream, with a typical increase in water level of 0.03 m adjacent to the existing Curragh Mine. Impacts during the 50 and 100 year ARI design events are smaller than those shown in Figure 5.1.

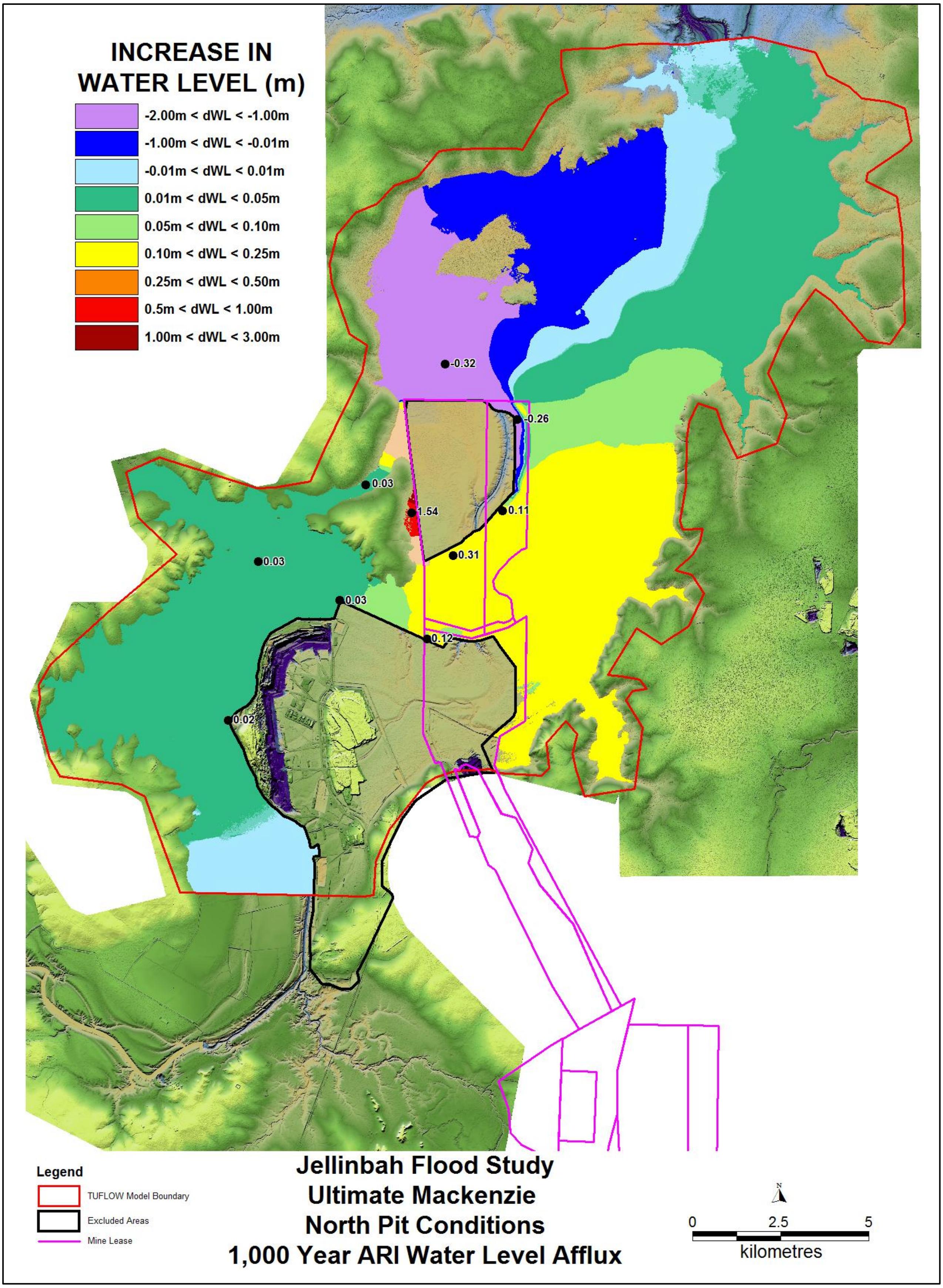


Figure 5.3 1,000 Year ARI Design Event Ultimate Mackenzie North Pit Project Afflux

The proposed levee and haul road results in a loss of Mackenzie River floodplain storage. Figure 5.4 compares the design 100 year ARI hydrographs for the approved and ultimate conditions, downstream of the Mackenzie North Project. The figure shows the project will result in a less than 1% increase in the peak design flow downstream of the project.

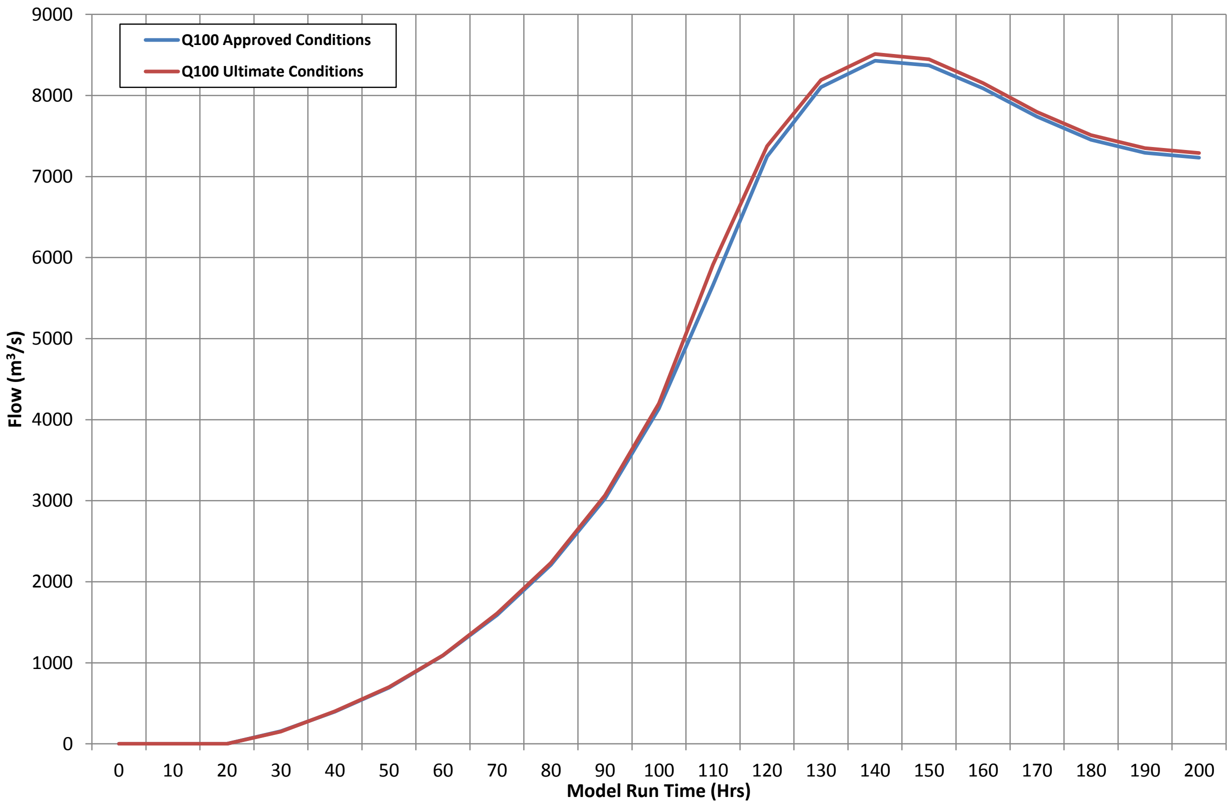


Figure 5.4 Comparison of 100 Year ARI Model Flow Output – Approved and Ultimate Conditions

The conceptual design of the anabranch diversion has been sized to mimic the geometry and flow conditions in the existing diversion. However, there will be some changes to flow conditions, due to the loss of floodplain conveyance in the mining area. Table 5.1 summarises the modelled 50 year ARI flow conditions in the diversion and the existing anabranch at the cross-sections shown in Figure 4.4. Guideline values from the "*Watercourse Diversions – Central Queensland Mining Industry*" (DERM, 2011) are shown for comparison. While average velocity, stream power and shear stress would increase under the proposed design, these parameters are all well within guideline values. The diversion design will be refined prior to approval and construction, while ensuring consistency with the guidelines.

Table 5.1 Comparison of diversion flow conditions with existing and guideline conditions (50 year ARI design flood)

	Guideline	Cross Section 1		Cross Section 2		Cross Section 3	
		Existing	Diverted	Existing	Diverted	Existing	Diverted
Maximum Flow (m^3/s)		1,467	1,757	1,438	1,589	1,240	1,289
Top Width (m)		382	323	283	373	445	344
Flood Slope		0.00052	0.00051	0.00038	0.00043	0.00022	0.00029
Stream Power (W/m^2)	220	19.6	27.2	18.9	18.0	6.0	10.7
Shear Stress (N/m^2)	80	19.6	18.9	20.8	14.0	8.8	10.0
Average Velocity (m/s)	2.5	1.00	1.44	0.91	1.29	0.68	1.06

6 CONCLUSIONS

The impacts of the Ultimate Mackenzie North Pit Project on the Approved Conditions were analysed by developing and extending a calibrated TUFLOW hydraulic model, prepared for previous investigations, downstream of the proposed site. Simulations for the 50, 100 and 1,000 Year ARI design events were carried out for both the Approved and Ultimate Mackenzie North Pit conditions. Adjustment of the Approved Conditions hydraulic model was undertaken to include the diversion of a Mackenzie River Anabranch, a levee to protect the proposed Mackenzie North Project from floodwater and a proposed haul road linking the proposed site with the Jellinbah Mine.

The modelling results indicate that the presence of the proposed mine site results in a localised elevation of water levels adjacent to the proposed levee and haul road. This impact propagates upstream towards the Curragh Mine. However, the impact at the lease boundary is typically less than 0.03 m for most of the existing levee length for the 1,000 year ARI design event with smaller afflux occurring in the 50 and 100 year ARI design events.

The presence of the proposed Ultimate Mackenzie North Pit Project impacts on flow velocities and stream power, however the resultant conditions are likely to be within guideline values. During detailed design, the geometry will be further refined. The design will be consistent with the intent of the Guideline for Watercourse Diversions - Central Queensland Mining Industry (DERM, 2011).

7 REFERENCES

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APPENDIX A

DETAILS OF AVAILABLE RAINFALL AND STREAMFLOW DATA

Table A1 Details of Rainfall Stations, Mackenzie River Catchment

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
535001	Redcliffe GS 130316A	-24.3289	149.574	1990 -	Continuous
535002	17.2 Km GS 130504A	-23.6486	148.556	1991 -	Continuous
535006	Bingegang GS130106A	-23.0769	149.031	1996 -	Continuous
535007	Boxvale 1 Standalone	-25.5168	148.467	1900 -	Continuous
535008	Brackenley Standalone	-24.1953	149.269	1964 -	Continuous
535009	Boxvale 2 Standalone	-25.4114	148.619	1985 -	Continuous
535010	Tambo (Old Alpha Rd)	-24.8342	146.312	1993 -	Continuous
535011	Tarabah RN00330004	-24.5578	146.444	1993 -	Continuous
535012	Lake Brown GS 130502B	-24.8436	148.693	1995 -	Continuous
535013	Rewan GS 130509A	-24.9794	148.387	1995 -	Continuous
535014	Sandy Ck at Clermont GS130207A	-22.7992	147.579	1996 -	Continuous
535015	Duckponds GS130219A	-23.4828	148.473	1996 -	Continuous
535016	Theresa Ck at Valeria GS130210A	-23.1878	147.893	1996 -	Continuous
535017	Craigmore GS130209A	-23.8903	147.755	1996 -	Continuous
035040	Westgrove TM	-25.5811	148.481	1996 -	Operational
035068	Waddy Brae TM	-25.6103	148.944	1996 -	Operational
035145	Rolleston	-24.4667	148.619	1983 -	Operational
035226	Westgrove	-25.5831	148.478	1989 -	Operational
035229	Alpha	-23.65	146.645	1992 -	Operational
035291	Drensmaine TM	-25.2117	146.482	1998 -	Operational
535015	Beckers TM	-24.0833	149.833	1993 -	Operational
535019	Fairbairn Dam TM	-23.6525	148.074	2002 -	Operational
535020	Duckponds TM	-23.4833	148.472	1996 -	Operational
535023	Bingegang H/W TM	-23.0769	149.031	1995 -	Operational
535025	Comet Weir TM	-23.6111	148.551	1995 -	Operational
535026	Bedford Weir TW TM	-23.3733	148.839	1998 - 2000	Operational
535027	Bedford Weir Hw TM	-23.3733	148.839	1953 - 1998	Operational
535028	Clermont TM	-22.7992	147.576	1996 -	Operational
535029	Craigmore TM	-23.8903	147.755	2002 -	Operational
535033	Bogantungan TM	-23.6481	147.29	2002 -	Operational
535035	Emerald TM	-23.5297	148.166	2002 -	Operational
535037	Mantuan Downs TM	-24.4128	147.246	2002 -	Operational
535038	Wharton Ck TM	-24.6283	147.403	2002 -	Operational
535039	Raymond TM	-24.2317	147.645	2002 -	Operational
535040	Penjobe TM	-24.4114	148.042	2002 -	Operational
535041	Mt Playfair TM	-24.8647	146.946	2002 -	Operational
535042	Springsure TM	-24.1219	148.087	2003 -	Operational
535043	Tambo TM	-24.8817	146.256	2003 -	Operational
034075	New Corry Stn	-22.6075	147.842	1968 -	Daily
035000	Alpha Post Office	-23.6497	146.641	1963 -	Continuous
035000	Alpha Post Office	-23.6497	146.641	1986 -	Daily
035001	Anakie Richardson St	-23.5522	147.746	1889 -	Daily
035002	Arcturus Downs	-24.0344	148.406	1895 -	Daily
035003	Ardurad	-23.8825	148.964	1934 -	Daily
035004	Babbiloora Stn	-25.1933	147.135	1923 -	Daily
035005	Old Banchory Stn	-22.9883	147.125	1890 - 1961	Daily
035007	Bauhinia Downs Store	-24.5711	149.292	1890 -	Daily
035008	Currajong	-25.5039	149.279	1998 -	Daily
035009	Blackwater Post Office	-23.585	148.883	1895 - 1995	Daily
035010	Blair Athol	-22.6528	147.558	1972 -	Continuous
035011	Blair Athol Sfr 127	-22.7	147.5	1921 - 1955	Daily

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
035012	Bluff Post Office	-23.5822	149.069	1899 -	Daily
035015	The Sandstone	-25.4025	149.104	1998 -	Daily
035016	Capella Post Office	-23.0856	148.024	1898 -	Daily
035018	Carnarvon Stn	-24.8089	147.753	1924 -	Daily
035019	Clermont Sirius St	-22.8239	147.643	1870 -	Daily
035019	Clermont Sirius St	-22.8239	147.643	1870 -	Synop
035020	Cocklebinda	-24.3	149.6	1940 - 1954	Daily
035021	Comet Post Office	-23.6042	148.546	1895 -	Daily
035022	Coorada	-25.0125	149.501	1912 -	Daily
035023	Craven	-23.2	147.083	1871 - 1936	Daily
035024	La Ringo	-23.7667	148.033	1899 - 1983	Daily
035025	Dingo Post Office	-23.6456	149.331	1963 -	Continuous
035025	Dingo Post Office	-23.6456	149.331	1896 -	Daily
035026	Duaringa Post Office	-23.7139	149.673	1886 -	Daily
035028	Fernlees Post Office	-23.8667	148.133	1912 - 1978	Daily
035030	Gindie State Farm	-23.7	148.1	1898 - 1970	Daily
035031	Glentana	-24.6017	147.573	1911 -	Daily
035032	Gordon Downs	-23.2333	148.333	1890 - 1976	Daily
035033	Harden Park	-24.3419	146.76	1917 - 2001	Daily
035034	Humboldt	-24.0972	148.824	1940 -	Daily
035035	Huntly	-22.7	147.9	1888 - 1952	Daily
035037	Kilcumin	-22.3833	147.517	1880 - 1952	Daily
035038	Terang	-23.9658	148.758	1986 - 2001	Daily
035041	Malthoid	-23.1	147.75	1916 - 1931	Daily
035043	Memooloo	-24.0031	148.721	1928 -	Daily
035044	Miclere	-22.5167	147.6	1937 - 1960	Daily
035045	Mount Playfair	-24.9	146.983	1888 - 1958	Daily
035046	Nandowrie	-24.25	147.617	1950 -	Daily
035048	Nardoo	-24.6	147.6	1918 - 1949	Daily
035051	Orion	-24.2644	148.382	1886 -	Daily
035052	Peak Downs	-23	148.017	1886 - 1956	Daily
035053	Peakvale Stn	-23.1864	147.354	1922 -	Daily
035054	Pine Hill Railway Stn	-23.6497	146.95	1889 - 1992	Daily
035055	Planet Downs	-24.5333	148.883	1935 - 1977	Daily
035056	Rainworth	-24.125	147.928	1888 -	Daily
035057	Reedy Ck Stn	-25.1833	149.35	1897 - 1976	Daily
035058	Yackadoo	-22.4231	147.631	1960 -	Daily
035059	Rolleston Meteor St	-24.4619	148.626	1987 -	Continuous
035059	Rolleston Meteor St	-24.4619	148.626	1889 -	Daily
035059	Rolleston Meteor St	-24.4619	148.626	1889 -	Synop
035060	St Aubins	-23.55	148.55	1919 - 1959	Daily
035061	Sandhurst Park	-23.9	149.1	1932 - 1950	Daily
035062	Sapphire Post Office	-23.4622	147.721	1923 -	Daily
035063	Somerby	-24.2111	148.74	1924 -	Daily
035064	Spring Ck Stn	-24.4481	147.899	1950 -	Daily
035065	Springsure Dame St	-24.1222	148.087	1969 - 2003	Continuous
035065	Springsure Dame St	-24.1222	148.087	2003 -	Continuous
035065	Springsure Dame St	-24.1222	148.087	1865 -	Daily
035065	Springsure Dame St	-24.1222	148.087	1865 -	Synop
035066	Springwood Stn	-24.5325	148.351	1950 -	Daily
035067	Sunlight	-24.3	148.8	1927 - 1976	Daily
035069	Tambo Post Office	-24.8819	146.256	1963 -	Continuous

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
035069	Tambo Post Office	-24.8819	146.256	1877 -	Daily
035069	Tambo Post Office	-24.8819	146.256	1877 -	Synop
035071	Telemon Stn	-24.1858	147.72	1887 -	Daily
035072	Tambo Stn	-24.8856	146.278	2000 -	Daily
035074	Tresswell	-24.25	147.5	1924 - 1951	Daily
035077	Warrinilla	-24.9214	148.601	1963 - 1972	Continuous
035077	Warrinilla	-24.9214	148.601	1884 -	Daily
035078	West Quarter	-25.2	146.383	1912 - 1984	Daily
035079	Wharton Ck Stn	-24.6217	147.406	1946 -	Daily
035080	Withersfield Railway Stn	-23.5833	147.567	1933 - 1984	Daily
035082	Demipique	-22.9481	148.275	1949 -	Daily
035085	Yandarloo	-25.1667	146.5	1908 - 1981	Daily
035086	Minette Downs	-23.3	149.1	1961 - 1967	Daily
035087	Betanga	-23.6317	146.344	1899 -	Daily
035088	Birraban	-24.3339	147.943	1952 -	Daily
035089	Highland Plains	-22.6833	148.167	1953 - 1971	Daily
035090	Rewan Stn	-24.9606	148.376	1972 -	Continuous
035090	Rewan Stn	-24.9606	148.376	1910 -	Daily
035091	Coorumbene	-24.5	148.7	1909 - 1921	Daily
035092	Dysart Stn	-22.615	148.353	1956 -	Daily
035093	Mt Moffatt National Park	-25.0208	147.951	1959 -	Daily
035094	Winvic	-22.4831	147.517	1962 -	Daily
035095	Mackenzie	-23.05	149.192	1961 - 1981	Daily
035098	Emerald DPI Town Site	-23.5	148.15	1962 - 1983	Continuous
035098	Emerald DPI Town Site	-23.5	148.15	1955 - 1983	Daily
035100	Lumeah	-23.8	147.6	1920 - 1935	Daily
035101	Minerva	-24	148.117	1925 - 1931	Daily
035102	Aldinga Park	-24.7822	148.388	2002 -	Daily
035103	Lansdowne Stn	-25.0636	146.265	1880 -	Daily
035104	Kilmacolm	-22.4	147.533	1963 - 1982	Continuous
035104	Kilmacolm	-22.4	147.533	1964 - 1982	Daily
035105	Pearl Ck	-23.7667	149.5	1894 - 1917	Daily
035107	Meteor Downs	-24.3822	148.332	1898 -	Daily
035108	Lachlan	-23.1601	149.11	2004 -	Daily
035109	Booroondarra	-22.8181	148.49	1929 -	Daily
035110	Cloyne	-23.9103	147.158	1966 -	Daily
035111	Tannyfoil	-23.8014	148.928	1966 -	Daily
035112	Wyntoon	-23.8772	148.311	1952 -	Daily
035114	Ashgrove	-23.2	149.083	1926 - 1982	Daily
035116	Korcha	-25.4439	148.664	1966 - 1993	Daily
035118	Glenhaughton	-25.3667	149.367	1922 - 1983	Daily
035119	Carinya	-23.9483	149.611	1951 -	Daily
035120	Linga Longa	-25.3639	148.832	1966 -	Daily
035122	Billabalong	-25.1431	148.619	1965 -	Daily
035125	Raby Ck Stn	-23.9667	149.383	1968 - 1975	Daily
035126	Norwich Park	-22.7	148.417	1967 - 1970	Daily
035127	Mount Oscar	-22.7775	147.856	1967 - 1997	Daily
035128	Sorrel Hills	-23.55	149.667	1968 - 1973	Daily
035131	Talagai	-23.1331	148.527	1968 -	Daily
035132	New Caledonia	-23.4292	148.927	1968 -	Daily
035133	Meroo	-24.0833	148.6	1968 - 1972	Daily
035136	Charlevue Homestead	-23.6564	149.177	1968 -	Daily

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
035137	Kullanda	-24.0528	148.938	1968 - 2001	Daily
035138	Glendon	-23.6333	147.8	1969 - 1977	Daily
035140	Mowbray	-23.8667	147.6	1969 - 1975	Daily
035142	Caldervale Stn	-25.1011	146.831	1935 -	Daily
035145	Rolleston	-24.4667	148.619	1983 -	Daily
035147	Emerald DPI Field Stn	-23.4669	148.152	1983 -	Continuous
035147	Emerald DPI Field Stn	-23.4669	148.152	1967 -	Daily
035148	Moonah	-25.7889	148.922	1971 -	Daily
035149	Brigalow Research Stn	-24.8353	149.8	1967 - 1998	Continuous
035149	Brigalow Research Stn	-24.8353	149.8	2000 -	Continuous
035149	Brigalow Research Stn	-24.8353	149.8	1968 -	Daily
035149	Brigalow Research Stn	-24.8353	149.8	1968 -	Synop
035151	Mount Kingsley	-25.2797	148.85	1965 -	Daily
035152	Sunrise	-25.3333	148.1	1970 - 1976	Daily
035153	Mount Lowe	-22.9239	148.138	1970 -	Daily
035155	Ducabrook	-23.9	147.45	1970 - 1975	Daily
035156	Tango	-23.4333	147.017	1978 - 1988	Daily
035157	Walton	-23.6	149.133	1898 - 1908	Daily
035158	Hillview	-22.8667	147.467	1921 - 1924	Daily
035159	Medway Stn	-23.75	147.333	1973 - 1985	Continuous
035160	Tulach Ard	-23.5833	148.767	1973 - 1984	Daily
035163	Warrong Stn	-25.1667	147.917	1909 - 1929	Daily
035164	Monklands	-23.4078	146.464	1971 -	Daily
035165	Durrandella	-24.0717	146.614	1958 -	Daily
035166	Thalmera	-24.6333	149.633	1972 - 1975	Daily
035167	Karamea	-24.52	149.77	1968 - 1989	Daily
035168	Burkan	-23.22	149.473	1953 -	Daily
035169	Cheshire	-24.2547	146.45	1972 -	Daily
035170	Wilpeena	-23.1014	148.923	1972 -	Daily
035171	Oakey Farm	-22.8172	147.477	1961 - 1997	Daily
035172	Melmoth	-23.4542	149.261	1914 -	Daily
035173	Fairview	-24.3225	147.012	1972 -	Daily
035174	Yantumara	-24.4686	149.266	1972 -	Daily
035175	Mount Nicholson	-24.8444	149.1	1967 -	Daily
035176	Mooramin	-22.5514	147.855	1931 - 2000	Daily
035177	Araleun	-22.69	147.666	1972 -	Daily
035178	Broadmere	-25.5086	149.526	1917 -	Daily
035179	Natoma Downs	-22.95	147.833	1967 - 1976	Daily
035180	Waddy Brae	-25.6097	148.945	1965 -	Daily
035181	Bedourie Stn	-25	149.05	1949 - 1987	Daily
035183	Bathampton	-22.7953	147.578	1964 -	Daily
035184	Karvella	-23.6	148.433	1972 - 1978	Daily
035188	Yandaburra	-24.6978	147.497	1940 -	Daily
035189	Consuelo	-24.6553	148.459	01-01-1888 -	Daily
035191	Wooroona	-24.05	149.4	1918 - 1981	Daily
035192	Cooroorah	-23.3283	148.785	1969 - 2003	Daily
035193	Leichhardt Park	-23.2	149.15	1971 - 1975	Daily
035194	Wyseby	-24.9606	148.531	1948 -	Daily
035195	Maywin Park	-23.0286	148.469	1965 -	Daily
035196	Oak Park	-23.0383	148.644	1971 -	Daily
035197	Lorraine	-23.725	148.144	1971 -	Daily
035198	Abor Downs	-22.75	148	1914 - 1959	Daily

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
035199	Mount Wilkin	-22.2756	147.443	1923 -	Daily
035200	Greendale Stn	-24.7886	146.111	1908 -	Daily
035202	Ghinghinda	-25.0997	149.728	1905 -	Daily
035203	Washpool	-24.2	148.817	1973 - 1977	Daily
035204	Ganadero	-24.0606	148.821	1968 -	Daily
035205	Woorarra	-24.0247	147.921	1924 -	Daily
035206	Bungawarra	-24.455	148.96	1969 -	Daily
035207	Mountain View	-24.2236	148.096	1973 -	Daily
035208	Glenrock	-24.4639	147.613	1973 - 1998	Daily
035209	Albinia Downs	-24.4222	148.483	1973 -	Daily
035210	Willows Post Office	-23.6667	147.483	1973 - 1975	Daily
035211	Kurrajong	-22.6217	147.659	1961 -	Daily
035212	Ronnoc Downs	-23.8878	148.049	1963 -	Daily
035213	Hayden Parke	-23.0167	147.767	1973 - 1973	Daily
035214	Riverside	-24.3167	147.467	1973 - 1978	Daily
035215	Willows Gemfields	-23.7417	147.539	1963 -	Daily
035216	Barkala	-24.7314	148.808	1973 - 1990	Daily
035217	Freitag	-24.3981	148.118	1973 -	Daily
035218	Wanatta	-24.2161	147.915	1973 - 2000	Daily
035219	Cairo	-22.4394	147.377	1973 -	Daily
035220	Cometside	-24.7311	148.76	1973 -	Daily
035221	Lucknow	-23.3039	148.106	1973 -	Daily
035222	Westlyn	-24.2333	148.333	1973 - 1983	Daily
035223	Glenidol	-24.8833	148.833	1973 - 1988	Daily
035224	Karmoo	-23.0808	147.379	1947 -	Daily
035225	Cardbeign	-24.2897	148.105	1953 -	Daily
035226	Westgrove	-25.5831	148.478	1890 -	Daily
035227	Karamea	-24.52	149.77	1994 -	Daily
035228	Weimby Downs	-22.8544	147.925	1960 -	Daily
035229	Alpha	-23.65	146.645	1992 -	Daily
035230	Aviemore	-23.4236	147.696	1973 -	Daily
035231	Langley Downs	-23.3781	148.303	1936 -	Daily
035232	Valeria	-23.1858	147.897	1994 -	Daily
035233	Mount Pleasant	-24.6197	148.496	1965 -	Daily
035234	Portion Eleven	-24.5736	148.888	1968 - 2001	Daily
035235	Carina Downs	-24.2294	148.471	1970 -	Daily
035236	Rivington	-23.9608	146.561	1994 - 1999	Daily
035236	Rivington	-23.9608	146.561	1999 -	Daily
035237	Galgatha	-23.7833	148.567	1974 - 1989	Daily
035238	Goathlands	-24.5	148.067	1950 - 1974	Daily
035241	Fairbairn Dam	-23.6525	148.074	1969 -	Daily
035243	Blackridge	-22.6167	147.55	1907 - 1912	Daily
035244	Wallaroo	-25.2958	148.706	1971 -	Daily
035245	Merivale	-25.5333	148.267	1889 - 1914	Daily
035246	Mount Enniskillen	-24.5978	146.184	1910 -	Daily
035247	Birkhead	-24.55	146.367	1912 - 1971	Daily
035248	Darkwater	-25.3297	147.863	1933 -	Daily
035252	Hillside	-22.7439	147.525	1972 -	Daily
035258	Moramana	-22.2375	147.513	1972 -	Daily
035262	Balmy Hills	-24.2817	147.465	1979 - 1994	Daily
035263	Austral Park	-25.0906	148.769	1968 -	Daily
035264	Emerald Airport	-23.5694	148.176	1992 -	Continuous

Station Number	Station Name	Latitude	Longitude	Period of Record	Station Type
035264	Emerald Airport	-23.5694	148.176	1992 - 1998	Daily
035264	Emerald Airport	-23.5694	148.176	1992 -	Synop
035265	Arizona	-23.1125	149.196	1982 -	Daily
035267	Coovin	-22.4269	147.548	1983 -	Continuous
035267	Coovin	-22.4269	147.548	1983 -	Daily
035270	Newlands	-23.9114	149.845	1989 -	Daily
035274	Juanita	-23.8467	148.108	1962 -	Daily
035275	Islay Plains	-23.2103	146.878	1988 -	Daily
035278	Dysart Post Office	-22.5864	148.342	1988 -	Daily
035279	Kilcool Stn	-23.5772	147.147	1988 -	Daily
035280	Allambee	-24.8706	148.77	1988 -	Daily
035283	Drensmaine	-25.2117	146.482	1992 -	Daily
035287	Warrigal	-23.4583	149.195	1991 - 1994	Daily
035288	Eldorado	-23.0131	147.907	1994 -	Daily
035290	Blackwater Water Treatment Plant	-23.5961	148.875	1995 -	Daily
035290	Blackwater Water Treatment Plant	-23.5961	148.875	1995 -	Synop
044190	Lochinvar	-25.4697	146.843	1980 -	Daily

Table A2 Details of Stream Gauging Stations, Mackenzie River Catchment

Station Number	Station Name	Latitude	Longitude	Catchment Area (km^2)	Period of Record
130504	Comet Weir TM	-23.6111	148.551		1995 -
130101A	St Aubins	-23.5567	148.537	28,480	1919 - 1960
130103A	Carnangarra	-23.4783	148.652	45,370	1967 -
130104A	Bedford Weir Headwater	-23.3733	148.84	46,847	1973 -
130111A	Bedford Weir Tailwater	-23.3733	148.84	46,847	1997 -
130201A	Emerald	-23.5317	148.167	16,501	1919 - 1946
130201B	Emerald	-23.5317	148.167	16,501	1946 - 1975
130202A	Raymond	-24.2317	147.645	8,380	1949 - 1985
130202B	Raymond	-24.2317	147.645	8,380	1985 - 1988
130203A	Clermont Railway	-23.4117	148.118	6,793	1949 - 1964
130204A	The Gap	-23.6633	148.06	16,320	1952 - 1956
130205B	Selma Weir Headwater	-23.5467	148.138	16,478	1956 - 1988
130206A	Main Rd	-23.43	148.15	8,485	1956 -
130209A	Craigmore	-23.89	147.755	13,876	1972 -
130210A	Valeria	-23.1883	147.893	4,421	1971 -
130212A	Mowbray	-23.8367	147.595	1,108	1972 - 1988
130213A	Clarke Lagoon	-24.475	147.143	1,498	1972 - 1988
130216A	Fairbairn Dam Headwater	-23.6533	148.072	16,173	1973 -
130217A	Theresa Ck Dam	-22.9767	147.557	735	1984 - 1992
130218A	Kilmarnock	-23.06	147.482	563	1983 - 1992
130219A	Duck Ponds	-23.4833	148.473	27,130	1993 -
130501A	Comet Weir	-23.6133	148.55	16,457	1919 - 1973
130502A	Warrinilla	-24.92	148.653	2,956	1966 - 1993
130502B	Lake Brown	-24.8433	148.693	3,027	1984 -
130503A	Wyseby Stn	-24.97	148.527	561	1966 - 1992
130504A	17.2 Km	-23.6483	148.555	16,422	1971 -
130505A	Sunlight	-24.2817	148.785	356	1971 - 1988
130506A	124.2 Km	-24.3133	148.613	10,188	1972 -
130507A	Planet Downs	-24.5417	148.91	776	1972 - 1993
130508A	Springwood	-24.5717	148.282	541	1972 - 1988
130509A	Rewan	-24.98	148.387	351	1985 -
130103	Carnangarra TM	-23.45	148.7	-	1993 -
130104	Bedford Weir Hw TM	-23.3733	148.839		1953 -
130111	Bedford Weir TW TM	-23.3733	148.839	45,935	1995 -
130113	Riverlea TM (Rileys Crossing)	-23.5436	148.606	-	2005 -
130202	Raymond	-24.2317	147.645	8,420	1970 -
130206	Gregory HWY TM	-23.4333	148.15	8,485	1993 -
130207	Clermont TM	-22.7992	147.576	409	1996 -
130209	Craigmore TM	-23.8903	147.755	14,140	2002 -
130210	Valeria TM	-23.1833	147.9	-	1993 -
130216	Fairbairn Dam TM	-23.6525	148.074	16,320	1993 -
130219	Duckponds TM	-23.4833	148.472	27,130	1996 -
130504	Comet Weir TM	-23.6111	148.551	-	1995 -
130901	Rolleston	-24.4667	148.619	5,520	1983 -
130911	Emerald	-23.5297	148.166	16,720	1923 -
130920	Yakcam	-23.47	148.66	45,195	1984 -
130923	Fairbairn Dam	-23.6525	148.074	16,320	1973 -
130924	Valeria	-23.1858	147.897	4,390	1994 -
130928	Emerald TM	-23.5297	148.166	16,720	2003 -
130929	Raymond TM	-24.2317	147.645	8,420	2003 -

APPENDIX B

URBS MODEL CALIBRATION RESULTS

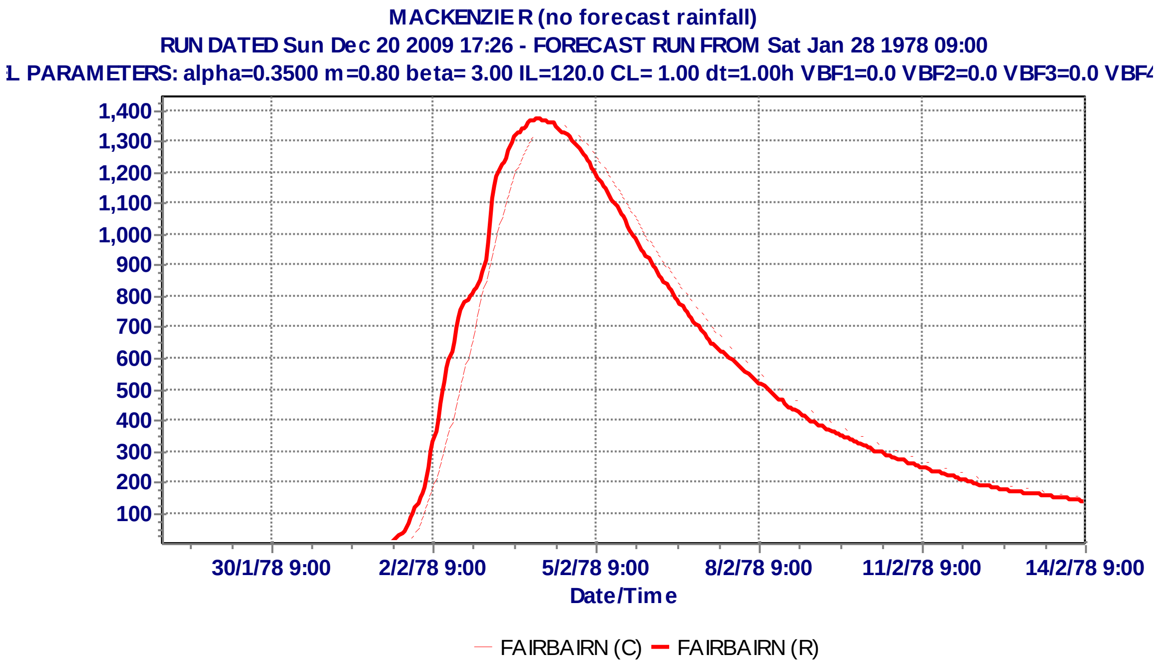


Figure D1 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Nogoa River Fairbairn Dam, 1978

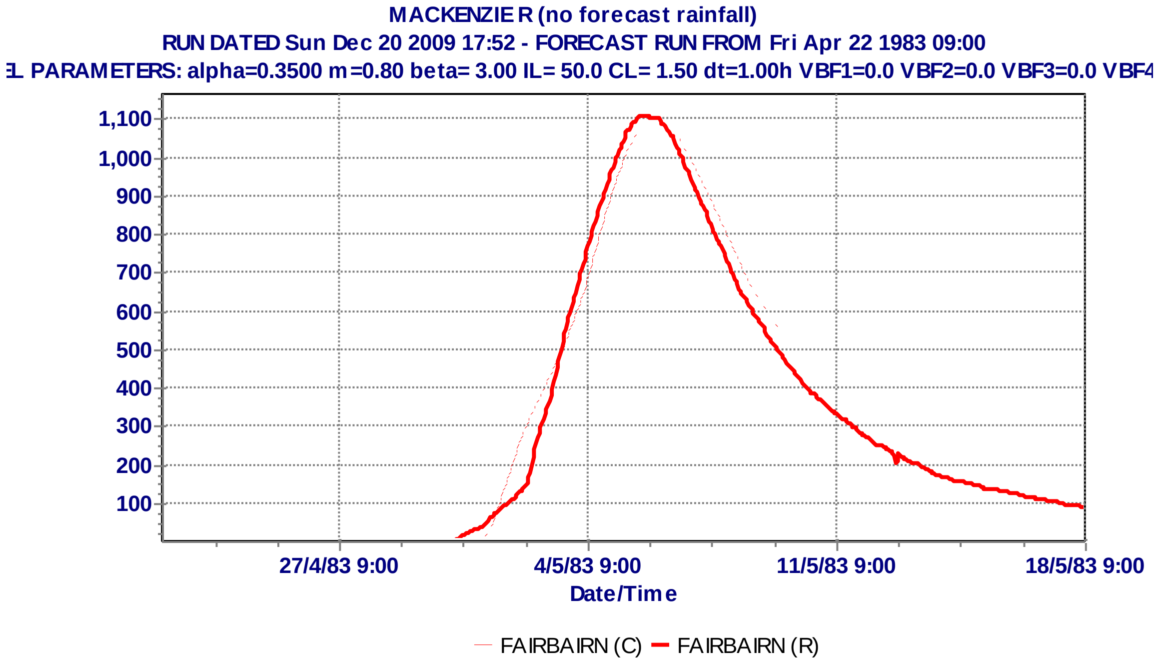


Figure D2 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Nogoa River Fairbairn Dam, 1983

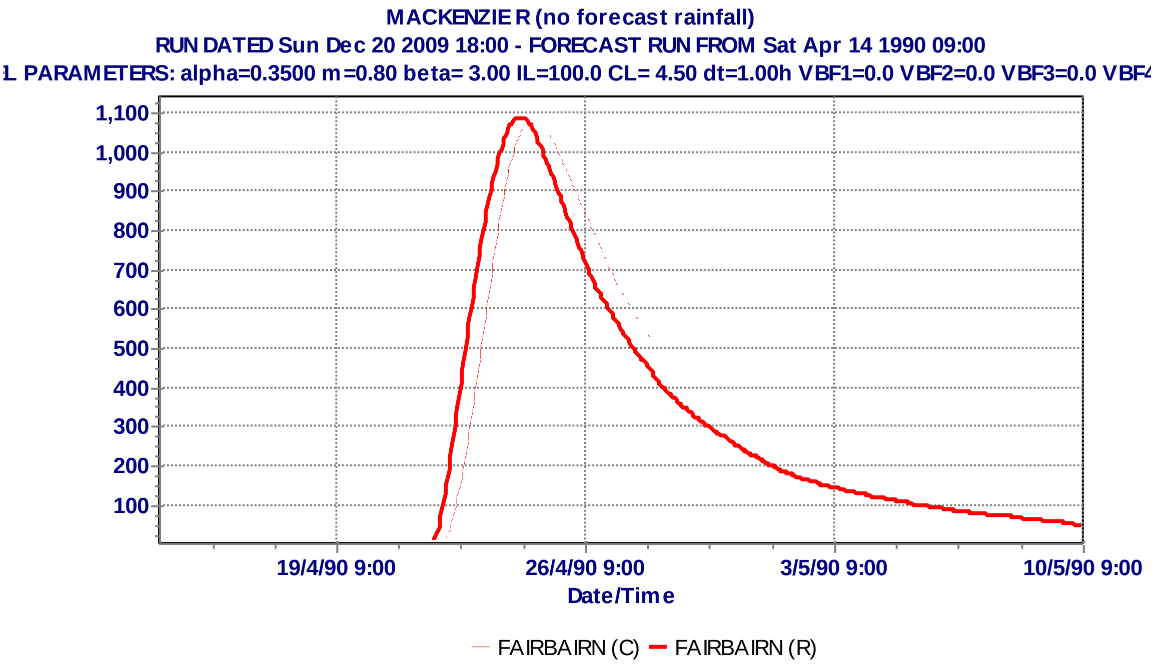


Figure D3 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Nogoa River Fairbairn Dam, 1990

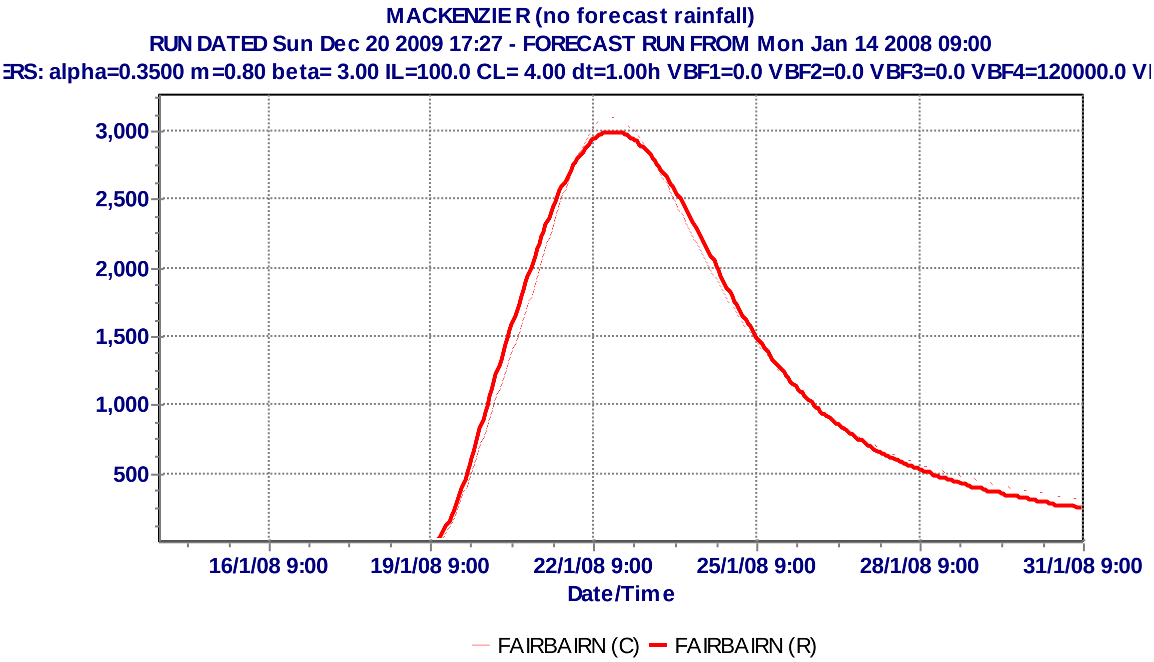


Figure D4 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Nogoa River Fairbairn Dam, 2008

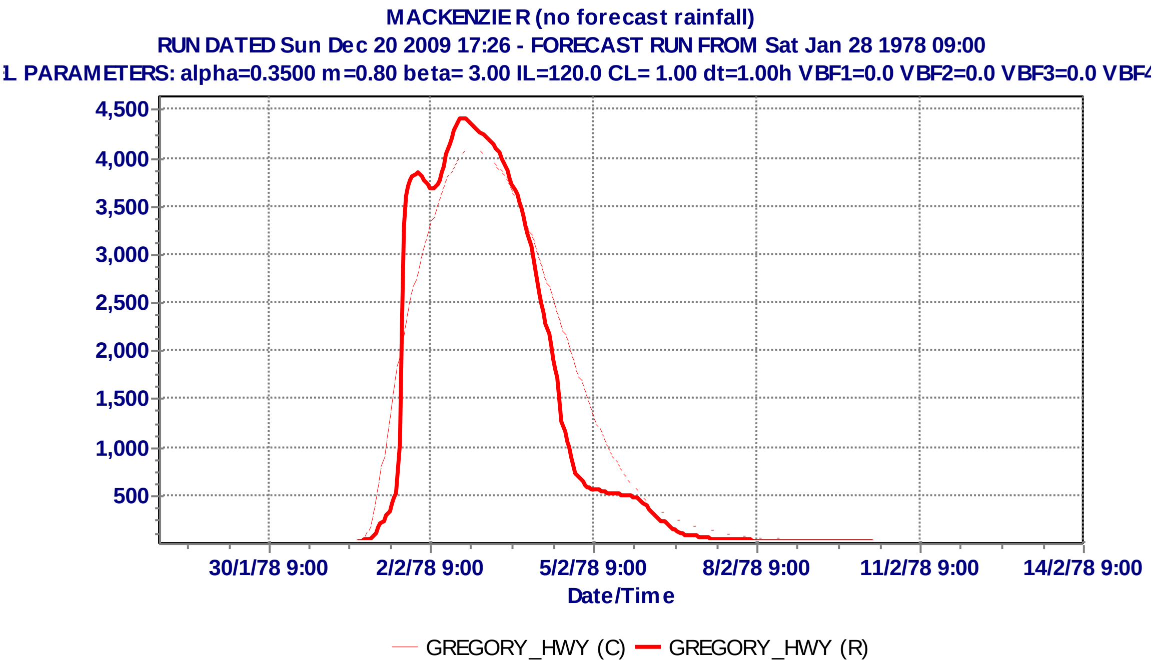


Figure D5 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Theresa Ck at Gregory Highway, 1978

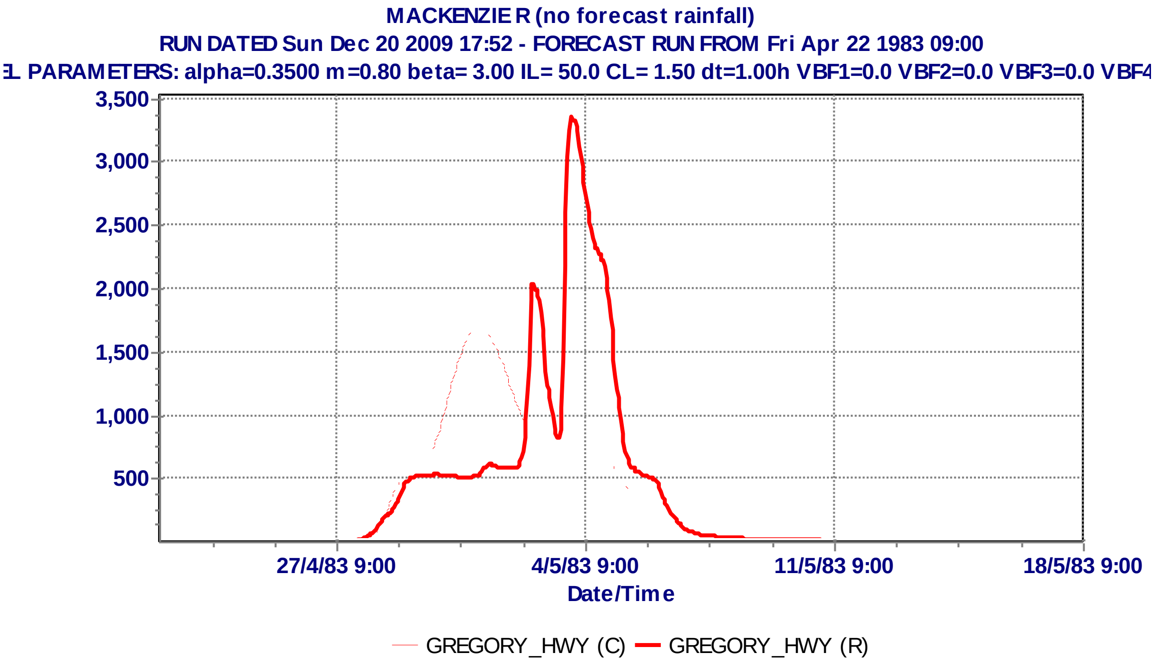


Figure D6 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Theresa Ck at Gregory Highway, 1983

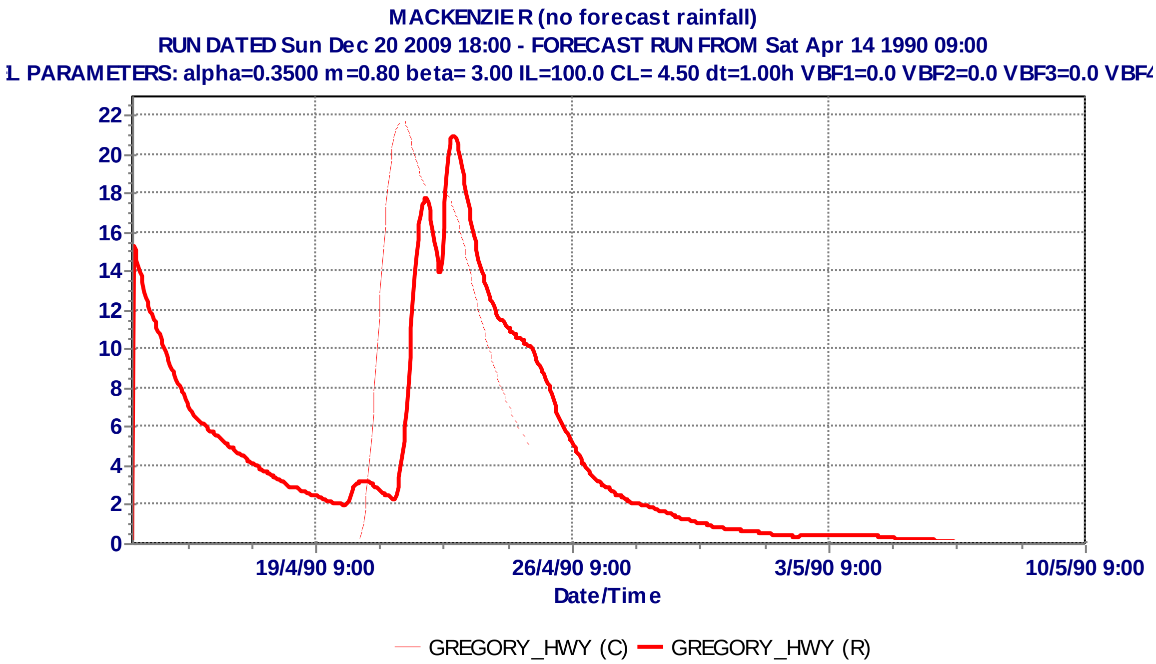


Figure D7 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Theresa Ck at Gregory Highway, 1990

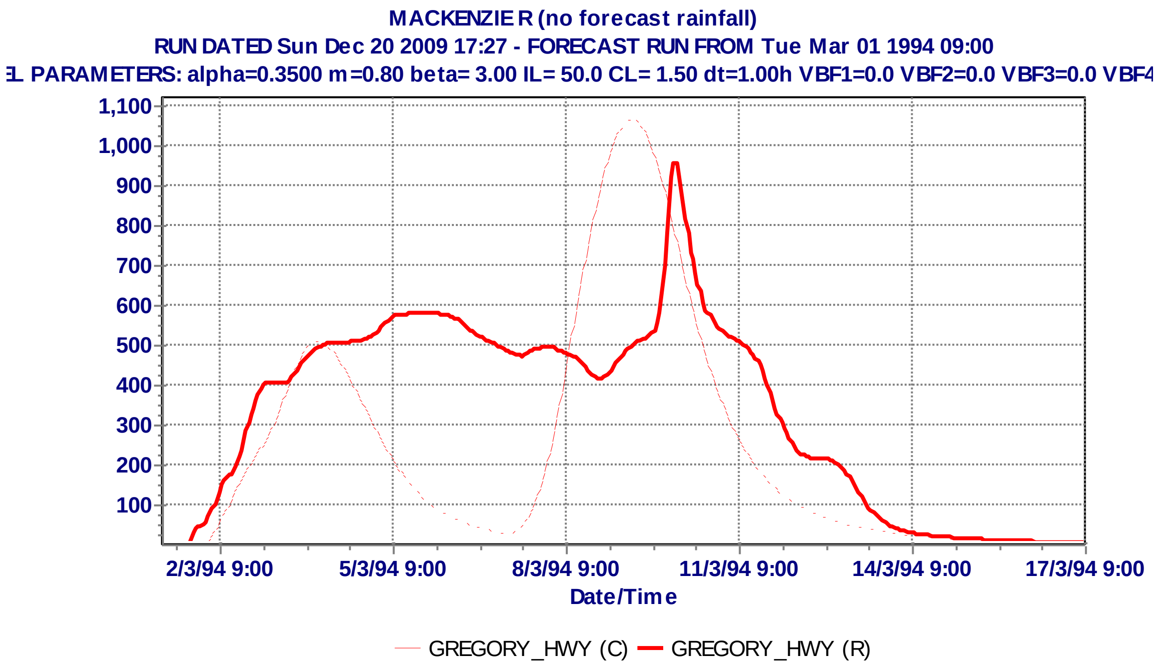


Figure D8 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Theresa Ck at Gregory Highway, 1994

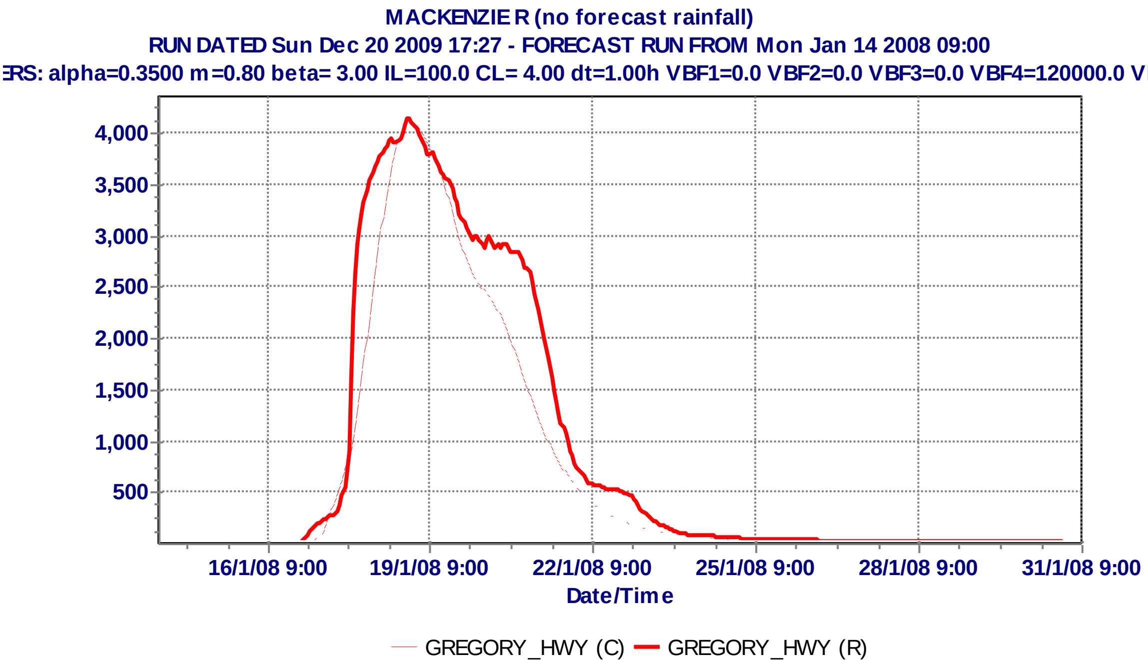


Figure D9 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Theresa Ck at Gregory Highway, 2008

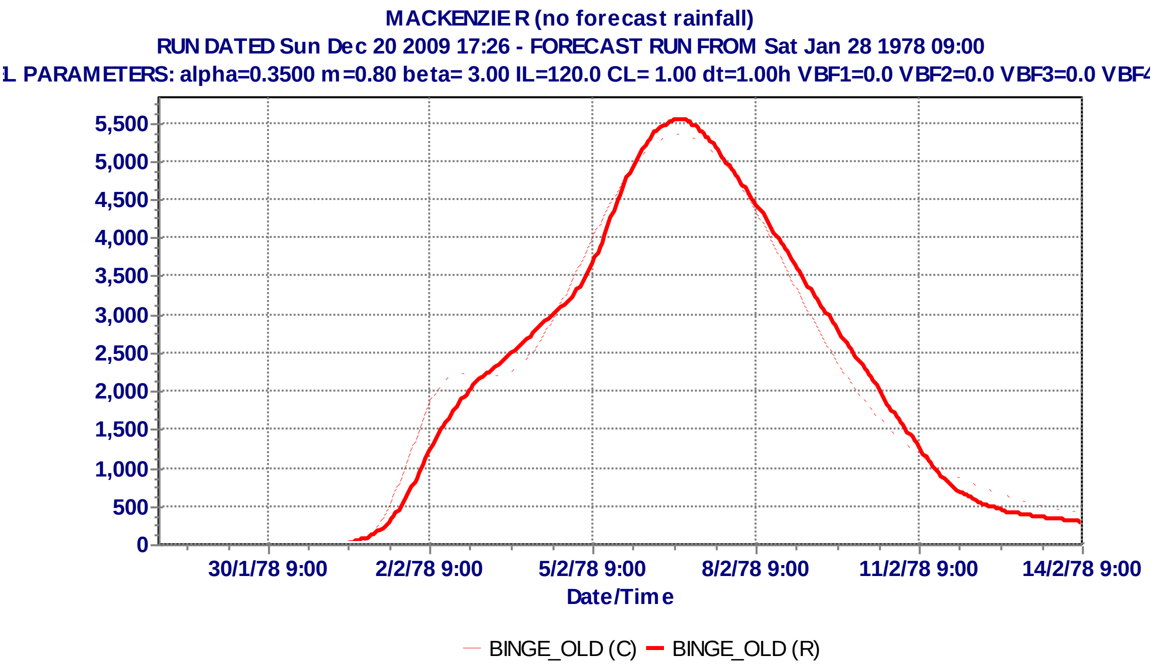


Figure D10 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Mackenzie River at Bingegang Weir HW, 1978

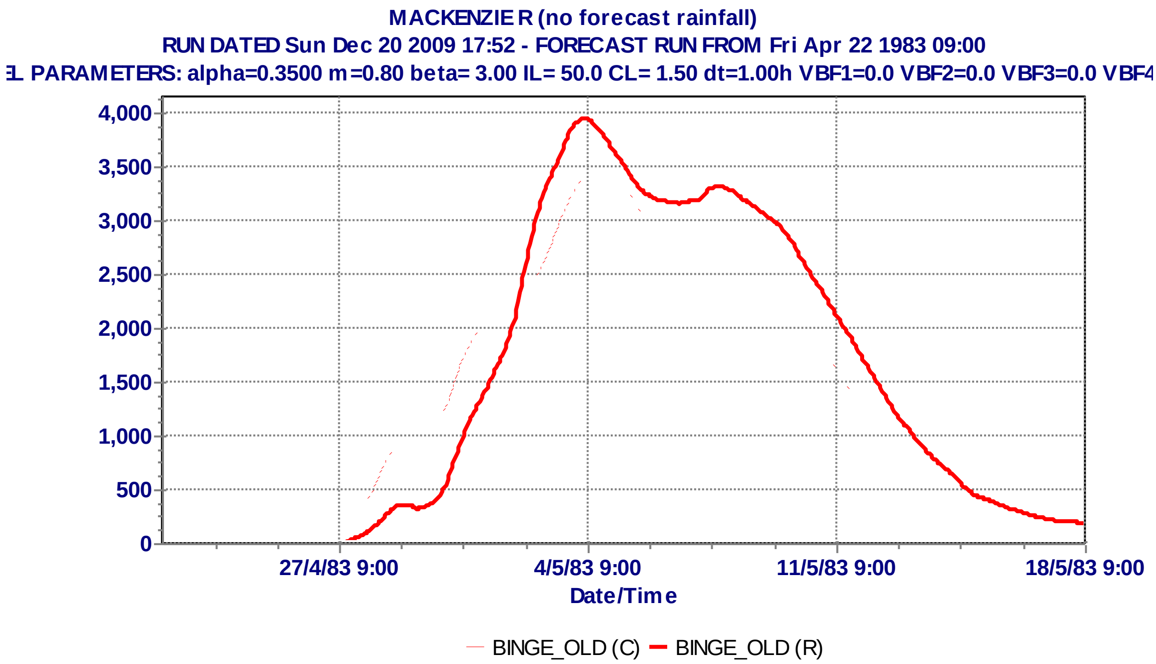


Figure D11 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Mackenzie River at Bingegang Weir HW, 1983

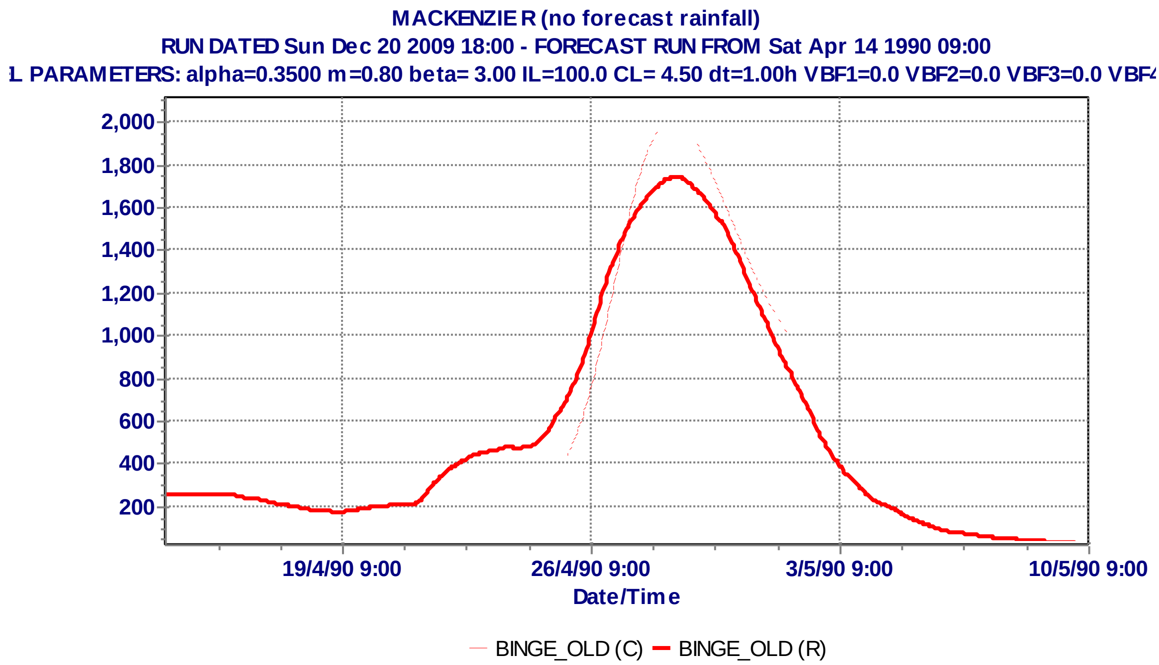


Figure D12 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Mackenzie River at Bingegang Weir HW, 1990

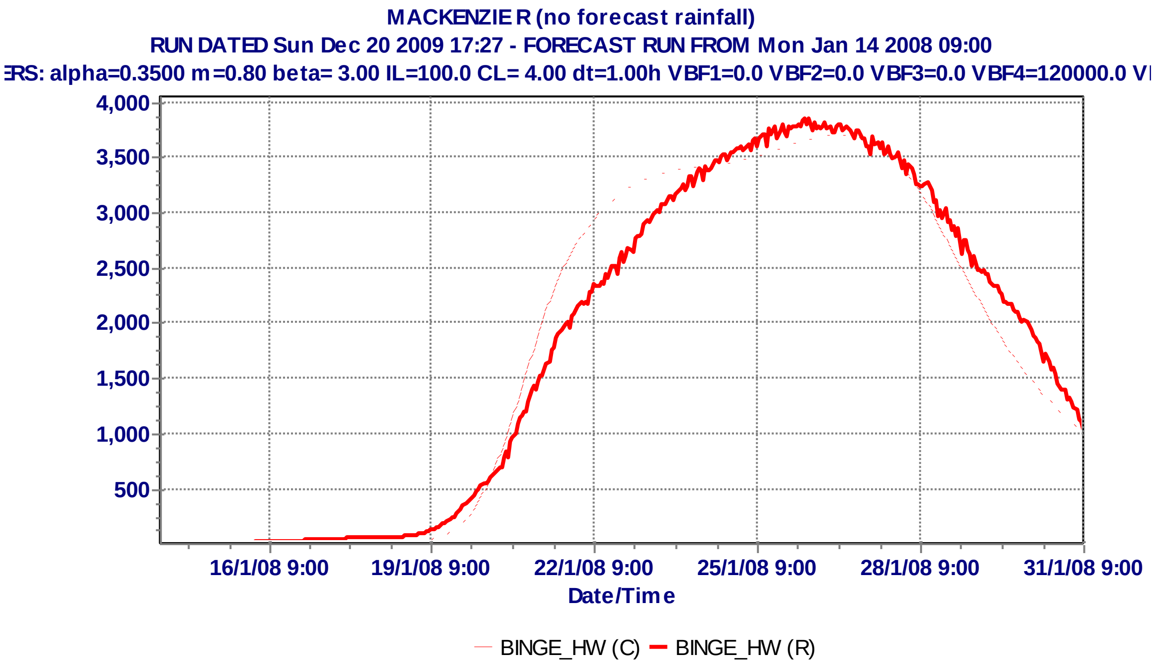
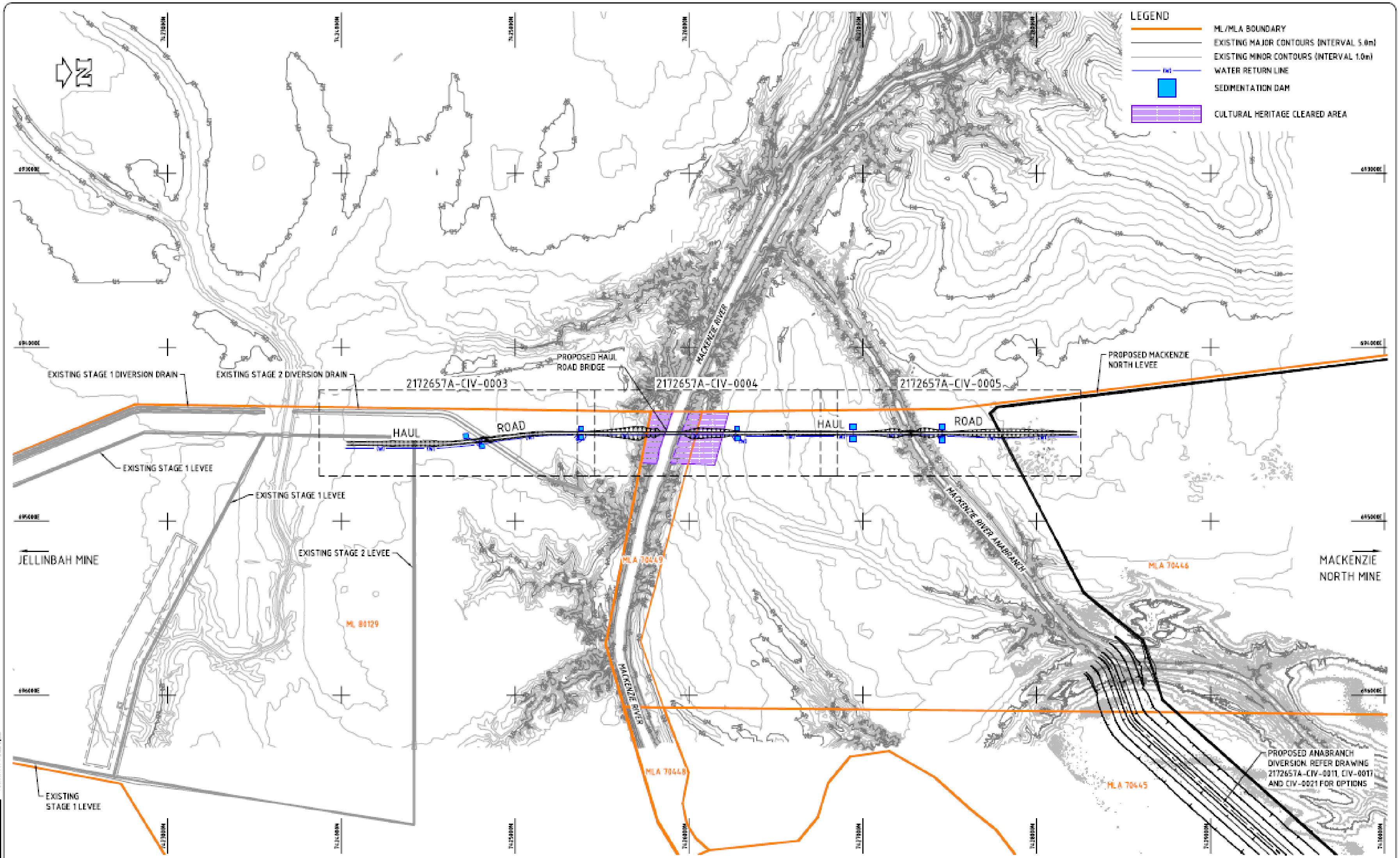


Figure D13 Comparison of Calculated (C) and Recorded (R) Discharge Hydrograph, Mackenzie River at Bingegang Weir HW, 2008

APPENDIX C

PRELIMINARY PROPOSED HAUL ROAD STRUCTURE DETAILS

2172657A-CIV-0002



CO-ORDINATE SYSTEM: AMG ZONE 55
DATUM: AHD

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A	18.03.13	ISSUED FOR COMMENT	MAH		RW	

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VERIFY ALL DIMENSIONS ON SITE

APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE RPEQ No

PARSONS BRINCKERHOFF

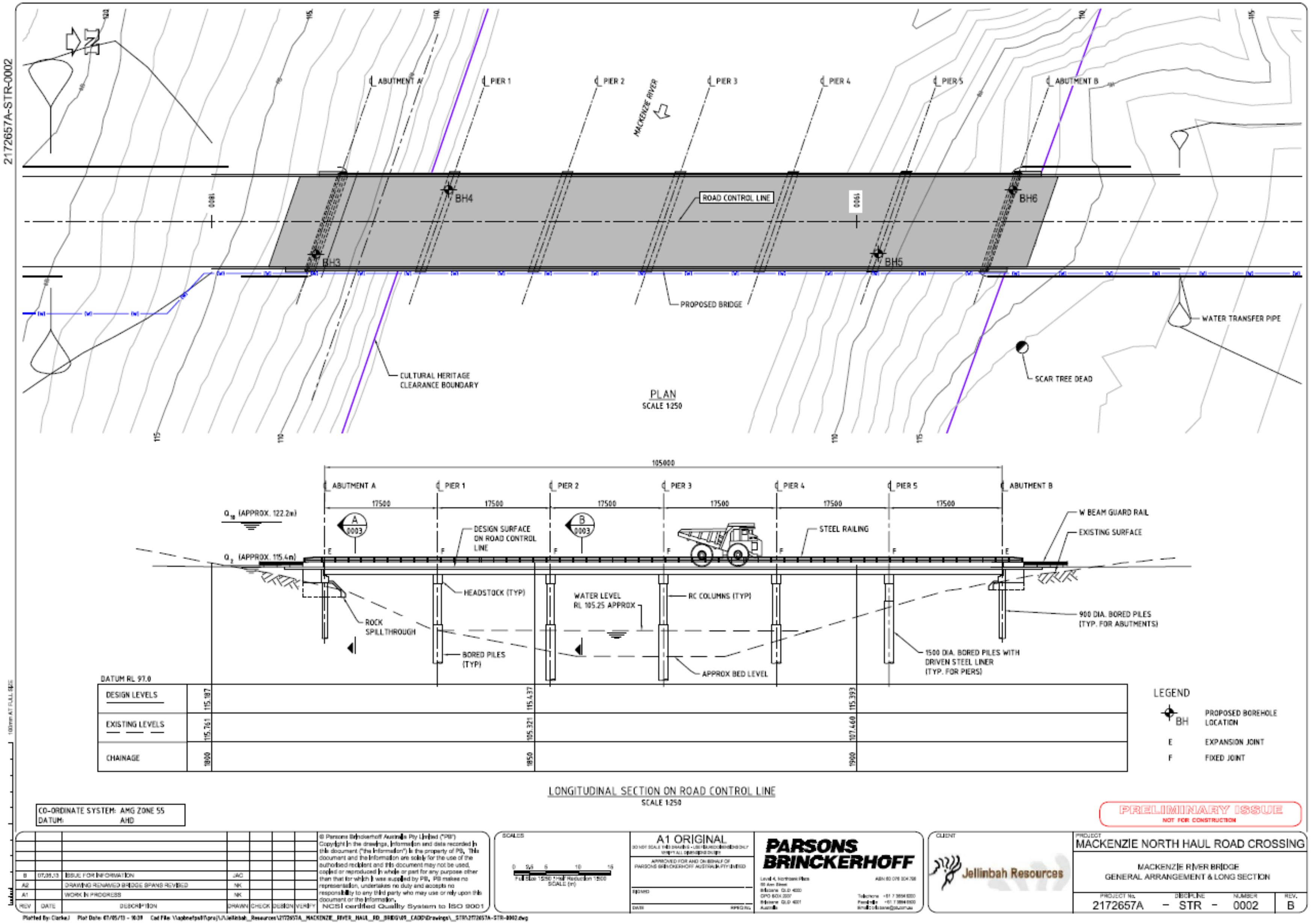
CLIENT
Jellinbah Resources

PROJECT
MACKENZIE NORTH HAUL ROAD CROSSING

OVERALL PLAN

PROJECT No.	DISCIPLINE	NUMBER	REV.
2172657A	CIV	0002	B

Plotted By: ONeillJ Plot Date: 06/05/13 - 16:09 Cad File: \\apbnefps01\proj\J\Jellinbah_Resources\2172657A_MACKENZIE_RIVER_HAUL_RD_BRIDGE\09_CADD\Drawings_CIV\2172657A-CIV-0002.dwg


2172657A-STR-0002
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℄ ABUTMENT A
℄ PIER 1
℄ PIER 2
℄ PIER 3
℄ PIER 4
℄ PIER 5
℄ ABUTMENT B
MACKENZIE RIVER
BH3
BH4
BH5
BH6
ROAD CONTROL LINE
1800
1900
PROPOSED BRIDGE
CULTURAL HERITAGE CLEARANCE BOUNDARY
WATER TRANSFER PIPE
SCAR TREE DEAD
PLAN
SCALE 1:250
105000
17500
Q100 (APPROX. 122.2m)
Q2 (APPROX. 115.4m)
DESIGN SURFACE ON ROAD CONTROL LINE
STEEL RAILING
W BEAM GUARD RAIL
EXISTING SURFACE
HEADSTOCK (TYP)
WATER LEVEL RL 105.25 APPROX
RC COLUMNS (TYP)
900 DIA. BORED PILES (TYP. FOR ABUTMENTS)
ROCK SPILLTHROUGH
BORED PILES (TYP)
APPROX BED LEVEL
1500 DIA. BORED PILES WITH DRIVEN STEEL LINER (TYP. FOR PIERS)
DATUM RL 97.0
DESIGN LEVELS
EXISTING LEVELS
CHAINAGE
115.187
115.437
115.393
115.761
105.321
107.460
1800
1850
1900
LEGEND
BH PROPOSED BOREHOLE LOCATION
E EXPANSION JOINT
F FIXED JOINT
LONGITUDINAL SECTION ON ROAD CONTROL LINE
SCALE 1:250
CO-ORDINATE SYSTEM: AMG ZONE 55
DATUM: AHD
PRELIMINARY ISSUE
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B 07.05.13 ISSUE FOR INFORMATION JAC
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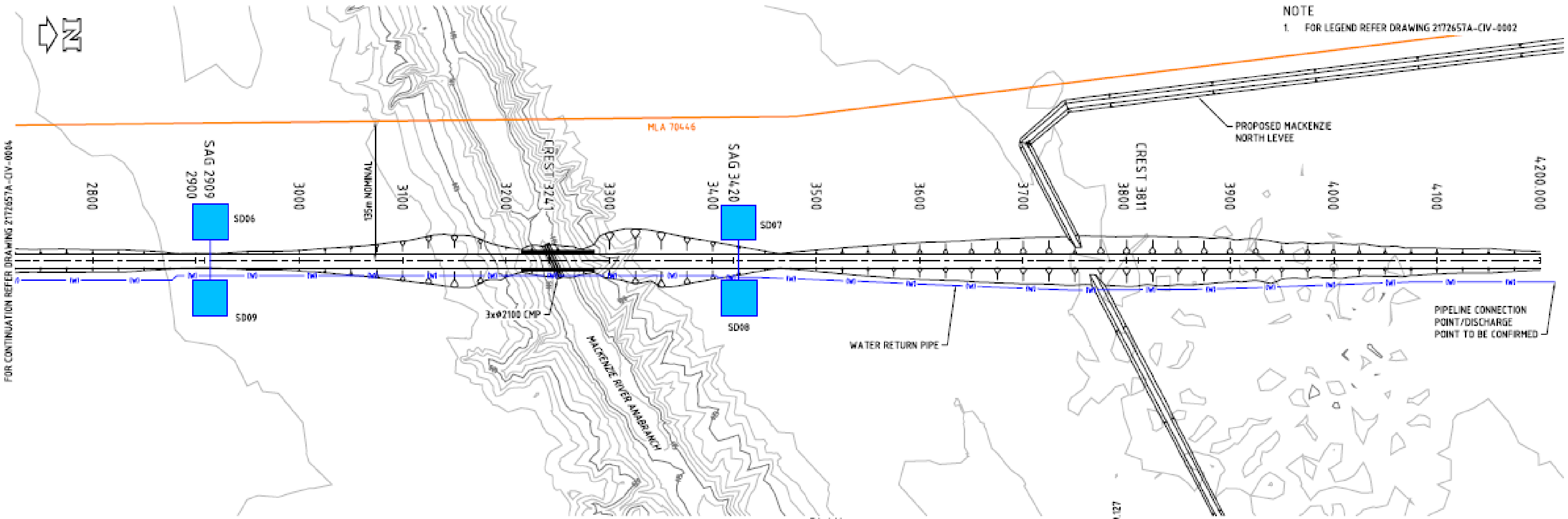
A1 WORK IN PROGRESS NK
REV DATE DESCRIPTION DRAWN CHECK DESIGN VERIFY
NCSI certified Quality System to ISO 9001
A1 ORIGINAL
PARSONS BRINCKERHOFF
Jellinbah Resources
MACKENZIE NORTH HAUL ROAD CROSSING
MACKENZIE RIVER BRIDGE
GENERAL ARRANGEMENT & LONG SECTION
2172657A - STR - 0002 B

2172657A-CIV-0005



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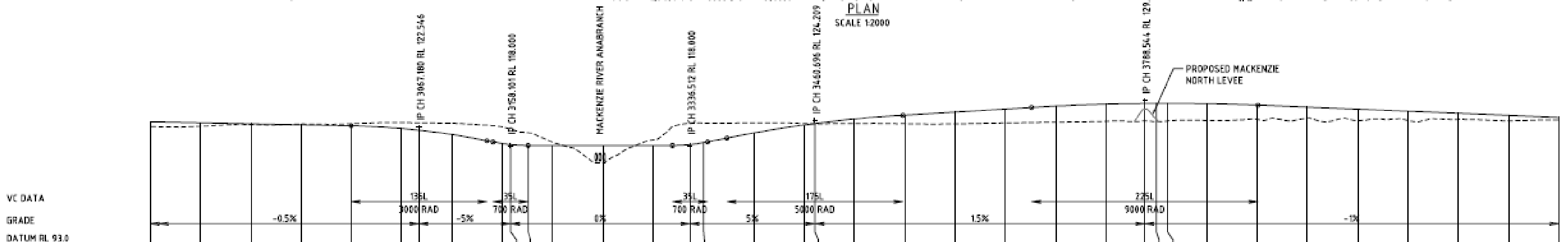

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DESIGN LEVELS	123.882	123.632	123.382	123.132	122.882	122.210	121.787	120.705	118.468	118.219	118.000	118.000
EXISTING LEVELS	122.691	122.774	123.214	123.355	123.404	123.711	123.640	123.561	122.653	122.063	121.173	118.781
CHAINAGE	2800	2850	2900	2950	3000	3050	3067.18	3100	3150	3158.101	3175.601	3200

DEPTH CUT(-)/FILL	4.320	-1.375	-5.283	-4.901	-2.561	-0.378	0.091	1.059	2.114	2.907	3.429	3.956
DESIGN LEVELS	118.000	118.000	118.219	118.686	121.103	123.085	123.444	124.566	125.549	126.299	127.049	127.767
EXISTING LEVELS	113.680	119.375	123.501	123.587	123.664	123.463	123.353	123.507	123.435	123.391	123.620	123.810
CHAINAGE	3250	3300	3336.512	3350	3400	3450	3460.696	3500	3550	3600	3650	3700

DEPTH CUT(-)/FILL	4.215	4.370	4.484	4.361	4.176	3.521	2.717	2.863	2.309	1.574	1.441	0.694
DESIGN LEVELS	128.245	128.424	128.445	128.452	128.368	128.012	127.512	127.012	126.512	126.012	125.512	125.012
EXISTING LEVELS	124.030	124.054	123.961	124.091	124.192	124.491	124.795	124.149	124.204	124.438	124.071	124.318
CHAINAGE	3750	3788.544	3800	3811.044	3850	3900	3950	4000	4050	4100	4150	4200

HORIZONTAL GEOMETRY

LONGITUDINAL SECTION
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SCALE: 1:500 VERTICAL

CO-ORDINATE SYSTEM: AMG ZONE 55
DATUM: AHD

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A	18.03.13	ISSUED FOR COMMENT	MAH		RW	

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SCALE (m)

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APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE

PARSONS BRINCKERHOFF

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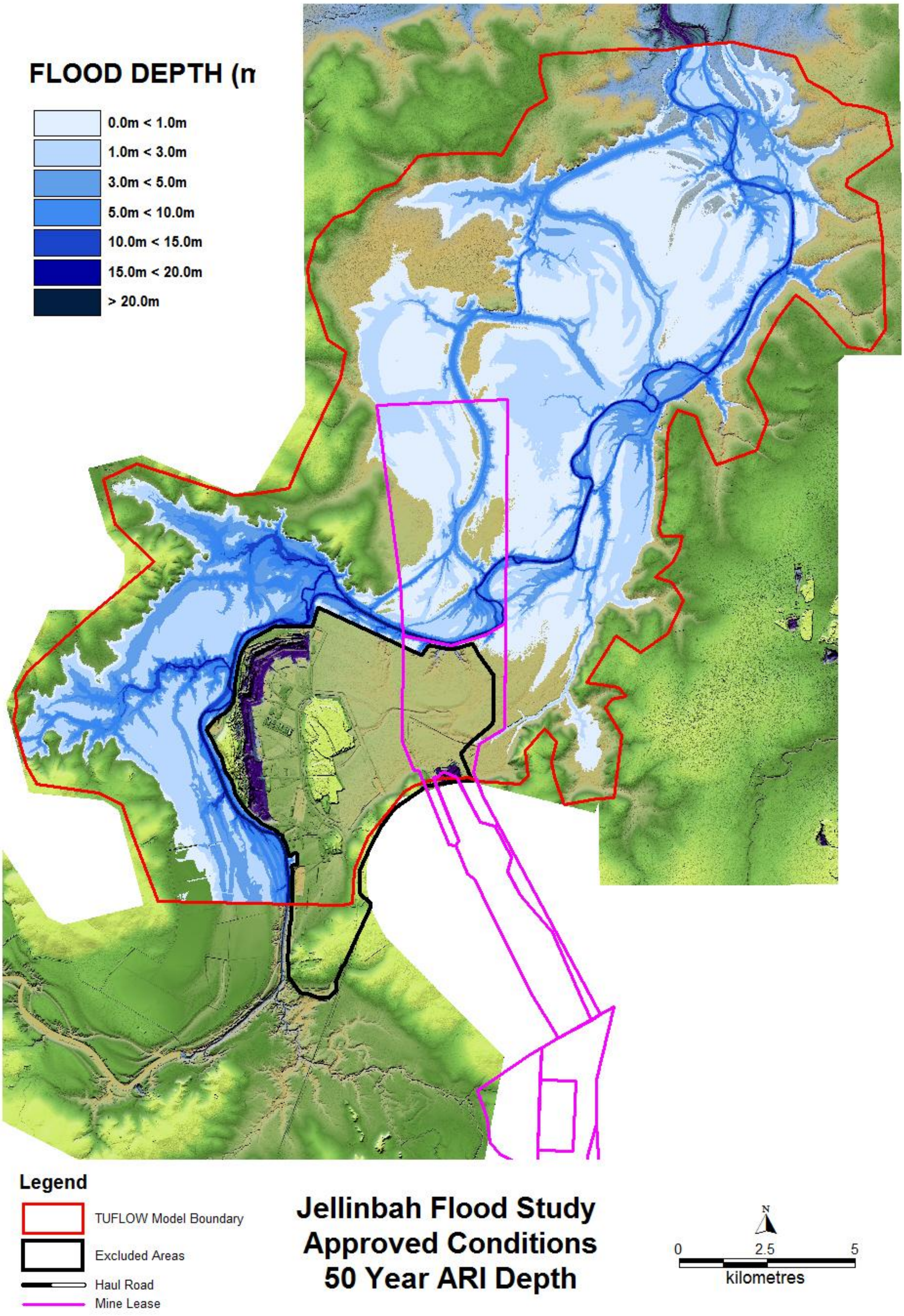
PROJECT
MACKENZIE NORTH HAUL ROAD CROSSING
HAUL ROAD
PLAN AND LONGITUDINAL SECTION
SHEET 3

PROJECT No.	DISCIPLINE	NUMBER	REV.
2172657A	CIV	0005	B

Plotted By: ONeilU Plot Date: 06/05/13 - 15:25

APPENDIX D

APPROVED CONDITIONS MODEL RESULTS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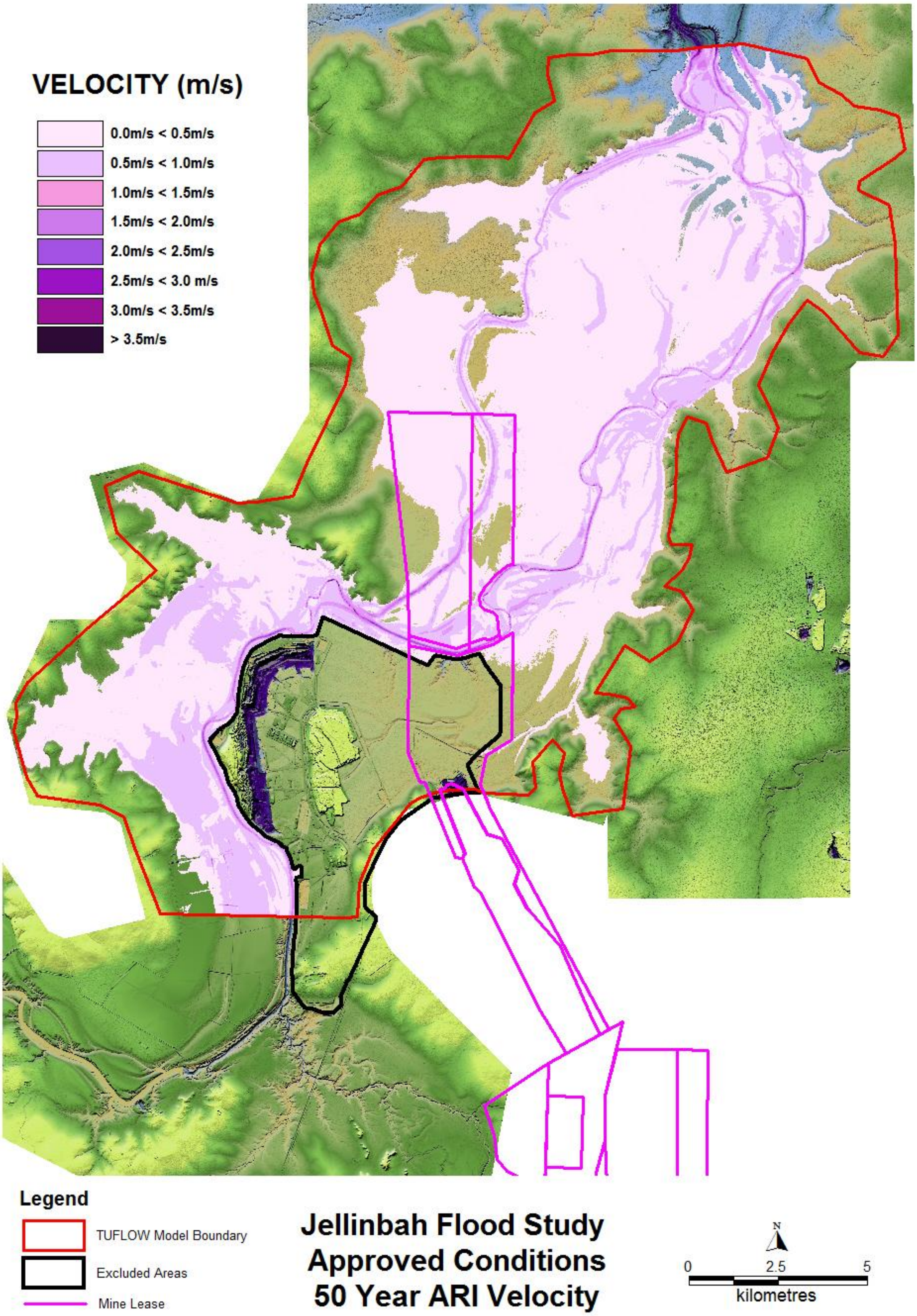
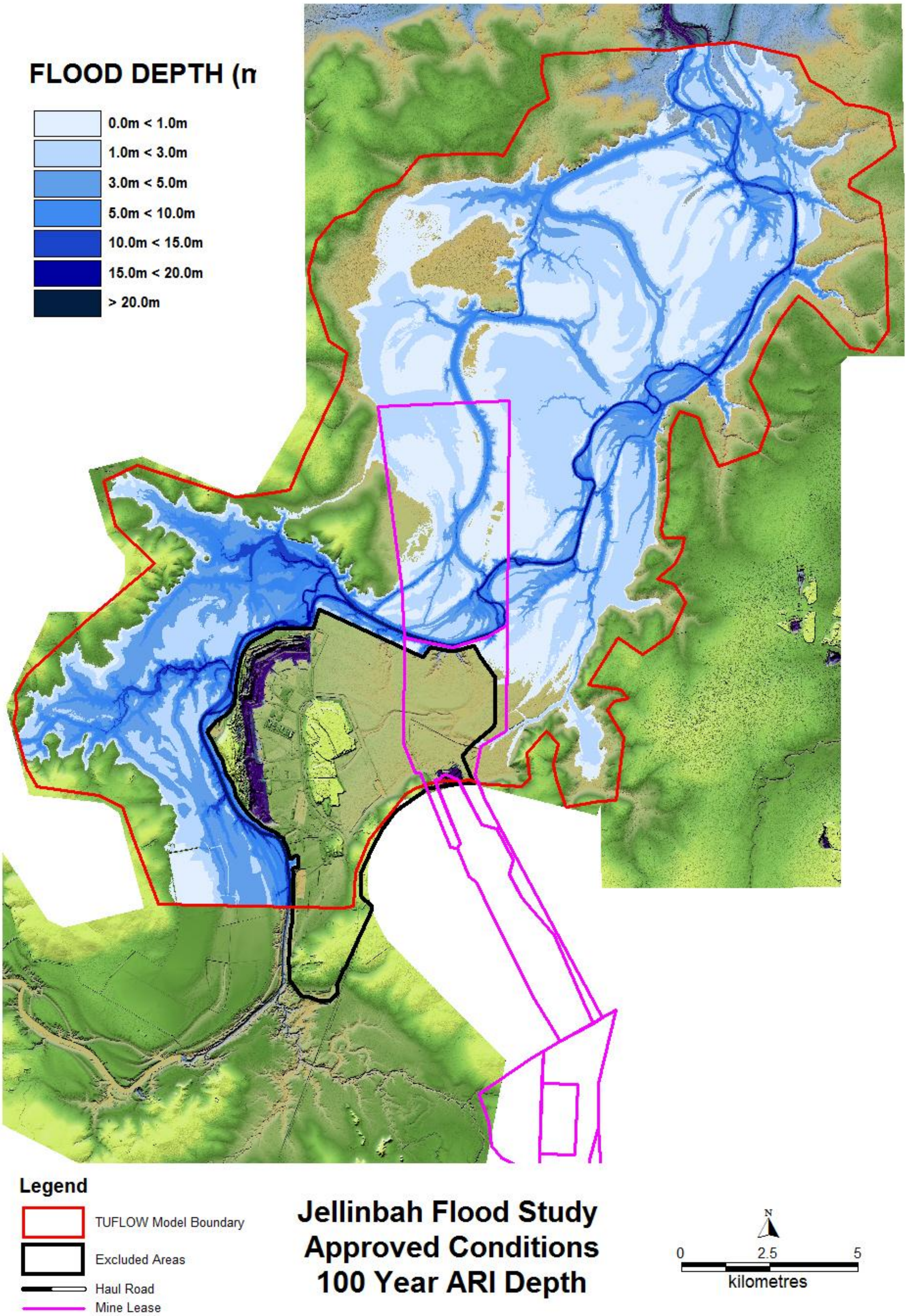
5.0m < 10.0m
10.0m < 15.0m
15.0m < 20.0m
> 20.0m
Legend
TUFLOW Model Boundary
Excluded Areas
Haul Road
Mine Lease
Jellinbah Flood Study
Approved Conditions
50 Year ARI Depth
N
0
2.5
5
kilometres



Jellinbah Flood Study
Approved Conditions
50 Year ARI Velocity



FLOOD DEPTH (m
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1.0m < 3.0m
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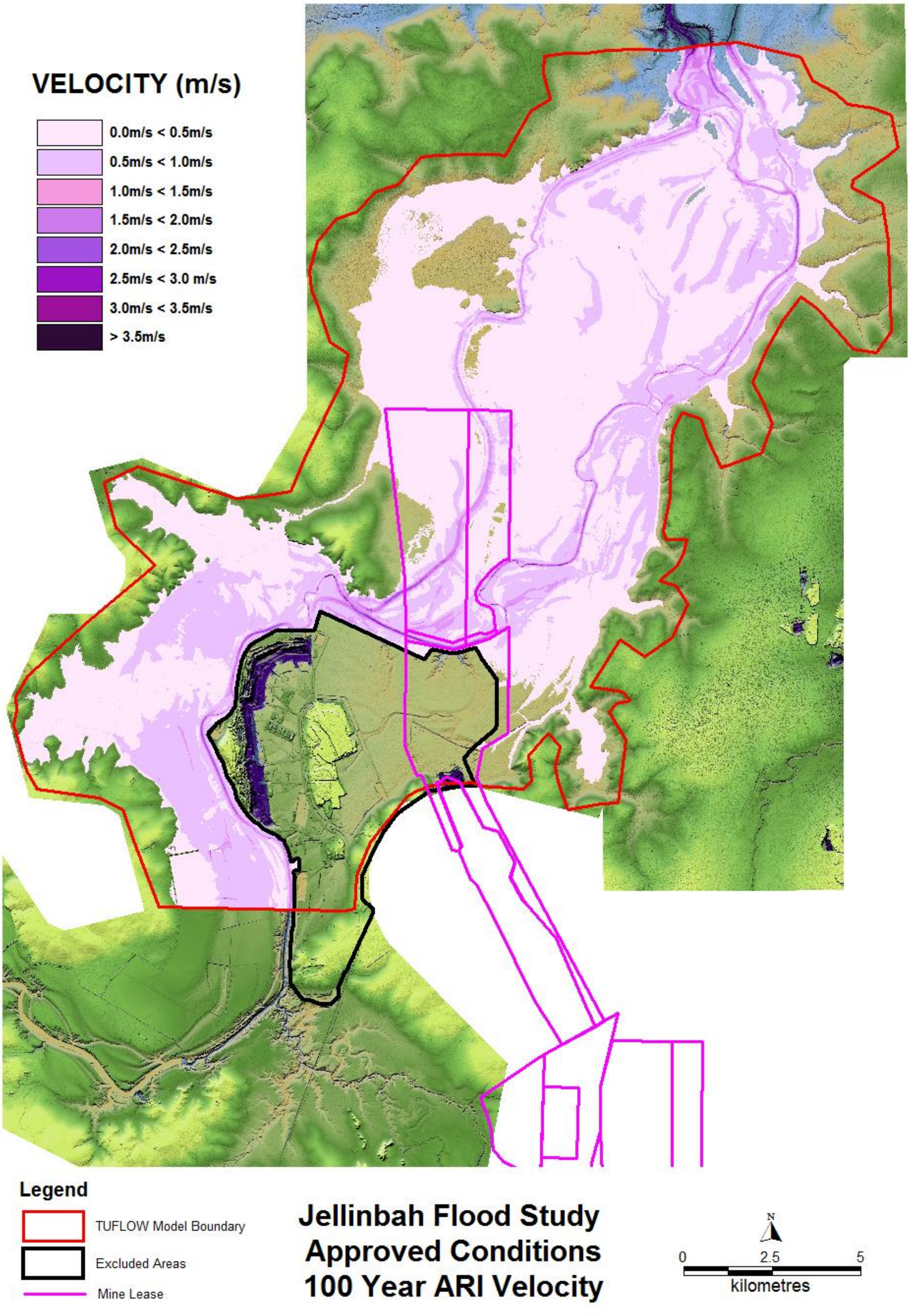
10.0m < 15.0m
15.0m < 20.0m
> 20.0m
Legend
TUFLOW Model Boundary
Excluded Areas
Haul Road
Mine Lease
Jellinbah Flood Study
Approved Conditions
100 Year ARI Depth
N
0
2.5
5
kilometres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2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
> 3.5m/s
Legend
TUFLOW Model Boundary
Excluded Areas
Mine Lease
Jellinbah Flood Study
Approved Conditions
100 Year ARI Velocity
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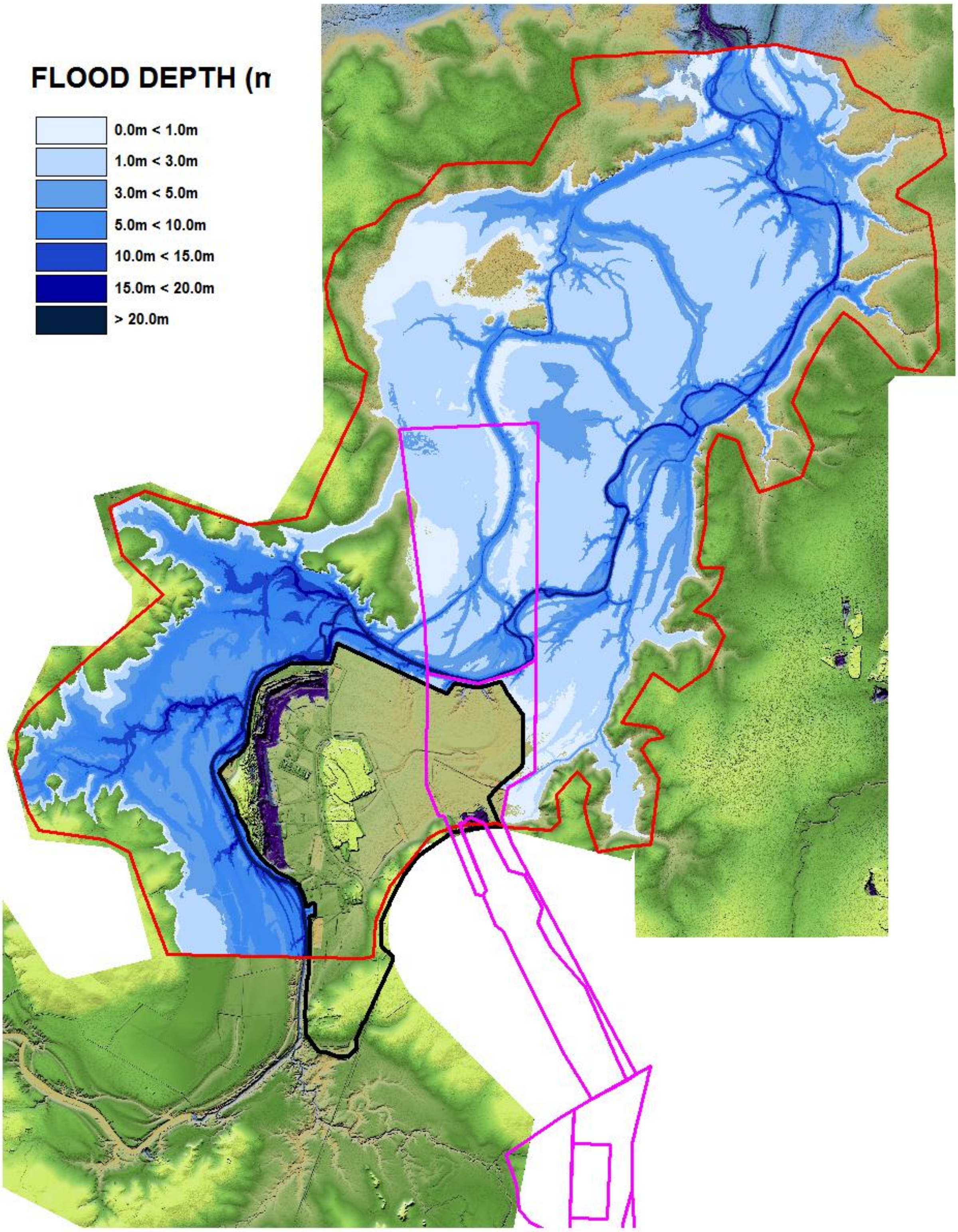
2.5
5
kilometres



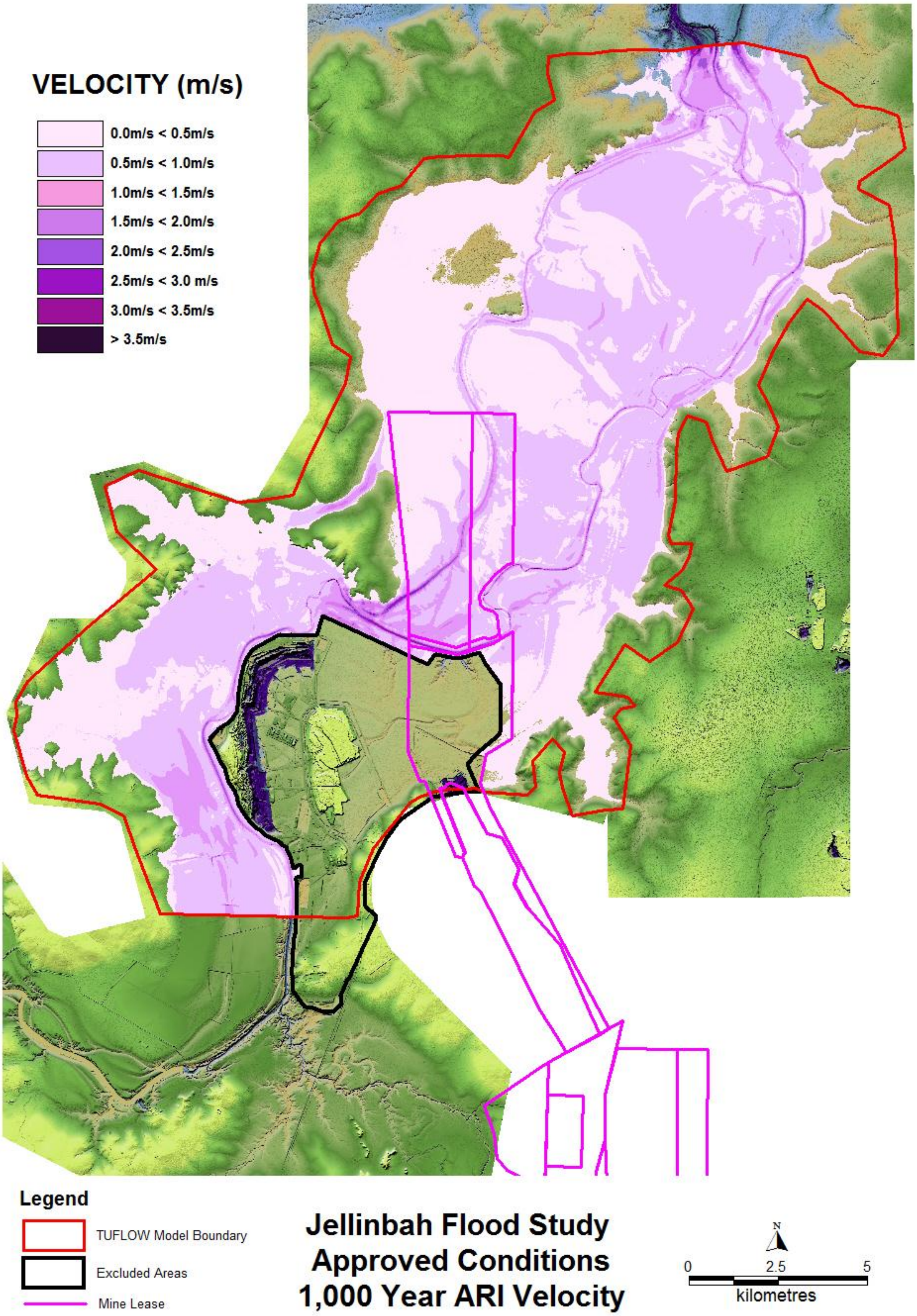
Legend

- TUFLOW Model Boundary
- Excluded Areas
- Haul Road
- Mine Lease

Jellinbah Flood Study
Approved Conditions
1,000 Year ARI Depth

N

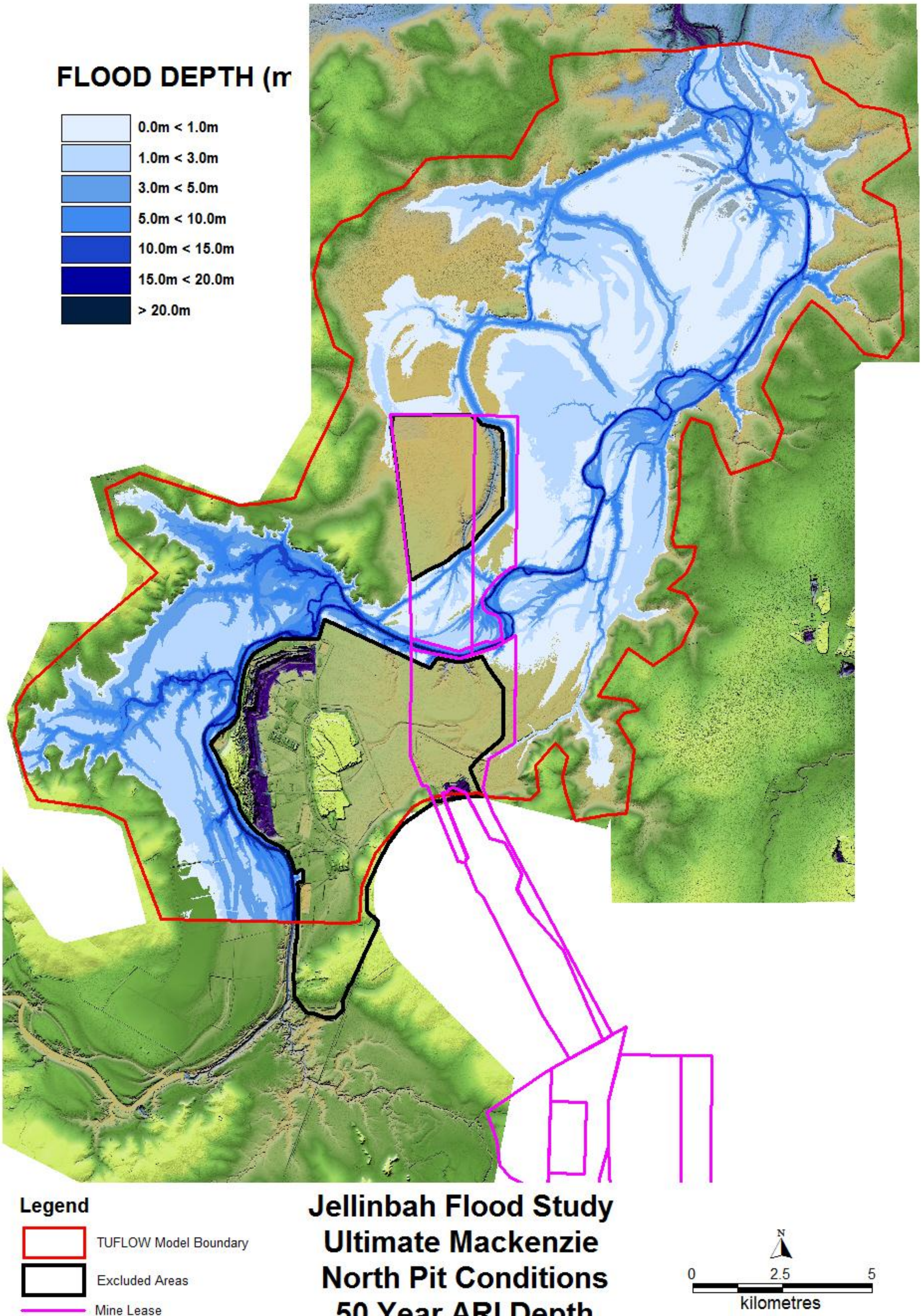
0 2.5 5
kilometres



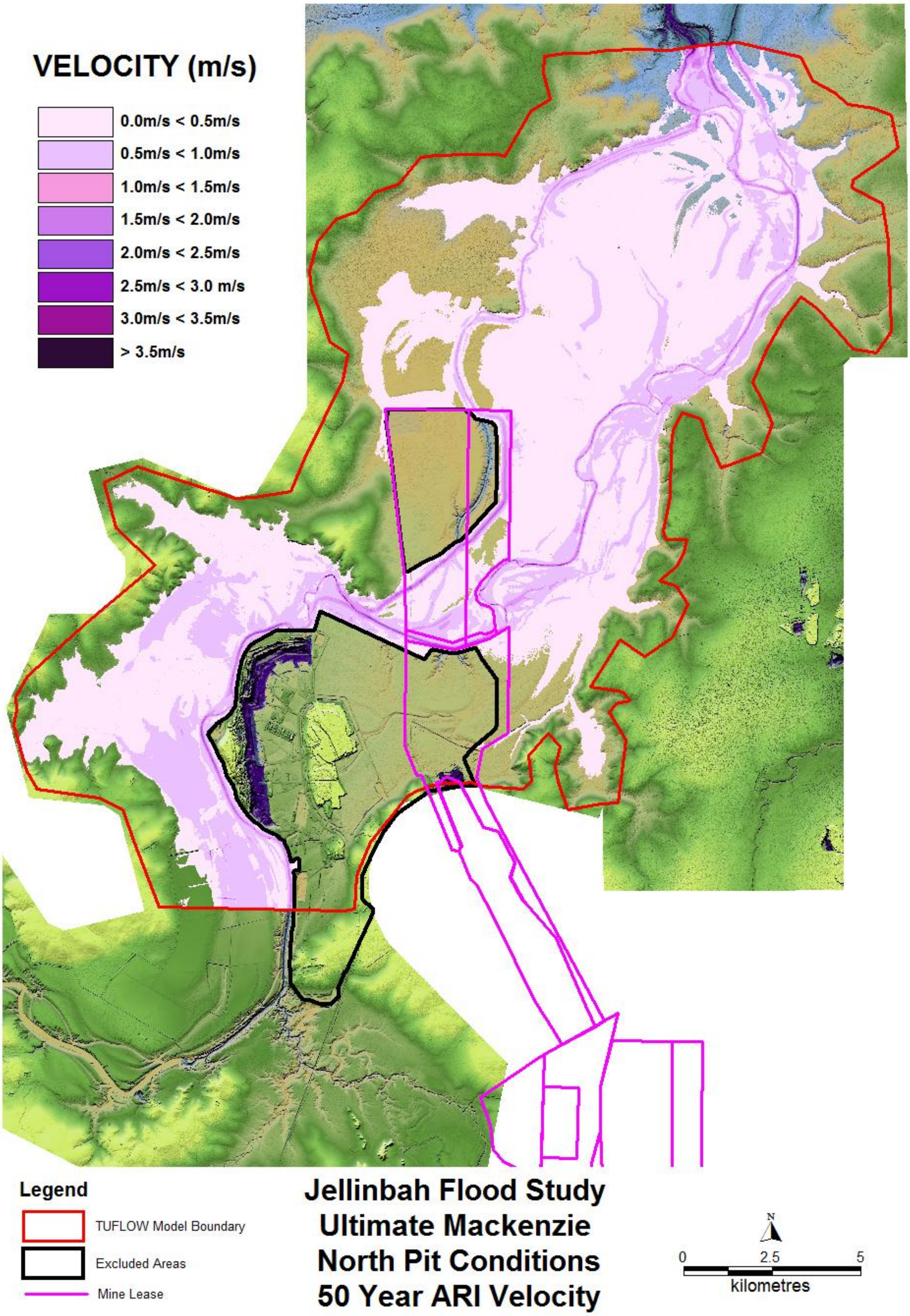
Jellinbah Flood Study
Approved Conditions
1,000 Year ARI Velocity

APPENDIX E

ULTIMATE CONDITIONS MODEL RESULTS



Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
50 Year ARI Depth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2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
> 3.5m/s
Legend
TUFLOW Model Boundary
Excluded Areas
Mine Lease
Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
50 Year ARI Velocity
N
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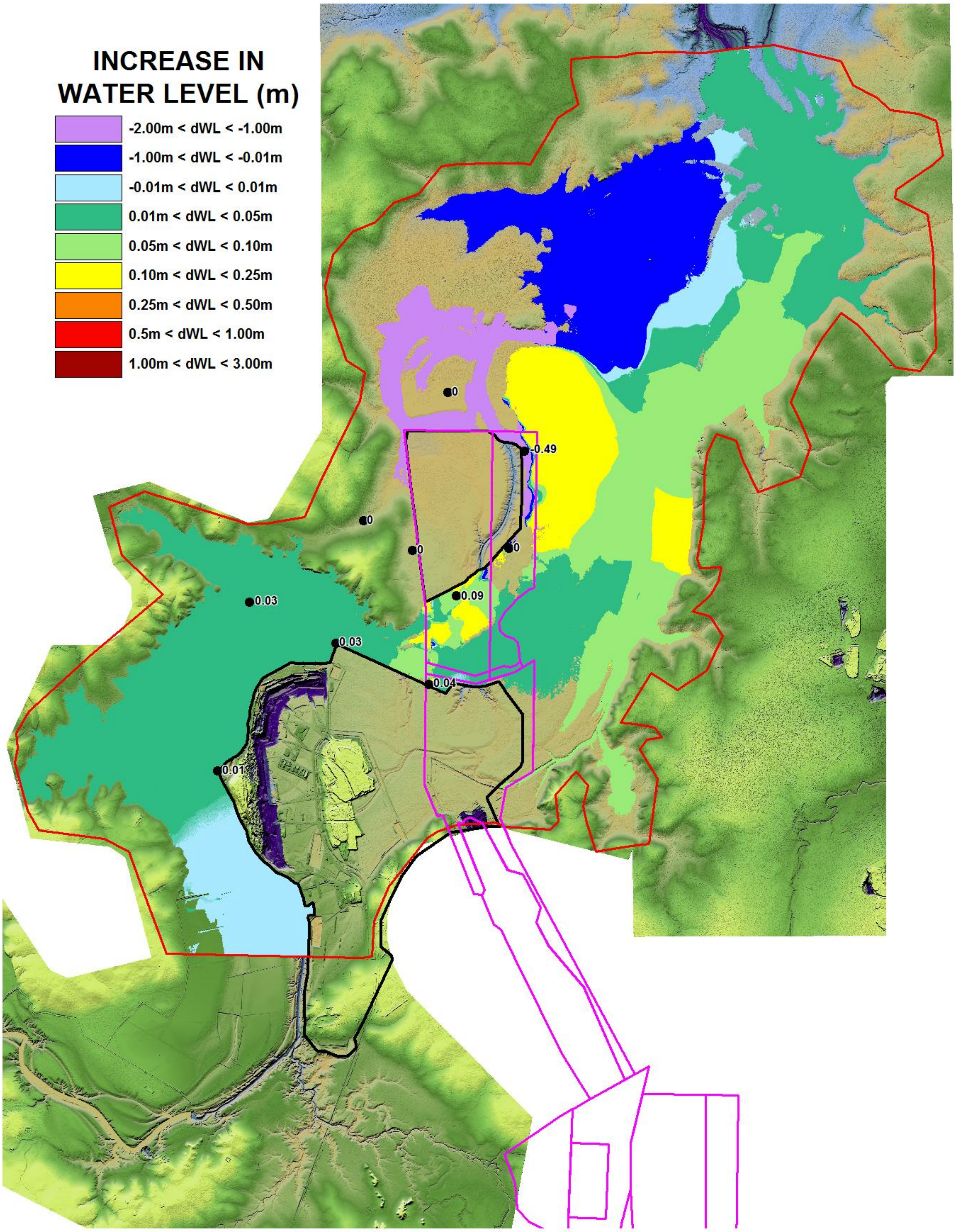
2.5
5
kilometres



Legend
TUFLOW Model Boundary
Excluded Areas
Mine Lease

Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
50 Year ARI Water Level Afflux

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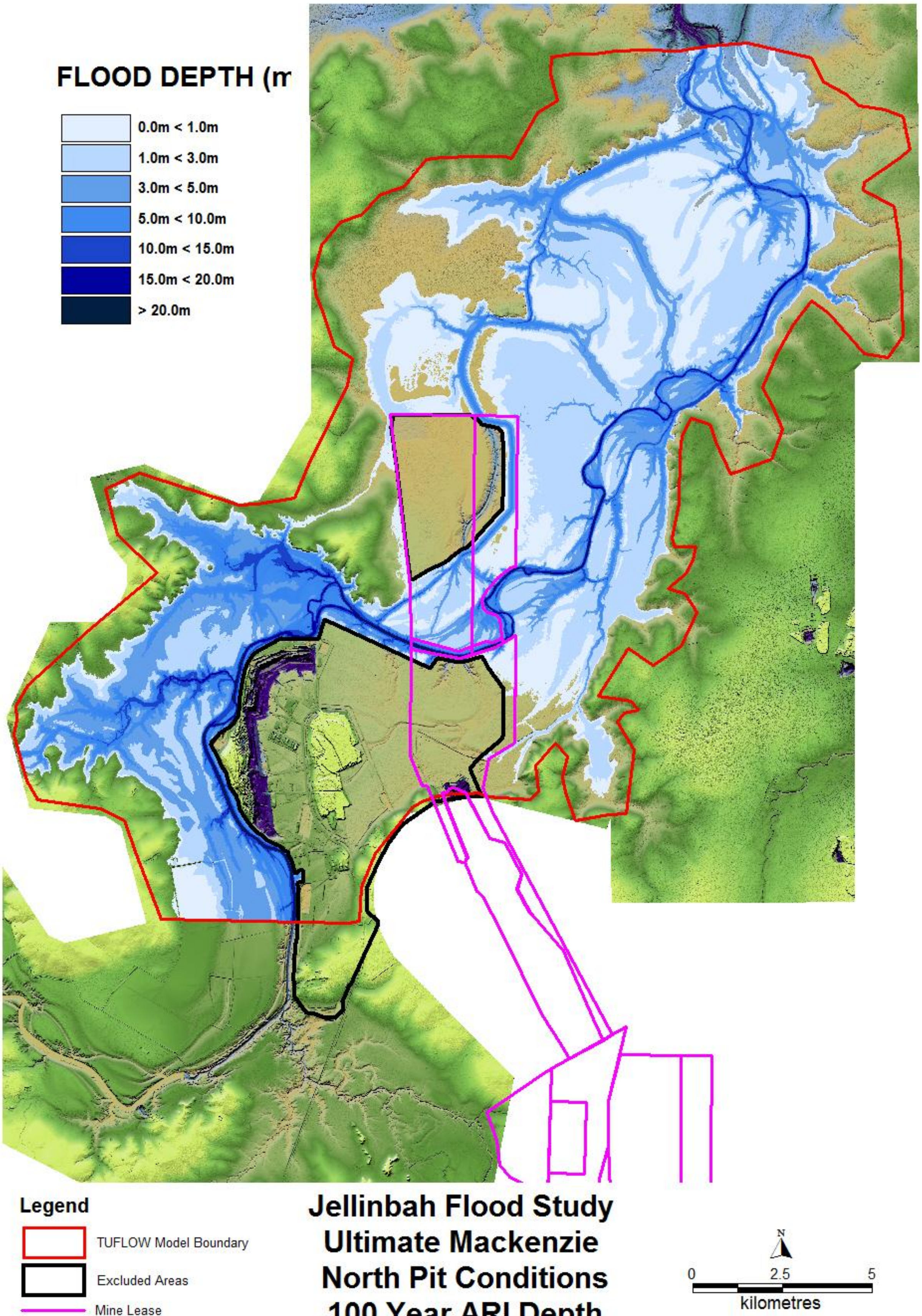
kilometres



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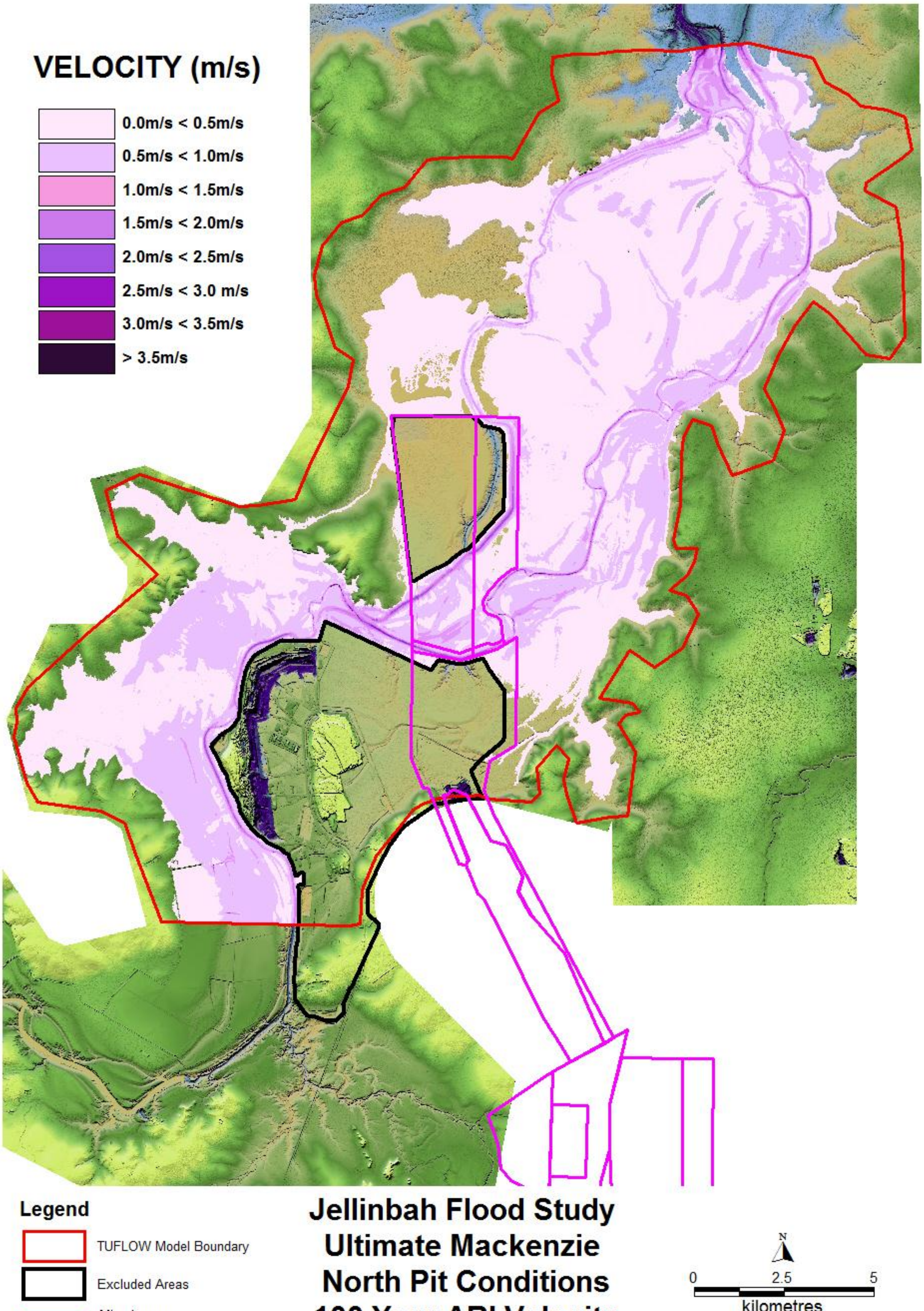
Ultimate Mackenzie
North Pit Conditions
100 Year ARI Depth



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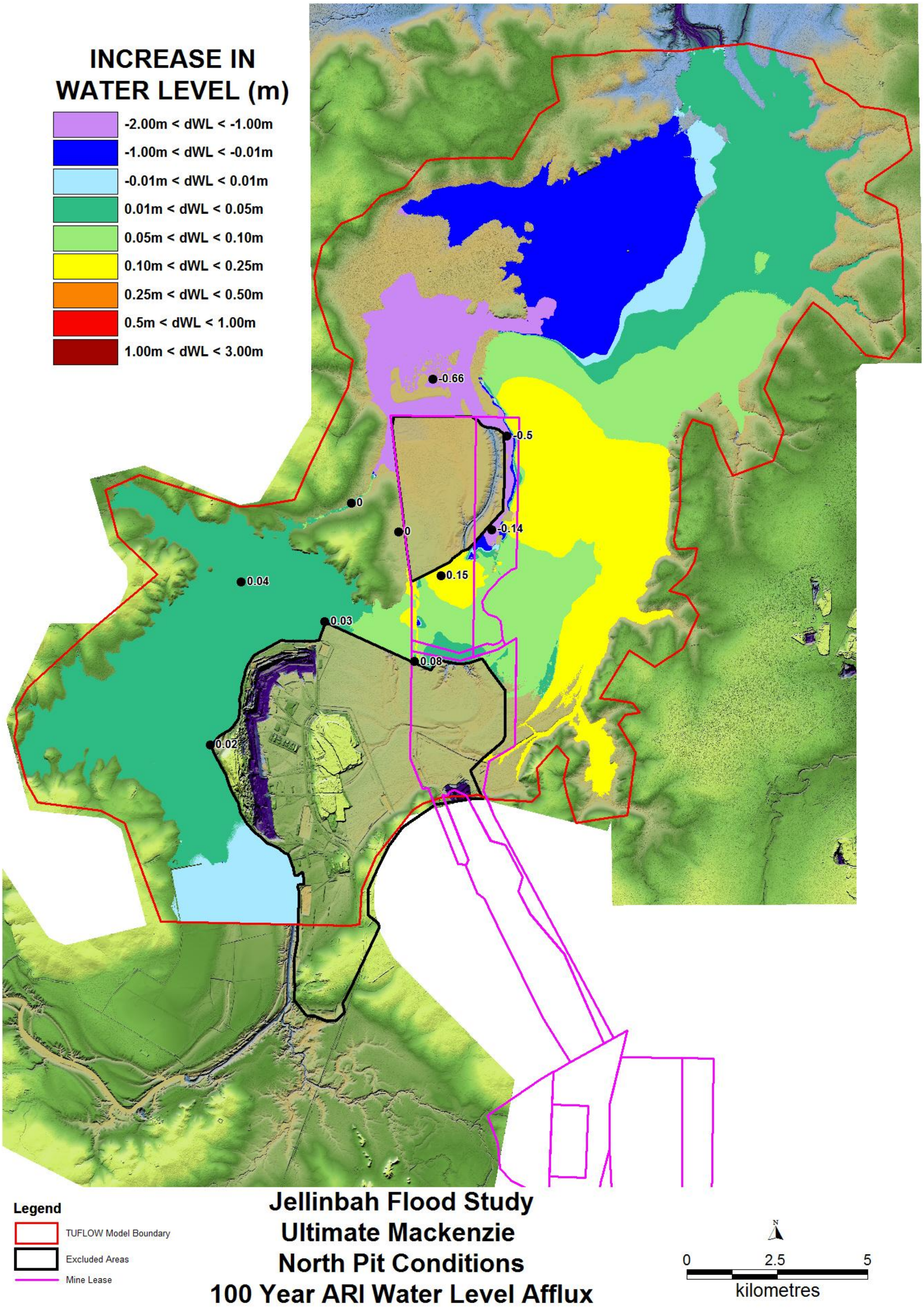
North Pit Conditions
100 Year ARI Velocity



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North Pit Conditions
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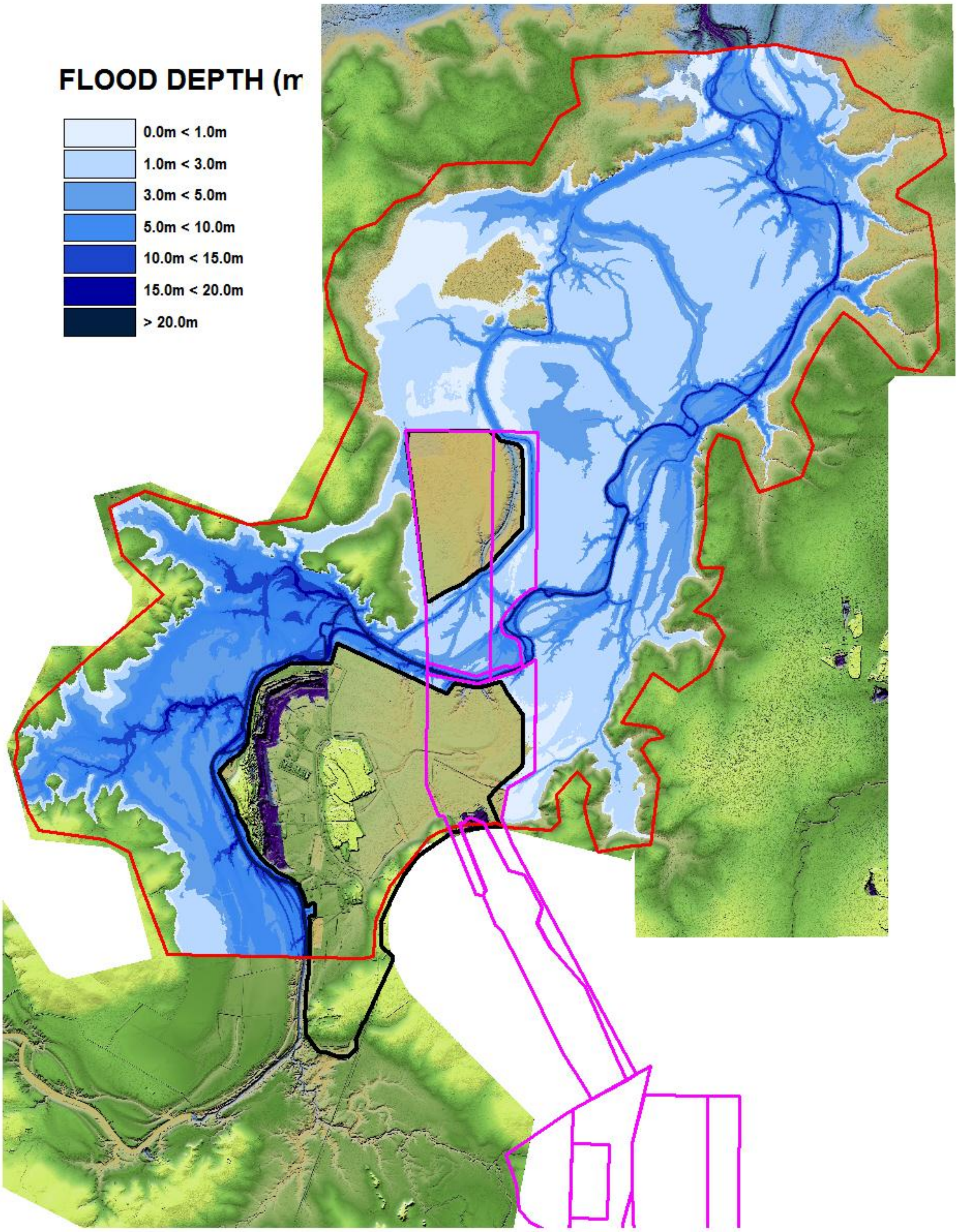

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TUFLOW Model Boundary

Excluded Areas

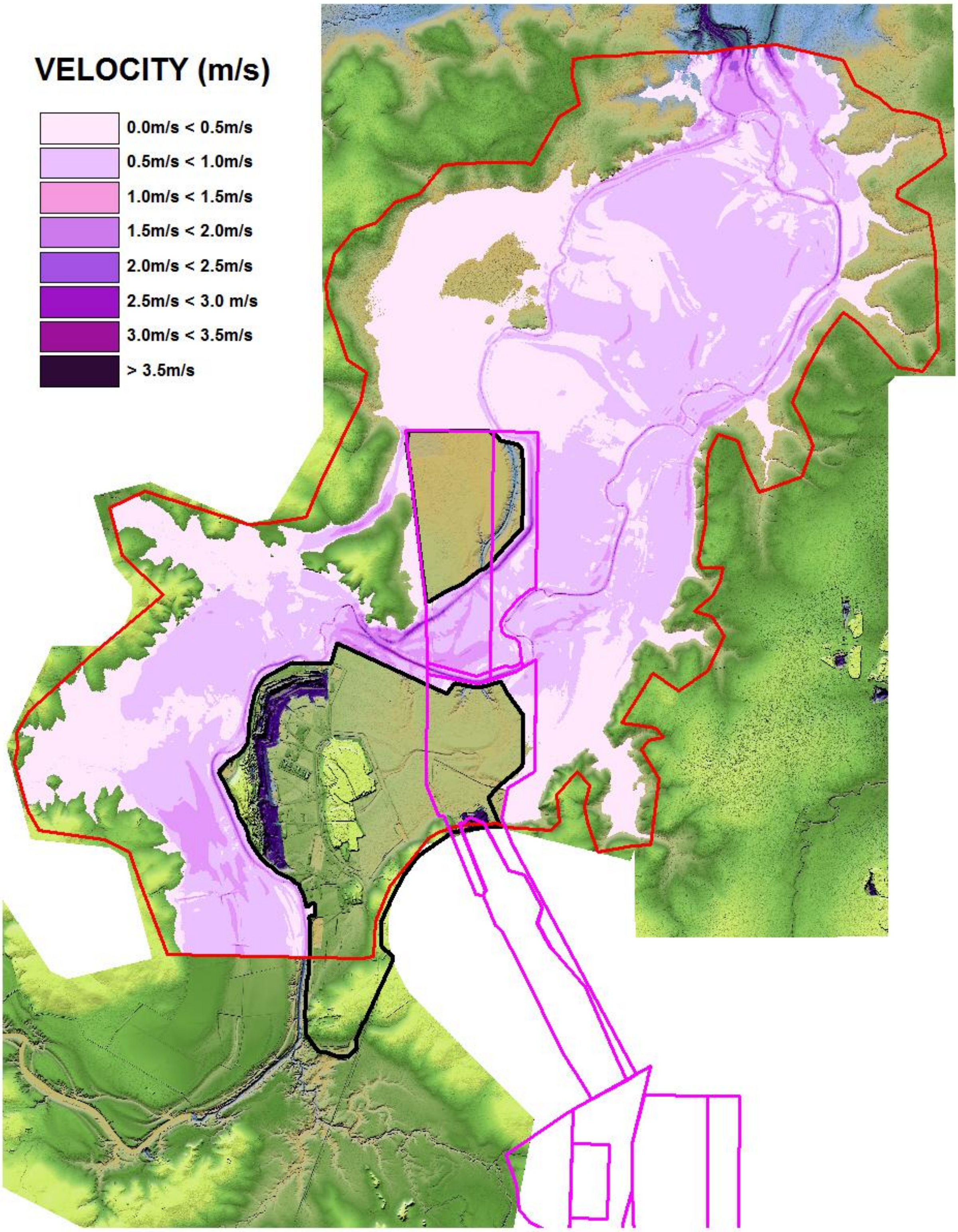
Mine Lease

Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
1,000 Year ARI Depth

N

0 2.5 5

kilometres



Legend

TUFLOW Model Boundary

Excluded Areas

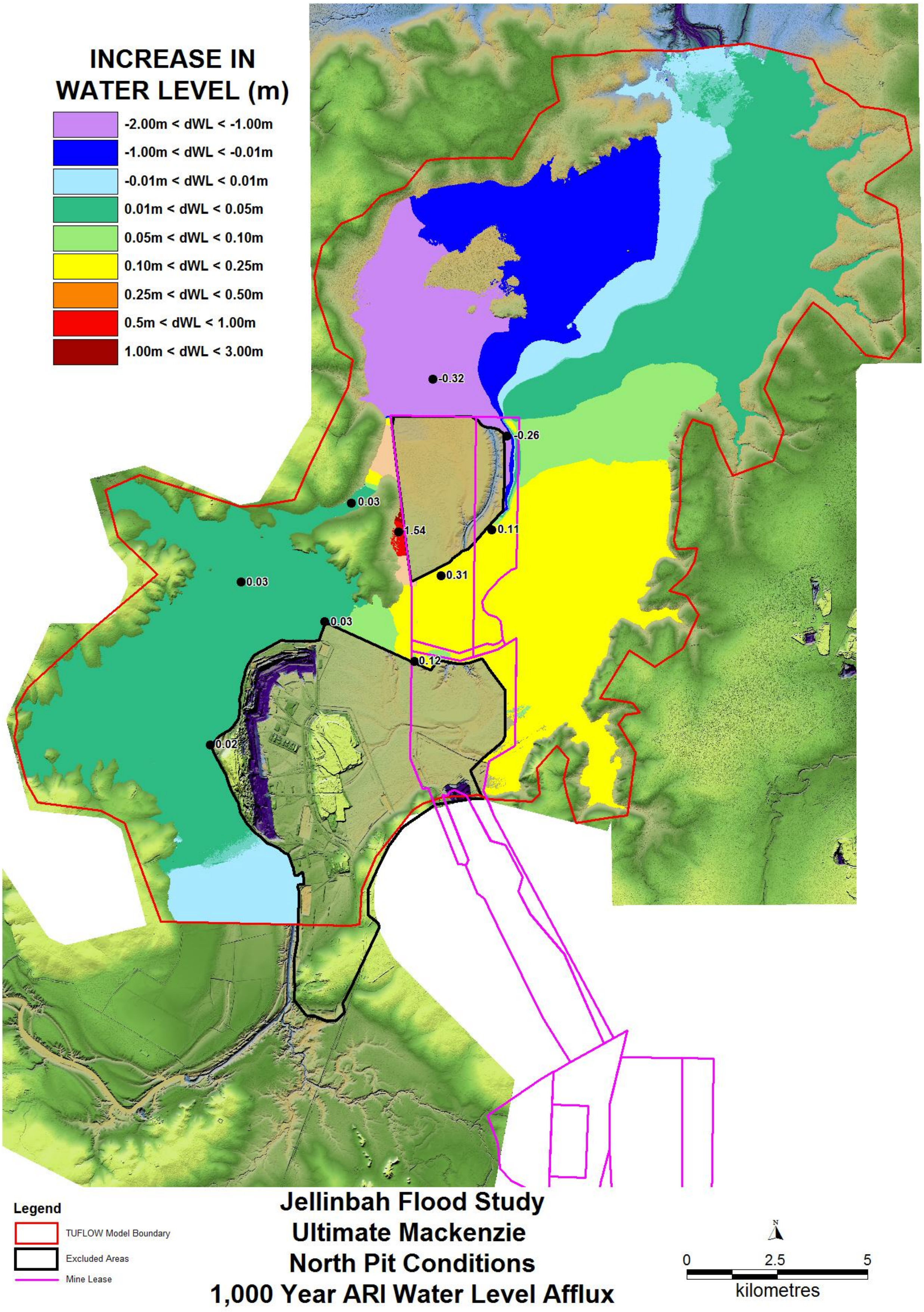
Mine Lease

Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
1,000 Year ARI Velocity

N

0 2.5 5

kilometres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0.05m < dWL < 0.10m
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0.5m < dWL < 1.00m
1.00m < dWL < 3.00m
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-0.26
0.03
1.54
0.11
0.31
0.03
0.03
0.12
0.02
Legend
TUFLOW Model Boundary
Excluded Areas
Mine Lease
Jellinbah Flood Study
Ultimate Mackenzie
North Pit Conditions
1,000 Year ARI Water Level Afflux
N
0
2.5
5
kilometres

JELLINBAH GROUP PTY LTD

CONCEPTUAL AND NUMERICAL GROUNDWATER MODELLING JELLINBAH CENTRAL NORTH EXTENSION (CNE) AREA

October 2019

JBT01-061-004 (Rev1)

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
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JBT-061-004	Final	G Bramston	22 March 2019	email
JBT-061-004 (Rev1)	Rev 1	G Bramston	25 October 2019	email

JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

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1.0 INTRODUCTION

1.1 Background

Jellinbah Resources Ltd (Jellinbah) operates the Jellinbah Coal Mine in central Queensland, which currently comprises two operating areas - Jellinbah Central and Jellinbah Plains. Jellinbah intends to progress the Jellinbah Central Mine north into the approved Central North (CN) area over the next few years and ultimately under a proposal known as the Central North Extension (CNE) will extend the Central North mining area downdip to the east by approximately 400 m relative to the CN operation. The location of the CNE relative to the Jellinbah Central, Jellinbah Plains and CN mining areas is shown below in Figure 1-1. The CNE includes three mining lease (ML) areas, including ML700011, ML700012 and ML700013. Mining of coal is to occur only within ML700011, with the other ML areas to be utilised for infrastructure and disposal of mined spoil. The Central North Extension is already authorised under state legislation. This groundwater report forms a component of an application for approval of the Project under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act 1999).

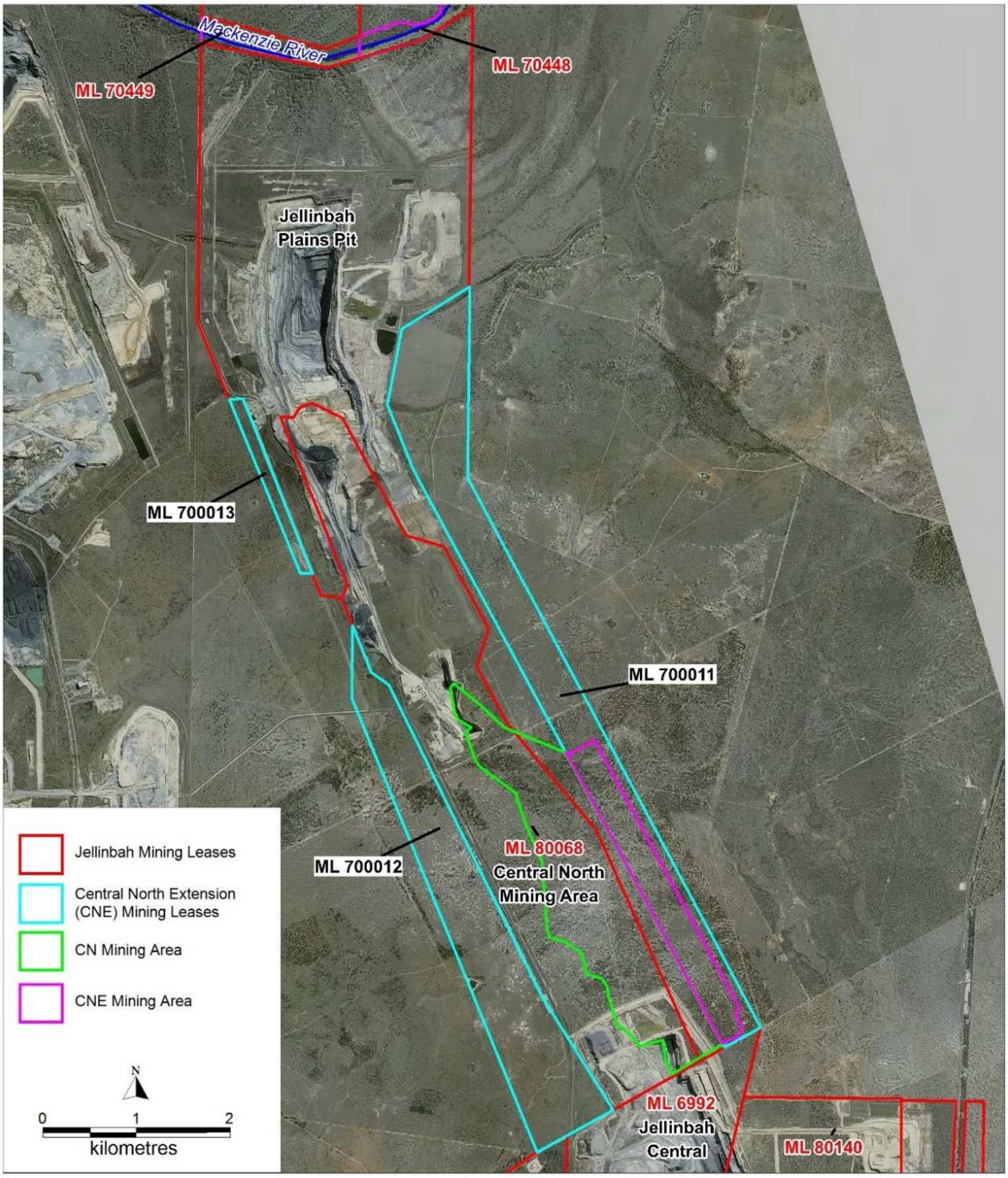


Figure 1-1: Project Layout

1.2 Responses to IESC Advice

This report has been updated to provide responses to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) information request[1]. Table 1-1 provides a list of the IESC questions that relate to groundwater, a summary response to the questions, and a reference to the section(s) of the report that have either been added or updated to address the advice.

Table 1-1: Summary of IESC Advice and Response

Advice No.	IESC Advice	Response and Reference
2a	Further justification is needed proving disconnect between shallow alluvium (Mackenzie River and 12 Mile Creek) and coal seam aquifers. If disconnect is proven then impacts on shallow alluvial aquifers, surface water pools and GDE's are unlikely	The regional groundwater level beneath 12 Mile Creek is interpreted to be in the order of 60 m below ground level (mbgl) and is therefore interpreted to be disconnected from the base of shallow alluvium and at too great a depth to be accessible to groundwater dependent ecosystems (GDE's). Predicted groundwater level drawdown from the CNE project does not extend to the limits of the Mackenzie River alluvium and the 2 m drawdown contour at post-mining equilibrium is predicted to be approximately 4.8 km south of the Mackenzie River. The above responses are discussed in further detail in Section 7.4 of this report.
2b	IESC suggests future groundwater level rebound could occur and suggests installing new monitoring bores	The proposed mining at the CNE extends to the eastern edge of the lease - it is not possible to drill monitoring bores to the east of the CNE due to land ownership and access constraints. The installation of monitoring bores to the north or south of the CNE (i.e. within the Jellinbah lease boundaries) is not regarded as necessary as the bores could only be located within Permian sediments that are close to the mining operation, where drawdown from mining is a given. The final void will act as a permanent groundwater sink (i.e. a cone of depression will remain around the final void); therefore, the only means of potential impacts via the groundwater system is interpreted to be if the final void water level rises to a level where outflow via unconsolidated sediments at the base of Tertiary is possible. The post-mining final void lake equilibrium level is assessed to be a maximum of 45.3 mAHD (Engeny 2019) and in the area of the CNE the base of Tertiary is interpreted to be in the order of 120 mAHD. Therefore it is concluded that there is no possibility of outflow via the base of Tertiary. This assessment is discussed further in Section 7.3
3b	If there is evidence for a hydraulic connection between the groundwater and surface water systems (particularly 12 Mile Creek), then a model should be developed to investigate the spatial	It is assessed that there is no hydraulic connection between the regional groundwater system and 12 Mile Creek. Refer response to 2a above as well as Section 7.4 of this report.

1 IESC (2019) Advice to decision maker on coal mining project IESC 2019-103: Jellinbah Coal Mine – Central North Extension (EPBC 2018/8139) – Expansion. Date of request 12 April 2019.

Advice No.	IESC Advice	Response and Reference
	variation and magnitude of likely impacts on surface water systems.	
14	Additional field and desktop surveys should be undertaken in larger area of potential drawdown (i.e. drawdown <5m) to verify whether any other GDE's are at risk. Cumulative impacts in the expanded area of potential drawdown have not been assessed. Baseline data is needed to assess effectiveness of mitigation and management issues.	Model output figures have been amended to include the 2 m drawdown contour. Refer response to 2a above as well as Sections 6.7 and 7.2 of this report.
26	A map showing the saturated zone/depth of water table should be provided, and overlaid with potential GDE's. This would indicate which GDE's at risk from drawdown and thus GDE's that would require management.	A map showing drawdown in relation to potential GDE's has been included as Figure 7.3 and is discussed in Section 7.4 of this report.
19b	Ecohydrological Model (looking at surface water and groundwater interaction) to assist in justifying effectiveness of proposed mitigation and management strategies.	Refer Sections 7.3 and 7.4 of this report.
3 & 3a	Justify why 2D (SEEP/W) model is better suited for purpose of predicting drawdown than 3D model. No evidence showing difference between 2D and 3D modelling, and no discussion as part of modelling strategy.	The justification for selection of the Seep/W model is presented in Section 6.1. It is not argued that a 2D (SEEP/W) model is inherently better than a 3D (e.g. MODFLOW) model for predicting drawdown, rather that the 2D model is appropriate to the assessment of impacts due to the CNE, for the following reasons: • The CNE represents a minor expansion of an existing mine (Central Pit) and already approved operation at Central North (CN); • The CNE occurs to the east of the CN mining area, therefore the main area for drawdown assessment is a distinct area to the east of the CNE and it is judged that a 2D model is an appropriate tool for assessment of groundwater drawdown impacts along a west-east flow line (i.e. in the direction where assessment of potential impacts is most critical) • A SEEP/W model is able to accurately represent the seepage face conditions that occur at an open pit face and to represent the transition from unconfined conditions (at and near the pit face) to confined conditions (at distance from the pit face). In this important respect, a 2D SEEP/W model is judged to be able to more accurately represent the seepage conditions and the prediction of drawdown along a west-east flow line than a 3D model such as MODFLOW, where mining tends to be represented via

Advice No.	IESC Advice	Response and Reference
		more simplistic approaches, such as the use of drain cells at the pit floor.
3c	No calibration data was supplied in groundwater report. Has the model been calibrated using site-specific data? Model predictions should be compared against historical data to assess performance.	The hydraulic conductivity values in the model have been altered to be consistent with values from a calibrated 3-dimensional model that was developed for the Mackenzie North Environmental Management Plan, and which covers the area of the CNE (refer Section 6.6.2) It has also been observed at the adjacent Central Pit that the mine is dry (i.e. no observable groundwater inflow) at pit depths of 100-120 m. This is not to say that no groundwater inflow from the coal measures is occurring; rather it is interpreted to indicated that groundwater inflow occurs at a rate that is less than evaporation. This observation provides valuable information for model calibration as the predicted rate of inflow to the pit, with the mine at similar depths, should at least be less than the rate of evaporation, to be consistent with observations from mining. During the modelling process a check was made of the modelled rate of inflow to establish whether the inflow rate was occurring at a rate that could be removed by evaporation. This is discussed further in Section 6.6.1.
3d	Justification is required for why a constant recharge value (1%) was chosen, given greater magnitude in sequencing and variability of wet and dry cycles. Methodology needs to be compared to other recharge calculation methods (i.e. chloride mass balance) and justified.	Chloride concentration data from groundwater monitoring bores within the Mackenzie River alluvium and the coal measures within the Mackenzie North lease area have been utilised to provide an estimate of recharge via the chloride mass balance (CMB) method (Section 6.5.1). Recharge to the model has been amended to 0.5% of annual average rainfall for the Tertiary sediments (which subsequently recharges the underlying coal measures) and 1% of annual average rainfall for areas of Quaternary alluvium.
3e	The uncertainty analysis range needs to be increased by an order of magnitude. A map of 1m drawdown contours should be provided to improve assessment of impacts on GDE's in alluvium.	The section on uncertainty analysis has been updated, with parameters such as horizontal and vertical hydraulic conductivity and storage coefficient increased by an order of magnitude. Uncertainty analysis is discussed in Section 6.8.

2.0 REGIONAL AND SITE STRATIGRAPHY

Regional and site stratigraphy is described below and is summarised in Table 2-1. Figure 2-1 shows the project location in relation to 1:100,000-scale surface geology. Figure 2-2 shows the project location in relation to the underlying Bowen Basin solid geology (i.e. the surficial unconsolidated Quaternary and Tertiary units have been removed, revealing the relationship between the underlying Triassic and Permian sediments as well as the prevalence of regional-scale faults). With reference to Figures 2-1 and 2-2 it is observed that:

- The open cut mines are developed in areas where the Rangal Coal Measures subcrop beneath the Tertiary cover, i.e. mining is undertaken in areas where the coal measures are shallowest. The dip of the coal seams is to the east or southeast, so that the CNE extends mining down-dip from the CN mining area;
- The Jellinbah mines are situated within the Jellinbah Thrust Belt, which lies between the Jellinbah fault to the west and the Yarrabee Fault to the east; the faults act to compartmentalise the various groundwater units in the project area.

Site and regional stratigraphy includes:

- Quaternary-age alluvium associated with current surface drainage features such as Blackwater Creek, Twelve Mile Creek and the Mackenzie River;
- Tertiary deposits comprising mudstone, sandstone, siltstone and conglomerate of the Duaringa Formation, as well as sediments that are derived from Tertiary weathering and remobilisation of older units;
- Triassic sediments of the Rewan Group, which comprise lithic sandstone and green to reddish brown mudstone and which occur in the eastern area of the CNE; and,
- Coal-bearing sediments of the Late Permian Blackwater Group, including the Rangal Coal Measures, which contains the target coal seam for mining within the CNE (Pollux Seam).

Table 2-1: Summary of Regional Stratigraphy

Age	Unit	Description	Thickness (m)
Quaternary	-	Unconsolidated soil, silt clay, sand and gravel associated with current surface drainage systems, e.g. Blackwater Creek and Mackenzie River	0 to 50 m
Tertiary	Duaringa Formation and residual units	Mudstone, sandstone, conglomerate, siltstone	0 to 30 m
Triassic	Rewan Group	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate at base	0 to 100 m+
Late Permian Blackwater Group	Rangal Coal Measures	Feldspathic and lithic sandstone, carbonaceous mudstone, siltstone, tuff and coal seams. Includes the Pollux Coal Seam, which is the target coal seam for mining within the CNE	0 to 100 m+ Aries Seam – 0 to 1 m Castor Seam – 0 to 1 m Pollux Seam - ~10 m
	Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff	0 to 90 m
	Gyranda Formation	Siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation); calcareous sandstone, mudstone and siltstone (upper part - Wiseman Formation)	0 to 500 m+

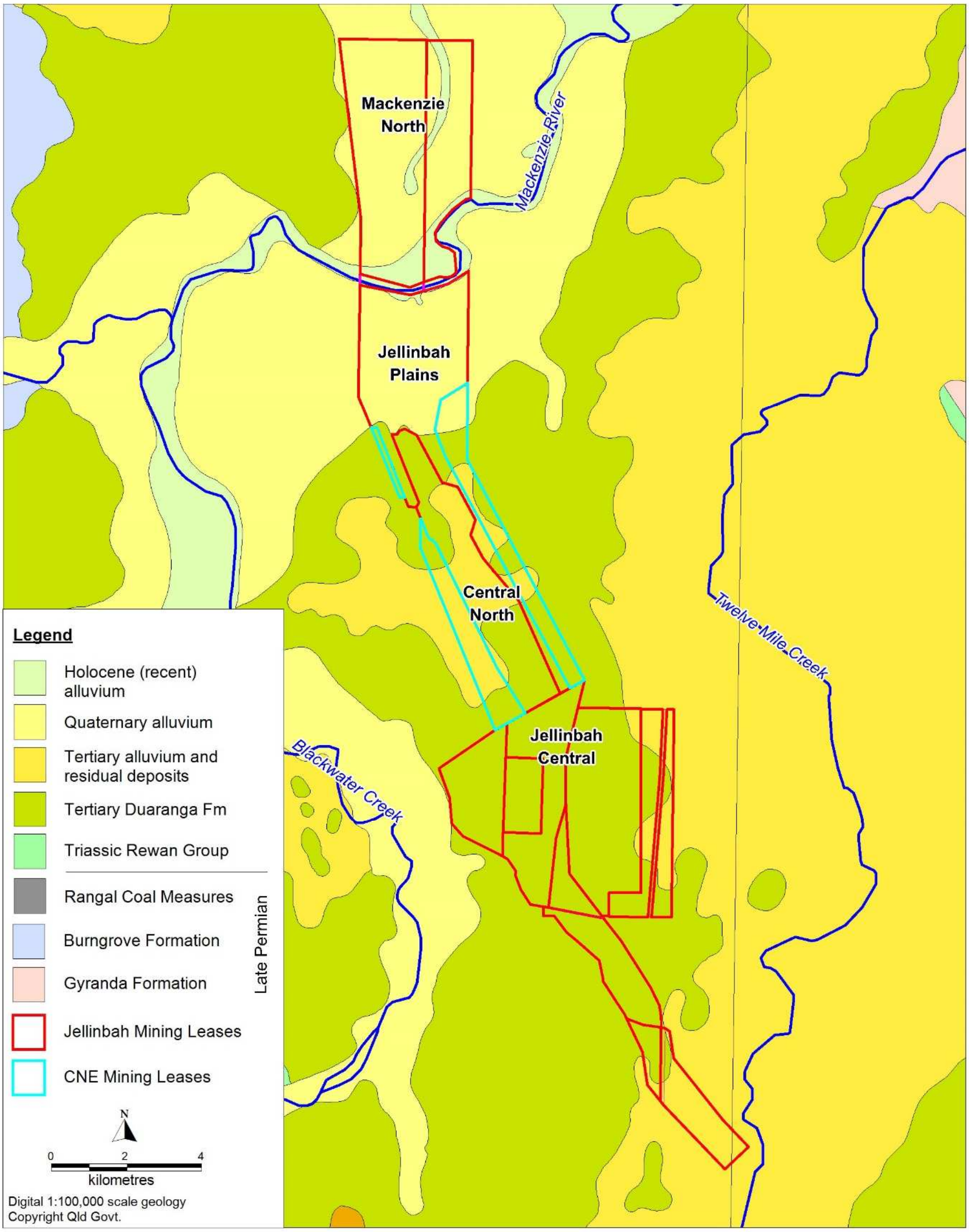


Figure 2-1: Project Location and Surface Geology (1:100,000 Scale Digital Geology)

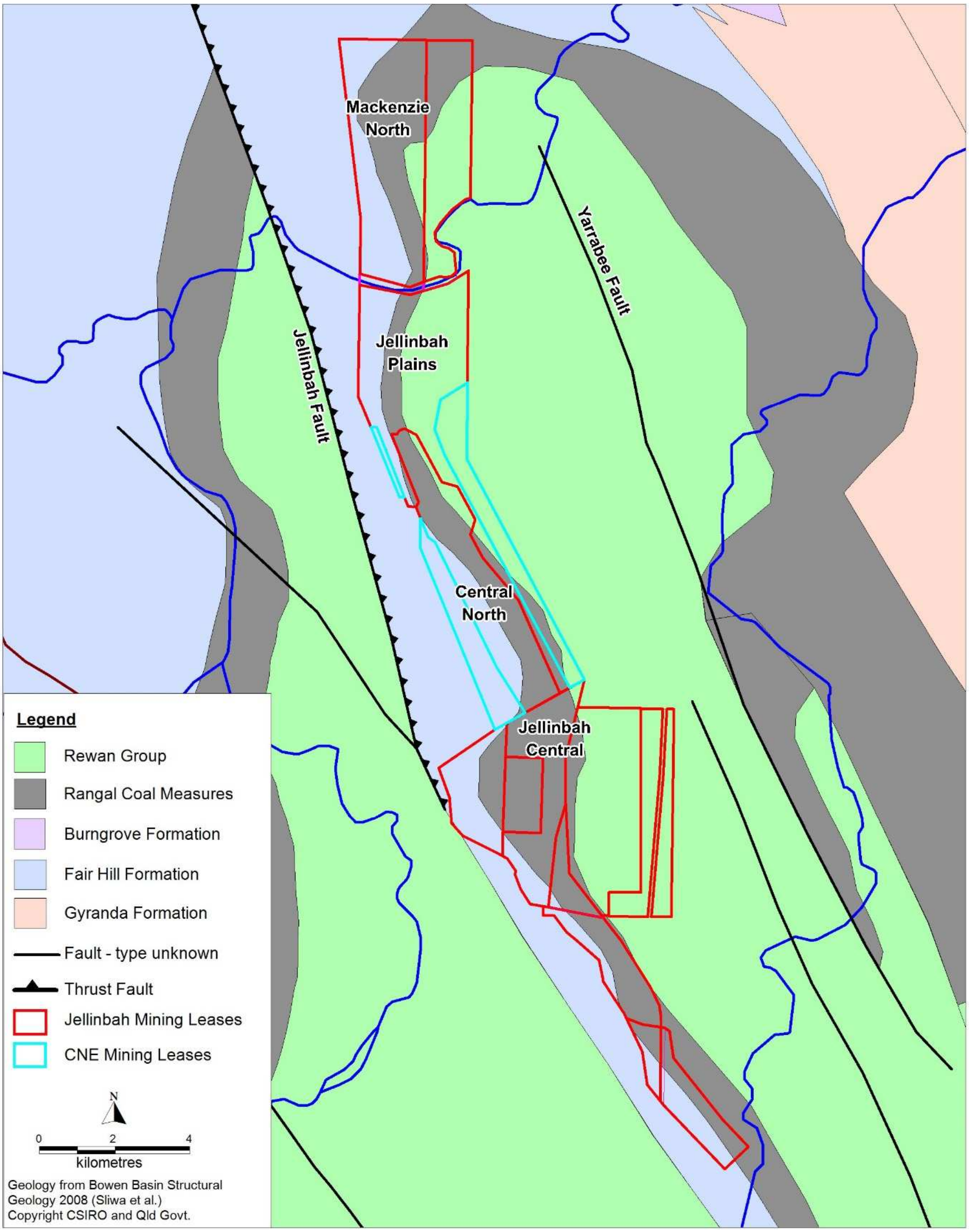


Figure 2-2: Project Location and Bowen Basin Solid Geology

3.0 HYDROGEOLOGY

3.1 Groundwater Occurrence

Two main groundwater-bearing units have been identified in the Jellinbah mining area, including:

- Quaternary alluvium, which is associated with prior channels and flood deposits of the Mackenzie River (to the north). In part due to the presence of water supply structures (e.g. Bingegang Weir upstream of the Jellinbah mining area and Tartrus weir downstream) the Mackenzie River tends to be a perennial stream adjacent to the Jellinbah mining area. Quaternary alluvium is encountered in the northern section of the Jellinbah Plains operation (Figure 2-1), but there are no Quaternary alluvial deposits within the Central North or Central North Extension mining areas.

  Quaternary alluvium is also associated with ephemeral streams such as Blackwater Creek (to the west of the Jellinbah mining area).

  It is noted that Twelve Mile Creek (to the east of the Jellinbah mining area) is mapped as occurring within Tertiary alluvium and residual deposits (Figure 2-1) and has no mapped Quaternary alluvium at 1:100,000 scale. From discussions with environmental personnel (AARC pers. comm.) it is understood that Twelve-Mile Creek is a minor drainage feature and has no associated riparian vegetation.

- Permian Coal Measures, which comprise interbedded siltstone, sandstone, shale (interburden) and coal. The Permian interburden is hydrogeologically “tight” and hence very low yielding, with the majority of groundwater storage and movement occurring within the coal seams (AGE 2016). Faults at site are generally identified as dry (AGE 2016 in discussion of Boyd 2015). It has been observed from face mapping within the Jellinbah Central Pit that faults and joints can act as conduits for water flow; however, this is interpreted to be related to the relaxation of the strata and associated structures adjacent to the pit, with the source of the water being predominantly surface water infiltration in the zone adjacent to the pit crest.

3.2 Groundwater Levels

Groundwater level data for the Jellinbah mining area south of the Mackenzie River is available from two sources, including:

1. Long-term monitoring of bores adjacent to the Mackenzie River, which is undertaken as part of the environmental authority (EA) conditions of the operation. Bores that are monitored are shown on Figure 3-1 and include:
   - MSP0209 (Mackenzie River alluvium), with the bore screened from 31-34 metres below ground level (mbgl)
   - MSP0213 (Mackenzie River alluvium), with the bore screened from 35-38 mbgl; and,
   - MS0203 (Pollux Seam), with the bore screened from 42-48 mbgl. This bore is located adjacent to MSP0213 and therefore monitors the Pollux Seam at a location where the seam subcrops beneath the alluvium.

Bore hydrographs are shown on Figure 3-2. From review of the bore hydrographs it is interpreted that:

- The alluvium is directly recharged by rainfall, as evident from the water level increase in 2010/2011 that shows a direct correlation with the rainfall residual mass curve (RRMC);
- The Pollux Seam is directly recharged by the alluvium at this location (i.e. this is a recharge location for the Permian coal measures) as the water level and water level response is almost identical for bore MS0203 (Pollux Seam) and bore MSP0213 (overlying alluvium at the same location); and,

- The waters level in the alluvium and Pollux Seam tend to follow the trend of the RRMC, which indicates a direct response to rainfall recharge. However, a downward trend in water levels is evident in data post 2016, at a time when a sharp increase in the RRMC is recorded due to above-average rainfall; this is interpreted to indicate that groundwater seepage is occurring towards the advancing Jellinbah Plains Pit.

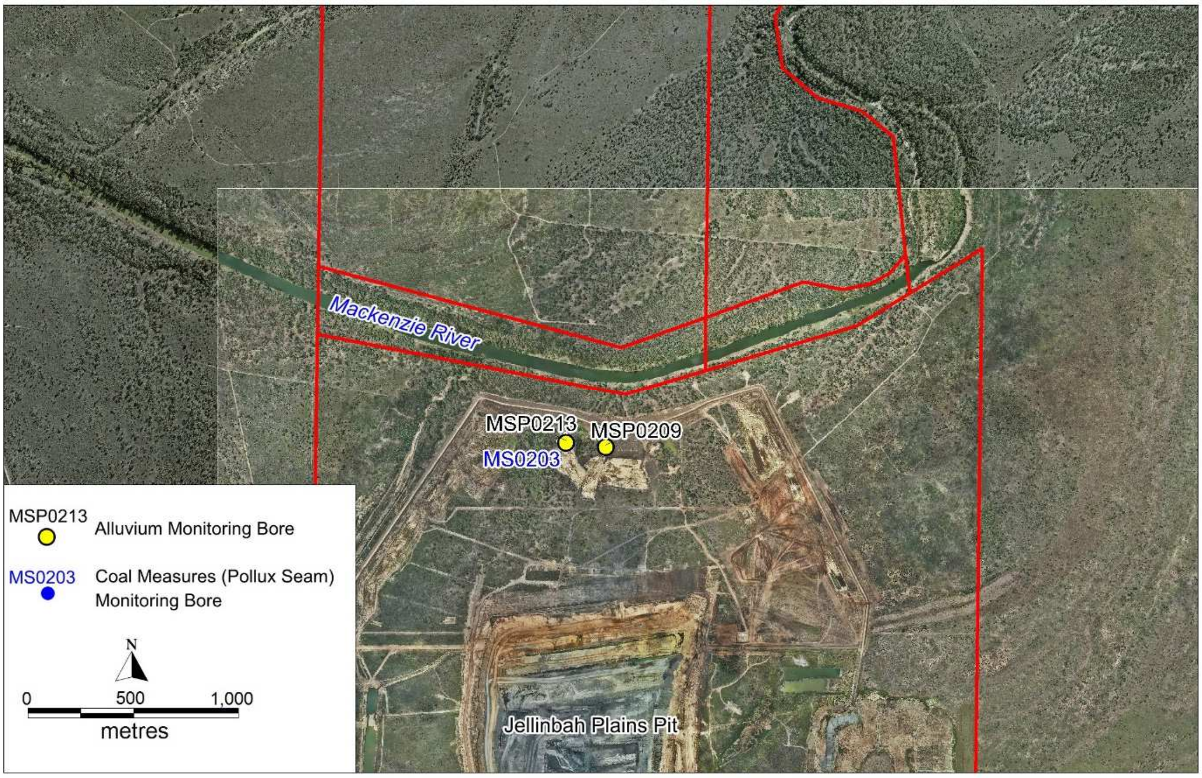


Figure 3-1: Location of Groundwater Monitoring Bores at Plains Pit

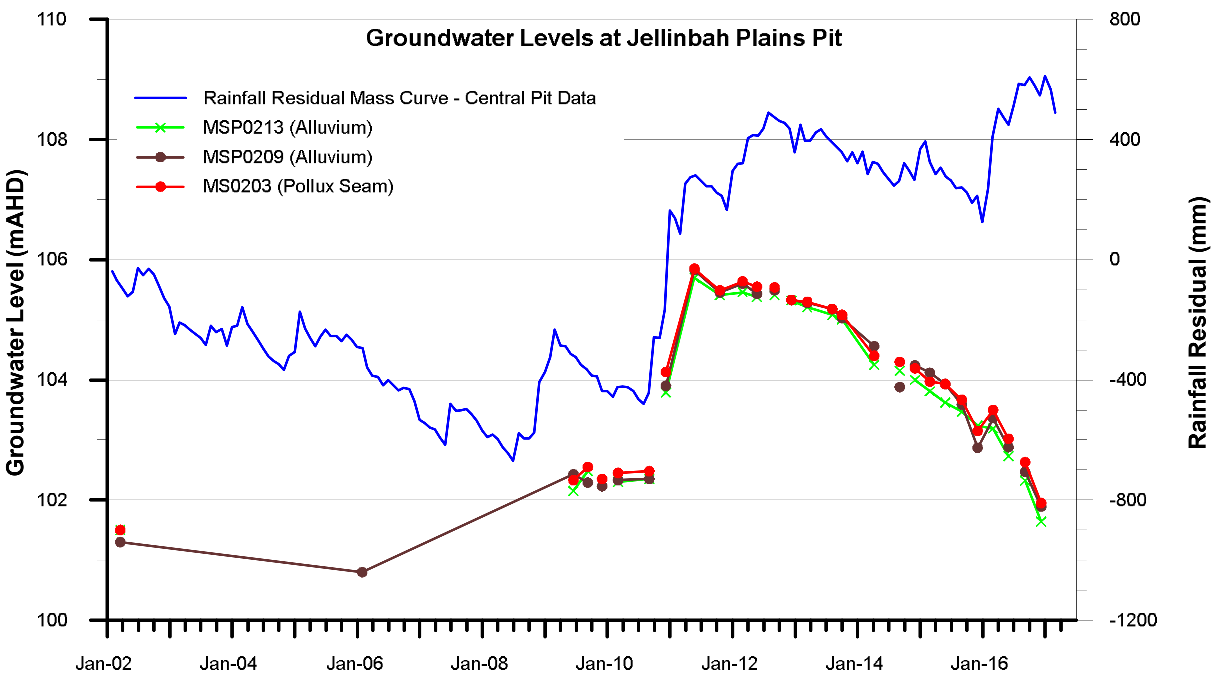


Figure 3-2: Hydrographs for Plains Pit Monitoring Bores

2. Water levels from exploration bores within the Central North (CN) and Central North Extension (CNE) lease areas, collected from a site visit undertaken by JBT in December 2015, are shown below in Figure 3-3. It is noted that the water levels are “bulk” water levels from the entire open sequence that has been intersected by the bores. However, the water levels are instructive in that they indicate a water level at this location of approximately 40 – 50 metres below ground level (mbgl) in this area. From review of bore logs for bores within the CNE lease area it is observed that:

   - The base of Tertiary occurs at depths between 8 mbgl (bore JPS0001) and 25 mbgl (bore JPS0005) in the CN area;
   - The recorded water level is within the Permian coal measures in overburden just below the base of weathering, or in the case of bore JPS0003, the water level is at 49.98 mbgl, which is below the bases of the Aries Seam (43.6 mbgl). The Tertiary sediments are therefore interpreted to be dry in the CN and CNE areas.

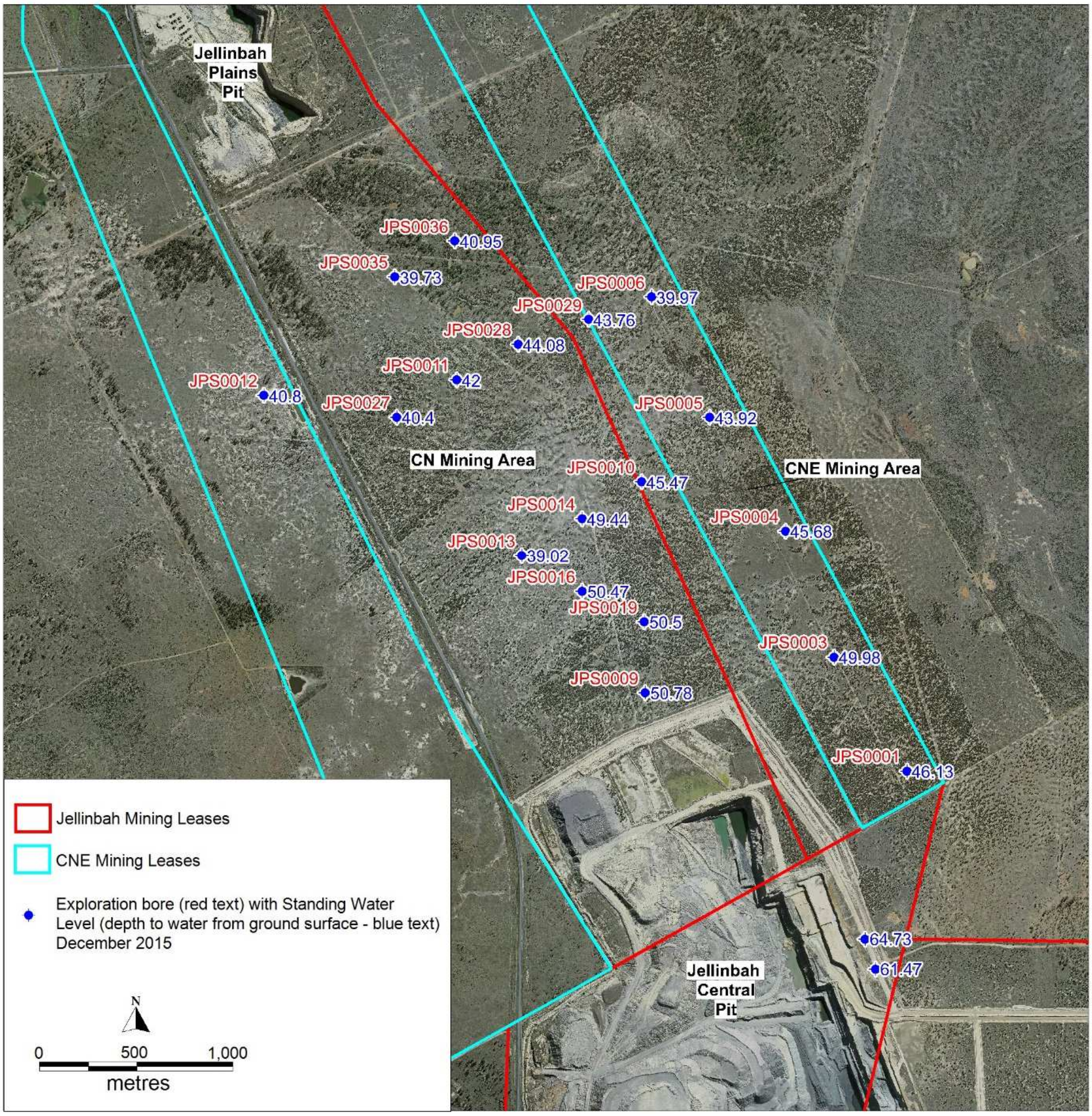


Figure 3-3: Groundwater levels within Exploration Bores – CN and CNE Areas

3.3 Aquifer Parameters

3.4 Hydraulic Conductivity

A total of 11 falling head tests were undertaken on monitoring bores for the Mackenzie North groundwater project (AGE 2013). Of the 11 bores, five were screened within the alluvium, three in the Pollux Seam and three into sandstone interburden. Summary hydraulic conductivity (K) data is shown below in Table 3-1, which indicate that the K of:

- alluvium ranges from 0.7 m/day to 3.7 m/day, with a geometric mean of 1.2 m/day;
- interburden sequences range from 0.06 m/day to 0.8 m/day, with a geometric mean of 0.1 m/day; and,
- coal seams (Pollux Upper) ranges from 0.005 m/day to 0.1 m/day, with a geometric mean of 0.014 m/day. AGE (2013) note that the lowest K occurs in the deepest bore and infer that the K of the groundwater units decreases with increasing depth.

Table 3-1: Summary of Hydraulic Conductivity Data – Mackenzie North (After AGE 2013)

Bore	Groundwater Unit	Hydraulic Conductivity (K)	
		m/day	m/second
JMR4WA	Alluvium	0.7	8.1E-06
JMR21WA	Alluvium	0.7	8.1E-06
JMR25WA	Alluvium	3.7	4.3E-05
JMR26WA	Alluvium	1.3	1.5E-05
JMR23WA	Alluvium	0.9	1.0E-05
Geometric Mean		**1.2**	**1.3E-05**
JMR4WP	Pollux Upper	0.1	1.2E-06
JMR15WP	Pollux Upper	0.006	6.9E-08
JMR22WP	Pollux Upper	0.005	5.8E-08
Geometric Mean		**0.014**	**1.7E-07**
JMR16WP	Pollux Upper & Siltstone	0.02	2.3E-07
JMR17WP	Interburden	0.8	9.3E-06
JMR24WP	Interburden	0.06	6.9E-07
Geometric Mean		**0.10**	**1.1E-06**

Figure 3-4 presents the range of hydraulic conductivity values for each aquifer type north of the Mackenzie River (Mackenzie North investigation, AGE 2013) as well as south of the Mackenzie River (ERM 2012). The major observations from review of Figure 3-4, as well as subsequent monitoring data, include:

- The Mackenzie River alluvium is more permeable on the southern side of the Mackenzie River than the northern side; and,
- The hydraulic conductivity (K) of the Pollux Seam is at the upper end of the K range on the southern side of the river (data from ERM 2012); however, it is noted that the coal seams were shallow at the locations tested by ERM and that the K is likely to be higher in shallow subcrop locations.

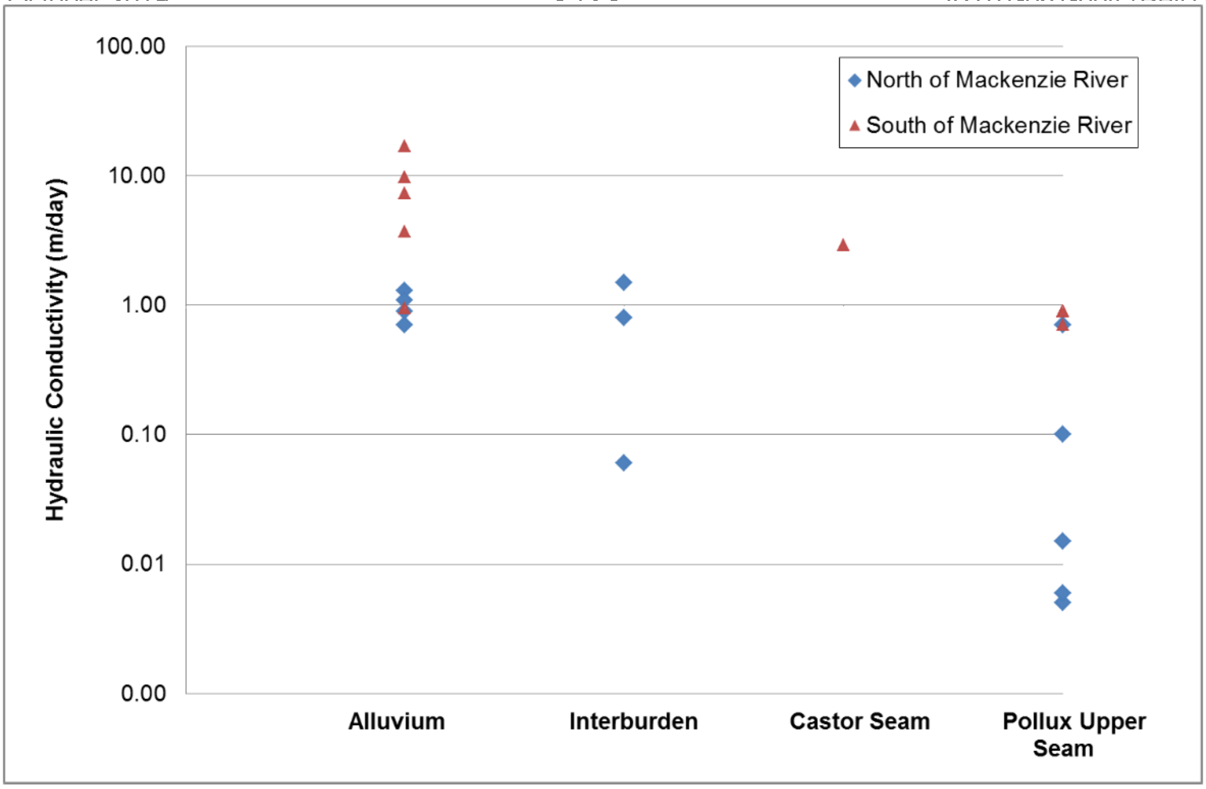


Figure 3-4: Comparison of Hydraulic Conductivity for Data North and South of Mackenzie River (Source: AGE 2013)

4.0 EXTENT OF PROPOSED MINING AT CNE

4.1 Data from Mine Block Model

Figure 4-1 shows the approved extent of mining at Jellinbah Central Pit and Central North mines, with further detail of the CN and CNE pits shown in Figure 4-2. Also shown on Figure 4-1 is the existing and/or proposed depth of mining. At Jellinbah Central Pit the current depth of mining is approximately 125 metres below ground level (mbgl), extending at full depth to approximately 225 mbgl. At Central North mine, the mine is projected to be in the order of 125 m deep. As mining progresses to the east into the CNE, the depth of mining will be approximately 145-150 mbgl.

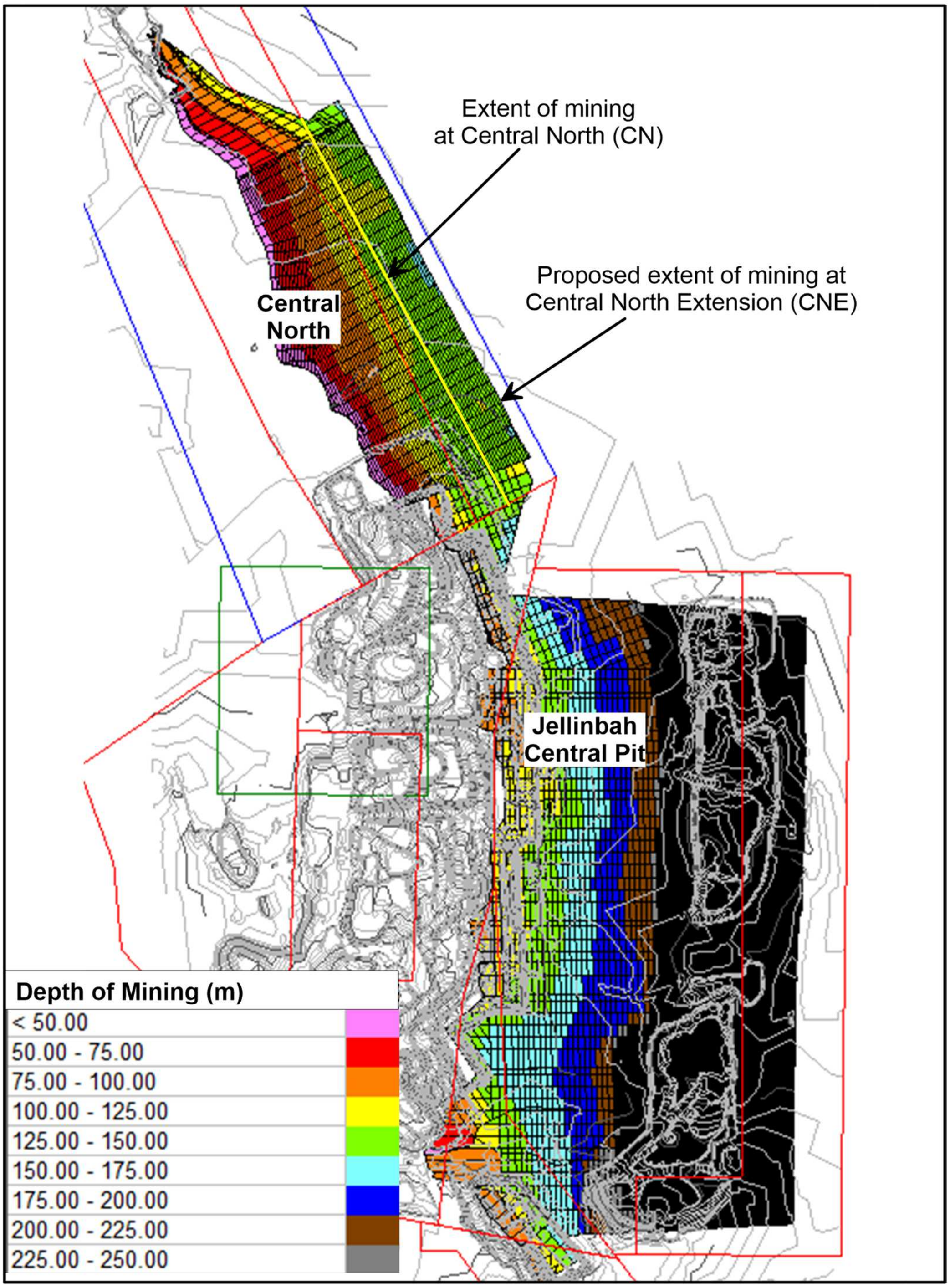


Figure 4-1: Extent of Mining at Jellinbah Central, CN and CNE Pits

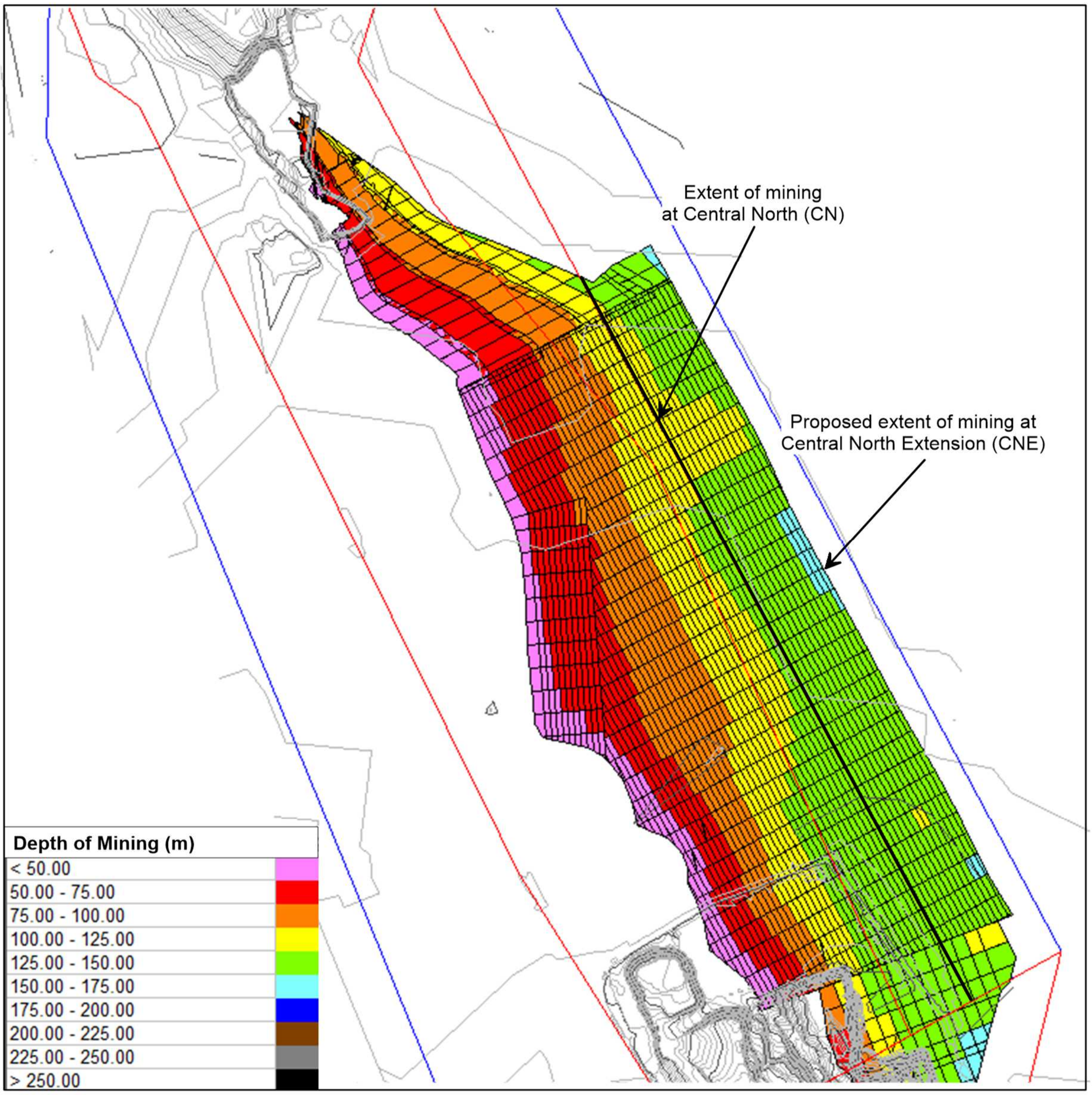


Figure 4-2: Extent of Proposed Mining at CNE vs Extent of Mining at CN

4.2 Geological Sections from Site Geological Model

Three west-east cross-sections were generated from the site geological model, with the sections including delineation of the extent of mining for both the CN and CNE operations. The geological cross-sections and cross-section locations are shown below in Figure 4-3. Of the cross-sections, section 2 was selected as being a representative section for inclusion in the cross-sectional groundwater model (discussed in Section 5.0). For the purpose of groundwater modelling the geology of areas to the west and east of the site geological model was interpreted from existing 1:00,000 scale surface geology (Figure 2-1) and Bowen Basin solid geology (Figure 2-2)

A long section through the CN mining area was also generated from the site geological model, with the section and section location shown below in Figure 4-4. For the purpose of groundwater modelling, the coal seams that occur to the north of the section were continued to the north to the Mackenzie River. The thickness of alluvium and coal seam depth in the area of the Mackenzie River/ northern area of Plains Pit was based on information obtained from drilling in that area, e.g. information from the groundwater monitoring bores that are discussed in Section 3.2.

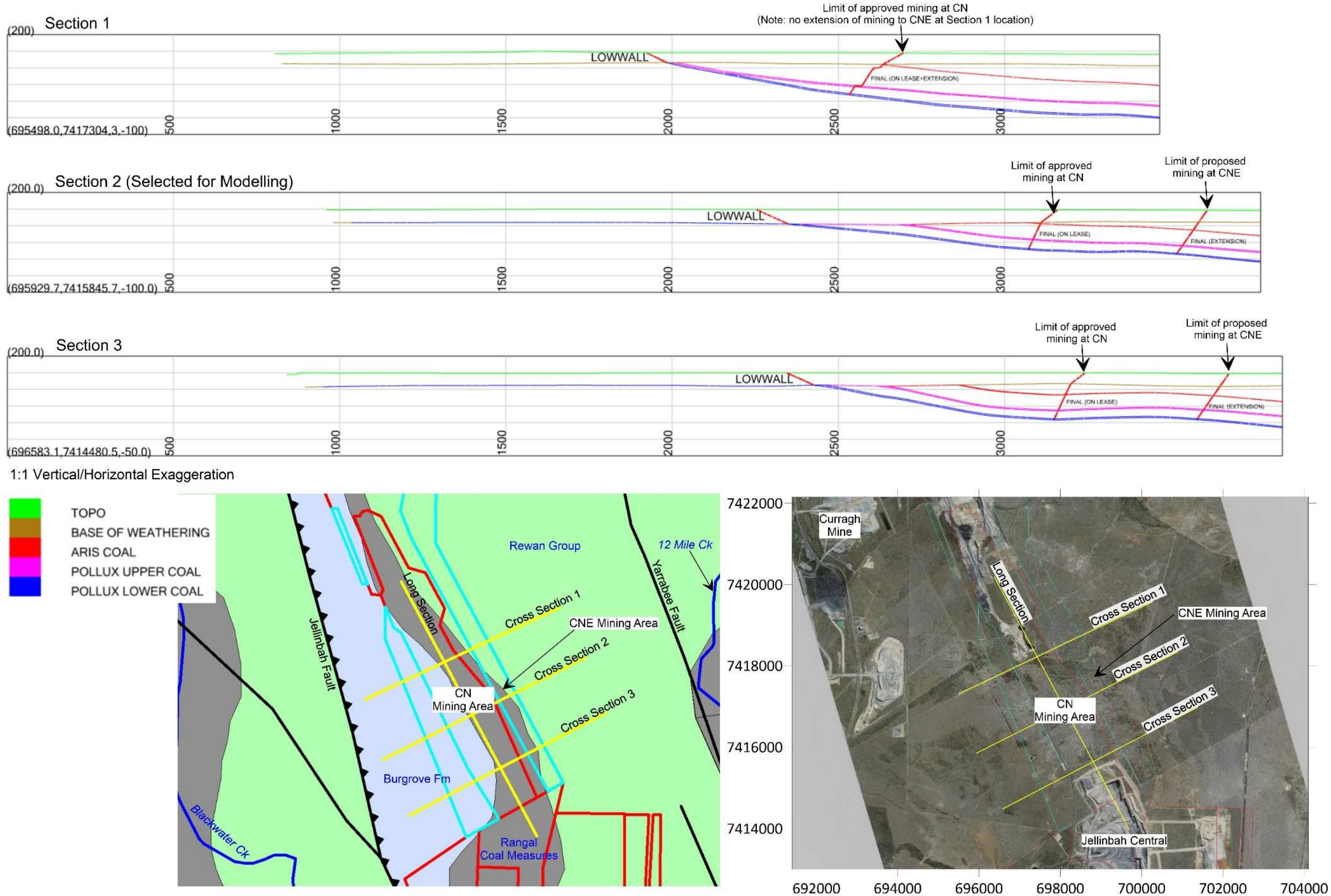
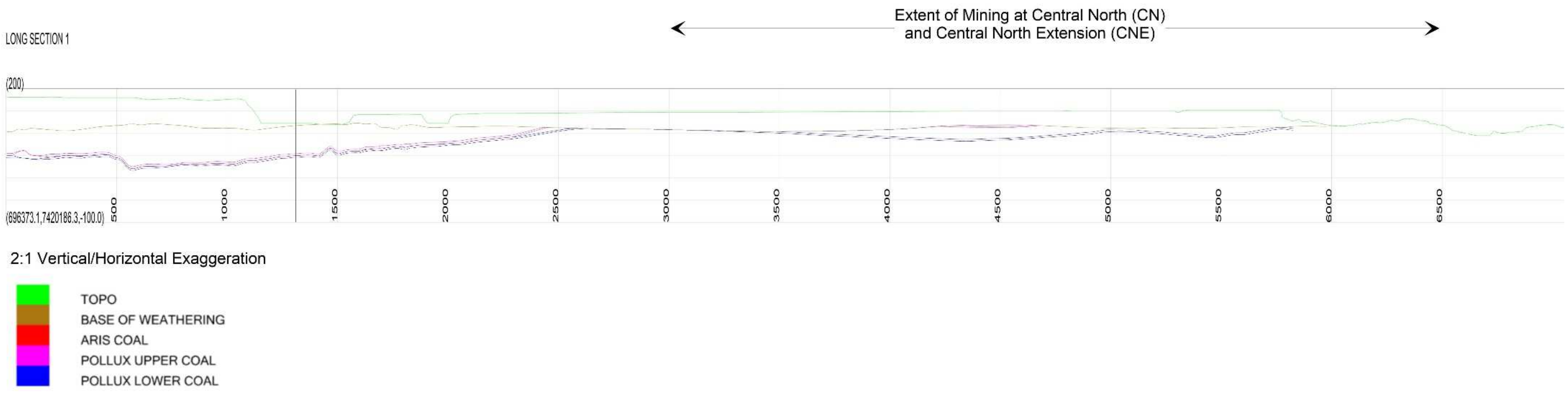


Figure 4-3: Cross-Sections from Site Geological Model



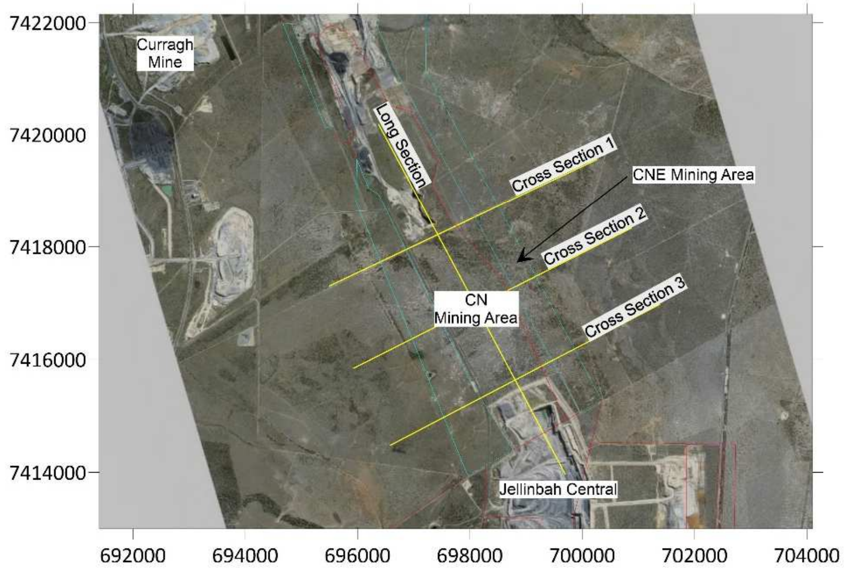


Figure 4-4: Long Section from Site Geological Model

5.0 CONCEPTUAL GROUNDWATER MODEL

Essential elements of the conceptual model that have informed numerical modelling include:

- The Tertiary deposits within the project area comprise mainly sediments of the Duaringa Formation and high-level Tertiary alluvial deposits. The thickness of the Tertiary sediments within the Project ranges from approximately 8 – 25 m. Exploration drilling and monitoring data indicates that the Tertiary sediments in the area of the CNE are dry and that the water level is generally below the base of weathering but generally above the upper coal seam. Therefore, conceptually, the base of weathering is regarded as the depth below which all units at site are saturated (i.e. the phreatic surface occurs at approximately the depth of the base of weathering);
- Recharge to Tertiary sediments is via direct rainfall recharge. The porosity/ permeability of the Tertiary sediments is variable, therefore rates of recharge through the sediments are also variable;
- Quaternary alluvium is associated with drainage features such as the Mackenzie River (to the north), Blackwater Creek (to the west). The Quaternary alluvium is directly recharged by rainfall. The degree of connectivity between the Quaternary alluvium and the Mackenzie River is uncertain. There is no quaternary alluvium within the area of Central North or the CNE;
- The coal seams are recharged primarily in subcrop areas, where the coal seams directly underlay Tertiary and/or Quaternary sediments (for example, where the Pollux Seam underlays alluvium in the Jellinbah Plains mining area – refer Section 3-2);
- The interburden (sediments between the coal seams) are less permeable that the coal seams, therefore the coal seams are the primary conduit for groundwater flow within the coal measures;
- Faults will tend to allow groundwater flow across the fault if more permeable units are connected (such as coal seam to coal seam), and will tend to act as barriers to flow if a conductive unit such as a coal seam is terminated against lower permeability interburden material.

6.0 GROUNDWATER MODELLING

6.1 Choice of Numerical Model

To estimate the extent of water level impact from the proposed project, 2-dimensional seepage modelling has been undertaken using the program Seep/W. The choice of model code has been based on an assessment of the model platform that would be appropriate to the study requirements.

A number of factors are assessed when choosing the appropriate modelling platform for a particular groundwater modelling study. Factors that are relevant to the CNE study include:

- The ability of the model to represent the essential elements of the conceptual groundwater model. At CNE this includes the ability of the model to accurately represent the complexity of the geology including faulting of strata, which acts to compartmentalise the geological and hydrogeological units, as faulting has the potential to significantly impact groundwater occurrence and flow; and,
- The ability of the model to adequately address the requirements of the scope of work. At CNE this includes assessment of the extent of groundwater level impact from mining, as well as assessment of the potential impact of groundwater level changes on any connected surface water and groundwater dependant ecosystems.

Based on assessment of the model requirements, including representation of the essential elements of the conceptual groundwater model, it was concluded that 2-dimensional cross-section modelling would be appropriate for the CNE project and on that basis the model Seep/W was selected. The use of a 2-dimensional Seep/W cross-section model was assessed to be appropriate to this investigation for the following reasons:

- The geology of the mining area is complex, and includes a number of local-scale and regional-scale faults which significantly disrupt the strata (refer Figure 2-2 for solid geology). It is possible within a 2-dimensional model to reproduce complex cross-sectional geology, whereas such detail could not be included practically within a 3-dimensional model;
- Seep/W is designed to simulate flow in both the saturated zone and the unsaturated zone. When mining occurs below the phreatic surface[1] an unsaturated zone is induced in the pit walls as seepage to the excavation occurs. Seep/W is well suited to investigation of groundwater level impacts resulting from seepage to open pits, particularly for projects such as CNE where mine dewatering via bores does not occur, and seepage to the excavation is the only means via which the mine removes water from the groundwater system;
- In open cut mines groundwater storage conditions transition from confined to unconfined in the zone adjacent to the pit walls. Seep/W models the rate of drainage to an excavation via a property called the volumetric water content (refer Section 6.3.2), which is able to accurately account for the rate of groundwater flow and the rate of change of the phreatic surface as groundwater conditions transition from confined to unconfined and gravity drainage of groundwater occurs to the excavation. Seep/W is able to model this important element of the groundwater system much more accurately than other groundwater flow models (such as Modflow);
- One of the main purposes of the model is to investigate the rate and extent of groundwater level drawdown in response to mining, especially in areas of potentially connected surface water and groundwater systems. This can be readily (and potentially more accurately) achieved through the use of a 2-dimensional cross-section models;
- The use of 2-dimensional models is valid in cases where the section can be oriented along a groundwater flow line so that all groundwater flow is along the section rather than across it. In open-cut mines where mining occurs below the water table, groundwater flow towards the excavation tends to dominate over the previous regional flow patterns, making it possible to orient a section along a groundwater flow line. Therefore the use of 2-dimensional cross-section models is assessed to be valid for the purposes of this investigation.

It should be noted that it is not argued that a 2D (SEEP/W) model is inherently better than a 3D (e.g. MODFLOW) model for predicting drawdown, rather that the 2D model is appropriate to the assessment of impacts due to the CNE, for the following reasons (in addition to those listed above):

- The CNE represents a minor expansion of an existing mine (Central Pit) and already approved operation at Central North (CN);
- The CNE occurs to the east of the CN mining area, therefore the main area for drawdown assessment is a distinct area to the east of the CNE and it is judged that a 2D model is an appropriate tool for assessment of groundwater drawdown impacts along a west-east flow line (i.e. in the direction where assessment of potential impacts is most critical)

The selected modelling platform (Seep/W) is an industry-standard finite-element model capable of modelling groundwater movement and pressure distribution within the saturated/unsaturated zone of porous materials such as soil and rock. Seep/W has been used in this study to predict the rate and

[1] The phreatic surface is a line of zero pore water pressure below which all pore spaces are saturated with water, and is analogous to the water table. The term phreatic surface is used throughout this report for consistency with Seep/W modelling terminology.

extent of change to the phreatic surface in response to the ongoing mining of the already approved Central North Mine, as well as the proposed extension of the operation into the extension area.

Two models were prepared for this study including a west-east cross-sectional model and a north-south cross-sectional model. The models are described below in Section 6.2. Other details of the models (e.g. hydraulic parameters, boundary conditions, representation of faulting etc. are discussed in subsequent sections).

6.2 Model Locations and Scenarios

Two models were generated for the study, including:

- Model 1 - a west-east cross-section model in the location of cross-section 2 (Figure 4-3). Details of the model construction and setup are as follows:
    - The model detail in the mining area was taken from a cross-section that was generated from the site geological model (Figure 4-3);
    - The model was extended to the east and west of the mining area by approximately 14 km in each direction to take the model boundaries beyond the location where the constant head boundary conditions would influence the model results. Detail of the model in the mining area is shown below in Figure 6-1;
    - In areas beyond the limits of the site geological model, the geology that was applied was based on interpretation of the 1:100,000-scale geology (Figure 2-1) and the Bowen Basin solid geology (Figure 2-2) and included representation of the major faults that were encountered along the section (refer Section 6.4 for discussion of faults).
    - Two scenarios were run for the cross-section model, as follows:
        - For scenario 1 the area of mining for the already-approved CN mining area was removed. The model was run for 1000 years, but it was found following model review that the drawdown had achieved steady-state by 150 years post-mining. All model results are therefore presented as drawdown at 150 years post-mining, which is taken to be post-mining equilibrium.
        - The extent of 2 m and 5 m drawdown was established for the Scenario 1 model (CN mining only) to enable comparison with the additional drawdown that would be generated from mining within the CNE;
        - For Scenario 2 the area of mining for the CNE was removed from the model, so that mining of both the CN and CNE mining areas was simulated (Figure 6-1);
    - The extent of 2 m and 5 m drawdown was established for the Scenario 2 model (CN and CNE mining included) and the results were compared with the results of Scenario 1 model, to account for the additional drawdown that is attributable to mining of the CNE.

2. Model 2 – a long section model oriented approximately north-south (Figure 6-2) that extends from the existing Jellinbah Central pit (in the south) to a location that is north of the Mackenzie River. Details of the model construction and setup are as follows:
    - The model detail in the mining area was taken from a cross-section that was generated from the site geological model (Figure 4-4);
    - The model terminates in the south at the Jellinbah Central mined void. The groundwater elevation is held constant at the southern boundary of the model at the floor elevation of the Jellinbah void;

- The model was extended to the north by approximately 14 km to take the model boundary beyond the location where the constant head boundary conditions would influence the model results. The northern boundary of the model is also approximately 8.5 km north of the location of the Mackenzie River. Detail of the model in the location of the CNE mining is shown in Figure 6-2;
- In areas beyond the limits of the site geological model, the geology that was applied was based on interpretation of the 1:100,000-scale geology (Figure 2-1) and the Bowen Basin solid geology (Figure 2-2);
- No mining was assumed for the area to the north of the CN/CNE mining areas. The intent of the model was to establish any additional drawdown that may be due to mining in the CNE area. However it is judged that, in reality, any significant drawdown to the north is unlikely due to the existing impacts of mining in the Jellinbah Plains area.
- Two scenarios were run for the cross-section model, as follows:
  - For scenario 1 the area of mining for the already-authorised CN mining area was removed. The model was run for 1000 years. As per the cross-sectional model (discussed above) it was found that the drawdown had achieved steady-state by 150 years post-mining; therefore, all model results are therefore presented as drawdown at 150 years post-mining, which is taken to be post-mining equilibrium. The detail of the geological section was adjusted so that the maximum depth to base of coal was 125 mbgl, to simulate the drawdown associated with the deepest area of mining in the CN mining area;
  - The extent of 2 m and 5 m drawdown was established for the Scenario 1 model (CN mining only) to enable comparison with the additional drawdown that would be generated from mining within the CNE;
  - For Scenario 2 the area of mining for the CNE was removed from the model, so that mining of both the CN and CNE mining areas was simulated (Figure 6-2). Detail from the geological section was adjusted so that the maximum depth to base of coal was 145 m, to simulate the drawdown associated with the deepest areas of mining in the CNE mining area;
- The extent of 2 m and 5 m drawdown was established for the Scenario 2 model (CN and CNE mining included) and the results were compared with the results of Scenario 1 model, to account for the additional drawdown that is attributable to mining of the CNE.

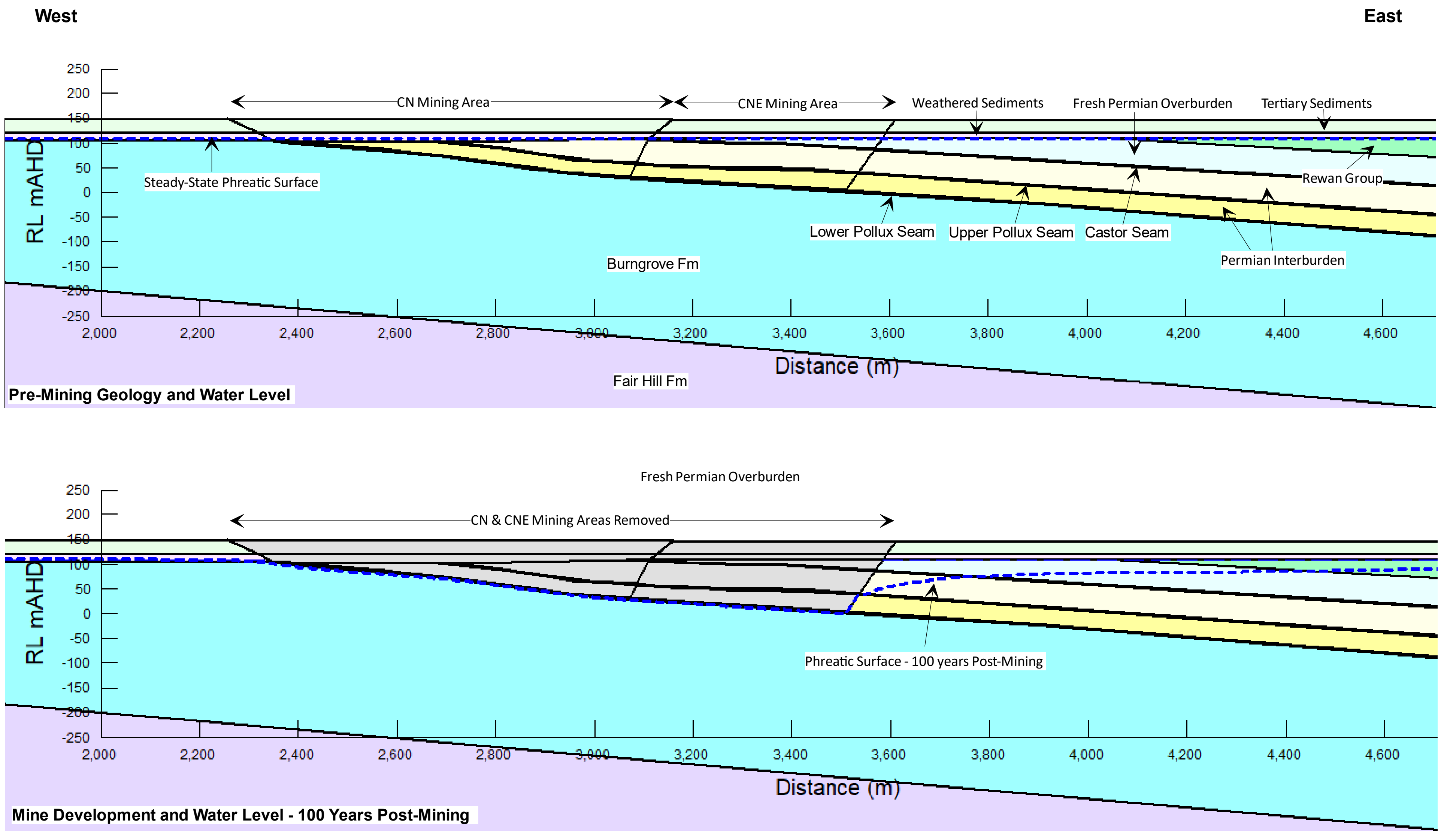


Figure 6-1: Model Detail in Mining Area – West-East Section

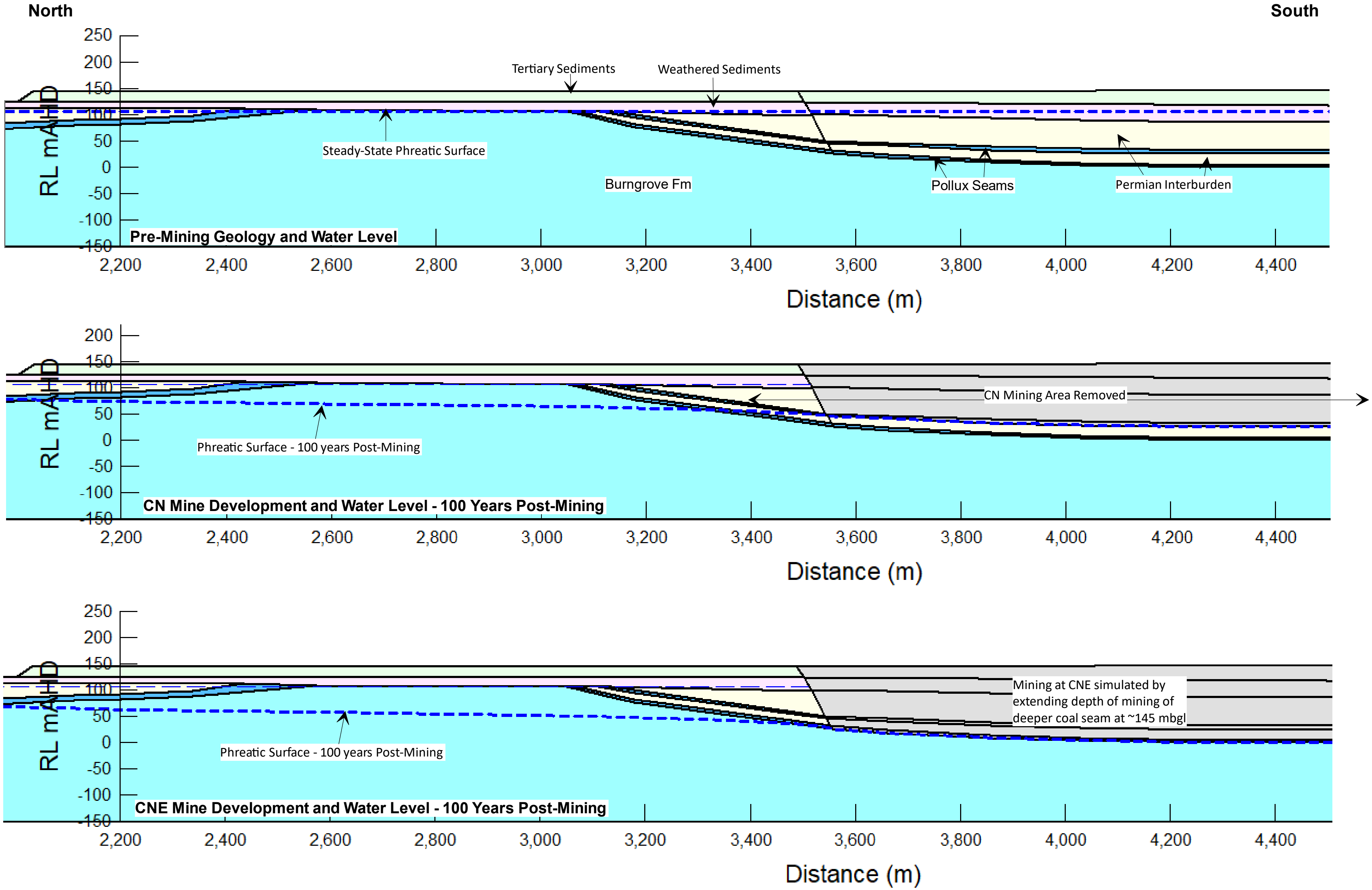


Figure 6-2: Model Detail in Mining Area – North-South Section

6.3 Hydraulic Properties

6.3.1 Hydraulic Conductivity

Hydraulic conductivity (K) data for the Seep/W model is based on calibrated model parameters for the Mackenzie North groundwater model, which is a Modflow model that was developed to support the Environmental Management Plan for the Mackenzie North Project, and which includes the area covered by the CNE project. (AGE 2013). The development of the Mackenzie North model took into consideration the site-specific parameters that were obtained during the field studies for that model and which are summarised in Section 6.6.2. The model values are provided below in Table 6-1 and the distribution of model parameters compared to field values are shown in Figure 6-3.

Table 6-1: Hydraulic Conductivity Values used in Seepage Modelling

Lithology	Hydraulic Conductivity (m/day)		Kz/Kh Ratio
	Horizontal (Kh)	Vertical (Kz)	
Mackenzie River Alluvium	7.0×10^{-1}	9.9×10^{-3}	0.014
Tertiary alluvium and residual deposits	1.0×10^{-2}	5.0×10^{-3}	0.455
Duaringa Formation	9.0×10^{-1}	1.0×10^{-2}	0.011
Rewan Group	9.4×10^{-4}	6.9×10^{-5}	0.073
Permian Overburden (weathered)	5.0×10^{-3}	5.0×10^{-4}	0.100
Permian Overburden (unweathered)	1.1×10^{-4}	5.0×10^{-5}	0.454
Castor/Aries Seams	8.0×10^{-1}	1.0×10^{-1}	0.125
Interburden 1	9.4×10^{-4}	6.9×10^{-5}	0.073
Pollux Upper Seam	8.0×10^{-1}	1.0×10^{-1}	0.125
Interburden 2	3.4×10^{-4}	1.0×10^{-4}	0.294
Pollux Lower Seam	8.0×10^{-1}	9.8×10^{-3}	0.012
Burngrove/ Fair Hill Formations	4.0×10^{-5}	1.1×10^{-6}	0.028

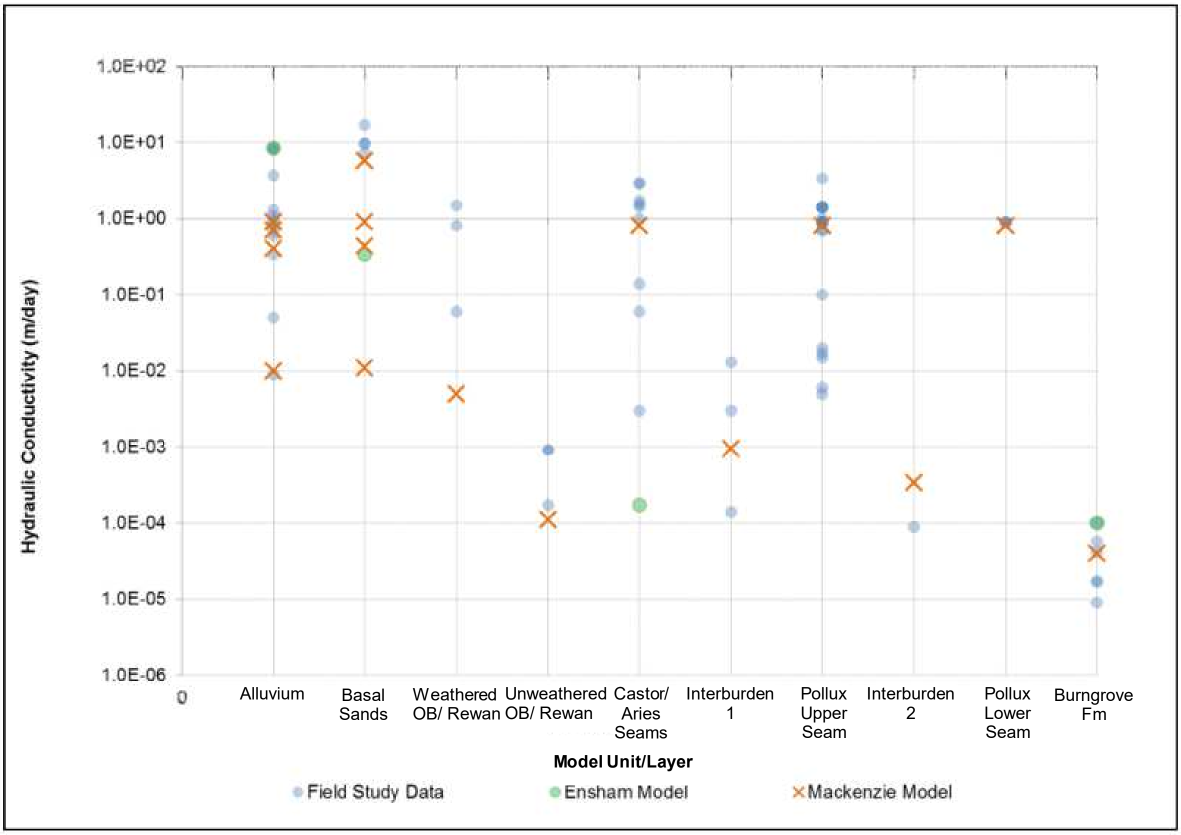


Figure 6-3: Distribution of Kh – Measured vs Modelled Values (adapted from AGE 2013)

6.3.2 Volumetric Water Content

6.3.2.1 Specific Yield

Seep/W represents the water content and drainage properties of different geological materials via a property called volumetric water content. In order to illustrate the concept, volumetric water content curves from two different material types used in the model are shown in Figure 6-3. With respect to concepts utilised in hydrogeology, and with reference to the example material types shown in Figure 6-3, the relationship is as follows:

- The maximum value for total water content is the same as the total porosity of the unit. For both material types shown in Figure 6-3 the porosity is 0.2 m^3/m^3 (20%);
- Total porosity is comprised of specific yield (the volume of water that will drain from the unit under gravity drainage conditions) and specific retention (the volume of water that remains trapped in the unit (e.g. in small pore spaces) even when the unit is fully drained);
- The lowest value on the volumetric water content curve represents specific retention. For the material types shown in Figure 6-3, alluvium has a specific retention of 0.12 m^3/m^3 (12%), while interburden has a specific retention of 0.19 m^3/m^3 (19%);
- The difference between the maximum and minimum volumetric water content is the specific yield (drainable yield) of the unit. For the material types shown in Figure 6-3, alluvium has a specific yield of 0.08 m^3/m^3 (8%), while Permian interburden has a specific yield of 0.01 m^3/m^3 (1%) ; and,

It should be noted that Seep/W only considers the total drainable yield (specific yield), and the rate at which drainage is allowed to occur. In other words, the starting porosity (maximum volumetric water content) is not important for seepage calculations – it is only the total drainable yield and the rate of drainage (in response to suction forces) that is considered by the model.

The specific yield values that were used in modelling are shown below in Table 6-2

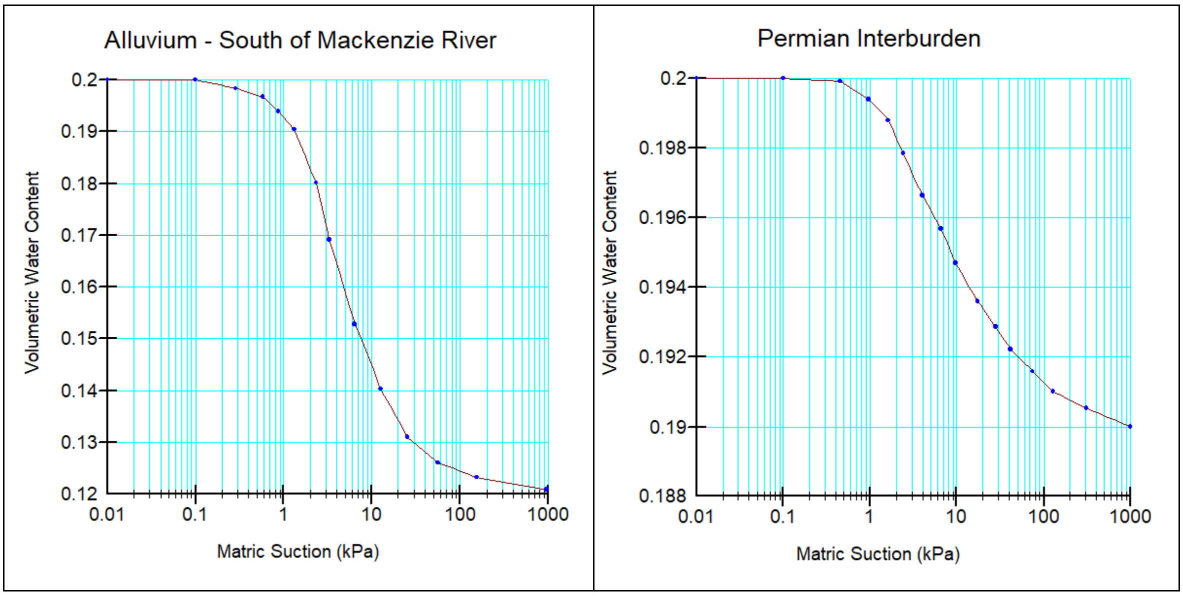


Figure 6-4: Example Volumetric Water Content applied to different material types

Table 6-2: Specific Yield used in Model

Lithology	Specific Yield (Sy)
Mackenzie River Alluvium	0.08 (8%)
Tertiary alluvium and residual deposits	0.05 (5%)
Duaringa Formation	0.01 (1%)
Rewan Group	0.01 (1%)
Permian Overburden (weathered)	0.01 (1%)
Permian Overburden (unweathered)	0.01 (1%)
Castor/Aries/Pollux Seams	0.02 (2%)
Permian Interburden	0.01 (1%)
Burngrove/ Fair Hill Formations	0.01 (1%)

6.3.2.2 Specific Storage

In Seep/W the specific storage (*Ss*) of the aquifer is accounted for via a related property called the coefficient of volume compressibility (*mv*). In areas where groundwater is draining to the pit void, the model utilises the specific yield (*Sy*) portion of the volumetric water content curve (as discussed above). With increasing distance from the pit wall the groundwater storage conditions become increasingly confined, Seep/W automatically transitions from unconfined to confined conditions (i.e. from the portion of the volumetric water content curve where pore pressures are at or below atmospheric pressure (and draining to the pit void) to the portion of the curve where pore pressures are positive) using the properties of the Coefficient of Volumetric Compressibility (*mv*). The relationship between the coefficient of volume compressibility (*mv*) and specific storage (*Ss*), can be established from the following equation (Geoslope 2012):

$$S_S = \rho_w g(\alpha + n\beta) = \rho_w g(mv)$$

Where:

Ss	=	Specific Storage
mv	=	Coefficient of volume compressibility
ρw	=	The density of water
g	=	Acceleration due to gravity
α	=	Compressibility of the aquifer skeleton
n	=	The porosity of the aquifer
β	=	Compressibility of water

The value for *mv* generally ranges from 1 x 10^{-6}/ kPa to 1 x 10^{-3}/kPa and for confined aquifers a value of 1 x 10^{-5}/kPa is generally appropriate (Geoslope 2012). An *mv* of 1 x 10^{-5}/kPa has therefore been applied to all groundwater units in the model.

6.4 Representation of Faulting

Faults are represented in the models as follows:

- The site geological model conforms to the solid geology as shown in Figure 2-2. For areas of the model that are beyond the boundaries of the site geological model the solid geology, including fault locations, is consistent with the geology shown on the solid geology map (Figure 2-2).
- Where faults are shown on the sections produced from the site geological model or regional geological data, the location of the faults has been accurately reproduced in the model. ;
- Figure 6-4 (below) shows the locations of the Jellinbah Fault (west of the CNE) and the Yarrabee Fault (east of the CNE). Note that the section is a continuous west-east section, but has been split

at the approximate location of the western edge of the CN pit to allow more detail to be shown on the section. It is noted that the actual throw on the faults is unknown; however, the geology as depicted conforms to the solid geology that is presented in Figure 2-2. The faults act to vertically disrupt the strata and will impact on groundwater flow where units of differing hydraulic conductivity abut each other. This will be more pronounced in the case of the Yarrabee Fault, where the Permian coal measures and coal seams are truncated against lower hydraulic conductivity sediments of the Burngrove Formation. At the location of the Jellinbah Fault the low hydraulic conductivity sediments of the Burngrove and Fair Hill Formations, which occur to the west of the Jellinbah mining area abut low hydraulic conductivity sediments of the Burngrove Formation and Rewan Group. Sediments of the Permian coal measures occur to the west of the Jellinbah Fault, but there is no continuity with the coal measures that occur in the Jellinbah mining area ;

- The faults have not been assigned any hydraulic properties, as no quantitative data exists to indicate whether individual faults act as groundwater conduits or as barriers to groundwater flow. Rather, the faults will act as described above, i.e. to allow transmission of groundwater across the fault if more permeable units are connected (such as coal seam to coal seam), and will tend to act as barriers to flow if a conductive unit such as a coal seam is terminated against lower permeability interburden material.

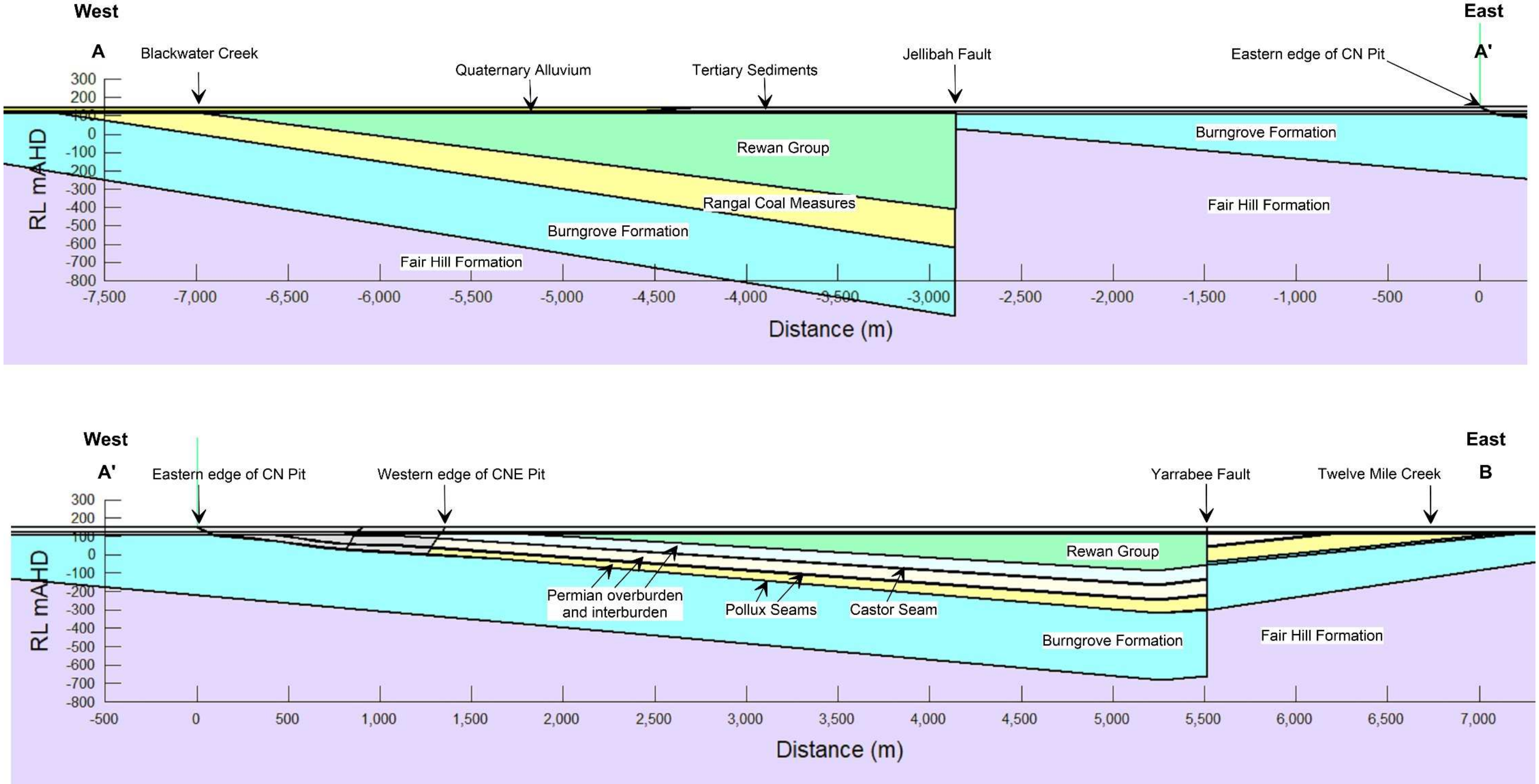


Figure 6-5: Representation of Faulting in West-East Groundwater Model

6.5 Boundary Conditions

6.5.1 Recharge

Groundwater data from site has been utilised 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:

- Mean annual rainfall for the CNE site of 559.4 mm (from SILO data).
- Mean chloride concentration in rainfall for the CNE site of 6.2 mg/L (CSIRO 2014[1]).
- Chloride concentration for groundwater of:
  - Alluvium – 20th percentile 64 mg/L; mean 485 mg/L; 80th percentile 1,490 mg/L;
  - Tertiary sediments – no data – Tertiary sediments unsaturated at site; and,
  - Permian coal seams - 20th percentile 582 mg/L; mean 2,417 mg/L; 80th percentile 5,190 mg/L.

The calculated recharge rates to groundwater are shown below in Table 6-3 and are summarised as follows:

- Recharge rates to the Mackenzie River alluvium are calculated to be between 0.42% of rainfall and 9.63% of rainfall (based on the 20th and 80th percentiles of rainfall) with a mean of 1.28%. It is noted that the Mackenzie River alluvium is not homogenous, but rather contains prior channels that are vertically separated and laterally discontinuous, interspersed with clayey flood-plain deposits; this lithological variation is reflected in the variability of recharge rate as well as the variability in groundwater retention times for this unit;
- Recharge rates to the coal seams are calculated to be between 0.12% and 1.06% of average annual rainfall (based on the 20th and 80th percentiles of the data) with a mean of 0.26%

Table 6-3: Calculated Groundwater Recharge Rates via CMB Method

Parameter	Description	Alluvium			Coal Seams		
		20th %	Mean	80th %	20th %	Mean	80th %
Cg	Chloride concentration in groundwater (mg/L)	64	485	1490	582	2417	5190
Cp	mg/L chloride in rainfall	6.2	6.2	6.2	6.2	6.2	6.2
P	Annual average rainfall (mm)	559.4	559.4	559.4	559.4	559.4	559.4
R	Annual average recharge (mm)	53.89	7.14	2.32	5.94	1.43	0.67
	Recharge as % of average annual rainfall	9.63	1.28	0.42	1.06	0.26	0.12

[1] CSIRO 2014 - Australian Chloride Deposition Rate https://doi.org/10.4225/08/545BEE54CD4FC

Based on the recharge rates calculated from the CMB method, recharge was applied to the model as follows:

- Recharge to areas of Mackenzie River alluvium (i.e. the northern area of the North-South Model) was applied at a rate of 1% of average annual rainfall.
- Recharge to the Tertiary sediments was applied at a rate of 0.5% of average annual rainfall, which is justified as follows:
  - The Tertiary sediments have been observed to be unsaturated in the CN and CNE mining areas; however, recharge to the Tertiary sediments will eventually report as recharge to the underlying coal measures, where recharge will preferentially occur in areas where the coal seams subcrop beneath Tertiary sediments;
  - The highest calculated recharge rates (via the CMB method) will occur in areas where the lowest salinity groundwater occurs, which is observed to be the areas where the coal seams subcrop directly beneath Tertiary sediments. In down-dip areas (e.g. to the east of the CNE and towards 12 Mile Creek) less recharge to the coal seams will occur due to the low permeability of the overlying overburden.
  - It is noted that in the area to the east of the CNE, Tertiary alluvium is mapped at surface. This unit is expected to be relatively thin and a recharge rate of 0.5% of average annual rainfall was also applied to this unit.

Recharge was applied to transient models as a flux boundary condition applied to the upper layer of the model (representing the ground surface). Rainfall was not applied to the steady-state model as the starting phreatic surface was generated based on fixed head boundary conditions at the edges of the model.

6.5.2 Starting Phreatic Surface

The initial phreatic surface was generated in the steady state model by applying fixed heads at the boundaries of the model. The boundaries were set at a distance of approximately 14 km from the edge of mining in order that the boundary conditions did not interfere with the groundwater response to mining.

The level of the fixed head boundary conditions was adjusted so that the initial phreatic surface within the mining area was just below the base of Tertiary and within the weathered Permian sediments, in accordance with observations from drilling and groundwater level monitoring. For the north-south section the boundary conditions at the north of the model were adjusted so that the water level just south of the Mackenzie River was at approximately RL102 mAHD, which placed the water level within the alluvium. This was done to be consistent with available water level monitoring data (refer Section 3.2 and Figure 3-2).

6.5.3 Groundwater Seepage to Voids

Seep/W requires the setting of seepage face review boundary conditions to allow water to leave the model and flow to the mine void. The seepage face boundary a flux boundary with total flux (Q) set at 0 m/day. The area of the mine void is set as a material type with no hydraulic properties; in practice the void is modelled as a zone with void into which groundwater flow can occur unimpeded.

6.6 Model Calibration

SEEP/W is not calibrated in the same ways as a model such as MODFLOW (e.g. via the matching of model water level predictions against observed values). Rather, the approach taken is generally to utilise realistic model parameters and to test for variability in results via uncertainty analysis. However, it is possible to undertake a check on the validity of model results for areas where an existing mine is present, such as for the CNE project, where observations are available from the existing and adjacent Central Pit. These observations are discussed further below

6.6.1 Comparison of Modelled Seepage with Observed Seepage

For Bowen Basin coal mines, it is generally observed (based on observations by JBT personnel over the course of approximately 20 years) that:

- For mine depths of less than 100-120 m, there are generally no observable groundwater inflows as the rate of groundwater inflow from the Permian coal measures tends to be so low that evaporation removes all seepage and the pit walls have the appearance of being dry;
- Beyond mine depths of 100-120 m there can be evidence of groundwater seepage that manifests as:
  - Initially, seepage is evident from higher permeability units such as coal seams, where patches of dampness become evident at the base of the coal seams;
  - With increasing depth (towards 150 m), damp interburden may become apparent and soft patches on the pit floor may also become more apparent;
  - As mines develop towards 180-200 m depth, visible seepage becomes apparent and groundwater will make up an increasing percentage of the water (that will include surface water runoff) that is collected in sumps and needs to be removed via pumping
  - Some seepage may be observed at shallower depths from faults and fractures, but it is our experience that this inflow tends to become evident after high rainfall periods and represents enhanced surface water recharge to the dilated zone around the pit, with faults and fractures acting as preferred pathways for flow. This inflow tends to be of relatively short duration and is not interpreted to represent true groundwater that is derived from the formation.
- The increase in seepage with depth is interpreted to be due:
  - In large part to the greater depth of mining below the phreatic surface and the higher hydraulic gradient that drives groundwater flow towards the mined void; and,
  - In smaller part to a reduction in the rate of evaporation with depth (due to shading, less wind etc.). A general rule of thumb is that evaporation is applied to seepage from the pit walls at a rate of 80% of pan evaporation near the ground surface, increasing linearly to 50% of pan evaporation at the base of the mine.

For mining at the adjacent Central Pit, it is observed that the pit is dry (in terms of groundwater inflow) at current mining depths of approximately 100 m below ground level. Therefore, the general observations above are judged to be applicable to the CNE operation. Observations from groundwater modelling are summarised as follows:

- From the SEEP/W model for the CN operation only:
  - the maximum depth of mining is approximately 120 m;
  - the calculated rate of seepage for a 1 m width of pit face at equilibrium is approximately 0.0015 L/s/m. The majority of this seepage occurs from the lower 30 m of the pit wall where a steady-state seepage face is developed;
  - For an average annual evaporation rate of 2,047 mm/year (SILO data), the calculated rate of evaporation (assuming 50% of pan evaporation for the base of the pit) is calculated as approximately 0.0019 L/s/m for the lower 30 m of the pit wall (where the seepage face is developed);

  - The rate of evaporation (0.0019 L/s/m of seepage face) is therefore in excess of the rate of seepage (0.0015 L/s/m of seepage face), which will result in the appearance of a dry pit wall;
  - The model results are therefore consistent with the observation of a dry pit at a similar depth to mining in the Central Pit.
- From the SEEP/W model for the CNE operation:
  - the maximum depth of mining is approximately 150 m;
  - the calculated rate of seepage for a 1 m width of pit face at equilibrium is approximately 0.002 L/s/m. As per the CN-only case, the majority of this seepage occurs from the lower ~30 m of the pit wall where a steady-state seepage face is developed;
  - For an average annual evaporation rate of 2,047 mm/year (SILO data), the calculated rate of evaporation (assuming 50% of pan evaporation for the base of the pit) is calculated as approximately 0.0019 L/s/m, for the lower 30 m of the pit wall (where the seepage face is developed)
  - The rate of seepage (0.002 L/s/m of seepage face) is therefore slightly in excess of the rate of evaporation (0.0019 L/s/m of seepage face) and is therefore consistent with the general observation of seepage in excess of evaporation at a depth of approximately 150 mbgl.

6.6.2 Use of Calibrated Model Parameters

As discussed in Section 6.6.2, the Seep/W model has been amended to include hydraulic parameters from the calibrated Mackenzie North groundwater model, which was developed for the Mackenzie North EMP and which covers the area of the CNE project. The calibrated model parameters are consistent with observed parameters from site (Mackenzie North).

6.7 Modelled Groundwater Level Impacts

6.7.1 Assessment Criteria

The modelled drawdown at 100 years post mining for the two modelled scenarios (CN only and CN plus CNE mining) is shown in Figure 6-5. The following observations are made with respect to modelled impacts on groundwater levels:

The Queensland *Water Act 2000* defines a “bore trigger threshold” (section 362) as:

> *a decline in the water level in the aquifer that is-*
>
> *(a) If a regulation prescribes the bore trigger threshold for an area in which the aquifer is situated – the prescribed threshold for the area; or*
>
> *(b) Otherwise-*
>
> *i. For a consolidated aquifer – 5 m; or*
>
> *ii. For an unconsolidated aquifer – 2 m.*

For the consolidated Permian coal measures it is judged to be appropriate to represent the extent of drawdown for up to 5 m from the original water level. The modelled drawdown beneath surface water features of interest (Mackenzie River to the north and Twelve Mile Creek to the east) is discussed in the text (Sections 6.6.2 and 7.4).

The drawdown beneath Blackwater Creek (to the west) is not discussed as significant groundwater drawdown to the west does not occur (discussed further is Sections 6.6.2 and 7.4).

Drawdown to the south is also not discussed as drawdown from both the CN and CNE operations could only extend as far as the Jellinbah Central void, which occurs immediately to the south of both operations.

6.7.2 Model Results

Modelled drawdown is discussed below for each direction (north/south/east/west) from the mining area. The model results have been utilised to provide an indication of the extent of the 2 m and 5 m drawdown contours around the mining area (i.e. results from the cross-section models have been used to generate extent of drawdown contours in plan view, with contours manually digitized). Results from modelling are shown in Figure 6-5 and predict:

- On the eastern (high wall) side of the mining area the 5 m extent of drawdown is approximately 3,500 m from the pit crest at post-mining equilibrium (drawdown results at 150 years post-mining were utilised as post-mining equilibrium for all model results), for the CN operation only. With the CNE operation included, the extent of 5 m drawdown extends to approximately 3,750 m from the pit crest at post-mining equilibrium (an increase of 250 m relative to the CN mining only case). The CNE operation extends mining by approximately 360 m to the east and extends the depth of mining from approximately 125 mbgl to 150 mbgl.

  The 2 m drawdown contour extends approximately 5,250 m from the pit crest for the post-mining equilibrium, CN-only case and approximately 5,500 m from the pit crest for the post-mining equilibrium CNE case (an increase of approximately 250 m relative to the CN-only case). The 2 m drawdown contour therefore extends beneath 12 Mile Creek in some areas, as shown in Figure 6-6.
- On the western (low wall) side of the mining area the 5 m and 2 m extent of drawdown contours do not extend appreciably (by less than 100m) due to mining. This is interpreted to be related to the lack of coal measures to the west of the mining area (due to the dip of the strata) and the relatively low permeability of the Burngrove Formation, which is the dominant unit to the west of the mining area.
- On the northern side of the mining area the 5 m extent of drawdown is approximately 2,300 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,400 m from the pit crest for the CNE case. The difference in drawdown to the north, relative to the modelled drawdown to the east, is interpreted to be related to the variability of the geology to the north, relative to the east.

  The 2 m drawdown contour extends approximately 2,400 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,800 m from the pit crest for the CNE case.

  It is noted that no mining was assumed for the area to the north of the CN/CNE mining areas. The intent of the model was to establish any additional drawdown that may be due to mining in the CNE area. However it is judged that, in reality, any significant additional drawdown to the north is unlikely due to the existing impacts of mining in the Jellinbah Plains area.
- No drawdown was considered to the south as the model terminates in the south at the Jellinbah Central mined void. The groundwater elevation is held constant at the southern boundary of the model at the floor elevation of the Jellinbah void.

Potential impacts from mining are discussed in Section 7.0.

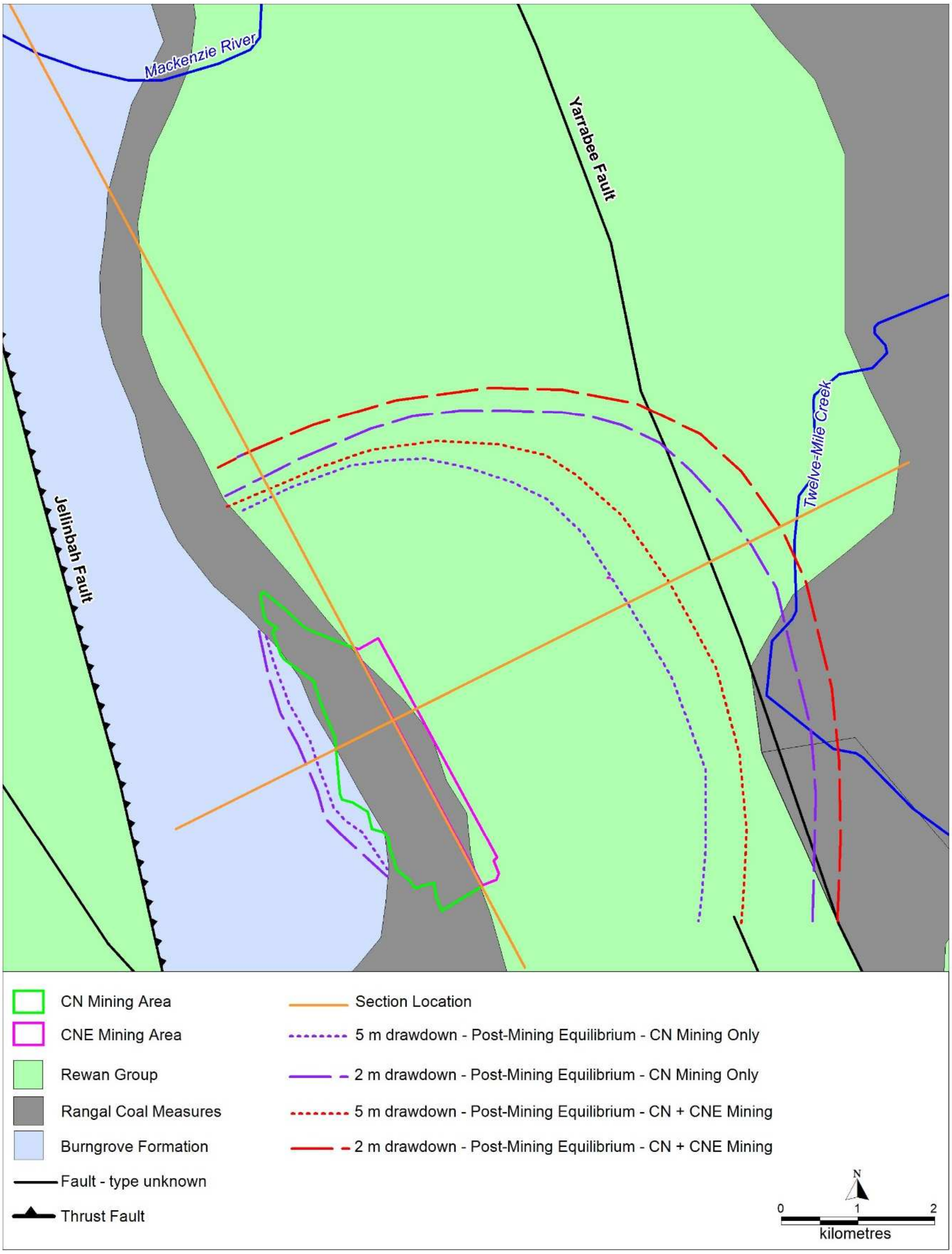


Figure 6-6: Water Level Drawdown for CN and CNE Mining Cases - Post-Mining Equilibrium

6.8 Uncertainty Analysis

6.8.1 Introduction

A sensitivity analysis of the groundwater model developed for the Jellinbah Central North Extension (CNE) has been undertaken with reference to the following documents:

- Barnett et al. (2012) *Australian Groundwater Modelling Guidelines*. Sinclair Knight Merz and National Centre for Groundwater Research and Training, Waterline Report Series No. 82, June 2012; and,
- Middlemis, H. & Peeters, L.J.M. (2018) *Explanatory Note, Uncertainty Analysis in Groundwater Modelling*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy (Draft).
- Reilly, T.E. & Harbaugh, A.W. (2004) *Guidelines for Evaluation of Groundwater Flow Models.* United States Geological Survey, Scientific Investigations Report 2004-5038.

A groundwater model sensitivity analysis involves the evaluation of model input parameters to see how much they affect model outputs, which are heads and flows (Reilly & Harbaugh 2004). The process of sensitivity analysis can be conducted manually or automatically; in the manual approach, multiple model simulations are made in which ideally a single parameter is adjusted by an arbitrary amount (Reilly & Harbaugh 2004). The emphasis of sensitivity modelling is on determining how sensitive the model is to each parameter tested, using a non-technical interpretation of "sensitive" (Barnett et al. 2012).

The explanatory notes for uncertainty analysis that were prepared for the IESC (Middlemis & Peeters 2018) outline three general approaches to uncertainty analysis; these are, in order of increasing complexity:

1. Scenario analysis with subjective probability;
2. Deterministic modelling with linear probability quantification; and,
3. Stochastic modelling with Bayesian probability.

The first method (scenario analysis with subjective probability) has been applied to this modelling study. This methodology is judged to be appropriate to the analysis of a Seep/W model, which utilises a single set of parameters for each material type

A sensitivity analysis of the CNE model was undertaken as follows:

- The base-case (final CNE) models were used to establish the extent of 5 m drawdown from the edge of the final void to the north, south, east and west of the mining area. The location of the section models, as well as detail from the models pre and post-mining, are shown in Attachment A. The sections highlight the relationship between the various groundwater units, including the degree to which faulting and folding compartmentalises the units;
- The base-case model was altered to make changes to specific parameters (discussed below) and to assess the impact that the change in parameters had on the location of the extent of the 5 m drawdown contour at the end of mining.
- The parameters that were selected for the sensitivity analysis are shown in Table 6-4 and include:
    - Scenario 1 - Horizontal hydraulic conductivity (Kh). The Kh of the Triassic and Permian non-coal units (Rewan Group, Interburden 1 and 2, Burngrove Formation) was increased by a factor of 10.

- Scenario 1 - Vertical hydraulic conductivity (Kz). The Kz of the above units was increased by a factor of 10. An increase in the vertical permeability of the coal measures allows an increase in the rate of downward seepage from overlying units and therefore increase the lateral extent to which drawdown of groundwater levels will occur;
- Scenario 3 - Specific yield (Sy) and coefficient of volume compressibility (*mv*), which is related to the specific storage (*Ss*) of the aquifer, were adjusted for the coal seams as follows:
  - the Sy of the coal seams was increased by a factor of 2. The specific yield, which describes the volume of water that can drain under gravity-drainage conditions, is the dominant aquifer storage property in zones that are close to the mine void; and,
  - the coefficient of volume compressibility (*mv*), which is related to specific storage as discussed in Section 6.3.2.2, was increased by a factor of 10 for the Permian coal seams.
- Scenario 4 – the Sy and mv of the overburden/ interburden units (Rewan Group, Interburden 1 and 2, Burngrove Formation) was altered as described above for Scenario 3, i.e. *Sy* was increased by a factor of 2 and *mv* was increased by a factor of 10;
- Scenario 5 – the recharge was doubled from:
  - Tertiary sediments - 0.5% of average annual rainfall to 1% of average annual rainfall; and,
  - Quaternary alluvium – 1% of average annual rainfall to 2% of average annual rainfall.

6.8.2 Results

The results of the sensitivity analysis are discussed below and are presented in Table 6-3 and on Figure 6-6. Figure 6-6 shows the extent of 5 m drawdown contours for each modelled scenario at post-mining equilibrium, over a background of the solid geology. The solid geology map is prepared by removing the Cainozoic cover units, revealing the relationships (including faulted contacts) between older rocks (Permian and Triassic) in the project area. Results are summarised as follows:

- Scenario 1 - An increase in the Kh of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 1,250 m (to the east) and 340 m (to the north), as shown on Figure 6-6. The variability in the extent of the 5 m drawdown contour is related to dominant rock type in each direction;
- Scenario 2 - An increase in the Kz of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 2,300 m (to the east) and 1,600 m (to the north), as shown on Figure 6-6. The model is more sensitive to changes in Kz than Kh;
- Scenario 3 - An increase in the specific yield (Sy) of the coal seams by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-860 m to the east and -560 m to the north) relative to the base case;
- A low value for *mv* (and *Ss*) indicates a geotechnically stiff (less compressible) aquifer. An increase in the aquifer *mv* (and hence *Ss*) will therefore result in a more compressible aquifer, which will act to decrease the extent of drawdown.
- Scenario 4 - An increase in the specific yield (Sy) of the non-coal Triassic and Permian sediments by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a

factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-1490 m to the east and -780 m to the north) relative to the base case;

- Scenario 5 – An increase (doubling) in the rate of recharge results in a decrease in the extent of the 5 m drawdown contour at post-mining equilibrium of -1,150 m to the east and -740 m to the north of the CNE.

The results highlight the sensitivity of the model to changes in key parameters and the need to utilise realistic model inputs (hydraulic parameters, recharge) for the base-case model.

It is noted that the Tertiary sediments at site are dry and that the regional groundwater system is developed within the Permian coal measures and is assessed to be disconnected from the surface water systems and alluvium (refer Section 7.4). Therefore it is concluded that variability in model input parameters from those used in the base-case model will only affect groundwater levels within Permian sediments and is unlikely to have practical impacts on water levels within the shallow groundwater systems in the area (i.e. alluvial aquifers).

Table 6-4: Change in the location of the 5 m Drawdown Contour, Relative to the Base-Case

Modelled Scenario		Base Case	Sensitivity Model	Change (m) in extent of 5 m drawdown contour*
East-West Section				
1	Increase horizontal hydraulic conductivity (Kh) x 10			
	Rewan Group	9.4×10^{-4} m/d	9.4×10^{-3} m/d	1250
	Interburden 1	9.4×10^{-4} m/d	9.4×10^{-3} m/d	
	Interburden 2	3.4×10^{-4} m/d	3.4×10^{-3} m/d	
	Burngrove Formation	4.0×10^{-5} m/d	4.0×10^{-4} m/d	
2	Increase horizontal hydraulic conductivity (Kh) x 10			
	Rewan Group	6.9×10^{-5} m/d	6.9×10^{-4} m/d	2300
	Interburden 1	6.9×10^{-5} m/d	6.9×10^{-4} m/d	
	Interburden 2	1.0×10^{-4} m/d	3.4×10^{-4} m/d**	
	Burngrove Formation	4.0×10^{-5} m/d	4.0×10^{-4} m/d	
3	Increase specific yield (*Sy*) of coal seams x 2	2%	4%	-860
	Increase compressibility (*mv*) of coal seams x 10	1×10^{-5}/kPa	1×10^{-4}/kPa	
4	Increase specific yield (*Sy*) of Rewan Group, Interburden 1&2, Burngrove Formation x 2	1%	2%	-1490
	Increase compressibility (*mv*) of above units x 10	1×10^{-5}/kPa	1×10^{-4}/kPa	
5	Increase Recharge x 2			
	Alluvium	1%	2%	-1150
	Tertiary Sediments	0.5%	1%	
North-South Section				
1	As above			340
2	As above			1600
3	As above			-560
4	As above			-780
5	As above			-740

* Change in the extent of the 5 m drawdown contour for the CNE mining case at post-mining equilibrium.

A positive value indicates an increase in the extent of drawdown, a negative value indicates a decrease in the extent of drawdown.

** Value changed by less than 10x original value, to the value of the Kh of this unit

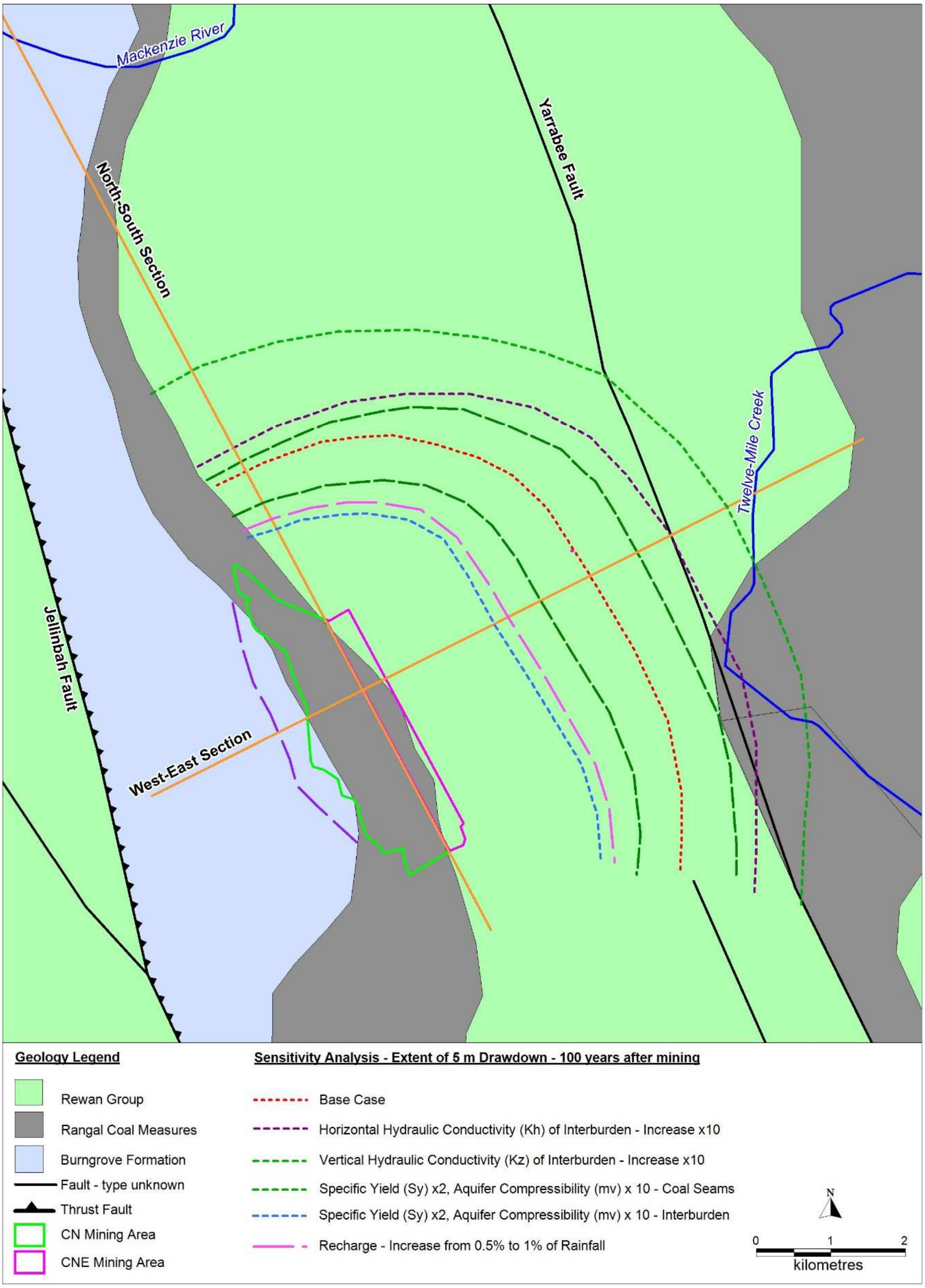


Figure 6-7: Results of Groundwater Model Sensitivity Analysis

7.0 GROUNDWATER IMPACTS FROM MINING

7.1 Impacts on Existing Groundwater Users

The most current version of the Department of Natural Resources, Mines and Energy (NRME) Groundwater Database (downloaded March 2019) was reviewed for the location of registered private groundwater bores. From the review it has been determined that there are no existing registered groundwater bores in the area between the Jellinbah and Curragh/Curragh North mining lease areas (i.e. to the west of the CNE) or in the area between the Jellinbah and Yarrabee mining lease areas (i.e. to the east to the CNE). Therefore it is concluded that there are no existing registered groundwater bores that could be impacted by the CNE operation.

7.2 Cumulative Impacts

Cumulative impact assessments are highly specific to the impact under analysis and may consider, for example, the following (Franks et al 2010):

- Multiple areas of groundwater abstraction (e.g. adjacent mining operations);
- Overlapping cones of drawdown;
- Dewatering discharge locations;
- Distribution of ecosystems around the Project area; and,
- Catchment-scale groundwater levels.

Existing projects that may combine with the Central North Extension to impact groundwater resources have been identified from the following sources:

- The Queensland Coordinated Projects Map (DSDIP 2014);
- Queensland's Mineral, Petroleum and Energy Operations and Resources map (State of Queensland 2012); and,
- Publicly available documentation (e.g. EIS documents that exist within the public domain).

Based on review of the above documentation it is concluded that the projects with the potential to contribute to cumulative groundwater impacts include:

- The existing Jellinbah Central operation that occurs immediately to the south of the CNE;
- The approved but as-yet unmined Central North (CN) operation, of which the CNE will be an extension;
- The existing Jellinbah Plains operation, which occurs to the north of the CN and CNE operations;
- The existing Curragh Central and Curragh North projects, which occur approximately 5 km west of the CNE; and,
- The existing Yarrabee Coal Mine, which is located approximately 6 km to the east of the CNE.

As the CNE is to be developed in the middle of existing Jellinbah mine operations it is taken as given that the drawdown from the CNE will coalesce with drawdown from existing Jellinbah operations to the north and south.

Based on searches undertaken for this study it is concluded that there is no information in the public domain on the extent of groundwater level drawdown due to the adjacent Curragh/Curragh North and Yarrabee operations, therefore it is only possible to discuss the potential for cumulative impacts in general terms.

In Section 6.7.2 (model results) it is noted that the predicted extent of the 2 m drawdown contour at the end of mining extends approximately 5,500 m to the east of the CNE at post-mining equilibrium and by less than 100 m to the west (for base-case hydraulic parameters). The depth of mining at operations to the west of the project (Curragh/Curragh North) and east of the project (Yarrabee) is unknown; however, given the distance of these existing mining projects from the CNE it is concluded that:

- Cumulative impacts to the west of the CNE are judged to be unlikely due to the relatively limited drawdown that is predicted to the west of the CNE (less than 100 m) and the fact that the Curragh/Curragh North operation is located approximately 5 km away. In any case, drawdown to the west from the CNE will be limited by the presence of the CN operation immediately to the west; and,
- There is potential for cumulative impacts between the CNE and the Yarrabee mining area to the east. This is based on the observation that the extent of 2 m drawdown from the CNE is approximately 5,500 m and that the Yarrabee operation occurs approximately 6 km to the east. Therefore there is potential for the cones of depression from these two operations to coalesce.

  It is noted, however, that the drawdown will occur within the Permian coal measures, which are assessed to be hydraulically disconnected from the alluvium (Section 7.4); therefore it is assessed that mining at the CNE, as well as any cumulative impacts with other mining operations, will have no impact on groundwater levels within the alluvium.

7.3 Impacts on Groundwater Quality

Groundwater modelling (Section 6.0) predicts that a permanent cone of depression will develop that will direct groundwater flow towards the final voids; therefore, the risk of the project impacting on water quality (via outflow to the groundwater system) is assessed to be low.

It is, however, assessed that the Project could impact groundwater quality if the water within the final void were able to exit the void via unconsolidated sediments (i.e. the base of Tertiary) and flow via the groundwater system towards sensitive environmental receptors such as 12 Mile Creek. For this reason, an assessment of the potential for water within the final voids to exit the void via the base of Tertiary sediments has been undertaken and is summarised as follows:

- The post-mining final void lake equilibrium level is assessed to be a maximum of 45.3 mAHD (Engeny 2019).
- In the area of the CNE the base of Tertiary is interpreted to be in the order of 120 mAHD, i.e. approximately 70-75 m higher than the final void water level.

It is therefore concluded that there is no possibility of outflow from the final void via the base of Tertiary and that there is a very low risk of the CNE project impacting the water quality of the surrounding groundwater system.

7.4 Potential Impacts to GDE’s

Creeks to the west and east of the project area (Blackwater Creek and Twelve Mile Creek respectively) are ephemeral and available groundwater level data indicates that the regional water table is generally below the base of Tertiary. Groundwater modelling predicts very limited drawdown to the west as the coal seams crop out in this direction and drawdown is limited by the low permeability of the interburden (non-coal) sediments. In addition, the CNE is developed to the east of the already-approved CN operation, therefore any additional drawdown will be to the east rather than to the west in the direction of the CN mine void.

As noted in Section 3.2, groundwater levels in the CN and CNE area are below the base of Tertiary, with water levels in the order of 40 m below ground level compared to a Tertiary thickness of approximately 15 m. An assessment has been undertaken of the potential depth of groundwater beneath 12 Mile Creek, which occurs to the east of the CNE and which may contain groundwater dependent ecosystems (GDE's). Figure 7-1 (below) shows available water level data in the CN and CNE area as well as interpreted water level elevation contours. The contours were developed as follows:

- Depth to groundwater data from geological bores was converted to reduced water level (RWL) data (i.e. the water level elevation in metres relative to the Australian Height Datum (mAHD);
- It is interpreted that the direction of groundwater flow will be from west to east, in the direction of the dip of the coal seams. Based on data from the site geological model and interpretation of available geological data, it is interpreted that the depth to the top of the uppermost coal seams (Castor/Aries Seams) increases from approximately 40 mbgl in the CN area to approximately 300 mbgl at the location of the Yarrabee Fault, which occurs just to the west of 12 Mile Creek;
- A conservative assumption of a 20 m decrease in water level from west to east, from the CNE area to 12 Mile Creek, was made. This equates to a 20 m reduction in water level over a horizontal distance of approximately 4,000 m, giving a hydraulic gradient of 0.005;
- A number of "dummy" points were generated in the area between the CNE (where water level data exists) and 12 Mile Creek, using topographic contours to guide the location of the points. The resulting data set of measured groundwater elevation data and "dummy" points was contoured to produce the groundwater elevation contours that are shown in Figure 7-1.

The groundwater elevation contours were then utilised to produce depth to groundwater contours, which are shown in Figure 7-2. These contours were developed as follows:

- Figure 7-2 shows available depth to groundwater data from geological bores in the CN and CNE areas, with this data utilised to produce the groundwater elevation contours that are shown in Figure 7-1;
- The grid file for the groundwater elevation contours was subtracted from the grid file for the surface topography contours, to produce a gridded surface of depth to groundwater data;
- The resultant depth to groundwater contours were manually smoothed and re-gridded to provide the depth to groundwater contours that are show in Figure 7-2

The depth to groundwater contours show an increase in depth to groundwater from approximately 40 mbgl in the CN/CNE area to approximately 60 mbgl in the area of 12 Mile Creek (a 20 m reduction in water level over approximately 4,000 m at a hydraulic gradient of 0.005, as discussed above).

The depth to groundwater contours, while based on interpretation as discussed above, are useful in demonstrating that the depth to groundwater in the area of 12 Mile Creek is likely to be in the order of 60 mbgl, which is beyond the depth that is accessible by vegetation (it is also noted that, if it is accepted that the direction of groundwater flow is down-dip to the east, then the depth to groundwater must at least be greater than the 40 mbgl that has been measured in the CN/CNE areas).

Figure 7-3 shows the location of potential aquatic and terrestrial GDE's from the BOM groundwater dependent ecosystem atlas, relative to the 5 m and 2 m drawdown predictions at post-mining equilibrium, for mining of the CNE.

From review of the information presented in Figures 7-1 to 7-3 it is concluded that:

- The depth to the regional groundwater level in the area of 12 Mile Creek is greater than 40 mbgl and interpreted to be approximately 60 mbgl;
- Any vegetation along 12 Mile Creek is likely to be dependent on surface water flows and on water that may be periodically stored within alluvium following recharge events;
- Mining at the CNE will have no impact on groundwater levels within the alluvium as mining will only impact on water levels within the Permian sediments and the water level within Permian sediments at the location of 12 Mile Creek is interpreted to significantly below ground level and below the base of alluvium (as any Quaternary alluvium within 12 Mile Creek is interpreted to be thin and of limited extent).

Quaternary alluvium exists to the north of the CNE, associated with the Mackenzie River main channel and flood plains (Figure 7-3). It is noted that the 2 m drawdown contour from CNE operations at post-mining equilibrium is more than 4.5 km from the Mackenzie River and does not extend to within the area of mapped Mackenzie River alluvium (Figure 7-3); therefore, any GDEs that are associated with the Mackenzie River to the north of the CNE are not considered to be at risk from any potential groundwater related impacts corresponding to the CNE.

In summary, it is not expected that the CNE will impact on any GDEs within the vicinity of the CNE project.

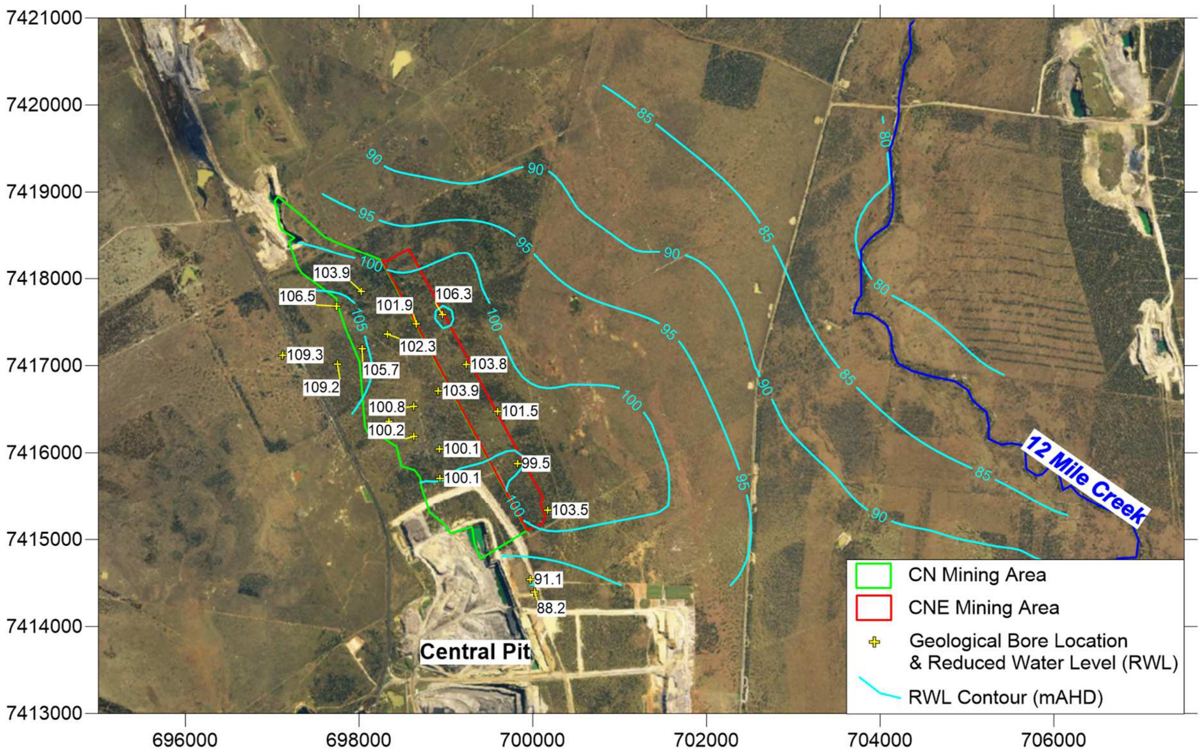


Figure 7-1: Groundwater Elevation Data and Interpretive Contours

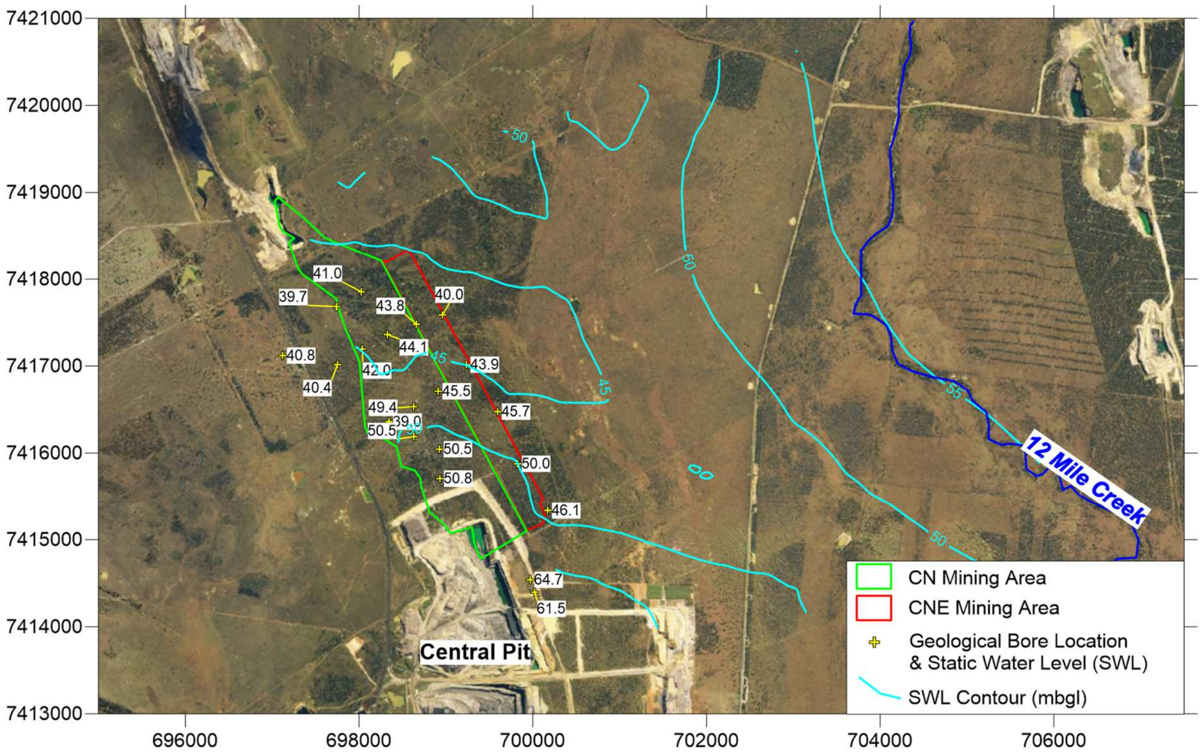


Figure 7-2: Depth to Groundwater Data and Interpretive Contours

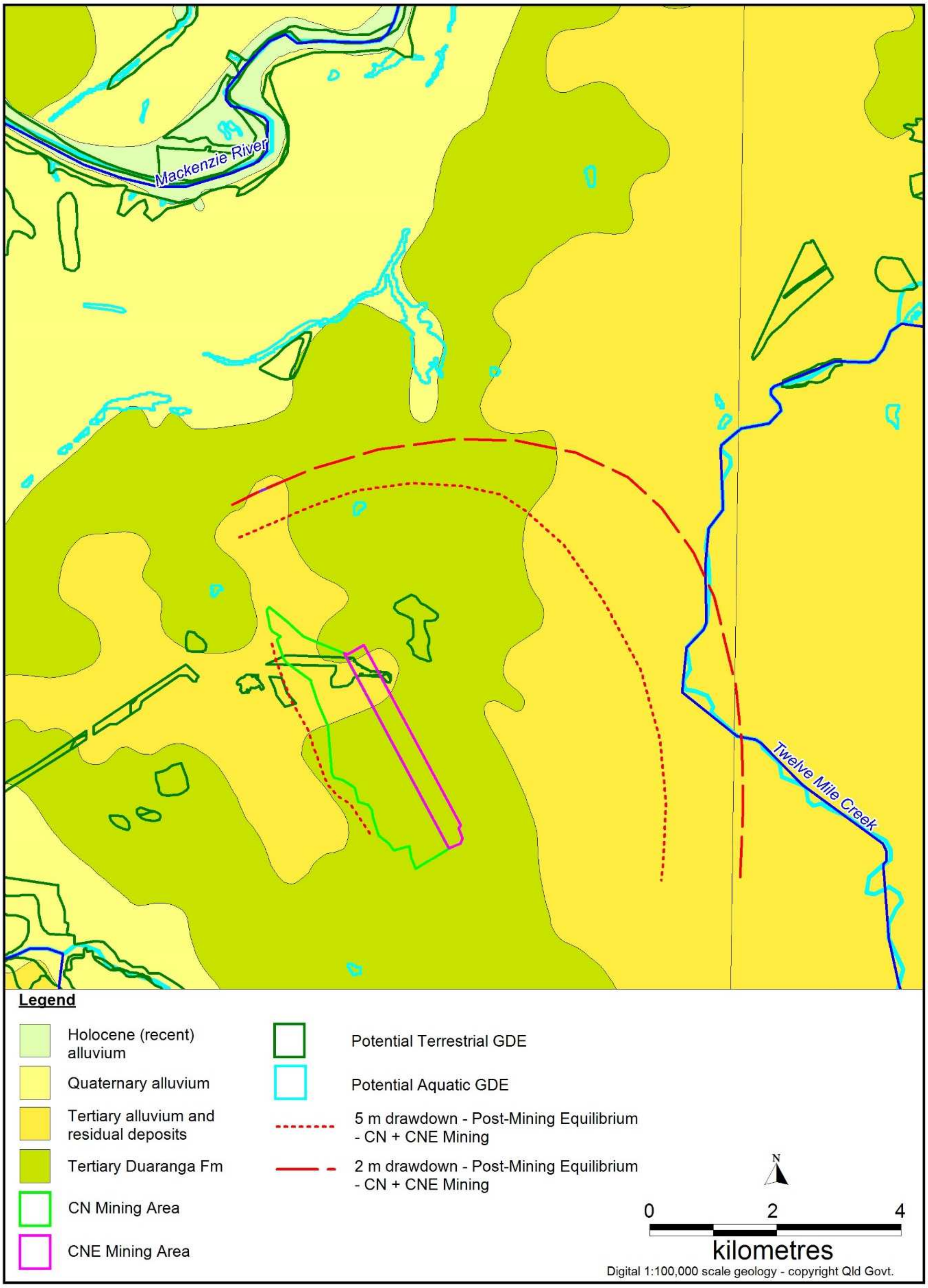


Figure 7-3: Location of Drawdown Contours with Respect to Potential GDE's

8.0 SUMMARY AND CONCUSIONS

The following summary and conclusions are presented following data analysis and modelling undertaken for this report:

- Model Development
  - Two cross-sectional 2-dimensional SEEP/W models were generated for this study, including:
    - Model 1 - a west-east cross-section model in the location of cross-section 2 (Figure 4-3); and,
    - Model 2 – a long section model oriented approximately north-south (Figure 4-4) that extends from the existing Jellinbah Central pit (in the south) to a location that is north of the Mackenzie River.
  - Two scenarios were run for each model, as follows:
    - For scenario 1 the area of mining for the already-approved CN mining area was removed and the extent of drawdown at 100 years post-mining was calculated; and,
    - For scenario 2 the extent the area of mining for the CNE was removed from the model, so that mining of both the CN and CNE mining areas was simulated. The extent of drawdown for mining of both the CN and CNE operations was calculated, to allow prediction of the additional drawdown that would be associated with the CNE operation relative to mining of the CN operation only;
- Model Results - results from modelling are shown in Figure 6-5 and predict:
  - On the eastern (high wall) side of the mining area the 5 m extent of drawdown is approximately 3,500 m from the pit crest at post-mining equilibrium (drawdown results at 150 years post-mining were utilised as post-mining equilibrium for all model results), for the CN operation only. With the CNE operation included, the extent of 5 m drawdown extends to approximately 3,750 m from the pit crest at post-mining equilibrium (an increase of 250 m relative to the CN mining only case). The CNE operation extends mining by approximately 360 m to the east and extends the depth of mining from approximately 125 mbgl to 150 mbgl.

    The 2 m drawdown contour extends approximately 5,250 m from the pit crest for the post-mining equilibrium, CN-only case and approximately 5,500 m from the pit crest for the post-mining equilibrium CNE case (an increase of approximately 250 m relative to the CN-only case). The 2 m drawdown contour therefore extends beneath 12 Mile Creek in some areas, as shown in Figure 6-6.
  - On the western (low wall) side of the mining area the 5 m and 2 m extent of drawdown contours do not extend appreciably (by less than 100m) due to mining. This is interpreted to be related to the lack of coal measures to the west of the mining area (due to the dip of the strata) and the relatively low permeability of the Burngrove Formation, which is the dominant unit to the west of the mining area;
  - On the northern side of the mining area the 5 m extent of drawdown is approximately 2,300 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,400 m from the pit crest for the CNE case. The difference in drawdown to the north, relative to the modelled drawdown to the east, is interpreted to be related to the variability of the geology to the north, relative to the east.

The 2 m drawdown contour extends approximately 2,400 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,800 m from the pit crest for the CNE case.

It is noted that no mining was assumed for the area to the north of the CN/CNE mining areas. The intent of the model was to establish any additional drawdown that may be due to mining in the CNE area. However it is judged that, in reality, any significant drawdown to the north is unlikely due to the existing impacts of mining in the Jellinbah Plains area.

  - No drawdown was considered to the south as the model terminates in the south at the Jellinbah Central mined void. The groundwater elevation is held constant at the southern boundary of the model at the floor elevation of the Jellinbah void.

- Sensitivity analysis - a sensitivity analysis was undertaken for five scenarios, where key model input parameters including vertical and hydraulic conductivity, storage parameters and recharge were altered by factors of between 2 (i.e. doubled) and 10. The results of the sensitivity analysis are summarised as follows:
  - Scenario 1 - An increase in the Kh of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 1,250 m (to the east) and 340 m (to the north), as shown on Figure 6-6. The variability in the extent of the 5 m drawdown contour is related to dominant rock type in each direction;
  - Scenario 2 - An increase in the Kz of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 2,300 m (to the east) and 1,600 m (to the north), as shown on Figure 6-6. The model is more sensitive to changes in Kz than Kh;
  - Scenario 3 - An increase in the specific yield (Sy) of the coal seams by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-860 m to the east and -560 m to the north) relative to the base case;

    A lower value for *mv* (and *Ss*) indicates a geotechnically stiffer (less compressible) aquifer. An increase in the aquifer *mv* (and hence *Ss*) will result in a more compressible aquifer, which will act to decrease the extent of drawdown.
  - Scenario 4 - An increase in the specific yield (Sy) of the non-coal Triassic and Permian sediments by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-1490 m to the east and -780 m to the north) relative to the base case;
  - Scenario 5 – An increase (doubling) in the rate of recharge results in a decrease in the extent of the 5 m drawdown contour at post-mining equilibrium of -1,150 m to the east and -740 m to the north of the CNE.

  The results highlight the sensitivity of the model to changes in key parameters and the need to utilise realistic model inputs (hydraulic parameters, recharge) for the base-case model.

  It is noted that the Tertiary sediments at site are dry and that the regional groundwater system is developed within the Permian coal measures and is assessed to be disconnected from the surface water systems and alluvium (refer Section 7.4). Therefore it is concluded that variability in model input parameters from those used in the base-case model will only affect groundwater levels within Permian sediments and is unlikely to have practical impacts on water levels within the shallow groundwater systems in the area (i.e. alluvial aquifers).

- The potential for groundwater impacts from mining is summarised as follows:
  - Impacts on existing groundwater users – no impacts are predicted on existing groundwater users as:
    - there are no private groundwater bores within the area of the images shown in Figure 6-5 (base case drawdown) or Figure 6-6 (sensitivity analysis); and,
    - There are no existing registered private groundwater bores in the area between the Jellinbah and Curragh/Curragh North mining lease areas (i.e. to the west of the CNE) or in the area between the Jellinbah and Yarrabee mining lease areas (i.e. to the east to the CNE).
  - Impacts on groundwater quality are summarised as follows:
    - a permanent cone of depression will develop that will direct groundwater flow towards the final voids;
    - There could be potential for water within the final void to impact on the groundwater system if outflow were possible via unconsolidated sediments (i.e. the base of Tertiary), which could direct flow via the groundwater system towards sensitive environmental receptors such as 12 Mile Creek. This was assessed to be not possible as:
      - The post-mining final void lake equilibrium level is assessed to be a maximum of 45.3 mAHD (Engeny 2019); and,
      - In the area of the CNE the base of Tertiary is interpreted to be in the order of 120 mAHD, i.e. approximately 70-75 m higher than the final void water level.

      It is therefore concluded that there is no possibility of outflow from the final void via the base of Tertiary and that there is a very low risk of the CNE project impacting the water quality of the surrounding groundwater system.
  - Potential for impacts on GDE's - it is not expected that the CNE project will have any impacts on GDE's as:
    - The depth to the regional groundwater level in the area of 12 Mile Creek is greater than 40 mbgl and interpreted to be approximately 60 mbgl;
    - Any vegetation along 12 Mile Creek is likely to be dependent on surface water flows and on water that may be periodically stored within alluvium following recharge events;
    - Mining at the CNE will have no impact on groundwater levels within the alluvium as mining will only impact on water levels within the Permian sediments and the water level within Permian sediments at the location of 12 Mile Creek is interpreted to significantly below ground level and below the base of alluvium (as any Quaternary alluvium within 12 Mile Creek is interpreted to be thin and of limited extent).
    - Quaternary alluvium exists to the north of the CNE, associated with the Mackenzie River main channel and flood plains (Figure 7-3). It is noted that the 2 m drawdown contour from CNE operations at post-mining equilibrium is more than 4.5 km from the Mackenzie River and does not extend to within the area of mapped Mackenzie River alluvium (Figure 7-3); therefore, any GDEs that are associated with the Mackenzie River to the north of the CNE are not considered to be at risk from any potential groundwater related impacts corresponding to the CNE.

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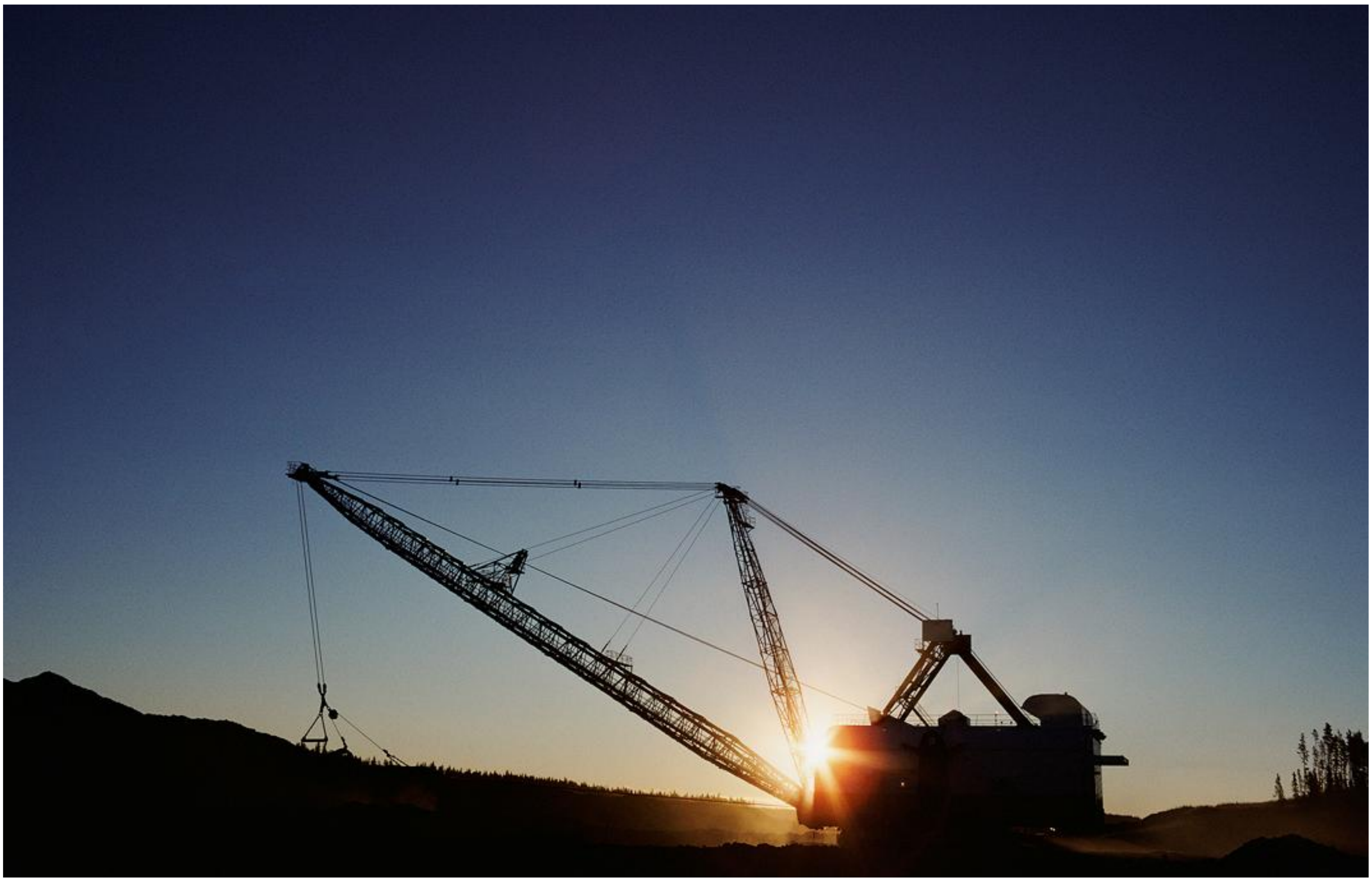
Jellinbah Resources

Jellinbah Stage 3 Levee — Consequence Assessment Report

14 August 2015



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1. Introduction

This report has been provided by Parsons Brinckerhoff Australia Pty Ltd (PB) on behalf of Jellinbah Mining to describe the details of the Consequence Category Assessment for the proposed design of the Stage 3 levee. The Stage 3 levee runs parallel to Mackenzie River on the northern bank and connects to the existing Stage 2 Levee to prevent flooding of the mine pits. As a result of the increased flood levels the western sides of the Stage 1 and 2 Levee are being raised. The Consequence Category Assessment was performed in accordance to the Department of Environment and Heritage Protection (DEHP) “Manual for Assessing Consequence Categories and Hydraulic Performance of Structures – Version 4” (November 2013).

2. Background

2.1 Project scope and location

Jellinbah Mine is an open cut coal mine located in Central Queensland approximately 180 km west of Rockhampton. It is located within the Duaringa Shire on the southern side of the Mackenzie River and is approximately 30 km north-east of Blackwater.

The proposed expansion of the mine would see the progression of the established open cut pit on the southern floodplain of the Mackenzie River further north towards the watercourse.

Parsons Brinckerhoff previously undertook the design and construction supervision of Stage 1 (2008) and Stage 2 (2010) of the levee. The Stage 1 levee was constructed as a U-shaped embankment between the topographic high, referred to locally as ‘Tertiary Ridge’ and the southern side of a flood return gully referred to as the ‘anabranch’. The Stage 2 levee was constructed as a northern extension of Stage 1 levee, along the western lease boundary up to the southern bank of the Mackenzie River and return along the eastern lease boundary to the eastern leg of the existing levee. Consistent with the existing levee, the Stage 2 levee was constructed around the perimeter of the proposed mine extension to provide protection from flood events up to the 1 in 1,000 year Annual Exceedance Probability (AEP) event.

The ultimate Stage 3 flood protection levee is anticipated to be similar to those constructed previously with an approximate length of 3 km. The levee embankment is anticipated to be mainly about 2 m to 4 m high with higher sections where it crosses the anabranch and other gullies. Locally available alluvial material is anticipated to be used for construction. The east-west trending portion of the Stage 2 levee is to be removed following the construction of the Stage 3 levee and the conclusion of the Stage Two mining activities. As the crest level on the Stage 3 levee is higher than the current Stage 1 and 2 levee, the Stage 1 and 2 levee crest level will be lifted to the new 1 in 1,000 year AEP event level.

Provided in Appendix A is a layout of the proposed Stage 3 levee (Drawing 2188238A-CIV-0002).

2.2 Hydrology

Detailed hydrologic and hydraulic analysis, report reference 0684-04-C1, of the nearby Mackenzie River was undertaken using flood models previously developed by WRM Water and Environment Pty Ltd (WRM) for other nearby projects, in particular, Wesfarmers’ Curragh North Pit V Expansion Project and Jellinbah Resources’ Mackenzie North Project.

The above referenced report by WRM presents hydrology and hydraulic performance of the site and should be read in conjunction with this report.

3. Methodology

The methodology adopted for the Consequence Category Assessment of the proposed Stage 3 levee comprised of the following tasks:

- desktop review of reports and drawing
- use of DEHP manual for identifying the consequence category for the Stage 3 levee ("Manual for Assessing Consequence Categories and Hydraulic Performance of Structures – Version 4, November 2013").

4. Legislative requirements and guidelines

4.1 Legislative requirements

Under the current legislation, the Queensland Department of Environment and Heritage Protection regulates dams in Queensland under provisions of the *Environmental Protection Act 1994*, licensed through an Environmental Authority (EA) for the mine. The site operates under Environmental Authority (EA) EPML00516813. Table 4.1 lists the EA conditions pertaining to the consequence category assessment.

Table 4.1 Environmental Authority – Consequent category assessment conditions

EA Condition Number	Condition
D1	The hazard category of any dam must be addressed and certified by a suitably qualified and experienced person: 1. In accordance with the "Manual for Assessing Hazard Categories and Hydraulic Performance of Structures – Version 4". 2. In any of the following situations: a) Prior to the design and construction of the structures b) prior to any change in its purpose or its stored contents c) In accordance with the "Manual for Assessing Hazard Categories and Hydraulic Performance of Structures – Version 4".
D2	A hazard assessment report and certification must be prepared for any structure assessed and the report may include a hazard assessment for more than one structure.
D3	The holder must, on receipt of the hazard assessment report and certification, provide to the administering authority one paper copy and one electronic copy of the hazard assessment report and certification.

4.2 Criteria and assessment to determine consequence category

The likely consequence impacts of the Stage 3 levee were identified upon a review of design drawings along with site visits inspecting the relevant areas for the "failure to contain" and "dam break" scenarios given in the DEHP Manual for Assessing Consequence Categories and Hydraulic Performance of Structures – Version 4, November 2013.

Tables 4.2 and 4.3 from the DEHP Manual for Assessing Consequence Categories and Hydraulic Performance of Structures – Version 4, November 2013 were used in the consequence category assessment.

The consequence category of the levee is classified into three categories which are "low", "significant" or "high" category. Table 1 of the DEHP manual (reproduced here as Table 4.2) contain the criteria for assessing the consequence category based on impacts from the different failure scenarios. The highest category determined from Table 4.2 is adopted as the overall consequence category of the levee.

Based on the consequence category and whether the levee is a regulated structure, the DEHP manual provides guidance on the AEP for the levee as reproduced in Table 4.3.

Table 4.2 Failure to contain scenarios

Environmental harm	Consequence category		
	High	**Significant**	**Low**
Harm to humans	Location such that people are routinely present in the failure path and if present loss of life to greater than 10 people is expected[2]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario	Location such that people are routinely present in the failure path and if present loss of life to 1 person or greater but less than 10 people is expected[2] Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario	Location such that people are not routinely present in the failure path and loss of life is not expected[2] Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario
	Location such that contamination of waters (surface and/or groundwater[3]) used for human consumption could result in the health of 20 or more people being affected[4]	Location such that contamination of waters (surface and/or groundwater[3]) used for human consumption could result in the health of 10 or more people but less than 20 people being affected	Location such that contamination of waters (surface and/or groundwater[3]) used for human consumption could result in the health of less than 10 people being affected
General environmental harm	Location such that: ▪ contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions of this authority subject to any applicable offset commitment (significant values) ▪ adverse effects[5] on significant values are likely ▪ the adverse effects are likely to cause at least one of the following: ‣ loss or damage or remedial costs greater than $50,000,000 ‣ remediation of damage is likely to take 3 years or more ‣ permanent alteration to existing ecosystems ‣ the area of damage (including downstream effects) is likely to be at least 5 km^2	Location such that contaminants may be released so that adverse effects (that are not already authorised to be disturbed to at least the same extent under other conditions of this authority subject to any applicable offset commitment) either: ▪ would be likely to be caused to Significant values but those adverse effects would not be likely to meet the thresholds for the High consequence category and instead would be likely to cause at least one of the following: ‣ loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000 ‣ remediation of damage is likely to take more than 6 months but less than 3 years ‣ significant alteration to existing ecosystems ‣ the area of damage (including downstream effects) is likely to be at least 1 km^2 but less than 5	Location such that either: ▪ contaminants are unlikely to be released to areas of Significant Values or Moderate Values ▪ contaminants are likely to be released to those areas, but would be unlikely to meet any of the minimum thresholds specified for the significant consequence category for adverse effects

Environmental harm	Consequence category		
	High	**Significant**	**Low**
		km^2 ■ would be likely to be caused to environmental values classed as slightly or moderately disturbed waters[6] , wetland of general ecological significance[7], riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the adverse effects are likely to cause at least one of the following: ▸ loss or damage or remedial costs greater than $20,000,000 ▸ remediation of damage is likely to take more than 1 year ▸ significant alteration to existing ecosystems ▸ the area of damage (including downstream effects) is likely to be at least 2 km^2	
General economic loss or property damage	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or rectification costs8.	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs8.	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require less than $1 million in rehabilitation, compensation, repair or rectification costs8.

(1) To be used for all failure event scenarios

(2) People routinely present in the failure path' could be considered to be people who occupy buildings or other places of occupation that lie within the failure impact zone. For the purposes of this Manual, this should refer to people other than site personnel engaged by the resource operation and located on the tenements and tenure associated with the resource operation; for other ERAs, it would be the 'premises referred to in the authority'. It should be noted that while this is appropriate for the assessment of consequence categories in accordance with this Manual, adherence to the requirements of this Manual does not limit, amend or change in any way, any other requirements to be complied with under relevant health and safety acts or legislation that requires the safety of site personnel to be considered

(3) When considering potential impacts on groundwater, it is not envisaged that a full hydrogeological assessment will be required in all cases. Any consideration of potential impacts on groundwater systems should consider the water quality of the potential receiving aquifer as well as the quality of fluid stored in the regulated dam. Existing groundwater drawdown in areas surrounding resource operations (e.g. drawdown as a result of mine pit or underground mine dewatering) can also be considered when assessing the consequence of dam seepage on groundwater systems

(4) 'An adverse effect on human health means a physiological effect on human health and does not include an impact on the quality of downstream water that merely negatively affects taste and which is unlikely to cause persons to become physically ill

(5) Adverse effects includes chronic and acute effects where an acute effect is on living organism/s which results in severe symptoms that develop rapidly, and a chronic effect is an adverse effect on a living organism/s which develops slowly. In some instances, it may be necessary to carry out or reference existing ecological/toxicological studies to assess the impacts of contaminants on living organisms

(6) See Water EPP for definitions

(7) Wetland of general ecological significance' means a wetland shown on a map of referable wetland as a 'general ecologically significant wetland' or 'wetland of other environmental value'

(8) This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder

Table 4.3 Hydrological design criteria

Consequence category for 'dam break'scenario[19]	Design criteria — flood level for embankment crest levels
Levees determined to be regulated structures[20]	1: 1000 AEP

(19) The design criteria identified in this table are relevant to a dam break scenario that is caused by flood ingress over the tops of the banks. As such, they are not relevant to dam break failure modes where no overtopping occurs, such as failure caused by piping. Consideration by the suitably qualified and experienced person may need to be given to the appropriateness of the consequence category for the 'dam break' scenario and the correct application of the design criteria in this table if there is a significant difference in consequence between the different failure modes

(20) Refer definition of a levee. Table 4.3 consequence assessments are not necessarily used to assign a consequence category to a levee; refer to the Appendix for further guidance. All regulated levees are required to provide a minimum of 1:1000 AEP flood protection

4.3 Failure to contain scenario

The failure to contain scenario describes the consequences and failure modes of the levee when it fails to contain its contents. Typical failure modes that could occur for the "failure to contain" scenario could include the following:

- seepage through foundation or the levee embankment
- storm event in exceedance of the design AEP.

4.4 Dam break scenario

The "dam break" scenario describes the consequences and failure modes of the levee for the case where the levee embankment fails. Typical failure modes that could occur for the "dam break" scenario could include the following:

- levee embankment batter slope instability
- settlement and loss of freeboard
- erosion of levee embankment
- internal erosion and piping of levee embankment
- liquefaction of foundation and/or levee embankment.

4.5 Contaminant concentrations

While the contaminant concentration table has been removed from Version 4 of the DEHP manual, the table from the previous superseded version (Version 3.1) has been used as a guide to distinguish between low and significant consequence categories under the general environmental harm attribute. Relevant columns of this table are reproduced in Table 5.1 of this report. If the contaminant levels exceed but are close to those nominated in Table 3 of Version 3.1, the relevant consequence category is deemed to be low.

Neither the current nor previous versions of the manual provide cut-off concentration levels between significant and high consequence categories. For purposes of this design process, the consequence category is deemed to be high if at least one chemical concentration is approximately five times the limit shown in Table 5.1.

5. Levee data

5.1 Levee details

5.2 Typical cross section

The typical cross section of the Stage 3 levee extension varies as described below and shown on drawings 2188238A-CIV-0110 and 2188238A-CIV-0210 in Appendix A.

5.2.1 Stage 3

The typical cross section features for the Stage levee are:

- 5 m crest width
- 1V:3H batter slope on river side
- 1V:2H batter on pit side for heights under 7 m
- 1V:3H batter on pit side for heights over 7 m
- 3% one way crossfall to pit side
- 0.25 m topsoil respread and grass seed to batters.

5.2.2 Stage 1 and 2 lift

The typical cross section features for the Stage 1 and 2 levee lift are:

- 5 m crest width
- 1V:3H batter slope on river side
- Interface with proposed haul road on pit side
- 3% one way crossfall to pit side
- 0.25 m topsoil respread and grass seed to batters
- excavation of spoil dump next to the existing levee, to construct general fill under the levee lift.

5.3 Horizontal alignment

5.3.1 Stage 3

The alignment of the flood protection levee has been provided by Jellinbah Resources (Jellinbah) based on their current mine planning. The alignment provided by Jellinbah formed the centre-line for the levee design. It has been ensured that the associated river sides batters remains inside the clearance zones. The eastern and western wings of the levee tie into Stage 2. The northern section of the levee runs parallel to the Mackenzie River.

The total length of the Stage 3 levee is 3,766m.

5.3.2 Stage 1 and 2 lift

The alignment of the Stage 1 and 2 lift follows the existing alignment of the Stage 1 and 2 levee.

The total length of the Stage 1 and 2 lift is 2,458 m.

5.4 Vertical alignment

5.4.1 Stage 3

The south-eastern end of the Stage 3 levee extension joins to the crest level of the existing Stage 2 levee at RL 127.76. The crest level decreases at a slight grade to tie into the existing eastern levee at RL 124.86 at the western end. The crest level along the levee has been set by the hydrological modelling (refer to Section 4) with a 0.5m freeboard.

5.4.2 Stage 1 and 2 lift

The Stage 1 and 2 lift is raising the crest level of the existing levee due to increase in flood height. The southern end of the lift is at RL 127.805. The crest level decreases at a slight grade to RL 127.762 at the northern end. The crest level along the levee has been set by the hydrological modelling (refer to Section 4) with a 0.5m freeboard.

5.5 Water quality

The water quality information is the most recent representative water quality data, from June 2015, and has been used in this assessment. These sets of results, along with Version 3.1 DEHP limits are summarised in Table 5.1.

Table 5.1 Water quality data

Contaminant	Version 3.1 DEHP limits (liquor)	Results from 26/6/2015 (liquor) [1, 2]
Arsenic	1.0 mg/L	0.005
Boron	5.0 mg/L	-
Cadmium	0.01 mg/L	0.001
Cobalt	1.0 mg/L	0.005
Copper	1.0 mg/L	0.005
Lead	0.5 mg/L	0.005
Mercury	0.002 mg/L	-
Nickel	1.0 mg/L	0.007
Selenium	0.02 mg/L	-
Zinc	20 mg/L	0.005
Cyanide (un-ionised HCN)	10 mg/L	-
pH	Outside 5 to 9 (range)	8.7
TPH C6 – C36	90 mg/L	-
TPH C6 – C14	60 mg/L	-
Benzene	0.1 mg/L	-
Phenol	3 mg/L	-
Benzo(a)Pyrene	0.001 mg/L	-
Chloride	2,500 mg/L	-
Fluoride	2.0 mg/L	0.5
Sulphate	1,000 mg/L	120
Salinity (electrical conductivity)	4,000 µS/cm	19,000

(1) Total solids not sampled

(2) " –" indicates not sampled

6. Consequence category assessment results

6.1 Failure to contain - overtopping

Only the salinity exceeds the limit in Table 5.1. Accordingly the failure to contain - general environmental harm is assessed as Significant.

The failure to contain – overtopping consequence category is deemed to be Significant.

The results of the “failure to contain” scenario can be summarised below:

Table 6.1 Consequence category results (failure to contain scenario)

Environmental harm	Consequence category
Harm to humans	Low
General environmental harm	Significant
General economic loss or property damage	Low

6.2 Dam break

For the approval of the 22 km long levee at Curragh North Mine, the Director Dam Safety of the then Department of Natural Resources and Mines required a failure impact assessment for the levee, not from an inward collapse toward the pit, but for a breach discharge into the Mackenzie River under the hypothetical condition of water confined within the levee up to the embankment crest level (PB, 2005). The hydraulic analysis was undertaken along an approximately 100 km reach of the river with a dozen homesteads above the banks. The breach volume was based on the total area enclosed by the levee (21.7 km^2). No homestead would be inundated and thus the population at risk (PAR) was zero.

By comparison, the total area enclosed by the Jellinbah levees downstream would be 6.85 km^2. The difference in area is clear from the plan in Appendix B figure 2.1. Accordingly a breach of Stage 3 levee would result in no PAR for the homesteads along the river.

For a breach inwards toward the pit, Table 4.2 note 2 excludes 'site personnel engaged in the resource operation' when assessing PAR. No non mine people are involved.

The failure to contain – harm to humans attribute is assess as Low.

Failure of levee inwards would cause ingress of floodwater resulting in an excessive accumulation of contaminated waters, particularly in the pit. Under the general environmental harm for dam break, the consequence category is deemed to be significant.

The results of the “dam break” scenario can be summarised below:

Table 6.2 Consequence category results (dam break scenario)

Environmental harm	Consequence category

Environmental harm	Consequence category
Harm to humans	Low
General environmental harm	Significant
General economic loss or property damage	Low

6.3 Summary

Based on the Consequence Category Assessment using the “Failure to contain” and “Dam break” scenario criteria given in Table 4.1 results indicate that the Stage 3 levee is classified as consequence category Significant. Table 4.2 – Hydrological design criteria indicates that all regulated levees are required to provide a minimum of 1 in 1000 AEP flood protection with 0.5 m freeboard.

7. Conclusion

As stated in the DEHP manual the Consequence Category of the levee is the highest consequence category under any of the assessment criteria for “Failure to Contain” and “Dam Break” scenarios.

Based on the failure event scenarios given in Section 6.1 and 6.2, the consequence category is Significant for the Stage 3 levee and is to be designed for a minimum of 1 in 1000 years AEP with 0.5 m freeboard.

8. References

Queensland Department of Environment and Heritage Protection, 2013. Manual for Assessing Consequence Categories and Hydraulic Performance of Structures, EM635 Version 4, November 2013.

Queensland Department of Environment and Resource Management, 2012. Manual for Assessing Hazard Categories and Hydraulic Performance of Dams, EM635 Version 3.1, February 2012.

Queensland Department of Environment and Heritage Protection, Environmental Authority (EA) EPML00516813.

Parsons Brinckerhoff, 2005. Curragh North Mine Levee System Failure Impact Assessment, October 2005.

9. Certification

Name of Registered Professional Engineer: Brian Philip Walford

Address: 30 Glenrosa Road, Red Hill, Brisbane, Queensland, 4059

Statement of relevant experience

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of certification

All relevant material relied upon by me is provided in this report *2015 Consequence Category Assessment* (2188238-CIV-REP-0002) dated 12th August 2015.

I hereby certify that the Consequence Category Assessment report entitled *2015 Consequence Category Assessment (*2188238-CIV-REP-0002) dated 12th August 2015 for the design of the Jellinbah Stage 3 Levee.

I, Brian Philip Walford, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed:____________________RPEQ No 4141

Date: 12th August 2015

10. Limitations

10.1 Scope of services and reliance of data

This report has been prepared in accordance with the scope of work/services set out in the contract, or as otherwise agreed, between Parsons Brinckerhoff and the client. In preparing this report, Parsons Brinckerhoff has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, Parsons Brinckerhoff has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Parsons Brinckerhoff will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Parsons Brinckerhoff.

10.2 Study for benefit of client

This report has been prepared for the exclusive benefit of the client and no other party. Parsons Brinckerhoff assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with in this report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in this report (including without limitation matters arising from any negligent act or omission of Parsons Brinckerhoff or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in this report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

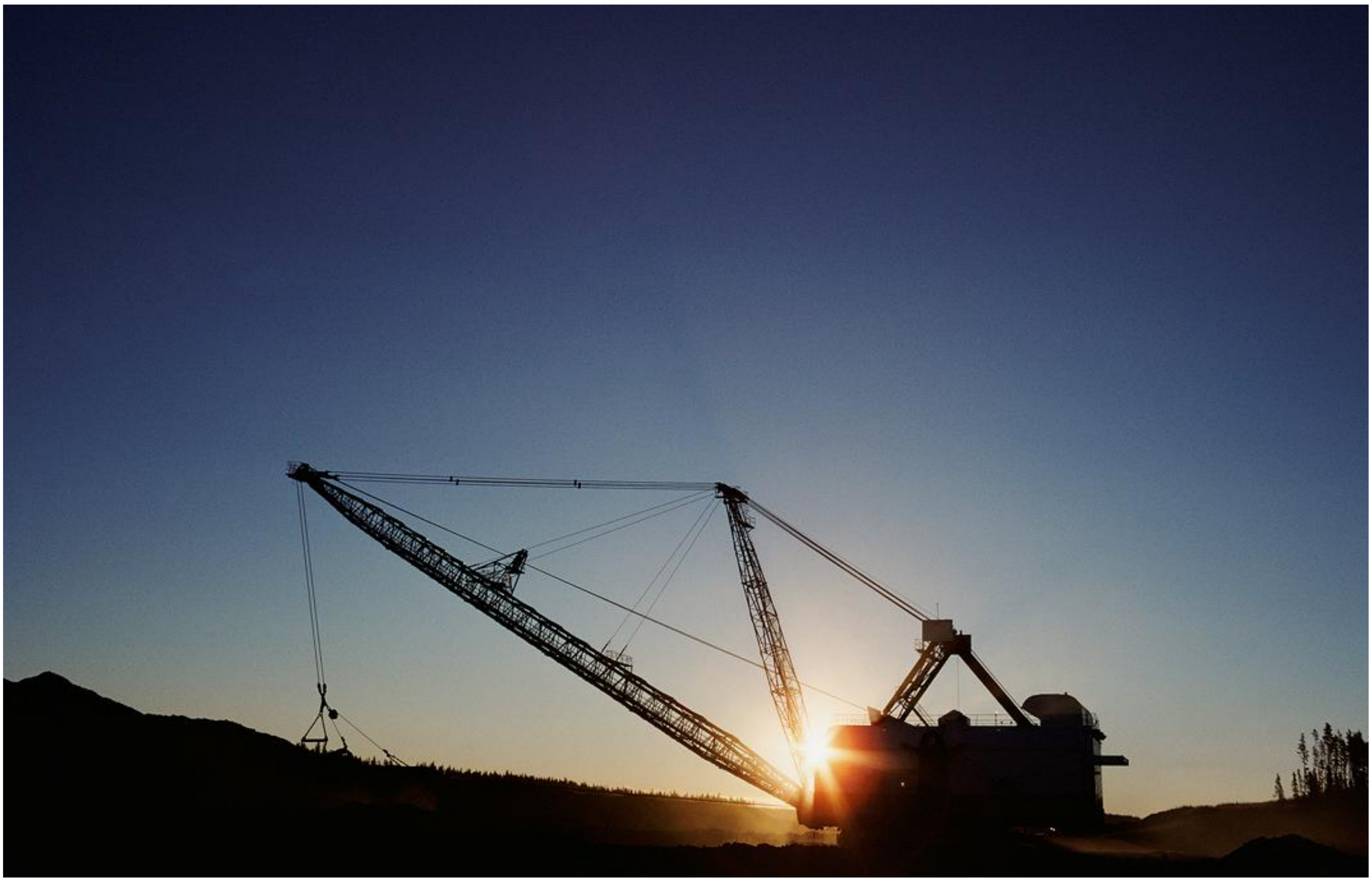
10.3 Other limitations

To the best of Parsons Brinckerhoff's knowledge, the facts and matters described in this report reasonably represent the conditions at the time of printing of the report. However, the passage of time, the manifestation of latent conditions or the impact of future events (including a change in applicable law) may have resulted in a variation to the conditions.

Parsons Brinckerhoff will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

Appendix A

Drawings



A1. Drawings

2188238A-CIV-0001

JELLINBAH RESOURCES

JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3

LOCALITY PLAN
SCALE 1:50000

DRAWING INDEX

GENERAL

2188238A-CIV-0001	LOCALITY PLAN AND DRAWING INDEX
2188238A-CIV-0002	OVERALL SITE PLAN, GENERAL NOTES AND LEGEND

FLOOD LEVEE STAGE 3

2188238A-CIV-0100	PLAN AND LONGITUDINAL SECTION SHEET 1
2188238A-CIV-0101	PLAN AND LONGITUDINAL SECTION SHEET 2
2188238A-CIV-0102	PLAN AND LONGITUDINAL SECTION SHEET 3
2188238A-CIV-0110	TYPICAL SECTIONS
2188238A-CIV-0111	TIE IN DETAILS

LEVEE RAISE

2188238A-CIV-0200	PLAN AND LONGITUDINAL SECTION SHEET 1
2188238A-CIV-0201	PLAN AND LONGITUDINAL SECTION SHEET 2
2188238A-CIV-0202	PLAN AND LONGITUDINAL SECTION SHEET 3
2188238A-CIV-0203	PLAN AND LONGITUDINAL SECTION SHEET 4
2188238A-CIV-0210	TYPICAL SECTIONS
2188238A-CIV-0220	CROSS SECTIONS SHEET 1
2188238A-CIV-0221	CROSS SECTIONS SHEET 2

100mm AT FULL SIZE

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 500 1000 2000 3000
Full Size 1:50000 ; Half Reduction 1:100000
SCALE (m)

A1 ORIGINAL
DO NOT SCALE THIS DRAWING - USE FIGURED DIMENSIONS ONLY VERIFY ALL DIMENSIONS ON SITE
APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE 14/8/15 RPEQ No. 4141

PARSONS BRINCKERHOFF
ABN 80 078 004 798
Level 4, Northbank Plaza
69 Ann Street
Brisbane QLD 4000
GPO BOX 2907
Brisbane QLD 4001
Australia
Telephone +61 7 3854 6200
Facsimile +61 7 3854 6500
Email: brisbane@pb.com.au

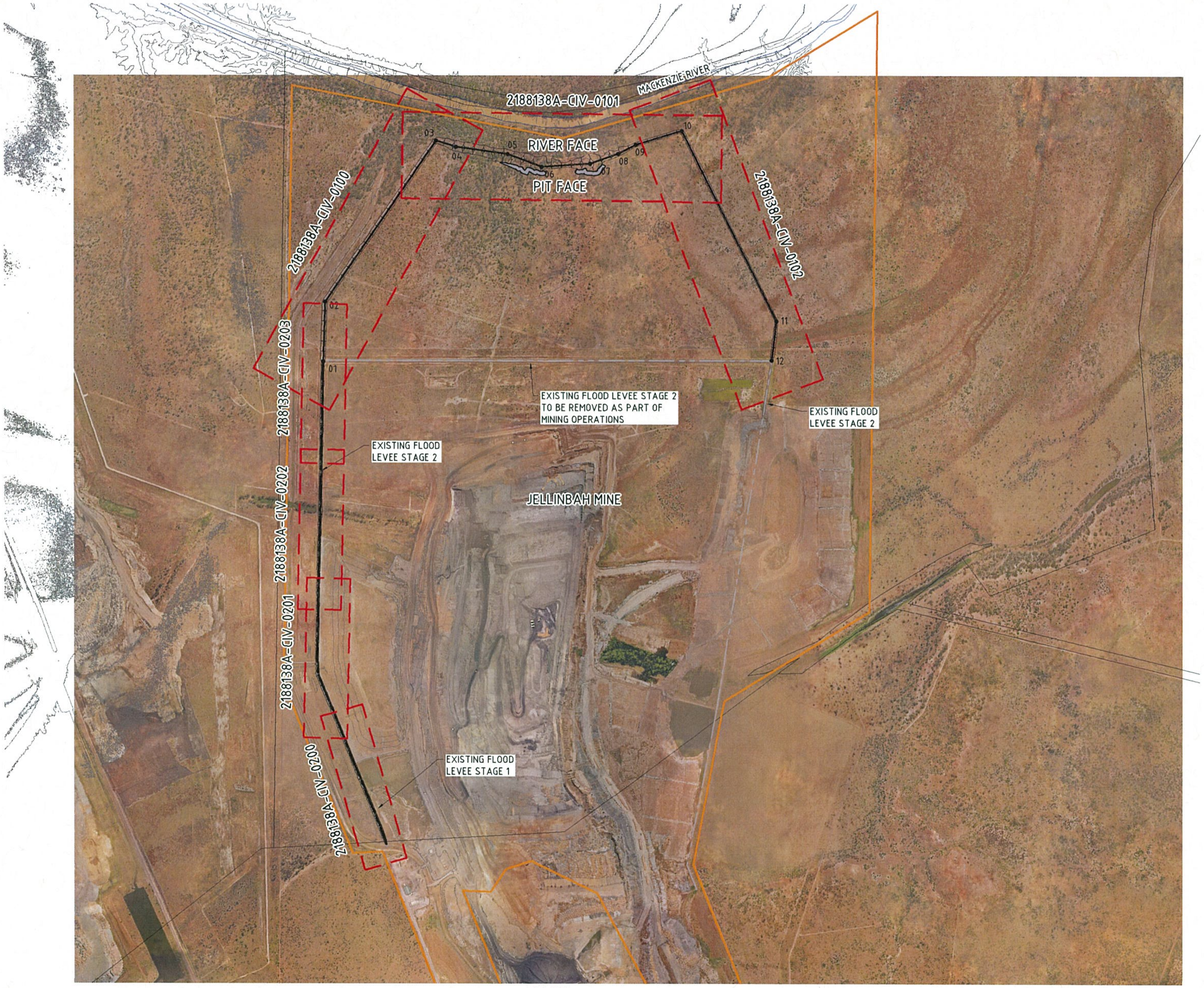
CLIENT
Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
GENERAL
LOCALITY PLAN AND DRAWING INDEX

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0001	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:45 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0001.dwg

2188238A-CIV-0002



GENERAL NOTES

1. ALL CONSTRUCTION WORK SHALL COMPLY WITH THE QUEENSLAND WORK HEALTH AND SAFETY ACT AND THE COAL MINING SAFETY AND HEALTH ACT AND REGULATIONS (CURRENT VERSIONS). CONTACT THE NEAREST OFFICE OF THE DIVISION OF WORKPLACE HEALTH AND SAFETY FOR INFORMATION.
2. THE CONTRACTOR SHALL TAKE ALL REASONABLE AND PRACTICAL MEASURES TO PREVENT OR REDUCE HARM TO THE ENVIRONMENT AS SET OUT IN THE ENVIRONMENTAL PROTECTION ACT (CURRENT VERSION), AS PER THE ENVIRONMENTAL AUTHORITY AND EMP's FOR THE SITE.
3. OBTAIN A PERMIT TO DIG PRIOR TO ALL EXCAVATION.
4. MANUALLY EXPOSE AND LOCATE ALL EXISTING SERVICES WHEN EXCAVATING, OR WORKING, CLOSER THAN 10m.
5. EXISTING GROUND LEVELS, LEVEE HEIGHTS AND DRAIN INVERTS TO BE CONFIRMED ON SITE.
6. EROSION AND SEDIMENT CONTROL MEASURES SHALL BE CARRIED OUT IN ACCORDANCE WITH THE SITE LICENSE.

LEGEND

PROPOSED

LEVEE CENTRE LINE

EXISTING

EXISTING MAJOR CONTOUR (2.0m INTERVAL)
EXISTING MINOR CONTOUR (0.5m INTERVAL)
MINE LEASE BOUNDARY
CADASTRAL BOUNDARY
WATER COURSE

SETOUT

1. CONTROL LINE SETOUT INFORMATION HAS BEEN PROVIDED ON THE DRAWINGS AND ADDITIONAL SETOUT INFORMATION IN DIGITAL MODEL FILES.
   1.1. STAGE 1 AND 2
   - **2188238A-CIV-9000.dxf**

   1.2. STAGE 3
   - **2188238A-CIV-9100.dxf**
   - **2188238A-CIV-9110.dxf**
   - **2188238A-CIV-9120.dxf**
   - **2188238A-CIV-9130.dxf**
2. IT IS THE CONTRACTORS RESPONSIBILITY TO CHECK THAT ALL THE DIGITAL SETOUT DATA AGREES WITH THE DRAWINGS PRIOR TO ANY WORK COMMENCING.

SETOUT CO-ORDINATES

POINT	EASTING	NORTHING
01	694522.365	7424413.216
02	694531.770	7424706.808
03	695080.797	7425507.205
04	695179.543	7425476.641
05	695435.159	7425441.060
06	695605.437	7425377.290
07	695845.945	7425393.781
08	695983.729	7425442.261
09	696070.393	7425487.010
10	696298.375	7425555.912
11	696768.225	7424613.320
12	696744.418	7424419.204

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

PLAN
SCALE 1:10000

CONSTRUCTION ISSUE

100mm AT FULL SIZE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

NCSI certified Quality System to ISO 9001

SCALES
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Full Size 1:10000 ; Half Reduction 1:20000
SCALE (m)

A1 ORIGINAL
DO NOT SCALE THIS DRAWING - USE FIGURED DIMENSIONS ONLY
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SIGNED
DATE 14/8/15
RPEQ No. 4141

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69 Ann Street
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GPO BOX 2907
Brisbane QLD 4001
Australia
ABN 80 078 004 798
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Facsimile +61 7 3854 6500
Email: brisbane@pb.com.au

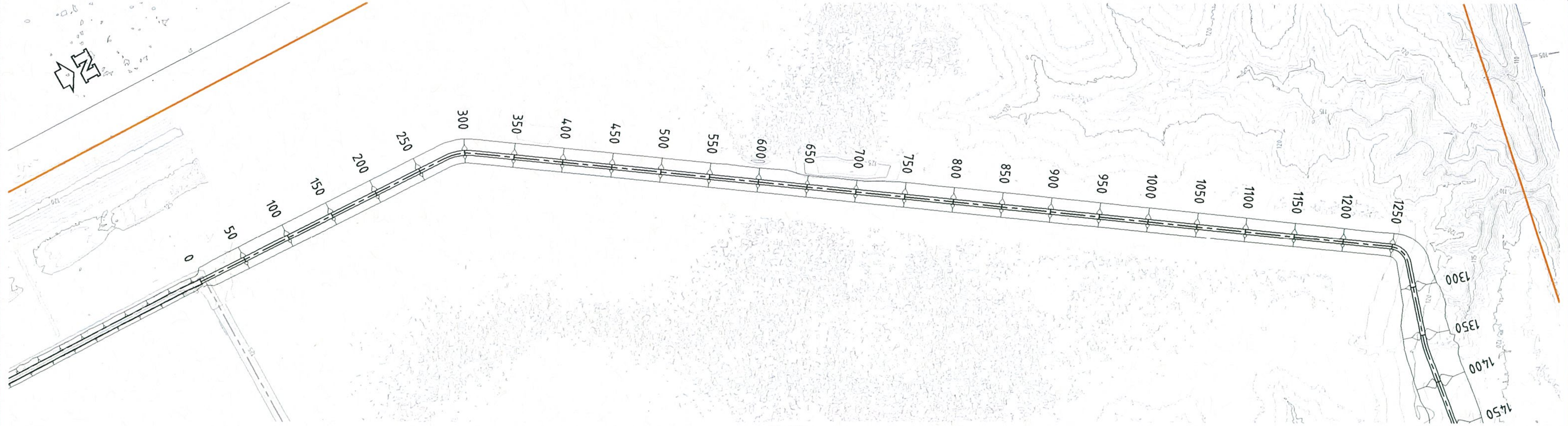
CLIENT
Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
GENERAL
OVERALL SITE PLAN
GENERAL NOTES AND LEGEND

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0002	0

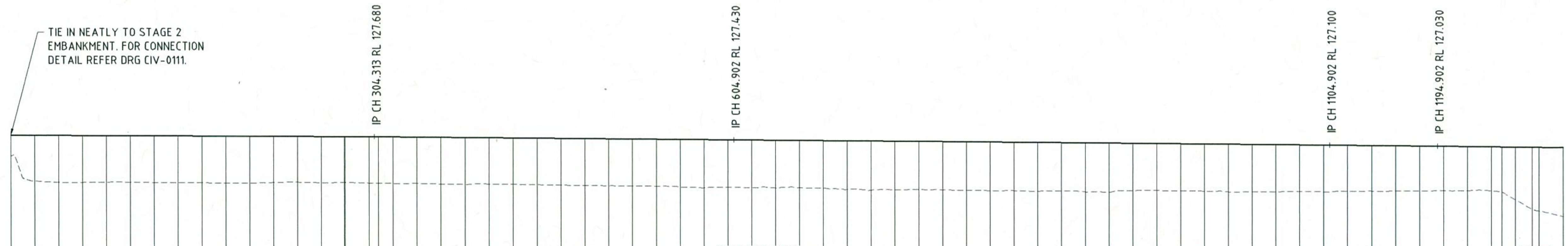
Plotted By: HamillM Plot Date: 31/07/15 - 13:45 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0002.dwg

2188238A-CIV-0100



PLAN
SCALE 1:2000

TIE IN NEATLY TO STAGE 2 EMBANKMENT. FOR CONNECTION DETAIL REFER DRG CIV-0111.



TYPE: TYPE 1 MATERIAL (CH 0 – 1248.817); TYPE 2 MATERIAL (CH 1248.817 – 1300)

GRADE: -0.03% | -0.08% | -0.07% | -0.08% | -0.11%

DATUM RL 113.0

CHAINAGE	DEPTH CUT(-)/FILL	DESIGN LEVELS	EXISTING LEVELS
0	1.738	127.761	126.023
20	3.826	127.755	123.929
40	3.918	127.750	123.832
60	3.927	127.745	123.818
80	3.886	127.739	123.853
100	3.883	127.734	123.851
120	3.910	127.729	123.819
140	3.913	127.724	123.811
160	3.914	127.718	123.804
180	3.933	127.713	123.780
200	3.928	127.708	123.779
220	3.881	127.702	123.822
240	3.841	127.697	123.856
260	3.893	127.692	123.799
279.116	3.857	127.687	123.829
280	3.857	127.686	123.829
300	3.900	127.681	123.781
307.576	3.907	127.677	123.771
320	3.910	127.667	123.757
340	3.893	127.650	123.757
360	3.922	127.634	123.712
380	3.932	127.617	123.685
400	3.884	127.600	123.717
420	3.894	127.584	123.690
440	3.912	127.567	123.655
460	3.903	127.551	123.647
480	3.918	127.534	123.616
500	3.932	127.517	123.586
520	3.927	127.501	123.574
540	3.939	127.484	123.545
560	3.981	127.467	123.486
580	4.028	127.451	123.423
600	3.979	127.434	123.455
620	3.996	127.420	123.424
640	4.014	127.407	123.392
660	3.964	127.394	123.429
680	3.991	127.380	123.389
700	4.072	127.367	123.295
720	4.105	127.354	123.249
740	4.069	127.341	123.272
760	4.036	127.328	123.292
780	4.038	127.314	123.276
800	4.078	127.301	123.223
820	4.077	127.288	123.211
840	4.059	127.275	123.216
860	4.081	127.262	123.181
880	4.056	127.248	123.192
900	4.117	127.235	123.119
920	4.115	127.222	123.107
940	3.966	127.209	123.242
960	3.942	127.196	123.254
980	3.941	127.182	123.242
1000	3.966	127.169	123.203
1020	4.007	127.156	123.149
1040	3.986	127.143	123.157
1060	3.952	127.130	123.178
1080	3.930	127.116	123.186
1100	3.929	127.103	123.174
1120	3.847	127.088	123.241
1140	3.830	127.073	123.243
1160	3.790	127.057	123.267
1180	3.780	127.042	123.261
1200	3.725	127.024	123.299
1220	3.692	127.001	123.309
1240	3.684	126.978	123.294
1248.817	3.776	126.968	123.192
1260	4.401	126.955	122.554
1274.212	5.160	126.939	121.779
1280	5.311	126.932	121.621
1300	5.787	126.910	121.123

HORIZONTAL GEOMETRY: RAD 50 (CH 279.116 – 307.576); RAD 20 (CH 1248.817 – 1274.212)

LONGITUDINAL SECTION

SCALE: 1:2000 HORIZONTAL
SCALE: 1:200 VERTICAL

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:2000 ; Half Reduction 1:4000
SCALE (m)
0 2 4 8 12
Full Size 1:200 ; Half Reduction 1:400
SCALE (m)

A1 ORIGINAL
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APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE 14/8/15 4141 RPEQ No.

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Brisbane QLD 4001
Australia
ABN 80 078 004 798
Telephone +61 7 3854 6200
Facsimile +61 7 3854 6500
Email: brisbane@pb.com.au

CLIENT
Jellinbah Resources

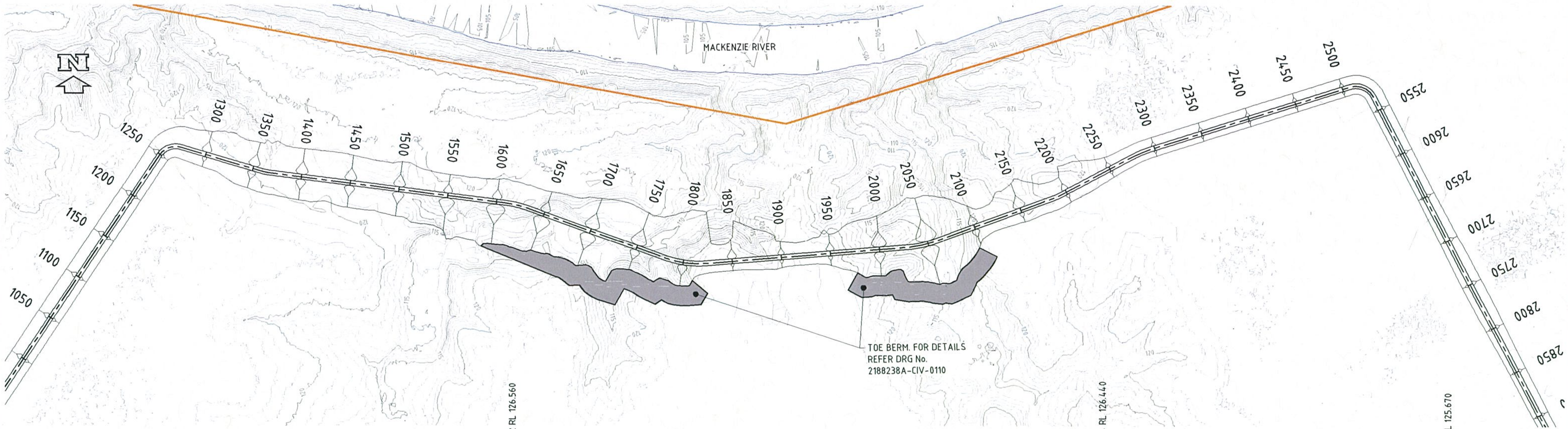
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3
PLAN AND LONGITUDINAL SECTION
SHEET 1

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0100	0

100mm AT FULL SIZE

Plotted By: HamillM Plot Date: 31/07/15 - 13:45 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0100.dwg

2188238A-CIV-0101



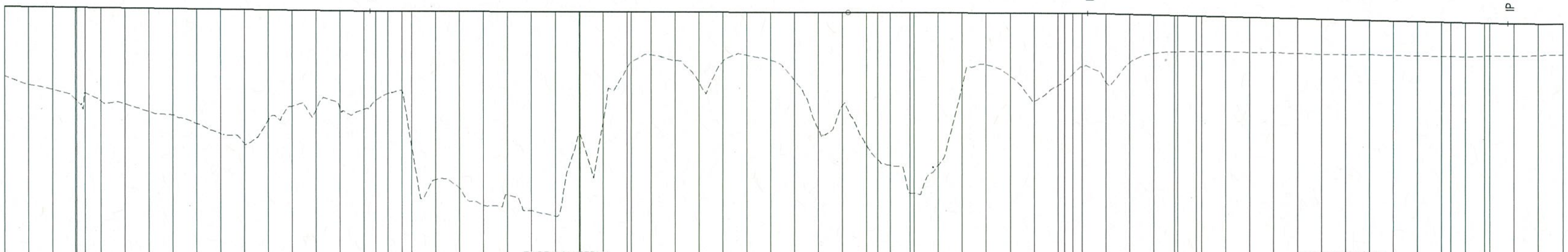
PLAN

SCALE 1:2000

IP CH 1604.902 RL 126.560

IP CH 2204.984 RL 126.440

IP CH 2554.981 RL 125.670



TYPE: TYPE 2 MATERIAL (to CH 2240); TYPE 1 MATERIAL (from CH 2240)

GRADE: -0.11% (to CH 1609.865); -0.02% (to CH 2192.414); -0.22% (to CH 2535.76); -0.06%

DATUM RL 101.0

CHAINAGE	EXISTING LEVELS	DESIGN LEVELS	DEPTH CUT(-)/FILL
1300	121.123	126.910	5.787
1320	120.419	126.887	6.468
1340	120.014	126.864	6.850
1358.793	119.196	126.842	7.646
1360	119.075	126.841	7.765
1366.885	119.736	126.833	7.097
1380	119.072	126.818	7.745
1400	118.823	126.795	7.972
1420	118.192	126.772	8.580
1440	117.914	126.749	8.835
1460	117.196	126.726	9.530
1480	116.367	126.703	10.337
1500	115.505	126.680	11.175
1520	117.493	126.657	9.164
1540	118.634	126.634	8.001
1560	118.348	126.611	8.263
1580	118.397	126.589	8.192
1600	118.397	126.566	8.168
1609.865	119.138	126.559	7.421
1620	119.720	126.557	6.837
1631.868	119.926	126.555	6.629
1640	115.207	126.553	11.346
1660	112.518	126.549	14.031
1680	111.811	126.545	14.734
1700	110.372	126.541	16.169
1720	111.263	126.537	15.274
1740	109.957	126.533	16.575
1760	109.491	126.529	17.038
1780	116.352	126.525	10.173
1780.979	116.251	126.525	10.274
1800	117.305	126.521	9.216
1820	121.853	126.517	4.664
1823.659	122.342	126.516	4.174
1840	122.959	126.513	3.554
1860	122.480	126.509	4.029
1880	120.682	126.505	5.823
1900	122.399	126.501	4.102
1920	122.914	126.497	3.583
1940	122.496	126.493	3.997
1960	120.829	126.489	5.660
1980	116.782	126.485	9.703
2000	118.768	126.481	7.713
2020	115.407	126.477	11.070
2029.486	114.221	126.475	12.255
2040	113.758	126.473	12.715
2056.473	111.452	126.470	15.017
2060	111.435	126.469	15.034
2080	113.768	126.465	12.697
2100	120.371	126.461	6.090
2120	122.167	126.457	4.290
2140	121.187	126.453	5.266
2160	119.103	126.449	7.346
2180	120.404	126.445	6.041
2185.498	120.795	126.444	5.649
2192.414	121.397	126.443	5.046
2200	122.013	126.441	4.428
2220	120.754	126.407	5.653
2240	122.343	126.363	4.020
2260	123.127	126.319	3.192
2277.303	123.266	126.281	3.015
2280	123.277	126.275	2.998
2295.617	123.292	126.241	2.948
2300	123.289	126.231	2.942
2320	123.287	126.187	2.900
2340	123.235	126.143	2.908
2360	123.239	126.099	2.859
2380	123.159	126.055	2.896
2400	123.101	126.011	2.910
2420	123.064	125.967	2.902
2440	123.085	125.923	2.838
2460	123.017	125.879	2.862
2480	122.984	125.835	2.851
2500	122.955	125.791	2.836
2507.722	122.946	125.774	2.828
2520	122.926	125.747	2.821
2535.76	122.970	125.712	2.742
2540	122.987	125.703	2.716
2560	122.994	125.667	2.673
2580	123.024	125.656	2.632
2600	123.071	125.645	2.574

HORIZONTAL GEOMETRY: RAD -50 (CH 1358.793–1366.885); RAD 100 (CH 1609.865–1631.868); RAD -100 (CH 1780.979–1823.659); RAD -100 (CH 2029.486–2056.473); RAD -50 (CH 2185.498–2192.414); RAD 100 (CH 2277.303–2295.617); RAD 20 (CH 2507.722–2535.76)

LONGITUDINAL SECTION

SCALE: 1:2000 HORIZONTAL
SCALE: 1:200 VERTICAL

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

100mm AT FULL SIZE

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:2000 ; Half Reduction 1:4000
SCALE (m)
0 2 4 8 12
Full Size 1:200 ; Half Reduction 1:400
SCALE (m)

A1 ORIGINAL
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APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE 14/8/15 RPEQ No. 4141

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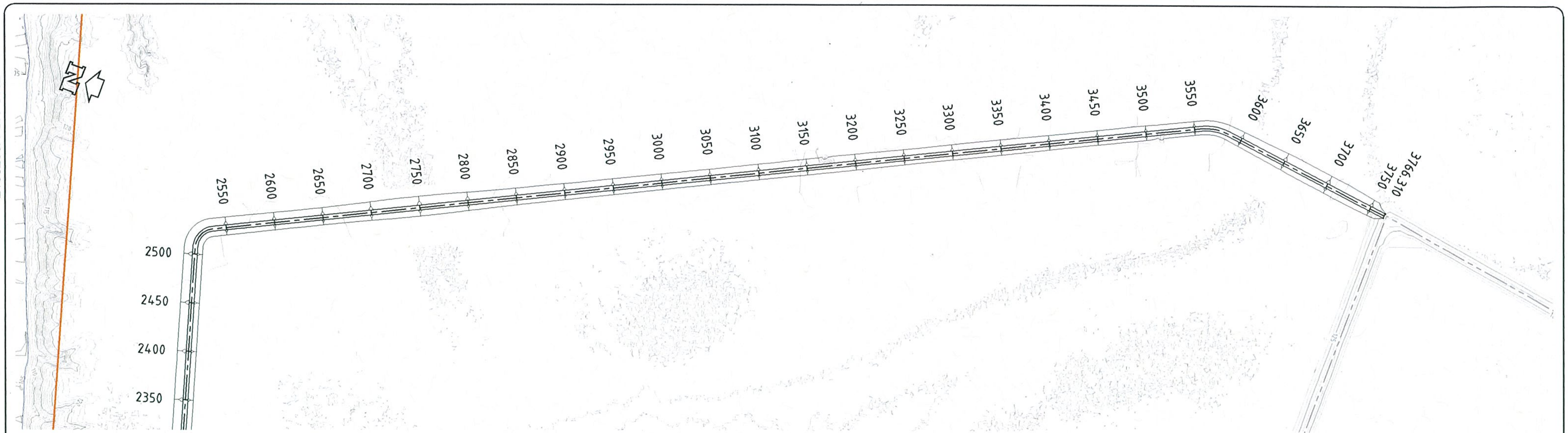
CLIENT
Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3
PLAN AND LONGITUDINAL SECTION
SHEET 2

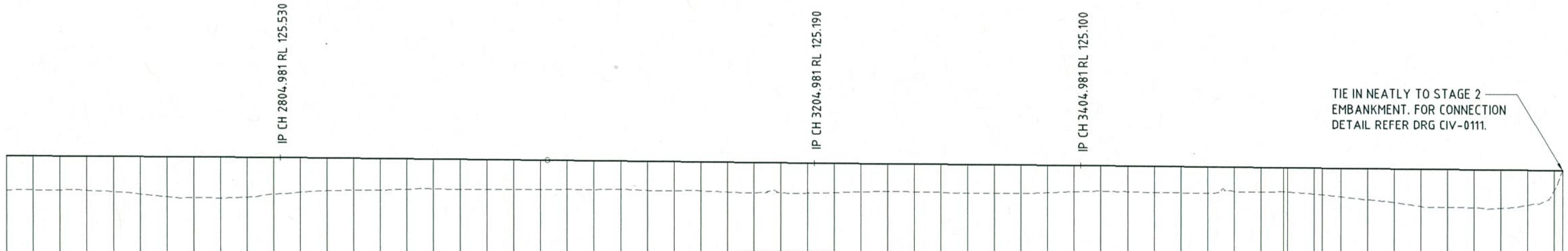
PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0101	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:46 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0101.dwg

2188238A-CIV-0102



PLAN
SCALE 1:2000



TYPE: TYPE 1 MATERIAL

GRADE: -0.06% (2600–2804.981); -0.09% (2804.981–3204.981); -0.05% (3204.981–3404.981); -0.07% (3404.981–3766.31)

DATUM RL 113.0

CHAINAGE	DEPTH CUT(-)/FILL	DESIGN LEVELS	EXISTING LEVELS
2600	2.574	125.645	123.071
2620	2.554	125.634	123.079
2640	2.550	125.622	123.072
2660	2.566	125.611	123.045
2680	2.657	125.600	122.943
2700	2.803	125.589	122.786
2720	3.000	125.578	122.578
2740	3.038	125.566	122.528
2760	3.058	125.555	122.497
2780	2.984	125.544	122.560
2800	2.737	125.533	122.796
2820	2.584	125.517	122.933
2840	2.455	125.500	123.045
2860	2.383	125.483	123.100
2880	2.369	125.466	123.097
2900	2.286	125.449	123.163
2920	2.229	125.432	123.204
2940	2.252	125.415	123.164
2960	2.239	125.398	123.160
2980	2.207	125.381	123.174
3000	2.210	125.364	123.154
3020	2.160	125.347	123.187
3040	2.162	125.330	123.169
3060	2.123	125.313	123.191
3080	2.171	125.296	123.125
3100	2.187	125.279	123.092
3120	2.175	125.262	123.087
3140	2.236	125.245	123.009
3160	2.279	125.228	122.950
3180	2.228	125.211	122.984
3200	2.249	125.194	122.945
3220	2.193	125.183	122.990
3240	2.118	125.174	123.056
3260	2.064	125.165	123.101
3280	2.085	125.156	123.071
3300	2.109	125.147	123.038
3320	2.153	125.138	122.985
3340	2.146	125.129	122.983
3360	2.113	125.120	123.007
3380	2.060	125.111	123.051
3400	1.973	125.102	123.129
3420	1.911	125.090	123.179
3440	1.933	125.077	123.144
3460	1.963	125.064	123.101
3480	1.971	125.050	123.079
3500	1.981	125.037	123.056
3520	1.853	125.024	123.171
3540	1.843	125.011	123.168
3557.044	1.813	124.999	123.186
3560	1.831	124.998	123.167
3580	1.949	124.984	123.035
3586.266	2.003	124.980	122.977
3600	2.143	124.971	122.828
3620	2.348	124.958	122.610
3640	2.524	124.945	122.421
3660	2.808	124.931	122.124
3680	2.846	124.918	122.072
3700	2.865	124.905	122.040
3720	2.877	124.892	122.014
3740	2.630	124.878	122.248
3760	1.514	124.865	123.351
3766.31	-0.000	124.861	124.862

HORIZONTAL GEOMETRY: RAD 50

LONGITUDINAL SECTION
SCALE: 1:2000 HORIZONTAL
SCALE: 1:200 VERTICAL

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

100mm AT FULL SIZE

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 20 40 80 120
Full Size 1:2000 ; Half Reduction 1:4000
SCALE (m)
0 2 4 8 12
Full Size 1:200 ; Half Reduction 1:400
SCALE (m)

A1 ORIGINAL
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SIGNED
DATE 14/8/15
RPEQ No. 4141

PARSONS BRINCKERHOFF
Level 4, Northbank Plaza
69 Ann Street
Brisbane QLD 4000
GPO BOX 2907
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Telephone +61 7 3854 6200
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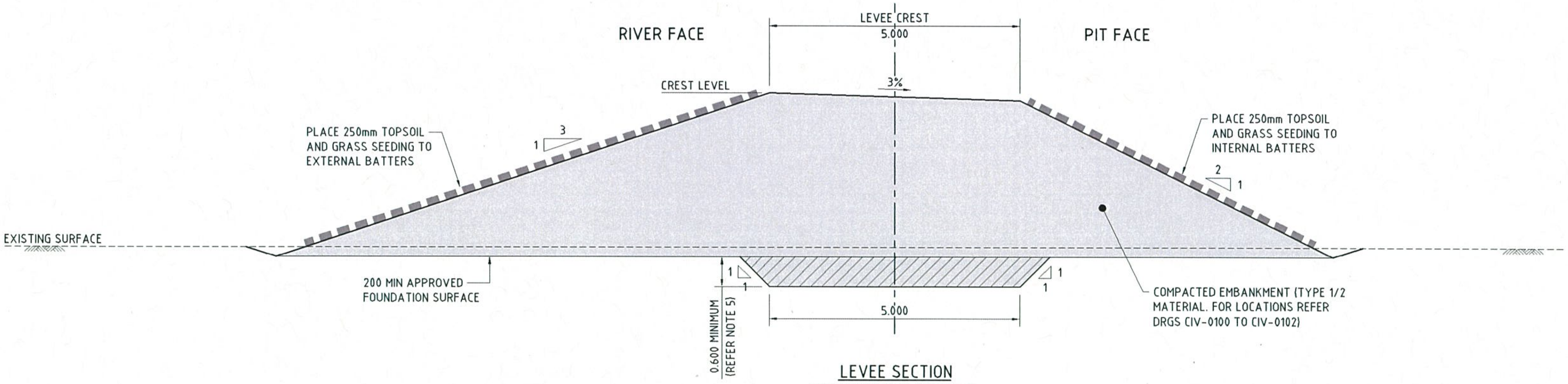
CLIENT
Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3
PLAN AND LONGITUDINAL SECTION
SHEET 3

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	- CIV -	0102	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:46 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0102.dwg

2188238A-CIV-0110



LEVEE SECTION
EMBANKMENT UP TO 7m
SCALE 1:50

EARTHWORKS NOTES

1. CLEAR AND GRUB TO 3m, MAXIMUM, BEYOND THE LIMIT OF EARTHWORKS
2. EMBANKMENT MATERIAL IS TO ACHIEVE THE FOLLOWING PARAMETERS;

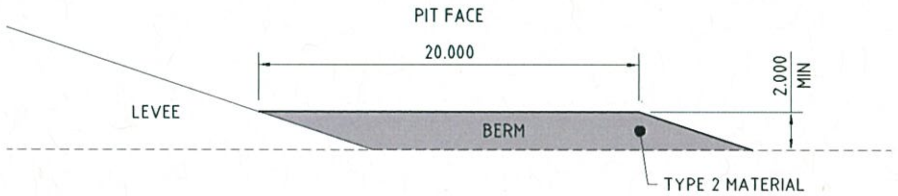
TYPE 1 (EMBANKMENT UP TO 4m)

- LIQUID LIMIT 30% < LL < 45%
- PLASTICITY INDEX 15% < PI < 35%
- COMPACTION ≥ 98% RDD
- MOISTURE CONTENT -1% to +2% OMC
- > 35% PASSING 75 μm
- LINEAR SHRINKAGE ≤ 14%

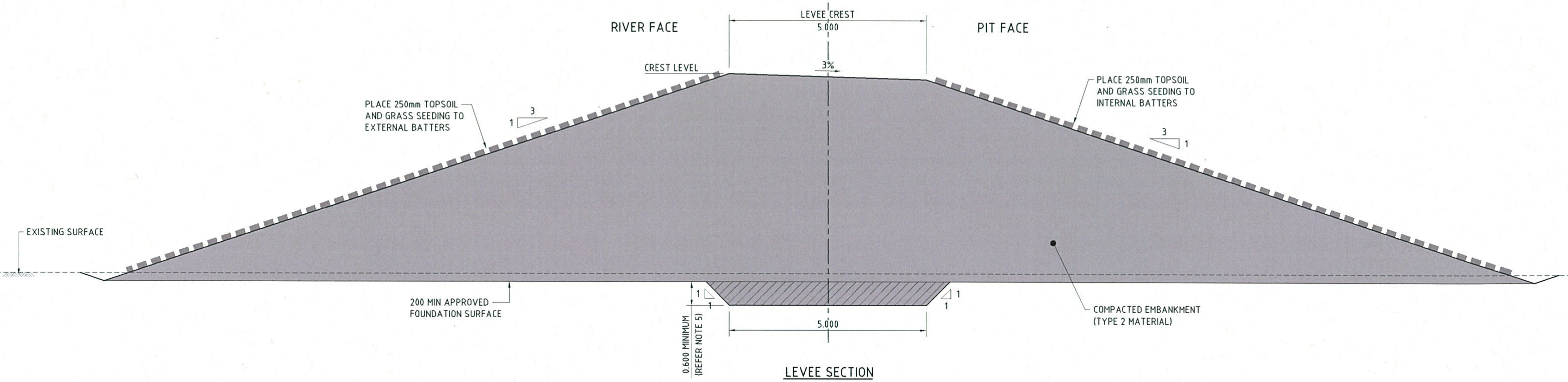
TYPE 2 (EMBANKMENT GREATER THAN 4m)

- LIQUID LIMIT 30% < LL < 45%
- PLASTICITY INDEX 15% < PI < 30%
- COMPACTION ≥ 98% RDD
- MOISTURE CONTENT -1% to +2% OMC
- > 35% PASSING 75 μm
- LINEAR SHRINKAGE ≤ 12%

3. COMPACTION & MOISTURE CONTENT TESTS ARE TO BE CONDUCTED AT A MINIMUM OF 1/2000m3 IN ACCORDANCE WITH TECHNICAL SPECIFICATION.
4. LAYERS ARE TO BE PLACED AT THICKNESS OF BETWEEN 100mm - 200mm AFTER COMPACTION.
5. ALL LEVEE FOUNDATIONS AND KEY TRENCHES ARE TO BE INSPECTED BY A SUITABLY QUALIFIED ENGINEER IN ACCORDANCE WITH THE SPECIFICATION, PRIOR TO EMBANKMENT MATERIAL PLACEMENT. ANTICIPATED EXCAVATION DEPTHS MAY VARY AS A RESULT OF THE INSPECTIONS.



TOE BERM
CH1600 - 1800 & CH1950 - 2100
SCALE 1:200



LEVEE SECTION
EMBANKMENT OVER 7m
SCALE 1:50

100mm AT FULL SIZE

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 0.5 1 2 3
Full Size 1:50 ; Half Reduction 1:100
SCALE (m)

A1 ORIGINAL
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PARSONS BRINCKERHOFF
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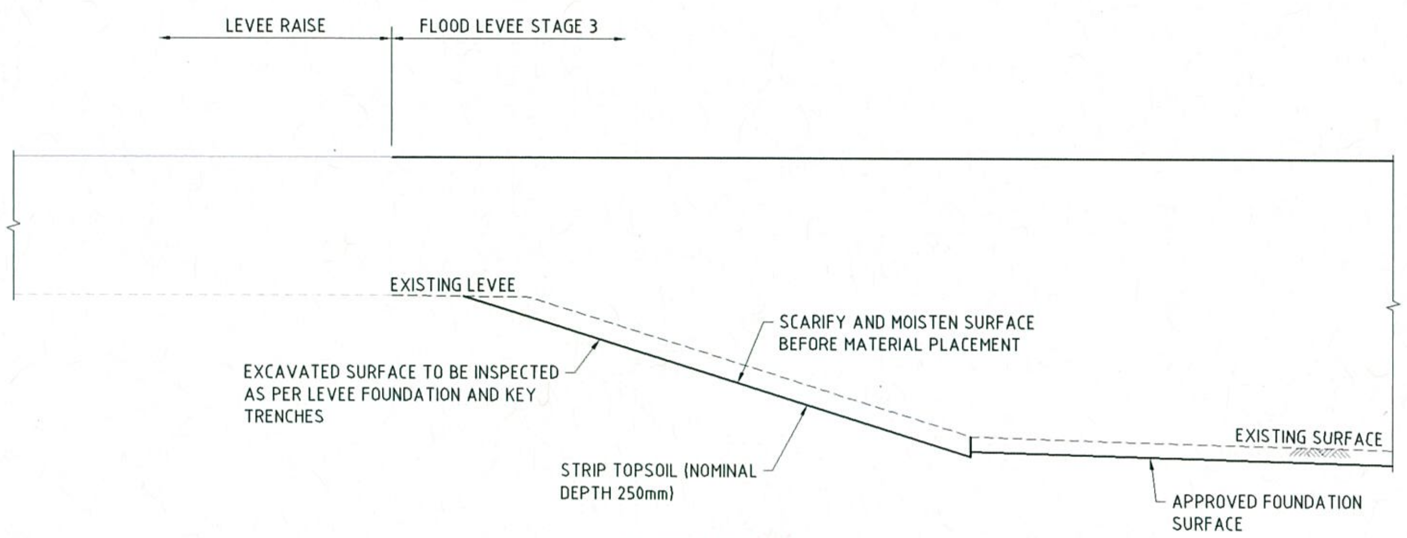
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3
TYPICAL SECTIONS

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0110	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:46 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0110.dwg

2188238A-CIV-0111



LEVEE SECTION
TIE IN TO EXISTING LEVEE
SCALE 1:50

100mm AT FULL SIZE

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 0.5 1 2 3
Full Size 1:50 ; Half Reduction 1:100
SCALE (m)

A1 ORIGINAL
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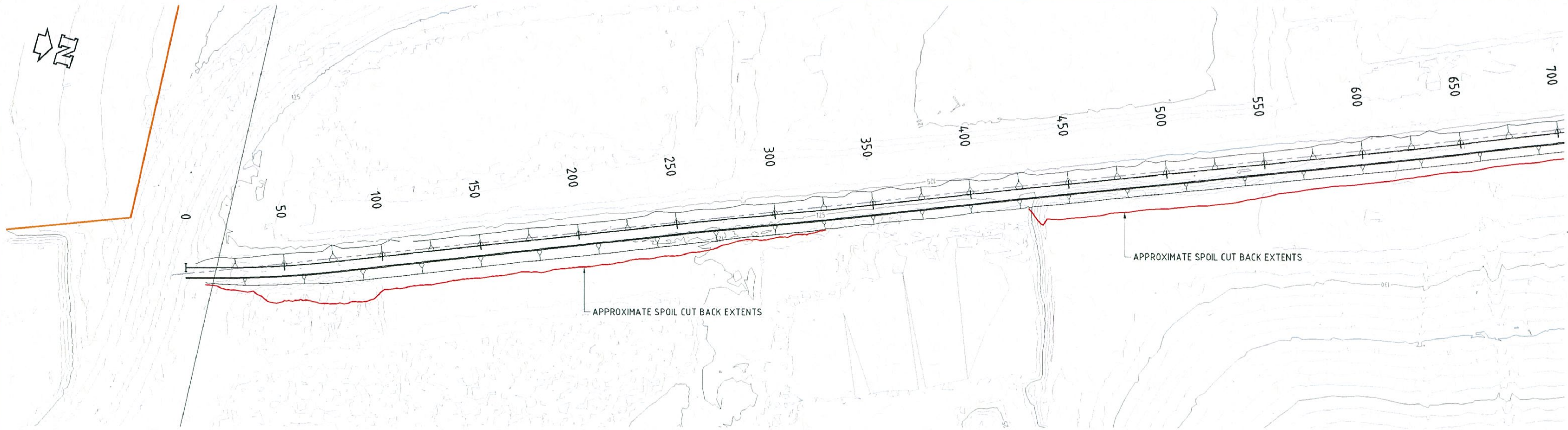
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
FLOOD LEVEE STAGE 3
TIE IN DETAILS

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0111	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:46 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0111.dwg

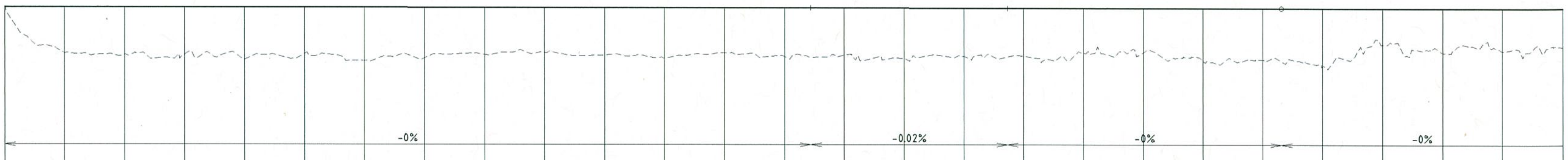
2188238A-CIV-0200



PLAN
SCALE 1:1000

IP CH 335.917 RL 127.792

IP CH 418.271 RL 127.778



VC DATA

GRADE: -0% | -0.02% | -0% | -0%

DATUM RL 121.0

CHAINAGE	EXISTING LEVELS	DESIGN LEVELS	DEPTH CUT(-)/FILL
0	127.841	127.805	-0.036
25	125.893	127.804	1.911
50	125.850	127.803	1.953
75	125.848	127.802	1.954
100	125.633	127.801	2.168
125	125.867	127.800	1.933
150	125.587	127.799	2.213
175	125.694	127.798	2.105
200	125.834	127.797	1.963
225	125.924	127.797	1.873
250	125.819	127.796	1.977
275	125.674	127.795	2.121
300	125.915	127.794	1.879
325	125.757	127.793	2.036
350	125.827	127.790	1.963
375	125.694	127.786	2.092
400	125.780	127.782	2.002
425	125.796	127.778	1.982
450	125.911	127.778	1.867
475	125.939	127.778	1.839
500	125.591	127.778	2.187
525	125.636	127.778	2.142
550	125.361	127.777	2.416
575	126.276	127.776	1.501
600	125.936	127.775	1.839
625	126.005	127.774	1.769
650	126.174	127.773	1.599

HORIZONTAL GEOMETRY: RAD -500 | RAD -5000 | RAD 1000 | RAD -50 | RAD 50 | RAD -50

LONGITUDINAL SECTION

SCALE: 1:1000 HORIZONTAL
SCALE: 1:100 VERTICAL

100mm AT FULL SIZE

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:1000 ; Half Reduction 1:2000
SCALE (m)
0 1 2 4 6
Full Size 1:100 ; Half Reduction 1:200
SCALE (m)

A1 ORIGINAL
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SIGNED
DATE 14/8/15
RPEQ No. 4141

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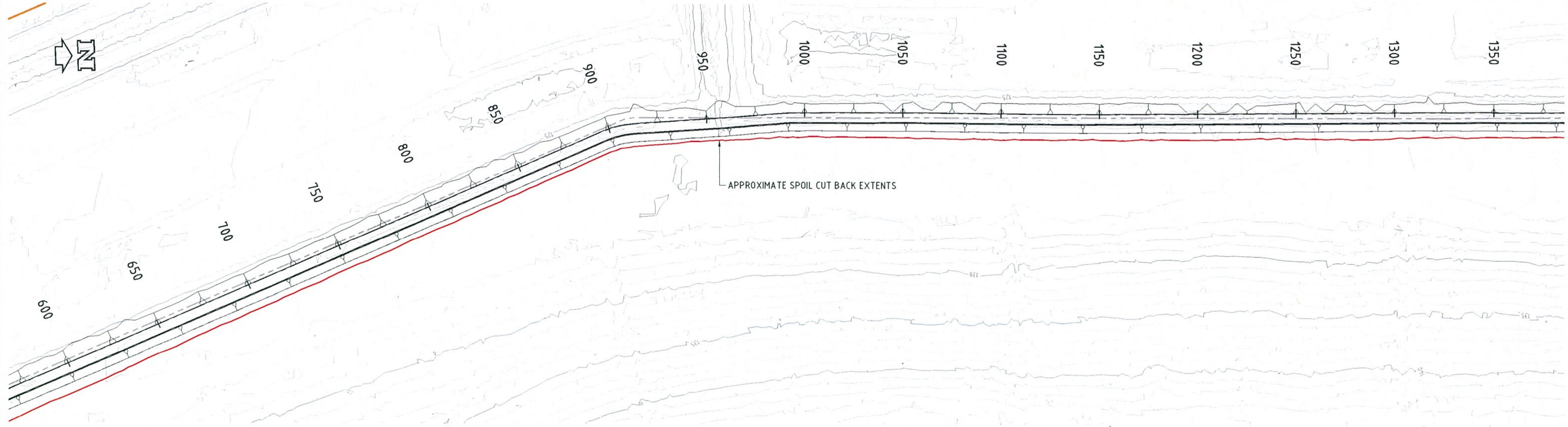
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
PLAN AND LONGITUDINAL SECTION
SHEET 1

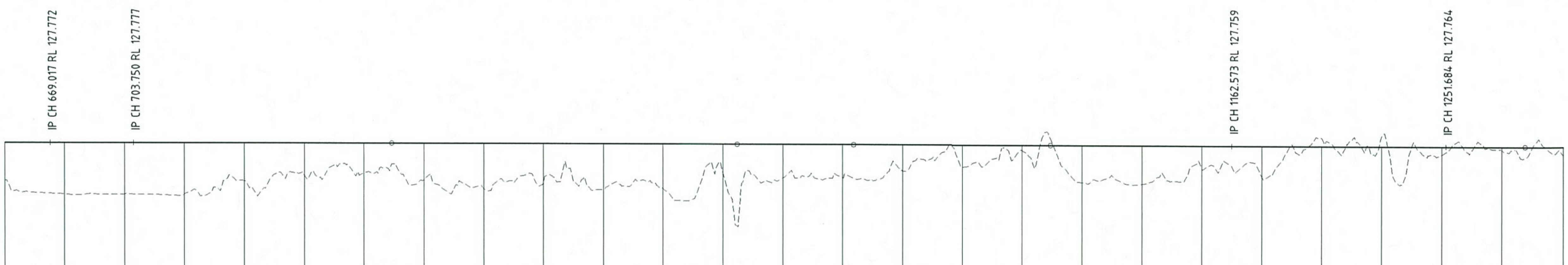
PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0200	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:46 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0200.dwg

2188238A-CIV-0201



PLAN
SCALE 1:1000



VC DATA

GRADE: -0% | 0.01% | -0% | -0.01% | -0% | -0% | 0.01% | -0% | -0%

DATUM RL 120.0

DEPTH CUT(-)/FILL	1.599	2.157	2.158	2.148	1.602	1.356	1.255	1.540	1.898	1.577	1.917	1.884	1.229	1.419	1.397	1.111	0.931	0.236	1.564	1.629	0.953	1.289	-0.334	-0.429	0.355	0.162	0.375
DESIGN LEVELS	127.773	127.773	127.776	127.777	127.776	127.776	127.775	127.774	127.773	127.771	127.769	127.768	127.766	127.765	127.765	127.764	127.763	127.762	127.762	127.761	127.760	127.760	127.761	127.763	127.764	127.763	127.762
EXISTING LEVELS	126.174	125.616	125.618	125.628	126.174	126.419	126.520	126.234	125.875	126.194	125.852	125.883	126.537	126.347	126.368	126.653	126.833	127.526	126.198	126.131	126.806	126.471	128.095	128.192	127.409	127.602	127.387
CHAINAGE	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000	1025	1050	1075	1100	1125	1150	1175	1200	1225	1250	1275	1300

HORIZONTAL GEOMETRY: RAD 50 | RAD -50 | RAD 50 | RAD 50 | RAD -50 | RAD -50

LONGITUDINAL SECTION
SCALE: 1:1000 HORIZONTAL
SCALE: 1:100 VERTICAL

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

CONSTRUCTION ISSUE

100mm AT FULL SIZE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:1000 ; Half Reduction 1:2000
SCALE (m)
0 1 2 4 6
Full Size 1:100 ; Half Reduction 1:200
SCALE (m)

A1 ORIGINAL
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DATE RPEQ No.

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Email: brisbane@pb.com.au

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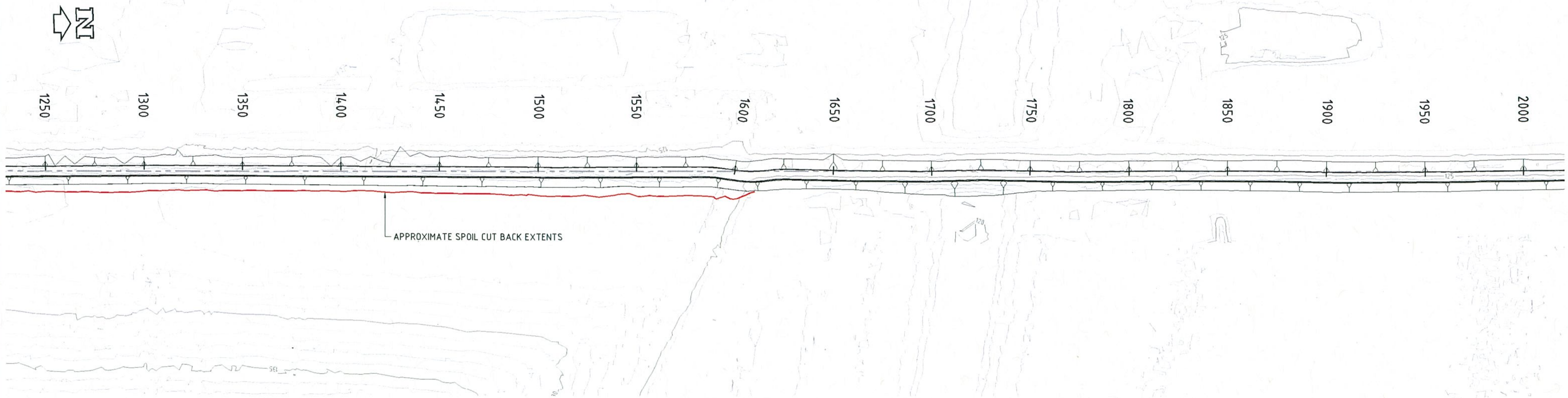
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
PLAN AND LONGITUDINAL SECTION
SHEET 2

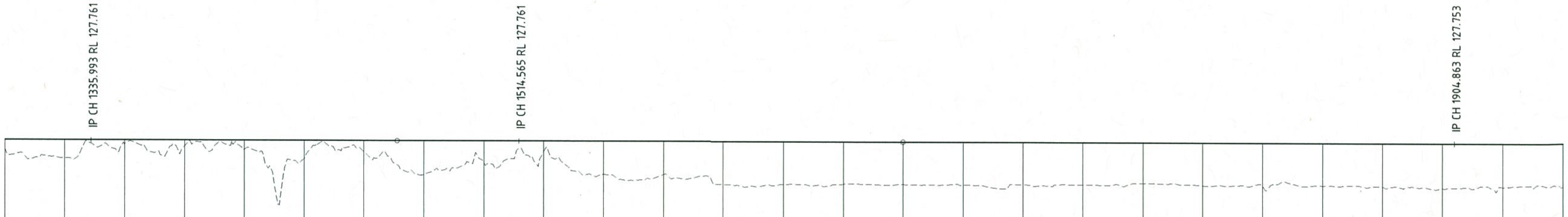
PROJECT No.		DISCIPLINE		NUMBER	REV.
2188238A	-	CIV	-	0201	0

Plotted By: HamilM Plot Date: 31/07/15 - 13:47 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0201.dwg

2188238A-CIV-0202



PLAN
SCALE 1:1000



VC DATA

GRADE -0% 0% -0% -0% 0%

DATUM RL 121.0

DEPTH CUT(-)/FILL	0.375	0.752	0.169	0.244	0.367	0.753	0.464	1.398	0.908	0.436	1.379	1.385	1.795	1.777
DESIGN LEVELS	127.762	127.761	127.761	127.761	127.761	127.761	127.761	127.761	127.761	127.761	127.760	127.759	127.758	127.758
EXISTING LEVELS	127.387	127.010	127.592	127.516	127.394	127.008	127.297	126.363	126.853	127.325	126.381	126.374	125.963	125.981
CHAINAGE	1300	1325	1350	1375	1400	1425	1450	1475	1500	1525	1550	1575	1600	1625

DEPTH CUT(-)/FILL	1.761	1.773	1.780	1.761	1.761	1.693	1.784	1.794	1.770	1.807	1.870	1.809	1.798
DESIGN LEVELS	127.757	127.756	127.756	127.755	127.755	127.755	127.754	127.754	127.754	127.753	127.753	127.753	127.753
EXISTING LEVELS	125.995	125.983	125.976	125.994	125.994	126.062	125.970	125.961	125.983	125.946	125.883	125.944	125.955
CHAINAGE	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900	1925	1950

HORIZONTAL GEOMETRY RAD 50 RAD 50 RAD -50 RAD 50 RAD 50 RAD -50 RAD 50 RAD -50 RAD -50 RAD 50 RAD -50 RAD 50 RAD 50 RAD -50

LONGITUDINAL SECTION
SCALE: 1:1000 HORIZONTAL
SCALE: 1:100 VERTICAL

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

CONSTRUCTION ISSUE

100mm AT FULL SIZE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:1000 ; Half Reduction 1:2000
SCALE (m)
0 1 2 4 6
Full Size 1:100 ; Half Reduction 1:200
SCALE (m)

A1 ORIGINAL
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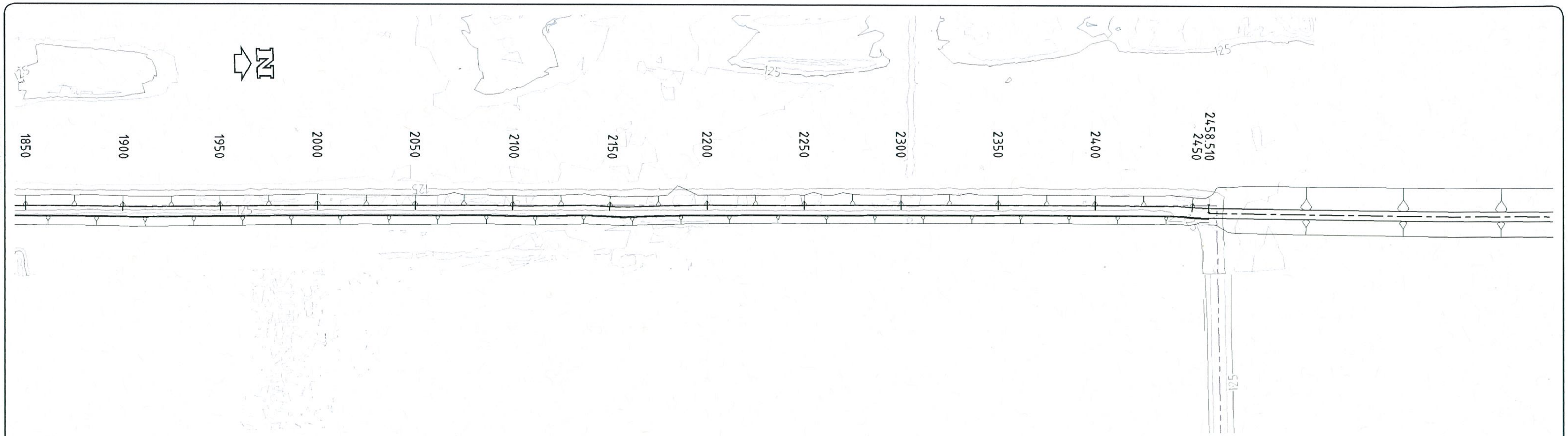
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
PLAN AND LONGITUDINAL SECTION
SHEET 3

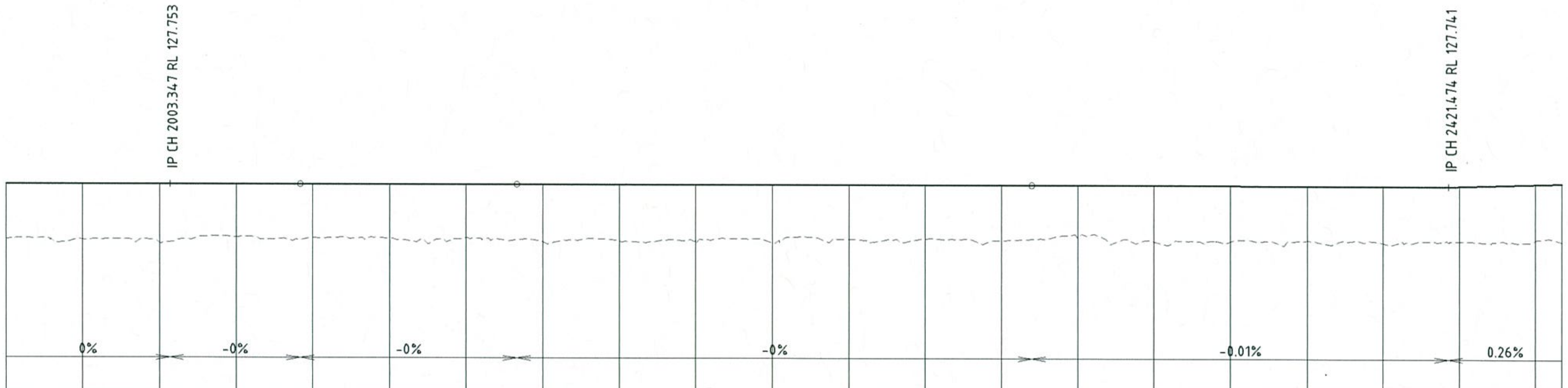
PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0202	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:47 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0202.dwg

2188238A-CIV-0203



PLAN
SCALE 1:1000



VC DATA

GRADE: 0% | -0% | -0% | -0% | -0.01% | 0.26%

DATUM RL 121.0

DEPTH CUT(-)/FILL	1.798	1.809	1.910	1.723	1.741	1.755	1.738	1.874	1.836	1.863	1.890	1.767	1.747	1.806	1.706	1.834	1.824	1.793	1.865	1.800	1.833	1.906
DESIGN LEVELS	127.753	127.753	127.753	127.752	127.752	127.752	127.752	127.752	127.751	127.751	127.750	127.750	127.750	127.749	127.748	127.747	127.745	127.744	127.742	127.750	127.814	127.836
EXISTING LEVELS	125.955	125.944	125.843	126.030	126.011	125.997	126.014	125.878	125.916	125.888	125.860	125.983	126.002	125.943	126.042	125.913	125.921	125.951	125.877	125.950	125.980	125.929
CHAINAGE	1950	1975	2000	2025	2050	2075	2100	2125	2150	2175	2200	2225	2250	2275	2300	2325	2350	2375	2400	2425	2450	2458.51

HORIZONTAL GEOMETRY: RAD 50 | RAD 50 RAD -50 | RAD 50 RAD -50 | RAD 500 | RAD 50 | RAD 50 RAD -100

LONGITUDINAL SECTION

SCALE: 1:1000 HORIZONTAL
SCALE: 1:100 VERTICAL

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

100mm AT FULL SIZE

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
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Full Size 1:1000 ; Half Reduction 1:2000
SCALE (m)
0 1 2 4 6
Full Size 1:100 ; Half Reduction 1:200
SCALE (m)

A1 ORIGINAL
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DATE 24/8/15
RPEQ No. 4141

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Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
PLAN AND LONGITUDINAL SECTION
SHEET 4

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0203	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:47 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0203.dwg

2188238A-CIV-0210

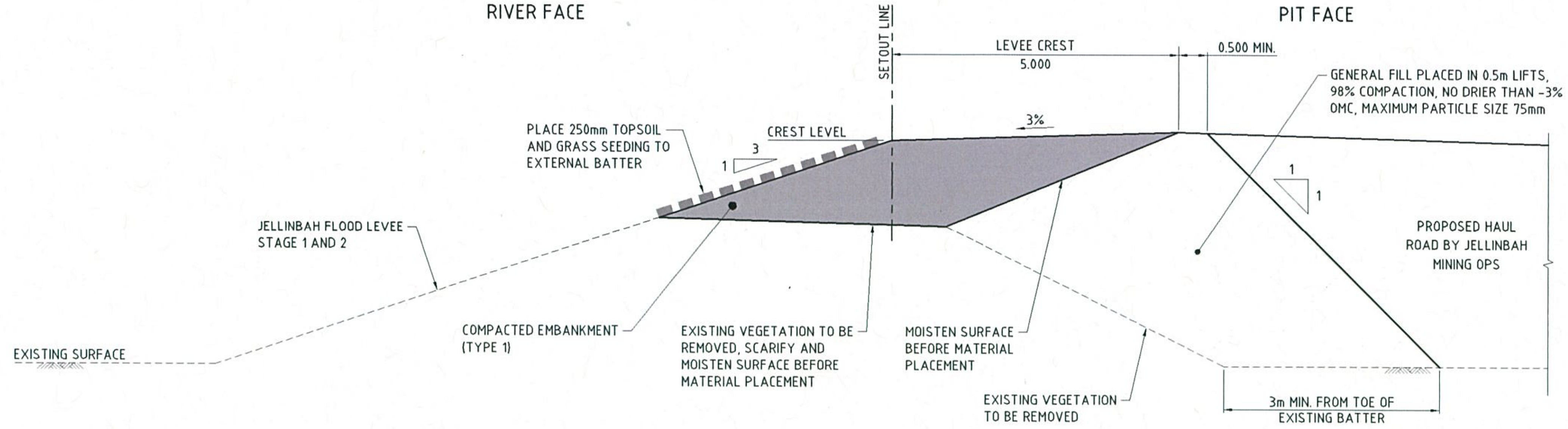
EARTHWORKS NOTES

1. CLEAR AND GRUB TO 3m, MAXIMUM, BEYOND THE LIMIT OF EARTHWORKS
2. EMBANKMENT MATERIAL IS TO ACHIEVE THE FOLLOWING PARAMETERS;

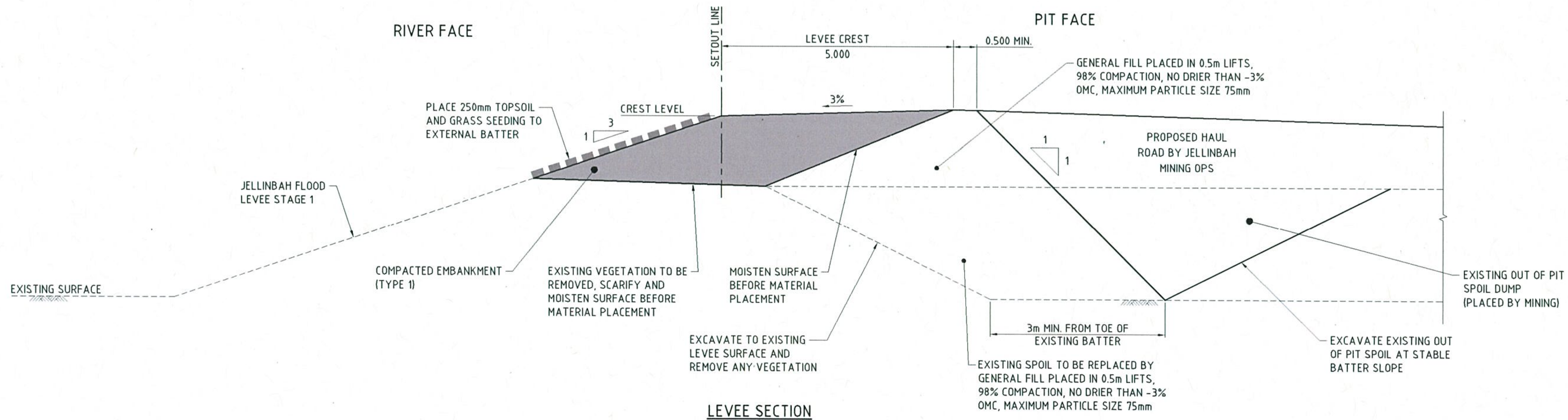
TYPE 1

- LIQUID LIMIT 30% < LL < 45%
- PLASTICITY INDEX 15% < PI < 30%
- COMPACTION ≥ 98% RDD
- MOISTURE CONTENT -1% to +2% OMC
- > 35% PASSING 75 μm
- LINEAR SHRINKAGE ≤ 14%

3. COMPACTION & MOISTURE CONTENT TESTS ARE TO BE CONDUCTED AT A MINIMUM OF 1/2000m3 IN ACCORDANCE WITH TECHNICAL SPECIFICATION.
4. LAYERS OF TYPE 1 MATERIAL ARE TO BE PLACED AT THICKNESS OF BETWEEN 100mm - 200mm AFTER COMPACTION.
5. ALL PREPARED SURFACES ARE TO BE INSPECTED BY A SUITABLY QUALIFIED ENGINEER IN ACCORDANCE WITH THE SPECIFICATION, PRIOR TO PLACEMENT EMBANKMENT MATERIAL. EXCAVATION DEPTHS MAY VARY AS A RESULT OF THE INSPECTIONS.



LEVEE SECTION
RAISE ADJACENT TO HAUL ROAD
SCALE 1:50



LEVEE SECTION
RAISE ADJACENT TO HAUL ROAD AND SPOIL
SCALE 1:50

CO-ORDINATE SYSTEM: JELLINBAH PLAINS SITE
DATUM: AHD

CONSTRUCTION ISSUE

100mm AT FULL SIZE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 0.5 1 2 3
Full Size 1:50 ; Half Reduction 1:100
SCALE (m)

A1 ORIGINAL
DO NOT SCALE THIS DRAWING - USE FIGURED DIMENSIONS ONLY VERIFY ALL DIMENSIONS ON SITE
APPROVED FOR AND ON BEHALF OF PARSONS BRINCKERHOFF AUSTRALIA PTY LIMITED
SIGNED
DATE 4/8/15
RPEQ No. 4141

PARSONS BRINCKERHOFF
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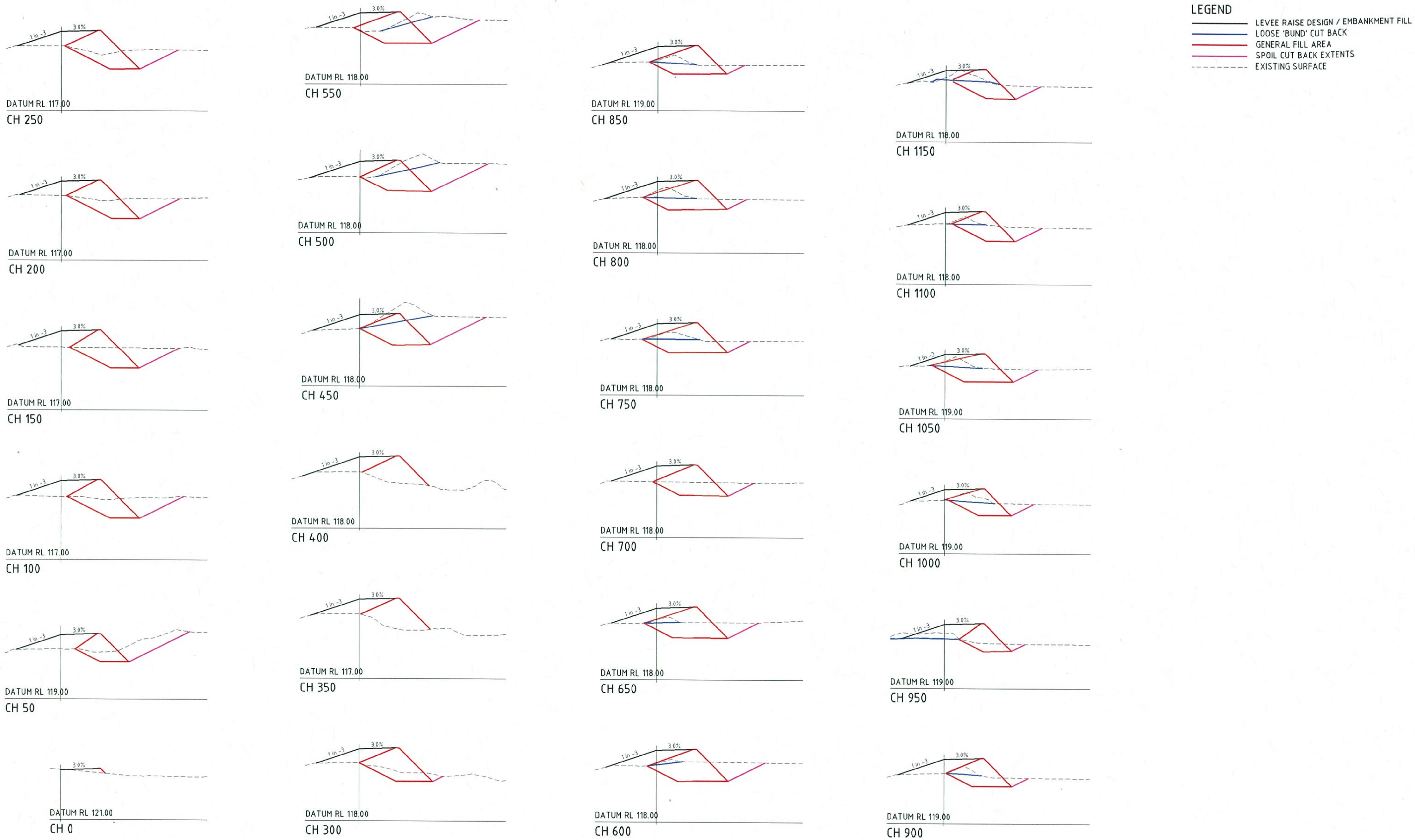
CLIENT
Jellinbah Resources

PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
TYPICAL SECTIONS

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0210	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:48 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0210.dwg

2188238A-CIV-0220



100mm AT FULL SIZE

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 2.5 5 10 15
Full Size 1:250 ; Half Reduction 1:500
SCALE (m)

A1 ORIGINAL
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DATE 12/8/15 4141 RPEQ No.

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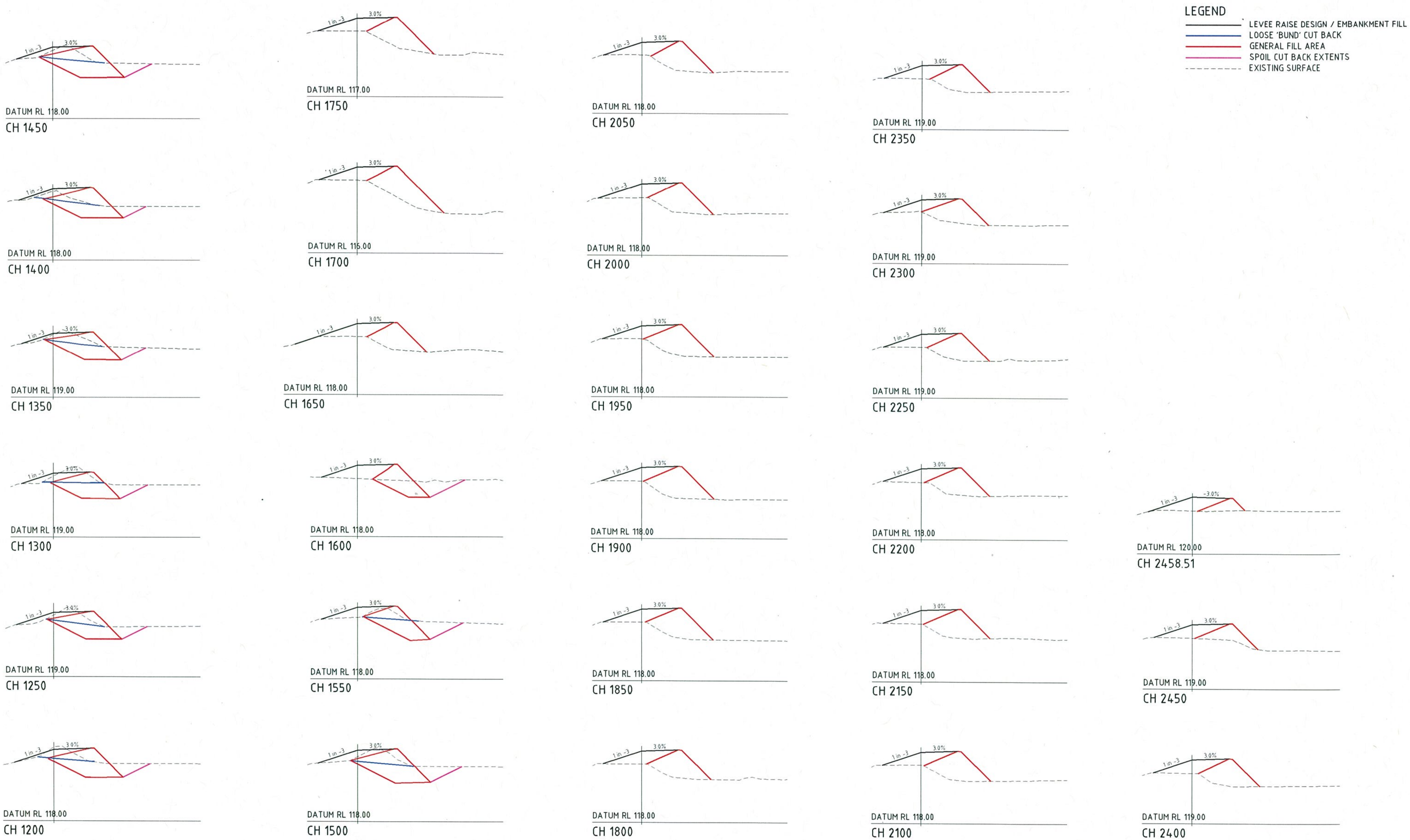
PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
CROSS SECTIONS
SHEET 1

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	CIV	0220	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:48 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0220.dwg



100mm AT FULL SIZE

CO-ORDINATE SYSTEM:	JELLINBAH PLAINS SITE
DATUM:	AHD

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY
0	31.07.15	ISSUE FOR CONSTRUCTION	MH	SR	MS	BW

SCALES
0 2.5 5 10 15
Full Size 1:250 ; Half Reduction 1:500
SCALE (m)

A1 ORIGINAL
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PROJECT
JELLINBAH RESOURCES
JELLINBAH MACKENZIE SOUTH
LEVEE RAISE
CROSS SECTIONS
SHEET 2

PROJECT No.	DISCIPLINE	NUMBER	REV.
2188238A	- CIV -	0221	0

Plotted By: HamillM Plot Date: 31/07/15 - 13:48 Cad File: \\APBNEFIL03\proj\J\Jellinbah_Resources\2188238A_MACKENZIE_SOUTH_LEVEE_FINAL\09_CADD\Drawings\2188238A-CIV-0221.dwg