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REHABILITATION FLOOD MODELLING - DAUNIA MINE

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARR	Australian Rainfall & Runoff

AWS	Automatic Weather Station
BMA	BHP Mitsubishi Alliance
DEM	Digital Elevation Model
DES	Department of Environment and Science
DNM	Daunia Mine
DNRME	Department of Natural Resources, Mines and Energy
EA	Environmental Authority
FRP	Flooding Risk Profile
GSDM	Generalised Short-Duration Method
GTSMR	Revised Generalised Tropical Storm Method
LiDAR	Light Detection and Ranging
MIA	Mine Industrial Area
NUMA	Non-use Management Area
PDM	Peak Downs Mine
PMC	Pre-mining conditions
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QRT	Quantile Regression Technique
PRC	Progressive Rehabilitation and Closure
RCP	Representative Concentration Pathway (climate change emissions scenario)
RFFE	Regional Flood Frequency Estimation
SRTM	Shuttle Radar Topography Mission

1 INTRODUCTION

1.1 PROJECT BACKGROUND

BHP Mitsubishi Alliance (BMA) is Australia's largest producer and supplier of seaborne metallurgical coal, and it operates several mines within the Bowen Basin. As such, BMA are subject to the Queensland Government's Mined Land Rehabilitation Policy, which ensures that land disturbed by mining activities is rehabilitated progressively to a safe and stable landform as it becomes available. The rehabilitation must minimise the risks of environmental impacts and reduce cumulative areas of disturbed land throughout the life of a site.

To comply with the Queensland Government's Mined Land Rehabilitation Policy and the Environmental Protection (Rehabilitation Reform) Amendment Regulation 2019, BMA are required to develop Progressive Rehabilitation and Closure (PRC) Plans for the Daunia Mine (DNM). The PRC plans detail how and where activities will be carried out to allow the progressive rehabilitation of the land to a stable condition. Because DNM is a pre-existing mine for which BMA already hold an Environmental Authority (EA)/Land Outcome Document, the 'transitional' provisions provided for within the Mineral and Energy Resources (Financial Provisioning) Act 2018 (MERFP Act) apply to the DNM PRC plan.

This rehabilitation flood modelling report has been prepared to inform the development of the DNM transitional PRC plan, scheduled for submission in July 2023. The completed scope specifically aims to address the 'Flooding' requirements outlined in Section 3.6.1 – General Rehabilitation Practices of the Department of Environment and Science (DES) 2021 Guideline – Progressive rehabilitation and closure plans (PRC plans). The scope of this assessment does not include voids in floodplain modelling, which has been completed under separate cover.

This report has been prepared and reviewed by appropriately qualified engineers in accordance with DES PRC Guideline's definition of an appropriately qualified person - *"a person who has professional qualifications, training, skills and experience relevant to the subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods and literature"*.

1.2 PROJECT OBJECTIVES AND SCOPE

The objective of the project has been to deliver the supporting information pertaining to flooding that is considered by the administering authority to be necessary for underpinning the development of rehabilitation and management methodologies for DNM.

The project was divided into several phases. The scope of each phase is briefly outlined below.

Preliminaries

- Kick Off Meeting; and
- Collection and review of available data such as:
 - BMA available LiDAR data, contour data and aerial imagery for mining lease areas;
 - Existing flood models and data;
 - Pre-mining landform; and
 - Preliminary landform designs.

Hydrologic Modelling

- Preliminary assessment of the landform design and existing voids in floodplain models;
- Required updates to catchment characterisation and delineation based on pre- and post-mining landforms;
- Model calibration (if/where data is available);
- Rerunning of hydrologic models in accordance with Australian Rainfall & Runoff (ARR) 2019 guidelines;
- Modelling of the 50%, 10%, 5%, 1%, 0.1% Annual Exceedance Probability (AEP) and Probable Maximum Precipitation (PMP) storms as well as climate change scenarios; and

- Selection of critical design storm events.

Hydraulic Modelling

- Development/update of TUFLOW 1D/2D hydraulic models in accordance with ARR2019 guidelines for pre- and post-mining conditions;
- Simulation of all required scenarios (pre- and post-mining) and design storm events (50%, 10%, 5%, 1%, 0.1% AEP and Probable Maximum Flood (PMF) events, as well as climate change scenarios);
- Processing of simulation results;
- Flood assessment including a detailed understanding of the following:
 - Drainage and flooding behaviours in the vicinity of the voids;
 - Potential extent of flooding and any interactions with the voids;
 - Drainage and flooding behaviours over backfilled material; and
 - Assessment of any potential alteration to flows upstream and downstream; and
- Development of a flooding risk profile using the BHP established qualitative risk method.

Reporting and Mapping

- Documentation of study approach, methodology, inputs and outcomes;
- Floodplain mapping for all modelled scenarios and events showing peak flood results, including water levels, depths, velocities, and stream power; and
- Workshop with BMA – Results Briefing.

Project Finalisation

- Finalisation of report based on comments and feedback received from BMA on draft report; and
- Handover of final report, all study materials and model files.

1.3 STUDY AREA

DNM is an open pit coal mine located southwest of Nebo in Queensland's Bowen Basin. It is one of several mines in the area. Daunia operations mine the Moranbah Coal Measures, blending from up to 11 coal seams. DNM is located immediately east of the Poitrel Mine operated by Stanmore.

Mining operations commenced at DNM in 2013. Coking coal is extracted through open cut pits and processed on site through a Coal Handling and Processing Plant (CHPP). Processed coal is loaded out by rail to the Hey Point Coal Terminal.

Upon project initiation three main watercourses were identified in the vicinity of Daunia Mine. These watercourses included the Isaac River and two tributaries of the Isaac River, New Chum Creek, and North Creek. The two creek tributaries flow from north to south either side of the mine. The tributaries meet the Isaac River south of the mine and the river continues to the southeast. The watercourse and tributary catchments are defined by ranges and open plains with the catchment land use comprising of natural wooded areas and grassland.

Initial review of the PRC Landform Design #2 indicated that most of the existing mine's footprint will be covered by the future landform backfill, with pits located at the most northern and southern ends of this landform. The future Pandora Void to the south, was identified as vulnerable to ingress from the Isaac River while the Titan Voids to the north were considered potentially vulnerable to ingress from the nearby tributaries.

The study area and key waterways are illustrated in Figure 1-1.

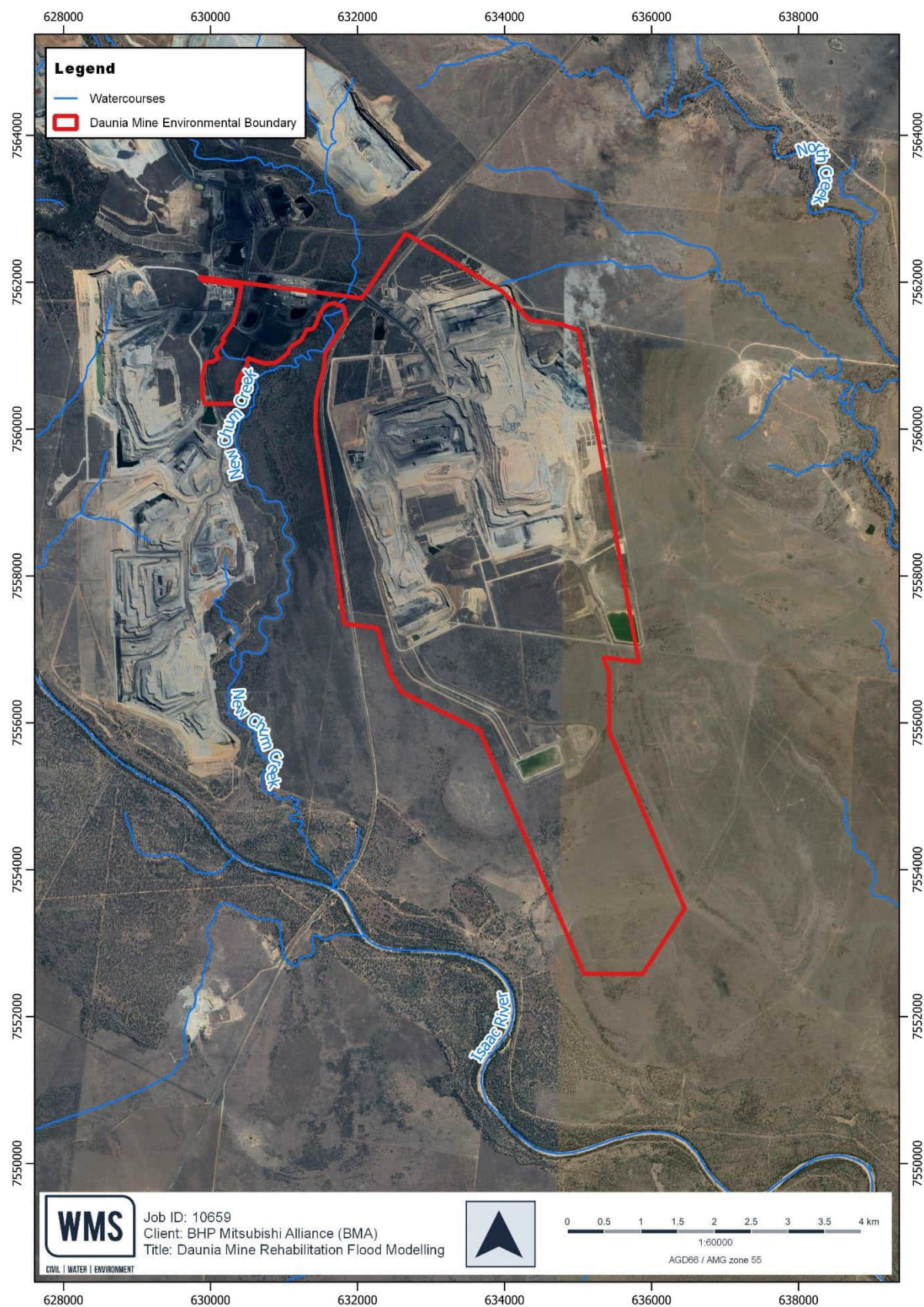


Figure 1-1 Daunia Mine Study Area

1.4 PRC LANDFORM DESIGN

The BMA approach to the PRC plans includes three iterations of the landform design. This approach allows for an iterative development of the landforms based on the results of the supporting PRC plan technical studies. The landform design approach includes the following:

- **Landform Design #1:** Initial concept based on EA and current activities. This version has been used to inform the Voids in Floodplain modelling, select geotechnical studies, soil evaluations and diversion concept designs.
- **Landform Design #2:** Revised design taking into consideration the results of the technical studies that were based on Landform Design #1. This landform design provided a more accurate consideration of the landform slopes, void extent, void flood protection landforms, final void design, etc. Landform Design #2 was used in the first stage of this rehabilitation flood modelling project.
- **Landform Design #3:** Final iteration of the landform design, informed by the results of the modelling undertaken based on Landform Design #2.

The results presented in this report relate to Landform Design #3, which is illustrated in Figure 1-2.

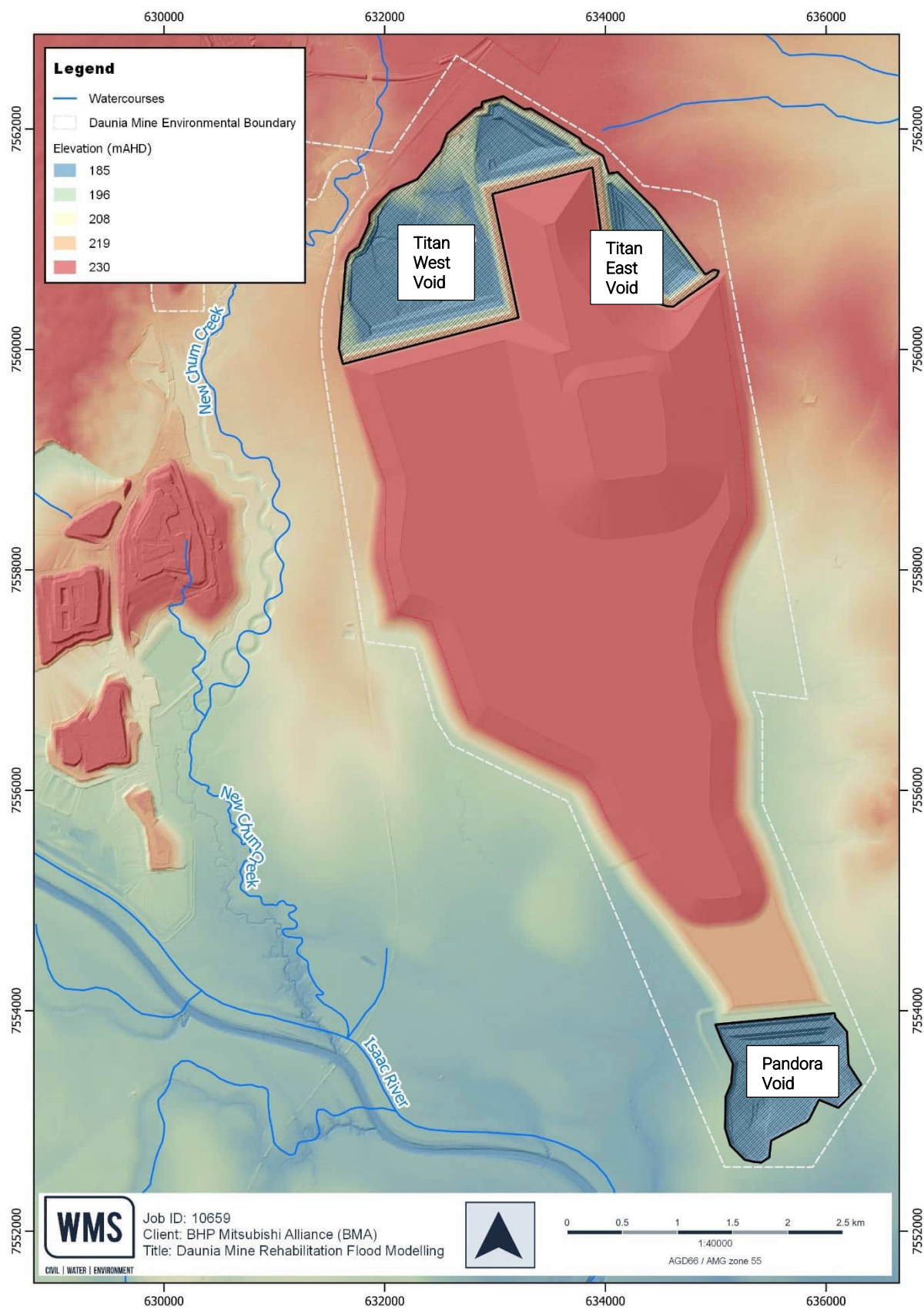


Figure 1-2 Daunia Mine PRC Landform Design #3

1.5 KEY ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations are applicable to the data used for the investigation, modelling results and mapping deliverables. The modelling results should therefore be viewed in light of these limitations.

Table 1-1 *Key Assumptions and Limitations*

Assumptions	
1	Calibration was done for the baseline hydrologic model provided by BMA. The baseline model was calibrated in 2019 against records of the stream gauging station at Isaac River Deverill and Goonyella Rail station. It has been assumed that the calibration carried out previously is fit for purpose and no further calibration is required.
2	Watercourse structure details have been adopted from previous modelling but due to lack of data were not verified. Accuracy of these details cannot be assured. Sensitivity testing has been undertaken to mitigate this risk.
3	A terrain modifier was used to remove the rail embankment over New Chum Creek where two large culverts are located near the rail loop that services the mine. Approximately 50m of embankment has been removed over the main channel under the assumption that the rail line will be discontinued following mine closure.
Limitations	
1	Coarse 1 second resolution (~30) SRTM data has been used to supplement the other model surfaces on the periphery of the hydraulic model due to an absence of better data. Model results may therefore be less accurate beyond 3 km south of the mine and within some parts of North Creek.
2	The future landform conditions and pit arrangement of the neighbouring Poitrel Mine at the time of Daunia Mine closure is unknown. This mine is within the Isaac River floodplain and may influence river hydraulics at the DNM site in the future. Poitrel Mine pits have been filled in to remove any associated flood storage which may not be present at mine closure.

2 INPUT DATA

Data for the current assessment was provided by BMA and included topographic data, design surface data for the PRC landform, aerial imagery and previous studies and models. Further data was obtained for use in the assessment from public sources, including additional topographic data, rainfall data and catchment specific hydrologic data.

Further detail on the data utilised in the assessment is provided below.

2.1 PREVIOUS STUDY

2.1.1 WRM Flood Modelling and Risk Assessment

Other studies have been undertaken for the DNM study area. BMA provided WMS with a copy of the Draft Flood Modelling and Risk Assessment for Daunia Mine, carried out by WRM in 2019.

The report was reviewed at the start of this assessment to gain a better understanding of the study area and its key hydrologic and hydraulic features. Furthermore, the hydrologic and hydraulic models developed as part of the WRM study were provided to WMS to be used as a basis for the modelling in the PRC assessment.

The purpose of the WRM study was to define baseline flood conditions at the existing mine site and assess Dam 5 flood risk from local drainage and Isaac River flooding. WRM adopted the XP-RAPTS Isaac River hydrologic model from the Goonyella Riverside flood study. The hydrologic model was updated and calibrated to the February 2008, December 2010 and March 2017 historic flood events at the Deverill stream gauge located immediately south of Daunia Mine near the confluence with North Creek. WRM also carried out a Flood Frequency Analysis (FFA) based on 51 years of annual maxima streamflow data.

As part of the study a separate local hydrologic model and hydraulic model were developed to assess Dam 5 and the drainage line to the east of New Chum Creek. These mine features are not a part of the PRC design. The associated local modelling was also found to be of insufficient coverage so these elements of the WRM study were not adopted. WMS has adopted the hydrologic and hydraulic modelling associated with the Isaac River modelling for further refinement.

2.1.2 Existing Models

Hydrologic and hydraulic models for the Isaac River were previously developed within the DNM study area as part of the Daunia Mine Flood Modelling and Risk Assessment (WRM, 2019). The existing models provided to WMS are summarised in Table 2-1. The existing models were used as a starting point for this assessment and were modified/updated where required.

Further details on model updates and new model build are provided in Section 4.

Table 2-1 Existing DNM Models Provided to WMS

Model Name	Hydrologic Model Software	Hydraulic Model Software	Hydraulic Model Grid Resolution (m)	Source
Isaac River	XP-RAFTS	TUFLOW	8	Daunia Mine Flood Modelling and Risk Assessment (WRM, 2019)

2.2 TOPOGRAPHY

Topography data within the study area was available in the form of several digital elevation models (DEMs) that were provided by BMA. These are summarised in Table 2-2. DNM Landform Design #3 forms the basis of the PRC assessment with other surfaces used to supplement the design where terrain was required outside the area covered by the designed rehabilitation landforms. The Daunia Mine Pre-Mining Surface was the surface representative of pre-mining conditions (PMC) prior to 2013. This surface was used for the PMC assessment.

Table 2-2 Available Digital Elevation Models

DEM Name	Terrain Conditions	Area Covered	Resolution (m)	Date Created/ Sourced	Source
Daunia Mine Landform Design Surface #3	Design	DNM	1	06/12/2022	BMA
Daunia Mine Existing Surface – LiDAR	Existing	DNM	2	2022	BMA
Daunia Mine Existing Surface – LiDAR Large Extent	Existing	DNM	2	2020	BMA
1 second SRTM Derived Hydrological Digital Elevation Model	Existing	DNM	~30	2000	BMA
Daunia Mine Pre-Mining Surface	Pre-Mining	DNM	1 ¹	Pre 2013	SLR

2.3 AERIAL IMAGERY

Satellite imagery of the DNM area was used within the mine extent, imagery was sourced from online imagery services (i.e., Google Satellite, Queensland Globe). The aerial was used to assist in the parametrisation of the models and gain an appreciation of the Site characteristics but neither the PRC nor PMC scenarios of this study are indicative of present-day conditions.

3 HYDROLOGIC MODELLING

As previously mentioned, hydrologic modelling for the Isaac River was adopted from the Daunia Mine Flood Modelling and Risk Assessment (WRM, 2019). This model was provided to WMS and used as the basis for hydrologic modelling in this assessment. The key parameters of the provided model remained unchanged unless there was a justifiable reason to alter them. To incorporate the PRC landform, updates were made to the models' catchment configuration, reach lengths and storm definitions. The latest draft BHP climate change scenarios were also incorporated into each hydrologic model.

The following sections present the key details and parameters of the hydrologic modelling following the updates.

3.1 MODELLING SOFTWARES

The existing hydrologic model provided to WMS was developed using XPRAFTS and incorporated the full catchment area of the Isaac River inclusive of the mining area. XP-RAFTS is an industry standard modelling package that is widely used in hydrological studies across Australia. A high-level review was carried out on the received model and they were deemed fit for purpose and appropriate for use in this assessment.

3.2 CATCHMENT DELINEATION

The catchment delineations developed for the Flood Modelling and Risk Assessment (WRM, 2019) were updated and refined to reflect the PRC conditions based on the DNM Landform Design #2. The catchment delineation was modified in the portion of the river catchment in the vicinity of the mine. Sub-catchments of the upper catchment outside of the mining lease area have not been redefined and will remain generally unchanged after mine closure.

The PRC spoil dump landforms will be designed to retain runoff on the top of the dumps and minimise the potential for runoff that could impact the stability/erosion of the outer batters/slopes. The collected water will be allowed to infiltrate into the spoil and evaporate and will not contribute runoff into the catchments. To account for the associated changes in catchment area, the hydrographs extracted from the hydrologic models were scaled in TUFLOW based on the percentage decrease in area of respective donor catchments.

The PRC catchment delineations are presented in Figure 3-1, and a summary of key catchment parameters is provided in Table 3-1.

Table 3-1 PRC Catchments Parameters

Model	Scenario	Number of Sub-catchments	Total Catchment Area (km ²)	Adopted Fraction Impervious
Isaac River	PRC	116	4079	0%

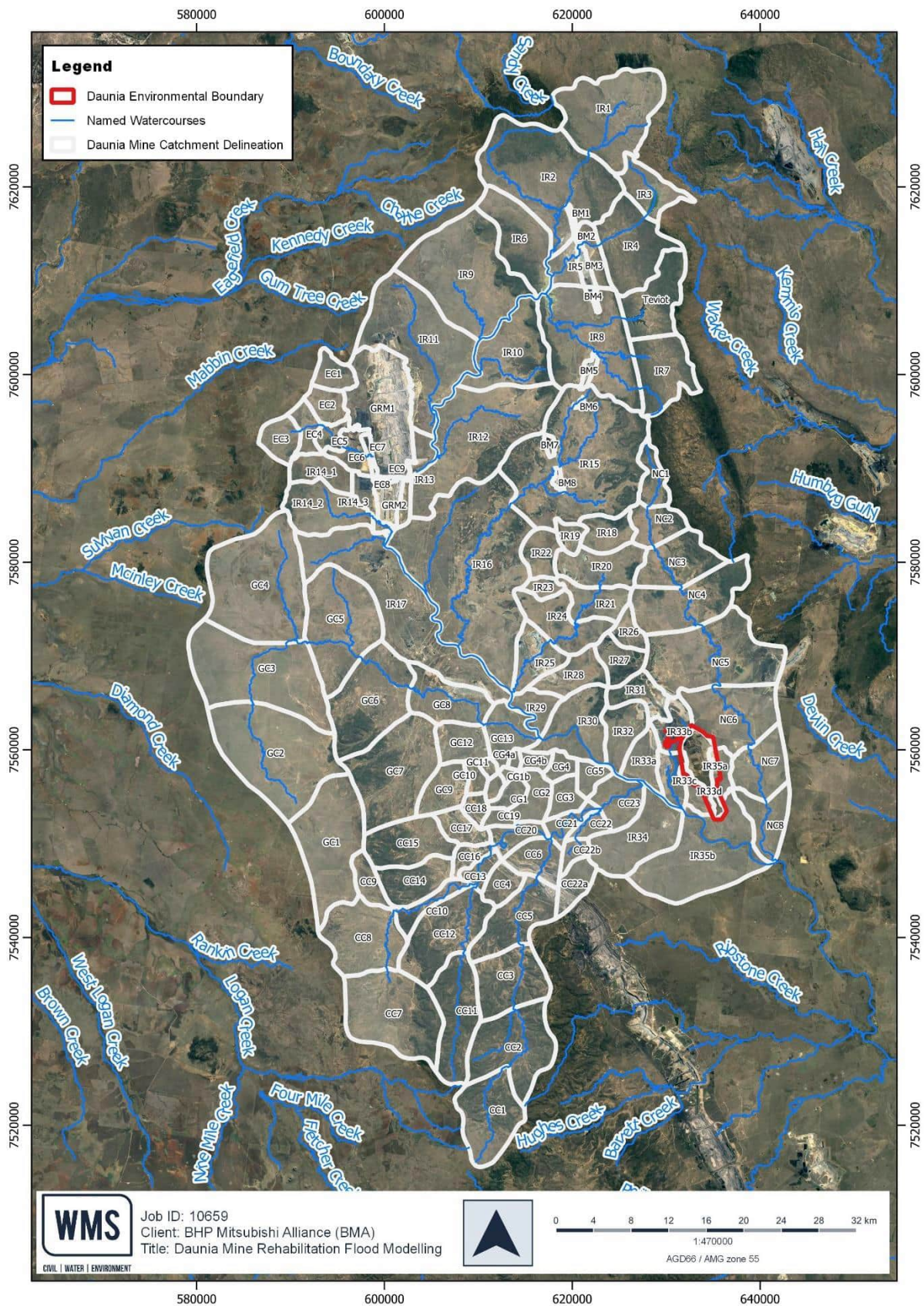


Figure 3-1 Daunia Mine PRC Catchment Delineation

3.3 DESIGN RAINFALL

The design rainfall was defined in XP-Rafts using regionally varying rainfall. Due to the large size of the Isaac River catchment four sets of design rainfall were used in the hydrologic model to somewhat account for the spatial variation of storm activity. To achieve this the hydrologic model catchments were split into regions for New Chum Creek, North Creek, the Upper Isaac River and Lower Isaac River. Rainfall from the centroids of these regions were extracted from the ARR BOM via the ARR datahub and allocated to the corresponding sub-catchments in the hydrologic model. The design rainfalls were broadly consistent with the rainfall totals used in previous modelling and vary up to approximately 10% between the defined rainfall regions. Design rainfall for the 50%, 10%, 5%, 1% and 0.1% AEP events is shown in Table 3-2, Table 3-3, Table 3-4 and Table 3-5 for each of the Isaac River regions.

Table 3-2 New Chum Creek ARR2019 BOM Design Rainfall

Duration	Rainfall Totals (mm) per Annual Exceedance Probability (AEP)				
	50% AEP	10% AEP	5% AEP	1% AEP	0.1% AEP
60 min	38.2	59.9	67.6	83.9	134
120 min	46.3	73.8	83.9	106	169
180 min	50.8	82	93.6	119	191
270 min	55.3	90.5	104	135	216
360 min	58.6	97	112	148	236
540 min	63.8	107	125	168	269
720 min	67.9	116	135	185	296
1080 min	74.8	129	152	214	342
1440 min	80.5	141	167	238	380
1800 min	85.4	150	179	258	411
2160 min	89.8	159	190	276	438
2880 min	97.3	174	209	306	486

Table 3-3 North Creek ARR2019 BOM Design Rainfall

Duration	Rainfall Totals (mm) per Annual Exceedance Probability (AEP)				
	50% AEP	10% AEP	5% AEP	1% AEP	0.1% AEP
60 min	38	59.6	67.3	83.4	133
120 min	46.1	73.6	83.6	105	168
180 min	50.5	81.9	93.6	120	191
270 min	55	90.7	104	136	217
360 min	58.4	97.6	113	149	239
540 min	63.8	109	127	172	275
720 min	68.1	118	138	191	305
1080 min	75.3	133	157	222	356
1440 min	81.4	145	173	249	397
1800 min	86.6	156	187	271	432
2160 min	91.3	166	199	291	463
2880 min	99.3	182	220	324	515

Table 3-4 Upper Isaac River ARR2019 BOM Design Rainfall

Duration	Rainfall Totals (mm) per Annual Exceedance Probability (AEP)				
	50% AEP	10% AEP	5% AEP	1% AEP	0.1% AEP
60 min	37.6	58.8	66.3	82.2	132
120 min	45.2	72.1	81.9	103	165
180 min	49.5	80.1	91.6	117	187
270 min	54	88.9	102	133	214
360 min	57.5	95.9	111	147	236
540 min	63.3	107	125	170	274
720 min	68.3	117	137	189	306
1080 min	76.7	134	158	222	358
1440 min	83.9	148	175	249	400
1800 min	90.3	160	189	273	434
2160 min	95.9	170	202	293	463
2880 min	106	188	224	326	511

Table 3-5 Lower Isaac River ARR2019 BOM Design Rainfall

Duration	Rainfall Totals (mm) per Annual Exceedance Probability (AEP)				
	50% AEP	10% AEP	5% AEP	1% AEP	0.1% AEP
60 min	37.9	59.7	67.5	84	133
120 min	45.7	73	83	105	166
180 min	50	80.7	92.2	118	187
270 min	54.5	88.7	102	132	210
360 min	57.8	94.9	109	144	229
540 min	63.2	105	121	163	259
720 min	67.5	113	131	179	285
1080 min	74.7	126	147	205	326
1440 min	80.7	137	161	227	360
1800 min	85.9	147	172	245	386
2160 min	90.5	155	182	262	410
2880 min	98.4	170	199	288	449

3.4 PMP AND EXTREME RAINFALL

Probable Maximum Precipitation (PMP) is not available through the BOM website. To calculate PMP, the Generalised Short-Duration Method (GSDM) was used. This method is based on an analysis of convective thunderstorms and is appropriate for durations up to 6 hours. The GSDM PMP rainfall calculation procedure followed the instructions detailed in 'The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method' (BoM, 2003).

For durations exceeding 6 hours, the revised Generalised Tropical Storm Method (GTSMR) was used. The GTSMR is appropriate to calculate PMP rainfall totals for durations greater than 24 hours, in areas of Australia affected by tropical storms and includes most of the continent except for the south-east. For durations between 6 hours and 24 hours, the PMP rainfall totals were determined by interpolation between the GSDM and GTSMR estimates.

The GSDM PMP rainfall totals and GTSMR PMP rainfall totals are summarised in Table 3-6 for each rainfall region.

Table 3-6 *PMP Design Rainfall*

Duration	Rainfall Totals (mm) per Model			
	New Chum Creek	North Creek	Upper Isaac River	Lower Isaac River
60 min	350	280	150	150
120 min	520	420	280	280
180 min	630	520	260	260
270 min	745	605	355	355
360 min	830	670	360	360
540 min	860	730	440	440
720 min	900	780	530	530
1080 min	960	890	690	690
1440 min	1030	1000	860	860
1800 min	1150	1110	930	930
2160 min	1260	1210	1000	1000
2880 min	1420	1420	1420	1420

3.5 TEMPORAL PATTERNS

For flood events from the 50% AEP event up to the 1% AEP, East Coast (north) ARR Data Hub point source temporal patterns were adopted. For storm durations of 12 hours or longer, East Coast (north) areal temporal patterns were adopted. For some of the longer durations were data allowed, both the point source and areal temporal patterns were simulated for a total of 20 temporal patterns per duration.

For the larger rainfall events including the 0.1% AEP and PMP events, temporal patterns are based on the paper 'Growth curves and temporal patterns of short duration design storms for extreme events' (Jordan, P., 2005). This methodology is in line with ARR Guidelines, which recommend the use of Jordan temporal patterns for extreme event modelling.

3.6 RAINFALL LOSSES

Rainfall losses used in the Daunia Mine Flood Modelling and Risk Assessment (WRM, 2019) were reviewed against the ARR Data Hub losses in the Isaac River catchment. The Data Hub losses were noticeably higher compared to the WRM losses. The WRM study had adjusted the losses down in the hydrologic model to fit the FFA results carried out at the Deverill stream gauge located south of Daunia Mine on the Isaac River.

It was considered prudent to adopt the WRM losses for the PRC landform design modelling due to their more conservative nature and FFA verification. All hydrologic models incorporated PMP event initial and continuing loss values of 0 mm and 1 mm/h respectively, in accordance with ARR2019 Guidelines (Book 8, Section 6.4). Loss values for the remaining events are summarised in Table 3-7.

Table 3-7 Adopted Rainfall Losses

Flood Event (AEP)	Initial Loss (mm)	Continuing Loss (mm/h)
0.1%	0	2.0
1%	5	2.5
5%	10	2.5
10%	25	2.5
50	25	2.5

3.7 AREAL REDUCTION FACTORS

The areal reduction factor (ARF) is a multiplier applied to the design rainfall to account for increased spatial variability that occurs over larger catchments. The ARF is calculated using region specific parameters and the total catchment area upstream of the study site. For the Daunia PRC Landform Design there are two key areas of interest with regard to the study site, the Pandora Void to the south of the landform, and the Titan Voids, East and West, to the north of the landform. The Pandora Void is susceptible to Isaac River ingress, while the Titan Voids are close to the tributaries. Initial model testing indicated that the North Creek flood extent was more than 2km from Titan East Void. As such it was considered appropriate to focus just on New Chum Creek near the Titan West Void.

Calculation of storm ARF within the DNM catchments was based on the methodology for catchments between 10 km² and 1,000 km², and between 1,000 km² and 30,000 km² in accordance with ARR2019 recommendations (Book 2, Chapter 4, Section 4.3), using ARF parameters for the Semi-arid Inland QLD zone (refer Table 2.4.2 of ARR2019, Book 2, Chapter 4) and the catchment areas outlined in Table 3-8.

Table 3-8 ARF Areas

Model	ARF Area (km ²)
Isaac River	3580
New Chum Creek	18.90

3.8 HYDROLOGIC STORAGE PARAMETERS

XP-Rafts storage parameters have remained unadjusted from the previous study where calibration took place. The hydrologic model was calibrated to discharge hydrographs recorded at the Deverill and Goonyella stream flow stations with priority given to the Deverill gauge close to Daunia Mine. The calibration was performed on flood years 2008, 2010 and 2017.

The hydrologic model storage parameter, B_x, is summarised in Table 3-9.

Table 3-9 Adopted Hydrologic Storage Parameters

Model	XP-Rafts B _x Value
Isaac River	1

3.9 CLIMATE CHANGE ASSESSMENT

The climate change assessment complies with BMA's *Guideline for Climate Change Adaptation in Mine Water Planning and Hydrologic Assessment_Rev1* (CTD-WTR-GLD-001). The BMA climate change approach combines the previous 2070 and 2099 future climate periods into one 2061 – 2099 period. The period includes 10th, 50th and 90th percentile projections for both moderate climate change (RCP 4.5) and upper climate change (RCP 8.5) emissions trajectories. Following project start up, BMA requested that WMS utilise the revised procedure in preparation of climate change scenarios for the 1% AEP and 0.1% AEP events. This has required a total of six climate change simulations per event for each watercourse. These include:

- 2061 – 2099 period, RCP 4.5 10th percentile (5% rainfall intensity increase);

- 2061 – 2099 period, RCP 4.5 50th percentile (11% rainfall intensity increase);
- 2061 – 2099 period, RCP 4.5 90th percentile (20% rainfall intensity increase);
- 2061 – 2099 period, RCP 8.5 10th percentile (8% rainfall intensity increase);
- 2061 – 2099 period, RCP 8.5 50th percentile (17% rainfall intensity increase); and
- 2061 – 2099 period, RCP 8.5 90th percentile (28% rainfall intensity increase).

3.10 CRITICAL DURATION ASSESSMENT

A critical duration assessment was carried out in the hydrologic models for all events in accordance with ARR2019 guidelines. A range of durations were simulated for each event. The range of durations tested was between 1 and 18 hours for New Chum Creek and between 12 and 72 hours for the Isaac River.

For each duration an ensemble of 10 or 20 temporal patterns were simulated as outlined in Section 3.5. Peak flows from the temporal patterns were ranked and the event above median selected as representative of each duration. The critical durations were determined based on the highest median peak flow. The assessments were carried out at the hydrological node at the future pit locations to the north and south of the landform. This was node IR31 for New Chum Creek and node DN14 for the Isaac River. The critical duration event and durations either side of the critical were taken forward for hydraulic modelling in TUFLOW. The additional storms were taken forward as the critical duration can vary between hydrological and hydraulic results.

The flood level surfaces from the hydraulic models were interrogated to confirm the critical duration event. The identified critical durations were found to produce the highest flood levels at key areas near the pit locations. The final critical durations confirmed by hydraulic modelling are listed in Table 3-10.

Table 3-10 Critical Duration Summary

Model	Event	Critical Duration (h)	Temporal Pattern
New Chum Creek	50% AEP	9	9
	10% AEP	9	4
	5% AEP	6	7
	1% AEP	6	5
	0.1% AEP	6	10
	PMF	4.5	3
Isaac River	50% AEP	18	3
	10% AEP	24	8
	5% AEP	24	19
	1% AEP	30	8
	0.1% AEP	30	8
	PMF	24	2

3.11 PEAK FLOW VALIDATION

To assess the appropriateness of hydraulic model flows, peak flows at the critical locations upstream of the pits were compared to results from the hydrologic model, to the WRM results, and to peak flows estimated using the following methods:

- Regional Flood Frequency Estimation Model (RFFE): the RFFE requires the catchment centroid and outlet coordinates, and the catchment area. The RFFE transfers flood frequency characteristics from a group of stream gauged catchments to the location of interest. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (<http://rffe.arr-software.org/>).
- Quantile Regression Technique (QRT): the QRT uses several gauged catchments in a selected region from which the historical flood records are collected and used in a flood frequency analysis to provide flood quantities. These results and corresponding

catchment characteristics are used in a regression analysis, which provides an equation that best describes the relationship between the two sets of data. This equation can then be used to estimate design flows for ungauged locations. The QRT analysis for Queensland included all suitable stream gauging stations in the state and the equations developed predict design flows based on catchment area and the rainfall intensity. The QRT for Queensland is appropriate for small and medium sized catchments up to 1000 km².

A summary of the peak flow validation is provided in Table 3-11. Note that this comparison is based on Stage #2 model results. The RFFE and QRT methods are not shown for the Isaac River due to the large catchment size being outside the limits of the methodologies. The table also includes the FFA flow results from the WRM study for comparison. All Isaac River flows were taken from the Deverill gauge location south of Daunia Mine immediately downstream of the confluence with North Creek. The New Chum Creek flows were taken from downstream of catchment IR33b south of the Daunia MIA.

For the Isaac River hydrologic model, peak flows are slightly lower than the WRM peak flows, up to the 1% AEP event. Lower flows are not unexpected as there is slightly less catchment area in the PRC model due to the landform design that retains runoff on top of the spoil. The distributed rainfall approach that has been adopted has also revised the peak flows and selection of critical storms resulting in some general variation between results. Peak flows from the hydraulic model are somewhat lower than the hydrologic model peak flows. This is as expected in considering the sizable floodplain storage that is available in the hydraulic model. The modelled PRC flows match well to the WRM FFA results. The Isaac River peak flows can be considered within expected tolerances.

The validation flows for New Chum Creek vary significantly with increasing event magnitude a reflection of the limitations in the techniques and limited gauge data in the region. The hydrologic and hydraulic flows lie between the two validation techniques suggesting that the models are producing a reasonable estimation of peak flow in New Chum Creek.

Table 3-11 Peak Flow Validation Summary

Model	Event	Peak Flow (m ³ /s)					
		Hydrologic Model (RORB/XPRAFTS)	Hydraulic Model (TUFLOW)	WRM (2019) XP Rafts at Deverill	WRM FFA	RFFE	QRT
Isaac River	50% AEP	451	390	NA	NA	NA	NA
	10% AEP	1,822	1,665	1,951	1,880	NA	NA
	5% AEP	2,709	2,592	2,869	2,699	NA	NA
	1% AEP	4,911	4,952	5,046	4,750	NA	NA
	0.1% AEP	10,368	*10,157	10,180	NA	NA	NA
	PMF	39,327	*34,615	36,474	NA	NA	NA
New Chum Creek	50% AEP	17	17	NA	NA	16.8	17
	10% AEP	60	58	NA	NA	34.5	86
	5% AEP	92	90	NA	NA	42.5	130
	1% AEP	137	133	NA	NA	63.5	252
	0.1% AEP	263	261	NA	NA	NA	NA
	PMF	1434	1,402	NA	NA	NA	NA
*Flow influenced by pit ingress							

4 HYDRAULIC MODELLING

A TUFLOW 2D hydraulic model was developed to determine flood behaviour around the PRC landform and voids. TUFLOW is widely used in Australia for flooding and drainage studies. The recent TUFLOW version (2020-10-AD) has been adopted for this study. The latest versions of TUFLOW incorporate the HPC (Heavily Parallelised Compute) model run engine. TUFLOW HPC is an explicit solver for the full 2D Shallow Water Equations, including a sub-grid scale eddy viscosity model. HPC can be used in GPU (Graphics Processing Unit) mode to improve simulation speed. TUFLOW HPC GPU was used for this assessment.

4.1 MODEL RESOLUTION, EXTENT AND TOPOGRAPHY

Layouts and key features of the hydraulic model are presented in Figure 4-1.

Due to the large size of the DNM PRC hydraulic model domain a moderate size has been selected which aims to balance the model run times with the required resolution. The model resolution allows for detailed representation of the channel and floodplain flow paths. The cell size is consistent with previous modelling carried out for DNM and is summarised in Table 4-1.

Table 4-1 Model 2D Cell Sizes

Model	Cell Size (m)
Daunia Isaac River	8

The model extent was delineated to capture all flood events and their anticipated wetted areas upstream, downstream and throughout the PRC landform design and pits. Compared to previous flood models, the model domain was expanded and extended a significant distance north to capture the New Chum Creek and North Creek study areas.

The PRC design surface was supplied by BMA and incorporated into the model. Additional topographic layers were used to supplement the surface at areas on the periphery of the modelled floodplain that had not been incorporated into the design. These surfaces are noted in Section 2.2.

During review of the landform design and accompanying topography several areas in need of topographic modification were found. The available LiDAR footprint did not extend to the periphery of the floodplain model and SRTM topography data was needed to supplement areas of the model on the southern and eastern edges of the model extent. Due to the disparity in dataset elevations terrain modifications were required to tie the surfaces together and ensure there were no artificial obstructions to flow. Further terrain modifications were required to fill the existing Poitrel Mine pits within the model extent and not covered by the PRC design. BMA were in agreement with this approach to ensure the mine voids would not act as a sink to modelled flow. The rail line toward the rail loop north of the MIA was found to be obstructing the New Chum Creek channel. Additional terrain modifiers were used to open up the channel at this location.

4.2 BOUNDARY CONDITIONS

4.2.1 Inflow Boundaries and Initial Conditions

The hydrographs extracted from the XP-Rafts model were applied to the TUFLOW model as 2D boundary conditions. Two types of inflow boundaries were used:

- '2d_bc' Lines
'2d_bc' lines were used to apply the hydrographs for the sub-catchments located outside the model extent. These inflows are applied to the model edges and include total flow hydrographs for the main watercourses in the modelled area.
- '2d_sa' Polygons
'2d_sa' polygons were used to apply the local hydrographs for the sub-catchments located within the model extent. The polygons were positioned at appropriate locations along the watercourse, consistent with the hydrologic model package, and within their respective local sub-catchments.

4.2.2 Outflow Boundaries

Downstream boundaries were applied to the TUFLOW model to allow flow to exit the study area. All downstream boundaries were based on a water profile slopes. The main river downstream boundary was positioned approximately 10 kilometres downstream from the future Pandora Void location and perpendicular to the watercourses.

Pit outflow boundaries were positioned along the perimeter of the pits to extract flow from the model. Outflow rates were based on steep water profiles to approximate the overtopping of pits at the floodplain periphery. The model outflow boundaries are in the model layout figures.

4.3 HYDRAULIC ROUGHNESS

The hydraulic roughness (Manning's 'n') values used in the model are outlined in Table 4-2. Values are within the ranges recommended by ARR 2019 Guidelines. The delineation of land use was based on identifiable features within the PRC topography and inspection of existing aerial imagery. No revegetation plan was available to inform possible ground cover changes under post closure conditions. It has been assumed that the unvegetated areas of the mine will remain in a similar condition for some time after closure, but it should be noted post closure ground conditions are likely to change over the long term. Sensitivity testing has been carried out on the manning n values. This is summarised in Section 4.5.

Table 4-2 Adopted Hydraulic Roughness Values per Land Use

Land Use	Adopted Manning's 'n'
Compacted soil, roads, and impervious areas	0.025
Active channel	0.035
Uncompacted spoil/waste dump/ grass	0.04
Light brush	0.06
Dense vegetation	0.1

4.4 WATERCOURSE STRUCTURES

Drainage and watercourse structures within the mine site remediation areas are to be removed and are therefore not needed in the model. Any structures outside of the mining lease are likely to remain beyond mine closure. The rail line south of DNM crosses the Isaac River upstream of the future Pandora Void and so has potential to influence flows reaching the areas of interest. The rail embankment over the floodplain includes four bridges modelled in 2D and two culvert crossings modelled in 1D.

4.4.1 2D Bridges

Bridge structures are typically modelled in 2D as layered flow constrictions. Layered flow constrictions define the bridge geometry in the vertical plain and apply form losses to these vertical layers. The layered flow constriction parameters were adopted from previous modelling and are outlined in Table 4-3. Firsthand details of the structure details were not available for verification, so sensitivity testing was carried to improve confidence in the model results. Details of the sensitivity testing are outlined in Section 4.5.

Table 4-3 *Bridge Structure Details*

Bridge	Soffit RL (mAHD)	Road Surface Level (mAHD)	Deck Thickness (m)	Pier form Loss	Pier Blockage of Bridge Opening (%)
River	192.1	194.3	2.2	0.3	5
Southern Tributary	191.7	192.4	0.7	0.3	10
Southern Floodplain	191.5	192.5	1	0.3	10
Northern Floodplain	192.3	193	0.7	0.3	10

4.4.2 Culverts

The railway embankment includes two banks of culverts modelled as 1D structures. Culvert details are shown in Table 4-4.

Table 4-4 *Culvert Structure Details*

ID	Manning's n Roughness	Type	Dimensions	US Invert	DS Invert
Culvert 1	0.015	RCP	900 mm	191.75	191.7
Culvert 2	0.015	RCP	900 mm	190.75	190.7

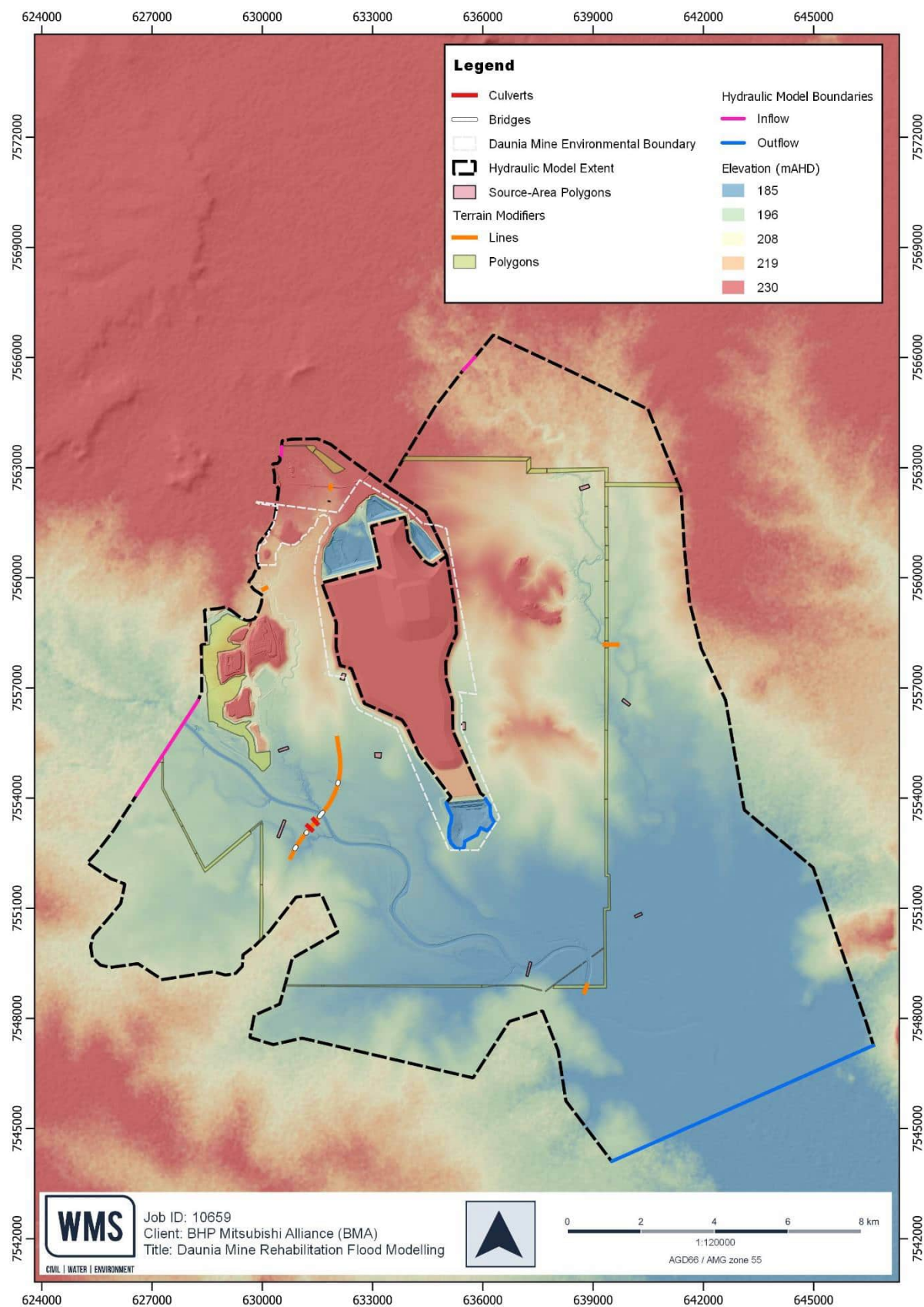


Figure 4-1 Daunia Mine PRC TUFLOW Model Layout

4.5 SENSITIVITY TESTING

4.5.1 Manning's Sensitivity

Sensitivity testing on the 2D manning's n roughness values was performed on the hydraulic model. The global manning's roughness values were increased and decreased by 20% and the 0.1% AEP climate change RCP 8.5 P90 event was simulated for each scenario. A summary of sensitivity testing results is provided in Table 4-5 and show levels vary by a few hundred millimetres.

4.5.2 Rail Bridge Layered Flow Constriction Removal

As discussed in Section 4.4.1 the adopted rail bridge details were unable to be confirmed so sensitivity testing was carried out. To do this the layered flow constriction file was removed for all four bridges. Table 4-5 demonstrates that results in key areas of the model are insensitive to the removal of the bridge geometry and form losses. The larger level differences of approximate 200 mm are located directly under the river bridge and taper away very quickly upstream and downstream.

Table 4-5 Sensitivity Testing Summary

Daunia Isaac River Model	Maximum Decrease in Water Level (mm)	Maximum Increase in Water Level (mm)	Maximum Level Change near Pandora Void (mm)	Maximum Level Change in New Chum Creek (mm)
20% Increase in Global Manning's	0	450	300	200
20% Decrease in Global Manning's	530	0	-500	-300
Rail Bridge Removal	200	200	5	-25

4.6 PRE-MINING CONDITIONS MODELLING

To assess how flood characteristics and flow paths have changed as a result of mining operations, a pre-mining conditions (PMC) scenario was developed within the models as a comparison to the PRC model results. TUFLOW scenario switches were used to read in the additional model files. This section outlines the model build approach for the PMC scenario. Where parameters or methods are not stated, they remain unchanged from the PRC model.

Layouts and key features of each hydraulic model for the PMC scenario are presented in Figure 4-2.

4.6.1 PMC Extent and Topography

The basis of the PMC model scenario was the Daunia Mine Pre-Mining DEM based on 1m LiDAR flown prior to commencement of mine operations in 2013. The digital surface was provided by BMA and of good quality. The PMC model code was delineated based on the Pre-Mining DEM to accommodate areas of minor drainage paths where the PRC landform had previously been located outside of the model extent.

4.6.2 PMC Inflows and Boundaries

For the modelling of the pre-mining scenario, the catchment delineation developed for the PRC scenario was modified to reflect the pre-mining sub-catchment arrangement. Updated local sub-catchment hydrographs were derived by scaling flows in TUFLOW based on the relative areas of the respective PRC catchments. All modified sub-catchments were located over the mining area and represented local inflows only. These inflows were read into the TUFLOW model with updated '2d_sa' polygons. This was considered an appropriate method as the modified local sub-catchments only represented a small portion of the total flow traversing the mine site areas. Total inflow hydrographs at the upstream model extents and the downstream boundaries remained unchanged.

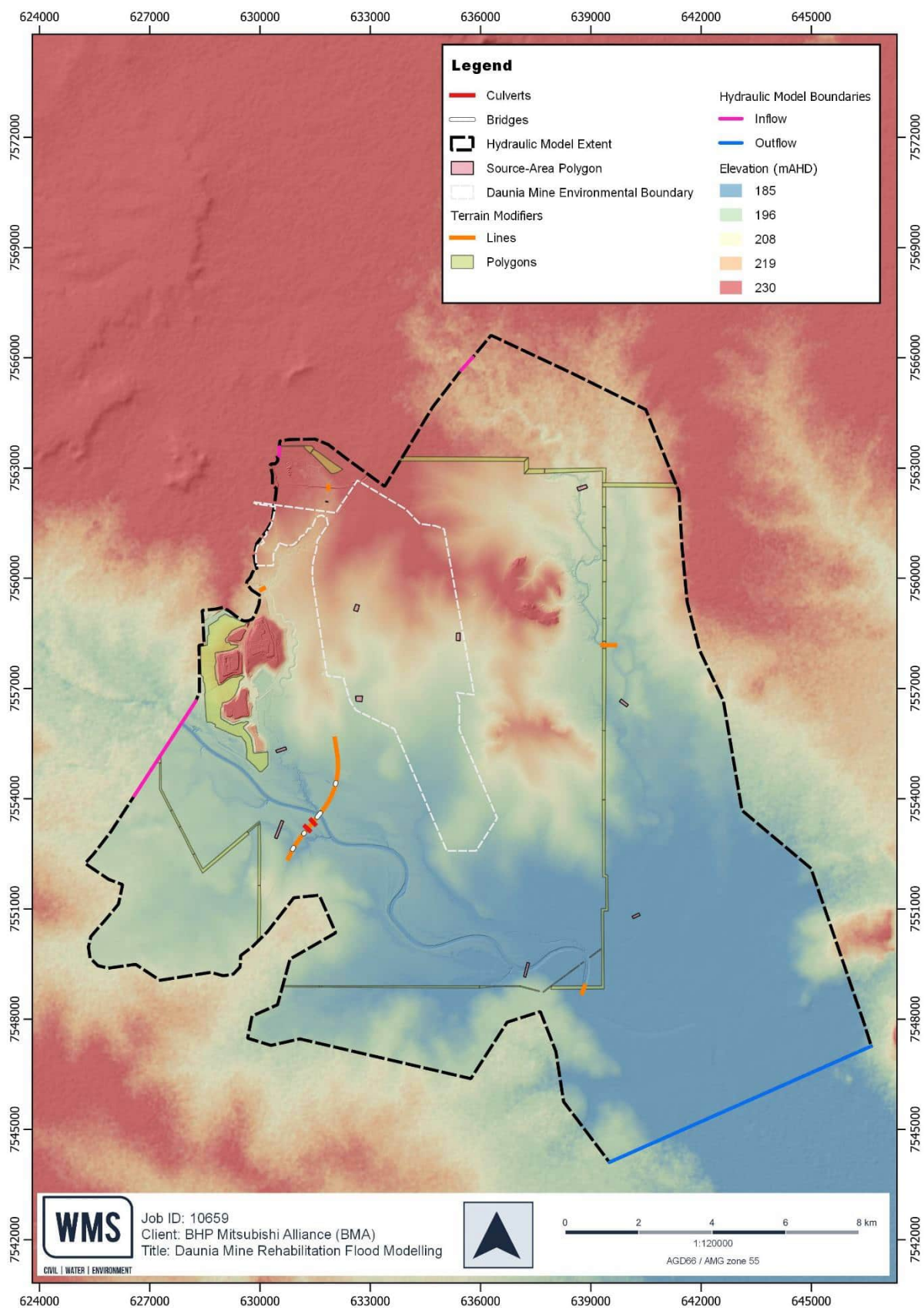


Figure 4-2 Daunia Mine PMC TUFLOW Model Layout

5 RESULTS AND DISCUSSION

Mapped model results for each of the study watercourses are presented in the appendices as follows:

- **Appendix A – Isaac River**
 - Maps 1 – 18: PRC peak depth and water level contours, peak velocities and peak stream power for 50% AEP, 10% AEP, 5% AEP, 1% AEP, 0.1% AEP and PMF events.
 - Maps 19 – 30: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 4.5 (P10 P50 P90) and RCP 8.5 (P10 P50 P90).
 - Maps 31 – 48: PMC peak depth and water level contours, peak velocities and peak stream power for 50% AEP, 10% AEP, 5% AEP, 1% AEP, 0.1% AEP and PMF events.
 - Maps 49 – 60: PMC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 4.5 (P10 P50 P90) and RCP 8.5 (P10 P50 P90).
- **Appendix B– New Chum Creek**
 - Maps 1 – 18: PRC peak depth and water level contours, peak velocities and peak stream power for 50% AEP, 10% AEP, 5% AEP, 1% AEP, 0.1% AEP and PMF events.
 - Maps 19 – 30: PRC peak depth and water level contours for 1% AEP and 0.1% AEP climate change events, RCP 4.5 (P10 P50 P90) and RCP 8.5 (P10 P50 P90).

5.1 FLOOD INGRESS TO VOIDS

It is the intention of BMA that prior to mine closure all voids be immune from flood ingress up to and including the 0.1% AEP climate change RCP 8.5 P90 event. Modelling of Landform Design #2 showed that the Pandora Void was subject to pit ingress in this event and some more frequent events. Landform Design #3 includes the addition of a flood protection landforms on the west side of the Pandora Void to address the river ingress. Landform Design #3 modelling results show the Pandora Void is no longer subject to ingress from the west in the 0.1% AEP climate change RCP 8.5 P90 event.

Modelling of Landform Design #2 also showed that the Pandora Void was subject to pit ingress from the east side due to the presence of a drainage feature that approaches from the north. Minor ingress at this locations begins in the 0.1% AEP event. Following discussions with BMA it is understood that the pit ingress from this drainage feature does not warrant mitigation due to the low volumes of ingress expected. The PRC Void Water Balance Report determined that the Pandora Void would have an available storage capacity below the groundwater level of between 26, 800 ML and 27,800 ML. This is well in excess of even the PMF ingress volume on the eastern side of the void.

The floodwater ingress to the Pandora Void for Landform Design #3 is summarised in Table 5-1. The Titan East and Titan West voids north of the landform do not experience ingress in any modelled event.

Table 5-1 Floodwater Ingress to Pandora Void Summary

Location	Event of Initial Spill	0.1% AEP CC RCP 8.5 P90 Ingress Volume (ML)	PMF Ingress Volume (ML)
Western Side of Void	PMF	0	102,530
Eastern Side of Void	0.1% AEP	1,835	8,116

5.2 INTERACTIONS WITH THE LANDFORM

The PRC results have been inspected to identify locations where floodwaters interact with the landform design. As recommended by BMA, particular attention was paid to areas where floodwaters pond against the landform, or where particularly high stream power or velocities occur.

There are several locations across the study area where floodwaters spill out of the main watercourse channel and make contact with the landform. As these locations are at the edge of the floodplain, the velocities and stream power are generally low, however

some locations where values are generally higher than the surroundings do occur. The key locations where water makes contact with the landform features, as well as locations where particularly high velocities occur, are shown in Figure 5-1.

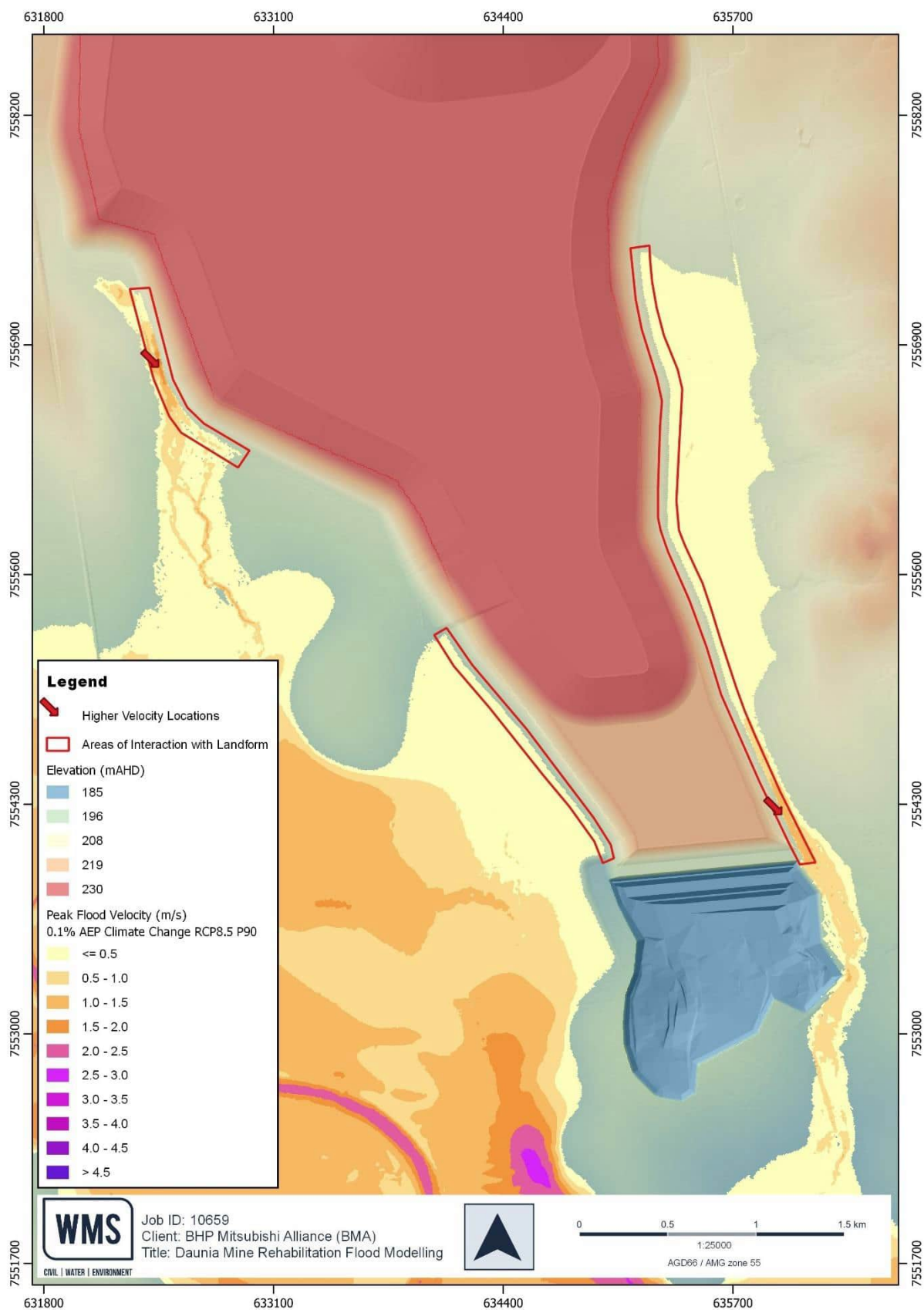


Figure 5-1 Key Locations of Interaction with the Landform

5.3 CONSIDERATION OF ALTERATION OF FLOWS

As part of the PRCP guidelines consideration should be given to the alteration of flows upstream and downstream of the mine site. Flows upstream of the mine site can be considered unaltered as the upstream catchments are unaffected by mining operations.

For the assessment of flow alteration in the vicinity and downstream of the mine site, peak flows and total volumes from the PRC and PMC scenarios have been extracted from three key locations, which are illustrated in Figure 5-2. Peak flows and total volumes through the selected downstream locations are shown in Table 5-2 for a range of events.

Table 5-2 Peak Flow and Total Volume Comparison – PRC vs PMC

Model	Event	Peak Flow (m³/s)			Total Volume (ML)		
		PRC	PMC	Percentage Change	PRC	PMC	Percentage Change
Location 1	50% AEP	17	17	-3.2%	513	543	-5.5%
	10% AEP	58	60	-3.1%	1,883	1,949	-3.4%
	5% AEP	91	92	-1.9%	2,463	2,545	-3.2%
	1% AEP	132	135	-2.2%	3,538	3,651	-3.1%
	0.1% AEP CC RCP8.5 P90	331	341	-2.8%	7,981	8,218	-2.9%
	PMF	1,184	1,228	-3.6%	23,743	24,461	-2.9%
Location 2	50% AEP	403	405	-0.4%	21,702	21,831	-0.6%
	10% AEP	1,581	1,583	-0.1%	116,553	117,037	-0.4%
	5% AEP	2,380	2,384	-0.2%	195,479	196,203	-0.4%
	1% AEP	4,391	4,401	-0.2%	399,038	400,413	-0.3%
	0.1% AEP CC RCP8.5 P90	12,744	12,771	-0.2%	1,150,877	1,154,491	-0.3%
	PMF	34,616	34,670	-0.2%	2,693,081	2,702,662	-0.4%
Location 3	50% AEP	402	403	-0.2%	18,595	18,692	-0.5%
	10% AEP	1,524	1,534	-0.6%	106,118	107,258	-1.1%
	5% AEP	2,330	2,346	-0.7%	181,848	183,682	-1.0%
	1% AEP	4,447	4,478	-0.7%	378,867	382,514	-1.0%
	0.1% AEP CC RCP8.5 P90	12,983	13,040	-0.4%	1,126,910	1,135,358	-0.7%
	PMF	32,597	35,439	-8.0%	2,590,290	2,713,451	-4.5%

In acknowledging the ongoing terrain alterations at DNM over the mine life, some alteration to the watercourse flow regime is to be expected. As demonstrated in Table 5-2, there has been a decrease in peak flows and volumes in the PRC scenario compared to the PMC scenario. The decrease is relatively limited, with percentage decreases below 6%. The exception to this is the peak flow at Location 3 in the PMF event, where the percentage decrease is 8%. This reduction is partly caused by the ingress of floodwaters into the Pandora Void and subsequent decrease in flow arriving at Location 3 further downstream. A contributing factor to the reduction in flow for all events is the PRC landform design that retains runoff on top of the spoil resulting in a slightly reduced PRC catchment area.

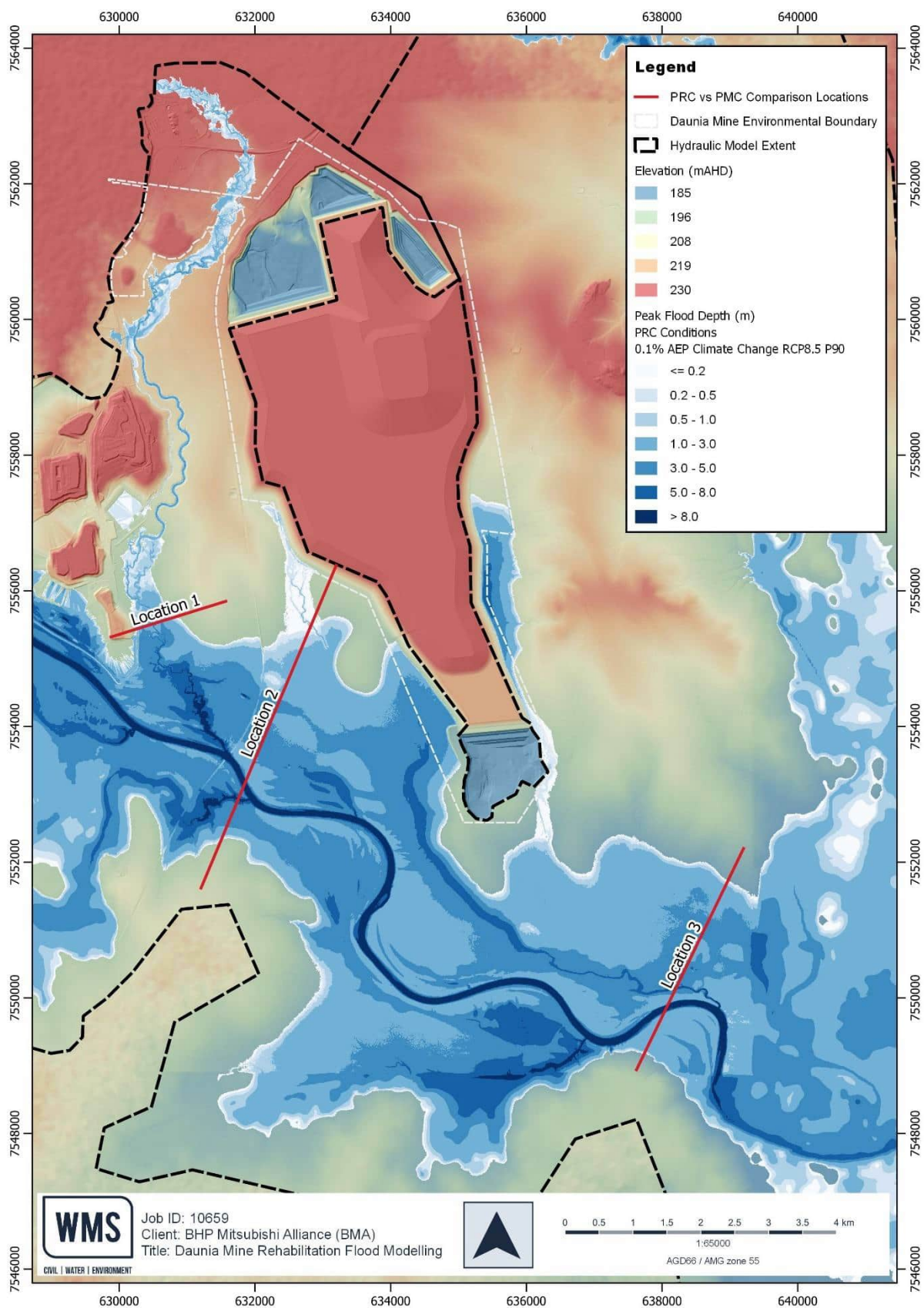


Figure 5-2 Peak Flow and Total Volume Comparison Locations – PRC vs PMC

6 FLOODING RISK PROFILE

A Flood Risk Profile (FRP) was developed by WMS based on BHP's *"Risk Management Our Requirements"* document and review of the *"Risk Assessment Approach"* provided by BHP. The FRP has been developed for the PRC scenario and uses the model results to inform potential future flood risks. The identified risks have been discussed in Section 5 but the FRP goes further to quantify, classify, and suggest mitigation for the risks. The process can be outlined as follows:

1. Risk identification based on model results.
2. Quantify risk in terms of Maximum Foreseeable Loss (MFL) as defined in the Severity and Likelihood table in Appendix A of BHP's Risk Management Document.
3. If the MFL is rated 4 or above identify control measures, type, and purpose.
4. Assess the residual severity to determine the Residual Risk Rating (RRR) following implementation of the control measures.
5. Determine the emerging risks likelihood factor following implementation of control measures.
6. Use the RRR heat map provided in BHP's Risk Management Document to determine if the risk appetite is exceeded for each risk. RRR < 90 denotes an acceptable risk.

Details of the FRP are provided in Appendix C.

The FRP identifies the MFL impacts associated with the remaining pit ingress, flood water contact with landform and PRC flow alteration. All risks have an MFL less than 4, and so do not require additional controls.

7 SUMMARY AND RECOMMENDATIONS

WMS was engaged by BMA to undertake Rehabilitation Flood Modelling for DNM to provide supporting technical information for the DNM PRC plans.

Hydrologic and hydraulic modelling has been undertaken for the two key watercourses within the study area that interact with the mine site. These watercourses include the Isaac River and New Chum Creek. North Creek to the east of DNM has also been modelled but was not included as a focus area due to its lack of interaction and proximity to DNM.

The modelling utilised software packages XP-Rafts and TUFLOW and has incorporated Landform Design #3, which was provided to WMS as a digital surface. Landform Design #2 was assessed prior to Landform Design #3. The Stage #2 model results were used to refine the Stage #3 design that incorporated a bund to the west of the Pandora Void.

To assess how flood characteristics and flow paths have changed as a result of mining operations, a pre-mining conditions (PMC) scenario was developed within the hydraulic model as a comparison to the PRC model results.

As requested in the project brief, the models were run for the 50%, 10%, 5%, 1%, 0.1% AEP and PMF events, as well as six climate change scenarios for the 1% and 0.1% AEP events. Mapping of peak depth and water level contours, velocities and stream power has been provided as appendices to this report.

The Landform Design #3 flood modelling results have been interrogated to identify potential issues in the interaction of floodwaters with the landform design. The key findings of this assessment were:

- The Titan East and Titan West PRC voids achieves immunity in all flood events including the PMF.
- The Pandora Void achieves immunity from Isaac River flood ingress up to and including the 0.1% AEP climate change RCP 8.5 P90 event, and the only event where Isaac River flood ingress to voids is observed is the PMF.
- The Pandora Void achieves immunity from the drainage feature to the north in the 1% AEP event with minor ingress initiating in the 0.1% AEP. Ingress from the 0.1% AEP climate change RCP 8.5 P90 event has been deemed tolerable by BMA due to the low volume of water entering the void.
- Ponding of floodwater against the landform occurs in several locations, to varying degrees. This occurs in events as frequent as the 50% AEP at some locations. Figures illustrating key locations of interaction in the 0.1% AEP climate change RCP 8.5 P90 have been provided for BMA's consideration.

The modelling results have also been interrogated to assess the alteration of flows upstream and downstream of the mine site, by comparing peak flows from the PRC and PMC scenarios. The key conclusions from the assessment were:

- Flows upstream of the mine site can be considered unaltered as the upstream catchments are unaffected by mining operations.
- Hydraulic model flows have been compared at locations adjacent to and downstream of DNM with results indicating a slight reduction in PRC flows and velocities. None of the modelled events have shown a flow increase in the PRC scenario.
- Flow reductions are 4.5% in the PMF event where some flood waters overtop into the Pandora Void for Landform Design #3.
- For events more frequent than the PMF, decreases in PRC flow can generally be attributed to a slight decrease in the catchment area, or to flow being retained, diverted, or slowed down within the PRC hydraulic model by terrain features.

8 REFERENCES

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APPENDIX A

ISAAC RIVER

Appendix A-1

PRC Conditions
Peak Depth & Water Level Contours
50% AEP

LEGEND

- Water Level Contours (mAHD)
- ▬ Hydraulic Model Extent
- ▭ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022

0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-2

PRC Conditions
Peak Velocity
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-3

PRC Conditions
Peak Stream Power
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Stream Power (W/m²)

- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-4

PRC Conditions
Peak Depth & Water Level Contours
10% AEP

LEGEND

- Water Level Contours (mAHD)
[Dashed Line] Hydraulic Model Extent
[Dotted Line] Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-5

PRC Conditions
Peak Velocity
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-6

PRC Conditions
Peak Stream Power
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-7

PRC Conditions Peak Depth & Water Level Contours 5% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River



CIVIL | WATER | ENVIRONMENT

Appendix A-8

PRC Conditions
Peak Velocity
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-9

PRC Conditions
Peak Stream Power
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Stream Power (W/m²)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-10

PRC Conditions
Peak Depth & Water Level Contours
1% AEP

LEGEND

- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-11

PRC Conditions
Peak Velocity
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-12

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-13

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP

LEGEND

- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-14

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-15

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

-  Hydraulic Model Extent
-  Daunia Environmental Authority Boundary

Elevation (mAHD)

-  170
-  190
-  210
-  230
-  250

Peak Stream Power (W/m²)

-  ≤ 25
-  25 - 35
-  35 - 45
-  45 - 60
-  60 - 100
-  100 - 150
-  150 - 250
-  > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-16

PRC Conditions Peak Depth & Water Level Contours PMF

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

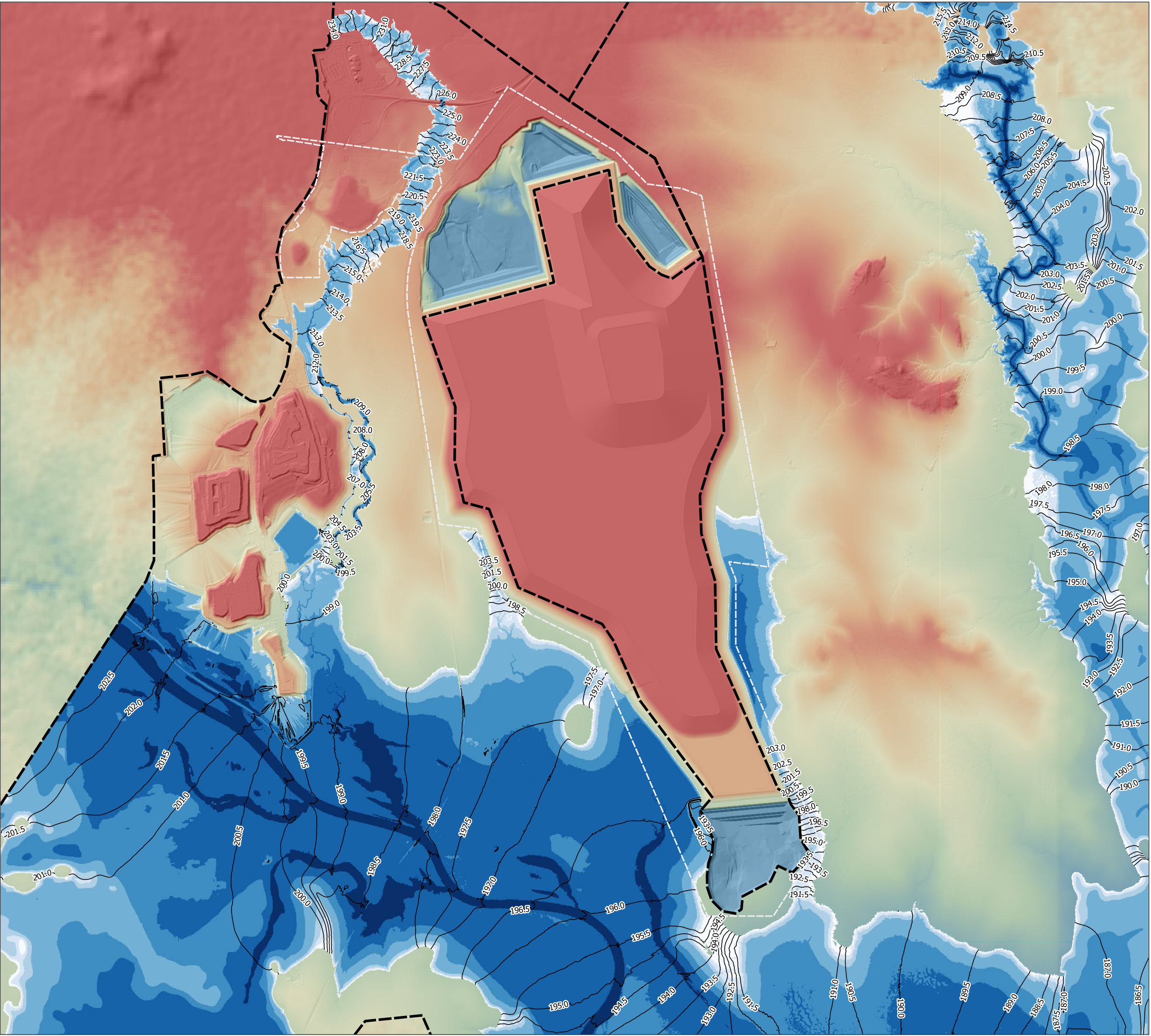
Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km





CIVIL | WATER | ENVIRONMENT

Appendix A-17

PRC Conditions
Peak Velocity
PMF

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-18

PRC Conditions
Peak Stream Power
PMF

LEGEND

-  Hydraulic Model Extent
 Daunia Environmental Authority Boundary

Elevation (mAHD)

-  170
 190
 210
 230
 250

Peak Stream Power (W/m^2)

-  ≤ 25
 25 - 35
 35 - 45
 45 - 60
 60 - 100
 100 - 150
 150 - 250
 > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-19

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P10 (5% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km



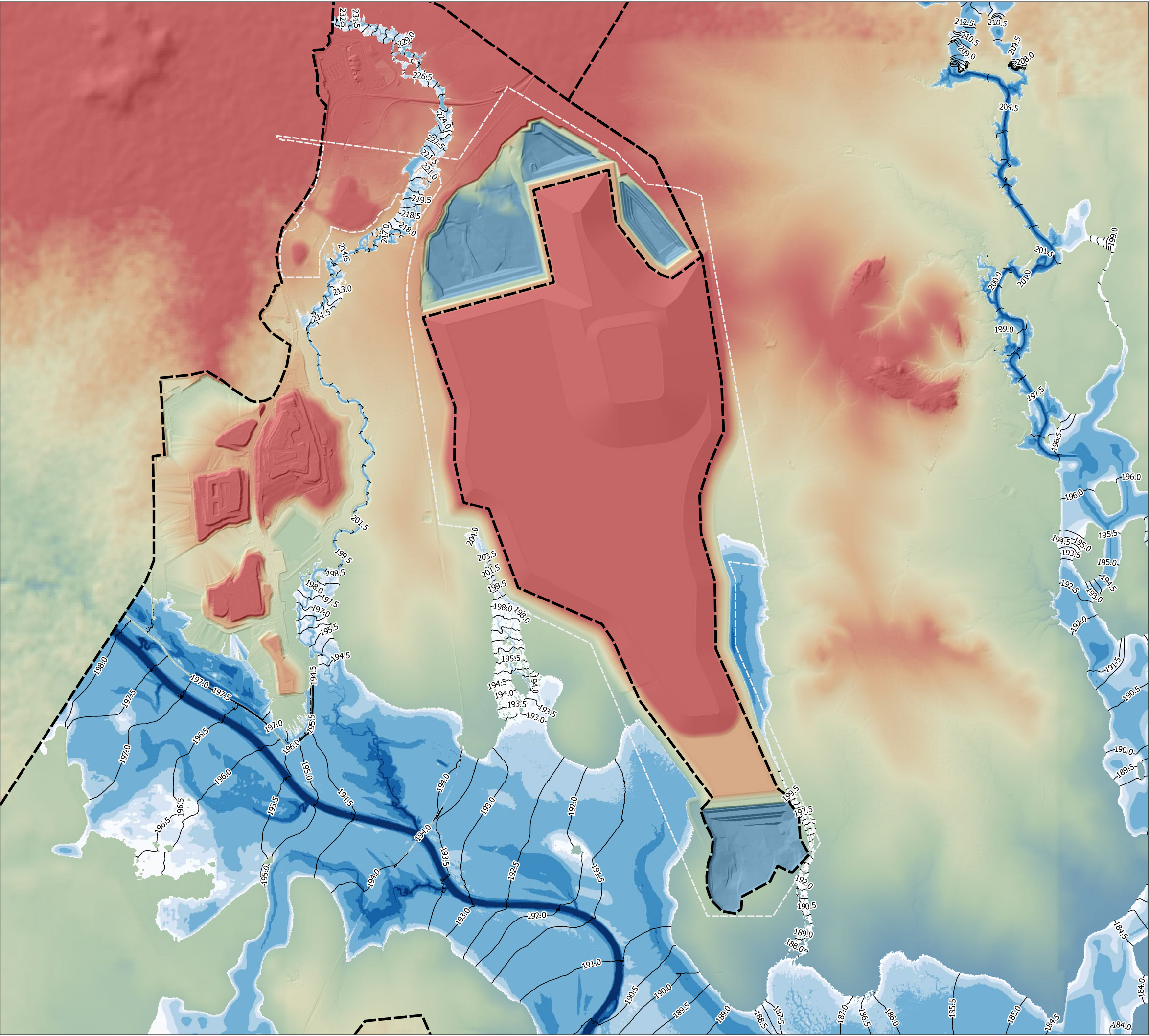
CIVIL | WATER | ENVIRONMENT

Appendix A-20

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0



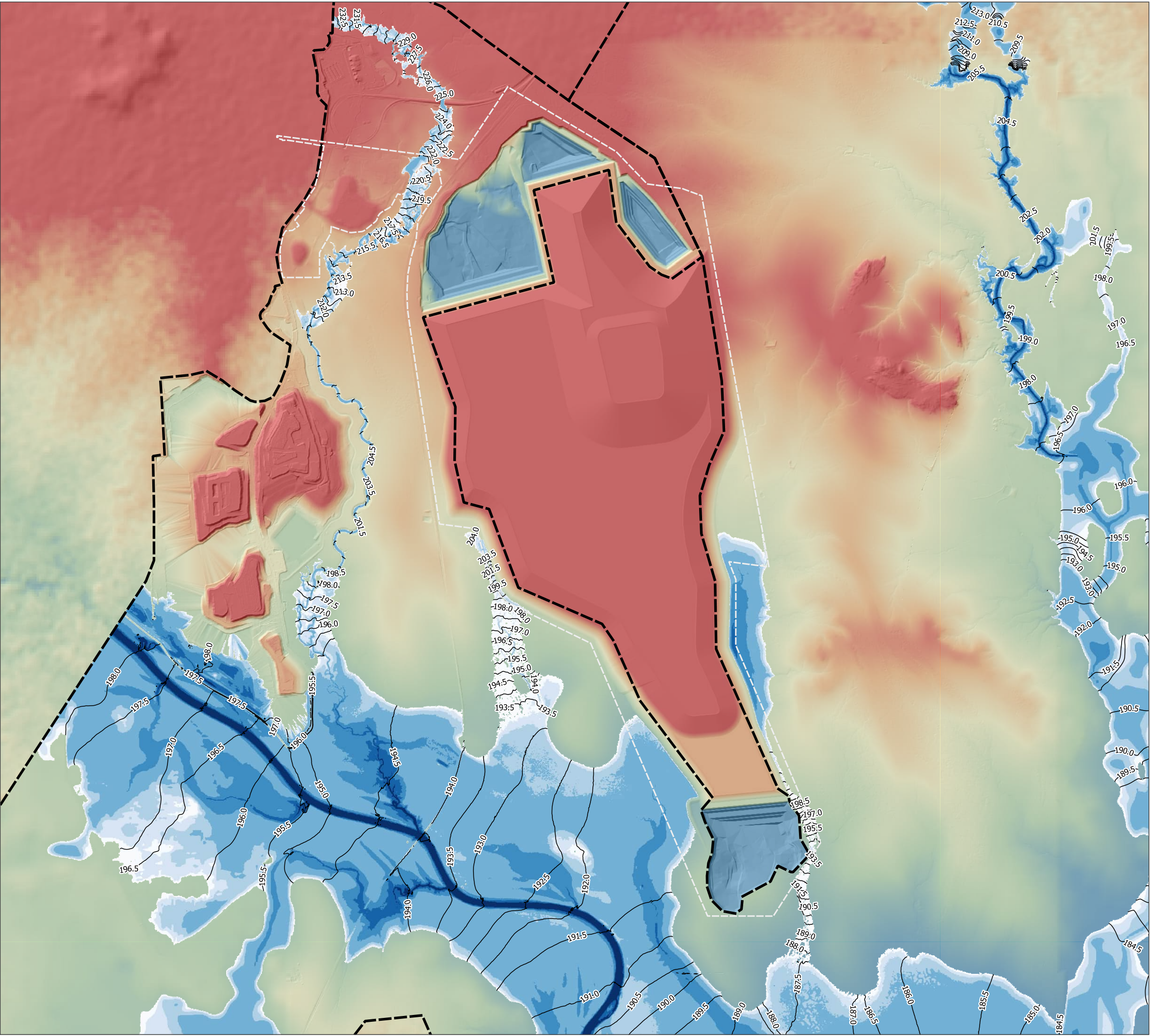
Daunia Mine Rehabilitation Flood
Modelling
Isaac River

Appendix A-21

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0



Daunia Mine Rehabilitation Flood Modelling
Isaac River

WMS

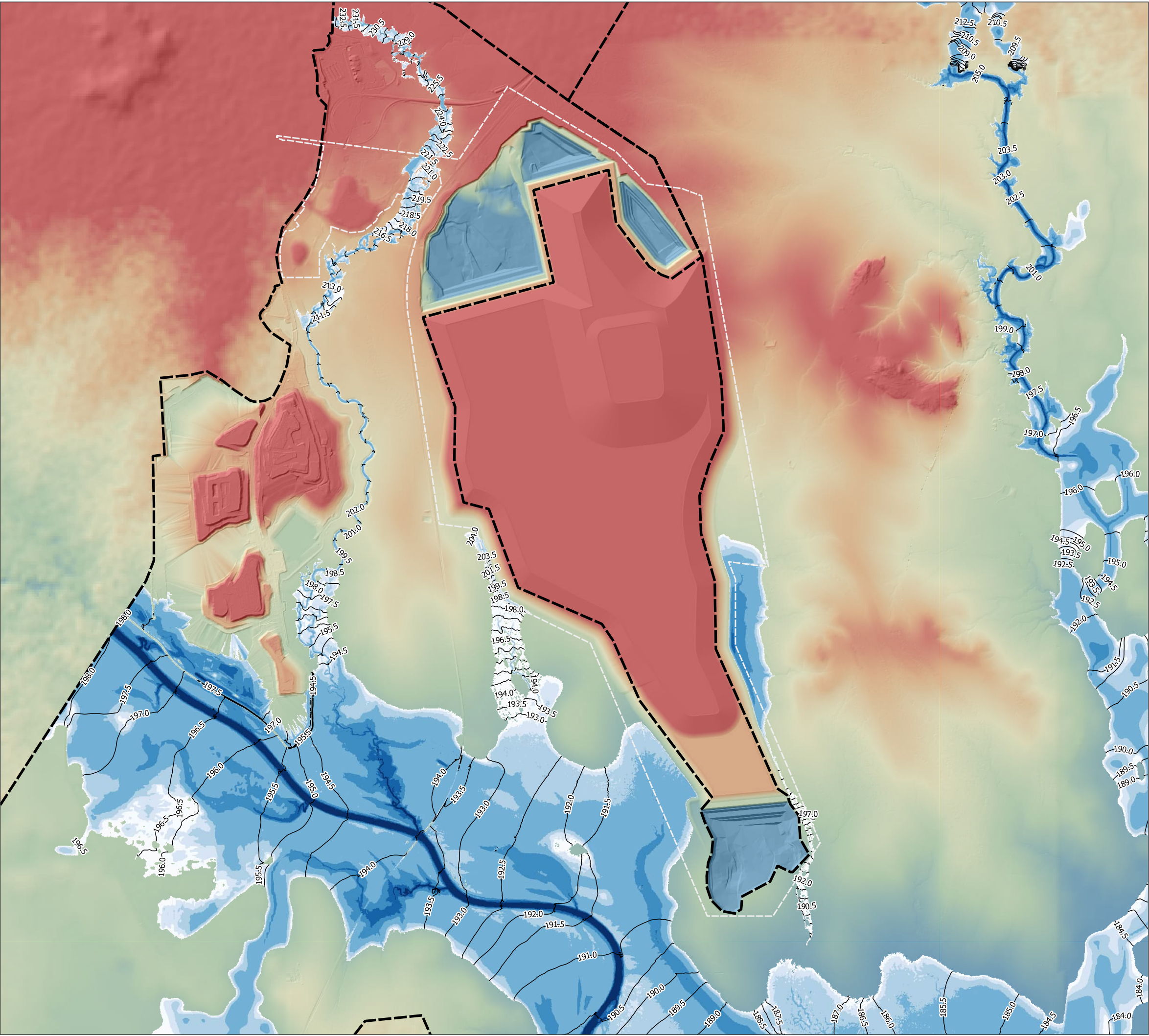
CIVIL | WATER | ENVIRONMENT

Appendix A-22

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P10 (8% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0



Daunia Mine Rehabilitation Flood
Modelling
Isaac River

Appendix A-23

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P50 (17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-24

PRC Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P90 (28% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-25

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P10 (5% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-26

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-27

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

WMS

CIVIL | WATER | ENVIRONMENT

Appendix A-28

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P10 (8% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



0 1 2 3 km

Appendix A-29

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P50 (17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:45000

Job No: 10659
Date: 14/12/2022



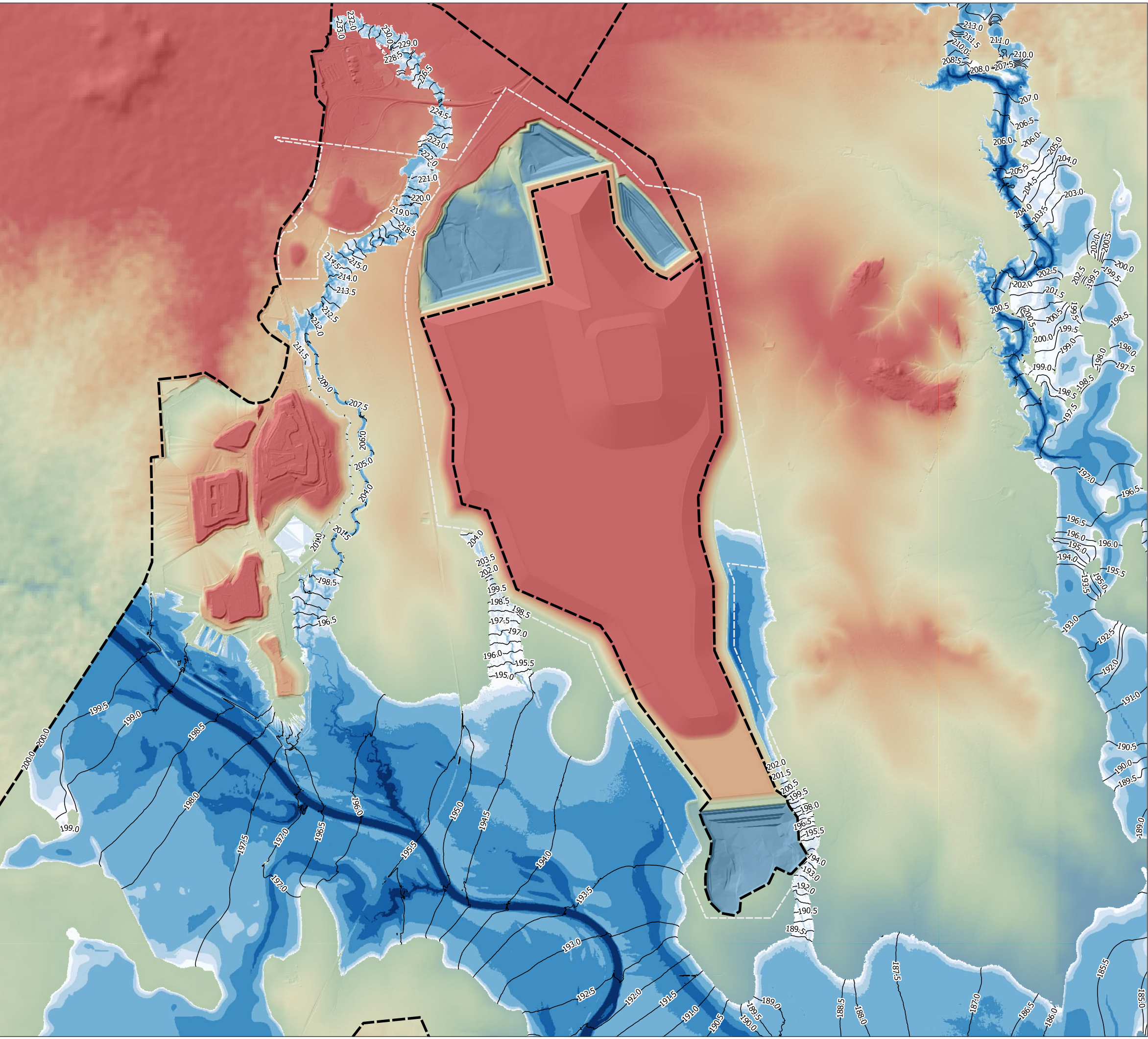
0 1 2 3 km

Appendix A-30

PRC Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P90 (28% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0



Daunia Mine Rehabilitation Flood Modelling Isaac River

Appendix A-31

Pre-mining Conditions Peak Depth & Water Level Contours 50% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River



CIVIL | WATER | ENVIRONMENT

Appendix A-32

Pre-mining Conditions
Peak Velocity
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-33

Pre-mining Conditions
Peak Stream Power
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-34

Pre-mining Conditions Peak Depth & Water Level Contours 10% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-35

Pre-mining Conditions
Peak Velocity
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-36

Pre-mining Conditions
Peak Stream Power
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-37

Pre-mining Conditions Peak Depth & Water Level Contours 5% AEP

LEGEND

- Water Level Contours (mAHD)
 - ▬ Hydraulic Model Extent
 - ▬ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

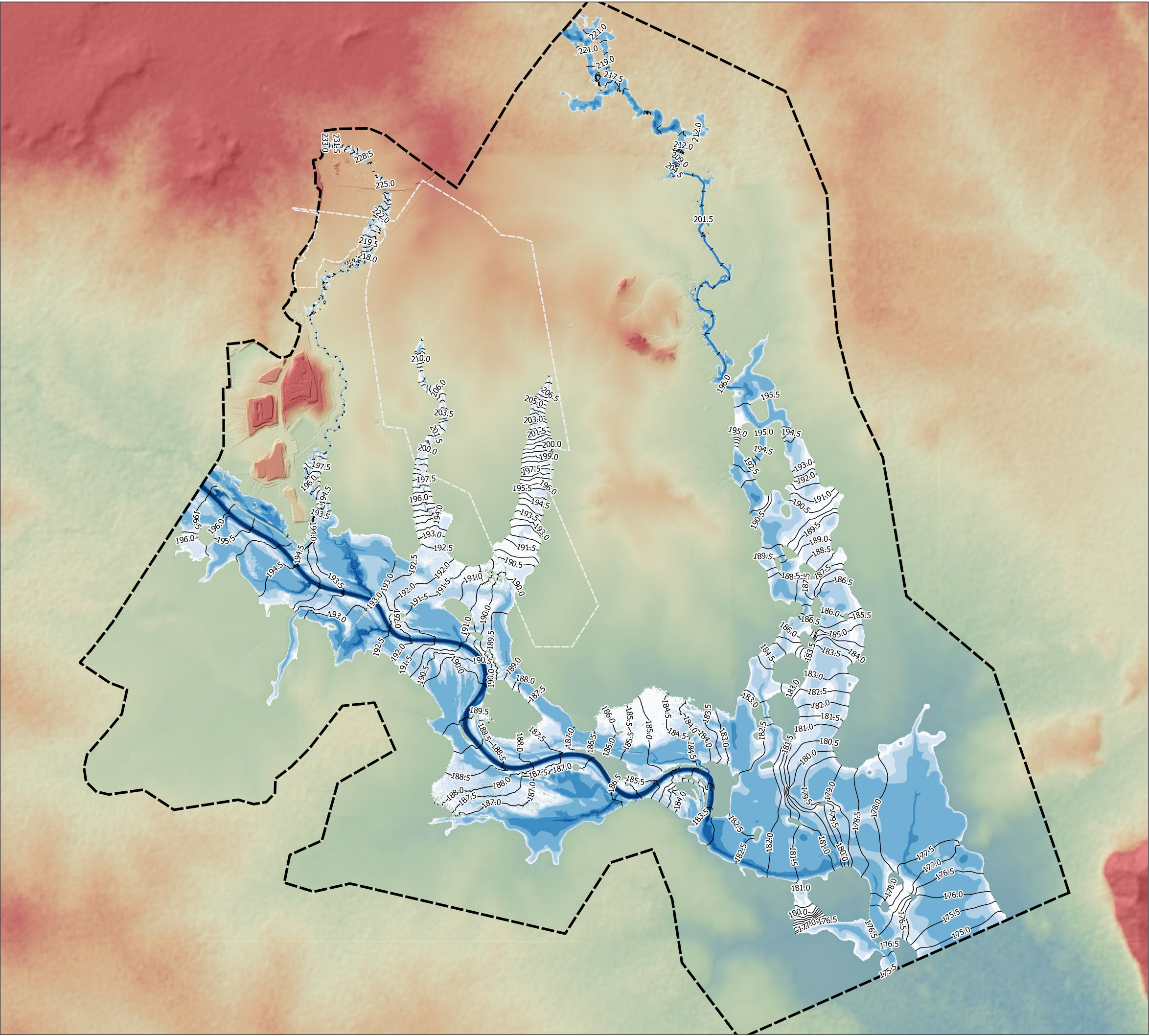
Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km





CIVIL | WATER | ENVIRONMENT

Appendix A-38

Pre-mining Conditions
Peak Velocity
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-39

Pre-mining Conditions
Peak Stream Power
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km

Appendix A-40

Pre-mining Conditions Peak Depth & Water Level Contours 1% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

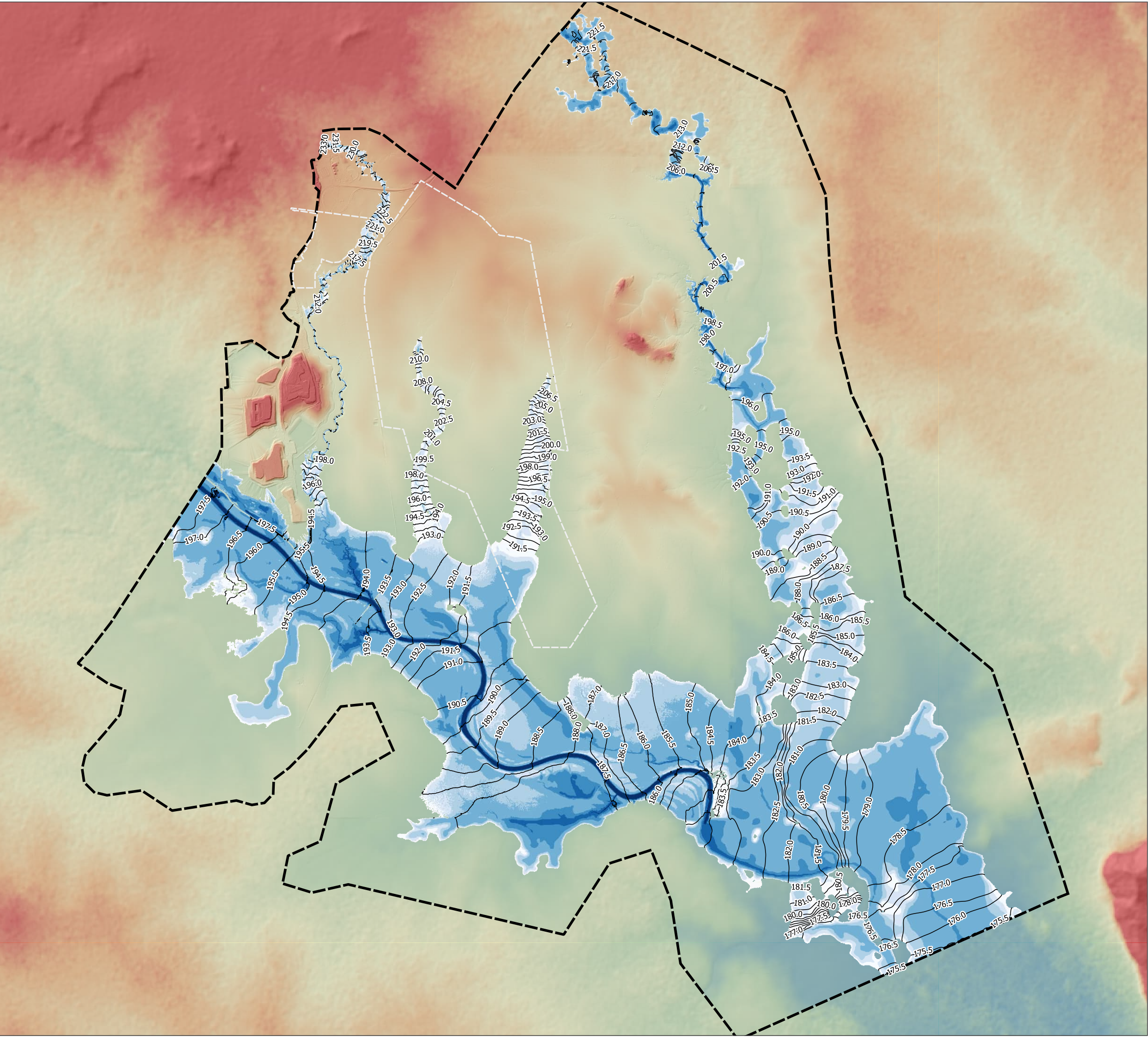
Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km





CIVIL | WATER | ENVIRONMENT

Appendix A-41

Pre-mining Conditions
Peak Velocity
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-42

Pre-mining Conditions
Peak Stream Power
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-43

Pre-mining Conditions Peak Depth & Water Level Contours 0.1% AEP

LEGEND

-  Water Level Contours (mAHD)
 -  Hydraulic Model Extent
 -  Daunia Environmental Authority Boundary
- Elevation (mAHD)
-  170
 -  190
 -  210
 -  230
 -  250
- Peak Flood Depth (m)
-  <= 0.2
 -  0.2 - 0.5
 -  0.5 - 1.0
 -  1.0 - 3.0
 -  3.0 - 5.0
 -  5.0 - 8.0
 -  > 8.0

Daunia Mine Rehabilitation Flood Modelling Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-44

Pre-mining Conditions
Peak Velocity
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-45

Pre-mining Conditions
Peak Stream Power
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-46

Pre-mining Conditions Peak Depth & Water Level Contours PMF

LEGEND

- Water Level Contours (mAHD)
 - ▬ Hydraulic Model Extent
 - ▬ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

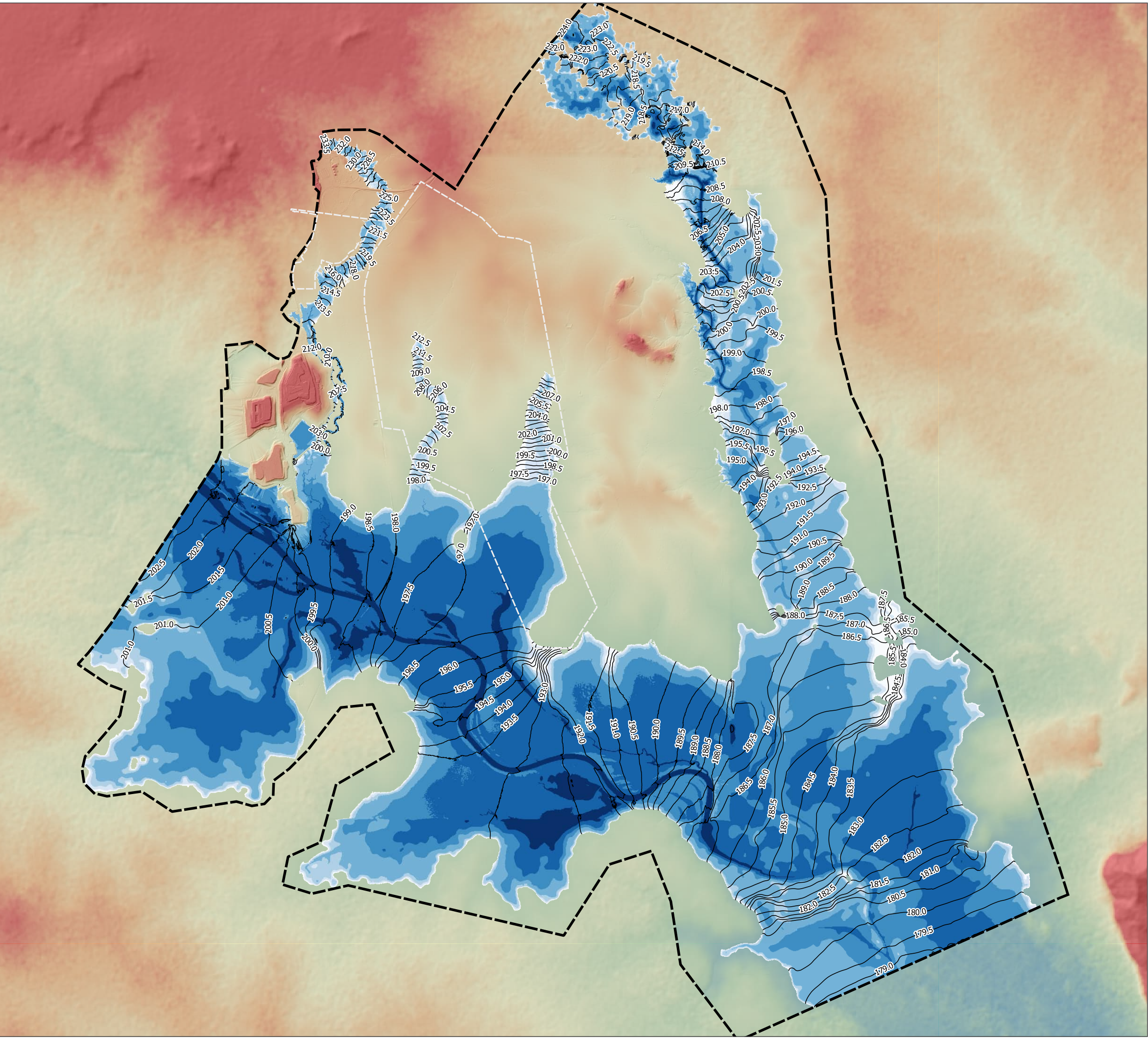
Daunia Mine Rehabilitation Flood Modelling Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km





CIVIL | WATER | ENVIRONMENT

Appendix A-47

Pre-mining Conditions
Peak Velocity
PMF

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Velocity (m/s)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-48

Pre-mining Conditions
Peak Stream Power
PMF

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Stream Power (W/m^2)

- ≤ 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-49

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P10 (5% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

Appendix A-50

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-51

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - ▬ Hydraulic Model Extent
 - ▬ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-52

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P10 (8% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km

Appendix A-53

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P50 (17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - ▬ Hydraulic Model Extent
 - ▬ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-54

Pre-mining Conditions
Peak Depth & Water Level Contours
1% AEP Climate Change RCP8.5
P90 (28% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

Appendix A-55

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P10 (5% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km

Appendix A-56

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P50 (11% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 170
- 190
- 210
- 230
- 250

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-57

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP4.5
P90 (20% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

Appendix A-58

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P10 (8% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km



CIVIL | WATER | ENVIRONMENT

Appendix A-59

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P50 (17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River



A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022

0 1 2 3 km

Appendix A-60

Pre-mining Conditions
Peak Depth & Water Level Contours
0.1% AEP Climate Change RCP8.5
P90 (28% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - ▬ Hydraulic Model Extent
 - ▬ Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 170
 - 190
 - 210
 - 230
 - 250
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood
Modelling
Isaac River

A3 Scale: 1:80000

Job No: 10659
Date: 30/11/2022



0 1 2 3 km

APPENDIX B

NEW CHUM CREEK



CIVIL | WATER | ENVIRONMENT

Appendix B-1

PRC Conditions
Peak Depth & Water
Level Contours
50% AEP

LEGEND

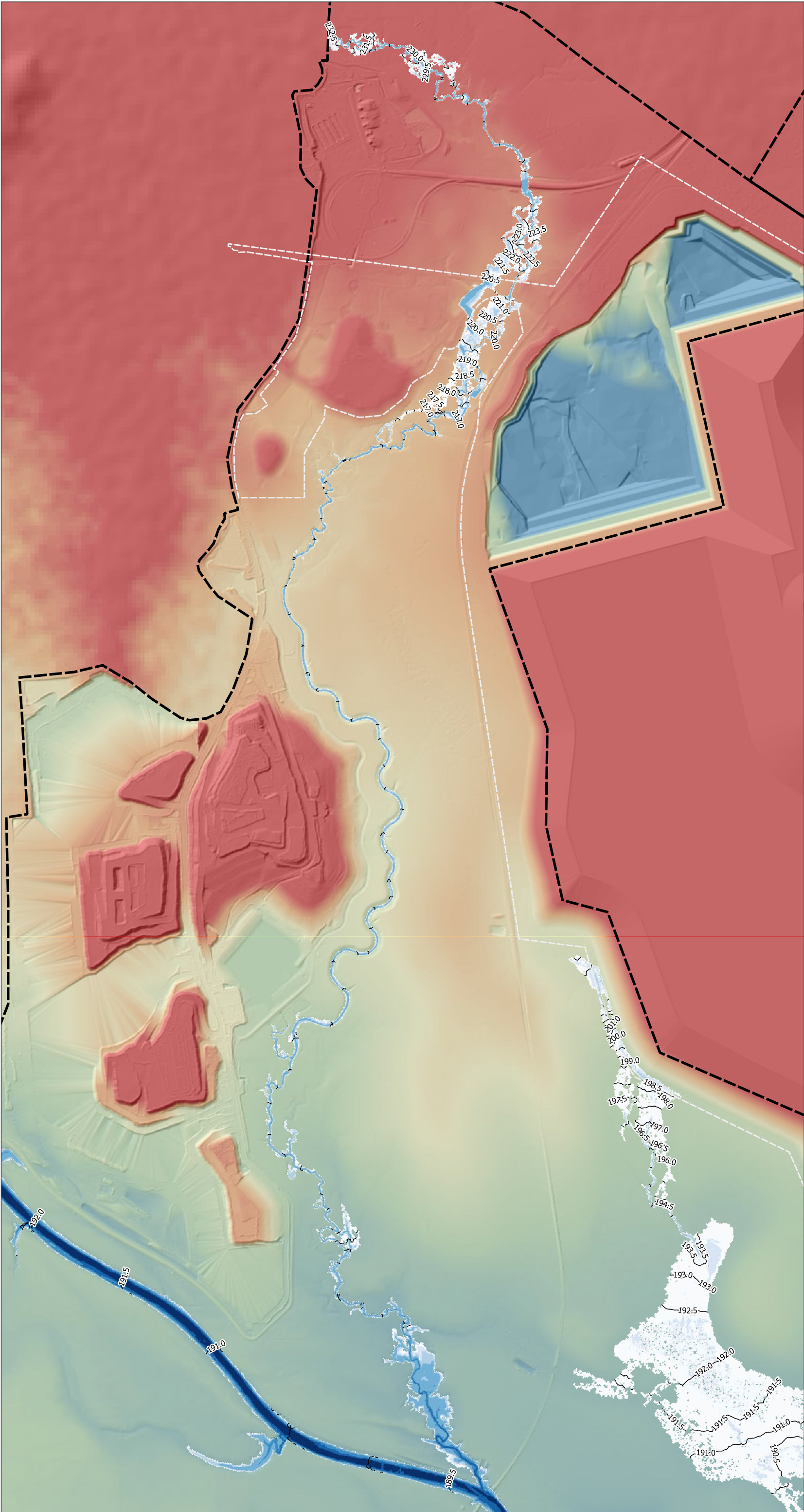
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling

New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-1

PRC Conditions
Peak Depth & Water
Level Contours
50% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-2

PRC Conditions
Peak Velocity
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
- 196
- 208
- 219
- 230
- Peak Flood Velocity (m/s)
- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-3

PRC Conditions
Peak Stream Power
50% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Stream Power (W/m²)
- <= 25
 - 25 - 35
 - 35 - 45
 - 45 - 60
 - 60 - 100
 - 100 - 150
 - 150 - 250
 - > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-4

PRC Conditions
Peak Depth & Water
Level Contours
10% AEP

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-5

PRC Conditions
Peak Velocity
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Velocity (m/s)
- <= 0.5
 - 0.5 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - 2.0 - 2.5
 - 2.5 - 3.0
 - 3.0 - 3.5
 - 3.5 - 4.0
 - 4.0 - 4.5
 - > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-6

PRC Conditions
Peak Stream Power
10% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
 - 185
 - 196
 - 208
 - 219
 - 230
- Peak Stream Power (W/m²)
 - <= 25
 - 25 - 35
 - 35 - 45
 - 45 - 60
 - 60 - 100
 - 100 - 150
 - 150 - 250
 - > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-7

PRC Conditions
Peak Depth & Water
Level Contours
5% AEP

LEGEND

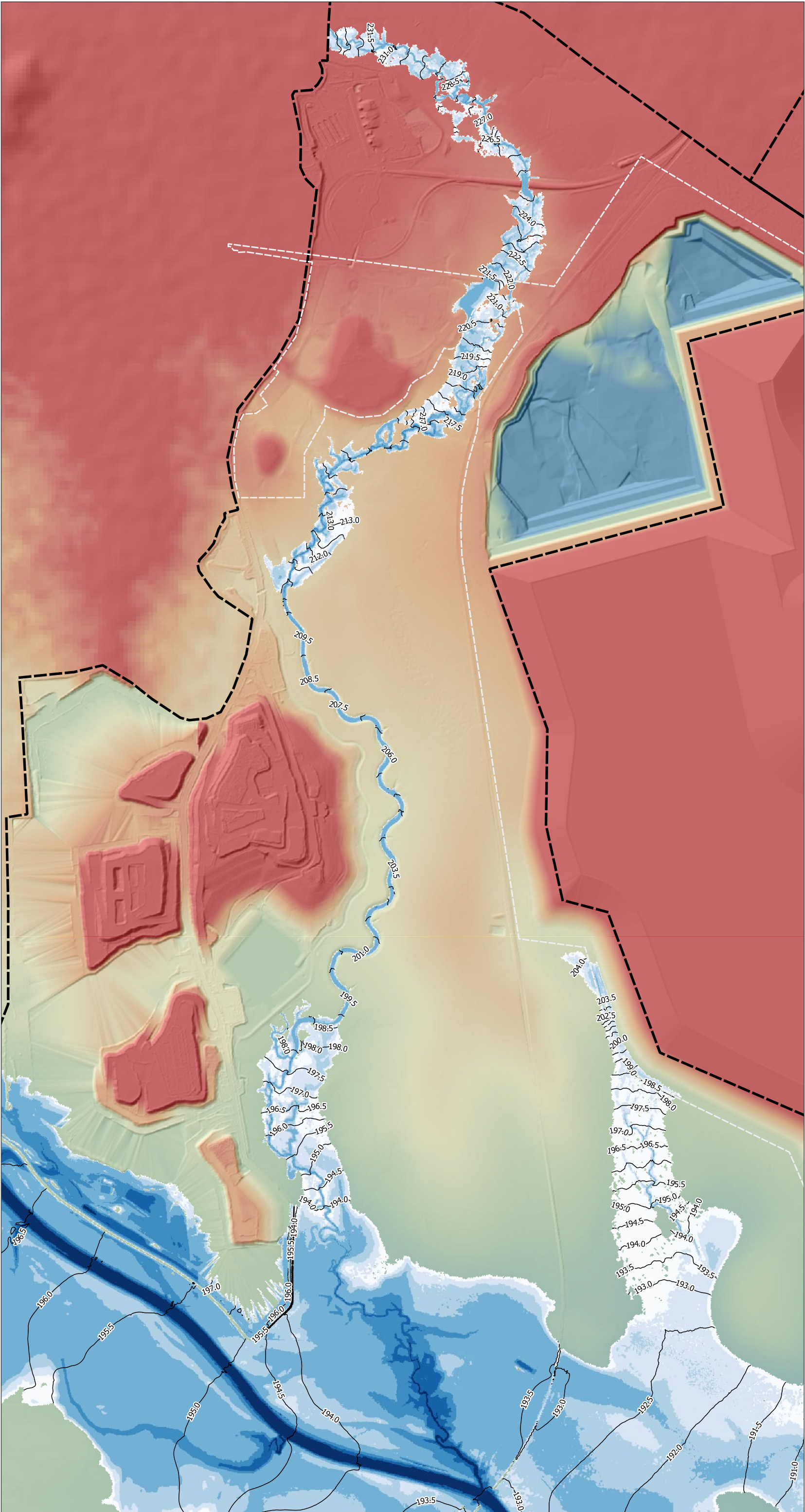
- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km





CIVIL | WATER | ENVIRONMENT

Appendix B-8

PRC Conditions
Peak Velocity
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Velocity (m/s)
- <= 0.5
 - 0.5 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - 2.0 - 2.5
 - 2.5 - 3.0
 - 3.0 - 3.5
 - 3.5 - 4.0
 - 4.0 - 4.5
 - > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-9

PRC Conditions
Peak Stream Power
5% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
 - 185
 - 196
 - 208
 - 219
 - 230
- Peak Stream Power (W/m²)
 - <= 25
 - 25 - 35
 - 35 - 45
 - 45 - 60
 - 60 - 100
 - 100 - 150
 - 150 - 250
 - > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP

 Water Level Contours (mAHD)
 Hydraulic Model Extent
 Daunia Environmental Authority Boundary

	185
	196
	208
	219
	230

Color	Number of species per 100m²
White	≤ 0.2
Lightest Blue	0.2 - 0.5
Light Blue	0.5 - 1.0
Medium Blue	1.0 - 3.0
Dark Blue	3.0 - 5.0
Very Dark Blue	5.0 - 8.0
Black	> 8.0





CIVIL | WATER | ENVIRONMENT

Appendix B-11

PRC Conditions
Peak Velocity
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Velocity (m/s)
- <= 0.5
 - 0.5 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - 2.0 - 2.5
 - 2.5 - 3.0
 - 3.0 - 3.5
 - 3.5 - 4.0
 - 4.0 - 4.5
 - > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-12

PRC Conditions
Peak Stream Power
1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
- 196
- 208
- 219
- 230
- Peak Stream Power (W/m²)
- <= 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60 - 100
- 100 - 150
- 150 - 250
- > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-13

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP

LEGEND

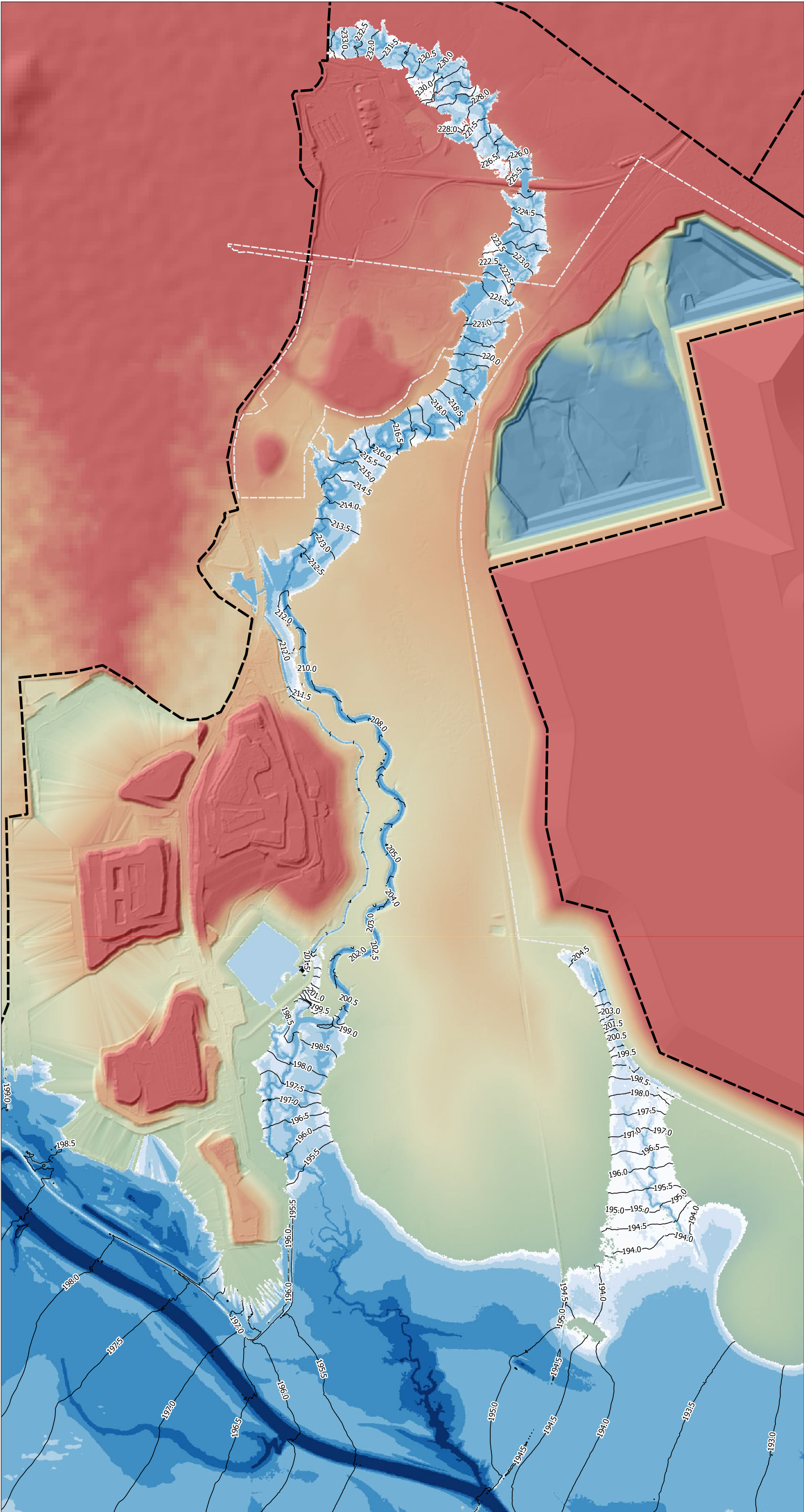
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-14

PRC Conditions
Peak Velocity
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Velocity (m/s)
- <= 0.5
 - 0.5 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - 2.0 - 2.5
 - 2.5 - 3.0
 - 3.0 - 3.5
 - 3.5 - 4.0
 - 4.0 - 4.5
 - > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-15

PRC Conditions
Peak Stream Power
0.1% AEP

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
 - 185
 - 196
 - 208
 - 219
 - 230
- Peak Stream Power (W/m²)
 - <= 25
 - 25 - 35
 - 35 - 45
 - 45 - 60
 - 60 - 100
 - 100 - 150
 - 150 - 250
 - > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-16

PRC Conditions
Peak Depth & Water
Level Contours
PMF

LEGEND

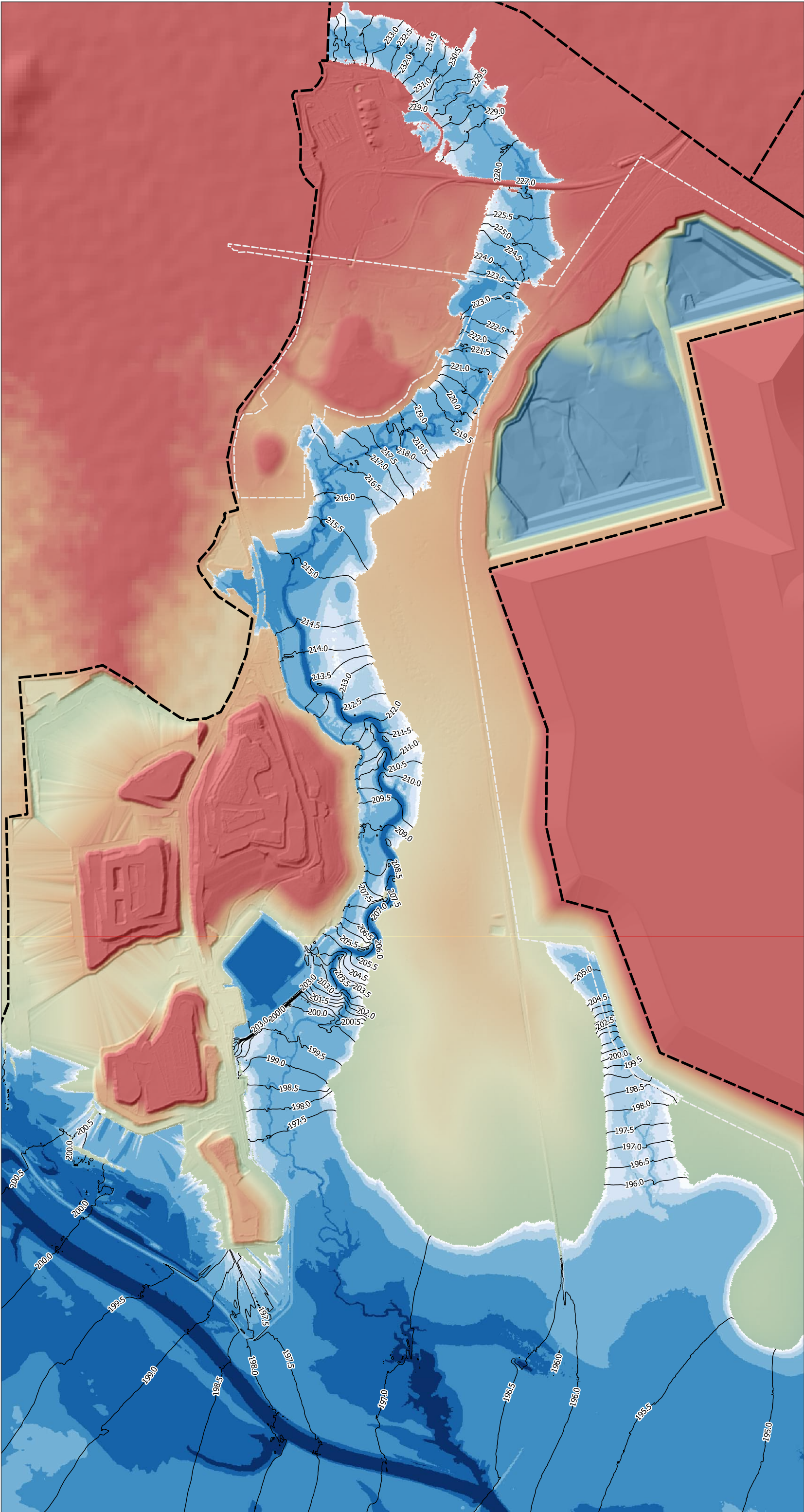
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling

New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-17

PRC Conditions
Peak Velocity
PMF

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Velocity (m/s)
- <= 0.5
 - 0.5 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - 2.0 - 2.5
 - 2.5 - 3.0
 - 3.0 - 3.5
 - 3.5 - 4.0
 - 4.0 - 4.5
 - > 4.5

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-18

PRC Conditions
Peak Stream Power
PMF

LEGEND

- Hydraulic Model Extent
- Daunia Environmental Authority Boundary
- Elevation (mAHD)
 - 185
 - 196
 - 208
 - 219
 - 230
- Peak Stream Power (W/m²)
 - <= 25
 - 25 - 35
 - 35 - 45
 - 45 - 60
 - 60 - 100
 - 100 - 150
 - 150 - 250
 - > 250

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-19

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP4.5 P10
(5% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-20

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-21

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-22

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP8.5 P10
(8% Rainfall Increase)

LEGEND

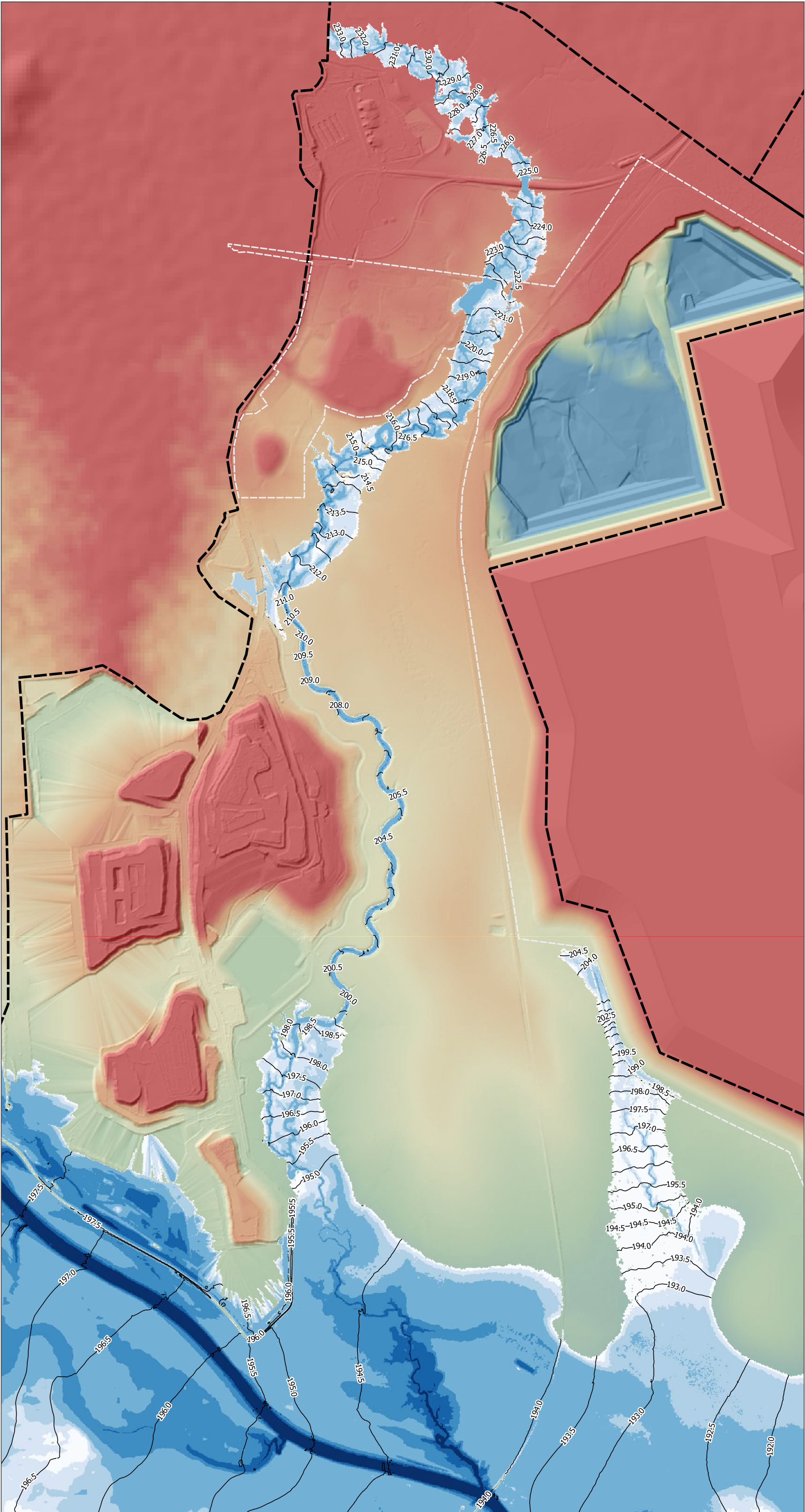
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-23

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP8.5 P50
(17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-24

PRC Conditions
Peak Depth & Water
Level Contours
1% AEP Climate
Change RCP8.5 P90
(28% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
 - Hydraulic Model Extent
 - Daunia Environmental Authority Boundary
- Elevation (mAHD)
- 185
 - 196
 - 208
 - 219
 - 230
- Peak Flood Depth (m)
- <= 0.2
 - 0.2 - 0.5
 - 0.5 - 1.0
 - 1.0 - 3.0
 - 3.0 - 5.0
 - 5.0 - 8.0
 - > 8.0

Daunia Mine Rehabilitation Flood Modelling New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-25

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP4.5 P10
(5% Rainfall Increase)

LEGEND

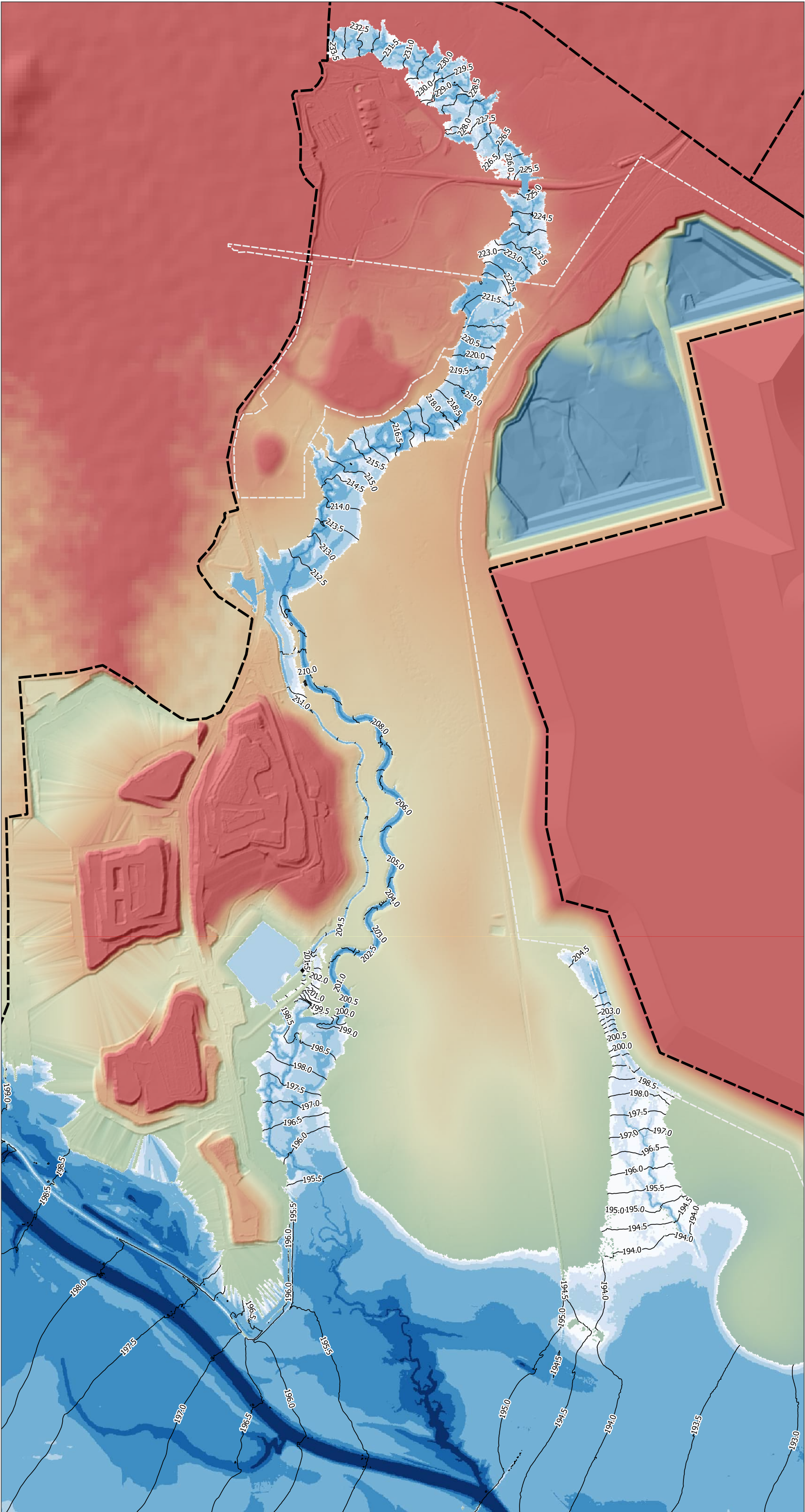
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-26

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP4.5 P50
(11% Rainfall Increase)

LEGEND

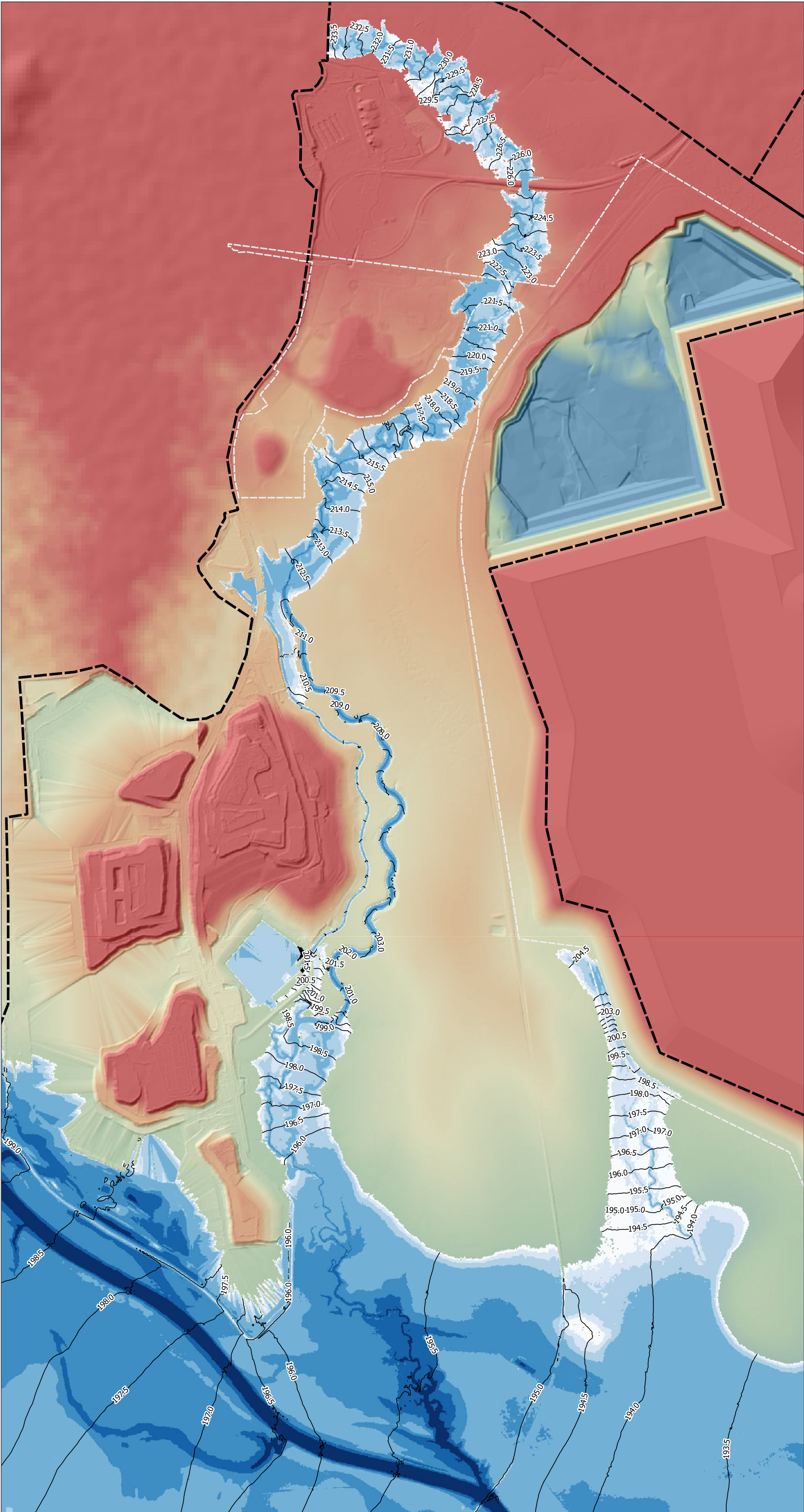
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-27

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP4.5 P90
(20% Rainfall Increase)

LEGEND

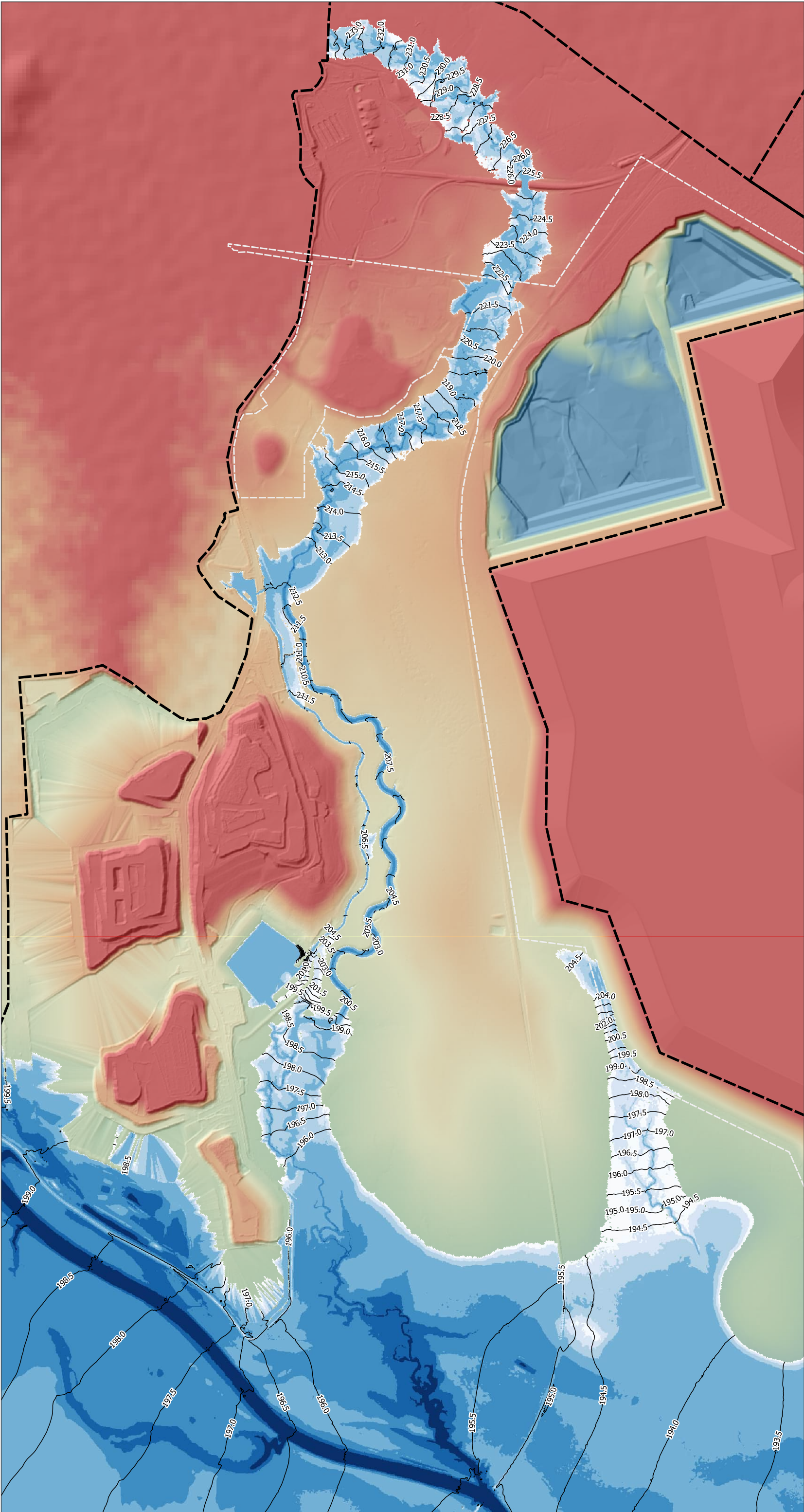
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-28

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP8.5 P10
(8% Rainfall Increase)

LEGEND

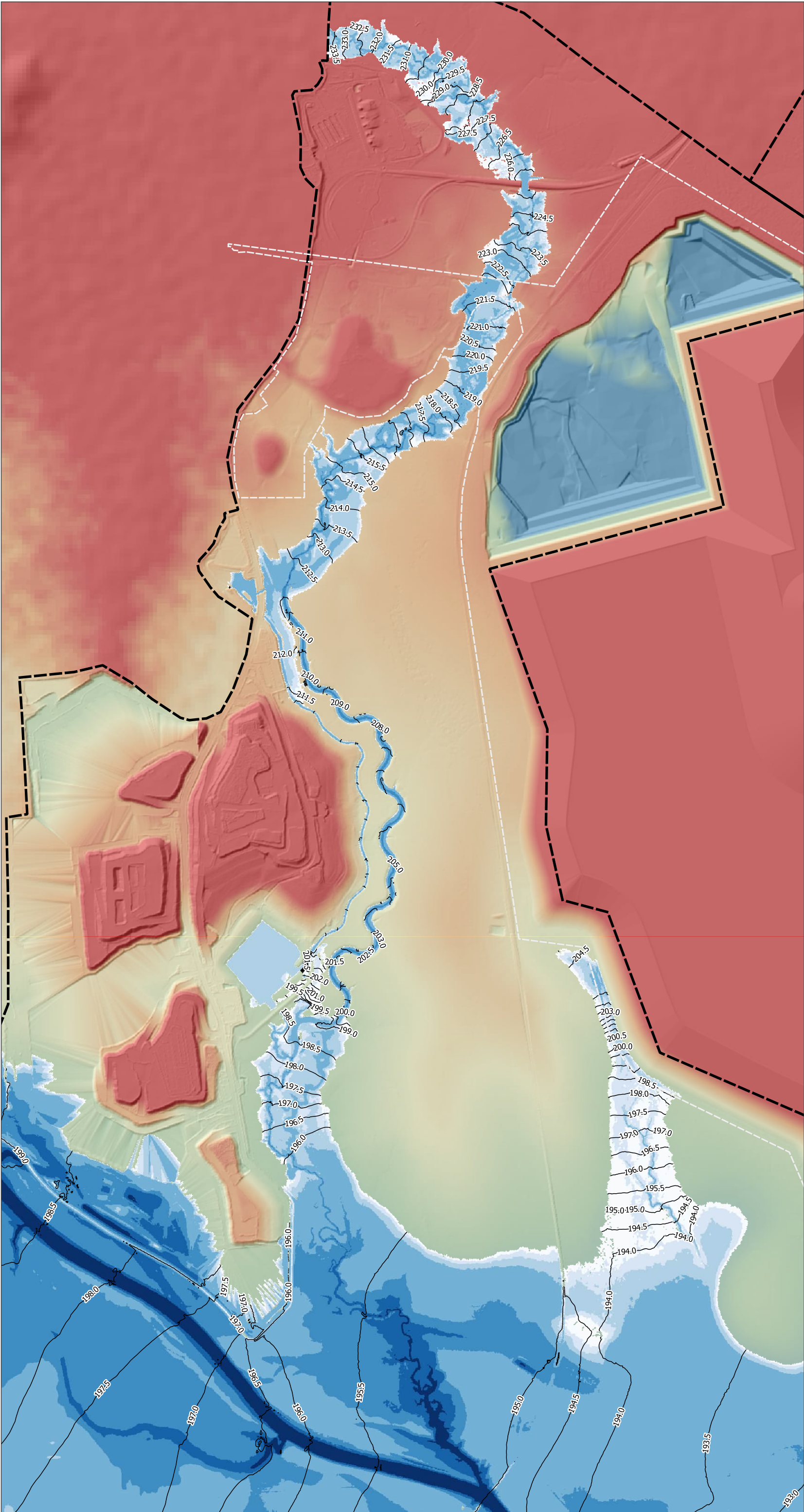
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-29

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP8.5 P50
(17% Rainfall Increase)

LEGEND

- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0

Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km



CIVIL | WATER | ENVIRONMENT

Appendix B-30

PRC Conditions
Peak Depth & Water
Level Contours
0.1% AEP Climate
Change RCP8.5 P90
(28% Rainfall Increase)

LEGEND

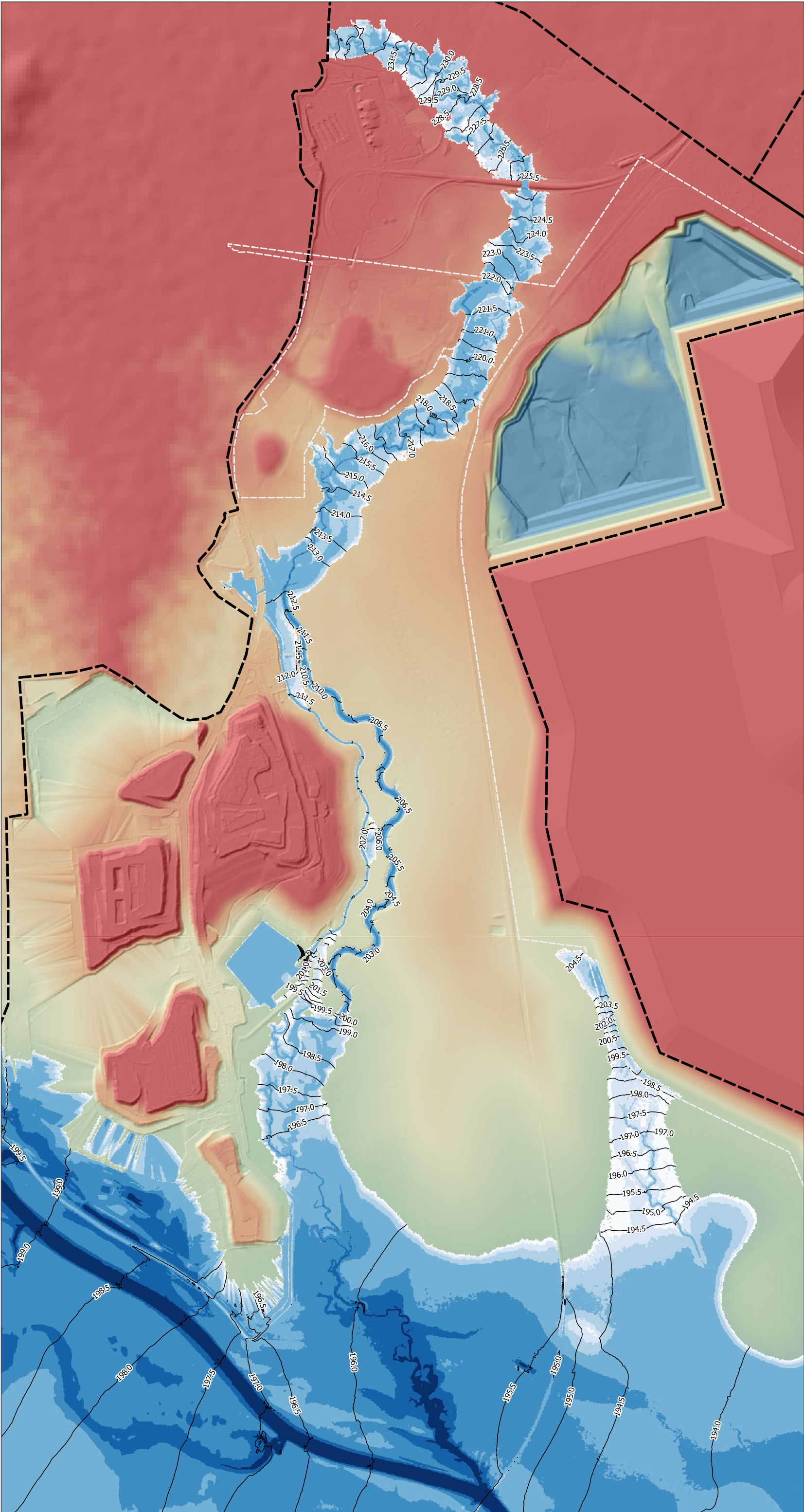
- Water Level Contours (mAHD)
- Hydraulic Model Extent
- Daunia Environmental Authority Boundary

Elevation (mAHD)

- 185
- 196
- 208
- 219
- 230

Peak Flood Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0
- 3.0 - 5.0
- 5.0 - 8.0
- > 8.0



Daunia Mine
Rehabilitation Flood
Modelling
New Chum Creek

A3 Scale: 1:25000 Job No: 10659
Date: 14/12/2022



0 0.25 0.5 0.75 1 km

APPENDIX C

FLOODING RISK PROFILE



Daunia Mine

Progressive Rehabilitation and Closure Plan

Environmental Geochemical Characterisation and Risk Assessment of Mineral Waste

08 June 2023

Version 1.0

Authors

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EXECUTIVE SUMMARY

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials associated with Daunia Mine (DNM), as supporting information for the progressive rehabilitation and closure plan (PRCP) for DNM.

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at DNM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

DNM is located approximately 20 km east of the town of Moranbah in the Bowen Basin, Central Queensland. DNM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, coal stockpiles, coal processing facilities, process water and raw water dams, surface water drains and administration areas.

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Short-term storage of run of mine (ROM) coal on the ROM Pad;
- ROM coal processing at the coal handling and preparation plant (CHPP), which produces:
 - MPR. Mixed plant rejects. Trucked to designated in-pit disposal areas and buried within spoil.
 - Fine rejects. Combined with coarse rejects in the CHPP to form MPR (see above).
 - Coarse rejects. Combined with fine rejects in the CHPP to form MPR (see above).
- Short-term storage of product coal on the product Coal Stockpile, awaiting off-site transport by rail;
- The operation of raw water and process water dams and sediment control structures as stipulated in DNMs Environmental Authority (EA).

The mine domains of direct relevance to mineral waste characterisation and management at closure for DNM are:

- Residual voids: Titan North/Central Pit, Titan East Pit and Pandora Pit.
- Spoil dump: due to the configuration of the site, this is considered as a single spoil landform at DNM.
- Coal stockpiles: ROM coal pad and stockpile; Product coal pad and stockpile.

DNM has no tailings storage facility. Tailings are dewatered at the CHPP via a belt press filter to produce fine rejects, which is co-disposed (into spoil) with coarse rejects as MPR.

DNM has two main types of mineral waste. The geochemical characteristics and potential hazards associated with the main types of mineral waste materials:

- Spoil (overburden and interburden) currently comprises approximately 98.5% of all mineral waste at DNM and includes weathered (Tertiary and Permian-age) and fresh (unweathered, Permian-age) wastes. Approximately 52% of spoil is fresh and the remainder (approximately 48%) is weathered/oxidised.
 - Spoil is comprised of approximately 94% non-carbonaceous material (typically claystone, siltstone and sandstone) and 6% carbonaceous material (typically present as carbonaceous siltstone).
- Rejects are generated at the CHPP. Rejects currently comprises approximately 1.5% of all mineral waste at DNM.
 - Rejects is primarily generated (and disposed) as MPR, which comprises approximately 80% coarse rejects and 20% fine rejects mixed together at the CHPP.
- The proportion of spoil (98.5% of all mineral waste) and rejects (1.5% of all mineral waste) are not expected to materially change over the life of asset mine plan.

Coal is also included in the assessment; however, coal is generally not considered mineral waste, with the exception of small quantities of sub-economic coal that may report to the spoil dumps, and remnant coal exposed on the residual void highwalls.

Mineral waste (and coal) samples have undergone environmental geochemical characterisation and assessment with regard to their potential to generate acid and metalliferous drainage (AMD), which comprises acid drainage (AD), neutral and metalliferous drainage (NMD) and/or saline drainage (SD) [salinity due to sulphate derived from sulphide oxidation]. Additionally, samples have been assessed with regard to their potential to generate salinity (non-oxidative) and, for spoil materials, their sodicity and dispersion potential.

AMD Potential of Mineral Waste and Coal Material Types

AMD Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 94% of spoil (of which about 41% is weathered), is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for sedimentary materials in the Bowen Basin.

The total S (S) concentration of non-carbonaceous spoil is very low, with a 95th percentile total S concentration of 0.03% for weathered spoil and 0.11% for fresh spoil. As such, and combined with high acid neutralising capacity (ANC) values (median 24 kg H₂SO₄/t), approximately 99% of non-carbonaceous spoil samples tested (500 out of 505 samples) were classified as non-acid forming (NAF). Two samples out of 505 were classified as UC(NAF). The three remaining samples were classified as potentially acid forming (PAF) or had some uncertainty in their classification but were expected to be PAF.

The test-work demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be approximately 67% (median) available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Siderite, present in minor quantity, does not provide any net ANC. Overall, non-carbonaceous spoil has excess acid neutralising capacity.

Non-carbonaceous spoil has low enrichment in total metals and metalloids compared to average element abundance in soil in the earth's crust. A small number of samples (i.e. 3 out of 91 samples) had significant enrichment with respect to beryllium (Be) and S. The enrichment in Be in a small number of samples is not cause for concern; the enrichment in S was consistent with geochemical data. Forty-nine samples had minor enrichment with regard to one or more of silver (Ag), arsenic (As), barium (Ba), cobalt (Co), chromium (Cr), mercury (Hg), molybdenum (Mo), nickel (Ni) and/or zinc (Zn). There was no correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment.

Soluble multi-element results (from 92 samples) indicate that leachate from NAF non-carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids. Four samples produced moderate soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of: aluminium (Al), As, manganese (Mn), Mo, antimony (Sb), selenium (Se).

Peroxide leaching undertaken on one non-carbonaceous spoil classified as uncertain (but expected to be NAF) [UC(NAF)] show sample to be moderate to weekly acidic and low in metals.

Based on the results, non-carbonaceous spoil – being essentially all NAF and characterised by very low total S concentration – has a negligible potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Spoil – carbonaceous

Carbonaceous spoil represents approximately 6% of spoil material at DNM and – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil.

The total S concentration of carbonaceous spoil is low, with a 95th percentile total S concentration of 0.18% for weathered spoil and 0.24% for fresh spoil. A small number of samples had low-moderate to moderate total S (and sulphide [Scr]) concentrations. Combined with generally low ANC values (median 10 kg H₂SO₄/t for weathered spoil and 1 kg H₂SO₄/t for fresh spoil) approximately 87% of carbonaceous spoil samples (91 out of 104 samples) were classified as NAF. Five out of 104 samples (5% of all carbonaceous samples) were classified as UC(NAF) and only 8% of the carbonaceous spoil, that is 8 samples, were classified as PAF, PAF-LC or UC(PAF).

ANC in carbonaceous spoil is expected to be about 26% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, carbonaceous spoil has relatively limited acid neutralising capacity, however due to the generally low total S concentration, it is expected that carbonaceous spoil will be net NAF.

Carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks. In particular, total metal and metalloid concentrations from 11 carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. One sample assayed (out of 12 samples) had significant enrichment with respect to As and three (out of 12 samples) had minor enrichment with respect to Be. Five carbonaceous spoil samples had minor enrichment with regard to one or more of As, Be, Mo, S, Sb and/or U. There was no correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment.

Soluble multi-element results (from 15 samples) indicate that leachate from carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. One sample (classified as NAF) produced low-moderate soluble metal concentrations, primarily due to slightly elevated soluble As.

Peroxide leaching undertaken on one carbonaceous spoil classified as UC(NAF) showed the sample to be weakly acidic and low in metals.

Based on the results, carbonaceous spoil as a bulk material has a low potential to generate AD and/or NMD and/or SD. A small proportion of this material type has some potential to generate low-level AD and/or NMD and/or SD. This small proportion of materials at potential for AMD is distributed amongst the bulk NAF material and therefore it is predicted that the spoil is bulk NAF. As stated earlier, carbonaceous spoil represents approximately 6% of all spoil, therefore it is expected that the proportion of carbonaceous spoil that may have potential for AMD reporting to the spoil will be immaterial.

AMD Potential of Rejects

Rejects are expected to generate pH-alkaline contact water (run-off and seepage), however a small proportion of rejects may have the potential to generate mildly acidic contact water if allowed to completely oxidise.

The total S concentration of rejects is generally low-moderate, with a 95th percentile total S concentration of 0.97%. About 60% of the total S is present as sulphide (Scr). Combined with generally moderate-high ANC values (median 52 kg H₂SO₄/t), low-moderate MPA values (median 15 kg H₂SO₄/t), indications are that approximately 95% of rejects samples tested are likely NAF [including 7 sample classified as UC(NAF)] and the remaining 5% of rejects samples were classified as PAF, PAF-LC or UC(PAF).

ANC is generally expected to be about 70-90% available under field conditions with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of rejects.

With some exceptions, the total metal and metalloid concentrations from 46 samples tested are generally low compared to average element abundance in soil in the earth's crust. Five rejects samples were significantly enriched with regard to sulphur, which is consistent with the ABA data showing a small number of samples having moderate total S concentrations. Several rejects samples had minor enrichment with regard to one or more of Ag, Mo, and/or S. There was no correlation found between AMD classifications of the reject samples compared to elemental enrichment.

Solubility data indicates that leachate from rejects under freshwater (deionised water) and saline water leaching conditions is expected to contain low concentrations of soluble metals and metalloids. Mildly saline (brackish) water was used in some leaching tests to simulate the water quality in the CHPP during ROM coal processing.

Based on the results, approximately 95% of rejects has a low potential to generate AMD as either AD and/or NMD and/or SD. However, approximately 5% of rejects has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, rejects has a low potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time before being processed. However, some minor coal seams/plys will report directly to the spoil as waste, and remnant coal (seams) will be exposed on residual void highwalls at closure.

Coal represents approximately 6% of all lithological material at DNM and, considering almost all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste. Most waste 'coal' will report as rejects. Remnant coal (in the highwalls of residual voids) is estimated to comprise about 3% to 6% of exposed highwall in Titan North/Central void, Titan East void and Pandora void respectively.

ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

The total S concentration of coal is generally low-moderate, with a 95th percentile total S concentration of 0.52%. The total S distribution in the coal geochemical samples tested (n=77) is comparable to the total S distribution in the coal quality database samples (n=1499). Approximately 29% (median value) of the total S is present as sulphide (Scr), however the proportion of total S as sulphide (from 76 samples) ranges from 5% (almost no sulphide) to 100% (all sulphide). Generally, a significant proportion of S in coal is present as organic S, which does not contribute to AD.

Coal samples have a wide range of ANC values from less than 0.2 to 114 kg H₂SO₄/t, however the median ANC is low (9 kg H₂SO₄/t) and the median MPA is also low (7 kg H₂SO₄/t) and similar to the ANC. As such, 52% of samples were classified as NAF or UC(NAF) and 48% of samples classified as PAF, PAF-LC or UC(PAF). The classification of the samples based on total S is conservative and classifying approximately 48% of coal samples as PAF (of some type) is likely an upper limit. The generally low S concentrations in coal samples, combined with the generally low proportion of S present as sulphide, indicate that the sulphate loads from sulphide oxidation would likely be low.

Assay data available for nine coal samples show that the total metal and metalloid concentrations are low compared to average element abundance in soil in the earth's crust. One sample was significantly enriched with regard to S and another sample was significantly enriched with regard to Mo. Several coal samples had minor enrichment with regard to one or more of Be, Co, Hg, Mo, and/or S. There was no correlation found between AMD classifications of the coal samples compared to elemental enrichment.

Soluble multi-element results from 16 out of 18 coal samples tested indicated that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids. The remaining two samples showed potential to mobilise elevated concentration of metals (i.e. Co, Cu, Mn, Ni and Zn). Peroxide leaching (NAG leach) undertaken on four PAF coal samples showed the samples to be acid generating and producing leachate with moderate soluble metal and metalloid concentrations – indicating that PAF coal, as expected, can generate AD and/or NMD if allowed to fully oxidise.

Based on the results, although a small proportion of coal would have a moderate to high potential to generate AMD, as bulk material coal (ROM, residual and waste) is assessed as having a low potential to generate AMD as either AD, NMD and/or SD.

Salinity, Sodicity and Dispersion Potential of Mineral Waste and Coal Material Types

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has EC values (from 704 samples) ranging from 51 to 2520 microSiemens per centimeters (μS/cm), with median and 90th percentile values of 330 and 844 μS/cm, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally non-saline to slightly saline (<900 μS/cm), either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of weathered non-carbonaceous samples produced moderately saline leachate.

Non-carbonaceous spoil is expected to be sodic to strongly sodic with potential for dispersion (based on high sodicity values). In particular, non-carbonaceous spoil samples (n=334) had modest cation exchange capacity

(CEC) values and generally high exchangeable sodium percentage (ESP) values, resulting in approximately 44% of samples being classified as 'strongly sodic' and almost all remaining samples being classified as 'sodic'. Emerson aggregate class testing, conducted on a non-carbonaceous sample sub-set (n=132), reported 56% of samples (74 out of 132 samples) are likely to undergo 'some dispersion', 15% of samples (20 out of 132 samples) are found to be dispersive, and the remaining 38 samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has EC values (from 200 samples, which were predominantly fresh carbonaceous samples) ranging from 58 to 2200 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 236 and 391 $\mu\text{S}/\text{cm}$, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples (n=36) had low CEC and high ESP values comparable to non-carbonaceous samples, resulting in 70% (25 out of 36 samples) being classified as 'strongly sodic' and almost all remaining being classified as 'sodic'. As such, and based solely on the high sodicity values, carbonaceous spoil is expected to be strongly sodic with potential for dispersion. Sixteen samples also underwent Emerson aggregate class testing to directly measure dispersion, which found that 3 out of 16 samples to be dispersive, 4 samples displaying some dispersion and remaining samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity Potential of Rejects

Rejects samples (n=160) have EC values ranging from 56 to 1050 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 288 and 459 $\mu\text{S}/\text{cm}$, respectively. On this basis, contact water (run-off and seepage) from most rejects material is expected to be non-saline to slightly saline (<900 $\mu\text{S}/\text{cm}$). A small number of rejects samples produced moderately saline leachate. Most rejects have low-moderate total S concentrations, therefore the potential for SD (from sulphide oxidation) is low to low-moderate.

Salinity Potential of Coal

Coal samples (n=92) have EC values ranging from 12 to 788 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 132 and 347 $\mu\text{S}/\text{cm}$, respectively, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk material, is expected to be non-saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of coal samples produced slightly saline leachate.

Geochemical Source Hazard Assessment of Material Types

A source hazard geochemical assessment was conducted for the source material types comprising carbonaceous and non-carbonaceous spoil, rejects and coal (where relevant). The source hazard score is a formula devised by the authors that takes into account the propensity (ability) to generate AMD, the AMD capacity (severity) and the quantity (volume/tonnage) of material that could produce AMD. The AMD source hazard scores are as follows:

- Spoil – non-carbonaceous: AMD source hazard score = **Low**
- Spoil – carbonaceous: AMD source hazard score = **Moderate**
- Rejects: AMD source hazard score = **Moderate-High**

Taking into account the proportion of PAF material of each type relative to the total proportion of all materials in the final spoil landform and the residual voids, the AMD hazard score for the final spoil landform (i.e. rehabilitated spoil dumps), final void highwalls and final void floors, at closure is as follows:

- The hazard for AMD generation from the spoil landform, which comprises approximately 98.5% spoil and approximately 1.5% rejects, is **Low** and the likelihood for AMD generation from the spoil landform is **Highly Unlikely**.
- The hazard for AMD generation from Titan North/Central pit, Titan East pit and Pandora pit highwalls is **Low** and the likelihood for AMD generation from these highwalls is **Unlikely**.

- The hazard for AMD generation from Titan North/Central pit floor, Titan East pit floor and Pandora pit floor – is **Moderate** and the likelihood for AMD generation from these pit floors – prior to flooding – is **Probable/Likely**. As groundwater recovers in the pits and pit floors are inundated (flooded), the likelihood for AMD generations from the flooded pit floors is **Unlikely**.

Geochemical Source-Pathway-Receptor (SPR) Assessment

The source-pathway-receptor (SPR) assessment includes the likelihood of the event occurring (e.g. the likelihood of AMD impacting a local creek), the severity of the event (should it occur) and the calculated risk rating (likelihood times severity). A risk rating was calculated for the final spoil landform and the final residual voids with respect to plausible surface water and groundwater receptors.

A post-closure conceptual site model (CSM), which applies to the spoil landform and residual voids at DNM, and the relationship that the spoil landform and residual voids have with surface water and groundwater in the district has been produced by SLR consultants (2023). The CSM assists with the SPR assessment with regard to potential environmental geochemical impacts from mineral waste facilities.

With regard to the final spoil landform and residual voids, the plausible mechanism for AMD affected water and/or non-oxidative salinity, if any, to report to receptors are:

- Surface water run-off and seepage from the final spoil landform into nearby creeks (e.g. New Chum Creek / Isaac River).
- Seepage from low-wall of final spoil landform into residual voids.
- Surface water run-off and seepage from pit highwalls into residual voids.

The hydrogeological assessment (SLR, 2023) indicates there may be shallow permeable strata present sporadically along (and/or near to) several creeks at DNM (primarily New Chum Creek and Isaac River). If shallow groundwater is present, then, it is expected to be well below the base of all creeks in the area; suggesting that connectivity between shallow permeable strata and surface water feature at DNM is unlikely. Furthermore, groundwater modelling (including particle tracking) undertaken by SLR (2023) found no evidence of connectivity between groundwater and surface water features. The model suggests that shallow groundwater (and by extension shallow seepage) migrating through the site will eventually report to the residual voids. The general downward migration of shallow groundwater (and seepage) into deeper groundwater and towards the mine pits (residual voids) is logical, given the very large drawdown (sink) of the pits.

The assessment found that all receptors are at low risk of environmental impact from mineral waste with respect to AMD (including acid/acidity, NMD and SD) and non-oxidative salinity.

SPR risk rating of final spoil landform

There are plausible surface water and residual void receptors associated with final spoil landform; and the run-off and seepage pathways linking the sources (final spoil landform) to these receptors have been identified. However, the mineral waste materials within the landforms (source) pose a low AMD hazard and therefore overall SPR risk rating from final spoil landform with respect to AMD is **Low**. With respect to non-oxidative salinity the overall SPR risk from the final spoil landform is rated as **Low to Medium**.

SPR risk rating of residual voids

The final receptors for seepage from the low-wall of the final spoil landform and run-off from the highwall (of each void) are the three residual voids. The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure residual void floor (of any of the voids) would impact on residual void water quality to any significant degree, as other processes such as evapoconcentration are the key drivers of residual void water quality (WSP, 2023; SLR, 2023). Therefore, the AMD SPR risk rating on the overall water quality of the residual void is **Low** for each void.

Groundwater or surface water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2023) shows that seepage from the pit lake of each void into groundwater, if any, would be limited.

Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by mineral wastes likely to be present at closure are low. As such, no specific AMD management measures (e.g. alkaline amendment or capping systems) are expected to be required to manage mineral wastes during rehabilitation and closure – outside of operational mixing/burial of PAF waste amongst NAF waste, spoil placement and landform reshaping activities already proposed (refer to the main volume of the PRCP for detailed information).

- Residual voids:
 - Titan North/Central void;
 - Titan East void; and
 - Pandora void.
- Spoil dumps: will be reshaped, covered with soil and seeded.
- Rejects: Managed during operations (disposed as MPR within spoil) and progressively covered by spoil. No specific AMD management measures are proposed for the rejects (at closure). The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment prior to covering.
- ROM pad and coal stockpiles: Remove remnant coal and dispose within spoil. The areas will be reshaped where required, covered with soil, and seeded.

Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

GLOSSARY OF TERMS

Key terms and definitions as used in this report are listed below:

Acid	A measure of hydrogen ion (H^+) concentration in water; generally expressed as pH.
Acidity	A measure of hydrogen concentration and latent acidity generated by metal hydroxylation, expressed as mg/L $CaCO_3$ equivalent.
Acid-Base Account (ABA)	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determined by the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below. See also ANC and MPA.
AMD	Acid and metalliferous drainage. AMD encompasses 3 drainage types: acid drainage (AD), pH- neutral and metalliferous drainage (NMD) and/or sulphide-derived saline drainage (SD) – and/or any combination of these, all generated by sulphide oxidation processes +/- neutralisation reactions.
ANC	Acid neutralising capacity, expressed as kg H_2SO_4 per tonne of rock/material. A measure of a sample's maximum potential ability to neutralise acid.
ANC/MPA ratio	Ratio of the acid neutralising capacity (ANC) to the maximum potential acidity (MPA) of a sample. Used to assess the risk of a sample generating acid conditions. See also ANC and MPA.
CHPP	Coal handling and preparation plant.
Co-Disposal	The practice of disposing different waste types together. For example, MPR is the co-disposal of coarse rejects and fine rejects.
Coal rejects	Also called Rejects. The general term given to fine rejects, coarse rejects and mixed plant rejects (MPR), produced during the processing of coal from the CHPP.
Coarse rejects	Coarse sand to cobble-sized rock material produced during coal processing. Coarse reject is typically associated with the roof, floor and partings of coal seams and is separated from ROM coal in the CHPP. Coarse rejects produced at DNM are co-disposed with fine rejects as mixed plant rejects (MPR). Coarse reject also includes a small proportion of what is called 'mid rejects', which is coarse to very coarse sand and fine gravel and is combined with coarse rejects prior to disposal.
DNM	Daunia Mine. The name of the site subject to this PRCP.
EC	Electrical conductivity, expressed as $\mu S/cm$.
Fine rejects	Very fine to medium grained sand, silt and clay-sized material, which is commonly coaly and carbonaceous, produced during coal washing. Fine rejects is associated with coal seams and is separated from ROM coal in the CHPP. Fine rejects produced at DNM is co-disposed with coarse reject as mixed plant rejects (MPR).
Interburden	Potential spoil material located between mined coal seams. See also Overburden, Mineral waste and Spoil.
Kinetic test	Procedure used to measure the geochemical/weathering behaviour of a sample of mine material over time.
Mineral waste	Material comprising mine spoil, $\pm$ rejects, $\pm$ waste coal. Sometimes called 'mine waste' or 'mining waste'.
MPR	Mixed Plant Rejects. A mixture of approximately 80% coarse rejects and 20% fine rejects disposed within spoil.

BHP

MPA	Maximum potential acidity. Calculated by multiplying the total sulphur (S) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H ₂ SO ₄ per tonne of rock/material (kg H ₂ SO ₄ /t). Assumes all sulphur is present as sulphide and will oxidise to generate acid.
NAF	Non-acid forming. Geochemical classification criterion for a sample that is unlikely to be acid generating. These samples have excess acid neutralising capacity compared to their acid generating capacity. NAF material are generally inert, but may still develop NMD and/or SD, depending on sulphur concentration.
NAG	Net acid generating test. A pulp sample is reacted with hydrogen peroxide to encourage rapid oxidation. Any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity (after neutralising material is consumed) is measured and expressed as kg H ₂ SO ₄ /t. Following a NAG test, the solution can be measured for soluble parameters (e.g. metals, sulphate) to understand their solubility under acidic or low pH conditions.
NAPP	Net acid producing potential, expressed as kg H ₂ SO ₄ per tonne of rock/material (kg H ₂ SO ₄ /t). Calculated by subtracting the ANC from the MPA.
NMD	Neutral and metalliferous drainage. A component of AMD, NMD occurs where drainage is pH-neutral or higher yet contains elevated trace metals and metalloids in solution.
Org S	Organic sulphur.
Overburden	Mineral (mining) waste located above (overburden proper) or between (interburden) coal seams and reports to spoils dumps. Typically comprises non-coaly and non-carbonaceous material, such as sandstone, siltstone and claystone/mudstone, but also includes a small percentage of carbonaceous material (e.g. carbonaceous siltstone) and sub-economic waste coal.
OxCon	Oxygen consumption test. A type of kinetic (dynamic) test for estimating the sulphide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological materials.
PAF	Potentially acid forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions. A sample classified as PAF has an acid generating potential (MPA) that exceeds the inherent acid neutralising capacity (ANC) of the material. This means that such a material is likely to generate acidic drainage (AD) if exposed to atmospheric conditions. See also PAF-LC.
PAF-LC	Potentially acid forming (low capacity). Geochemical classification criterion for a sample that has the potential to generate relatively low-level AD.
PRCP	Progressive rehabilitation and closure plan.
Product coal	Coal produced from the CHPP after being washed/processed. Coal that is ready for sale.
ROM	Run-of-Mine. The term given to mined coal before being processed at the CHPP.
ROM pad	Location where ROM coal is temporarily stored pending processing at the CHPP.
S	Sulphur.
Scr	Chromium reducible sulphur. Analytical procedure to determine the sulphide-sulphur concentration in a sample. This typically represents the proportion of sulphur associated with sulphide (reactive) minerals.
SD	Saline drainage. A component of AMD, SD occurs where drainage is saline due to elevated sulphate as a result of sulphide oxidation and neutralisation reactions.
SO₄	Sulphate.

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Spoil	Rock material overlying and between ‘target’ coal seams, which will report as waste. Waste rock overlying a coal seam is called overburden. Waste rock between mined coal seams is called interburden. See also Overburden and Interburden.
Spoil dump	In-pit or out-of-pit landform containing mineral waste.
SPR	Source-pathway-receptor.
Static test	Procedure for characterising the geochemical nature of a sample at one point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid-Base Account.
Tailings	Fine rejects prior to being dewatered at the CHPP. See Fine rejects.
Uncertain	In the context of classifying a material (sample) as NAF or PAF. An ‘Uncertain’ (UC) classification applies when there is an apparent conflict in results such that neither NAF nor PAF classification can be given, or there is insufficient information to unequivocally classify as NAF or PAF. UC samples are sometimes given a tentative sub-classification, such as UC(NAF) or UC(PAF) where preliminary data suggests the sample may be NAF or PAF, respectively.
Waste coal	Sub-economical coal that reports directly to the spoil dumps as waste (i.e. not ROM coal). Waste coal can be fresh or weathered (oxidised). All weathered/oxidised and coked (cindered) coal is waste.
Water extract	A method to determine the water-soluble parameters in soil. Solid samples undergo a bottle leach method where 10 g of pulped solid (85% passing 75 µm) is combined with 20 grams or 50 grams of water (leaching fluid) into a glass bottle. Depending on the type of leaching undertaken the leaching fluid may be deionised water (DI water extract) or saline water (saline water extract). The 1:2 or 1:5 solution (1 part solid to 2 or 5 parts water) is tumbled end-over-end for one hour. Solutes are leached from the soil by the continuous suspension and agitation. The water extract solution is measured for pH and electrical conductivity (EC) prior to filtering for solute analysis (e.g. metals/metalloids and major ions).

1 Introduction and Context

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials associated with Daunia Mine (DNM), as defined under the current Environmental Authority (EA) EPML00561913, held by BHP Mitsubishi Alliance (BMA). In this report the term ‘mineral waste’ refers to all geologic material generated by or associated with DNM during the course of mining, handling and processing coal.

It is a requirement of a Progressive Rehabilitation and Closure Plan (PRCP) that mineral waste is adequately characterised such that appropriate rehabilitation strategies can be selected and implemented. The PRCP guidance document: “*Guideline – Progressive Rehabilitation and Closure Plans*” (DES, 2021) outlines the requirements and considerations for producing a PRCP, including documenting the relevant aspects of mineral waste characterisation for the purposes of PRCPs.

1.1 Approach

The general approach to mineral waste characterisation and assessment includes the following key steps:

- Briefly describe the current/existing background information for DNM of relevance to the generation and ultimate storage/disposal of mineral waste materials;
- Document the methodology used to characterise mineral waste materials (samples);
- Present and discuss the geochemical results;
- Describe the potential environmental geochemical hazards with respect to mineral waste materials;
- Present the conceptual site model (CSM), which illustrates the relationship between AMD and salinity sources, potential environmental and human health receptors and plausible pathways between the AMD and salinity sources and the receptors (Source-Pathway-Receptor [SPR]) at closure;
- Present the acid and metalliferous drainage (AMD) and salinity SPR risk assessment undertaken on the mineral waste materials;
- Outline the AMD specific management and rehabilitation measures proposed for mineral waste materials; and
- Outline a forward work plan to address any gaps identified from the assessment.

1.2 Objective

The objective of this assessment is to evaluate the geochemical nature of mineral waste currently at DNM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

2 Background

2.1 Site Overview

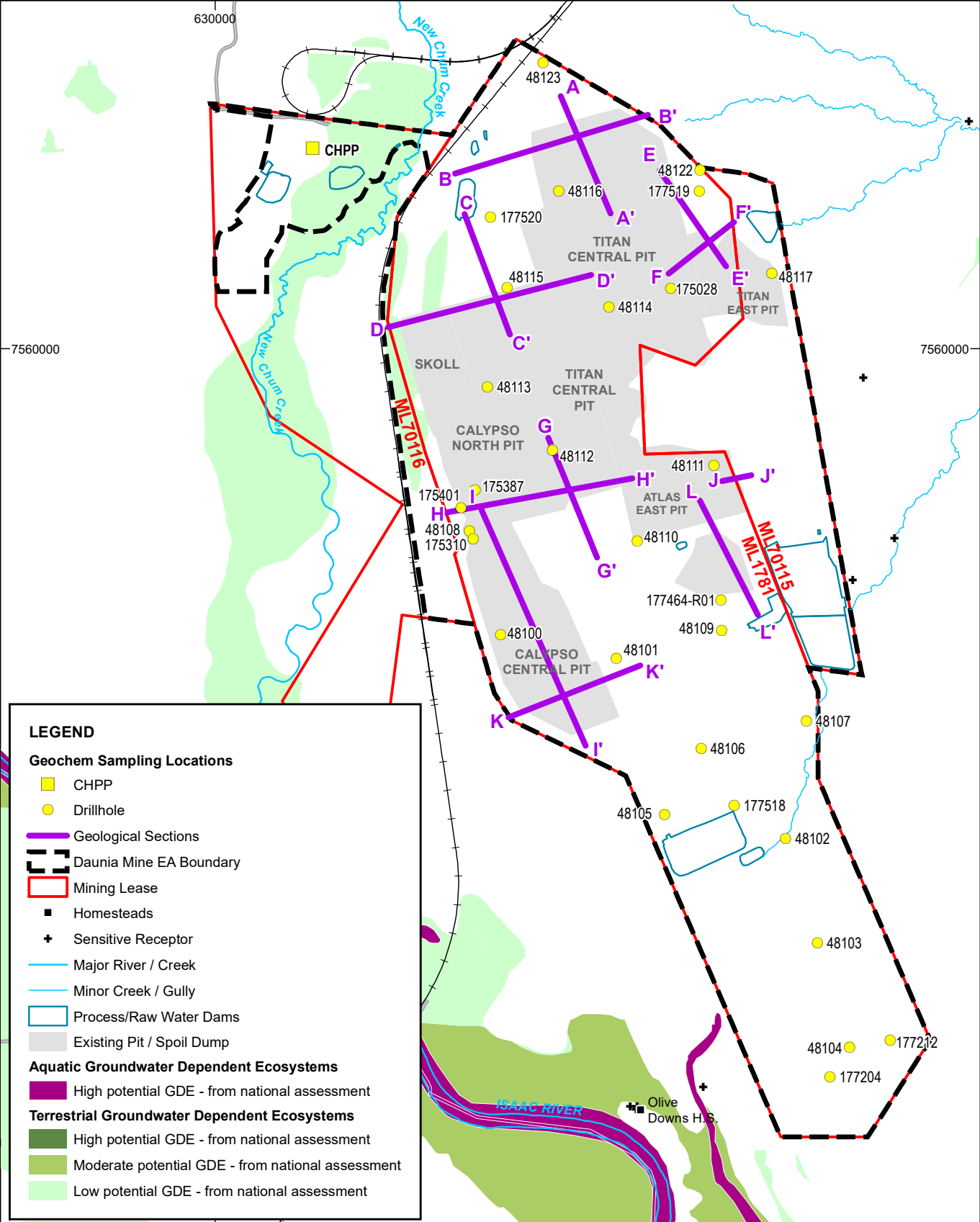
DNM is an open cut coal mine located approximately 25 km south-east of the town of Moranbah in the Bowen Basin, Central Queensland. DNM is located close to several other coal mines and coal mining development projects: Poitrel Mine and Red Mountain Infrastructure (coal processing facility) to the west, Millennium Mine to the north-west, Moorvale Mine to the Northeast, proposed Winchester South project to the south-west, proposed Moorvale South Project to the south-east and proposed Isaac River coking coal project to the east. DNM commenced operations in 2013.

DNM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, stockpiles, coal processing facilities, process water and raw water dams, surface water drains and administration areas. The key facilities and natural features at DNM of relevance to this waste characterisation report are shown on **Figure 1**. [Also shown on **Figure 1** are geochemical sampling locations and the locations of geological sections along and across each pit].

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Short-term storage of run of mine (ROM) coal on the ROM Pad;
- ROM coal processing at the coal handling and preparation plant (CHPP), which produces:
 - MPR. Mixed plant rejects. Trucked to designated disposal areas and buried within spoil.
 - Fine rejects. Combined with coarse rejects in the CHPP to form MPR (see above). Fine rejects is sometimes disposed as monofill to meet operational requirements.
 - Coarse rejects. Combined with fine rejects in the CHPP to form MPR (see above). Coarse rejects is sometimes disposed as monofill to meet operational requirements.
- Short-term storage of product coal on the product Coal Stockpile, awaiting off-site transport by rail;
- The operation of raw water and process water dams and sediment control structures as stipulated in the EA.

An overview of the proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report are outlined in **Section 8 (Management and Rehabilitation Measures)**.



**FIGURE 1. PROJECT LAYOUT
GEOCHEMICAL SAMPLE LOCATIONS
AND GEOLOGICAL SECTIONS**

Drawn: reedka9

Date: 31/01/2023

Checked: R. Hattingh

Filename: 20221213-6_mxd

BHP

Geospatial Data Team
Brisbane

0 1 2 km

Transverse Mercator Projection
GDA 1994 MGA Zone 55



2.2 Mine Domains

The mine domains of direct relevance to mineral waste characterisation and management at DNM are:

- Residual voids: Titan East, Titan Central and Pandora.
- Spoil dumps: due to the configuration of the site, this is considered a single spoil landform.
- Coal stockpiles: ROM coal pad and stockpile; and Product coal pad and stockpile

DNM has no tailings storage facility (TSF). Tailings are dewatered at the CHPP to produce fine rejects, which is co-disposed (into spoil) with coarse rejects as MPR or periodically disposed into spoil directly as fine rejects (i.e. not co-disposed with coarse rejects). Tailings liquor from the dewatering process is recycled for use within the CHPP.

2.2.1 Material Types and Quantities

DNM has two main types of mineral waste:

- Spoil (overburden and interburden) currently comprises approximately 98.5% of all mineral waste at DNM and includes weathered waste (Tertiary and Permian-age – in approximately equal proportions) and fresh (unweathered) waste (all Permian-age). Approximately 52% of spoil is fresh and the remainder (approximately 48%) is weathered/oxidised.
 - Spoil is comprised of approximately 94% non-carbonaceous material (93.6% of all spoil) and 6% carbonaceous material (i.e. 6.4% of all spoil).
- Rejects are generated at the CHPP. Rejects currently comprises less than 1.5% of all mineral waste at DNM.
 - Rejects is primarily generated (and disposed) as MPR, which comprises approximately 80% coarse rejects and 20% fine rejects mixed together at the CHPP.

The proportion of spoil and rejects are not expected to materially change over life of the operation.

Coal is also included in the assessment; however, coal is generally not considered mineral waste. Coal is primarily representative of ROM coal, however is also representative of potential waste coal from sub-economic seams and remnant coal exposed on pit highwalls (such as in residual voids).

2.3 Baseline Information

2.3.1 Topography

The regional topography of the Bowen Basin is dominated by flat to gently sloping landforms and low rolling hills. DNM lies within the north-eastern areas of the Bowen Basin. Topography across DNM is generally of low relief and dominated by flat to gently undulating rural plains. DNM lies between an elevation of approximately 240 mAHD in the north down to approximately 190 mAHD in the south, with a slope typically between 1 and 2%, except in the southern portion where there is a broad drainage floor that has more gentle slopes.

At a catchment scale, the mine site lies within a sub catchment of the Fitzroy Basin, which includes the major tributaries of the Isaac, Connors, and Comet rivers. The catchment is flanked by the Denham and Peak Downs Ranges in the west and the Connor Ranges in the east. These ranges form the prominent topographic features in an otherwise low-relief landscape.

2.3.2 Climate

DNM is located within Queensland's semi-arid climatic zone, which is characterised by high summer temperatures, warm dry winters and a distinct wet and dry season. Weather data was collected at the Moranbah Water Treatment Plant (Station No. 034038) between 1972 and 2012 and since 2012 it has been collected at the Moranbah Airport (Station No. 034035) (bom.gov.au, 2021). The Moranbah Airport weather station is located about 25 km west of DNM. The Moranbah Water Treatment Plant is located about 35 km west of DNM.

Maximum temperatures range from 24°C in June/July to 34°C in December/January, with minimum temperatures ranging from 10°C in July to 22°C in January. Rainfall occurs throughout the year, though it is more prevalent in the summer months of December, January and February. The average annual rainfall (and averaged between the two weather stations) is approximately 570mm per year. The evaporation rate is highest in the summer months - mean daily rate of 8.5 mm in December, and lowest in the cooler months - mean daily rate of 3.5mm in June. The mean monthly rate of evaporation is 78mm. The annual average rate of evaporation is 2,373mm, which greatly exceeds the annual rainfall, a characteristic of semi-arid environments. Rainfall events are often associated with thunderstorms, which are typically short-lived, intense and have variable coverage. Sustained rainfall over a large landscape area is experienced when tropical lows with cyclonic activity occur in coastal area. However, periods of prolonged drought do occur within the region.

2.3.3 Geology

DNM is located on the western limb of the northern Bowen Basin. The Bowen Basin (at DNM) is characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation. DNM lies near the western boundary of one of the sedimentary troughs, the Taroom Trough, which was filled by a thick accumulation of mainly terrestrial sediments during the Permo-Triassic period. DNM occurs within a shallow basinal structure immediately east of the New Chum Fault, which separates DNM from Poitrel deposit to the west. New Chum Creek, which flows from north to south between DNM and Poitrel Mine, broadly follows the fault line.

The coal bearing sequences at DNM are the late Permian-age Rangal Coal Measures (RCM), comprising the following seam groups in stratigraphic order, from youngest to oldest:

- Leichhardt Seam: L1, L2 and L3 plys (when combined L1 and L3 plys together are referred as L13 ply)
- Lower Leichhardt Seam: L4 ply
- Upper Vermont Seam: V1, V2 and V3 plys (when combined V2 and V3 plys together are referred as V23 ply. V23 is sub-economic and not mined)
- Lower Vermont Seam: VL ply (not mined)

Non-coal Permian sediments consist of moderately weak to strong sandstones, siltstones, minor mudstones and carbonaceous mudstones. Sandstone units are commonly greater than 2m thick. Interbedded and interlaminated siltstone occurs within some sandstone units. The Yarrabee Tuff 'marker horizon' is widespread throughout the RCM and at DNM is located immediately above the Vermont Lower (VL) ply.

An indicative stratigraphic column showing the seam groups is provided at **Figure 2**, which also includes the number of geochemical samples collected from each overburden, interburden and seam zone (refer to **Section 4.2** for information regarding sample collection). Geological long-sections (indicatively north-south) along Titan North/Central pit and Titan East pit high-wall are provided at **Figure 3** and **Figure 4**. Geological cross-sections (indicatively west-east) through Titan North/Central pit and Titan East pit are provided in **Figure 5** and **Figure 6**. Refer to **Figure 1** for section locations. The seam groups are shown in the geological sections.

In coal environments (i.e. at coal mines) fresh carbonaceous materials typically have higher sulphide concentrations compared with fresh non-carbonaceous materials and, as such, typically pose a greater environmental geochemical hazard compared with fresh non-carbonaceous material. Comparatively, non-carbonaceous lithologies are essentially void of (or have negligible) carbonaceous material and thus have low or nil sulphide mineral concentration.

Due to the eastward dip of the seams, the location of the weathered zone shown in the stratigraphic column (**Figure 2**) has ranged from above the Leichhardt seam at the start of mining operations to the current location (at the highwall) above the Vermont seam in Titan North/Central pit and Titan East pit (refer to the geological long-sections in **Figure 3 - Figure 4**, and cross-sections in **Figure 5 - Figure 6** respectively)

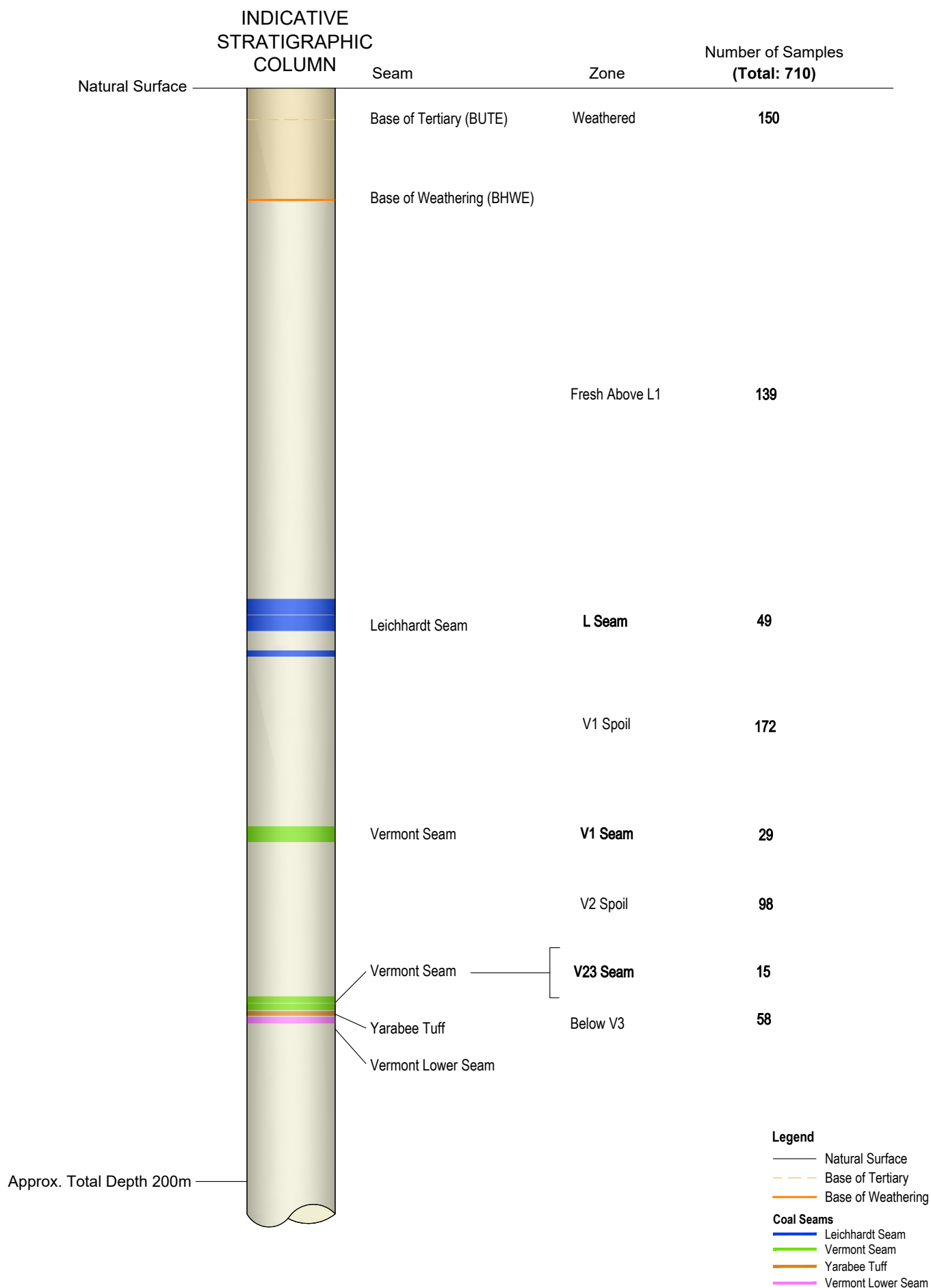
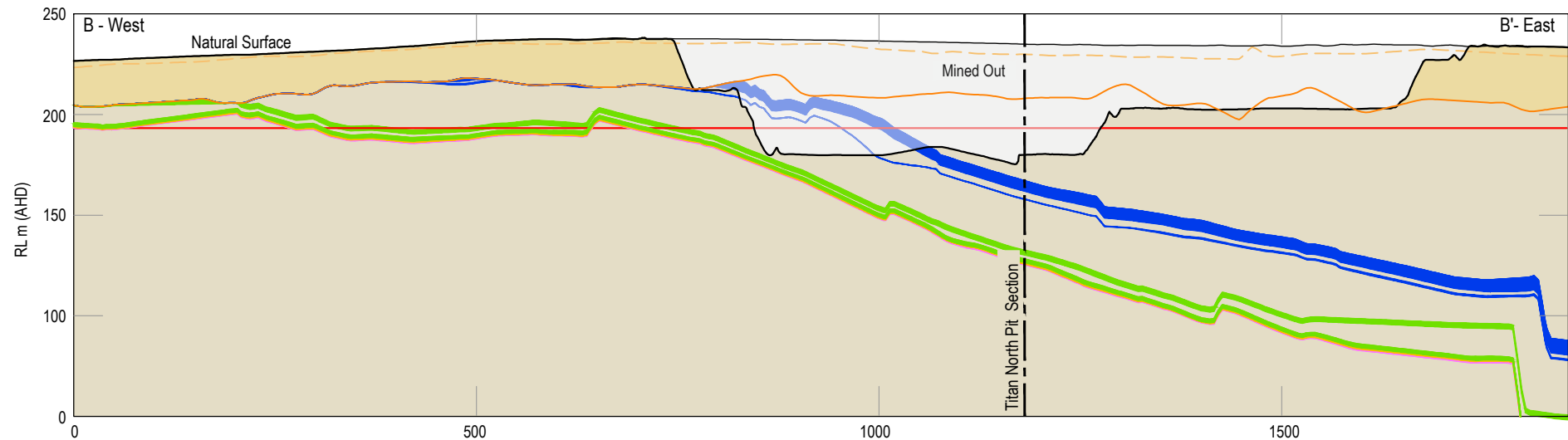
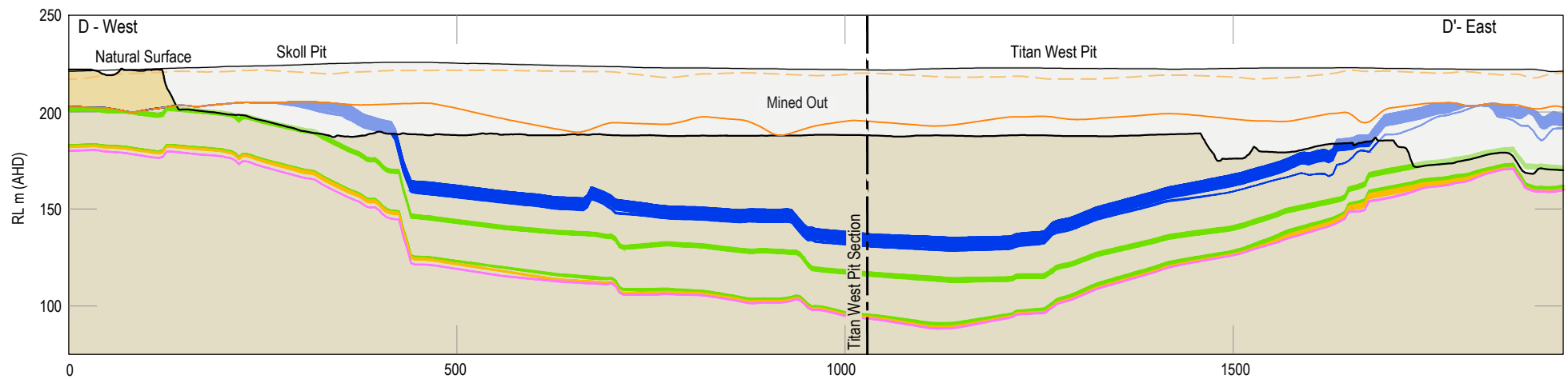


Figure 2. Indicative stratigraphic column

LONG SECTION | Titan North/Central Pit
Viewed Looking North (Vertical Exaggeration x2.5)



LONG SECTION | Titan North/Central Pit
Viewed Looking North (Vertical Exaggeration x2.5)



- | Legend | |
|------------------------|----------------------|
| — Natural Surface | — Leichhardt Seam |
| - - - Base of Tertiary | — Vermont Seam |
| — Base of Weathering | — Yarabee Tuff |
| — Current Pit Shell | — Vermont Lower Seam |

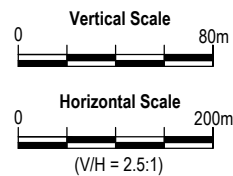
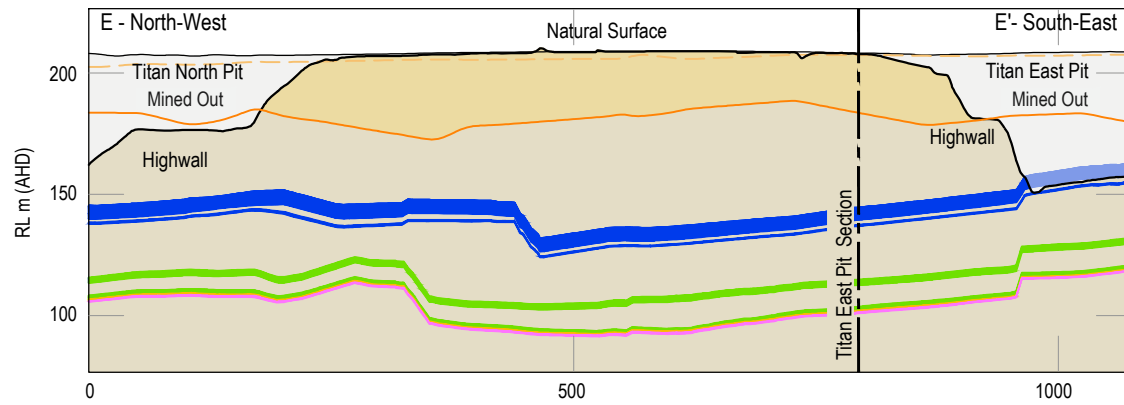


Figure 3. Pit highwall long-sections for Titan North/Central pit

LONG SECTION | Tital East Pit

Viewed Looking North-East (Vertical Exaggeration x2.5)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- Leichhardt Seam
- Vermont Seam
- Yarabee Tuff
- Vermont Lower Seam

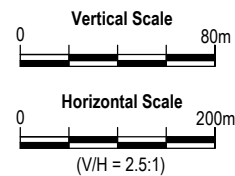
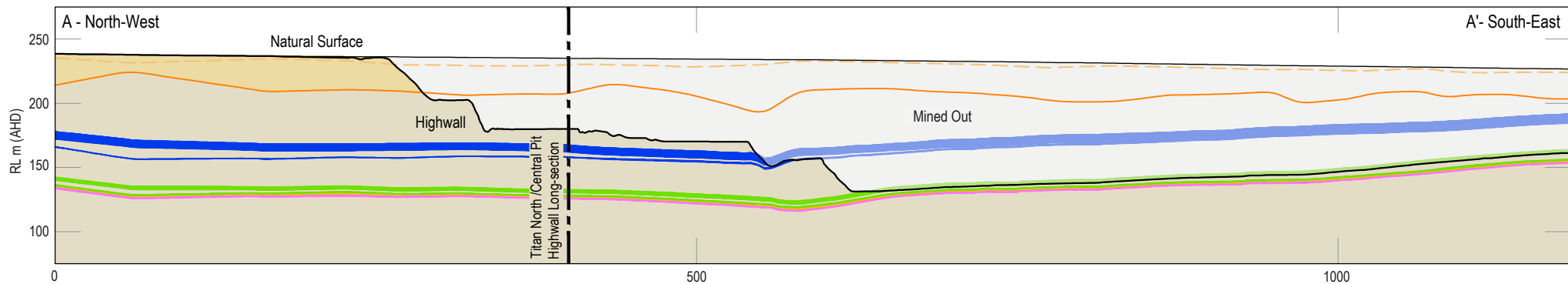


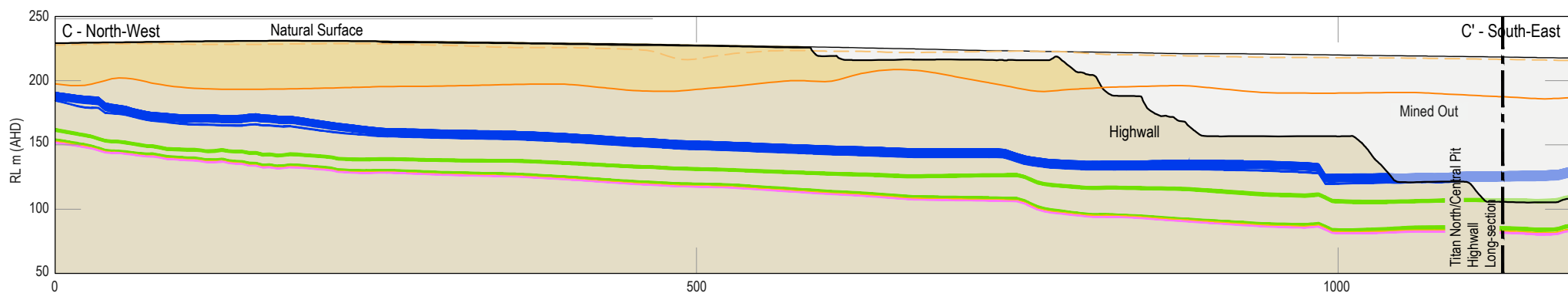
Figure 4. Pit highwall long-section for Titan East pit

Figure 4

CROSS SECTION | Titan North/Central Pit



CROSS SECTION | Titan North/Central Pit



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- Leichhardt Seam
- Vermont Seam
- Yarabee Tuff
- Vermont Lower Seam

Horizontal Scale

(V/H = 1)

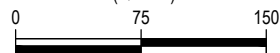


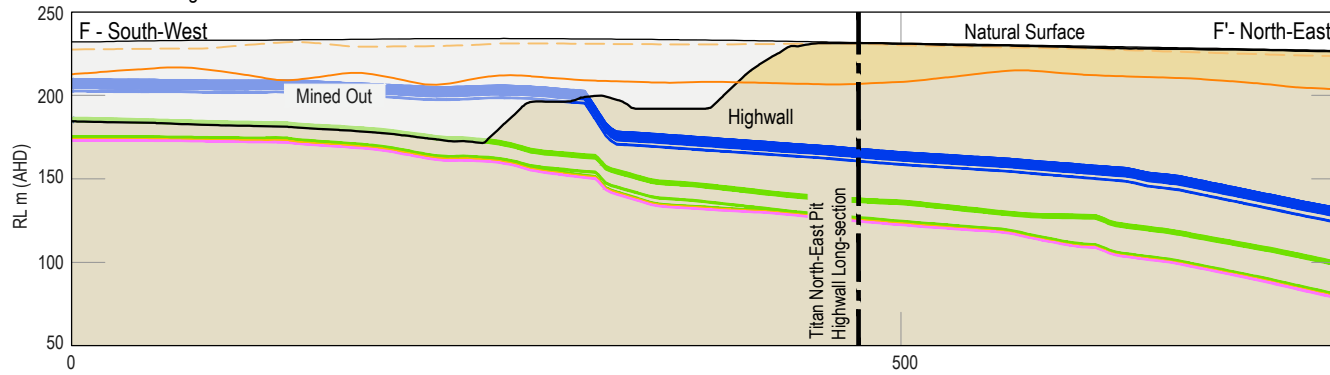
Figure 5. Pit cross-sections for Titan North/Central pit

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CROSS SECTION | Titan East Pit

Viewed Looking North-West



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- Leichhardt Seam
- Vermont Seam
- Yarabee Tuff
- Vermont Lower Seam

Horizontal Scale

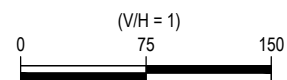


Figure 6. Pit cross-sections for Titan East pit

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2.3.4 Surface Water / Hydrology

The following information about surface water / hydrology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about surface water environment at DNM.

DNM is located in the Upper Isaac surface water catchments of the Isaac River Sub-Basin. The topography of the DNM gradually slopes from northeast to southwest towards Isaac River, with elevations ranging from approximately 210 mAHD to 240 mAHD. All water courses and tributaries within DNM are ephemeral and only flow briefly after rainfall.

The key surface water features are shown on **Figure 1** and include:

- Isaac River (Upstream of DNM)
- New Chum Creek (west of DNM)
- Unnamed drainage feature (west of DNM)
- North Creek (east of DNM)
- Three Unnamed drainage feature (east of DNM)

The Isaac River is the major drainage feature of the region and flows from northwest to southeast in the vicinity of DNM (**Figure 1**). The New Chum Creek, a tributary of Isaac River, traverses northeast to southwest across the northern section of mining lease, before running south adjacent to Poitrel Mine to the west of the ML70116 (**Figure 1**). An unnamed drainage feature runs parallel to the western boundary of ML1781 before forming minor tributary to Isaac River approximately 4 km southeast at DNM (**Figure 1**). There are three unnamed drainage feature approximately 1 km from ML70115 that drains into North Creek which is approximately 3.5 km east of DNM, draining north to south and joining the Isaac River approximately 7.5 km downstream at DNM.

All creeks in DNM are ephemeral with no semi-permanent or permanent waterholes and generally dominated by sandy substrate, with gravel bars dispersed throughout New Chum Creek. No creeks within DNM have a permanent groundwater baseflow. The only significant waterway within the vicinity of DNM is the Isaac River, which is an ephemeral water course.

2.3.5 Groundwater / Hydrogeology

The following information about groundwater / hydrogeology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about hydrogeology at DNM.

Two distinct aquifers occur in the proximity of DNM. Namely, a Quaternary age alluvium unit and a Permian age unit. The Quaternary age alluvium consists of clay, silt, sand and gravel and is located in receiving environments in the proximity of Isaac River and North Creek. Quaternary alluvium has not been identified within the DNM lease areas. Where present, these sediments act as an unconfined (water table) aquifer. The Rewan Group and Rangel Coal Measures also act together as a minor fractured rock aquifer. The formations consist of sandstone, siltstone, mudstone, shale and coal. The permeability of this aquifer is highly variable and dependent on the size and degree of interconnectivity between the fractures within the aquifer. Given the large impermeable nature of the Permian age sandstone/siltstone occurring between, above and below the coal seams, the aquifer constituting the coal seam unit is considered confined to semi-confined.

The main factors influencing natural groundwater levels are groundwater recharge, evapo-transpiration and regional flow patterns. Recharge of the aquifers in the region occurs predominantly in the topographically higher areas and along creek beds during and immediately following rainfall events. Recharge to the Quaternary age alluvium unit occurs in the areas of thin soil cover or along creek beds (i.e. the Isaac River) where surface water can readily permeate into the aquifer during and following rainfall events. The Permian age RCM will recharge via leakage from the overlying alluvium units or via direct rainwater infiltration in regions where the formation outcrops or sub-crops. Groundwater flow in the Permian Coal Measures are shown to follow a general northwest to southeast trend, with local modifications in the vicinity of the active mine pit voids. Local groundwater flow is therefore towards active mine voids, whilst regional flow remains towards the southeast (SLR, 2023).

The physico-chemical results from groundwater sampling at DNM indicate the water chemistry is typically pH-neutral for all geological formations. Groundwater associated with alluvium and coal seams have variable salinity levels [measured as electrical conductivity (EC)], ranging from fresh to highly saline (SLR, 2023). The metal concentrations for all parameters analysed in DNM bores were either below the laboratory detection limit or below the relevant guideline level (SLR, 2023). The alluvial groundwater was found to record concentrations of total and dissolved iron (Fe) and manganese (Mn) (SLR, 2023).

The hydrogeological units at DNM are outlined in **Table 1**.

Table 1. Hydrogeological units at DNM

Age	Group	Geological Unit	Aquifer
Quaternary	Undifferentiated alluvium and colluvium	Alluvium (mainly clay, silt, sand and gravels)	Sand and gravel deposits associated with the Isaac River and North Creek form an unconfined aquifer. Quaternary alluvium has not been identified within the DNM tenements.
Tertiary	Undifferentiated sediments	Soil, alluvium, gravel, scree, sand	Unconfined and largely unsaturated unit bordering alluvium.
Permian	Rewan Group	Siltstone, sandstone, calcareous and carbonaceous shale	The low permeability sedimentary rocks and clays typically with aquitard properties.
		Rangal Coal Measures (Sandstone, siltstone, mudstone, coal, tuff, conglomerate)	The Leichardt and Upper Vermont coal seams are identified as a semi-confined to confined minor aquifers within the coal measures; the sandstone/siltstone of the interburden/overburden have low permeability.
	Blackwater Group	Sandstone, conglomerate, mudstone, carbonaceous shale, coal, cherty tuff	Low permeability with aquitard properties and is typically dry or very low yielding.

2.3.6 Potential Environmental and Human Health Receptors

A conceptual environmental geochemical model (source-pathway-receptor (SPR) model) for DNM identified the potential environmental and human health receptors and is discussed within this report. Of relevance to this assessment (i.e. hazards and risks posed by AMD), the following potential receptors are noted:

Potential surface water receptors:

The primary surface water feature is the Isaac River and flows from western to southern boundary of DNM and comes within 1 km of ML boundary. The New Chum Creek flows from northeast to southwest in the vicinity of DNM (~1km east from ML boundary) and drains into the Isaac River. An unnamed drainage feature traversing parallel to western boundary of DNM and joining Isaac River approximately 4 km southeast of DNM was considered as

potential surface water receptor. Due to its distance from the DNM (approximately 3.5 km), North Creek was not identified as a potential surface water receptor. DNM shares the Isaac River Catchment with several other coal mines upstream and downstream.

Potential groundwater receptors

Aquatic and terrestrial groundwater dependent ecosystems (from national assessment) are shown in **Figure 1**.

Potential domestic (human) receptors

Consideration was also made to people living in the homesteads near DNM, of which the closest is 'Olive Downs' located approximately 1 km west of the ML boundary at the far southern end of the site.

2.3.7 Acid and Metalliferous Drainage

Environmental geochemical information with regard to AMD from mineral waste materials at DNM has been sourced from the BHP Coal Geochemical Database (hereafter called 'the geochemical database') and is presented and discussed within this report.

2.3.8 Salinity, Sodicity and Dispersion

Environmental geochemical information with regard to salinity, sodicity and dispersion of mineral waste materials at DNM has been sourced from the geochemical database and is presented and discussed within this report. Refer to the main volume of the PRCP for detailed information about soils and rehabilitation of spoil dumps at DNM.

3 Potential Environmental Geochemical Hazards

3.1 Acid and Metalliferous Drainage

The term 'AMD' is used to describe low-quality seepage or drainage (from mineral waste) that has been affected by the oxidation of sulphide minerals (primarily pyrite and marcasite) and/or by the dissolution of acid generating sulphate minerals (primarily alunite and jarosite) and associated neutralisation reactions, if any. The term AMD is used to describe any drainage type affected by this process.

AMD may be produced when sulphide minerals (such as pyrite) are exposed to oxygen and water. Oxidation of sulphide minerals may result in the production of acid(ity), sulphate (SO_4) and, depending on mineralogy, the release of metals and salinity. AMD comprises three key components, which are defined below as per recognised Australian and international guidelines (INAP, 2009; DIIS, 2016). BHP (2019a) has adopted these recognised definitions:

- Acid drainage (AD): where contact water is acidic and, in most cases, also contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid generating capacity exceeds the acid neutralisation capacity of a sample.
- Neutral and metalliferous drainage (NMD): where contact water is pH-neutral/alkaline and contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid neutralising capacity exceeds the acid generating capacity of a sample.
- Saline drainage (SD): where contact water contains elevated sulphate concentration due to oxidation of sulphide minerals or leaching of acid sulphate salts, and very low metal/metalloid concentration. This drainage type is generated when the acid neutralising capacity vastly exceeds the acid generating capacity of a sample with high sulphide concentration.

Whether contact water is impacted by AD, NMD and/or SD largely depends on the relative proportion of acid generating minerals (sulphides / sulphates) and acid neutralising minerals (carbonates) in the source materials.

3.2 Salinity, Sodicity and Dispersion

An assessment of salinity characteristics of mineral waste materials has been undertaken on materials using available EC data from the geochemical database. An assessment of sodicity and dispersion characteristics of potential final landform materials has also been undertaken using exchangeable cation and Emerson Class data from overburden/interburden samples (data obtained from the geochemical database). Salinity released from the dissolution of geogenic salts (non-oxidative) is a separate and distinct process from SD associated with sulphide oxidation / leaching of acid sulphate salts.

4 Assessment Methodology

This section provides the methodology used for the geochemical characterisation and assessment of spoil and coal rejects (mineral wastes) and coal at DNM.

4.1 Information Review

Sampling and laboratory test-work has been undertaken by BHP and consultants throughout the development and operation of DNM. The geochemical database contains all available geochemical data for mineral waste samples. All data has been compiled and reviewed by BHP specifically to support the PRCP, to provide a unified and consistent interpretation of all available data. Past characterisation reports are superseded by this review and assessment undertaken to support the PRCP.

4.2 Sample Collection

Drill-hole Samples – representing spoil, ROM coal, pit walls and pit floor

All data used to assess spoil and coal has been derived from drill-hole sampling. Drill-hole samples have been collected from 31 drill-holes located throughout DNM, dating from exploration drilling undertaken in 2008 during pre-feasibility of the project (i.e. before operations commenced) through to the most recent drill-hole sampling at DNM undertaken in 2022.

The drill-hole samples that have undergone test-work are representative of the geology/stratigraphy, and the mineral waste types and proportions likely to be mined until closure. The DNM coal resource model provides an estimate of coal resources from current pit highwall (at each pit) through to the final extent of the mine (where residual voids will be located). The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of the residual voids is broadly consistent with the current proportions on the relevant pit highwalls. The model also shows that the proportion of each seam group is expected to be broadly similar to current seam group proportions on the highwall of the current pits (as relevant to the voids remaining at closure). As such, it is reasonable to assume that the mineral waste types assessed, and their relative proportions, are representative of the mineral waste types and proportions likely to be mined through closure.

Geochemical data is available for 709 drill-hole samples that had total S measured. These comprise 83 drill-chip samples measured for at least total S collected from 2008 to 2009 and 626 drill-core samples collected from 2020 to 2022 measured for at least total S.

Geochemical samples collected and tested to date were sourced from the following key mineral waste domains:

- Weathered, non-carbonaceous spoil. 138 samples.
- Weathered, carbonaceous spoil, including weathered coal. 11 samples (all Permian age).
- Fresh, non-carbonaceous spoil. 391 samples (all Permian-age).
- Fresh, carbonaceous spoil. 92 samples (all Permian age). These samples typically include carbonaceous (carb) siltstone, (carb) sandstone, (carb) mudstone and coaly shale, but also includes similar coaly and carbonaceous materials other than coal. Some of this material represents seam roof, parting and floor.
- Fresh, coal. 77 samples (all Permian age).

Drill-chip samples were typically collected at set intervals (e.g. every 1 or 2 m) or within targeted sampling zones. Drill-core samples were collected as discrete samples – typically a 15-25 cm interval of core within targeted sampling zones. Drill-core samples were collected semi-continuously across the entire stratigraphic sequence, with greater emphasis placed on those stratigraphy's posing a greater AMD hazard (i.e. carbonaceous spoil, roof/parting/floor, and coal).

The majority of fresh coal will report to ROM coal and be processed. A small fraction of coal may be dumped as spoil (waste) due to coal quality and mining considerations, and a small proportion of coal will remain exposed in seams on pit walls and floor at closure. The coal samples discussed herein represent 'pure' coal and do not include

associated roof, parting and floor samples that would ordinarily be mined with the seam as ROM coal. Carbonaceous roof, parting or floor samples are included in the ‘fresh, carbonaceous’ sample group, although these materials are likely to report to the CHPP as rejects.

The geochemical sampling locations are shown on **Figure 1** (site layout) and the number of drill-hole samples from each stratigraphic zone is shown on **Figure 2** (indicative stratigraphic column).

Coal Rejects Samples – representing process waste

Geochemical data is available (within the BHP Coal Geochemical Database) for 164 coal rejects samples collected from the CHPP. These samples are assumed to be representative of all coal processing waste generated at DNM, past, present and future.

4.3 Sample Characterisation

The aim of the environmental geochemical test-work is to understand the geochemical characteristics of the mineral waste materials with respect to AMD, geogenic salinity, erosion and dispersion potential; and to inform management and closure options for these materials.

A phased approach was implemented to define the geochemical behaviour of the key material types generated at DNM, as discussed below.

Solid Samples – Static Tests

Rejects and spoil samples have generally undergone similar test-work methods. Test-work was generally undertaken in stages, with most samples being subjected to ‘screening’ tests followed by more detailed test-work undertaken on selected samples.

The vast majority of the samples have undergone ‘screening’ tests (stage 1 tests) for:

- pH and electrical conductivity (EC) on 1:5 w:v water extracts (on pulps [85% passing 75 microns]);
- Net acid producing potential (NAPP) test, which comprises total sulphur (total S) and acid neutralising capacity (ANC) determination. The NAPP test provides the fundamental information about the theoretical maximum amount of acid-producing and acid-neutralising material that a sample could produce;

Based on the results of the screening tests, selected samples were subjected to some or all of the following tests:

- Total carbon (total C), and organic carbon (C-org) [tailings and rejects samples only].
- Total sulphate (SO₄);
- Sulphide (chromium reducible sulphur – Scr);
- Acid buffering characterisation curve (ABCC) - a test to determine the proportion of ANC that's in a readily-available form and to provide an indication of the carbonate mineralogy of the neutralising material;
- Net Acid Generation (NAG) [single addition] - a test that encourages the oxidation of a sample to determine if acid can be produced, and how much acid could be produced;
- Sequential net acid generation test (S-NAG) – a refinement of the single addition NAG test to resolve potential issues associated with incomplete oxidation of samples with high sulphide concentrations;
- Extended boil net acid generation test (NAG Extended) – a refinement of the NAG test to resolve uncertainty due to potential organic acid interference (where non-acid generating organic acids can provide false positive results in the NAG test);
- Total metals and metalloids by 4-acid (mixed) or 2-acid (aqua regia) digest with analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and/or Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Flow Injection Mercury System (FIMS);
- Quantitative x-ray diffraction (QXRD) – to determine the mineralogical composition;
- Short-term leaching tests, including:

- Deionised water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using de-ionised water, with filtered leachate analysed for:
 - Major and minor ions [calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), SO₄, chloride (Cl) and fluoride (F)];
 - Alkalinity [total alkalinity, bicarbonate (HCO₃) and carbonate (CO₃)] and Acidity (pH dependent);
 - Soluble metals and metalloids [approximately 28 elements by ICP-MS, ICP-AES and FIMS].
- Saline water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using saline water (2 g/L NaCl), with filtered leachate analysed for the soluble analytes listed above.
- Peroxide (NAG) leach – analysis of the solution on completion of the NAG or NAG Extended test, with filtered leachate analysed for the same (or similar) suite of soluble analytes as listed above.
- Exchangeable cations (Calcium [Ca], Magnesium [Mg], Sodium [Na], Potassium [K]) (with pre-treatment for salinity, if required). Results were used to calculate the cation exchange capacity (CEC);
- Emerson Aggregate Class testing.

For most samples, excluding some historical samples/data, laboratory test work was undertaken by ALS Environmental (ALS) Brisbane, using National Association of Testing Authorities (NATA) accredited methods (where such accreditation exists). Mineralogical analysis (QXRD) was undertaken by a university (research) mineralogical laboratory in Melbourne (via Earth Systems Consulting).

Solid Samples – Kinetic OxCon Tests

Oxygen consumption and carbon dioxide (CO₂) generation (OxCon) test-work was undertaken by Earth Systems (Melbourne) seven samples sourced from the Rangal Coal Measures. The sample were selected on the basis of earlier static test results.

OxCon is a laboratory-scale kinetic geochemical test for the estimation of sulphide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological materials.

Prior to the OxCon test the sample is 'washed' to remove any pre-existing salts and oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological minerals. Test-work then involves isolating a known mass of sulphide-bearing material in a known volume of oxygen inside a sealed vessel and allowing pyrite oxidation to proceed. Once the test is initiated, oxygen in the vessel is consumed via sulphide oxidation. Oxygen consumption is measured directly on an hourly basis and logged over the test-work period (1-8 weeks, depending upon the sample). Carbon dioxide generation is measured hourly and logged for estimation of the extent of acid neutralisation by carbonate minerals or the rate of biological organic carbon oxidation, if any, during testing.

At the conclusion of OxCon test, the solid undergoes a bottle leaching procedure at a 1:2 solid:water ratio and the leachate was analysed to determine the pH, acidity/alkalinity and concentration of soluble metals/metalloids and salts.

4.4 Geochemical Source Hazard Assessment

Geochemical data was assessed with regard to the samples potential to generate AMD. Only after making such an assessment to understand the potential AMD hazard can appropriate AMD specific management measures be formulated to adequately mitigate the risks, as required.

AMD Classification

The Acid-Base Account (ABA) method was used to assess the acid-neutralising and acid-generating characteristics of the samples in order to determine an acid (AD) classification for the mineral waste materials.

The maximum potential acidity (MPA) and acid neutralising capacity (ANC) represent each side of the acid-base account. MPA is calculated from total S and is the theoretical maximum potential acidity that can be generated if all of the S, assumed to be associated entirely with pyritic sulphide, is able to oxidise and generate acid (H₂SO₄). ANC represents the theoretical maximum amount of acid-neutralising capacity of a sample assuming all neutralising

material is in a readily available form. The net acid producing potential (NAPP) is the difference between the MPA and the ANC. In simple terms, a negative NAPP indicates an excess of ANC and the sample is likely to be non-acid forming (NAF) and a positive NAPP indicates an excess of MPA and the sample is likely to be potentially acid forming (PAF) – though there can be exceptions to this simplified interpretation. Note that NAF samples have the potential to generate NMD and SD, depending on the sulphur concentration.

Sample classification of mineral waste material follows some general rules. Samples were initially classified using Total S, NAPP and ANC/MPA ratio (and NAG data, where available), into three broad categories:

- **NAF** Non-acid Forming;
- **PAF** Potentially Acid Forming;
- **Uncertain** Those samples with inconclusive results, leading to a degree of uncertainty about their ability to generate acid

Where available, additional geochemical information such as Scr, ABCC, NAG extended and NAG sequential results were used to resolve acid classification uncertainties. The general approach was to build in a level of conservatism in the preliminary classification, as shown in **Table 2**.

Table 2. Preliminary AMD classification criteria

Preliminary classification	Sulphur %	NAPP kg poils ₄ /t	ANC/MPA ratio	NAGpH (if data available)
NAF	≤0.01	-	-	-
	≤ 1	< 0	≥ 2	-
	≤ 1	< 0	-	≥ 4.5
NAF-Sulphur (NAF-S)	> 1	< 0	≥ 2	-
	> 1	< 0	-	≥ 4.5
PAF – Low Capacity (PAF-LC)	≤ 1	≥ 0 and < 10	< 2	-
	-	≥ 0 and < 10	-	< 4.5
PAF	-	≥ 10	< 2	-
	-	≥ 10	-	< 4.5
Uncertain	Any result outside of the above criteria, or results that appear to significantly conflict with the expected result based on lithology or mineralogy			

Total S data was unavailable for 1 drill-core sample, which means that the MPA and NAPP cannot be calculated. This sample was classified using ANC and NAGpH data only, adopting a conservative classification as shown in **Table 3**.

Table 3. Preliminary AMD classification criteria for samples without total sulphur data

Preliminary classification	ANC kg H ₂ SO ₄ /t	NAGpH	NAG capacity kg H ₂ SO ₄ /t
NAF (weathered samples)	-	≥ 4.5	< 0.5
NAF (fresh samples)	≥ 10	≥ 4.5	< 0.5
Uncertain-NAF UC(NAF)	≥ 10	≥ 4.5 and < 7	< 0.5
	< 10	≥ 7	< 0.5
Uncertain-PAF UC(PAF)	< 10	≥ 4.5 and < 7	-
PAF	-	< 4.5	-

Sulphur Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific total S cut-off values were used to discuss sulphur data, as shown in **Table 5**.

Table 4. Sulphur category and associated cut-off

Sulphur category	Total S wt. %
Very low	< 0.1
Low	0.1 – 0.5
Low-moderate	0.5 – 1.0
Moderate	1.0 – 1.5
High	> 1.5

ANC Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific ANC cut-off values were used to discuss ANC data as shown in **Table 5**.

Table 5. ANC category and associated cut-off

ANC category	ANC kg H ₂ SO ₄ /t
Very low	< 5
Low	5 - 15
Moderate	15 - 30
High	30 - 50
Very high	> 50

Soil Salinity

The term 'soil' salinity (and 'soil' pH – refer below) is an industry-adopted term to refer to the salinity and pH measured on any solid geologic matrix, such as soil, spoil, rock, sediment, tailings, rejects, etc. That is, in this context, the term 'soil' applies to all solid samples, not just shallow surface (root zone) material.

Classifying whether a sample/material is non-saline, highly saline, or somewhere in between will depend upon the methods used to measure soil salinity. Soil salinity data is obtained from a 1:5 (w:v) [and 1:2 w:v] water extract

procedure typically on pulp samples (pulping the sample minimises the potential to underestimate salinity on sandy samples/materials). The soil salinity classes shown in **Table 6** are expressed in units of microSiemens per centimeter ($\mu\text{S}/\text{cm}$) and are based on a 1:5 w:v method. These soil salinity classes are used as an indicative guide. The classes are broadly based on soil salinity classes reported by DME (1995).

Table 6. Soil salinity classification

Soil salinity classification	EC1:5 $\mu\text{S}/\text{cm}$
Non-saline	< 450
Slightly saline	450 - 900
Moderately saline	900 - 2000
Saline	2000 - 4000
Strongly saline	> 4000

Soil pH type

Classifying whether a sample/material is acid, pH-neutral or alkaline or somewhere in between will depend upon the methods used to measure soil pH. Soil pH data is obtained from a 1:5 (w:v) water extract procedure typically on pulp samples. The soil pH types shown in **Table 7** are based on a 1:5 w:v method. These soil pH types are used as an indicative guide.

Table 7. Soil pH type and associated cut-off

Soil pH type	pH1:5
Highly acid	< 3.0
Moderately acid	3.0 – 4.5
Weakly acid	4.5 – 6.0
Near neutral	6.0 – 7.5
Alkaline	7.5 – 9.0
Highly alkaline	> 9.0

Mineralogy

Mineralogical data (QXRD) provides supporting information for the geochemical data, particularly with regard to sulphide and carbonate mineralogy of a sample, showing results for mineralogical forms (e.g. what sulphide or carbonate minerals are present) and their concentrations (reported in weight %). These data are also used to validate the results from ABCC test-work and assist with interpretation of the ABA data.

Element Enrichment

The total concentration for each element were compared to average element abundance in soil in the earth's crust (Bowen, 1979) to measure how the total elemental concentrations in the samples compare against average elemental concentrations in unmineralised soil (worldwide). Such a comparison is undertaken to identify samples that contain what may be regarded as 'elevated' concentrations of metals and metalloids to identify potential element of concern. However, enrichment in any metals/metalloids in the solids, does not translate to enhanced leachability or mobilization and/or bioavailability of that specific element.

From the comparison with average crustal abundance in rocks a geochemical abundance index (GAI) was calculated. The GAI quantifies an assay result for a particular element in terms of the average abundance for that element (in sedimentary rocks). The index, based on a log 2 scale, is expressed in seven integer increments (0 to 6), which correspond to enrichment factors from 0 to over 96 times average crustal abundance, as shown in **Table 8**.

Table 8. Geochemical abundance index (GAI)

GAI	Enrichment factor	GAI	Enrichment factor
0	Less than 3-fold enrichment	4	24 to 48-fold enrichment
1	3 to 6-fold enrichment	5	48 to 96-fold enrichment
2	6 to 12-fold enrichment	6	Greater than 96-fold enrichment
3	12 to 24-fold enrichment		

As a general rule, a GAI greater than or equal to three indicates enrichment compared to unmineralised soil that may warrant further investigation to assess their mobility under laboratory conditions.

Elements identified as enriched may not necessarily be a concern for revegetation and rehabilitation, human and animal health or drainage water quality. Similarly, if an element is not enriched it does not mean it would not be mobilised, because under some conditions (e.g. low pH, reducing conditions) the geochemical behavior of metals/metalloids such as Al, As, Cu, Cd and Zn can change (i.e. become less or more mobile).

Solubility

Metal/metalloid mobility from samples has been assessed using deionised water, saline water and peroxide (NAG) leaching methods. The deionised water and saline water leaches assess the initial solubility under fresh water and saline water conditions, whereas the peroxide water leach assesses the solubility after the samples have been oxidised. The objective of the saline leaching procedure is to mimic the brackish to moderately saline water commonly used in CHPP to process ROM coal.

The solubility data from bottle leaching provides an indication of likely solubility/release of salt and metals/metalloids under field pH and redox (oxidation) conditions (and/or saline or low-pH conditions, where applicable). Peroxide (NAG) leachate data provides an indication of potential acidity and concentrations of metals and metalloids that could be released from samples that are fully and rapidly oxidized. This test provides an assumed 'worst case' scenario in term of metal/metalloid mobility. Solubility data from OxCon testing provides an indication of likely solubility/release of salt and metals/metalloids when the samples are oxidised and can be used to estimate release rates.

To ensure a consistent approach to describe the samples geochemical characteristics, specific concentration cut-off values were used to discuss leachate composition as shown in **Table 9**.

Table 9. Soluble trace element concentration category and associated cut-off

Classification	Trace element soluble concentration mg/L
Close to detection	≤ 0.001
Very low	> 0.001 – 0.05
Low	> 0.05 – 0.1
Moderate	> 0.1 – 1.0
High	> 1.0 – 10
Very high	> 10

A classification scheme initially developed by Ficklin *et al.* (1992) has been adapted to summarise major attributes of the solubility data by plotting pH against soluble metal and metalloid concentrations for groups of elements, with the classification scheme shown in **Figure 7**. The soluble metal and metalloid concentrations are shown as the sum of soluble metal concentrations for base metals (Cd + Co + Cu + Ni + Pb + Zn) and/or the sum of soluble As + Mn + Mo + Se. These two groups of elements are chosen because they remain in solution across a wide range of pH and are not only associated with AD conditions, but also with NMD/SD conditions.

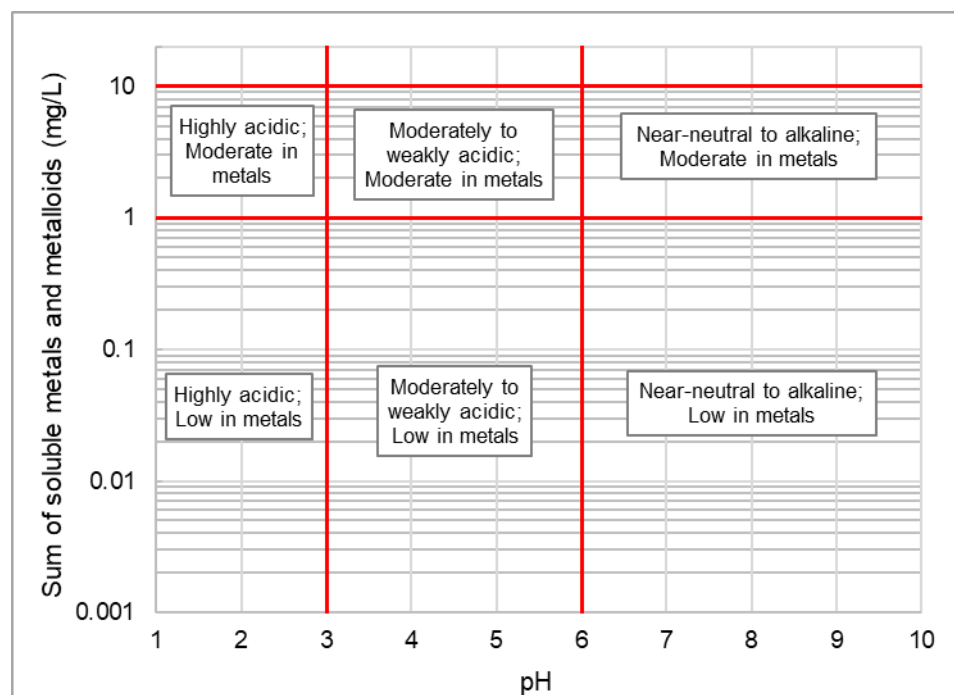


Figure 7. Classification of soluble metals and metalloids as a function of pH

No comparison is made between leachate results and water quality guideline values, such as ANZG (2018), as such a comparison is inappropriate. The guideline values provided in ANZG (2018) are for receiving water environments (e.g. creeks), whereas the soluble element data in this assessment is 'point source' obtained from a finely pulped sample subjected to rigorous and artificial extraction to obtain a concentration approaching 'near maximum'. Furthermore, contact water will undergo a number of geochemical reactions along a pathway from source to receptor, including: retardation, adsorption and precipitation – and also likely dilution, which will attenuate the concentration as seepage/contact water migrates from the source. These processes are not accounted for in a laboratory setting.

Sodicity and Dispersion

Potential spoil samples (representing material that is likely to report to final landform surface) are broadly classified with respect to sodicity on the basis of the exchangeable sodium percentage (ESP) value, as shown in **Table 10** (after Northcote and Skene, 1972; Isbell, 2002):

Table 10. Sodicity classification

Sodicity classification	ESP %
Non-sodic	≤ 6
Sodic	6 – 14
Strongly sodic	> 14

The sodicity will depend upon a range of factors, such as clay mineralogy, soil sodium concentration, soil salinity and irrigation water (rainwater) chemistry, which may enhance or limit that potential for soil to be sodic or become sodic over time. Therefore, values of 6% ESP and 14% ESP to represent soils as being sodic or strongly sodic are used as a general guide only and should not be taken as definitive. Sodicity assessments only apply to materials likely to report to final landform surfaces, such as spoil (i.e. not coal rejects or waste coal).

Sodicity information is broadly used to understand potential revegetation and dispersion aspects, and is supported by Emerson Aggregate Class test information, which provides a direct measure of soil slaking and dispersion based on the Standards Australia (2017) classification. Soils are divided into classes on the basis of their coherence in water and presence (or absence) of calcium-rich minerals (**Table 11**).

Slaking occurs when dry soil crumbs, after being immersed in deionised water, break up and run along the bottom of the beaker into a flat pile. Most dry soil crumbs slake when immersed in deionised water. Dispersion describes the tendency for the clay fraction of a soil to go into colloidal suspension in deionised water. Materials are generally regarded as being dispersive (or prone to dispersion) if they have an Emerson Class number of three or less.

Table 11. Emerson classifications

Class	Description	Class	Description
1	Slaking and complete dispersion	5	No calcite or gypsum present; dispersion
2	Slaking and some dispersion	6	No calcite or gypsum present; flocculation
3	Dispersion [remoulded]	7	Non-slaking and swelling
4	Calcite or gypsum present; dispersion	8	Non-slaking and non-swelling

4.4.1 Using Coal Quality Data for AMD Classification

Coal quality data has been used to aid in the assessment of the AMD hazard associated with coal seams. In particular, the BHP coal quality database was used to supplement the geochemical database and provide additional understanding of the AMD potential of potential coal (i.e. ROM coal, remnant coal, waste coal) and rejects. Coal plys were grouped into their respective seam groups on a per-pit basis, such as Leichhardt seam group and Upper Vermont seam group for DNM.

Total S concentrations can be used conservatively to assess the AMD hazard for any given sample; thus, statistical analyses were conducted on total S as a function of seam group and for all seams combined to define the AMD hazard of coal.

The data was used to understand the sulphur grade range for each seam group to gain an understanding of the potential AMD hazard posed by each coal seam group (and by inference, potential rejects materials). The results were then compared with detailed geochemical data available for coal and rejects to 'calibrate' the coal quality total sulphur data.

Coal samples from less than 20m depth were assumed to be completely or predominantly oxidised and were assigned as 'weathered carbonaceous spoil' and, therefore, excluded from the assessment of potential ROM coal. For context, of the 26,798 m of drill-hole data available from the coal quality database, approximately 58m were assigned as 'weathered coal'. Acid producing sulphate minerals, such as jarosite, may be present within the weathered coal and carbonaceous material, however, mineralogical data available from DNM suggests that jarosite is likely an insignificant mineral.

4.4.2 Residual Void Highwall Assessment

An assessment of the AMD hazard associated with all lithological materials, such as remnant coal, weathered materials, fresh non-carbonaceous and carbonaceous overburden expected to be exposed on the residual void highwall was undertaken.

The frequency of occurrence of relevant material types within each pit was determined from the stratigraphic distribution within selected drill holes under the assumption that the frequency of distribution of each material type is broadly indicative of their respective surface exposures on current highwalls. For example, if Leichhardt seam group had a frequency of occurrence of 5% in the drill-hole data set, then the assumption is that the same coal seam group would represent approximately 5% of the surface exposure on the highwall. This method – whilst being relatively simple – provides an acceptable approximation with regard to which seam groups or mineral waste types are most likely to be significantly present in pit walls versus those material types present in relatively minor proportions.

The following method was used for estimating the proportion of key material domains on the highwalls in each pit:

Exploration drill-holes in proximity to the current/recent highwall/s were selected by BHP Coal Geology Planners for each pit. The holes extended to depths approximating future pit floor depths. Titan North/Central void used data from 146 drillholes, Titan East void used data from 97 drillholes and Pandora void used data from 59 drillholes.

Stratigraphy, age, weathering, location with respect to the water table, and major stratigraphic horizons (as recorded in the BHP coal geology database) were used to assign individual (discrete) lithological units to a material domain as follows:

- Weathered, non-carbonaceous (Tertiary);
- Weathered, non-carbonaceous (Permian);
- Weathered, carbonaceous [includes weathered coal] (Permian);
- Fresh, non-carbonaceous;
- Fresh, carbonaceous;
- Fresh, coal.

Coal plys were grouped into their respective seam groups, such as Leichhardt seam group, Vermont seam group etc.

For each pit highwall, a statistical assessment was conducted on each drill-hole sub-set (as applicable to each pit) to summarise the frequency of occurrence of drill core intervals as a function of each of the material groups listed above.

The inherent AMD hazard of each material group listed above was inferred from the environmental geochemical database and coal quality database for similar material types. The combined AMD hazard for the material groups likely to be exposed on the highwall was then used to estimate the AMD hazard of the highwall at each pit.

In addition, the DNM coal resource model was used to estimate coal resources and overburden/interburden proportions for the locations of the highwall expected at closure. Note that some current pits will be backfilled as mining progresses – therefore the pit highwall assessment has only been undertaken on those pits that remain as residual voids at closure. The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of all residual voids is consistent with the proportions estimated for the current pit highwalls. The model also shows that the proportion of each seam group exposed on the residual voids highwall is similar to the seam group proportions estimated for the current pit highwalls for all three pits. As such, the proportions of the various mineral waste types on the residual voids highwall (and floor for all pits) will not change significantly from those shown.

Therefore, the overall AMD hazard posed by the pit highwall and floor of the residual voids at end of mining is expected to be similar to that shown in the current highwalls and pits.

4.4.3 Residual Void Floor Assessment

An assessment of the AMD hazard associated with exposures of remnant coal on the pit floor was undertaken.

As explained in **Section 4.4.1** coal quality data was assessed to understand the potential AMD hazard associated with coal. For the task of assessing the AMD hazard specific to pit floors (on a per pit basis), only the coal quality data from the seam group likely to form the pit floors at a given pit was assessed. At DNM, the base of mineable

coal is the V3 ply (base of the Vermont Upper V2/3 seam group) and therefore forms the floor of residual voids (**Figure 2**).

It is acknowledged that there are generally minor geochemical differences between the various plys of any given seam group. Also, the AMD hazard of the floor of a pit may change depending on whether a significant proportion of the pit floor resides on coal(ly) or non-carbonaceous material. Furthermore, the AMD hazard of any pit floor is not just associated with its surface exposure, but more so with the composition of the sub-drill zone, which represents an extensively fractured coal / interburden comprising the upper sections of a pit floor. For this assessment, the AMD hazard was estimated only for assumed surface exposures of coal / plys.

4.4.4 AMD Hazard Scoring

Estimating the AMD hazard is the first step in estimating the geochemical risk associated with potential sulphide oxidation of mineral wastes. The authors have developed an internal procedure to standardise the AMD hazard assessment to maintain consistency across all BHP coal sites and material domains, with the process described below.

AMD hazard scoring and the AMD geochemical likelihood ranking describe the Geochemical Hazard. The former describes the hazard for AMD generation and the latter describes the likelihood of an AMD event to occur.

A source material is a distinct material type (e.g. non-carbonaceous spoil or rejects), whereas a landform is a domain comprising one or more source material types (e.g. rejects disposed within non-carbonaceous and carbonaceous spoil). AMD hazard scorings are assigned using individual source materials reporting to a landform as well as to landform domain properties as a whole.

The likelihood of a landform developing AMD was determined based on the AMD hazard scoring of a landform. AMD hazard scores (**terial types** for each landform.

Table 12) are estimated by analysing three key components, which are used to describe the geochemical hazard of a source material/landform:

1. Geochemical propensity to generate AMD;
2. AMD capacity; and
3. AMD quantity.

In undertaking the AMD hazard assessment, the assumption is that the source materials (within the landforms) will predominantly be dry or moist, but not wet or saturated. That is, the landforms will be unsaturated. This assumption is realistic, since most spoil landforms are generally unsaturated. This assumption is also conservative, since the potential for oxidation (to some degree) is assumed.

AMD Propensity is the geochemical propensity of a given material type to generate AMD. The propensity to generate AMD is determined based on the proportion of samples that have expressed potential for AMD as determined from laboratory test-work and the subsequent assessment – the higher the percentage of materials that can generate AMD within a sample set, the greater the AMD propensity.

AMD Capacity represents the 'severity' of AMD generation, with total S concentrations used as a proxy for scoring this component, which represents a conservative approach as some sulphur is associated with non-acid generating minerals. For example, the higher the total S concentration in materials with potential for AMD, the higher the hazard, the higher the score. Furthermore, the AMD capacity also takes into account the type of drainage a source material can produce, i.e. AD, NMD and/or SD, where discrimination or prediction is possible. The various drainage types should be differentiated (where the data allows) to reflect the difference in impact severity and difficulty to manage or treat. For example, on an equal quantity basis, AD is likely going to cause more severe impacts than NMD or SD and therefore is assigned a higher score.

As a first approximation, the AMD Capacity of each material type is estimated based on 75th percentile value of the total S concentration for the samples classified as PAF. This is a conservative assumption, as not all total S is associated with reactive minerals and choosing the S-75th percentile value to assess the AMD capacity will attract a higher AMD Capacity scoring. For example, if two material types had the same proportion of samples with the same propensity for AMD, but one has a higher total S concentration associated with PAF materials, then this sample would receive a higher AMD Capacity score. The tool is also applied to NMD/SD type waste in the same manner.

AMD Quantity is the amount of material (tonnages) that has the potential to generate AMD. The greater the tonnage of AMD generating material the greater the hazard scoring. The AMD Quantity scores are assigned to material types for each landform.

Table 12. AMD hazard scoring matrix

Component	Rating	Category	Definition
Propensity for AMD generation All material types/domains - Non-carbonaceous - Coaly & carbonaceous - Rejects Per spoil landform	1	Implausible	Geochemical properties suggest that the vast majority of the material has a negligible potential for AMD generation (less than 5% of the samples identified at potential for AMD in the samples set)
	5	Plausible	Geochemical properties suggest that significant proportion of the material may have potential for AMD generation (5-40% of the samples identified at potential for AMD in the samples set)
	7	Expected	Geochemical properties strongly suggest that the material has a high potential for AMD generation but has not yet been observed in the field (due to lag time) - (>40% of the samples identified at potential for AMD in the samples set)
	15	Certain	AMD issues have been observed in the field
AMD Capacity All material types/domains - Non-carbonaceous - Coaly & carbonaceous - Rejects Per spoil landform	1	Low	Source has a negligible potential for AMD generation with 75 th percentile total S less than 0.1%
	3	Moderate-Low (NMD)	Dominant AMD sources contain material that will likely generate NMD and/or SD (related to sulphide oxidation). Assumed to be bulk NAF but sulphide bearing, with NAF samples having 75 th percentile total S greater than 1%
	5	Moderate	Dominant AMD sources with 75 th percentile total S concentration ranging 0.2-0.5% and with potential to generate AD.
	7	Moderate-High	Dominant AMD sources with 75 th percentile total S ranging 0.5-1% and with potential to generate AD.
	10	High	Dominant potential AMD sources with 75 th percentile total S >1% and with potential to generate AD.
AMD Quantity All material types/domains: - Non-carbonaceous - Coaly & carbonaceous - Rejects Per spoil landform	1	Low	All material rated LOW for AMD capacity; or less than 5% of waste is rated MODERATE-LOW for AMD Capacity
	3	Moderate-Low	Less than 5% of mineral waste rated as MODERATE for AMD capacity
	5	Moderate	Greater than 5% of mineral waste rated as MODERATE or MODERATE-LOW for AMD capacity
	7	Moderate-High	Less than 5% of mineral waste rated as MODERATE-HIGH or HIGH for AMD capacity
	10	High	Greater than 5% of mineral waste rated as MODERATE-HIGH or HIGH for AMD capacity
AMD Quantity Residual void (pit) highwall & floor Per residual void	1	Low	Less than 10% of drill-hole meters (or less than 10% of pit floor exposure) are classified as PAF
	3	Moderate-Low	Between 10% and 30% of drill-hole meters (or 10-30% of pit floor exposure) are classified as PAF
	7	Moderate-High	Greater than 30% of drill-hole meters (or greater than 30% of pit floor exposure) are classified as PAF
	10	High	Observed AMD on highwall or pit floor or AMD affected water in pit

4.4.5 AMD Likelihood Ranking

The AMD likelihood ranking is correlated to the AMD hazard scoring ranking. The AMD hazard ranking is estimated by analysing two key components:

1. AMD source material hazard rating; and
2. AMD landform domain hazard rating.

AMD source material hazard rating: It is used to describe the likelihood for AMD generation by the respective material type. It is estimated from the weighted combined scores of each component used to describe the AMD source hazard:

- Propensity to generate AMD. Assigned a 50% weighting (weighting = 1);
- AMD capacity. Assigned a 25% weighting (weighting = 0.5); and
- AMD quantity. Assigned a 25% weighting (weighting = 0.5)

AMD landform domain hazard rating: It is used to describe the likelihood for AMD generation by landform domain. It is estimated from the AMD source material hazard scores for each material type assumed to be present within that specific landform. At closure, DNM has three residual void domains, which will form a single spoil landform as outlined in **Section 2.2**.

- **Spoil landform:** the AMD landform score estimated using the weighted average of the AMD source material scores and the PAF and NAF-S quantities (as a proportion of total waste within the landform) likely to report to the landform from each material type. Note that only one sample (out of 1046 samples in total) was classified as NAF-S. As such, the proportion of NAF-S samples in spoil dumps is insignificant relative to PAF samples and other NAF samples.
- **Residual voids:** the AMD landform score estimated from the average of the AMD source material hazard scores for each material type likely to be exposed on the highwalls or floor of each residual void.

The AMD hazard scores as determined in **Section 4.4.4** are assigned likelihood rankings (**Table 13**) as consistent as possible with BHP Risk Management Methodology, which is aligned with ISO 31000. ISO 31000 is a family of standards relating to risk management codified by the International Organization for Standardization.

Table 13. AMD hazard ranking and landform AMD likelihood ranking

AMD hazard ranking	Landform AMD likelihood ranking
0 - 5	Highly Unlikely: Highly unusual; may occur in extreme circumstances
5 - 10	Unlikely: Known to occur, but only rarely
10 - 15	Probable: May occur
15 - 20	Likely: Could easily occur
>20	Highly Likely: Expected to occur

For landforms domains (including voids) with AMD hazard ranking greater than 10, a conservative likelihood ranking of 'Likely' should initially be assigned, if no kinetic data are available to provide a time frame for AMD generation. This likelihood ranking can be revised as more data becomes available, such as kinetic or field data becomes available.

5 Results

Environmental geochemical data (e.g., NAF, PAF, or a sub-classification) is available for 849 samples (that comprises of 609 spoil, 164 rejects and 77 coal samples). The samples are representative of the following mineral waste and coal groups:

Spoil

- Weathered Non-carbonaceous.: Weathered non-carbonaceous overburden. 136 drill-hole samples;
- Weathered Carbonaceous: Weathered carbonaceous overburden [includes weathered coal]. 11 drill-hole samples;
- Fresh, Non-carbonaceous.: Fresh non-carbonaceous overburden/interburden. 369 drill-hole samples;
- Fresh, Carbonaceous: Fresh carbonaceous overburden/interburden. 93 drill-hole samples;

Coal

- Fresh Coal: Fresh coal, representative of ROM coal. 77 drill-hole samples

Rejects

- Rejects: Coal rejects (primarily CHPP samples). 164 samples.

Coal rejects are disposed into spoil and comprises approximately 1.5% of all mineral waste at DNM, with overburden/interburden comprising the dominant 98.5% of mineral waste (**Section 2.2.1**). The environmental geochemical and mineralogical test-work results for all samples are presented around the material groups listed above, as defined in **Section 4.2**.

5.1 Mineralogy

Data is available for 10 potential spoil samples and 8 rejects samples that underwent mineralogical analysis by Quantitative X-Ray Diffraction (QXRD).

The spoil samples were selected to cover a broad range of spoil types – weathered (3 samples), fresh, carbonaceous (2 samples) and fresh non-carbonaceous (5 samples). The results, summarised in **Figure 8**, show that most samples are dominated by silicate group minerals – predominantly quartz and clay minerals, with variable contributions of other silicate minerals and carbonate.

Amorphous (non-crystalline) material was detected in all samples – with a wide range of concentration from 0.2% to 54.3% - but generally present in greater proportions in the rejects and carbonaceous spoil samples compared to the non-carbonaceous samples. The nature of the non-crystalline material is largely unknown, although for rejects and carbonaceous waste it may be associated with organic carbon.

All samples have low sulphide mineral proportions, with the highest concentrations being in the reject samples. Sulphide is present mostly as pyrite with minor marcasite (marcasite is another form of FeS_2 , similar to pyrite). All samples have low (negligible) sulphate concentrations.

Carbonate group minerals predominantly comprise ankerite (Fe-dolomite), calcite and siderite in variable proportions. ABCC data for these samples indicated that iron-dolomite, dolomite and siderite were the likely dominant carbonate minerals, which is broadly consistent with the mineralogy data.

Water quality data is available for liquor (supernatant) associated with rejects production (with the liquor recycled back into the CHPP). The data shows that liquor generally has a low alkalinity, therefore water from the CHPP is not likely to be a significant contributor to the carbonate present in rejects from the CHPP.

In summary the key acid generating mineral is pyrite (+/- marcasite), and the key acid neutralising minerals are iron-dolomite, dolomite and calcite. Although siderite is a carbonate, it provides no net acid neutralising capacity.

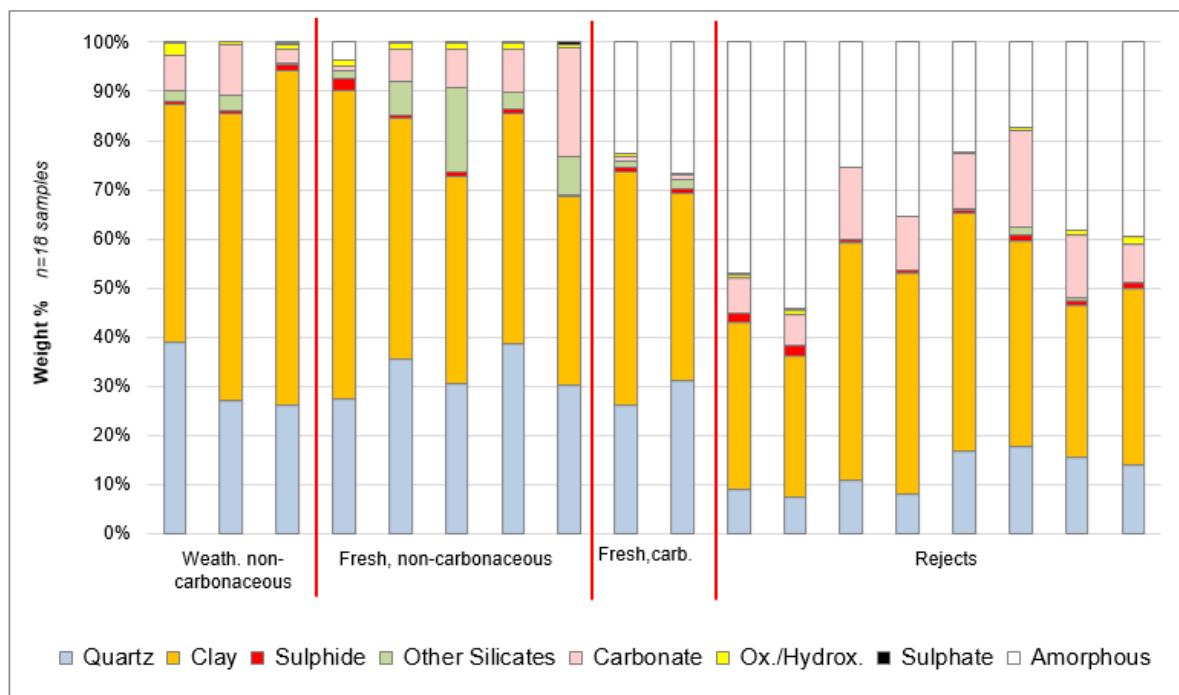


Figure 8. Mineral distribution within spoil and rejects samples

5.2 Acid-Base Accounting (Potential for AMD)

Acid-base accounting (ABA) is a theoretical balance between the potential for a sample to generate acid and neutralise acid, and is expressed in units of kilograms of sulphuric acid per tonne of sample (kg H₂SO₄/t). The ABA results for the samples that underwent geochemical characterisation are statistically summarised in **Table 15** (spoil) and **Table 14** (coal and rejects) and discussed in the following sections. Full results can be provided on request.

Table 14. ABA results statistics for spoil materials

		Total S ¹	Scr ² (s)	ANC	MPA ³	NAPP	ANC/MPA	NAGpH ⁴
		%		kg H ₂ SO ₄ /t			ratio	pH units
Potential Spoil Weathered, non- carbonaceous.	Count (n)	138	3	136	138	136	136	1
	Maximum	0.42	0.10	225	13	0	1469	8
	95 th Percentile	0.03	0.09	124	0.9	-5.5	583	-
	75 th Percentile (Q3)	0.01	0.06	57	0	-10	234	-
	Median (Q2)	0.01	0.01	22	0	-22	101	-
	25 th Percentile (Q1)	0.01	0.01	10	0.2	-57	46	-
	5 th Percentile	<0.01	0.01	5.7	0.2	-124	10.6	-
	Minimum	<0.01	0.01	0.3	0.2	-225	1.6	8
Potential Spoil Weathered, carbonaceous.	Count (n)	11	5	11	11	11	11	1
	Maximum	0.20	0.10	30	6	-3.0	20	5.1
	95 th Percentile	0.18	0.09	27	5	-3.0	20	-
	75 th Percentile (Q3)	0.09	0.03	13	3	-4.0	15	-
	Median (Q2)	0.07	0.01	10	2	-6.0	11	-
	25 th Percentile (Q1)	0.01	0.01	5.7	0.3	-10	3.7	-
	5 th Percentile	0.01	0.01	3.7	0.3	-24	2.5	-
	Minimum	0.01	0.01	3.4	0.3	-28	1.6	5.1
Potential Spoil Fresh, non- carbonaceous.	Count (n)	391	59	369	391	369	369	13
	Maximum	0.76	0.73	490	23	19	3200	9.3
	95 th Percentile	0.11	0.18	135	3.4	-6.9	431	9.0
	75 th Percentile (Q3)	0.04	0.08	63	1	-18	122	8
	Median (Q2)	0.02	0.04	32	1	-32	53	7
	25 th Percentile (Q1)	0.01	0.01	19	0.3	-62	22	5.8
	5 th Percentile	<0.01	0.01	8.8	0.2	-134	5.3	2.6
	Minimum	<0.01	0.01	0.3	0.2	-490	0.1	2.5
Potential Spoil Fresh, carbonaceous.	Count (n)	92	29	93	92	93	93	14
	Maximum	0.91	0.87	66	28	15	82	9.7
	95 th Percentile	0.24	0.28	38	7	0	41	9.3
	75 th Percentile (Q3)	0.11	0.11	18	3	-5	18	7
	Median (Q2)	0.04	0.07	13	1	-10	8	6
	25 th Percentile (Q1)	0.03	0.04	8.1	0.8	-16	3.1	4.2
	5 th Percentile	0.016	0.02	2.6	0.5	-37	0.9	2.8
	Minimum	0.01	0.01	<0.1	0.2	-62	0.1	2.3
All Potential Spoil	Count (n)	633	96(96)	609	632	609	609	29
	Maximum	0.91	0.87(0.91)	490	28	19	3200	9.70
	95 th Percentile	0.14	0.19(0.34)	119.60	4.29	-3.37	469.36	9.22
	75 th Percentile (Q3)	0.04	0.09(0.15)	54.90	1.23	--11.87	123.51	7.80

		Total S ¹	Scr ² (s)	ANC	MPA ³	NAPP	ANC/MPA	NAGpH ⁴
		%		kg H ₂ SO ₄ /t			ratio	pH units
	Median (Q2)	0.02	0.04(0.11)	24.30	0.61	-23.69	44.41	6.60
	25 th Percentile (Q1)	0.01	0.02(0.06)	13.40	0.31	-53.93	16.73	4.70
	5 th Percentile	<0.01	0.01(0.04)	5.48	0.2	-120	2.86	2.54
	Minimum	<0.01	0.01(0.04)	<0.1	0.2	-490	0.1	2.30

¹ Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.

² Scr was generally measured on potential spoil and coal samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results. Scr values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.

³ MPA calculated from total S.

⁴ NAGpH is final pH as NAG single addition and/or NAG extended

Table 15. ABA results statistics for coal and rejects materials

		Total S ¹	Scr ² (s)	ANC	MPA ³	NAPP	ANC/MPA	NAGpH ⁴
		%		kg H ₂ SO ₄ /t			ratio	pH units
Coal	Count (n)	77	76	78	77	77	77	1
	Maximum	2.21	1.80	114	68	66	27	2.4
	95 th Percentile	0.52	0.26	54	16	14	10	2.4
	75 th Percentile (Q3)	0.29	0.11	14	9	5	2	2
	Median (Q2)	0.24	0.06	9	7	-2	1	2
	25 th Percentile (Q1)	0.18	0.03	2.9	5.5	-6.6	0.3	2.4
	5 th Percentile	0.118	0.02	0.3	3.6	-48	0.0	2.4
	Minimum	0.04	0.01	0.2	1.2	-110	0.0	2.4
Rejects	Count (n)	164	137	164	164	164	164	155
	Maximum	1.59	1.34	222	49	17	33.3	10.6
	95 th Percentile	0.97	0.71	132	30	0	13.9	9.8
	75 th Percentile (Q3)	0.64	0.44	72	20	-19	6	9
	Median (Q2)	0.51	0.33	52	15	-34	4	8
	25 th Percentile (Q1)	0.34	0.22	36	10	-57.9	2.1	7.8
	5 th Percentile	0.16	0.08	16.6	5	-114	1.0	3.7
	Minimum	0.12	0.02	10.0	3.7	-206	0.4	2.5

¹ Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.

² Scr was generally measured on potential spoil and coal samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results.

³ MPA calculated from total S.

⁴ NAGpH is final pH as NAG single addition and/or NAG extended

Sulphur and Sulphide

The total sulphur (total S) concentration of spoil samples was generally very low to low – with a very low median value of 0.02% and low 95th percentile value of 0.14% (**Figure 9**). The total S distribution in rejects samples was higher than potential spoil samples and ranged from 0.12% to 1.59%, with a low-moderate median value of 0.51% and a low-moderate 95th percentile value of 0.97% (**Figure 9**).

Coal samples had relatively low total S values, with median and 95th percentile values of 0.24% and 0.52%, respectively. For comparison, total S data is available within the BHP coal quality database for 1499 coal (seam) samples from DNM, had median and 90th percentile total S values of 0.39% and 0.53%, respectively. The total S

distribution in coal from the smaller geochemical dataset (n=112) is comparable to the total S distribution in coal from the much larger coal quality dataset (n=1499).

As evident in **Figure 9**, the total S concentrations were higher in the coaly and carbonaceous materials compared to the non-carbonaceous materials, however were still generally low.

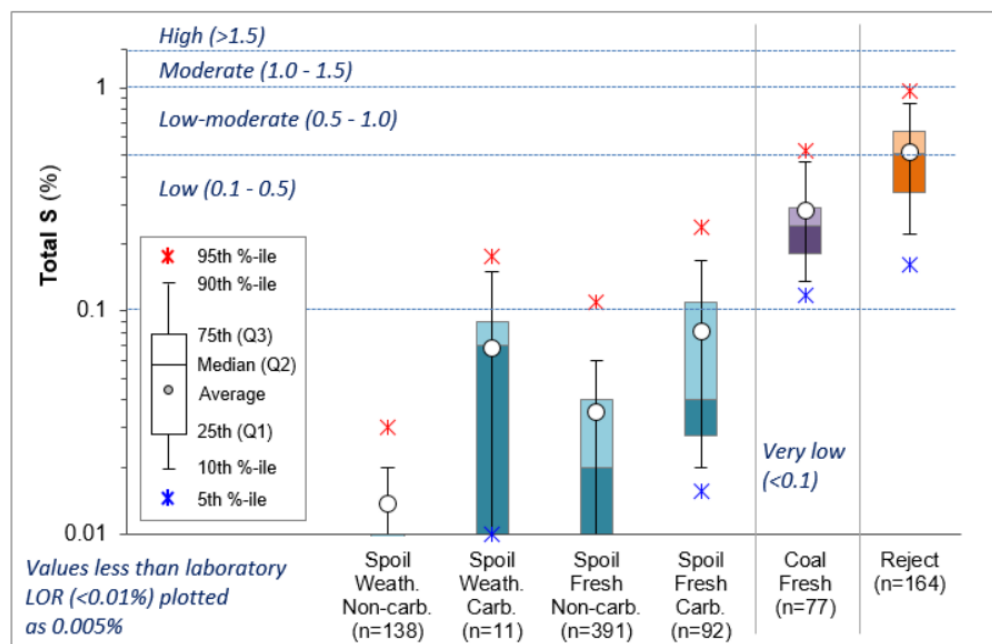


Figure 9. Sulphur (S) distribution [all samples]

Chromium reducible sulphur (Scr) data is available for 309 samples (96 potential spoil samples, 76 coal samples and 137 rejects samples). For the spoil and coal samples, Scr was generally measured on samples with total S values greater than 0.1%, therefore the Scr distribution is skewed slightly higher for spoil and coal samples generally. Where sulphide was measured in weathered samples, this was generally only in those samples described as being 'slightly' weathered.

For the rejects samples, Scr data is available for about 84% of the samples, but selection for Scr analysis was not based on total S.

The total S and Scr distribution is shown at **Figure 10**. Scr values in most samples were generally low – consistent with the generally low total S values, with median and 95th percentile values of 0.13% and 0.69%, respectively.

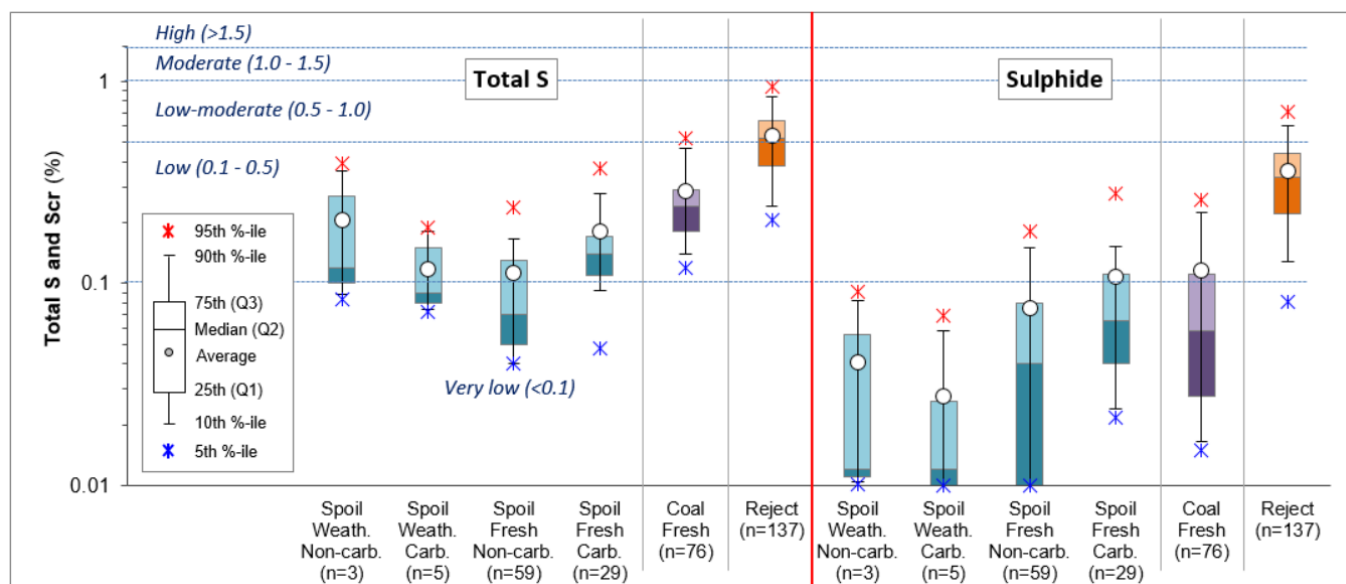


Figure 10. Sulphur (S) and sulphide (Scr) distribution [for samples where Scr data is available]

As a proportion of total S, Scr accounts for 64% (median value) of total S in rejects samples; 53% in non-carbonaceous spoil samples; 51% in carbonaceous spoil samples and 29% in coal samples. This means that the proportion of acid generating sulphur is generally highest in rejects samples and lowest in coal samples – the lower Scr proportions in coal samples is likely due to coal containing a greater proportion of organic sulphur. These results indicate that the maximum potential acidity (MPA) that could be generated by all material domains is generally very low and that using total S as an indication of AMD hazard will result in a conservative outcome. The relationship between Scr and total S (for samples where Scr data is available) is shown in **Figure 11**.

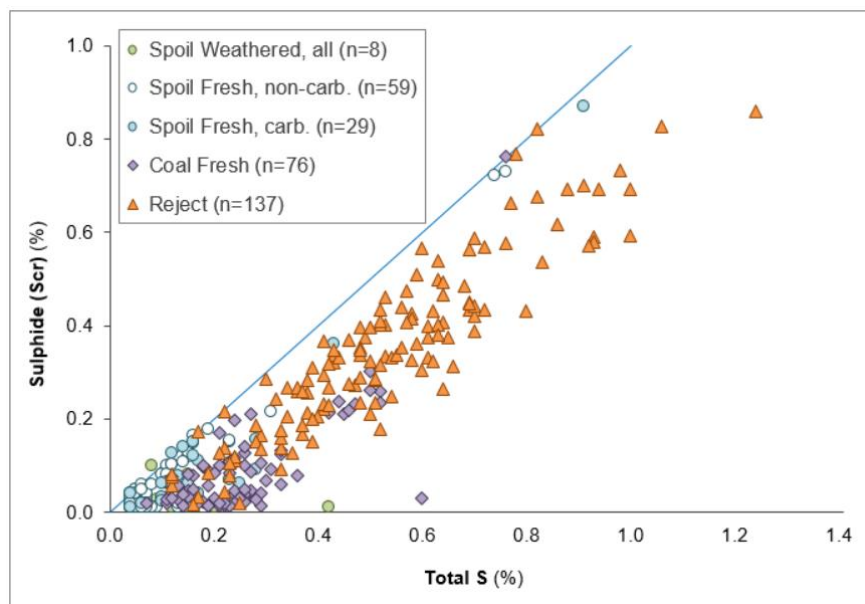


Figure 11. Sulphide (Scr) versus sulphur (S) [for samples where Scr data is available]

Maximum Potential Acidity

MPA is calculated from total S, therefore the MPA distribution for each material type mimics the total S distribution for the same samples (refer to **Figure 9**). Due to the generally very low to low total S (and Scr) values for carbonaceous and non-carbonaceous samples (representing spoil), the MPA for these samples – was correspondingly low, with a 95th percentile MPA of 4.29 kg H₂SO₄/t. As such, spoil – represented by these samples

– is expected to have negligible potential to generate acid/acidity and negligible potential to release sulphate-derived salinity from sulphide oxidation.

Rejects samples had higher total S and Scr values compared to potential spoil samples – and produced correspondingly higher MPA values (MPA calculated from total S), with median and 95th percentile MPA values of 15 and 30 kg H₂SO₄/t, respectively.

Coal samples produced MPA values somewhere between the MPA of spoil and rejects samples, with relatively low median and 95th percentile values of 7 and 16 kg H₂SO₄/t, respectively. As discussed above, the proportion of total S associated with sulphide minerals is low, with most sulphur in caoly samples likely associated with organic sulphur. Therefore, MPA values calculated from total S for coal samples is very conservative. For comparison, the 95th percentile MPA value for coal samples (n=77) calculated from Scr is 7.94 kg H₂SO₄/t – i.e. about half of the 95th percentile MPA value calculated from total S.

Acid Neutralising Capacity

The ANC distribution for all samples is presented in **Figure 12**. The ANC values of spoil samples are typically well in excess of the MPA values and span a very large range, from less than 0.1 to 490 kg H₂SO₄/t, with a moderate median ANC value for spoil samples of 24.6 kg H₂SO₄/t and a 10th percentile value of 8 kg H₂SO₄/t, respectively. In other words, 90% of spoil samples have an ANC greater than 8 kg H₂SO₄/t which, if all ANC was readily available, would neutralise the acidity generated by material containing 0.26 wt% S.

The ANC for the rejects samples (n=164) was generally moderate to very high, ranging from 10 to 222 kg H₂SO₄/t, with high median and moderate 10th percentile values of 52 and 22.3 kg H₂SO₄/t, respectively. Coal samples had ANC values generally lower than rejects samples, with a low median and very low 10th percentile ANC values of 9 and 0.3 kg H₂SO₄/t, respectively.

As evident in **Figure 12**, the weathered carbonaceous samples (n=11), which comprises a very small proportion of mineral waste [and coal, which is generally not waste as it reports to ROM], have the lowest median ANC values and the fresh non-carbonaceous samples (n=369), which is the dominant spoil type, has the second highest median ANC values, with rejects being the material type with the highest ANC (n=164).

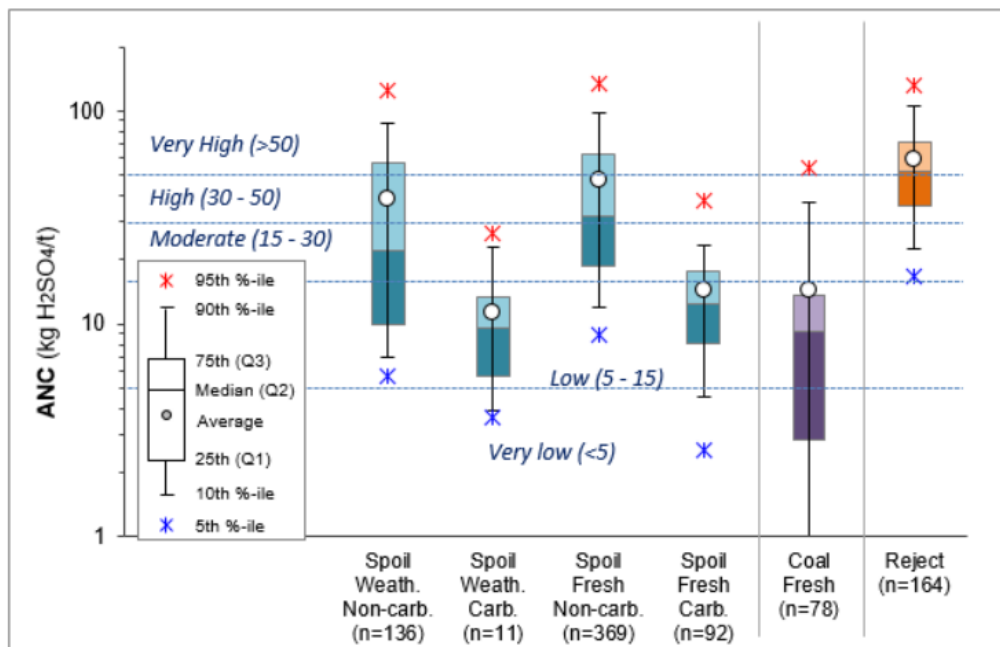


Figure 12. Acid neutralising capacity (ANC) distribution

Available Acid Neutralising Capacity

The availability of neutralising material is generally determined by the mineralogy of the sample – with calcite and dolomite (carbonate minerals) being more readily-available to neutralise acidity compared with, for example, silicates. Siderite, although a carbonate, has no net acid neutralising capacity. However, routine ANC tests assumes that all ANC measured is readily available to neutralise acid, when in the field is not always the case. Hence, acid buffering characterisation curve (ABCC) (and mineralogical) test-work is undertaken to understand the effective (readily available) ANC.

ABCC tests were undertaken on 45 spoil samples and 30 rejects samples to assess the proportion of ANC that may be 'readily available' (i.e. short-acting) in these materials under field conditions and provide some indication of what carbonate minerals are providing the ANC. 'Ready availability' is regarded as the proportion of ANC that is available for buffering reaction at pH 4.5. The results are summarised in **Figure 13 top** and **bottom** for spoil and rejects samples, respectively.

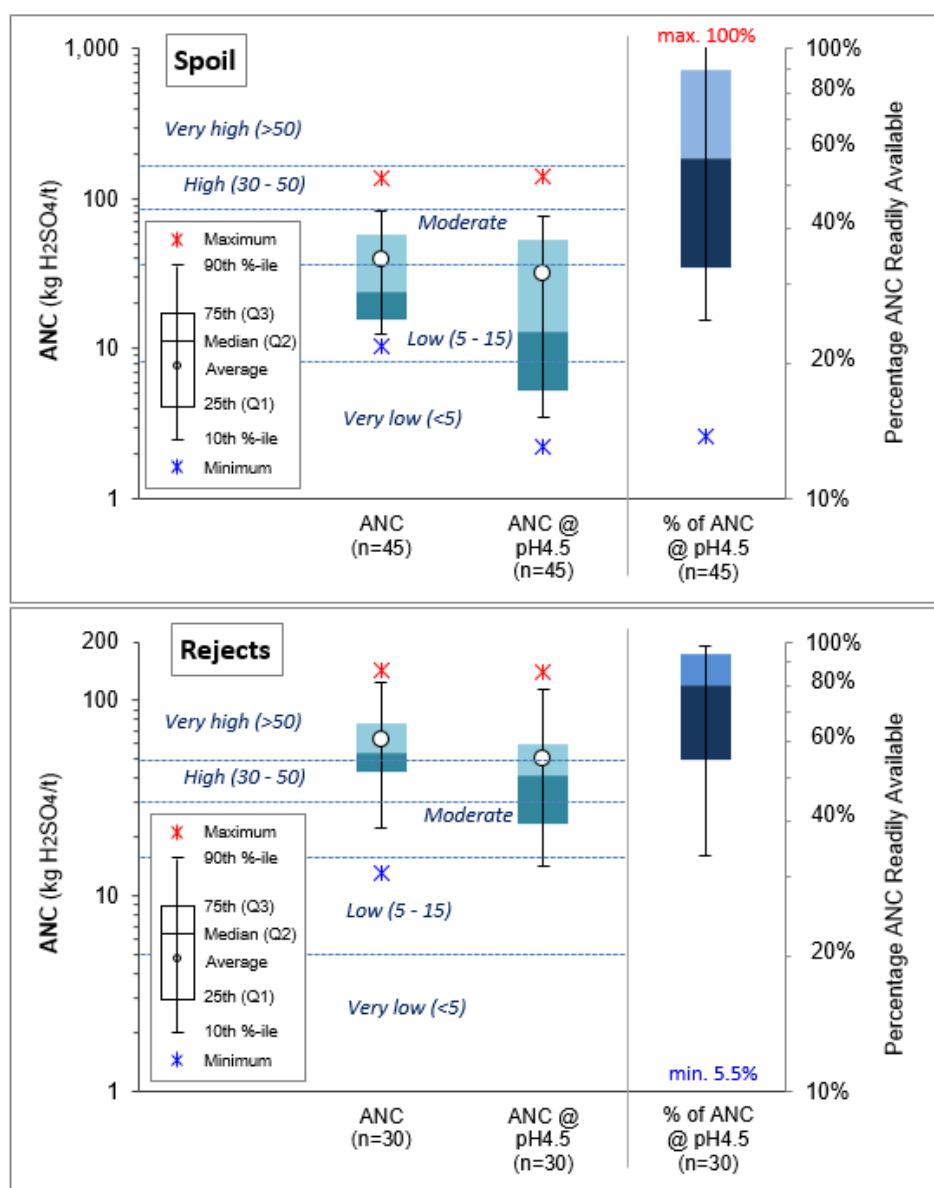


Figure 13. Distribution of acid neutralising capacity (ANC) [total], ANC at pH4.5 and proportion (%) of ANC expected to be readily available

For the 45 spoil samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 13% to nominally 100% of the ANC, with a median of approximately 57%¹.

For the 30 rejects samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions was slightly higher, overall, compared to spoil samples with a median of approximately 80%³.

The relationship between ANC @ pH 4.5 [i.e. ABCC ANC] and ANC [total] (for samples where ABCC data is available) is shown in **Figure 14**.

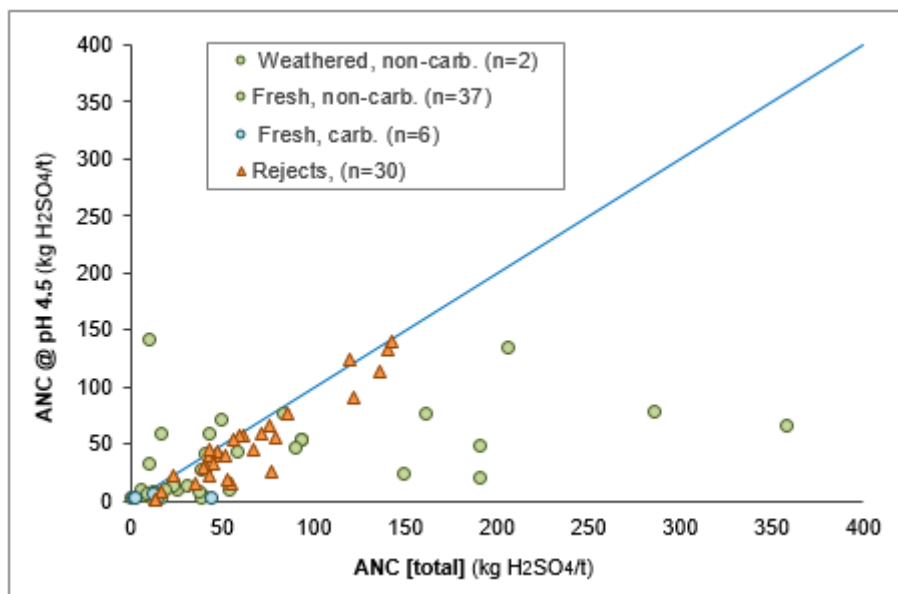


Figure 14. ABCC ANC [ANC @ pH 4.5] versus ANC [for samples where ABCC data is available]

The shape of the ABCC curves (the reaction rate) can also be used to infer likely carbonate mineralogy based on standard curves/data for different carbonate minerals at varying ANC values. ABCC reaction rate curves can be provided on request. For all samples, iron dolomite (Fe-dolomite) appears to be the dominant carbonate mineral (based on the ABCC curves), with minor siderite. Siderite is fairly common throughout the Permian sediments of the Bowen Basin, albeit in generally relatively small amounts. Several samples appear to have trace amounts of dolomite and calcite.

Based on the above, and supported by the QXRD data (**Section 5.1**), the carbonate mineral in bulk spoil is likely to be Fe-dolomite +/- siderite with varying influence from dolomite and calcite.

ANC / MPA Ratio

Generally, those samples with an ANC/MPA ratio greater than two are considered to have a negligible/low risk of acid generation (DIIS, 2016; INAP, 2009), especially where sulphide concentrations are very low and reactive ANC is moderate to high – as is the case with the potential spoil samples. The results, illustrated in **Figure 15**, show that 585 of the 609 spoil samples (96% of spoil samples) have an ANC/MPA ratio greater than two. Approximately 14% of fresh carbonaceous samples (13 out of 93 samples) have an ANC/MPA ratio less than two.

Only 30% of coal samples had an ANC/MPA ratio greater than two whereas 80% rejects samples (130 out of 164 samples) had an ANC/MPA ratio greater than two. Comparatively, the ANC/MPA ratio for coal and rejects samples calculated from Scr reveals that 66% of coal samples and 86% of rejects samples had ANC/MPA ratios greater than two.

¹ Because the ABCC test is a separate test to the ANC test – performed on different sample splits – it is possible to achieve results with greater than 100% ANC being readily available for the same sample. Such a result effectively means that all of the ANC for that sample is in a readily available form (i.e. a practical maximum of 100% availability). Similarly, at the lower end, the lowest 'readily available' amount may actually be slightly greater.

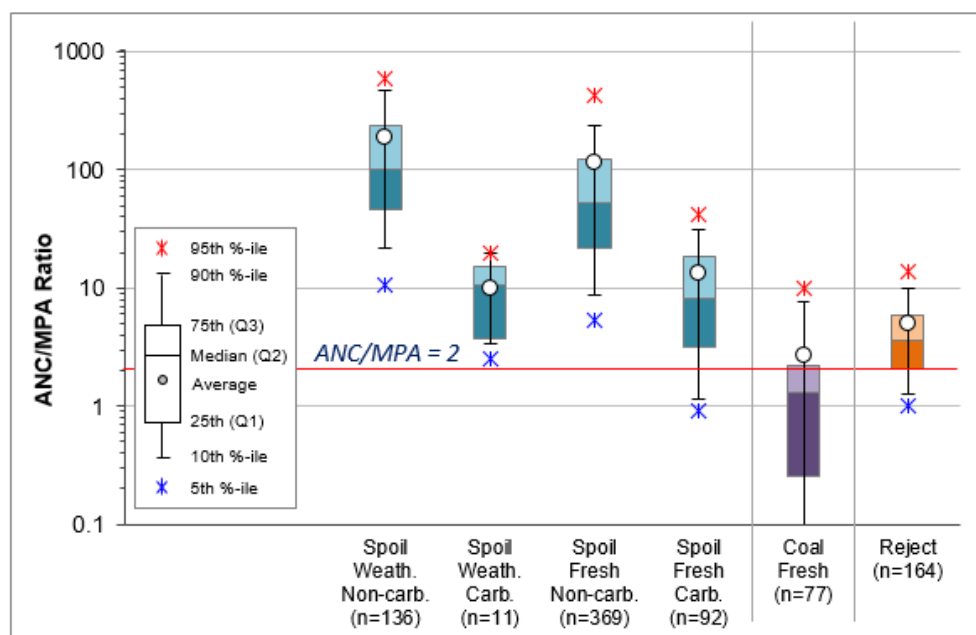


Figure 15. Distribution of the ratio of acid neutralising capacity (ANC) to maximum potential acidity (MPA) [ANC/MPA ratio]

Net Acid Producing Potential and Net Acid Generation Capacity

Based on the generally low MPA and higher ANC values (relative to the MPA), the calculated NAPP values are negative for the vast majority of spoil and rejects samples (**Figure 16**). On the other hand, approximately 40% of coal samples (31 out of 77) have low positive NAPP values. The results indicate that, overall, there is significantly excess neutralising capacity (ANC) compared to potential acidity (MPA) for spoil and rejects samples (mineral waste materials).

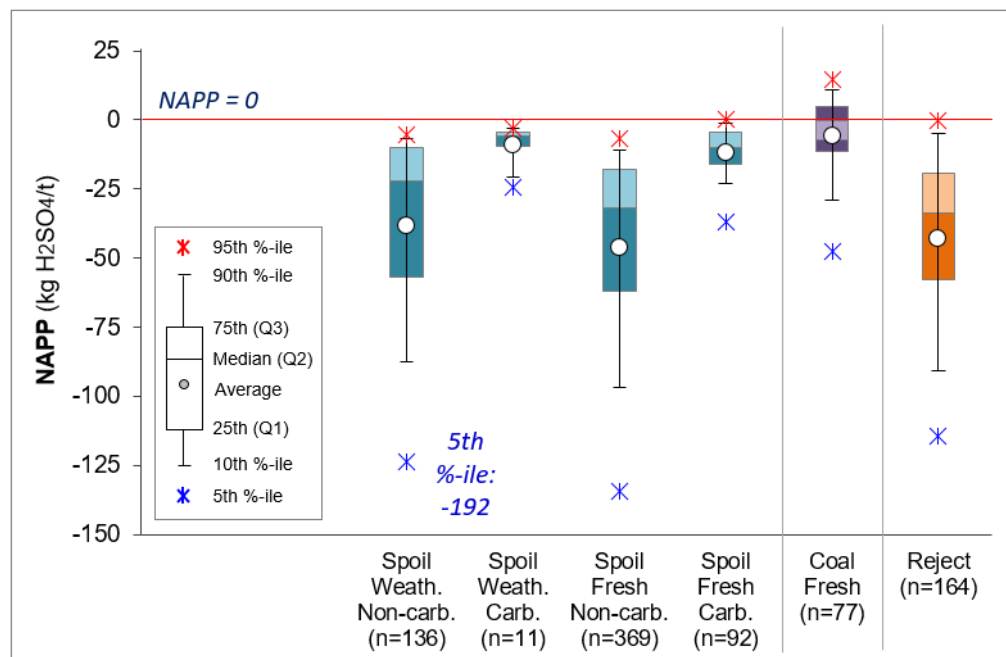


Figure 16. Distribution of net acid producing potential (NAPP)

NAG test results are used in conjunction with NAPP values in determining the AMD classification of samples. The calculated NAPP value assumes that all sulphur (present as sulphide) will oxidise to generate acid (MPA) and that

all neutralising material in a sample is in a readily available form to neutralise any acid that could be generated (ANC). Unlike the theoretical basis of the NAPP test, in a NAG test a sample is encouraged to oxidise by reaction with hydrogen peroxide and any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity is measured and expressed as kg H₂SO₄/t.

Samples with NAGpH values greater than pH 4.5 are considered to be NAF. Samples with NAGpH values less than or equal to pH 4.5 (i.e. acid-generating) would also be expected to have measurable NAG capacity (i.e. NAG capacity greater than 0.1 kg H₂SO₄/t). As a guide, NAG capacity values between 0.1 and 5 kg H₂SO₄/t are considered 'low capacity' (AMIRA, 2002).

NAG test data is available for 29 potential spoil samples, 1 coal sample and 155 rejects samples, with the NAGpH distribution shown in **Figure 17**. Of the spoil samples, 76% of those tested had NAGpH values greater than pH4.5. For rejects samples, 93% of samples tested reported values greater than pH4.5.

As per general practice, especially historically, NAG tests tend to be undertaken on samples with higher total S values and/or those samples potentially considered to have a greater potential to generate AMD – hence the large number of rejects samples with NAG data. As such, the proportion of potential spoil and coal samples with NAGpH values less than pH4.5 is not representing the actual proportion of material in the field that can generate acid conditions, but is indicative of the type of material (based on total S and ANC concentrations) that may generate AD under field conditions.

The NAG test can be influenced by organic acid (i.e. organic acid can produce NAGpH between approximately pH 4 to 4.5, thus providing a 'false positive' for sulphuric acid). Organic acid is typically produced by samples with high organic carbon content – such as coal and highly carbonaceous samples. To circumvent this issue and clarify the uncertainty associated with the 'single addition' NAG test for coal and highly carbonaceous samples, two carbonaceous samples (one weathered and one fresh), 53 coal samples and 2 rejects samples underwent an Extended Boil NAG method (NAG Extended). Twenty-six of these 57 samples (or 47% of samples) returned Extended NAGpH values greater than pH4.5 – thus indicating that the NAG results for these coal and highly carbonaceous samples were likely influenced by organic acid.

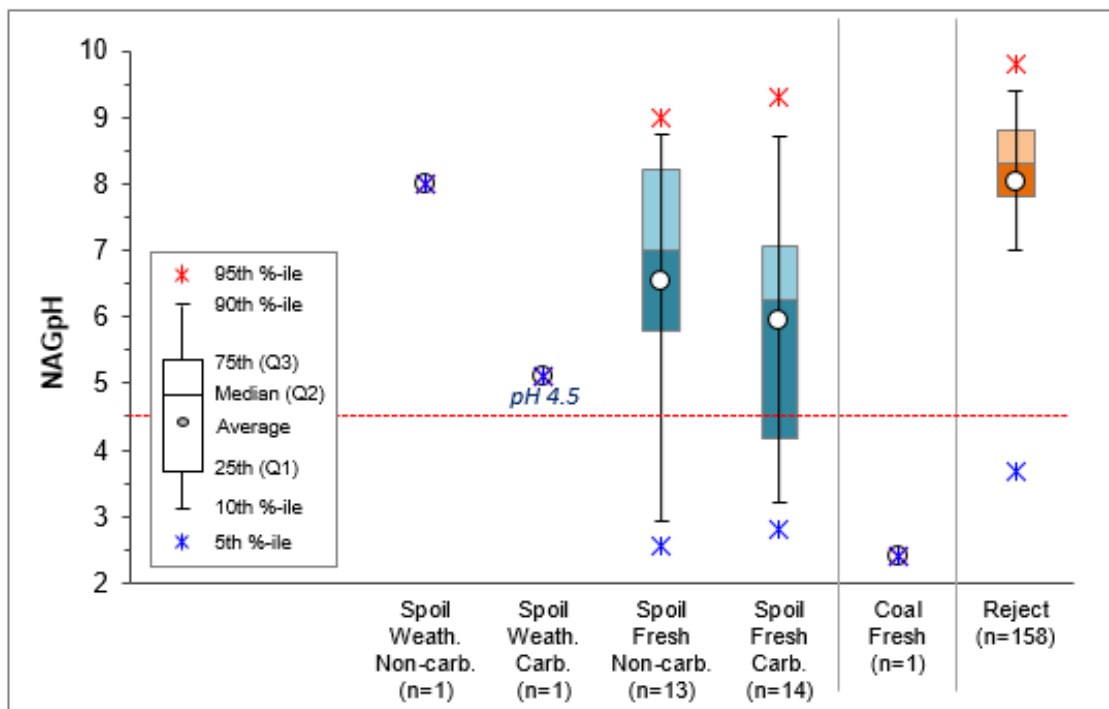


Figure 17. Distribution of net acid generation pH (NAGpH single or NAG Extended)

AMD Classification

The ABA results presented in this section have been used to classify the acid forming nature of the samples following the classification criteria outlined in **Section 4.4**. Additional relevant data, such as ABCC and Extended NAG test results were used to aid in the classification of samples where there was uncertainty following the preliminary AMD classification. The acid forming nature of these samples is summarised in **Table 16**.

Table 16. Geochemical classification of samples

Material Type	NAF	NAF-S	UC(NAF)	UC(PAF)	PAF-LC	PAF
	Number and (%) of samples					
Weathered non-carbonaceous spoil (n=136)	136 (100%)	0	0	0	0	0
Weathered carbonaceous spoil (n=11)	10 (91%)	0	0	0	1 (9%)	0
Fresh non-carbonaceous spoil (n=369)	364 (99%)	0	2 (<1%)	1 (<1%)	1 (<1%)	1 (<1%)
Fresh carbonaceous spoil (n=93)	81 (87%)	0	5 (~6%)	3 (~3%)	1 (1%)	3 (~3%)
Spoil [all] (n=609)	591 (97%)	0	7 (~1%)	4 (<1%)	3 (<1%)	4 (~1%)
	598 (98%)			11 (2%)		
Coal (n=77)	23 (30%)	0	17 (22%)	0	29 (38%)	8 (10%)
	40 (52%)			37 (48%)		
Rejects (n=164)	144 (88%)	4 (2%)	7 (4%)	6 (4%)	3 (2%)	0
	155 (95%)			9 (5%)		

Spoil

The classifications in **Table 16** show that 98% of spoil samples (n=598) were classified as NAF or were expected to be NAF (and have been classified as UC(NAF)). These spoil samples (and spoil material represented by these samples) have very low sulphur concentration, significant excess ANC (relative to the MPA) and clearly have negligible capacity to generate AMD. Two percent (11 out of 609) of spoil samples – were classified as PAF, PAF-LC or UC(PAF). Out of the 11 PAF, PAF-LC or UC(PAF) samples, eight samples were carbonaceous.

Data show that potential spoil, as a bulk material, would be overwhelmingly NAF. Furthermore, the very low sulphur concentrations in spoil indicates that the sulphate concentration that could be generated in spoil from sulphide oxidation (in addition to any salinity unrelated to sulphide oxidation) would also be very low.

Coal

Coal samples had higher total S values and lower ANC compared to spoil, thus resulting in 48% of coal samples classified as PAF, PAF-LC or UC(PAF). The proportion of PAF, PAF-LC and UC(PAF) samples is comparable across all coal seam groups being mined at DNM. It is worth noting that 29 of the 37 coal samples classified as some form of 'PAF' showed limited capacity to generate acidity, suggesting that 'PAF' coal is unlikely to generate significant acid(ity).

Approximately 52% of coal samples tested (40 out of 77 samples) were classified as NAF or UC(NAF), and seam material represented by these samples has very low sulphur values, excess ANC (relative to the MPA) and clearly has no capacity to generate acidity or release significant sulphate from sulphide oxidation.

These results suggest that coal represented by these samples and stored on a ROM pad, located within pit walls and un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would likely be bulk NAF.

Rejects

The results show that approximately 95% of rejects samples were classified as NAF, NAF-S or UC(NAF). Nine out of the 164 rejects samples (5% of reject samples) were classified as PAF-LC or UC(PAF). From an acid generating perspective rejects, as a bulk material, rejects has a low potential to generate AMD as either AD and/or NMD and/or SD.

5.3 Total Metals and Metalloids

Multi-element (metal and metalloid) data is available for 253 potential spoil samples [91 weathered non-carbonaceous, 151 fresh non-carbonaceous, 7 weathered carbonaceous and 4 fresh carbonaceous], nine coal samples and 46 rejects samples. The degree of enrichment with respect to elements potentially of environmental interest is shown in **Figure 18** top, middle and bottom for spoil, rejects and coal respectively.

The GAI values show that 3 (out of 253) spoil samples were significantly enriched [$GAI \geq 3$] with regards to one or more of the following elements, i.e., arsenic (As), barium (Ba), beryllium (Be), and/or sulphur (S). The level of S enrichment in these samples is consistent with ABA data for these samples. The enrichment in As, Ba and Be in a small number of samples is not cause for concern.

Five out of 46 rejects samples were significantly enriched [$GAI \geq 3$] with sulphur (S) which are consistent with ABA data for these samples. Two out of 9 coal samples were significantly enriched [$GAI \geq 3$] with S or molybdenum (Mo).

The GAI values also show that a considerable number of samples tested (of all material types) had minor enrichment ($GAI = 1$ or 2) with regard to one or more of the following, i.e., As, Be, Co, mercury (Hg), Mo, nickel (Ni), S, antimony (Sb), uranium (U) and Zinc (Zn).

Overall, the results suggest that bulk mineral waste materials have generally low levels of metal and metalloid enrichment, which is consistent with Permian-age coal measures throughout eastern Australia. A small proportion of samples (of all material types) have a higher degree of enrichment in some metals – notably Be – however enrichment in Be in these materials is not cause for concern.



Figure 18. Frequency distribution of geochemical abundance indices (GAI) of selected elements in spoil, rejects and coal

5.4 Initial Solubility in Deionised Water

To evaluate the initial solubility of multi-elements in samples, water extract test results for pH and EC were conducted for 1070 samples, comprising 818 spoil samples, 92 coal samples and 91 rejects samples. Test results for major ions and soluble metals/metalloids are available for 78 spoil samples, 5 coal samples and 160 rejects samples. Therefore, a relatively large dataset is available to assess the potential for leaching of salt and environmentally important elements from spoil, coal and rejects at DNM. Water extract tests provide a preliminary indication of the elements that may be readily mobilised from any given material type.

The samples underwent a 1:5 w:v (solid:water) deionised water bottle leach procedure on fine pulps. Note that the use of fine pulped materials in water extract tests will enable a high level of reaction and dissolution. The results from these tests are summarised and discussed below. Tabulated results can be provided on request.

The test-work has found that the mineral wastes are pH-alkaline, generally slightly to moderately saline and have very low concentrations of soluble metals and metalloid concentrations – within the range typical for Permian sedimentary materials in Queensland. For most samples, the soluble metals and metalloids are at concentrations below or marginally above the laboratory limit of reporting (LOR).

Electrical Conductivity (EC) and pH

EC and pH data is available for 1070 samples at 1:5 w:v on pulp (**Figure 19**). The EC_{1:5} of 818 spoil samples spanned a large range from 51 to 2520 $\mu\text{S}/\text{cm}$, with median, 75th and 90th percentile EC_{1:5} values of 328, 516 and 844 $\mu\text{S}/\text{cm}$, respectively. As evident in **Figure 19** the fresh (unweathered) samples, which comprise the greatest proportion of spoil, are generally slightly saline and have lower EC_{1:5} values compared to the weathered samples, which are generally slightly to moderately saline. These EC_{1:5} results are common (if not typical) for Bowen Basin Permian and Tertiary material in the region.

Coal samples (n=92) are non-saline to slightly saline with median EC_{1:5} values of 132 $\mu\text{S}/\text{cm}$. Rejects samples (n=160) have slightly higher EC_{1:5} values compared to coal are generally slightly saline.

The pH distribution by material type (**Figure 19**) shows the samples to be generally alkaline to highly alkaline, with a median pH of 9.0 and 5th percentile pH of 7.7 (all 818 samples) – indicating no readily soluble acidity from these samples. These pH results are common (if not typical) for Bowen Basin Permian and Tertiary material in the region. Of the 818 spoil samples, one fresh carbonaceous sample had acidic pH of 3.1 and two highly weathered non-carbonaceous samples were weakly acid with pH_{1:5} values of 5.4 and 4.7. Out of the 92 coal samples, five samples were weakly acid with pH_{1:5} ranging from 4.5 to 5.2. All rejects samples (n=175) reported alkaline to highly alkaline pH_{1:5} values.

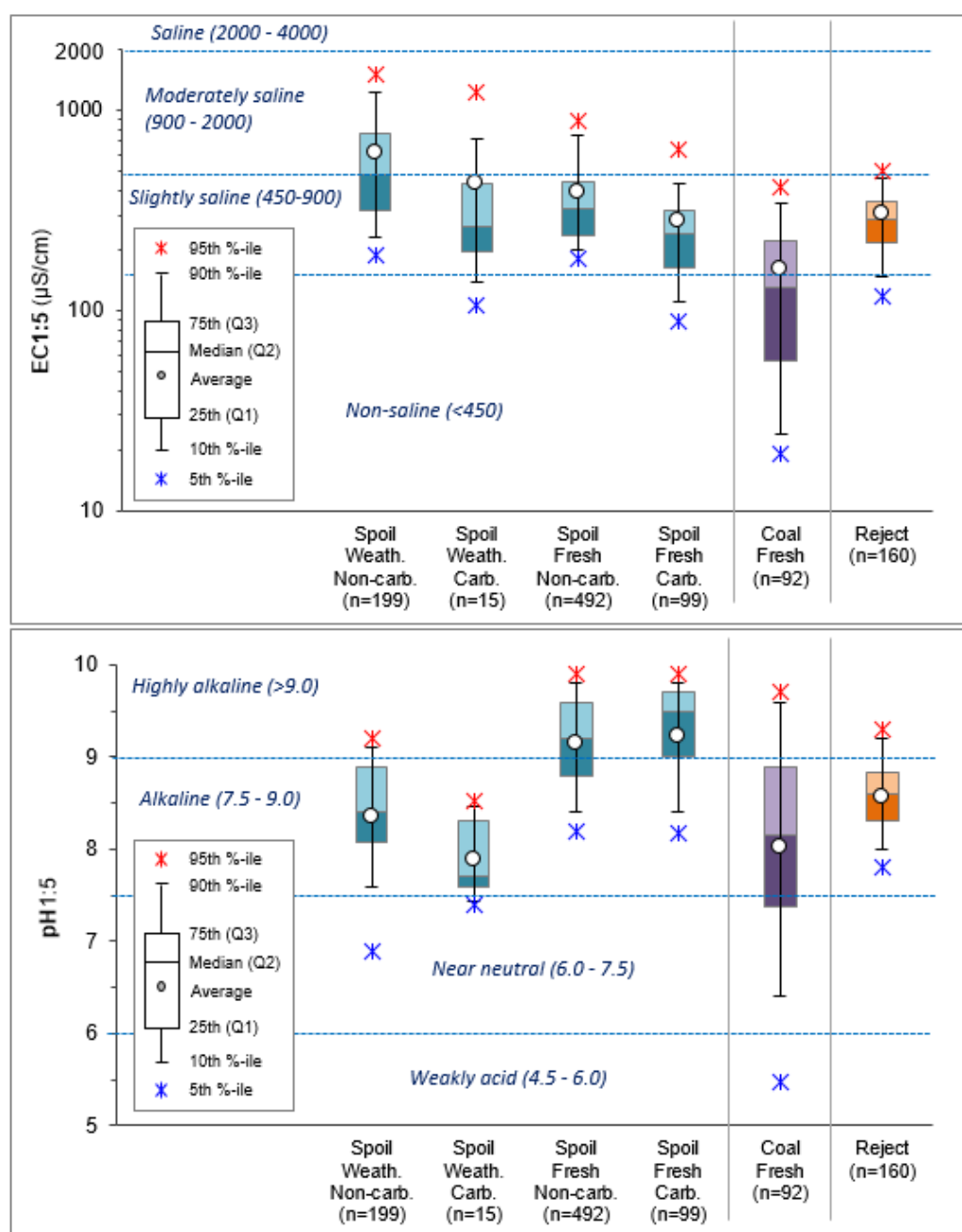


Figure 19. Electrical conductivity (EC) and pH distribution

Soluble Metals and Metalloids

Deionised water extract (leaching) data for major ions and metals/metalloids is available for 107 spoil samples, 18 coal samples and 31 rejects samples. All samples underwent a 1:5 w:v (solid:water) water extract procedure on pulps.

The samples were collected under different sampling programs with different objectives and, as such, some of the samples were analysed by a higher resolution method (ICP-MS) compared to other samples (analysed by ICP-AES). Thus, the samples analysed by ICP-AES have laboratory LOR values that are generally greater than the laboratory LOR for samples analysed by ICP-MS.

The sum of 16 environmentally important elements are plotted as a function of pH in **Figure 20**, in a modified version of what is referred to as a Ficklin plot (after Ficklin *et al.*, 1992). The 16 selected metals/metalloids

comprise: aluminium (Al), Sb, As, cadmium (Cd), Co, chromium (Cr), copper (Cu), lead (Pb), Hg, manganese (Mn), Mo, Ni, selenium (Se), U, V and Zn.

As evident in **Figure 20** all rejects samples showed low soluble metals concentrations. Among spoil and coal samples (n=125), all except five spoil and two coal samples also reported low soluble metals concentrations. The five spoil samples with slightly moderate soluble metals concentrations are represented by four fresh (non-weathered) non-carbonaceous spoil samples and one fresh carbonaceous spoil sample. The vast majority of the samples have alkaline to highly alkaline pH.

In pH-neutral to alkaline waters, many metals/metalloids cannot remain in solution and, thus, trace metal/metalloid concentrations are generally low. Comparatively, in acid(ic) waters, many metals/metalloids are highly soluble and remain in solution and, thus, trace metal/metalloid concentrations are generally high. Notable exceptions to these general rules include elements such as As, Mn, Sb and Se, which remain soluble through a wide pH range. Other trace metals that are somewhat soluble under pH-neutral to alkaline conditions include Cd, Cr, Mo and Zn. As such, under the pH-alkaline conditions of the leach, the mobility of these elements would not be inhibited.

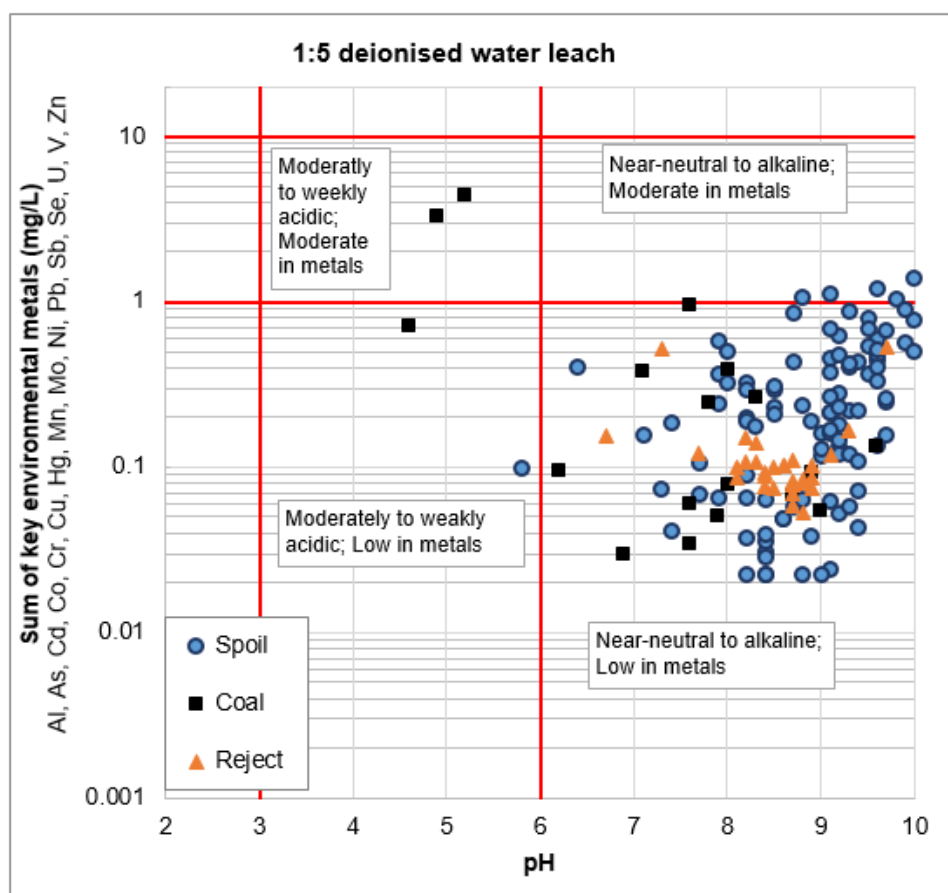


Figure 20. Sum of key environmental metals versus pH in deionised water extracts

The median concentrations of major ions and environmentally important metals/metalloids in deionised water extracts are shown in **Table 17**.

Table 17. Median concentrations of major ions and selected elements in deionised water extracts

Median concentration mg/L	Spoil (n=107)	Coal (n=18)	Rejects (n=31)
≤ 0.0001	Cd, Hg	Cd, Hg	Hg
≤ 0.001	Ag, Be, Bi, Co, Cr, Cu, Mn, Ni, Pb, Sn, Th, Tl, U, W	Ag, As, Be, Bi, Cd, Co, Cr, Cu, Ni, Pb, Sb, Sn, Th, Tl, U, V, Zn	Ag, Be, Bi, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Th, Tl, U, V, Zn
≤ 0.01	Sb, Se, Ti, V, Zn, Zr	Mn, Mo, Se, Ti, V, Zn, Zr	Al, As, Mn, Se, Sn, Ti, V, Zn, Zr
≤ 0.1	Al, As, B, Ba, Fe, Mo, Sr	Al, B, Ba, Fe	B, Ba, Mo, Fe
≤ 1.0	F, P	F, P, Sr	P, Sr
≤ 10	Ca, Mg, K, Cl	Ca, Mg, K, Cl	Mg, K, Cl
≤ 100	SO ₄ , Na	SO ₄ , Na	Ca, Na, SO ₄ ,

5.5 ‘Saline’ Water Solubility of Rejects

Twenty-two rejects samples underwent a 1:5 w:v (solid:water) mildly saline (brackish) water extract procedures on pulps using a 2 g/L sodium chloride (NaCl) leaching solution. This leach was undertaken to determine the solubility of metals and metalloids under ‘brackish’ conditions – which better simulate the normal (brackish) water quality of the CHPP process water. Note that the salinity of CHPP process water varies from fresh to brackish on a day-to-day basis depending upon the source of the water from within the mine water management system.

The results from these tests found that the soluble metals and metalloid concentrations were very low and very similar to the concentrations from the de-ionised water (freshwater) leaching tests for these same samples.

Soluble barium (Ba) and strontium (Sr) concentrations were higher in the ‘brackish’ leachate solution compared to the freshwater leachate for the same samples – a trend that has been observed in similar ‘brackish’ and ‘saline’ leaches of tailings solutions from other Permian coal mines in the Bowen Basin. For the other elements there was little difference between the soluble concentrations in the ‘brackish’ leachate compared to the freshwater leachate.

Overall, the results have shown that the solubility of rejects is low under ‘brackish’ leaching conditions.

5.6 Peroxide Leachate Solutions

Peroxide leachate (NAG leach) data is available for:

- One fresh non-carbonaceous spoil sample classified as UC(NAF) and one fresh carbonaceous sample classified as UC(NAF).
- Four coal samples classified as PAF(LC)

Peroxide leachate is the solution remaining from the NAG test after the sample has been oxidised with peroxide to encourage oxidation and neutralising reactions, if ANC is available. The test encourages complete and rapid oxidation, with the resulting leach representing and assumed ‘worse case’ scenario in term of metal/metalloid mobility. The purpose of this test is to understand what metals/metalloids can be mobilised following full oxidation. The samples submitted for this test were selected to assess the hazard of similar waste type or to assist clarifying borderline geochemical properties.

The peroxide leachate of the all the samples (n=6) was measured after undertaking a single addition (standard) NAG test. The fresh non-carbonaceous sample – having little to no carbonaceous material – would not be expected to be influenced by organic acids. However, the ‘acidity’ of the coal samples may be influenced by organic acids

producing acidity and corresponding elevated soluble metals concentrations unrelated to AMD. As such, the result for the coal samples should be interpreted with this in mind.

Three PAF-LC coal samples produced low NAG leachate pH values of 2.42, 3.73 and 2.59 respectively confirming their AD classifications. One PAF-LC coal sample produced weakly acid pH value of 4.78.

The UC spoil samples produced NAG leachate pH of 5.92 (for carbonaceous spoil) and 6.55 (for non-carbonaceous spoil).

The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the peroxide leachate solution in **Figure 21**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach.

As evident in **Figure 21** both spoil samples have low soluble metals concentrations. All four coal samples reported high soluble metal concentrations, which may be due to organic acids producing acidity and correspondingly elevated soluble metals concentrations unrelated to AMD.

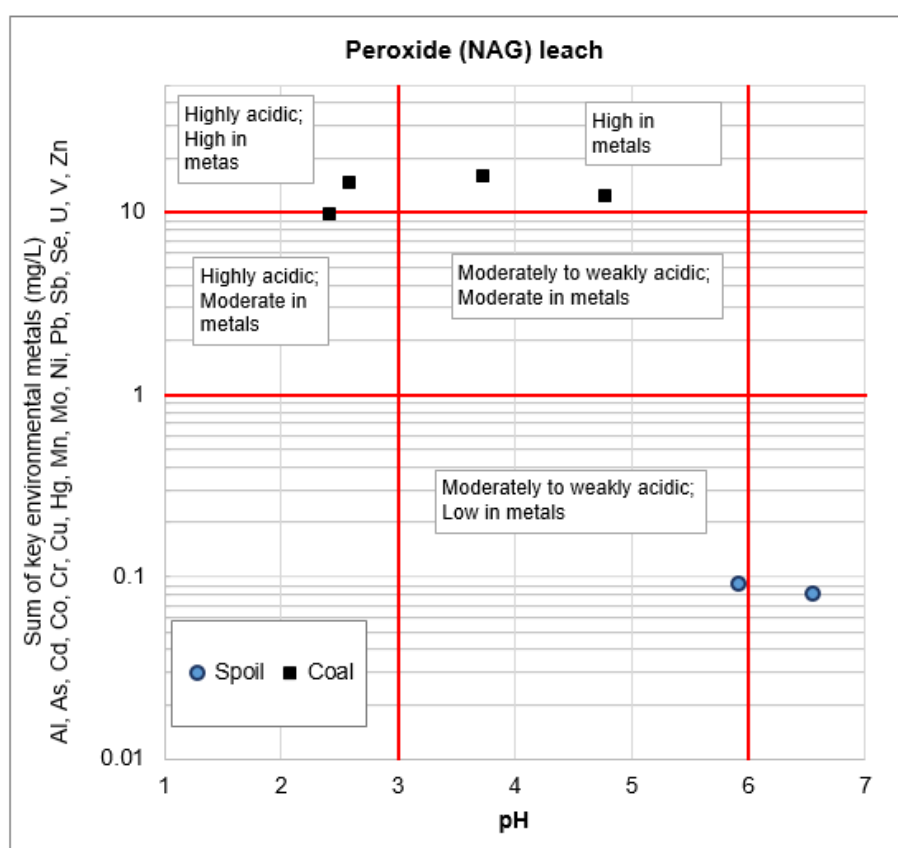


Figure 21. Sum of key environmental metals versus pH in peroxide (NAG) leachate solution

Compared to the 1:5 deionised water extract solutions, the median concentration of several metals and metalloids in the peroxide leach is higher, notably Al, Cu, Fe, Mn and Ni, however the concentrations of all other elements, and major ions, are comparable to the deionised water solubility concentrations. The results suggest that coal samples under acidic conditions are capable of generating elevated metal and metalloid loads, they are not of concern as majority of coal gets shipped off site. Furthermore, the water quality associated with coal samples are likely to be affected by organic acid. Two spoil samples tested for NAG leach were moderately to weekly acidic and low in metals.

5.7 Cation Exchange Capacity, Sodicity and Dispersion of Spoil

Exchangeable cation concentrations are used to evaluate the potential ‘soil quality’ of materials. Exchangeable cation data [as cation exchange capacity (CEC)] is available for 370 potential spoil samples. The results are summarised in **Figure 22**.

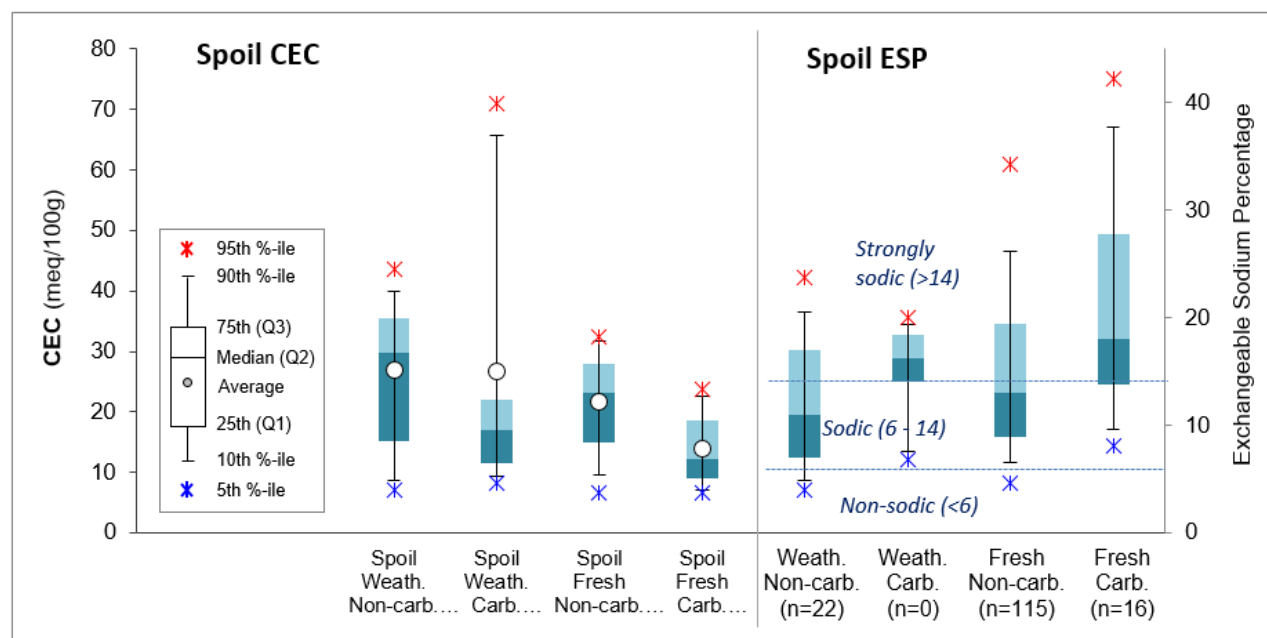


Figure 22. Cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) of spoil

The CEC spans a large range from 2.4 to 76 milliequivalents per 100 grams (meq/100g), with a relatively modest median CEC value of 24 meq/100g. The weathered samples generally had slightly higher CEC values compared to the fresh samples – which is typical for sedimentary materials in the Bowen Basin.

The exchangeable sodium percentage (ESP) results range from <1% to 54%, with a median ESP of 13%. Approximately 44% of samples had ESP values greater than 14% and 45% of samples had ESP values between 6 and 14%. Therefore, based on the ESP values alone, essentially all spoil is regarded as being ‘sodic’ or ‘strongly sodic’ and, as such, a significant proportion of mine spoil at DNM can be expected to have potential for dispersion.

A subset of 154 spoil samples also underwent Emerson aggregate class tests to determine whether these samples were dispersive. Emerson aggregate class tests are a direct measure of soil dispersion, whereas ESP values are used as an indirect measure of the *potential* for a sample to have structural stability problems and hence *may be* dispersive. The results show that about 51% of the samples (79 out of 154 samples) – most (74 out of 79) of which were non-carbonaceous samples – had some dispersion [slaking] (Class 2). Another 23 samples had Emerson (Class 3) - dispersive [remoulded dispersion] and 3 samples had no dispersion - Emerson (Class 4). The remainder of the samples had Emerson Class 7 and 8 values (non-slaking). No samples were ‘completely dispersive’ (Class 1). Refer to **Section 4.4** for class descriptions. These results are broadly consistent with the dispersion predictions from the CEC and ESP results.

Based on the CEC, ESP and Emerson aggregate class test results, a significant proportion of spoil at DNM is expected to be sodic to strongly sodic, and dispersive to varying degrees – with little distinction between lithology or degree of weathering.

These exchangeable cation (and Emerson aggregate class) results are common (if not typical) for Bowen Basin Permian and Tertiary material in the region – and highlight that spoil is likely to have mixed sodicity and dispersion potential.

5.8 OxCon Test-work

OxCon test-work data is available for seven samples sourced from the Rangal Coal Measures:

- A composite coal sample (being a composite of 4 individual coal samples from L12 ply); initially classified as PAF
- A carbonaceous siltstone sample from within L1 seam considered to be representative of 'potential' rejects material should material represented by this sample be mined as part of ROM coal, initially classified as PAF.
- 2 coarse and 3 fine rejects sourced from the CHPP, with Scr ranging from 1.32 to 0.21 wt%. All samples but one (TailsUF_03_07-13Oct2020 with Scr of 1.32 wt%) were classed as NAF.

The samples were selected for OxCon test-work on the basis of earlier static leach test. The ABA data for the individual coal samples used to create the composite coal samples were relatively simplistic, and, as such, all the four coal samples were initially (conservatively) classified as 'PAF' of some type. Hence, the composite coal sample that underwent OxCon testwork was expected to be 'PAF' of some type.

The testwork – summarised in **Table 18** – broadly confirmed the 'PAF' classifications [UC(PAF), PAF-LC, PAF]] of the samples initially classified at potential for AD.

The testwork indicates that samples classed as PAF, if not managed appropriately, can generate AMD, however, the rate of acid production is very low and suggest that if these PAF materials are disposed with waste characterised by excess acid buffering capacity, such acidity can easily be buffered in situ.

Lastly the kinetic tests suggests that the PAF rejects tested have a low to moderate potential for acidity generation and are unlikely to be a source for NMD/SD. Similarly, the NAF samples tested have been characterised as being unlikely to generate NMD or SD.

Table 18. Summary for OxCon results

Sample ID	Source	Avg. O2 consumption rate (mmol O2/kg/day)	Max. acidity generation rate (kg H ₂ SO ₄ /t/year)	Pyrite oxidation rate (wt.% pyrite/year)	Longevity of sulphide oxidation (years)	Lag time until ANC consumed (years)	Peak net acidity generation rate (kg H ₂ SO ₄ /t/year)
DNM_177204_2 4.7-24.9_CS	L1 ply	0.75	14.4	47.53	9	~1	10
DNM_Coal_Ore_Comp1	L12 ply	0.68	13.0	0.42	3	~2	1.2
Reject_01_04Nov-10Dec2020	RCM	0.25	4.7	0.39	3	N/A	<0.1
Reject_02_25Nov-02Dec2020	RCM	0.44	8.4	0.59	2	N/A	<0.1
TailsUF_03_07-13Oct2020	RCM	0.32	6.1	28.36	17	14	0.001
TailsUF_04_14-20Oct2020	RCM	0.15	2.8	69.81	6	N/A	<0.1
TailsUF_05_15-21Aug2021	RCM	0.21	4.1	86.45	5	N/A	<0.1

6 Discussion

The geochemical characteristics of overburden/interburden, rejects and coal (potentially reporting to the ROM or the spoil as waste) samples from DNM have been assessed to define the environmental geochemical characteristics of these material types. Results from this assessment were used to identify appropriate AMD management measures with regard to mine rehabilitation and closure.

Spoil currently comprises a significant majority (approximately 98.5%) of mineral waste at DNM and will continue to do so for the expected life of the operation. Rejects will comprise the remaining 1.5% (approximately) of all mineral waste over the life of the operation. The spoil is comprised of approximately 94% non-carbonaceous material and approximately 6% of fresh carbonaceous material. Almost half of current spoil is weathered and the proportion of weathered to relative fresh material would remain the same as mining progresses due to seams at DNM being relatively flat (as opposed to sites where the pit gets a lot deeper).

6.1 AMD Potential of Mineral Waste and Coal Material Types

AMD Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 94% of spoil (of which about 41% is weathered), is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for sedimentary materials in the Bowen Basin.

The total S concentration of non-carbonaceous spoil is very low, with a 95th percentile total S concentration of 0.03% for weathered spoil and 0.11% for fresh spoil. As such, and combined with high ANC values (median 24 kg H₂SO₄/t), which is significantly higher than the MPA (median 0.61 kg H₂SO₄/t), approximately 99% of non-carbonaceous spoil samples tested (500 out of 505 samples) were classified as NAF. Two samples out of 505 were classified as UC(NAF).

The test-work demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be approximately 67% (median) available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Siderite, present in minor quantity, does not provide any net ANC. Overall, non-carbonaceous spoil has excess acid neutralising capacity.

Non-carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks. In particular, total metal and metalloid concentrations from 91 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. A small number of samples (i.e. 3 out of 91 samples) had significant (GAI≥3) enrichment with respect to Be and S, while 49 samples had minor enrichment with regard to one or more of Ag, As, Ba, Co, Cr, Hg, Mo, Ni and/or Zn. There was no correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment.

Soluble multi-element results (from 92 samples) indicate that leachate from NAF non-carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids. Four samples produced moderate soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of the following elements: Al, As, Mn, Mo, Sb, Se. Peroxide leaching undertaken on one non-carbonaceous spoil shows sample to be moderate to weekly acidic and low in metals.

Based on the results, non-carbonaceous spoil – being essentially all NAF characterised by very low total S concentration – has a negligible potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Spoil – carbonaceous

Carbonaceous spoil represents approximately 6% of spoil material at DNM and – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil.

The total S concentration of carbonaceous spoil is low, with a 95th percentile total S concentration of 0.18% for weathered spoil and 0.24% for fresh spoil. A small number of samples had low-moderate to moderate total S (and sulphide [Scr]) concentrations. Combined with generally low ANC values (median 10 kg H₂SO₄/t for weathered spoil and 1 kg H₂SO₄/t for fresh spoil) and relatively low MPA values (median 2 kg H₂SO₄/t for weathered spoil and

1 kg H₂SO₄/t for fresh spoil), approximately 87% of carbonaceous spoil samples (91 out of 104 samples) were classified as NAF. Five samples (~5% of samples) were classified as UC(NAF) and eight samples were classified as PAF, PAF-LC or UC(PAF).

ANC in carbonaceous spoil is expected to be about 26% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, carbonaceous spoil has relatively limited acid neutralising capacity.

Carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks. In particular, total metal and metalloid concentrations from 11 carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. One sample assayed (out of 12 samples) had significant (GAI≥3) enrichment with respect to As and three (out of 12 samples) had minor enrichment with respect to Be. Five carbonaceous spoil samples had minor enrichment (GAI=1 or 2) with regard to one or more of As, Be, Mo, S, Sb and/or U. There was no correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment.

Soluble multi-element results (from 15 samples) indicate that leachate from carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. One sample produced low-moderate soluble metal concentrations, primarily due to slightly elevated soluble As. Peroxide leaching undertaken on one carbonaceous spoil classified as UC(NAF) show sample to be weakly acidic and low in metals.

Based on the results, carbonaceous spoil as a bulk material has a low potential to generate AD and/or NMD and/or SD. A small proportion of this material type has some potential to generate low-level AD and/or NMD and/or SD. This small proportion of materials at potential for AMD is distributed amongst the bulk NAF material and therefore it is predicted that the spoil is bulk NAF. As stated earlier, carbonaceous spoil represents approximately 6% of all spoil, therefore it is expected that the proportion of carbonaceous spoil that may have potential for AMD reporting to the spoil will be immaterial.

AMD Potential of Rejects

Fresh rejects (from the CHPP) are expected to generate pH-alkaline contact water (run-off and seepage), however a small proportion of rejects may have the potential to generate mildly acidic contact water if allowed to completely oxidise.

The total S concentration of rejects is generally low-moderate, with a 95th percentile total S concentration of 0.97%. About 60% of the total S is present as sulphide (Scr). Combined with generally moderate-high ANC values (median 52 kg H₂SO₄/t), low-moderate MPA values (median 15 kg H₂SO₄/t), indications are that approximately 95% of rejects samples tested are likely NAF [including 7 samples classified as UC(NAF)] and the remaining 5% of rejects samples were classified as PAF, PAF-LC or UC(PAF).

ANC is generally expected to be about 70-90% available under field conditions with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of rejects.

With some exceptions, the total metal and metalloid concentrations from 46 samples tested are generally low compared to average element abundance in soil in the earth's crust. Five rejects samples were significantly enriched (GAI≥3) with regard to sulphur (S), which is consistent with the ABA data showing a small number of samples having moderate total S concentrations. Several rejects samples had minor enrichment (GAI = 1 or 2) with regard to one or more of Ag, Mo, and/or S. There was no correlation found between AMD classifications of the reject samples compared to elemental enrichment.

Solubility data indicates that leachate from rejects under freshwater (deionised water) and saline water leaching conditions is expected to contain low concentrations of soluble metals and metalloids. Mildly saline (brackish) water was used in some leaching tests to simulate the water quality used in the CHPP during ROM coal processing.

Based on the results, approximately 95% of rejects has a low potential to generate AMD as either AD and/or NMD and/or SD. However, approximately 5% of rejects has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, rejects has a low potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time before being processed. However, some minor coal seams/plys will report directly to the spoil dump as waste, and remnant coal (seams) will be exposed on residual void highwalls at closure.

Coal represents approximately 6% of all lithological material at DNM and, considering almost all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste. Most waste 'coal' will report as coal rejects. Remnant coal (in the highwalls of residual voids) is estimated to comprise about 3% to 6% of exposed highwall in Titan North/Central void, Titan East void and Pandora void respectively (refer to **Section 7.1.2**).

ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

The total S concentration of coal is generally low-moderate, with a 95th percentile total S concentration of 0.52%. The total S distribution in the coal geochemical samples tested (n=77) is comparable to the total S distribution in the coal quality database samples (n=1499). Approximately 29% (median value) of the total S is present as sulphide (Scr), however the proportion of total S as sulphide (from 76 samples) ranges from 5% (almost no sulphide) to 100% (all sulphide). Generally, a significant proportion of S in coal is present as organic S, which does not contribute to AD.

Coal samples have a wide range of ANC values from less than 0.2 to 114 kg H₂SO₄/t, however the median ANC is low (9 kg H₂SO₄/t) and the median MPA is also low (7 kg H₂SO₄/t) and similar to the ANC. As such, 52% of samples were classified as NAF or UC(NAF) and 48% of samples classified as PAF, PAF-LC or UC(PAF). The classification of the samples based on total S is conservative and classifying approximately 48% of coal samples as PAF (to some type) is likely an upper limit. The generally low sulphur concentrations in coal samples, combined with the generally low proportion of S present as sulphide, indicate that the sulphate loads from sulphide oxidation would likely be very low.

Assay data available for nine coal samples show that the total metal and metalloid concentrations are low compared to average element abundance in soil in the earth's crust. One sample was significantly enriched (GAI ≥3) with regard to sulphur (S) and another sample was significantly enriched (GAI ≥3) with regard to Mo. Several coal samples had minor enrichment (GAI=1 or 2) with regard to one or more of Be, Co, Hg, Mo, and/or S. There was no correlation found between AMD classifications of the coal samples compared to elemental enrichment.

Soluble multi-element results from 16 out of 18 coal samples tested indicated that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids. Remaining two samples showed potential to mobilise elevated concentration of metals (i.e. Co, Cu, Mn, Ni and Zn). Peroxide leaching (NAG leach) undertaken on four PAF coal samples showed the samples to be acid generating and producing leachate with moderate soluble metal and metalloid concentrations – indicating that PAF coal is capable of generating AD and/or NMD.

Based on the results, and as a bulk material, ROM coal is assessed as having a low potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal would have a moderate to high potential to generate AMD.

6.2 Salinity, Sodicity and Dispersion Potential of Mineral Waste and Coal Material Types

Salinity, Sodicity, and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has EC values (from 704 samples) ranging from 51 to 2520 µS/cm, with median and 90th percentile values of 330 and 844 µS/cm, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally non-saline to slightly saline (<900 µS/cm), either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of weathered non-carbonaceous samples produced moderately saline leachate.

Non-carbonaceous spoil is expected to be sodic to strongly sodic with potential for dispersion (based on high sodicity values). In particular, non-carbonaceous spoil samples (n=334) had modest CEC values and generally

high ESP values, resulting in approximately 44% of samples being classified as 'strongly sodic' and almost all remaining samples being classified as 'sodic'. Emerson aggregate class testing, conducted on a non-carbonaceous sample sub-set (n=132), reported 56% of samples (74 out of 132 samples) are likely to undergo 'some dispersion', 15% of samples (20 out of 132 samples) are found to be dispersive, and the remaining 38 samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity, Sodicity, and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has EC values (from 200 samples, which were predominantly fresh carbonaceous samples) ranging from 58 to 2200 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 236 and 391 $\mu\text{S}/\text{cm}$, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples (n=36) had low CEC and high ESP values comparable to non-carbonaceous samples, resulting in 70% (25 out of 36 samples) being classified as 'strongly sodic' and almost all remaining being classified as 'sodic'. As such, and based solely on the high sodicity values, carbonaceous spoil is expected to be strongly sodic with potential for dispersion. Sixteen samples also underwent Emerson aggregate class testing to directly measure dispersion, which found that 3 out of 16 samples to be dispersive, 4 samples displaying some dispersion and the remaining nine samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity Potential of Rejects

Rejects samples (n=160) have EC values ranging from 56 to 1050 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 288 and 459 $\mu\text{S}/\text{cm}$, respectively. On this basis, contact water (run-off and seepage) from most rejects material is expected to be non-saline to slightly saline (<900 $\mu\text{S}/\text{cm}$). A small number of rejects samples produced moderately saline leachate. Most rejects have low-moderate total S concentrations, therefore the potential for SD (from sulphide oxidation) is low to low-moderate.

Salinity Potential of Coal

Coal samples (n=92) have EC values ranging from 12 to 788 $\mu\text{S}/\text{cm}$, with median and 90th percentile values of 132 and 347 $\mu\text{S}/\text{cm}$, respectively, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk material, is expected to be non-saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of coal samples produced slightly saline leachate.

7 Risk Assessment

7.1 Geochemical Source Hazard Assessment

7.1.1 Spoil Landform

There is a single spoil landform at DNM that will remain at closure with two residual voids located at the north of the landform (Titan North/Central void and Titan East void) and one residual void located at the south of the landform (Pandora void). The general layout of the spoil landform (and the residual voids) at closure is shown in **Figure 23**.

The landform comprises mining overburden and interburden disposed behind the active mining face to form a low-wall spoil dump, with coal rejects (MPR, fine/coarse rejects) disposed into and encapsulated by spoil. Coal rejects are trucked from the CHPP and disposed into the northern half of the landform (i.e. closest to CHPP near Titan North/Central and Titan East residual voids). Rejects compromise approximately 1.5% of all mineral waste at DNM.

At closure, the dump will be reshaped, topsoiled and seeded (refer to the PRC Plan for spoil dump rehabilitation details).

The geochemical assessment has found that, from an environmental geochemical perspective, the geochemical differences between weathered and fresh materials are relatively minor. Considering that source materials within the spoil dumps are mainly represented by fresh material, the geochemical source hazard assessment has combined weathered and fresh mineral waste.

The source hazard assessment methodology outlined in **Section 4.4.4** (AMD hazard scoring) and **Section 4.4.5** (AMD likelihood ranking) has been applied to the spoil and coal rejects materials. Based on the geological database, carbonaceous spoil (overburden/interburden) comprises approximately 6.4% of all spoil, with non-carbonaceous spoil (overburden/interburden) comprising the remaining approximately 93.6% of all spoil.

At closure, overburden/interburden materials will account for 98.5% of all mineral waste and remaining 1.5% as rejects.

DNM final spoil landform

- Overburden/interburden – non-carbonaceous (92.2%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (6.3%);
- Rejects (1.5%)

The source hazard assessment, summarised in **Table 19** for DNM landform and has found that non-carbonaceous spoil poses a Low AMD source hazard, carbonaceous/coaly spoil poses a Moderate-Low AMD source hazard and rejects poses a Moderate-High AMD source hazard. On this basis, and taking into account material quantities (proportions):

- DNM final spoil landform poses a Low AMD hazard, with AMD generation rated as Highly Unlikely.

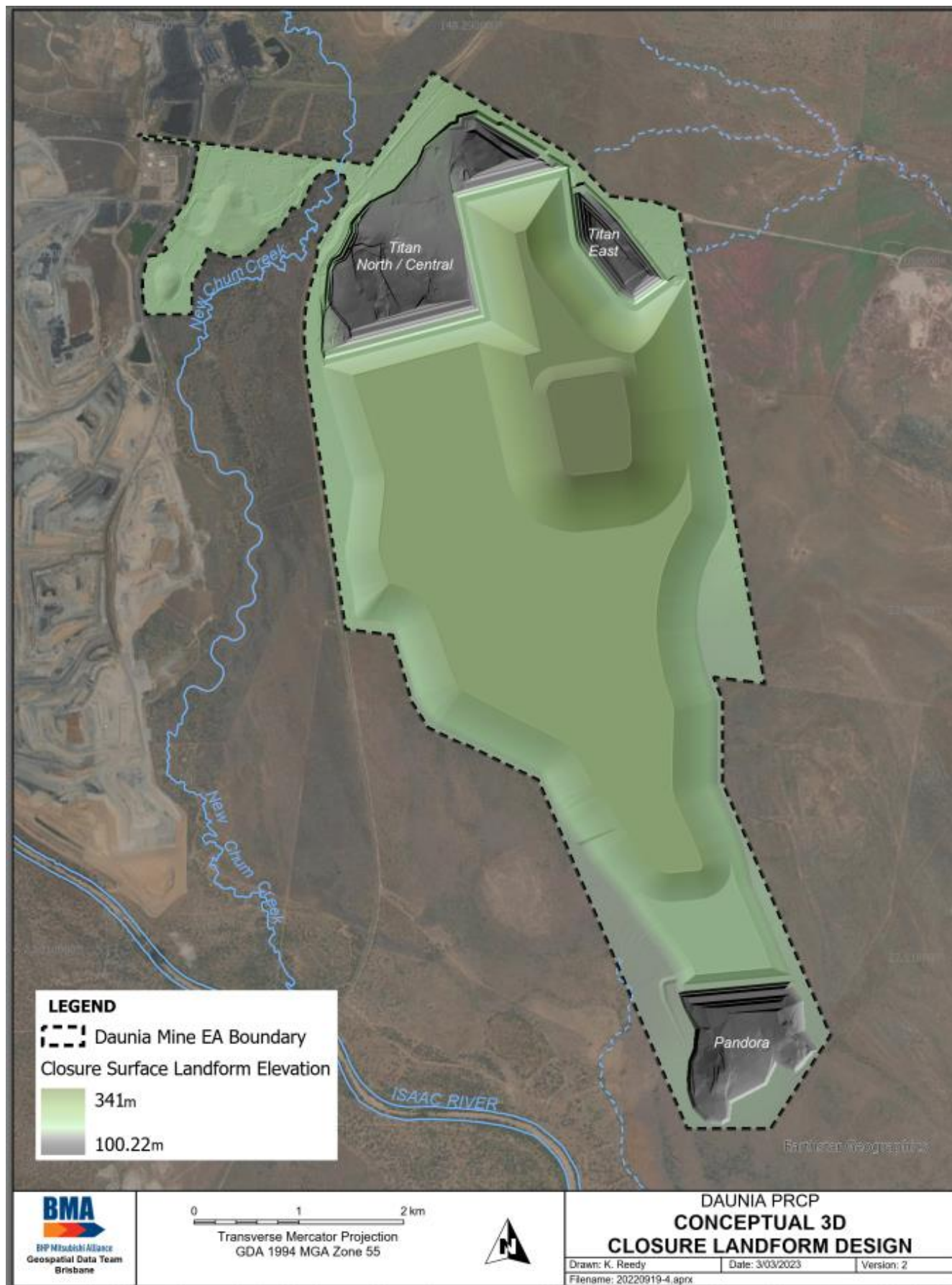


Figure 23. Closure Landform

Table 19. AMD hazard scoring for source materials and likelihood for AMD generation from DNM final landform

Landform components	Estimated material proportion within landform %	% of samples of each type as PAF	% of material in landform estimated to be PAF	Comment	AMD Propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard scoring	Likelihood for AMD generation from DNM Landform
Non-carbonaceous spoil Distributed throughout	92.2%	0.6%	0.5%	Very small proportion of PAF samples [incl. UC(PAF) and PAF-LC]. Total S is very low (75 th percentile = 0.01%). Non-carb spoil comprises at least 92% of mineral waste in DNM final landform.	1 <i>Implausible</i>	1 <i>Low</i>	1 <i>Low</i>	2 <i>Low</i>	1.0 <i>Low</i>	Bulk spoil is overwhelmingly NAF with very low sulphur and excess neutralising capacity. The hazard for AMD generation in the DNM final landform is based on 1.5% of the landform being rejects, of which about 5% is PAF and 6.3% of the landform being carbonaceous spoil, of which about 8% is conservatively estimated to be PAF. Overall, about 1.1% of the landform is expected to be either PAF, PAF-LC or UC(PAF) material. All rejects and carbonaceous spoil is buried well within non-carbonaceous spoil. All rejects are co-disposed with spoil (segregation and selective handling). Carbonaceous spoil is comingled with non-carbonaceous spoil (operating mixing). The likelihood for AMD generation from the final (spoil) landform at DNM is considered to be LOW .
Coaly and/or carbonaceous spoil Distributed throughout	6.3%	8%	0.5%	Based on sample numbers, up to 8% of coaly and carbonaceous spoil is classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75 th percentile S value of 0.11%. AMD quantity conservatively assumes proportion of PAF coaly/carb spoil samples approximates the proportion of coaly/carb spoil that is PAF. Assumes all coaly/carb spoil is distributed amongst non-carb spoil.	5 <i>Plausible</i>	5 <i>Moderate</i>	5 <i>Moderate</i>	10 <i>Moderate</i>		
Rejects	1.5%	5%	0.1%	5% of rejects are PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75 th percentile S value of 0.64%. Some rejects samples will generate AMD. AMD quantity assumes proportion of PAF rejects samples approximates the proportion of rejects that are PAF. Rejects disposed within predominantly non-carb and NAF spoil.	5 <i>Plausible</i>	7 <i>Moderate High</i>	10 <i>High</i>	14 <i>Moderate High</i>		

7.1.2 Exposed Walls and Floor

There are three residual voids remaining at DNM at closure – Titan North/Central pit, Titan East pit (north of landform) and Pandora pit (south of landform).

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD risk associated with pit highwalls and pit floors, as explained in **Sections 4.4.1 to 4.4.3**. Note that the source hazard assessment methodology outlined in **Sections 4.4.1 to 4.4.3** has been applied to the materials expected to be exposed on the pit highwalls and floor at closure.

The source materials within the highwall and floor of each pit comprise weathered and fresh materials, although fresh materials make up the large majority of exposure material. The depth of weathering is generally consistent across the site. Therefore, as mining progresses and pits become deeper, the proportion of fresh material to weathered material will increase – thus the highwall will have a greater proportion of fresh material to weathered material at end of mining.

The statistical distribution of pit highwall materials and the proportion of exposed coal seam (groups) for current and future exposures is shown in **Figure 24** for the Titan North/Central pit and **Figure 25** for Titan East pit. The statistical distribution of expected pit highwall materials and the proportion of expected exposed coal seam (groups) for Pandora pit is shown in **Figure 26**.

Based on the information from the BHP Coal geological database, all pit highwalls are dominated by weathered and fresh non-carbonaceous materials. The current exposed seams on the highwall on Titan North/Central and Titan East are the Leichhardt Seam and Lower Leichhardt Seam and are expected to comprise about 5% (Titan North/Central) and 7% (Titan East) of the pit highwalls. Remnant coal (Upper Vermont and Leichhardt seams) at Pandora pit is expected to comprise 4% of the pit highwalls.

The residual void highwall and floor assessment are summarised in **Table 20** for Titan North/Central residual void, **Table 21** for Titan East residual void and **Table 22** for Pandora. The assessment shows that the residual voids have approximately 4% to 6% of the pit highwall and approximately 48% of the pit floor – for all the pits – are estimated to be PAF, which includes material classified as PAF-LC and UC(PAF).

The assessment has found that AMD generation from the Titan North/Central, Titan East and Pandora pit highwalls is **Unlikely**. It is worth noting that the expected coal coverage of the pit floors at closure is highly conservative, as most of the coal would have been removed prior to closure. However, in this assessment it is assumed that the economical coal is left on the pit floor at the end of mining.

The assessment has found that – prior to groundwater recovery and pit floor inundation – the hazard for AMD generation from Titan North/Central, Titan East and Pandora pit floors is **Moderate**; and the likelihood for AMD generation from these pit floors is **Probable/Likely**. However, as groundwater recovers in the pits and pit floors are inundated (flooded), the likelihood for AMD generation from the flooded pit floors (of the residual voids) is **Unlikely**.

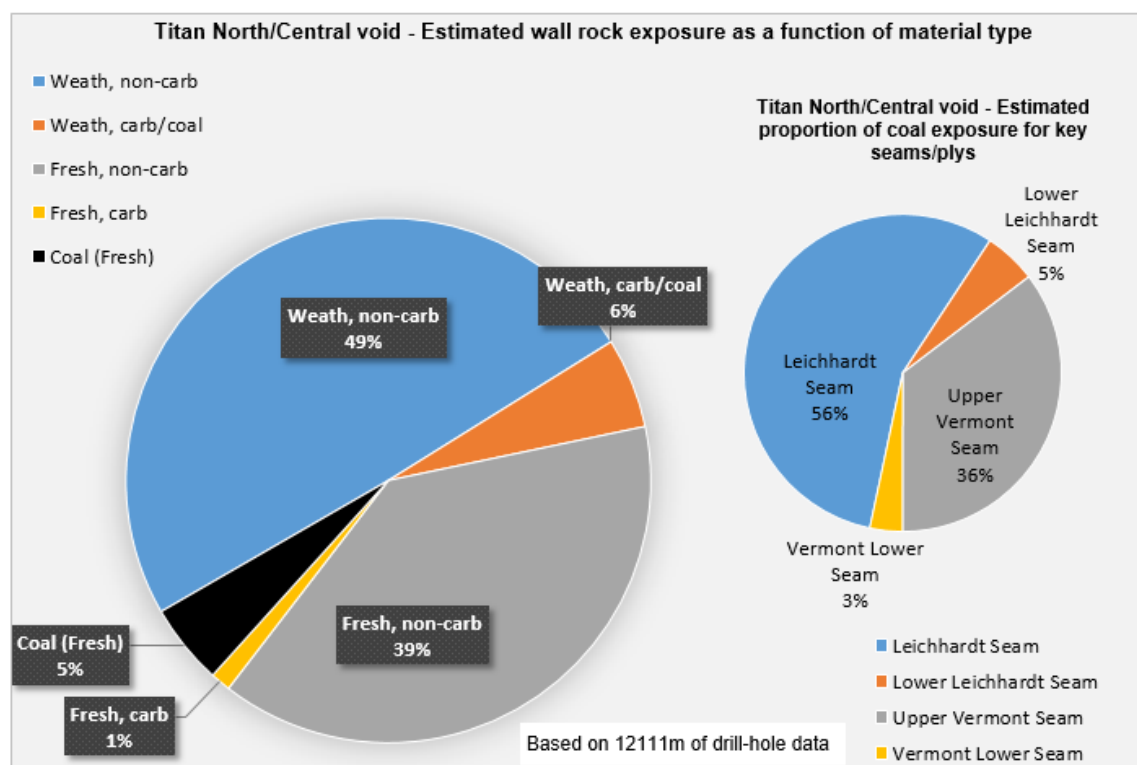


Figure 24. Estimated Titan North/Central residual void highwall exposure by material type and proportion of coal exposure

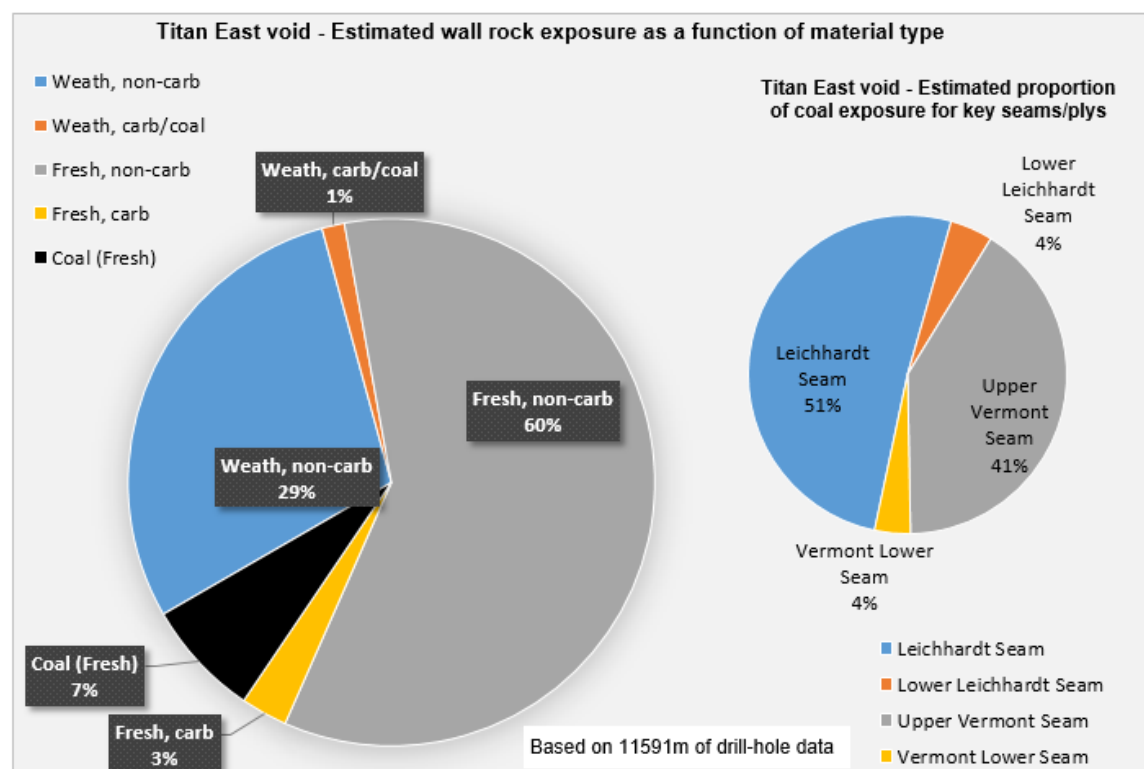


Figure 25. Estimated Titan East residual void highwall exposure by material type and proportion of coal exposure

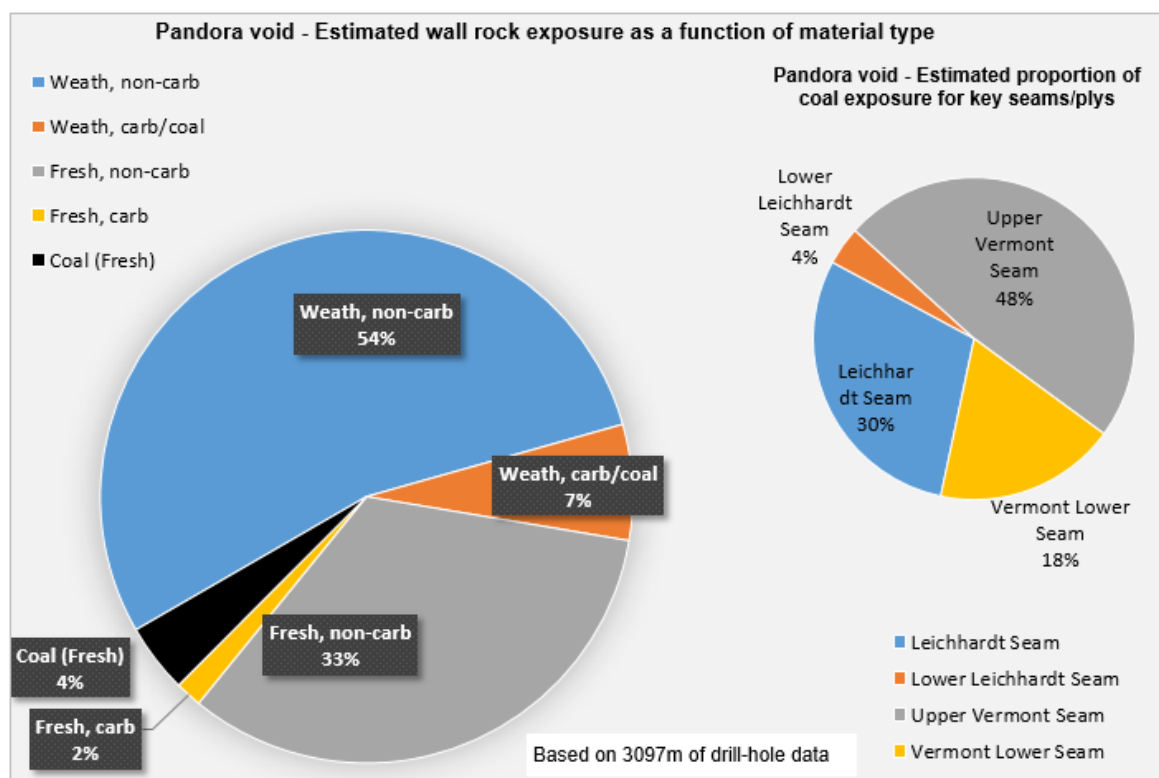


Figure 26. Estimated Pandora residual void highwall exposure by material type and proportion of coal exposure

Table 20. AMD hazard scoring for source materials and likelihood for AMD generation from Titan North/Central pit walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Titan North/Central highwall
Titan North/Central Pit Highwall	Weathered, non-carbonaceous	49.5	47%	53%	53%	0%	Total 0% of weathered non-carbonaceous samples (out of 136) were PAF-LC or PAF (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.0	This material is expected to comprise approximately 49.5% of the pit wall material by meterage. All weathered material (extremely to slightly). Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.01%.	1	1	1	2	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any.
	Weathered, carbonaceous & coaly	5.6	26%	74%	74%	9%	Approximately 9% of weathered carbonaceous or coaly samples (1 sample out of 11) was PAF-LC (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is predominantly NAF. Approximately 26% of this material is currently above the water table and would be potentially subject to oxidation.	0.5	All weathered material, 9% of the samples collected from similar geological horizons were classed as UC(PAF) or PAF-LC. This material comprises less than 1% of the exposed highwall and does not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.31%. The 75th percentile total S is 0.09%.	5	7	1	9	The potential exposure of PAF materials on the highwall is estimated to represent less than 5% (vertical meterage). PAF domains may be largely confined to coal horizons. However, these will be embededd in a matrix of NAF and ANC-rich materials.
	Fresh, non-carbonaceous	38.7	45%	55%	100%	1.0%	Approximately 1% of fresh, non-carbonaceous samples were PAF or PAF-LC or UC(PAF) (data from geochemical database) [3 out of 369 samples]. Approximately 45% of this material is currently above the water table and would be potentially subject to oxidation.	0.4	This material is estimated to comprise approximately 38.7% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. Based on the large number of samples tested (n=369) across DNM there is confidence that the proportion of PAF samples present within this material domain is negilgibly small (~1% of samples classified as UC(PAF), PAF-LC or PAF). This material horizon is overwhelmingly NAF. The 75th percentile total S value is 0.04%.	1	1	1	2	Pit wall run-off reporting to the pit void is unlikely to produce acidity.
	Fresh, carbonaceous	1.2	28%	72%	100%	8%	7 out of 93 samples (8% of samples) were PAF or UC(PAF) or PAF-LC (data from geochemical database). Approximately 28% of this material is currently above the water table and would be potentially subject to oxidation.	0.1	Generation of AMD from fresh carbonaceous units cannot be excluded as 8% of the samples tested were classed as PAF. UC(PAF) or PAF-LC. However, some carbonaceous overburden has excess ANC. The 75th percentile value for S is 0.11%.	5	7	1	9	The hazard for AMD generation from Titan North/Central highwall = LOW .
	Coal (fresh)	5.0	40%	60%	100%	48%	37 out of 77 samples (48% of samples) were PAF or PAF-LC (data from geochemical database). Approximately 40% of this material is currently above the water table and would be potentially subject to oxidation.	2.4	Fresh coal is expected to comprise about 5% of the pit wall material by meterage. Geochemical data is available for 77 coal samples sourced from across DNM seams. Of these, 8 samples were PAF and 29 were PAF-LC [i.e. 48% were PAF of some type]. The 75th percentile S value for all coal samples is low at 0.29%.	7	7	1	11	The likelihood for AMD generation from Titan North/Central highwall = UNLIKELY
	Unknown	0.0	n/a	n/a	n/a	n/a	No 'unknown' material types from drill-hole database	n/a	No 'unknown' material types from drill-hole database	-	-	-	-	
									Source Scoring (average of all domains)	4	5	1	-	
Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data								3.4	Landform Scoring (50% weighting applied to AMD capacity and quantity)	7				
Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (geochemical database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Titan North/Central Pit floor	
Titan North/Central Pit Floor	Coal: Upper Vermont Seam (V1, V2, V3, V23)	100%	0%	100%	100%	48%	PAF proportion estimated by applying a total S 'cut-off' of 0.40% to the coal quality data for Upper Vermont Seam samples (V1, V2, V3 and V23) (1499 samples). The S cut-off was based on the median total S value for PAF reject and coal samples (combined) from the geochemical database. Based on coal database, 43% of 1499 coal samples were PAF. Based on the geochemical database, 48% of 77 coal samples were PAF or PAF-LC, therefore the estimate of 48% of the pit floor being PAF is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	48%	The floor of Titan North/Central pit is likely to be Upper Vermont seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.45%. Conservatively, 43% of Upper Vermont seam coal samples from DNM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Conservatively, approximately 48% of the pit floor may comprise PAF coal. The geochemical hazard for Titan North/Central Pit floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Titan North/Central Pit floor = PROBABLE/LIKELY

Table 21. AMD hazard scoring for source materials and likelihood for AMD generation from Titan East pit walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Titan East pit highwall
Titan East Pit Highwall	Weathered, non-carbonaceous	29.1	79%	21%	21%	0%	Total 0% of weathered non-carbonaceous samples (out of 136) were PAF-LC or PAF (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.0	This material is expected to comprise approximately 29.1% of the pit wall material by meterage. All weathered material (extremely to slightly). Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.01%.	1	1	1	2	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any.
	Weathered, carbonaceous & coaly	1.4	31%	69%	69%	9%	Approximately 9% of weathered carbonaceous or coaly samples (1 sample out of 11) was PAF-LC (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is predominantly NAF. Approximately 26% of this material is currently above the water table and would be potentially subject to oxidation.	0.1	All weathered material, 9% of the samples collected from similar geological horizons were classed as UC(PAF) or PAF-LC. This material comprises less than 1.5% of the exposed highwall and does not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.31%. The 75th percentile total S is 0.09%.	5	7	1	9	The potential exposure of PAF materials on the highwall is estimated to represent less than 5% (vertical meterage). PAF domains may be largely confined to coal horizons. However, these will be embedded in a matrix of NAF and ANC-rich materials.
	Fresh, non-carbonaceous	59.5	20%	80%	100%	1%	Approximately 1% of fresh, non-carbonaceous samples were PAF or PAF-LC or UC(PAF) (data from geochemical database) [3 out of 369 samples]. Approximately 45% of this material is currently above the water table and would be potentially subject to oxidation.	0.6	This material is estimated to comprise approximately 59.5% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. Based on the large number of samples tested (n=369) across DNM there is confidence that the proportion of PAF samples present within this material domain is negligibly small (~1% of samples classified as UC(PAF), PAF-LC or PAF). This material horizon is overwhelmingly NAF. The 75th percentile total S value is 0.04%.	1	1	1	2	Pit wall run-off reporting to the pit void is unlikely to produce acidity.
	Fresh, carbonaceous	2.9	18%	82%	100%	8%	7 out of 93 samples (8% of samples) were PAF or UC(PAF) or PAF-LC (data from geochemical database). Approximately 28% of this material is currently above the water table and would be potentially subject to oxidation.	0.2	Generation of AMD from fresh carbonaceous units cannot be excluded as 8% of the samples tested were classed as PAF. UC(PAF) or PAF-LC. However, some carbonaceous overburden has excess ANC. The 75th percentile value for S is 0.11%.	5	7	1	9	The hazard for AMD generation from Titan East highwall = LOW .
	Coal (fresh)	7.2	15%	85%	100%	48%	37 out of 77 samples (48% of samples) were PAF or PAF-LC (data from geochemical database). Approximately 40% of this material is currently above the water table and would be potentially subject to oxidation.	3.5	Fresh coal is expected to comprise about 7.2% of the pit wall material by meterage. Geochemical data is available for 77 coal samples sourced from across DNM seams. Of these, 8 samples were PAF and 29 were PAF-LC [i.e. 48% were PAF of some type]. The 75th percentile S value for all coal samples is low at 0.29%.	7	7	1	11	The likelihood for AMD generation from Titan East highwall = UNLIKELY
	Unknown	0.0	n/a	n/a	n/a	n/a	No 'unknown' material types from drill-hole database	n/a	No 'unknown' material types from drill-hole database	-	-	-	-	
									Source Scoring (average of all domains)	4	5	1	-	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							4.4	Landform Scoring (50% weighting applied to AMD capacity and quantity)	7				
Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (geochemical database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Titan East Pit floor	
Titan East Pit Floor	Coal: Upper Vermont Seam (V1, V2, V3, V23)	100%	0%	100%	100%	48%	PAF proportion estimated by applying a total S 'cut-off' of 0.40% to the coal quality data for Upper Vermont Seam samples (V1, V2, V3 and V23) (1499 samples). The S cut-off was based on the median total S value for PAF reject and coal samples (combined) from the geochemical database. Based on coal database, 43% of 1499 coal samples were PAF. Based on the geochemical database, 48% of 77 coal samples were PAF or PAF-LC, therefore the estimate of 48% of the pit floor being PAF is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	48%	The floor of Titan East pit is likely to be Upper Vermont seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.45%. Conservatively, 43% of Upper Vermont seam coal samples from DNM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Conservatively, approximately 48% of the pit floor may comprise PAF coal. The geochemical hazard for Titan East Pit floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Titan East Pit floor = PROBABLE/LIKELY

Table 22. AMD hazard scoring for source materials and likelihood for AMD generation from Pandora pit walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Pandora Pit highwall
Pandora Pit Highwall	Weathered, non-carbonaceous	54	52%	48%	48%	0%	Total 0% of weathered non-carbonaceous samples (out of 136) were PAF-LC or PAF (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	0.0	This material is expected to comprise approximately 54% of the pit wall material by meterage. All weathered material (extremely to slightly). Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.01%.	1	1	1	2	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any.
	Weathered, carbonaceous & coaly	7.0	36%	64%	64%	9%	Approximately 9% of weathered carbonaceous or coaly samples (1 sample out of 11) was PAF-LC (data from geochemical database). It is expected that weathered material is completely or prodominantly oxidised and, as such, this material is predominantly NAF. Approximately 26% of this material is currently above the water table and would be potentially subject to oxidation.	0.6	All weathered material, 9% of the samples collected from similar geological horizons were classed as UC(PAF) or PAF-LC. This material comprises less than 1% of the exposed highwall and does not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.31%. The 75th percentile total S is 0.09%.	5	7	1	9	The potential exposure of PAF materials on the highwall is estimated to represent less than 5% (vertical meterage). PAF domains may be largely confined to coal horizons. However, these will be embededd in a matrix of NAF and ANC-rich materials.
	Fresh, non-carbonaceous	33.2	27%	73%	100%	1%	Approximately 1% of fresh, non-carbonaceous samples were PAF or PAF-LC or UC(PAF) (data from geochemical database) [3 out of 369 samples]. Approximately 45% of this material is currently above the water table and would be potentially subject to oxidation.	0.3	This material is estimated to comprise approximately 33.2% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. Based on the large number of samples tested (n=369) across DNM there is confidence that the proportion of PAF samples present within this material domain is negilgibly small (~3% of samples classified as UC(PAF), PAF-LC or PAF). This material horizon is overwhelmingly NAF. The 75th percentile total S value is 0.04%.	1	1	1	2	Pit wall run-off reporting to the pit void is unlikely to produce acidity.
	Fresh, carbonaceous	1.6	24%	76%	100%	8%	7 out of 93 samples (8% of samples) were PAF or UC(PAF) or PAF-LC (data from geochemical database). Approximately 28% of this material is currently above the water table and would be potentially subject to oxidation.	0.1	Generation of AMD from fresh carbonaceous units cannot be excluded as 8% of the samples tested were classed as PAF. UC(PAF) or PAF-LC. However, some carbonaceous overburden has excess ANC. The 75th percentile value for S is 0.11%.	5	7	1	9	The hazard for AMD generation from Pandora highwall = LOW .
	Coal (fresh)	4.2	20%	80%	100%	48%	37 out of 77 samples (48% of samples) were PAF or PAF-LC (data from geochemical database). Approximately 40% of this material is currently above the water table and would be potentially subject to oxidation.	2.0	Fresh coal is expected to comprise about 4.2% of the pit wall material by meterage. Geochemical data is available for 77 coal samples sourced from across DNM seams. Of these, 8 samples were PAF and 29 were PAF-LC [i.e. 48% were PAF of some type]. The 75th percentile S value for all coal samples is low at 0.29%.	7	7	1	11	The likelihood for AMD generation from Pandora highwall = UNLIKELY
	Unknown	0.0	n/a	n/a	n/a	n/a	No 'unknown' material types from drill-hole database	n/a	No 'unknown' material types from drill-hole database	-	-	-	-	
									Source Scoring (average of all domains)	4	5	1	-	
Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data								3.1	Landform Scoring (50% weighting applied to AMD capacity and quantity)	7				
Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (geochemical database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Pandora Pit floor	
Pandora Pit Floor	Coal: Upper Vermont Seam (V1, V2, V3, V23)	100%	0%	100%	100%	48%	PAF proportion estimated by applying a total S 'cut-off' of 0.40% to the coal quality data for Upper Vermont Seam samples (V1, V2, V3 and V23) (1499 samples). The S cut-off was based on the median total S value for PAF reject and coal samples (combined) from the geochemical database. Based on coal database, 43% of 1499 coal samples were PAF. Based on the geochemical database, 48% of 77 coal samples were PAF or PAF-LC, therefore the estimate of 48% of the pit floor being PAF is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	48%	The floor of Pandora pit is likely to be Upper Vermont seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.45%. Conservatively, 43% of Upper Vermont seam coal samples from DNM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	7	5	7	13	Conservatively, approximately 48% of the pit floor may comprise PAF coal. The geochemical hazard for Pandora Pit floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Pandora Pit floor = PROBABLE/LIKELY

7.2 Geochemical Source-Pathway-Risk Assessment

A post-closure conceptual site model (CSM), which applies to the spoil landform and residual voids at DNM, and the relationship that the spoil landform and residual voids have with surface water and groundwater in the district, has been produced by SLR Consultants (2023) (**Figure 27**). The CSM assists with the source-pathway-receptor (SPR) assessment with regard to potential environmental geochemical impacts from mineral waste facilities. The CSM, which focusses on the relationship with surface water and groundwater (these being the most relevant pathways and receptors for AMD and salinity), is used to illustrate the relationship between potential sources of run-off and seepage (e.g. spoil), plausible receptors (e.g. creeks and groundwater) and the pathways between the two (e.g. seepage, drainage).

The residual voids are classified as non-use management areas (NUMAs). The spoil landform is emplaced behind the residual voids and will drain into the voids. Therefore, seepage from the spoil landform and the run-off from the highwalls reports to the residual voids. Groundwater modelling undertaken by SLR (2023) shows the residual voids will ultimately be groundwater ‘sinks’ – that is, the residual voids will be receptors of run-off and seepage from the final landforms and run-off from void highwalls, as illustrated in the CSM (**Figure 27**). As such, the residual voids are not likely AMD sources of groundwater or surface water receptors.

The hydrogeological assessment undertaken for the PRCP (SLR, 2023) indicates that the nearest ‘true’ alluvial aquifer of any significant spatial extent is along the Isaac River floodplain, approximately 3 km west of DNM (from southern end). The hydrogeological assessment indicates there may be shallow permeable strata present sporadically along (and/or near to) several creeks at DNM. If shallow groundwater is present, then, it is expected to be well below the base of all creeks in the area; suggesting that connectivity between shallow permeable strata and surface water feature at DNM is unlikely. Furthermore, groundwater modelling (including particle tracking) undertaken by SLR for the PRCP found no evidence of connectivity between groundwater and surface water features. The model suggests that shallow groundwater (and by extension shallow seepage) migrating through the site will be eventually report to the residual voids. The general downward migration of shallow groundwater (and seepage) into deeper groundwater and towards the mine pits (residual voids) is logical, given the very large drawdown (sink) of the pits.

The assessment of shallow groundwater at DNM – particularly where shallow permeable strata may not be present in some areas, may be discontinuous and/or not interconnected – is limited by/to the distribution of the shallow bore network, which is sporadic. Therefore, despite the apparent low likelihood of substantial connection between shallow permeable strata and surface water features, the SPR assessment has adopted a highly conservative approach and assumed a plausible pathway may exist between shallow permeable strata and surface water features.

In an event of significant rainfall, New Chum Creek which is in close vicinity of Titan North/Central dump landform could be a plausible receptor for run-off from Titan North/Central dump. In such significant rainfall events, New Chum Creek provides recharge to Isaac River Alluvium. There are three unnamed tributaries of North Creek, north and northeast of the ML. The head of these tributaries are located on the highwall side of the Titan North/Central and Titan East residual voids and, as such, are implausible receptors for significant surface water run-off from the site.

At the southern end of DNM, an unnamed tributary (**Figure 1**) drain into Isaac River within close proximity to Pandora residual void. During significant rainfall events Isaac River wetlands could be a plausible receptors of run-off from the spoil landform near Pandora void (i.e. the southern end of the spoil landform) due to its distance from the unnamed tributary (approximately 1.5 km) and Isaac River (approximately 3 km).

For assessing the sources, plausible receptors and potential pathways between the sources and receptor, it is assumed that the overwhelmingly majority of spoil is in-pit and sediments have been mined out to the base of the Vermont Upper (V2/3) coal seams, as indicatively illustrated in the CSM (**Figure 25**).

With regard to the post-closure mineral waste facilities (spoil landform and residual voids), the plausible mechanism for AMD affected water and/or non-oxidative salinity to report to receptors are identified in **Table 23**.

Table 23. Sources, plausible receptors and potential pathways between the source and receptor

Source	Potential Pathway	Plausible Receptor
Spoil landform zones		
Titan North/Central (i.e. northern zone of the spoil landform)	Surface water run-off	• New Chum Creek • Titan North/Central residual void
	Seepage [shallow permeable strata]	• New Chum Creek
	Seepage [groundwater]	• Titan North/Central residual void
Titan East dump (i.e. north-eastern zone of the spoil landform)	Surface water run-off	• Titan East residual void
	Seepage [groundwater]	• Titan East residual void
Pandora dump (i.e. southern zone of the spoil landform)	Surface water run-off	• Isaac River • Pandora residual void
	Seepage [shallow permeable strata]	• Isaac River
	Seepage [groundwater]	• Pandora residual void
Void highwalls		
Titan North/Central	Surface water run-off	• Titan North/Central residual void
Titan East	Surface water run-off	• Titan East residual void
Pandora	Surface water run-off	• Pandora residual void

SW

NE

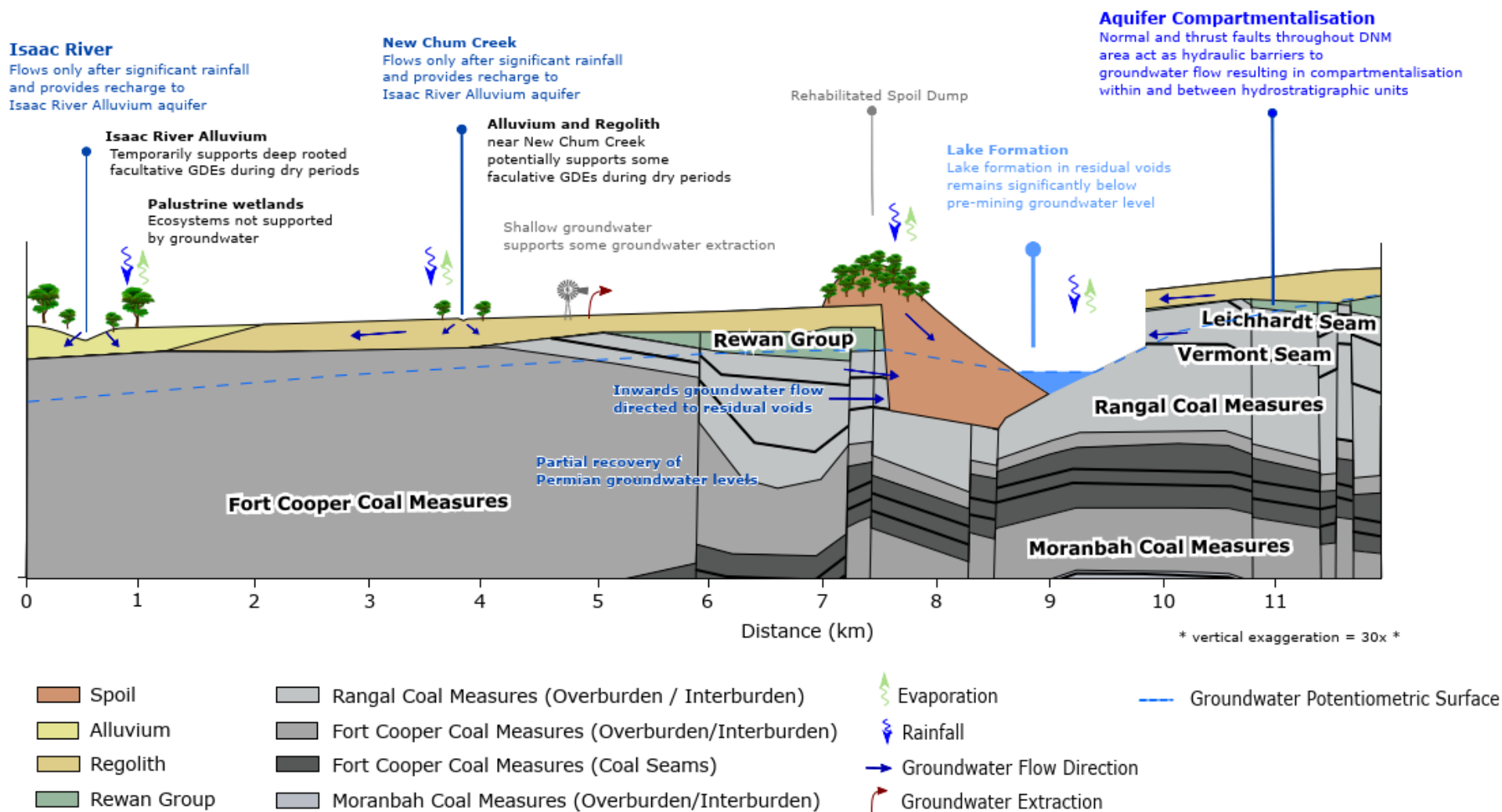


Figure 27. Source-Pathway-Receptor (SPR) conceptual site model post-closure (SLR, 2023)

The geochemical source hazard assessment (**Section 7.1**) found that the landform, which comprises approximately 92% non-carbonaceous spoil, had an AMD hazard score of 'Low', with AMD generation from the single DNM landform as 'Highly Unlikely'.

The BHP residual risk heating map (**Table 24**) has been adopted to assess the risks associated with the SPR assessment from the single DNM landform.

In reference to the Risk Matrix, the SPR assessment includes the likelihood of the event occurring, the severity of the event (should it occur) and the calculated risk rating (likelihood x severity).

Table 24. Risk matrix for SPR assessment

Risk Rating = Likelihood x Severity		Severity				
		S1	S2	S3	S4	S5
Likelihood	Highly Likely	Medium	Medium to High	High	High	High
	Likely	Low to Medium	Medium	Medium to High	High	High
	Probable	Low	Low to Medium	Medium	Medium to High	High
	Unlikely	Low	Low	Low to Medium	Medium	Medium to High
	Highly Unlikely	Low	Low	Low	Low to Medium	Medium

The risk rating for the spoil dump final landform with respect to plausible surface water and residual void receptors is shown in **Table 25** and **Table 26**, respectively and discussed in **Section 7.2.1**. The risk rating for the residual voids with respect to the void receptor is shown in **Table 27** and discussed in **Section 7.2.2**. The potential impact of seepage, if any, from the residual voids into the Permian groundwater aquifer is discussed in the void closure plan (WSP, 2023).

The overall rating of the Source assessment showed that the risk rating for AMD to impact receptors is Low; and the risk rating for non-oxidative salinity to impact receptors is conservatively rated as Low based on 75th percentile EC value applied to the source.

The assessment shows that all receptors are at low risk of direct environmental impact from mineral waste with respect to AMD (including acid/acidity, NMD and SD) and non-oxidative salinity.

The 'Low' risk rating was assigned with consideration for the key aspects for each key facility/domain.

7.2.1 Final spoil landform (rehabilitated spoil dump)

Source materials hazard

The spoil landform is comprised of approximately 92% non-carbonaceous overburden/interburden with coaly and carbonaceous material (predominantly in the form of rejects) comprising the remaining 8% of the final landforms. Non-carbonaceous overburden/interburden from Permian-age material in the Bowen Basin is widely recognised as posing a low-moderate AMD risk. Rejects at DNM poses a moderate AMD hazard, however is disposed (encapsulated) well within general spoil and does not report to final landform surfaces.

Source materials generally have low to low-moderate EC values and are expected to produce slightly to moderately saline run-off and seepage, with release of (non-oxidative) salinity rated as a low-hazard. The overall low total S and excess ANC of the combined mineral waste materials results in a 'Highly Unlikely' hazard score for AMD generation.

Pathways

Surface water

The closest surface water receptors to the Titan North/Central dump zone (i.e. the northern end) of the final landform is New Chum Creek located within 300 m from the western extent of the final landform. Therefore, it is plausible for surface water run-off from the rehabilitated landform to reach New Chum Creek.

The closest surface water receptor to the Pandora dump zone (i.e. the southern end) of the final landform is an unnamed tributary that drains into the Isaac River. The unnamed tributary is within 200 m of the southern zone of the landform. Therefore, it is plausible for surface water run-off from the southern zone of the final landform to reach the unnamed tributary draining into the Isaac River.

Seepage

The water table is expected to intersect the deeper zones of the in-pit final landform within the Permian Rangel Coal Measures (SLR, 2023). It is plausible for seepage from the near-surface and unsaturated zone of the in-pit final landforms to migrate downwards into the water table. However, groundwater is captured by the residual void, which is a groundwater sink, in the long-term. Therefore, although a direct connection is expected to exist between deeper parts of the residual void and groundwater (the water table), the local groundwater will report and be contained within the residual void.

Receptors

Plausible receptors identified in this qualitative assessment include the ephemeral New Chum Creek (and an unnamed creek), the Isaac River and the residual voids. Due to the geochemical nature of the final landform, the likelihood of undiluted salinity or AMD (if any) to impact on the water quality of surface water receptors or final void water quality has been rated 'Highly Unlikely'.

Consideration was also made to people living in the homesteads near DNM, of which the closest is 'Olive Downs' located approximately 1 km west of the ML boundary as the far southern end of the site. Groundwater modelling shows Pandora residual void to be 'groundwater sink' - that is, the Pandora residual void will be a receptor of run-off and seepage from the southern zone of the final landform and run-off from the Pandora pit highwall, as conceptually illustrated in the CSM (**Figure 27**). There is also an unnamed tributary (ephemeral drainage gully) located between the Olive Downs homestead and the southern zone of the landform. This gully would intersect (capture) surface water run-off from the landform, if any. Therefore, the potential for Olive Downs homestead to be impacted by AMD or saline drainage from the final landform is implausible.

SPR risk rating of final landforms

There are plausible surface water and final void receptors and the run-off and seepage pathways linking the sources (final spoil landforms) to these receptors have been identified. However, the mineral waste materials within the final spoil landforms (source) pose a low AMD and non-oxidative salinity hazard. Therefore, the overall SPR risk rating from the final spoil landform is **Low**.

7.2.2 Residual voids

Source materials hazard

The surfaces of residual void highwalls comprise approximately 87 to 88% non-carbonaceous overburden/interburden, about 4 to 6% coaly and carbonaceous overburden/interburden and about 4 to 7% coal (seams). Approximately 49% of the current Titan North/Central Pit highwall and approximately 29% of the current Titan East Pit highwall and 54% of the Pandora Pit highwall at closure are predicted to comprise weathered non-carbonaceous material. Fresh and weathered non-carbonaceous overburden/interburden from Permian-age material in the Bowen Basin is widely recognised as posing a low AMD risk. Coal seams at DNM pose a low to moderate AMD risk.

Generally, highwall materials have low EC values, with release of (non-oxidative) salinity rated as a low-hazard.

Overall, the hazard for AMD of residual void highwall material is low and the likelihood for AMD generation from final void highwalls is 'Unlikely'.

Pit floor (comprised of Upper Vermont seam in each void) is conservatively estimated to comprise approximately 48% PAF coal – assuming 100% of the floor is coal and not some other material. The pit floor (of each residual void), as described, poses a moderate AMD hazard – which does not take into account likely mitigating factors, such as pit floor flooding. After flooding, the pit floor (of each void) would be expected to pose a low AMD hazard.

Pathways

Surface water

There are no plausible pathways between the residual voids and surface water. Surface water run-off from the void highwall will report to the void lake and, therefore, will remain within the final void.

Seepage

Each residual void will act as a groundwater sink and the water table will intersect the deeper zones of each void, resulting in the formation of a relatively small pit lake within each void (SLR, 2023; and **Figure 27**) that will submerge the pit floor and lower section of the pit highwall. Seepage from the final landform (low-wall of the spoil dump) and run-off from the highwall will report to the residual void closest to that part of the spoil landform.

Receptors

Modelling undertaken by SLR (2023) shows the final voids to be 'sinks' – receiving surface water run-off and seepage from final landforms and surface water run-off from pit (void) highwalls. The final void are expected to receive inflow from the Permian groundwater aquifer. The water quality of the pit void and potential impact of water seeping, if any, from the final voids into the Permian groundwater aquifer will be discussed in the void closure plan (WSP, 2023).

Due to the geochemical nature of the materials exposed in the highwall of each void, the likelihood of undiluted salinity or AMD (if any) to impact on final void water quality has been rated 'Highly Unlikely'.

Pit floor (final void floor) will be covered post-closure by water as groundwater partially recovers and forms a pit lake. As such, PAF coal will no longer be exposed to atmospheric conditions and the risk of AMD being generated is greatly reduced. The likelihood of undiluted salinity or AMD from a flooded post-closure final void floor to impact on final void water quality to any significant degree has been rated 'Unlikely'.

Consideration was also made to people living in the homesteads near the project area, of which the closest is 'Olive Downs Homestead' located approximately 1 km west of the ML boundary at the far southern end of the site and, post-closure, will be located over 1 km from the Pandora Pit residual void. The potential for this homestead to be impacted by AMD from the Pandora residual void is implausible.

SPR risk rating of residual voids

The final receptors for seepage from the low-wall of the final landform and run-off from the highwall are the three residual voids. The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure final void floor (of any of the voids) would impact on final void water quality to any significant degree, as other processes such as evapoconcentration are the key drivers of residual void water quality (WSP, 2023; SLR, 2023). Therefore, the AMD SPR risk rating on the overall water quality of the residual voids is **Low** for each void.

Groundwater or surface water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2023) shows that seepage from the pit lake of each void into groundwater, if any, would be limited.

Table 25. Source-Pathway-Receptor (SPR) assessment of spoil landform (to surface water receptors)

Source	Pathway	Receptor	Event (potential harm)	Likelihood of Event	Severity of Event	Risk Rating
<i>Titan North/Central, Titan East and Pandora spoil dump final landforms (post-closure)</i> <i>Comprised of approximately 92.2% non-carbonaceous overburden, approximately 6.3% coaly and carbonaceous material and 1.5% rejects material.</i> <i>AMD source hazard: Low</i> <i>Salinity (non-oxidative) source hazard: Probable</i>	Surface water run-off from Titan North/Central landform into ephemeral New Chum Creek that flows into Isaac River. Distance ~1 km to receptor (north-west) <i>Potential for AMD to enter pathway: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to enter pathway: Unlikely</i>	Ephemeral creek (New Chum Creek @ northern-western end of Titan landform and ML boundary) <i>Potential for AMD to reach receptor: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to reach receptor: Unlikely</i>	Acid/acidic drainage Low pH water impacting surface water	Unlikely	S1	Low
			Neutral metalliferous drainage Metals impacting surface water	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting surface water	Unlikely	S1	Low
			Saline drainage (non-oxidative) Salt impacting surface water	Unlikely	S1	Low
	Surface water run-off from Pandora landform into ephemeral unnamed tributary, which flows into the Isaac River. Distance ~200 m to receptor (west) <i>Potential for AMD to enter pathway: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to enter pathway: Probable</i>	Ephemeral creek (Unnamed Tributary draining into the Isaac River @ western end of Pandora landform). <i>Potential for AMD to reach receptor: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to reach receptor: Probable</i>	Acid/acidic drainage Low pH water impacting surface water	Unlikely	S1	Low
			Neutral metalliferous drainage Metals impacting surface water	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting surface water	Unlikely	S1	Low
			Saline drainage (non-oxidative) Salt impacting surface water	Probable	S2	Low to Medium

Table 26. Source-Pathway-Receptor (SPR) assessment of final spoil landform (to residual void receptor)

Source	Pathway	Receptor	Event (potential harm)	Likelihood of Event	Severity of Event	Risk Rating
Titan North/Central, Titan East and Pandora spoil dump final landforms (post-closure) <i>Comprised of approximately 92% non-carbonaceous overburden, approximately 6.5% coaly and carbonaceous material and 1.5% rejects material.</i> AMD source hazard: Low Salinity (non-oxidative) source hazard: Probable	Seepage / percolations into groundwater, which flows into residual voids. Residual voids are expected to intersect the water table. Residual voids are groundwater 'sinks', drawing al groundwater within landform catchment towards residual void. <i>Potential for AMD to enter pathway: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to enter pathway: Probable</i>	Residual voids (NUMA's) <i>Potential for AMD to reach residual receptor void: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to reach residual void: Unlikely</i>	Acid/acidic drainage Low pH water impacting residual void water quality	Unlikely	S1	Low
			Neutral metalliferous drainage Metals impacting residual void water quality	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting residual void water quality	Unlikely	S1	Low
			Saline drainage Salt impacting residual void water quality	Unlikely	S2	Low

Table 27. Source-Pathway-Receptor (SPR) assessment of highwall and floor (to residual void receptor)

Source	Pathway	Receptor	Event (potential harm)	Likelihood of Event	Severity of Event	Risk Rating
Titan North/Central, Titan East and Pandora pit highwall and pit floor (post-closure) Highwalls comprised of approximately 86 to 88% non-carbonaceous overburden and approximately 12 to 14% coaly and carbonaceous material including coal seams. PAF exposure on highwalls expected to be less than 6% (vertical meterage). PAF exposure on pit floors conservatively estimated at approximately 48%, however pit floors will be submerged AMD source hazard from exposed highwalls and submerged pit floors: Low Salinity (non-oxidative) source hazard: Probable	Surface water run-off from highwall into residual void. All voids are groundwater sinks. <i>Potential for AMD to enter pathway: Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to enter pathway: Probable</i>	Residual voids (NUMA's) <i>Potential for AMD to reach receptor (residual void): Unlikely</i> <i>Potential for salt (non-oxidative) >900 µS/cm to reach residual void: Unlikely</i>	Acid/acidic drainage Low pH water impacting residual void water quality	Highly Unlikely	S1	Low
			Neutral metalliferous drainage Metals impacting residual void water quality	Unlikely	S1	Low
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting residual void water quality	Highly Unlikely	S1	Low
			Saline drainage Salt impacting residual void water quality	Unlikely	S2	Low

8 Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by mineral wastes likely to be present at closure are low. As such, no specific AMD management measures (e.g. alkaline amendment or capping systems) are expected to be required to manage mineral wastes during rehabilitation and closure – outside of operational mixing/burial of carbonaceous spoil and / or rejects, spoil placement and landform reshaping activities already proposed (refer to the main volume of the PRCP).

- Residual voids:
 - Titan North / Central void;
 - Titan East void; and
 - Pandora void.
- Spoil dumps: will be reshaped, covered with soil and seeded.
- Rejects: Managed during operations (disposed within spoil) and progressively covered by spoil. No additional remediation for the rejects (at closure) is required. The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment prior to covering.
- ROM pad and coal stockpiles: Remove remnant coal and dispose within spoil. The areas will be reshaped where required, covered with soil, ripped and seeded.

Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

9 Forward Work Program

The environmental geochemical characterisation and assessment of mineral waste samples outlined in this report is representative of the mineral waste materials likely to require rehabilitation at closure. However, BHP will continue to undertake sampling of likely mineral waste materials (and subsequent characterisation and assessment of those samples) from DNM during operations and into decommissioning – to validate the findings of the current assessment, ensure the risks continue to be understood and the management measures proposed are commensurate with the risks. Where required, management measures will be revised and implemented.

10 References

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EROSION AND LANDFORM EVOLUTION SIMULATIONS TO SUPPORT WASTE LANDFORM DESIGN: DAUNIA MINE

November 2022



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1 SUMMARY

For waste landforms at Daunia Mine, Landloch Pty Ltd has completed:

- initial WEPP runoff/erosion model simulations;
- derivation of parameters for the SIBERIA landform evolution model; and
- landform evolution simulations for 3-dimensional waste landforms provided by BHP.

All WEPP simulations considered:

- batter slopes 140 m high,
- gradients ranging from 15% to 25%, and
- vegetation cover levels ranging from 50 – 80% surface contact cover.

Erodibility data for materials considered in WEPP simulations were sourced from previous Daunia studies, and included:

- Topsoil D1, which is a clay soil;
- Tertiary waste D3, which is a sodic weathered material of clay texture; and
- A mix of Permian waste D5 with topsoil D1.

The D5 Permian waste sample had limited fine material and therefore extremely high permeability. This material would create a final surface protected by rock armour, and the addition of fine material (similar to the topsoil D1 or equivalent) to the rocky waste, plus ameliorants, would create an alternative growth medium to retain water and nutrients and support plant growth. For modelling purposes, it was assumed that the D5 waste sourced would have a D_{50} of 55 mm, so that critical flow shear stress for rill initiation is close to 35 Pa.

In deriving and applying SIBERIA parameters, it was assumed that:

- Topsoil D1 will be placed on outer batter slopes on 15% gradient and vegetation (largely grass) cover of $\geq 80\%$ will be established.
- Alternative (manufactured) growth medium with properties consistent with D5 mixed with D1 and amended to create a manufactured growth medium will be used to construct low walls on 25% gradient, supporting vegetation cover of $\geq 50\%$.

It is considered that those simulations cover all of the options currently being considered for Daunia landforms.

Final landforms were developed by BHP on the basis of the WEPP output, and landform evolution simulations carried out. Model output for a period of 300 years showed both outer batter slopes and low wall batters to erode at rates consistent with erosion targets.

2 INTRODUCTION

2.1 Overview

Landloch has been engaged by BMA to carry out specific specialist studies for soils and capping, landform design and cover design, to provide information for the subsequent compilation of transitional Progressive Rehabilitation and Closure Plans (PRCPs) for its existing operational coal assets located within the Bowen Basin.

This report specifically considers the design of stable waste landforms on the Daunia Mine (DNM).

2.2 Objectives of landform design

The key consideration for landform design is to demonstrate that the landforms can confidently be expected to be stable over the long term, while supporting the target Post Mining Land Use (PMLU). As part of that assessment, this study reports:

- Materials to be used in landform rehabilitation and their erodibility;
- Erosion assessments for a range of material and slope profile options, considering interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify options that will achieve acceptable erosion rates over a 100-year period; and
- Landform evolution simulations using the SIBERIA landform evolution model (LEM) to assess stability of 3-dimensional waste landform designs over a period of 300 years.

3 LANDFORM STUDY METHODS

The landform study consisted of four stages:

- a) Sourcing and review of input data and information;
- b) Simulations of runoff and erosion for a range of landform options using the WEPP model (Flanagan and Livingston 1995);
- c) Derivation of parameters for the SIBERIA LEM (Willgoose et al. 1989); and
- d) Landform evolution simulations using SIBERIA for landforms provided by BHP.

3.1 Data sources

Soil erodibility parameters for the WEPP runoff/erosion model were taken from a previous study for the Daunia Mine (Landloch (2017)).

3.1.1 Topsoils

Preliminary soil mapping for the site (GT Environmental 2012) indicated that the bulk of the area was occupied by two soil units (termed DB1 and DB2 in that report) that are quite similar in properties. When Landloch (2017) investigated soil erodibility, grab samples of soil were taken from topsoil stockpiles at the north and south of the mine that would represent DB1 and DB2 respectively. Analysis of those samples showed minimal

difference between the two topsoil samples in terms of chemical and physical properties, and on that basis, Landloch concluded that one topsoil (termed D1 in Landloch's study) was representative of the bulk of the topsoil on the site.

3.1.2 Wastes

Three Daunia mine wastes were investigated by Landloch. These were:

- A finely textured weathered Tertiary waste (D3); and
- Two blocky Permian wastes (D5 and D6).

Photographs of the various soil and waste materials tested by Landloch (2017) are shown in Figures 1 and 2.



Figure 1: Flumes showing application of flow to D1 (topsoil) (left) & D3 (tertiary) (right) samples.



Figure 2: Flumes of Permian waste rock (left) (sample D6), showing surface flow developing on the lower half of the plot only, and of waste rock (D5) mixed with topsoil (D1) (right) prior to application of flow.

The extremely high permeability of the coarse Permian rock samples created difficulties for the experimental measurement of erodibility parameters, as it was not possible to measure infiltration capacity, which simply exceeded the capacity of the measurement methods (Landloch 2017).

Flume studies had a similar problem with high permeability of the coarse materials, so flumes were run with a 4:1 mix of D5:D1 (coarse waste:topsoil), and parameters for the D5:topsoil mix were derived from that data – with some amendment where considered appropriate (Landloch 2017).

3.1.3 Erosion model parameters used

For the topsoil (D1), measured erodibility parameters as reported in Landloch (2017) were used. For a waste:topsoil mixture (assumed representative of an alternative or manufactured growth medium), critical shear and rill detachment values reported by Landloch (2017) for the D5:topsoil mixture were used.

However, on the basis that the fine component mixed with rock has potential to control infiltration (if all large voids are filled with fines), a steady infiltration rate and hydraulic conductivity somewhat lower than that reported for the D5:topsoil mix by Landloch (2017) was adopted. It was decided to assign the steady infiltration rate and hydraulic conductivity measured for the Tertiary waste D3. These values are approximately twice the values determined experimentally for D1, but considerably lower than the hydraulic conductivity value suggested in Landloch (2017). This was done because - in Landloch's experience - rock:topsoil mixtures commonly, though by no means always, have steady infiltration rates similar to those of the topsoil alone. In this case, the infiltration parameter adopted represents a conservative approach to describing the runoff potential of that mixture.

The sediment settling velocity distribution measured for D1 was input to the model for all simulations.

3.2 WEPP simulations

3.2.1 Slopes and materials

WEPP simulations were carried out for:

- Batter slopes 140 m high, at 15% gradient, surfaced with topsoil D1 with vegetation cover levels of 50%- 80%.
- Batter slopes 140 m high, at 25% gradient, surfaced with a manufactured growth medium with assumed erodibility properties of a 4:1 blend of D5:D1 waste:topsoil, either bare or with 50% vegetation cover.

3.2.2 Vegetation impacts

Impacts of vegetation cover on infiltration rates were estimated using the relationship between vegetative cover reported by Kato et al. (2009), and direct impacts of cover on erosion rates were estimated using Cover (C) factors for the Revised Universal Soil Loss Equation (RUSLE) (Renard et al. (1993) listed in Rosewell (1993).

A monitoring report for Daunia (ELA 2019) reports vegetative cover of 95% on a site rehabilitated six years earlier. Similarly, Landloch (2017) noted high levels of vegetative cover (Figure 3).



Figure 3: Groundcover (grass) on rehabilitated area, Daunia Mine (Landloch 2017)).

Consequently, it was concluded that vegetative cover levels $\geq 80\%$ are achievable on rehabilitation carried out on topsoil at Daunia Mine. As a conservative approach, erosion simulations considered a cover level of 50% for materials of potentially lower fertility (wastes/alternative growth medium) and 50-80% for more fertile materials (topsoils).

3.2.3 Assumptions with respect to effects of cover on erosion

Two points should be noted:

- a) In considering “vegetation cover” or “surface cover”, this report specifically considers contact cover of vegetation on the soil surface. Practically, this means a combination of grass cover and anchored (not readily moved) surface litter.
- b) Considerations of surface cover do not include rock. Where rocky materials have had erodibility measured experimentally and those parameters are used in WEPP simulations, then effects of the rock are already accounted for within the parameters used.

3.2.4 Climate

All simulations used a synthetic 100-year climate file prepared to match all relevant characteristics of Moranbah climate.

3.2.5 Key assumptions – landforms and vegetation

The simulations are based on two key assumptions:

- a) There will be no uncontrolled discharge of runoff from landform tops onto outer batter slopes; and
- b) The assumed vegetative cover levels will be achieved sustainably, with those levels being set as triggers for investigation and remedial action should monitoring indicate that they are not being achieved.

It should be recognised there are also underlying assumptions of good rehabilitation practice such that:

- there will not be discharges of concentrated flows onto any batter slopes at any point of their rehabilitation;
- batter slopes will not be formed with flow-concentrating profiles (e.g. variations in surface elevation such that there is cross-slope concentration of flow into consistent depressions running downslope);
- any cross-slope ripping will be carried out strictly on the contour; and
- soil management (including stripping, stockpiling, replacement, amendment, and fertilisation) will be carried out effectively to maximise early and continuing plant growth.

3.2.6 Soil loss targets

This study used runoff, and erosion modelling to identify landform options that would erode at rates low enough to provide long-term stability. Effectively, the landforms are planned to be consistent with tolerable rates of soil loss. Wischmeier and Smith (1978) defined tolerable soil loss for cropland as "the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely."

A value of 11.2 t/ha/y averaged over an area of interest is often cited as a tolerable soil loss rate, but that value was derived by US soil conservation agencies for deep, fertile cultivated soils, and has little relevance to most rehabilitated minesites. Using similar criteria to those applied for crop land, a lower soil loss tolerance value of 4.5 t/ha/y was developed by US agencies for erosion of rangeland soils and shallow cultivated soils (Wight and Siddoway 1979).

Lower tolerance values are relevant to rangeland and minesite situations, as not only are the soils shallower and more susceptible to fertility decline, but the lack of regular tillage or disturbance means that any rills or points of scour that form are more likely to extend and develop into gullies over time. These are typically of concern for minesite landforms where there is no bedrock layer at depth to limit long-term depths of incision.

For that reason, a key priority in setting a tolerable erosion target is the prevention of significant rill or gully development. On that basis, for slopes where long-term erosion risk (for a range of reasons) is considered high, then a maximum rate of erosion of 5

t/ha/y at any point on the batter slopes being modelled has commonly been applied by Landloch on the basis that - at that value - rilling is largely if not completely absent.

Typically, the high risk category includes slopes where the overall landform height is greater than 50 metres, and situations where – due to either or both rainfall limitations or soil fertility concerns – vegetation growth is unlikely to rapidly colonise and stabilise any rills that form.

As the landforms at Daunia are planned to be considerably higher than 50 metres, the adopted target erosion value for this assessment is a maximum at any point of the outer batter slopes of 5 t/ha/y. However, for low wall slopes that drain to pits, there are no potential off-site impacts of erosion, and planned PMLU is typically native vegetation. For those situations, a slightly higher erosion target (a maximum of 10 t/ha/y) has been adopted.

The elimination of rilling greatly reduces the potential for channelised flow to form gullies, and experience to date with a large number of waste landforms designed by Landloch has shown that the target soil loss values adopted have achieved acceptable levels of stability to erosion.

3.3 Derivation of SIBERIA parameters

To run SIBERIA, the parameters β_1 , m_1 , n_1 , β_3 , and m_3 are usually needed. However, if the batter area to be modelled is identical to the batter for which erosion data are available for calibration, m_3 and β_3 can be taken as 1.0 (Willgoose, pers. comm.), and a value of $n_1 = 1.5$ can be adopted for situations where slope gradient does not affect slope erodibility (Willgoose, pers. comm.). Therefore, the two key parameters that require derivation are β_1 and m_1 .

Effectively, the β_1 parameter could be described as a “rate parameter”, as it primarily controls the rate of sediment movement. The m_1 parameter could be considered as primarily controlling slope length responses. However, in practice, there is interaction between all of the parameters with the result that an almost infinite number of parameter sets will all show the same rate of erosion though some aspects of the pattern of erosion that is predicted will vary. It is for this reason that, where possible, fixed values of n_1 and m_3 are adopted – thereby reducing the difficulty of deriving parameter values.

Input parameters for SIBERIA are typically derived by fitting the various model equations to time series data of runoff and erosion. To generate the necessary data, Landloch has developed method that involves:

- Run the WEPP model to generate data sets of runoff and erosion for slopes consistent with the proposed landforms and for materials of interest using site specific climate data.
- Analyse the WEPP output to derive the required SIBERIA input parameters.

This approach ensures that SIBERIA parameters are effectively benchmarked to the WEPP output, and thereby, effectively based on measured erodibility parameters for site materials and on-site climate.

3.4 Landform evolution simulations

Proposed final landforms for Daunia Mine were provided by BHP in .dxf format. These landforms were designed on the basis of WEPP model runoff/erosion results for potential surface covers to be applied (Figure 4).

The landforms include areas of level dump top that will not discharge onto the adjoining batter slopes. Inclusion of that design feature greatly reduces the risk of high rates of erosion on the adjoining batters and is, therefore, strongly recommended.

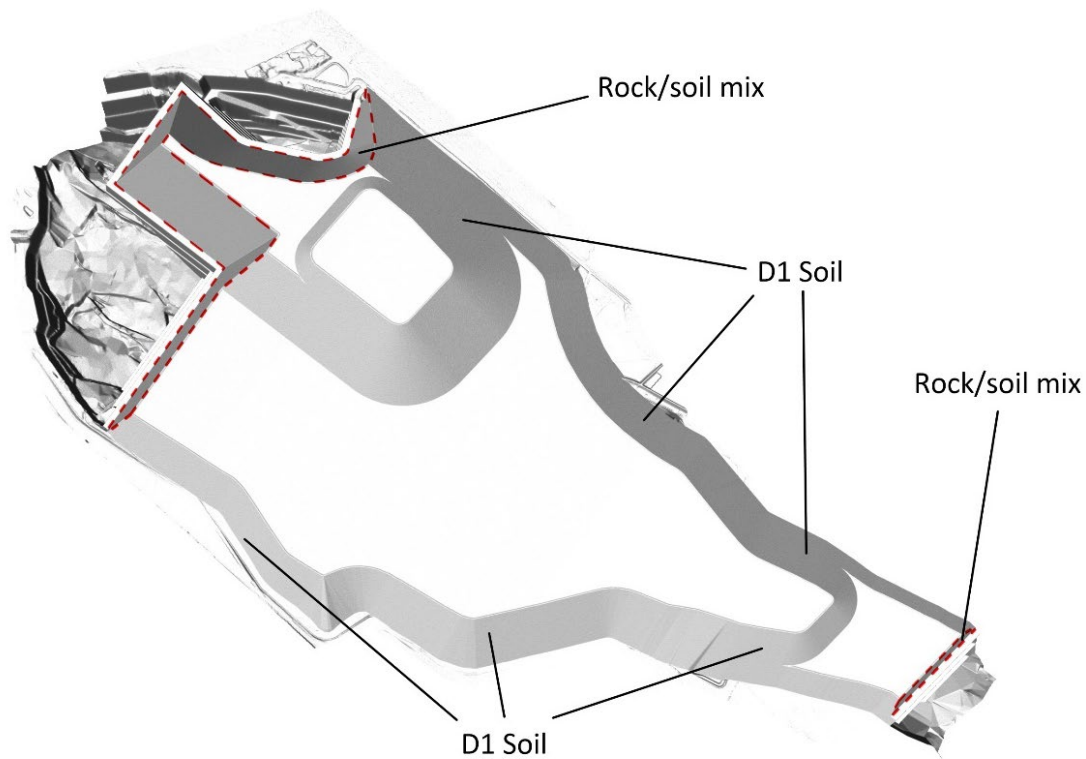


Figure 4: Final waste landform, Daunia Mine. White areas on the landform are level and capped with D1 soil.

Key assumptions in the landform evolution modelling based on WEPP results were:

- Topsoil D1 will be used for rehabilitation of outer batter slopes, with vegetation cover of 80% developed;
- Alternative growth medium with properties consistent with the D5:D1 mixture will be used to construct low walls and ramp walls for all pits.

Using input parameters derived for the materials to be used on the landforms, the SIBERIA model was run for 300 years, with outputs provided at years 50, 150, and 300.

At each output year, visualisations of the rate of erosion and gully development are provided, together with a table that includes erosion rates for each material on the landform.

4 RESULTS OF WEPP SIMULATIONS

4.1 Outer batter slopes surfaced with vegetated topsoil

Simulations considered a batter height of 140 m. The target erosion rate for modelling outer batters was a maximum of 5 t/ha/y at any point on the batter slope. Simulations indicate that 140 m high batter slopes on gradients of 15% will be stable provided a vegetative cover level of 80% can be sustainably achieved (Figure 5).

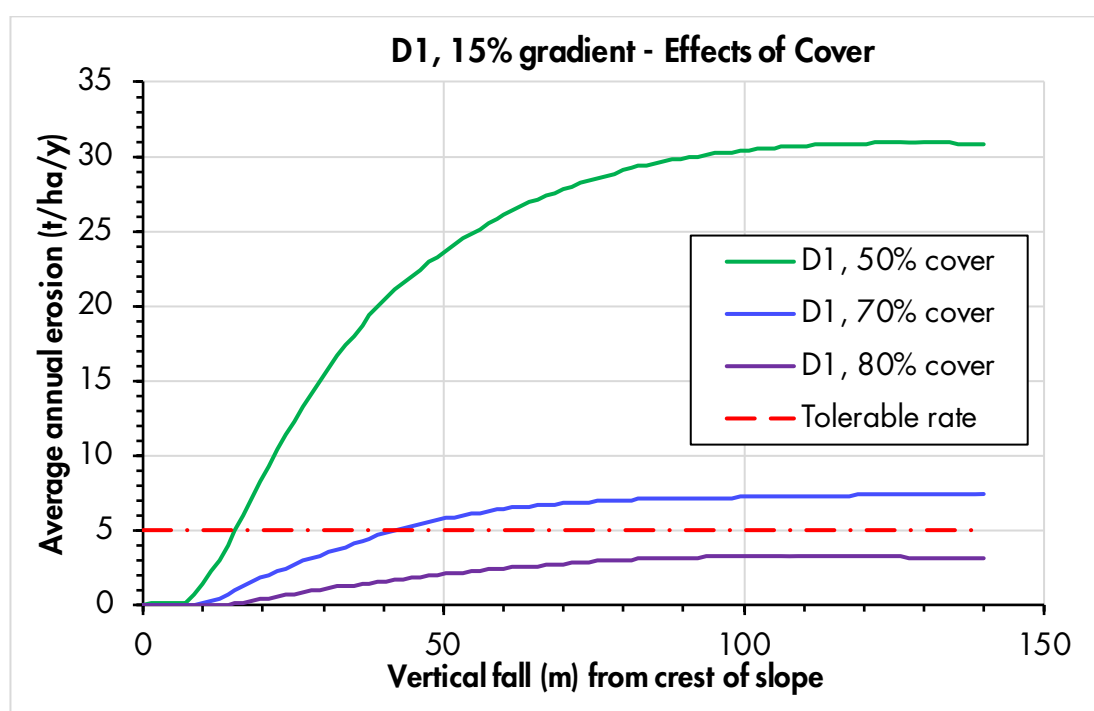


Figure 5: Predicted erosion rates along 15% gradient batter slopes with clay topsoil (D1) capping.

4.2 Low wall batters with alternative growth medium

These simulations considered batter slopes 140 m high, with a gradient of 25%.

As the material will remain rocky with reduced soil water storage capacity in the surface layers, achievement of relatively high levels of grass cover is considered unlikely, leading to the decision to assume a vegetative cover level of 50%.

The simulations show that – at that level of vegetative cover – the material is predicted to meet the soil erosion target of a maximum rate of 10t/ha/y, and to largely achieve the more stringent outer batter target of <5 t/ha/y (Figure 6) at heights less than 120m.

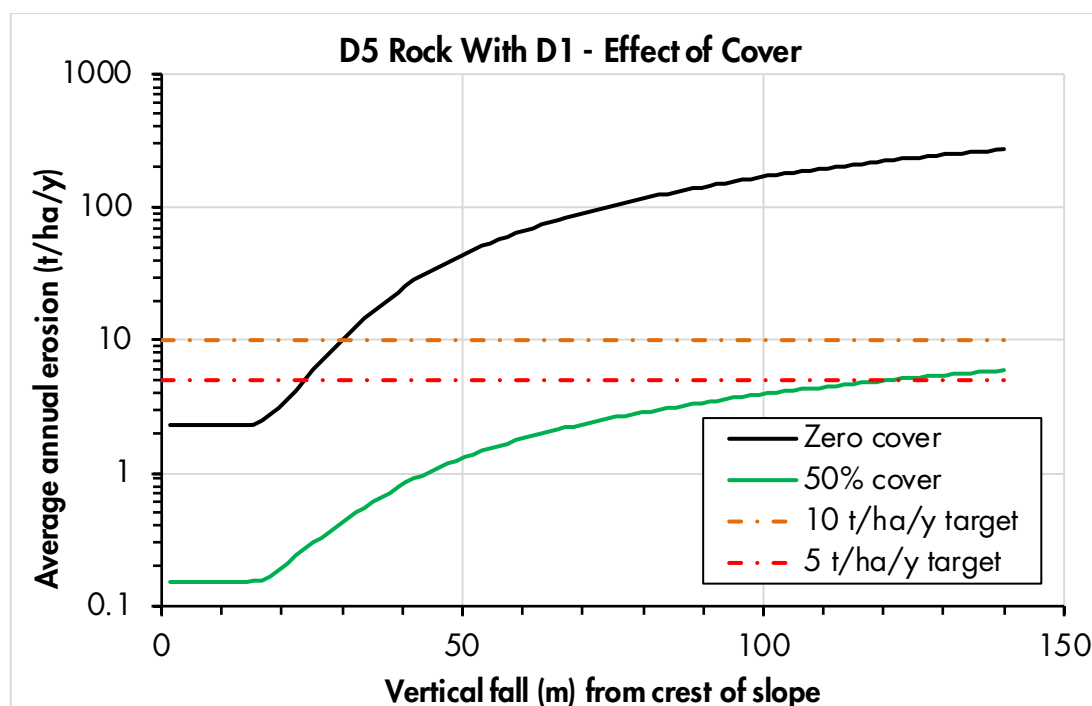


Figure 6: Predicted erosion rates for rocky waste placed at 25% gradient.

4.3 Landform design

Based on the WEPP simulations, the materials proposed for use in the final landform and for the landform evolution modelling are:

- Topsoil D1 will be used for rehabilitation works on outer batter slopes; and
- Alternative growth medium with properties consistent with a D5:D1 mixture and amendment to create a growth medium will be used to construct low walls and ramp walls for all pits.

5 SIBERIA PARAMETER DEVELOPMENT

SIBERIA model parameters derived from WEPP simulations are shown in Table 1. As noted previously (section 3.2.2), the vegetation cover levels assumed are conservative, with some variation to account for lower fertility of the wastes.

Table 1: Estimated SIBERIA parameters

Material	Vegetation cover	m_1	β_1
D1 Topsoil	80%	1.2735	0.0150
Alternative growth media of D5:D1 mixture	50%	1.6923	0.000034

It should be noted that the method of deriving parameters attempts to ensure that the m_1 parameter is optimised so that SIBERIA simulations show a similar impact of slope length to that predicted by WEPP. However, because the two models use different methods to consider impacts of slope length, it is not reasonable to expect complete agreement between the two models over the full range of slope lengths considered.

6 LANDFORM EVOLUTION OUTPUTS

Erosion rates predicted by the SIBERIA landform evolution model for the proposed Daunia landform are shown in Tables 2 and 3. Figures 7–9 show SIBERIA output after 50, 150, and 300 years of simulation.

Table 2: Predicted erosion rates and gully depths for the outer batters with 15% gradient, topsoil D1, and 80% vegetation cover.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
20m high batters			
50	-	4.1	16
100	-	4.0	31
200	0.3	3.9	62
300	0.3	3.9	91
30m high batters			
50	-	4.5	17
100	-	4.5	34
200	0.3	4.4	69
300	0.4	4.4	103
40m high batters			
50	-	4.6	18
100	-	4.6	35
200	0.3	4.5	70
300	0.4	4.5	105
60m high batters			
50	-	4.8	18
100	-	4.8	37
200	0.3	4.7	73
300	0.4	4.7	110
80m high batters			
50	-	4.6	18
100	-	4.6	35
200	0.3	4.6	70
300	0.4	4.6	105
115m high batters			
50	-	4.4	17
100	-	4.4	34
200	-	4.4	68
300	0.3	4.4	102

Table 3: Predicted erosion rates and gully depths for the low wall batters with 25% gradient, alternative D5:D1 growth medium, and 50% vegetation cover.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
20m high batters			
50	-	1.7	6
100	-	1.6	13
200	-	1.6	25
300	0.3	1.6	37
40m high batters			
50	-	3.7	14
100	0.3	3.6	28
200	0.5	3.6	56
300	0.6	3.6	83
100m high batters			
50	0.3	5.1	20
100	0.4	5.1	39
200	0.8	5.1	79
300	1.1	5.1	118

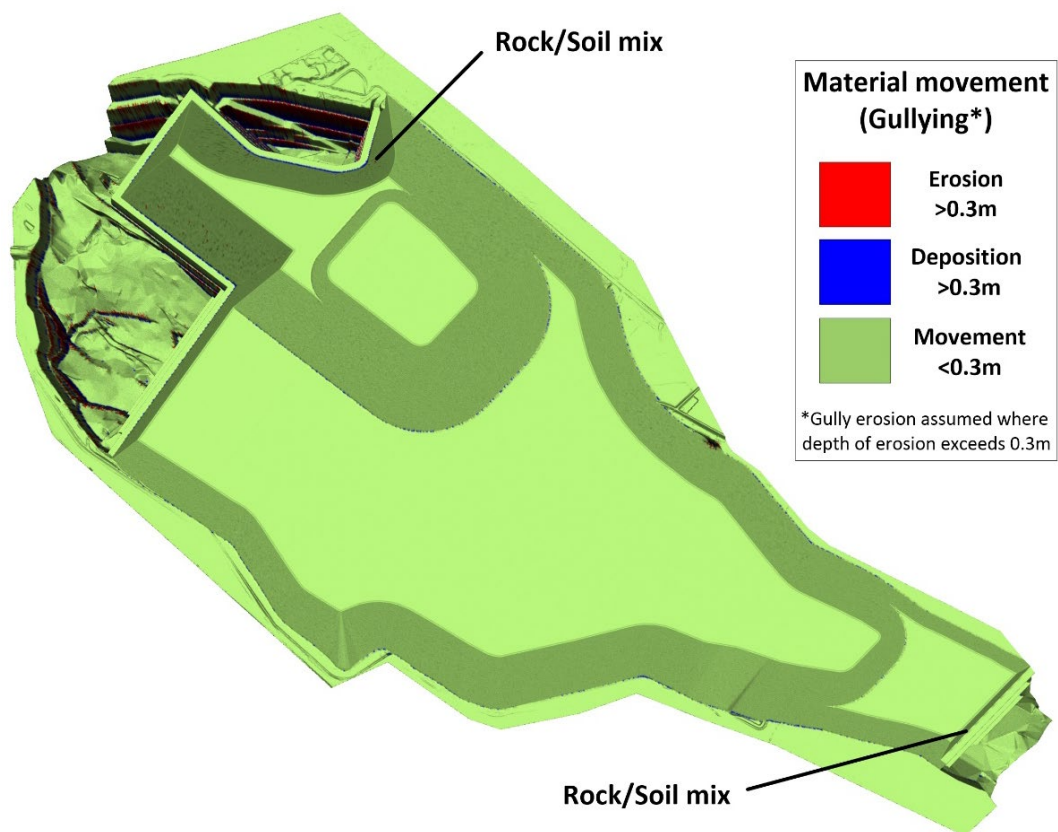


Figure 7: SIBERIA output after 50 years.

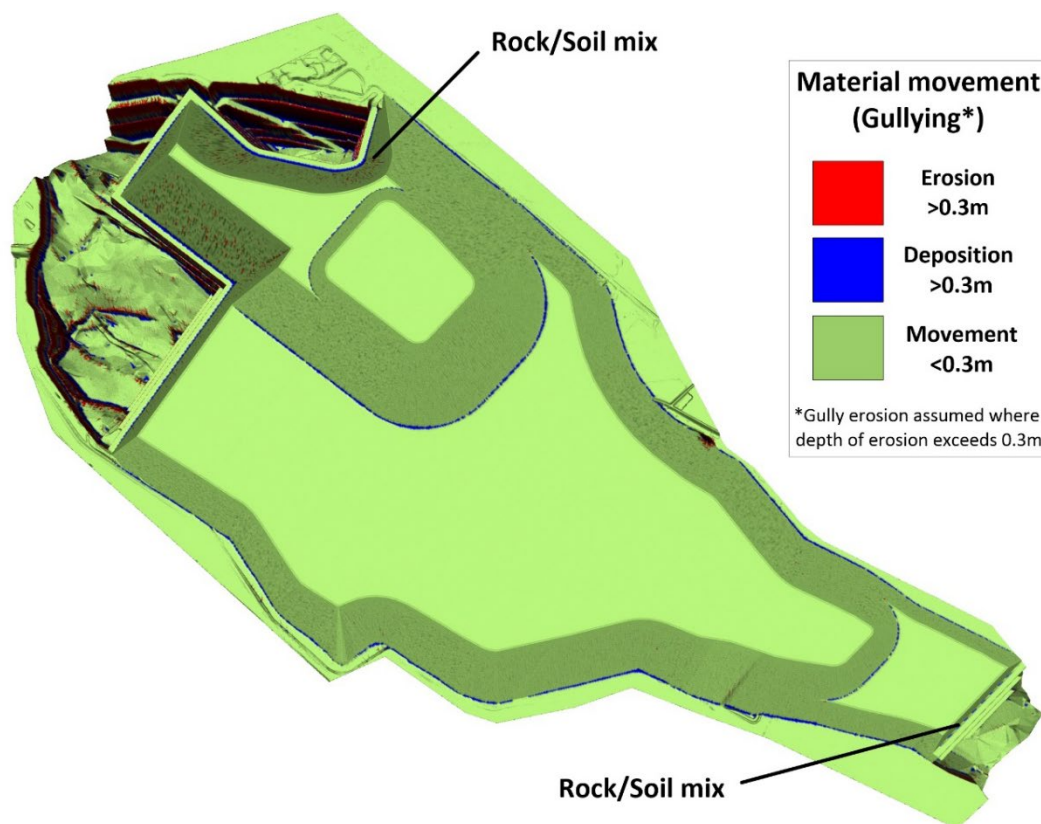


Figure 8: SIBERIA output after 150 years.

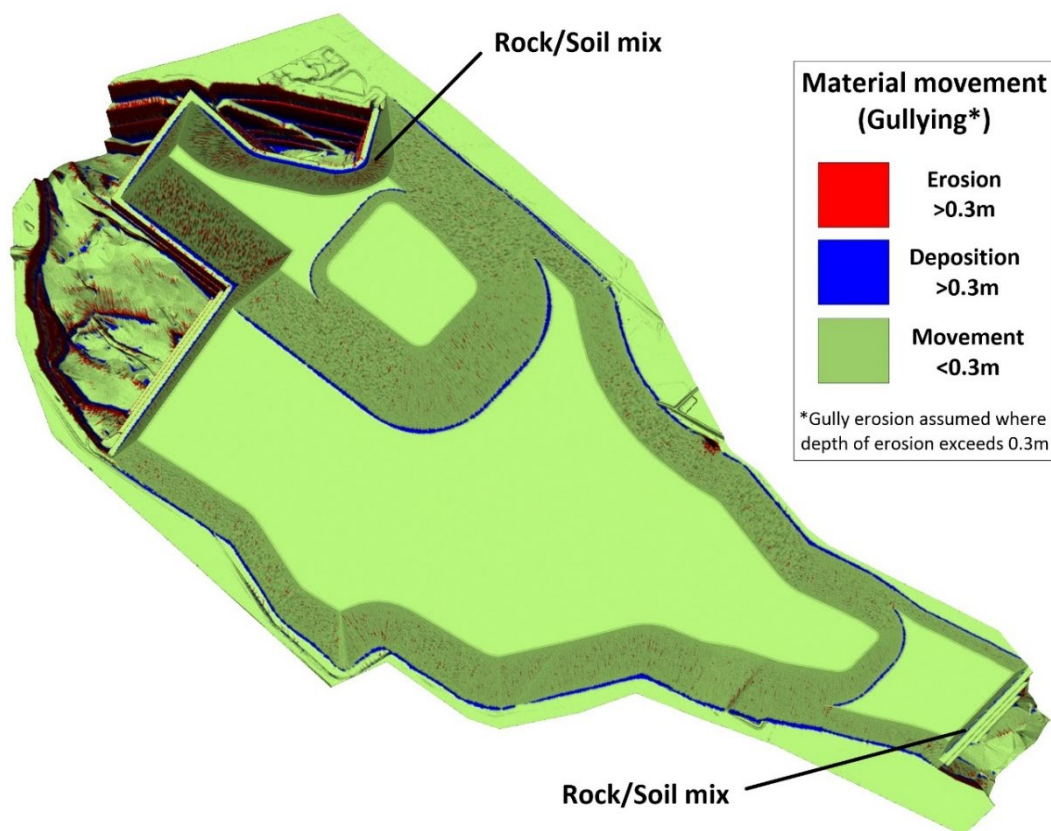


Figure 9: SIBERIA output after 300 years.

Consistent with the WEPP simulations, they indicate that:

- at a vegetative cover level of 80%, predicted erosion rates of the outer batter slopes capped with topsoil D1 are slightly below the target level of 5 t/ha/y.
- at a vegetation cover level of 50%, predicted erosion rates of the low wall batters capped with a rocky alternative growth medium of erosion properties similar to a D5:D1 mix are largely below the 5 t/ha/y target, and well below the 10 t/ha/y target suggested for low walls draining to a pit.

7 WATER MANAGEMENT

Water management recommendations for waste landforms at Daunia Mine can be summarised as:

- No construction of permanent berms or graded banks and rock chutes on batter slopes. (Temporary berms to be only used where considered absolutely essential.)
- Prevention of discharge from the level dump top onto the dump slopes.

Simulations of runoff and erosion indicate that – once vegetation is established – there is no requirement for installation of berms or graded banks to reduce slope length and erosion risk. It is anticipated that batter slope rehabilitation will be carried out progressively, working gradually up from the bottom of the slope, so that there will be increasing vegetative cover on lower sections of a slope as the works gradually (over a number of years) move towards the top of the slope.

It should be noted that – on well vegetated surfaces – annual rainfall excess on average will be 2-5% of annual rainfall, so preventing water discharge onto the slopes results in only a very small increase in the amount of water retained on the land surface and made available for vegetation growth.

It is – equally – noted that the quite small increase in drainage to depth that will be caused by retention of runoff on the tops of the landforms will be insignificant, with drainage reporting to the final voids and no potential to cause impacts on water amounts or quality.

8 CONCLUSIONS

Both runoff/erosion simulations using the WEPP model and landform evolution simulations using the SIBERIA model indicate that the proposed waste landform at Daunia Mine can be expected to be stable over the long term (up to 300 years) provided the target levels of vegetation cover are achieved. (Simulations used site specific data in terms of both materials and climate.)

Water management recommendations for the site include prevention of discharge from the small areas of level dump tops onto the slopes, and avoidance of any permanent bunds or rock chutes on batter slopes.

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Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, watercourse) use is not achieved	PMLU 1	Failure of landform	1. Erosional instability 2. Geotechnical instability 3. Incorrect geotechnical assessment 4. Differential settlement (spoil and backfilled dams) 5. Insufficient materials to achieve design (rock, growth media) 6. Unsuitable materials used on final landform surface 7. Flooding 8. Not achieving design 9. Selection of inappropriate PMLU	- Erosion - Growth media loss - Failure of vegetation - Slumping and settlement - Mass movement of landform	4	- Monitoring of landform stability and rehabilitation success to be undertaken post rehabilitation - Identify requirements for rectification works - Complete maintenance	2	- Ongoing materials characterisation - Selective handling of materials for placement - Review the topsoil, growth media and rock material balance periodically during operations to ensure sufficient volumes for the rehabilitation needs - No permanent berms or water management on slopes - Landform surrounding the spoil dumps and voids to be reshaped to be free-draining where required to prevent impacts - Groundcover including vegetation to provide erosion resistance - Compliance to plan - Growth media and spoil assessment by an Appropriately Qualified Person (AQP) to determine ameliorant and fertiliser surface treatment requirements.	With all controls in place, including ongoing monitoring and maintenance, landform failure on a large scale is unlikely	Unlikely	0.1	3
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, watercourse) use is not achieved	PMLU 2	Alteration of hydrogeological conditions	1. Release of contaminants to groundwater 2. Change in groundwater flow, recharge and/or discharge characteristics resulting in changes to the hydrogeological system 3. Drawdown of groundwater due to void lakes acting as a sink due to losses associated with evaporation	- Groundwater chemistry altered rendering it not suitable for extraction and/or to support PMLU - Groundwater quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the site is located - AMD, NDM, SD reporting to shallow and deep groundwater systems - Reduction of groundwater height within surrounding extraction bores - Degradation of terrestrial and aquatic groundwater dependant ecosystems (GDEs)	3	- Assessment and remediation of impacted material, where appropriate - Development and approval of a Site Management Plan to assist with ongoing management and restriction to future land use activities where appropriate - Implementation of management controls and monitoring programs outlined in an approved Site Management Plan - Re-establishment of impacted ecosystems - Decommissioning of impacted supply bores and re-instatement in suitable location	2	- Storing and use of imported hazardous materials in accordance with relevant standards and removed from site on completion of mining - At the completion of operations, all stored hazardous materials and infrastructure within the MIA and CHPP, that have the potential to release contaminants to groundwater, will be removed from site - Contaminated land investigation to be undertaken at the completion of operations to identify contamination that has the potential to cause impacts to groundwater - Implementation of remediation and/or management plans as required to reduce potential groundwater impact risks - Mine affected water dams to be decommissioned (including investigation for potential contamination and groundwater impacts). - Groundwater monitoring to be undertaken in accordance with EA conditions - Residual void catchments to be designed and created to establish sinks that provide for the collection of seepage from former operational areas and spoil dumps - Appropriate management, placement, and monitoring of waste (spoil, rejects) during operations - Landforms constructed to minimise the potential for flooding of the residual voids	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the PMLU is highly unlikely due to alternation of hydrogeological conditions	Highly Unlikely	0.03	0.9

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Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 3	Alteration of surface water systems	1. Release of contaminants to surface water resources 2. Changes to alignments and ecosystems of drainage lines and creek 3. Changes to hydraulic flows 4. Changes to flood patterns/distribution 5. Alteration of surface water infiltration rates 6. Surface water flows over unvegetated/disturbed soils where revegetation has not re-established 7. Overland discharges from neighbouring landforms and rehabilitated areas 8. Creeks and drainage lines not attaining successful rehabilitated state	- Surface water chemistry altered rendering it not suitable for PMLU - AMD, NDM and SD reporting to surface water - Degradation of ecosystems and land uses connected to surface water flows and floodplains on and down gradient of the mine - Sedimentation of downstream surface water drainage lines resulting in changes to their hydraulic properties and impacting ecosystems - Surface water quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the mine is located - Accelerated erosion rates from surface water flows in disturbed areas and degraded ecosystems - Reduction in rehabilitation success rates due to reduced surface water quality - Alteration of soil properties associated with contaminants carried by surface waters, including erodibility and geotechnical qualities	3	- Surface water monitoring data to be collected in accordance with the EA. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Any loss of hazardous contaminants that cause contaminated land/environmental harm will be reported and investigated/remediated as appropriate - Remedial works will be undertaken where releases from site result in impacts to surface waters, which may include alteration of the landforms, implementation of a Site Management Plan, implementation of additional controls/measures that reduce the potential for surface water impacts and/or re-establishment of impacted ecosystems where appropriate - Rehabilitated landforms that do not attain a stable state to be repaired and revegetated	2	- All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Mine affected water dams to be decommissioned and areas rehabilitated - Surface water monitoring to be undertaken in accordance with EA conditions - Monitoring of surrounding ecosystems will be undertaken in accordance with EA conditions - A contaminated land investigation will be undertaken at the completion of operations and remediation works undertaken as appropriate - Rehabilitation of disturbed areas will be undertaken as soon as practicable after land becomes available - Rehabilitation and monitoring of disturbed reaches of creeks undertaken - Appropriate management, placement, and monitoring of waste (spoil, rejects) during operations - Landforms constructed to minimise the potential for flooding of the residual voids	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the PMLU is unlikely due to alternation of surface water conditions	Unlikely	0.1	3
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 4	Contaminated land impacting on environmental receptors, rehabilitation and attainment of PMLUs	Discharges and accumulation of hazardous contaminants (including emerging contaminants) from operational activities.	Contaminants present within soil or water that present an unacceptable risk to the receiving environment or PMLU - Alteration of soil chemistry that impacts on structural characteristics - Contaminants reducing the soil suitability for rehabilitation species	3	- Investigate and remediate contamination incidents - Implement a Site Management Plan to manage impacts, where required - Removal of primary or secondary sources - Restrict site usage - Undertake ongoing monitoring to manage contaminated land risks	2	- Cleaning up of spills upon identification - Remediation or management of residual risk - Contaminated land investigation to be undertaken during operations and at closure and areas of contamination remediated and/or managed as appropriate - Ongoing surface water and groundwater monitoring providing an earlier indication of contamination - Management of operational activities to limit any potential contamination	The current contaminated land investigation is providing an initial understanding of the contaminated land risks. Due to the age, duration and nature of the heavy industrial site use, some remediation/management are anticipated to be required to render the site suitable for the intended PMLUs and reduce the potential for environmental harm post-mining. Based on the current understanding/uncertainty of site contamination, the likelihood of contamination preventing the attainment of a stable condition and the PMLU, without remediation/management, has been qualitatively assessed to be 30-60% and therefore probable. On-going modernisation of current practices/infrastructure, and potentially remediation works, will be required during operations to manage contaminated land risk prior to closure.	Probably	0.3	9
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 5	Flooding influences on rehabilitation and final landforms	1. Water inundation of landforms 2. Saturation of materials within landforms 3. Velocities of floodwaters on rehabilitated landforms 4. Inaccurate modelling	- Reduction in geotechnical stability of landforms causing failure of the landforms - Activation of dispersive materials resulting in accelerated erosion and sedimentation - Mobilisation of any contaminants contained within the landforms and impacts to downstream water and groundwater quality - Alteration of terrestrial ecology through introduction of weeds, sedimentation, or damage to rehabilitation species not able to withstand flooding - Erosion of landforms due to increased velocities of flood waters - Introduction of weeds and impacts to rehabilitation vegetation establishment - Loss of flood waters/environmental flows to residual voids	2	- Assessment of landform failure and required rectification works upon safe access to site immediately after the flood event. Assessment to include identification of measures that would limit potential for ongoing impacts. - Re-engineering of landforms to mitigate future failures followed by re-construction of landforms, and rehabilitation works. - Assessment of downstream impacts and undertake remediation/rehabilitation as required to re-establish drainage line hydraulics and ecosystems in liaison with the administering authority. - Monitoring of landform stability and rehabilitation success to be undertaken	1	- Removal of infrastructure from watercourses, decommissioning of dams and remediation of contaminated material where required - Design of landforms within flood extents that are stable and able to withstand flooding and water velocities - Establishment of vegetation suitable for the environment and reduces erosion risks	Flood modelling indicates limited flood water interaction with rehabilitated-landforms and velocities outside of the creeks and diversions is unlikely to impact rehabilitated landforms. Preventative controls include decommissioning of dams and culverts that could contribute to, or impact flood conditions. Modelled floodwater ingress into Pandora residual void within the void's capacity below the groundwater level.	Unlikely	0.1	1

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Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 6	Rehabilitated landforms result in alteration of flood hydrology upstream and downstream	1. Changes to drainage network hydraulics. 2. Artificial landforms reducing or increasing flood extent and changing velocities/flows. 3. Changes to vegetation cover and soil type which alter runoff and infiltration rates.	- Increasing/decreasing of flood extents, frequency and severity - Degradation of ecosystems due to altered flows, flood extent, duration or frequency - Infrastructure damage - Health and safety risks to on-site and off-site land users associated with increased flood heights, velocities and frequency	2	Due to the off-site nature of the impacts, which occur during significant flood events, available mitigating controls at the time of the impact are limited due to safety and accessibility restrictions. After flooding has receded, landform design and alteration could be undertaken to reduce possible future events.	1	- Removal of infrastructure that would adversely interfere with stream hydraulics (culverts) and decommissioning of dams - Establishment of landforms that are stable and provide appropriate level of flood protection to the residual voids - Undertake monitoring and maintenance works where required to maintain landforms	With preventative controls implemented, identified impacts associated with alteration of flood hydrology are unlikely.	Unlikely	0.1	1
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 7	Insufficient or inappropriate growth media and rock resources required for rehabilitation activities	1. Insufficient growth media and rock quantities of suitable quality 2. Unstable material (erosive, dispersive, saline materials) 3. Weed infestation (soil is already infested with weed seeds) 4. Insufficient placement depth and surface treatment 5. Incorrect soil and rock characterisation and amelioration 6. Inappropriate topsoil and rock stockpiling and management	- Erosion - Growth media loss - Topsoil deficit - Failure of vegetation (poor vegetation growth or incorrect vegetation affecting PMLU)	3	- Monitoring of growth media and landform stability and rehabilitation success to be undertaken post rehabilitation to confirm stability and identify requirements for rectification works. - Repair erosion areas, retest growth media and revegetate.	2	- Topsoil surveys and mapping - Review the topsoil, growth media and rock resource quantities periodically during operations to ensure sufficient volumes for the rehabilitation needs. - Undertake rehabilitation planning and preparation in accordance with the requirements for growth media, rock, seed and management for the PMLU - Management of topsoil and rock stockpiles and application during rehabilitation. - Growth media assessment by AQP to determine use of ameliorant and surface treatment requirements. - Amelioration surface treatments applied as per assessment - Selective handling of materials for placement - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, insufficient or inappropriate growth media and rock for use on rehabilitation is unlikely	Unlikely	0.1	3
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 8	Insufficient management of mineral waste	1. Poor material characterisation 2. Geochemistry not correctly defined for materials stored in permanent landforms 3. Inappropriate placement of adverse material 4. Poor landform execution 5. Inappropriate mineral waste management strategy 6. Generation and release of AMD/SD/NMD from coal processing waste and / or coal during operation accumulating in groundwater, surface water, soils	- Release of contaminants to surface water and groundwater from rehabilitated landforms. - Vegetation failure - Impact to fauna - Water cannot be used by end user (human and ecosystem)	3	- Monitoring of growth media and spoil to be undertaken post rehabilitation to confirm stability and identify requirements for rectification works. - Rehabilitation maintenance and/or corrective actions - NUMAs are acting as sinks for groundwater - Spoil materials have buffering capacity (high neutralising ANC)	1	- Material characterisation (outcomes to be stored into GeoBank) in line with BHP Materials Management Standard (5 pillars) - Remove and / or cover undesirable materials - Sampling of course and fine rejects from processing plant - Sampling of overburden / interburden - Appropriate material placement and selective handling during operations - Management of operational activities to limit any potential contamination - Appropriate water quality monitoring for surface and groundwater to enable tracking of processes affecting water quality during operation and into closure - Undertaking appropriate fate and transport modelling during operations	With all controls in place, including ongoing monitoring and maintenance insufficient management of waste characterisation is unlikely	Unlikely	0.1	1

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Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 9	Inadequate and/or inappropriate revegetation	1. Unfavourable climatic conditions and/or weather events 2. Incorrect species mix 3. Poor seed quality 4. Weed contaminated seed 5. Poor quality growth media or seed bed preparation 6. Erosion 7. Land contaminants	- Exposed soils due to poor vegetation establishment and growth, resulting in enhanced erosion rates. - Increased weed establishment and growth. - Reduction in land capability of PMLU (woodland habitat and/or cattle grazing) - Need for ongoing corrective action - soil sampling and analysis, amelioration and re-vegetation.	3	- Monitoring of landform stability and rehabilitation success to be undertaken post operations to confirm stability and identify requirements for rectification works. - Repair erosion areas, retest materials, review seed mix and revegetate.	1	- Growth media and spoil assessment by an AQP person to determine ameliorant and surface treatment requirements. - Management of seed selection, provenance and quality. - Plant at optimal time of year. - Revegetation species aligned to growth media, landforms and PMLU	With all controls in place, including revegetating with species aligned to growth media, landforms and PMLUs, as well as monitoring and maintenance activities, total failure of revegetation is unlikely	Unlikely	0.1	1
Stable condition (safe, stable, non-polluting and sustainable) for land described as a post-mining land (reference DNM EA E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU 10	Deterioration of built infrastructure conditions	1. Potential soil contamination around mine industrial areas	- Reduced soil fertility to support PMLU land capability - Potential contamination of surface water runoff affecting integrity of local catchments	3	- Undertake a preliminary contaminated land assessment prior to the completion of the approved activities, identify if any areas require a further Detailed Site Investigation and remediation plan developed if required. - Conduct ongoing maintenance	1	- Clean up and remediate contamination during operational period. - Undertake contaminated land assessment and remediation/management where required post mining	With all controls in place, including ongoing monitoring and maintenance, deterioration of built infrastructure is unlikely	Unlikely	0.1	1
NUMA does not achieve safe, structurally stable condition or causes environmental harm	NUMA 1	Void walls do not achieve geotechnical stability	1. Geotechnical instability 2. Geochemical instability 3. Increase/decrease in predicted void water levels 4. Incorrect geotechnical assessment	- Failure of void walls leads to instability beyond NUMA extent	3	- Geotechnical monitoring - Identify requirements for rectification works.	1	- Geotechnical assessment to be completed by AQP - Wall designs based on geotechnical assessment. - Pit floor treatments as required during operations to improve low-wall stability. - Geotechnical monitoring during operations. - Updated geotechnical assessment to be completed as mining approaches final limits and wall design and NUMA extent adjusted if required. - NUMA extents designed to include the required factor of safety (FoS) limit. - Bunding, fencing and signage placed at FoS limit.	With all controls in place, including ongoing monitoring and maintenance, wall failure beyond the NUMA limit is unlikely	Unlikely	0.1	1
NUMA does not achieve safe, structurally stable condition or causes environmental harm	NUMA 2	Uncontrolled access to NUMA	1. Inappropriate design, management and construction of safety bund 2. Inadequate/poorly maintained fencing and signage	- Unmanaged access to NUMA by people or livestock	1	- Compliance checks as part of monitoring	1	- Safety bund, fencing and signage placed at FoS limit, where required. - Safety bund designed by AQP - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, failure of bunding, fencing and signage is unlikely	Unlikely	0.1	1
NUMA does not achieve safe, structurally stable condition or causes environmental harm	NUMA 3	Uncontrolled flooding into residual voids	1. Flood mitigation (landforms) is not constructed or installed correctly 2. Inaccurate flood modelling	- Uncontrolled capture of flood waters - Altered/changed alignment of creeks and drainage lines - Removal of downstream environmental flows - Filling of residual void with water and interconnecting groundwater units - Geotechnical instability of residual void - Contamination of clean surface water flows, within residual void - Contamination of groundwater resources	4	- Compliance checks as part of monitoring	2	- Flood modelling completed by AQP - Flood mitigation designed to correct flood event - Flood mitigation (landforms) installed - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, flooding of the voids is unlikely. The volume of water that would flow into the eastern side of the Pandora residual void via a minor drainage line are within the modelled holding capacity of the void below the stabilised groundwater. Therefore would not impact on the long-term operation of the void as a groundwater sink.	Unlikely	0.1	3
NUMA does not achieve safe, structurally stable condition or causes environmental harm	NUMA 4	Water in the void causes environmental harm outside of the mining tenure	1. Groundwater outflow seepage in the long term stabilised voids is not identified by groundwater modelling 2. Poor water quality 3. Overtopping or interconnection of the void lake with shallow groundwater water units	- Reduction in surface and/or groundwater quality down gradient of the site - Degradation of ecosystems interacting with impacted water - Changes to the chemistry of shallow groundwater units - Groundwater extraction/use off site impacted	4	- Rectification works on impacted ecosystems or bores - Installation of engineering controls to limit potential for ongoing impacts	1	- Modelling completed by AQP - Flood mitigation (landforms) designed to provide an appropriate level of protection - Groundwater quality and level monitoring - Water quality monitoring - Containment of potential sediment as a result of erosion from the low-wall within the residual void	With all controls in place, including ongoing monitoring and maintenance, any water in voids causing environmental harm outside of mining tenure is highly unlikely. Modelling indicates the voids will act as long-term sinks and water levels will remain below the groundwater levels and the shallower geological units.	Highly Unlikely	0.03	0.3