WHITEHAVEN COAL

Concept Cover Designs for Waste Storage Facilities at Blackwater Mine

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DOCUMENT AMENDMENT RECORD

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1. INTRODUCTION

Whitehaven Coal requested Henderson Geotech Pty Ltd to develop conceptual cover designs for Tailings Storage Facilities (TSFs) and coarse rejects areas at Blackwater Mine, in Central Queensland. The cover designs are intended to support preparation of the rehabilitation planning part of the progressive rehabilitation and closure plan (PRC Plan) for the mine.

This report provides an overview of relevant characteristics of potential cover materials (mining spoil) and waste materials (tailings and coarse rejects). It then describes the existing waste emplacements and potential hazards after mining, leading to objectives for earthen covers. Finally cover designs proposed to meet those rehabilitation objectives for the following facilities:

- NCPP TSF;
- Bonnie Doon TSF;
- Laleham TSF;
- Ramp 72 WSF (tailings and coarse rejects);
- Ramp 74 TSF;
- Bottom Dam TSF and ROM3 Rejects Area WSF; and
- Ramp 36 WSF.

Note that the cover designs have been developed based on material characteristics and accepted practice as understood at the time of preparing this report (August 2024). Before cover construction commences, detailed cover designs will be developed that will use the latest information and data available for each specific facility.

1.1 Limitation

This report has been prepared by Henderson Geotech Pty Ltd for Whitehaven (Client) for the purpose of supporting the Progressive Rehabilitation and Closure Plan for Blackwater Mine. No parties other than the Client and the Department of Environment, Science and Innovation are authorised to rely on this report without the prior written consent of Henderson Geotech Pty Ltd.

This report is, in part, based on information provided by the Client or by other parties on behalf of the Client (Client-supplied information) in addition to data collected by Henderson Geotech Pty Ltd from the public domain. Henderson Geotech Pty Ltd has not always verified the accuracy of such information and makes no representations regarding its accuracy. Henderson Geotech Pty Ltd is not responsible for the consequences of any error or omission in Client-supplied information.

Henderson Geotech Pty Ltd has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same specialist field for projects of a similar nature and at the time and in the jurisdiction where the services were rendered. Henderson Geotech Pty Ltd makes no warranty, express or implied.

The conceptual cover designs described in this report do not have the level of analysis required for detailed design and are applicable only to the scenarios and inputs also described herein. A new concept design will be required for the particular waste storage facility if there are changes to:

- Final landform geometry;
- Post-mining land use, especially a change requiring different vegetation;
- The approach to surface water management on the relevant final landforms (i.e. free-draining or ponding); or
- The understanding of end-of-mining and long-term groundwater levels in the vicinity of in-pit TSFs.

2. COVER MATERIALS

Spoil at Blackwater Mine is produced by the excavation of sedimentary strata overlying and between coal seams within the Rangal Coal Measures and broadly comprises:

- Unconsolidated and poorly consolidated sediments – small proportions of sandy Quaternary alluvium, usually mixed with Tertiary gravelly, sandy and silty clays.
- Weathered Permian –sand-silt clay mixtures with similar characteristics to Tertiary.
- Fresh Permian – spoil derived from predominantly fine to medium grained sandstone is typically clayey sandy gravel. Overburden/interburden with a higher proportion of siltstone/mudstone produces spoil trending toward gravelly clayey sand; some of the gravel fragments may break down over time.

2.1 Spoil Properties

2.1.1 Tertiary Spoil

Regionally, Quaternary alluvium is generally very shallow and limited to creek floodplains. Consequently, it is rarely excavated as a discrete stratum but is instead combined with Tertiary spoil. At pit and mine scale, the proportion of Quaternary alluvium is rarely sufficient to affect spoil properties.

Figure 2-1 summarises grading and index properties of Tertiary spoil from test results reported for Blackwater and various other mines across the Bowen Basin. It shows that the material is ‘typically’ sandy or silty clay with minor gravel; however, the size grading of individual samples varies over a wide range. The small number of Blackwater samples were typical of the norm and did not include any results with higher proportions of sand or gravel. Experience is that gravel fragments – being weathered rock – often break down with moisture and handling. Basic geochemical properties are summarised in Figure 2-2: using the categories in Hazelton & Murphy (2007), Tertiary spoil is typically moderately to strongly alkaline, moderately to highly saline, strongly sodic, and potentially dispersive. Once again, a proportion of results were well outside the main cluster. The samples from Blackwater Mine trended toward the high side of the distributions for alkalinity and salinity.

Physical and geochemical properties of weathered Permian spoil are usually similar to those of Tertiary spoil. Hence, the two materials are often not differentiated in spoil management practice.

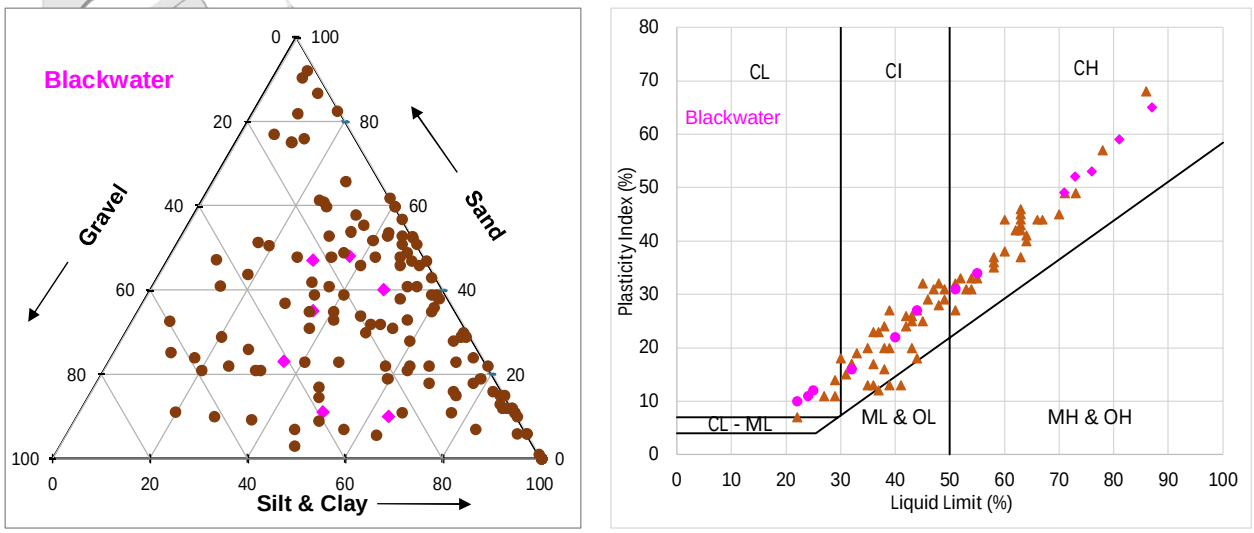


Figure 2-1: Physical Characteristics of Tertiary Spoil

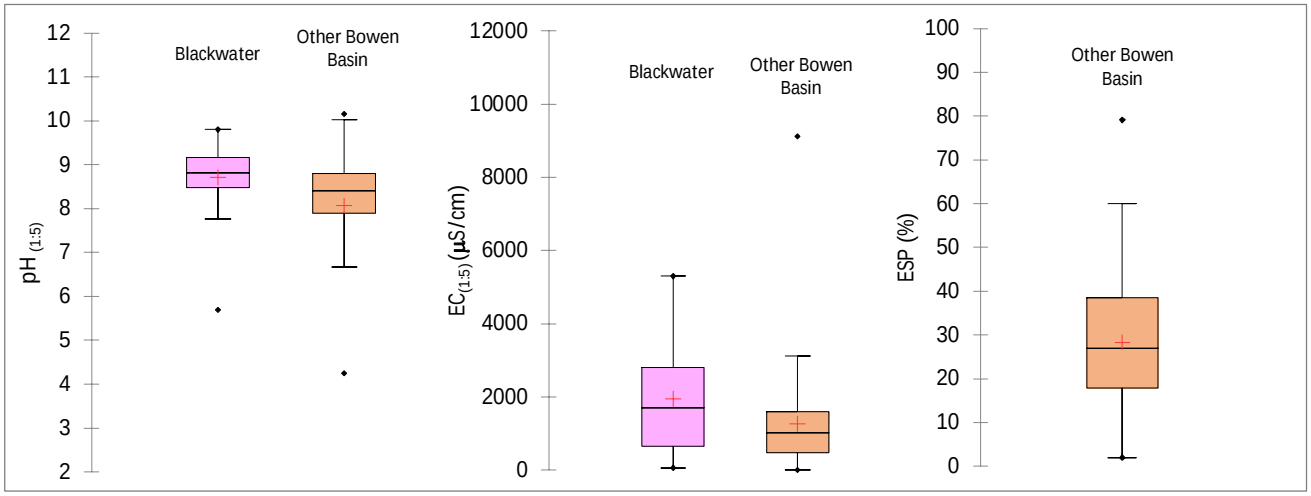


Figure 2-2: Geochemical Characteristics of Tertiary Spoil

2.1.2 Unweathered Permian Spoil

In a similar manner, Figure 2-3 summarises grading and index properties of spoil from fresh Permian overburden/interburden at Blackwater Mine and in the Bowen Basin generally. In contrast to Tertiary spoil, gravel is generally the major size fraction in fresh Permian spoil; however, the limited results available from Blackwater suggest a higher proportion of silt and clay than is typical of the Bowen Basin. Geotechnically, the spoil would be Category 2 (Simmons & McManus, 2004), that is, 'matrix supported'. Note also that the fines do not exhibit high plasticity, both at Blackwater Mine and throughout the Bowen Basin.

Geochemically, fresh Permian spoil ranges from mildly to-strongly alkaline, is variable with regard to salinity and sodicity, and is potentially dispersive (Figure 2-4). If the small number of Blackwater samples are typical of Permian spoil at the mine, it will tend toward the low end for salinity and sodicity.

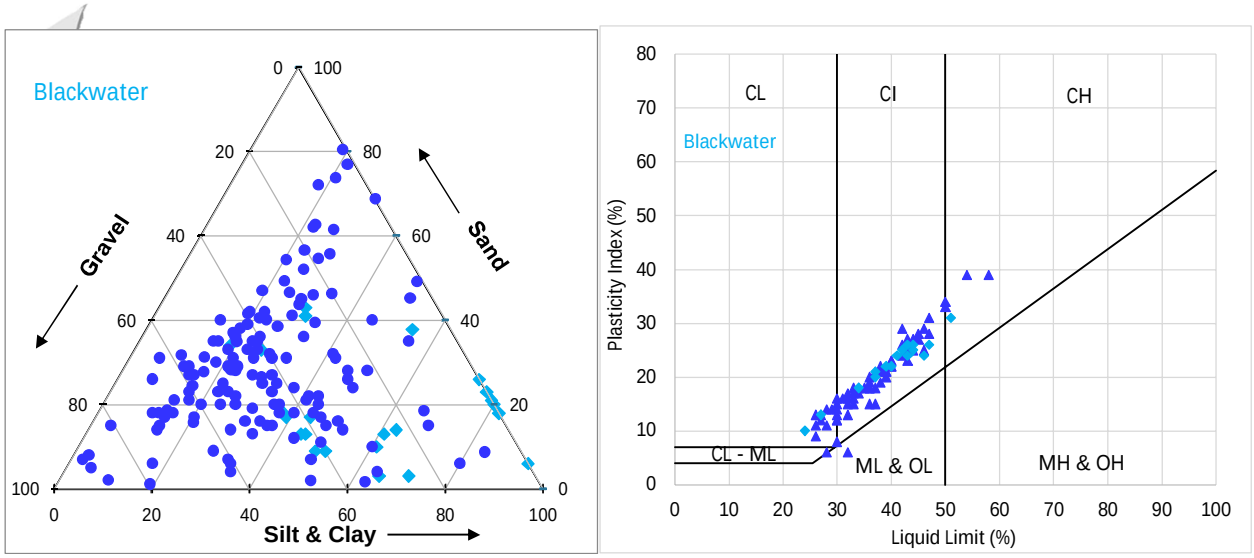


Figure 2-3: Physical Characteristics of Fresh Permian Spoil

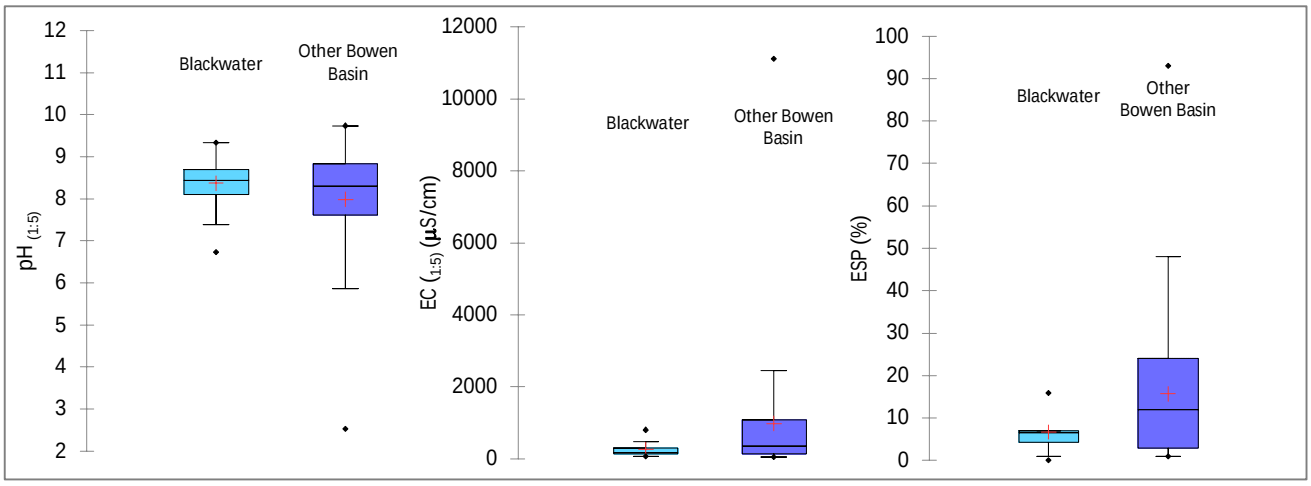


Figure 2-4: Geochemical Characteristics of Fresh Permian Spoil

2.2 Desirable Cover Material Properties

A cover system over chemically hostile material will ideally

- Allow shallow rainfall infiltration to support vegetation and reduce erosion from runoff;
- Not allow infiltration to seep down to the hostile material;
- Not allow solute from the hostile material to flow upward into the root zone or into surface waters;
- Decrease oxygen penetration to restrict acid generation reactions, if there is significant net Potential Acid Generation.

These criteria impose conflicting requirements on cover materials: high permeability allows initial infiltration but low permeability limits deeper seepage; greater clay content reduces permeability but lower clay content reduces matric (capillary) water suction potential. For example, clay-rich spoil from Tertiary and weathered Permian overburden/interburden could be placed to achieve

low permeability but doing so would increase its tendency to allow upward water movement due to capillary action (matric suction potential). Conversely, gravelly spoil would have less tendency to promote upward water movement but might be too permeable to prevent deep infiltration into the tailings.

Water is the most effective barrier to oxygen penetration – either as a permanent water cover or, more commonly, filling pore spaces in the cover material and in tailings themselves. This again presents a conflict in the tailings: maintaining saturation would decrease oxygen movement but dewatering promotes strength gain. In the cover, a higher clay content generally leads to greater water-holding capacity and therefore a higher degree of saturation (water in the pore spaces).

The outcome of this is that a multi-layer cover system is often required, with different spoil types placed to utilise the desirable properties of each and to balance the conflicting requirements. An alternative would be a thick cover of undifferentiated spoil, with the depth of material compensating for poorer cover properties.

Based on geologic boundaries along the planned final highwalls, the thickness of Tertiary/weathered overburden ranges from about 15m to 60m. The 40km of pit length in the middle of the mine will be more than 120m deep. On these bases, and allowing for bulking, future mining of a strip 60m wide will produce more than 1Mm^3 of Tertiary/weathered spoil and 10Mm^3 of fresh Permian spoil per kilometre of length. 1Mm^3 would provide 2m depth of cover over 50Ha of CHPP waste. Consequently, the quantities of both weathered and unweathered spoil available will be easily sufficient to allow selection of suitable materials.

3. WASTE MATERIALS

3.1 Tailings Characterisation

3.1.1 Physical Properties

WSP (2023) presents grading and plasticity index test results for tailings samples from Blackwater Mine. Based on those data, in accordance with AS 1726:2017 (Standards Australia Limited, 2017), the tailings are generally classified as low liquid limit Sandy SILT (ML) and intermediate plasticity Sandy CLAY (CI). A larger private database of results confirmed these descriptions and provided further information, specifically, tailings from NCPP TSF (the historic Blackwater operation) tended to contain more sand while tailings from the old South Blackwater operation contained more silt. However, both fall within the size range encountered across the Bowen Basin and are expected to behave cohesively (like intermediate plasticity clay).

Median solid particle density of samples from NCPP TSF was 1.7 t/m^3, with 80% of results falling tin the range from 1.5 t/m^3 to 2.4 t/m^3. By contrast the median for samples from the southern CHPP was 1.6 t/m^3 and the eighty percentile range was 1.4 t/m^3 to 1.7 t/m^3. Considering the different soil particle densities of coal (~1.4t/m^3) and general overburden (~2.6t/m^3), this suggests that the tailings vary from essentially all coal to no coal. The lower particle densities in the southern TSFs probably reflect the particular configuration of the CHPP that produced them.

Oedometer consolidation tests were reported for five samples, with the following median parameter values:

- Compression Index C_c = *0.14*

- Recompression Index C_r = *0.02*
- Coefficient of permeability k_{sat} = *2e-9 m/s*
- Coefficient of consolidation c_v = *60m²/yr*, but varied over a wide range

These values are close to the median of collated results measured for coal tailings in the Bowen Basin.

3.1.2 Chemical Properties

Geochemical characterisation studies for two TSFs and the NCPP at Blackwater Mine (Terrenus Earth Sciences, 2024) found that half of the tailings (current and historic) have moderate to high potential to generate AMD when they are able to oxidise. The other half of the samples analysed had relatively low potential to generate AMD. Historically, low pH in CHPP waters was an issue for the old South Blackwater Mine operations.

Fresh tailings were assessed as generally slightly saline, while aged tailings were generally slightly to moderately saline. The difference may be partly due to sulphide having oxidised to sulphate in the aged tailings, but might also reflect geochemical differences in the coal, roof and floor being mined at particular times.

3.1.3 In Situ Properties

In the context of rehabilitation, the most important physical properties of tailings are: strength profiles, which constrain safe placement of capping; and moisture-density profiles, which – in combination with consolidation properties - dictate how much water is squeezed out during consolidation, the consequent vertical settlement, and the timeframe over which that consolidation occurs (The Minserve Group et al, 2003).

Tailings has minimal shear strength when initially discharged (being fluid) and strength is only gained over time as the deposit dewaters, densifies, and develops a drier surface crust. WSP (2023) includes plots from a large number of Cone Penetrometer Tests (CPTs) on NCPP TSF that measure in situ strength based on the resistance to pushing a cone-tipped instrument vertically into the tailings. Only five of the tests were located more than 100m from the walls and many were pushed through a wall lift into the underlying tailings. Where the tailings surface was exposed, the drier (and stronger) crust was typically 1-2m thick, below which the tailings were variable but typically of soft or firm-stiff consistency.

The same report presents 16 CPT plots from Laleham TSF, again with most located close to the edge of the storage area. Existing spoil cover and crusted or consolidated tailings ranged from about 2-9m thick and there were thick layers of soft tailings at depth. Only three CPTs are included for R72 TSF. Two tests in the pit indicated a 3-4m thick desiccated crest with soft-firm tailings below, while the single test in the ramp section (the historic decant pond) showed <1m thick crust over very soft tailings. EDG (2024) presents 7 CPTs for Bottom Dam TSF. The crust depth in these ranged from 1-3m and the underlying tailings were generally of soft consistency but sometimes soft-firm.

It is understood that no strength profiling has yet been undertaken on R74 TSF. Bonnie Doon TSF is still active and profiling will be undertaken after tailings deposition has ceased and the fine waste has had some time to dewater and consolidate.

It is emphasised that strength in TSFs varies with location, depth, and time. As a consequence, testing carried out significantly in advance of cover construction may be useful for planning purposes, but detailed cover design should be based on testing undertaken closer to the start of cover construction. Even then, considering the inevitable variability throughout the emplaced tailings, the construction methodology and schedule should be adaptable to actual conditions encountered.

3.2 Coarse Rejects Characterisation

3.2.1 Physical Properties

Historic size grading data collated from mines in the Bowen Basin and summarised on Figure 3-1 indicates a composition ranging from *GRAVEL with sand* to *Sandy GRAVEL* (Standards Australia Limited, 2017). Current NCPP waste handled as rejects comprises about 80% from the Coarse Circuit that treats the 50mm to 1.4mm size range. The remainder is from the Fine Circuit and is in the 1.4mm to 0.25mm size range. Rejects comprise about 75% of waste produced by NCPP (tailings are produced from the ultra-fine circuit). Noting that gravel is >2.36mm and sand is 2.36mm to 0.075mm, these ranges confirm that coarse rejects currently produced are consistent with the collated historic data.

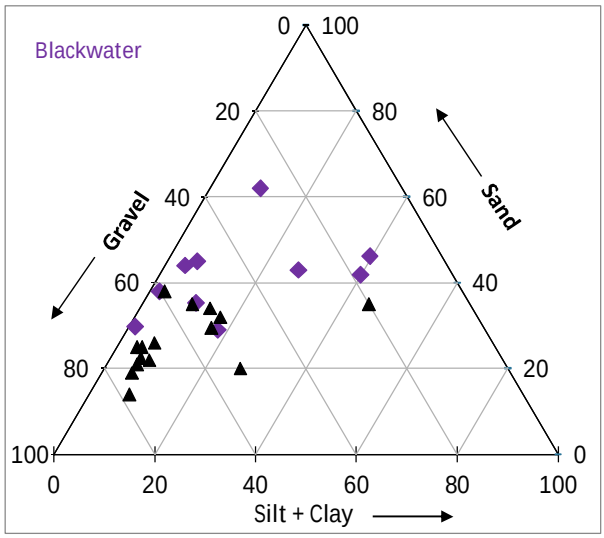


Figure 3-1: Particle Size Distribution of Coarse Rejects in the Bowen Basin

The classification of Sandy GRAVEL is also consistent with field observation that coarse rejects are a non-cohesive non-plastic material exhibiting frictional strength and high permeability.

In coarse rejects, solids particle density (specific gravity) varies with the ratio of fresh Permian spoil (from seam roof and floor) to coal. For example, 20% coal would produce an average solids particle density of about 2.4t/m^3 whereas 40% coal would produce an average of about 2.1t/m^3.

As an unsaturated non-cohesive material, coarse rejects will not experience consolidation settlement overtime. Some settlement is expected as the cover is constructed and imposes vertical load on the rejects and there may be further settlement due to moisture adjustment and particle breakage, but significant movement after the first few years is unlikely.

3.2.2 Chemical Properties

A geochemical characterisation study found that slightly less than half of the coarse rejects sampled at Blackwater Mine have moderate to high potential to generate AMD while the remainder had low to low-moderate potential to generate AMD (Terrenus Earth Sciences, 2024).

Samples of fresh coarse rejects were found to be generally non-saline, whereas aged rejects ranged from non-saline to moderately saline. Based on total sulphur concentration, the potential for saline drainage from sulphide oxidation was assessed as low to low-moderate.

3.2.3 In Situ Properties

The gravelly character of coarse rejects makes them difficult to test appropriately in situ. Five samples from the NCPP tested in 1974, gave a median dry density of 1.3t/m^3. Seventeen laboratory shear test results collated from mines in the Bowen Basin gave a median friction angle of 34° with three-quarters of the results within the range of 28° to 30°.

Because the waste is free draining (highly permeable) and not subject to consolidation settlement, density-moisture profiles are not important for rehabilitation design.

4. CONCEPTUAL COVER DESIGNS

4.1 Hazards at Closure

The Minserve Group (2003) identified potential hazards that may need to be addressed in tailings dam closure. The drivers and controls for these hazards are summarized in Table 4-1. Because Ramp 72, Ramp 36 WSF and ROM 3 Rejects Area also contain coarse rejects, the hazards have been re-phrased for ‘waste’ rather than only tailings, although the hazards relating to strength and consolidation will rarely apply to coarse rejects. As foreshadowed in Section 2.2, some hazard control objectives can impose conflicting requirements on cover systems, with complex interactions. These are discussed in the following paragraphs.

A cover constructed over the tailings at closure may have conflicting effects on seepage hazards (a & b): cessation of tailings discharge and removal of the decant pond both reduce seepage; but the weight of cover layers could temporarily increase pore water pressures in the tailings and consequently increase seepage; and rainfall infiltration through the landform into the tailings and coarse rejects could provide water to continue seepage. The weight effect will decrease over time as excess pore pressure equilibrates, but the cover system should aim to minimise recharge of tailings moisture from deep infiltration. Restricting recharge in this way will control seepage in the long term; however, measures separate from cover system design – for example, cut-off or collection trenches – may also be required over the initial period post-mining.

Acid drainage and/or neutral metalliferous drainage and moderate salinity are the geochemical hazards associated with tailings at Blackwater Mine (refer Section 3.1.2). Acidity and salinity can both have adverse effects on vegetation and consequent metal elevation might have impacts on the higher food chain. Oxygen is required for the chemical reactions that produce acid; to a large extent, oxygen cannot penetrate into water-saturated tailings and consequently, tailings with a degree of saturation greater than about 85% are not expected to produce acid drainage regardless of their acid generating capacity. The unsaturated surface layer of tailings already

contains oxygen for the reactions to proceed – in fact, those tailings have usually already oxidized to some extent before the cover is placed. A saturated layer within the cover system would limit ingress of further oxygen but in practice such a layer would be difficult to sustain in the drought-susceptible central Queensland climate. Furthermore, limiting oxygen penetration would not reduce the hazard from salinity. Given this context, adverse effects on vegetation could occur if water from the tailings flowed upward through the cover or seeped out of the walls or base.

The mechanisms that might drive upward flow against gravity are: soil suction (e.g. capillary action) drawing moisture from more saturated to less saturated layers; and consolidation settlement pushing water upwards out of the matrix of tailings solids. To mitigate the hazards to vegetation (d & e), the cover system should be designed to provide a barrier between solutes in the tailings and the topsoil and subsoil layers.

Consolidation settlement (hazard g) occurs when the loads on saturated tailings cause excess pore water pressures and water flows out of the material to reduce those pore pressures until equilibrium is achieved. The amount of settlement varies with depth and water content of the tailings and with height of overlying landform; consequently, settlement is unlikely to be constant over the TSF. All else being equal, a thinner cover would produce less settlement itself, but there is often a component of ongoing consolidation in the lower tailings due to the overlying tailings, and other hazard control objectives that are not served by minimising cover thickness. In addition, in the long term, greater consolidation has beneficial effects, including that it increases tailings strength to better support surface loads, it reduces the tendency to liquefaction, and it may cause upward flow of pore water that will re-saturate some of the near-surface tailings and thus limit future acid generation. In summary, the cover system needs to accommodate consolidation settlement but should not (and generally cannot) aim to avoid it.

Table 4-1: Potential Hazards at Closure

	Hazard	Source	Receptor	Cover System Controls
a	Contaminants seeping to groundwater	Waste has soluble contaminants that may leach at elevated concentrations AND TSF has permeable layers below base	There is a groundwater resource within the seepage path	Conflicting and complex effects, refer accompanying discussion
b	Contaminants seeping to surface water	Waste has soluble contaminants that may leach at elevated concentrations AND TSF has permeable layers in base	The seepage path daylights at ground surface	Conflicting and complex effects, refer accompanying discussion
c	Contaminants spilling to surface water	Waste has soluble contaminants that may leach at elevated concentrations AND Water can pond at surface	There is a watercourse within the overflow path	Shape landform to shed water OR Shape landform to maintain a permanent water cover without overflow
d	Contaminants affecting vegetation	Waste has soluble contaminants that may leach at elevated concentrations	Vegetation that is sensitive to the contaminants will grow on or near the facility	Complex effects, refer accompanying discussion
e	Contaminants entering food chain	Waste has soluble contaminants that bio-accumulate that may leach at elevated concentrations	Stock or native fauna will regularly eat affected vegetation	Complex effects, refer accompanying discussion
f	Interference with natural surface drainage	The facility significantly alters surface topography	There is a watercourse whose flow regime is significantly altered	Cover system cannot mitigate this; it must be addressed by landform/landscape design
g	Consolidation settlement affecting landform surface drainage	At least part of the waste is saturated and will compress under the weight of overlying tailings and cover	Surface drainage is sensitive to changes in ground slopes and gradients	Conflicting and complex effects, refer accompanying discussion
h	Minor release of waste solids due to erosion	Waste is erodible	Surrounding land or watercourses would be adversely affected by ongoing small amounts of waste	Any intact physical cover will prevent this
i	Major release of waste solids due to embankment failure	At least part of the waste has insufficient shear strength to hold a stable landform without embankment support	Surrounding land or watercourses would be adversely affected by a large amount of waste	Cover system cannot significantly mitigate this; it must be addressed by long-term embankment/ landform design
j	Combustion of waste	At least part of the waste is unsaturated and contains sufficient coal to burn	Surrounding vegetation could be ignited by burning waste OR Air quality is a significant value in the surrounding environment	Any intact physical cover thicker than about 0.1m will prevent this
k	Dust generation	Waste at the surface is unsaturated and includes fine particles	Air quality is a significant value in the surrounding environment	Any intact physical cover will prevent this
l	Equipment bogging in, or sinking into, waste[1]	Waste profile has low strength	Land use requires equipment or infrastructure to be on the landform	Design cover system to support and spread surface loads associated with land use

[11] This hazard was not identified in The Minserve Group (2003)

4.2 Objectives and Concepts

The hazard control measures arrived at in the preceding section essentially reflect the ideal cover material characteristics outlined in Section 2.2 with additional requirements related to load bearing capacity and consolidation. Paraphrasing those requirements, the key objectives of the covers for TSFs at Blackwater Mine are:

- To allow shallow infiltration but minimise recharge of tailings moisture from deep infiltration of rainfall;
- To avoid upward movement of solutes from tailings into the vegetation rooting zone;
- To support and spread pressures from anticipated surface loads enough that the bearing capacity of the tailings is not exceeded; and
- To accommodate long-term consolidation settlement in the tailings, such that the first two objectives and surface erosional stability are not compromised.

On mounded landforms that do not pond water, these objectives can potentially be achieved by two conceptual earth cover configurations, namely:

- A multi-layer cover comprising (from tailings to surface):
    - *Porous, low clay content material placed directly over the waste to limit upward flow;*
    - *A layer of lower permeability material finished with a mounded top surface so that any seepage that does reach it will tend to move laterally rather than downward; and*
    - *Uncompacted subsoil and topsoil shaped to a gently mounded surface, to allow shallow infiltration during rainfall but no surface ponding that would drive deeper seepage.*
- A single cover layer of Category 2 or Category 2-3 spoil (connected matrix of fine-grained material), loose placed but thick enough to perform the required functions without specifically differentiated permeability and matric suction properties.

In situations where it is not practical to construct a mounded cover that will not pond water, the cover will require a different design approach depending on whether the surface pond is ephemeral or permanent.

For ephemeral surface water:

- A multi-layer cover with an engineered very low permeability layer comprising (from base of cover to surface):
    - *Porous, low clay content material placed directly over the waste to limit upward flow;*
    - *A thin compacted clay layer to minimise downward flow;*
    - *A layer of medium- or coarse-grained spoil (*Simmons & McManus, 2004 Category 2-3, 3 or 4) to protect the clay layer from drying and physical damage, and to limit entrapment of fauna.

For permanent surface water:

- The water itself will be the cover, justified by the findings of Senes Consultants (2002) that shallow water covers are effective at greatly reducing the rates of sulphide oxidation, and therefore controlling the consequent production of mobile contaminants. In central Queensland, this type of cover may be appropriate for in-pit TSFs where a permanent pit lake can establish over the tailings, but several other specific constraints would also need to be met.

The choice of cover system for each TSF depends on the specific situation and hazards, availability of cover materials, and vision for landform and land use, as described in following reports sections.

5. NCPP TSF

5.1 Description

NCPP is an active aboveground (turkey's nest) TSF located at the west and south-west of the CHPP and rail loop, and bounded by a minor public road at the north-west.

The original tailings dam commenced in 1970 and comprised a single earthfill embankment across a northern tributary of Deep Creek. The facility has been raised and extended in various stages since then, with downstream and upstream wall lifts constructed of earthfill and, in recent decades, mainly coarse rejects. A final small raise was constructed in 2022 and routine tailings deposition ceased in 2023. There is a small emergency storage capacity remaining.

The TSF is 1.4km north-south and 1.7km east-west, with a footprint, of about 198Ha. Depth of tailings ranges up to 32m. The deposited tailings beach down to a decant pond inside the southern wall of the dam.

5.2 Surrounding Environment

At the northern side, the toe of the TSF is less than 40m from the rail loop. The CHPP is east of that, about 600m from the TSF, but part of the associated industrial area is closer. The north-western wall runs about 40m from a minor public road outside the lease boundary, with a rail line west of the road. Natural ground falls broadly from west to east, such that the TSF is upslope of the CHPP and associated buildings. The tributary of Deep Creek was diverted about 300m south of NCPP TSF, then the creek channel flows north to within about 60m of the eastern wall toe before flowing eastward through a culvert under the main mine haul road. Prior to mining and outside the area of mine disturbance, the dominant land use has been low intensity grazing, except in Amaroo State Forest more than 1.5km west and south-west of the TSF. Regulated vegetation (endangered regional ecosystem comprising acacia dominated open forest, woodland or shrublands) is mapped to the south-west of the TSF; regulated vegetation (riverine) is mapped along Deep Creek.

The final landform design for NCPP TSF is a stand-alone elevated landform surrounded by undisturbed and rehabilitated land at essentially pre-mining elevation. Deep Creek is a watercourse defined by the Water Act 2000.

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian Rangal Coal Measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). That report also included flow path simulations to assess the movement of water particles within the groundwater system post-mining. However, the particles were positioned at mid-depth in the highest saturated aquifer at the start of the simulation. That is, the simulation indicated to fate of water from a surface storage, such as NCPP TSF, if it seeped downward into groundwater, but not the likelihood of such seepage occurring. Geology mapped for the footprint of NCPP TSF is regolith weathered from the Burngrove Formation that stratigraphically underlies the Rangal Coal Measures, with a small area of cemented Tertiary sediment along the western edge. Given this context, NCPP TSF is unlikely to be hydraulically connected to any significant aquifers.

5.3 Cover Design

5.3.1 Specific Hazards

The planned final landform is a mounded shape that will not pond water, so there is no risk of spill to surface water (hazard c in Table 4-1). The TSF altered natural surface drainage as it was constructed, mainly by changing where overland flow from the TSF area enters Deep Creek, but closure will not have significant additional impact (hazard f). Given the proximity, there is the possibility of shallow seepage out of the TSF and into Deep Creek. If seepage did occur, the rate would decrease over time since tailings deposition has ceased (hazard b). A cover system designed to minimize deep infiltration would also reduce long-term seepage. However, as noted in Section 4.1, direct control measures unrelated to cover design might also be required. Any deep seepage from the TSF would tend to follow the excavated ground surface into a final void and therefore would not measurably reach regional groundwaters (hazard a).

As an aboveground TSF, embankments are required to structurally contain low strength tailings, and so embankment failure is a credible scenario (hazard i). However, the cover can only influence embankment stability indirectly and in a limited way – by avoiding accumulation of water and consequent pore pressure increase – and so this hazard will be separately addressed through detailed design for overall decommissioning of the TSF.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

5.3.2 Cover Concept Design

In the context of being rehabilitated to a separate elevated landform, the thick simple cover would generate a larger footprint because the higher surface elevation would involve longer slopes down to natural ground level. It might also be difficult to have a cover thick enough to meet infiltration objectives without it being so thick that its weight would cause excessive consolidation settlement. Consequently, the preferred cover for this TSF is the multi-layer system.

Gravelly fresh Permian spoil would be suitable for the base cover layer. Clay-rich spoil from Tertiary and weathered Permian overburden may be used for the lower permeability layer. Fresh Permian spoil is expected to have lower salinity and sodicity, which would make it also suitable for the subsoil layer, subject to chemical amelioration if testing suggest that is necessary.

Tailings consolidation settlement will vary with tailings depth and water content profile (or conversely, density profile) and with cover thickness, and is expected to occur over a long timeframe – potentially decades. Conceptually, this settlement can be accommodated by making the relevant layers of the cover thicker in the areas where greater settlement is predicted so that mounded interfaces and surfaces will remain mounded after the settlement has occurred.

5.3.3 Design Details

The over-arching objective for rehabilitation of NCPP TSF is to create a landform that permanently contains tailing solids, limits any release of solutes to levels that will not cause environmental harm, and can support managed grazing within a wider grazing enterprise. The following specify minimum layer thicknesses, but actual dimensions could be greater, either to create a landform that sheds rainfall runoff without ponding but also without causing excessive erosion, or from considerations of constructability:

- Bulk shaping fill comprising low clay content spoil and/or coarse rejects with low AMD potential will be spread over crusted tailings. Thickness will be as needed to provide a mounded, free-draining subsurface. The spoil/rejects will have minimal compaction to limit moisture suction potential;
- A 1m minimum thickness layer of selected weathered Permian and/or Tertiary spoil, will be spread and worked so as to be at least ten times less permeable than material above and below it. The surface will be shaped to shed any deep infiltration out of the landform when constructed and after consolidation settlement has occurred. This will require the surface of the layer to extend over the crests of the engineered embankments so that any such drainage would exit the landform;
- A 2m minimum thickness of more permeable material such as gravelly fresh Permian spoil will be placed over the low permeability layer. The thickness may be greater than 2m if needed to maintain separation between the vegetation rooting zone and the low permeability layer, and to allow a final ground surface that will shed rainfall without ponding with slopes not greater than those on rehabilitated spoil emplacement areas;
- Topsoil and erosion management practices consistent with those on rehabilitated spoil emplacement areas.

The magnitude and rate of consolidation settlement depend on composition (size grading), existing pre-consolidation, and the disposition of drainage paths, all of which vary within the three-dimensional tailings deposit. Consequently, estimates are not included in the conceptual cover design; instead, settlement will be assessed and allowed for as part of detailed design and especially by adaptive design revision during the construction phase.

5.3.4 Construction Methodology

The challenge in placing a first layer of cover material over soft fine waste is that the cover needs to be thick enough to spread the weight of the construction equipment (so that the resultant pressure is low enough to avoid bearing failure), without being so thick that the weight of the cover material itself causes bearing failure. The strength and thickness of the tailings surface crust is critical to being able to meet both constraints, but the in situ testing referred to in Section 3.1.3, was restricted to the edges of the tailings deposit. More testing will be required before cover works commence to understand strength conditions across the whole tailings surface and to accommodate those in the construction process.

That is, the construction sequence requires its own geomechanical design, separate from detailed design of the cover system. This will typically involve bearing capacity and/or stability analysis to determine combinations of thickness of the first layer of the bulk shaping and construction plant ground pressures that do not overload tailings strength profiles across the TSF. Even then, considering the inherent variability across the TSF, it should be expected that the cover design and the construction schedule will be further modified based on monitoring as the initial layers are placed.

Once the first layer has been placed, it may possible to proceed using normal spoil dumping practices up to the underside of the low permeability player. The actual dumping strategy should be confirmed by further geomechanical analysis, including estimation of consolidation settlement, after the first layer is completed. Topographic (survey) monitoring should continue until an appropriately qualified geotechnical engineer has reviewed the monitoring results and confirmed that predicted remaining differential settlement will not compromise the final mounded shape of the subsequent low permeability layer.

It is recommended that QC/QA for the low permeability layer be based on coefficient of permeability, which is the geomechanical property that most directly affects cover system performance. For QC, test areas could be prepared using the proposed spoil material and construction methodology for each cover layer. In situ infiltration tests would be undertaken to measure permeability, and the materials and/or methods modified as necessary, until the design coefficients of saturated permeability are consistently achieved. The resultant materials and methods can then be used to construct the whole layer, with further infiltration testing as appropriate to provide QA.

To ensure the desired contrast in permeability, spoil directly above the low permeability layer should be spread in thicker layers where practicable. As the constructed surface approaches the levels of the final landform, areas with the greatest predicted remaining consolidation settlement may be over-dumped to hasten and balance that settlement.

After completion of bulk earthworks, the landform may be left for a period while further consolidation settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile. The area would then be rehabilitated in accordance with normal site practices for spoil dumps, including topsoil placement and construction of erosion control measures. The vegetation species mix should be consistent with roots of mature plants not reaching the low permeability layer and with the post-mining land use of managed grazing.

6. LALEHAM TSF

6.1 Description

Laleham is an inactive TSF with in-pit and aboveground sections, the latter being formed by embankments across a hillslope, with the western end possibly founded in spoil. It is located about 1.2km south-east of the old South Blackwater Mine CHPP.

The in-pit section was present in 1984 and the embankment was under construction. The tailings surface was capped with clayey spoil by the end of 1994 but the exposed (downstream) embankment slope has not been structurally modified since original construction.

The TSF extends 0.4km north-south and 0.6km east-west, with a footprint of about 13 Ha. The depth of tailings in the in-pit section is not known but the main embankment is about 10m high. The capped surfaces are generally flat, except for a depression at the eastern side of the aboveground section that was probably caused by tailings consolidation.

6.2 Surrounding Environment

The in-pit area of the TSF wraps around the end of a laterised sandstone ridge to the north. Two small mine water dams, Duck Pond and Fish Bowl, are 100-200m to the west. The eastern side of the aboveground part of the TSF is bounded by a road around the western toe of the Ramp 74 northern in-pit spoil dump; Ramp 74 in-pit TSF is about 700m east of Laleham TSF. There are several vegetated spoil dumps around the southern side of the TSF, with Sirius Creek at the southern side of those, about 35m from Laleham TSF. Prior to mining, the dominant land use was low intensity grazing. Regulated vegetation is mapped on the sandstone ridge and an area to the south-west of the TSF, described as endangered acacia dominated open forest and of-concern eucalypt open forest respectively.

For the final landform, it is planned to re-handle spoil from some of the smaller nearby dumps to cover the TSF and create a broad mound abutting the natural sandstone ridge draining south to Sirius Creek.

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian Rangal Coal Measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). Flow path simulation included in SLR (2024) may be relevant to the in-pit part of the TSF and indicated that if any seepage reached the groundwater system it would flow toward R74 void. Surface geology mapped for the footprint of Laleham TSF is Emerald Formation Tertiary sediment, with Rangal Formation sub-cropping south of Sirius Creek. Over the forty years since tailings were first deposited in-pit, there have been no reports of shallow seepage from the TSF being detected in Sirius Creek.

6.3 Cover Design

6.3.1 Specific Hazards

The planned final landform is a mounded shape that will not pond water, so there is no risk of spill to surface water (hazard c in Table 4-1). The TSF did not greatly alter natural surface drainage because it followed the pre-existing ground-slope direction (hazard f). As noted in the previous section, there is the possibility of shallow seepage out of the TSF and into Sirius Creek, although there is not a clear hydrogeologic connection. If seepage did occur, the rate would decrease over time since tailings deposition has ceased, and a cover system designed to minimize deep infiltration would also reduce long-term seepage. Any deep seepage from the TSF would follow the excavated ground surface into Ramp 74 void (another TSF) and therefore would not measurably reach regional groundwaters (hazard a).

As a TSF with some aboveground containment, embankments are required to structurally contain low strength tailings, and so embankment failure is a credible scenario (hazard i). However, the cover can only influence embankment stability indirectly and in a limited way – by avoiding

accumulation of water and consequent pore pressure increase – and so this hazard is separately addressed through detailed design for overall decommissioning of the TSF.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

6.3.2 Concept Cover Design

The tailings surfaces (in-pit and out-of-pit) were covered with 1m minimum depth of spoil about thirty years ago. There are historically rehabilitated spoil dumps nearby and future mining is planned within that area of the minesite. Given this context, the preferred cover type is a thick layer of general spoil, including the material that is already in place. Final surface gradients, topsoil thickness and vegetation will be consistent with other spoil landforms rehabilitated to the same post-mining land use.

Tailings consolidation settlement varies with tailings depth and water content profile (or conversely, density profile) and with cover thickness. Considering that tailings deposition ceased so long ago, it is likely that a significant amount of settlement has already occurred. However, the additional weight of cover spoil will trigger a new stage of consolidation that theoretically might take decades to complete (although consolidation follows a logarithmic timeframe which means that most of the settlement happens in the early years). For detailed cover design, the rate of consolidation and total and differential settlement will need to be estimated and allowed for, typically by adjusting the cover thickness to compensate.

6.3.3 Design Details

The high level design objective for rehabilitation of Laleham TSF is to create a landform that permanently contains tailing solids, limits any release of solutes to levels that will not cause environmental harm, and can support managed grazing within a wider grazing enterprise. In addition to providing a cover function, the spoil also needs to create the required landform topography. Consequently, the following specifies a minimum spoil thickness, but in some areas the actual thickness will be greater, to create a surface that sheds rainfall runoff without ponding but also without causing excessive erosion.

- 5m thickness of spoil (including that already placed), dumped and spread in such a way that dispersive spoil with high fines content is not placed in the outer 1m of the landform. This may be achieved by selective placement or by chemically treating the top metre of spoil to reduce sodicity;
- Topsoil and erosion management practices consistent with those on other rehabilitated spoil areas.

Tailings consolidation settlement will vary with tailings depth and water content profile (or conversely, density profile) and with spoil thickness, and is expected to occur over a long timeframe – potentially decades. Conceptually, this settlement can be accommodated by making the relevant layers of the cover thicker in the areas where greater settlement is predicted so that mounded interfaces and surfaces will remain mounded after the settlement has occurred.

6.3.4 Construction Methodology

The greatest challenge in constructing a cover over soft fine waste is usually in placing an initial layer that can support construction equipment without breaking through the crusted surface itself. In the case of Laleham TSF, that first layer is already in place; however, its thickness and condition is not known in detail. Consequently, further strength profiling is recommended to support detailed design of the cover system and selection of construction equipment with appropriate ground pressure configurations.

All vegetation and the topsoil/root matter should be removed before fresh spoil placement commences. Spoil placement may then proceed as determined to suit strength conditions; however, considering the inherent variability across the TSF, the construction methodology may be further modified based on monitoring as work proceeds.

Because the proposed cover system is essentially simple bulk spoil fill, no specific testing is required for QC/QA during construction except to confirm minimum cover thickness. After completion of bulk earthworks, the landform may be left for a period while further consolidation settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile. The area would then be rehabilitated in accordance with normal site practices for spoil dumps, including topsoil placement and construction of erosion control measures.

7. R72 WSF

7.1 Description

R72 is an inactive tailings and coarse rejects storage facility with the waste mainly below ground, but rainfall and runoff are intermittently stored over tailings behind an aboveground embankment. It is located just north of the loadout rail line into South Blackwater.

Ramp 72 was mined sometime before 1985. Tailings were discharged to the pit from the early 1990's until December 2001; at some stage during that period, a 4m high embankment was constructed at the top (western end) of the ramp to contain the decant pond as the tailings level rose slightly above natural ground level and decant drained to that end of the ramp. Mixed CHPP waste was dumped into the southern end of the pit, over the tailings, from about 2005 until it reached a couple of metres below pre-mining ground level. In 2010, the embankment was raised 6m to better contain rainfall runoff from the pit and surrounding catchment.

The pit section of the WSF is about 950m long and 150m wide, while the ramp section is about 650m long with a width opening from 50m at the top of the ramp to 160m where it joins the pit. Depth of tailings ranges from a couple of metres at the top of the ramp to about 40m in-pit, and the mixed rejects in the southern end are about 16m thick over the tailings.

7.2 Surrounding Environment

The WSF is bound by the rail line at the south, a mine access/haul road at the west, other mine voids at the north and presently, highwall spoil at the east. As noted, at closure there will be a new residual void further east, with an in-pit spoil dump in between. The southern rail loop is about 1km to the south-west with old mine building and the SCPP at the eastern side of the loop. It is

understood that most of that infrastructure will be removed prior to closure. In this part of the mine, the pre-mining ground surface and its watercourses drained from east to west, and a natural drainage line flows from the top of the ramp into Sirius Creek about 4km downstream to the south-west. That drainage line is mapped as regulated vegetation (endangered regional ecosystem comprising remnant acacia dominated woodland to open forest on gilgai clay plains). Prior to mining, the land use was mainly low intensity grazing, and this continues in areas outside the area of mine disturbance.

The final landform for the mine involves burying R72 under a new spoil dump generated from mining down-dip (east) of the previous pit. The depth of spoil over CHPP waste will range from at least 5m at the top of the ramp to more than 100m at the current highwall. The final void from new mining will be about 1.2km east of R72 WSF.

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian Rangal Coal Measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). Flow path simulation included in that report indicated that the TSF would remain a groundwater sink, and therefore tailings-contacted water would not flow out into the broader groundwater system. Surface geology mapped for the footprint of R72 WSF is cemented Tertiary sediment (duricrust) on deeply weathered regolith. The planned future mining will remove Tertiary and Permian overburden down to coal floor; consequently, any seepage from R72 would be eastward through in-pit spoil to that subsequent final void.

7.3 Cover Design

7.3.1 Specific Hazards

The proposed final landform over R72 WSF is sloping ground that will not pond water, so there is no risk of spill to surface water (hazard c in Table 4-1). No watercourse or defined drainage feature is directly impacted by the WSF; the rehabilitated landform will locally increase the catchment draining to a gully that flows into Sirius Creek but it will not interfere with the watercourse alignment (hazard f). There is a slight possibility of seepage through the western embankment and into the gully, however this (hazard b) was addressed in the embankment design. If seepage has occurred, the rate will decrease after the decant pond is removed. A cover system designed to minimize deep infiltration would also reduce long-term seepage. As was also noted in the preceding report section, any deep seepage from the WSF would likely follow the excavated ground surface into a final void and therefore would not measurably reach regional groundwaters (hazard a).

As the WSF contains tailings stored aboveground, the embankment is required to structurally contain low strength tailings in the long-term, and so embankment failure is a credible scenario (hazard i). However, the hazard of embankment failure will be separately addressed through detailed design for decommissioning of the overall TSF structure.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

7.3.2 Concept Cover Design

Given the location of R72 WSF within a large spoil landform, a thick cover of general spoil material is proposed to achieve cover performance objectives. At concept design level, gravelly spoil or coarse rejects will be spread over the exposed tailings surface to provide an initial support layer, then a thicker layer of general spoil will be placed over that. Final surface gradients, topsoil thickness and vegetation will be consistent with other spoil landforms rehabilitated to the same post-mining land use.

Tailings consolidation settlement varies with tailings depth and water content profile (or conversely, density profile) and with cover thickness. Consolidation actually occurs throughout the life of the facility and beyond, and it is likely that a significant amount of settlement has already occurred. However, the additional weight of spoil will trigger a new stage of consolidation. Consolidation theory indicates that the process might take decades to complete (although consolidation follows a logarithmic timeframe which means that most of the settlement happens in the early years). For detailed cover design, the rate of consolidation and total and differential settlement will need to be estimated and allowed for, typically by adjusting the spoil thickness to compensate.

7.3.3 Design Details

The high-level objective for rehabilitation of R72 WSF is to incorporate it in a larger spoil landform such that the whole area has consistent topography and land use capabilities. The thickness of spoil required to achieve this varies markedly across the facility. The following, therefore, are proposed minimum layer thicknesses, to be refined in the detailed design:

- 1.5m thickness of coarse rejects or gravelly spoil – for example, spoil from fresh non-carbonaceous sandstone-siltstone overburden and/or interburden - over the exposed tailings;
- Spoil, 3.5m thick at the top of the ramp, 5m thick over coarse rejects and as required over the remainder of the WSF, dumped and spread in such a way that dispersive spoil with high fines content is not placed in the outer 1m of the landform (spoil may be chemically ameliorated to achieve this); and
- Topsoil and erosion management practices consistent with those on the adjoining rehabilitated spoil areas.

The magnitude and rate of consolidation settlement depend on composition (size grading), existing pre-consolidation, and the disposition of drainage paths, all of which will vary throughout the tailings deposit. Consequently, estimates are not included in the conceptual cover design; instead, settlement will be assessed and allowed for as part of detailed design and especially by adaptive design revision during the construction phase.

7.3.4 Construction Methodology

As described in Section 5.3.4, the first layer over tailings is the most difficult to construct because it needs to balance the conflicting effects of supporting construction equipment and loading the tailings. The strength and thickness of the tailings surface crust is critical to being able to meet both constraints. For this reason, the ramp section must be dewatered continuously and allowed to desiccate for several years before in situ strength profiles are measured and used to undertake geomechanical design of the construction sequence. This will typically involve bearing capacity

and/or stability analysis to determine combinations of thickness of the first layer of cover material and construction plant ground pressures that do not overload tailings strength profiles across the WSF. Even then, considering the inherent variability in tailings due to changes in CHPP feed and product targets, and the effects of beaching and sorting at discharge, it should be expected that the cover design and the construction schedule will be further modified based on monitoring as the initial layer is placed. If the surface cannot be strengthened sufficiently within an acceptable timeframe, special construction support such as geogrid may be required.

Once the first layer has been placed, it may be possible to proceed using normal spoil dumping practices to complete the bulk shape of the final landform. The actual dumping strategy should be confirmed by further geomechanical analysis, including estimation of consolidation settlement, after the first layer is completed. Topographic (survey) monitoring should continue until an appropriately qualified geotechnical engineer has reviewed the monitoring results and confirmed that predicted remaining differential settlement will not compromise the final surface drainage plan.

Because the proposed cover system is essentially simple bulk spoil fill, no specific testing is required for QC/QA during construction, except to confirm minimum cover thickness. After completion of bulk earthworks, the landform may be left for a period while further consolidation settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile. The area would then be rehabilitated in accordance with normal site practices for spoil dumps, including topsoil placement and construction of erosion control measures.

8. R74 TSF

8.1 Description

R74 is an inactive in-pit tailings storage facility with no aboveground storage. The pit was mined sometime before 2001. The northern half of the pit is aligned roughly north-west to south-east while the southern part is nearly north to south. The northern endwall is about 1.8km south-west of the SCPP, with various mine small mine-affected water dams and Laleham TSF in between.

From December 2001 until 2008, tailings were discharged from the northern endwall and allowed to beach down toward the southern end. Based on the site geological model, the tailings surface is below the base of weathering except at the location of the pre-mining alignment of Sirius Creek, and it is more than 10m below spill level. Since tailings deposition ceased, the pit has at times been used to store excess mine-affected water, apparently without infrastructure to recover the water.

R74 TSF is about 1.9km long from northern to southern endwall and has a footprint of about 41Ha. Based on limited historic survey, it is estimated that the depth of tailings varies from about 24m in the south to 32m in the north. The beach angle of the tailings is about 0.6%.

8.2 Surrounding Environment

R74 TSF is not close to any third party infrastructure. A power line easement to the SCPP passes about 0.4km north of the northern endwall, but the only other nearby infrastructure are mine access roads. Prior to mining, Sirius Creek flowed east-to-west across the southern area of the pit, and a diversion was constructed around the southern endwall. An upgraded creek diversion

and associated flood protection structures have been designed but the alignment near R74 will not change greatly. In keeping with creek-flow direction, unmined ground east of the highwall slopes gently toward the pit. Spoil west of the pit lowwall has undergone rehabilitation. Prior to mining, the dominant regional land use was low intensity grazing but a significant area of land east of the highwall is uncleared woodland mapped as MSES regulated vegetation (Category B – endangered) comprising sub-dominant shrubby open forest. A smaller area about 1km south of the TSF (on the other side of Sirius Creek is mapped as high ecological significance wetlands comprising dominant endangered open forest.

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian coal measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). Flow path simulation included in that report indicated that the TSF would remain a groundwater sink, and therefore tailings-contacted water would not flow out into the broader groundwater system. The site geological model shows typically 10-20m depth of Tertiary/ Quaternary soil and rock overlying weathered Permian rock with unweathered Permian Rangal Coal Measures generally 20-25m below pre-mining ground level. The exception is at the original channel of Sirius Creek, where the depth of weathering increases to about 35m.

As noted in Section 10.1, the tailings surface is more that 10m below surrounding ground level and more than 5 million cubic metres of spoil would be required to completely backfill the void. Considering geological changes, proximity to Sirius Creek and the presence of regulated endangered vegetation about a kilometre east of the current highwall, no further mining is planned in the vicinity. The spoil that was produced from R74 pit has been rehabilitated up to the lowwall and so re-handling from that source would have a negative environmental outcome. Consequently, the final landform design for R74 TSF is a residual void that is a NUMA approved under existing Land Outcome Documents. This imposes different requirements on cover design, as discussed in the following sections.

8.3 Cover Design

8.3.1 Specific Hazards and Concept Cover Design

As an in-pit TSF with no aboveground storage, there is no mechanism for embankment failure (hazard i). In addition, because the void will be a NUMA, hazards d and e, regarding uptake of contaminants by vegetation, are not relevant. Consequently, the most important specific hazards relate to seepage or spill of tailings-contacted water (hazards a, b, and c). Iterative final landform design, hydrogeological modelling and void water balance modelling (SLR, 2024 and WSP, 2024) have shown that by constructing a thick single-layer spoil cover from the northern end down to about 650m from the southern endwall, a water cover always at least 1m deep will establish over the remaining (southern) section and the void will remain a long-term groundwater sink with no risk of overflow to surface waters.

Tailings consolidation settlement (hazard g) will vary with tailings depth and water content profile (or conversely, density profile) and with spoil cover thickness, and is expected to occur over a long timeframe – potentially decades. Conceptually, this settlement can be accommodated by making the cover thicker in the areas where greater settlement is predicted so that surface drainage is maintained after the settlement has occurred. Settlement under the permanent water cover will not affect cover performance.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

8.3.2 Design Details

As a NUMA, the over-arching objective for closure of R74 TSF is to create a stable landform that permanently contains tailing solids and limits any release of solutes to levels that will not cause environmental harm. The following are preliminary specifications for the combined spoil and water covers:

- 5m minimum thickness of spoil will be placed over the tailings, from the northern end of the TSF to nominally 650m north of the southern endwall. The spoil layer will be battered down at an angle assumed to be 1:3 for planning purposes but to be determined by stability analyses at detailed design;

- A pit lake will be established south from the spoil batter to act as a permanent water cover with a minimum depth of 1m over the tailings that are not covered by spoil.

The magnitude and rate of consolidation settlement depend on composition (size grading), existing pre-consolidation, and the disposition of drainage paths, all of which vary within the three-dimensional tailings deposit. Consequently, estimates are not included in the conceptual cover design; instead, settlement will be assessed and allowed for as part of detailed design and especially by adaptive design revision during the construction phase.

8.3.3 Construction Methodology

As described in Section 5.3.4, the first layer over tailings is the most difficult to construct because it needs to balance the conflicting effects of supporting construction equipment and loading the tailings. The strength and thickness of the tailings surface crust is critical to being able to meet both constraints. For this reason, mine-affected water stored in the void must be pumped down to allow the tailings north of about 600m from the southern endwall to desiccate for several years before in situ strength profiles are measured and used to undertake geomechanical design of the construction sequence. This will typically involve bearing capacity and/or stability analysis to determine combinations of thickness of the first layer of cover material and construction plant ground pressures that do not overload tailings strength profiles across the TSF. Even then, considering the inherent variability in tailings due historic to changes in CHPP feed and product targets, and the effects of beaching and sorting at discharge, it should be expected that the cover design and the construction schedule will be further modified based on monitoring as an initial layer of spoil is placed.

Once a first layer has been placed, it may be possible to place the remaining thickness of spoil cover in one pass. The actual dumping strategy should be confirmed by further geomechanical analysis, including estimation of consolidation settlement, after the first layer is completed. Topographic (survey) monitoring should continue until an appropriately qualified geotechnical engineer has reviewed the monitoring results and confirmed that predicted remaining differential settlement will not prevent the final surface from draining freely to the water cover at the northern end.

Because the proposed northern cover is essentially simple bulk spoil fill, no specific testing is required for QC/QA during construction, except to confirm minimum cover thickness. After completion of bulk earthworks, the landform may be left for a period while further consolidation

settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile.

The water cover at the southern end is expected to establish readily once dewatering ceases. If this does not occur within a desired timeframe, for example if closure occurred during drought conditions, water could be pumped onto the tailings until conditions equilibrated.

9. BOTTOM DAM TSF & ROM3 AREA WSF

9.1 Description

The ROM3 Area coarse rejects dump is located against an east-facing natural slope about 0.7k south of the SCPP. The dump batter is at angle of repose and about 38m high; the flat top ranges up to 120m wide and the total footprint is 5.5Ha.

Bottom Dam abuts the eastern toe of the dump, about half-way along. It is bound by sloping ground at the north, a 6m high earthfill embankment at the east, and a spoil dump at the south. The footprint of Bottom Dam TSF is 3.2Ha Geotechnical drilling suggests that the storage is up to 15m deep and founded within the regolith, that is, above fresh Permian coal measures.

Bottom Dam was originally a process water storage forming part of the SCPP water management system. It received overflow from No.1 Dam (upslope to the north) and into flowed though a culvert to Duck Pond at the east, on the other side of a mine road. The dam also incidentally received coal fines and other sediment washed in from No.1 Dam and the rejects dump but it was not designated as a TSF until sometime after 2012.

The tailings surface is close to the embankment crest level and is fairly flat except for a small sump around the culvert to Duck Pond. Scrubby mid-storey has established over more than half of the tailings surface. Recent geotechnical investigation showed a desiccated surface crust typically 1-2m thick.

9.2 Surrounding Environment

The combined WSF is in the middle of the old South Blackwater Mine industrial area, with ROM3 Area and the CHPP on natural high ground to the west and north respectively, other mine dams immediately east and Laleham TSF further east again, a spoil dump immediately to the south and natural ground draining to Sirius Creek about to the south-east. Prior to mining the dominant land use on the mining lease was low intensity grazing, with significant areas of uncleared woodland. Some of the latter remain in the vicinity of ROM3 Area/Bottom Dam and are mapped as Category B regulated vegetation (endangered and of-concern eucalyptus woodland to open forest).

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian Rangal Coal Measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). Similar to NCPP TSF, flow path simulation included in SLR (2024) does not reflect the risk of seepage to the groundwater system. Surface geology mapped for the footprint of the combined WSF is Emerald Formation Tertiary weathered siltstone and claystone; the ridge to the west and north has Tertiary duricrust, and Sirius Creek runs through

regolith of Permian Burngrove formation. That is, the WSF is unlikely to have direct hydrogeologic connection with Sirius Creek.

For the final landform, it is planned to push the rejects down over the tailings to create a slope abutting the Tertiary ridge with runoff draining freely to the south and south-east.

9.3 Cover Design

9.3.1 Specific Hazards

The planned final landform is a sloping shape that will not pond water, so there is no risk of spill to surface water (hazard c in Table 4-1). The rejects dump and TSF did not greatly alter natural surface drainage because they broadly followed the pre-existing ground-slope direction (hazard f). As noted in the previous section, shallow seepage out of the TSF and into Sirius Creek is unlikely because there is not a clear hydrogeologic connection. Deep seepage from the TSF might flow toward Sirius Creek as indicated by the flow path simulations (SLR, 2024), however it is unlikely (hazard a).

As a TSF with some aboveground containment, embankments are required to structurally contain low strength tailings, and so embankment failure is a credible scenario (hazard i). However, the cover can only influence embankment stability indirectly and in a limited way – by avoiding accumulation of water and consequent pore pressure increase – and so this hazard will be separately addressed through detailed design for overall decommissioning of the TSF.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

9.3.2 Concept Cover Design

The present batter of the rejects dump is steep and eroded and requires significant re-shaping to create an acceptable final landform. Bottom Dam TSF has been colonised by shrubby vegetation but has formed a shallow surface depression that would intermittently pond and potentially overflow. Hence, it is planned to push the rejects down over the TSF to flatten the slope and fill the depression. There is a spoil dump immediately south of Bottom Dam but the spoil characteristics are unknown; the same applies to the next closest potential sources of cover material. Given this context, the preferred cover type is a thick layer of general spoil. Final surface gradients, topsoil thickness and vegetation will be consistent with other spoil landforms rehabilitated to the same post-mining land use.

Tailings consolidation settlement varies with tailings depth and water content profile (or conversely, density profile) and with cover thickness. Considering that tailings deposition ceased so long ago, it is likely that a significant amount of settlement has already occurred. However, the additional weight of cover spoil will trigger a new stage of consolidation that theoretically might take decades to complete (although consolidation follows a logarithmic timeframe which means that most of the settlement happens in the early years). For detailed cover design, the rate of consolidation and total and differential settlement will need to be estimated and allowed for, typically by adjusting the cover thickness to compensate.

9.3.3 Design Details

The high level design objective for rehabilitation of Bottom Dam TSF and ROM3 Area WSF is to create a landform that permanently contains tailing solids, limits any release of solutes to levels that will not cause environmental harm, and can support managed grazing within a wider grazing enterprise. The coarse rejects will be pushed over Bottom Dam to create the bulk landform topography, so in this case the spoil will only be required to provide cover function – limiting the movement of solutes both downward and upward. The following specifies a minimum spoil thickness, but in some areas the actual thickness may be greater, to create a surface that sheds rainfall runoff causing excessive erosion.

- 5m thickness of spoil, dumped and spread in such a way that dispersive spoil with high fines content is not placed in the outer 1m of the landform. This may be achieved by selective placement or by chemically treating the top metre of spoil to reduce sodicity;
- Topsoil and erosion management practices consistent with those on other rehabilitated spoil areas.

Tailings consolidation settlement will vary with tailings depth and water content profile (or conversely, density profile) and with spoil thickness, and is expected to occur over a long timeframe – potentially decades. Conceptually, this settlement can be accommodated by making the relevant layers of the cover thicker in the areas where greater settlement is predicted so that mounded interfaces and surfaces will remain mounded after the settlement has occurred.

9.3.4 Construction Methodology

As described in Section 5.3.4, the first layer over tailings is the most difficult to construct because it needs to balance the conflicting effects of supporting construction equipment and loading the tailings. On Bottom Dam TSF, that first layer will be coarse rejects rather than spoil; this is an advantage because the rejects are both lighter and stronger. However, the strength and thickness of the tailings surface crust will still be critical to being able to meet both construction constraints. The in situ strength profiles recently measured may be sufficient to undertake geomechanical design of the construction sequence. This will typically involve bearing capacity and/or stability analysis to determine combinations of thickness of the first layer of rejects and construction plant ground pressures that do not overload tailings strength profiles across the TSF. Even then, considering the inherent variability in tailings due to changes in CHPP feed and product targets, and the effects of beaching and sorting at discharge, it should be expected that the cover design and the construction schedule will be further modified based on monitoring as the initial layer is placed. If the surface cannot be strengthened sufficiently within an acceptable timeframe, special construction support such as geogrid may be required.

Once the first layer has been placed, it may be possible to complete the coarse rejects re-handling and subsequent spoil cover placement using normal earthworks practices. However, the actual dumping strategy should be confirmed by further geomechanical analysis, including estimation of consolidation settlement, after the first layer is completed. Topographic (survey) monitoring should continue until an appropriately qualified geotechnical engineer has reviewed the monitoring results and confirmed that predicted remaining differential settlement will not compromise the final surface drainage plan.

Because the proposed cover system is essentially simple bulk spoil fill, no specific testing is required for QC/QA during construction except to confirm minimum cover thickness. After completion of bulk earthworks, the landform may be left for a period while further consolidation

settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile. The area would then be rehabilitated in accordance with normal site practices for spoil dumps, including topsoil placement and construction of erosion control measures.

10. BONNIE DOON TSF

10.1 Description

Boonie Doon is an active in-pit TSF located at the northern end of current mining. It comprises four straight pit sections connected by two ramps (R10 and R12).

The lowest part of the mined pit floor was RL 119m. Tailings deposition commenced in December 2023 and will continue until the tailings reach RL 160m just north of R10, beaching down from about RL 179m at the southern end. The maximum tailings elevation was reduced from the level specified in the design plan, both to keep the operating tailings and decant pond levels below the base of weathering exposed in the highwall (ranging from RL 172m to RL 185m), and to ensure that the storage facility remains a sink relative to possible groundwater aquifers in the Tertiary and Quaternary sediments.

The TSF is 2.7km north-south and has a footprint of about 42Ha. When filled, the depth of tailings will range from about 25m in the north to 60m at the southern end. The location of tailings discharge and the decant pond may change throughout the operational life but by closure, the tailings surface will drain toward the north with beach slope in the order of 1-1.5%.

10.2 Surrounding Environment

The northern end of the TSF is about 1.5km south of the Capricorn Highway and 5km south-west of the town of Blackwater. The two pit ramps run about 1km down from the main mine access road at the west and the mine's rail line is at the western side of the road. Sagittarius Creek is located about 3.7km east of the TSF highwalls and flows northward. Several unnamed gullies (that are defined drainage features under the Water Act 2000) collect overland flow from the area east the TSF and feed it into the creek. Prior to mining the dominant land use was low intensity grazing and this continues outside the area of mine disturbance. Regulated vegetation (Category R – GBR riverine) is mapped along the upslope ends of some of those drainage features but there are no other Matters of State Environmental Significance near the TSF.

In and around the mine area, groundwater occurs mainly in the coal seams in the Permian Rangal Coal Measures and potentially in poorly consolidated Tertiary sediments. Quaternary alluvium is limited to some current drainage features and watercourses and investigations to date suggest that any groundwater is ephemeral and associated with creek flows, rather than representing a sustained water table (SLR, 2024). Surface geology mapped for the footprint of Boonie Doon shows most of the highwall edging into Triassic Rewan Formation overburden that overlies the mined Permian Rangal Formation. The exception is at the northern end, where Quaternary alluvium comprising sheetwash and flood-out sheets is mapped. Hence Bonnie Doon TSF, like all pits mined at Blackwater, intersects the unmined portions of coal seam aquifers; however, this TSF could also contact shallow local aquifer(s) in the surface alluvium, if the tailings and decant pond level were not restricted to avoid it.

Because of the constraints on maximum tailings level described in Section 10.1, the final tailings surface will be 20-40m below surrounding ground level. Within the current life-of-mine plan, there will not be mining close to Bonnie Doon when the TSF is undergoing closure so no close-haul spoil will be produced at the time. Much of the spoil that was produced by mining Bonnie Doon is already under rehabilitation, so re-handling enough of that spoil to fill the TSF to ground level would be high cost and have negative environmental impact. Consequently, the final landform design for Bonnie Doon TSF is a residual void that is a NUMA approved under existing Land Outcome Documents. This imposes different requirements on cover design, as discussed in the following sections.

10.3 Cover Design

10.3.1 Specific Hazards and Concept Cover Design

As an in-pit TSF with no aboveground storage, there is no mechanism for embankment failure (hazard i in Table 4-1). In addition, because the void will be a NUMA, hazards d and e, regarding uptake of contaminants by vegetation, are not relevant. Consequently, the most important specific hazards relate to seepage or spill of tailings-contacted water (hazards a, b, and c). Iterative final landform design, hydrogeological modelling and void water balance modelling (SLR, 2024 and WSP, 2024) have shown limiting the tailings level to RL 160m at the end of R10, and constructing a thick single-layer spoil cover south of R10 will maintain the void as a long-term groundwater sink, avoid seepage into any shallow alluvial aquifers, and avoid overflow to surface waters. This configuration will also provide a permanent water cover, at least 1m deep, over tailings north of R10.

Tailings consolidation settlement (hazard g) will vary with tailings depth and water content profile (or conversely, density profile) and with spoil cover thickness, and is expected to occur over a long timeframe – potentially decades. Conceptually, this settlement can be accommodated by making the cover thicker in the areas where greater settlement is predicted so that surface drainage is maintained after the settlement has occurred. Settlement under the permanent water cover will not affect cover performance.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

10.3.2 Design Details

As a NUMA, the over-arching objective for closure of Bonnie Doon TSF is to create a stable landform that permanently contains tailing solids and limits any release of solutes to levels that will not cause environmental harm. The following are preliminary specifications for the combined spoil and water covers:

- The final tailings elevations in the TSF will be RL 160m at the end of R10, with the surface sloping down to the north and up to the south;

- 5m minimum thickness of spoil will be placed over the tailings, from the southern end of the TSF to nominally 150m south of the endwall at R10. The spoil layer will be battered down at an angle assumed to be 1:3 for planning purposes but to be determined by stability analyses at detailed design;

- A pit lake will be established north from the spoil batter to act as a permanent water cover with a minimum depth of 1m over the tailings that are not covered by spoil.

The magnitude and rate of consolidation settlement depend on composition (size grading), existing pre-consolidation, and the disposition of drainage paths, all of which vary within the three-dimensional tailings deposit. Consequently, estimates are not included in the conceptual cover design; instead, settlement will be assessed and allowed for as part of detailed design and especially by adaptive design revision during the construction phase.

10.3.3 Construction Methodology

As described in Section 5.3.4, the first layer over tailings is the most difficult to construct because it needs to balance the conflicting effects of supporting construction equipment and loading the tailings. The strength and thickness of the tailings surface crust is critical to being able to meet both constraints. For this reason, after the tailings reach final design level, the decant pond must be pumped down continuously to allow the tailings south of the endwall at R10 to desiccate for several years before in situ strength profiles are measured and used to undertake geomechanical design of the construction sequence. This will typically involve bearing capacity and/or stability analysis to determine combinations of thickness of the first layer of cover material and construction plant ground pressures that do not overload tailings strength profiles across the TSF. Even then, considering the inherent variability in tailings due to changes in CHPP feed and product targets, and the effects of beaching and sorting at discharge, it should be expected that the cover design and the construction schedule will be further modified based on monitoring as an initial layer of spoil is placed.

Once a first layer has been placed, it may be possible to place the remaining thickness of spoil cover in one pass. The actual dumping strategy should be confirmed by further geomechanical analysis, including estimation of consolidation settlement, after the first layer is completed. Topographic (survey) monitoring should continue until an appropriately qualified geotechnical engineer has reviewed the monitoring results and confirmed that predicted remaining differential settlement will not prevent the final surface from draining freely to the water cover at the northern end.

Because the proposed southern cover is essentially simple bulk spoil fill, no specific testing is required for QC/QA during construction, except to confirm minimum cover thickness. After completion of bulk earthworks, the landform may be left for a period while further consolidation settlement occurs. When topographic monitoring indicates that the remaining settlement is within a manageable range (nominally <0.3m), the surface may be trimmed to final design profile.

The water cover at the northern end is expected to establish readily once dewatering ceases. If this does not occur within a desired timeframe, for example if closure occurred during drought conditions, water could be pumped onto the tailings until conditions equilibrated.

11. RAMP 36 REJECTS DUMP

11.1 Description

Ramp 36 Rejects Dump is a long narrow WSF located south-east of the NCPP TSF, on the southern side of Deep Creek and the western side of the main haul road. It has a footprint of

72Ha, with a high mound at the southern end reaching about 30m above surrounding ground levels. The batters in that area are at angle-of-repose.

It is understood that the WSF received coarse rejects over the period from 1967 to 2007 and that rejects were also removed from the WSF at times, to use in construction of wall lifts on the NCPP TSF.

11.2 Surrounding Environment

The is a small sediment pond at the northern end of the WSF, about 30m from the culvert where Deep Creek flows under the haul Road. At the east and south, it appears that runoff is directed into the haul road side drains. Taurus Creek flows under the haul road about 2km to the south.

Current mining pits are about 1.6km east of the haul road; partly rehabilitated spoil dumps at the back of the pits drain west toward the haul road. Under the Life-of-Mine Plan, the final Deep Creek Void will be about 0.9km further east from the present location.

Prior to mining and outside the area of mine disturbance, the dominant land use has been low intensity grazing, except in Amaroo State Forest more than 3km west and up-slope of the WSF. An are of regulated vegetation (sub-dominant of-concern regional ecosystem comprising remnant acacia dominated open forest, woodland and shrublands) is mapped south-east of the WSF; regulated vegetation (riverine) is mapped along Deep Creek and Taurus Creek and their tributaries. Deep Creek and Taurus Creek are watercourses defined by the Water Act 2000.

The final landform design for Ramp 36 is a stand-alone elevated landform with about the same footprint as the current facility. Some coarse rejects will be moved within that area to flatten slopes down to the same gradients being applied to spoil dumps.

11.3 Cover Design

11.3.1 Specific Hazards

Coarse rejects are geotechnically competent and do not need physical containment, so hazards g, i, and l in Table 4-1 are not relevant. In addition, the waste was dry-placed and contains much less water than tailings, so the risk of deep seepage to groundwater is much reduced (hazard a).

The proposed final landform is a mounded shape that will not pond water, so there is no risk of spill to surface water (hazard c). The WSF did not alter surface drainage except in its immediate vicinity - runoff draining east and west is presently captured but after rehabilitation it will follow normal drainage paths north and south to Deep Creek and Taurus Creek respectively (hazard f). Shallow seepage out of the WSF, in particular to Deep Creek, is feasible (hazard b) so minimising infiltration below the rooting zone will be a focus of detailed cover design.

Other relevant potential hazards will be addressed by the general controls outlined in Table 4-1.

11.3.2 Concept Cover Design

Because coarse rejects do not require containing embankments, Ramp 36 WSF can be re-shaped and covered essentially within its existing footprint (unlike NCPP TSF). In this context, a thick layer of general spoil is proposed for rehabilitation, with spoil sourced from future mining of the Deep Creek Pits. Final surface gradients, topsoil thickness and vegetation will be consistent with other spoil landforms rehabilitated to the same post-mining land use.

11.3.3 Design Details

The high level design objective for rehabilitation of Ramp 36 WSF is to create a landform that limits any release of solutes to levels that will not cause environmental harm, and can support managed grazing within a wider grazing enterprise. Coarse rejects presently in the emplacement will be re-handled to create a rough landform shape such that the required cover layer thickness will be fairly uniform, with details as follow:

- 5m thickness of spoil, dumped and spread in such a way that dispersive spoil with high fines content is not placed in the outer 1m of the landform. This may be achieved by selective placement or by chemically treating the top metre of spoil to reduce sodicity;
- Topsoil and erosion management practices consistent with those on other rehabilitated spoil areas.

Coarse rejects do not experience consolidation settlement. Due to the uncompacted nature of the waste, there may be some settlement due to the weight of the cover layer but most of this will occur as the cover is constructed and does not need to be specifically addressed in design.

11.3.4 Construction Methodology

Given the geotechnical competence of coarse rejects, construction of the thick spoil cover will be straight forward, typically comprising a simple dump and spread operation. Because the thick spoil is essentially simple bulk fill, no specific testing is required for QC/QA during construction except to confirm minimum cover thickness.

After completion of bulk earthworks, it would be advisable to leave the landform for a period to allow any residual settlement to occur. When topographic monitoring suggests that minimal further movement is likely, the area would then be rehabilitated in accordance with normal site practices for spoil dumps, including topsoil placement and construction of erosion control measures. The vegetation species mix should be consistent with the post-mining land use of managed grazing.

12. FUTURE WORK

The cover systems described herein are conceptual designs based on information available at August 2024.

As emphasised in the sections discussing construction methodology, construction design for the TSF covers cannot be finalised until in situ strength profiles are measured and this should be done as short a time as possible before cover works commence.

Spoil that may be suitable for the various cover layers should be identified as mined and/or in spoil dumps close to each TSF. Ideally, spoil should have been aged in dump for at least a couple of years to observe slaking and other degradation before samples for classification testing including silt/clay fraction and plasticity. In situ infiltration tests to confirm construction materials and methodology may be undertaken after suitable spoils have been identified and must be completed before the design is finalised.

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ENGENY

WHITEHAVEN COAL

PRCP Concept Design Report

Sirius Creek Diversion

BBNE04877_0045-REP-002-0

3 OCTOBER 2025

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the SIrius Creek Diversion which satisfies the conditions under Environmental Authority (EA) EPML00717813. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Blackwater Mine (BWM)

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for BWM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options Assessment.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion remediation option (outcome from Stage 1) to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology approach was adopted:

- A desktop geomorphic assessment of Sirius Creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

Design Process

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Sirius Creek is an ephemeral tributary of the Comet River, situated within the Fitzroy River basin. The creek originates in a relatively low relief range to the east of Blackwater Mine. The creek flows from east to west through the southern part of Blackwater Mine operations and south of Laleham Pit and Ramp 74, eventually joining Comet River some 47 km west of Blackwater Mine. The catchment upstream of the diversion is approximately 100 km^2 and currently flows through "Old Cut 4" Dam. The diversion was likely constructed in 1977-1978 (Alluvium, 2010), at a length of approximately 2.7 km, to allow mining in Laleham Pit and form part of the flood mitigation for this pit. Refer to Figure 2.1 for the location of the Sirius Creek Diversion.

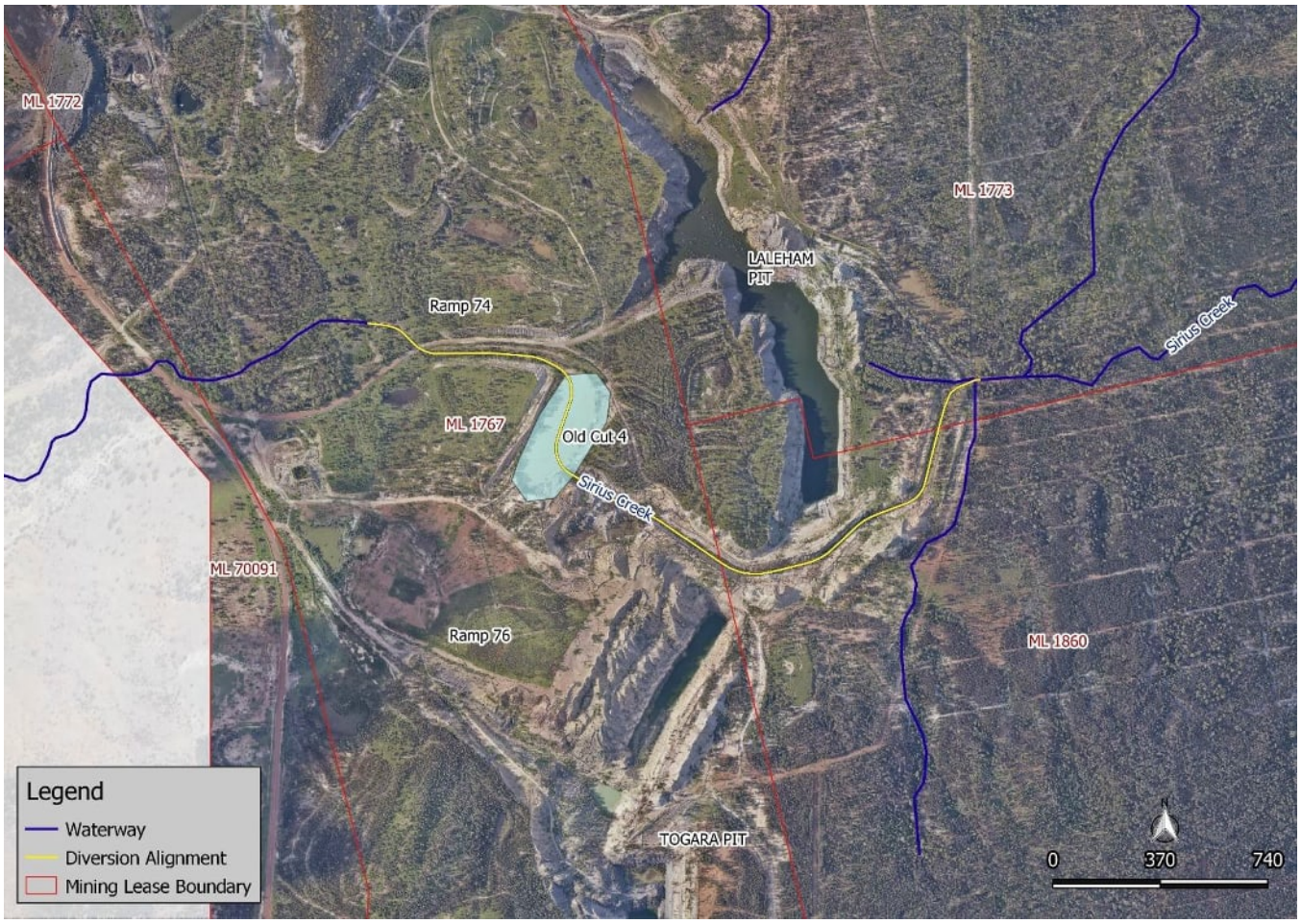


Figure 2.1:Location of the Sirius Creek Diversion at Blackwater Mine

2.2 Natural Reaches

The upstream, downstream and diversion reaches of Sirius Creek have been described as follows (Alluvium, 2010):

- **Upstream reach –** The upstream reach of the Sirius Creek diversion is a moderate sinuosity channel with low capacity, channel depths varying between 1-4 m and top width between 8-20 m. The channel does not have an excess supply of bedload sediment with native vegetation and habitat diversity enhanced due to woody debris. Some minor clearings have resulted in erosion heads along parts of the upstream channel. Generally, the upstream reach is representative of the natural environment of the surrounding land.
- **Downstream reach –** The downstream channel of the Sirius Creek diversion comprises of a moderate sinuosity low flow channel of low capacity, set within a broad floodplain. The riparian vegetation along the reach is subject to grazing and mining influences, with "Old Cut

4" dam impacting the sediment flow regime within the diversion. The dam is not allowing sediments to pass through the system freely and as a result sediment is accumulating within the diversion. The downstream reach is approximately 1-3 m deep with the low flow channel top width ranging from 10-20 m.

- **Diversion reach (pre-mining)** - The Sirius Creek diversion reach (pre-mining) was approximately 2.5 km long. It was gently meandering across the southern extent of what is now Laleham Pit.

The upstream, downstream and diversion reaches of the Sirius Creek diversion at Blackwater Mine are shown in Figure 2.2.

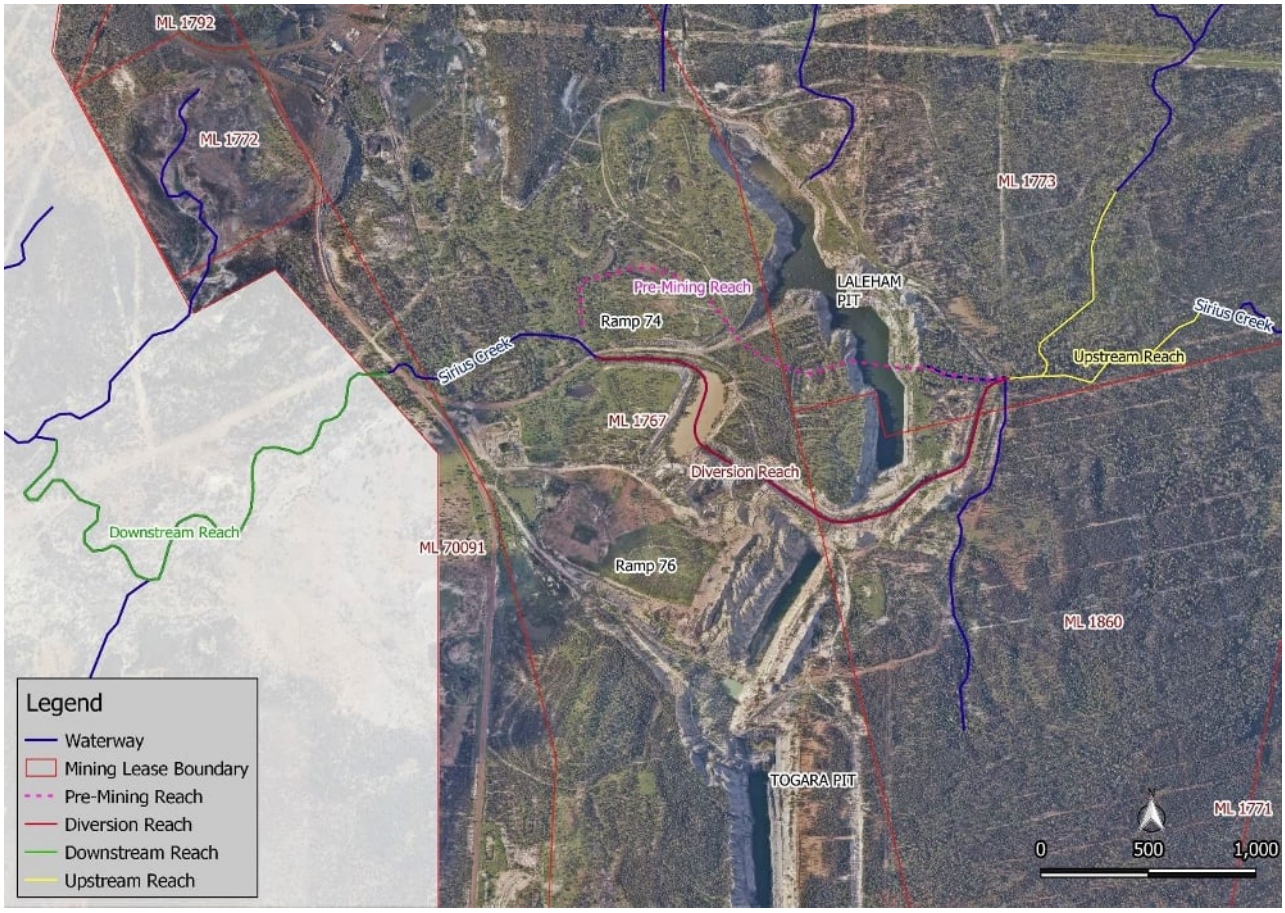


Figure 2.2: Upstream, Downstream and Diversion Reaches of the Sirius Creek Diversion

2.3 Diversion Reach

Monitoring of Sirius Creek diversion has been undertaken since 2010 and was last completed in 2017. As part of the major monitoring, the latest condition of the Sirius Creek diversion has been described as follows (Engeny, 2017):

- The upstream reach and downstream reach have remained relatively stable overall with a minor improvement in riparian vegetation condition. Prior to the last minoring assessment, the riparian condition was deteriorating steadily.
- There is an existing dam within the diversion reach, called "Old Cut 4" which is influencing the flow regime within the diversion as well as sediment supply of the reach.
- The diversion reach continues to remain in poor condition due to the nature of the diversion, the inability to function as a natural system and excess supply of sediment from spoil dumps and bank erosion.

Based on the current condition of the Sirius Creek diversion, it is highly unlikely that the diversion will achieve the water license relinquishment criteria prior to mine closure without intervention.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions. Details of the guidelines that have been used to design the Sirius Creek diversion are summarised below.

3.1 DNRME Guideline

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Sirius Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Sirius Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.

- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
2-year ARI (no vegetation) (39% AEP)	<35	<1.0	<40
2-year ARI (vegetated) (39% AEP)	<60	<1.5	<40
50-year ARI (2% AEP)	<150	<2.5	<80[1]

1. DNRME values are taken from ACARP 2002 as the <50N/m^2 value in DNRME 2019 is incorrect.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, which included an analogous approach, where channel dimensions are selected from a reference reach; a hydraulic geometry approach where dimensions are determined from regression relationships; and an analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be represented of stable watercourses within the Bowen Basin and are summarised in Table 3.2.

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Stream Power (W/m^2)	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass	40
Structurally diverse suite of established native vegetation	120

The long-term performance of the diversion under both operating and closure scenarios is assessed with the following objectives, based on industry standard closure objectives:

- The diversion demonstrates to be in a safe, stable, non-polluting and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Reference rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining landuse of the 'Watercourses' which is applicable for the watercourse diversion.
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

3.3 Environmental Authority EPML00717813

The land schedule within the Blackwater Mine EA (EPML00717813) requires that all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified Rehabilitation Requirements. The EA provides the rehabilitation landform criteria for the post mining land use of watercourses (refer to Figure 3.1). Some indicators reference the Index of Diversion Condition (IDC) method, which is a component of ongoing diversion monitoring.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

Figure 3.1: Blackwater Mine EA EPML00717813 Rehabilitation Requirements for Watercourses

4. OPTIONS IDENTIFICATION

Engeny identified four potential remediation options for the Sirius Creek diversion based on the current alignment, final landform consideration and the future mine plan. To inform the remediation concept design, the geomorphic features of the pre mining drainage path were incorporated and utilised as well as the upstream and downstream channel geometry and grade.

The objective was to identify suitable options for the permanent remediation of the Sirius Creek diversion and identify a preferred option to carry though to concept design. A maximum of three options were required, where four options were identified for Sirius Creek and taken forward into further assessment. The process to define the options includes a review of the natural waterway geometry, the existing creek diversion geometry, original design reports and current diversion design parameters.

Each option was defined with a concept cross section, longitudinal profile and meandering characteristics, if applicable. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of floodplain.
- Proposed tie-in locations to the existing waterway.
- Development Class 5 capital cost estimate.

Where applicable, the earthworks quantities include the filling quantity for existing dams or depressions which would be ultimately remediated in closure.

The options identification also includes the assessment of key risks and opportunities regarding potential staging, possible impacts to downstream infrastructure, reinstating the flood plain and post mining land-use risks in the context of closure. The main focus for each option was to determine the impacts and interaction between the PRCP final landform and the proposed diversion. Refer to Figure 4.1 for the potential options identified and Table 4.1 for further details.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2	Option 3	Option 4
Description	Re-instating natural alignment of the creek	Remediation of existing diversion channel	Diverting channel south through spoil and final landform	Diverting channel north around final void
Likelihood that diversion will achieve state of dynamic equilibrium	High – stream length similar to natural	Low – stream length increased >10%	Medium – stream length increased <10%	Low- stream length increased >10%
Diversion constructed through spoil	No	Yes	Yes	No
Order of magnitude cost estimate*	$10.6 M	$19.2 M	$190 M	$40 M
Ability to isolate diversion from flows during establishment period	Yes	No	Yes	Yes

*Cost estimate based on average $10/m^3 and Option 2 including quantities to fill 'Old Cut 4 Dam'

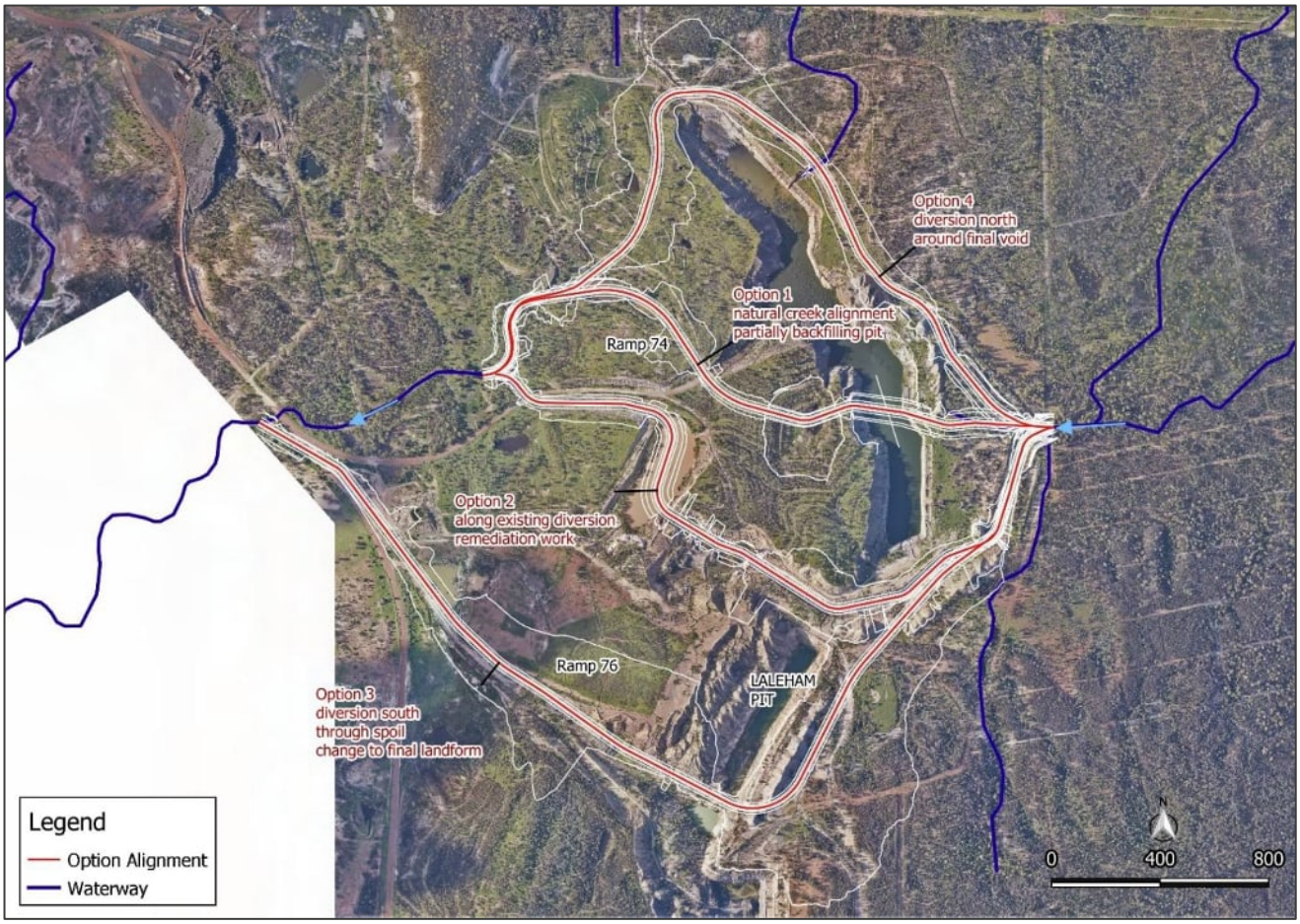


Figure 4.1: Sirius Creek Diversion Remediation Options

5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criteria was determined and agreed upon with a BHP and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criteria against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	40%
Diversion constructed through spoil	30%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 2 to be carried forward into concept design as a preferred option, since it scored highest out of all three options without a fatal flaw and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2	Option 3	Option 4
Overall Weighted Score	-0.6	-0.9	-1.0	-1.2
Relative Risk	Highest Risk	High Risk	Highest Risk	High Risk
Fatal Flaw	Yes	No	Yes	No

6. CONCEPT DESIGN

6.1 Design Parameters

Table 6.1 describes the parameters within each outcome described in Section 3 forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND THE AUSTRALIAN COAL ASSOCIATION RESEARCH PROGRAM (ACARP) PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral dysconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	*Outcome 5 –* Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Diversion Alignment

Option 2 was identified to be the preferred option alignment using the MCA, retaining and remediating the diversion on its current alignment due to the voids north and south. The alignment was further refined to optimise quantities and is consistent with pre-mining stream length and grade.

Previously, a design was provided for an early revision of the final landform. The design has now been updated to be consistent with Final Landform 3.6.1. Figure 6.1 shows the proposed permanent diversion alignment design and general arrangement. The preferred option design is included in Appendix C and the concept design and interaction with the PRCP landform in Appendix D.

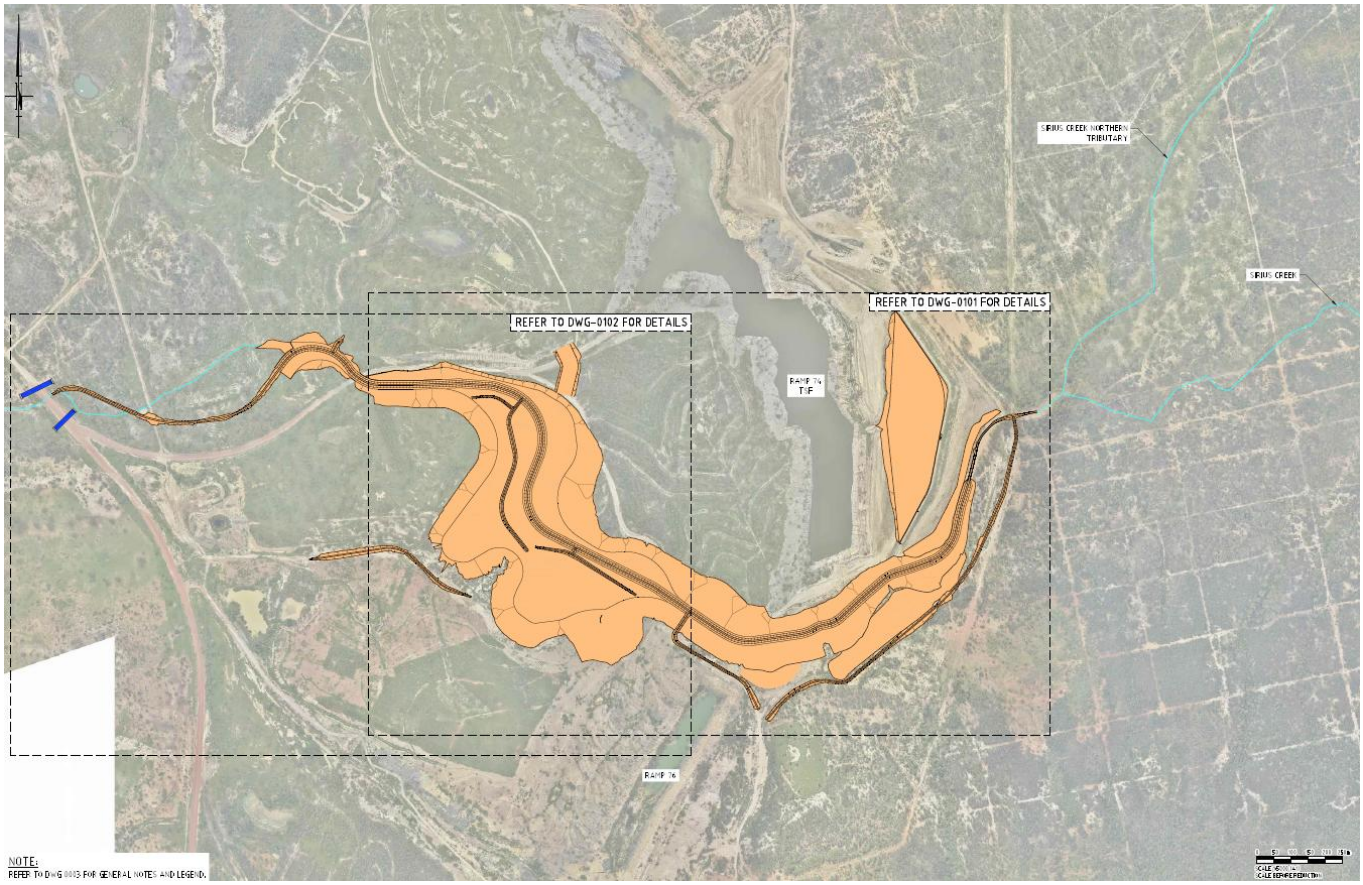


Figure 6.1: Option 2 General Arrangement

6.3 Channel Geometry and Grade

The typical upstream and downstream channel geometries are presented in Figure 6.3 and Figure 6.4 below. These dimensions were based on the average natural upstream and downstream channel geometry topographic data and aerial imagery were used to evaluate the planform and cross section parameters of multiple reference reaches of Sirius Creek. Cross-sectional dimensions were compared and evaluated for a total of 10 cross-section locations. The locations of the cross-sections taken for the analysis are provided in Figure 6.2. The accuracy of the survey used at the time of writing is defining the accuracy of the natural channel cross sections and the final cross section used for the concept design. Table 6.2 and Appendix C show the detailed geometry and typical cross section of the concept design with longitudinal profile, respectively.

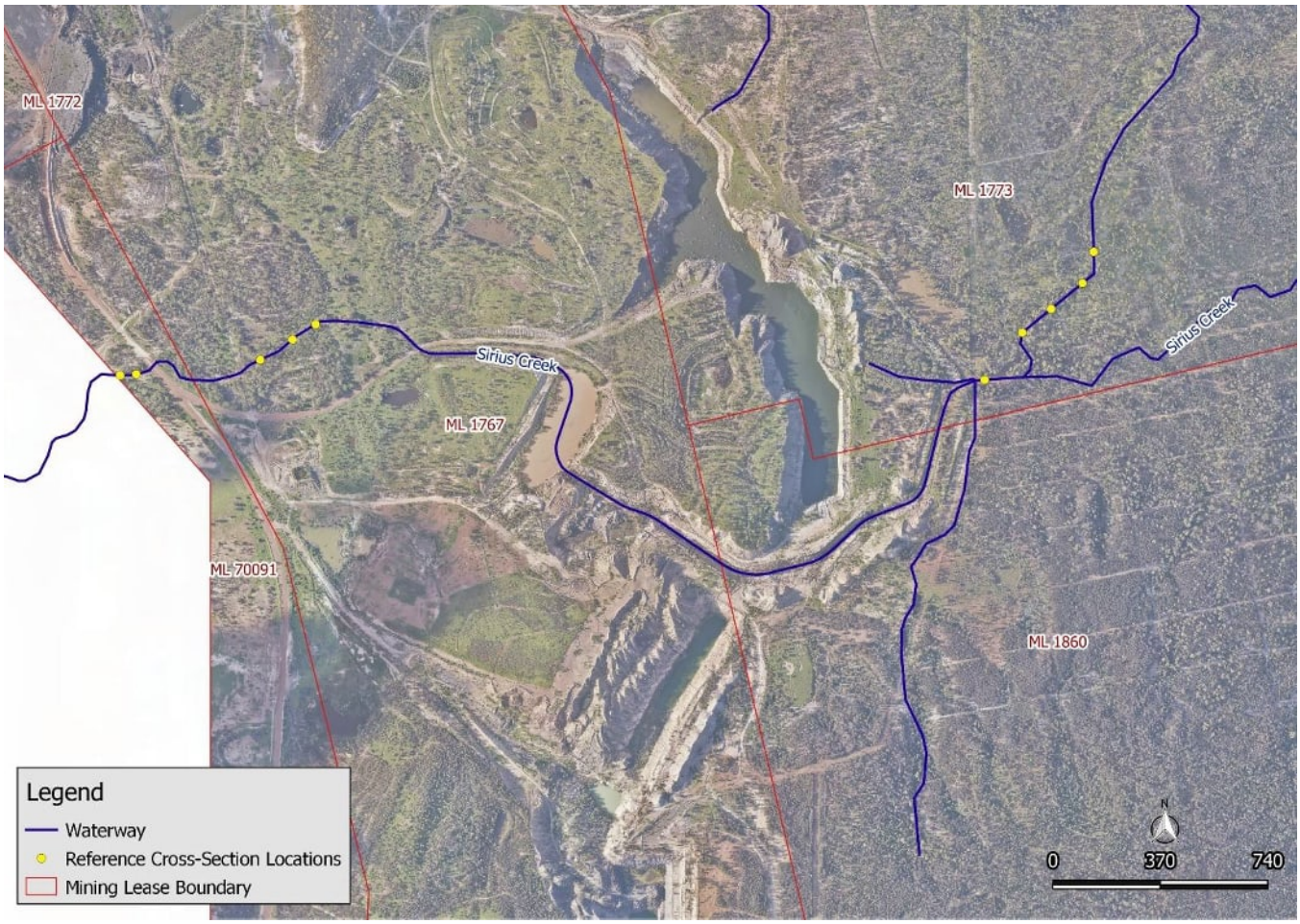


Figure 6.2: Locations of Reference Cross-Sectional Areas

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY

Channel Geometry	Quantity	Comments
Channel Bed Width	4 m	Based on the upstream reference reaches scaled by total catchment area
Batter Slope	1V:4H	Adopted based on scaled cross sectional area and construction safety. 1V:4H batters adopted over the majority of the diversion with 1V:3H batters adopted from approximate chainage 1000m to 1700m to reduce cut volume where the largest batters are present and reduce impact to certified rehab areas.
Channel Depth	2 m	Consistent depth of low flow channel at 2m
Bench Width	5 m	Bench only present between low flow and high flow channel

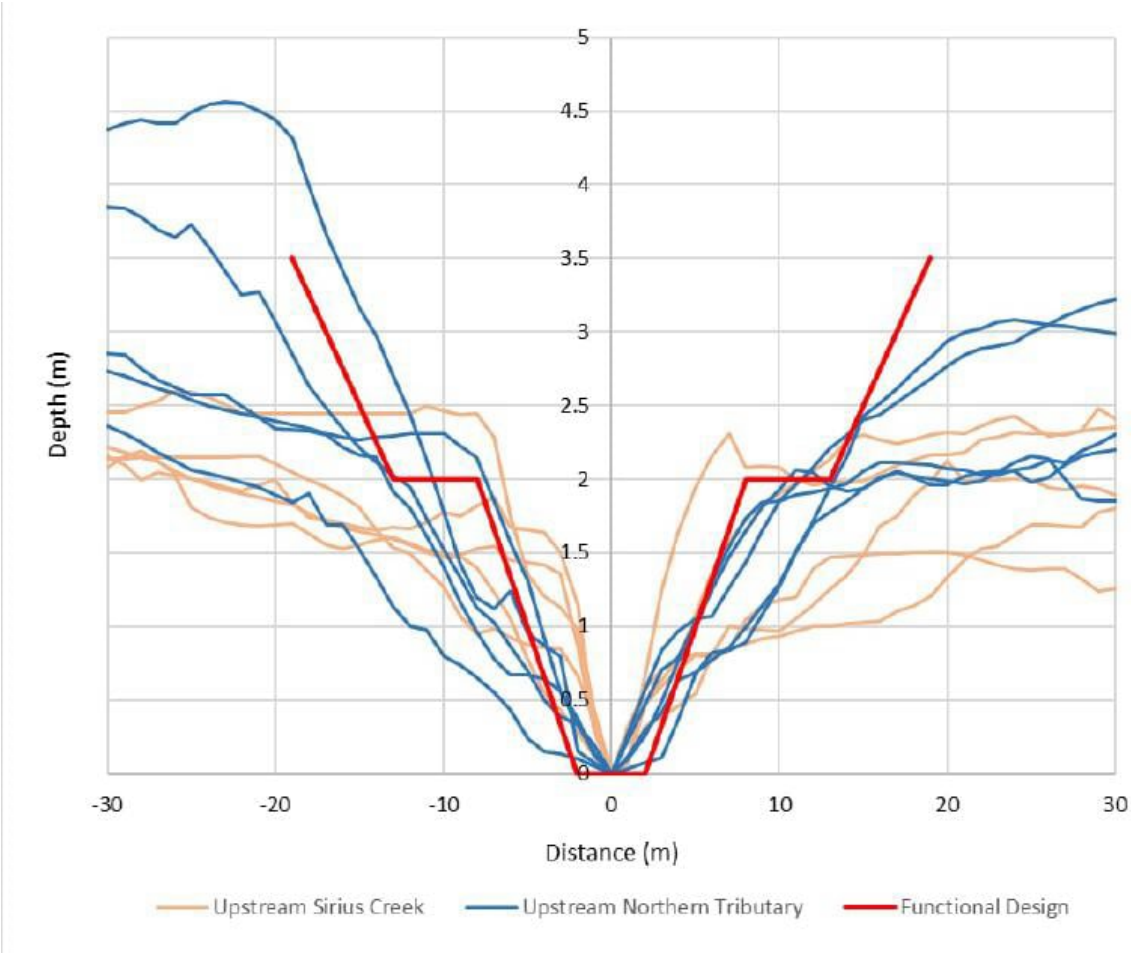


Figure 6.3: Typical Upstream Channel Cross Section and Design Cross Section

6.4 Hydrology

Peak flows for frequent events (39% AEP and2% AEP) for the Sirius Creek diversion remediation were estimated using the ACARP (2002) methods and are presented in Table 6.3. As described in Section 3, The hydraulic outcomes for diversion designs are only prescribed for frequent events (39% AEP and2% AEP). As such, hydraulic modelling of rare event (1% and 0.1% AEP) has not been undertaken as part of the diversion concept design. The Rehabilitation Flood Assessments undertaken separately as part of the PRCP should be referred to for the hydrologic and hydraulic modelling for the 1% AEP and 0.1% AEP flood events of Sirius Creek.

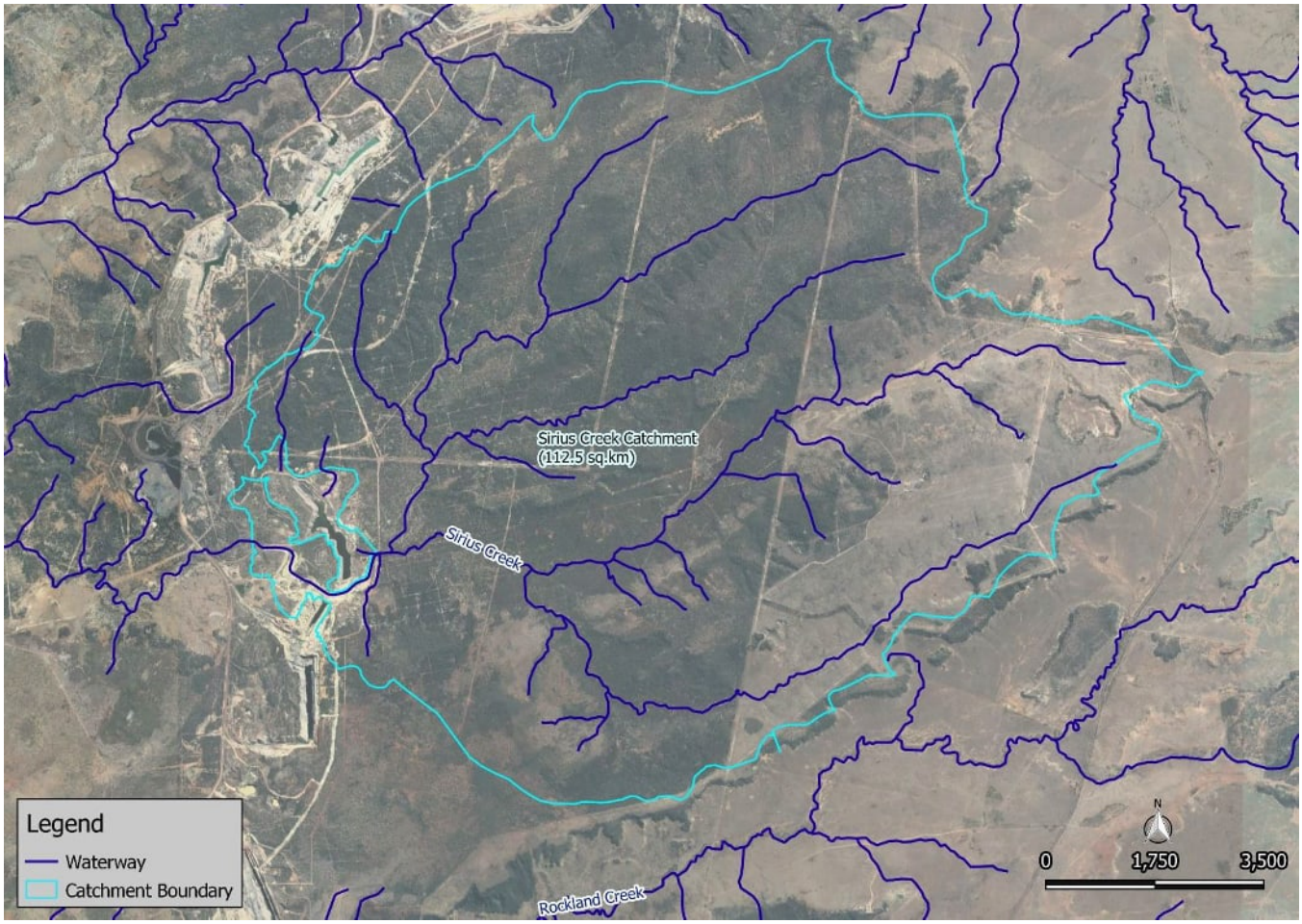


Figure 6.4: Map of Catchments

6.4.1 Frequent Events

The hydrologic model (Engeny, 2017) mentioned above was used to estimate flows through the diversion for the 39% AEP and 2% AEP flow events (refer toTable 6.3) in accordance with the ACARP (2002) method.

The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% AEP and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Sirius Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters.

TABLE 6.3: SIRIUS CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
39% AEP	61
2% AEP	141

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be summarized within the Rehabilitation Flood Assessments undertaken as part of the PRCP.

6.5 Hydraulics

The HEC-RAS hydraulic model was developed for assessing the diversion hydraulic results for the mine closure scenario against the hydraulic performance criteria in the DNRME hydraulic performance criteria. The HEC-RAS model was utilised for this assessment based on the fact that the criteria were originally developed by assessing existing diversions and Bowen Basin streams using 1-dimensional steady state modelling. Therefore, the performance criteria are based on cross section average values. The hydraulic model input parameters are summarised below:

- Manning's n: 0.06 for the left and right banks, 0.05 for the main channel.
  - Upstream boundary condition: 2-year ARI (39% AEP) peak discharge (refer Table 6.3).
  - 50-year ARI (2% AEP) peak discharge (refer Table 6.3).
- Downstream boundary condition – normal depth based on downstream channel grade.

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. Stream velocity is calculated by dividing the flow by the cross-sectional area (based on flow depth in the channel). The higher the velocity, the greater the erosive force of a stream and therefore more sediment will be freed and move through the system. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Average values were derived from the HEC-RAS model for the stream powers, stream velocity and shear stress in a 39% AEP and 2% AEP rainfall event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP		2% AEP	
Design Criteria	Diversion	DNRME Design Parameter (2019)	Diversion	DNRME Design Parameter (2019)
Stream Power (W/m^2)	24	<60	35	<150
Stream Velocity (m/s)	0.9	<1.5	1.0	<2.5
Shear Stress (N/m^2)	19	<40	23	<80[1]

[1]DNRME values are taken from ACARP 2014 as the <50N/m^2 value in DNRME 2019 is incorrect.

All diversion concept design parameters for stream power, stream velocity and shear stress for both 29% AEP and 2% AEP storm events, are within acceptable limits and below DNRME (2019) guideline values.

Appendix B illustrates the variability along the diversion channel for each design parameter.

6.6 Additional Design and Construction Considerations

6.6.1 Levee Design

The existing Ramp 74 levee was constructed in 2020 and was designed to provide 0.1% AEP flood protection to Ramp 74 but is not considered a permanent feature under a closure scenario due to ongoing maintenance requirements above and beyond the surrounding final land use. It is proposed that the existing landform levee modified to act as a landform levee by widening to sufficient width maintain a hydraulic gradient less than 5%, such that there is no credible piping failure mechanism through the embankment.

An additional low height flood levee is also required, as shown in the concept design drawings, to prevent inflows in the 0.1% AEP design flood event into Ramp 74 via the old access ramp. Based on preliminary analysis both levees are proposed to be constructed with a 120 m top width to manage long term piping failure risk. Further detailed analysis will be completed during the detailed design phase of the project.

6.6.2 Backfilling of Old Cut 4 Pit

In order to mitigate the risks associated with construction of a diversion through a backfilled pit it is proposed that the backfilling of Old Cut 4 will be completed using engineered fill as opposed to uncontrolled filling which could result in significant settlement and ongoing performance issues with the diversion. The decision to utilise engineered fill is based on the limited depth which is a maximum of 14 m and averages 2-3 m across the overall footprint of Old Cut 4 which is substantially less then would typically be associated with backfilling of a pit. Prior to execution of the works Old Cut 4 will need to be dewatered and silt removed from the base to expose a firm foundation. Filling will occur using select material placed in nominal 500 mm lifts with exact placement requirements determined following the geotechnical investigation with the intent to utilise material excavated from the diversion as the suitable fill material.

6.6.3 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.6.4 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Sirius Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the BWM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.

- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

Further, hydraulic modelling has demonstrated that the 39% AEP shear stress is within the ACARP (2014) guideline values for the vegetation establishment within a transport limited system. To ensure vegetation has sufficient time for establishment it is suggested to keep the diversion offline for 1 to 2 wet seasons. Revegetation will reflect the dominant ecosystem of *Eucalyptus populnea* (poplar box) and *Eucalyptus melanophloia* (silver-leaved ironbark) woodland on alluvial plains.

6.6.5 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with Whitehaven's watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable),and following periods of high flow in the diversion.

6.7 Risks and Mitigation Measures

The Table 6.5 below summarises the main risks for the diversion remediation design and construction. The risks were assessed in accordance with BHPs Risk Framework.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to extreme flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1
Significant erosion of channel due to extreme flood event	Probable	2	9	Construction of channel during dry season including a watering program for sufficient vegetation establishment prior to wet season	Unlikely	1	1
Vegetation establishment interrupted by extreme flow event (wash away of seeds and damage of plants)	Probable	2	9	Choosing a seed mix similar to the surrounding environment and apply topsoil treatment allowing for effective plant growth, construction during dry season with watering program	Unlikely	1	1

7. CONCLUSION

To develop a PRCP Chapter for the Sirius Creek diversion, a concept design for remediation of the Sirius Creek diversion will be developed. This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design was developed based on three guidelines, two of which are currently recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).
- EA condition for specified rehabilitation requirements.

Four options for the remediation of Sirius Creek were identified and the second option was selected to be carried forward into concept design, utilising the Multi-Criteria Analysis outlined in Section 5. The selected option has been further optimised following the final landform update (Landform 3.6.1). The final concept option design, typical cross sections and longitudinal section are presented in Section 6 and Appendix C. The main risks to the successful performance of the diversion are vegetation establishment and erosion which can be mitigated by construction timing, during dry season, the seed mix used and topsoil treatments to improve quality of the soil where necessary.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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(g) This Report does not provide legal advice.

9. REFERENCES

ACARP (2014) 'Criteria for functioning river landscape units in mining and post mining landscapes'.

Alluvium (2010) 'Sirius Creek Diversion Baseline Monitoring 2010, Blackwater Mine'.

DES (Department of Environment and Science) (2019) 'Environmental Authority EPML00717813'.

DNRME (2019) 'Guideline: Works that interfere with water in a watercourse for a resource activity - watercourse diversion authorised under Water Act 2000'.

Engeny (2017) 'Sirius Creek Diversion Major Monitoring Assessment'.

Engeny (2017) 'Flood Model and Water Balance Model Update; Blackwater Mine'.

Engeny (2025) 'Sirius Creek Closure Design Functional Design Report'

U.S. Department of Interior Bureau of Reclamation (USBR) (2014) 'Reclamation Managing Water in the West – Design Standard No. 13, Embankment Dams' Chapter 8: Seepage.

APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Sirius Creek Diversion

Project: PRCP Diversions FY21 (BWM)
Workshop Date: 2/11/2020

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Option 4	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and natural stream length. Ideally diversion length = natural stream length.	40%	1	-1	0	-1	Option 1 is the same length as natural stream. Other options are all longer by varying degrees.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	25%	-1	-1	-1	-1	Options 1, 2 and 4 would be constructed through existing rehabilitated spoil. Option 3 would be constructed through a combination of existing and future rehabilitated spoil (associated with currently approved mining). For Options 2 and 3, the PRCP final landform would need to me revised to acheive the required offset distances from the future rehabilitated spoil dumps to the south.
Order of magnitude cost estimate	**Assumes $10/m3 of cut.** Includes cost to backfill voids as not proposing to backfill voids as part of the PRCP (so as not to lose grandfathering provisions under the EA).	25%	-3	0	-3	-2	Option 1 includes cost to backfill Ramp 74 TSF - fatal flaw. Option 3 excessive amount of earthworks due to topography - fatal flaw. Option 2 includes cost to backfill Old Cut 4 based on recent storage curve.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	10%	0	-2	0	0	Not possible to isolate Option 2 as constructed on same alignment as the existing diversion. Risk of high flow events washing away topsoil during diversion establishment period.
	Overall Weighted Score		-0.6	-0.9	-1.0	-1.2	
	Is there a Fatal Flaw?		Fatal Flaw	No	Fatal Flaw	No	
	Relative Risk		Highest Risk	High Risk	Highest Risk	High Risk	

Figure A.1: Multi-Criteria Analysis Details

APPENDIX B: HYDRAULIC PARAMETER MODELLING RESULTS

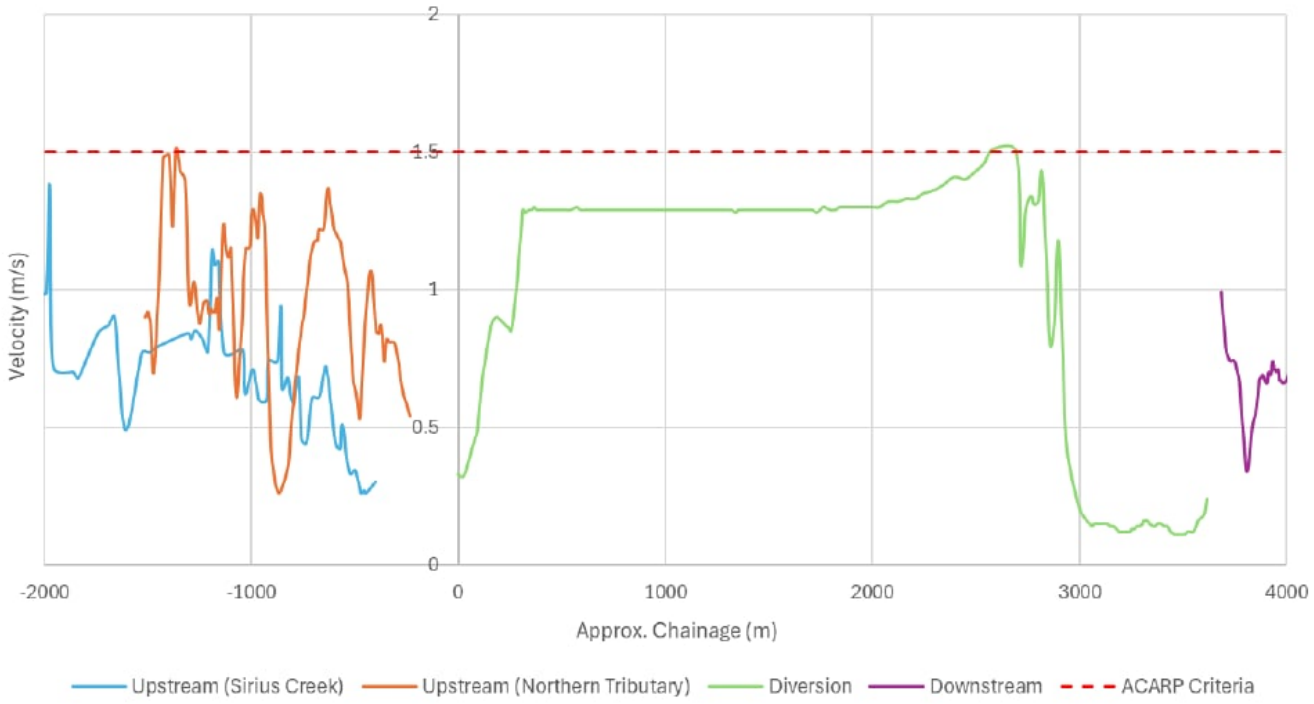


Figure B.1: YR ARI (39%AEP) Velocity Longitudinal Profile

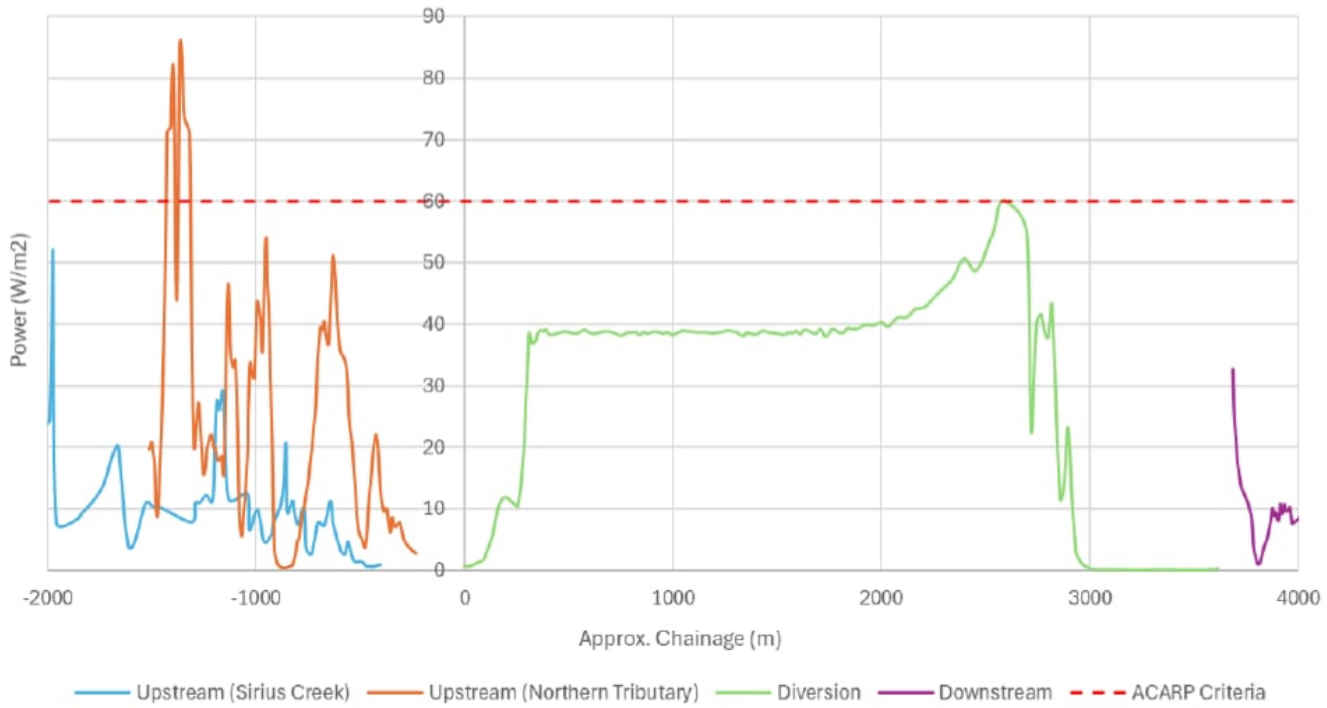


Figure B.2: 2-YR ARI (39%AEP) Stream Power Longitudinal Profile

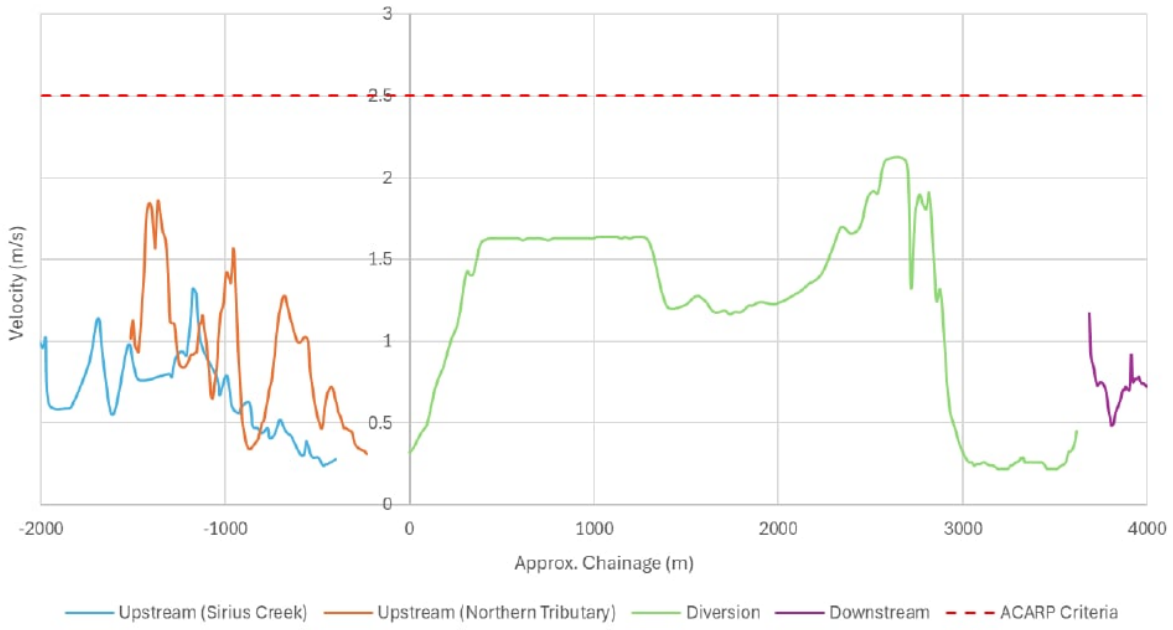


Figure B.3: 50-YR ARI (2%AEP) Shear Stress Longitudinal Profile

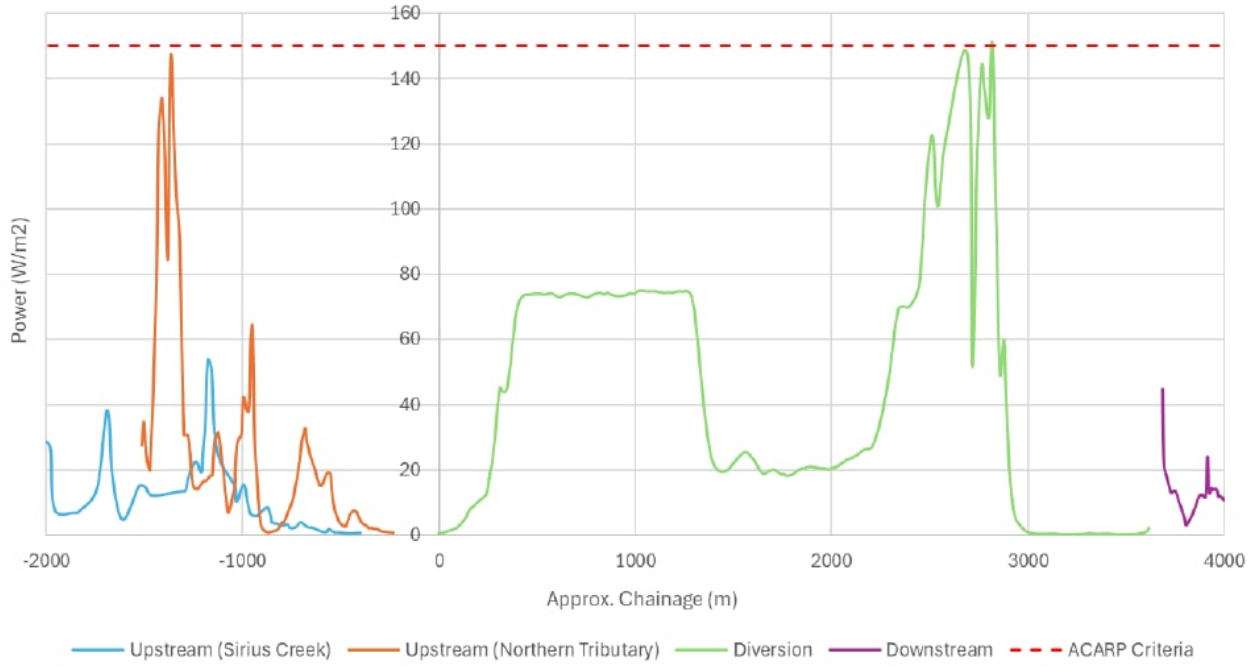


Figure B.4: 50-Yr ARI (2%AEP) Stream Power Longitudinal Profile

APPENDIX C: PREFERRED OPTION DESIGN SKETCHES

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SIRIUS CREEK CLOSURE



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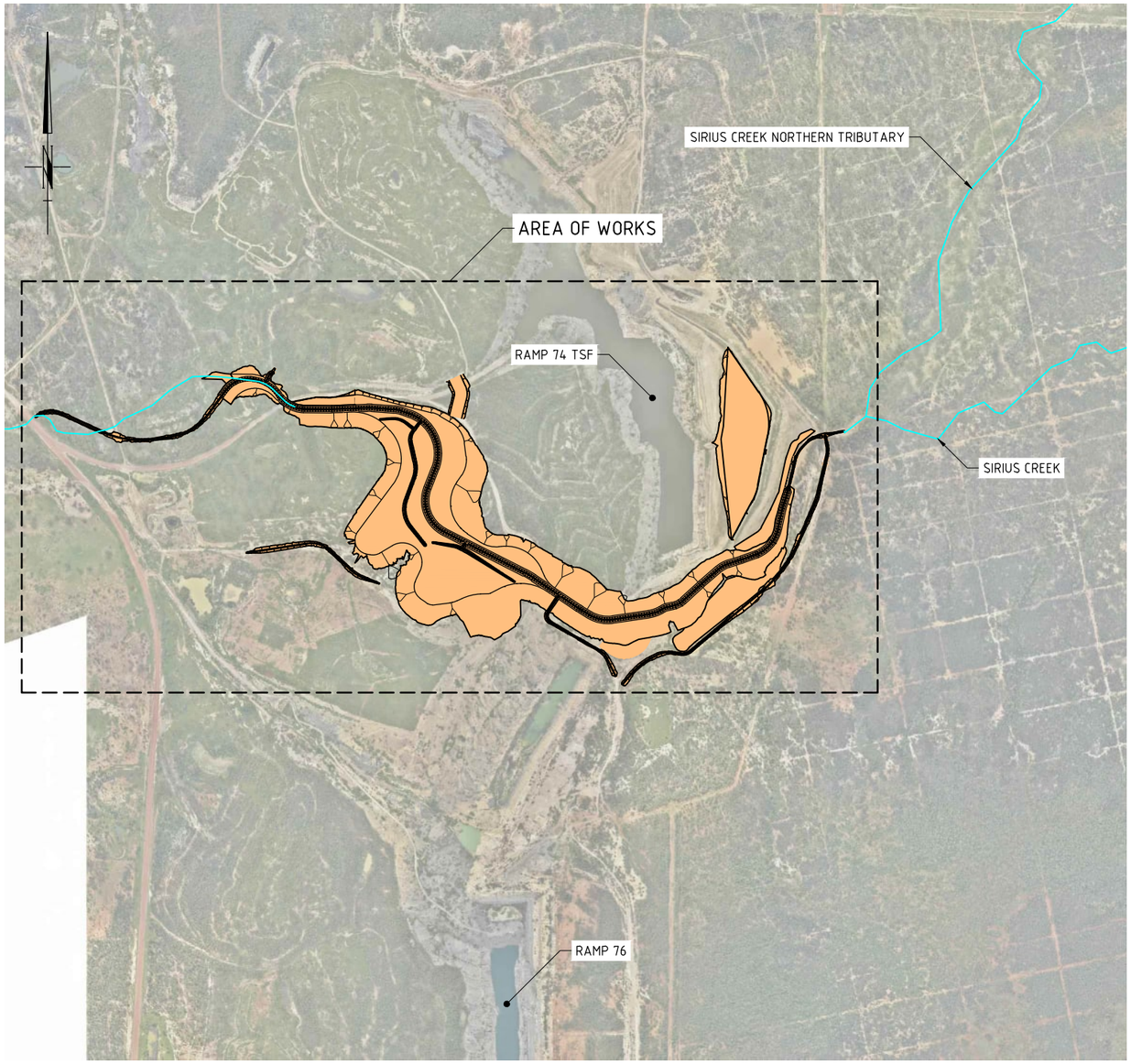
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SIRIUS CREEK CLOSURE
COVER SHEET

ORIGINAL SIZE A1 | DWG NO. BNE04877-0045-DWG-0001 | REV. D

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LOCALITY PLAN
SCALE 1:10000 m

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DRAWING No.	DRAWING TITLE	REVISION
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BNE04877-0045-DWG-0100	KEY PLAN	E
BNE04877-0045-DWG-0101	GENERAL ARRANGEMENT PLAN - SHEET 1 OF 2	E
BNE04877-0045-DWG-0102	GENERAL ARRANGEMENT PLAN - SHEET 2 OF 2	E
BNE04877-0045-DWG-0201	TYPICAL SECTIONS AND DETAILS - SHEET 1 OF 4	D
BNE04877-0045-DWG-0202	TYPICAL SECTIONS AND DETAILS - SHEET 2 OF 4	D
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BNE04877-0045-DWG-0304	LONGITUDINAL SECTIONS - LEVEES - SHEET 1 OF 1	D

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- 240 240 CONTOUR LABEL
- CONTOUR MAJOR (1.0m)
- CONTOUR MINOR (0.2m)
- WATERWAY

LEGEND - PROPOSED

- 240 240 CONTOUR LABEL
- CONTOUR MAJOR (1.0m)
- CONTOUR MINOR (0.2m)
- CIVIL WORKS EXTENT
- ENGINEERED FILL
- DUMPED ROCK EXTENTS
- SLOPE INDICATORS
- CONTROL LINE

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SCALE BEFORE REDUCTION

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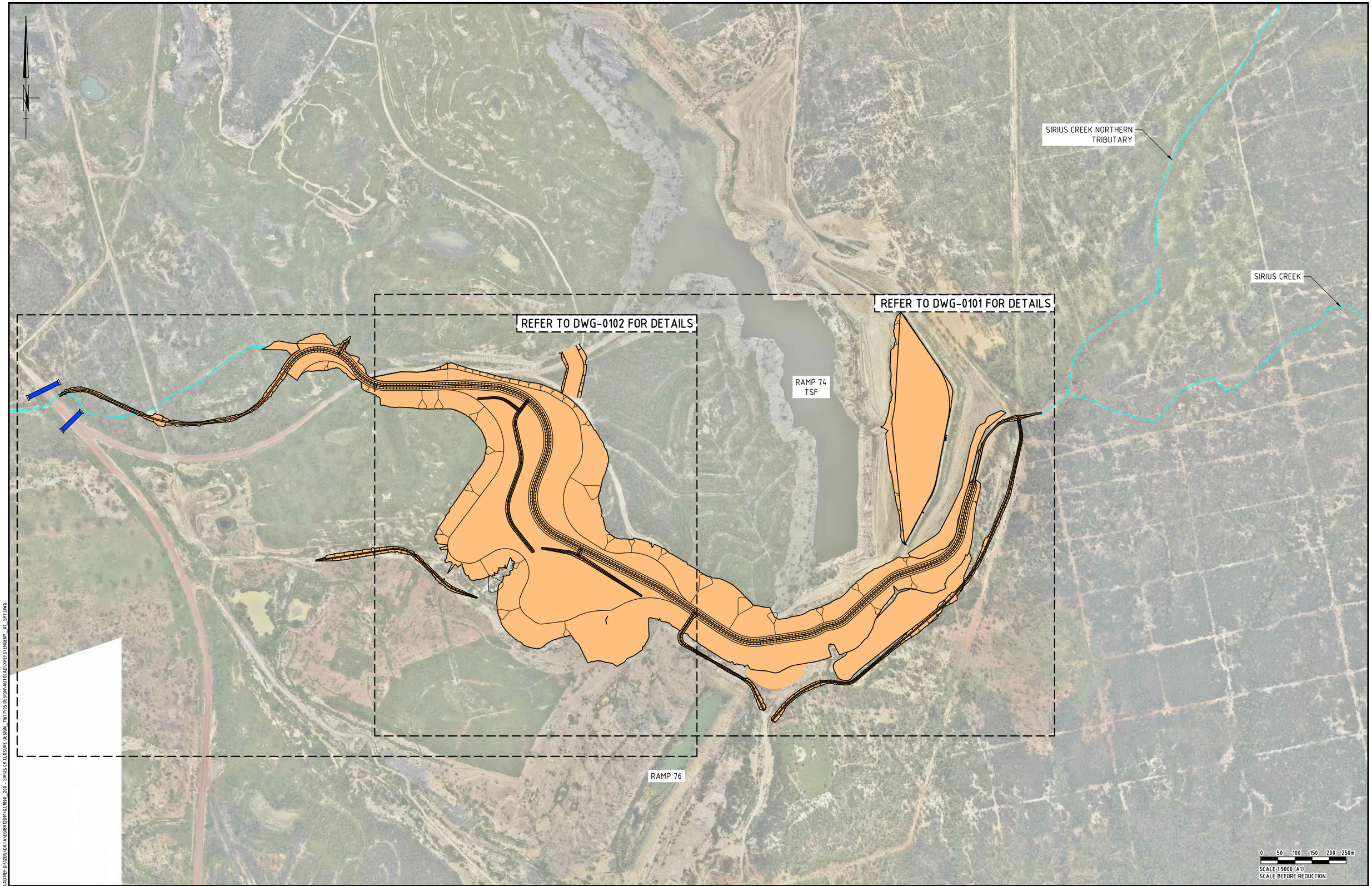
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SIRIUS CREEK CLOSURE
LOCALITY PLAN, DRAWING INDEX
GENERAL NOTES & LEGEND

ORIGINAL SIZE A1
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SIRIUS CREEK CLOSURE
KEY PLAN

ORIGINAL SIZE A1

DWG NO. BNE04877-0045-DWG-0100

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(OLD CUT 4 LEVEE)

CONTROL LINE MCE01
(RAMP 74 LANDFORM LEVEE)

RAMP 74 TSF

EXISTING RAMP 74 LEVEE

CONTROL LINE MCD01
(SIRIUS CREEK DIVERSION)

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

STOCKPILE REMOVAL

STOCKPILE REMOVAL

A 0201

B 0201

F 0203

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SIRIUS CREEK CLOSURE
GENERAL ARRANGEMENT PLAN
SHEET 1 OF 2

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0101
REV. E

CATCH DRAIN

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(SIRIUS CREEK DIVERSION)

CONTROL LINE MCE02
(OLD CUT 4 LEVEE)

5x1800 CMP'S
DETAILS TBC

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3750

3832.335

3500

3250

2750

2500

2250

2000

1750

1500

0000

50

100

1424.000

G
0202

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

5x1800 CMP'S
DETAILS TBC

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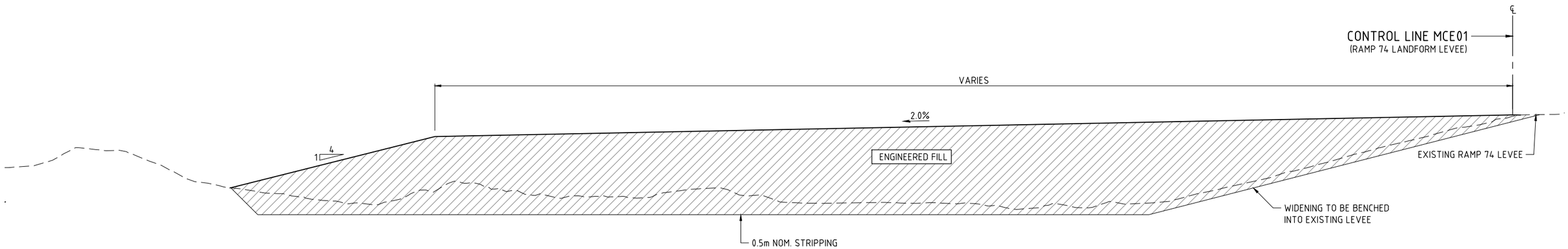
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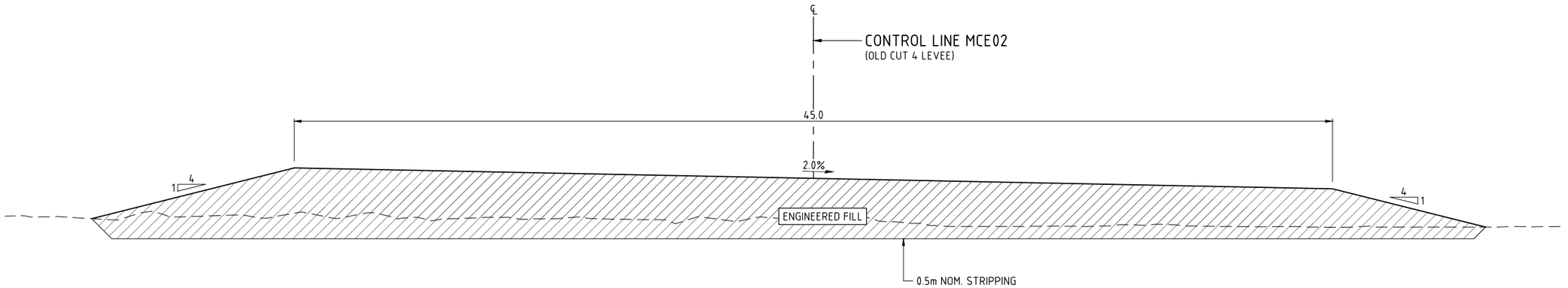
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SIRIUS CREEK CLOSURE
GENERAL ARRANGEMENT PLAN
SHEET 2 OF 2

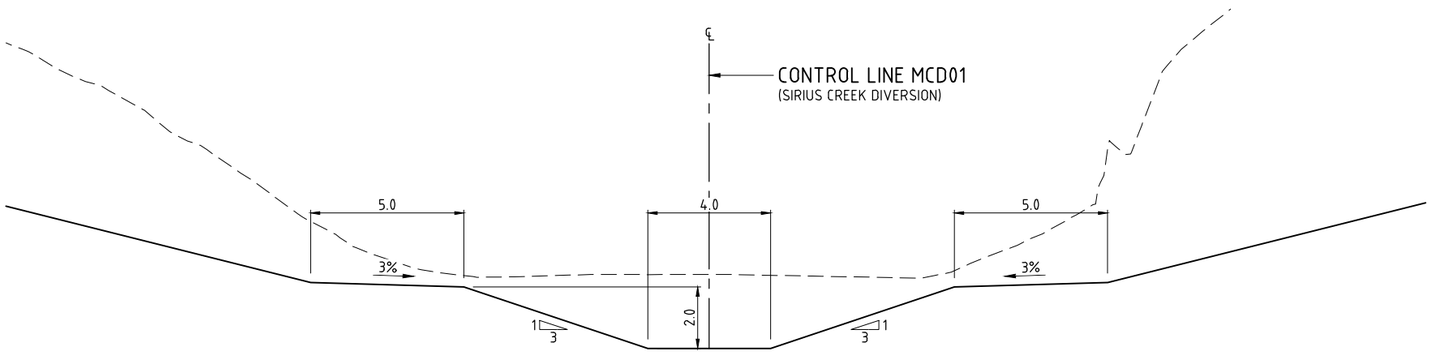
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SECTION B
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0101



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DESIGN SURFACE

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SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

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SCALE 1:200 (A1)
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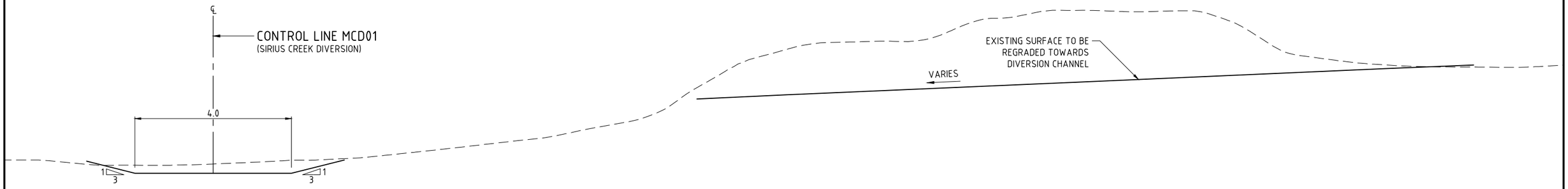
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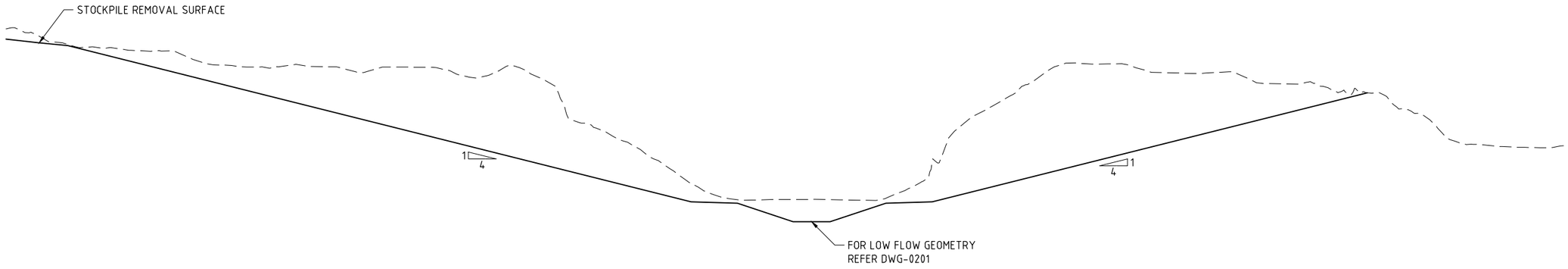
SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 1 OF 4

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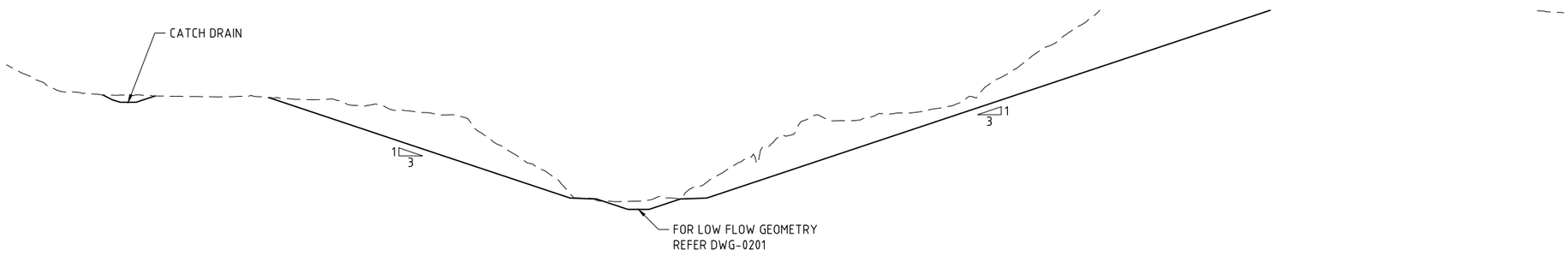
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SECTION C
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SECTION D
SCALE 1:250 0101



SECTION E
SCALE 1:500 0101

LEGEND

EXISTING SURFACE

DESIGN SURFACE

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SCALE BEFORE REDUCTION

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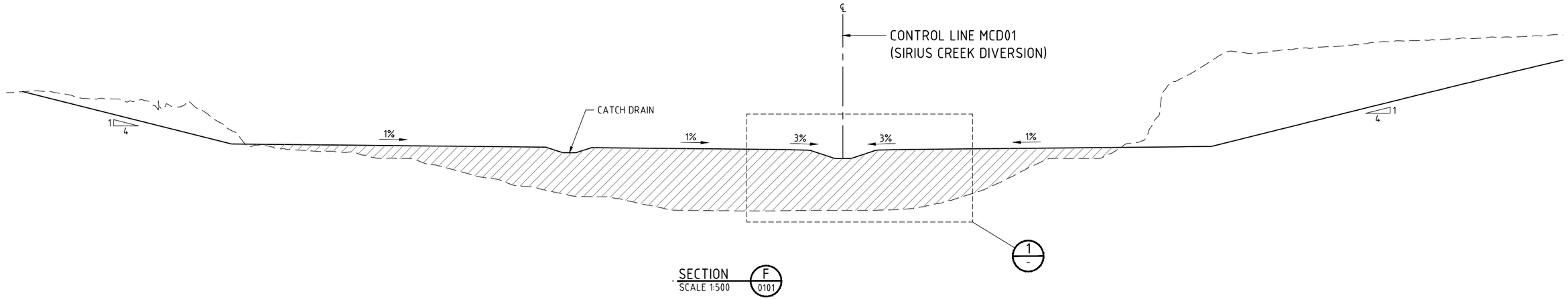
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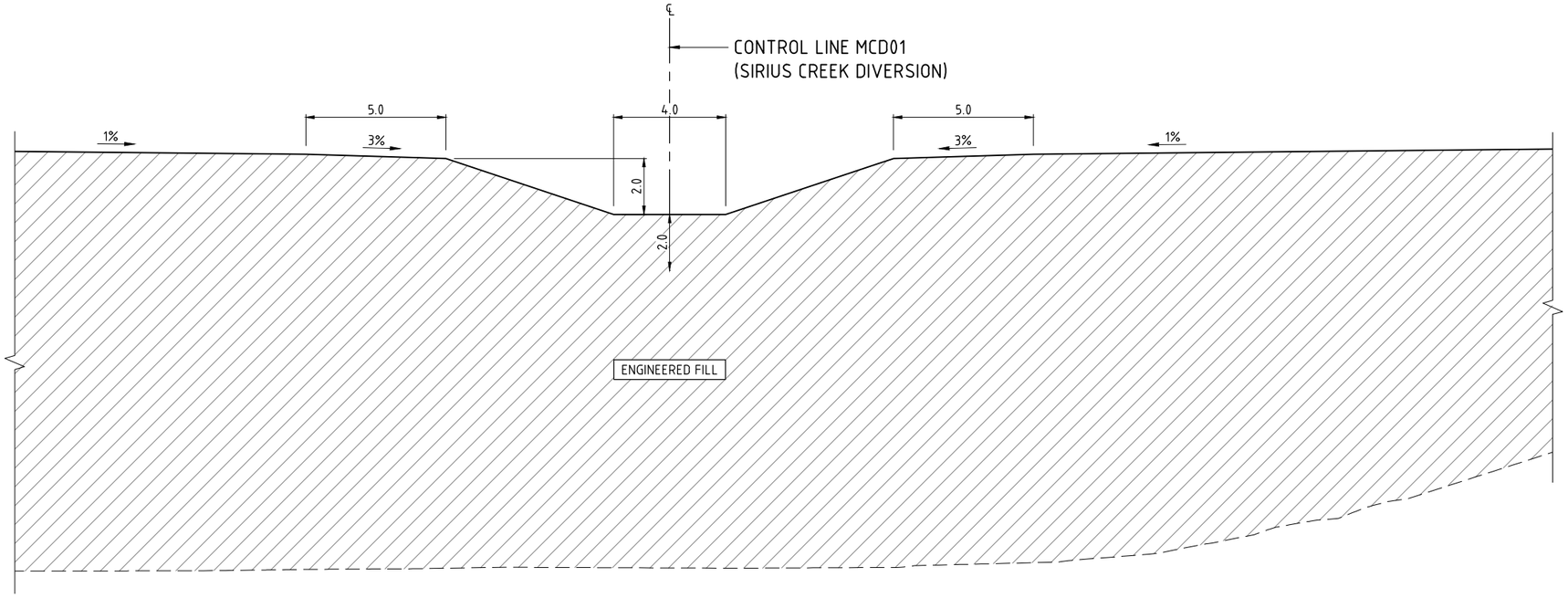
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SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 2 OF 4

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0202
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SECTION F
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LEGEND

EXISTING SURFACE

DESIGN SURFACE

DETAIL 1
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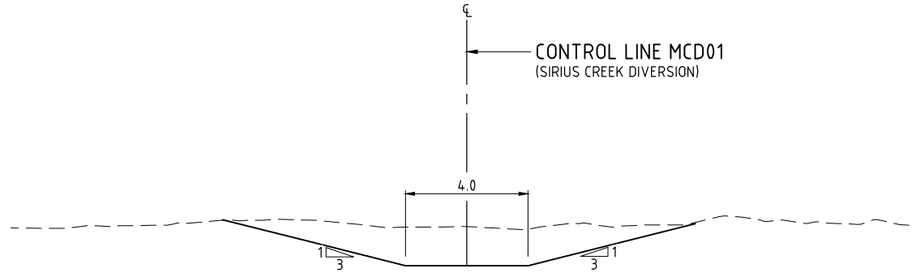
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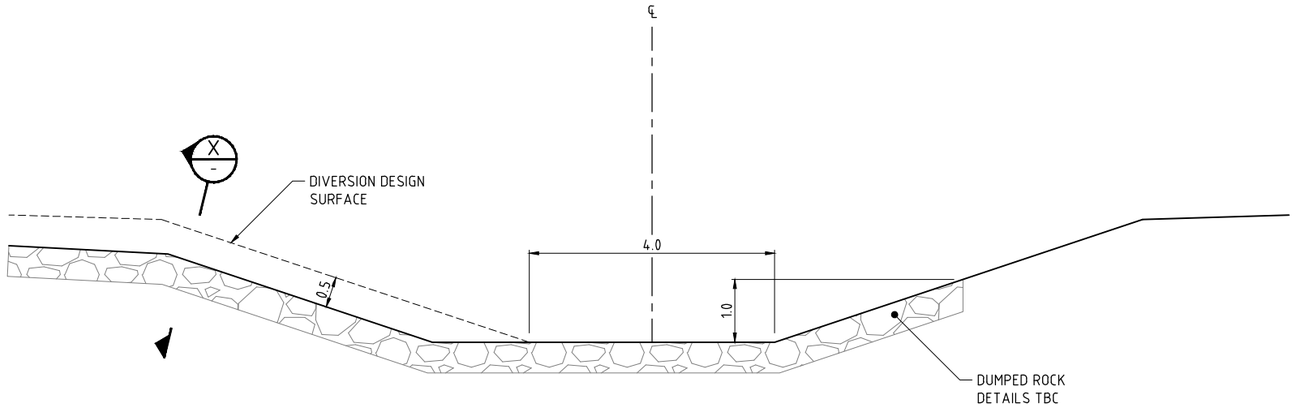
SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 3 OF 4

ORIGINAL SIZE A1
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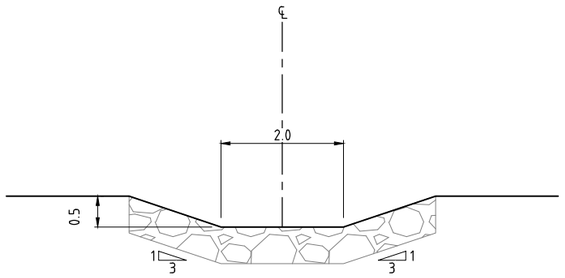
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SECTION G
SCALE 1:100



ROCK CHUTE TYPICAL SECTION
SCALE 1:100



SECTION X
SCALE 1:100

LEGEND

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DESIGN SURFACE

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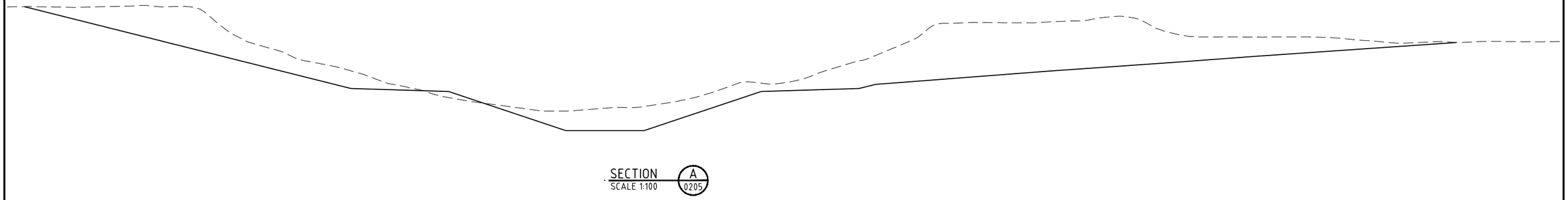
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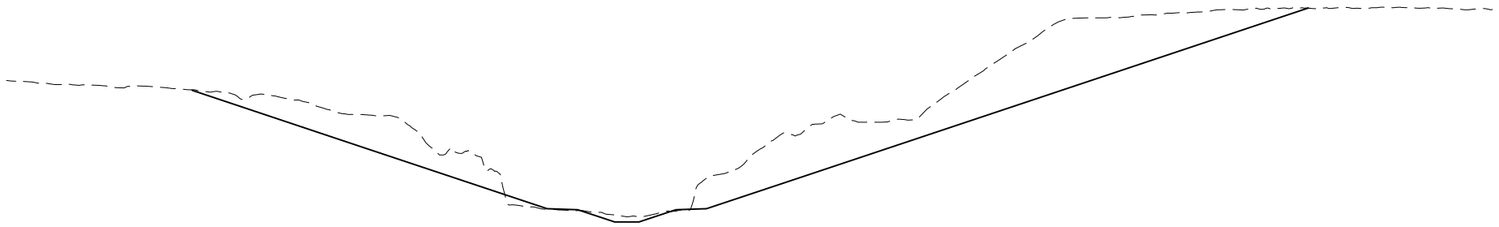
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SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 4 OF 4

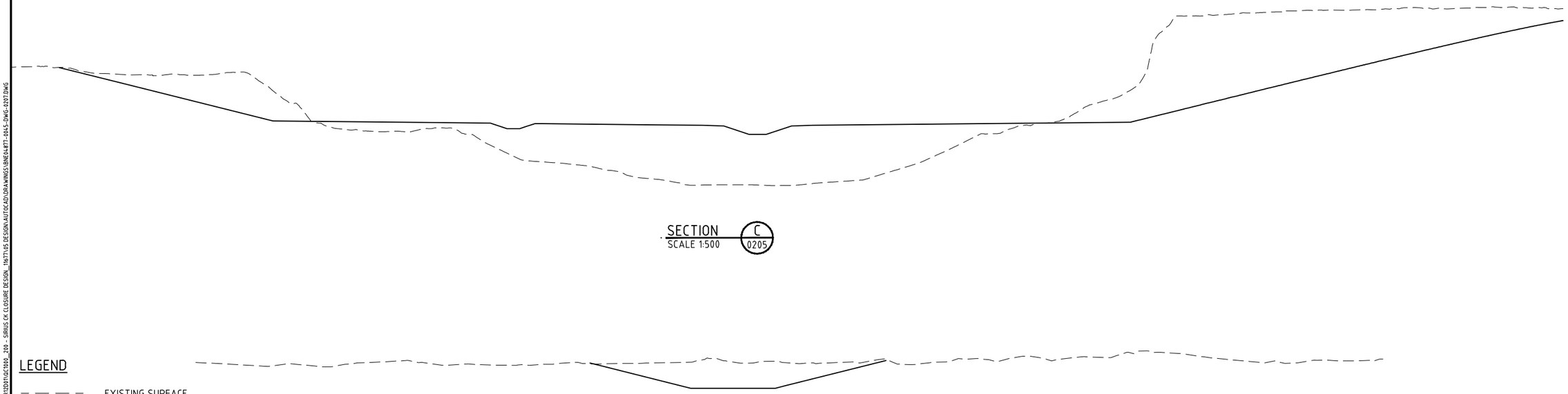
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0205



SECTION B
SCALE 1:500
0205



SECTION C
SCALE 1:500
0205

LEGEND

EXISTING SURFACE

DESIGN SURFACE

SECTION D
SCALE 1:100
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SCALE BEFORE REDUCTION

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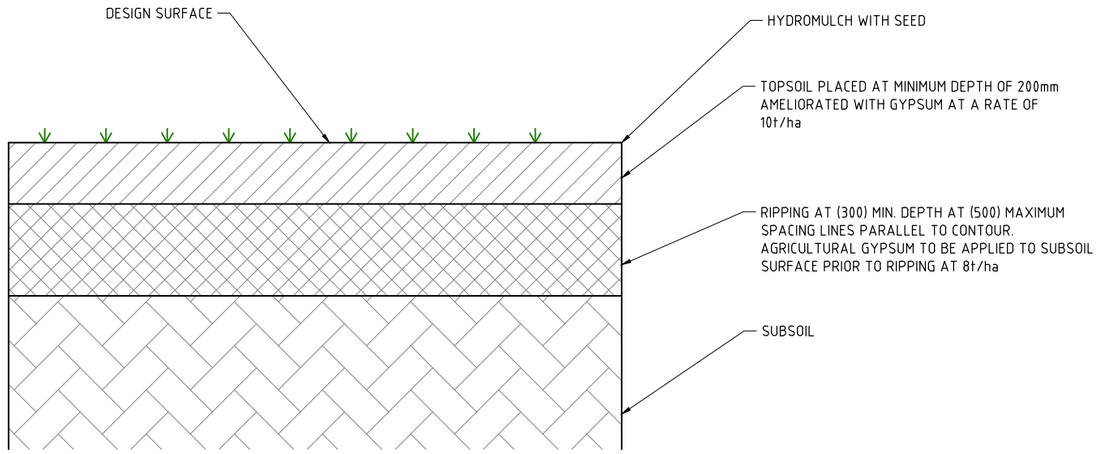
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SIRIUS CREEK CLOSURE REHABILITATION SECTIONS AND DETAILS - SHEET 1 OF 2

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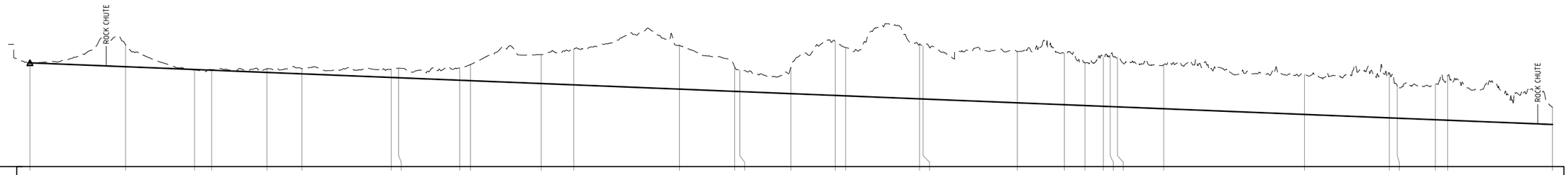
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SIRIUS CREEK CLOSURE
REHABILITATION
SECTIONS AND DETAILS - SHEET 1 OF 2

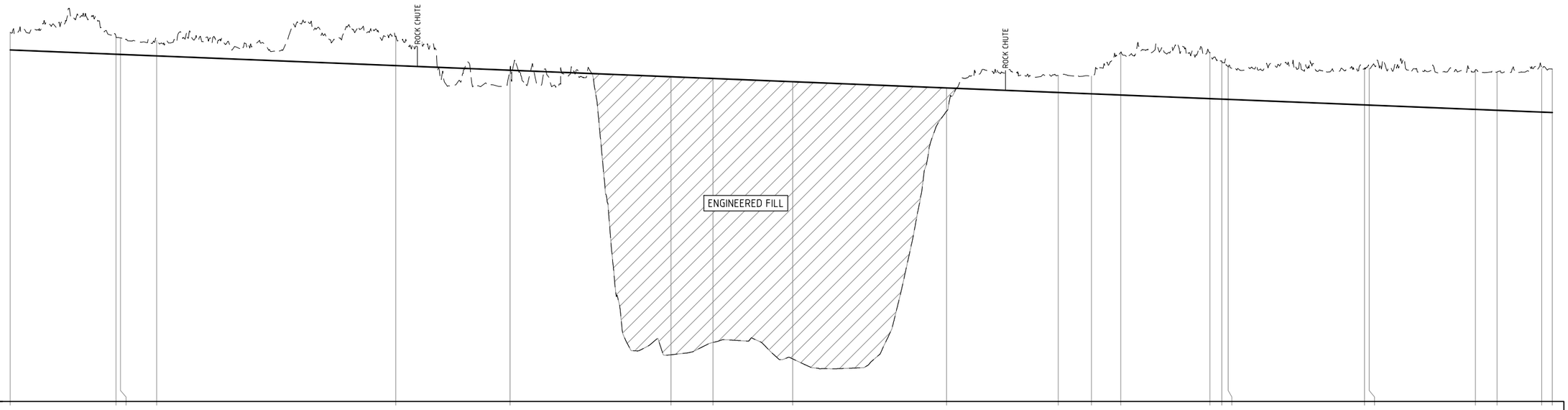
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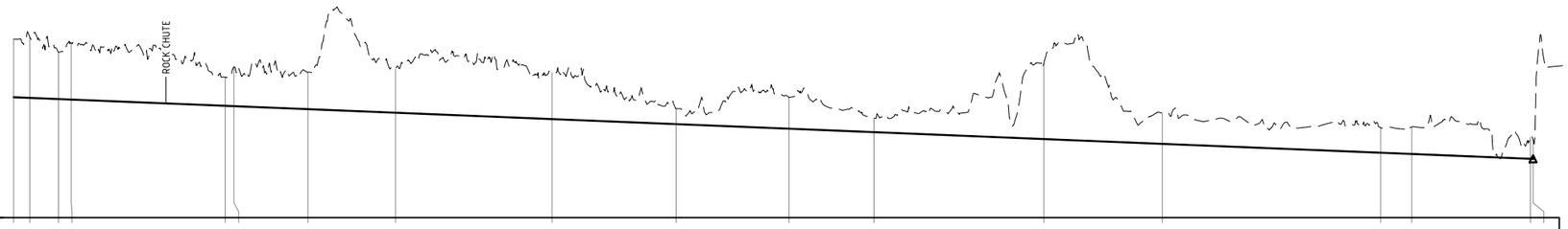
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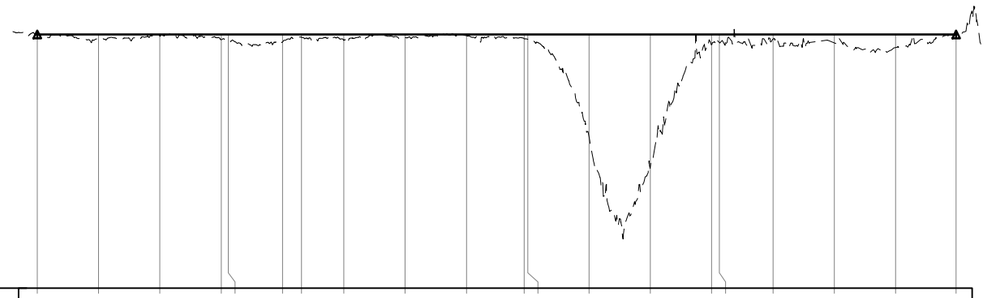
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APPENDIX D: CONCEPT DESIGN WITH PRCP LANDFORM INTERACTION

ML 1772

ML 1773

ML 1767

ML 1771

ML 70091

ML 1860

Sirius Creek

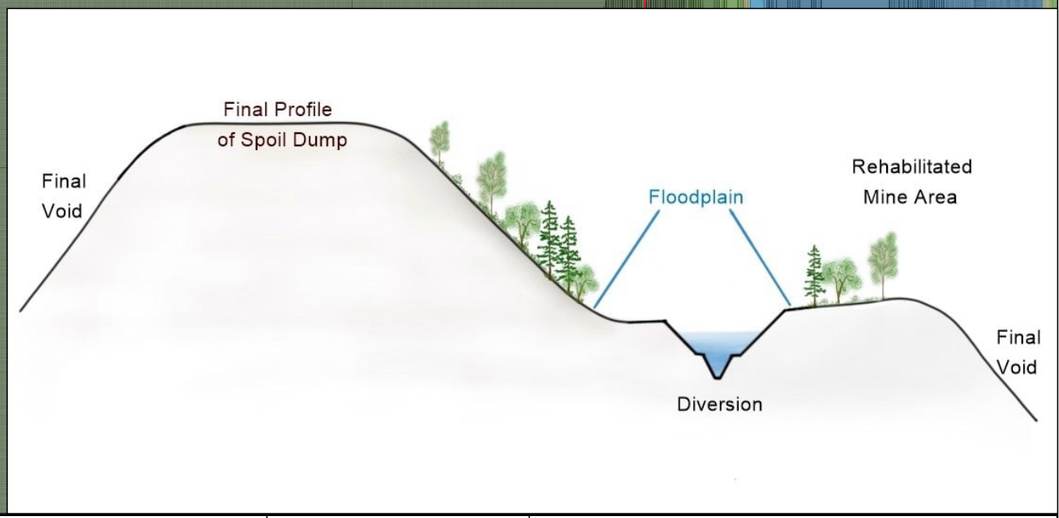
Sirius Creek

Legend

Mining Lease Boundary

PRCP Final Landform (m AHD)

- 255
- 260
- 265
- 280
- 300
- 320



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Whitehaven

0 260 520

Scale in metres (@ A4) 1:13,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

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Blackwater Mine
Conceptual Diversion Design and Closure Landform Interaction

A4 C

ENGENY

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PRCP Concept Design Report

Taurus Creek Diversion

BBNE04877_0045-REP-003-0

14 NOVEMBER 2025

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	14/11/2025	Final Issue	Sumaiya Sifa	Ben Kiernan	Louis North	Ben Kiernan
Signatures:					p.p Louis North 	

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Taurus Creek Diversion which satisfies the conditions under Environmental Authority (EA) EPML00717813. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Blackwater Mine (BWM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for BWM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose

The purpose of this document is to outline the concept design developed for the diversion remediation option to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of Taurus Creek was undertaken using historical aerial imagery and survey to identify the preferred option for the closure alignment.
- Application of ACARP (2002) flows to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Taurus Creek is an ephemeral tributary of Blackwater Creek, which ultimately flows into the Mackenzie River, a major tributary in the Fitzroy River catchment. Taurus Creek flows north-east across the Blackwater Mine lease through a diversion within an access corridor between the Ramp 40 pit and the Ramp 42 pit and joins Two Mile Creek before continuing northwards to the confluence with Blackwater Creek. The diversion is thought to have been constructed in the late 1980s to early 1990s (Alluvium, 2010), at a length of approximately 2.7 km and diverted again in 2001 at a length of 2.2 km (Hatch, 2001) including a licensed diversion reach of approximately 470 m. The diversion was constructed to allow mining in Taurus Creek Pit and Stewarton Pit.

The current catchment area for Taurus Creek upstream of the diversion channel is approximately 23.4 km^2 excluding the Emu Creek Diversion Catchment. Due to the Emu Creek diversion being constructed in early 2020 through to early 2021, the Emu Creek catchment contributes to the Taurus Creek catchment, increasing it to 42 km^2. Refer to Figure 2.1 for the location of the Taurus Creek Diversion.

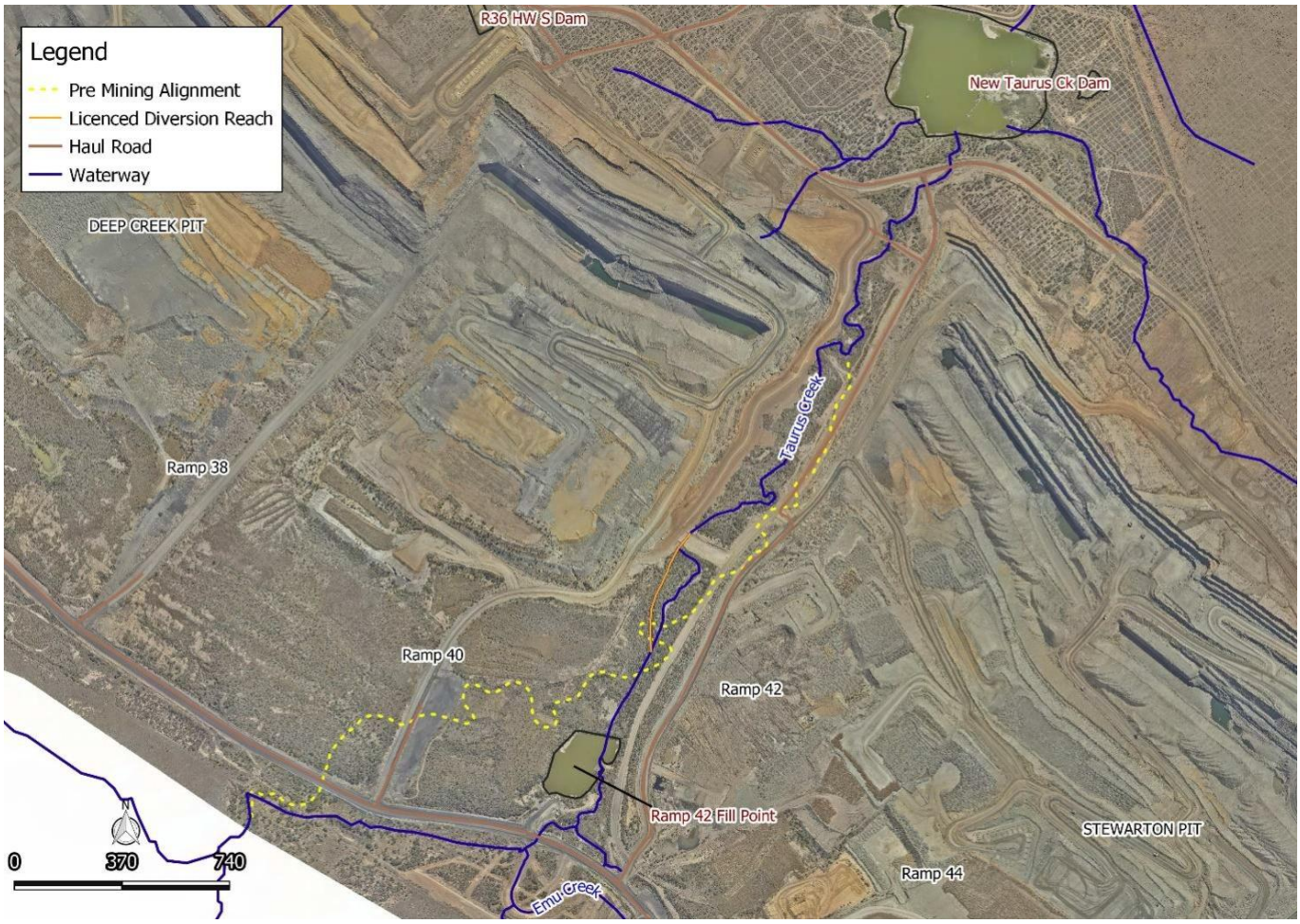


Figure 2.1: Location of the Taurus Creek Diversion at Blackwater Mine

2.2 Natural Reaches

The upstream, downstream and diversion reaches of Taurus Creek have been described as follows (Alluvium, 2010):

- **Upstream reach –** The majority of the upstream reach is located through grazing and some open woodland outside of the mine lease. It is generally of moderate sinuosity with low capacity of <1m depth and 5m top width. Sediment supply to the upstream reach is high due to clearing and grazing activities in the upstream catchment. The upstream channel consists of a single continuous alluvial channel within a broad floodplain (>100m). Riparian vegetation of the upstream channel consists of a continuous overstorey and poor groundcover due to grazing pressure.
- **Emu Creek Diversion Reach –** The Emu Creek diversion reach flows through catchments modified and impacted by vegetation clearing, grazing and mining activities. As described in the functional design report (Engeny, 2019) the Emu Creek diversion channel consists of a moderate sinuosity low flow channel with 2m base width and 2m depth, 1V:3H batter slopes and 0.44% channel bed slope designed to achieve a stable, non-polluting diversion channel in accordance with DNRM and ACARP guideline values.
- **Downstream reach –** The downstream channel of the Taurus Creek diversion comprises of a moderate sinuosity, low-capacity single alluvial channel (8-14m top width, 3m depth), set within a broad floodplain (>100m width). The downstream reach channel bed consists of exposed bedrock in several locations.
- **Diversion reach (pre-mining)** - The Taurus Creek diversion reach (pre-mining) was approximately 2.7 km long, meandering through what is now Ramp 38 and Ramp 40.

The upstream, downstream and diversion reaches of the Taurus Creek diversion at Blackwater Mine are shown in Figure 2.2.

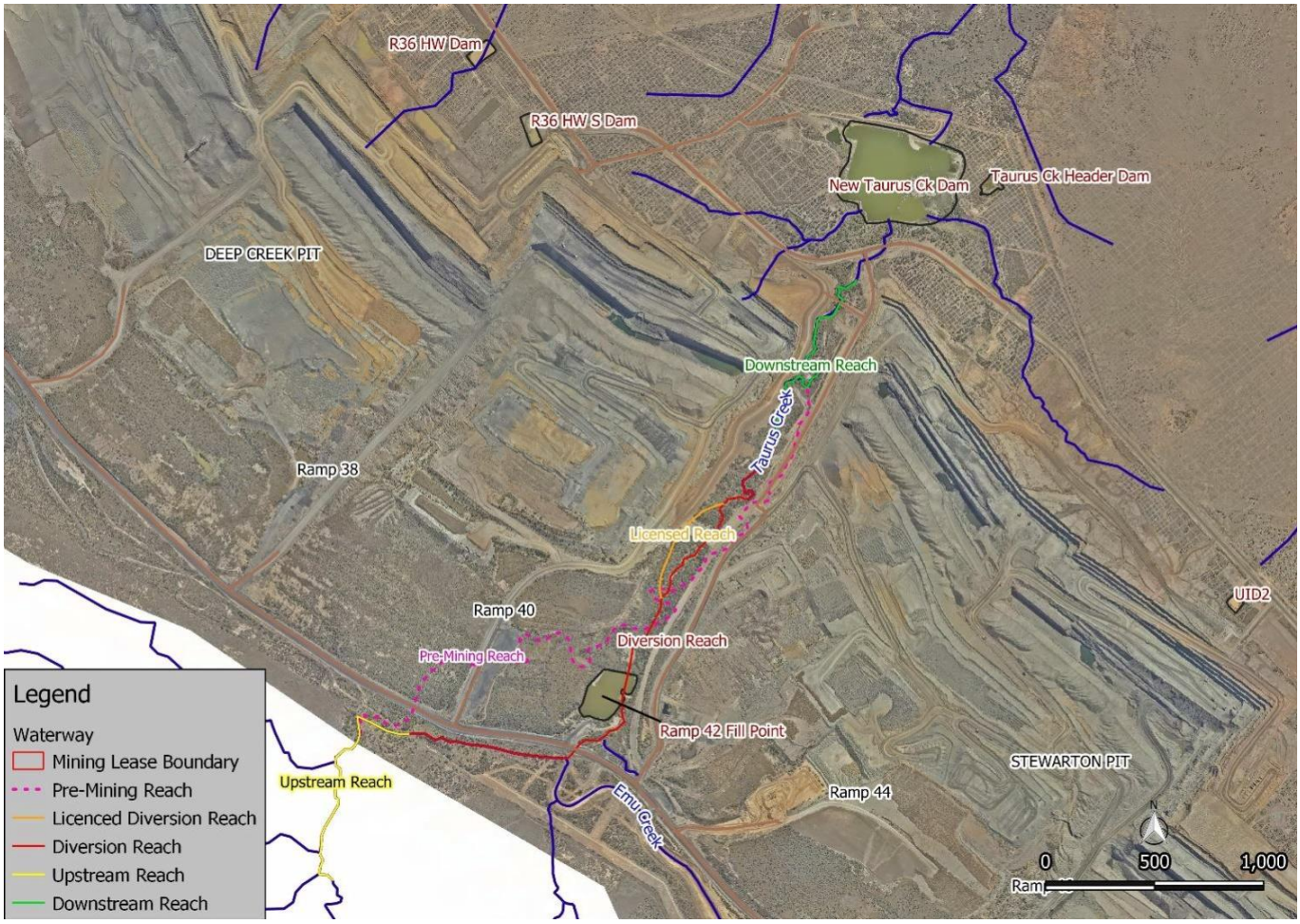


Figure 2.2: Upstream, Downstream and Diversion Reaches of the Taurus Creek Diversion

2.3 Diversion Reach

Monitoring of Taurus Creek diversion has been undertaken since 2010 and was last completed in 2019. As part of the major monitoring, the latest condition of the Taurus Creek diversion has been described as follows (Engeny, 2017a):

- Clearing work, realignment of the creek, Ramp 42 Fillpoint Dam as well as spoil runoff are the main contributors to excess sediment supply and erosion within the creek. Culvert crossings under haul roads and dragline crossings as well as dams online of the diversion prohibit continuous sediment transport through the system and contribute to sediment build up within the diversion reach.

The above monitoring assessment outcomes have been addressed as part of the Ramp 47 Execution Support project (Engeny, 2020) which resulted in three distinct issues remaining with the diversion:

- Vertical grade of the diversion is much steeper than the pre-mining channel grade, resulting in erosion issues.
- A drop structure north of the haul road crossing which requires ongoing maintenance.
- Ramp 48 Fill Point dam located within Taurus Creek impeding sediment transport.

Based on the current condition of the Taurus Creek diversion, it is highly unlikely that the diversion will achieve the water license relinquishment criteria prior to mine closure without intervention.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions. Details of the guidelines that have been used to design the Taurus Creek diversion are summarised below.

3.1 DNRME Guideline

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Taurus Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Taurus Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.

- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m²)	Velocity (m/s)	Shear Stress (N/m²)
2-year ARI (no vegetation)	<35	<1.0	<40
2-year ARI (vegetated)	<60	<1.5	<40
50-year ARI	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m² has been adopted.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, which included an analogous approach, where channel dimensions are selected from a reference reach; a hydraulic geometry approach where dimensions are determined from regression relationships; and an analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be represented of stable watercourses within the Bowen Basin and are summarised in Table 3.2: .

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Stream Power (W/m²)	Stream Power 2-year ARI (W/m²)	Stream Power 50-year ARI (W/m²)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3: .

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m²)
Buffel grass	40
Structurally diverse suite of established native vegetation	120

The long-term performance of the diversion under both operating and closure scenarios is assessed with the following objectives, based on industry standard closure objectives:

- The diversion demonstrates to be in a safe, stable, non-polluting and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Reference rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining landuse of the 'Watercourses' which is applicable for the watercourse diversion.
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

3.3 Environmental Authority EPML00717813

The land schedule within the Blackwater Mine EA (EPML00717813) requires that all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified Rehabilitation Requirements. The EA provides the rehabilitation landform criteria for the post mining land use of watercourses (refer to Figure 3.1). Some indicators reference the Index of Diversion Condition (IDC) method, which is a component of ongoing diversion monitoring.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

Figure 3.1: Blackwater Mine EA EPML00717213 Rehabilitation Requirements for Watercourses

4. CONCEPT DESIGN

4.1 Diversion Alignment

Figure 4.1 shows the permanent diversion alignment design of Taurus Creek. The alignment was selected to achieve a similar pre-mining channel grade, while also aligning with the most recent final landform (Landform 3.6.1). The full concept drawing package is included in Appendix B.

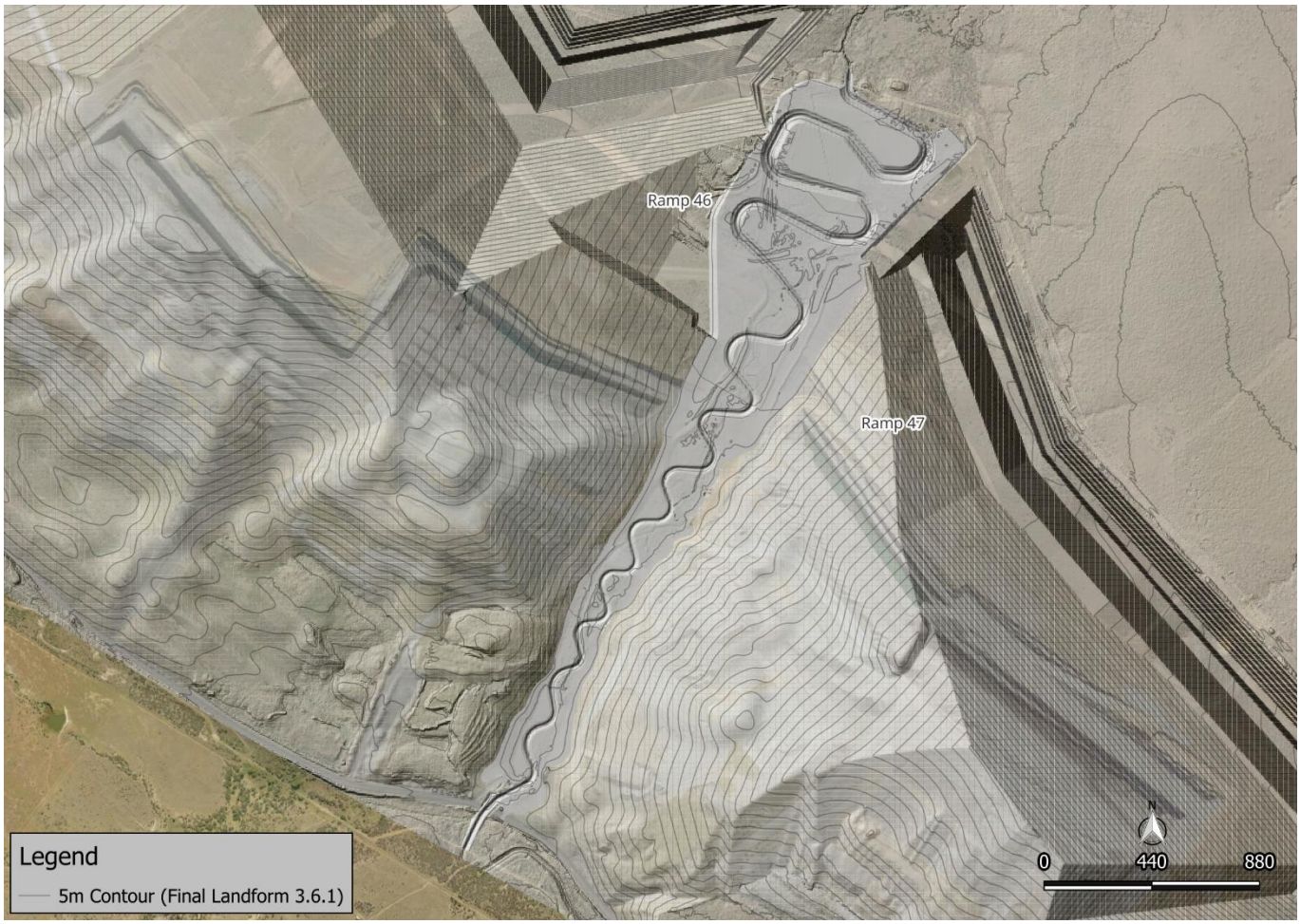


Figure 4.1: Taurus Creek Alignment General Arrangement

4.2 Channel Geometry and Grade

The typical upstream and downstream channel geometries are presented in Figure 4.2 and Figure 4.3. The concept diversion design dimensions were based on the average natural upstream and downstream channel geometry topographic data and aerial imagery were used to evaluate the planform and cross section parameters of multiple reference reaches of Taurus Creek.

The concept design drawings in Appendix B show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

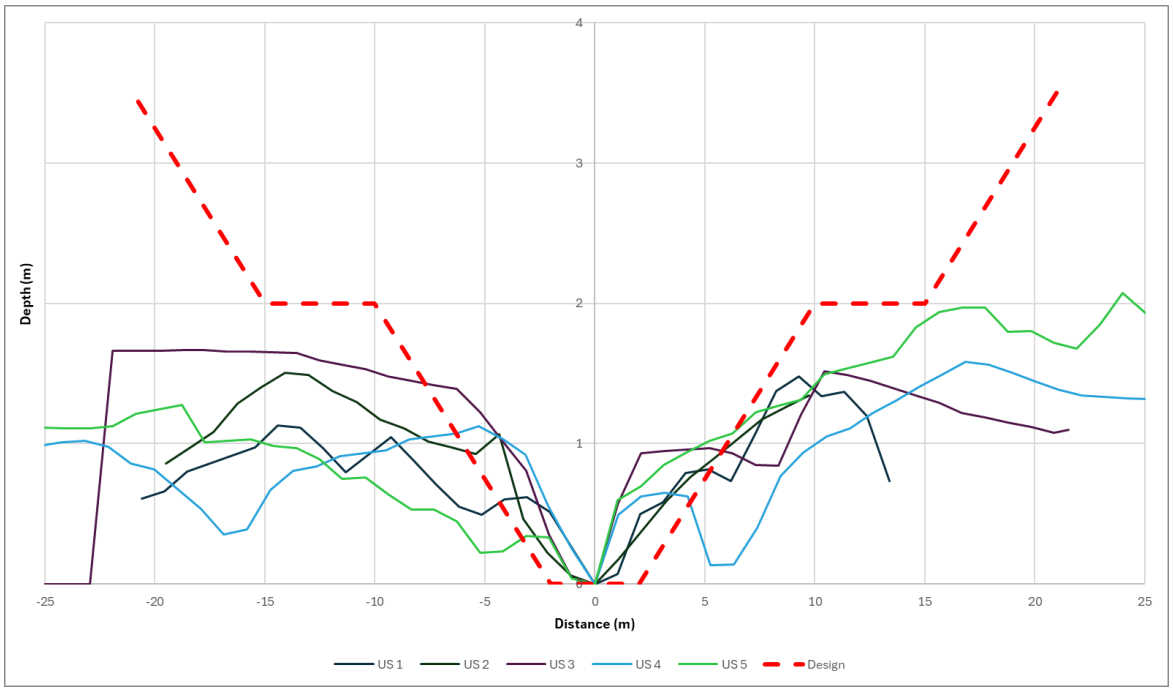


Figure 4.2: Typical Upstream Channel Cross Section

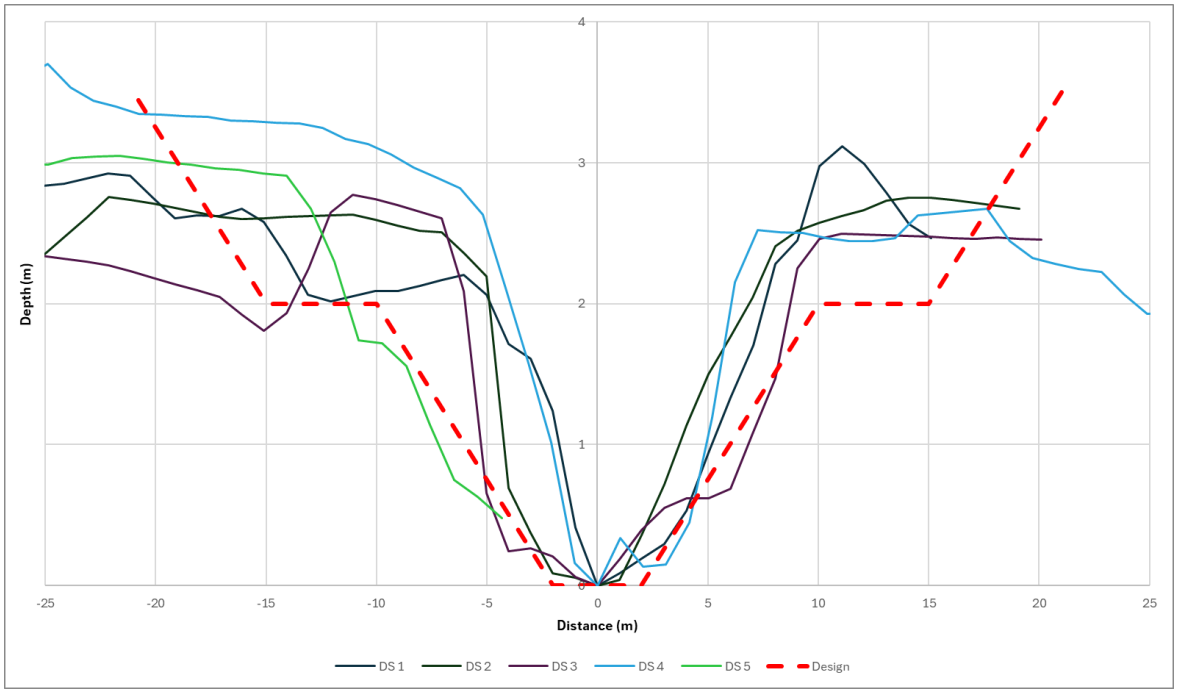


Figure 4.3: Typical Downstream Channel Cross Section

4.3 Hydrology

Peak flows for frequent events (39% AEP and2% AEP) for the Taurus Creek diversion remediation were estimated using the ACARP (2002) methods and are presented in Table 4.1. The current catchment area of Taurus Creek is approximately 42 km², which is projected to increase to 57.2 km² under the final landform (Landform 3.6.1) (refer to Figure 4.4). The catchment boundary based on the final landform was adopted for the ACARP flow estimations.

As described in Section 3, The hydraulic outcomes for diversion designs are only prescribed for frequent events (39% AEP and 2% AEP). As such, hydraulic modelling of rare event (1% and 0.1% AEP) has not been undertaken as part of the diversion concept design. The Rehabilitation Flood Assessments undertaken separately as part of the PRCP should be referred to for the hydrologic and hydraulic modelling for the 1% AEP and 0.1% AEP flood events of Sirius Creek.

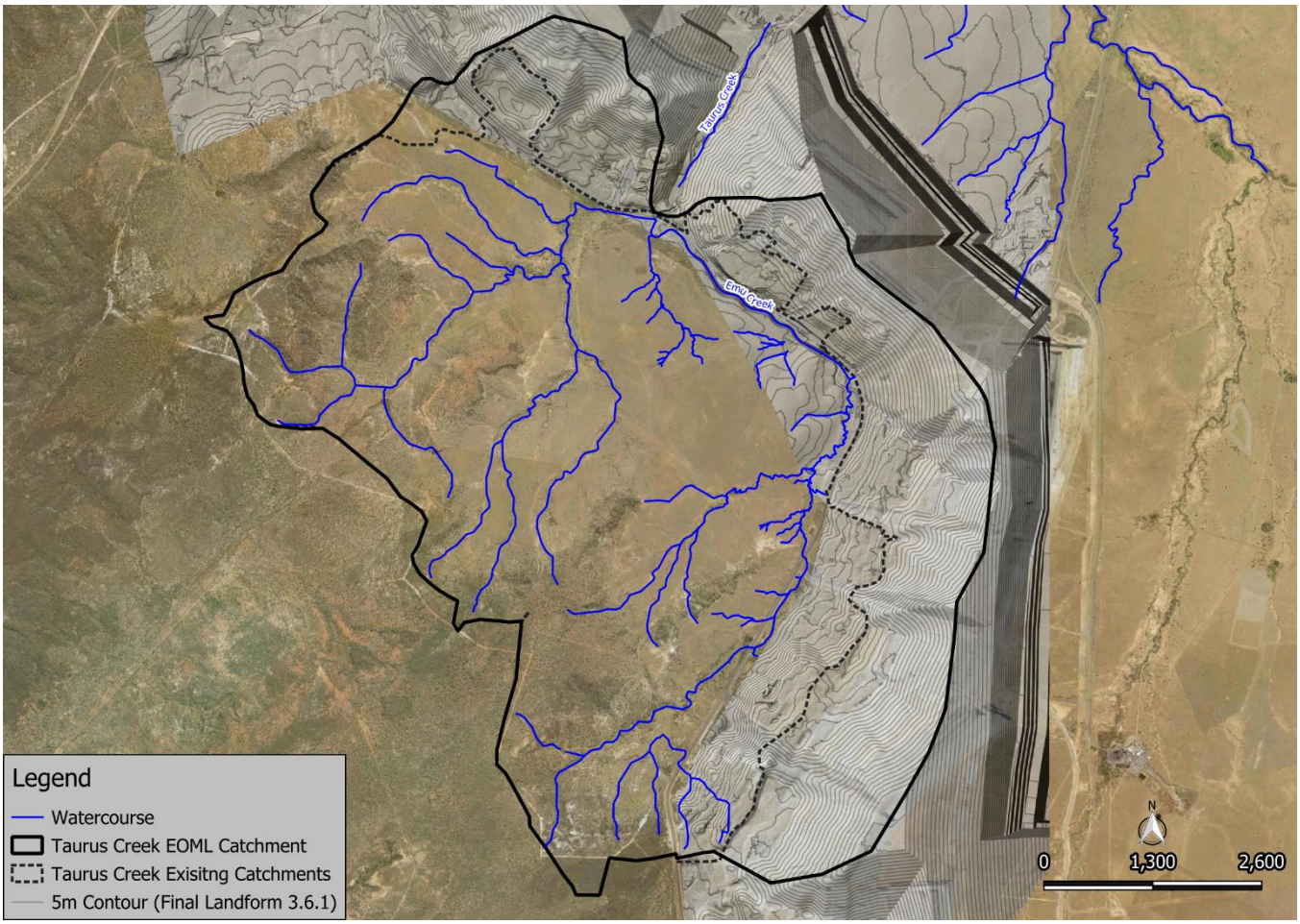


Figure 4.4: Map of Catchments

4.3.1 Frequent Events

The hydrologic model was used to estimate flows through the diversion for the 2 year ARI and 50 year ARI flow events (refer to Table 4.1). The flows have been compared to the ACARP (2014) diversion channel design parameters. A steady flow analysis was undertaken to assess the diversion design against guideline criteria.

TABLE 4.1: TAURUS CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
2 year ARI	83.6
50 year ARI	41.1

4.3.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be summarized within the Rehabilitation Flood Assessments undertaken as part of the PRCP.

4.4 Hydraulics

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. Stream velocity is calculated by dividing flow by cross-sectional area. The higher the velocity, the greater the erosive force of a stream. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Threshold values for velocity, stream power and shear stress listed in the ACARP Guidelines (Table 13 of the DNRME Guideline) were determined using a 1D HEC-RAS model. HEC-RAS (1D) calculates hydraulic conditions on a cross-sectional basis, outputting results as a cross-sectional mean. Due to this, the threshold values listed in the ACARP and DNRME guideline should be considered as cross-sectional average values. As such, modelling has been conducted utilising the 1D HEC-RAS software. (refer to Table 4.2). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 4.2: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	2-year ARI		50-year ARI	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	60	<60	70.1	<150
Stream Velocity (m/s)	1.4	<1.5	1.5	<2.5
Shear Stress (N/m^2)	43.4	<40	47.2	<80[1]

[1] *DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.*

It can be seen from Table 4.2 that the shear stress for the 39% AEP (2yr ARI) exceeds the guideline value. All other parameters are within acceptable limits.

Even though the shear stress is exceeding guideline values, it still falls below the threshold of 120 N/m^2 at which a channel with established native vegetation is considered stable, as per Table 3.3. The design of the diversion will be able to be refined in future phases to ensure shear stresses are within guideline values.

It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated, as per Table 3.1. It is expected that the channel achieves stability during a flood of this magnitude when the vegetation is fully established.

Appendix A illustrates the variability along the diversion channel for each design parameter.

4.5 Additional Design and Construction Considerations

4.5.1 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

4.5.2 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Taurus Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the BWM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

Further, hydraulic modelling has demonstrated that 2yr ARI stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated, as per Table 3.1. To ensure vegetation has sufficient time for establishment it is suggested to keep the diversion offline for 1 to 2 wet seasons. The concept design could be optimised in detailed design to further reduce the stream power and velocity in conjunction with a planned diversion revegetation strategy.

4.5.3 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with Whitehaven's watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.

- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable),and following periods of high flow in the diversion.

4.5.4 Closure Landform and Considerations

The PRCP landform can be reconfigured if the diversion is in close proximity to it and its alignment and re-instatement of the floodplain is inhibited by the closure landform. The concept design is required to inform the PRCP closure landform and will be offset to final voids by at least 100 m so seepage to or from voids is not expected.

4.6 Risks and Mitigation Measures

Table 4.3 below summarises the main risks for the diversion remediation design and construction.

TABLE 4.3: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Vegetation establishment and erosion potential	Probable	2	9	Channel taken offline during construction and vegetation establishment phase, vegetation type and seed-mix selected based on local environment	Unlikely	1	1
Damage to new diversion channel due to extreme flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1

5. CONCLUSION

To develop a PRCP Chapter for the Taurus Creek diversion, a concept design for remediation of the Taurus Creek diversion will be developed. This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design was developed based on three guidelines, two of which are currently recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).
- EA condition for specified rehabilitation requirements.

The final concept option design was selected to achieve a similar pre-mining channel grade, while also aligning with the most recent final landform (Landform 3.6.1). The final concept option design, typical cross sections and longitudinal section are presented in Appendix B.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

6. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

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(g) This Report does not provide legal advice.

7. REFERENCES

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APPENDIX A: HYDRAULIC PARAMETER MODELLING RESULTS

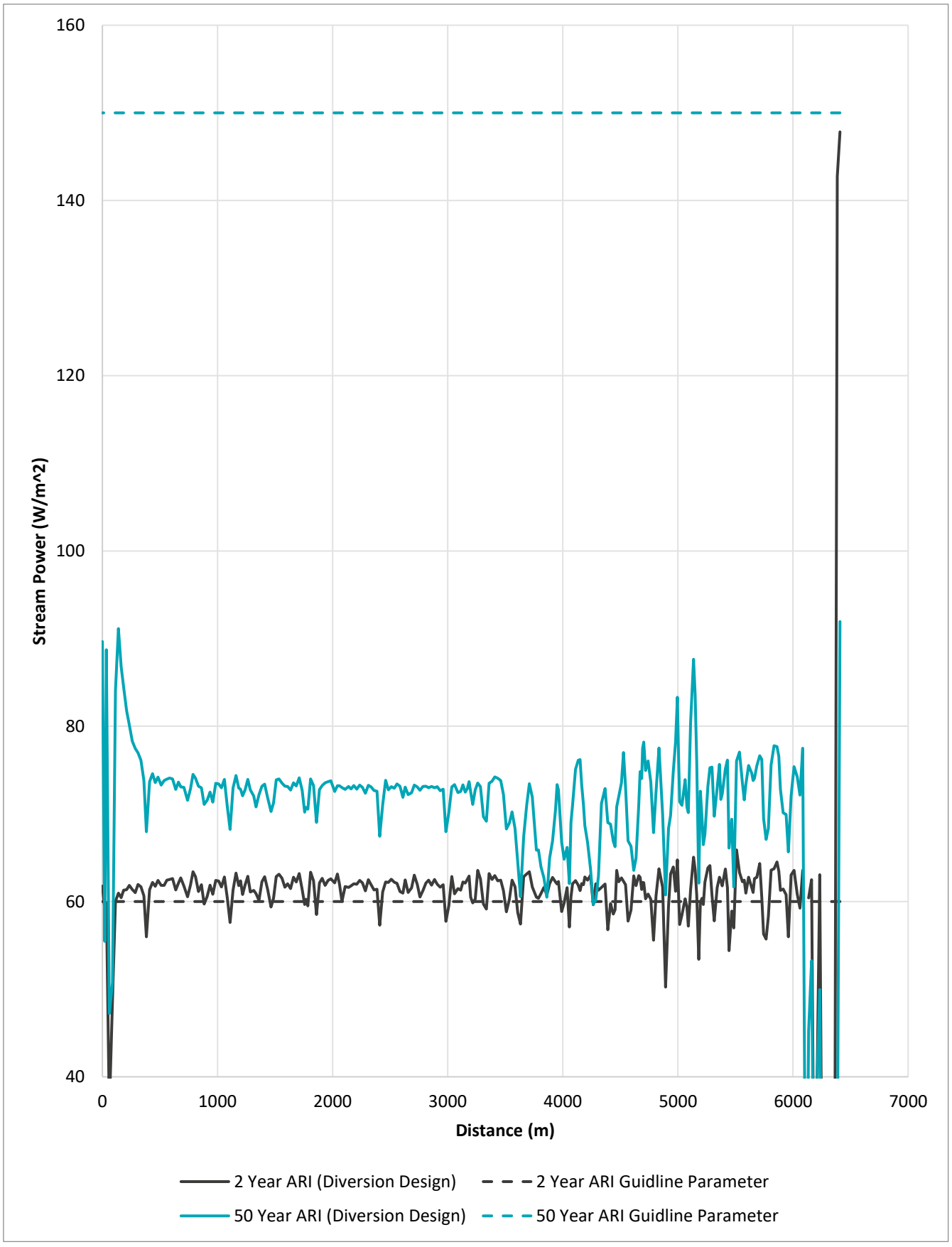


FIGURE A.1**: STREAM POWER HEC-RAS MODEL RESULTS**

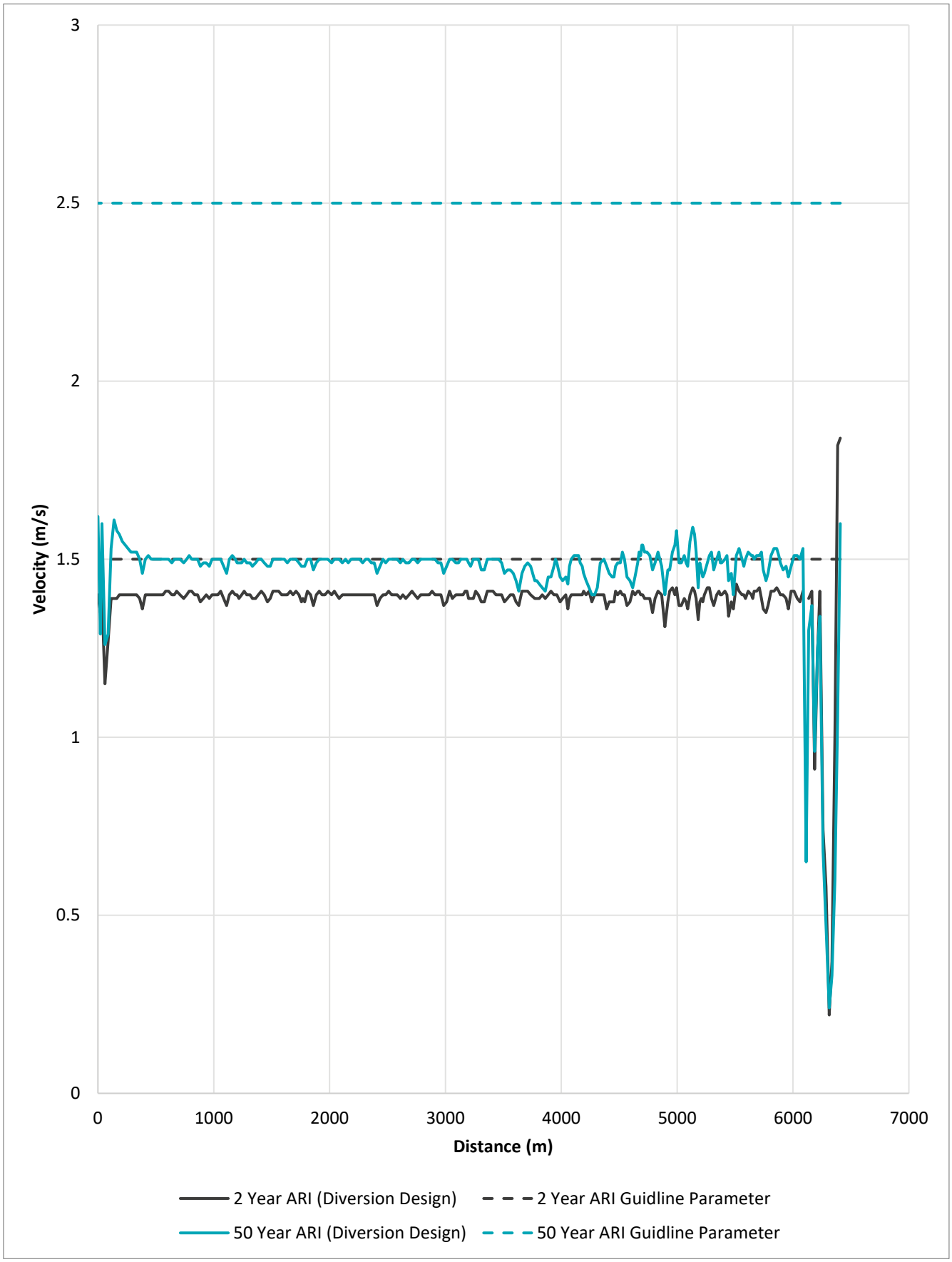


FIGURE A.2: VELOCITY HEC-RAS MODEL RESULTS

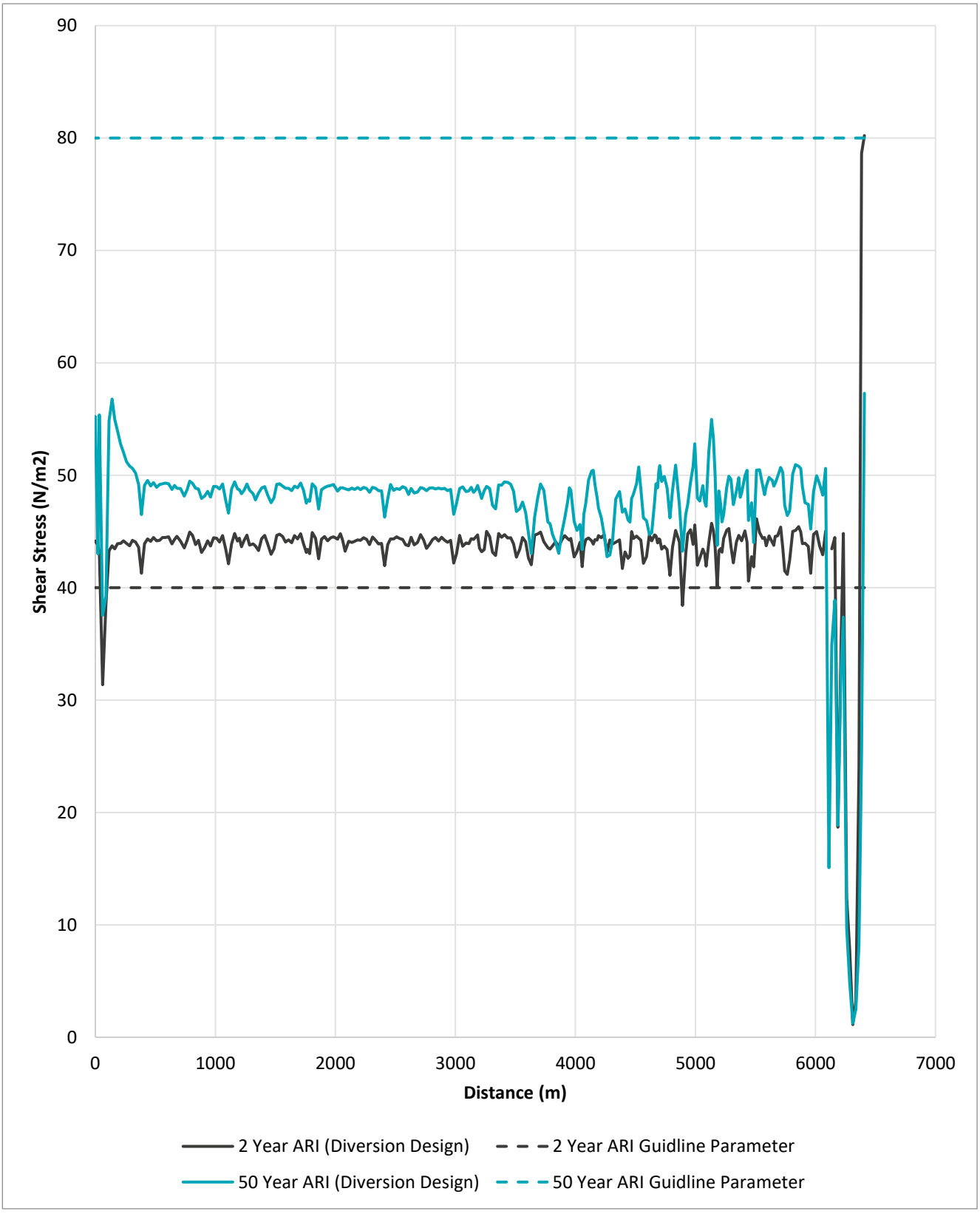
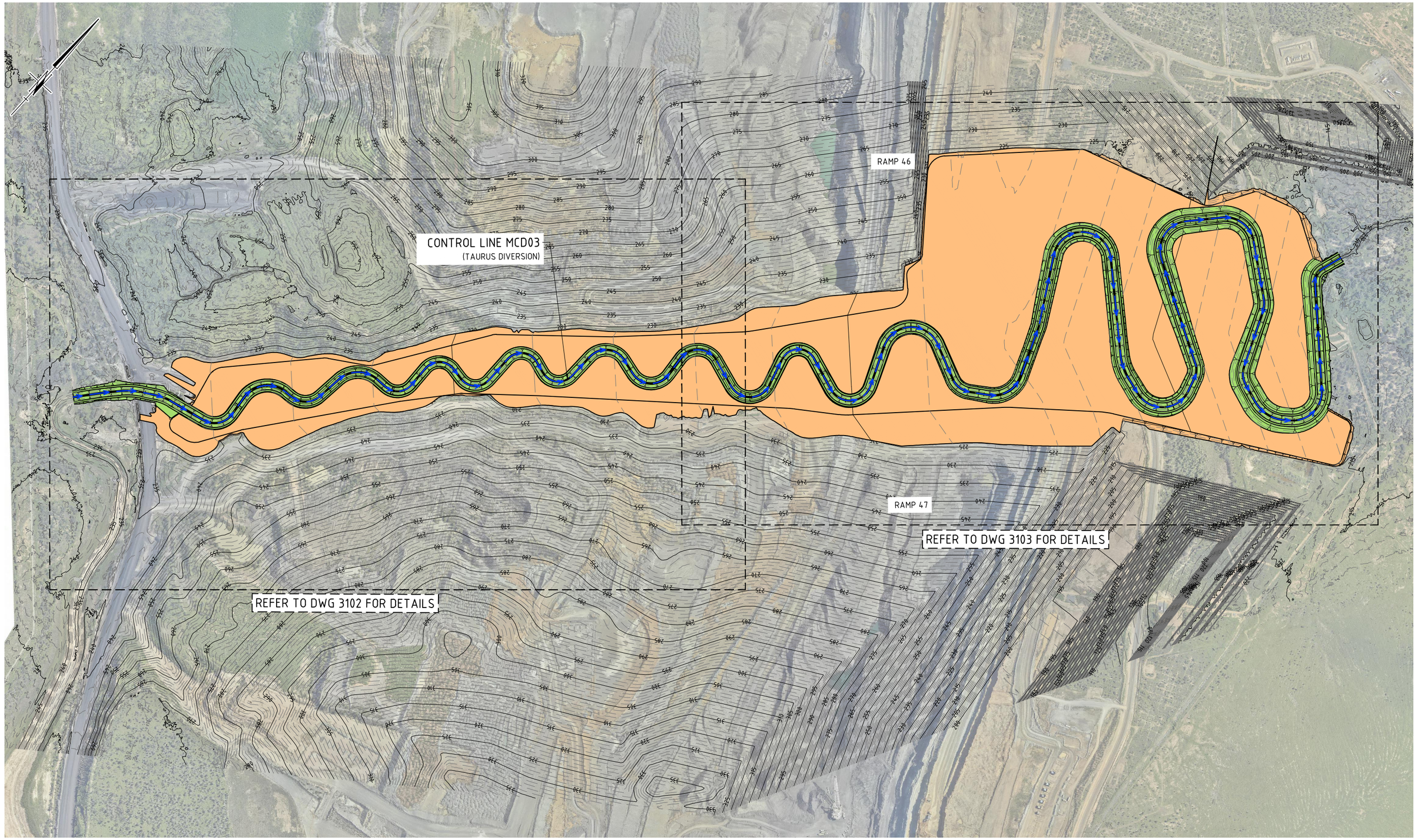


FIGURE A.3: SHEAR STRESS HEC-RAS MODEL RESULTS

APPENDIX B: PREFERRED OPTION



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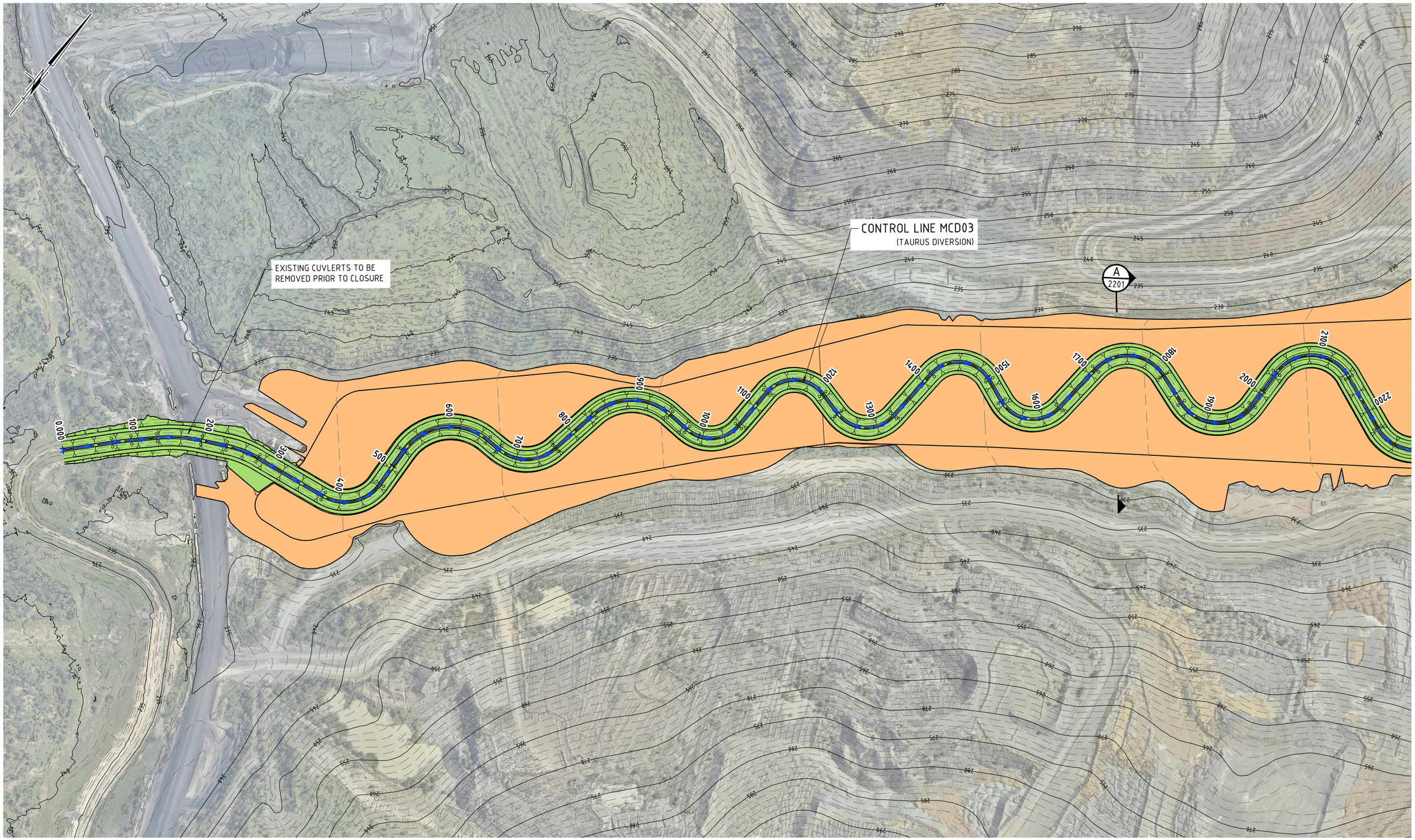
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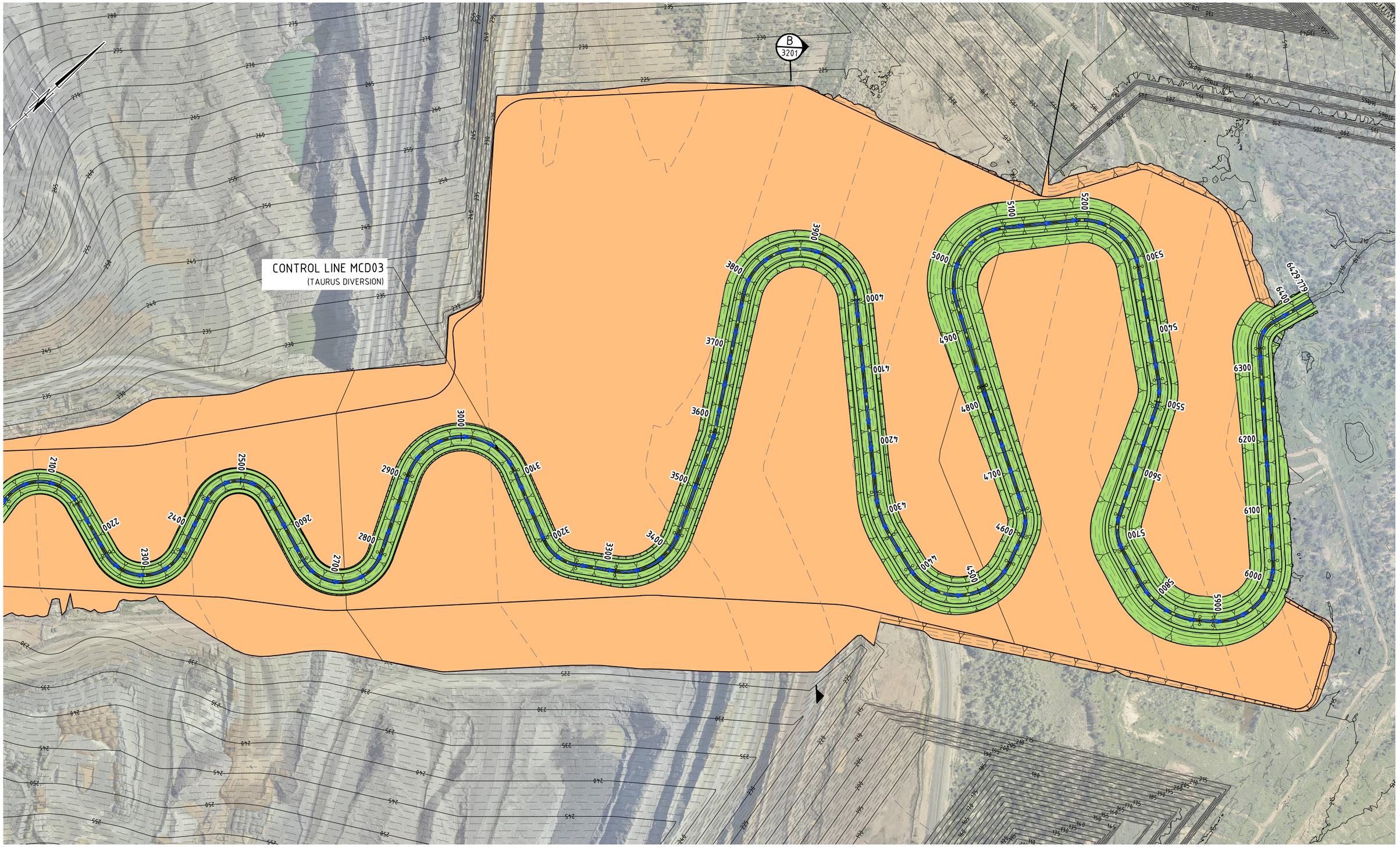
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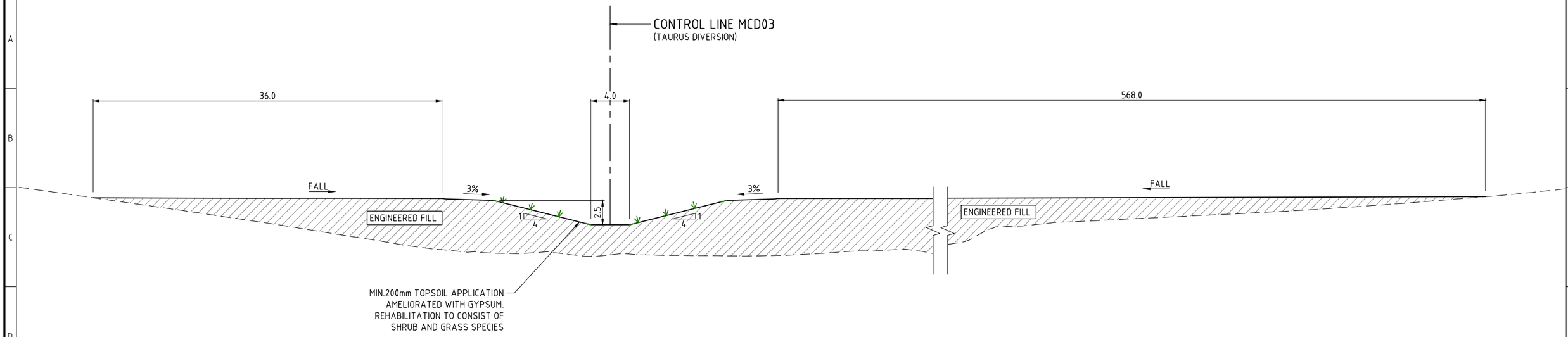
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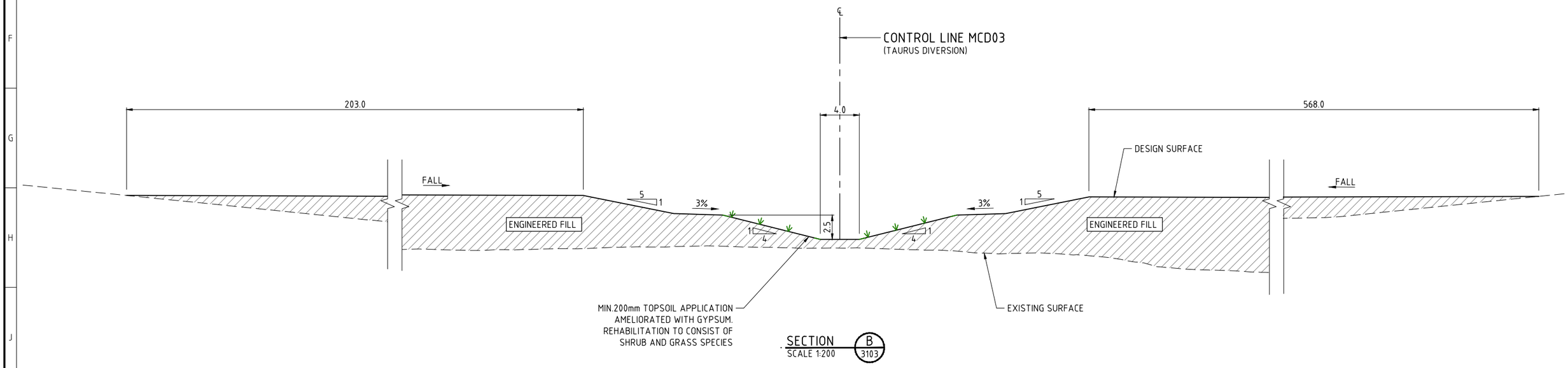
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SECTION B
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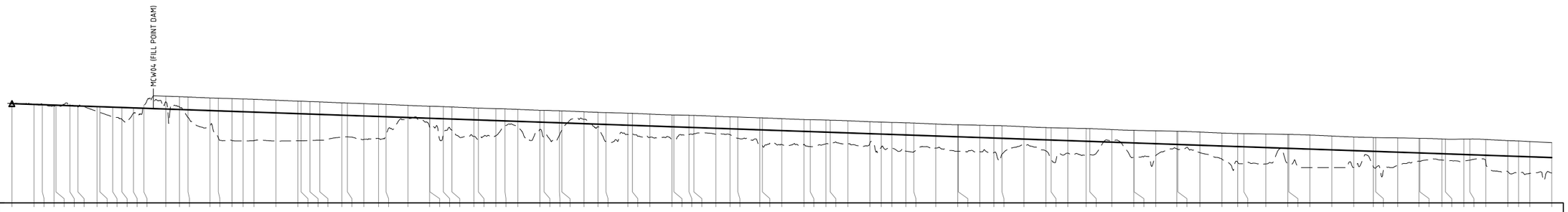
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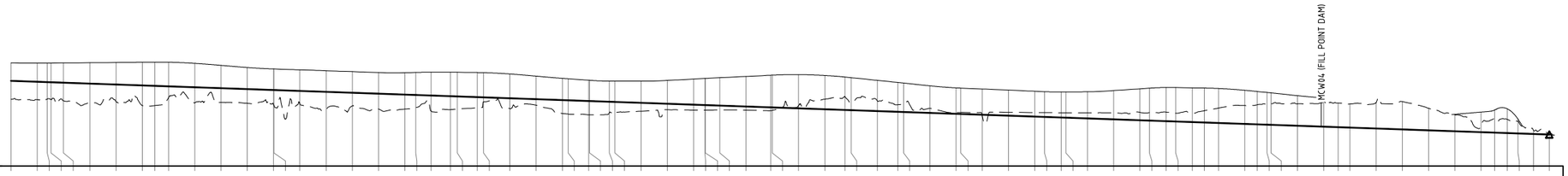
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PRCP Concept Design Report

Rockland Creek Diversion

BBNE04877_0045-REP-001-0

30 OCTOBER 2025

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Rockland Creek Diversion which satisfies the conditions under Environmental Authority (EA) EPML00717813. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Blackwater Mine (BWM)

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for BWM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose & Scope

The purpose of this document is to outline the concept design developed for the preferred diversion remediation option to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of Rockland Creek was undertaken using historical aerial imagery and survey to identify the preferred option for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

Design Process

1.2.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Rockland Creek is an ephemeral tributary of the Comet River, situated within the Fitzroy River basin. The creek originates in a relatively low relief range to the east of Blackwater Mine. The creek flows from east to west, through the south Blackwater Mine operations, the Rockland Creek Dam and eventually joining Humboldt Creek some 22 km west of Blackwater Mine. The diversion was likely constructed in 1993, at a length of approximately 1.5 km, to allow mining within Marshmead Pit. The diversion as well as the Rockland Dam, were constructed as part of the flood mitigation for this Pit. Refer to Figure 2.1 for the location of the Rockland Creek Diversion.

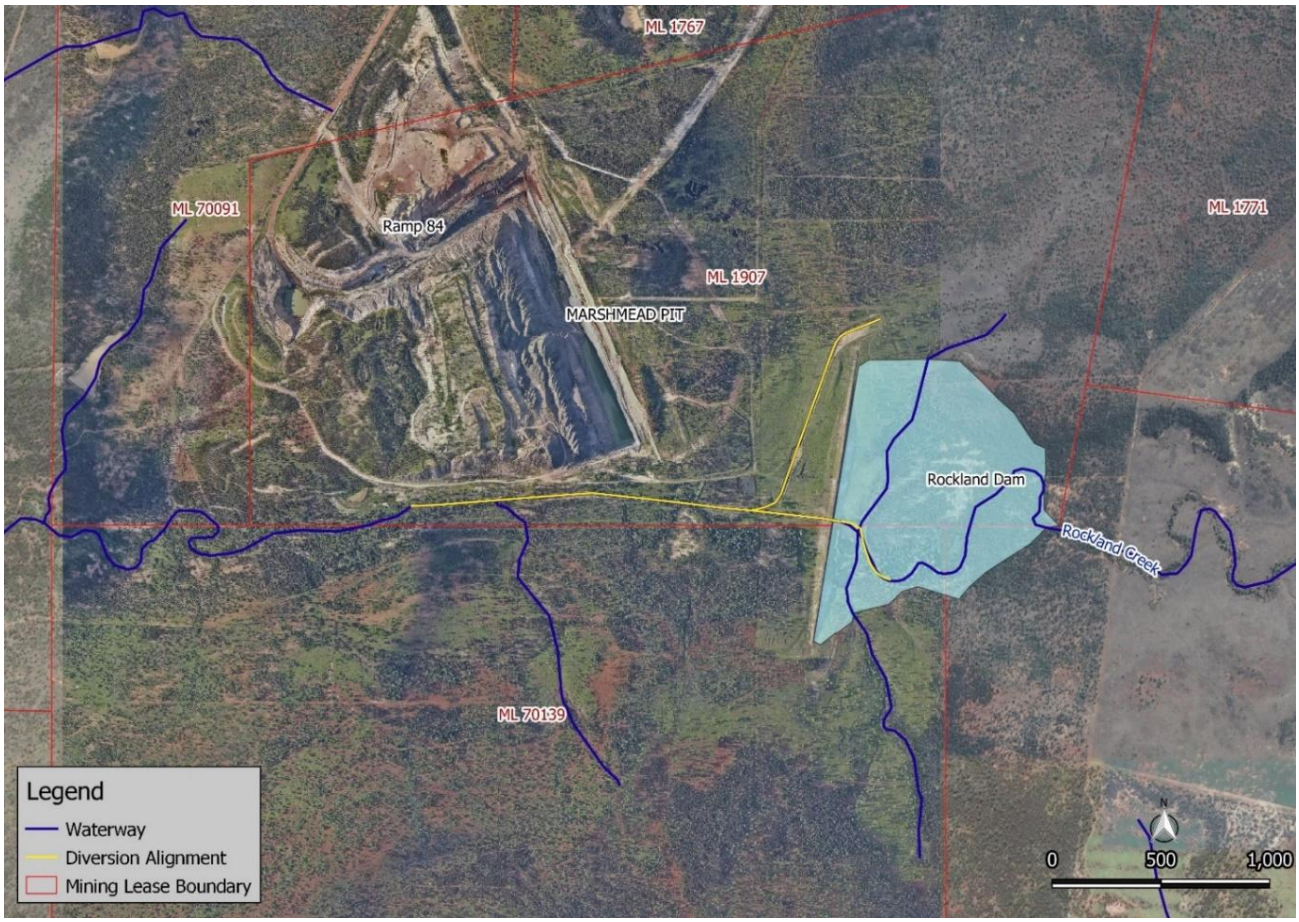


Figure 2.1: Location of the Rockland Creek Diversion at Blackwater Mine

2.2 Natural Reaches

The upstream, downstream and diversion reaches of Rockland Creek have been described as follows (Alluvium, 2010):

- **Upstream reach –** The upstream reach of the Rockland Creek diversion is within the mine lease and within the backwater influence of Rockland Dam. Much of the riparian, floodplain and hill slopes in the area are either uncleared or have well established regeneration. The upstream drainage network consists of moderate sinuosity channels with predominantly alluvial boundaries. The channel consists of a clear low flow channel within a high flow channel. The high flow channel varies in capacity with top width ranging from 30-60m and depth from 2 to 5m.
- **Downstream reach –** Downstream of the Rockland Creek diversion, the drainage network is comprised of a moderate sinuosity single low capacity low flow channel with predominantly clay boundaries. The floodplain has a moderate width of 40 to 60m with the low flow

channel depths ranging from 0.5 to 2.5m. The downstream reach is mainly influenced by the Rockland Dam Embankment with notable aggradation within the channel bed due to excess sediment inputs from the eroding diversion and spillway channel.

- **Diversion reach (pre-mining)** - The Rockland Creek diversion reach (pre-mining) was approximately 3.1 km long. It was gently meandering across the southern extent of what is now Marshmead Pit.

The upstream, downstream and diversion reaches of the Rockland Creek diversion at Blackwater Mine are shown in Figure 2.2.

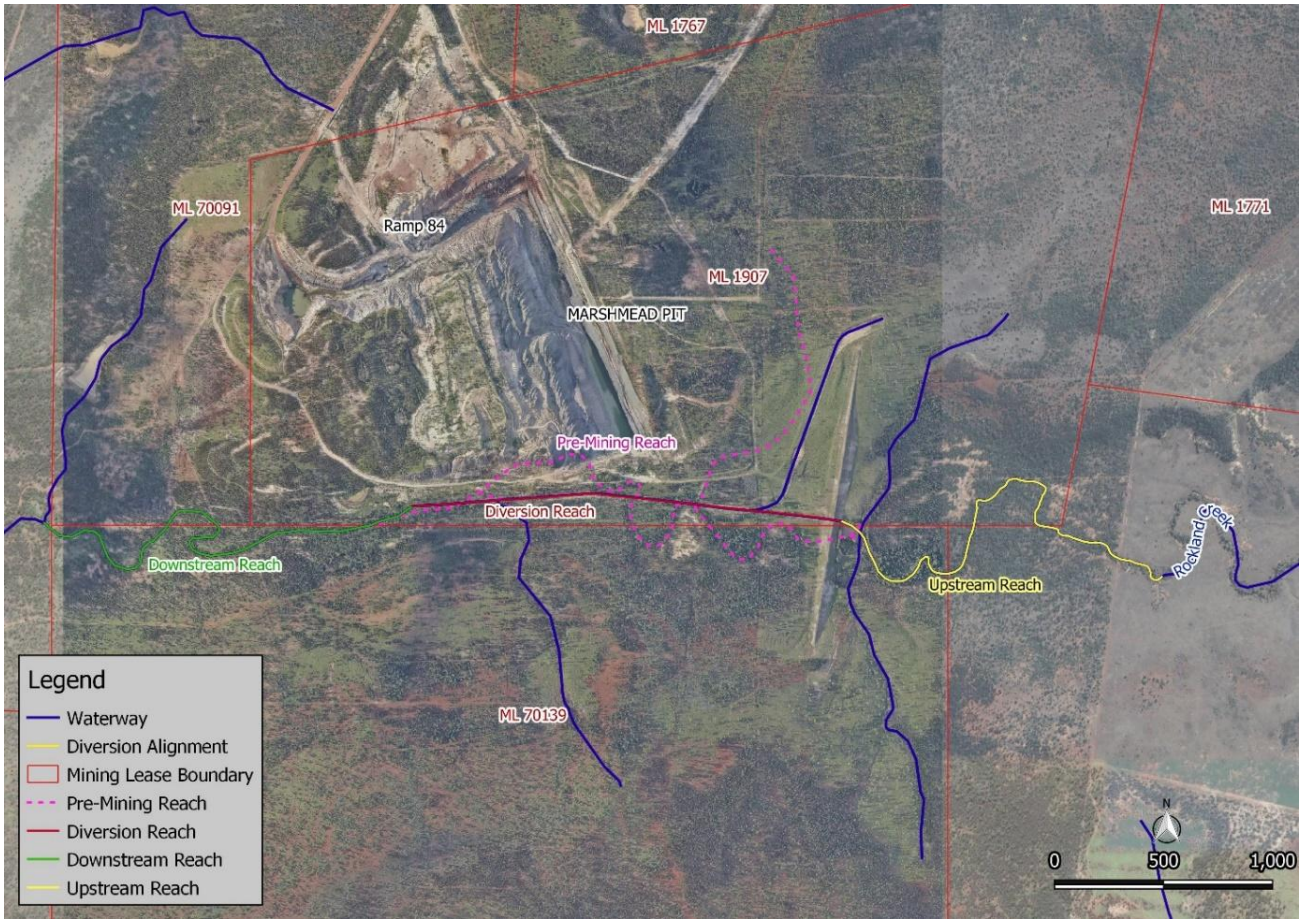


Figure 2.2: Upstream, Downstream and Diversion Reaches of the Rockland Creek Diversion

2.3 Diversion Reach

Monitoring of Rockland Creek diversion has been undertake since 2011 and was last completed in 2016. As part of the major monitoring, the latest condition of the Rockland Creek diversion has been described as follows (Engeny, 2016):

- The upstream reach is continuing to deteriorate due to the impacts of the Rockland Dam inhibiting sediment transport and long term ponding which has also resulted in a significant impact to vegetation, reducing the cover through all layers of the riparian vegetation.
- This is also artificially altering the upstream reach which as a result is no longer representative of the natural system.
- There is an existing drop structure within the diversion reach. The reach beyond this structure is showing signs of improvement in both geomorphic and riparian condition. Improvements in conditions prior to the drop structure are expected to be limited due to the impacts of Rockland Dam.
- The downstream reach geomorphic conditions remain relatively unchanged with a decrease in riparian condition attributed to drought stress and observed reduction in ground cover.

Based on the current condition of the Rockland Creek diversion, it is highly unlikely that the diversion will achieve the water license relinquishment criteria prior to mine closure without intervention.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014)

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions. Details of the guidelines that have been used to design the Rockland Creek diversion are summarised below.

3.1 DNRME Guideline

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Deep Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Rockland Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
2-year ARI (no vegetation)	<35	<1.0	<40
2-year ARI (vegetated)	<60	<1.5	<40
50-year ARI	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, which included an analogous approach, where channel dimensions are selected from a reference reach; a hydraulic geometry approach where dimensions are determined from regression relationships; and an analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be represented of stable watercourses within the Bowen Basin and are summarised in Table 3.2: .

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Stream Power (W/m^2)	Stream Power 2-year ARI (W/m^2)	Stream Power 50-year ARI (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3: .

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass	40
Structurally diverse suite of established native vegetation	120

The long-term performance of the diversion under both operating and closure scenarios is assessed with the following objectives, based on industry standard closure objectives:

- The diversion demonstrates to be in a safe, stable, non-polluting and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Reference rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining landuse of the 'Watercourses' which is applicable for the watercourse diversion.
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

3.3 Environmental Authority EPML00717813

The land schedule within the Blackwater Mine EA (EPML00717813) requires that all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified Rehabilitation Requirements. The EA provides the rehabilitation landform criteria for the post mining land use of watercourses (refer to Figure 3.1) Some indicators reference the Index of Diversion Condition (IDC) method, which is a component of ongoing diversion monitoring.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

Figure 3.1: Blackwater Mine EA EPML00717213 Rehabilitation Requirements for Watercourses

4. CONCEPT DESIGN

4.1 Diversion Alignment

Figure 4.1 shows the permanent diversion alignment design of Rockland Creek. The alignment was selected based on the most recent final landform (Landform 3.6.1). The design is included in Appendix B.

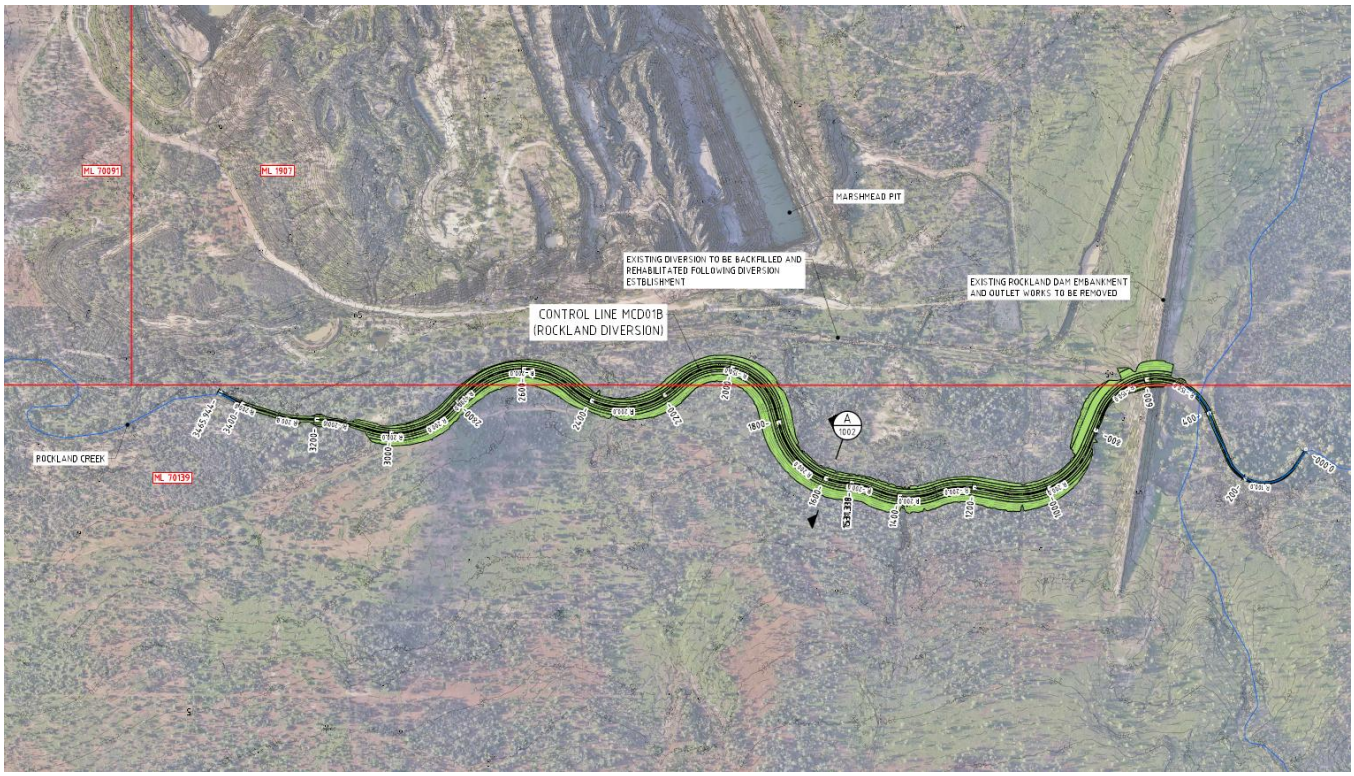


Figure 4.1: Rockland creek alignment General Arrangement

4.2 Channel Geometry and Grade

The typical upstream and downstream channel geometries are presented in Figure 4.2 and Figure 4.3 below. These dimensions were based on the average natural upstream and downstream channel geometry.

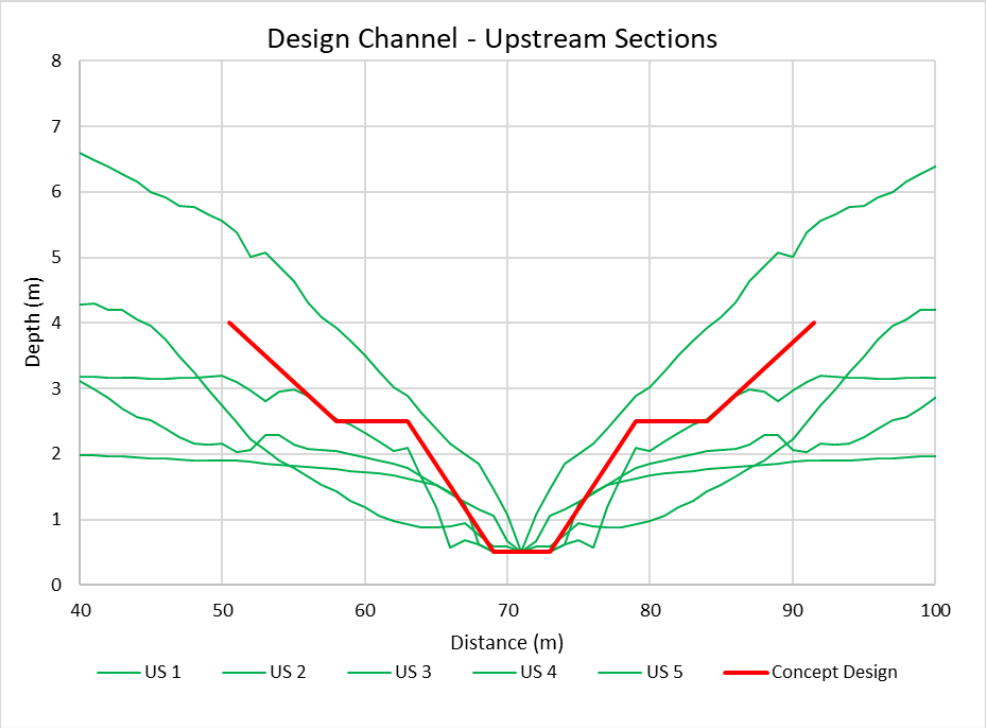


Figure 4.2: Typical Upstream Channel Cross Section

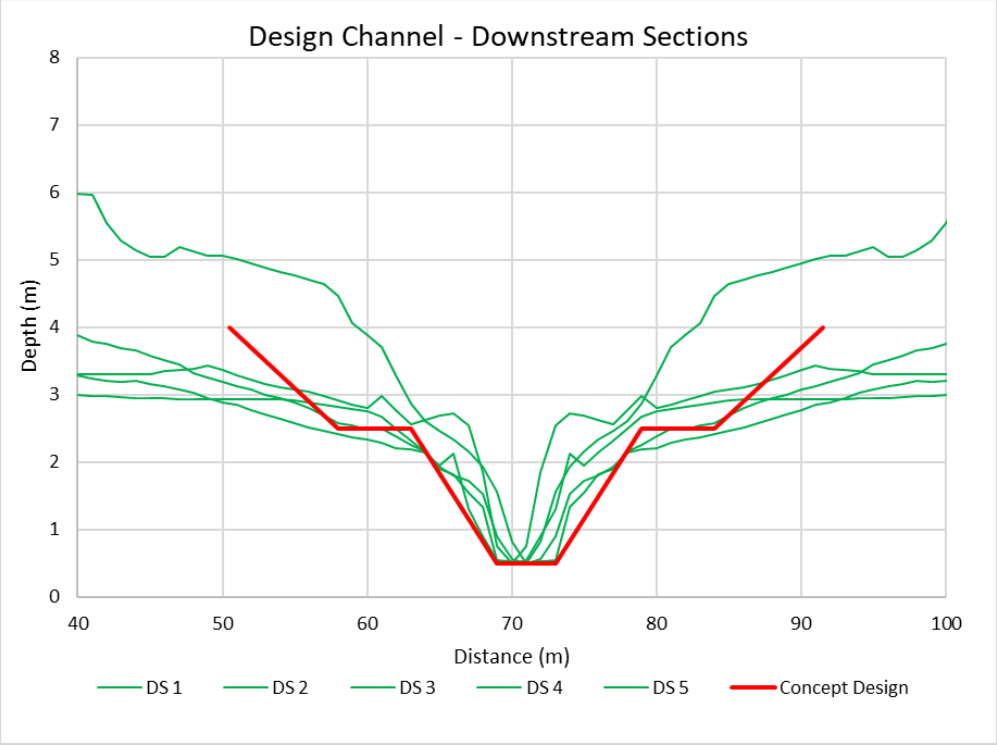


Figure 4.3: Typical Downstream Channel Cross Section

4.3 Hydrology

Peak flows for frequent events (39% AEP and2% AEP) for the Rockland Creek diversion remediation were estimated using the ACARP (2002) methods and are presented in Table 4.1. As described in Section 3, The hydraulic outcomes for diversion designs are only prescribed for frequent events (39% AEP and2% AEP). As such, hydraulic modelling of rare event (1% and 0.1% AEP) has not been undertaken as part of the diversion concept design. The Rehabilitation Flood Assessments undertaken separately as part of the PRCP should be referred to for the hydrologic and hydraulic modelling for the 1% AEP and 0.1% AEP flood events of Sirius Creek.

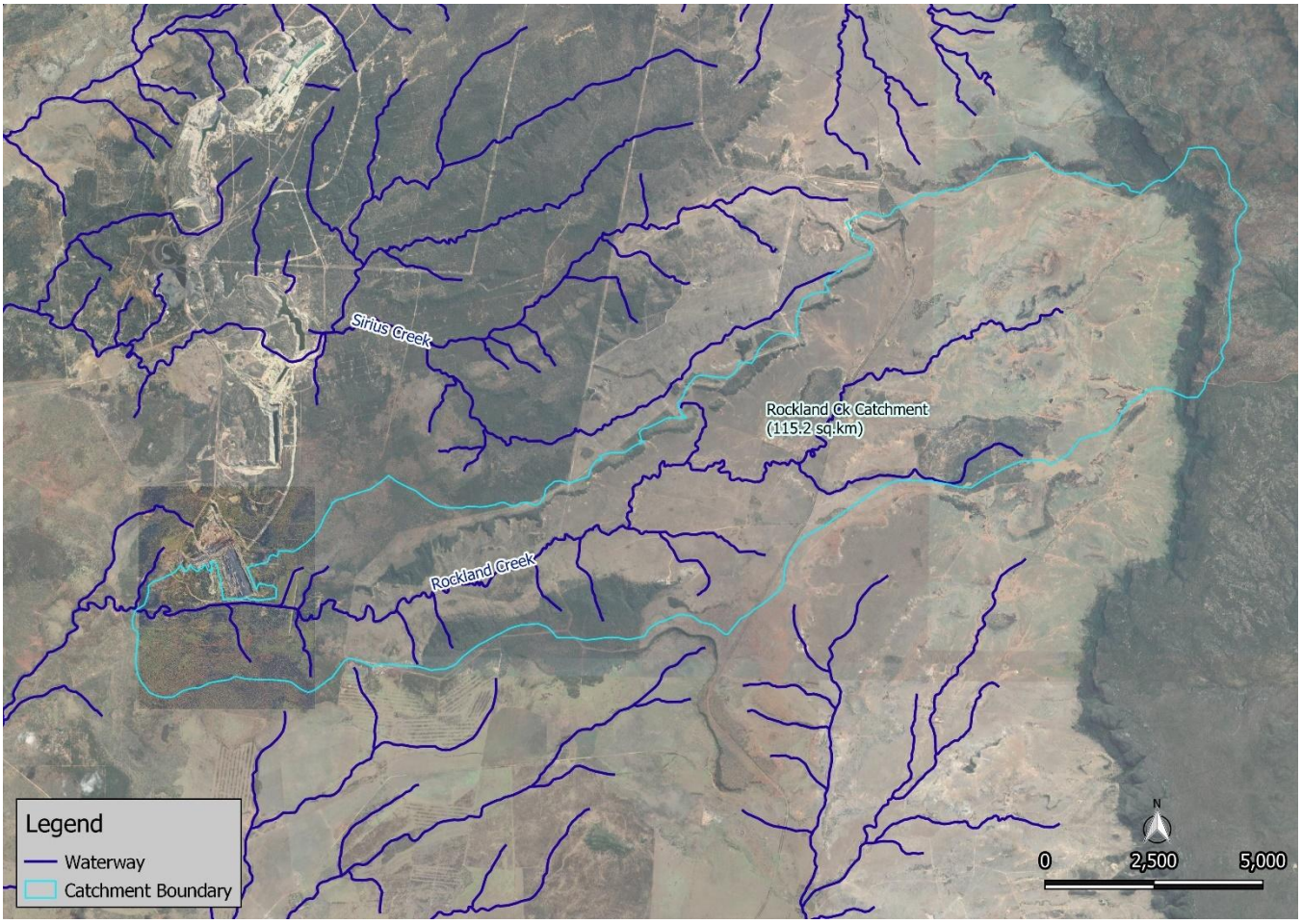


Figure 4.4: Map of Catchments

4.3.1 Frequent Events

The hydrologic model was used to estimate flows through the diversion for the 2 year ARI and 50 year ARI flow events (refer to Table 4.1). The flows have been compared to the ACARP (2014) diversion channel design parameters. A steady flow analysis was undertaken to assess the diversion design against guideline criteria.

TABLE 4.1: ROCKLAND CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
2 year ARI	60.4
50 year ARI	148.7

4.3.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be summarized within the Rehabilitation Flood Assessments undertaken as part of the PRCP.

4.4 Hydraulics

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. Stream velocity is calculated by dividing flow by cross-sectional area. The higher the velocity, the greater the erosive force of a stream. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Threshold values for velocity, stream power and shear stress listed in the ACARP Guidelines (Table 13 of the DNRME Guideline) were determined using a 1D HEC-RAS model. HEC-RAS (1D) calculates hydraulic conditions on a cross-sectional basis, outputting results as a cross-sectional mean. Due to this, the threshold values listed in the ACARP and DNRME guideline should be considered as cross-sectional average values. As such, modelling has been conducted utilising the 1D HEC-RAS software. (refer to Table 4.2). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 4.2: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	2-year ARI		50-year ARI	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	55.7	<60	110.4	<150
Stream Velocity (m/s)	1.6	<1.5	2.1	<2.5
Shear Stress (N/m^2)	32.3	<40	48.6	<80[1]

[1] *DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.*

It can be seen from Table 4.2 that the stream velocity for the 2-year ARI is slightly above its guideline value. All other parameters are within the acceptable limits.

It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated, as per Table 3.1. The 2-year ARI shear stresses are below the threshold of 120 N/m^2 at which an established native vegetation is considered stable, as per Table 3.3. It is expected that the channel achieves stability during a flood of this magnitude when the vegetation is fully established.

Appendix A illustrates the variability along the diversion channel for each design parameter and shows a drop in values when the diversion channel opens up to a wider floodplain in the last 500m of the diversion.

4.5 Additional Design and Construction Considerations

4.5.1 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.

- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

4.5.2 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Rockland Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the BWM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

Further, hydraulic modelling has demonstrated that 2yr ARI stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated, as per Table 3.1. To ensure vegetation has sufficient time for establishment it is suggested to keep the diversion offline for 1 to 2 wet seasons. The concept design could be optimised in detailed design to further reduce the stream power and velocity in conjunction with a planned diversion revegetation strategy.

4.5.3 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with Whitehaven's watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable),and following periods of high flow in the diversion.

4.5.4 Closure Landform and Considerations

The PRCP landform can be reconfigured if the diversion is in close proximity to it and its alignment and re-instatement of the floodplain is inhibited by the closure landform. The concept design is required to inform the PRCP closure landform and will be offset to final voids by at least 100 m so seepage to or from voids is not expected.

4.6 Risks and Mitigation Measures

The Table 4.3 below summarises the main risks for the diversion remediation design and construction.

TABLE 4.3: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Vegetation establishment and erosion potential	Probable	2	9	Channel taken offline during construction and vegetation establishment phase, vegetation type and seed-mix selected based on local environment	Unlikely	1	1
Damage to new diversion channel due to extreme flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1

5. CONCLUSION

To develop a PRCP Chapter for the Rockland Creek diversion, a concept design for remediation of the Rockland Creek diversion will be developed. This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design was developed based on three guidelines, two of which are currently recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014)
- EA condition for specified rehabilitation requirements

The final concept option design was selected based on the most recent final landform (Landform 3.6.1). The final concept option design, typical cross sections and longitudinal section are presented in Appendix B.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

6. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

(c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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7. REFERENCES

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APPENDIX A: HYDRAULIC PARAMETER MODELLING RESULTS

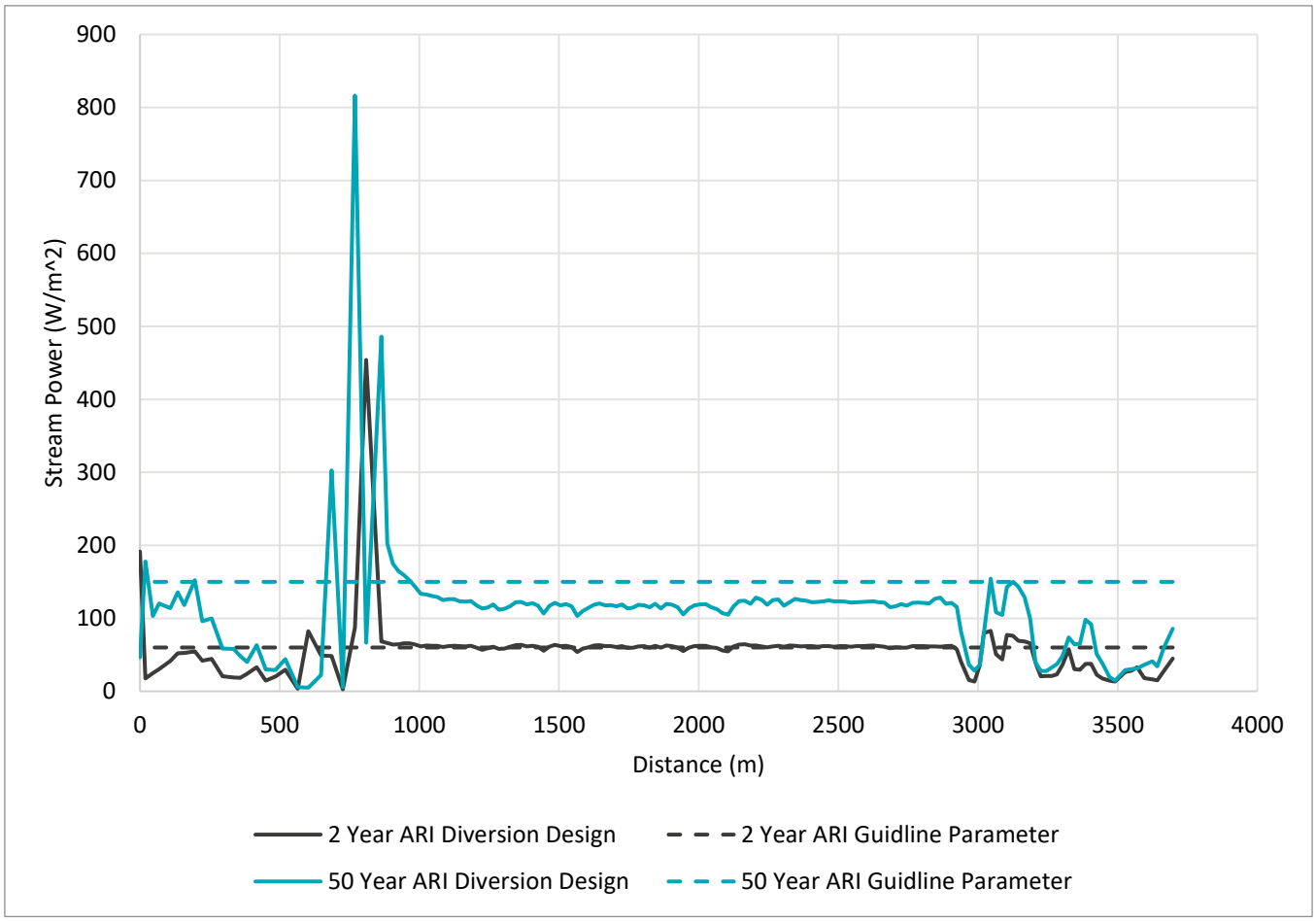


FIGURE A.1: STREAM POWER HEC-RAS MODEL RESULTS

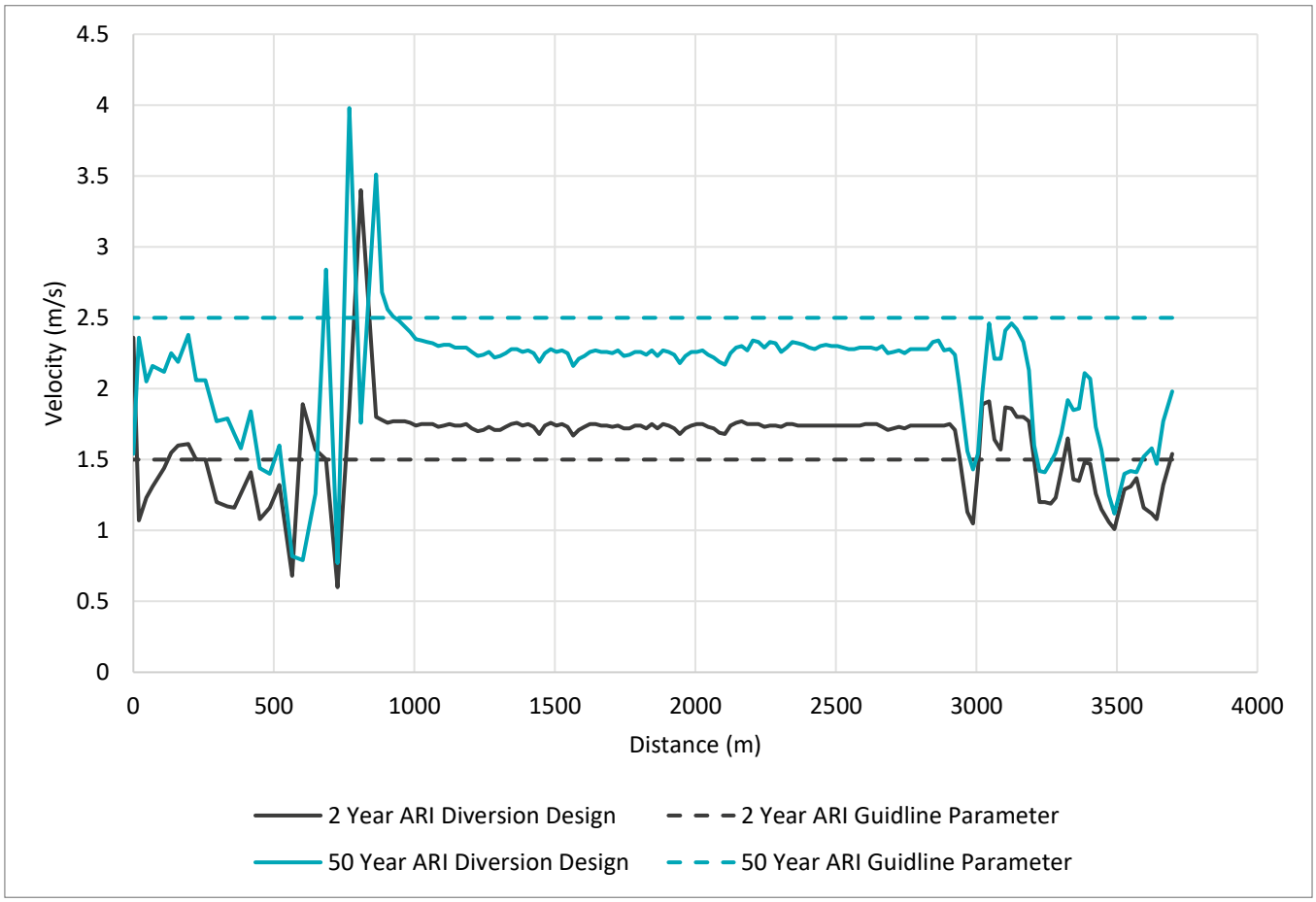


FIGURE A.2: VELOCITY HEC-RAS MODEL RESULTS

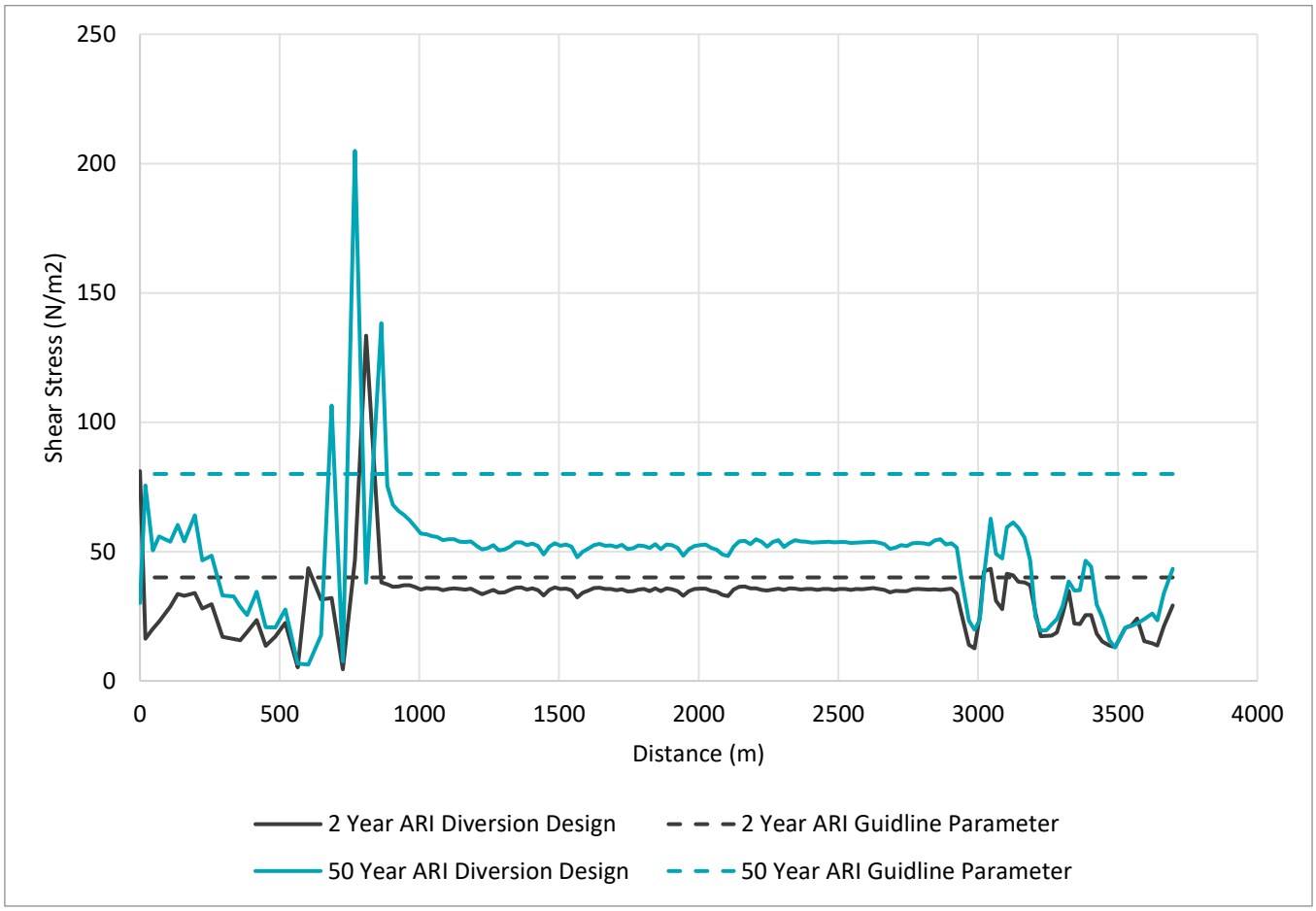
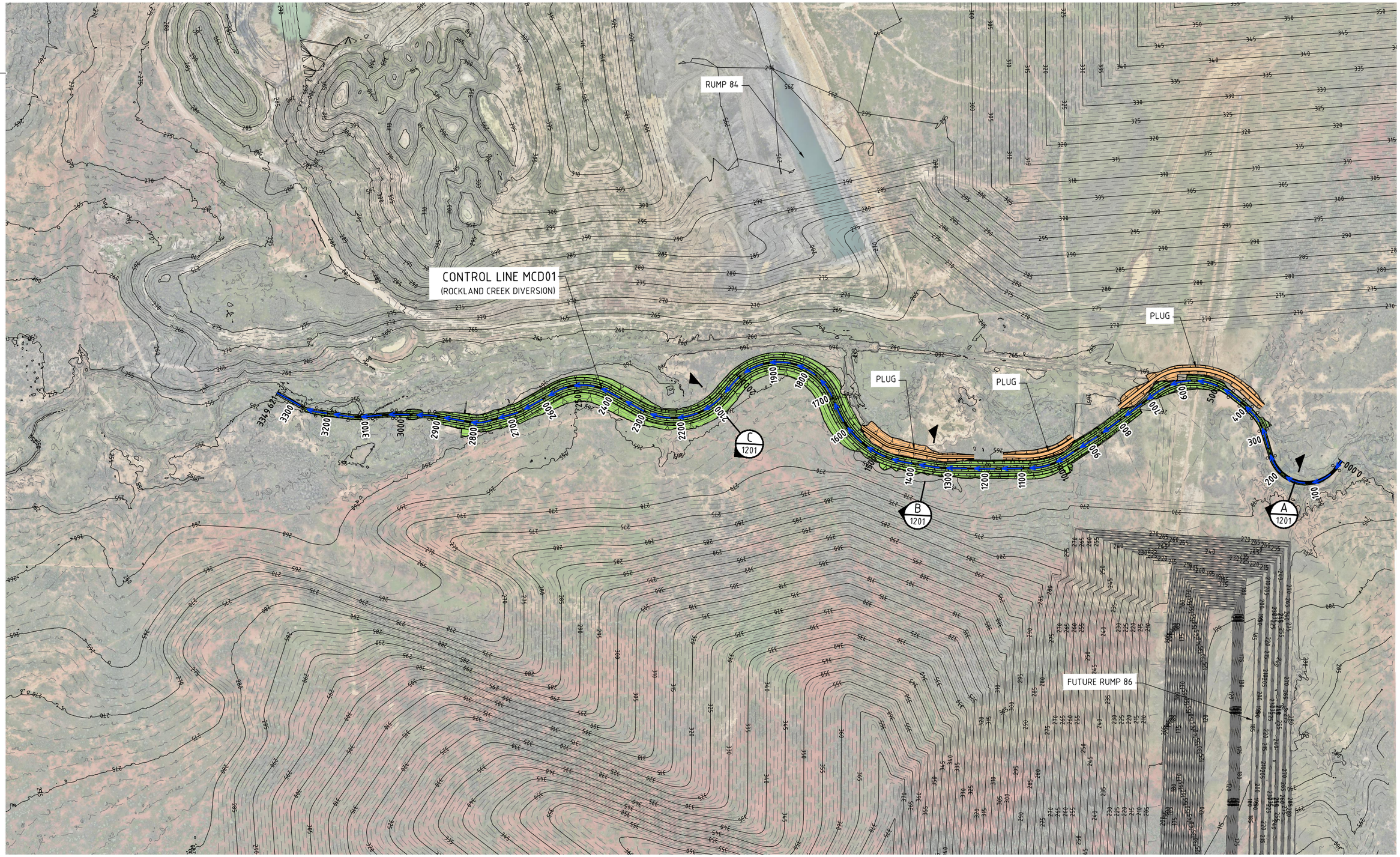


FIGURE A.3: SHEAR STRESS HEC-RAS MODEL RESULTS

APPENDIX B: PREFERRED OPTION



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SCALE 1:5000 (A1)
SCALE BEFORE REDUCTION

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BNE04877-0045-DWG-1101

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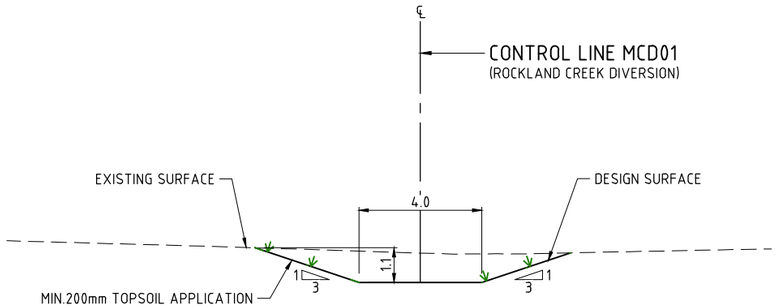
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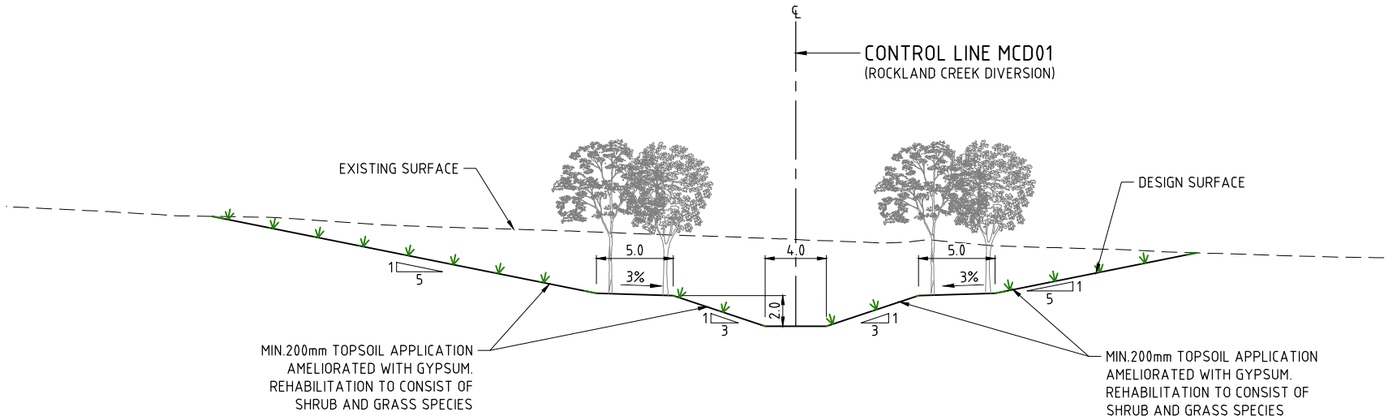
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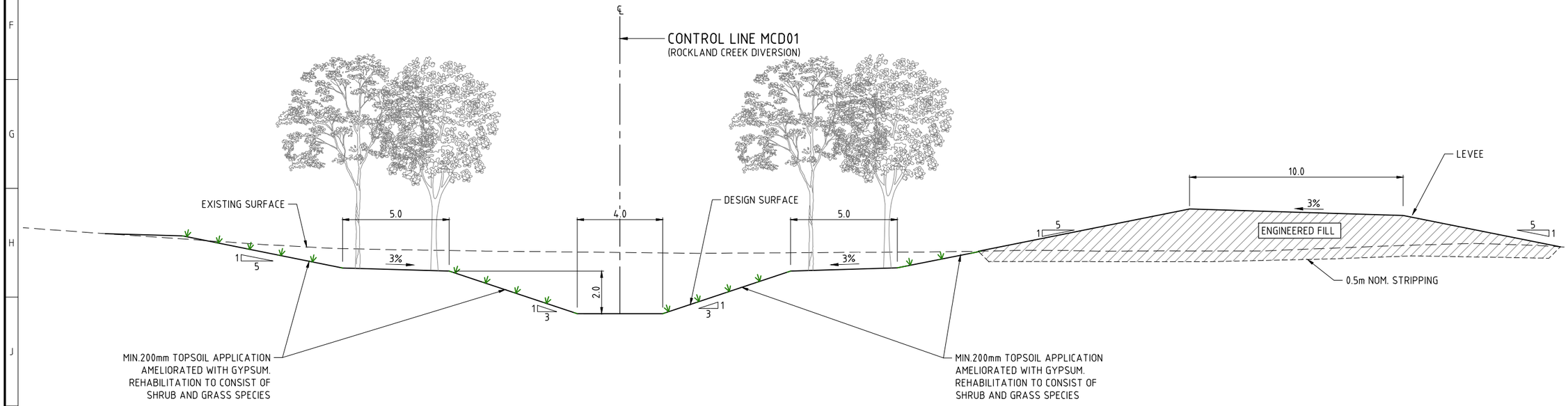
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SECTION C
SCALE 1:200
1101



SECTION B
SCALE 1:100
1101

LEGEND

EXISTING SURFACE

DESIGN SURFACE

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SCALE BEFORE REDUCTION

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SCALE 1:200 (A1)
SCALE BEFORE REDUCTION

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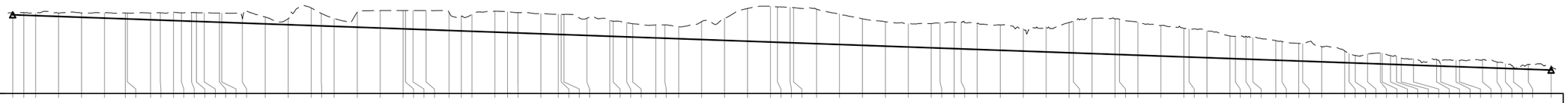
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ROCKLAND DIVERSION
TYPICAL SECTIONS AND DETAILS

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PRCP Concept Design Report

Deep Creek Diversion

BBNE04877_0045-REP-004-0

14 NOVEMBER 2025

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the Deep Creek Diversion which satisfies the conditions under Environmental Authority (EA) EPML00717813. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Blackwater Mine (BWM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for BWM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose

The purpose of this document is to outline the concept design developed for the diversion remediation option to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of Deep Creek was undertaken using historical aerial imagery and survey to identify the preferred option for the closure alignment.
- Application of ACARP (2002) flows to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Deep Creek is an ephemeral tributary of Blackwater Creek, which ultimately flows into the Mackenzie River, a major tributary in the Fitzroy River catchment. Deep Creek flows east across the Blackwater Mine lease through a diversion within an access corridor between the Ramp 30S (Besgrove Pit) and Ramp 34S (Deep Creek Pit) and joins Taurus Creek before continuing northwards to the confluence with Blackwater Creek. Deep Creek originates approximately six kilometres to the south-west of the Blackwater Mine operations. At the most upstream point of the existing diversion, it has a catchment area of approximately 23 km^2.

The creek was diverted in 2002 to allow progression of mining in Ramp 30S and has since constrained further advancement of the pit since the creek discharges into New Deep Creek Dam, located on the Ramp 30 highwall. The existing diversion channel was constructed solely for the purpose of flood conveyance and protection of the adjacent pits and as a result the current diversion geometry or riparian vegetation is not reflective of the natural upstream and downstream reaches. Deep Creek is designated as a watercourse under the Water Act 2000 commencing at the Haul Road. The existing diversion is currently licensed under Licence Number 609051 as a temporary structure. Refer to Figure 2.1 for the location of the Deep Creek Diversion.

2.2 Natural Reaches

The upstream, downstream and diversion reaches of Deep Creek have been described as follows (Engeny, 2018) :

- **Upstream reach –** The upper reaches of the catchment drainage consisted of poorly defined, narrow, and shallow low-flow channels with low sinuosity, confined by adjacent valley margins. Channel slopes ranged between approximately 0.006 and 0.02 m/m, with channel depths varying between 0.5 m and 2 m, and top widths ranging from 10 m to 20 m. Given the proximity of the valley margins and the shallow soil profiles, these reaches are likely to be predominantly bedrock controlled.
- **Downstream reach –** The downstream reach of Deep Creek consisted of a low to moderately sinuous (~1.17–1.5), irregularly meandering channel incised into a shallow valley. The construction of the New Deep Creek Dam has reduced sediment delivery to this reach, contributing to further incision. The upstream sections of this reach lack coarse bed sediment and exhibit widespread, but minor, toe scour and isolated bank failures. Channel bed and bank materials are primarily composed of underlying soils, ranging from cracking clays to sandy/loamy duplex soils.
- **Diversion reach (pre-mining)** - The Deep Creek diversion reach (pre-mining) was approximately 5 km long.

The upstream, downstream and diversion reaches of the Deep Creek diversion at Blackwater Mine are shown in Figure 2.1.

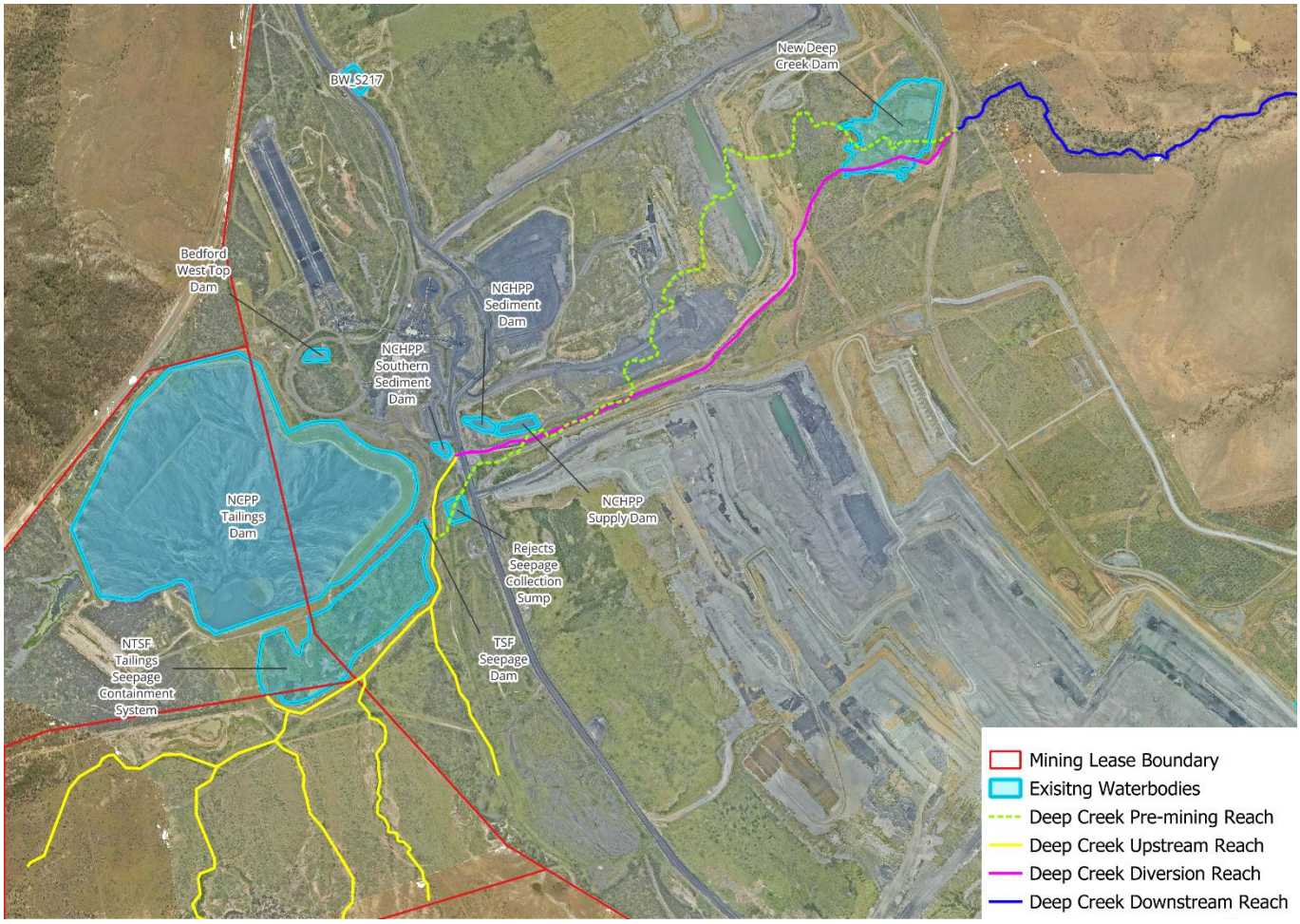


Figure 2.1: Upstream, Downstream and Diversion Reaches of the Deep Creek Diversion

2.3 Diversion Reach

Monitoring of Deep Creek diversion has been undertaken since 2010 and was last completed in 2019. As part of the major monitoring, the latest condition of the Deep Creek diversion has been described as follows (Engeny, 2019):

- The upstream reach has remained relatively static, showing a slight improvement in condition mainly due to dense groundcover (including weed species) and the development of vegetated in-stream benches.
- The diversion reach continues to show improvement following extensive clean-up works initiated before the 2017 inspection and further desilting undertaken in 2019, though geomorphic instabilities persist at the downstream end and riparian diversity and continuity remain low.
- The downstream reach remains in a similar condition to previous years, with a slight decline in overall IDC score attributed to localised bank erosion from grazing impacts and dry conditions prior to the inspection.

Based on the current condition of the Deep Creek diversion, it is considered unlikely that the existing diversion with the dam structure will achieve a state of dynamic equilibrium and be suitable to achieve the water license relinquishment criteria prior to mine closure without intervention.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions. Details of the guidelines that have been used to design the Deep Creek diversion are summarised below.

3.1 DNRME Guideline

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Deep Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Deep Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.

- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m²)	Velocity (m/s)	Shear Stress (N/m²)
2-year ARI (no vegetation)	<35	<1.0	<40
2-year ARI (vegetated)	<60	<1.5	<40
50-year ARI	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m² has been adopted.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, which included an analogous approach, where channel dimensions are selected from a reference reach; a hydraulic geometry approach where dimensions are determined from regression relationships; and an analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be represented of stable watercourses within the Bowen Basin and are summarised in Table 3.2: .

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Stream Power (W/m²)	Stream Power 2-year ARI (W/m²)	Stream Power 50-year ARI (W/m²)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3: .

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m²)
Buffel grass	40
Structurally diverse suite of established native vegetation	120

The long-term performance of the diversion under both operating and closure scenarios is assessed with the following objectives, based on industry standard closure objectives:

- The diversion demonstrates to be in a safe, stable, non-polluting and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Reference rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining landuse of the 'Watercourses' which is applicable for the watercourse diversion.
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

3.3 Environmental Authority EPML00717813

The land schedule within the Blackwater Mine EA (EPML00717813) requires that all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified Rehabilitation Requirements. The EA provides the rehabilitation landform criteria for the post mining land use of watercourses (refer to Figure 3.1). Some indicators reference the Index of Diversion Condition (IDC) method, which is a component of ongoing diversion monitoring.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

Figure 3.1: Blackwater Mine EA EPML00717213 Rehabilitation Requirements for Watercourses

4. CONCEPT DESIGN

4.1 Diversion Alignment

Figure 4.1 shows the permanent diversion alignment design of Deep Creek. The alignment was selected to achieve a similar pre-mining channel length and grade, while also aligning with the most recent final landform (Landform 3.6.1). The full concept drawing package is included in Appendix B.

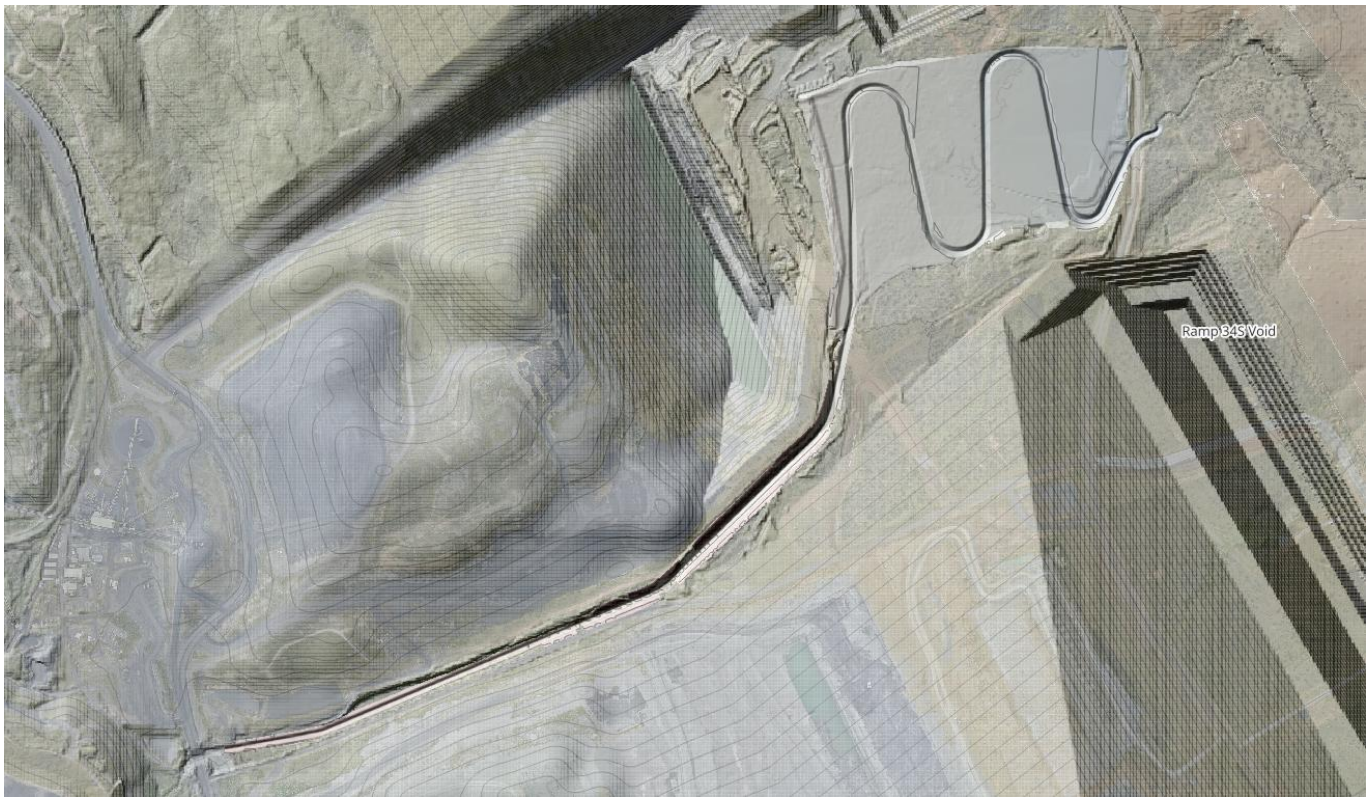


Figure 4.1: Deep Creek Alignment General Arrangement

4.2 Channel Geometry and Grade

The following cross-sections as presented in Figure 4.2 were used to evaluate the planform and cross-section parameters of the Deep Creek Reference Reach channel, as documented in the assessment undertaken by Engeny in 2018 (Engeny, 2018). Cross-sectional dimensions were evaluated for a total of 30 cross-section locations downstream of New Deep Creek Dam.

Based on the assessed cross-sections, a representative channel cross-section of Deep Creek was selected for the concept design. The concept design drawings in Appendix B show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

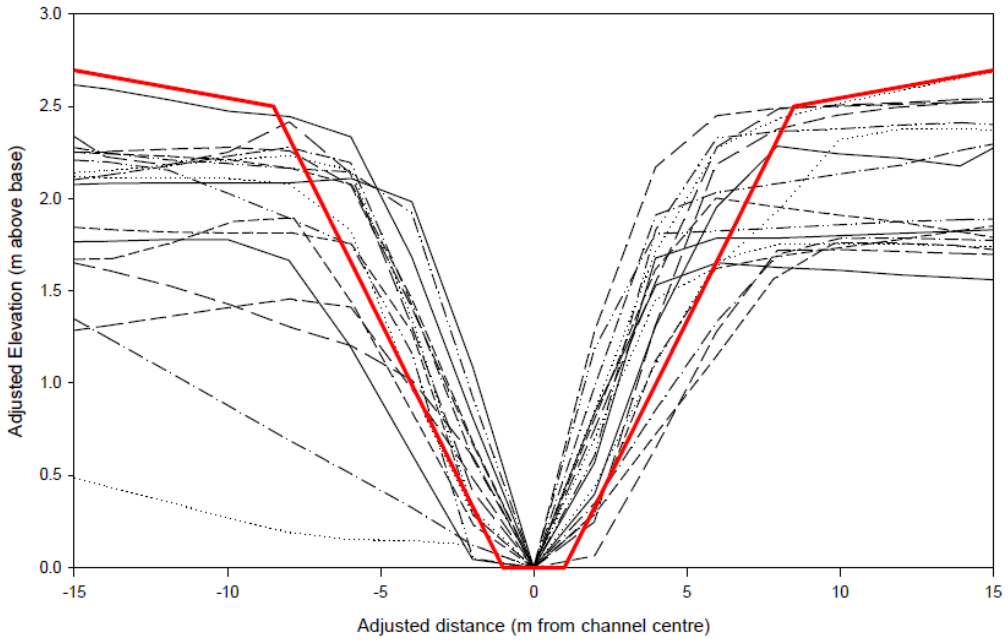


Figure 4.2: Deep Creek Channel Dimensions Downstream of NDCD (Engeny, 2018)

4.3 Hydrology

Peak flows for frequent events (39% AEP and2% AEP) for the Deep Creek diversion remediation were estimated using the ACARP (2002) methods and are presented in Table 4.1. As described in Section 3, The hydraulic outcomes for diversion designs are only prescribed for frequent events (39% AEP and2% AEP). As such, hydraulic modelling of rare event (1% and 0.1% AEP) has not been undertaken as part of the diversion concept design. The Rehabilitation Flood Assessments undertaken separately as part of the PRCP should be referred to for the hydrologic and hydraulic modelling for the 1% AEP and 0.1% AEP flood events of Sirius Creek.

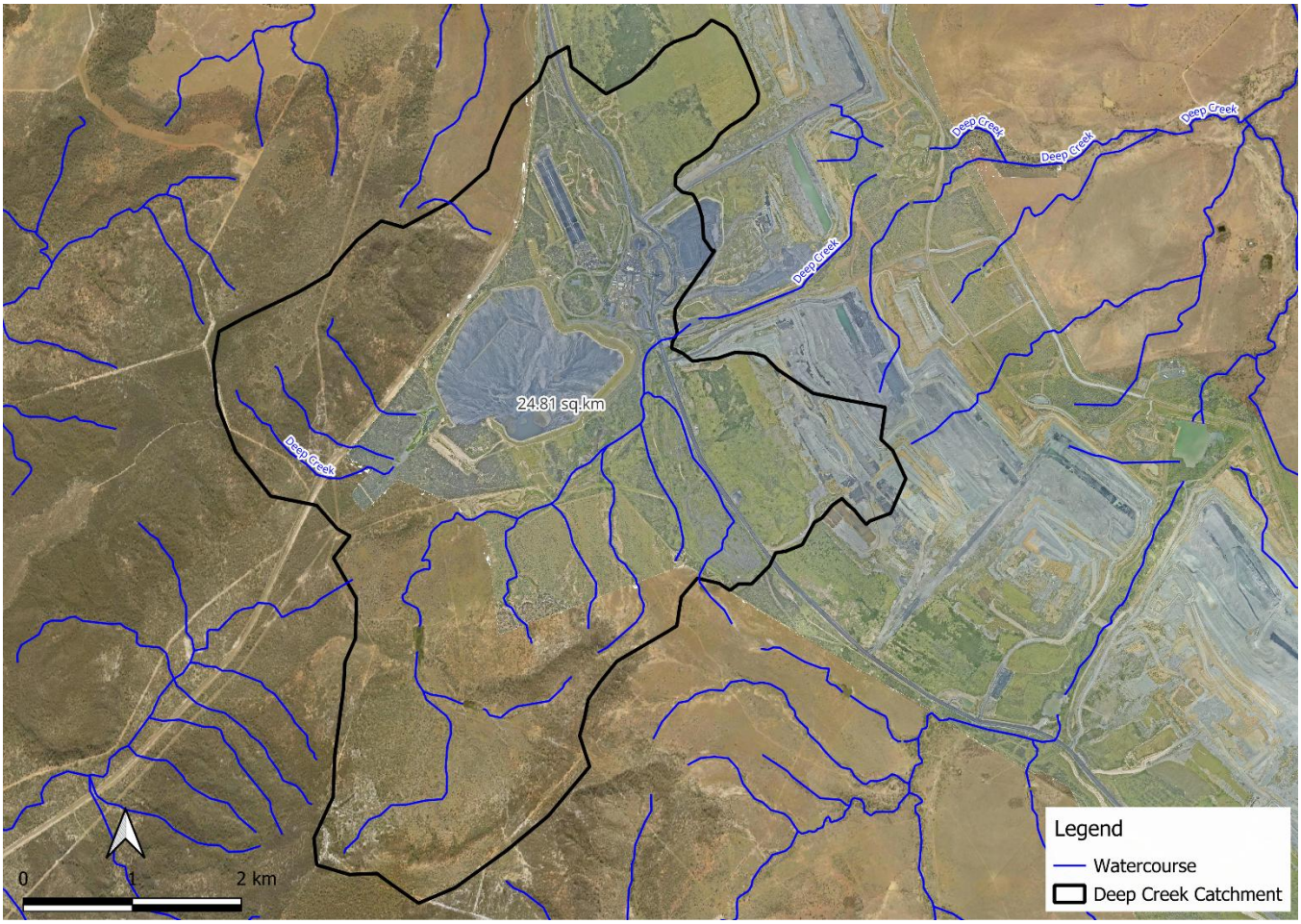


Figure 4.3: Catchment Map

4.3.1 Frequent Events

The hydrologic model was used to estimate flows through the diversion for the 2 year ARI and 50 year ARI flow events (refer to Table 4.1). The flows have been compared to the ACARP (2014) diversion channel design parameters. A steady flow analysis was undertaken to assess the diversion design against guideline criteria.

TABLE 4.1: DEEP CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
2 year ARI	24.9
50 year ARI	42.2

4.3.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be summarized within the Rehabilitation Flood Assessments undertaken as part of the PRCP.

4.4 Hydraulics Assessment

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. Stream velocity is calculated by dividing flow by cross-sectional area. The higher the velocity, the greater the erosive force of a stream. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Threshold values for velocity, stream power and shear stress listed in the ACARP Guidelines (Table 13 of the DNRME Guideline) were determined using a 1D HEC-RAS model. HEC-RAS (1D) calculates hydraulic conditions on a cross-sectional basis, outputting results as a cross-sectional mean. Due to this, the threshold values listed in the ACARP and DNRME guideline should be considered as cross-sectional average values. As such, modelling has been conducted utilising the 1D HEC-RAS software. (refer to Table 4.2). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 4.2: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	2-year ARI		50-year ARI	
Design Criteria	**Diversion**	**DNRME Design Parameter (2019)**	**Diversion**	**DNRME Design Parameter (2019)**
Stream Power (W/m^2)	51.7	<60	71.4	<150
Stream Velocity (m/s)	1.3	<1.5	1.5	<2.5
Shear Stress (N/m^2)	39.5	<40	47.9	<80[1]

[1] *DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m² has been adopted.*

It can be seen from Table 4.2 that that all parameters are within the acceptable limits.

It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated, as per Table 3.1. The 2-year ARI shear stresses are below the threshold of 120 N/m^2 at which an established native vegetation is considered stable, as per Table 3.3. It is expected that the channel achieves stability during a flood of this magnitude when the vegetation is fully established.

Appendix A illustrates the variability along the diversion channel for each design parameter.

4.5 Additional Design and Construction Considerations

4.5.1 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles

etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

4.5.2 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Deep Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the BWM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower banks (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

4.5.3 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with Whitehaven's watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable) and following periods of high flow in the diversion.

4.5.4 Closure Landform and Considerations

The PRCP landform can be reconfigured if the diversion is in close proximity to it and its alignment and re-instatement of the floodplain is inhibited by the closure landform. The concept design is required to inform the PRCP closure landform and will be offset to final voids by at least 100 m so seepage to or from voids is not expected.

5. CONCLUSION

To develop a PRCP Chapter for the Deep Creek diversion, a concept design for remediation of the Deep Creek diversion will be developed. This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design was developed based on three guidelines, two of which are currently recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).
- EA condition for specified rehabilitation requirements.

The final concept option design was selected to achieve a similar pre-mining channel length and grade, while also aligning with the most recent final landform (Landform 3.6.1). The final concept option design, typical cross sections and longitudinal section are presented in Appendix B.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

6. QUALIFICATIONS

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7. REFERENCES

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APPENDIX A: HYDRAULIC PARAMETER MODELLING RESULTS

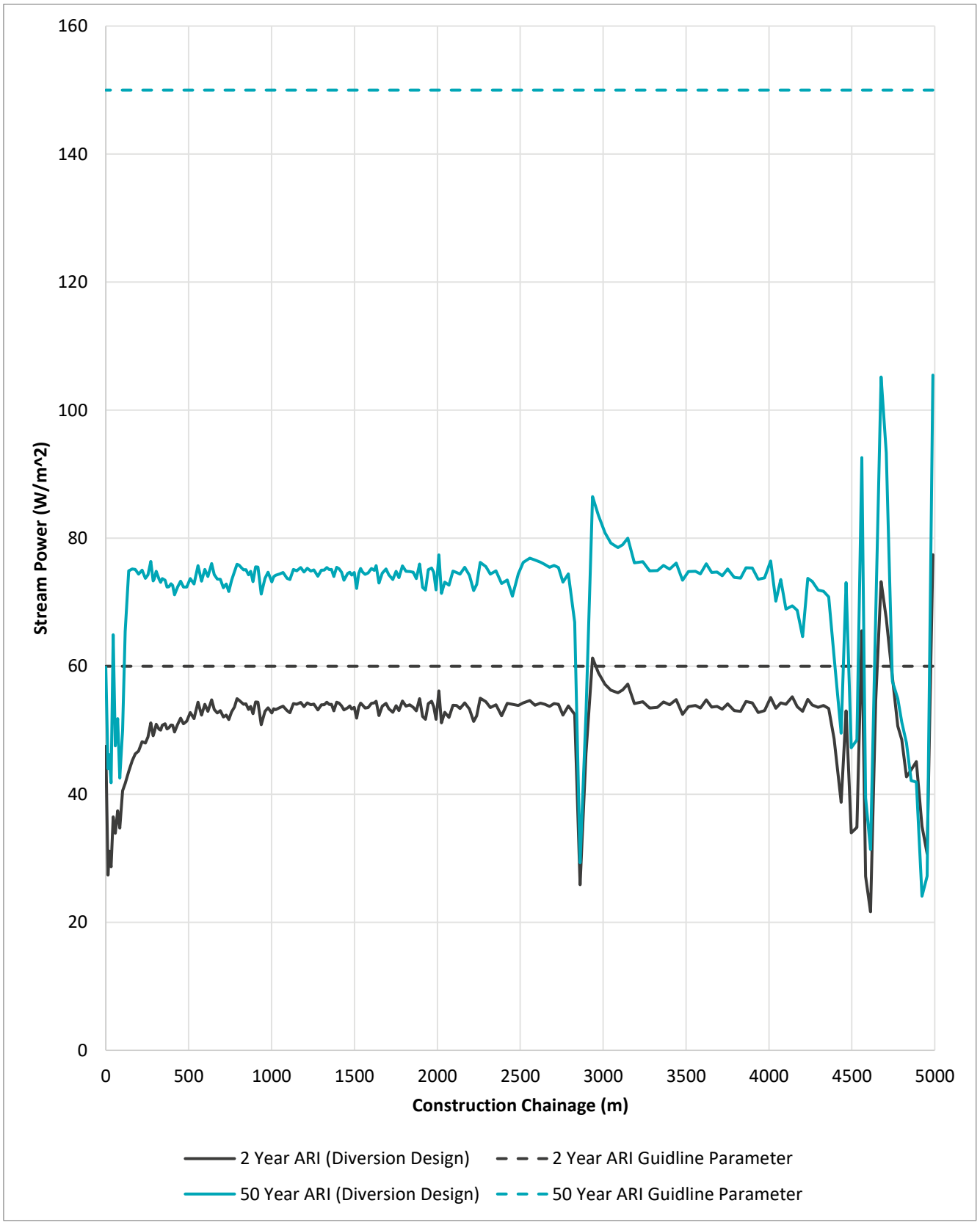


FIGURE A.1: STREAM POWER HEC-RAS MODEL RESULTS

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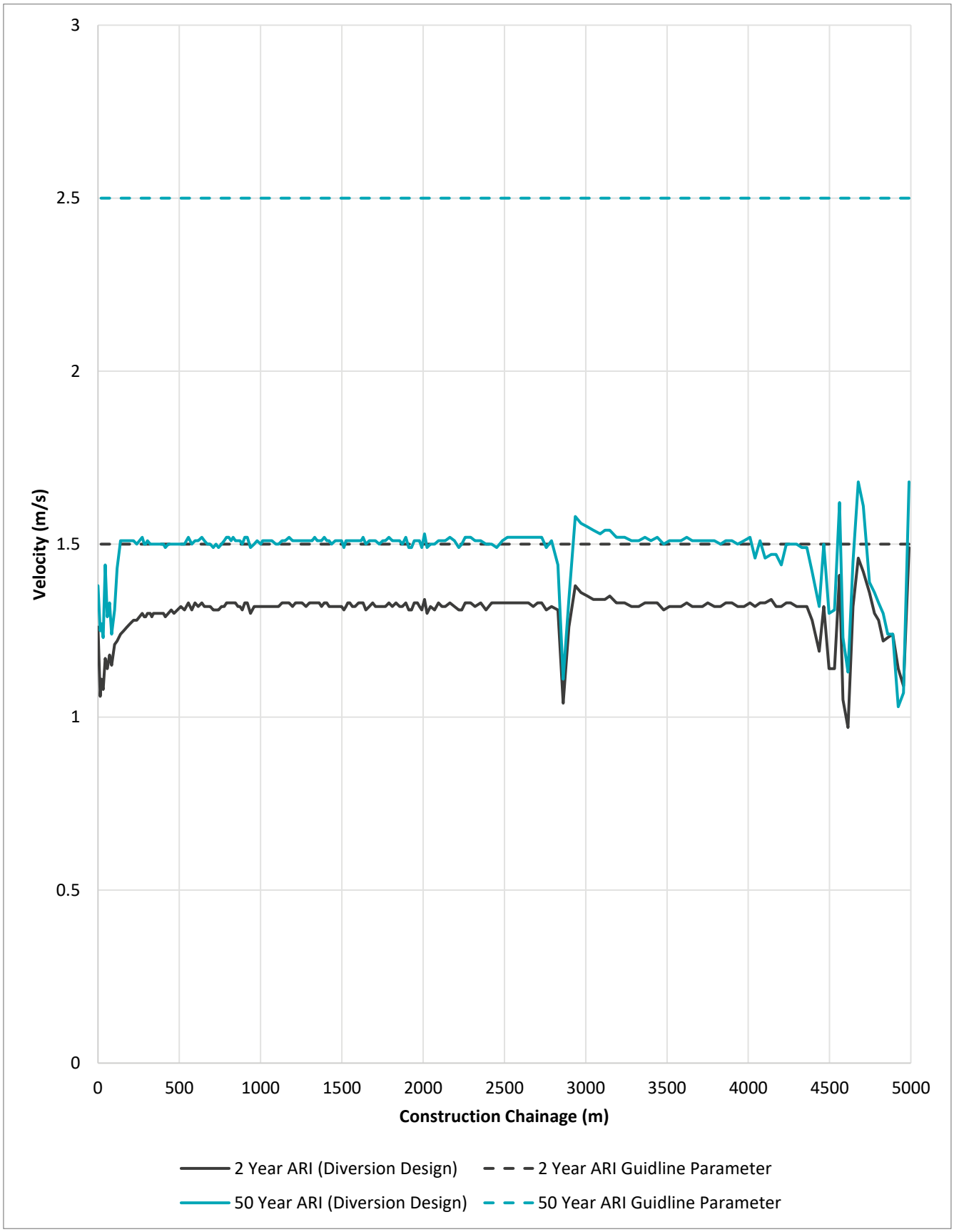


FIGURE A.2: VELOCITY HEC-RAS MODEL RESULTS

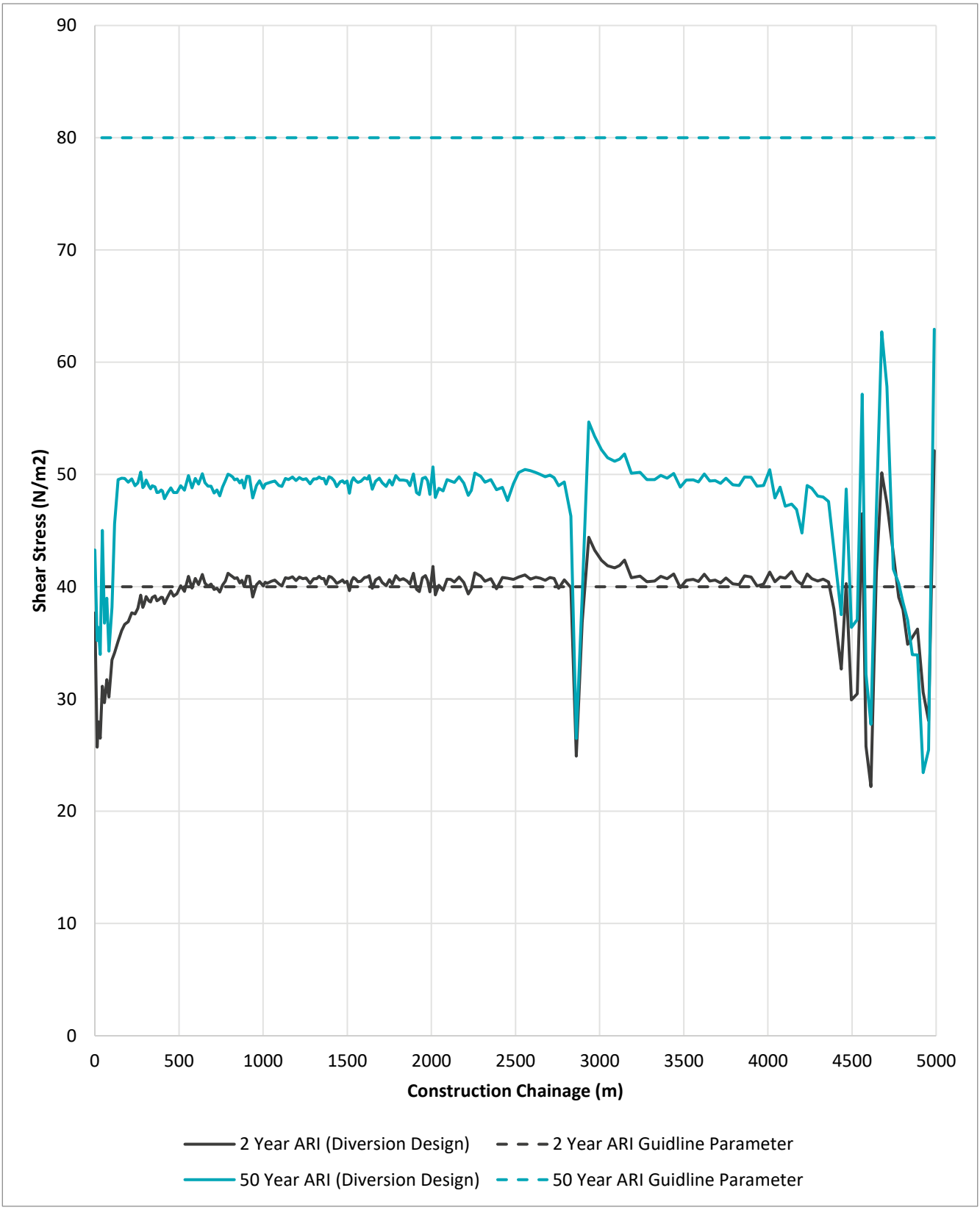


FIGURE A.3: SHEAR STRESS HEC-RAS MODEL RESULTS

APPENDIX B: PREFERRED OPTION



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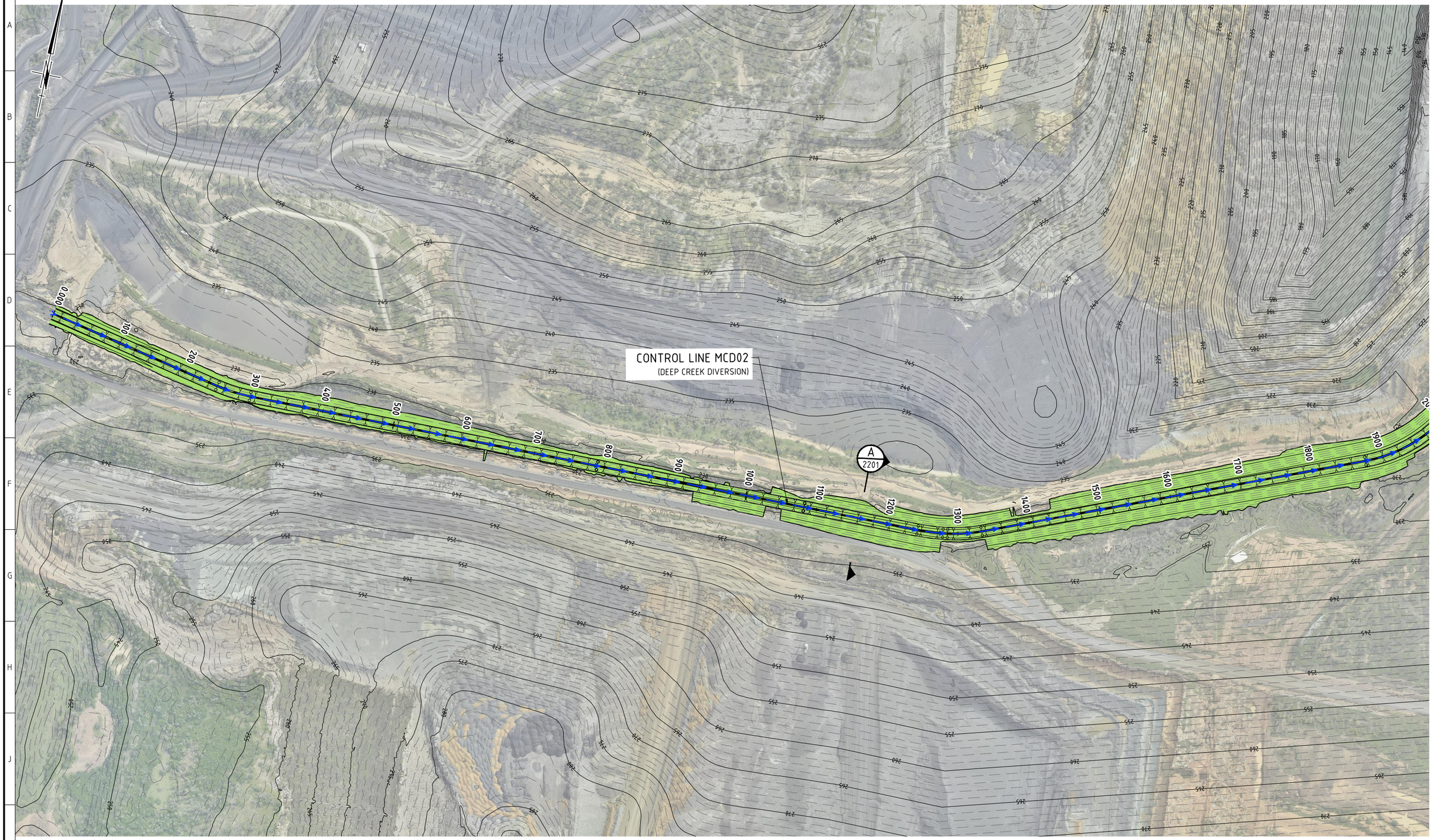
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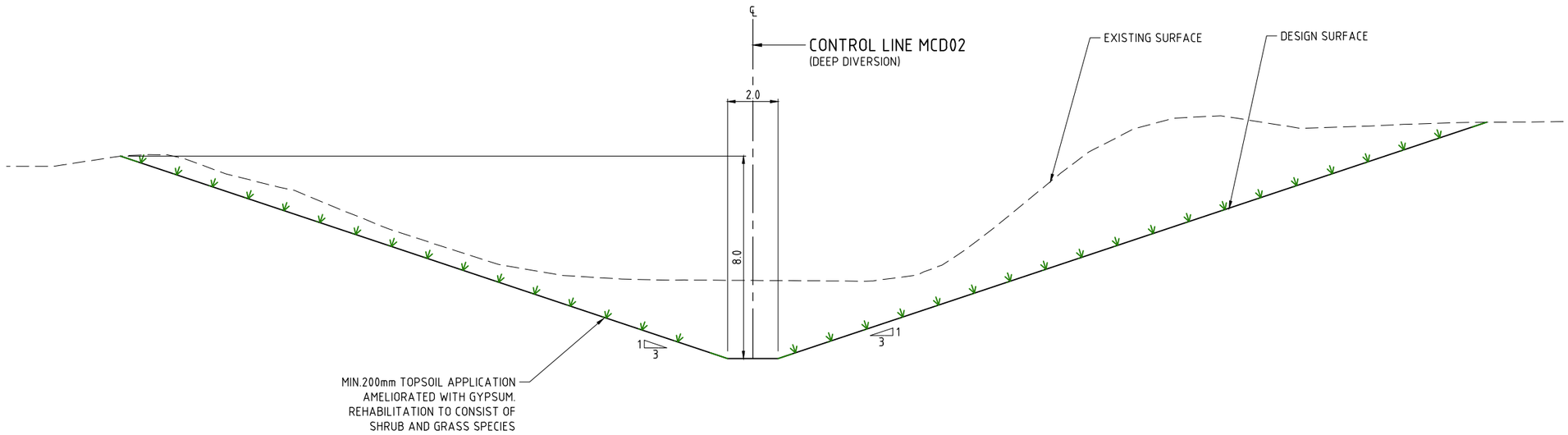
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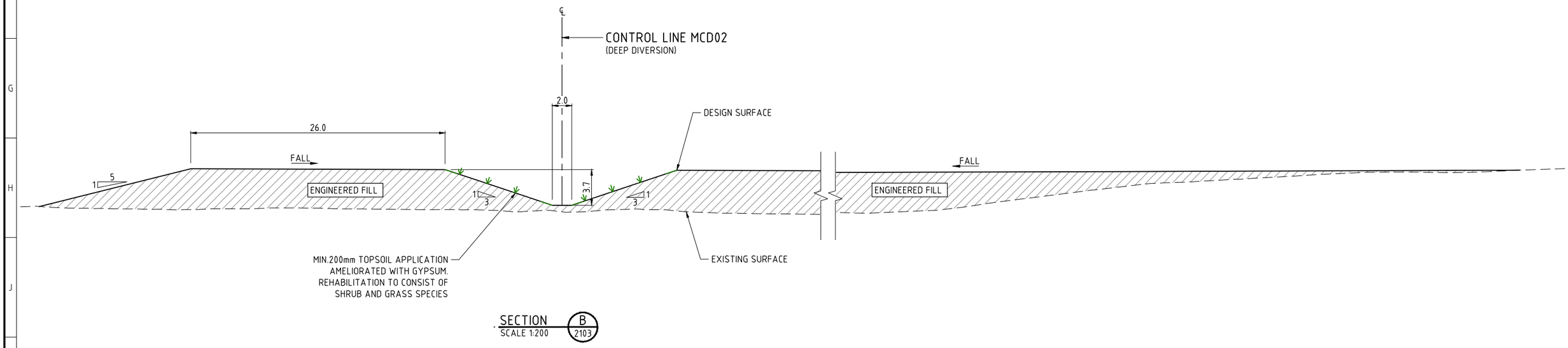
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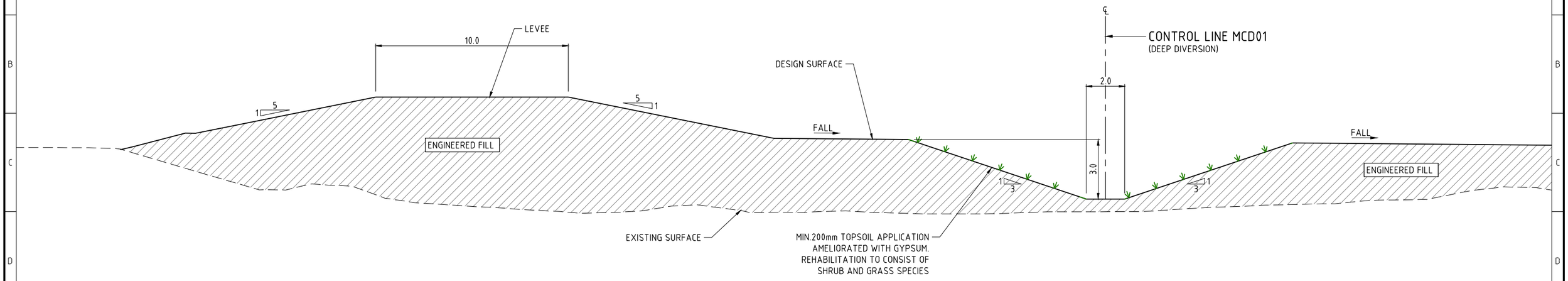
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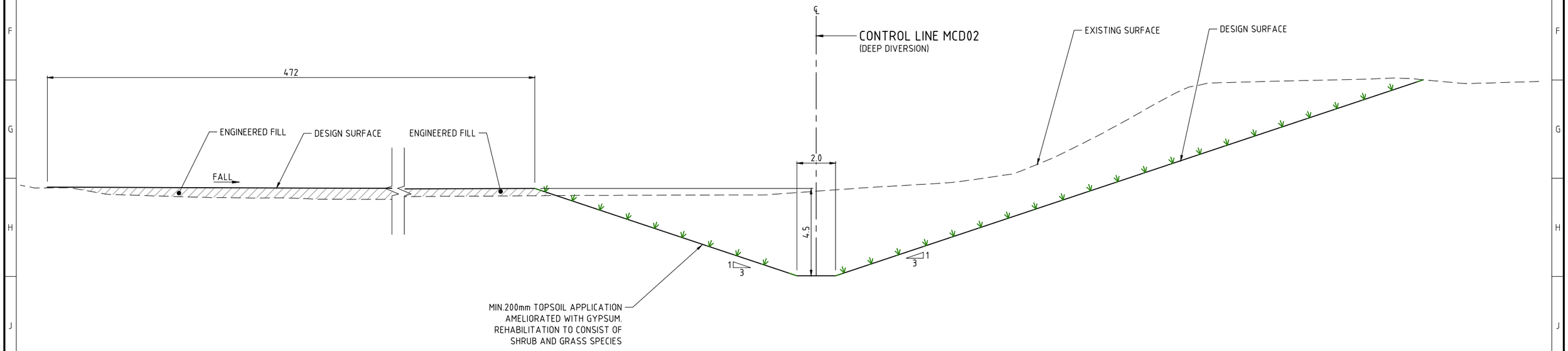
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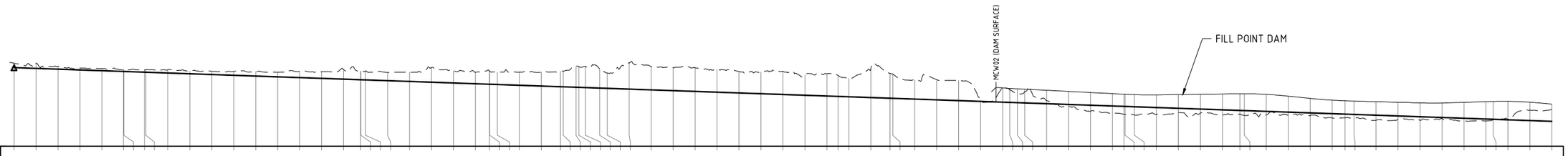
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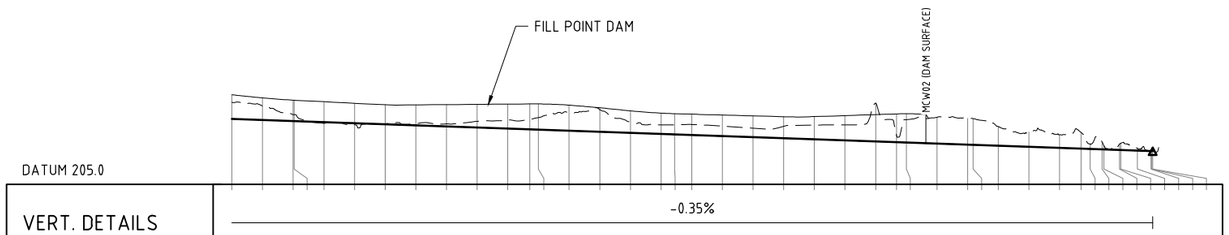
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Whitehaven

Void Closure Plan

Blackwater Mine

DATE
6 October 2026

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CLIENT NAME	Whitehaven Coal

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Final	3	Isabelle Simonsson	Andrew Osborn	Chris Gimber	06 October 2026	Revised after IR by DETSI: *A-PRCP-AMD-101134179*

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
3D	Three-dimensional
AEP	Annual exceedance probability
AHD	Australian height datum
AQP	Appropriately qualified person
ARR	Australian Rainfall and Runoff
AWBM	Australian Water Balance Model
BNEP	Blackwater North Extension Project
BoM	Bureau of Meteorology
BWM	Blackwater Mine
C	(Geochemical) controls
CCS	Consistent Climate Scenario
CHPP	Coal handling and processing plant
CSM	Conceptual site model
DEM	Digital elevation model
EA	Environmental Authority
Eh	Electrode potential of hydrogen (measured electric potential)
EEP Water	Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (Qld)
EP Act	*Environmental Protection Act* 1994
ERM	Environmental Resources Management Pty Ltd
ESA	Environmentally sensitive area
EV	Environmental value
FoS	Factor of safety
GDE	Groundwater dependent ecosystem
GLM	General lake model
GMA	Groundwater management area
HES	High ecological significance

Acronym	Description
IA	Improvement Area
IFD	Intensity Frequency Duration
LOD	Land outcome document
ML	Mining lease
MM	Management Milestone
NC	No (geochemical) controls
NC Act	Nature Conservation Act 1992
n.d.	No date
NUMA	Non-use management area
pe	Logarithmic scale of electron activity
pH	Logarithmic scale of hydrogen activity
PMF	Probable maximum flood
PRC Plan	Progressive Rehabilitation and Closure Plan
PRCP	Progressive Rehabilitation and Closure Plan
QLD	Queensland
RCM	Rangal Coal Measure
RE	Regional ecosystem
ROM	Run-of-mine
SA	Surface area
SI	Saturation index
TDS	Total dissolved solids
the Mine	Blackwater Mine
TSF	Tailings storage facility
URBS	Unified River Basin Simulator
VCP	Void closure plan
Water Act	Water Act 2000
WBM	Water balance model
Whitehaven	Whitehaven Coal Ltd
WQO	Water quality objective

UNITS

Acronym	Description
°	Degrees

Acronym	Description
g	Gram
ha	Hectare
kg	Kilogram
km	Kilometre
L	Litre
m	Metre
m^3	Cubic metre
mAHD	Meters relative to the Australian Height Datum
ML	Megalitre
mole	$6.022*10^{23}$ particles
mV	Millivolt
t	Tonnes
V	Volt
yr	Year

1. INTRODUCTION

Blackwater Mine (BWM, *the Mine*) is an open-cut metallurgical coal mine with historical underground workings, owned and operated by Whitehaven Coal Ltd (Whitehaven), approximately 4.5 kilometres (km) south-west of Blackwater in the Bowen Basin, Queensland. BWM operates across various mining leases (MLs), namely ML1959, ML1760, ML1761, ML1767, ML1771, ML1772, ML1773, ML1792, ML1800, ML1812, ML1929, ML1860, ML1962, ML1907, ML70091, ML70104, ML70139, ML70167, and ML70329.

BWM is approved under the Environmental Authority (EA) EPML00717813 and the *Environmental Protection Act 1994* (the EP Act) requires EA holders to submit a Progressive Rehabilitation and Closure (PRC) Plan.

Environmental Resources Management Australia Pty Ltd (ERM) has been engaged by Whitehaven to develop a void closure plan (VCP) (this document), which serves as an appendix to the BWM PRC Plan as required by the Department of Environment, Tourism, Science and Innovation (DETSI) *Progressive rehabilitation and closure plan (PRC plans) Statutory Guideline (version 3.01),* known as the *PRCP Guideline*, last reviewed on 16 September 2024 (DETSI, 2024).

The scope of the BWM PRC Plan Revision 3 includes the Blackwater North Extension Project (BNEP) (the Project), which involves the extension of open cut mining operations to the north-east of the existing BWM mining area within ML1759 Surface Area (SA) 10 and ML1762 SA 7. The Project has an anticipated commencement date of around 2030. The Project forms part of the operational footprint relevant to the BWM PRC Plan Revision 3 and therefore has been incorporated into this VCP. The BNEP results in changes to the extent and configuration of several residual voids and associated NUMAs, with a net increase in total NUMA footprint relative to the BWM PRC Plan Revision 2 (Section 3.1).

The current final landform design is referred to as version 4.4.

This VCP has been prepared using the following technical assessments that consider the updated final landform designs:

- Blackwater Mine Transitional PRC Plan Hydrogeology Assessment – Revision 2 (SLR, 2026);
- Blackwater Mine Progressive Rehabilitation and Closure Plan Final Landform Flood Assessment (WRM, 2026a);
- Blackwater Mine Progressive Rehabilitation and Closure Plan Voids in Floodplain Modelling (WRM, 2026b);
- Progressive Rehabilitation and Closure Planning - Blackwater Mine –Final Void Water Balance (WRM, 2026c);
- Long-Term Geotechnical Stability of Highwalls and Endwalls at Blackwater Mine (Henderson Geotech, 2026a);
- Assessment of Geotechnical Stability of LF#4.4 Residual Void Lowwalls at Blackwater Mine (Henderson Geotech, 2026b); and
- Residual Void Water Quality and Limnology Assessment – Blackwater Mine (ERM, 2026).

This Void Closure Plan provides supporting technical evidence for the proposed designation of residual voids as non-use management areas (NUMAs), including consideration of the requirements of Sections 126C and 126D of the EP Act.

1.1 PURPOSE AND OBJECTIVES

BWM mines multiple open-cut pits at various stages of operation and with varying completion dates. The final landform design (version 4.4) retains 15 residual voids. Two of these, Bonnie Doon and Ramp 74, also function as in-pit tailings storage areas.

The residual voids present in the final landform design version 4.4 are:

- Ramp 8;
- Bonnie Doon;
- Mimosa/Besgrove;
- Ramp 30;
- Deep Creek;
- Stewarton North;
- Stewarton South;
- Tannyfoil;
- South Ballamoo;
- Kenmare;
- Ramp 74;
- Togara/North Marshmead;
- South Marshmead;
- Kennedy West; and
- Comet Downs East.

The objective of this VCP is to outline an approach to achieving safe, stable and non-polluting residual voids at closure. This plan also supports the broader rehabilitation strategy by aiming to:

- Reduce environmental and safety risks associated with the residual voids and surrounding NUMA areas;
- Minimise the need for ongoing active management post-closure; and
- Prevent unmitigated access by people and livestock.

This document addresses the requirements of sections 3.4 and 3.6.3 of the PRC Plan Guideline as outlined in Table 1-1 below.

TABLE 1-1 ALIGNMENT OF VCP SECTIONS WITH PRCP GUIDELINES

Reference in PRCP Guidelines	Content Summary	Section(s) in this VCP
Section 3.4 – Voids in flood plains	Voids in flood plains must be rehabilitated to a stable condition to be approved in the PRCP schedule.	Section 5 – Flooding Assessment
	Flood plain modelling is required in accordance with ARR 2019 and must exclude artificial features. The flood plain model report must include specific technical details (e.g. model inputs, groundwater influence, spatial data, calibration).	

Reference in PRCP Guidelines	Content Summary	Section(s) in this VCP
	All voids in flood plains must have an associated PMLU and be identified in the PRCP schedule.	Section 3 – Proposed Residual Voids
	Transitional arrangements apply to pre-existing NUMAs in land outcome documents.	
	The PRC plan must demonstrate how void locations minimise environmental risk.	
Section 3.6.3 – Voids	Options available for minimising final void area and volume (where a final void is proposed).	Section 3 – Proposed Residual Voids; Section 9 8.4.2– Residual Void Management
	Proposed final dimensions of the void (i.e. depth, length and width).	
	Proposed final slope angles of high wall, low wall and end walls of each final void.	
	Pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events.	Section 7 – Geotechnical Stability; Section 8 – Geochemical Stability
	Void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow.	Section 4 – Groundwater; Section 6 – Void Water Balance; Section 8 – Geochemical Stability
	Groundwater modelling to determine whether the void is acting as a sink or a source for groundwater.	Section 4 – Groundwater
	A water balance study including an assessment of void surface and groundwater interactions such as: • groundwater lowering/reduction in hydraulic head (from new voids) (e.g. caves/karst systems); • cones of depression and associated impacts; • the drainage and flooding behaviours of surface waters in the vicinity of the void; • the potential extent of flooding and implications of interactions with the void; • a conceptual model that incorporates all projected inflows, outflows and recharge rates; • water storage and long-term water balance; • each of the major water fluxes into and out of the void; and • the sources of surface water within the mine catchment that are likely to influence the water quality in the void.	Section 4 – Groundwater Section 6 – Void Water Balance

Reference in PRCP Guidelines	Content Summary	Section(s) in this VCP
	Predicted water quality in the long-term including potential stratification.	Section 8 – Geochemical Stability
	A 3D void design plan.	Section 3 – Proposed Residual Voids; Section 9 8.4.2– Residual Void Management
	Rehabilitation strategies.	Section 9.1 – Void Rehabilitation

1.2 RELEVANT GUIDELINES AND LEGISLATION

This VCP has been developed in accordance with the legislative and regulatory framework applicable to mine closure and residual voids in Queensland. The following documents have informed the preparation of this plan:

- *Environmental Protection Act 1994* (Qld): The primary legislation governing environmental protection, including requirements for progressive rehabilitation and mine closure.
- *Progressive Rehabilitation and Closure Plan Guideline*, Version 3.01 (September 2024): Provides the required structure and content for PRC plans.
- *Environmental Authority EPML00717813*, dated 20 April 2026: Defines site-specific conditions for environmental management, residual voids and rehabilitation activities at BW. Specifically in relation to residual voids, conditions E10 and E11 require:
    - Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority; and
    - The investigation must at a minimum include the following:

        (a) a study of options available for minimising final void area and volume;

        (b) develop design criteria for rehabilitation of final voids;

        (c) a void hydrology study, addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term;

        (d) a pit wall stability study, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events;

        (e) a study of void capability to support native flora and fauna; and

        (f) a proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes.

2. SITE OVERVIEW

BWM is a conventional strip mine open-cut metallurgical coal mine with historic underground workings and is located approximately 4.5 km southwest of Blackwater in the Bowen Basin, Central Queensland. The Bowen Basin is a major coal-producing region and BWM is located near several other operational open-cut coal mines.

Mining activities at BWM include topsoil removal and stockpiling, followed by drilling and blasting of overburden and interburden. These materials are removed using draglines and truck-and-shovel fleets. Coal is also mined using truck-and-shovel fleets. As mining progresses, overburden and interburden are placed into spoil dumps within the voids created by previous mining strips. In-pit spoil placement increases as pits deepen, reducing the need for out-of-pit dumping.

Coal is transported from the pits to the run-of-mine (ROM) area or to stockpiles. It is processed at the coal handling and preparation plant (CHPP). The CHPP generates coal fines, which are disposed of in dedicated tailings storage facilities (TSFs), and coarse rejects, which are placed in spoil dumps. Product coal is loaded onto trains at the load-out facility located next to the CHPP and product stockpiles.

Mining at BWM began in 1967. Current life-of-mine planning supports continued mining of the approved area until 2113, based on existing production rates.

An overview of the existing environmental conditions at and around BWM is provided in the PRC Plan and is not repeated in this VCP.

3. PROPOSED RESIDUAL VOIDS

This section describes the location, dimensions and characteristics of residual voids to be retained at closure. It is required under the PRCP Guideline to justify why full rehabilitation is not feasible.

This section also addresses:

- *Options considered for minimising the final void area and volume.*
- *Proposed final dimensions of each void, including depth, length and width.*
- *A 3D design plan illustrating the final landform configuration.*

In addition, to support the requirement that void locations minimise environmental risk, this section includes:

- *A conceptual site model illustrating key environmental and geotechnical interactions.*
- *An ecological impact assessment identifying potential impacts to flora, fauna and habitats.*
- *An assessment of groundwater environmental values, including beneficial uses and connectivity.*
- *An assessment of surface water environmental values, including potential impacts to downstream environments.*

This section outlines the characteristics of the 15 residual voids at BWM. It contains a conceptual site model (CSM), a summary of ecological assessment findings and a review of groundwater environmental values (EVs) relevant to the post-mining landform.

The residual voids at BWM are identified and authorised under Schedule E (Conditions E10 and E11) of the BWM EA, as the primary Land Outcome Document (LOD) for BWM as pre-approved NUMAs.

Residual voids will be partially backfilled with spoil to reduce their size. The extent of each residual void has been designed to ensure the area is safe for both people and wildlife. This includes the area below natural ground level (high-wall, end-walls, low-wall, floor), setback distances from the crest to achieve a factor of safety (FoS) of at least 1.5 and the provision of a safety bund and fencing.

The total proposed NUMA area is 3,360 hectares (ha). This area has been minimised by backfilling ramp voids during mining and by backfilling parts of the final voids at the end of operations.

A three-dimensional (3D) representation of the BWM residual voids, including potential void lakes, is shown in Figure 3-1 (North) and Figure 3-2 (South). Indicative final dimensions of the residual voids are provided in Table 3-1.

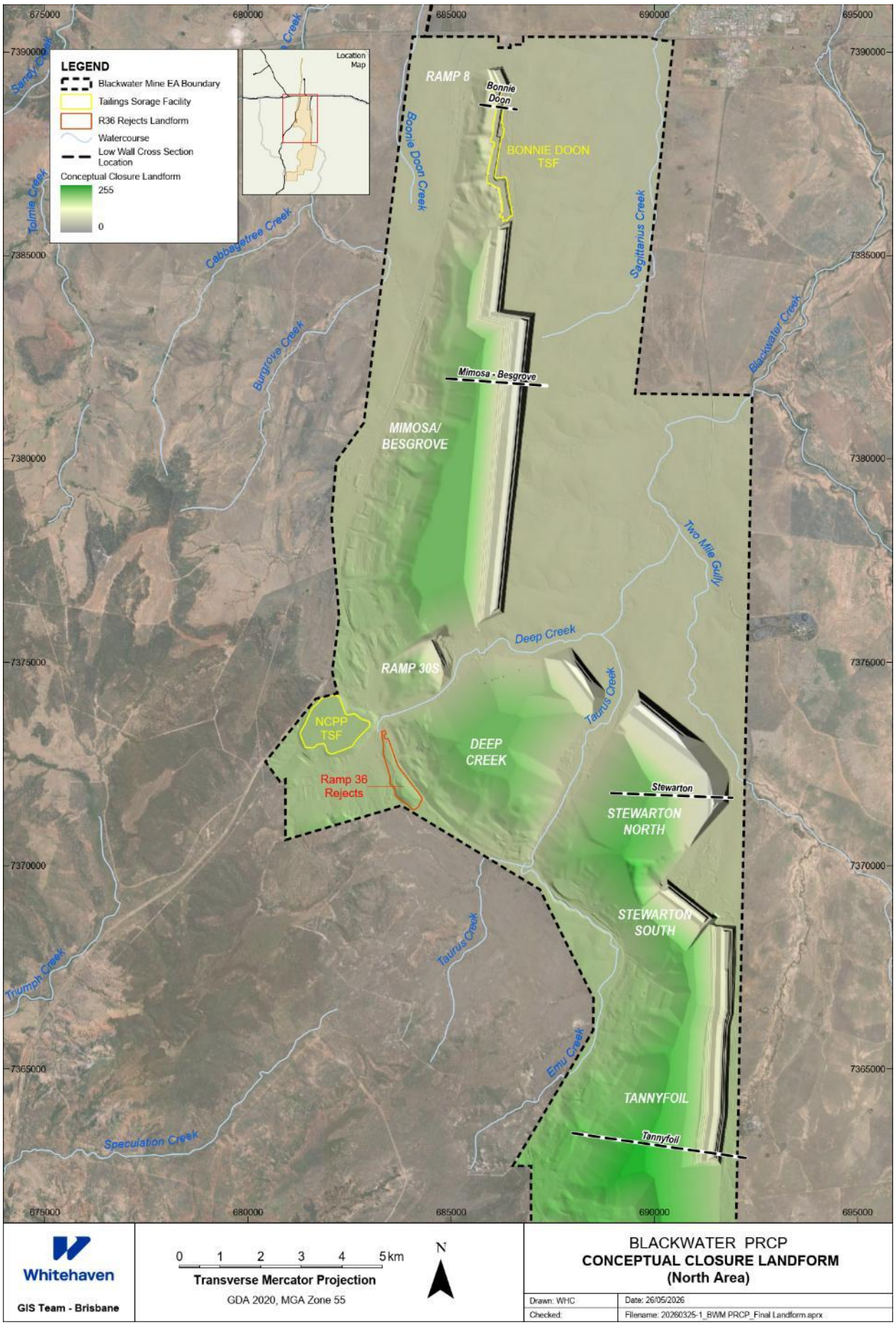


FIGURE 3-1 BWM CONCEPTUAL FINAL LANDFORM DESIGN – NORTHERN AREA

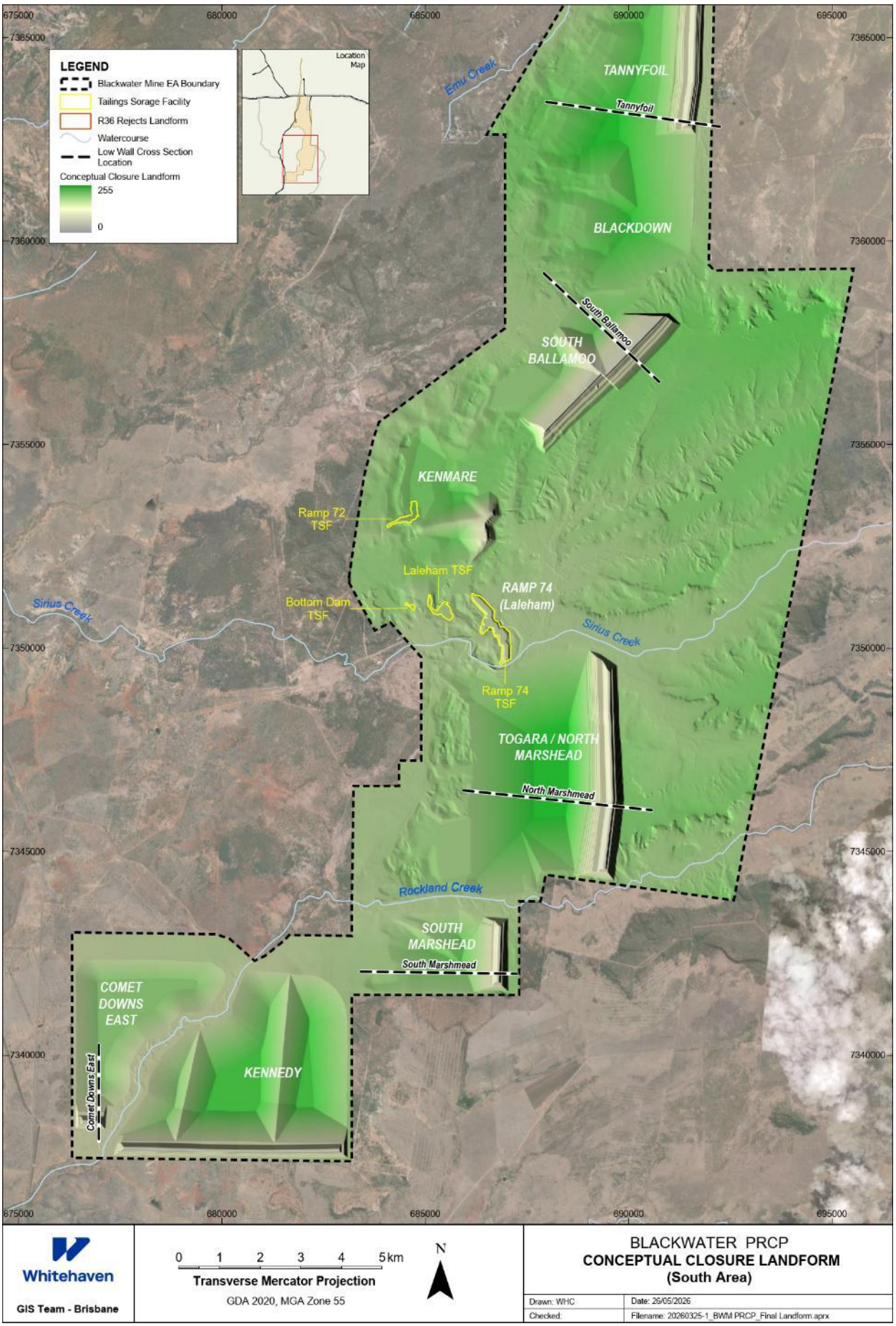


FIGURE 3-2 BWM CONCEPTUAL FINAL LANDFORM DESIGN – SOUTHERN AREA

TABLE 3-1 INDICATIVE RESIDUAL VOID DIMENSIONS

Residual Void	Indicative Length	Indicative Width	Crest at Spill Point	Indicative Depth	Volume to Crest	NUMA Area	Highwall Grade	Endwall Grade	Low Wall Grade
Unit	*m*		*mAHD*	*m*	*ML*	*ha*	*Degrees (°)*		
Ramp 8	650	360	188[1]	66	6,530	26	40	40	27
Bonnie Doon	3,000	250	188[1]	26	3,630	105	36.5	40	29
Mimosa/Besgrove	10,100	650	200	176	375,000	701	42	41	18
Deep Creek	1,600	600	202	150	54,900	102	43	16	27
Stewarton North	3,700	800	204	208	303,000	334	44	41	20
Stewarton South	1,400	500	232	140	42,600	93	41	39	19
Kenmare	1,800	500	297	122	93,800	85	20	20	17
Togara/North Marshmead	5,500	850	271	202	293,000	511	42	41	20
South Marshmead	1,800	650	270	162	74,700	123	43.5	40	22
Kennedy	5,700	700	221	122	93,800	357	45.5	42	20
Comet Downs East	800	570	222	132	20,400	49	44.5	41	20
Ramp 74	2,000	300	266	32	9,950	59	34	38	30
South Ballamoo	4,600	1,100	290	206	377,000	350	28	32	17
Tannyfoil	6,000	630	237	122	160,000	400	36.5	34	19
Ramp 30	1,200	300	217	78	16,300	64	34	17	18

[1] 188 mAHD represents the elevation at which the Ramp 8 and Bonnie Doon residual voids would spill to the receiving environment. The internal crest level between Ramp 8 and Bonnie Doon residual voids is 175 mAHD. Source: Whitehaven Coal Final Landform Version 4.4.

3.1 VOID EXTENT MINIMISATION

The PRC Plan must demonstrate that the size and potential for environmental harm from the NUMAs has been minimised. The proposed NUMA area has been progressively reduced through multiple iterations of mine planning and rehabilitation design. Since the original PRC Plan submission by Whitehaven (Revision 1) which was predominantly based on former owner's (BMA) mine plans, the total NUMA area was reduced by 789 ha from approximately 3,967 ha (Revision 1) to 3,178 ha (Revision 2). This reduction was achieved through:

- Reducing the number of ramp voids through backfilling during mining operations, and backfilling sections of the residual voids at the end of mining;
- Reshaping remaining ramp voids to a suitable slope to allow a PMLU; and
- Redefining the low-wall NUMA extent to be based on a geotechnical FOS of 1.5, which has enabled revegetation of a greater portion of residual void low-walls, which now form part of the designated PMLU areas.

Further reductions to NUMA areas are not technically achievable under the current mine design and closure assumptions, including those associated with the BNEP, due to:

- The depth and geometry of remaining voids, which exceed the safe angle of repose for reprofiling;
- Geotechnical constraints preventing reshaping of the pit floor and lower benches to meet rehabilitation slope requirements; and
- The requirement to maintain wall stability and avoid unacceptable geotechnical risks if additional slope reduction were attempted.

In addition, the residual voids at BWM are predicted to function as a hydraulically connected system in which most voids act as groundwater sinks, with inward hydraulic gradients and inter-void flow processes resulting in containment of groundwater and associated solutes within the tenure boundary. These conditions would be altered if voids were backfilled, potentially reducing the capacity of the system to contain solutes within the mine domain.

The above constraints have been assessed through iterative mine planning and closure design and remain applicable under Revision 3.

Consistent with the constraints outlined above, including limitations as associated with void depth and geometry, geotechnical stability requirements and hydrogeological behaviour, retention of the residual voids represents the minimum and lowest risk closure outcome. Further reduction through backfilling or re-profiling would introduce additional environmental and geotechnical risks and would not achieve a safer or more sustainable post-mining landform.

The BNEP results in changes to the extent and configuration of several voids, and consequently the NUMA footprint, including:

- Mimosa/Besgrove void extending to the north and a large proportion progressing further east;
- A Deep Creek final void location further to the northeast; and
- Segregation of the Stewarton void into Stewarton North and Stewarton South; with
    - The new Stewarton North final void located further to the northeast; and
    - The new Stewarton South final void not progressing as far northeast as planned in Revision 2.

The NUMA footprint of the Mimosa/Besgrove residual void increases by 140 ha and the NUMA footprint of the combined Stewarton North and South residual voids, when compared to the single Stewarton residual void planned in Revision 2, increases by 131 ha. The Deep Creek residual void NUMA footprint has reduced by 87 ha.

Overall, these changes result in a net increase in NUMA footprint of 182 ha, increasing the total NUMA area from 3,178 ha (Revision 2) to 3,360 (Revision 3).

Accordingly, the current 3,360 ha NUMA footprint represents the minimum safely achievable area while maintaining compliance with geotechnical, hydrological and safety requirements.

3.1.1 IMPACT OF VOID LOCATION ON ENVIRONMENTAL RISKS

In accordance with the PRCP guideline, this VCP provides justification for the selected residual void locations and demonstrates how they minimise long-term risks to the environment.

The placement of each residual void has been determined through an integrated assessment of hydrology, hydrogeology, geotechnical stability, land use compatibility and environmental values. The final locations reflect a balance between operational feasibility and environmental performance, as outlined below:

- **Surface water value:** Most residual voids are positioned outside the modelled 0.1% Annual Exceedance Probability (AEP) and Probable Maximum Flood (PMF) pre-mining flood plain extents. The Deep Creek residual void is partially within 0.1% AEP flood extents of Taurus Creek. Protection against the 0.1% AEP flood event will be achieved by incorporating a relatively minor amendment to the final landform along the southern endwall of the Deep Creek residual void. The landform in this area will be raised to ensure it is above the 0.1% AEP event and will be reviewed during closure execution and upgraded if necessary. The Ramp 74 void is situated across the Sirius Creek inundation extent for the 0.1% AEP flood event and will require protection by a permanent diversion. Modelling that includes the existing temporary Sirius Creek diversion shows immunity from the 0.1% AEP flood event can be achieved;
- **Groundwater-dependent ecosystems:** Hydrogeological modelling indicates that the selected void locations do not intersect with known groundwater dependent ecosystems (GDEs) and the likelihood of actual GDEs being present is low due to the depth to groundwater in many locations. Drawdown impacts in locations with potential to support GDEs are interpreted to be a result of the approved mining activities and not the final landform;
- **PMLU compatibility:** The positioning of the voids supports landform drainage, landform surface stability and visual integration with the surrounding post-mining landscape. The location of residual voids is not anticipated to affect the surrounding PMLUs; and
- **Water quality risk management:** The geochemical stability of a selection of residual voids has been modelled to identify likely water quality conditions. This modelling has considered geochemistry of the highwall, geochemistry of inflow sources (groundwater, catchment runoff), rainfall and evaporation. Whilst some residual void lake water quality is predicted to become hypersaline (i.e. total dissolved solids (TDS) > 35,000 mg/L (SWRCB, 2017)), most residual voids are groundwater sinks. Groundwater outflows from the four residual voids predicted to have net outward fluxes will be drawn towards the neighbouring voids with lake levels at lower elevations rather than away from the mined areas. No residual voids were predicted to overtop to surface waters under any of the modelled scenarios.

3.2 ALTERNATIVE PMLUS

Residual voids at BWM are proposed to remain as long-term water bodies post-closure. Alternative PMLUs were considered as part of the closure planning process, such as partial/complete backfilling and land-based rehabilitation. These options were assessed in the context of geotechnical feasibility, available spoil volumes, final landform configuration and environmental performance.

Complete backfilling was found to be impractical due to significant additional disturbance to adjoining landforms and excessive economic implications.

As such, the proposed use of voids as permanent, stable water bodies is considered the most practicable, safe and environmentally acceptable post-closure option.

3.3 CONCEPTUAL SITE MODELS

An end-of-mining conceptual site model (CSM) and a post-mining CSM were developed to conceptually represent the hydrogeological and surface water regime of the site in the presence of residual voids both when mining is anticipated to cease (~2110) and once residual void lake levels and groundwater recovery levels have stabilised (SLR, 2026).

Visual representations of the CSMs for the northern area of BWM and the southern area of BWM are provided in Figure 3-3 to Figure 3-4.

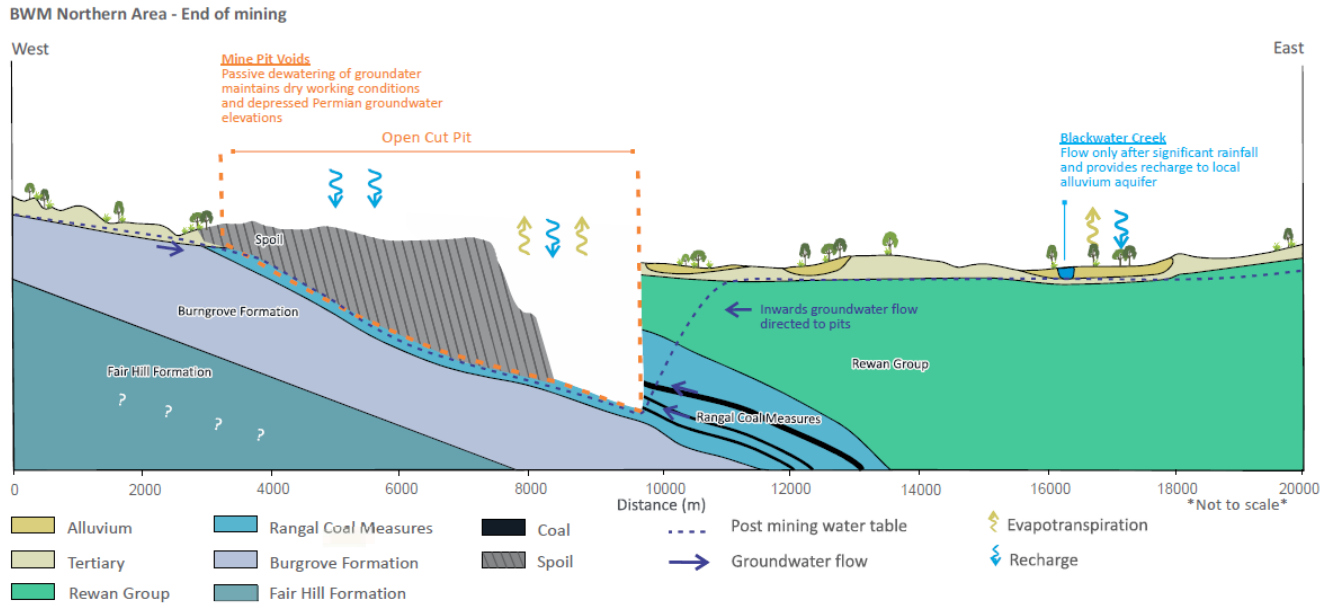
Key features of the CSMs are summarised in Table 3-2.

TABLE 3-2 END OF MINING AND POST-MINING CONCEPTUAL HYDROGEOLOGICAL MODEL SUMMARY

Category	**Groundwater Conditions**	
	End of Mining	**Post-Mining**
Groundwater levels and drawdown	Groundwater level drawdown of the Rangal Coal Measures, associated with passive dewatering into the active BWM mine pit voids.	Partial groundwater system recovery outside the residual voids, primarily in the Rangal Coal Measures.
	The magnitude of the drawdown will be most significant in the immediate vicinity of the pits, but will extend northwards, eastwards and southwards of BWM by several kilometres.	Continued groundwater drawdown in the Rangal Coal Measures is driven by evaporative discharge from the void lakes. Inward hydraulic gradients persist, maintaining groundwater discharge to the residual voids as sinks.
Hydraulic gradients and seepage	Residual voids capture seepage from spoil emplacements due to the local hydraulic gradient oriented towards the residual voids.	Continued groundwater drawdown within the Rangal Coal Measures maintains inward hydraulic flow gradients and ongoing groundwater discharge to the residual voids, keeping them as groundwater sinks.
Shallow hydrostratigraphic units	Limited potential for groundwater level drawdown in the alluvium and Tertiary strata due to limited saturation, and poor lateral connectivity of water-bearing zones.	Formation of residual void lakes, with lake levels stabilising significantly below shallow post-Permian strata, including the base of surficial weathering and shallow

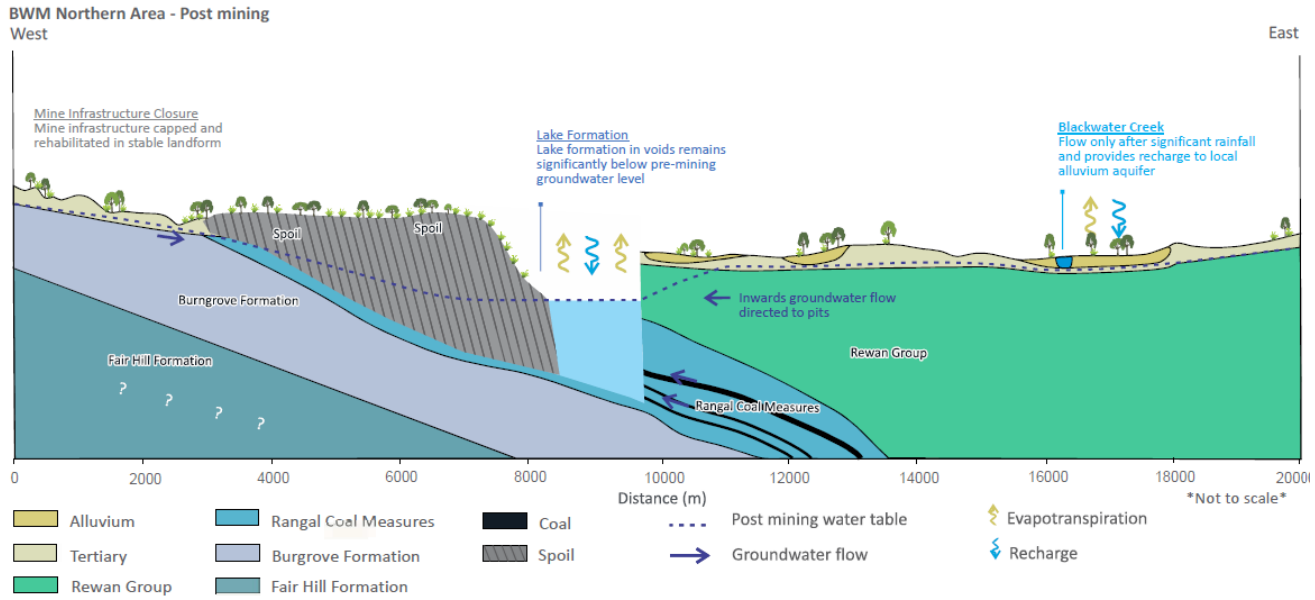
Category	**Groundwater Conditions**	
	End of Mining	**Post-Mining**
	No groundwater level drawdown of the alluvium away from BWM.	hydrostratigraphic units (i.e. alluvium and Tertiary strata). This applies to all voids but Ramp 74 and Comet East Downs.
GDEs	Limited potential exists for groundwater level drawdown impacts to terrestrial GDEs, due to the limited predicted drawdown in the alluvium and Tertiary strata, and no aquatic or subterranean GDEs have been identified within 5 km of BWM, indicating negligible risk to these receptors.	
Residual void behaviour	-	Residual void lake formation, with lake levels stabilising significantly below any shallow post-Permian strata, including the base of surficial weathering and shallow hydrostratigraphic units (i.e. alluvium and Tertiary strata) for most voids except Ramp 74 and Comet East Downs.
		Potential for ongoing salinisation of the residual void lakes associated with evaporative discharge from the lakes.
Underground workings	-	Reflooding of historical underground workings.
Groundwater quality – spoil	No potential for groundwater quality impacts outside of BWM associated with spoil dumps, due to the inward groundwater flow gradients towards the pit voids capturing all potential seepage.	No potential for groundwater quality impacts outside of the BWM Area associated with residual voids or spoil emplacements, due to the inward groundwater flow gradients towards the residual voids continuing to capture all potential seepage.
Groundwater quality – tailings	-	No potential for groundwater quality impacts outside of the BWM Area associated with in-pit tailings emplacements at Bonnie Doon and Laleham, due to the inward groundwater flow gradients towards the residual voids continuing to capture all potential seepage.

Source: SLR, 2026.



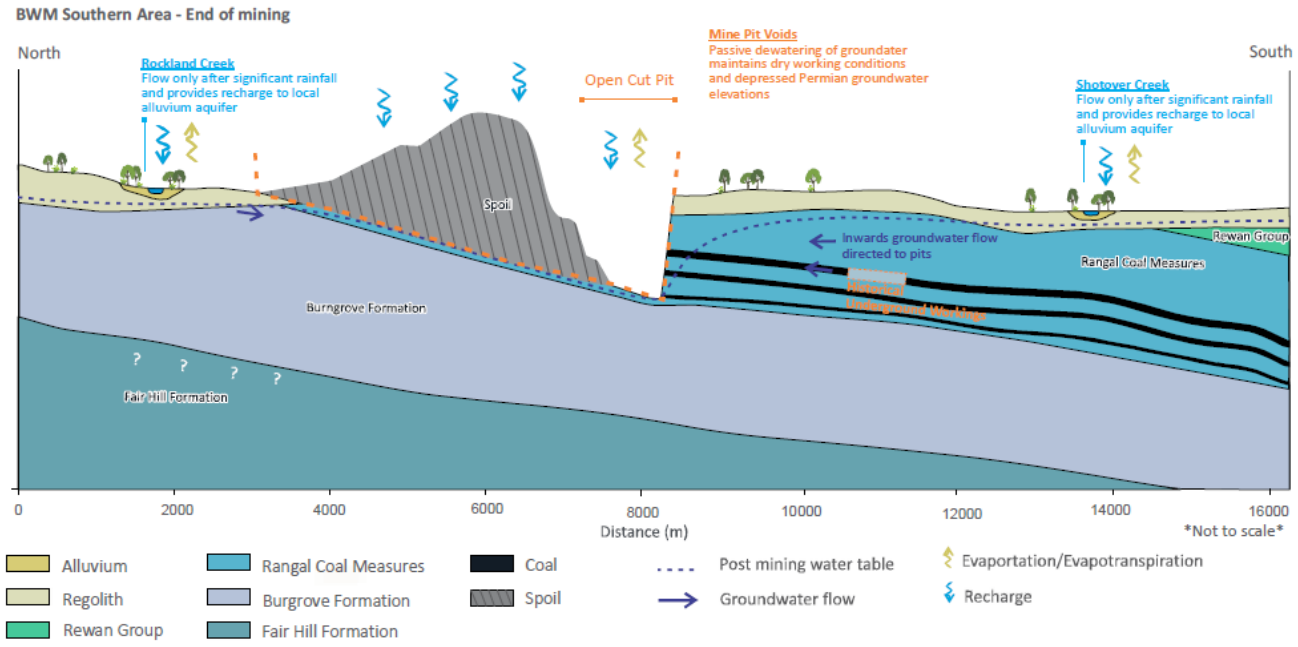
Source: SLR, 2026.

FIGURE 3-3 END OF MINING CONCEPTUAL HYDROGEOLOGICAL MODEL – BWN NORTH



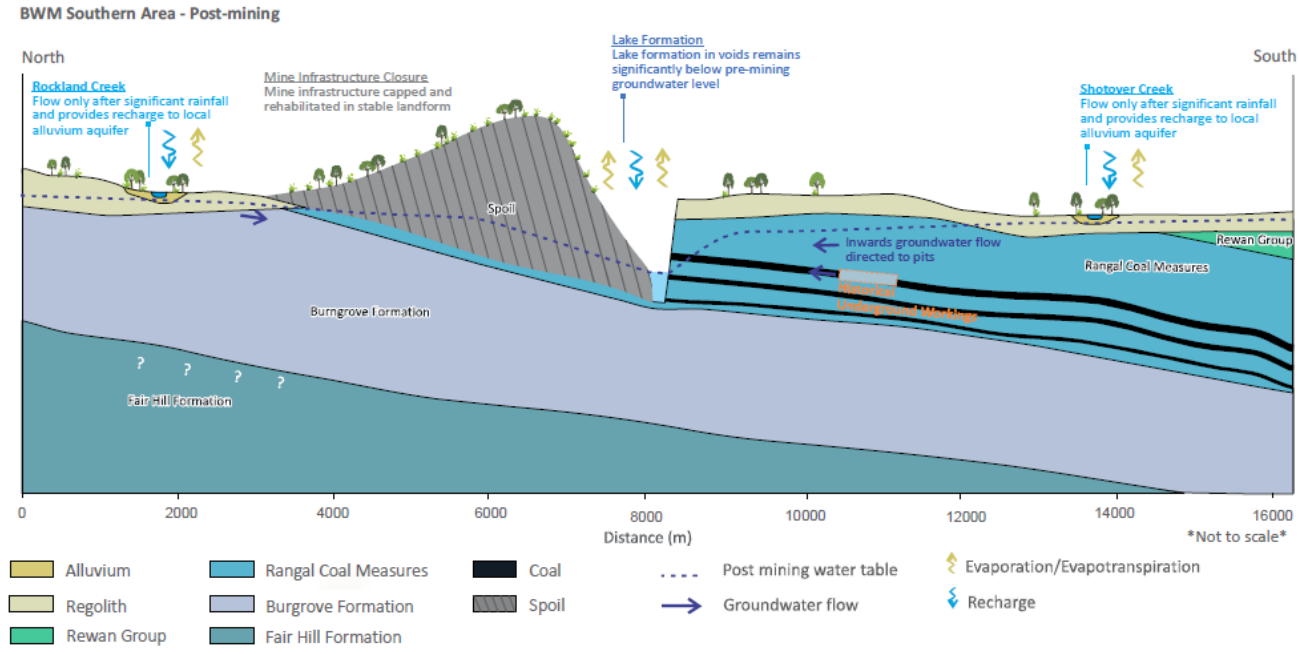
Source: SLR, 2026.

FIGURE 3-4 POST-MINING CONCEPTUAL HYDROGEOLOGICAL MODEL – BWM NORTH



Source: SLR, 2026.

FIGURE 3-5 END OF MINING CONCEPTUAL HYDROGEOLOGICAL MODEL – BWM SOUTH



Source: SLR, 2026.

FIGURE 3-6 POST-MINING CONCEPTUAL HYDROGEOLOGICAL MODEL – BWM SOUTH

3.4 ECOLOGICAL ASSESSMENT

The BWM site has experienced extensive vegetation disturbance due to historical agricultural clearing and mining development. The most heavily modified area runs along a central north-south corridor; however, significant remnants of native vegetation persist in the south-western and south-eastern parts of the site. Ground-truthed regional ecosystems (REs) include a

variety of communities adapted to Cainozoic sand and clay plains, with several classified as *Endangered* under Queensland's Vegetation Management Act 1999 and listed as Category B Environmentally Sensitive Areas (ESAs) under the *Environmental Protection Regulation 2019 (Qld)* (Figure 3-7).

Endangered REs identified on site include:

- RE 11.3.1: *Acacia harpophylla* and/or *Casuarina cristata* open forest (alluvial plains);
- RE 11.4.3, 11.4.7–11.4.9a: Brigalow woodlands and open forests dominated by *A. harpophylla*, *Casuarina cristata*, *Eucalyptus populnea*, *E. cambageana*, *Terminalia oblongata*, and *Lysiphyllum carronii;*
- RE 11.5.15–11.5.16: Semi-evergreen vine thickets and open forests on Cainozoic sand plains;
- RE 11.8.13: Semi-evergreen vine thicket and microphyll vine forest on igneous substrates; and
- RE 11.9.1, 11.9.5: Brigalow-dominated open forests on sedimentary rock.

These ecosystems support important habitat for a range of threatened plant and animal species.

3.4.1 THREATENED FLORA SPECIES (NC ACT)

The following flora species listed under the *Nature Conservation Act 1992 (Qld)* have been recorded at BWM:

- *Solanum elachophyllum* – Endangered; found on cracking clays in brigalow communities with *Eucalyptus thozetiana* or *E. cambageana;*
- *Solanum dissectum* – Endangered; found in solodic clay soils within RE11.4.8;
- *Cadellia pentastylis* (*ooline*) – Vulnerable; recorded on lower scarps of RE11.7.1 and 11.7.2; and
- *Cerbera dumicola* – Near Threatened; found in vine forests and woodlands on sandstone and acidic soils (e.g. RE11.7.2).

3.4.2 THREATENED AND NOTABLE FAUNA SPECIES (NC ACT)

Several threatened fauna species are known to occur on site, including:

- *Phascolarctos cinereus (*Koala*)* – Endangered; habitat mapped along drainage lines with preferred feed trees (*Eucalyptus camaldulensis*, *E. tereticornis*, *E. populnea*, *E. coolabah*, *E. melanophloia*, *E. crebra*, *Corymbia citriodora*);
- *Denisonia maculata (*Ornamental snake*)* – Vulnerable; prefers gilgai landscapes within brigalow and *E. coolabah* woodlands;
- *Geophaps scripta scripta (*Squatter pigeon*)* – Vulnerable; associated with open woodlands near water;
- *Rostratula australis (*Australian painted snipe*)* – Endangered; found in shallow ephemeral wetlands (gilgai and farm dams);
- *Gallinago hardwickii (*Latham's snipe*)* – Special Least Concern; occurs in wetland habitats.
- *Tachyglossus aculeatus (*Short-beaked echidna*)* – Special Least Concern; broadly distributed;

- Migratory birds:
  - *Hirundapus caudacutus (*White-throated needletail*)* – Vulnerable;
  - *Apus pacificus (*Fork-tailed swift*)* – Special Least Concern; and
  - *Rhipidura rufifrons (*Rufous fantail*)* – Special Least Concern.

Potential habitat for Koala, the Ornamental snake and Squatter Pigeon is shown in Figure 3-8.

3.4.3 REHABILITATION STRATEGY

The rehabilitation strategy at BWM prioritises restoring woodland and watercourse PMLUs in areas adjacent to undisturbed or high-value regrowth ecosystems. This aims to re-establish ecological connectivity and support habitat requirements for species of conservation concern (e.g. *Phascolarctos cinereus*, *Tachyglossus aculeatus*). Revegetation will include *Eucalyptus spp.*, *Corymbia spp.*, and suitable understorey species to provide long-term structural and functional habitat diversity for both mobile and sedentary fauna.

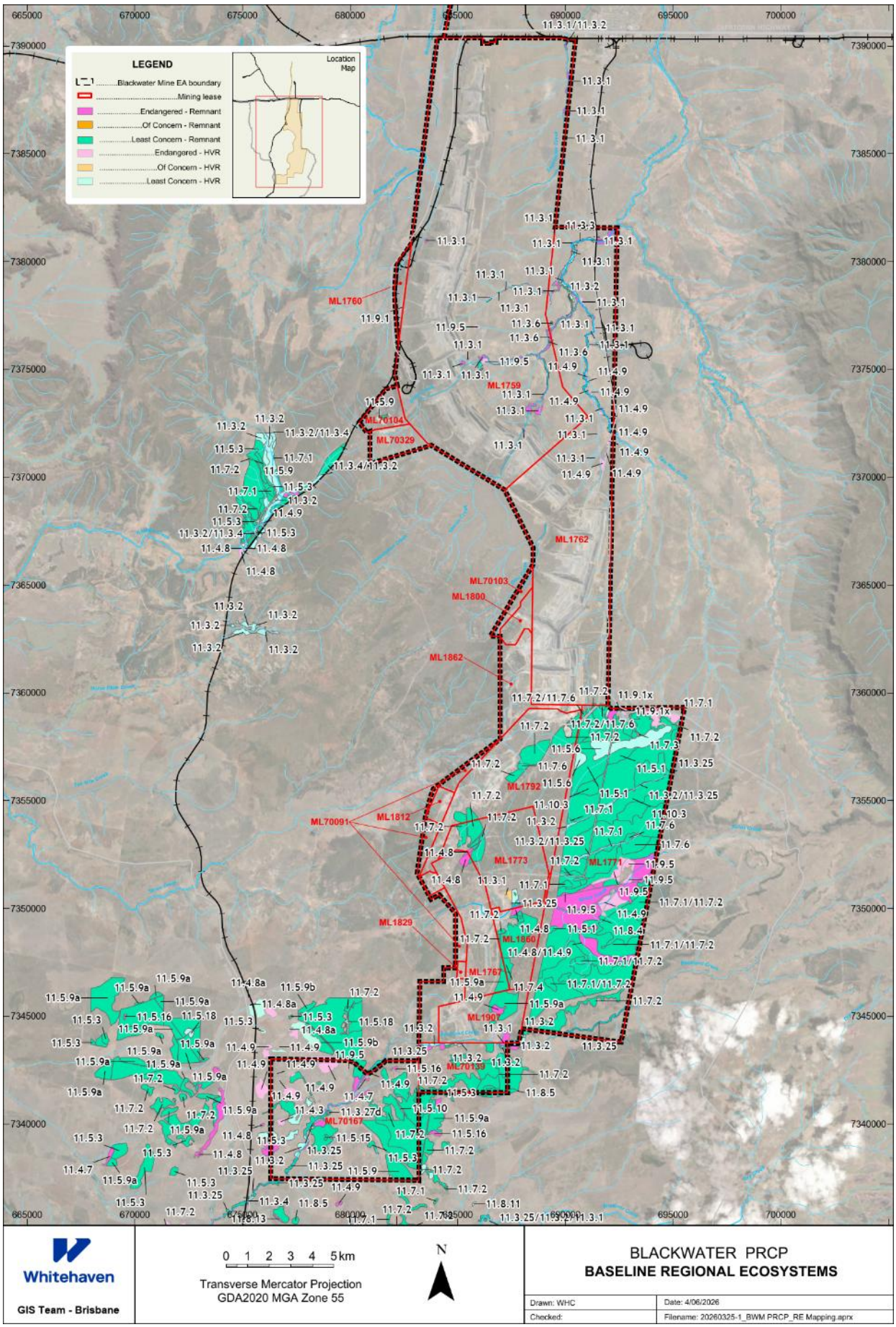


FIGURE 3-7 BWM BASELINE REGIONAL ECOSYSTEM

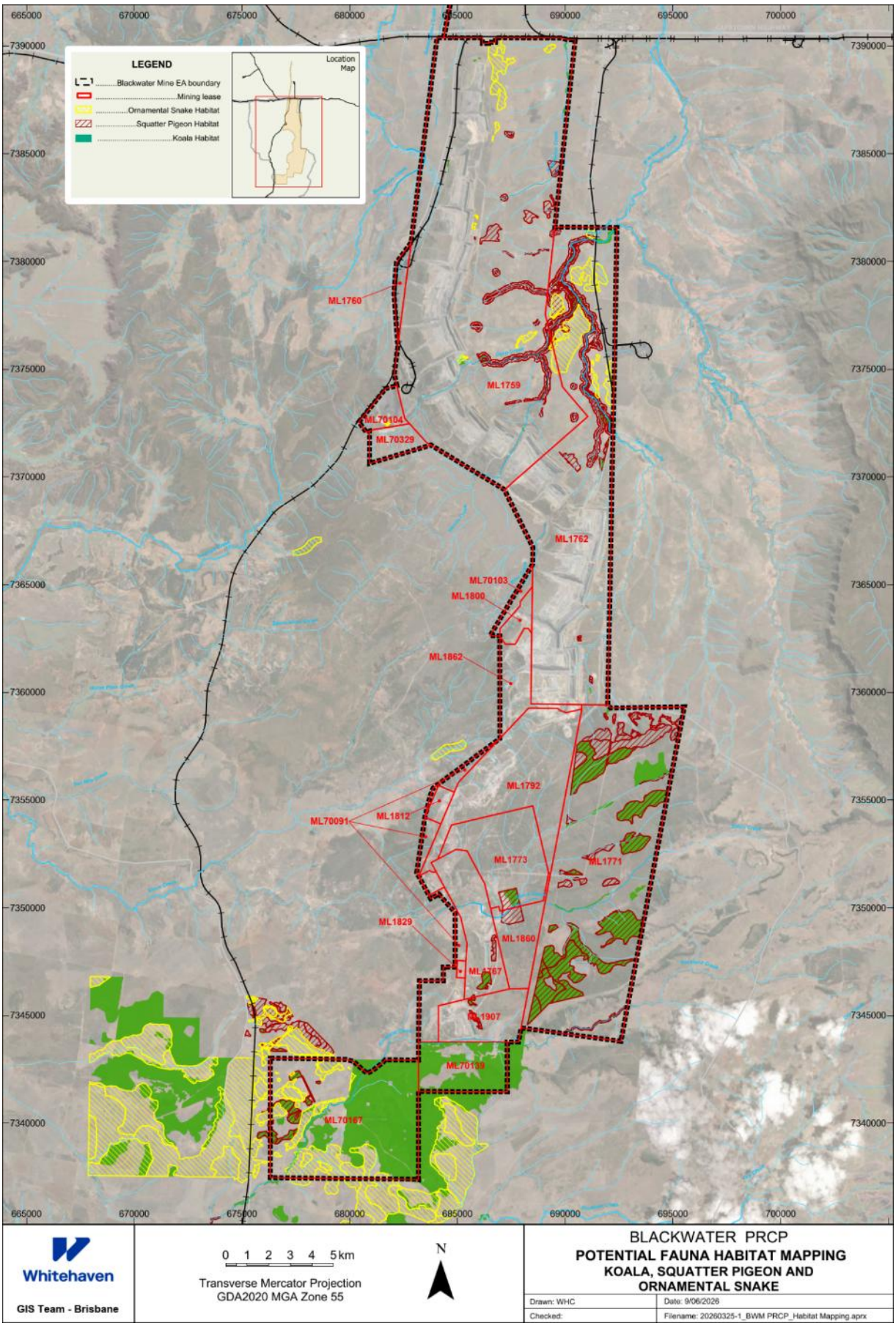


FIGURE 3-8 BWM BASELINE POTENTIAL FAUNA HABITAT MAPPING FOR KOALA, ORNAMENTAL SNAKE AND SQUATTER PIGEON

3.5 GROUNDWATER ENVIRONMENTAL VALUES

BWM is within the Highlands Groundwater Management Area (GMA) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011. The Highlands GMA consists of the following:

- Highlands Groundwater Unit 1, containing the aquifers of the Quaternary alluvium associated with the Sandy Creek Alluvium sub-area (to the distant northwest of BWM but not located within the Study Area); and
- Highlands Groundwater Unit 2, containing all sub-artesian aquifers within the Highlands GMA other than the aquifers included in Highlands Groundwater Unit 1.

Volumetric limits apply to extraction of groundwater within the GMA for non-stock and domestic purposes.

Groundwater resources are scheduled under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (Qld) (EP Water) as Comet Groundwaters and Mackenzie Groundwaters of the Fitzroy Basin water plan (WQ1310). The legislated environmental values EVs for these Groundwaters are show in Table 3-3 along with a comparison of potential EVs based on the bore census results in EMM (2019).

TABLE 3-3 GROUNDWATER ENVIRONMENTAL VALUES

Environmental Values	Comet Groundwaters	Mackenzie Groundwaters	EMM (2019) Bore Census
Aquatic ecosystems	✓	✓	✓
Irrigation	✓	✓	
Farm supply/use	✓	✓	✓
Stock water	✓	✓	✓
Aquaculture			
Human consumer			
Primary recreation	✓		
Secondary recreation			
Visual recreation			
Drinking water	✓	✓	
Industrial use	✓	✓	✓
Cultural and spiritual value	✓	✓	

Source: SLR, 2026.

EMM (2021) concluded that based on the bores that were surveyed in the 2019 bore census:

> "The environmental values for groundwater in the area are limited to farm supply/use, stock water and industrial use (i.e. mining). Aquatic ecosystems may also be associated with shallow alluvial systems".

Further discussion on groundwater quality and its suitability for supporting EVs is provided in Section 4.5 and greater detail is provided in SLR (2026). A comparison by SLR (2026) of available groundwater quality data from the monitoring bore network indicates that all hydrostratigraphic units at BWM generally exceed one or more relevant parameter criteria (e.g. salinity as TDS for the scheduled EVs.

3.5.1 GROUNDWATER USERS

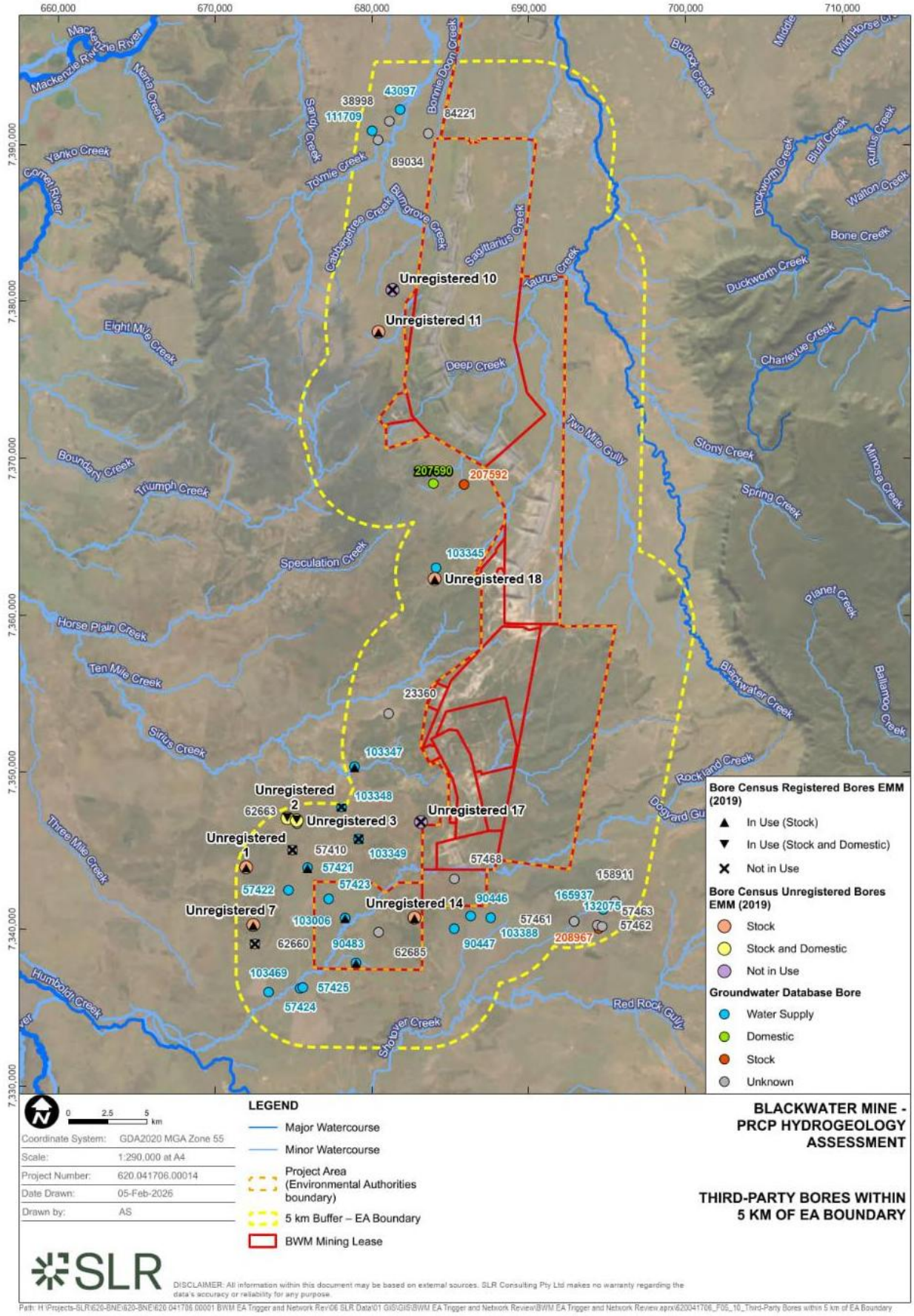
A search of groundwater receptor data was conducted using the Queensland Government's Registered Groundwater Bore Database (DRDMW, 2026) and the Bureau of Meteorology's National Groundwater Information System (BoM, 2017), with results reviewed by SLR (2026).

The search identified 315 registered bores within and surrounding the BWM mining lease area. Bore registrations were attributed to the following uses:

- 238 mine monitoring bores;
- One petroleum exploration bores;
- 19 sub-artesian monitoring bores;
- One water resource investigation bores;
- 19 water supply bores;
- Seven stock bores, two stock/domestic bores and one domestic bore;
- 13 unknown use bores; and
- 21 decommissioned bores.

In addition, a landholder bore census undertaken by EMM (2019), identified 44 third-party or potential third-party bores within 5 km of the BWM EA boundary, of which 18 have been subject to a bore census to confirm location, status and usage. Additional unregistered bores may also be present.

The locations of the third party groundwater bores within 5 km of BWM are shown in Figure 3-9.



Source: SLR, 2026.

FIGURE 3-9 THIRD-PARTY BORES WITHIN 5 KM OF BWM

3.6 SURFACE WATER ENVIRONMENTAL VALUES

Surface water resources are also scheduled under the EPP Water. Details of the prescribed surface water EVs and Water Quality Objectives (WQOs) are contained in the following Department of Environment and Heritage Protection (DEHP) documents:

- Mackenzie River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Mackenzie River Sub-basin September 2011; and
- Comet River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Comet River Sub-basin September 2011.

EVs of the sub-catchments at BWM are summarised in Table 3-4.

TABLE 3-4 SURFACE WATER ENVIRONMENTAL VALUES

Environmental Values	Comet Eastern Tributaries	Mackenzie Southern Tributaries
Aquatic ecosystems	✓	✓
Irrigation	✓	
Farm supply/use	✓	✓
Stock water	✓	✓
Aquaculture		
Human consumer	✓	✓
Primary recreation	✓	✓
Secondary recreation	✓	✓
Visual recreation	✓	✓
Drinking water	✓	✓
Industrial use	✓	✓
Cultural and spiritual value	✓	✓

The northern portion of BWM predominantly lies at the top of the local creek catchments with surface runoff from the eastern side draining towards Sagittarius and Taurus Creeks and the western side draining to Burngrove Creek. Sagittarius, Taurus and Burngrove Creeks run in a northerly direction towards the Mackenzie River.

The surface water drainage within the southern portion of BWM generally runs from east to west and the site falls within the local creek catchments of Sirius and Rockland creeks. Sirius Creek runs through a diversion channel to the south of the Laleham Pit/Ramp 72 tailings storage before running in a north-westerly direction towards the Comet River. Rockland Creek traverses the site to the south of Marshmead Pit, through the Rockland Creek Dam and a diversion channel. Rockland Creek beyond the EA boundary flows in a south westerly direction towards Comet River.

The watercourses and drainage lines are highly ephemeral, with flows only occurring for short periods during and immediately after rainfall events. The watercourses that intersect BWM are shown in Figure 3-10.

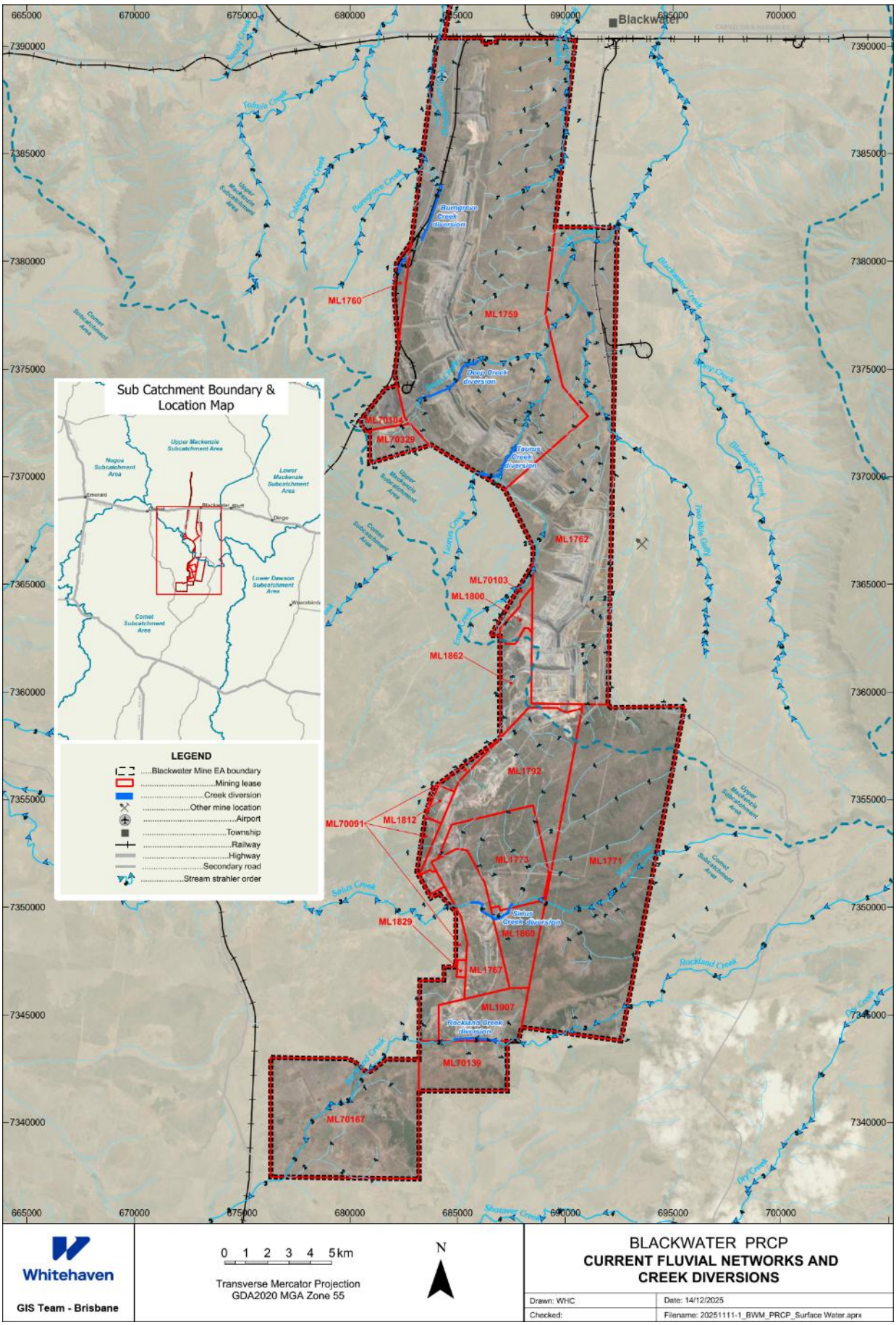


FIGURE 3-10 CURRENT FLUVIAL NETWORK AND CREEK DIVERSIONS

4. GROUNDWATER

This section assesses how residual voids interact with groundwater systems post-mining, supporting the PRCP requirements to evaluate containment, recovery and risks to environmental values.

It includes groundwater modelling to determine whether each residual void will function as a sink (drawing in groundwater) or a source (discharging to the surrounding aquifer), and assess the implications for:

- *Groundwater flow paths and hydraulic gradients;*
- *Connectivity with surrounding aquifers and surface water systems;*
- *Potential for contaminant migration or dilution; and*
- *Long-term changes in groundwater levels and quality.*

This section assesses how residual voids interact with groundwater systems post-mining, supporting the PRCP requirements to evaluate containment, recovery and risks to environmental values. It includes the results of the groundwater modelling undertaken by SLR (2026) to determine whether each residual void will function as a sink (drawing in groundwater) or a source (discharging to the surrounding aquifer), and assess the implications for:

- Groundwater flow paths and hydraulic gradients;
- Connectivity with surrounding aquifers and surface water systems;
- Potential for contaminant migration or dilution; and
- Long-term changes in groundwater levels and quality.

The calibrated BWM regional numerical groundwater model was updated to MODFLOW-USG Transport, recalibrated to Revision 3 of the PRCP, and the final landform design version 4.1 was replicated for the post-mining period. MODFLOW-USG is a recent version of industry standard MODFLOW code and was determined to be the most suitable modelling code for accomplishing the model objectives.

The primary objective of the hydrogeological assessment was to assess the potential groundwater related impacts at the completion of mining and until conditions stabilise post-mining (i.e. groundwater equilibrium). The focus was to demonstrate the suitability of the final landform for the intended PLMUs with respect to the groundwater system. The key objectives were to demonstrate:

- That the final landform is non-polluting with respect to groundwater:
  - The final landform overall is demonstrated to be a sink for groundwater, including groundwater contained within spoil; and
  - Final void lake levels remain below shallow groundwater bearing units, i.e. there is sufficient freeboard to negate risk of void water discharge to any shallow groundwater system;
- That there are minimal additional impacts to groundwater receptors post-closure caused by the final landform that have not already occurred as a result of approved mining:
  - Little to no additional groundwater drawdown at potential GDE locations; and
  - Little to no additional groundwater drawdown at anthropogenic bore users.

The BWM regional groundwater model was extended to simulate approved mining until 2110 and simulate the post-mining landform from 2110 until post mining equilibrium. The post mining period in the model extends for 1,930 years over 22 stress periods.

The groundwater model was used to predict:

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

Inflows were developed through an iterative process of model refinement with the water balance model until which time as the influence of changing groundwater flux on the water balance had reduced to a point considered acceptable. The model incorporated the 15 residual voids, associated spoil emplacements and the two in-pit tailings emplacements at Bonnie Doon and Ramp 74 (Figure 3-1 and Figure 3-2).

4.1 POST-MINING RESIDUAL VOID LAKE DEVELOPMENT AND FLUX DYNAMICS

4.1.1 STABILISED LAKE LEVELS

Residual void water level recovery is a process that takes decades to centuries, with the recovery rate generally declining as the lakes reach equilibrium conditions. For the majority of the residual voids, equilibrium water level conditions are reached after approximately 100 to 300 years (WRM, 2026c). The residual void lake levels at Kennedy and Comet Downs East take longer to stabilise at approximately 400 and 450 years respectively.

Predicted void lake levels remain significantly below the surface 'spill' point (Table 3-1) for each of the residual voids. The predicted stabilised water levels, approximate times to stabilisation and anticipated available freeboard is shown in Table 4-1. The modelled increase in water levels, above predicted stabilised levels, under a 0.1% AEP, 72-hour (3 day) design storm are also provided. Predicted freeboard values indicate that all residual void lake levels remain well below spill crest elevations at equilibrium and under the modelled extreme storm event.

TABLE 4-1 STABILISED RESIDUAL VOID LAKE LEVELS

Residual Void	Stabilised Water Level	Approx. Time to Stabilisation	Available Freeboard	Storm Event Increase
Unit	*mAHD*	*Years*	*m*	*m*
Ramp 8	146.5	200	41.5	2.2
Bonnie Doon	154.5	150	33.5	5.3
Mimosa/Besgrove	83.7	200	116.3	4.4
Deep Creek	134.5	300	67.5	2.6
Stewarton North	74.0	200	130.0	4.5
Stewarton South	103.9	100	121.8	11.6

Residual Void	Stabilised Water Level	Approx. Time to Stabilisation	Available Freeboard	Storm Event Increase
Kenmare	218.0	150	79.0	3.5
Togara/North Marshmead	165.7	300	105.3	2.0
South Marshmead	171.1	300	98.9	2.9
Kennedy	166.4	400	54.6	2.4
Comet Downs East	191.2	450	30.8	1.8
Ramp 74	234.1	100	31.9	10.2
South Ballamoo	141.5	300	148.5	2.8
Tannyfoil	144.7	250	92.3	3.6
Ramp 30	143.3	150	73.7	19.3

Source: WRM, 2026c.

The difference between the predicted residual void lake levels and the shallow geologic formations are provided in Table 4-2.

Predicted residual void lake levels remain below the base of the shallow geologic formations for each of the residual voids, with the exception of Comet Downs East. Residual void lake level modelling indicates that the Comet Downs East residual void lake will form above the base of the shallow formations at the start of the post-mining period and remain higher at equilibrium. Particle tracking (Section 4.3) shows that whilst the Comet Downs East residual void lake water is predicted to stabilise above the shallow geologic formations, the predicted lake elevations are higher than the neighbouring voids, resulting in a hydraulic gradient which drives any outflows from Comet Downs East towards the lower elevation neighbouring void lakes rather than away from the voids.

TABLE 4-2 PREDICTED DIFFERENCE BETWEEN RESIDUAL VOID LAKE LEVELS AND SHALLOW GEOLOGICAL FORMATIONS

Residual Void	Base of Shallow Formations[1]	Difference Between Base of Shallow Formations and Adjacent Void Lake Level[2]	
		Start of Post-mining	Post-mining Equilibrium
Unit	*mAHD*	*m*	
Ramp 8	176	29	31
Bonnie Doon	175	12	16
Mimosa/Besgrove	187	103	103
Deep Creek	204	55	65

Residual Void	Base of Shallow Formations[1]	Difference Between Base of Shallow Formations and Adjacent Void Lake Level[2]	
		Start of Post-mining	Post-mining Equilibrium
Stewarton North	204	128	130
Stewarton South	204	105	99
Kenmare	269	52	54
Togara/North Marshmead	251	111	87
South Marshmead	222	83	52
Kennedy West	187	44	26
Comet Downs East	188	-46	-1
Ramp 74	241	7	7
South Ballamoo	251	114	111
Tannyfoil	218	73	75
Ramp 30	210	63	67

[1] The lowest elevation of the base of shallow unconsolidated sediments adjacent to the void.

[2] A negative value indicates the void lake level is higher than the base of shallow formations by that value.

Source: SLR, 2026.

The predicted lake levels in the Kenmare residual void are above the Kenmare Underground and Laleham Underground workings. This indicates that the Kenmare Underground and Laleham Underground workings remain permanently flooded and there is no potential for oxidisation within the underground workings. This is consistent with the post-mining conceptual hydrogeological model, which assumes long-term saturation of underground mine workings.

4.1.2 GROUNDWATER INFLOW CONTRIBUTIONS AND RATES

Model results indicate that across all the voids with net groundwater inflow at equilibrium, spoil contributes between 90% to 100% of the total net groundwater inflows to the void. The equilibrium groundwater inflows to the voids represent a range of approximately 0% (Bonnie Doon, Stewarton South, Ramp 30) to 70% (Comet Downs East) of the total volumetric inflow to each residual void's water balance, indicating that groundwater inflows plays an important role for some voids, but are not always the dominant driver of predicted residual void lake levels (Table 4-3). This includes the volume of water moving between void and is not exclusively groundwater flowing towards the voids.

During early model stress periods prior to equilibrium, groundwater flux between the residual voids and the adjacent spoil and geological formations are more variable than towards the end of the recovery simulation. However, as equilibrium conditions are approached, groundwater flux stabilises and most residual voids behave as net groundwater sinks.

The equilibrium sink behaviour of the residual voids is driven by evaporative losses from the void lakes as predicted by the residual void water balance (WRM, 2026). The direct evaporation from the surface of the void lake maintains void lake levels lower than the surrounding groundwater levels in the long-term equilibrium state. All residual voids, except for Stewarton South, Ramp 30, Ramp 74 and Bonnie Doon, are predicted to behave as groundwater sinks at post-closure equilibrium with no net outflows to spoil or natural geology and the groundwater gradient remains towards the voids. The Stewarton South, Ramp 30, Ramp 74 and Bonnie Doon residual voids have net negative fluxes via movements of water between final voids. These residual voids are predicted to lose void water to adjacent voids via the natural geology between the voids at relatively small rates. Each of these voids have predicted lake elevations that are higher than the neighbouring voids (Table 4-1), resulting in a hydraulic gradient between the voids that drives this outwards flux from each void to its neighbouring void. Therefore, the outwards water flux is driven by, and would eventually be captured by, the adjacent voids with lower lake levels.

TABLE 4-3 EQUILIBRIUM GROUNDWATER INFLOW TO THE RESIDUAL VOIDS

Residual Void	**Average Equilibrium Groundwater Inflow Rate**			
	Spoil	**Tailings**	**Natural Geology**	**Total**
Unit	*ML/day*			
Bonnie Doon[1]	-0.12	-0.01	-0.01	**-0.14**
Ramp 74[1]	-2.33	-0.01	0.01	**-2.32**
Comet Downs East	0.85	0.00	0.10	**+0.94**
Kennedy	2.31	0.00	0.04	**+2.36**
South Marshmead	0.89	0.00	0.00	**+0.89**
Togara/North Marshmead	3.29	0.00	0.03	**+3.33**
Kenmare	0.49	0.00	0.00	**+0.50**
South Ballamoo	1.83	0.00	0.00	**+1.83**
Tannyfoil	1.51	0.00	0.02	**+1.52**
Stewarton North	1.23	0.00	0.05	**+1.28**
Stewarton South[1]	-0.05	0.00	0.00	**-0.05**
Deep Creek	0.79	0.00	0.00	**+0.79**
Ramp 30[1]	-0.21	0.00	0.00	**-0.21**
Mimosa/Besgrove	2.38	0.00	0.02	**+2.40**
Ramp 8	0.35	0.00	0.02	**+0.37**

[1] *Negative values indicate the void acts as a groundwater source.*

Source: SLR, 2026.

4.2 GROUNDWATER SYSTEM RECOVERY AND PREDICTED POST-MINING LEVELS

Groundwater levels surrounding the residual voids are controlled by the predicted residual void lake levels, which in turn are controlled by the rate of evaporation from the void lakes balancing surface inflows and groundwater inflows to the lakes. At equilibrium, the residual void lakes system acts as long-term groundwater sink, with evaporative losses maintaining inward hydraulic gradients.

The water table is predicted to remain depressed in the immediate vicinity of the residual voids in the long term, driven by the ongoing inwards groundwater flow gradients towards most residual void lakes (Figure 4-1).

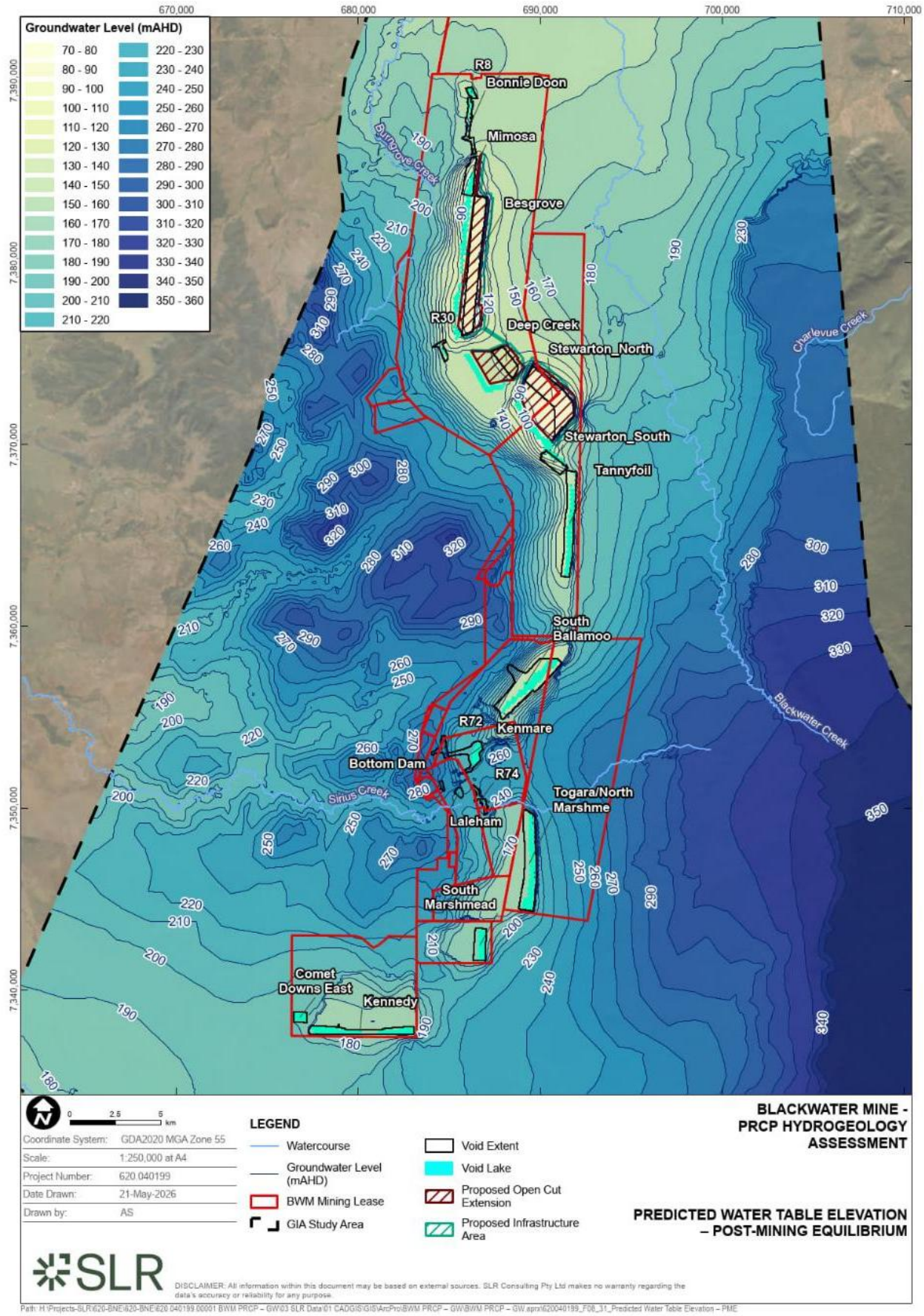
Predicted groundwater levels for the Aries, Castor and Pollux Seams of the Rangal Coal Measures indicate groundwater levels in the Permian sequence will remain depressed in the long term, driven by the residual void lakes. This condition reflects residual drawdown associated with mining and ongoing equilibration, rather than additional drawdown induced by the post-mining landform.

Figures showing predicted groundwater contours for the seams of the Rangal Coal Measures as well as the Burngrove Formation are provided in SLR (2026).

Some saturation is predicted west of the residual voids in the model layers that formerly represented the coal seams but now represents emplaced spoil within former mining pits. These zones reflect localised storage within spoil materials, with groundwater movement remaining directed toward, and ultimately captured by, adjacent residual void lakes.

Groundwater flow paths indicate that water migrating within the system is captured by residual void lakes, with no predicted migration beyond the mine lease.

Predictive hydrographs indicate that groundwater responses during the post-mining period are dominated by system stabilisation rather than continued regional change. Groundwater level behaviour at surrounding monitoring locations and third-party bores therefore reflects ongoing equilibration of conditions established during mining. In areas where drawdown persists, groundwater depths remain sufficiently deep to limit interaction with potential groundwater dependent ecosystems, indicating no additional risk associated with the final landform.



Source: SLR, 2026.

FIGURE 4-1 POST-MINING PREDICTED WATER TABLE ELEVATION

Predictive hydrographs for locations adjacent to residual void lakes are provided in SLR (2026).

The hydrographs demonstrate the vast majority of groundwater level drawdown in the coal measures occurs during active mining. While deeper coal seams show partial recovery from peak drawdown conditions in the post-mining phase, groundwater levels generally remain below pre-mining conditions. Most shallow groundwater units show persistent drawdown post-recovery.

4.3 GROUNDWATER CONTAINMENT AND FLOW PATHWAYS

Particle tracking modelling was undertaken for two scenarios:

- Scenario 1: Particles released at the start of the post mining period (year 2094) until the end of the post mining simulation period (year 4040) for a simulation period of 1,946 years; and
- Scenario 2: Particles released at post mining equilibrium (year 2641) until the end of the post mining period in the model (year 4040) for a simulation period of 1,399 years. Year 2641 was selected based on the final void hydrographs, where all final voids have reached equilibrium (i.e. flat lined).

Scenario 1 flow path analysis indicates the particles generally move toward the void lakes, with all of the particles captured in the voids. This behaviour reflects inward hydraulic gradients maintained by evaporative losses from residual void lakes.

Particles shown to be moving away from residual voids represent the four residual voids that have net outward fluxes, but for which outflows travel toward neighbourhood residual void lakes with an equilibrium water level at lower elevations.

This can be observed in the particle movements shown on Figure 4-2 with:

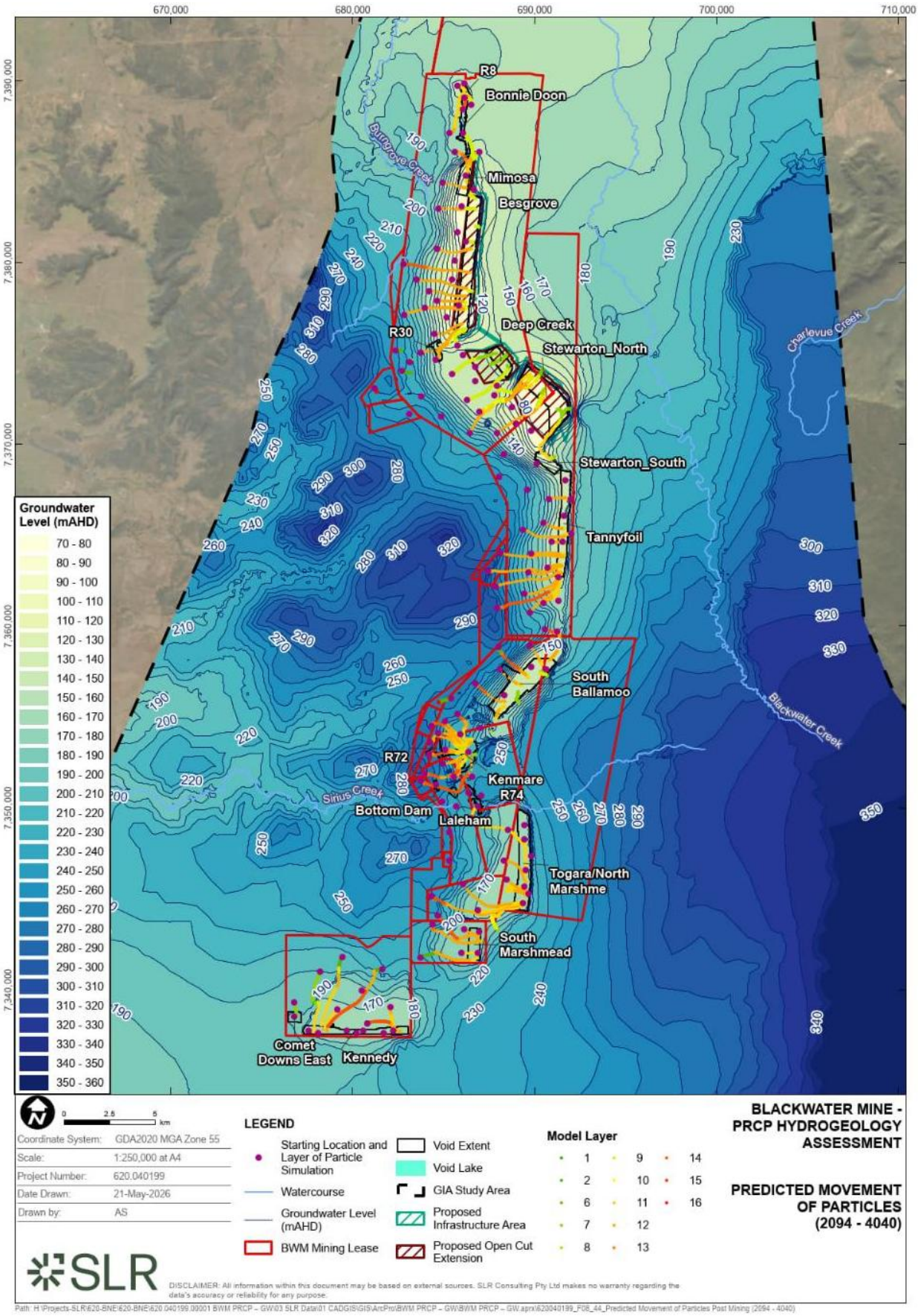
- Particles released to the west of Ramp 30 moving toward Mimosa/Besgrove;
- Particles released to the southwest of Ramp 30 moving toward Deep Creek;
- Particles released to the north of Bonnie Doon moving toward Ramp 8; and
- Particles released to the east of Ramp 74 moving toward Togara/North Marshmead.

These flow paths confirm that outward groundwater flux is redistributed internally between adjacent voids rather than migrating away from the mine domain.

Differences in the flow paths between Scenarios 1 and 2 are minimal. A comparison of the two results indicates some particles travel a slightly different path; however, their destinations do not change. For particles still traveling at the end of the simulation, i.e. not captured by evapotranspiration or final void lakes, particles in the Scenario 1 simulation travel a slightly longer distance owing to the longer simulation period.

Across both scenarios, particle tracking results demonstrate that groundwater movement remains confined within the mine lease and is ultimately captured by residual void lakes. No particles are predicted to travel beyond the mine lease in either scenario.

Further detail of the particle tracking simulations are provided in SLR (2026).



Source: SLR, 2026.

FIGURE 4-2 SCENARIO 1 PREDICTED PARTICLE TRACKING (2094-4040)

4.4 POST-MINING CONCEPTUAL HYDROGEOLOGICAL MODEL

The post mining conceptual hydrogeological model indicates that groundwater behaviour at BWM is governed by residual void lakes, which act as the primary hydraulic control on the system following mine closure. Groundwater conditions reflect a transition from mining induced disturbance toward long term equilibrium, with flow systems becoming progressively stable over time.

Key characteristics of the post-mining groundwater system include:

- Residual void lakes act as long-term groundwater sinks, maintaining inward flow gradients driven by evaporation;
- Groundwater flow is directed toward voids via spoil and surrounding geological units, with spoil pathways typically dominant;
- Localised inter-void flow may occur, where higher elevation voids discharge to adjacent lower elevation voids; this represents internal redistribution rather than external loss;
- Groundwater movement remains contained within the mine domain, with no predicted migration beyond the lease boundary; and
- Hydrogeological conditions reflect continuation of mining induced drawdown, with gradual stabilisation toward equilibrium rather than new impacts associated with the final landform.

Overall, the system evolves toward a stable, internally contained groundwater regime, with residual void lakes providing long term hydraulic control and no predicted offsite impacts.

4.5 GROUNDWATER QUALITY

A detailed discussion of the baseline groundwater quality at BWM is provided in SLR (2026).

Baseline groundwater quality at BWM varies between hydrostratigraphic units and reflects a wide range of salinity conditions as defined by TDS. As shown in Table 4-4 and Figure 4-3, groundwater spans classifications from fresh through to highly saline, with variability both within and between hydrostratigraphic units.

Groundwater is predominantly sodium-chloride type and is generally unsuitable for most environmental values, with limited suitability for stock watering in selected units.

Key observations for each hydrostratigraphic units are as follows:

- Alluvium (Quaternary):
  - Groundwater is Na-Cl type with neutral pH, indicating evaporative concentration under low flushing conditions;
  - Elevated solute concentrations result in unsuitability for all assessed environmental values; and
  - Interpretation is constrained by limited data availability (single monitoring bore);
- Tertiary Sediments:
  - Groundwater is Na-Cl to Na-CO_3-HCO_3 type with a wide pH range, indicating mixed recharge influence and variable water-rock interaction;

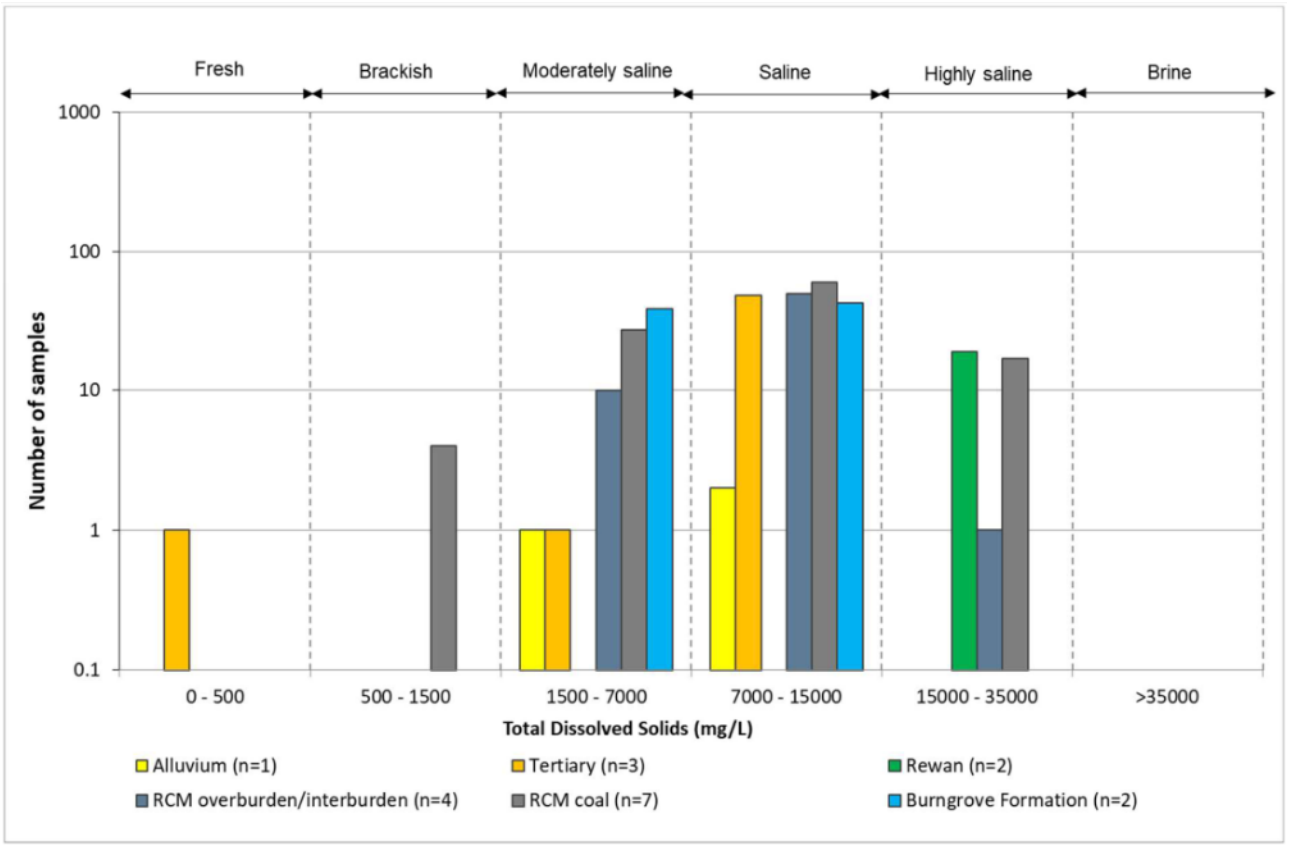
- Elevated solute concentrations result in unsuitability for drinking and irrigation uses. Localised suitability for stock watering is observed where water quality is less saline; and
- Groundwater quality is highly variable between bores, reflecting heterogeneous lithology and recharge conditions;

- Rewan Group:
  - Groundwater is Na-Cl type with near-neutral pH, indicating chemically evolved conditions under low permeability and limited recharge;
  - Consistently elevated solute concentrations result in unsuitability for all environmental values; and
  - Assessment is based on a limited dataset, reducing confidence in spatial variability;
- Rangal Coal Measures:
  - Groundwater is Na-Cl to Na-Cl-HCO_3 type with a broad pH range, indicating heterogeneous geochemical conditions and variable redox environments within coal seams;
  - Elevated salinity and solute concentrations result in widespread unsuitability for drinking and irrigation uses. Most monitoring bores exceed stock watering criteria; and
  - This unit exhibits the greatest variability and highest overall salinity conditions across the groundwater system;
- Burngrove Formation:
  - Groundwater is Na-Cl type with a moderately alkaline and relatively stable pH range, indicating more consistent geochemical conditions;
  - Elevated solute concentrations result in unsuitability for aquatic ecosystem, drinking water and irrigation uses. Groundwater is generally suitable for stock watering, with only isolated exceedances; and
  - This unit displays comparatively lower salinity and improved water quality relative to the Rangal Coal Measures.

TABLE 4-4 SUMMARY OF BASELINE GROUNDWATER QUALITY BY HYDROSTRATIGRAPHIC UNIT

Hydrostratigraphic Unit	Groundwater Type	Salinity Range	EV Suitability				Key Notes
			Aquatic Ecosystem	Drinking Water	Irrigation	Stock Watering	
Alluvium (Quaternary)	Na-Cl, neutral pH	Brackish to moderately saline	Not suitable				Limited data (single bore); highly saline groundwater
Tertiary Sediments	Na-Cl/ Na-CO_3-HCO_3, large pH range: 3.3-8.4 (median 7.4)	Fresh to moderately saline	Not suitable			Variable (locally suitable)	High variability between bores; direct rainfall recharge influence

Hydrostratigraphic Unit	Groundwater Type	Salinity Range	EV Suitability				Key Notes
			Aquatic Ecosystem	Drinking Water	Irrigation	Stock Watering	
Rewan Group	Na-Cl, near neutral pH	Highly saline	Not suitable				Elevated salinity and limited permeability
Rangal Coal Measures	Na-Cl/Na-Cl-HCO_3, large pH range: 6.9-11.9 (median 7.7)	Brackish to highly saline	Not suitable			Mostly not suitable	Wide range in salinity
Burngrove Formation	Na-Cl, pH range: 7.1-8.9 (median 8.0)	Moderately saline to saline	Not suitable			Generally suitable	Lower salinity relative to coal measures; isolated exceedances



Note: n = number of bores

Source: SLR, 2026.

FIGURE 4-3 SALINITY RANKING BY HYDROSTRATIGRAPHIC UNIT

4.5.1 GROUNDWATER QUALITY SUMMARY

Groundwater quality at BWM is variable across hydrostratigraphic units but is generally characterised by elevated solute concentrations that exceed relevant criteria for most EVs. This reflects the combined influence of lithology, groundwater residence time and limited flushing within much of the groundwater system.

The post-closure groundwater system at BWM is predicted to be dominated by the residual voids acting as groundwater sinks, maintaining inward hydraulic gradients and limiting outward migration of groundwater and solutes. Outflows from the Bonnie Doon, Ramp 30, Ramp 74 and Stewarton South residual voids move towards adjacent lower elevation voids, resulting in a localised (internal) redistribution of groundwater rather than interaction with the surrounding groundwater system.

Accordingly, the residual voids are not anticipated to result in any material change to groundwater quality beyond the project area.

4.6 GROUNDWATER-DEPENDENT ECOSYSTEMS

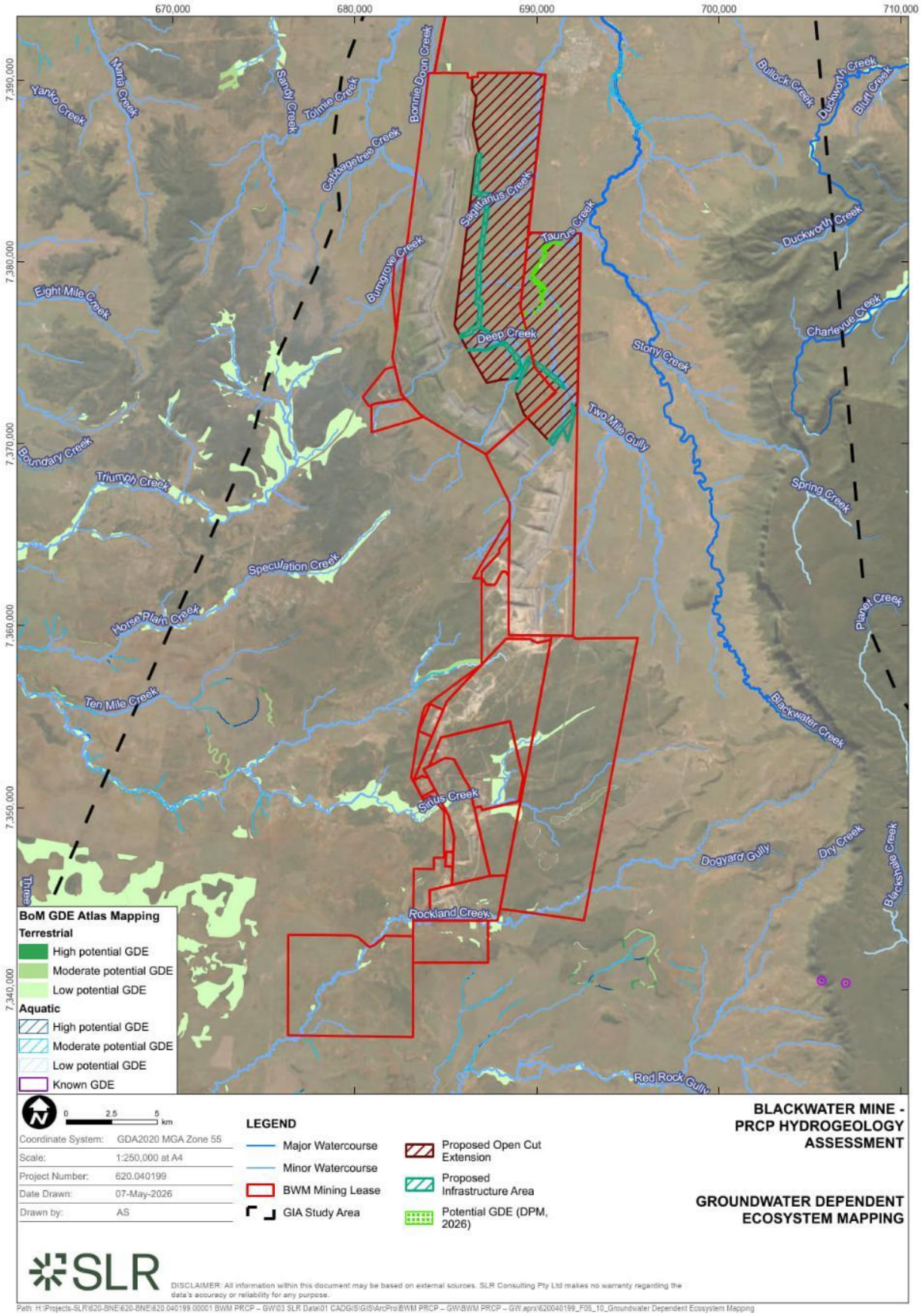
Areas with potential for terrestrial and aquatic GDEs in the southern BWM project area are shown in Figure 4-4. These locations are based on the Bureau of Meteorology (BoM) GDE Atlas data and ground-truthing results from 2026 (Section 4.6.2). Given the absence of indicators identified during field verification surveys in the northern Project Area, the GDE Atlas mapping is considered conservative and may not accurately reflect local site conditions.

In addition:

- There are no registered springs within a 10 km buffer of the Project area. The closest registered spring is located approximately 14.8 km southeast from the Project area. At this distance it is not considered relevant to the Project's impact assessment; and
- No wetlands of High Ecological Significance (HES) have been identified within a 10 km buffer of the Project area. The closest wetland is located approximately 19.7 km southeast from the Project area and is not considered relevant to the Project's impact assessment.

Predictive hydrographs prepared by SLR (2026) indicate that several of the sites are unlikely to contain actual GDEs based on the predicted depth to groundwater being greater than 8 to 10 m. At these depths, groundwater is unlikely to be accessible to vegetation, reducing the potential for groundwater dependency.

Drawdown in the vicinity of potential GDEs is predicted to occur prior to the end of mining (i.e. associated with approved active mining). Post-mining groundwater level trends represent continuation of these pre-existing conditions, with no additional drawdown attributable to the final landform in the future.



Source: SLR, 2026.

FIGURE 4-4 GROUNDWATER DEPENDENT ECOSYSTEMS

4.6.1 HISTORICAL GDE ASSESSMENTS

Ground-truthed regional ecosystems in BWM North that may represent terrestrial GDEs are shown in Figure 4-4. Potential GDEs are limited to riparian vegetation associated with Taurus Creek along the eastern margin of the Project Area and a small area along Sagittarius Creek to the north. Field verification surveys of these areas were summarised in EMM (2023) as follows:

> "Prolonged dry conditions in the lead-up to the December 2019 surveys provided ideal conditions for identifying surface expressions of groundwater (i.e. aquatic GDEs). However, no flows, salt seeps, hydrophytes, or other obvious indicators of aquatic GDEs were encountered. Further, the concentration and relative proportion of major anions and cations in surface water samples collected from the survey area in December 2019 and May 2020 showed no obvious groundwater influence. Field verification of riparian vegetation and aquatic habitats of the survey area found no obvious on-ground indicators of aquatic GDEs."

4.6.2 2026 GDE ASSESSMENTS

Recent investigations (DPM Enviroscienses, 2026) provide the most up to date assessment of groundwater dependent ecosystems within the BWM North Study Area. The assessment identified that:

- Terrestrial GDEs are present but limited in extent, occurring only within parts of the Taurus Creek riparian corridor;
- No aquatic or subterranean GDEs were identified, with no surface groundwater expression observed; and
- No stygofauna were detected during targeted sampling, indicating the absence of subterranean groundwater dependent ecosystems.

Subsequent ecological assessment (E2M, 2026) supports these findings and refines the interpretation of terrestrial GDE occurrence. Potential groundwater dependency is restricted to facultative species within the Taurus Creek corridor, while vegetation communities in other areas (e.g. Two Mile Gully and upstream reaches) are unlikely to rely on groundwater due to species composition and rooting characteristics.

The mapping produced by DPM Enviroscienses (2026) has been adopted for this assessment and provides the basis for identifying GDE extent within the Project Area.

4.7 THIRD-PARTY GROUNDWATER BORES

Forty-eight (48) third party water supply bores have been identified surrounding the project area and within study area (Figure 3-9). These bores are generally used for stock or farm supply purposes.

Predictive hydrographs (SLR, 2026) were prepared to assess the potential for additional impacts attributable to the final landform that may occur in the post-mining period and are unrelated to those that have occurred as a result of approved mining.

The following summarises the predicted impacts on third-party groundwater bores:

- Hydrographs for bores interpreted to be screened within the weathered zone are not predicted to experience additional groundwater drawdown of greater than the relevant 2 m drawdown 'bore trigger threshold' for unconsolidated aquifers (Chapter 3, *Water Act 2000;* Water Act) during the post-mining period:

    - This indicates negligible additional impact attributable to the final landform;
- Hydrographs for bores interpreted to be screened in the Burngrove Formation are not predicted to experience additional groundwater drawdown of greater than the relevant 5 m drawdown 'bore trigger threshold' for consolidated aquifers in the Water Act during the post-mining period:
    - This indicates no material post-mining impact;
- Hydrographs for three of the seven bores interpreted to be screened in the Rewan Formation indicate negligible to no additional drawdown over the post-mining period:
    - The remaining four bores show additional drawdown; however, this is interpreted to represent continuation of drawdown from approved mining rather than an impact of the final landform;
- Drawdown in the bores screened in the Rangal Coal Measures is also interpreted to be a continuation of the drawdown from approved mining and not the final landform. No Rangal Coal Measure bores are predicted to experience additional drawdown of more than the relevant 5 m 'bore trigger threshold' from the Water Act, with predicted additional drawdown generally remaining below threshold levels.

Overall, predicted groundwater responses at third-party bores reflect continuation of mining-induced drawdown, with no additional or significant impacts attributable to the post-mining landform.

4.8 CONCLUSIONS

The groundwater assessments indicate that post-mining conditions at BWM are controlled by residual void lakes, which act as long-term hydraulic sinks. These maintain inward groundwater gradients driven by evaporation and therefore dominate post-closure groundwater behaviour.

- Groundwater levels reflect continuation of mining-induced drawdown, with gradual stabilisation rather than new impacts. The final landform does not introduce additional drawdown beyond approved mining;
- Groundwater flow remains contained within the mine domain. Localised outward flux represents internal redistribution between voids, not migration to the surrounding system;
- Groundwater quality is variable and characterised by elevated solute concentrations; however, no material offsite impacts are expected from the final landform;
- GDEs are limited in extent and largely confined to parts of the Taurus Creek corridor. Predicted groundwater depths indicate these ecosystems are unlikely to rely on groundwater influenced by the final landform; and
- Third-party bores are predicted to experience minimal groundwater level changes within applicable trigger thresholds, with any drawdown representing continuation of mining-related impacts.

Overall, the residual void landform will result in a stable, internally contained groundwater system with no material adverse impacts to surrounding third party users or receptors, and represents the lowest risk closure outcome when compared to further disturbance or modification of the residual voids.

5. FLOODING ASSESSMENT

This section evaluates flood risk to residual voids under current and future climate conditions. It aims to ensure voids are protected from inundation, in line with PRCP Guideline sections 3.4 and 3.6.3.

In accordance with the Mined Land Rehabilitation Policy (DES, n.d.), and relevant provisions of the EP Act and EP Regulation, the assessment must demonstrate that residual voids are not located within flood plains, or if they are, that they will be rehabilitated to a stable, safe, and sustainable condition.

The flood plain modelling must:

- *Be undertaken in accordance with Australian Rainfall and Runoff (2019) (ARR) guidelines;*
- *Exclude artificial features within the tenure boundary;*
- *Include hydrologic and hydraulic modelling, calibration, sensitivity analysis and spatial mapping;*
- *Identify all relevant watercourses, diversions and potential groundwater influences; and*
- *Assess impacts of 0.1% AEP flood levels to determine floodplain extent.*

Where floodwaters may interact with voids or backfilled areas, assessments must consider:

- *Erosion risks and wall instability from floodwater ingress;*
- *The hydraulic properties of backfilled material; and*
- *Design modifications required to maintain long-term stability.*

A Final Landform Flood Modelling Assessment was prepared by WRM (2026a) for the BWM final landform design version 4.2. The assessment addresses the requirements of Section 3.6.1 – General rehabilitation practices (flooding) of the PRCP guideline (DETSI, 2024).

Further to the Final Landform Flood Modelling Assessment, WRM (2026b) also prepared a Voids in Flood Plains Assessment to specifically address the requirements of the Information Sheet - Void in flood plains (ESR/2019/4966; Version 1.02). The voids in flood plain assessment identified the proposed residual voids in the BWM final landform would be situated wholly or partially in a "flood plain", defined in PRCP guideline as land that is the same height as, or lower than, the level modelled as the peak water level during a 0.1% (1 in 1,000) AEP flood event for a relevant watercourse.

5.1 METHOD OF ASSESSMENTS

Hydrologic models were developed using the URBS (Unified River Basin Simulator) software package. URBS incorporates the latest climate change guidance from Australian Rainfall and Runoff 2019 Version 4.2 (ARR 2019 v. 4.2) (Ball et al, 2019).

Seven URBS hydrologic models for the catchments that drain BWM were developed, calibrated and validated. The modelled catchments are:

- Bonnie Doon Creek;
- Sagittarius Creek;
- Burngrove Creek;
- Blackwater Creek (including Taurus Creek and Two Mile Gully);
- Speculation Creek;
- Sirius Creek; and
- Rockland Creek.

These models formed the foundation for both the Final Landform Flood Modelling Assessment (WRM, 2026a) and the Void in Floodplain Modelling Assessment (WRM, 2026b). The URBS models were calibrated to recorded rainfall and water level data for the March 2017 and January 2020 flood events.

Existing TUFLOW hydraulic models were updated to incorporate the updated final landform as well as updated design inflows from the new URBS hydrologic models. Hydrologic and hydraulic modelling were undertaken for the 1% (1 in 100) and 0.1% (1 in 1,000) AEP events as well as the PMF model event.

The Final Landform Flood Modelling Assessment (WRM, 2026a) considered the risk of flood water ingress into the final voids, as well as the risk of erosion and scour due to floodwater being in contact with rehabilitated landform. The Void in Floodplain Modelling Assessment (WRM, 2026b) specifically considered only the pre-mining 0.1% AEP flood event for 'relevant watercourses'. Relevant watercourses are defined as stream order 4 or higher under the Strahler stream order classification system. Relevant watercourses at BWM for the Void in Floodplain Modelling Assessment are:

- Blackwater Creek;
- Two Mile Gully;
- Taurus Creek (downstream of the Emu Creek confluence); and
- Sirius Creek.

Detailed accounts of the modelling approach and methods of calibration and validation are documented in the Hydrologic Model Development, Calibration and Validation Report, provided as Appendix E of WRM (2026a) and Appendix B of WRM (2026b).

5.2 FINAL LANDFORM FLOOD ASSESSMENT

Hydraulic modelling was undertaken for the 1% AEP, 0.1% AEP and PMF design flood events under proposed final landform conditions by WRM (2026a). Modelling for the Final Landform Flood Assessment was completed using the SSP2-4.5 (year 2100) future climate scenario, with design rainfall inputs adjusted in accordance with ARR (2019) climate change guidance.

The full set of flood maps showing flood depths, levels, extents and velocities are provided in WRM (2026a).

When considering erosion risk, the Final Landform Flood Modelling Assessment assumed the final landform, including flood protection landforms and rehabilitated dumps, will be:

- Rehabilitated to achieve at least 70% groundcover;
- Erosion resistant materials will be placed along the toe of landforms which are subjected to flooding; and
- The topographic gradient along the toe of the landform would generally be less than 1%.

5.2.1 FLOOD IMMUNITY

Flood immunity of the residual voids was assessed based on hydraulic modelling results for the 0.1% AEP design event and PMF under final landform conditions, with PMF results used to evaluate performance under extreme conditions. The assessment considers the extent of modelled flooding relative to each void, as well as the influence of diversion structures, local topography and catchment characteristics on potential floodwater ingress.

All residual voids are modelled to be immune to ingress from the 0.1% AEP design event under final landform conditions.

Whilst the current diversions at BWM are considered temporary, conceptual designs for permanent diversions are under development. The final landform with the inclusion of permanent diversions will maintain at least the current level of flood protection for the residual voids.

Flood depth maps for all study catchments and events are provided in WRM (2026a).

A flood risk profile was prepared to assess the risk associated with flood ingress during a PMF event. The risk of flood ingress to residual voids during a PMF event, accounting for the proposed 0.1% AEP mitigation measures, was deemed to be low. This is largely attributed to the rarity of a PMF occurring.

5.2.2 EROSION AND SCOUR RISK

Modelling results indicate flood protection landforms and rehabilitated dumps are located in areas where flood velocities are lower than 2 m/s for all events up to the 0.1% AEP. As such, the final landform is expected to remain stable for all events up to the 0.1% AEP design flood event. For events rarer than 0.1% AEP, such as the PMF, elevated erosion and scour are expected to occur throughout the catchment during PMF events, consistent with natural responses to extreme flooding conditions.

5.3 VOIDS IN FLOOD PLAINS ASSESSMENT

The Voids in Flood Plains Assessment focused on the voids within the flood plains of the following relevant watercourses:

- Blackwater Creek;
- Two Mile Gully;
- Taurus Creek (downstream of the Emu Creek confluence); and
- Sirius Creek.

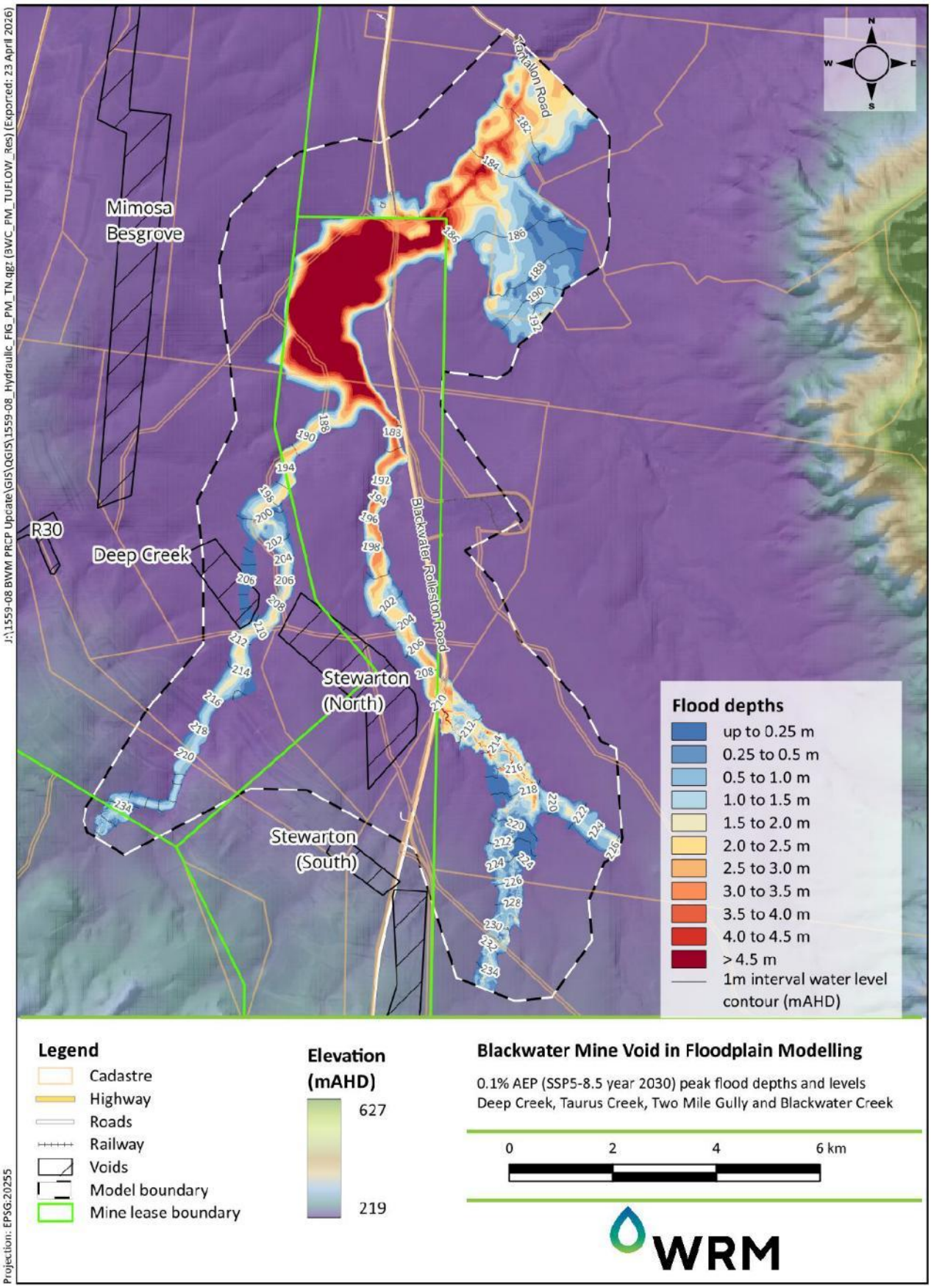
Unlike the Final Landform Flood Assessment, based on the post-mining final landform conditions, voids in flood plain modelling must represent the flood plains at a time when all temporary structures or features have been removed. Therefore, the detailed topographic data used for the Final Landform Flood Assessment was not suitable as it contained levees, mining pits, overburden dumps, stream diversion channels as well as road, rail and cross drainage infrastructure.

Floodplain hydraulic modelling was therefore undertaken by excluding all mine-related features to represent pre-mining conditions. The Fitzroy River catchment 25 m resolution Digital Elevation Model (DEM) embedded in the previous hydraulic model was considered to be the best representation of pre-mining topography within the BWM mine lease area and was adopted for areas within the BWM mine leases for the Voids in Flood Plains Assessment.

The other aspect of the voids in flood plains modelling that differed from the Final Landform Flood Assessment was to adopt the SSP5-8.5 (year 2030) climate scenario rather than the SSP2-4.5 climate scenario. Design Intensity-Frequency-Duration (IFD) design rainfall intensities were scaled up using uplift factors obtained from ARR datahub. The associated pre-

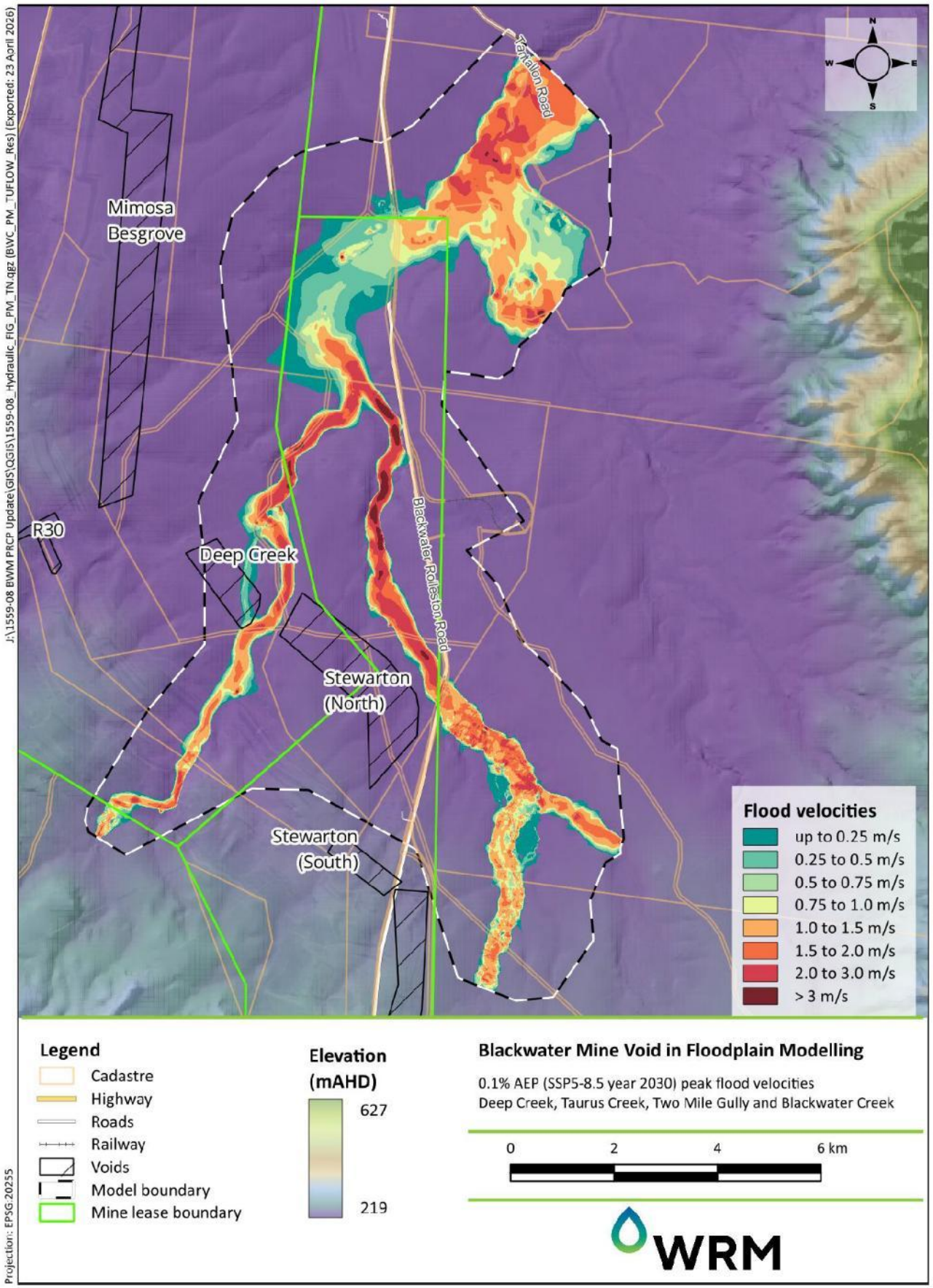
burst rainfalls were also scaled up accordingly. The SSP5-8.5 climate adjustments account for approximately 1.3°C of global warming up to 2025 since the historical baseline period of 1961-1990.

The predicted peak flood extents, levels, depths and velocities along Taurus Creek, Two Mile Gully and Blackwater Creek are provided in Figure 5-1 and Figure 5-2. Predicted peak flood extents, levels, depths and velocities along Sirius Creek are provided in Figure 5-3 and Figure 5-4.



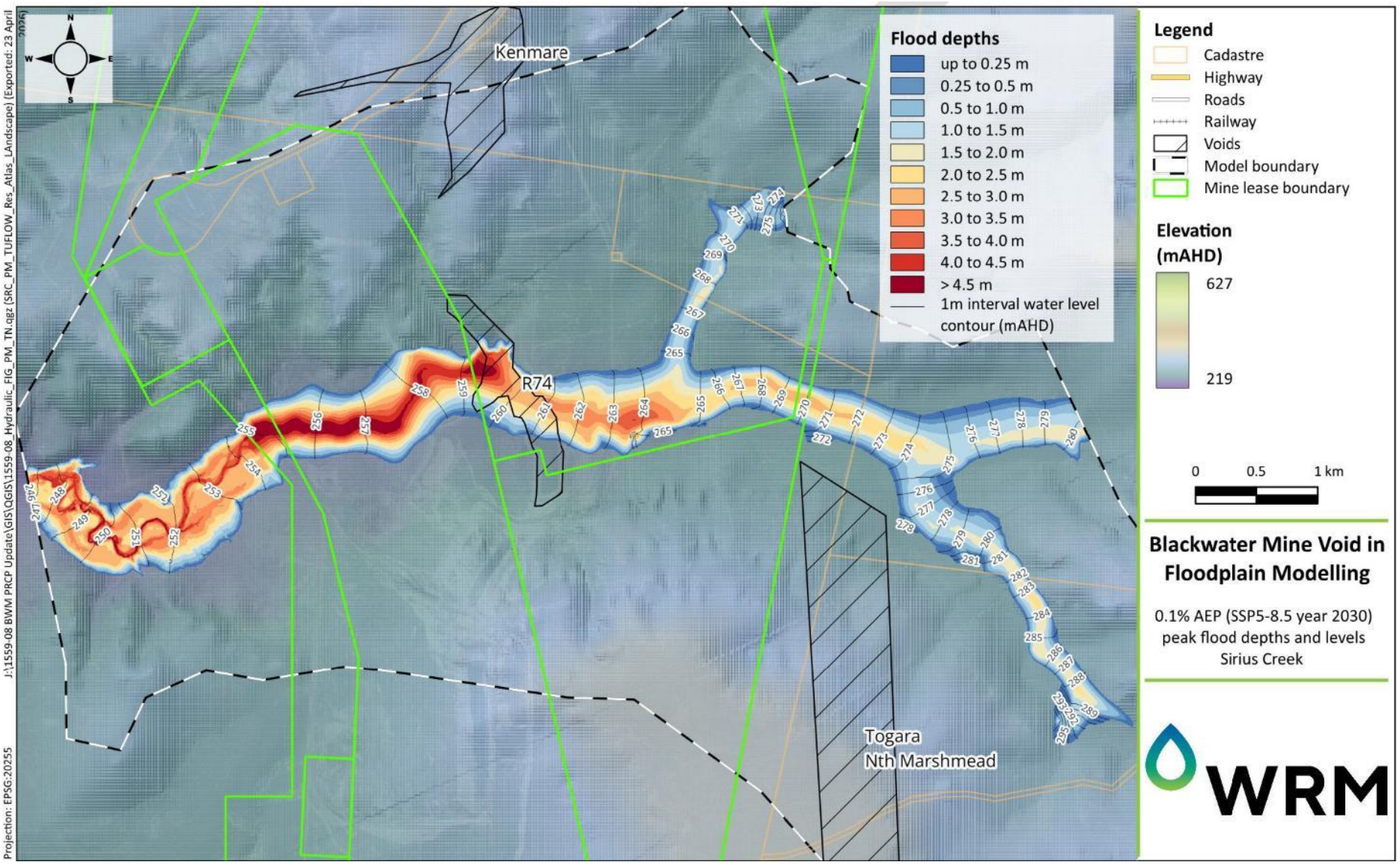
Source: WRM (2026b).

FIGURE 5-1 PEAK FLOOD EXTENT, LEVELS AND DEPTHS FOR THE 0.1% AEP EVENT – BLACKWATER CREEK



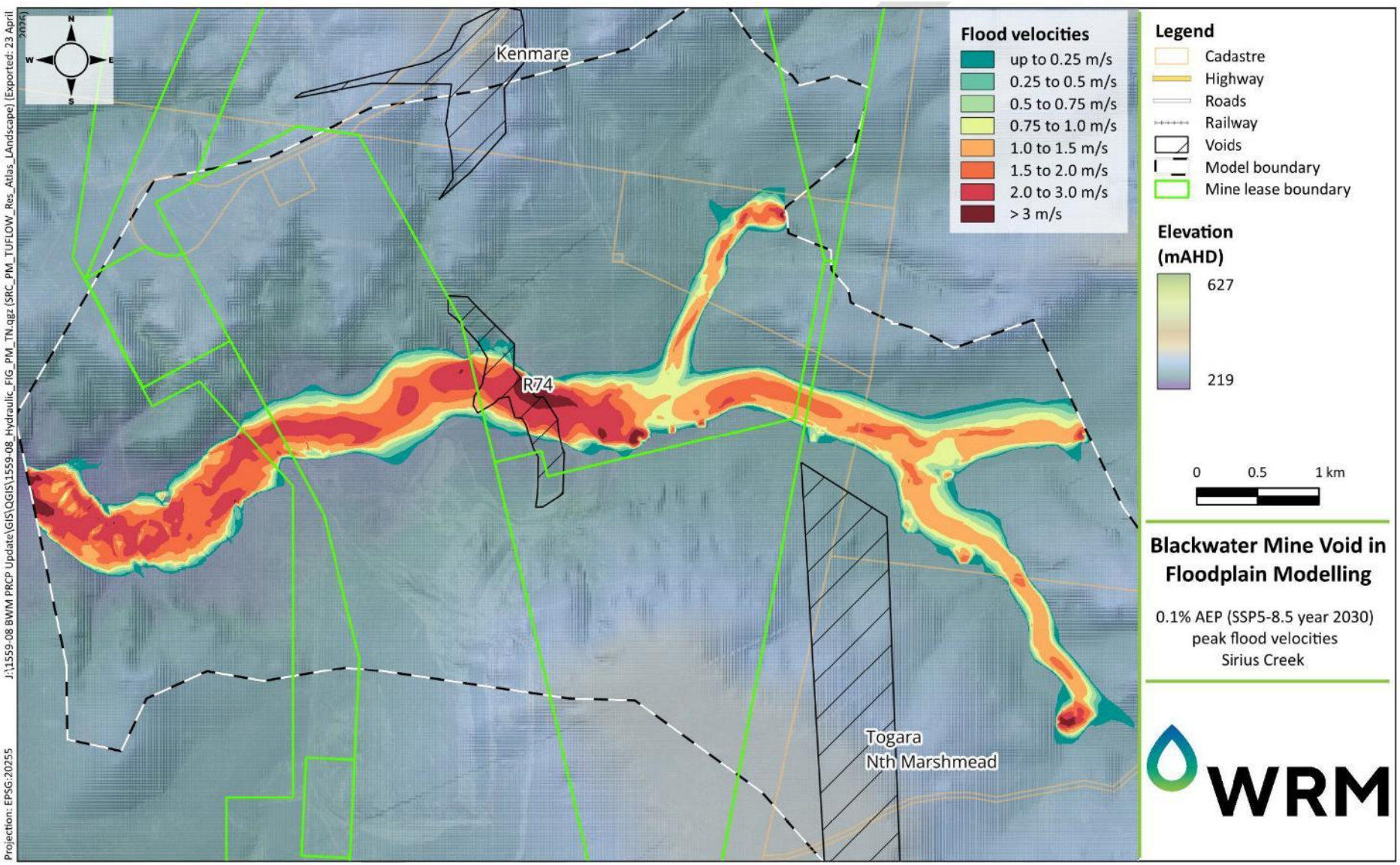
Source: WRM (2026b).

FIGURE 5-2 PEAK FLOOD VELOCITIES FOR THE 0.1% AEP EVENT – BLACKWATER CREEK



Source: WRM (2026b).

FIGURE 5-3 PEAK FLOOD EXTENT, LEVELS AND DEPTHS FOR THE 0.1% AEP EVENT – SIRIUS CREEK



Source: WRM (2026b).

FIGURE 5-4 PEAK FLOOD VELOCITIES FOR THE 0.1% AEP EVENT – SIRIUS CREEK

Residual voids were assessed against the modelled 0.1% AEP flood extent for relevant watercourses to determine whether they are located within a floodplain as defined by the PRCP guideline (DETSI, 2024). As summarised in Table 5-1, the majority of residual voids are located outside of the 0.1% AEP flood extent and are therefore not situated within a floodplain.

The Deep Creek residual void is partially located within the Taurus Creek inundation extent and the Ramp 74 residual void is situated within the Sirius Creek inundation extent.

The final landform design will prevent floodwater ingress to the Deep Creek void under the 0.1% AEP flood event.

The Ramp 74 void is situated within the Sirius Creek inundation extent for the 0.1% AEP flood event. Under current (operational) conditions, there is a licensed temporary diversion that diverts Sirius Creek around the southern end of the existing Ramp 74 void. The Ramp 74 void stores tailings and will remain under post-mining conditions as the Ramp 74 residual void and TSF. To maintain free drainage of the Sirius Creek catchment under post-mining conditions, a permanent diversion of Sirius Creek is required. A conceptual design for this permanent diversion is currently being developed in accordance with the watercourse diversion guideline (DNRME, 2019).

TABLE 5-1 RESIDUAL VOID LOCATIONS RELATIVE TO 0.1% AEP FLOOD EXTENT

Residual Void	Floodplain Status (0.1% AEP)	Relevant Watercourse	Basis
Deep Creek	Partially within flood extent	Taurus Creek	Partially intersected by inundation extent; final landform design intended to prevent floodwater ingress
Ramp 74	Within flood extent	Sirius Creek	Intersects inundation extent; temporary diversion in place; permanent diversion required post-mining
All remaining voids	Outside flood extent	-	Located outside the 0.1% AEP inundation extent and not within a floodplain as defined by DETSI (2024)

Source: WRM (2026b).

6. VOID WATER BALANCE

This section presents predicted long-term void water balance behaviour of the proposed residual voids. It also aims to support the assessment of geotechnical and geochemical stabilities over time.

As required under the PRCP framework, this section addresses:

- *Long-term water balance modelling results of inflows, outflows and equilibrium lake levels of the residual voids;*
- *Interactions with groundwater, including drawdown, hydraulic head reduction and potential cones of depression;*
- *Potential for stratification and connection to surrounding groundwater systems;*
- *Flooding and drainage behaviours of nearby surface waters, and potential void interactions;*
- *Conceptual water balance model incorporating all projected inflows, outflows and recharge rates;*
- *Assessment of each major water flux into and out of the voids; and*
- *Identification of catchment surface water sources likely to influence void water quality.*

A void water balance assessment was completed by WRM (2026c) to evaluate the hydrological behaviour of the 15 residual voids following the completion of mining.

6.1 WATER BALANCE MODEL

A GoldSim water balance model was used to simulate the generation, movement, and loss of water on a daily time-step within a residual void over a 1,000-year period, commencing the year mining is estimated to cease in each individual void.

The Australian Government Consistent Climate Scenarios (CCS) project was used to generate climate change adjusted rainfall and evaporation data from an historical climate dataset for the period 1960 and 2024 (64 years). The CCS project provides climate projections as a daily time series across Australia on a 0.05-degree grid. The grid point closest to the centre of BWM was selected for the assessment.

The Shared Socioeconomic Pathway SSP2-4.5 was selected as the emission pathway with a base case global warming sensitivity for the Year 2070. The Year 2070 was selected as it represents a general mid-point for when mining ceases across all voids.

The 64 years of historical climate data adjusted rainfall and evaporation data was looped to create a long-term (1,000-year) climate sequence.

Pan evaporation was converted to Morton's Lake (mLake) and Morton's Wet (mWet) evapotranspiration to account for evapotranspiration losses from the pit lake and catchment.

The final landform design version 4.2 was used to generate the residual void geometries provided in Table 6-1. The year mining is estimated to cease in each void is also included in this table.

TABLE 6-1 RESIDUAL VOID GEOMETRIES

Residual Void	Year[1]	Floor Level	Crest Level	Depth	Volume to Crest	Surface Area at Crest
Unit	-	*mAHD*		*m*	*ML*	*ha*
Ramp 8	2031	109	175[2]	66	6,528	21.0
Bonnie Doon	2041	150	175[2]	26	3,633	30.3
Mimosa/Besgrove	2089	24	200	176	374,878	597.2
Deep Creek	2050	52	202	150	54,895	109.4
Stewarton North	2037	-4	204	208	302,582	380.1
Stewarton South	2037	92	232	140	42,632	82.5
Kenmare	2095	161	297	136	51,258	116.4
Togara/North Marshmead	2110	69	271	202	292,542	363.8
South Marshmead	2097	108	270	162	74,727	112.8
Kennedy	2093	99	221	122	93,791	192.8
Comet Downs East	2103	90	222	132	20,377	41.7
Ramp 74	2023	234	266	32	9,954	60.5
South Ballamoo	2101	84	290	206	376,755	447.9
Tannyfoil	2041	115	237	122	160,141	303.2
Ramp 30S	2027	139	217	78	16,316	59.7

[1] The year mining is estimated to cease in that void.

[2] 175 mAHD represents the internal crest level between Ramp 8 and Bonnie Doon residual voids. Both Ramp 8 and Bonnie Doon residual voids will spill to the receiving environment at 188 mAHD.

Source: WRM, 2026.

6.1.1 CATCHMENT AREAS

The catchments were derived from the final landform design version 4.2 and were assigned as either natural, spoil or rehabilitated spoil. The void floor was characterised as spoil. Catchment boundaries are shown in WRM (2026c) and are summarised in Table 6-2.

TABLE 6-2 RESIDUAL VOID CATCHMENT AREAS

Residual Void	Contributing Catchment (ha)			
	Natural	Spoil	Rehabilitated Spoil	Total
Ramp 8	33.7	22.0	21.8	77.5
Bonnie Doon	98.1	84.1	184.4	366.6
Mimosa/Besgrove	39.1	596.5	622.4	1,258

Residual Void	Contributing Catchment (ha)			
	Natural	Spoil	Rehabilitated Spoil	Total
Deep Creek	0	52.9	167.3	220.2
Stewarton North	0	195.2	678.1	873.3
Stewarton South	0	50.9	150.3	201.2
Kenmare	0	146.1	236.0	382.1
Togara/North Marshmead	7.4	458.0	249.1	714.5
South Marshmead	0	119.4	80.3	199.7
Kennedy	0	188.6	481.1	669.7
Comet Downs East	8.9	27.7	69.4	106.0
Ramp 74	10.1	58.3	112.9	181.3
South Ballamoo	0	365.0	267.4	632.4
Tannyfoil	0	388.1	458.6	846.7
Ramp 30	0	24.1	149.2	173.3

Source: WRM, 2026c.

6.1.2 MODEL PARAMETERS

The GoldSim model incorporates the Australian Water Balance Model (AWBM) to estimate daily runoff from daily rainfall. The adopted AWBM parameters are discussed further in WRM (2026c).

Groundwater inflow parameters were developed by SLR (2026) as an output of the hydrogeological assessment (Section 4).

6.2 RESIDUAL VOID WATER BALANCE

The water balance model was used to predict residual void water levels for all 15 voids over a 1,000-year simulation period. Predicted residual void lake levels for all residual voids are plotted in WRM (2026c) and summarised in Table 4-1.

No residual voids overtopped during the simulation period, with most residual voids maintaining more than 30 m freeboard above the mean predicted residual void lake levels. The largest freeboard of approximately 148.5 m occurs in the South Ballamoo residual void. Most residual void lakes reach an equilibrium within approximately 100 to 300 years (SLR, 2026). The residual void lake levels at Kennedy and Comet Downs East take longer to stabilise at approximately 400 and 450 years respectively.

An assessment of the impact of an extreme storm event was also undertaken. The extreme event selected for assessment was the 0.1% AEP 72-hour (3 day) design storm. To further increase the conservatism of the assessment, residual void lake levels were set to their peak modelled long-term water levels and runoff from the event was increased to 100% of the surface catchment reporting to the residual voids, i.e. no losses.

No residual voids overtopped during the event, with freeboards within the voids being maintained at more than 16 m for most residual voids and 6.8 m for Comet Downs East. A summary of the impact of the storm event is provided in Table 6-3.

TABLE 6-3 RESIDUAL VOID WATER BALANCE – STORM EVENT ASSESSMENT

Residual Void	Runoff Volume	Lake Level Increase	Final Volume	Storm Event Lake Level	Crest Level	Freeboard
Unit	*ML*	*m*	*ML*	*mAHD*		*m*
Ramp 8	221	2.2	2,180	148.7	188[1]	39.3
Bonnie Doon	1,045	5.3	1,430	159.8	188[1]	28.2
Mimosa/Besgrove	3,585	4.4	25,763	88.1	200	111.9
Deep Creek	628	2.6	9,741	137.1	202	64.9
Stewarton North	2,489	4.5	59,120	78.5	204	125.5
Stewarton South	573	11.6	732	115.5	232	116.5
Kenmare	1,089	3.5	6,152	221.5	297	75.5
Togara/North Marshmead	2,036	2.0	39,873	167.7	271	103.3
South Marshmead	569	2.9	10,211	174.0	270	96.0
Kennedy	1,909	2.4	26,516	168.8	221	52.2
Comet Downs East	302	1.8	10,334	193.0	222	29.0
Ramp 74	517	10.2	795	244.3	266	21.7
South Ballamoo	1,802	2.8	14,952	144.3	290	145.7
Tannyfoil	2,413	3.6	11,023	148.3	237	88.7
Ramp 30	494	19.3	892	162.6	217	54.4

[1] 188 mAHD represents the elevation at which the Ramp 8 and Bonnie Doon residual voids would spill to the receiving environment. The internal crest level between Ramp 8 and Bonnie Doon residual voids is 175 mAHD.

Source: WRM, 2026c.

6.2.1 INFLOWS AND OUTFLOWS

The residual void water balance is dominated by direct rainfall, evaporation and groundwater exchange, with runoff providing a secondary, episodic contribution (Table 6-4). Modelled void water levels over 1,000 years are presented in Section 6.3 below.

- Across all voids, direct rainfall and evaporation are the dominant and most persistent fluxes:
  - Direct rainfall occurs in approximately 47-85% of timesteps for most voids (locally as low as ~7.8% at Ramp 74). Mean direct rainfall inputs range from ~0.16 to 38.3 ML/month; and

    - Evaporation is active in >90% of timesteps at nearly all sites. Mean evaporation rates range from ~0.28 to 143.8 ML/month, indicating a strong evaporative control on long-term void water balance;
- Rainfall runoff is episodic and typically minor, occurring in ~25-39% of timesteps, with median values of zero across all voids. Mean runoff contributions are low (typically ~1.3 to 27.5 ML/month), although higher maximum values (up to ~3,000 ML/month at Mimosa/Besgrove) demonstrate that runoff can be significant during high-rainfall events;
- Groundwater inflows are persistent in several voids, occurring in >90% of timesteps at many locations, i.e. Ramp 8, Mimosa/Besgrove, Togara/North Marshmead, Kennedy, South Ballamoo and Tannyfoil:
    - Mean inflows range from ~0.0004 to 94.8 ML/month for these voids;
    - Median groundwater inflows are commonly elevated (e.g. ~73 ML/month at Mimosa/Besgrove and ~102 ML/month at Togara/North Marshmead), indicating sustained hydraulic connection with surrounding hydrostratigraphic units at these sites;
    - In contrast, some voids (e.g. Bonnie Doon, Stewarton North) exhibit negligible groundwater inflow;
- Groundwater outflows are variable and site-specific.
    - Groundwater outflows occur in a small proportion of timesteps (typically <2%) at most voids; however, persistent outflow occurs at Bonnie Doon (~84%), Stewarton North (~89%), South Marshmead (~66%), Ramp 30 (~63%) and Kenmare (~54%), indicating sustained discharge conditions at these sites.

Net groundwater fluxes, following mine completion, show three distinct behaviours based on net groundwater exchange:

- Persistent net inflow (no net outflow at any time): Ramp 8, Mimosa Besgrove, Togara/North Marshmead, Kennedy, Tannyfoil, South Ballamoo, Comet Downs East and Deep Creek.
- Persistent net outflow: Bonnie Doon, Ramp 30, Stewarton South and Ramp 74.
- Variable net flux (alternating net inflow and net outflow): Stewarton North, South Marshmead and Kenmare.

Through time, most voids stabilise towards consistent net behaviour (either inflow- or outflow-dominated).

Overall, the BWM residual voids are an evaporation-dominated system, with sustained groundwater inflow at many locations and net groundwater outflow at Bonnie Doon, Ramp 30, Stewarton South and Ramp 74.

As discussed in Section 4.1.2, the outflows from these residual voids will be captured by neighbouring residual voids at lower elevations. Evaporation acts as the primary control on water balance across all voids, consistently removing water over long periods and limiting the potential for net accumulation. While groundwater inflow provides an ongoing source of water at some locations, this input is spatially variable and does not occur uniformly across all voids.

In contrast, groundwater outflow is either absent, intermittent, or persistently focused at a limited number of voids, meaning that water is primarily redistributed within the void network rather than lost from the system. Runoff contributions are irregular and dependent on rainfall events, resulting in short-term increases in inflow that do not persist over time.

Together, these dynamics indicate that the void system functions as a semi-closed system, where long-term behaviour of the residual voids is governed by evaporative concentration processes and internal groundwater redistribution, rather than continuous throughflow.

TABLE 6-4 SUMMARY OF AVERAGE WATER BALANCE FLUXES OVER 1,000 YEARS

Residual Void	Runoff	Direct Rainfall	Evaporation	Groundwater		
				In	Out	Net
Unit	*ML/month*					
Ramp 8	1.33	4.46	-16.7	11.1	0	+11.1
Bonnie Doon	7.89	1.85	-6.46	0.00036	-3.23	-3.23
Mimosa/Besgrove	27.5	34.7	-130	70.4	-0.076	+70.3
Ramp 30	4.15	0.555	-1.85	0.107	-2.95	-2.84
Deep Creek	4.58	9.87	-37.1	23.9	-0.473	+23.4
Stewarton North	19.3	20.3	-76.2	38.5	-0.471	+38.0
Stewarton South	4.80	1.27	-4.61	0.047	-1.46	-1.41
Tannyfoil	18.8	22.9	-86.0	45.3	-0.026	+45.3
South Ballamoo	13.5	23.7	-89.0	53.1	-0.066	+53.0
Kenmare	8.57	8.37	-31.5	15.1	-0.061	+15.0
Ramp 74	4.30	0.163	-0.276	0.304	-4.50	-4.20
Togara/North Marshmead	14.2	38.3	-144	94.8	0	+94.8
South Marshmead	4.03	9.91	-37.2	24.3	-0.070	+24.2
Kennedy	13.6	28.2	-106	66.6	0	+66.6
Comet Downs East	1.74	10.1	-37.8	27.1	-0.224	+26.9

Source: Adapted from BWM_PRCP_Rev3_FV_Outputs_HYDROBALANCE.xlsx dated 20 May 2026.

6.3 MODELLED RESIDUAL VOID LAKE LEVELS

Long-term residual void lake water levels for all BWM residual voids as modelled over 1,000 years are presented in Figure 6-1 to Figure 6-15 (WRM, 2026c).

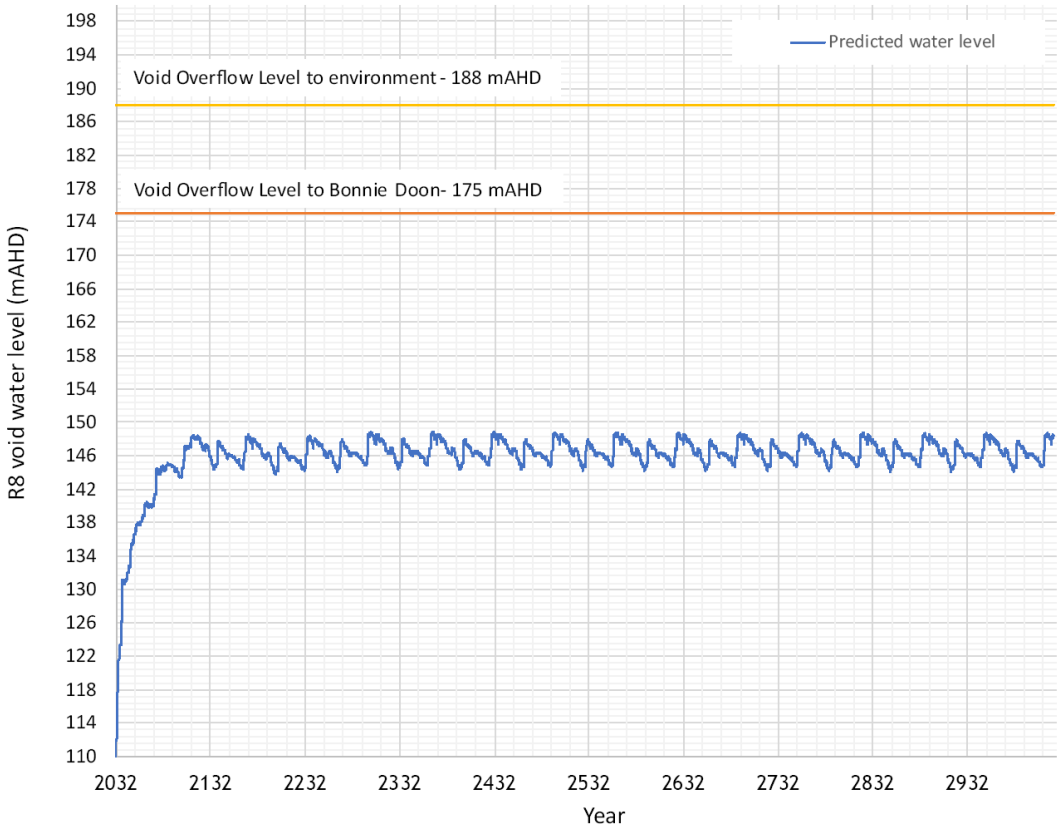


FIGURE 6-1 MODELLED RAMP 8 RESIDUAL VOID LAKE WATER LEVELS

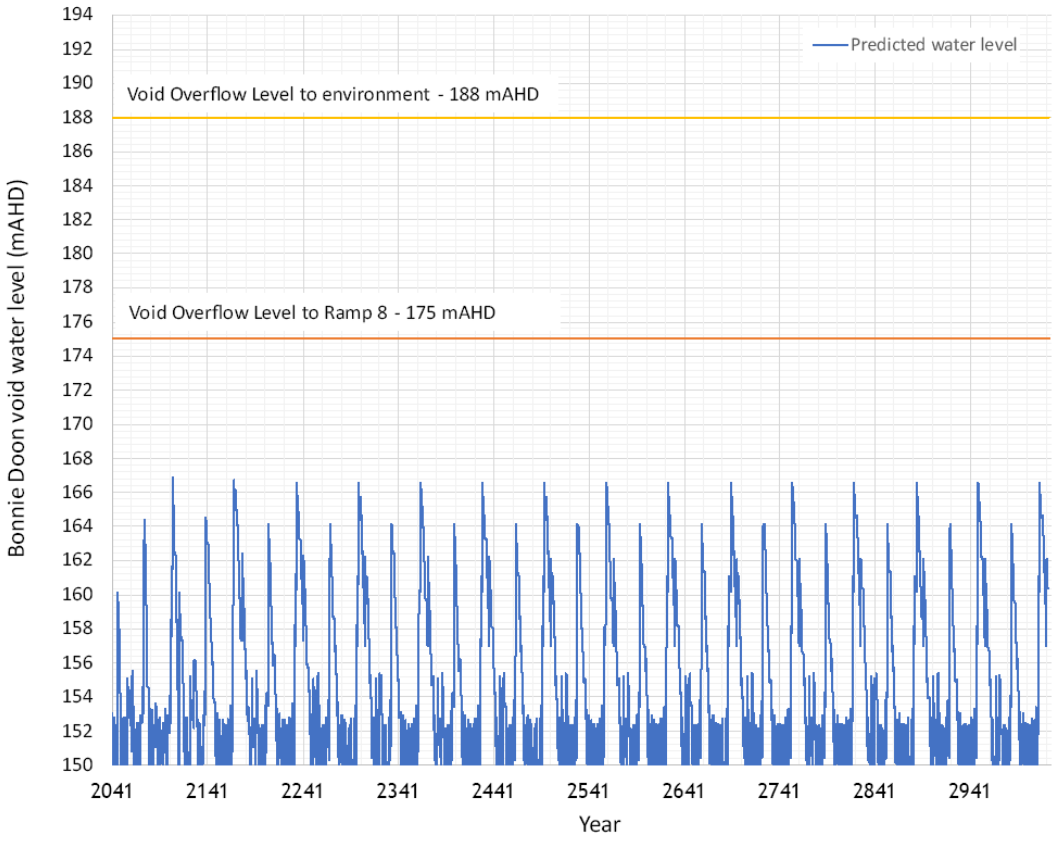


FIGURE 6-2 MODELLED BONNIE DOON RESIDUAL VOID LAKE WATER LEVELS

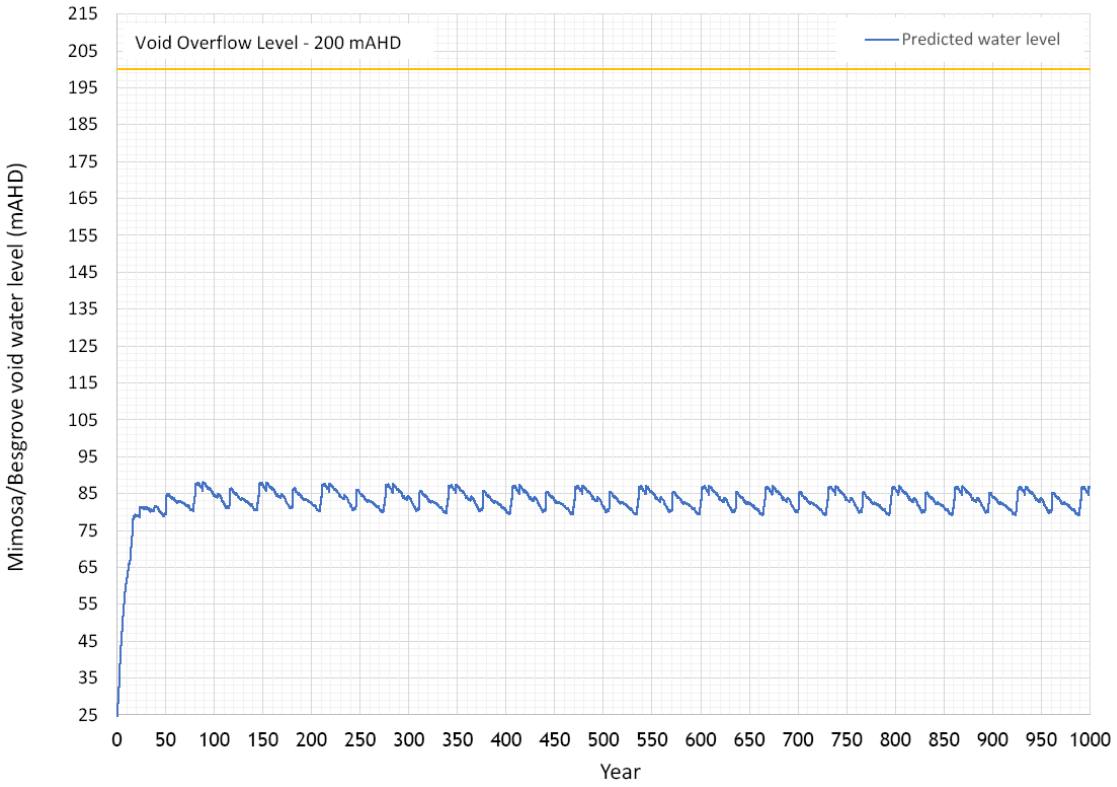


FIGURE 6-3 MODELLED MIMOSA/BESGROVE RESIDUAL VOID LAKE WATER LEVELS

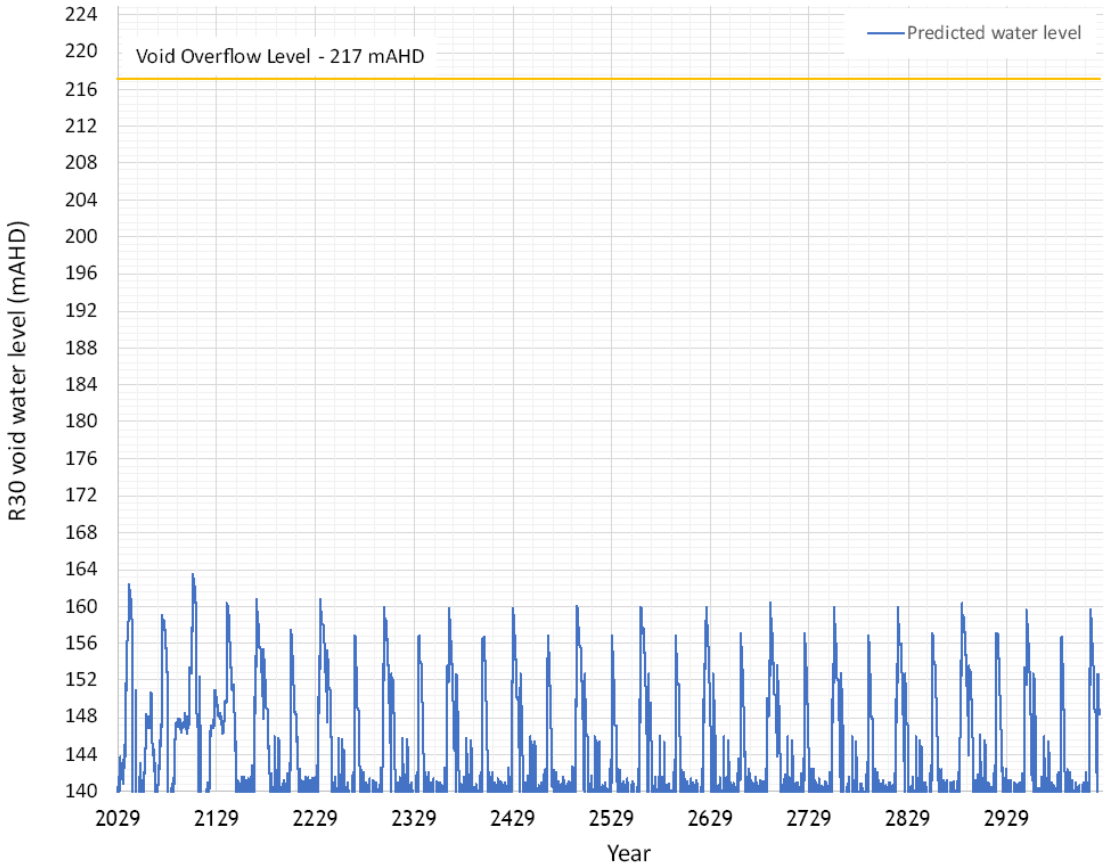


FIGURE 6-4 MODELLED RAMP 30 RESIDUAL VOID LAKE WATER LEVELS

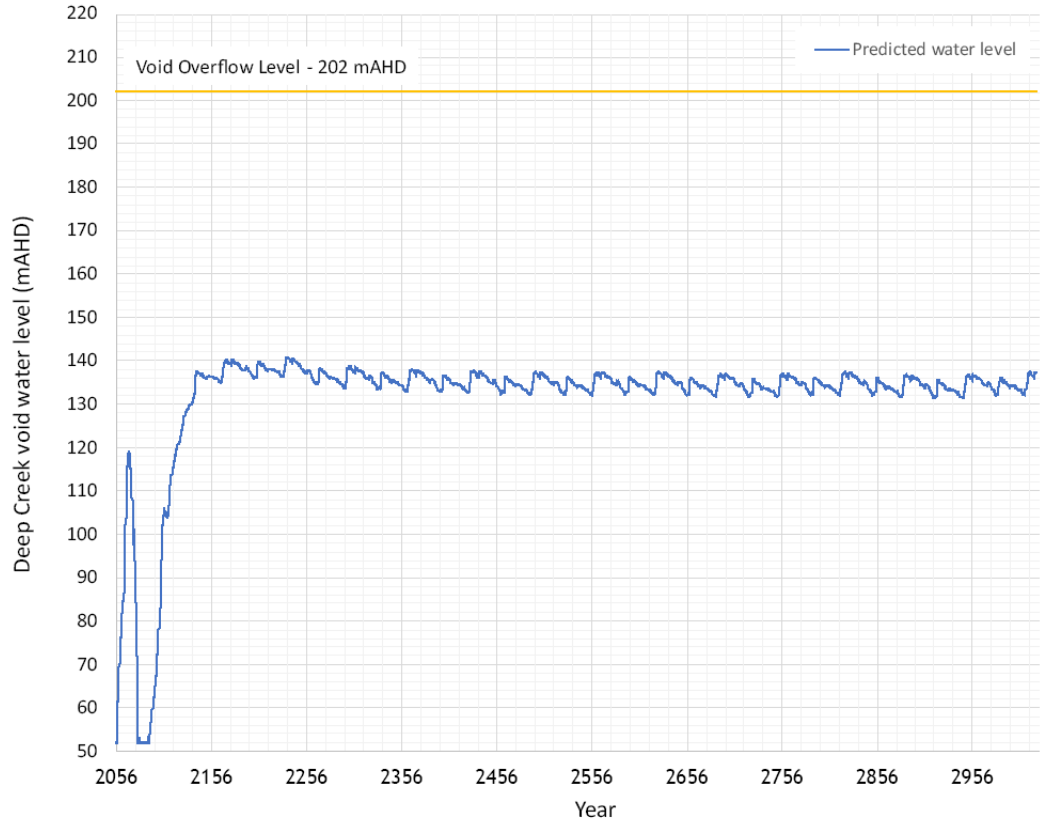


FIGURE 6-5 MODELLED DEEP CREEK RESIDUAL VOID LAKE WATER LEVELS

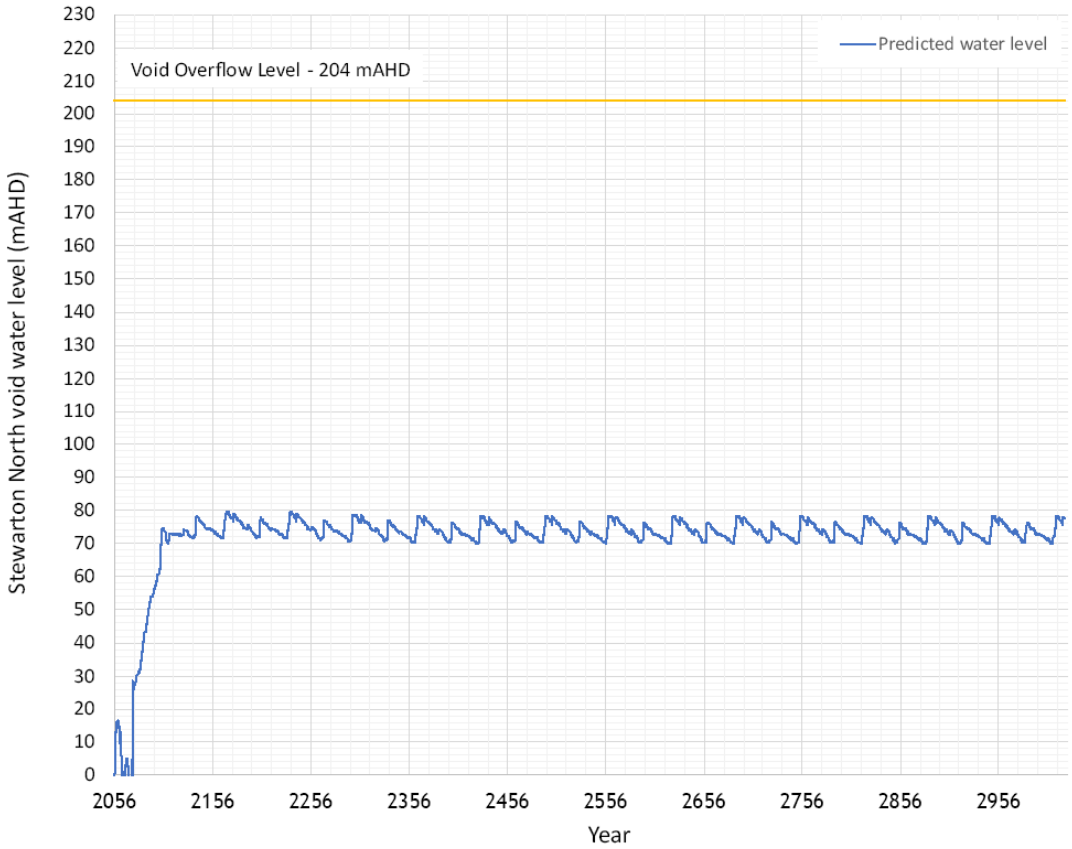


FIGURE 6-6 MODELLED STEWARTON NORTH RESIDUAL VOID LAKE WATER LEVELS

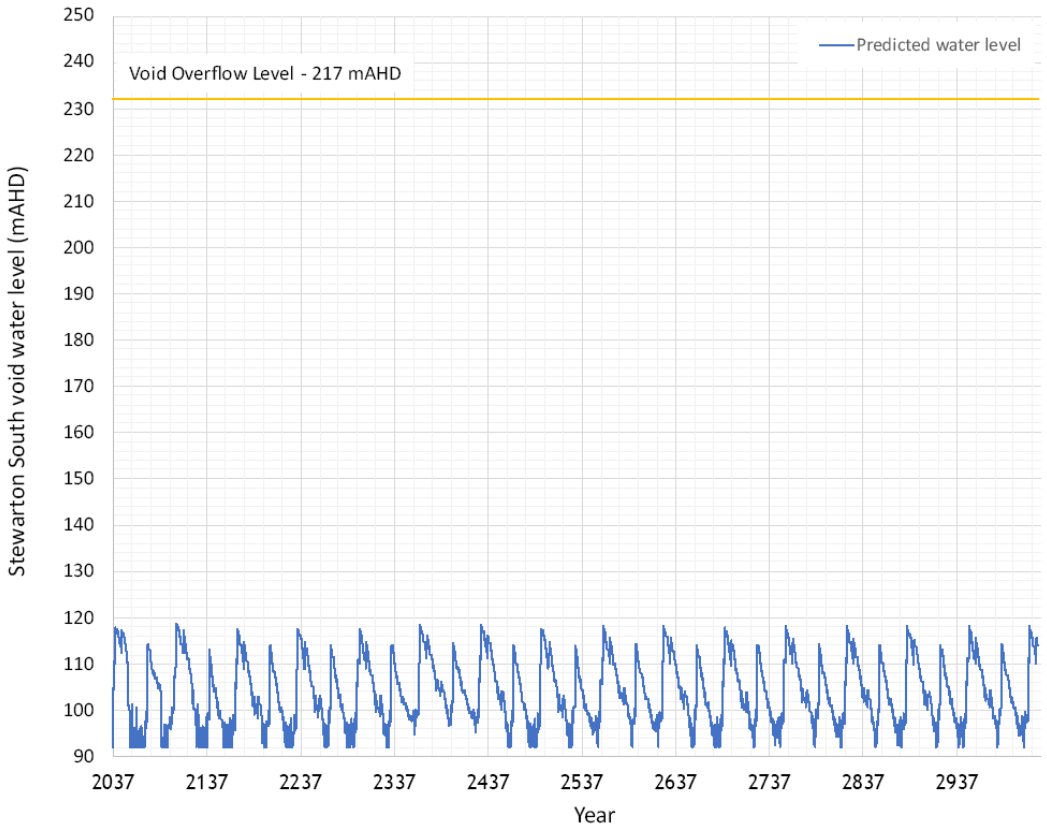


FIGURE 6-7 MODELLED STEWARTON SOUTH RESIDUAL VOID LAKE WATER LEVELS

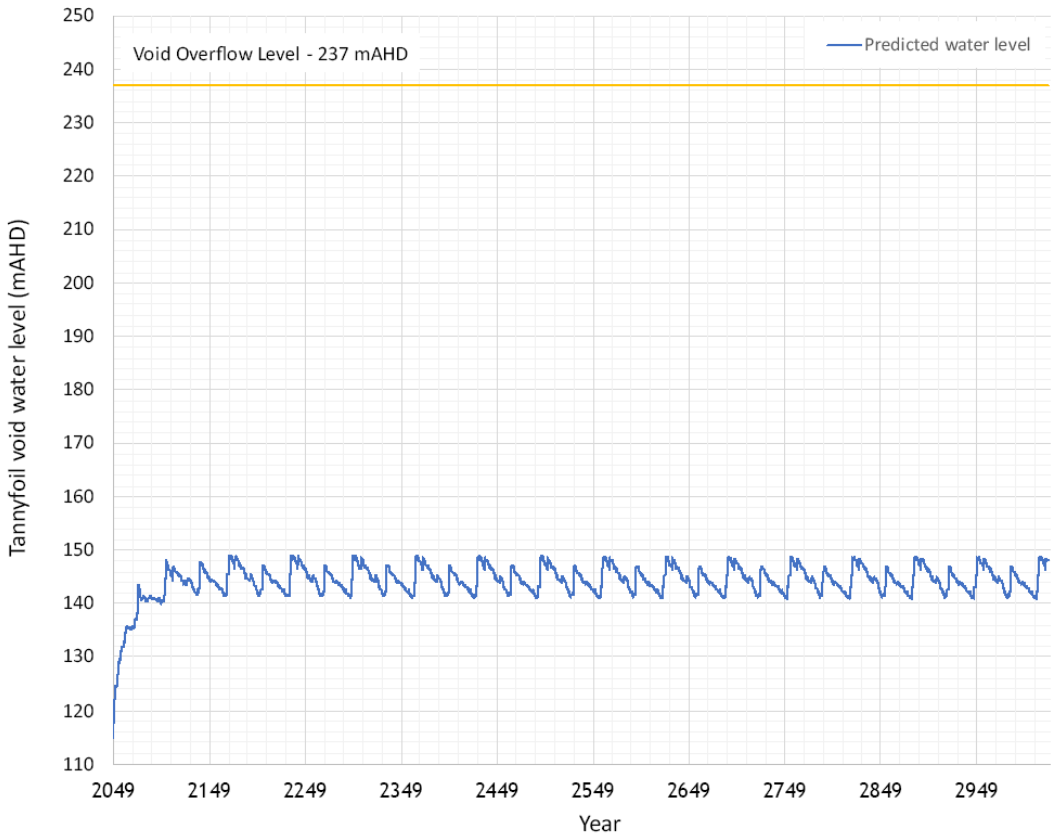


FIGURE 6-8 MODELLED TANNYFOIL RESIDUAL VOID LAKE WATER LEVELS

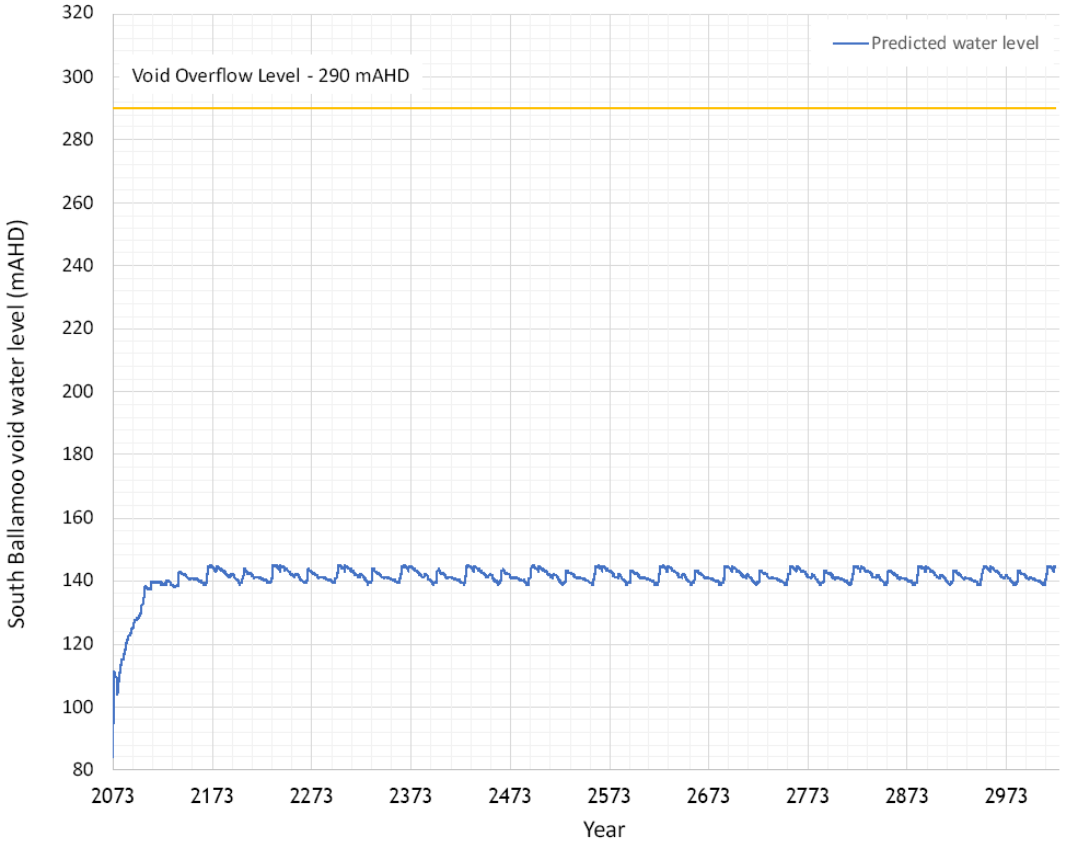


FIGURE 6-9 MODELLED SOUTH BALLAMOO RESIDUAL VOID LAKE WATER LEVELS

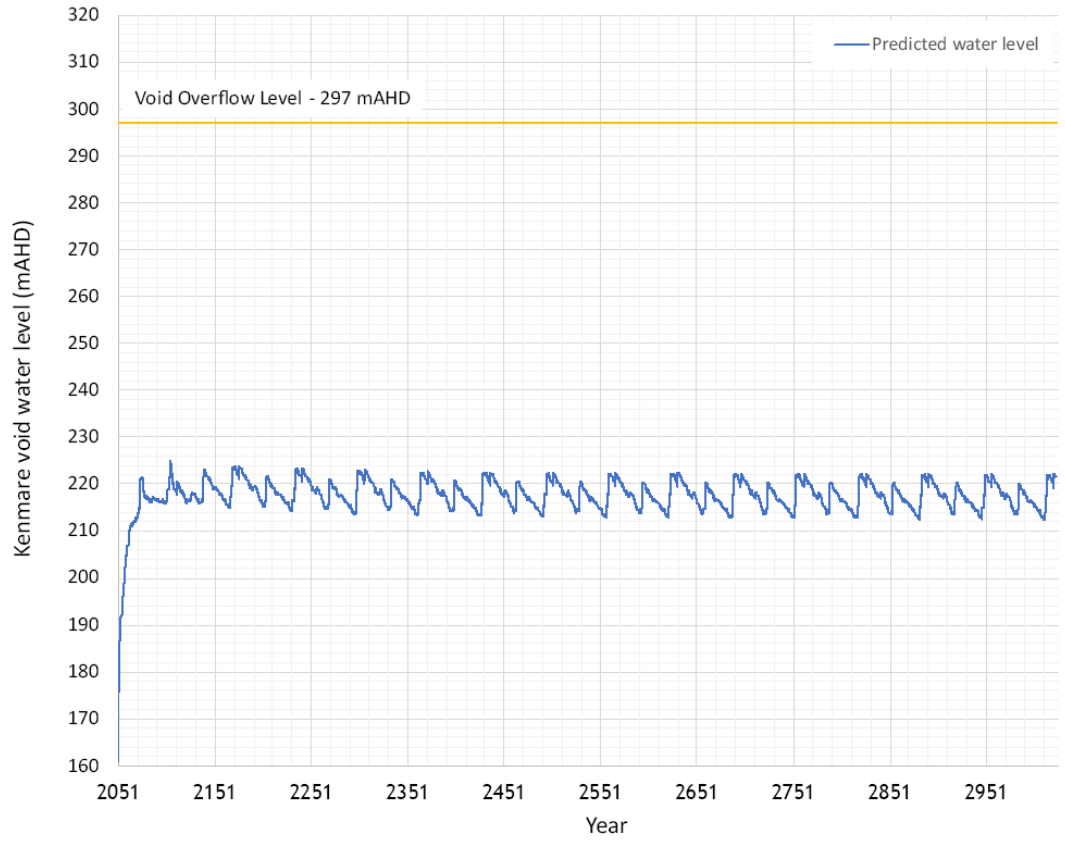


FIGURE 6-10 MODELLED KENMARE RESIDUAL VOID LAKE WATER LEVELS

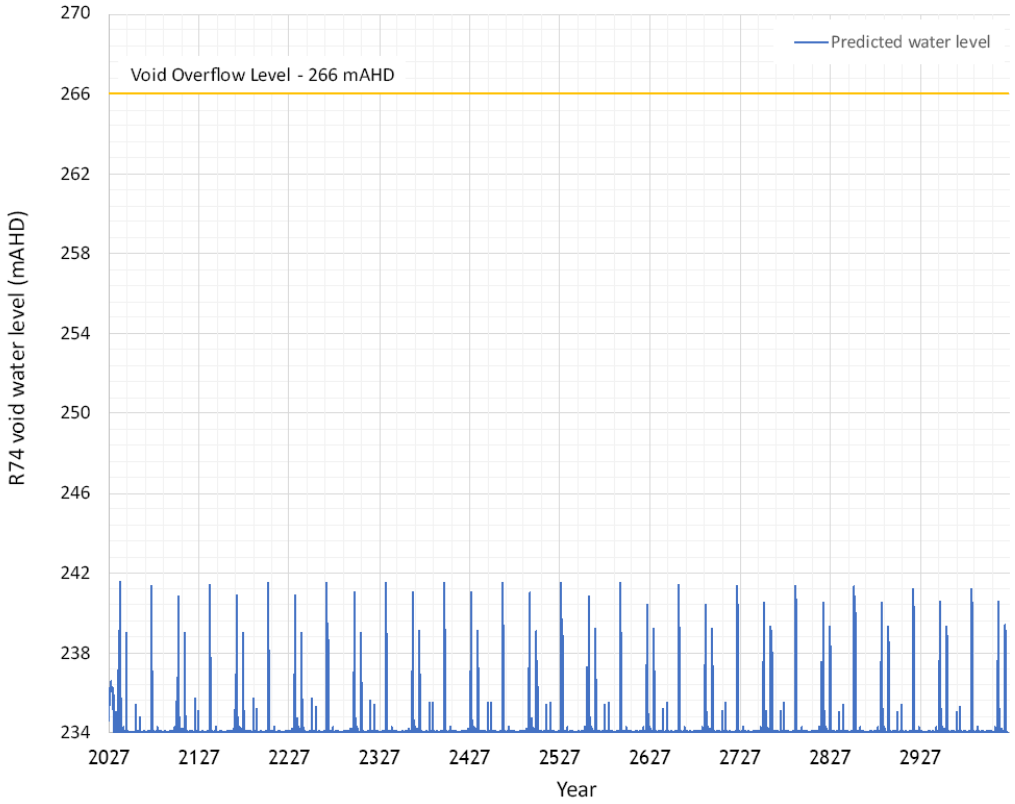


FIGURE 6-11 MODELLED RAMP 74 RESIDUAL VOID LAKE WATER LEVELS

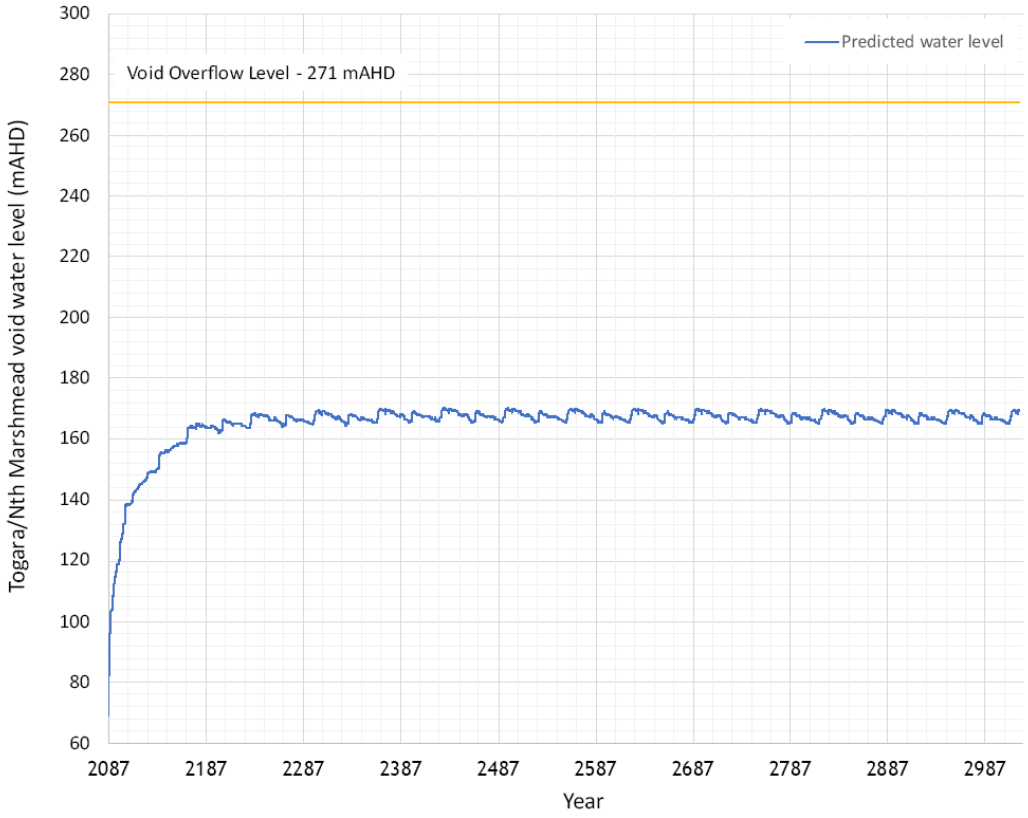


FIGURE 6-12 MODELLED TOGARA/NORTH MARSHMEAD RESIDUAL VOID LAKE WATER LEVELS

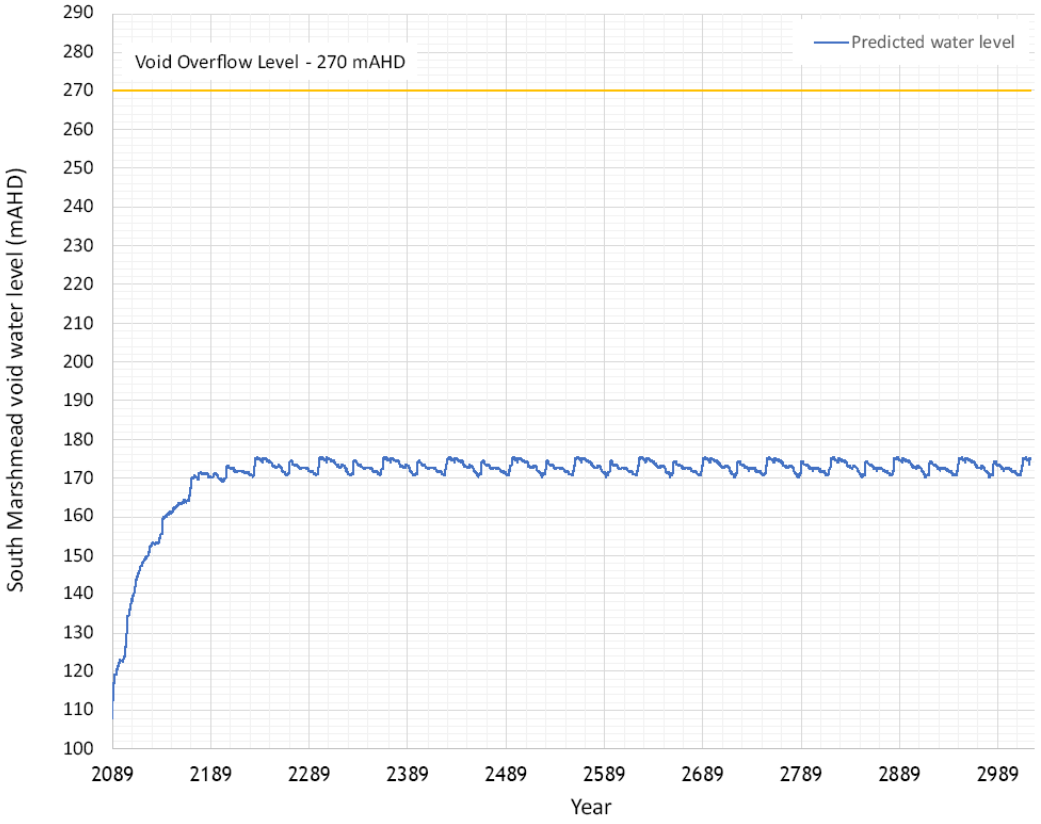


FIGURE 6-13 MODELLED SOUTH MARSHMEAD RESIDUAL VOID LAKE WATER LEVELS

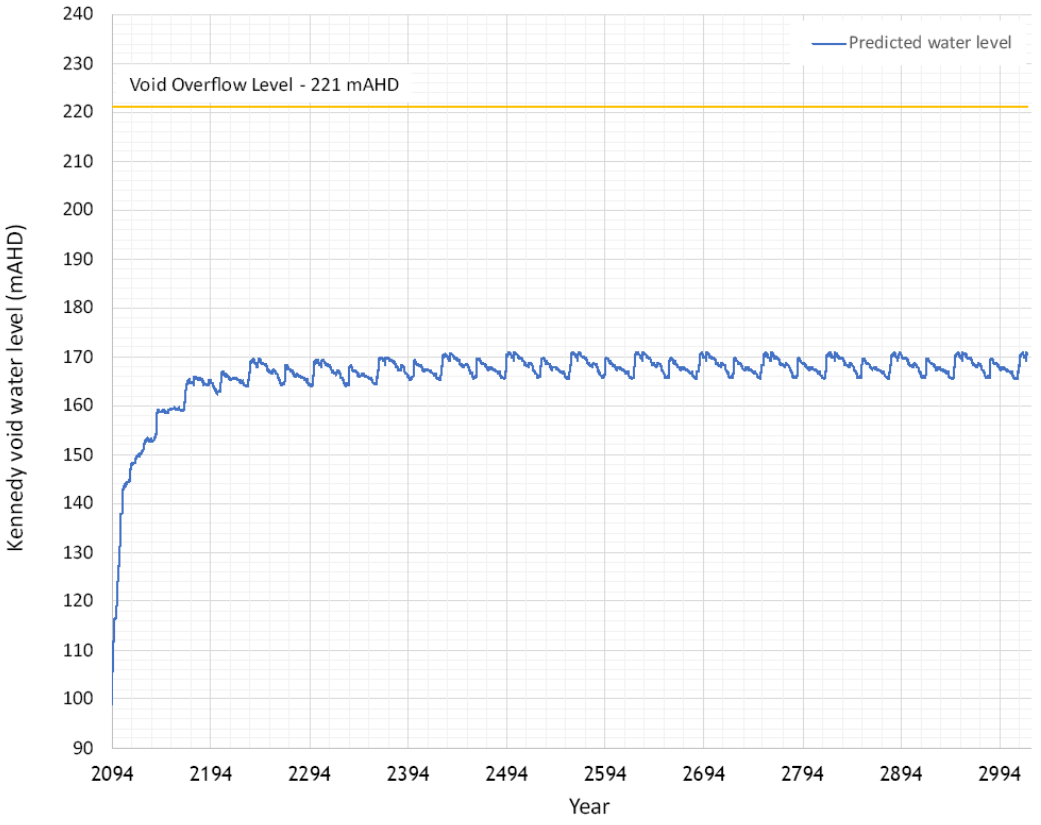


FIGURE 6-14 MODELLED KENNEDY RESIDUAL VOID LAKE WATER LEVELS

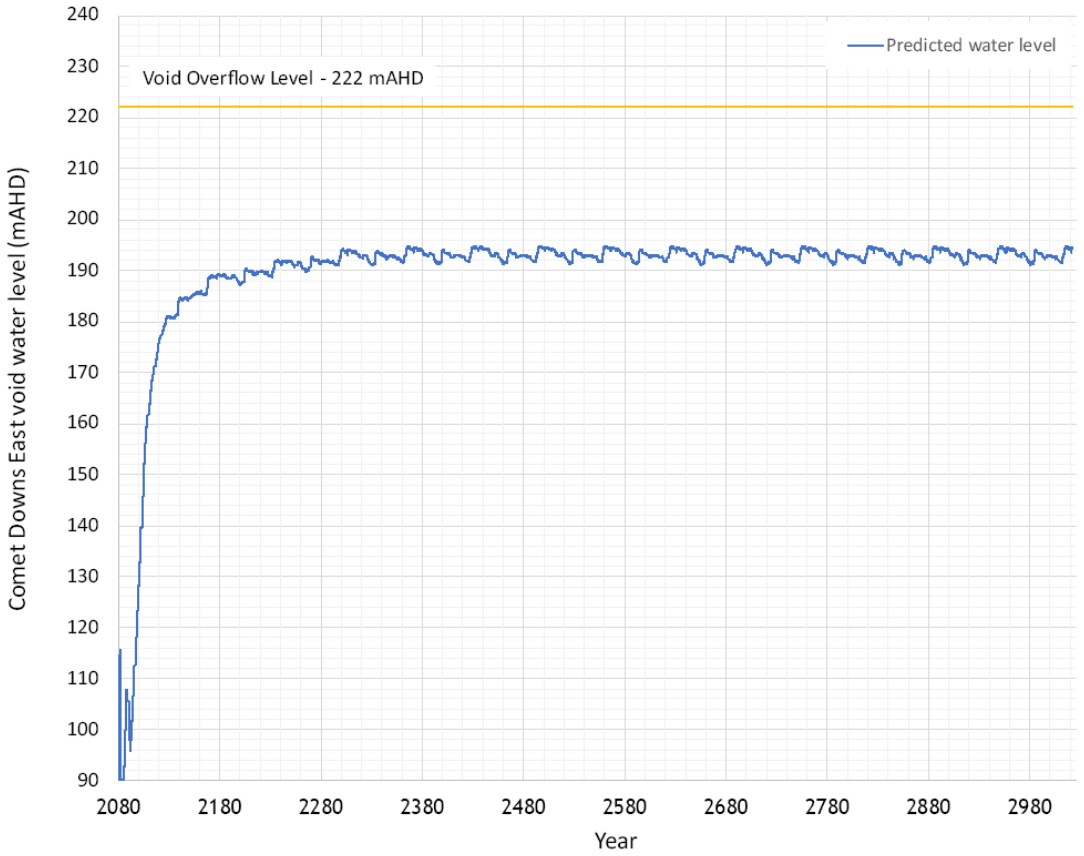


FIGURE 6-15 MODELLED COMET DOWNS EAST RESIDUAL VOID LAKE WATER LEVELS

6.4 CONCLUSIONS

Water balance modelling for the 15 proposed residual voids at BWM demonstrates:

- Residual void lakes reach an equilibrium level within 100 to 500 years after mining ceases, with most voids equilibrating within 100 to 300 years;
- The peak modelled water level is below the pit crest level for all residual voids and there are no modelled spills to the receiving environment over the 1,000-year simulation period, with freeboard typically exceeding 30 m and increasing to approximately 150 m in the largest voids:
  - No residual voids overtopped during the 1,000-year simulation period under the SSP2-4.5 emission pathway;
- The extreme storm event assessment shows runoff from a 0.1% AEP 72-hour storm event (with zero losses) is unlikely to result in an overflow to the receiving environment, with no overtopping predicted and freeboard maintained at more than 21 m in all residual voids; and
- Several residual void lakes (e.g. Ramp 8, Bonnie Doon and Ramp 74) exhibit cyclical behaviour, periodically approaching empty conditions during extended dry periods, indicating sensitivity to climatic variability. Water balance fluxes are dominated by evaporation, with sustained groundwater inflow at selected voids and generally negligible groundwater outflow. Runoff contributions are episodic, indicating that void behaviour is controlled by long-term evaporative losses rather than continuous throughflow.

7. GEOTECHNICAL STABILITY

This section assesses the geotechnical stability of the final void landforms. It is required to demonstrate that the landform is safe and stable over time under PRCP Section 3.6.3.

In summary, this section covers the following:

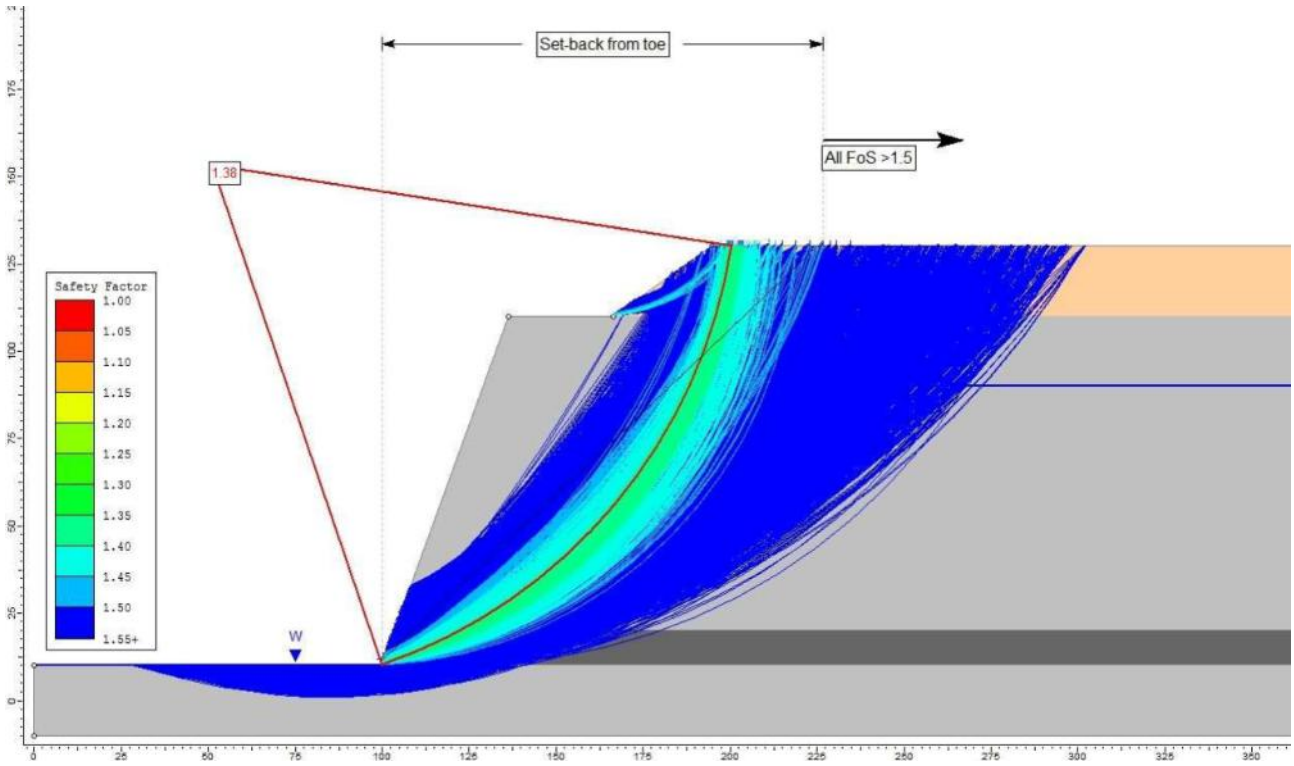
- *How post-closure void slopes will be stable and consistent with closure planning objectives;*
- *Measures to achieve geotechnical stability (e.g. backfilling, regrading, buttressing, benching):*
  - *Techniques for creating safe slope configurations must be specified where relevant.*
- *Potential effects of long-term erosion, weathering and hydrological impacts; and*
- *Proposed final slope angles of high-walls, low-walls and end-walls of each residual void.*

Geotechnical assessments were completed by Henderson Geotech (2026a; 2026b) to show that the conceptual high-wall, end-wall and low-wall slopes of the BWM residual voids within the final landform design are expected to remain stable in the long-term. This section outlines the key findings of the geotechnical stability assessments as they relate to the residual voids.

7.1 HIGH-WALL AND END-WALL STABILITY ASSESSMENT

The limit equilibrium method was used to assess the stability of the BWM residual void highwalls and endwalls. This method compares the resisting forces along a potential failure surface to the driving forces that could cause movement. It calculates a FoS, which is the ratio of these forces. A FoS greater than 1 indicates the slope is stable. A FoS less than 1 means instability is likely. For closure at BWM, a FoS of 1.5 has been adopted.

To avoid having to unnecessarily disturb more land by laying back the wall crest to achieve a FoS ≥1.5, the FoS is used to inform a set-back distance from the toe of the wall and in turn inform the boundary of the residual void NUMA. At closure, no third-party assets or PMLUs will be within zones where the FoS ≤1.5. This concept is demonstrated in Figure 7-1.



Source: BHP, 2023.

FIGURE 7-1 DEFINING THE SET-BACK DISTANCE/NUMA BOUNDARY USING A FoS ≥ 1.5.

A design tool, developed by the previous owner of BWM and based on a large number of stability analyses covering the range of expected scenarios for Bowen Basin coal mines, has been used to define the set-back distances for 11 of the 15 residual voids in the final landform design. Further details on the tool, its development and the bounds within which it can be used are provided in Henderson Geotech (2026a).

The geometries of the Bonnie Doon and Ramp 74 residual voids where outside the bounds of the design tool with depths of fresh Permian being <50 m due to both voids being partially backfilled with tailings. Auger mining of the Ramp 74 highwall also precluded the use of the tool in this void. The design tool is also not suitable for assessing the wall stability of Comet Downs East as the residual void lake is predicted to be above the base of weathering (Section 4 and Section 6). Bespoke geotechnical stability analyses were undertaken for those residual voids using the same general approach and material properties as the design tool. The Slide2 Modeler, 2D Limit Equilibrium Analysis for Slopes was used to perform these analyses.

7.1.1 WEATHERING AND EROSION

In rare cases, minor weathering (physical and/or chemical) may affect geotechnical stability post-closure. For example, if weak, degradable rock lies beneath stronger layers, the weaker material may break down and fall away, leaving the stronger layer unsupported. This could lead to localised failures. These situations are generally only discovered during excavation. They cannot be fully predicted during planning but will be assessed and managed at the detailed design stage once mining ends (Henderson Geotech, 2026a).

On highwalls and endwalls in the Bowen Basin, erosion in fresh rock is generally minimal. Most erosion is limited to slaked or weathered material, as fresh, intact rock is too strong to break apart easily. Above the base of weathering, particles are more easily detached, and erosion can occur along flow paths.

In rare cases, intersecting erosion gullies could form a wedge-type failure. However, these are managed using surface water and erosion control measures, not by altering slope design. Overall, weathering and long-term erosion are not expected to significantly impact pit wall stability (Henderson Geotech, 2026a).

7.1.2 SIGNIFICANT HYDROGEOLOGICAL EVENTS

Water balance modelling for the BWM residual voids (see Section 6) indicates that long-term average void water levels will remain tens of metres below the base of weathering. Therefore, water is only expected to contact fresh rock. As a result, no adverse impact on pit wall stability is anticipated from long-term water storage in the voids (Henderson Geotech, 2026a).

The most serious potential impact of severe rainfall events would be inrush of floodwaters to the void. However, this scenario will be prevented by including appropriate drainage diversions and landforms to protect the voids from inundation (Section 5).

Draw-down failure is the other mode of instability related to water storage. Draw-down failure can occur when pore water pressures in the containing earth and rock have equilibrated with the water level in the storage and that water level is then lowered quicker than the containing materials can drain and the pore pressures are no longer balanced. This is not considered a risk for the BWM residual voids as evaporation will not lower the water level quick enough to establish this imbalance. Due to the propensity of some of the residual void lakes to become hypersaline, the water is not anticipated to be useful for typical agricultural uses post closure. However, should a novel use for residual void lake water arise in the future that involves movement of large volumes of water, such as pumped hydro energy storage, stability under draw-down will need to be considered.

7.1.3 LOCAL MODEL INPUTS

Long sections extracted from the current geological model provided void wall profile data. This data is summarised in Table 7-1.

TABLE 7-1 GEOTECHNICAL PROFILES FOR RESIDUAL VOID WALLS

Residual Void	Depth of Tertiary/ Weathered Overburden			Depth of Fresh Overburden			Total Wall Depth		
	Ave.	Range	>90%	Ave.	Range	>90%	Ave.	Range	>90%
Unit	m								
Ramp 8	16	14-18	-	60	53-68	-	76	67-87	-
Bonnie Doon	15	10-21	21	13	0-40	33	29	10-50	45
Mimosa/ Besgrove	18	7-27	25	138	68-175	169	156	91-196	190

Residual Void	Depth of Tertiary/ Weathered Overburden			Depth of Fresh Overburden			Total Wall Depth		
	Ave.	Range	>90%	Ave.	Range	>90%	Ave.	Range	>90%
Deep Creek	12	11-12	12	118	90-147	145	130	101-159	157
Stewarton North	15	11-24	21	152	68-202	197	167	82-213	213
Stewarton South	20	15-24	24	104	59-126	123	124	83-141	139
Kenmare	47	38-53	52	106	82-124	120	153	131-163	163
Togara/North Marshmead	71	24-97	89	156	125-199	187	227	169-270	260
South Marshmead	67	54-82	79	118	104-125	125	185	157-206	204
Kennedy	34	28-43	41	84	57-126	114	118	90-167	148
Comet Downs East	36	35-37	-	97	96-97	-	134	133-135	-
Ramp 74	20	14-28	23	6	0-11	9	26	22-30	30
South Ballamoo	61	45-81	77	192	148-224	222	253	215-290	286
Tannyfoil	16	12-23	21	114	79-135	132	130	101-151	149
Ramp 30	11	11-12	-	72	70-72	-	75	62-83	-

Note: - indicates insufficient data to calculate values.

Source: Henderson Geotech (2026a).

For the three bespoke analyses, a typical cross-section was considered for each void. More precise geotechnical profiles were used, in particular with Tertiary overburden and weathered Permian overburden differentiated. Pit lake levels and hydraulic properties were adopted from, or broadly consistent with those provided in SLR (2026). The specific details used for analysis of these residual voids are provided in Henderson Geotech (2026a).

7.1.4 ASSESSMENT RESULTS

Highwall and endwall stability assessment results for the 11 residual voids assessed using the design tool are summarised in Table 7-2. The complete computations are provided in Henderson Geotech (2026a). Results are provided for average fresh Permian wall angles of 50° and 60°. Set-back distances will determine the boundary of the NUMAs adjacent to the highwalls and endwalls.

TABLE 7-2 HIGHWALL AND ENDWALL SET-BACKS TO ACHIEVE FoS≥1.5 (DESIGN TOOL)

Residual Void	Set-back Distance from Wall Toe (m)					
	50°[1]			60°[1]		
	Ave.	Range	>90%	Ave.	Range	>90%
Ramp 8	104	95-113	111	99	91-96	94
Mimosa/Besgrove	180	120-248	236	176	102-249	236
Deep Creek	146	121-171	169	136	98-180	175
Stewarton North	207	107-295	290	201	89-298	293
Stewarton South	146	113-157	157	124	98-142	138
Kenmare	186	169-198	195	163	147-175	173
Togara/North Marshmead	298	186-389	367	299	193-392	369
South Marshmead	232	194-273	267	213	167-253	249
Kennedy	149	125-195	173	129	110-183	144
South Ballamoo	356	277-434	423	359	277-438	427
Tannyfoil	148	122-166	163	129	99-161	153
Ramp 30	100	89-107	-	83	76-88	-

[1] *Average wall angle of fresh Permian overburden.*

Note: - indicates insufficient data to calculate values.

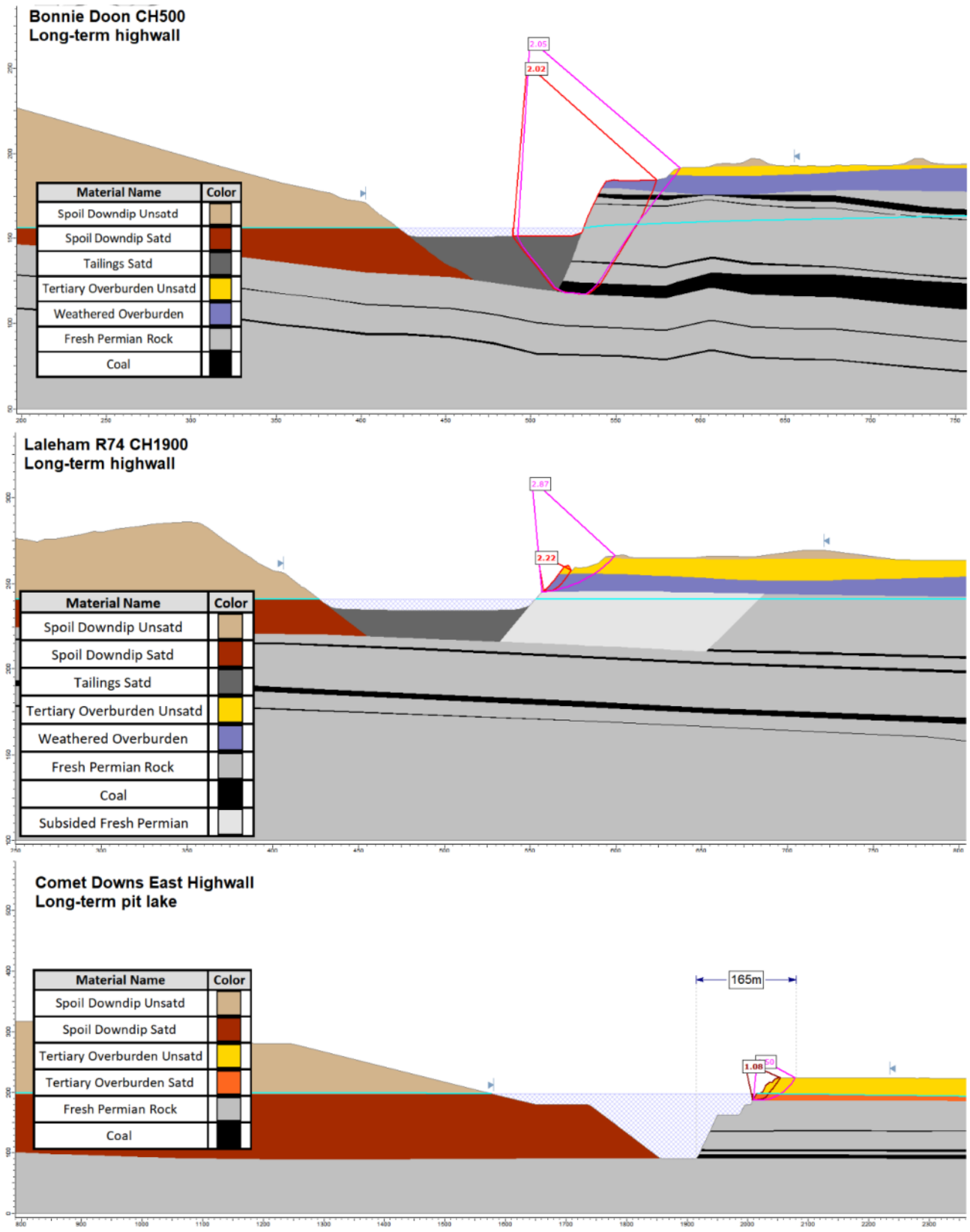
Source: Henderson Geotech (2026a).

The results of the bespoke analysis completed for Bonnie Doon, Ramp 74 and Comet Downs East is summarised in Table 7-3 and shown in Figure 7-2.

TABLE 7-3 LONG-TERM WALL STABILITY (BESPOKE ANALYSIS)

Design Property	*Unit*	Bonnie Doon (CH500)	Ramp 74 (CH1900)	Comet Downs East
Tertiary overburden	*m*	12	10	24
Weathered Permian overburden		29	10	11
Water cover below base of weathering		24	4	-11
Water depth		5	7	107
Tailings depth		32	18	N/A
Assumed angle of draw	*(°) Degrees*	N/A	60	N/A
Min. FoS	-	2.02	2.22	1.08
Set-back from wall toe to FoS≥1.5	*m*	Crest	Crest	165

Source: Henderson Geotech (2026a).



Source: Henderson Geotech (2026a)

FIGURE 7-2 BESPOKE STABILITY ANALYSIS RESULTS

7.2 LOW-WALL STABILITY

The geotechnical stability of selected residual void low walls was assessed to understand landform stability over the long-term. Eight cross sections were selected to represent, typical low walls, areas with the highest spoil, steepest floor dip and the deepest residual void lake. Analysis was completed on low walls of the following residual voids:

- Tannyfoil;
- South Marshmead;
- Stewarton North;
- Mimosa/Besgrove;
- Togara/North Marshmead;
- Comet Downs East;
- South Ballamoo; and
- Bonnie Doon.

The cross-sections were analysed using Slide2 Modeler, 2D Limit Equilibrium Analysis for Slopes. The analytical methods used initially were Morgenstern/GLE - Vertical Slices - Circular Surfaces and Sarma - Vertical Slices - Non-Circular Surfaces, both with Auto Refine Search Method. Groundwater and residual void pit lake levels used in the analysis were sourced from SLR (2026). The following three groundwater scenarios were applied in geotechnical stability analyses for each cross-section:

- End-of mining;
- Long-term equilibrium post-mining, and
- Interim condition, with pit lake half the long-term depth and total head boundaries mid-way between end-of-mining and long-term.

7.2.1 ASSESSMENT RESULTS

The results of the low wall stability analysis are provided in Figure 7-3 to Figure 7-10 (Henderson Geotech, 2026b). These results have been used to assist with defining several NUMA boundaries on the low wall side of the residual voids. This has led to a reduction in the area of NUMA and an increase in the area of PMLU.

A consequence category assessment for the low walls was undertaken in Henderson Geotech (2026b) and concluded there was:

- Negligible consequence for geotechnical instability within the NUMAs;
- Low consequence for geotechnical instability that extends into the Woodland PMLUs; and
- Low consequence for geotechnical instability that extends into the Grazing PMLUs.

Low wall PMLUs are expected to be geotechnically stable and achieve a FoS≥1.5 based on current NUMA boundaries. The geotechnical model and/or slope geometry within the NUMA should be reassessed as each pit approaches its final configuration when more detailed spoil characterisation is available and observation may justify changes to the conservative strength parameters applied in this initial stability analyses. During the final stages of operation, void design details can be refined to optimise the final landform and confirm it will achieve the required degree of stability in the long-term.

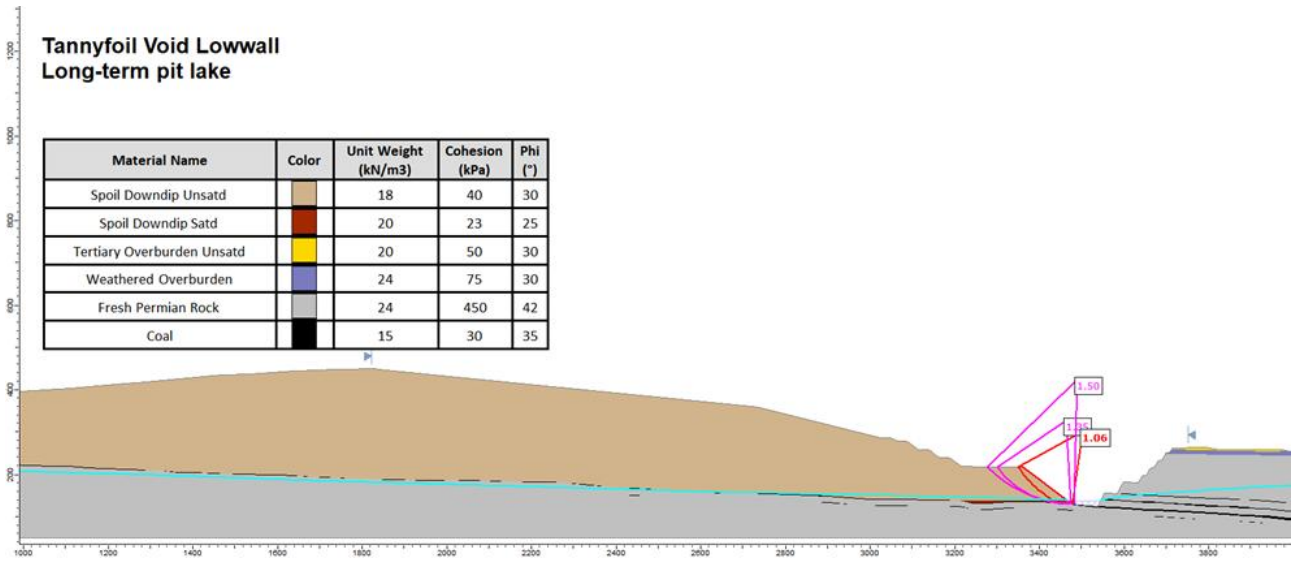


FIGURE 7-3 TANNYFOIL LOW WALL STABILITY ANALYSIS RESULTS

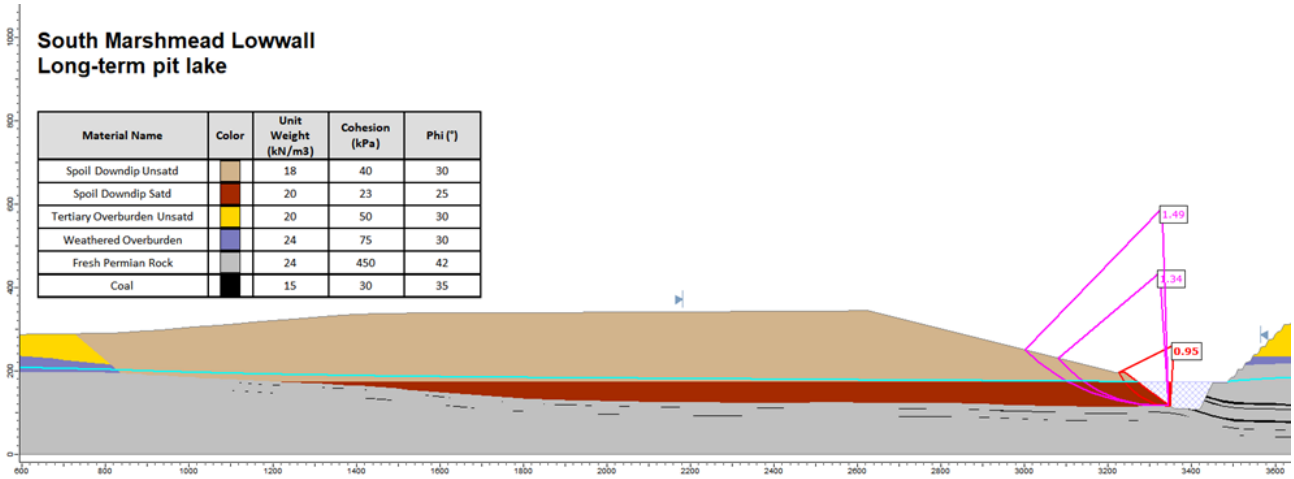


FIGURE 7-4 SOUTH MARSHMEAD LOW WALL STABILITY ANALYSIS RESULTS

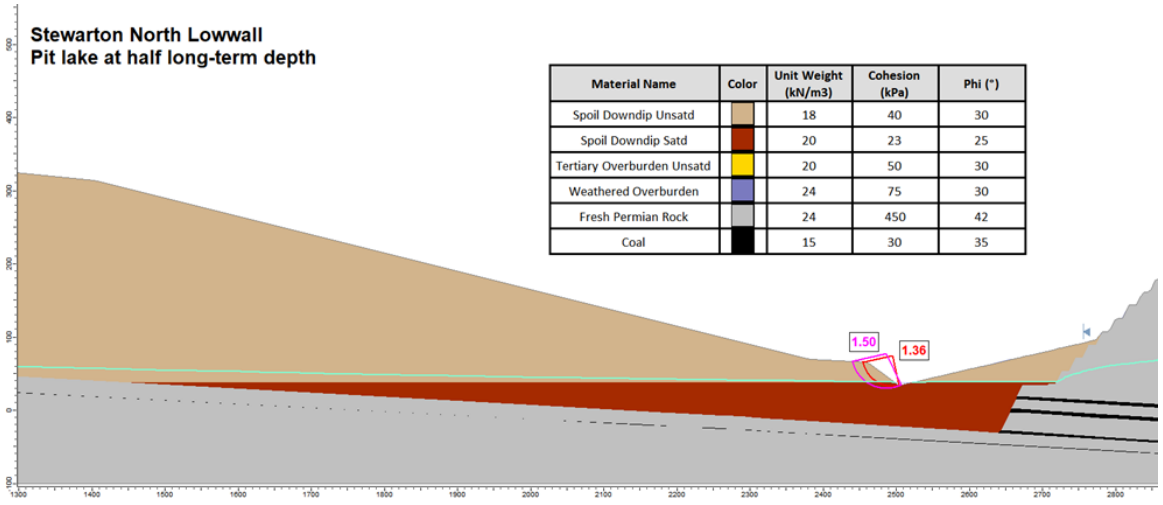


FIGURE 7-5 STEWARTON NORTH LOW WALL STABILITY ANALYSIS RESULTS

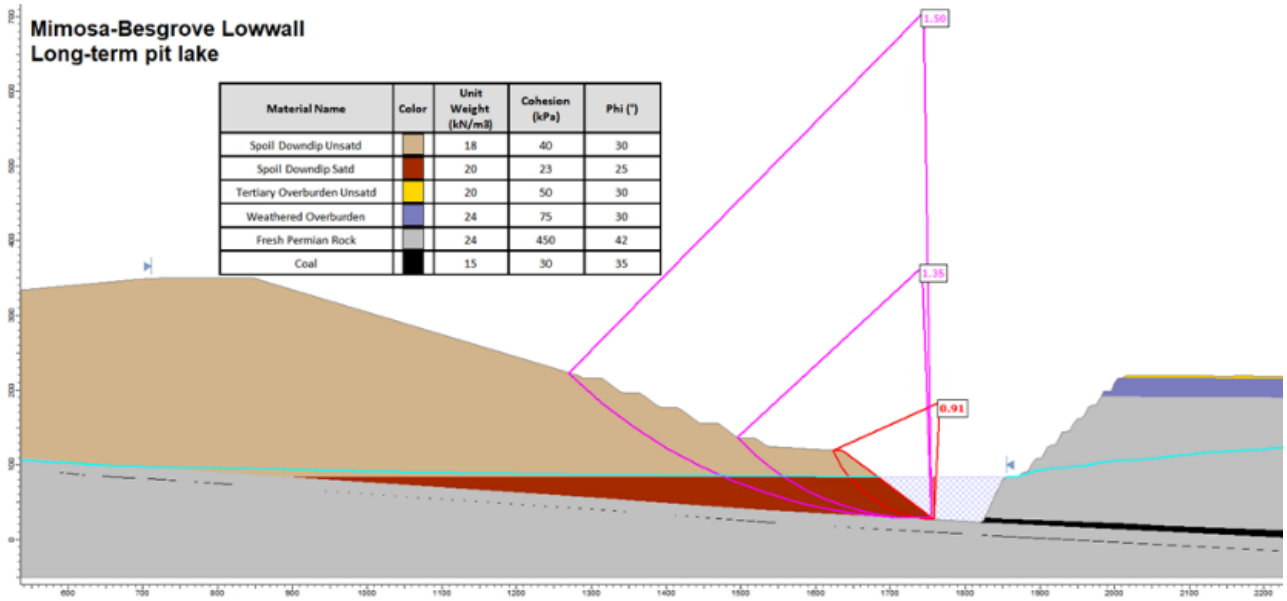


FIGURE 7-6 MIMOSA/BESGROVE LOW WALL STABILITY ANALYSIS RESULTS

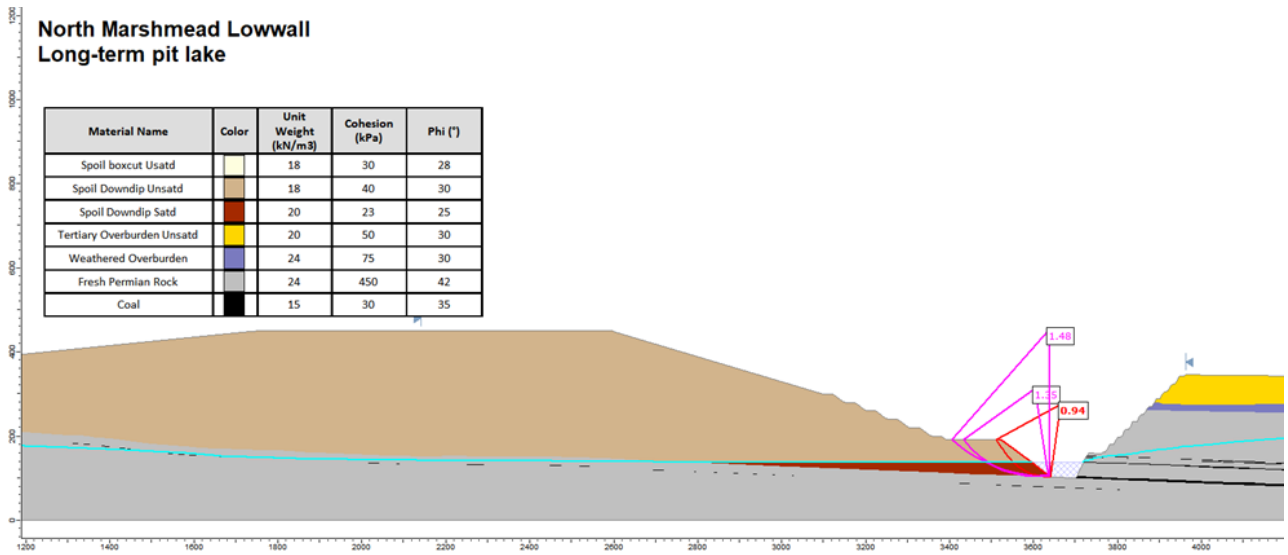
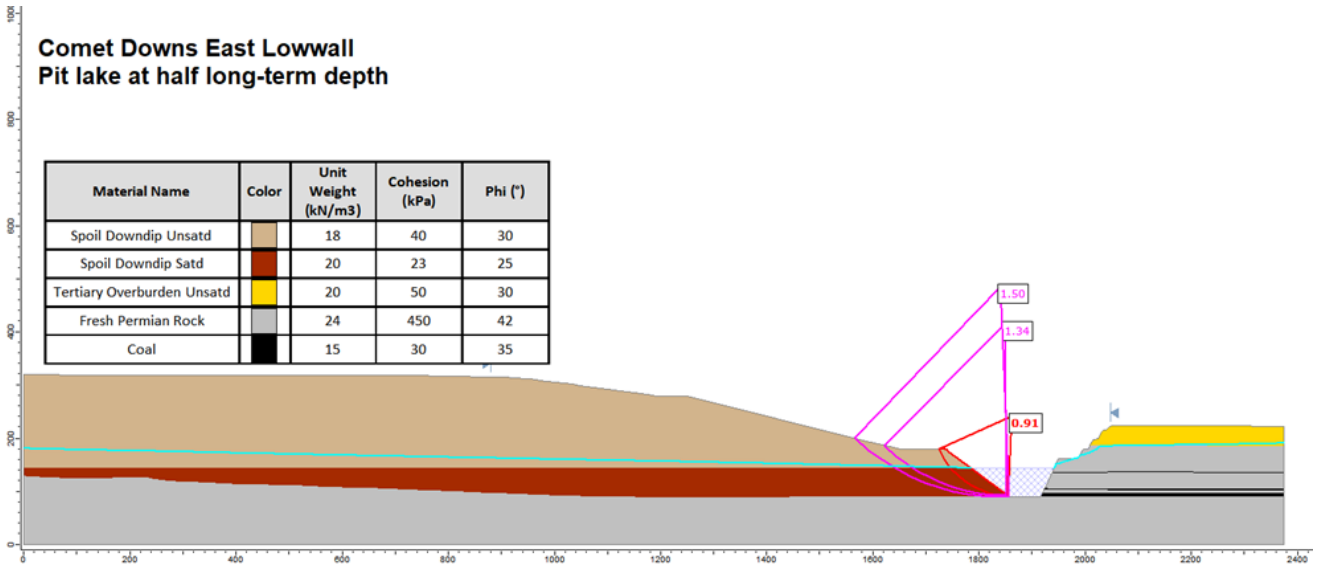


FIGURE 7-7 NORTH MARSHMEAD LOW WALL STABILITY ANALYSIS RESULTS



Note: The point where a FoS≥1.5 occurs is at a higher elevation when the residual void lake is partially filled. The point where a FoS≥1.5 occurs is lower once the lake has reached equilibrium. However, as Comet Downs East is estimated to take up to 450 years to reach equilibrium, the NUMA boundary will be informed by stability analysis under a partially filled residual void lake condition.

FIGURE 7-8 COMET DOWNS EAST LOW WALL STABILITY ANALYSIS RESULTS

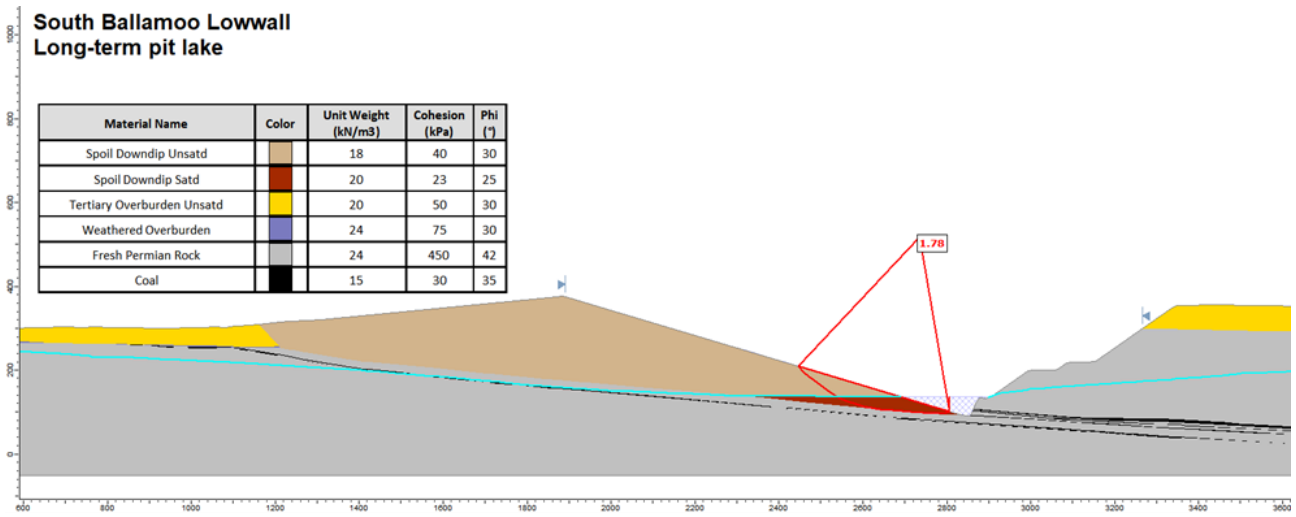


FIGURE 7-9 SOUTH BALLAMOO LOW WALL STABILITY ANALYSIS RESULTS

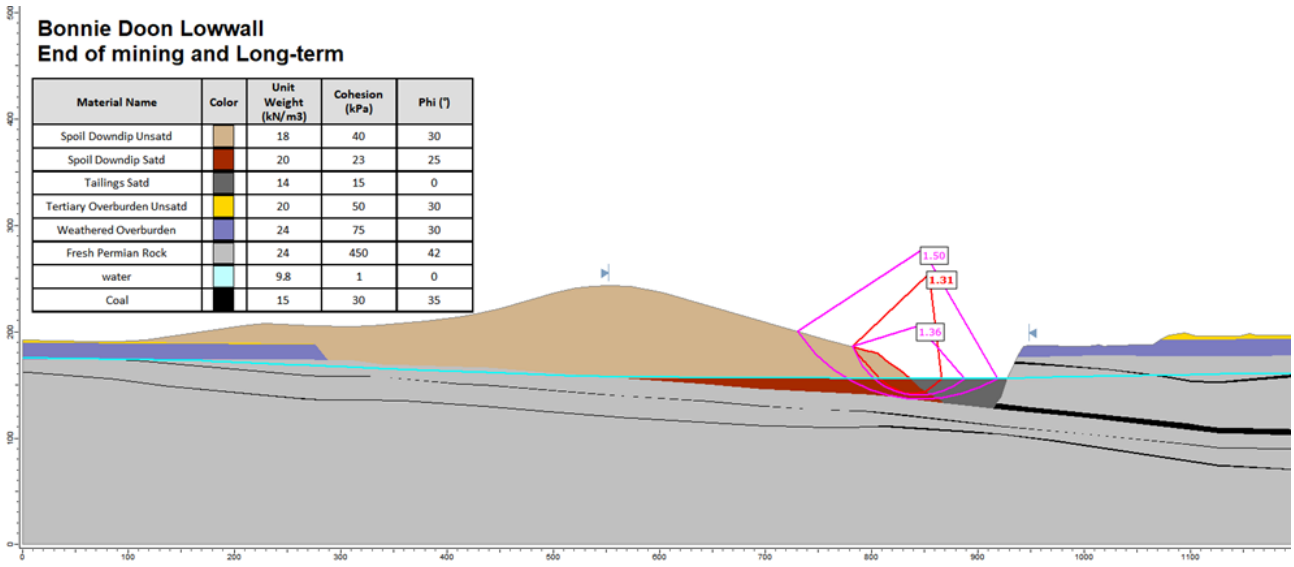


FIGURE 7-10 BONNIE DOON LOW WALL STABILITY ANALYSIS RESULTS

8. GEOCHEMICAL STABILITY

This section evaluates long-term water quality in the void lakes, including potential stratification. It supports the PRCP requirements in Section 3.6.3 to assess potential environmental risks from salinity and contaminants.

A geochemical assessment was conducted to evaluate long-term water quality in nine (9) of the 15 BWM residual voids under closure conditions. The assessment aimed to:

- Predict the long-term evolution of void lake water quality;
- Assess the potential for environmental impact by comparing predicted water quality to EA groundwater trigger values; and
- Identify whether stratification may develop within the voids.

8.1 MODEL SUMMARY

A geochemical water quality model was developed using PHREEQC (Parkhurst, 2013) with the minteq.v4 thermodynamic database.

Nine (9) of the fifteen (15) residual void pit lakes were modelled separately to simulate the evolution of pH, TDS, major ions and metal(loid)s over 900-1,000 years, depending on when the voids start accumulation water in the WBM.

Key features include:

- Source waters were combined at annual timesteps based on GoldSim-derived water balance flows by HydroBalance (2026) (Section 6.2.1);
- Modelling was incremental, using each previous timestep's lake water as input for the next; and
- Geochemical processes such as mineral precipitation/dissolution, gas exchange and surface adsorption.

The assumptions in Table 8-1 were applied in the PHREEQC modelling to represent long-term equilibrium behaviour. These are standard for pit lake geochemical simulations and are designed to isolate chemical processes from hydrodynamic and biological effects.

TABLE 8-1 PHREEQC MODEL ASSUMPTIONS AND IMPLICATIONS

Assumption	Description and Rationale	Potential Implications
Fully mixed water column	• The model assumes a single, well-mixed lake with uniform chemistry. • This is standard in equilibrium modelling, as PHREEQC does not simulate physical stratification. • Mixing and layering are addressed separately in the general lake model (GLM) limnology model (Section 8.4).	• Reasonable and typical assumption. • Physical stratification is discussed in Section 8.4.

Assumption	Description and Rationale	Potential Implications
Instant (equilibrium) geochemical reactions	• Reactions are assumed to occur rapidly enough to reach equilibrium each timestep. • This isolates equilibrium trends without the complexity of kinetic rate data.	• Conservative assumption. • Real systems may react more slowly, meaning actual chemical change would occur more gradually than modelled.
No initial mineral solids	• The model begins with dissolved inputs only, allowing minerals to precipitate or dissolve dynamically based on evolving water chemistry.	• Ensures secondary mineral formation is simulated directly.
No solute release from submerged wall rock, tailings or spoil	• Once submerged, wall rock, tailings and spoil are assumed to have negligible ongoing leaching. • Any early solute release is represented through the inflow source terms.	• Reasonable for closure conditions. • Supported by low PAF proportions (<5%) and realistic neutralising capacity of bulk spoil. • Minor early leaching would have limited long-term impact.
Methane release negligible	• Anaerobic methane generation is excluded due to low organic content and strongly oxidising conditions expected in the lake.	• Very low likelihood of significant methane production; exclusion has negligible influence.
No biological processes simulated	• Microbial reactions (e.g. sulfate reduction, iron oxidation) are not included, as PHREEQC does not handle biological kinetics.	• Typical for long-term models. • Biological effects may locally alter redox conditions but are unlikely to change the overall geochemical trajectory.

Sensitivity analyses were conducted to examine the influence of geochemical controls on predicted water quality (refer to Table 8-2). Note that depending on the type of precipitated iron oxide mineral in each simulation, either ferrihydrite ($Fe(OH)_3$) or lepidocrocite (γ-FeOOH) adsorption was modelled. The same specific surface area was used for both minerals (60 m^2/g), but their site densities differ: Ferrihydrite: 2.3 sites/nm^2 (Dzombak & Morel, 1991); Lepidocrocite: 1.67 sites/nm^2 (Zhang, 1992).

TABLE 8-2 PHREEQC SENSITIVITY ANALYSIS PARAMETERS

Simulation	Atmospheric CO_2 Equilibrium	Oxic/Anoxic Conditions	Mineral Precipitation	Surface Sorption
Geochemical controls (C)	Equilibrium at partial pressure $10^{-3.37}$ atm (~430 ppm)[1]	O_2 equilibrium at partial pressure 10^{-11} atm (pe ≈ 8.5; Eh ≈ 0.5 V)[2]	Equilibrium	Adsorption onto precipitated ferrihydrite or lepidocrocite particle surfaces.
No geochemical controls (NC)	No CO_2 equilibrium	No O_2 equilibrium	No equilibrium	No sorption

Simulation	Atmospheric CO_2 Equilibrium	Oxic/Anoxic Conditions	Mineral Precipitation	Surface Sorption

Notes:
[1] 430 ppm is representative of 2026 atmospheric CO_2 concentrations. Any future change of CO_2 levels in the atmosphere is not included in current model scenarios.
[2] pe = logarithmic scale of electron activity; Eh = measured electric potential; V = volt (unit).

8.1.1 GEOCHEMISTRY SCREENING LEVELS

Water quality modelling results were compared against the groundwater contaminant limits in Table 8-3 from Table I2 of the BWM EA. Note that for metals and metalloids, limits are for dissolved analytes. Relevant voids were chosen by proximity to each bore and were included to enable water quality comparison with PHREEQC geochemistry results. Locations of the groundwater monitoring bores are in Figure 8-1.

TABLE 8-3 GROUNDWATER CONTAMINANT LIMITS FOR BWM GROUNDWATER BORES (TABLE I2 OF THE EA)

Parameter	***Unit***	**MB1**	**MB18**	**MB21**	**MB19BW M2A**	**MB19BW M01P**	**MB19BW M08P**	**MB19BW M27P**	**MB20BW M03P2**	**BG-1**	**BG-2**	**MB02_02**	**MB15_01**	**MB17_01, MB17_02**
Relevant Void(s)	-	*Ramp 8, Bonnie Doon*	*Stewarton North, Stewarton South, Ramp 30*	*Ramp 74, Kenmare, Togara/ North Marshmead*	*Ramp 8, Bonnie Doon*	*Ramp 8, Bonnie Doon*	*Stewarton North, Stewarton South*	*Ramp 70, Mimosa/Besgrove, Deep Creek*	*Ramp 8, Bonnie Doon*	*Ramp 8, Bonnie Doon*	*Mimosa/Besgrove*	*Tannyfoil, South Ballamoo*	*Togara/ North Marshmead*	*Comet Downs East*
pH	-	6.3-7.4	6.5-8.5	6.1-7.1	6.0-6.3	6.5-8.5						6.5-8.7	3.08-3.24	6.5-8.5
EC	*µS/cm*	39,560	18,610	15,890	37,860	26,430	7,260	15,190	20,180	15,780	18,170	TBC		
TDS[1]	*mg/L*	26,505	12,469	10,646	25,366	17,708	4,864	10,177	13,520	10,572	12,174			
SO_4		426	210	600	530	210	210	210	210	210	1,660			
Al		0.055										0.55	62.00	0.55
As		0.019	0.013									TBC		
Fe		6.3	4.62	4.7	1.4	2.1	1.4	3.53	1.84	1.4	1.4			
Hg		0.0006												
Mo		0.034												
Sb		0.009												
Se		0.011												

Note: [1] TDS was calculated using an approximate conversion factor of TDS = EC × 0.67.

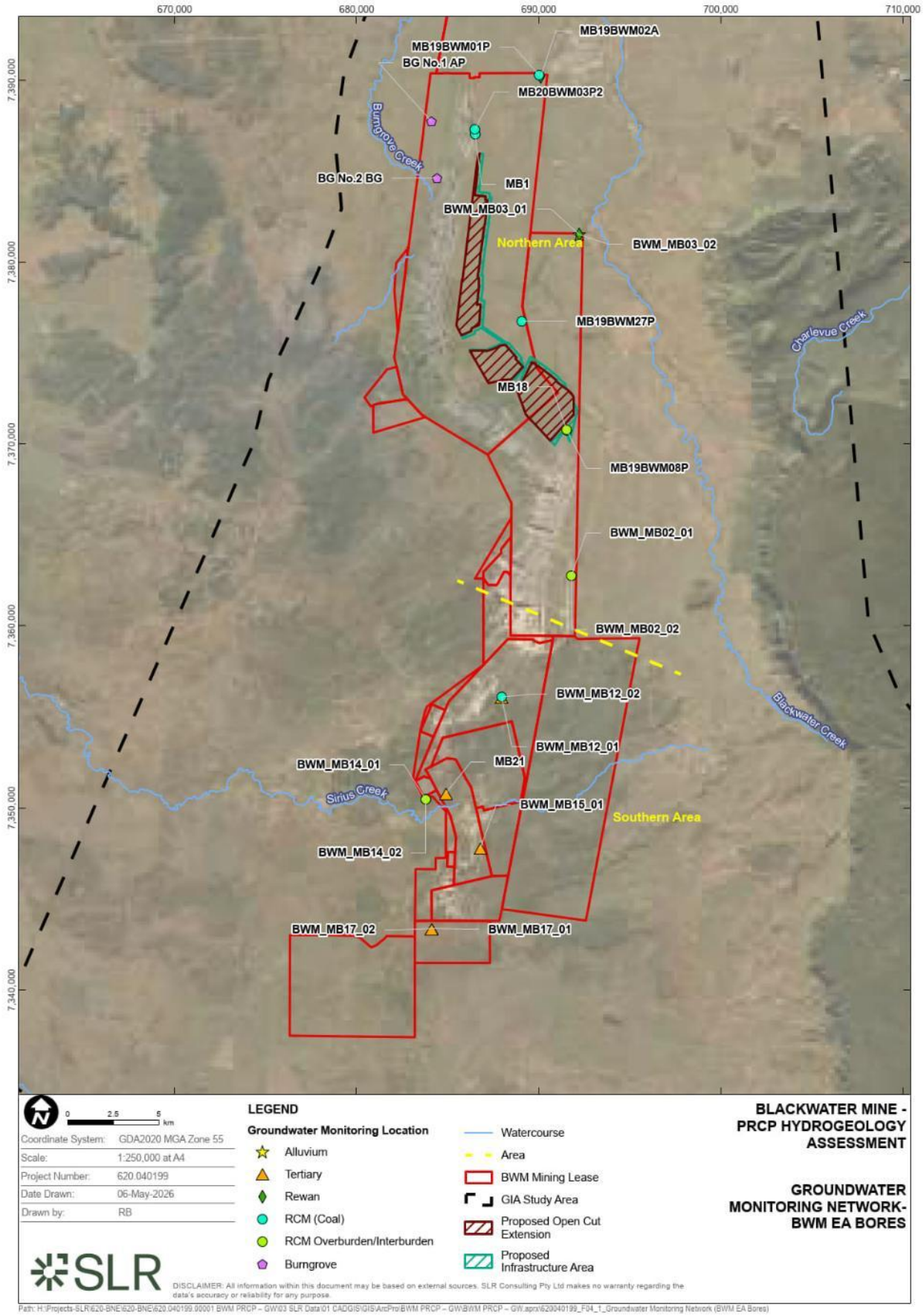


FIGURE 8-1 BWM EA GROUNDWATER MONITORING BORES (SLR, 2026)

8.1.2 VOID WALL MATERIAL COMPOSITION

Information on the composition of the residual void walls were obtained from *Blackwater Mine Environmental Geochemical Characterisation and Risk Assessment of Mineral Waste* (TES, 2026).

The geochemical assessment considered how different geological and mine waste materials at BWM may interact with water and influence solute release or immobilisation. Key interactions included rainfall and runoff contacting highwall lithologies, spoil, rejects, tailings and natural catchments. Infiltration into wall rock and spoil pore water was not modelled explicitly, as any associated solute release is represented within the source term chemistry for seepage and runoff.

BWM will retain 15 residual voids at closure, each with variable depth because the pit floors are not flat. Most void floors will expose the P&L Lower coal seam group, except Bonnie Doon and Ramp 74 which retain tailings. Geological logs, coal quality data and geochemical testing were used to characterise wall and floor materials to provide void wall runoff source terms for each residual void.

Key points from TES (2026) include:

- Highwalls contain a mix of weathered and fresh material, with 40% weathered and 60% fresh on average:
    - Coal exposure on walls is limited, generally 2-7% across voids; and
    - AMD likelihood from walls is low, with only about 3.5-6% of wall material classified as PAF;
- For voids without tailings, AMD from floors is also unlikely even under a conservative assumption of full coal exposure;
- Tailings floors in Bonnie Doon and Ramp 74 contain a high proportion of PAF material (~46-72%), so AMD is probable before capping and inundation; and
- Overall, AMD risk from void walls and non-tailings floors is low, while AMD risk from tailings floors is reduced once voids are capped or submerged post-closure.

Excavated wall materials were grouped into lithological domains based on weathering state and carbonaceous content (Table 8-4). Their distributions for each residual void were estimated using stratigraphic data from drillholes. Materials with unknown classifications were reassigned to carbonaceous or non-carbonaceous groups based on estimated carbonaceous content.

TABLE 8-4 ESTIMATED PERCENTAGES OF LITHOLOGIES IN THE RESIDUAL VOID WALLS

Residual Void	Weathered non-carbonaceous/coal	Weathered carbonaceous/coal	Fresh non-carbonaceous/coal	Fresh carbonaceous/coal	Unknown overburden/interburden	Coal, fresh
Unit	*%*					
Bonnie Doon (and Ramp 8[1])	17	0.1	73	3.5	-	6.7
Comet Downs East	33	0.6	54	3.0	6.3	3.3
Deep Creek	22	1.0	68	1.2	0.6	7.1
Kennedy	76	2.0	13	<0.1	6.8	1.9
Kenmare	25	<0.1	65	1.2	4.1	5.1
Mimosa/Besgrove (and Ramp 30[1])	20	0.6	70	1.2	2.4	5.4
Ramp 74	11	<0.1	82	0.8	-	6.0
Stewarton North, Stewarton South, Tannyfoil and South Ballamoo[2]	23	1.6	65	1.1	1.7	7.2
South Marshmead	59	1.3	37	0.7	-	2.6
Togara/North Marshmead	73	5.6	19	0.4	-	2.0

Notes:

[1] Ramp 8 and Ramp 30 could not be assessed individually due to limited data, so their wall rock and seam proportions were assumed to match nearby voids with similar geology.

[2] Stewarton North and South, Tannyfoil and South Ballamoo were assessed together and the values shown represent averaged conditions because differences between the three voids are minor.

Source: TES (2026)

8.1.3 GEOCHEMICAL SOURCE TERMS

Table 8-5 presents the types of water inflows considered in the PHREEQC model, along with their associated source term assumptions and data sources.

TABLE 8-5 SUMMARY OF DATA USED TO CALCULATE GEOCHEMICAL SOURCE TERMS

Water Inflow Type	Comment	Data Source
Rainfall runoff	Represented by leachate data from relative proportions of catchment type using weathered non-carbonaceous drill core samples.	BWM drill core database
Rehabilitated catchment/in-pit spoil runoff	Represented by leachate data from fresh non-carbonaceous drill core samples.	
High-wall runoff	Based on exposed lithological domains on the high-wall. The BWM drill core databases were used to derive source terms for each lithological domain/grouping.	
Groundwater inflow	Median water quality from BWM groundwater database.	BWM groundwater database
Direct rainfall	Characterised using rainfall chemistry data from the Newcastle region (77 samples from 11 rainfall events), adjusted for charge balance.	Evans (2006)

8.1.3.1 RUNOFF SOURCE TERMS

Table 8-6 presents the source terms for rainfall runoff for each residual void, derived from leachate results in combination with catchment runoff areas and wall lithology proportions by TES (2025). These values are considered representative solute concentrations derived from site runoff characterisation and provide the solute loads associated with rainfall runoff entering each pit lake.

In summary, runoff chemistry is broadly dilute across the site, with low major ion and trace metal concentrations except where elevated alkalinity or specific metals reflect local geology, such as higher alkalinity in Ramp 8 and Bonnie Doon or higher chromium and molybdenum in Ramp 74.

TABLE 8-6 RUNOFF GEOCHEMICAL SOURCE TERMS FOR THE RESIDUAL VOIDS

Parameter	*Unit*	Bonnie Doon	Comet Downs East	Deep Creek	Kenmare	Mimosa/ Besgrove	Ramp 30	Ramp 74	Ramp 8	Togara/North Marshmead
pH	-	8.48	7.84	7.70	7.70	7.72	7.70	8.28	8.44	7.72
pe		8	8	8	8	8	8	8	8	8
Al	*mg/L*	0.0855	0.0584	0.05	0.05	0.0509	0.05	0.0684	0.0935	0.051
Sb		0.0097	0.0047	0.005	0.005	0.005	0.005	0.0129	0.0037	0.005
As(3)		0.0165	0.0042	0.0005	0.0005	0.0009	0.0005	0.0092	0.0195	0.001

Parameter	Unit	Bonnie Doon	Comet Downs East	Deep Creek	Kenmare	Mimosa/ Besgrove	Ramp 30	Ramp 74	Ramp 8	Togara/North Marshmead
Ba		0.0122	0.0174	0.018	0.018	0.0179	0.018	0.0118	0.015	0.0179
Be		0.0003	0.0001	0.0001	0	0.0001	0.0001	0.0001	0.0005	0.0001
B		0.059	0.0542	0.05	0.05	0.0505	0.05	0.0464	0.0717	0.0505
Ca		0.634	0.542	0.5	0.5	0.504	0.5	0.528	0.717	0.505
Mg		0.762	0.771	0.75	0.75	0.752	0.75	0.684	0.859	0.753
Na		59.7	54.2	53	53	53.1	53	58.1	59.1	53.1
K		3.29	2.34	2.0	2.0	2.04	2.0	2.54	3.74	2.04
Sr		0.0294	0.013	0.005	0.005	0.0059	0.005	0.0088	0.0463	0.006
Fe		0.0477	0.0321	0.025	0.025	0.0258	0.025	0.0297	0.062	0.0259
Mn		0.0115	0.0028	0.003	0.003	0.003	0.003	0.0161	0.0021	0.003
Cu		0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0007	0.0005
Ni		0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0007	0.0005
Zn		0.0041	0.0039	0.0038	0.0037	0.0038	0.0037	0.0038	0.0043	0.0038
Cr		0.0451	0.0313	0.025	0.025	0.0257	0.025	0.0292	0.0576	0.0258
Mo		0.0052	0.0023	0.001	0.001	0.0011	0.001	0.0017	0.008	0.0012
Ag		0.0001	0.0001	0.0001	0	0	0.0001	0.0001	0.0001	0
Pb		0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0007	0.0005
Cd		0.0003	0.0001	0.0001	0	0.0001	0.0001	0.0001	0.0005	0.0001
Cl		22.7	33.0	35	35	34.8	35	25.0	24.6	34.8
S(6)		10.7	10.1	9.5	9.5	9.57	9.5	8.73	12.8	9.58
F		0.351	0.392	0.4	0.4	0.399	0.4	0.362	0.357	0.399
Si(4)		0.0505	0.0005	0.0005	0.0005	0.0005	0.0005	0.074	0.0003	0.0005
N(5)		0.0127	0.0187	0.02	0.02	0.0199	0.02	0.0143	0.0135	0.0198
C(4)		43.0	14.2	7.0	7.0	7.77	7.0	30.8	44.4	7.89

Note: Oxidation states for some elements are given in brackets.

8.1.3.2 GROUNDWATER AND RAINFALL SOURCE TERMS

Table 8-7 summarises the source water chemistry used in the PHREEQC models for all modelled residual voids at BWM.

The groundwater source terms were derived from the site-wide average analytical results obtained from the Blackwater groundwater monitoring database (WHC, 2025) with records from 2009 to 2025. The rain chemistry reflects regional median values from Evans (2006).

TABLE 8-7 PHREEQC SOURCE TERMS FOR GROUNDWATER AND RAINFALL

Parameter	Unit	Groundwater (Site-Wide Average)	Direct Rainfall (Evans, 2006)
pH	-	6.81	5
pe	-	2 (assumed)	8 (assumed)
Temperature	*°C*	26.96	25
Na	*mg/L*	1,180	9
Ca		113	3
Mg		202	-
K		11.3	-
Li		0.63	-
Sr		3.37	-
Cl		1,940	14
S(6) as SO_4		304	8
F		0.47	-
Br		9.34	-
C(4)		276 as HCO_3	0.00005 as $CaCO_3$
Si as SiO_2		44.3	-
N(-3) as NH_3		0.444	-
N(5) as NO_3		-	2.0
Ba		0.195	-
Fe		0.82	-
Mn		0.194	-
B		0.6	-
Zn		0.0693	-
Al		0.0131	-
Ni		0.0113	-

8.1.3.3 GEOCHEMICAL CONTROLS

The equilibrium mineral phase assemblage used in the "controlled" PHREEQC modelling are displayed in Table 8-8. It was selected based on two criteria:

- Only minerals that are realistic for mine void waters in the Bowen Basin were included.
- The phases were validated through initial saturation index screening of each pit lake to confirm that they were close to saturation.

The chosen assemblage stabilises model behaviour while remaining geochemically defensible:

- Carbonate phases regulate Ca, Mg, alkalinity and pH.
- Sulfate minerals control Na, K, Fe, Ca and Ba.
- Ferrihydrite, lepidocrocite, alunite, chalcedony and gibbsite provide realistic sinks for Fe, Si and Al under oxidised conditions.
- Gas phases for CO_2 and O_2 maintain atmospheric control on carbonate speciation and redox state.

TABLE 8-8 PHREEQC EQUILIBRIUM PHASE ASSEMBLAGE

Phase	Chemical Formula	SI/log Fugacity (f) Value	Initial Reservoir	Justification
Calcite	$CaCO_3$	0	0	Provides stable geochemical buffering that keeps pH and dissolved constituents within realistic environmental ranges while avoiding forced or unrealistic mineral precipitation.
Aragonite	$CaCO_3$	0	0	
Dolomite	$CaMg(CO_3)_2$	0	0	
Gypsum	$CaSO_4 \cdot 2H_2O$	0	0	
Barite	$BaSO_4$	0	0	
Gibbsite	$Al(OH)_3$	0	0	
Alunite	$KAl_3(SO_4)_2(OH)_6$	0	0	
Lepidocrocite	γ-FeO(OH)	0	0	
Jarosite	$XFe_3(SO_4)_2(OH)_6$ (X = Na, K, H)	0	0	
Chalcedony	SiO_2	0	0	
Ferrihydrite	$Fe(OH)_3$	0	0.007 moles (when needed)	Small seed mass stabilises Fe redox and adsorption behaviour. Prevents numerical instability.
$CO_2(g)$		-3.37 log $f(CO_2)$	0	Represents atmospheric CO_2 of 430 ppm. Ensures realistic carbonate speciation and buffering.
$O_2(g)$		-11 log $f(O_2)$	999999 moles	Produces oxidising conditions consistent with pe~8.5 and Eh~0.5 V. Large reservoir maintains stable redox conditions.

A set of mineral phases was intentionally suppressed to prevent unrealistic geochemical behaviour during the simulations. These phases either require extreme pH, pressure or redox conditions, or are not expected to form from dilute pit lake waters. Table 8-9 below summarises each suppressed phase and the rationale for excluding it from PHREEQC modelling.

TABLE 8-9 PHREEQC SUPRESSED MINERAL PHASES

Supressed Phase	Chemical Formula	Target SI	Initial Reservoir	Reason for Suppression
Alumina	Al_2O_3	999	0	High-temperature phase not relevant under low-temperature aqueous conditions.
Barium arsenate	$Ba_3(AsO_4)_2$			Would unrealistically constrain aqueous chemistry via solid-phase control.
Cupricferrite	$CuFe_2O_4$			High-temperature phase not relevant under low-temperature aqueous conditions.
Cuprousferrite	$CuFeO_2$			
Iron hydroxychloride	$Fe(OH)_{2.7}Cl_{0.3}$			Would unrealistically constrain aqueous chemistry via solid-phase control.
Iron vanadate	$Fe(VO_3)_2$			
Goethite	FeOOH			
Hematite	Fe_2O_3			High-temperature phase not relevant under low-temperature aqueous conditions.
Hercynite	$FeAl_2O_4$			
Magnetite	Fe_3O_4			Not compatible with oxidising conditions defined in the model.
Maghemite	Fe_2O_3			High-temperature phase not relevant under low-temperature aqueous conditions.
Magnesioferrite	Fe_2MgO_4			

8.2 RESIDUAL VOID WATER QUALITY

This section summarises the key findings of the PHREEQC modelling presented in the Residual Void Water Quality and Limnology Assessment (ERM, 2026). For the purpose of this VCP, only key parameters and their temporal trends and water quality assessments have been included.

The below tables include results for both simulations (geochemical controls – C, and no geochemical controls – NC) to compare the effect of these controls on void lake water quality. For the purpose of this study, the C results are considered the most realistic scenario.

Where applicable, groundwater quality comparisons were made using the EA trigger values for groundwater bores in Table 8-3. Note that the comparison to these trigger levels is provided for context only, as all residual voids at BWM will remain as NUMAs and not be subject to specific water quality criteria. The triggers offer a relevant local reference point and help illustrate how predicted water quality compares with surrounding groundwater conditions, rather than representing compliance requirements.

Precipitated minerals were included in this section to show the geochemical processes controlling each void's long-term water quality. These minerals directly influence pH, salinity and metal mobility through ongoing precipitation and dissolution, which explains why key parameters stabilise, rise or decline over time. Their inclusion highlights how differences in void lithology and inflow chemistry produce distinct mineral assemblages and water quality outcomes.

The annual timestep results for key parameters summarised in Table 8-10 to Table 8-18 are provided in Appendix A.

8.2.1 BONNIE DOON

The modelled water quality for Bonnie Doon in Table 8-10 remains stable throughout the simulation period. pH remains within the alkaline range and TDS remains very low with no upward trend. Major ions and metals show minor variability but do not accumulate over time. NC and C values are similar for pH, pe and TDS, and applying geochemical controls does not materially change the predicted outcomes.

Comparisons were made against EA trigger levels for bores near Bonnie Doon in Table 8-3, and all evaluated parameters remain within or below these thresholds.

Mineral precipitation increases slowly, but the total mass represents less than 0.03% of the lake's median water mass and less than 0.001% of its peak water mass, remaining small relative to lake volume and cumulative solute input and does not negatively influence water quality.

TABLE 8-10 BONNIE DOON PHREEQC SUMMARY OVER 982 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	7.95-8.32	7.88-8.38	Stable
pe	-	6.53-7.16	9.79-10.30	
TDS	*mg/L*	125-227	120-136	
Na		-	47.0-77.6	
K		-	2.46-3.05	
Ca		-	0.88-1.22	
Mg		-	0.58-0.69	
Cl		-	51.3-58.8	
SO_4		-	10.0-10.4	
HCO_3		-	32.1-37.7	
F		-	0.263-0.314	
Si		-	0.018-0.021	
Al		-	0.011-0.024	
Fe		-	0	
Mn		-	0.009-0.014	

Parameter	*Unit*	NC Value	C Value	Trend
Precipitated phases at end of run				
Dolomite	*tonnes*	-	0-0.20	Increasing
Ferrihydrite		-	1.27-9.22	
Gibbsite		-	0.91-16.6	
Barite		-	0	Stable
Gypsum		-	0	
Chalcedony		-	0	

8.2.2 MIMOSA/BESGROVE

The modelled water quality for Mimosa/Besgrove in Table 8-11 was simulated over 967 years and does not remain stable over the simulation period because the void is dominated by highly mineralised groundwater inputs in combination with evaporative concentration.

pH stays within a mildly acidic to neutral range for NC outputs and rises into a neutral range under geochemical controls, with no long term decline. TDS increases through the simulation, reflecting progressive concentration of salts as groundwater inflows exceed dilution capacity. Major ions and metals follow the same trajectory as TDS, with concentrations increasing across both NC and C outputs, with similar ranges indicating limited influence of geochemical controls on overall solute accumulation.

Comparisons were made against EA trigger levels for bores near Mimosa/Besgrove in Table 8-3. pH is within the MB18 containment limits but exceeds the upper limits for MB1 and MB19BW M2A at the upper bound of the C scenario. TDS and SO_4 exceed limits across much of the simulation, particularly at later stages. Arsenic exceeds trigger levels at the upper bound of the C scenario.

Mineral precipitation increases slowly but the total mass represents less than 1.5% of the lake's median water volume (1,810 ML) and less than 1.3% of its peak water volume (2,150 ML), remaining small relative to lake volume and cumulative solute input.

TABLE 8-11 MIMOSA/BESGROVE PHREEQC SUMMARY OVER 967 YEARS

Parameter	Unit	NC Value	C Value	Trend
pH	-	**5.55**-6.88	6.75-**7.96**	Decreasing
pe	-	5.59-7.62	9.98-11.2	Increasing
TDS	mg/L	2,430-**186,000**	2,590-**174,000**	
Na		694-53,100	755-53,300	
K		7.64-531	8.17-532	
Ca		65.6-5,040	56.3-1,170	
Mg		114-8,890	116-7,970	

Parameter	Unit	NC Value	C Value	Trend
Cl		1,320-101,500	1,430-102,000	
SO4		183-**13,700**	199-**8,220**	
HCO3		128-1,780	3.29-43.3	
F		0.478-27.5	0.490-27.6	
Si		11.7-912	12.8-915	
Al		**0.0756-1.13**	0	Stable
Fe		1.24-39.5	0	
Mn		0.129-8.66	0-1.87	Increasing
As	µg/L	0.36-**15.3**	0.35-**15.3**	
Cr		10.2-436	9.90-438	
Cu		1.01-12.7	1.01-12.8	
Mo	µg/L	**0.436-18.7**	**0.424-11.2**	Fluctuating, overall stabilising after 600 years
Ni		10.5-77.4	10.5-77.6	Increasing
Pb		2.31-21.5	1.83-21.6	
Sb		1.98-**84.9**	1.93-**85.2**	
Se		0.865-5.90	0.868-5.60	
Zn		2.21-67.4	2.18-67.6	
Precipitated phases at end of simulation				
Gypsum	*tonnes*	-	15,600	Increasing
Dolomite		-	11,500	
Lepidocrocite		-	100	
Pyrolusite		-	21.1	
Barite		-	24.1	
Diaspore		-	4.07	
Surface-adsorbed ions at end of simulation				
Ca	*g*	-	167	Increasing
Mg		-	813	
SO4		-	420	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.3 RAMP 30

The modelled water quality for Ramp 30 in Table 8-12 shows greater variability and higher maximum concentrations under NC conditions, compared to lower and more stable concentrations under C conditions throughout the simulation period. pH remains within near-neutral to slightly alkaline conditions, but exhibits fluctuations associated with periodic lake drying due to evaporation and groundwater outflow.

These drying events reduce water volume, concentrating solutes and causing short-term increases in TDS and dissolved constituents. Subsequent refilling dilutes concentrations, resulting in the observed fluctuations. pe is higher under C conditions (9.90-10.8) compared to NC conditions (5.48-8.05), indicating more consistently oxidising conditions when geochemical controls are applied.

TDS shows a wide range under NC conditions (140-10,700 mg/L), reflecting repeated concentration during dry periods, whereas under C conditions, TDS remains lower (138-2,830 mg/L), indicating that solute concentrations do not build up to the same extent despite the same hydrological fluctuations. Major ions and metals display similar behaviour, with higher peaks under NC conditions, and lower peak concentrations under C conditions.

Mineral precipitation is limited, with a total cumulative mass of approximately 24.1 tonnes across all phases (dominated by dolomite and diaspore). This represents approximately 0.014% of the modelled average water mass (172 ML) and 0.0012% of the maximum water mass (2,010 ML), confirming that precipitation is negligible relative to system scale.

Consistent with above, comparison of NC (no precipitation) and C (precipitation and surface adsorption enabled) results shows that aqueous solute concentrations are reduced under C conditions, but the overall trends and ranges remain similar, indicating that precipitation and adsorption limit peak concentrations rather than fundamentally altering system behaviour or controlling water quality evolution.

TABLE 8-12 RAMP 30 PHREEQC SUMMARY OVER 967 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	6.75-7.63	7.18-8.08	Fluctuating
pe	-	5.48-8.05	9.90-10.8	
TDS	*mg/L*	140-10,700	138-2,830	
Na		51.3-3,060	50.0-824	
K		1.52-33.0	1.42-8.22	
Ca		0.552-282	0.55-60.6	
Mg		0.753-498	0.75-128	
Cl		73.1-5,800	72.3-1,580	
SO_4		9.53-784	9.49-211	
HCO_3		6.49-489	6.39-54.0	
F		0.271-2.80	0.255-0.425	
Si		0.0016-51.0	0.002-14.2	

Parameter	*Unit*	NC Value	C Value	Trend
Al		0.025-0.26	0-0.001	
Fe		0.024-2.08	0	
Mn		0.003-0.49	0	
As	*µg/L*	0.155-2.34	0.125-0.537	
Cr		7.74-117	6.26-24.8	
Cu		0.155-2.34	0.125-0.496	
Mo		0.309-4.69	0.250-0.993	
Ni		0.479-29.1	0.460-7.88	
Pb		0.155-2.34	0.125-0.496	
Sb		1.55-23.4	1.25-4.96	
Se		0	0	
Zn		3.53-180	3.36-48.5	
Precipitated phases				
Diaspore	*tonnes*	-	0-5.57	Increasing
Dolomite		-	0-14.2	Decreasing
Lepidocrocite		-	**0-3.68**	Increasing
Pyrolusite		-	0.631	Increasing
Barite		-	0-0.0249	Decreasing
Surface-adsorbed ions				
Ca		-	0-190	Fluctuating
Mg		-	0-3,280	
SO4		-	0-908	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.4 RAMP 74

The modelled water quality for Ramp 74 in Table 8-13 remains stable throughout the simulation period. pH stays within a slightly alkaline range and TDS remains very low with no upward trend. Major ions and metals stay low in concentration and show no accumulation. NC and C values remain closely aligned for pH, pe and TDS, showing that applying geochemical controls does not materially change predicted outcomes.

Comparisons were made against EA limits for bores near Ramp 74 in Table 8-3, and all evaluated parameters remain within or below these thresholds for the full simulation.

Mineral precipitation is extremely small, totalling less than 0.01 tonnes at the end of the model run. This is negligible relative to the lake's median and peak water masses.

TABLE 8-13 RAMP 74 PHREEQC SUMMARY OVER 1,000 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	7.61-7.84	7.70-7.90	Stable
pe	-	7.45-7.83	10.3-10.5	Increasing
TDS	*mg/L*	222-842	112-124	Stable
Na		-	43.1-48.1	
K		-	1.76-2.03	
Ca		-	1.03-1.29	
Mg		-	0.47-0.55	
Cl		-	52.1-58.0	
SO_4		-	8.50-8.58	
HCO_3		-	21.2-24.3	
F		-	0.251-0.289	
Si		-	0.024-0.028	
Al		-	0.005-0.008	
Fe		-	0	
Mn		-	0.011-0.013	
Precipitated phases at end of run				
Dolomite	*tonnes*	-	0	Stable
Ferrihydrite		-	0.0002-0.0009	Stable
Gibbsite		-	0.0003-0.0096	
Barite		-	0	
Gypsum		-	0	
Chalcedony		-	0	

8.2.5 RAMP 8

The modelled water quality for Ramp 8 in Table 8-14 shows increasing solute concentrations over the simulation period due to the relatively small lake volume, high evaporative concentration and long term solute loading.

pH increases to a near-neutral range and major ions and metals stabilise under geochemical controls. NC and C values differ for pH, pe and TDS, but the C values show more stable long term behaviour.

Comparisons were made against EA trigger levels for bores near Ramp 8 in Table 8-3. Al and Fe remain within or below their respective triggers, while pH occasionally are below or above trigger levels. TDS and SO_4 exceed the relevant triggers but stabilise over time.

Mineral precipitation increases gradually but remains small relative to the lake's water mass. Total mineral mass remains less than 1% of median water mass and less than 0.5% of peak water mass, and therefore does not negatively influence water quality.

TABLE 8-14 RAMP 8 PHREEQC SUMMARY OVER 935 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	**5.99**-6.77	7.02-**7.76**	Increasing
pe	-	6.05-7.18	10.4-11.2	
TDS	*mg/L*	**13,700**-**136,000**	**13,300**-**127,000**	
Na		-	3,910-38,700	
K		-	38.2-378	
Ca		-	260-1,110	
Mg		-	594-5,850	
Cl		-	7,470-74,000	
SO_4		-	**1,010**-**6,600**	
HCO_3		-	31.2-6.40	Decreasing
F		-	1.66-16.4	Increasing
Si		-	7.04-3.86	Decreasing
Al		-	0.007-0.002	
Fe		-	0-1.70	Increasing
Mn		-	0.640-6.32	
Precipitated phases at end of run				
Dolomite	*tonnes*	-	1,440-24,100	Increasing
Ferrihydrite		-	15.1-231	
Gibbsite		-	0.510-9.42	
Barite		-	2.93-48.6	
Gypsum		-	0-27,500	
Chalcedony		-	368-6,430	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.6 DEEP CREEK

The modelled water quality for Deep Creek in Table 8-15 shows consistent increases in dissolved solids and major ions over the simulation period.

pH moves into a near-neutral range when geochemical controls are applied (C higher than NC: 6.99-8.26 vs 5.95-7.21), and pe also increases under C conditions. Most solutes display long-term upward trends driven by evaporative concentration and cumulative solute input. Geochemical controls reduce key dissolved constituents, particularly SO_4 (lower in C than NC) and metals (Fe and Mn substantially lower in C).

Comparisons were made against EA limits for bores near Deep Creek in Table 8-3. pH, Al and Fe remain within trigger levels. There are sustained increases in TDS, SO_4, F and Mn across the entire simulation period with no indication of reaching equilibration.

TDS and SO_4 exceed relevant EA limits at most times. F and Mn increase but have no applicable triggers for this void. None of these parameters stabilise or plateau, and the system does not approach geochemical equilibrium within the modelled timeframe.

Mineral precipitation is limited, with a total cumulative mass of approximately 99,800 tonnes across all phases (dominated by gypsum and dolomite). This represents approximately 1.1% of the modelled median water mass (9,170 ML) and 0.92% of the maximum water mass (10,900 ML), confirming that precipitation remains minor relative to overall system scale.

TABLE 8-15 DEEP CREEK PHREEQC SUMMARY OVER 968 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	5.95-7.21	6.99-8.26	Decreasing
pe	-	4.56-7.59	9.76-10.9	Increasing
TDS	*mg/L*	223-**138,000**	254-**129,000**	
Na		75.1-39,200	75.1-39,200	
K		1.67-381	1.67-381	
Ca		2.84-3,740	14.3-1,140	
Mg		4.84-6,620	11.8-5,920	
Cl		119-75,100	119-75,100	
SO_4		15.5-**10,100**	15.6-**6,670**	
HCO_3		10.9-1,770	5.69-77.2	
F		0.243-17.9	0.24-17.9	
Si		0.424-680	0.42-680	
Al		0.02-0.734	<0.001	Decreasing
Fe		0.041-27	<0.0001	Increasing
Mn		0.007-6.39	0-0.19	Negligible until 400 years, then increasing
As	*µg/L*	0.05-3.04	0-0.35	Increasing
Cr		2.32-152	2.19-111	
Cu		0.05-3.04	0.02-0.35	
Mo		0.09-6.08	0.09-3.72	Increasing up to 700 years, then steady
Ni		0.71-374	1.16-370	Increasing
Pb		0.05-3.04	0-0.61	Negligible until 300 years, then increasing
Sb		0.46-**30.4**	0.46-**30.4**	Increasing
Zn		4.93-2,300	7.57-2,290	

Parameter	*Unit*	NC Value	C Value	Trend
Precipitated phases at end of run				
Gypsum	*tonnes*	-	52,600	Starts forming after ~400 years, then steadily increasing
Dolomite		-	46,600	Increasing
Lepidocrocite		-	379	
Pyrolusite		-	87.7	
Barite		-	96.5	
Diaspore		-	14.5	
Surface-adsorbed ions at end of run				
Ca	*g*	-	136	Increasing
Mg		-	624	
SO_4		-	1,026	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.7 KENMARE

The modelled water quality for Kenmare in Table 8-16 shows a clear upward trajectory for all major salinity indicators.

pH increases to weakly alkaline and remains within limits. TDS, SO_4, F and Mn all increase over time with no sign of equilibrium. NC and C values remain closely aligned for pH, pe and TDS, showing that geochemical controls do not materially change predicted outcomes for these key metrics.

Comparisons were made against EA limits for groundwater bores near Kenmare in Table 8-3. TDS and SO_4 exceed the trigger levels at early stages of the simulation and continue to rise.

The cumulative mass of precipitated minerals remains small relative to the lake's median and peak water mass and does not drive negative changes in water quality.

TABLE 8-16 KENMARE PHREEQC SUMMARY OVER 929 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	6.34-6.79	7.26-7.84	Increasing
pe	-	6.09-6.76	10.3-10.9	
TDS	*mg/L*	8,210-**85,300**	7,980-**80,900**	
Na		-	2,350-24,400	
K		-	24.6-252	
Ca		-	157-1,090	
Mg		-	350-3,590	
Cl		-	4,470-46,400	

Parameter	*Unit*	NC Value	C Value	Trend
SO_4		-	**603-5,130**	
HCO_3		-	36.8-11.2	Decreasing
F		-	1.51-14.9	Increasing
Si		-	7.33-4.95	Decreasing
Al		-	0.008-0.003	
Fe		-	0	Stable
Mn		-	0.38-3.91	Increasing
Precipitated phases at end of run				
Dolomite	*tonnes*	-	1.21-23.1	Increasing
Ferrihydrite		-	0.0139-0.223	
Gibbsite		-	0.00078-0.0195	
Gypsum		-	0-0.0838	
Barite		-	0.00233-0.049	
Chalcedony		-	0.00484-101	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.8 TOGARA/NORTH MARSHMEAD

The modelled water quality for Togara/North Marshmead in Table 8-17 shows sustained increases in TDS, SO_4, F and Mn with no indication of reaching equilibration. pH remains near neutral throughout. NC and C values remain closely aligned for pH, pe and TDS, showing that geochemical controls do not materially change model outcomes.

Comparisons were made against EA limits for bores near Togara/North Marshmead in Table 8-3. TDS and SO_4 exceed their respective triggers throughout and continue increasing. pH exceeds the trigger levels towards the end of the simulation. F and Mn increase but have no applicable triggers.

Mineral precipitation increases gradually, and although some minerals accumulate to high absolute masses, these remain very small relative to the lake's median and peak water mass and cumulative solute input and do not negatively influence water quality.

TABLE 8-17 TOGARA/NORTH MARSHMEAD PHREEQC SUMMARY OVER 914 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	6.17-6.76	7.14-**7.78**	Increasing
pe	-	6.09-6.58	10.4-11.0	
TDS	*mg/L*	**11,300-111,000**	**10,900-104,000**	
Na		-	3,220-31,600	
K		-	31.7-313	

Parameter	*Unit*	NC Value	C Value	Trend
Ca		-	216-1,100	
Mg		-	488-4,750	
Cl		-	6,160-60,500	
SO_4		-	**830-5,850**	
HCO_3		-	32.8-8.40	Decreasing
F		-	1.55-15.6	Increasing
Si		-	7.20-4.36	Decreasing
Al		-	0.008-0.002	
Fe		-	0	Stable
Mn		-	0.52-5.14	Increasing
Precipitated phases at end of run				
Dolomite	*tonnes*	-	4.90-90.7	Increasing
Ferrihydrite		-	50.8-879	
Gibbsite		-	2.23-46.1	
Barite		-	10.2-188	
Gypsum		-	0-88,000	
Chalcedony		-	1,240-24,400	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.2.9 COMET DOWNS EAST

The modelled water quality for Comet Downs East in Table 8-18 shows increasing TDS, SO_4, F and Mn throughout the simulation with no evidence of equilibration. pH remains near neutral for the duration. NC and C values remain closely aligned for pH, pe and TDS, indicating that geochemical controls do not materially alter the predicted outcomes.

Comparisons were made against EA limits for bores near Comet Downs East in Table 8-3. TDS and SO_4 exceed the limits and continue to increase. F and Mn increase but have no applicable limits.

Mineral precipitation increases over time, and although some minerals accumulate at high absolute masses, these are very small relative to the lake's median and peak water mass and cumulative solute inputs and do not negatively influence water quality.

TABLE 8-18 COMET DOWNS EAST PHREEQC SUMMARY OVER 921 YEARS

Parameter	*Unit*	NC Value	C Value	Trend
pH	-	**6.33**-6.79	7.14-7.78	Increasing
pe	-	6.01-6.72	10.4-11.0	
TDS	*mg/L*	8,820-**86,600**	10,900-**104,000**	
Na		-	3,210-31,600	

Parameter	*Unit*	NC Value	C Value	Trend
K		-	31.8-314	
Ca		-	215-1,100	
Mg		-	486-4,730	
Cl		-	6,140-60,400	
SO_4		-	827-**5,850**	
HCO_3		-	32.9-8.50	Decreasing
F		-	1.54-15.5	Increasing
Si		-	7.21-4.37	Decreasing
Al		-	0.008-0.002	
Fe		-	0	Stable
Mn		-	0.52-5.13	Increasing
Precipitated phases at end of run				
Dolomite	*tonnes*	-	4.94-91.5	Increasing
Ferrihydrite		-	51.3-882	
Gibbsite		-	2.34-49.9	
Barite		-	9.34-189	
Gypsum		-	0-87,500	
Chalcedony		-	1,240-24,400	

*Note: Values outside groundwater bore trigger levels are marked in **bold**.*

8.3 WATER QUALITY SUMMARY TABLE

Table 8-19 summarises the predicted long term water quality outcomes for the residual voids based on the PHREEQC modelling. The table compares overall behaviour, identifies any parameters that fall outside the EA groundwater containment limits and highlights the dominant long term trends in salinity and major ions. Mineral precipitation outcomes are also included, as these reactions help explain the geochemical controls operating within each void lake.

The results also show a clear relationship between groundwater flux and salinity, where voids characterised by net groundwater outflow (Section 6.2.1) exhibit consistently low TDS, while voids dominated by net groundwater inflow develop moderate to very high TDS due to ongoing solute loading and evaporative concentration.

TABLE 8-19 SUMMARY OF RESIDUAL VOID WATER QUALITY OUTCOMES (C RESULTS ONLY)

Residual Void	Overall Water Quality	Parameters Outside Range	Long Term Trends	Mineral Precipitation
Bonnie Doon	Water quality remains stable due to net groundwater outflow with low salinity (TDS: 120-136 mg/L) and neutral to slightly alkaline pH (pH: 7.88-8.38).	None.	All parameters remain stable.	Negligible mass.
Mimosa/ Besgrove	Water quality is dominated by saline groundwater inflow and evaporative concentration, with pH from mildly acidic to neutral (pH: 5.55-7.96) and very high salinity (TDS: 2,590-174,000 mg/L).	TDS, As and Sb are outside range.	TDS, major ions and metals increase continuously with no stabilisation; Al and Fe remain low under C conditions.	Total mineral mass less than 1.5% of median lake water mass.
Ramp 30	Water quality remains stable due to net groundwater outflow with low salinity (TDS: 138-2,830 mg/L) and near-neutral to slightly alkaline pH (pH: 7.18-8.08), and fluctuations due to periodic drying and refilling.	None.	Concentrations fluctuate with drying cycles but do not show long-term accumulation under C conditions.	Negligible mass (~0.01% of median water mass).
Ramp 74	Water quality remains stable due to net groundwater outflow with very low salinity (TDS: 112-124 mg/L) and slightly alkaline pH (pH: 7.70-7.90).	None.	All parameters remain stable.	Negligible mass.
Ramp 8	Significant increase in salinity (TDS: 13,300-127,000 mg/L) due to small lake volume, evaporative concentration and solute loading. pH is around neutral (pH: 7.02-7.76).	TDS and SO_4 are outside range.	TDS and major ions increase continuously with no stabilisation.	Total mineral mass less than 1% of median lake water mass.
Deep Creek	Water quality shows sustained increases in salinity and major ions (TDS: 254-129,000 mg/L) with near-neutral pH (pH: 6.99-8.26).	TDS, SO_4 and Sb are outside range.	TDS and major ions increase continuously with no stabilisation.	Total mineral mass approximately 1% of median lake water mass.
Kenmare	Water quality shows a clear long term increase in salinity (TDS: 7,980-80,900 mg/L). pH is weakly alkaline (pH: 7.26-7.84).	TDS and SO_4 are outside range.	TDS and major ions increase continuously with no stabilisation.	Negligible mass.

Residual Void	Overall Water Quality	Parameters Outside Range	Long Term Trends	Mineral Precipitation
Togara/North Marshmead	Water quality shows sustained increases in salinity (TDS: 10,900-104,000 mg/L). pH remains near neutral (pH: 7.14-7.78).	TDS and SO_4 are outside range.	TDS, SO_4, F and Mn increase with no indication of stabilisation.	Negligible mass.
Comet Downs East	TDS and major ions increase over time with no equilibration (TDS: 10,900-104,000 mg/L). pH remains near neutral (pH: 7.14-7.78).	TDS and SO_4 are outside range.	TDS and major ions increase continuously with no stabilisation.	Negligible mass.

8.4 LIMNOLOGY ASSESSMENT

Numerical limnology modelling was undertaken using R and SILO climate data and water balance modelling results for Mimosa/Besgrove (Section 6.2) over the simulation period.

The Mimosa/Besgrove void was selected for detailed limnological modelling as it represents a residual void expected to form a substantial residual void lake, with a final water level of approximately 85.5 mAHD and a mean water depth of around 55 m.

The void lake was assessed for thermal, salinity and density stratification, and the temporal evolution of these properties within the water column over 100 years post-closure.

Given the consistent climatic and hydrogeological setting across BWM, the results provide a suitable analogue for understanding the general limnological behaviour of the other voids, noting that stratification and redox cycling will be less pronounced in the shallower systems.

8.4.1 GENERAL LAKE MODEL SETTINGS

This section describes the key properties of the GLM modelling. It is provided here to provide context and explain the results in the sections below. More detailed information can be found in ERM (2026).

Note that the initial model lake level was set at a depth of 5 m (~29 mAHD) as GLM requires a starting lake level to allow model simulation to occur.

8.4.1.1 GLM SETUP

The GLM setup defines the numerical structure and mixing processes used to simulate stratification and water column dynamics. The model was configured with a high vertical resolution and fixed layer thickness constraints (0.5 m), which ensured a consistently fine discretisation of the water column and allowed detailed representation of thermal and salinity gradients. A minimum layer volume threshold (1.0 m^3) was specified to maintain numerical stability.

Water density was calculated using the standard GLM equation of state, which accounts for temperature and salinity effects on density stratification.

8.4.1.2 MIXING CONFIGURATION

The mixing configuration controls how energy inputs drive vertical exchange within the lake. Surface mixing was enabled, with contributions from convective overturn, wind-driven stirring, shear production, background turbulence and Kelvin-Helmholtz instabilities. These coefficients collectively regulate the strength of mixing within the surface and metalimnetic layers.

Deep mixing was parameterised using scheme 2, which is a stability-based formulation (Weinstock-type approach). In this approach, mixing is generated by shear-driven turbulence but is dampened by density stratification, such that diffusivity decreases with increasing stratification strength and increases where shear or instabilities weaken the density gradient.

The hypolimnetic mixing coefficient was set to a relatively low value (0.05), which is below typical ranges reported for natural lakes (~0.3-0.7). This parameterisation reflects the expected physical behaviour of deep pit lakes, where the hypolimnion is strongly density-stratified and largely decoupled from surface forcing. In such systems, wind-driven mixing energy is dissipated in the upper water column, and vertical exchange across the thermocline

is limited by strong thermal and salinity gradients. As a result, hypolimnetic mixing was dominated by weak, diffusion-controlled processes that are several orders of magnitude lower than surface mixing rates. It represents a conservative and physically realistic assumption, promoting persistent stratification and limiting vertical redistribution of heat and solutes in the deeper water column, consistent with the expected behaviour of saline, groundwater-influenced pit lakes (Rimmer et al., 2006).

A molecular diffusivity term (1.0×10^{-5} m^2/s) was also applied, representing baseline diffusive transport of heat and solutes throughout the water column.

8.4.1.3 INFLOW PROPERTIES

The GLM inflow configuration defined two inflow sources: Surface runoff and groundwater, with distinct physical representations that influence mixing and stratification within the lake. Note that direct rainfall was handled in the meteorological input file.

Runoff was treated as a surface inflow, entering at the lake surface with relatively low entrainment, such that it primarily affects the upper water column with limited mixing into deeper layers. Groundwater inflow was simulated as a submerged inflow, entering below the surface. Both inflows were oriented perpendicular to the shoreline and routed over a gently sloping bed with moderate drag, which governs the movement of density-driven flows along the lake bed.

Time series inputs for flow, temperature and salinity were read from external files and scaled to consistent units for the model. Collectively, these settings control the delivery of heat and solutes to the lake, with runoff primarily influencing near-surface conditions and submerged groundwater inflows contributing to subsurface mixing and the evolution of salinity and density structure.

8.4.2 LIMNOLOGY RESULTS

This section examines the development of limnological conditions over time within the Mimosa/Besgrove residual void lake over the simulation period. The analysis was undertaken to understand how temperature, salinity and density stratification behaviours evolve over time, and to determine whether persistent stratification, seasonal mixing or long-term stability is likely to occur.

The primary aim of this assessment is to characterise the timing and progression of key physical processes that influence water column behaviour. This includes the onset and breakdown of stratification, the establishment of seasonal overturn and the approach toward long-term equilibrium.

Figure 8-2 presents the thermal, salinity and density stratification over the entire simulation period.

Note that the stratification plots for temperature, salinity, and density represent the modelled conditions from lake surface to the bottom of the lake. It is important to interpret the y-axis as lake level above the lake bed (m), rather than elevation (mAHD) or depth below surface.

Thermal Stratification

The lake develops seasonal thermal stratification throughout the simulation period. Surface waters warm to above 25-35°C during summer and cool down during winter (15-20°C). As

shown in Figure 8-3, the water column mixes fully each winter, and as the lake level increases due to influx of groundwater, rainfall and runoff, there is a clear thermocline forming each summer as the lake fails to fully mix.

The thermocline generally forms at a depth of 10-15 m, with minor variations as surface water runoff and groundwater inflows enters the lake. Surface runoff enters at the lake surface at approximately ambient air temperature and therefore primarily influences the upper water column. In contrast, groundwater inflows enter below the surface along the pit walls and benches as submerged inflows. Depending on their density relative to the receiving water, these inflows can remain at depth or intrude at intermediate levels within the water column, thereby modifying the vertical density structure and influencing the depth and strength of the thermocline. This behaviour is reflected in Figure 8-3, which shows persistent seasonal thermal stratification with a stable thermocline despite increasing lake levels over time, indicating that inflows are not sufficiently energetic or dense to disrupt seasonal stratification.

The results indicate that rainfall variability has limited effect on the lake's temperature profile compared to other factors, such as regional weather patterns and seasonal solar heating.

Salinity Stratification

Salinity increases progressively throughout the 100-year simulation period, reflecting the combined influence of saline groundwater inflows and evaporative concentration.

An initial weak halocline is shown in Figure 8-4 , however this weakens further as the lake deepens and mixing occurs, resulting in full vertical mixing by approximately 20 years.

There is a consistent pattern in the model results showing reduction of lake salinity for a short period whenever there is an increase in lake level due to significant rainfall events. The low salinity rain and subsequent runoff temporarily decreases the lake salinity and creates a weak halocline.

After ~25 years, the water column remains well mixed, with salinity increasing gradually and uniformly across all depths. By year 100, and a lake depth of ~60 m, salinity has increased to 15 g/L and does not show any indications of stabilising. The model results indicate limited potential for long-term salinity stratification, with the lake tending to maintain a vertically homogeneous salinity profile over the long term.

Density Stratification

Density stratification persists throughout the simulation, driven primarily by temperature, with salinity playing a secondary role where vertical gradients are present rather than being uniformly distributed through the water column.

Density differences between surface and deep waters increase steadily, promoting long-term stability of the density gradient and limited deep mixing. The seasonal thermal mixing events during the winter months temporarily reduce stratification and allow partial homogenization of the upper and mid-depth layers, although complete and sustained mixing is not achieved.

Summary

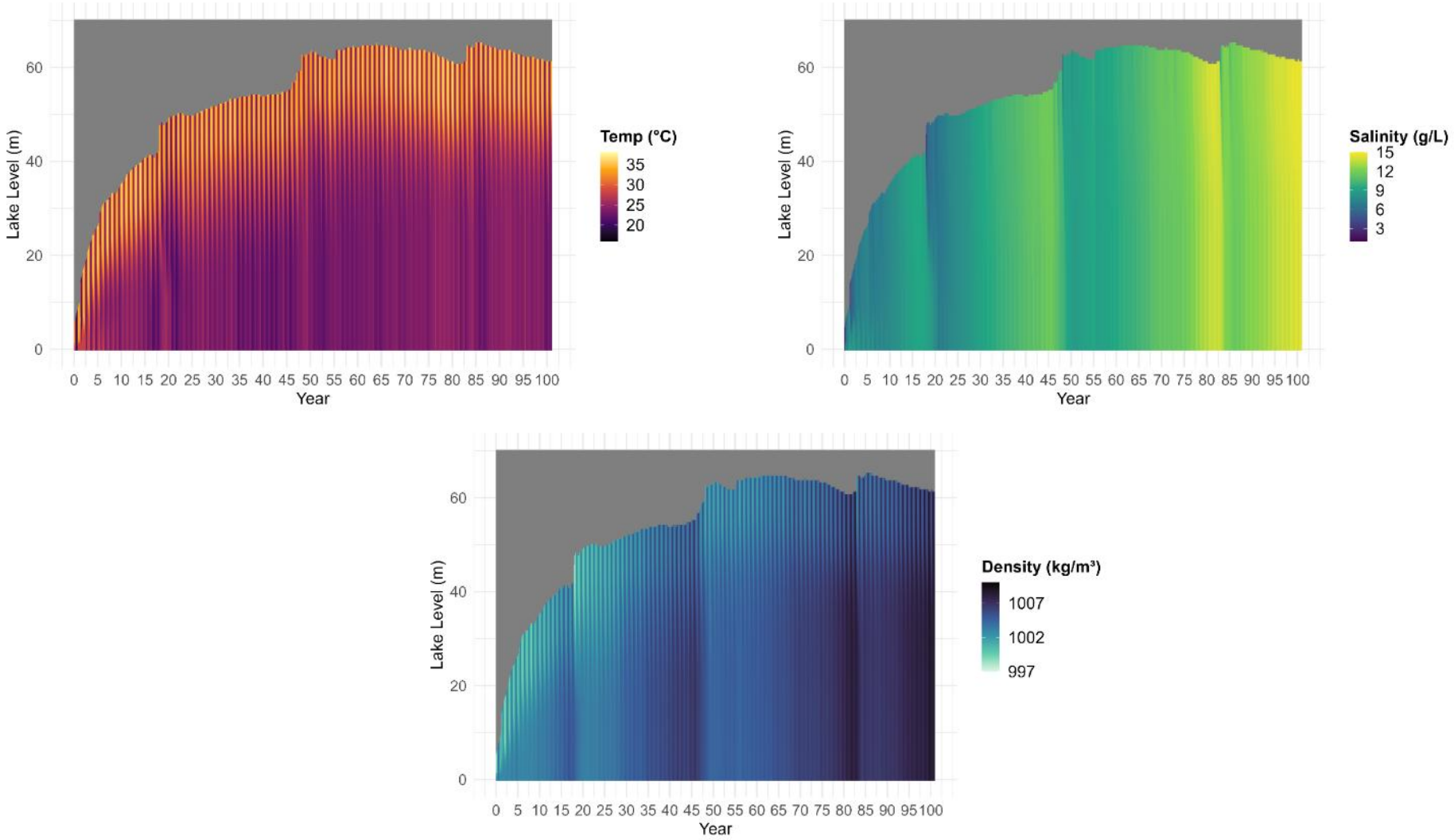
Overall, thermal effects exert the dominant control on short-term stratification, with surface heating generating strong seasonal density contrasts. Over time, salinity accumulation increasingly reinforces the density gradient, contributing to a progressive strengthening of

stratification rather than a stable or constant condition. As a result, Mimosa/Besgrove residual void lake limnology is expected to continue to evolve throughout the modelled period, with stratification becoming more persistent and resistant to complete mixing. While this trend is evident within the simulation timeframe, the long-term extent of strengthening and whether a steady state is ultimately reached beyond the model period remains uncertain.

Throughout the climatic period, rainfall intensity and inflow regime influence the magnitude and variability of stratification; however, these factors do not override the overall trend of increasing density-driven stability and limited deep mixing.

8.4.2.2 LIMNOLOGY EVOLUTION DURING SIGNIFICANT DECADES

Figure 8-3, Figure 8-4 and Figure 8-5 present temperature, salinity and density stratification results during ‘significant decades’ to illustrate the representative depth-dependent trends in temperature, salinity and density over time.



Note: Stratification profiles for temperature, salinity and density visualize the entire water column. While the y-axis indicates lake elevation measured upward from the lake bed (0 m), the uppermost edge of the plotted data physically represents the lake surface.

FIGURE 8-2 THERMAL, SALINITY AND DENSITY STRATIFICATION OF MIMOSA/BESGROVE RESIDUAL VOID OVER 100 YEARS

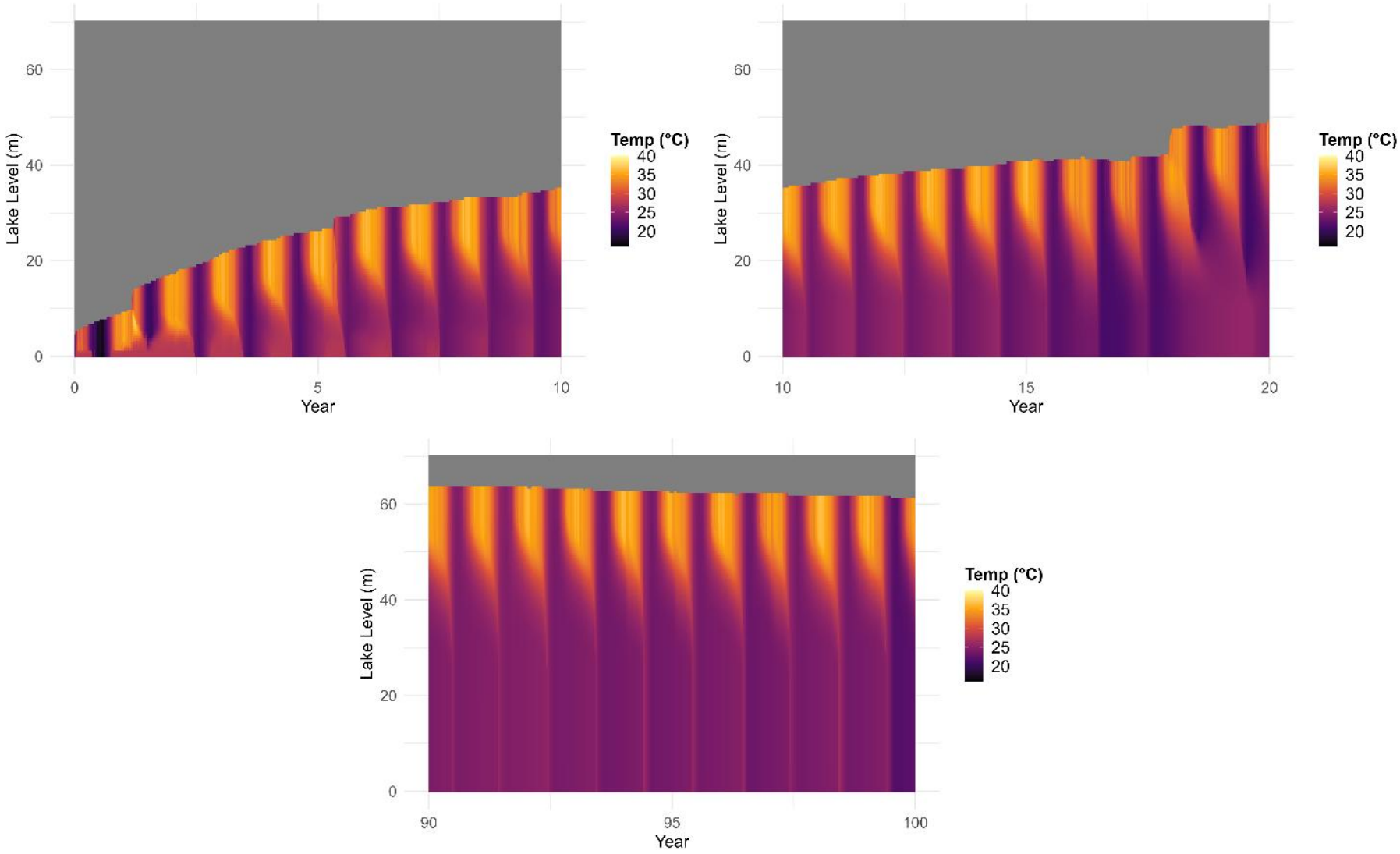


FIGURE 8-3 MIMOSA/BESGROVE THERMAL STRATIFICATION OVER SIGNIFICANT DECADES

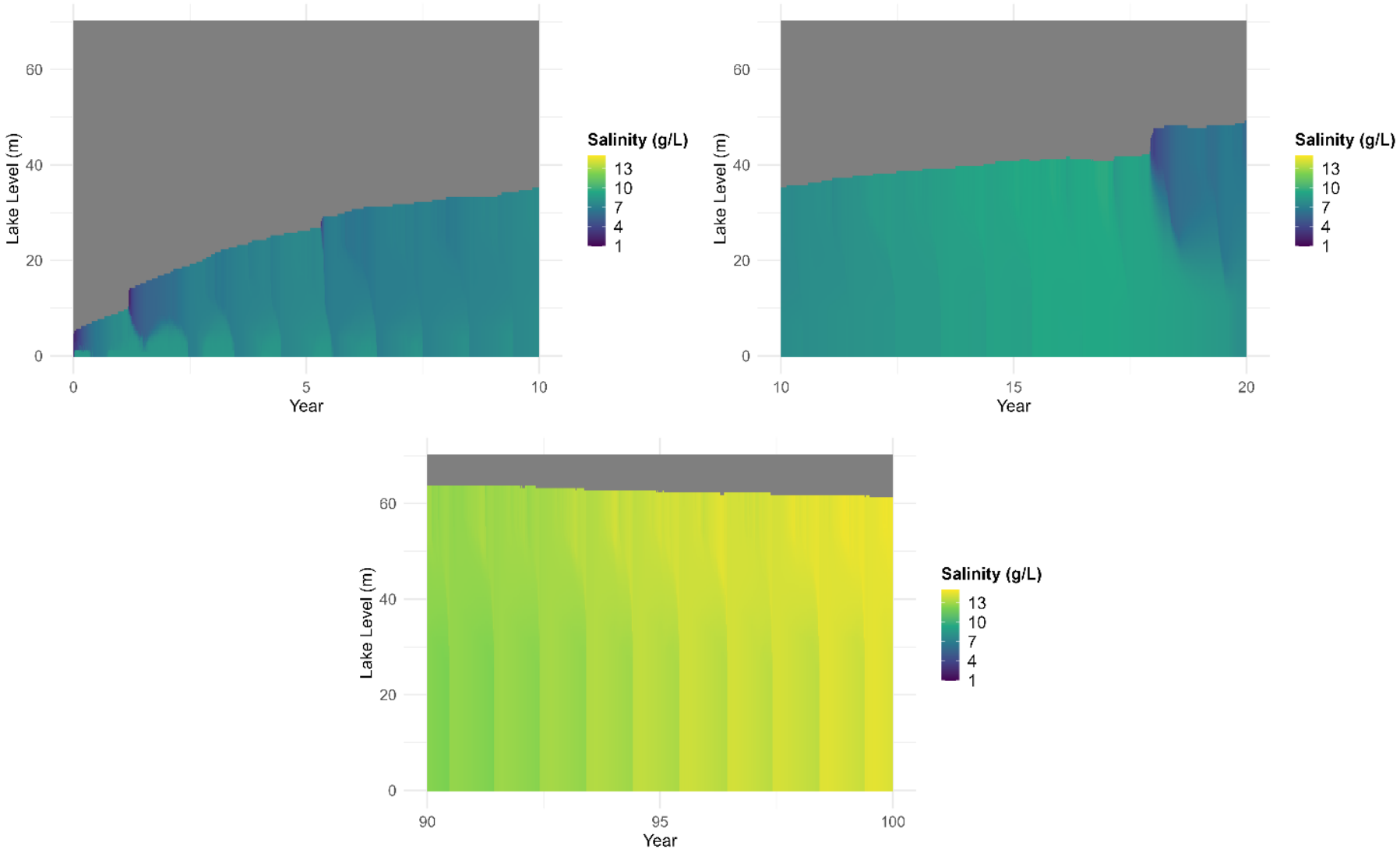


FIGURE 8-4 MIMOSA/BESGROVE SALINITY STRATIFICATION OVER SIGNIFICANT DECADES

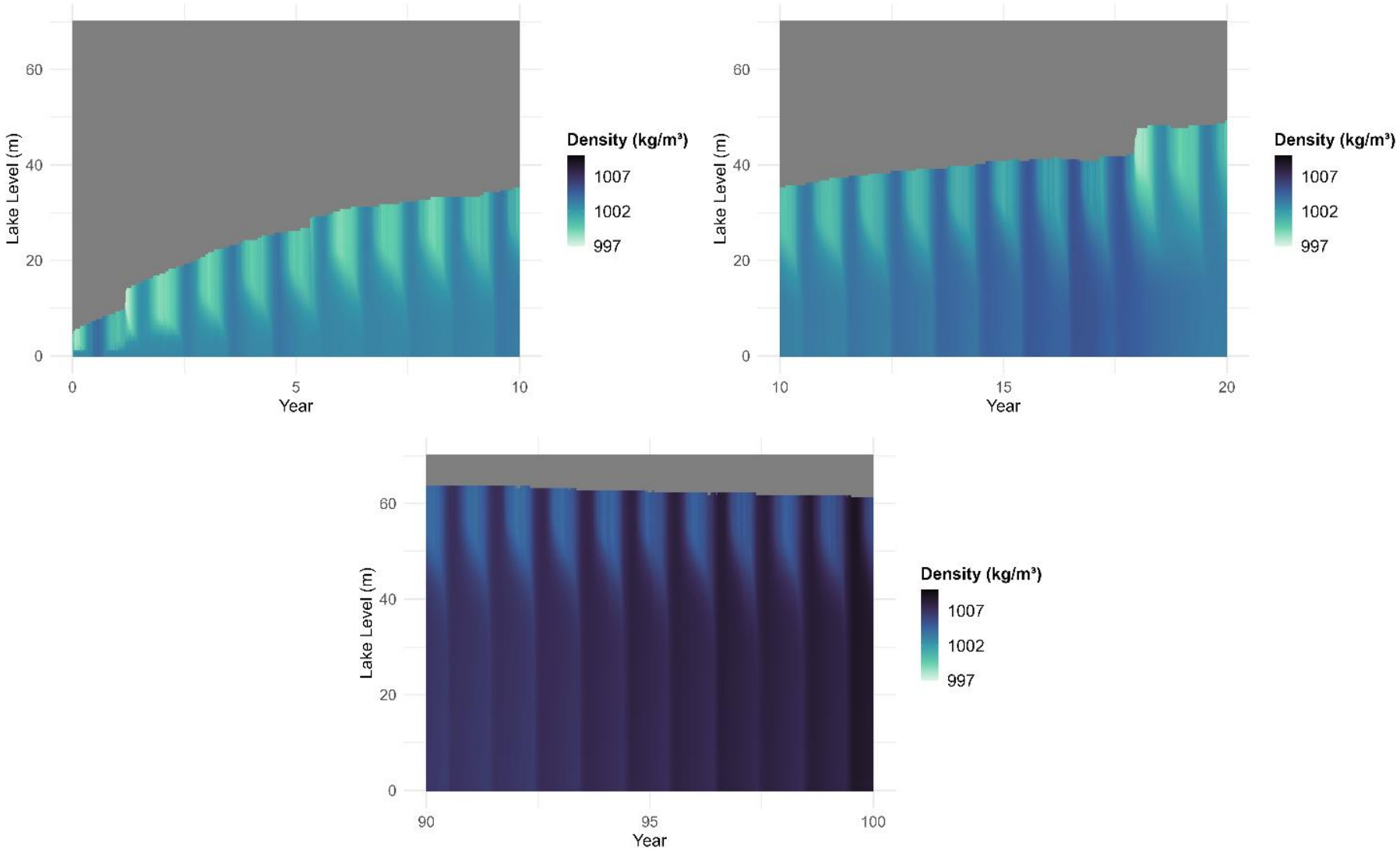


FIGURE 8-5 MIMOSA/BESGROVE DENSITY STRATIFICATION OVER SIGNIFICANT DECADES

8.4.2.3 TEMPORAL RESULTS SUMMARY

Table 8-20 summarises the simulated temporal variations across the 100-year simulation period during significant decades, representing early filling, mid-term transition and long-term equilibrium stages of pit lake development. Key observations include:

- Thermal behaviour remains consistently monomictic throughout the simulation, characterised by strong seasonal stratification and near-complete winter overturn; thermocline depth (~10-15 m) and overall thermal structure remain stable, with only short-lived disruptions associated with rapid lake level increases;
- Salinity progressively increases over time but becomes vertically uniform after ~20 years due to regular strong seasonal mixing, indicating that evaporative concentration drives long-term salinity trends rather than persistent salinity stratification; and
- Density stratification is strongest during early filling due to combined temperature and salinity gradients, but weakens over time as salinity becomes homogenised, resulting in density structure being increasingly dominated by seasonal thermal stratification rather than sustained salinity layering.

TABLE 8-20 SUMMARY OF MIMOSA/BESGROVE LIMNOLOGY RESULTS – TEMPORAL VARIATIONS

Aspect	Significant Decade	Results Summary
Thermal	Years 0-10	• Strong, seasonal thermal stratification forms each summer. A thermocline appears at around 15 m deep during the warmer months each year. • Each winter, the water column mixes fully, showing complete overturn.
	Years 10-20	• The same seasonal pattern continues, but the gradient becomes more consistent and slightly deeper. • Surface heating remains strong, but cooling penetrates deeper, indicating annual monomictic cycling during the winter months (one main mixing period per year). • Mixing cycle disruption occur around year 18, where a significant rainfall event rapidly increases the lake level from 40 to 48 m. This causes thermal stratification over several years as the water column fails to mix afterwards.
	Years 90-100	• Surface warming and winter mixing persist. • No evidence of long-term thermal isolation or stratification. • The lake behaves as a monomictic system with recurring seasonal stratification that fully mixes each winter. • Deep temperature remains steady (~16-21°C).
Salinity	Years 0-10	• Strong stratification develops immediately, with high salinity accumulating at lower depths due to saline groundwater inflow. • The lake becomes progressively saline as the lake level increases. • Mixing instabilities occur at Year 2 and 6, similar to lake temperature. Rising lake levels cause low salinity waters to float at surface level. Mixing cycle restabilises shortly after.
	Years 10-20	• The salinity gradient gradually increases. • Colours become nearly uniform from surface to bottom, i.e. clear evidence of complete vertical mixing. • Mixing cycle disruption occurs at year 18 with low salinity waters entering the lake as rainfall and runoff. Mixing cycle restabilises shortly after.
	Years 90-100	• Lake salinity progressively increases over time. • The water column shows uniform salinity at all depths (green to yellow shading ~13-14 g/L). • Lake salinity is recorded at 14.5 g/L at the end of simulation period. • No evidence of stratification or layering.

Aspect	Significant Decade	Results Summary
Density	Years 0-10	• Clear density stratification develops during early filling. • Significant stratification occurs at year 2 due to lake volume influx. Density stratification trend reverts back to normal shortly after. • The upper layer (teal-green) is less dense, forming a distinct two-layer system.
	Years 10-20	• The vertical density gradient weakens but remains visible, with surface and mid-depth layers mixing each winter. • Mixing cycle disruption occur at year 18, decreasing density levels from surface to 10 m. Density below 25 m did not show any significant changes despite the lake volume influx and instabilities. • The system undergoes seasonal overturn, with mixing extending to near the bottom each winter but not achieving complete full-depth mixing.
	Years 90-100	• Density increases and is nearly uniform through the column, with only minor differences between surface and bottom waters. • Seasonal density fluctuations occur in the upper 20 m, consistent with annual thermal mixing. • The system exhibits stable monomictic behaviour; nearly full mixing each winter, with a weak residual gradient as a result of more dense water in the bottom 40 m.

9. RESIDUAL VOID MANAGEMENT

This section outlines proposed monitoring and management measures for the residual voids. It ensures that residual risks are controlled post-closure, as required under the PRCP framework.

Specifically, this section contains strategies to address:

- *Monitoring during construction through supervision, verification and auditing of engineering works;*
- *Development and use of 'as built' profiles to assess consistency with design surfaces;*
- *Comparison of key earthworks criteria (e.g. compaction, settlement) against design specifications, with rectification of any shortcomings;*
- *Post-construction assessment of landform stability through visual inspection and survey; and*
- *Documentation of exclusion measures (if applicable) as part of ongoing post-closure management.*

The residual voids at BWM are proposed to remain as permanent features post-closure. In general, potential long-term risks associated with residual voids include water quality degradation, geotechnical instability and interaction with surrounding groundwater or surface water systems. These risks have to be managed through appropriate design measures, long-term monitoring and adaptive management planning.

Most residual voids act as groundwater sinks (Section 4). The flows from the four residual voids that have net outward fluxes (i.e. Bonnie Doon, Stewarton South, Ramp 30 and Ramp 74) are drawn to the neighbouring voids with lake levels at lower elevations rather than away from the mining area.

Flood modelling (Section 5) indicates that residual voids are either located outside mapped floodplains or are protected by the final landform configuration. All residual voids are predicted to be protected from floodwater ingress during the 0.1% AEP design event under final landform conditions. Modelling that includes the existing temporary Sirius Creek diversion shows a permanent creek diversion will provide flood immunity for the Ramp 74 residual void in a 0.1% AEP event.

The residual void water balance (Section 6) predicts no risk of water discharge or overtopping under a future climate scenario or extreme storm event. Freeboard ranges between 30-150 m for all residual voids.

Geotechnical modelling (Section 7) indicates satisfactory FoS values for all high-walls and end-walls can be achieved with appropriate set-backs used to delineate NUMA boundaries. FoS analysis of selected low walls has informed the NUMA boundaries on spoil dumps and contributed to a reduction in total NUMA footprint.

Geochemical modelling results (Section 8.2) predicts that five of the nine modelled residual void lakes will gradually become hypersaline due to evaporative concentration and inflow of saline groundwater: Mimosa/Besgrove, Ramp 8, Deep Creek, Kenmare, Togara/North Marshmead and Comet Downs East. All geochemically modelled hypersaline voids are groundwater sinks with inward hydraulic gradients and none of the voids have any risk of overtopping. Residual void lakes are not expected to pose a risk to surrounding groundwater environmental values.

Limnological modelling results (Section 8.4) of the Mimosa/Besgrove void lake over 100 years indicate that residual void lakes will exhibit persistent thermal stratification, characterised by recurring summer stratification and near-complete winter overturn (monomictic behaviour). Salinity stratification is not sustained over the long term, as regular seasonal mixing results in largely uniform salinity profiles despite progressive increases in overall salinity due to evaporative concentration and groundwater inputs. Density stratification is primarily thermally driven, with salinity contributing only where transient vertical gradients develop and reinforcing the density contrast rather than forming independent, stable chemical layering. Over time, increasing salinity may strengthen overall density gradients; however, stratification remains predominantly controlled by seasonal thermal processes.

Based on these findings, ongoing management requirements of the residual voids is expected to be minimal. A tailored monitoring program will be developed to confirm the stability of lake levels, water quality trends, void wall integrity over time and the condition of permanent creek diversions that provide flood immunity to the residual voids. Monitoring results will be reviewed periodically against closure performance criteria. If significant deviations are observed, adaptive management principles will be adopted and an adaptive management program will be developed closer to closure execution. Monitoring should also consider long-term salinity trends and potential density stratification behaviour within pit lakes where hypersaline conditions are predicted.

9.1 VOID REHABILITATION

Void rehabilitation at BWM will primarily involve shaping and stabilising pit walls to ensure long-term geotechnical stability and safe integration into the final landform. All final slopes have been designed in accordance with site-specific geotechnical investigations, and reshaped where necessary to meet minimum stability criteria.

The rehabilitation process will include:

- Completion of final earthworks to meet design surface levels and slope geometry;
- Construction QA/QC, including topographic validation against the final landform model;
- Erosion control measures (e.g. surface roughening, contour drains) where needed on areas of the low walls within the residual voids that have been assigned a PMLU;
- Installation of safety or exclusion infrastructure, such as fencing, bunding or signage where public access or fauna hazard is identified; and
- Documentation of the final constructed condition, including ‘as built’ survey data and photographic records.

9.1.1 LOW WALL REVEGETATION

The area and layout of the NUMAs for each residual void have been reviewed in line with *Management of Coal Mine Voids as Non-Use Management Areas*, published by the Queensland Mine Rehabilitation Commissioner. This guidance explains that voids approved under transitional arrangements may be retained as NUMAs under the EP Act. It also notes that some areas of a void, such as ramps or low walls, may be suitable for rehabilitation to stable condition and excluded from the NUMA footprint.

At BWM, the NUMA boundaries have been designed to maximise the extent of land that can be safely assigned a PMLU. All practicable areas where slope geometry, geotechnical stability and safety allow, are included in the PMLU footprint for future rehabilitation. Although some portions of the low wall may present as stable, active rehabilitation within the NUMA is not proposed due to access limitations, safety risks, and the geotechnical constraints inherent to void and adjacent landforms. Under the transitional provisions of the PRCP framework, rehabilitation is only required where it is safe, stable and practicable, and NUMA areas do not meet these criteria.

Vegetation establishment within the NUMA may occur through natural recruitment from the rehabilitated PMLU areas located above the NUMA boundary. This approach:

- Limits rehabilitation activities to landforms that can be safely accessed, constructed and maintained;
- Excludes NUMA low walls and pit floors from ground disturbing and revegetation works due to geotechnical and safety constraints; and
- Facilitates opportunity for natural recruitment from adjacent PMLU rehabilitation to contribute towards improved environmental outcomes within the NUMA.

Allows the PMLU rehabilitation areas above the residual voids to contribute towards long-term landform stability and minimisation of environmental harm void. The final NUMA and PMLU boundaries, including areas to be revegetated, are shown in Figure 9-1 (North) and Figure 9-2 (South).

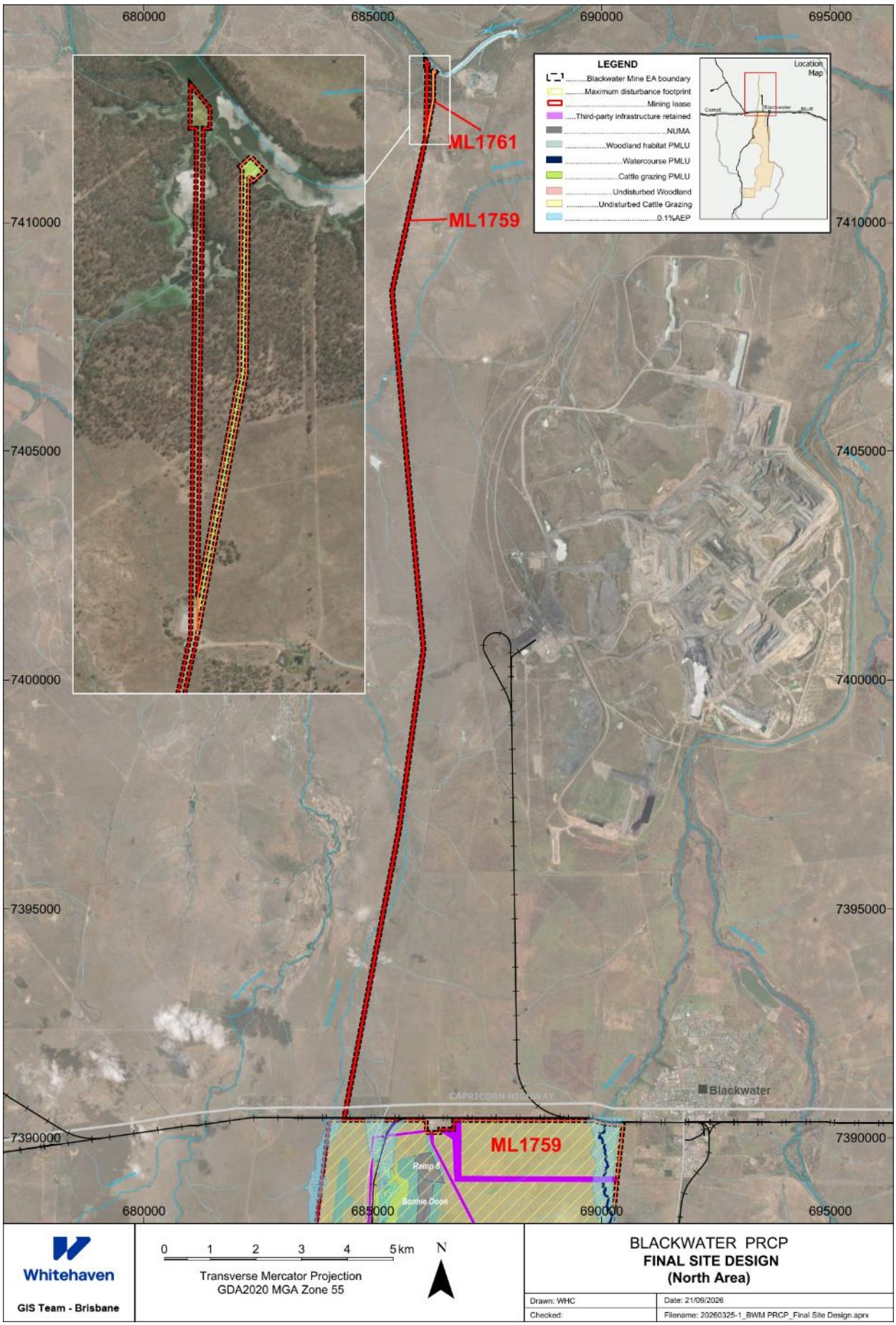


FIGURE 9-1 BWM NUMA AND PMLU AREAS (NORTH)

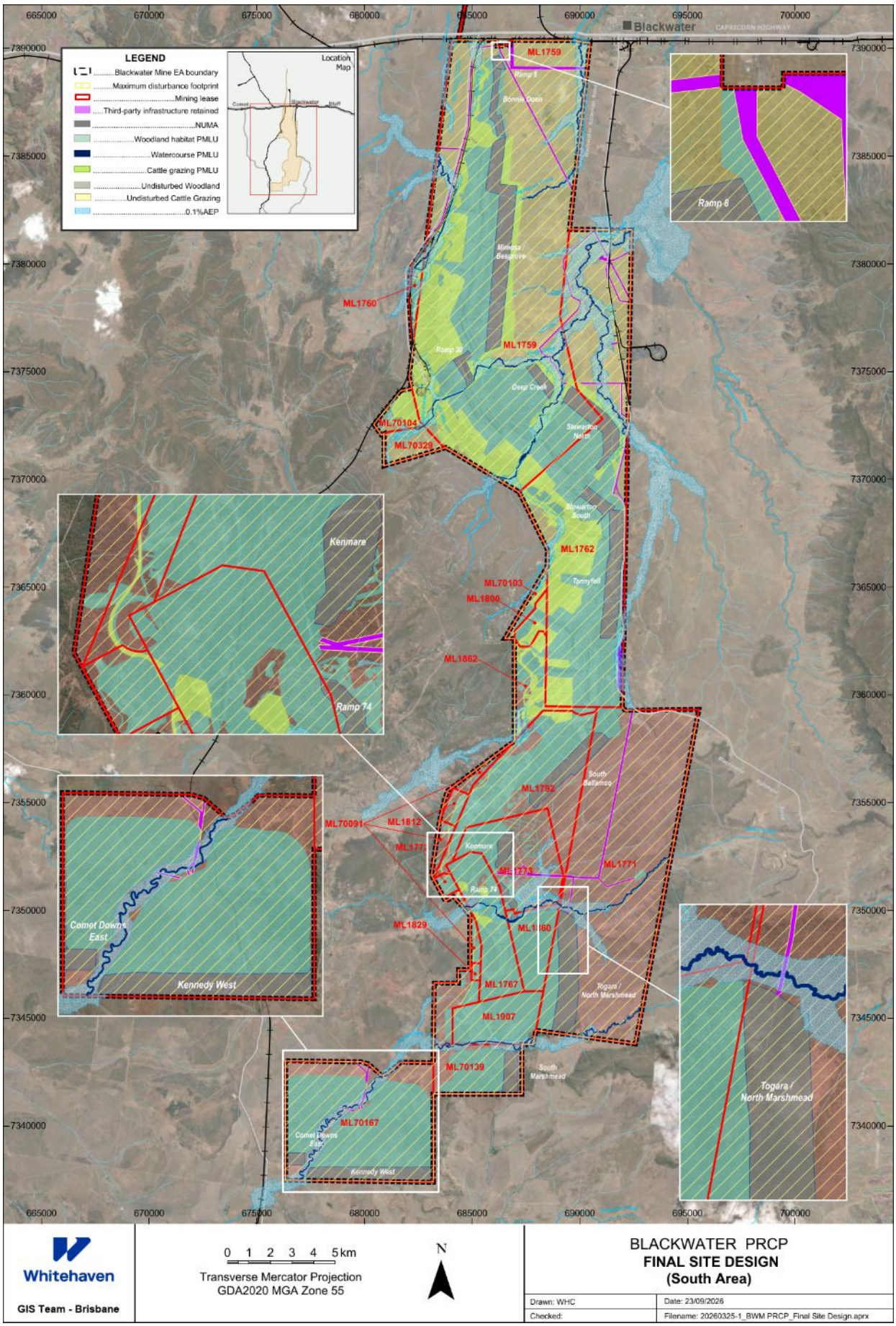


FIGURE 9-2 BWM NUMA AND PMLU AREAS (SOUTH)

9.2 MONITORING AND MANAGEMENT

A residual void monitoring program will be implemented post-closure, consistent with the site's overall rehabilitation monitoring framework.

Table 9-1 summarises the residual void monitoring program for Improvement Area (IA) 1 and IA 2 under the PRCP Schedule. The program is structured to demonstrate progressive achievement of the PRCP Management Milestones (MM):

- MM1 (structural stability);
- MM2 (cover system);
- MM3 (surface requirements); and
- MM4 (sufficient improvement).

Monitoring activities are designed to verify post-closure performance against model predictions, confirm compliance with these milestone criteria, and provide data to support adaptive management and certification by an appropriately qualified person (AQP).

TABLE 9-1 RESIDUAL VOIDS MONITORING PROGRAM

Monitoring Element	Description	Relevant PRCP Milestone(s)
Void water levels	• Automated or manual dip readings and groundwater bores to confirm modelled water balance and hydraulic sink behaviour. • Monitoring will verify predicted trends and confirm the void acts as a groundwater sink post-closure. • Data should be reviewed quarterly by the environmental team and certified by an AQP.	MM4.5-MM4.6
Water quality	• Periodic sampling and laboratory analysis to track salinity, pH, metals, major ions and other parameters relevant to closure performance and environmental harm criteria. • Results compared against model predictions and closure performance targets. • Bi-annual monitoring during the initial decade post-closure, then annual.	MM4.5-MM4.6
Slope and wall stability	• Visual inspections to confirm structural stability, erosion or slumping, and compliance with design FoS. • Inspections undertaken annually and after major rainfall events by a geotechnical engineer or AQP.	MM1.6-MM1.7
Cover Systems	• Periodic visual inspections to confirm differential settlement is not leading to erosion or impacting cover functionality. • Inspections undertaken annually and after major rainfall events by an AQP. • Periodic water level survey to verify minimum 1 m depth is maintained where water is used as a cover.	MM2.1 – MM2.2

Monitoring Element	Description	Relevant PRCP Milestone(s)
Safety bunds, fencing and signage	• Periodic inspection of bunds, fencing and safety signage to confirm integrity and continued effectiveness of exclusion controls in accordance with Australian Standards. • Includes annual maintenance and post-storm verification.	MM3.1-MM3.2, MM1.5 – 1.6 and MM4.4
Wildlife use and safety	• Visual and photographic monitoring to identify fauna interaction or hazard potential and guide mitigation measures. • Findings inform adaptive controls to ensure the NUMA remains safe to humans and fauna.	MM4.4
Adaptive management	• Engineering interventions-bench reshaping, erosion control, drainage improvements-plus model recalibration and revision of closure performance criteria or safety controls if monitoring shows deviation from predictions. • Actions should be implemented under AQP direction.	MM4.5-MM4.7
Certification and review	• All monitoring and inspection outcomes reviewed by an AQP to certify achievement of MM1-MM3 and confirm compliance with PRCP Schedule requirements.	MM4.8

If monitoring results show deviations from predicted trends (e.g. unexpected groundwater mounding, water quality degradation, wall instability, etc.), the following adaptive management responses may be considered:

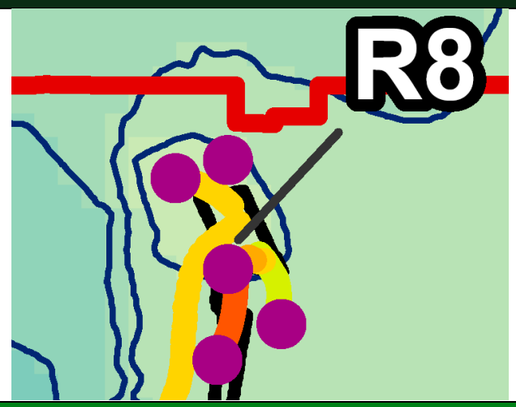
- Engineering interventions (e.g. bench reshaping, additional erosion control);
- Update of predictive models or assumptions;
- Recalibration of closure performance criteria; and
- Revision of exclusion or safety controls.

9.3 RESIDUAL VOID OVERVIEW TABLES

Table 9-2 through Table 9-16 summarise the results of the modelling and design work detailed in the above sections for the relevant residual voids at BWM. It contains the following information:

- Pit design parameters – Section 3;
- Hydrogeology and particle tracking – Section 4;
- Flooding risk – Section 5;
- Residual void lake water balance – Section 6;
- Geotechnical stability – Section 7; and
- Residual void lake geochemistry and limnology – Section 8.

TABLE 9-2 RAMP 8 SUMMARY TABLE

<table>
<tr><th colspan="6">Ramp 8</th></tr>
<tr><th colspan="6">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="3">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="3">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th colspan="2">Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 650 m
Max. Width: 360 m
Max. Depth: 66 m
Surface area: 26 ha</td><td>Void crest/Spill Level: 188 mAHD
Indicative void floor: 109 mAHD</td><td>Highwall: ~84%
Low wall: ~51%</td><td>Natural: 33.7 ha
Spoil: 22.0 ha
Rehabilitated Spoil: 21.8 ha
<u>Total: 77.5 ha</u></td><td colspan="2">Spoil: +0.35 ML/day
Tailings: 0.0 ML/day
Natural Geology: +0.02 ML/day
Total GW Inflow: +0.37 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="2" rowspan="2">50° Ave Wall Angle:
• Average: 104 m;
• Range: 95-113 m; and
• 90%< 111 m.

60° Ave Wall Angle:
• Average: 99 m;
• Range: 91-96 m; and
• 90%< 94 m.</td><td>Mean: 146.5 mAHD
Max.: 148.7 mAHD</td><td>200 years</td><td>Groundwater sink</td><td>Min. Freeboard: 39.3 m
Does not spill</td></tr>
<tr><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td>Outside 0.1% AEP design and PMF events.</td><td colspan="3">Near-neutral pH throughout.
Strongly hypersaline after ~200 years with a final TDS of 127 g/L after 935 years.
High concentrations of major ions, silicon and manganese.
Large amounts of precipitated mineral phases (dolomite, ferrihydrite, gypsum, chalcedony).
No observed geochemical equilibrium.</td></tr>
</table>

TABLE 9-3 BONNIE DOON SUMMARY TABLE

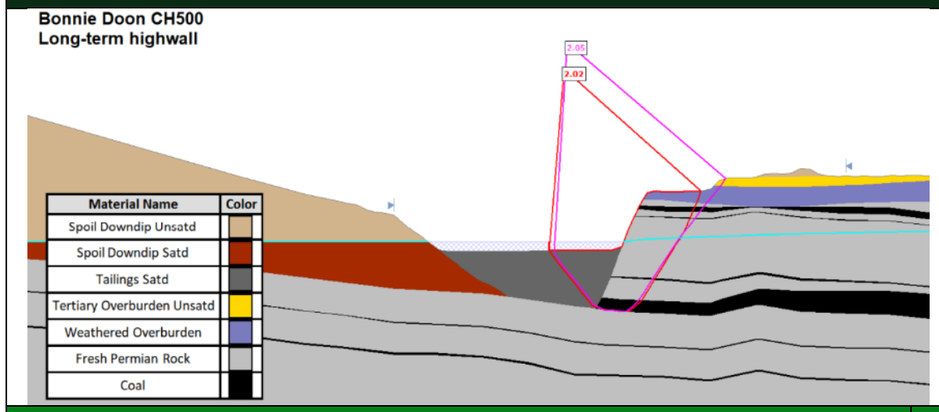
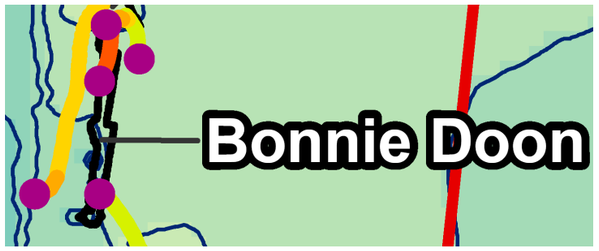
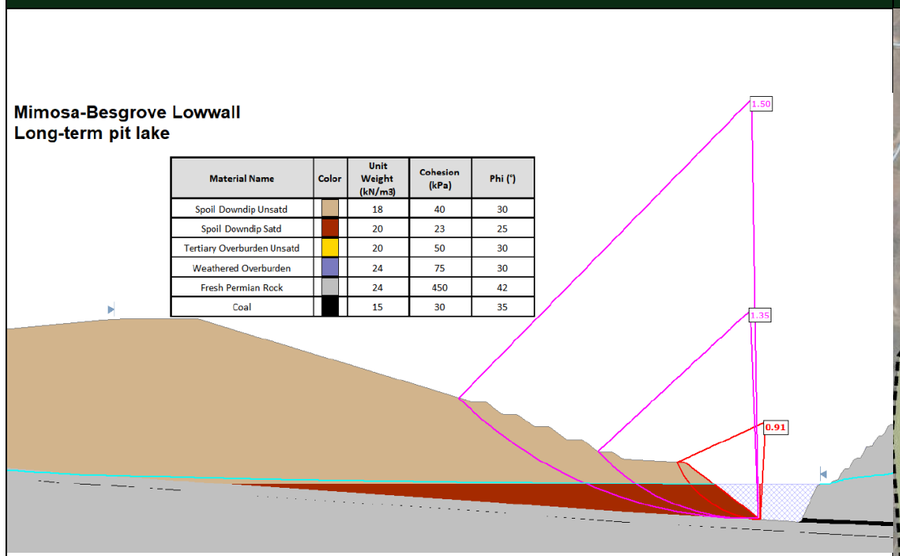
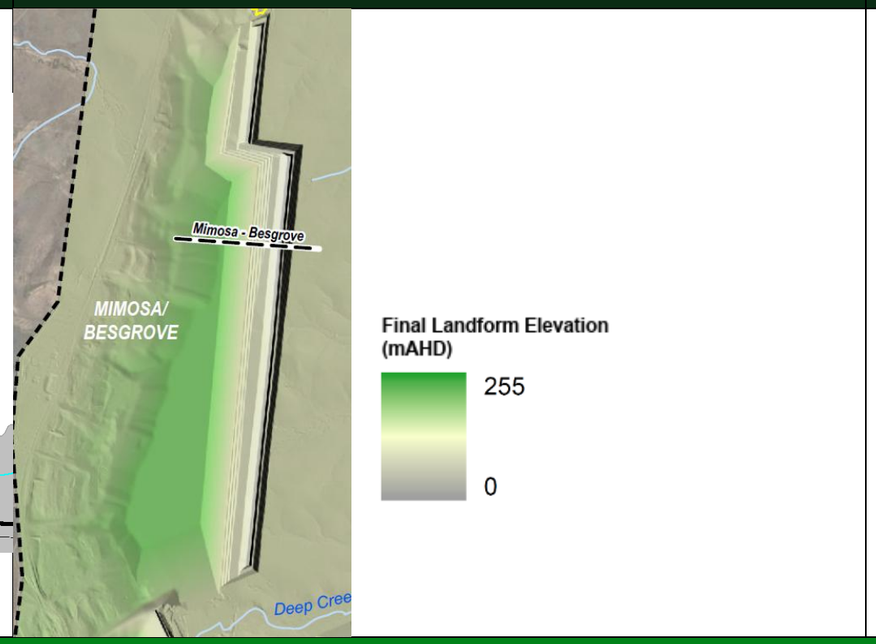
<table>
<tr><th colspan="5">Bonnie Doon</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr>
<td colspan="2">
</td>
<td colspan="2">
</td>
<td>
</td>
</tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr>
<td>Max. Length: 3,000 m
Max. Width: 250 m
Max. Depth: 26 m
Surface area: 105 ha</td>
<td>Void crest/Spill Level: 188 mAHD
Indicative void floor: 150 mAHD</td>
<td>Highwall: 74%
Low wall: ~55%</td>
<td>Natural: 98.1 ha
Spoil: 84.1ha
Rehabilitated Spoil: 184.4 ha
<u>Total: 366.6 ha</u></td>
<td>Spoil: -0.12 ML/day
Tailings: -0.01 ML/day
Natural Geology: -0.01 ML/day
Total GW Inflow: -0.14 ML/day</td>
</tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="2">Water Balance</th></tr>
<tr><th colspan="3">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr>
<td colspan="3" rowspan="2">FoS: 2.02
Set-back from wall toe to FoS>1.5: Crest</td>
<td>Cycles between dry and a maximum of: 159.8 mAHD</td>
<td>150 years</td>
<td>Groundwater Source</td>
<td>Min. Freeboard: 28.2 m</td>
</tr>
<tr><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr>
<td>Outside 0.1% AEP design and PMF events.</td>
<td colspan="3">Weakly alkaline pH (~8) throughout.
No hypersalinity due to net groundwater outflow.
Low concentrations of solutes and no values outside groundwater trigger levels.
Negligible amounts of precipitated mineral phases.
Geochemical equilibrium established almost immediately.</td>
</tr>
</table>

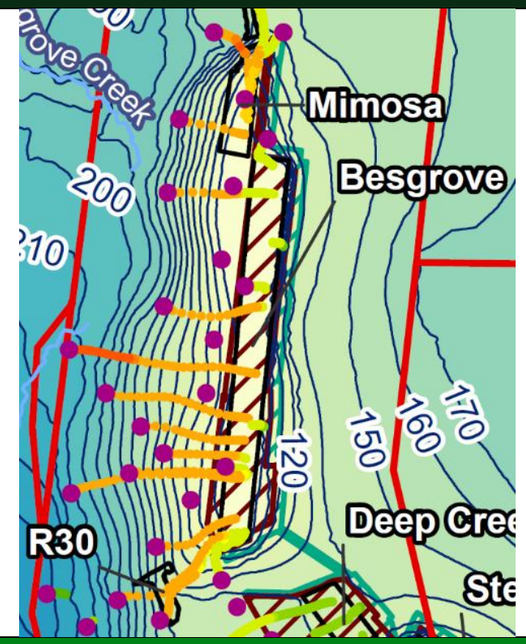
TABLE 9-4 MIMOSA/BESGROVE SUMMARY TABLE

Mimosa/Besgrove		
Overview		
End of Mining Cross-Section	**Final Landform Design**	**Particle Tracking**



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35





Design Parameters			Hydrology	
Indicative Dimensions	**Elevation**	**NUMA Slope Grades (overall)**	**Catchment Area**	**Equilibrium GW Inflow Rates**
Max. Length: 10,100 m Max. Width: 650 m Max. Depth: 176 m Surface area: 701 ha	Void crest/Spill Level: 200 mAHD Indicative void floor: 24 mAHD	Highwall: ~90% Low wall: ~32%	Natural: 39.1 ha Spoil: 596.5 ha Rehabilitated Spoil: 622.4 ha Total: 1,258 ha	Spoil: +2.38 ML/day Tailings: 0 ML/day Natural Geology: +0.02 ML/day Total GW Inflow: +2.40 ML/day

Geotechnical Stability		Water Balance			
Set-back Distance from Highwall/Endwalls		**Equilibrium Water Level**	**Time to Equilibrium Level**	**Outflows**	
		Mean: 83.7 mAHD Max.: 88.1 mAHD	200 years	Groundwater sink	Min. Freeboard: 111.9 m Does not spill
		Post-Mining Flooding Risk	**Residual Void Lake Geochemistry & Limnology**		
50° Ave Wall Angle: • Average: 180 m; • Range: 120-248 m; and • 90%< 236 m.	60° Ave Wall Angle: • Average: 176 m; • Range: 102-249 m; and • 90%< 236 m.	Outside 0.1% AEP design and PMF events.	Near-neutral pH throughout. Predicted to become hypersaline after ~200 years with a final TDS of 174 g/L after 967 years. Elevated concentrations of major ions, arsenic, chromium, antimony, silicon and manganese. Large amounts of precipitated mineral phases (gypsum, dolomite, lepidocrocite, pyrolusite, barite, diaspore). No observed geochemical equilibrium. With regards to limnology, thermal stratification is the dominant control on water column structure, with surface heating generating strong seasonal density contrasts and recurring summer stratification followed by winter overturn (monomictic behaviour). Salinity stratification is not sustained, as seasonal mixing produces largely uniform salinity profiles despite ongoing salinity increases. Consequently, density stratification is primarily thermally driven, with salinity contributing to density gradients where present and progressively reinforcing stratification over time rather than forming persistent chemical layering.		

TABLE 9-5 DEEP CREEK SUMMARY TABLE

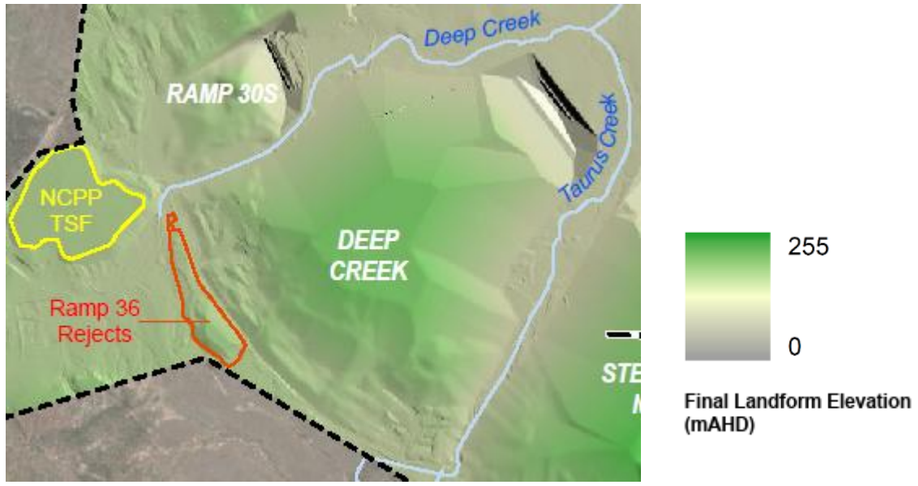
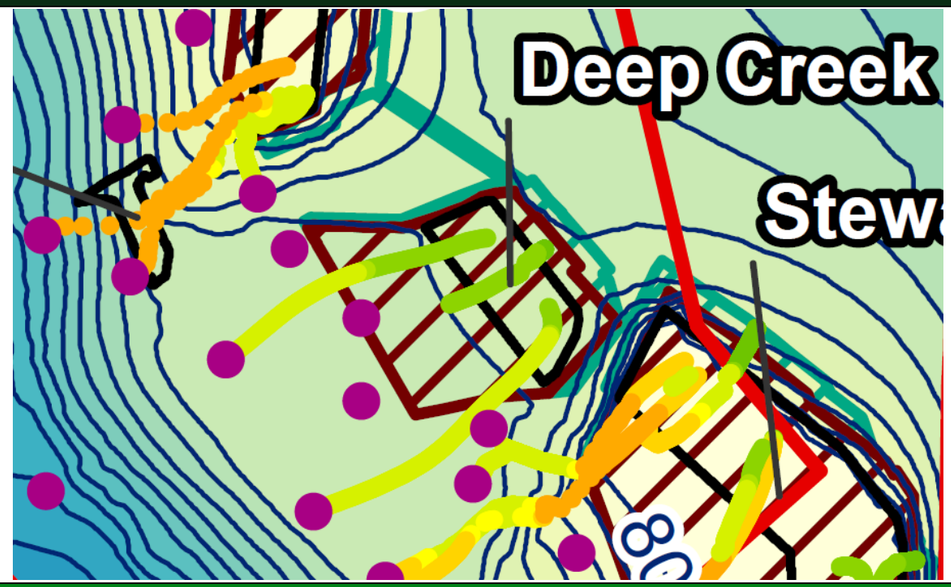
<table>
<tr><th colspan="6">Deep Creek</th></tr>
<tr><th colspan="6">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="3">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="3">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th colspan="2">Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 1,600 m
Max. Width: 600 m
Max. Depth: 150 m
Surface area: 102 ha</td><td>Void crest/Spill Level: 202 mAHD
Indicative void floor: 52 mAHD</td><td>Highwall: ~93%
Low wall: ~51%</td><td>Natural: 0.0 ha
Spoil: 52.9 ha
Rehabilitated Spoil: 167.3 ha
<u>Total: 220.2 ha</u></td><td colspan="2">Spoil: +0.79 ML/day
Tailings: 0.0 ML/day
Natural Geology: 0.0 ML/day
Total GW Inflow: +0.79 ML/day</td></tr>
<tr><th colspan="2">Geotechnical Stability</th><th colspan="4">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td>50° Ave Wall Angle:
• Average: 146 m;
• Range: 121-171 m; and
• 90%< 169 m.</td><td>60° Ave Wall Angle:
• Average: 136 m;
• Range: 98-180 m; and
• 90%< 175 m.</td><td>Mean: 134.5 mAHD
Max.: 137.1 mAHD</td><td>300 years</td><td>Groundwater sink</td><td>Min. Freeboard: 64.9 m
Does not spill</td></tr>
<tr><td colspan="2"></td><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2"></td><td>Outside 0.1% AEP event
Partially within PMF extent
(Taurus Creek)</td><td colspan="3">Initially weakly alkaline pH, becoming progressively neutral over time.
Becomes hypersaline after ~300 years with a final TDS of 129 g/L after 935 years.
High concentrations of major ions, silicon, chromium, nickel, antimony and zinc.
Large amounts of precipitated mineral phases (gypsum, dolomite, lepidocrocite, pyrolusite, barite, diaspore).
No observed geochemical equilibrium.</td></tr>
</table>

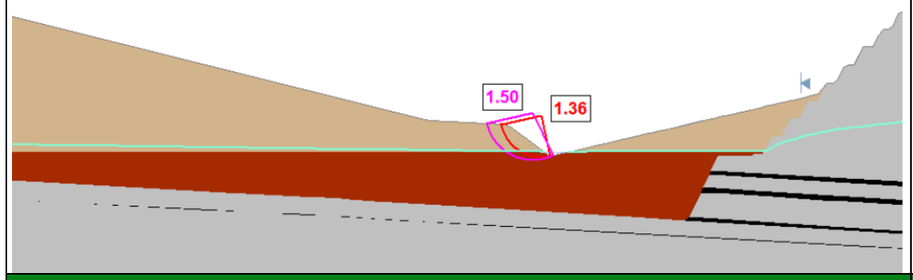
TABLE 9-6 STEWARTON NORTH SUMMARY TABLE

Stewarton North

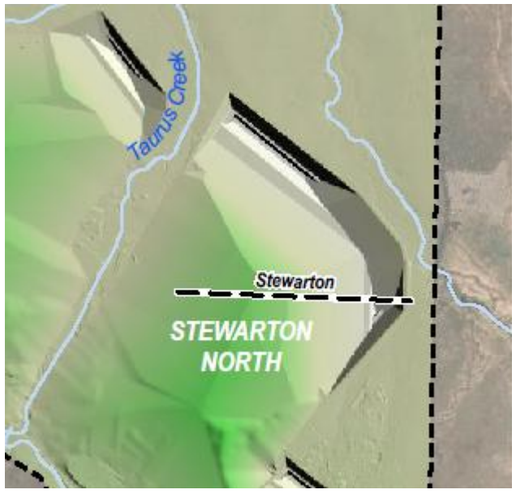
Overview

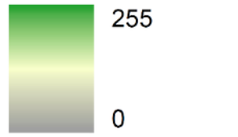
End of Mining Cross-Section

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

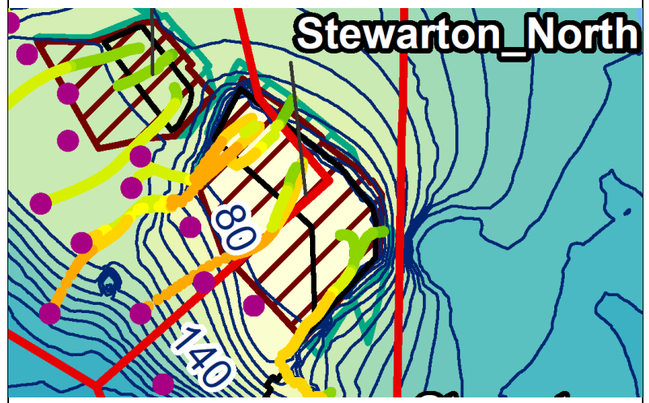


Final Landform Design





Particle Tracking



Design Parameters

Indicative Dimensions	Elevation	NUMA Slope Grades (overall)
Max. Length: 3,700 m Max. Width: 800 m Max. Depth: 208 m Surface area: 334 ha	Void crest/Spill Level: 204 mAHD Indicative void floor: -4 mAHD	Highwall: ~97% Low wall: ~36%

Hydrology

Catchment Area	Equilibrium GW Inflow Rates
Natural: 0.0 ha Spoil: 195.2 ha Rehabilitated Spoil: 678.1 ha Total: 873.3 ha	Spoil: +1.23 ML/day Tailings: 0.0 ML/day Natural Geology: +0.05 ML/day Total GW Inflow: +1.28 ML/day

Geotechnical Stability

Set-back Distance from Highwall/Endwalls	
50° Ave Wall Angle: • Average: 207 m; • Range: 107-295 m; and • 90%< 290 m.	60° Ave Wall Angle: • Average: 201 m; • Range: 89-298 m; and • 90%< 293 m.

Water Balance

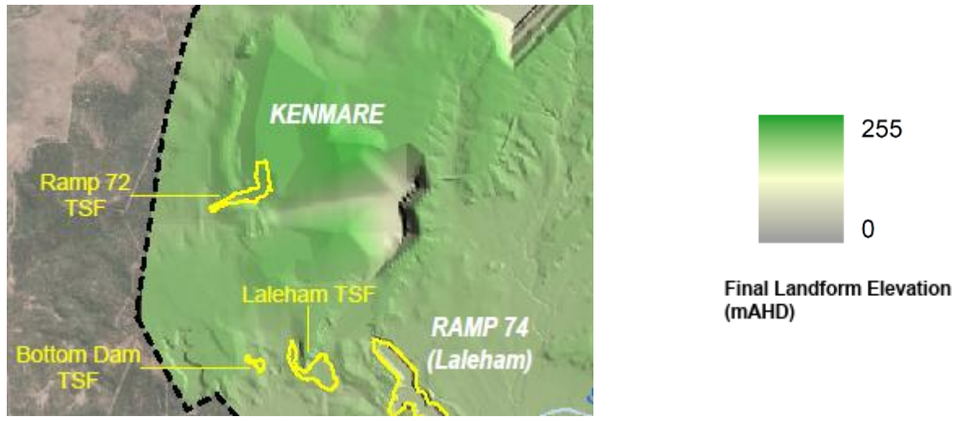
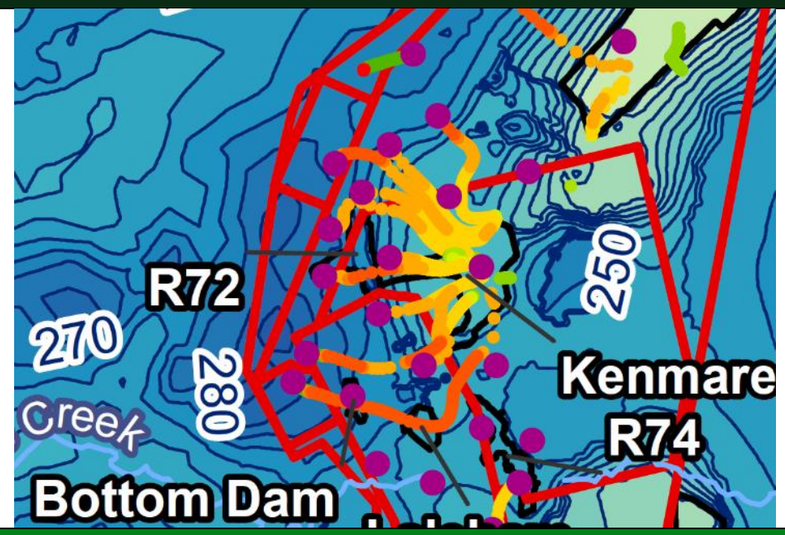
Equilibrium Water Level	Time to Equilibrium Level	Outflows	
Mean: 74.0 mAHD Max.: 78.5 mAHD	200 years	Groundwater sink	Min. Freeboard: 125.5 m Does not spill

Post-Mining Flooding Risk	Residual Void Lake Geochemistry
Outside 0.1% AEP design and PMF events.	N/A

TABLE 9-7 STEWARTON SOUTH SUMMARY TABLE

<table>
<tr><th colspan="5">Stewarton South</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="2">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 1,400 m
Max. Width: 500 m
Max. Depth: 140 m
Surface area: 93 ha</td><td>Void crest/Spill Level: 232 mAHD
Indicative void floor: 92 mAHD</td><td>Highwall: ~87%
Low wall: ~34%</td><td>Natural: 0.0 ha
Spoil: 50.9 ha
Rehabilitated Spoil: 150.3 ha
<u>Total: 201.2 ha</u></td><td>Spoil: -0.05 ML/day
Tailings: 0.0 ML/day
Natural Geology: 0.0 ML/day
Total GW Inflow: -0.05 ML/day</td></tr>
<tr><th colspan="2">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td>50° Ave Wall Angle:
• Average: 146 m;
• Range: 113-157 m; and
• 90%< 157 m.</td><td>60° Ave Wall Angle:
• Average: 124 m;
• Range: 98-142 m; and
• 90%< 138 m.</td><td>Mean: 103.9 mAHD
Max.: 115.5 mAHD</td><td>100 years</td><td>Groundwater source</td><td>Min. Freeboard: 116.5 m
Does not spill</td></tr>
<tr><td colspan="2"></td><th>Post-Mining Flooding Risk</th><th colspan="2">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2"></td><td>Outside 0.1% AEP design and PMF events.</td><td colspan="2">N/A</td></tr>
</table>

TABLE 9-8 KENMARE SUMMARY TABLE

<table>
<tr><th colspan="6">Kenmare</th></tr>
<tr><th colspan="6">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="3">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="3">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th colspan="2">Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 1,800 m
Max. Width: 500 m
Max. Depth: 122 m
Surface area: 85 ha</td><td>Void crest/Spill Level: 297 mAHD
Indicative void floor: 175 mAHD</td><td>Highwall: ~36%
Low wall: ~31%</td><td>Natural: 0.0 ha
Spoil: 146.1 ha
Rehabilitated Spoil: 236.0 ha
<u>Total: 382.1 ha</u></td><td colspan="2">Spoil: +0.49 ML/day
Tailings: 0.0 ML/day
Natural Geology: 0.0 ML/day
Total GW Inflow: +0.49 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="2" rowspan="2">50° Ave Wall Angle:
• Average: 186 m;
• Range: 169-198 m; and
• 90%< 195 m.

60° Ave Wall Angle:
• Average: 163 m;
• Range: 147-175 m; and
• 90%< 173 m.</td><td>Mean: 218 mAHD
Max.: 221.5 mAHD</td><td>150 years</td><td>Groundwater sink</td><td>Min. Freeboard: 75.5 m
Does not spill</td></tr>
<tr><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2">Outside 0.1% AEP design and PMF events.</td><td colspan="3">Near-neutral pH throughout.
Becomes hypersaline after ~100 years with a final TDS of 81 g/L after 929 years.
High concentrations of major ions, silicon and manganese.
Large amounts of precipitated mineral phases (dolomite, gypsum, chalcedony).
No observed geochemical equilibrium.</td></tr>
</table>

TABLE 9-9 TOGARA/NORTH MARSHMEAD SUMMARY TABLE

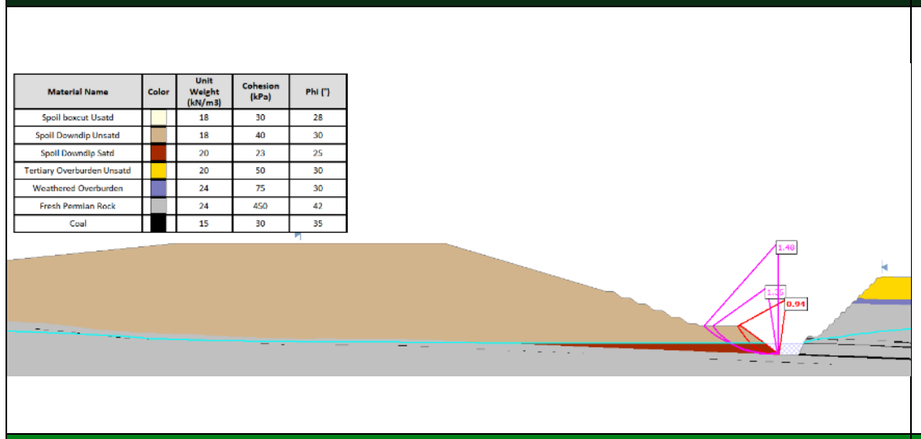
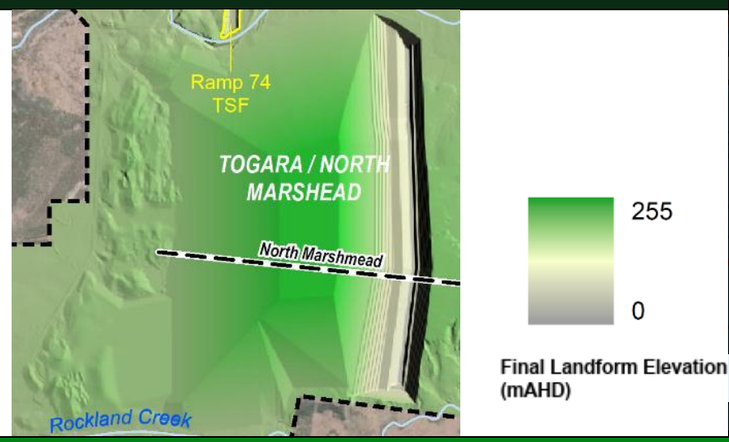
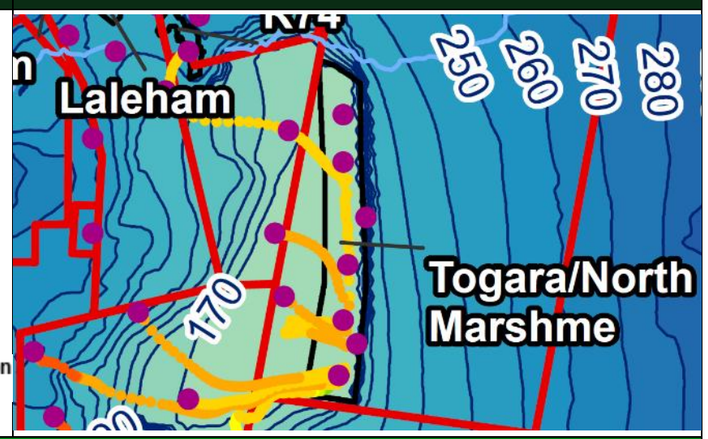
<table>
<tr><th colspan="5">Togara/North Marshmead</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td><td>
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 5,500 m
Max. Width: 850 m
Max. Depth: 202 m
Surface area: 511 ha</td><td>Void crest/Spill Level: 271 mAHD
Indicative void floor: 69 mAHD</td><td>Highwall: ~90%
Low wall: ~36%</td><td>Natural: 7.4 ha
Spoil: 458.0 ha
Rehabilitated Spoil: 249.1 ha
<u>Total: 714.5 ha</u></td><td>Spoil: +3.29 ML/day
Tailings: 0.0 ML/day
Natural Geology: +0.03 ML/day
Total GW Inflow: +3.3302 ML/day</td></tr>
<tr><th colspan="2">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td>50° Ave Wall Angle:
• Average: 298 m;
• Range: 186-389 m; and
• 90%< 367 m.</td><td>60° Ave Wall Angle:
• Average: 299 m;
• Range: 193-392 m; and
• 90%< 369 m.</td><td>Mean: 165.7 mAHD
Max.: 167.7 mAHD</td><td>300 years</td><td>Groundwater sink</td><td>Min. Freeboard: 103.3 m
Does not spill</td></tr>
<tr><td colspan="2" rowspan="2"></td><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td>Outside 0.1% AEP design and PMF events.</td><td colspan="3">Near-neutral pH throughout.
Strongly hypersaline after ~900 years with a final TDS of 104 g/L after 914 years.
High concentrations of major ions, silicon and manganese.
Large amounts of precipitated mineral phases (ferrihydrite, barite, gypsum, chalcedony).
No observed geochemical equilibrium.</td></tr>
</table>

TABLE 9-10 SOUTH MARSHMEAD SUMMARY TABLE

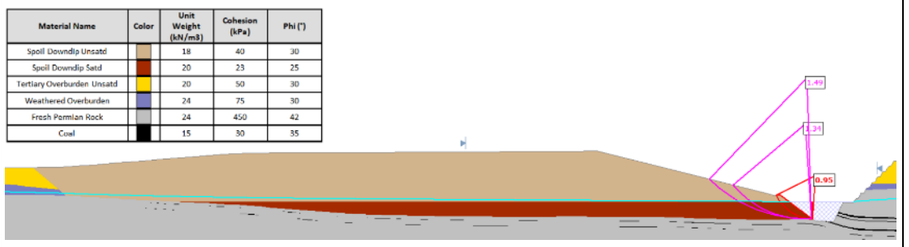
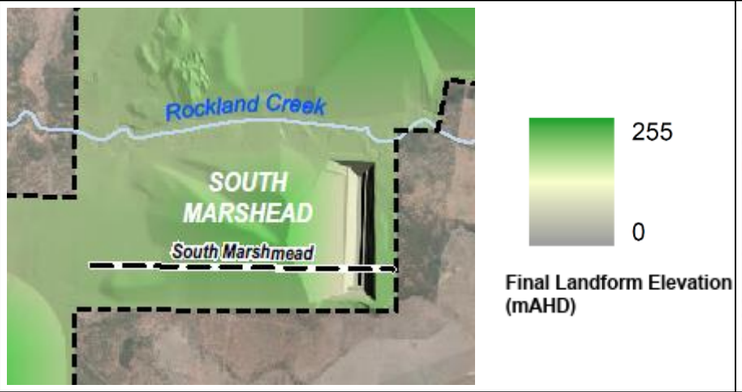
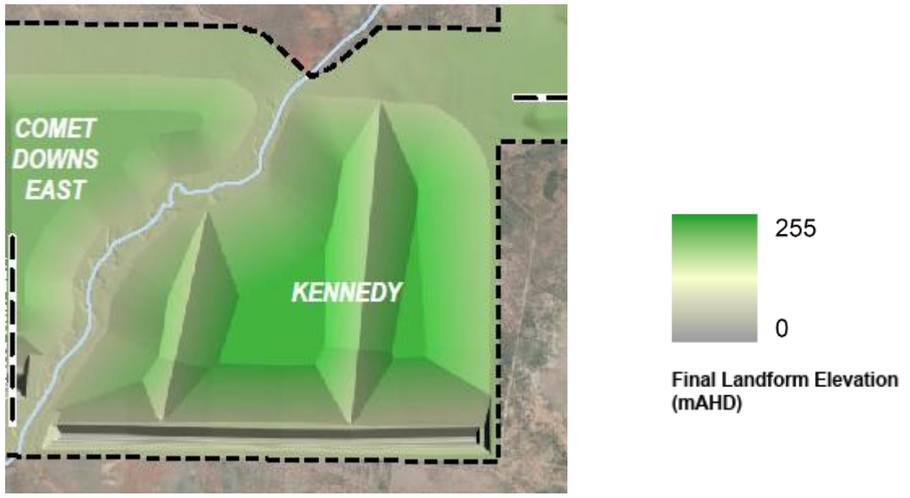
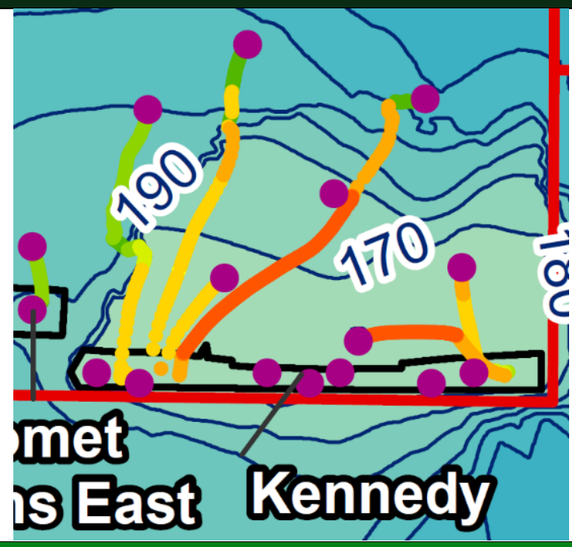
<table>
<tr><th colspan="5">South Marshmead</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr>
<td colspan="2">
</td>
<td colspan="2">
</td>
<td>
</td>
</tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 1,800 m
Max. Width: 650 m
Max. Depth: 162 m
Surface area: 123 ha</td><td>Void crest/Spill Level: 270 mAHD
Indicative void floor: 108 mAHD</td><td>Highwall: ~95%
Low wall: ~40%</td><td>Natural: 0.0 ha
Spoil: 119.4 ha
Rehabilitated Spoil: 80.3 ha
<u>Total: 199.7 ha</u></td><td>Spoil: +0.89 ML/day
Tailings: 0.0 ML/day
Natural Geology: 0.0 ML/day
Total GW Inflow: +0.89 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="2">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td>50° Ave Wall Angle:
• Average: 232 m;
• Range: 194-273 m; and
• 90%< 267 m.</td><td>60° Ave Wall Angle:
• Average: 213 m;
• Range: 167-253 m; and
• 90%< 249 m.</td><td>Mean: 171.1 mAHD
Max.: 174 mAHD</td><td>300 years</td><td>Groundwater sink</td><td>Min. Freeboard: 96 m
Does not spill</td></tr>
<tr><td colspan="2"></td><th>Post-Mining Flooding Risk</th><th colspan="2">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2"></td><td>Outside 0.1% AEP design and PMF events.</td><td colspan="2">N/A</td></tr>
</table>

TABLE 9-11 KENNEDY SUMMARY TABLE

<table>
<tr><th colspan="6">Kennedy</th></tr>
<tr><th colspan="6">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="3">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="3">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th colspan="2">Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 5,700 m
Max. Width: 700 m
Max. Depth: 122 m
Surface area: 357 ha</td><td>Void crest/Spill Level: 221 mAHD
Indicative void floor: 99 mAHD</td><td>Highwall: ~102%
Low wall: ~36%</td><td>Natural: 0.0 ha
Spoil: 188.6 ha
Rehabilitated Spoil: 481.1 ha
<u>Total: 669.7 ha</u></td><td colspan="2">Spoil: +2.31 ML/day
Tailings: 0 ML/day
Natural Geology: +0.04 ML/day
Total GW Inflow: +2.36 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="2" rowspan="2">50° Ave Wall Angle:
• Average: 149 m;
• Range: 125-195 m; and
• 90%< 173 m.

60° Ave Wall Angle:
• Average: 129 m;
• Range: 110-183 m; and
• 90%< 144 m.</td><td>Mean: 166.4 mAHD
Max.: 168.8 mAHD</td><td>400 years</td><td>Groundwater sink</td><td>Min. Freeboard: 52.2 m
Does not spill</td></tr>
<tr><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2">Outside 0.1% AEP design and PMF events.</td><td colspan="3">N/A</td></tr>
</table>

TABLE 9-12 COMET DOWNS EAST SUMMARY TABLE

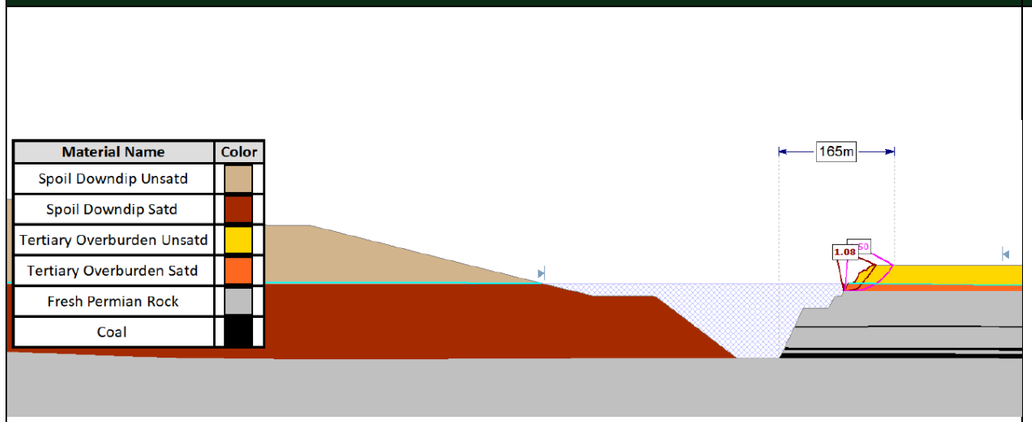
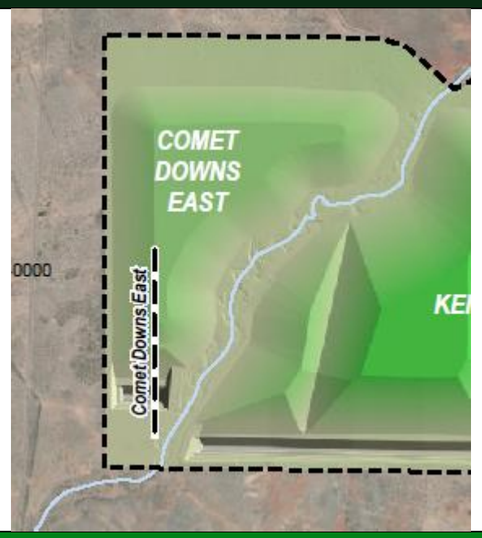
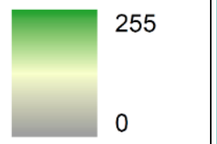
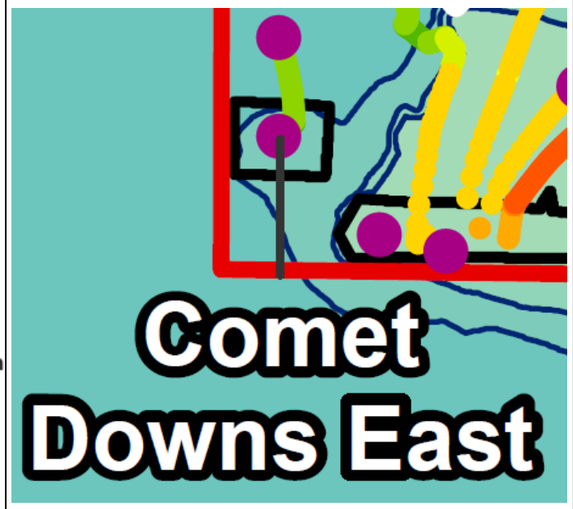
Comet Downs East					
Overview					
End of Mining Cross-Section		**Final Landform Design**		**Particle Tracking**	
					
Design Parameters			**Hydrology**		
Indicative Dimensions	**Elevation**	**NUMA Slope Grades (overall)**	**Catchment Area**	**Equilibrium GW Inflow Rates**	
Max. Length: 800 m Max. Width: 570 m Max. Depth: 132 m Surface area: 49 ha	Void crest/Spill Level: 222 mAHD Indicative void floor: 90 mAHD	Highwall: ~98% Low wall: ~36%	Natural: 8.9 ha Spoil: 27.7 ha Rehabilitated Spoil: 69.4 ha Total: 106.0 ha	Spoil: +0.85 ML/day Tailings: 0.0 ML/day Natural Geology: +0.10 ML/day Total GW Inflow: +0.94 ML/day	
Geotechnical Stability			**Water Balance**		
Set-back Distance from Highwall/Endwalls			**Equilibrium Water Level**	**Time to Equilibrium Level**	**Outflows**
FoS: 1.08 Set-back from wall toe to FoS>1.5: 165 m			Mean: 191.2 mAHD Max.: 193 mAHD	450 years	Groundwater sink Min. Freeboard: 29 m Does not spill
			Post-Mining Flooding Risk	**Residual Void Lake Geochemistry**	
			Outside 0.1% AEP design and PMF events.	Near-neutral pH throughout. Strongly hypersaline after ~900 years with a final TDS of 104 g/L after 921 years. High concentrations of major ions, silicon and manganese. Large amounts of precipitated mineral phases (ferrihydrite, barite, gypsum, chalcedony). No observed geochemical equilibrium.	

TABLE 9-13 RAMP 74 SUMMARY TABLE

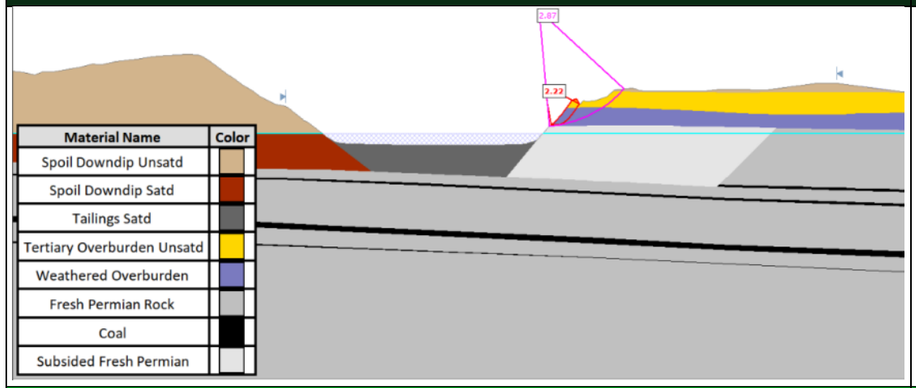
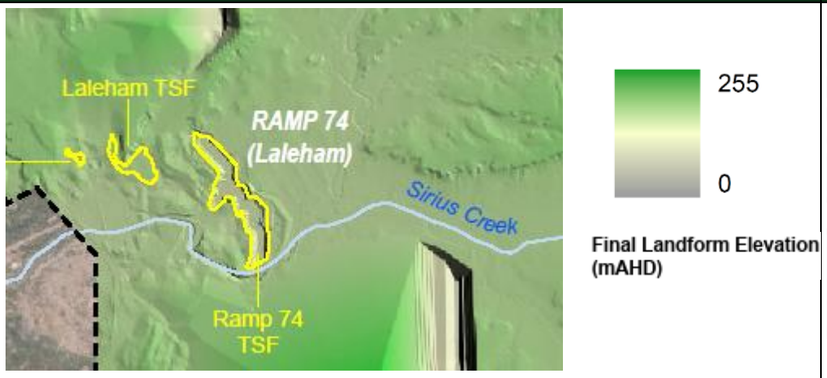
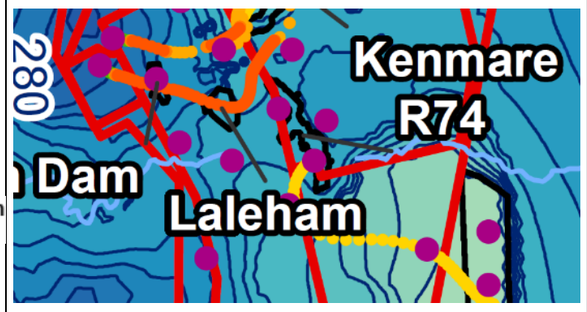
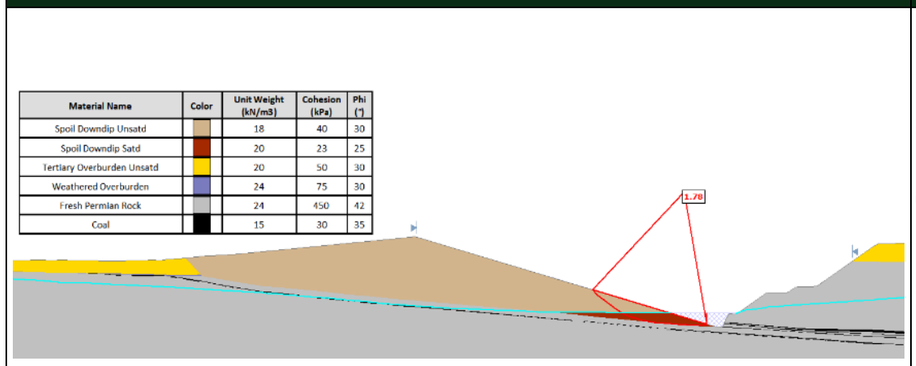
<table>
<tr><th colspan="5">Ramp 74</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr>
<td colspan="2">
</td>
<td colspan="2">
</td>
<td>
</td>
</tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 2,000 m
Max. Width: 300 m
Max. Depth: 32 m
Surface area: 59 ha</td><td>Void crest/Spill Level: 266 mAHD
Indicative void floor: 234 mAHD</td><td>Highwall: ~67%
Low wall: ~58%</td><td>Natural: 10.1 ha
Spoil: 58.3 ha
Rehabilitated Spoil: 112.9 ha
<u>Total: 181.3 ha</u></td><td>Spoil: -2.33 ML/day
Tailings: -0.01 ML/day
Natural Geology: +0.01 ML/day
Total GW Inflow: -2.32 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="3">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="3" rowspan="2">FoS: 2.22
Set-back from wall toe to FoS> 1.5: Crest</td><td>Cycles between dry and a maximum of: 244.3 mAHD</td><td>100 years</td><td>Groundwater source</td><td>Min. Freeboard: 21.7 m
Does not spill</td></tr>
<tr><td colspan="2">Post-Mining Flooding Risk</td><td colspan="3">Residual Void Lake Geochemistry</td></tr>
<tr><td colspan="2">Outside 0.1% AEP event
Inside PMF extents (Sirius Creek)</td><td colspan="3">Near-neutral pH throughout.
Low salinity throughout with a final TDS of 113 mg/L after 1,000 years due to net groundwater outflow.
Low concentrations of major ions, silicon and manganese.
Negligible amounts of precipitated mineral phases.
Geochemical equilibrium established almost immediately.</td></tr>
</table>

TABLE 9-14 SOUTH BALLAMOO SUMMARY TABLE

<table>
<tr><th colspan="5">South Ballamoo</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr>
<td colspan="2">
</td>
<td colspan="2">
</td>
<td>
</td>
</tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 4,600 m
Max. Width: 1,100 m
Max. Depth: 206 m
Surface area: 350 ha</td><td>Void crest/Spill Level: 290 mAHD
Indicative void floor: 84 mAHD</td><td>Highwall: ~53%
Low wall: ~31%</td><td>Natural: 0.0 ha
Spoil: 365.0 ha
Rehabilitated Spoil: 267.4 ha
Total: 632.4 ha</td><td>Spoil: +1.83 ML/day
Tailings: 0.0 ML/day
Natural Geology: +0.03 ML/day
Total GW Inflow: +1.83 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="2">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="2" rowspan="2">50° Ave Wall Angle:
• Average: 356 m;
• Range: 277-434 m; and
• 90%< 423 m.

60° Ave Wall Angle:
• Average: 359 m;
• Range: 277-438 m; and
• 90%< 427 m.</td><td>Mean: 141.5 mAHD
Max.: 144.3 mAHD</td><td>300 years</td><td>Groundwater sink</td><td>Min. Freeboard: 145.7 m
Does not spill</td></tr>
<tr><th>Post-Mining Flooding Risk</th><th colspan="2">Residual Void Lake Geochemistry & Limnology</th></tr>
<tr><td colspan="2">Outside 0.1% AEP design and PMF events.</td><td colspan="2">N/A</td></tr>
</table>

TABLE 9-15 TANNYFOIL SUMMARY TABLE

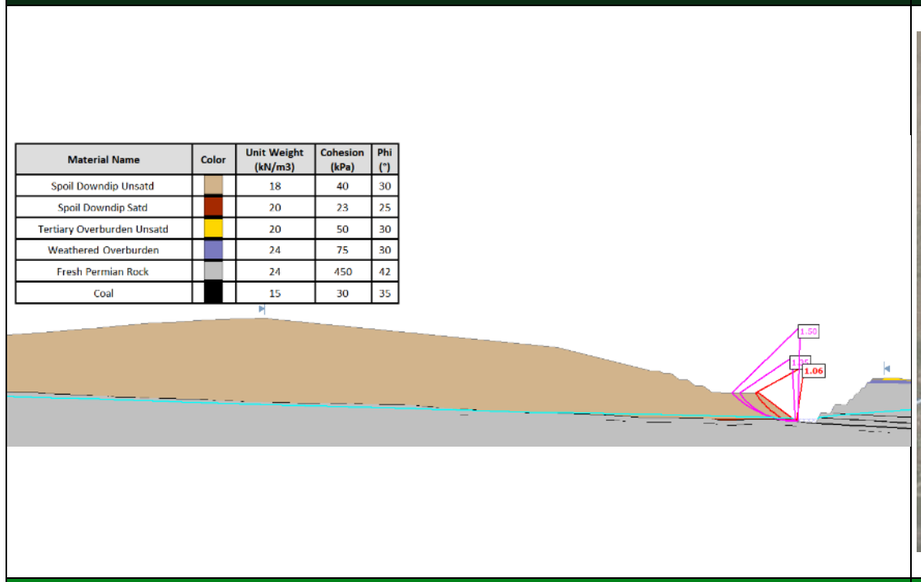
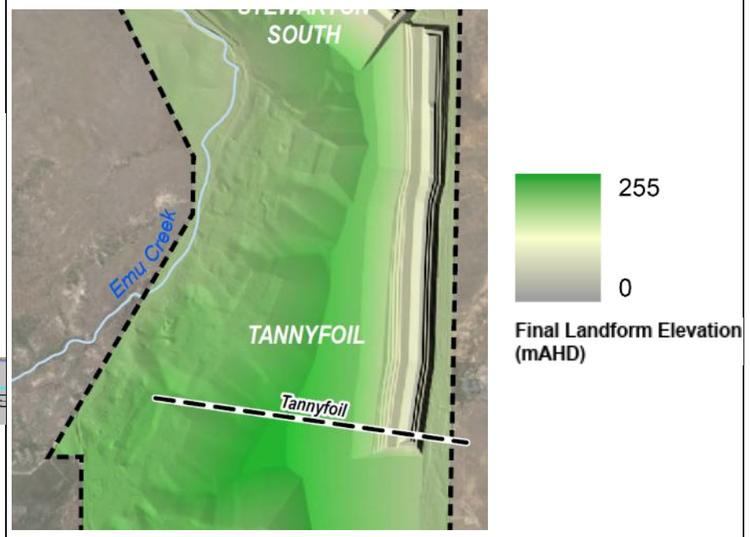
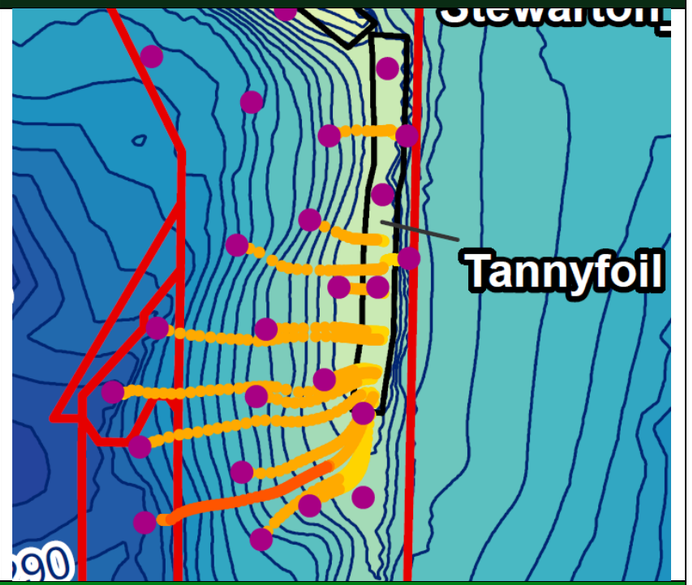
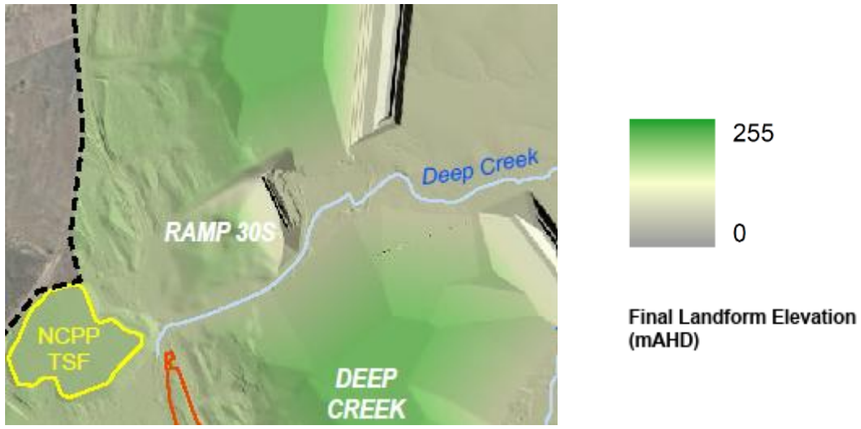
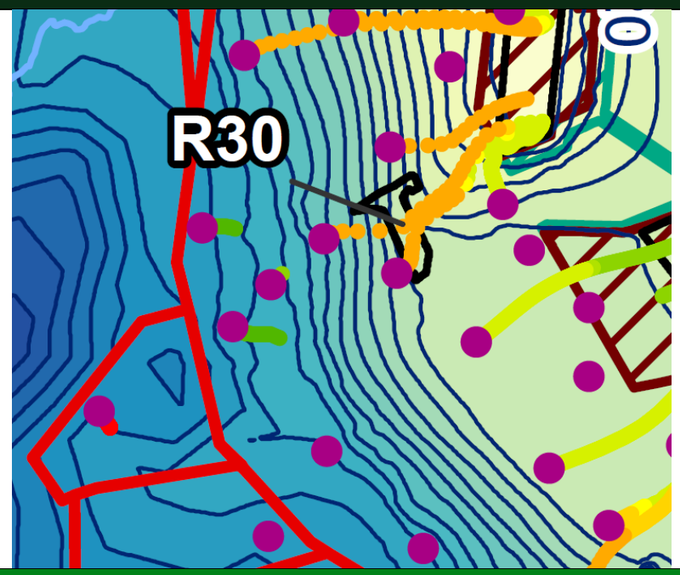
<table>
<tr><th colspan="5">Tannyfoil</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><th colspan="2">End of Mining Cross-Section</th><th colspan="2">Final Landform Design</th><th>Particle Tracking</th></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td><td>
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="2">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th>Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 6,000 m
Max. Width: 630 m
Max. Depth: 122 m
Surface area: 400 ha</td><td>Void crest/Spill Level: 237 mAHD
Indicative void floor: 115 mAHD</td><td>Highwall: 74%
Low wall: ~34%</td><td>Natural: 0 ha
Spoil: 388.1 ha
Rehabilitated Spoil: 458.6 ha
<u>Total: 846.7 ha</u></td><td>Spoil: +1.51 ML/day
Tailings: 0.0 ML/day
Natural Geology: +0.02 ML/day
Total GW Inflow: +1.52 ML/day</td></tr>
<tr><th colspan="3">Geotechnical Stability</th><th colspan="3">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td>50° Ave Wall Angle:
• Average: 148 m;
• Range: 122-166 m; and
• 90%< 163 m.</td><td>60° Ave Wall Angle:
• Average: 129 m;
• Range: 99-161 m; and
• 90%< 153 m.</td><td>Mean: 144.7 mAHD
Max.: 148.3 mAHD</td><td>250 years</td><td>Groundwater sink</td><td>Min. Freeboard: 88.7 m
Does not spill</td></tr>
<tr><td colspan="2"></td><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2"></td><td>Outside 0.1% AEP design and PMF events.</td><td colspan="3">N/A</td></tr>
</table>

TABLE 9-16 RAMP 30 SUMMARY TABLE

<table>
<tr><th colspan="6">Ramp 30</th></tr>
<tr><th colspan="6">Overview</th></tr>
<tr><th>End of Mining Cross-Section</th><th colspan="3">Final Landform Design</th><th colspan="2">Particle Tracking</th></tr>
<tr><td>N/A</td><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Design Parameters</th><th colspan="3">Hydrology</th></tr>
<tr><th>Indicative Dimensions</th><th>Elevation</th><th>NUMA Slope Grades (overall)</th><th colspan="2">Catchment Area</th><th>Equilibrium GW Inflow Rates</th></tr>
<tr><td>Max. Length: 1,200 m
Max. Width: 300 m
Max. Depth: 78 m
Surface area: 64 ha</td><td>Void crest/Spill Level: 217 mAHD
Indicative void floor: 139 mAHD</td><td>Highwall: ~67%
Low wall: ~32%</td><td colspan="2">Natural: 0.0 ha
Spoil: 24.1 ha
Rehabilitated Spoil: 149.2 ha
<u>Total: 173.3 ha</u></td><td>Spoil: -0.21 ML/day
Tailings: 0.0 ML/day
Natural Geology: 0.0 ML/day
Total GW Inflow: -0.21 ML/day</td></tr>
<tr><th colspan="2">Geotechnical Stability</th><th colspan="4">Water Balance</th></tr>
<tr><th colspan="2">Set-back Distance from Highwall/Endwalls</th><th>Equilibrium Water Level</th><th>Time to Equilibrium Level</th><th colspan="2">Outflows</th></tr>
<tr><td colspan="2" rowspan="2">50° Ave Wall Angle:
• Average: 100 m; and
• Range: 89-107 m.

60° Ave Wall Angle:
• Average: 83 m; and
• Range: 76-88 m.</td><td>Cycles between dry and a maximum of: 162.6 mAHD</td><td>150 years</td><td>Groundwater source</td><td>Min. Freeboard: 54.4m
Does not spill</td></tr>
<tr><td></td><th>Post-Mining Flooding Risk</th><th colspan="3">Residual Void Lake Geochemistry</th></tr>
<tr><td colspan="2"></td><td>Outside 0.1% AEP design and PMF events.</td><td colspan="3">Near-neutral pH throughout.
Low salinity throughout with a final TDS of 133 mg/L after 997 years due to net groundwater outflow.
Low concentrations of major ions, metals and metalloids.
Negligible amounts of precipitated mineral phases.
Geochemical equilibrium established almost immediately.</td></tr>
</table>

10. DISCUSSION

This section summarises the findings across all assessments. It identifies key risks, uncertainties and implications for closure and residual risk management.

The modelling and evaluations presented in this VCP demonstrate that the final landform will be safe, stable and non-polluting under the proposed closure configuration:

- Water balance and groundwater modelling show that the overall final landform, including spoil dumps and residual voids, will function as a terminal groundwater sink and are not predicted to overtop in any modelled scenario:
  - Four residual voids (Stewarton South, Ramp 30, Ramp 74 and Bonnie Doon) have net outward groundwater fluxes. However, the predicted lake elevations in these residual voids are higher than the lakes that form in neighbouring voids, resulting in a hydraulic gradient which drives outflows from these higher elevation lakes towards the lower elevation neighbouring void lakes rather than away from the voids;
- Water quality modelling using PHREEQC indicates that Mimosa/Besgrove, Ramp 8, Deep Creek, Kenmare, Togara/North Marshmead and Comet Downs East residual void lakes are predicted to experience progressive increases in salinity, with TDS and major ions increasing over time with no indication of stabilisation:
  - These void lakes show consistent evaporative concentration of solutes. This is consistent with the water balance and groundwater modelling results; they are predominantly terminal systems within the broader void network, resulting in retention of solutes over time; and
  - Although increasing salinity of the void lakes presents ecological limitations, the void lakes remain hydrologically contained within the mine footprint and are not expected to affect surrounding groundwater or surface-water systems;
- Water quality modelling by PHREEQC indicates that Bonnie Doon, Ramp 30 and Ramp 74 residual void lakes will maintain low to moderate salinity and stable water quality conditions over the long term:
  - This reflects their net groundwater outflows (toward neighbouring residual voids), which removes water and solutes from the system during the simulation, preventing evapoconcentration of solutes; and
  - These voids show no persistent increases in TDS or major ions, with concentrations remaining stable or fluctuating in response to climatic cycles rather than accumulating over time;
- Limnological modelling indicates that residual void lakes will exhibit persistent thermal stratification with seasonal overturn (monomictic behaviour), rather than permanent or meromictic conditions:
  - Thermal stratification develops each summer and breaks down during winter mixing, providing regular turnover of the water column and limiting long-term isolation of deep waters;

  - Salinity increases progressively over time due to evaporative concentration and groundwater inputs; however, seasonal mixing results in largely uniform salinity profiles, and sustained salinity stratification is not predicted;
  - As a result, density stratification is primarily controlled by temperature, with salinity contributing locally to density gradients but not forming stable, long-term chemical layering; and
  - Overall, stratification strength may increase over time as salinity accumulates, but the system continues to undergo seasonal mixing, and long-term stabilisation beyond the modelled period remains uncertain;
- Geotechnical assessments confirm that the final void slopes achieve the required Factors of Safety for closure stability; and
- Flood modelling indicates the final landform design, inclusive of permanent creek diversions, will provide protection for the residual voids from the 0.1% AEP flood event.

10.1 RISK AND UNCERTAINTY

While the assessment outcomes in this VCP support the long-term stability and containment of the residual voids, some level of uncertainty remains due to the nature of predictive modelling and future climate conditions. Key sources of uncertainty include:

- Climate variability and change, particularly the timing and intensity of rainfall and evaporation under different SSP scenarios;
- Catchment hydrology assumptions, including long-term performance of rehabilitated surfaces and erosion control measures;
- Void water quality evolution, especially under progressively increasing salinity and density stratification conditions in terminal pit lakes; and
- Material properties, such as variability in spoil geochemistry or uncharacterised lithologies within final wall exposures.

To manage these uncertainties, adaptive management strategies will be implemented as part of residual risk management. These may include long-term monitoring of water levels, salinity trends and slope stability, along with predefined trigger levels and response actions. The residual void management approach will be reviewed periodically and refined based on updated monitoring data or changes in closure assumptions.

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APPENDIX A ANNUAL VOID WATER QUALITY MODELLING RESULTS

The following figures (Figure A-1 to Figure A-18) to show annual timestep results, by parameter, for the nine residual void pit lakes modelled using PHREEQC. These results represent the simulation with active geochemical controls (Section 8.1.3.3).

As discussed in Section 4.1.2, the Boonie Doon, Ramp 30 and Ramp 74 residual voids have predicted net outflow fluxes. These residual voids are predicted to lose void water to adjacent voids via the natural geology between the voids. Each of these voids have predicted lake elevations higher than the neighbouring voids, resulting in a hydraulic gradient between the voids that drives this outwards flux to its neighbouring void. As such, they behave as flow through systems and do not demonstrate cumulative and concentrating characteristics. The nine modelled residual voids and the abbreviations used in the charts are listed in Table A-1

TABLE A-1 MODELLED RESIDUAL VOID ABBREVIATIONS

Modelled Residual Void	Abbreviation
Ramp 8	R8
Bonnie Doon	BD
Mimosa/Besgrove	MB
Ramp 30	R30
Deep Creek	DC
Kenmare	KEN
Ramp 74	R74
Togara/North Marshmead	TNM
Comet Downs East	CDE

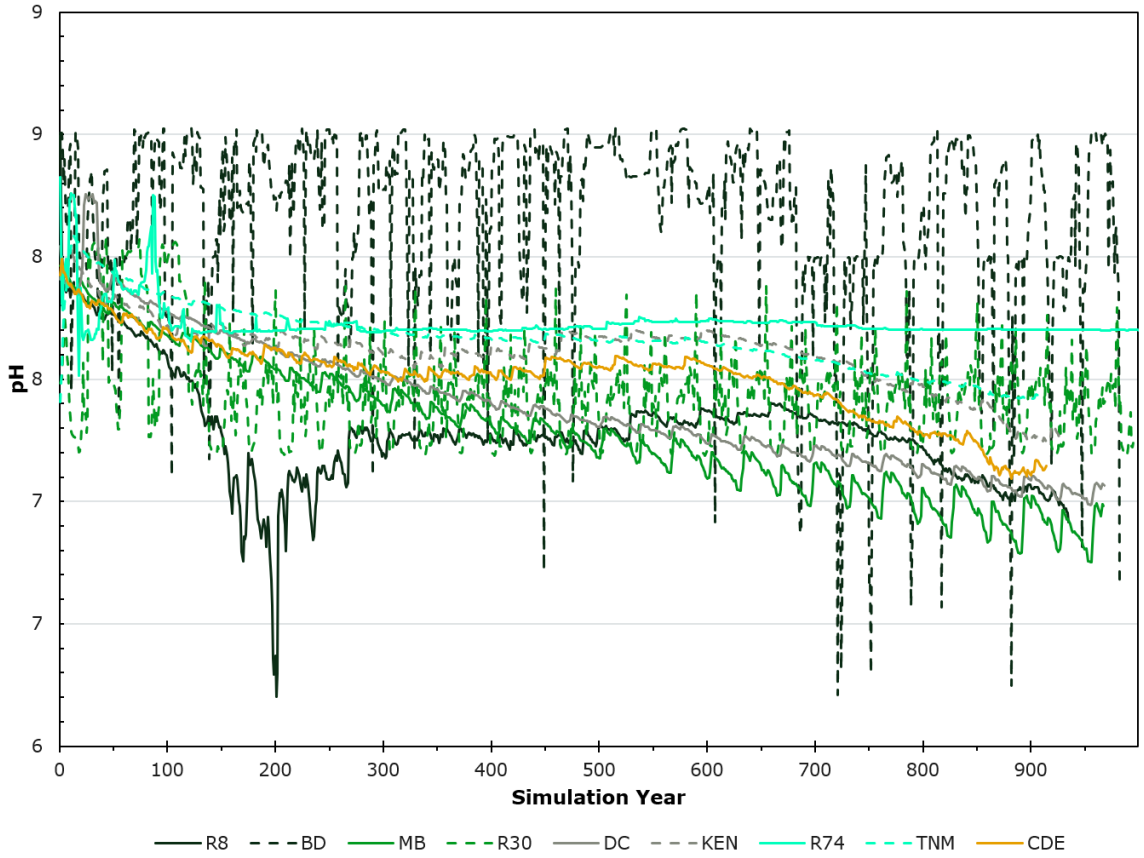


FIGURE A-1 pH

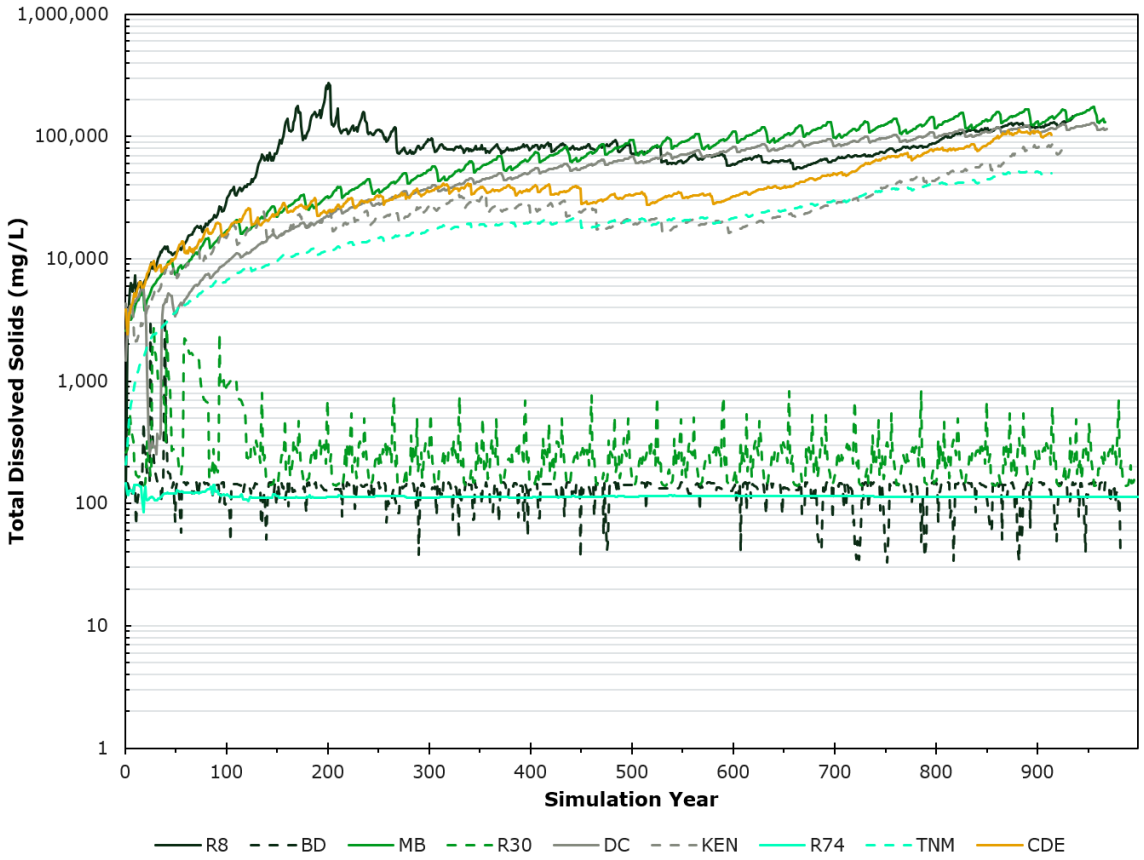


FIGURE A-2 TOTAL DISSOLVED SOLIDS

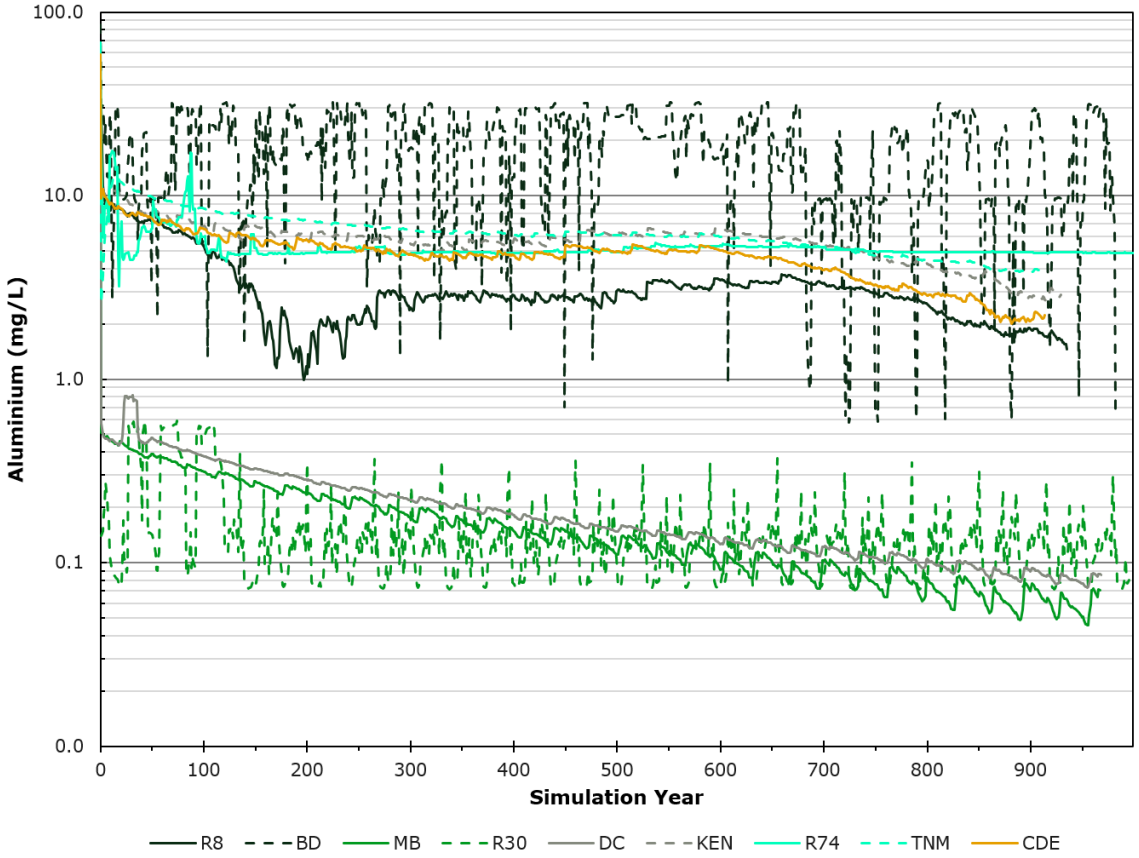


FIGURE A-3 ALUMINIUM

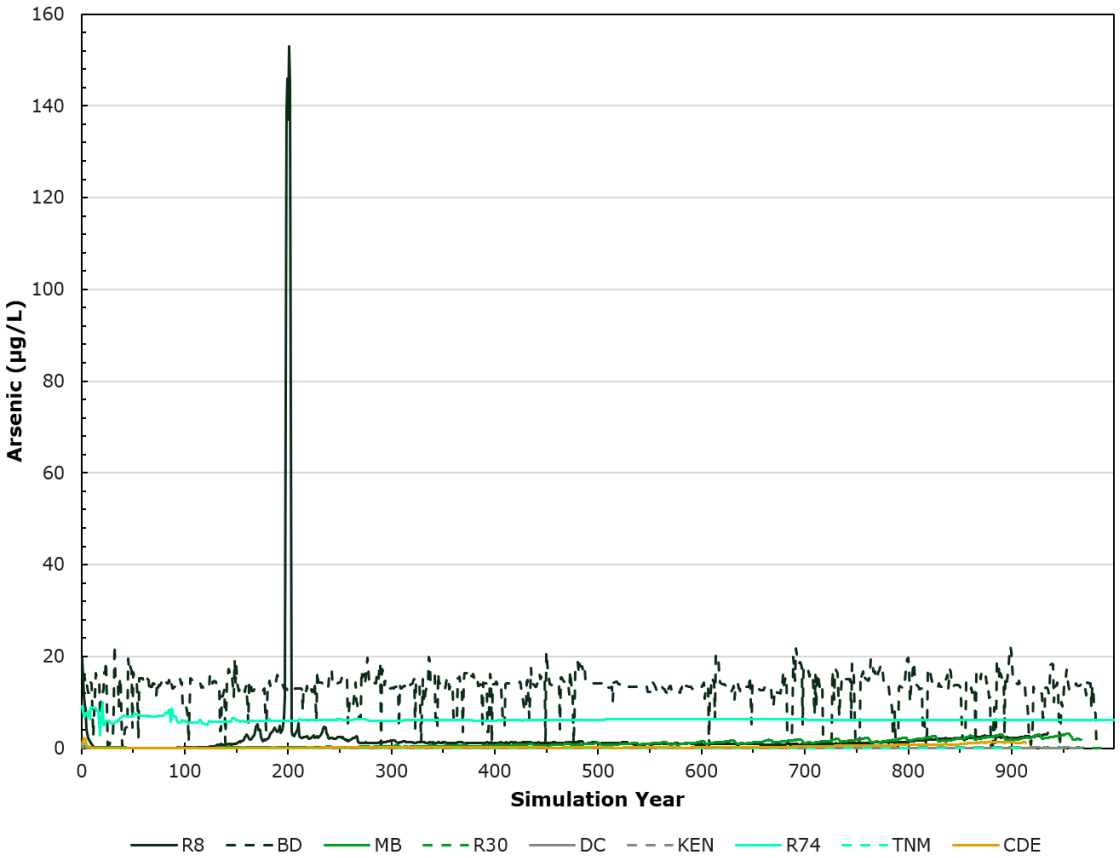


FIGURE A-4 ARSENIC

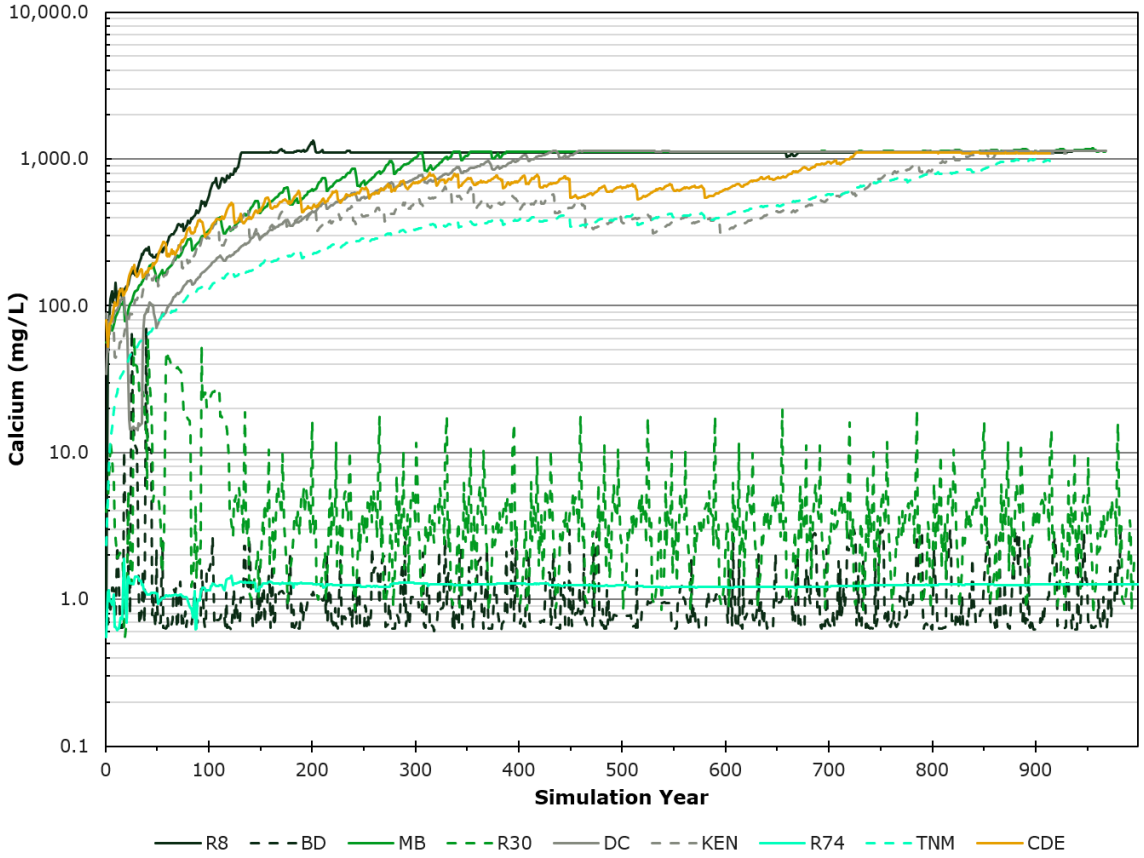


FIGURE A-5 CALCIUM

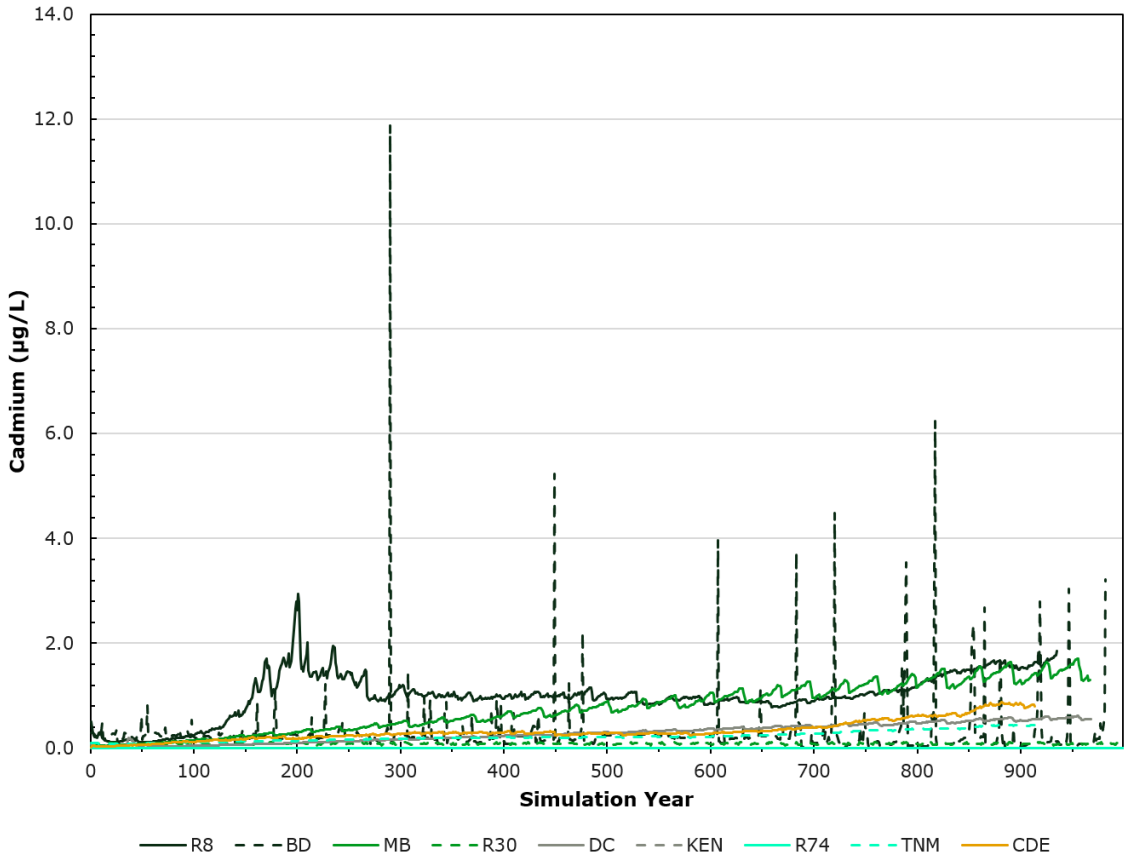


FIGURE A-6 CADMIUM

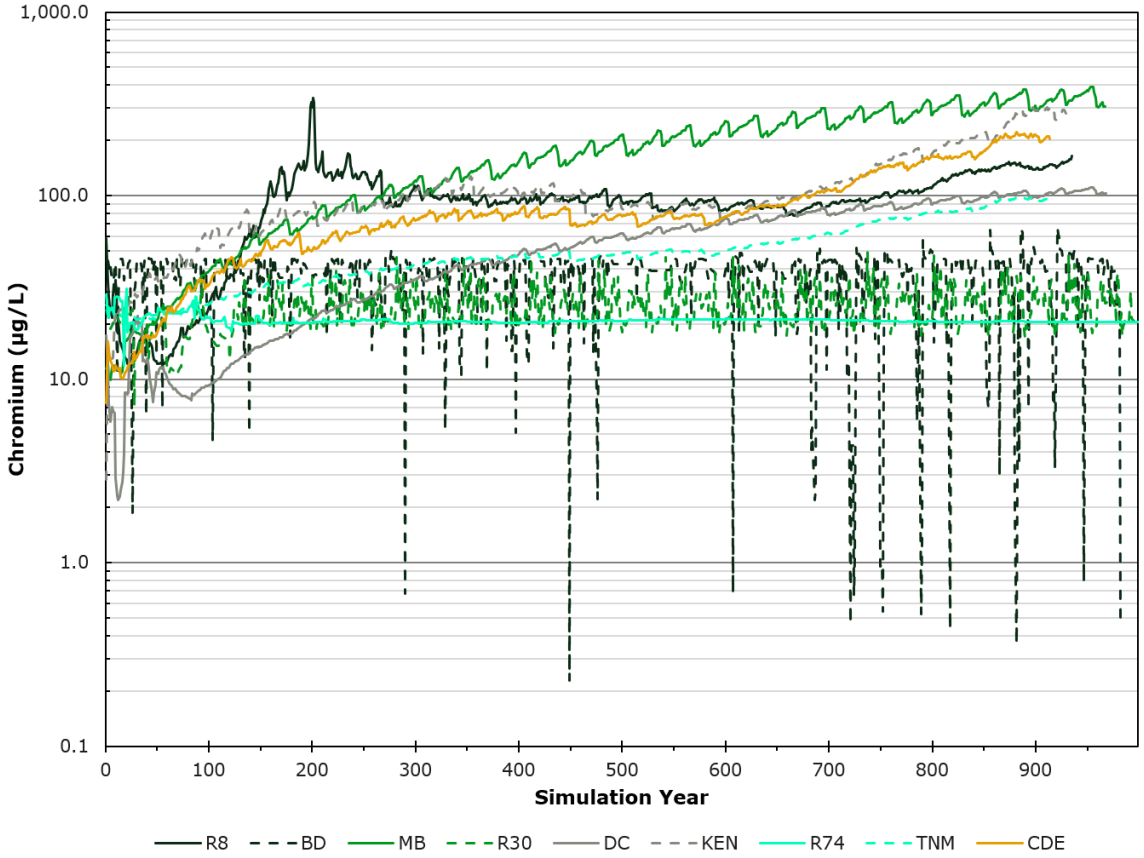


FIGURE A-7 CHROMIUM

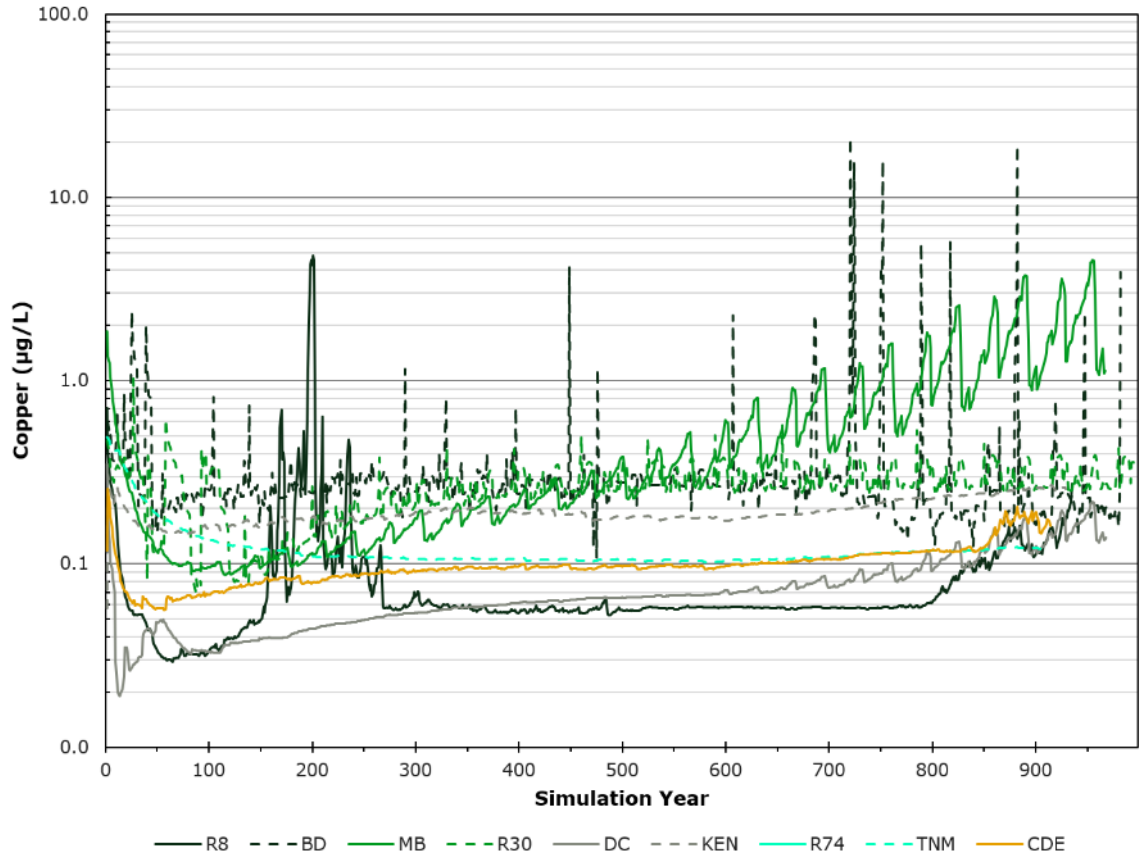


FIGURE A-8 COPPER

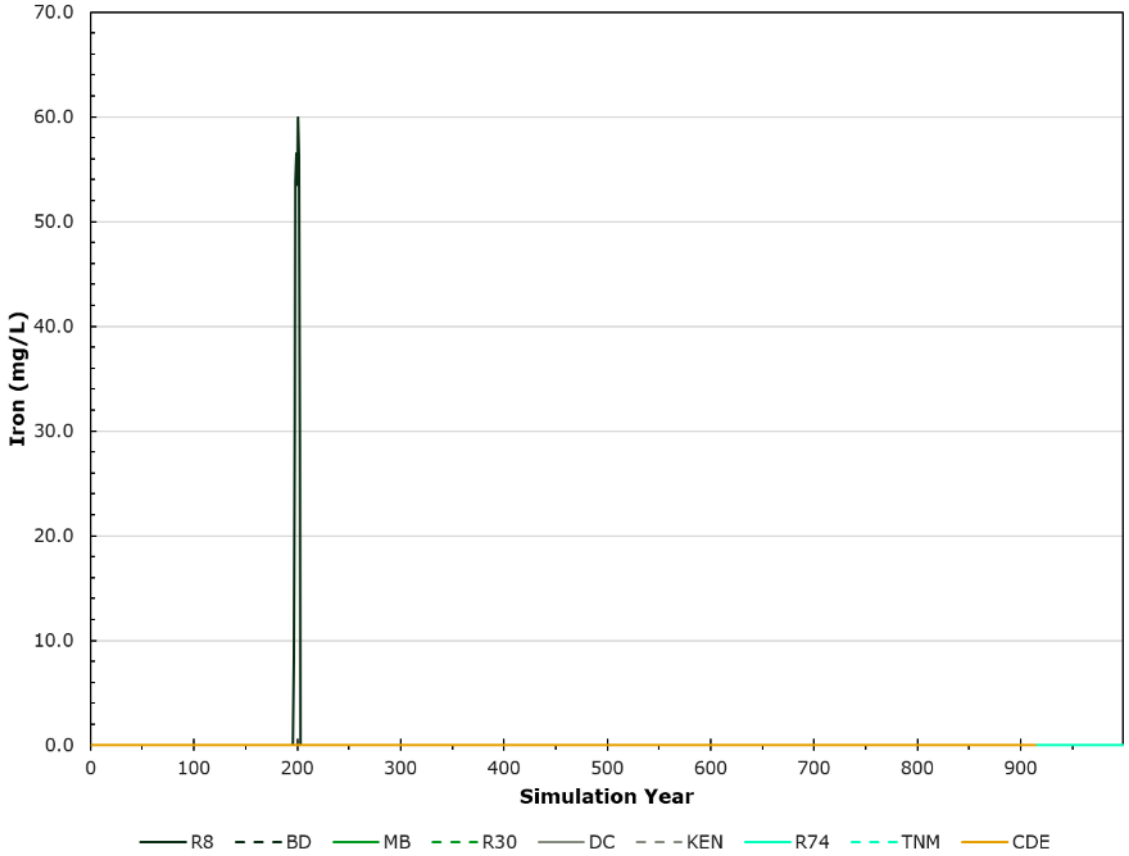


FIGURE A-9 IRON

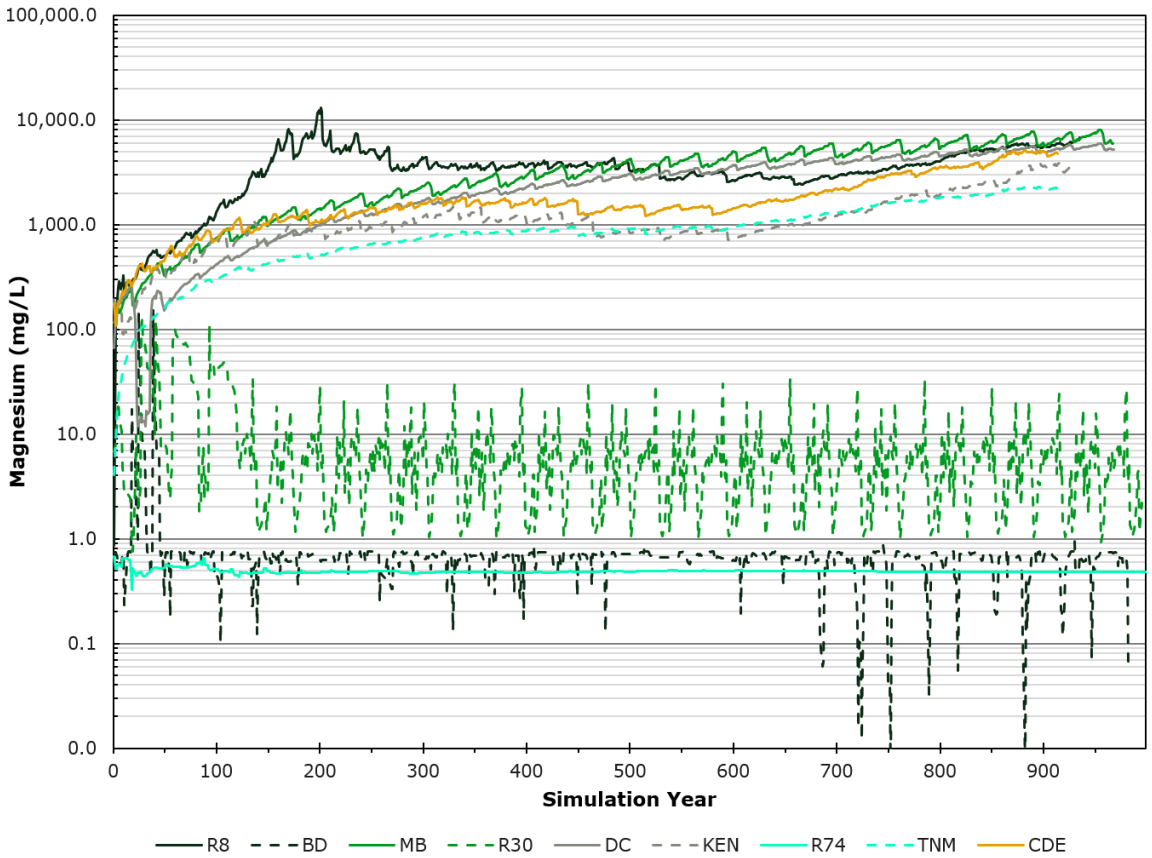


FIGURE A-10MAGNESIUM

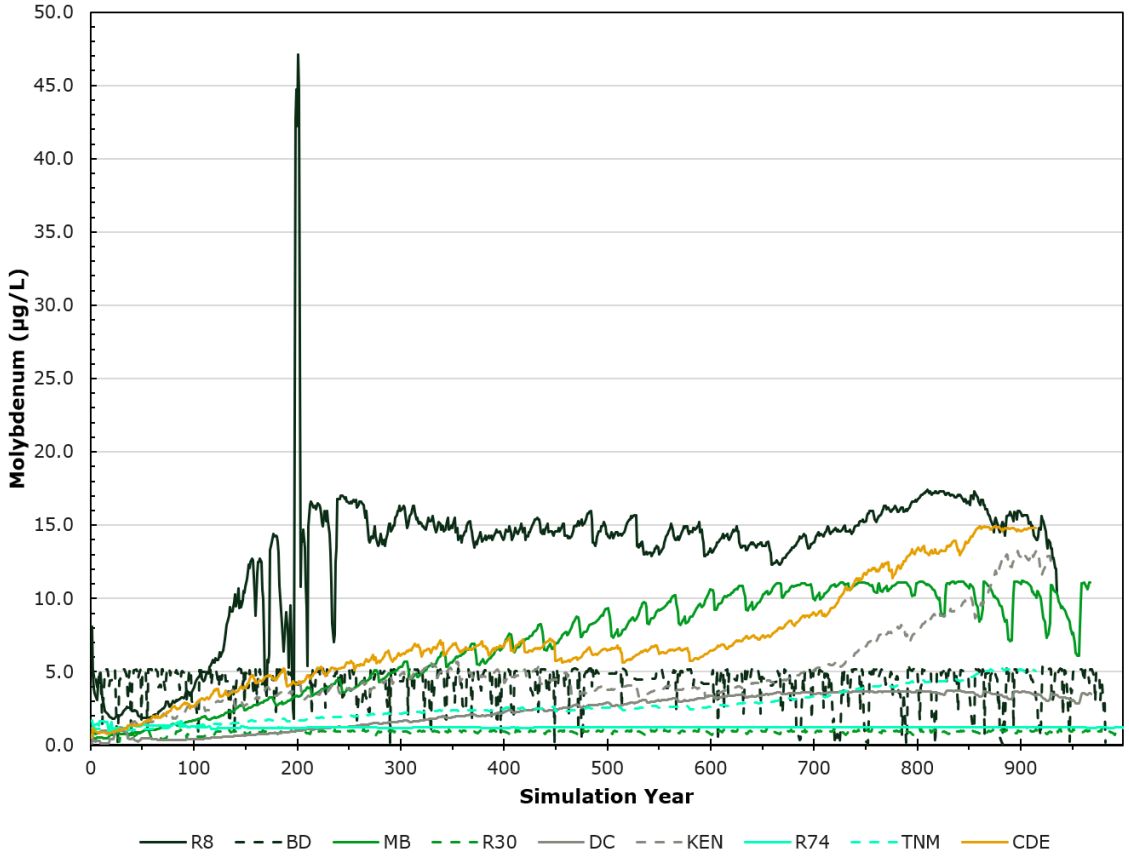


FIGURE A-11 MOLYBDENUM

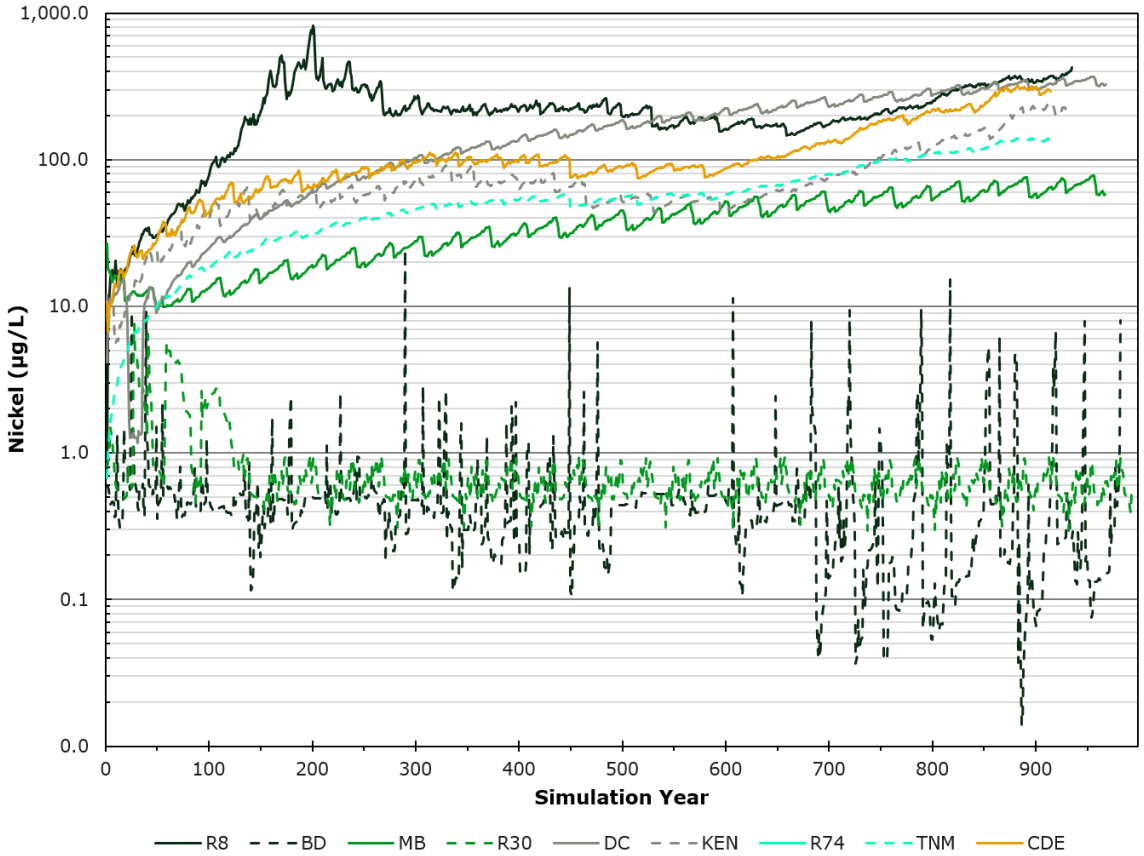


FIGURE A-12 NICKEL

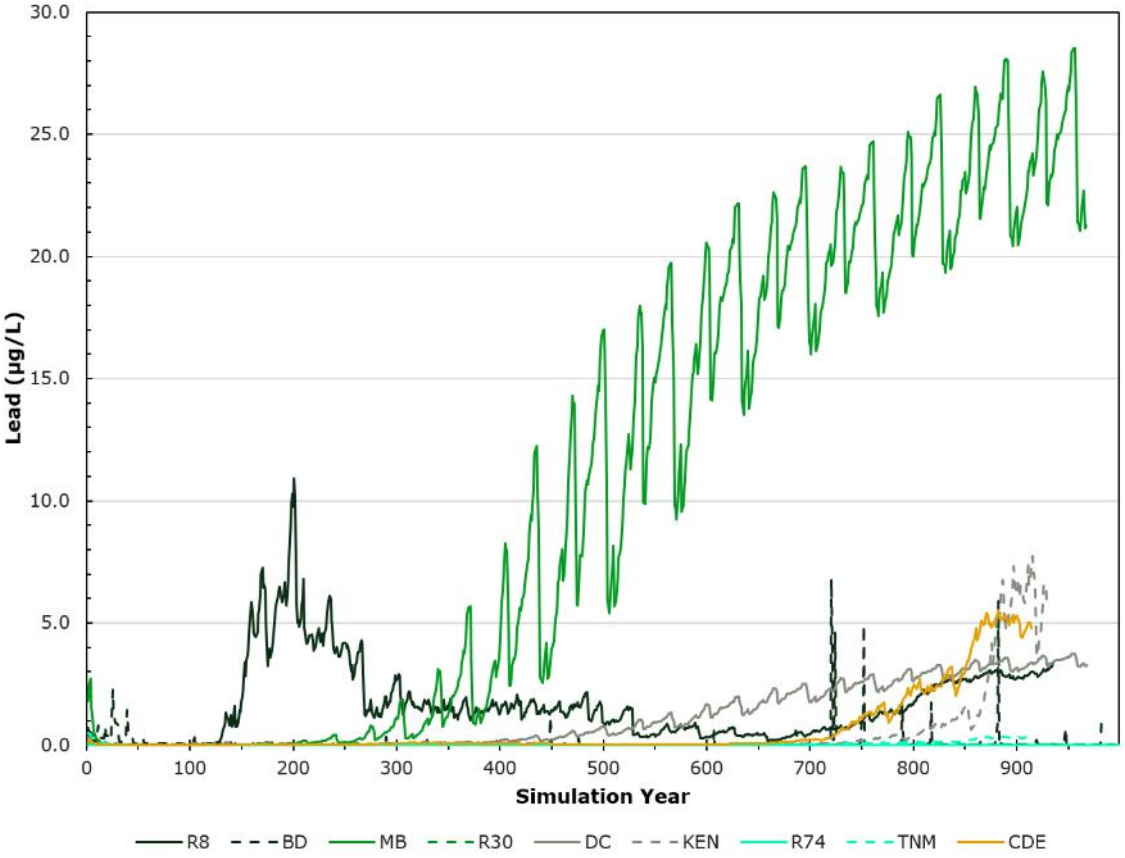


FIGURE A-13 LEAD

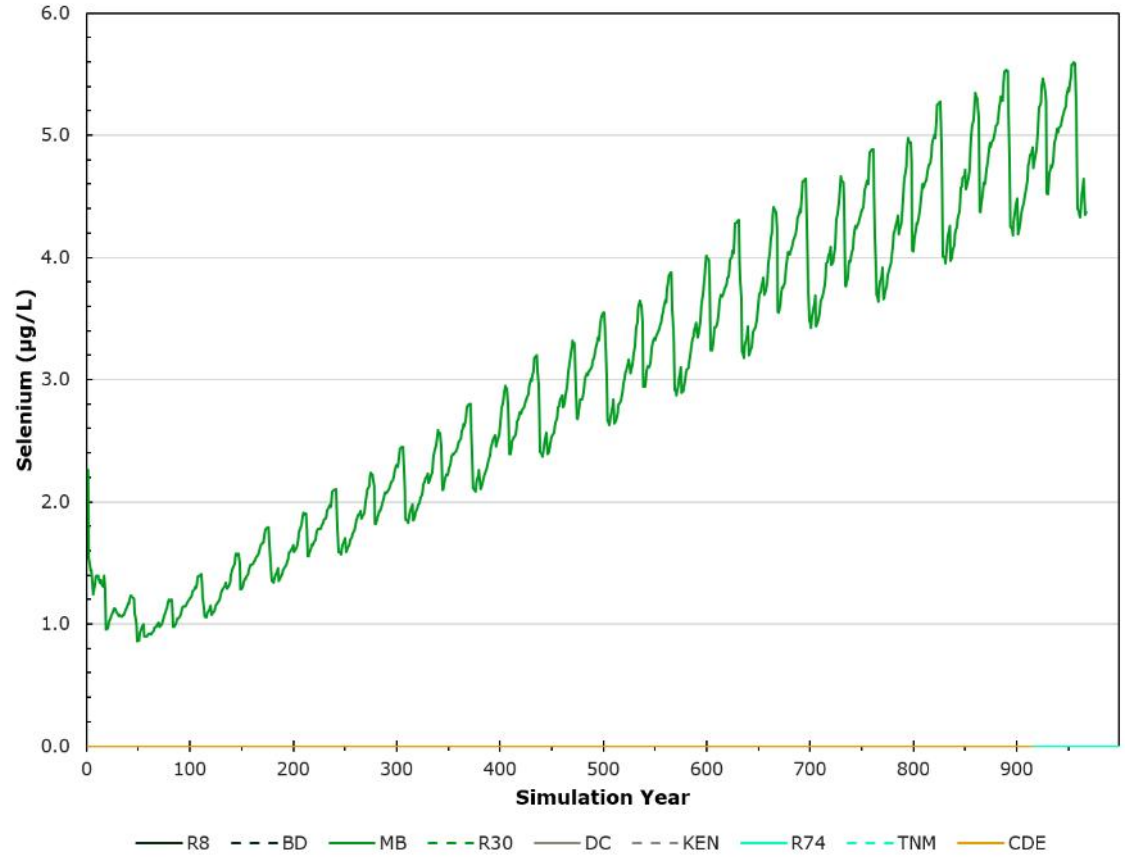


FIGURE A-14 SELENIUM

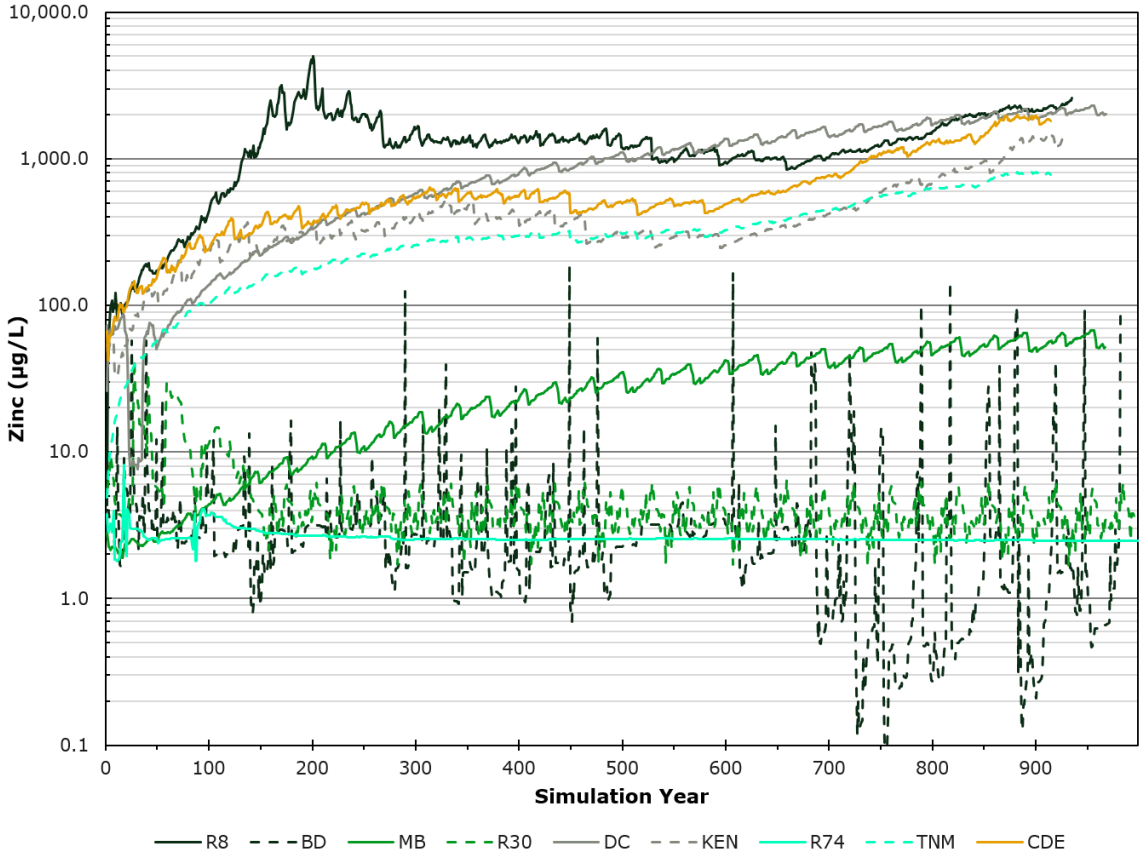


FIGURE A-15 ZINC

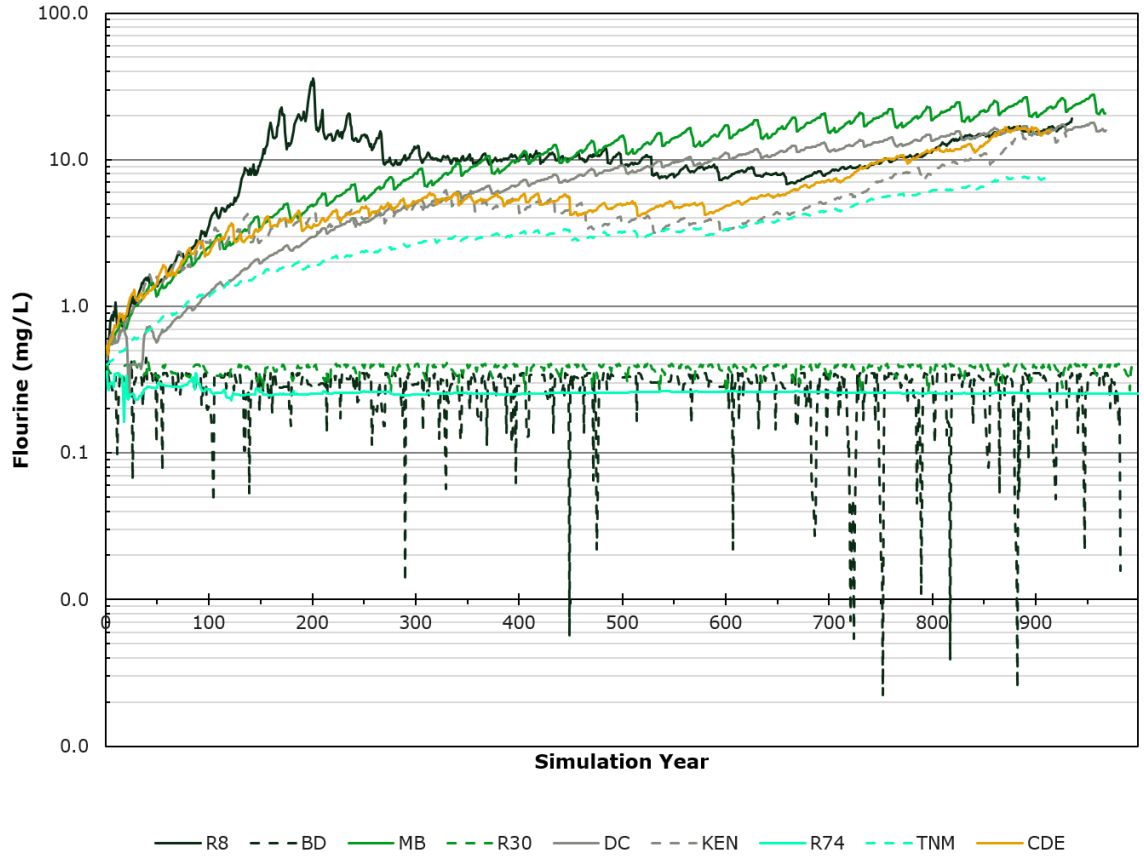


FIGURE A-16 FLUORINE

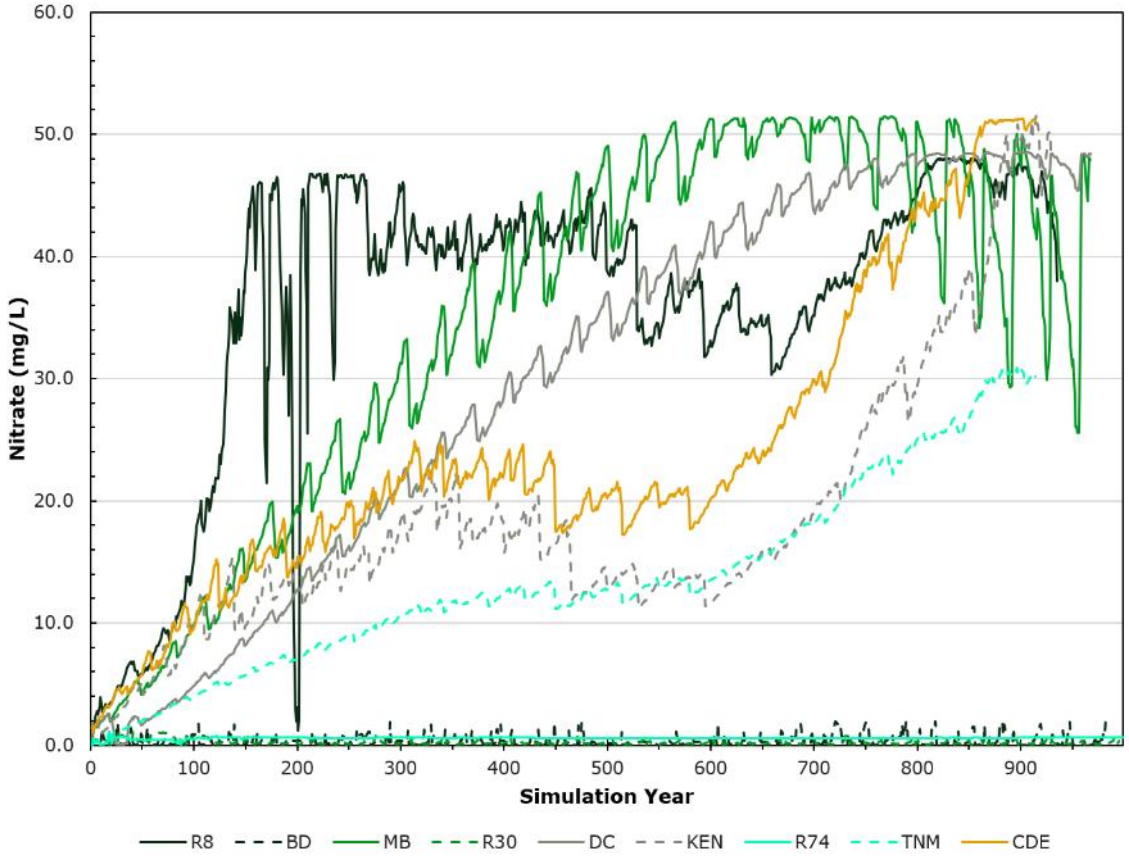


FIGURE A-17 NITRATE

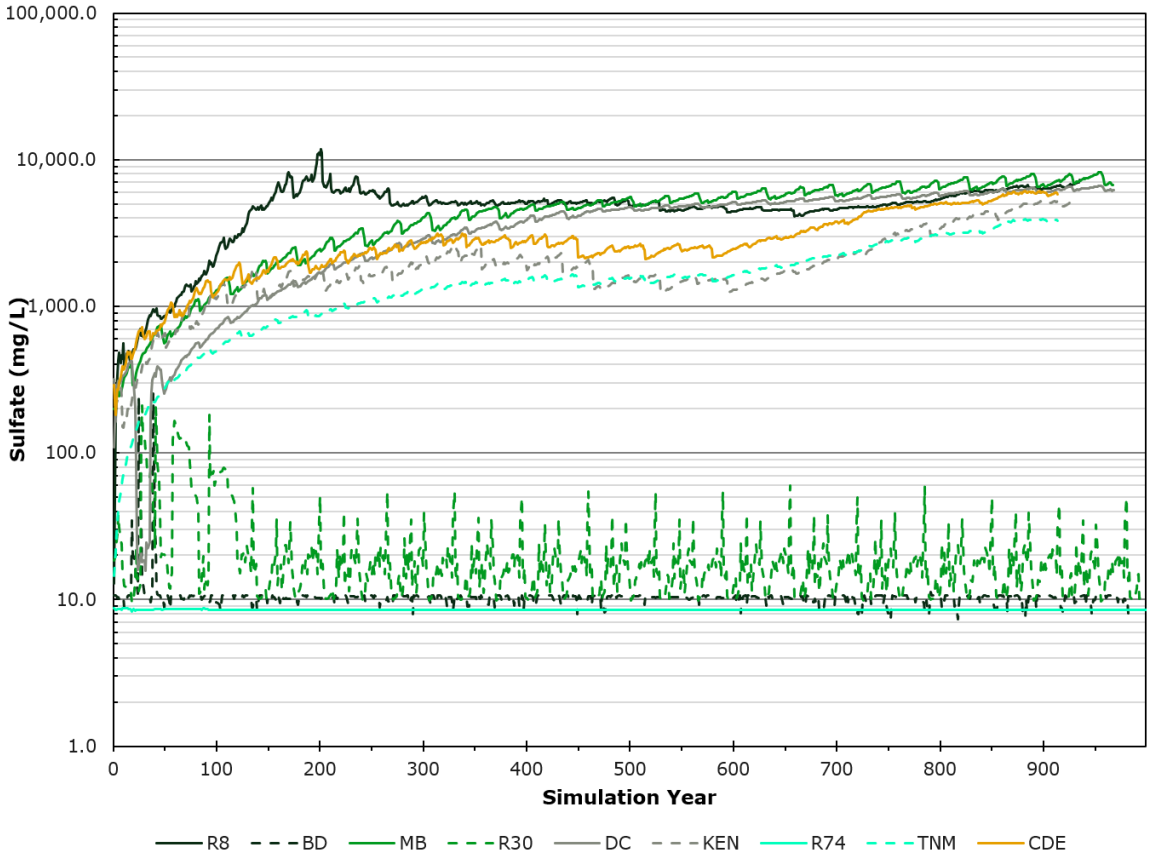


FIGURE A-18 SULFATE

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WHITEHAVEN COAL LTD

Long-Term Geotechnical Stability of Highwalls and Endwalls at Blackwater Mine

March 2026

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1. INTRODUCTION AND SCOPE

This report describes the results of a pit wall stability study for residual voids at Blackwater Mine undertaken for the purpose of informing development of the site's Progressive Rehabilitation and Closure Plan (PRCP) incorporating the final landform version LF#4.4.

The PRCP Guideline (Queensland Government, 2024) requires that the rehabilitation planning part of a PRCP include a void closure plan that in turn includes "*pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events*". This report addresses geotechnical stability of excavated pit walls (highwall and endwalls). Geochemical stability and erosional stability of spoil walls (lowwalls) are addressed as part of other specialist studies.

1.1 Limitation

This report has been prepared by Henderson Geotech Pty Ltd for Whitehaven Coal (Client) for the purpose of supporting preparation of Progressive Rehabilitation and Closure Plan for Blackwater Mine. It shall not be used or relied on for any other purpose. No parties other than the Client and the Department of Environment, Tourism, Science, and Innovation (DETSI) are authorised to rely on this report without the prior written consent of Henderson Geotech Pty Ltd.

This report is, in part, based on information provided by the Client or by other parties on behalf of the Client (Client-supplied information) in addition to data collected by Henderson Geotech Pty Ltd from the public domain. Henderson Geotech Pty Ltd has not always verified the accuracy of such information and makes no representations regarding its accuracy. Henderson Geotech Pty Ltd is not responsible for the consequences of any error or omission in Client-supplied information.

Henderson Geotech Pty Ltd has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same specialist field for projects of a similar nature and at the time and in the jurisdiction where the services were rendered. Henderson Geotech Pty Ltd makes no warranty, express or implied.

The outcomes described in this report are applicable only to the scenarios and inputs also described herein. A new assessment will be required if there are:

- Non-trivial changes to the location or geometry of the planned residual voids;
- Changes to proposed post-mining land uses of the voids or adjoining lands;
- Substantial changes to the understanding of stratigraphy or geotechnical properties; or
- Substantial changes to the understanding of end-of-mining and long-term groundwater levels or long-term pit lake levels.

2. BACKGROUND AND STUDY METHODOLOGY

2.1 Definition of Geotechnical Stability

The Macquarie Dictionary includes as definitions for “stability”: “firmness in position”; and “resistance to change, especially adverse change”. The Merriam Webster includes “strength to stand or endure”[1]. Note that these definitions do not require no change but do imply a threshold at which the change would be undesirable. Thresholds in turn attach to functions: for example, in the context of residual voids, what is ‘undesirable’ for water storage on a grazing property would be less onerous than that for a public recreational facility.

Practitioners take the term “geotechnical” to relate to mechanisms involving physical strength of soil and rock at an engineering scale. That is, it addresses mass movement triggered by mechanical disequilibrium between strengths and loadings. General landform erosion, which is cumulative surface transport at the particulate scale, is a different process.

In summary, for the purposes of this report, geotechnical stability is the state where mass movement related to the interaction of loadings and strength behind the wall face does not inhibit the post-mining land use of the land surrounding the void.

2.2 Mechanisms of Wall Instability

A typical highwall in the Bowen Basin comprises soil and geologically recent sediments (mainly Tertiary) overlying weathered Permian coal measure rocks, followed by fresh (unweathered) coal measure rocks down to the coal seam in the base of the wall. The characteristics of slope instability are different depending on which part of the overburden profile dictates geotechnical performance.

2.2.1 Instability in the Tertiary/Weathered Overburden

In general, the Tertiary and highly to completely weathered strata behave essentially as soil – the strength is low enough that failures will occur through the material mass, and structures such as joints and faults are rarely significant. Rockmass (or earth-mass) failures tend toward planar slip surfaces for granular soils and circular surfaces for clayey material (Figure 1). A common variant of mass failure in clayey overburden occurs when tension or shrinkage cracks open behind the wall face and subsequently fill with rainwater. The water exerts outward pressure that has to be resisted by shear strength (Figure 2). This situation is exacerbated if water also seeps into the clay and weakens it. PW Baker and Associates (2006) concluded that cracking and wetting was the predominant mechanism for instability in Tertiary and weathered overburden. However, observation in the years since then suggests that the wetting/weakening facet is not widespread and usually requires the pit to contain water higher than the base of weathering for an extended time.

[1] Stability Definition & Meaning - Merriam-Webster, accessed 16/12/2021.

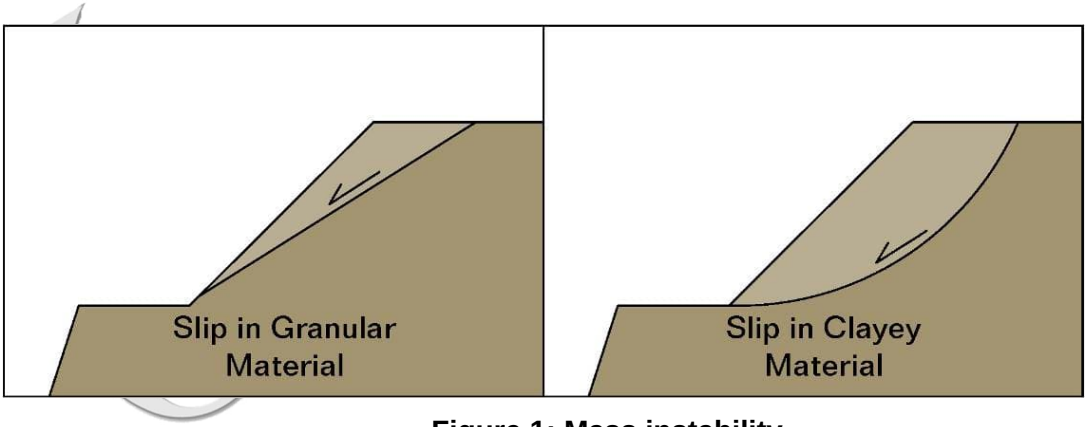


Figure 1: Mass instability

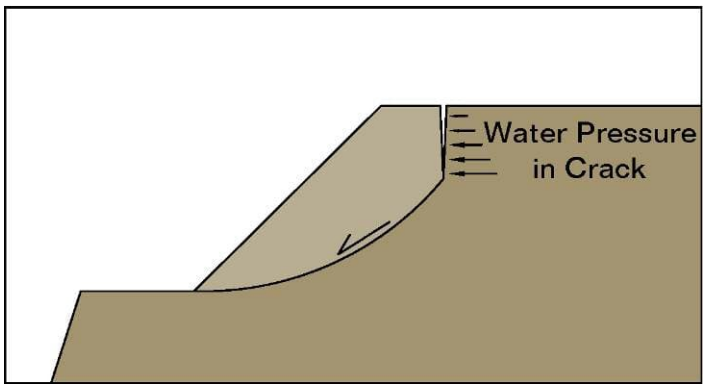


Figure 2: Mass instability with water-filled cracks

2.2.2 Instability dominated by fresh overburden

By contrast, within the fresh overburden instability generally occurs along weaker planes (defects) such as joints and faults. A common type of failure is when defects combine to define a wedge that can slide out of the wall (Figure 3). When distinct defects intersect, as is characteristic in localised 3D wedges, instability usually occurs as, or at most a few years after, the wall is excavated; hence it is addressed during mining operations and would rarely manifest after mine closure. When there are closely spaced defects such as joint sets, it may not be necessary for them to fully intersect to cause instability. Rather, they provide enough planes of weakness that the overall strength of the overburden is effectively reduced; slip surfaces can develop at least partly through the rockmass, although often in combination with distinct larger defects and weaker strata. This second type of composite wedge failure is the most common mechanism for pit wall failure and of most relevance to stability after closure, because it might take time for shears zones to develop (although observation of 20-year-old pit walls suggests that this is not a widespread occurrence). Bedding planes are another ubiquitous type of defect; however, being aligned with the coal seams, they normally dip into the highwall and so are not prone to causing instability except where local deformation has reversed the dip.

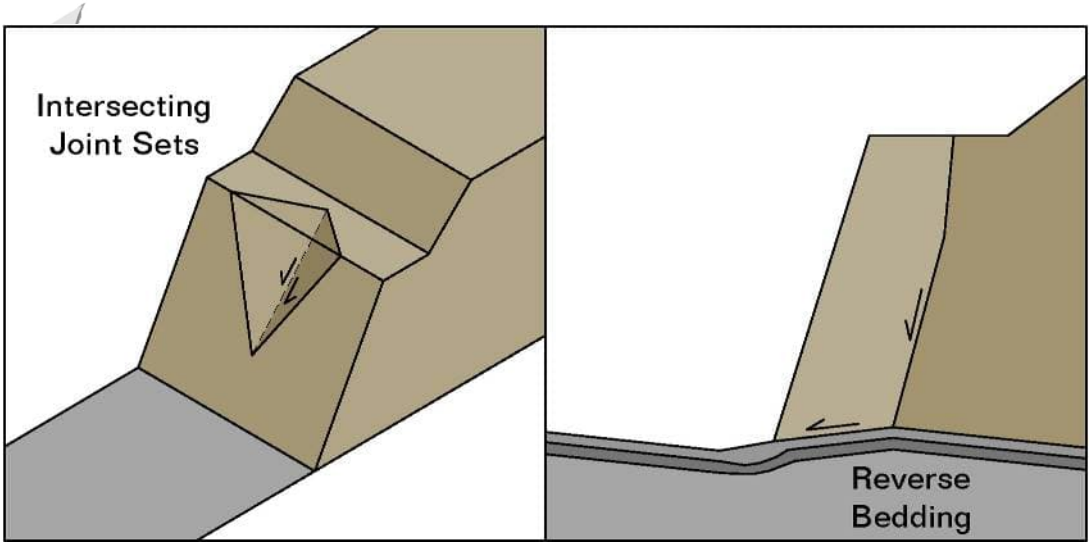


Figure 3: Defect controlled instability

Another mechanism is toppling failure, where the geometry is such that blocks can simply fall away from the defect rather than sliding along it (Figure 4). Once again, this mechanism is usually apparent, and dealt with, as mining occurs. In order for toppling failure to first occur after mining, there would need to be a set of persistent steeply dipping joints that had not been recognised and an underlying stratum that would crush or compress sometime after mining and cause that the blocks rotate outwards to the point of tipping. There is a final related mechanism – collapse - where bearing failure of a lower stratum (such as due to highwall mining or water-related weakening) initiates a slip encompassing overlying rock (Figure 5).

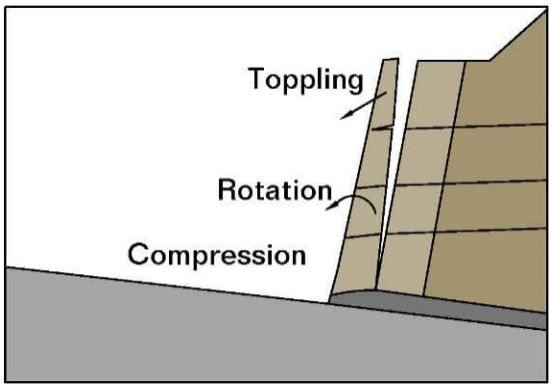


Figure 4: Toppling instability

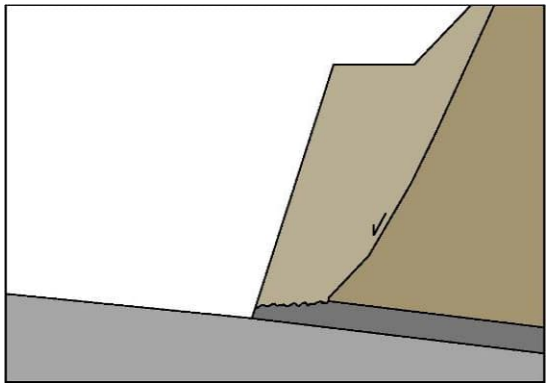


Figure 5: Collapse instability

Most types of instability in excavated walls are self-limiting in that the profile after failure is more stable than before, due to reduction in the average wall slope and to the slipped material partly supporting (buttressing) the wall. Exceptions are crack- initiated failure in clayey Tertiary and weathered overburden, and toppling failure in unweathered overburden. This is because both types of failure leave a steep new wall face behind which the same mechanism could develop, although the buttress effect of the failed material may still mitigate future instability.

2.3 Quantification

In theory, there are several broad industry accepted methods available to geotechnically assess and quantify risk of instability including:

- Limit equilibrium – compares forces on a surface with (limiting) strength if it was at the point of failing. Defects may be included explicitly as discrete strata when known, but more often are implicit within the strengths of broader material layers. Its main disadvantage is that the method assumes that all material along the surface can realise its peak strength at the same time; the significance of any consequent inaccuracy depends on the load-deformation behaviour of the particular materials.
- Kinematic assessment – the orientation (dip and strike) and distribution of various defects are plotted using stereographic projection and the result is examined to determine whether the defects can combine to 2D or 3D wedges that could slide out of the wall face. Normal geological and geotechnical drilling for open cut coal mines does not produce sufficient data for stereographic projection and hence this method is mainly used to review or refine stability assessment for pit walls once they are excavated.
- Displacement (deformation) analysis – movement of the wall face, or parts thereof, is obviously the parameter most directly related to function and safety. However, movement is caused by the interaction of force and strength on the stiffness (deformability) characteristics of the overburden materials. That is, analysis of movement requires knowledge of an extra set of geotechnical properties and more complex analyses. In addition, the correlation between load (force) and movement usually becomes very steep approaching failure so that small inaccuracy in the properties can produce large errors in predicted outcomes. Consequently, deformation analysis is rarely used for design in place of more simplistic but convenient and widely accepted limit equilibrium.
- Observation and measurement – most operational pit wall designs are at least partly based on observation of the performance of existing walls excavated in similar materials. However, at present this is largely based on undocumented experience of the particular geotechnical practitioner or team and so may be perceived as not sufficiently objective to provide quantifiable design criteria. This may change in the future, if observations by different practitioners and of different walls can be collated into a shared database.

In conclusion, although limit equilibrium is not the most rigorous or direct means of assessing geotechnical stability, it is currently generally accepted by industry as the most practical method available and so has been adopted for the PRCP for Blackwater Mine.

Factor of Safety computed by limit equilibrium is essentially a ratio of the strength available to hold a slope in place divided by the loads tending to move, or destabilise, material behind the slope face. Thus, a factor of safety less than 1 indicates instability, and a value greater than 1 implies that the slope is stable because the capacity to resist slipping is greater than the forces promoting slipping. Factor of safety is a relatively coarse and simplified measure of stability that was devised to use as a design methodology. In this context, a minimum value somewhat greater than 1 is specified to allow for inaccuracies and uncertainties in both the method and the input data. When a slope is actually constructed, much of the uncertainty disappears – if a slope exists and is not moving then it is obviously stable under current conditions, regardless of any computed measure. The important consideration should then be whether there is potential for those current conditions to change in a way that would then adversely affect stability.

2.4 Application

As a design or performance criterion, the selected minimum factor of safety should be appropriate to the consequences if instability did occur, which in the closure context in turn relates to land use (Martin and Stacey, 2018 p125 & PW Baker and Associates, 2006 p30). A minimum factor of safety of 1.5 is often adopted for long-term stability of civil engineering features such as road cuttings and dam walls, that is, features with broad public access. By contrast, factors of safety of 1.2 and 1.3 are typically applied to operational design for coal mine pit walls, where stability is required for a shorter time and with limited human exposure. Because the selected factor of safety encompasses more than just variability in material properties, it does not map uniquely to probability of failure; however accumulated experience suggests that a minimum of 1.5 typically provides much less than 1% likelihood of failure while coal open pit mining operates at around 10% likelihood of failure.

Pending industry research to develop observational methods and consequence assessment for long-term pit wall stability, for closure planning Whitehaven has adopted a minimum factor of safety of 1.5 for highwalls and endwalls. However, a too-conservative approach could lead to an unnecessary increase in void area at the expense of adjoining higher value land uses. If all void walls were flattened back to where the factor of safety is 1.5, in more than 99% of the cases that would have been unnecessary additional land disturbance. Hence, Whitehaven is applying the minimum factor of safety not to the physical crest of the pit wall but to a distance set back behind the crest, such that there are no environmental or third-party assets of significant value within that set-back. Reasoning from the other direction, final pit walls have been located such that their computed set-back does not include any valuable assets. This is a no-regret approach for the purposes of closure planning that allows the flexibility to apply improvements in stability practice in the future.

2.5 Design tool

A common engineering approach, when it is anticipated that designs will be required for a large number of similar scenarios, is to undertake upfront a large number of analyses to cover the range of expected scenarios and collate the results into a design tool, for example design charts or empirical formulae or lookup tables. It is important to appreciate that such tools do not omit design analyses, it is simply that all the analyses are carried out first so that when a particular scenario is considered, the result is already available. Set-backs for long term pit wall stability at coal mines clearly lends themselves to this approach – regional geology is broadly consistent; mining methods constrain the range of efficient wall geometries; and given the number of pits and different planning horizons, there will be a large number of specific scenarios to address over time.

BHP, the previous operator of Blackwater Mine, developed a pit wall stability design tool, as detailed in Section 4.1, and the key features are summarised below. As discussed in Section 4, the tool was not applicable to Bonnie Doon, Laleham-R74 and Comet Downs East voids. Consequently, bespoke geotechnical stability analyses were undertaken for those voids using the same general approach and material properties as the design tool.

3. INPUTS TO ASSESSMENT - REGIONAL

3.1 Regional geology and geotechnical (strength) properties

In the Bowen Basin, predominantly Permian age coal measure sedimentary rocks are unconformably overlain by younger, mainly Tertiary age, sediments. At some locations, the latter contain laterally confined basalt that was deposited in the early Tertiary.

In the context of wall stability, the important geological boundaries are Base of Tertiary and Base of Weathering; however, for simplicity in the design tool, Tertiary and weathered Permian rocks were treated as one material. This is a conservative assumption for slightly weathered rock but as noted in PW Baker and Associates (2006, p7), differences between Tertiary and weathered Permian sediments are more a matter of degree than character.

Stability analyses forming the basis of the design tool used the wall geometry summarised in Table 1 which was based on consultation with the BHP Geotechnical Team and examination of preliminary final landforms for all BHP coal mines in Queensland. Assumed strength properties, presented in Table 2, were the default values suggested in the Geotech Design, Operating and Monitoring Manual (BHP, September 2020).

Table 1: Wall geometry covered by stability design tool

Aspect	Value range
Average wall angle in Tertiary overburden	35° (constant)
Depth of Tertiary/weathered overburden	1m to 100m
Bench width at base of Tertiary overburden	30m (constant)
Average wall angle in Permian overburden	40° to 70°
Depth of Permian overburden incl. 10m coal	50m to 400m

Table 2: Strength properties applied in stability design tool

	Cohesion (kPa)	Friction Angle (°)	Unit Weight (kN/m^3)
Tertiary/weathered	50	30	22
Fresh Permian	450	42	24
Coal	30	35	15

3.2 Effect of weathering

It is obvious that weathering affects the character and strength of rocks. However, weathering that has occurred over geologic time before the pit wall is excavated is automatically accounted for in the strength properties adopted for operational wall design and so has no additional geomechanical impact on rehabilitation and post-mining landforms. Hence, additional effects of weathering on long-term stability would only relate to weathering that might occur after cessation of mining.

There are two phases to weathering, physical degradation and chemical decomposition. Degradation starts almost as soon as the rock face is exposed and is essentially larger fragments or rock breaking down into smaller fragments. This breakdown, or 'slaking', is mainly caused by salt crystals adsorbing moisture and swelling, by clay minerals adsorbing moisture and swelling (although salts are usually involved as well) and less commonly by cementing minerals being dissolved in water. Rainfall and in-pit storage cause immediate slaking in susceptible materials but humidity can produce the same result over a couple of years. Because degradation depends so heavily on water ingress, it is largely restricted to the surface of pit walls and does not penetrate far enough to cause geotechnical instability. An exception may be when particularly moisture-sensitive rock is below the long-term void water level, but this is addressed by adopting saturated strength properties and therefore does not need to be considered separately.

Chemical decomposition involves reactions of the actual rock minerals to form different minerals (ultimately, clay minerals). Because it occurs at the crystalline/molecular level and only where water and other reactants can reach, chemical weathering occurs mainly at the rock surface and along joints and bedding planes, but even there, it progresses at a very slow rate relative to other processes. For example, reported rates of soil formation throughout the world range from 0.01 to 7.7 mm/yr, with an average of about 0.1mm/yr (Morgan, 2005). As weathering is what causes soil formation, this implies that weathering penetrates less than 1m depth in a hundred years.

Both forms of weathering occur fastest in hot wet climates – rainfall providing the necessary moisture, and high temperature promoting chemical reactions. The climate at Blackwater Mine is hot but not wet and as shown on the Peltier diagram in Figure 6, only "very slight" ongoing weathering is expected.

There may be very specific situations where even a very small amount of additional weathering might affect pit wall stability, most notably where weak degradable strata underlie more resistant strata. As the degradable material ravels and falls away, the harder layer loses support and may subsequently fall. This is generally a localised scenario that may only be apparent when the pit wall is excavated. Hence it cannot generally be planned for but will be assessed and managed at the end of coal extraction.

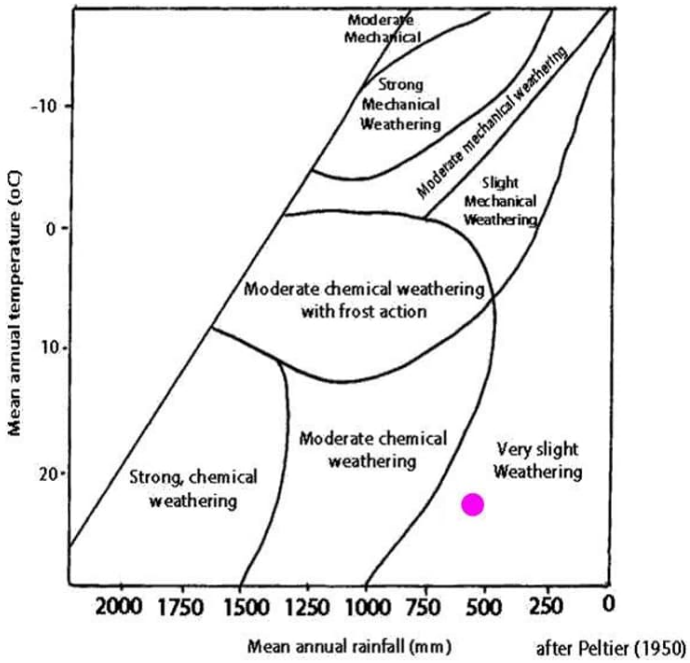


Figure 6: Weathering conditions at Blackwater Mine

3.3 Effect of long-term erosion

Erosion is the detachment of solid particles from the soil or rock mass and the subsequent transport of those particles away from their initial location. Most commonly, detachment occurs due to mechanical means – the impact of raindrops and the energy of flowing water – and the transport is also provided by flowing water. In this scenario, the severity of erosion depends on the character of the material – how easily particles are detached – and increases with catchment size and surface slope, both of which increase the volume and velocity of runoff flow.

In dispersive material, detachment can also occur by chemical means. In this case, the bonds and ionic charges within the material are such that clay particles will "disperse" into even static water that is not applying mechanical energy. However, flowing water is still required for the transport phase of erosion.

On highwalls and endwalls in the Bowen Basin, erosion in fresh rock is mainly limited to material that has already slaked because the intact rock is too strongly bound for particles to be readily detached. Above the base of weathering, particles are more easily detached. As particles are transported in water flow, erosion develops and progresses over time along flow lines and these are mainly perpendicular to the line of the wall. By contrast, slip failures involve surfaces that are at least sub-parallel to the line of the wall. Consequently, erosion rarely causes geomechanical instability. Even if an unusual arrangement of intersecting erosion gullies created the potential for a wedge-type failure, it would be addressed through surface water and erosion control measures rather than by slope stability design.

This prediction that weathering and long-term erosion will generally have little impact is supported by a study comprising visual assessment of 39 pit walls that were more than five years old which found that significant geotechnical instability was not correlated to wall age (Encompass Mining, 2018 and BHP, 2021). This is not to say that erosion is not a rehabilitation issue in its own right, but it is generally not a significant factor in pit wall geotechnical stability. Consequently, it has not been considered further in this study.

3.4 Effect of significant hydrological events

In Bowen Basin coal mines, weathered overburden is generally susceptible to softening when saturated, especially materials containing significant clay. Unweathered (fresh) coal measure rocks generally do not show significant strength loss on wetting, as evidenced by the large number of inactive pits that contain water without any noticeable change in wall stability. Some particular claystones/mudstones may be more sensitive to moisture but these tend to start slaking soon after exposure to humid air, and so are apparent during mining when wall designs can be amended to mitigate any impact on wall stability.

Water balance modelling for the proposed voids at Blackwater Mine predicts average and long-term void water levels many metres below the base of weathering. The long time series rainfall record used for water balance modelling included "significant hydrological events". Consequently, void water will only contact fresh rock and so will not affect geotechnical stability of excavated pit walls. The one exception was Comet Downs East Void, which was analysed separately.

The most serious potential impact of severe rainfall events would be inrush of floodwaters to the void. In theory, an initial inflow could scour a new channel through the ground between the

void and the watercourse, thus directing more water into the void at a greater flow rate. In practice however, this scenario will be prevented by including appropriate drainage diversions and landforms to protect the voids from inundation.

There is one other mode of instability related to water storage, namely draw-down failure. This can occur when pore water pressures in the containing earth and rock have equilibrated with the water level in the storage and that water level is then lowered quicker than the containing materials can drain, so that the pore pressures are no longer balanced out. This will not be an issue for voids to contain water passively or for normal stock water supply because evaporation and small capacity pumps will not lower the water level quickly enough to establish this imbalance. Stability under draw-down would be a consideration for PMLUs involving movement of large volumes of water, such as large-scale irrigation and pumped hydro energy storage, but such uses are not proposed for Blackwater Mine.

4. INPUTS TO ASSESSMENT - LOCAL

Long sections extracted from the current Blackwater Mine geological model provided void wall profile data as summarised in Table 3.

Bonnie Doon and Laleham-R74 voids have depths of fresh Permian overburden outside the limits for the design tool (refer Table 1), because both voids will be partly filled with tailings and covering much of the fresh Permian strata. In addition, auger mining had been carried out along part of the base of the Laleham R74 highwall. The predicted long-term pit lake for Comet Downs East void is above the base of weathering on the highwall, which is also inconsistent with the design tool. Consequently, bespoke stability analyses were undertaken for these voids.

For these analyses, one typical cross-section was considered for each void. More precise geotechnical profiles were used, in particular with Tertiary overburden and weathered Permian overburden differentiated. Pit lake levels were taken from SLR (2026 b) and hydraulic properties were broadly consistent with those in the calibrated hydrogeological model (SLR (2026 a). Strength properties for the additional materials required for these refinements are presented in Table 4.

Table 3: Geotechnical profiles for the residual void walls at Blackwater Mine

Geotechnical profile parameters		R08	Bonnie Doon	Mimose / Besgrove	Deep Creek	R30
Depth of Tertiary/ weathered overburden (m)	Average Range 90% less than	16 14 – 18	15 10 – 21 21	18 7 – 27 25	12 11 – 12 12	11 11 - 12
Depth of fresh overburden (m)	Average Range 90% less than	60 53 - 68	13 0 – 40 33	138 68- 175 169	118 90 – 147 145	72 70 - 72
Total Wall depth (m)	Average Range 90% less than	76 67 - 87	29 10 – 50 45	156 91 – 196 190	130 101 – 159 157	75 62 - 83

Geotechnical profile parameters		Stewarton North	Stewarton South	Tannyfoil	South Ballamoo	Kenmare
Depth of Tertiary/ weathered overburden (m)	Average Range 90% less than	15 11 – 24 21	20 15 – 24 24	16 12 – 23 21	61 45 – 81 77	47 38 – 53 52
Depth of fresh overburden (m)	Average Range 90% less than	152 68 – 202 197	104 59 – 126 123	114 79 – 135 132	192 148 – 224 222	106 82 – 124 120
Total Wall depth (m)	Average Range 90% less than	167 82 – 213 213	124 83 – 141 139	130 101 – 151 149	253 215 – 290 286	153 131 – 163 163

Geotechnical profile parameters		Laleham-R74	North Marshmead	South Marshmead	Kennedy West	Comet Downs East
Depth of Tertiary/ weathered overburden (m)	Average Range 90% less than	20 14 – 28 23	71 24 – 97 89	67 54 – 82 79	34 28 – 43 41	36 35 - 37
Depth of fresh overburden (m)	Average Range 90% less than	6 0 – 11 9	156 125 – 199 187	118 104 – 125 125	84 57 – 126 114	97 96 - 97
Total Wall depth (m)	Average Range 90% less than	26 22 – 30 30	227 169 – 270 260	185 157 – 206 204	118 90 – 167 148	134 133 - 135

Table 4: Additional strength properties used in bespoke analyses

	Cohesion (kPa)	Friction Angle (°)	Unit Weight (kN/m^3)
Unsaturated Spoil	40	30	18
Saturated Spoil	23	25	20
Unsaturated Tertiary	50	30	20
Unsaturated weathered Permian	75	30	24
Subsided Fresh Permian[@]	275	36.5	23
Tailings[#]	15	0	14

From BHP, 2020, except:
* cohesion assumed 40% value for unsaturated
[@] adopted properties mid-way between intact and blasted fresh Permian
[#] typical for normally consolidated saturated coal tailings with undrained load response

For the walls that were within the design tool limits, computations were made with two assumed wall angles, namely, 50° and 60°. Computed set-back from wall toe is not very sensitive to that parameter but steeper angles are slightly more conservative because they impose greater overburden weight on the potential slip surface.

4.1 Stability analyses

The procedure for estimation of set-back developed in the design tool is:

1. If D_{TW} =<47m, FoS_{TW} >=1.5 and $S_{TW} = D_{TW}/\tan(35°)$
2. Otherwise $S_{TW} = 2.58\ D_{TW} – 41.5$
3. $S_1 = S_{TW} + 30 + D_P/\tan(A_P)$
4. $FoS_P = 1.208 + 0.0655/\sqrt{D_{TW}} + 13.87/\sqrt{D_P} - 0.0168A_P$;
   if FoS_P >=1.5 then $S_P = D_P/\tan(A_P) + 30 + D_{TW}/\tan(35°)$
5. Otherwise, $S_P = 0.856D_{TW}^{1.15} + 3.727D_P^{0.94} + 39.35\tan(A_P)^{1.09} + 35.01FoS_P^{2.49} -389$
6. Required set-back from the wall toe = $\max(S_1, S_P)$

Where:

D_{TW} = depth of Tertiary/weathered overburden (m)

D_P = depth of fresh Permian overburden (m)

A_P = average wall angle in fresh Permian overburden (degrees)

S_{TW} = set-back for stability in Tertiary/weathered overburden (m), measured from the toe of the weathered overburden batter

FoS_{TW} = factor of safety for instability confined to the Tertiary/Weathered overburden

S_1 = set-back for whole operational wall design (m), measured from the toe of the whole wall

S_P = set-back for stability of whole wall (m), at FoS = 1.5

FoS_P = factor of safety for instability affecting the whole wall

The results for the pit set-backs computed using the design tool are tabulated in Appendix A and summarised in Table 5. The values in red show voids where the average factor of safety without set-back was less than 1.5, and therefore any adjoining PMLU must be set-back behind the wall. Note that when the factor of safety at the crest of the wall is greater than 1.5, the reported set-back from the toe of the wall is simply the distance from the toe to that crest.

Set-backs for endwalls will range from the value at the end of each highwall down to the value coinciding with the excavated wall crest as the exposed wall height reduces.

Table 5: Set-backs for long-term wall stability at Blackwater Mine (for pits using the design tool)

Geotechnical stability parameters		R08	Mimose / Besgrove	Deep Creek	R30	Stewarton North	Stewarton South	Tannyfoil
A_P (°)				**50**				
S_1 (m)	Average Range 90% less than	64 63 – 73 71	130 76 – 164 159	109 85 – 134 132	63 52 – 70	140 69 – 179 178	104 69 – 118 117	109 85 – 127 123
FoS_P	Average Range 90% more than	2.18 2.06 – 2.28 2.09	1.59 1.43 - 2.07 1.45	1.69 1.53 - 1.85 1.54	2.14 2.02 - 2.35	1.54 1.36 - 2.07 1.37	1.77 1.62 - 2.18 1.64	1.70 1.58 - 1.95 1.59
S_p (m)	Average Range 90% less than	104 95 – 113 111	180 20 – 248 236	146 121 – 171 169	100 89 – 107	207 107 - 295 290	146 113 – 157 157	148 122 – 166 163
Set-back from toe of wall (m)	Average Range 90% less than	104 95 – 113 111	180 120 – 248 236	146 121 – 171 169	100 89 – 107	207 107 – 295 290	146 113 – 157 157	148 122 – 166 163
A_P (°)				60				
S_1 (m)	Average Range 90% less than	44 39 – 50 49	90 52 – 113 110	75 58 – 92 91	44 36 – 48	96 47 – 123 122	72 48 – 81 81	75 58 – 87 85
FoS_P	Average Range 90% more than	2.01 1.89 – 2.12 1.92	1.42 1.27 - 1.90 1.28	1.52 1.36 - 1.68 1.37	1.97 1.85 - 2.18	1.38 1.20- 1.90 1.20	1.60 1.45 - 2.02 1.47	1.53 1.41 - 1.78 1.42
S_p (m)	Average Range 90% less than	88 81 – 96 94	176 102 – 249 236	136 98 – 180 175	83 76 – 88	201 89 – 298 293	124 98 – 142 138	129 99 – 161 153
Set-back from toe of wall (m)	Average Range 90% less than	99 91 – 96 94	176 102 – 249 236	136 98 – 180 175	83 76 – 88	201 89 – 298 293	124 98 – 142 138	129 99 – 161 153

Geotechnical stability parameters		South Ballamoo	Kenmare	North Marshmead	South Marshmead	Kennedy West
A_P (°)				**50**		
S_1 (m)	Average Range 90% less than	275 209 – 325 314	163 136 – 187 183	271 142 – 336 321	230 184-273 267	99 76 – 140 124
FoS_P	Average Range 90% more than	1.38 1.30-1.51 1.31	1.74 1.62 – 1.91 1.65	1.50 1.36 – 1.62 1.39	1.66 1.61 – 1.74 1.62	1.93 1.61 – 2.22 1.68
S_p (m)	Average Range 90% less than	355 263 – 434 423	186 169 – 198 195	291 186 – 389 367	225 194 – 251 247	149 125 – 195 173
Set-back from toe of wall (m)	Average Range 90% less than	356 277 – 434 423	186 169 – 198 195	298 186-389 367	232 194 – 273 267	149 125 – 195 173
A_P (°)				60		
S_1 (m)	Average Range 90% less than	224 143 – 271 263	132 94 – 158 155	229 98 – 296 279	200 157 – 241 234	68 52 – 97 85
FoS_P	Average Range 90% more than	1.22 1.14 – 1.35 1.14	1.57 1.46 – 1.74 1.48	1.33 1.19 – 1.45 1.22	1.49 1.45 – 1.57 1.45	1.76 1.45 – 2.06 1.51
S_p (m)	Average Range 90% less than	359 277 – 438 427	163 147 – 175 173	299 193 – 392 369	213 167 – 253 249	129 110 – 183 144
Set-back from toe of wall (m)	Average Range 90% less than	359 277 – 438 427	163 147 – 175 173	299 193 – 392 369	213 167 – 253 249	129 110 – 183 144

The relevant geometric parameters and results for bespoke analyses of Bonnie Doon TSF, Laleham-R74 TSF and Comet Downs East void are summarized in Table 6 and the graphic output for each section is included in Appendix B. For Laleham R74, a zone of subsided fresh Permian overburden was placed in the area affected by auger mining; however, this was not significant because the lower factors of safety occurred above the base of weathering. For both voids, the minimum factor of safety at representative cross-sections was greater than 1.5.

Table 6: Long-term wall stability for pits analysed by bespoke analysis)

		Bonnie Doon CH500	Laleham R74 CH1900	Comet Downs East
Tertiary overburden	m	12	10	24
Weathered Permian overburden	m	29	10	11
Water cover below base of weathering	m	24	4	-11
Water depth	m	5	7	107
Tailings depth	m	32	18	n/a
Assumed angle of draw	deg	n/a	60	n/a
Minimum FoS		2.02	2.22	1.08
Set-back from wall toe to FoS>1.5		crest	crest	165

5. IMPLICATIONS FOR RESIDUAL VOIDS

A computed factor of safety >1.5 implies that the required set-back from the wall toe is in front of the crest (that is, contained within the wall). Consequently, the crest itself may be taken as defining the boundary of the void NUMA. Where the factor of safety <1.5, the set-back approach to long-term geotechnical stability offers several options to meet the requirements for mine closure including:

1. Where the distance from the wall toe to crest equals the set-back distance, the wall has a Factor of Safety not less than 1.5 and no further action is necessary; otherwise
2. Stop the mining pit with the toe of each pit wall at least the set-back distance away from significant permanent assets including: lease boundaries, third-party infrastructure, and Matters of State Environmental Significance (MSES); or
3. Move the asset in question, for example to relocate a public road; or
4. Undertake more detailed geotechnical investigation and wall stability analysis to remove some of the conservatism imposed by the design tool; or
5. Investigate partially backfilling the residual void. In simple terms, this would reduce the (exposed) wall depth and depth of fresh Permian overburden, which would in turn reduce the set-back. However, partial backfill might result in a perched pit lake that acts as a source to groundwater.

It is expected that these options, and combinations thereof, will be considered on a case-by-case basis for highwalls and endwalls as each pit approaches its final location.

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APPENDIX A COMPUTED SET-BACKS BEHIND HIGHWALLS

R08 Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH250	14	53	56	2.28	95	95	39	2.12	81	81
CH500	16	59	63	2.19	103	103	43	2.03	87	87
CH650	18	68	73	2.06	113	113	50	1.89	96	96

Deep Creek Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH500	12	95	90	1.81	127	127	62	1.64	102	102
CH750	12	147	134	1.53	171	171	92	1.36	180	180
CH1000	12	139	127	1.56	164	164	87	1.39	163	163
CH1250	11	90	85	1.85	121	121	58	1.68	98	98

R30 Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH500	11	72	70	2.02	107	107	48	1.85	88	88
CH750	11	70	68	2.05	104	104	47	1.88	86	86
CH1000	12	50	52	2.35	89	89	36	2.18	76	76

Mimosa-Besgrove Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH250	23	68	76	2.07	120	120	52	1.90	102	102
CH500	23	88	92	1.86	136	136	64	1.70	113	113
CH750	17	94	93	1.81	133	133	64	1.64	109	109
CH1000	22	97	99	1.79	142	142	68	1.63	117	117
CH1250	22	107	108	1.72	151	151	74	1.55	123	123
CH1500	26	111	114	1.70	160	160	79	1.53	131	131
CH1750	25	119	120	1.66	165	165	83	1.49	143	143
CH2000	25	127	128	1.61	173	173	88	1.44	159	159
CH2250	23	132	131	1.59	174	174	90	1.42	166	166
CH2500	21	75	80	1.99	122	122	55	1.82	103	103
CH2750	18	88	89	1.86	130	130	61	1.69	106	106
CH3000	17	165	152	1.46	223	223	105	1.30	223	223
CH3250	15	175	159	1.43	242	242	110	1.27	243	243
CH3500	19	163	153	1.47	222	222	105	1.30	222	222
CH3750	17	169	155	1.45	231	231	107	1.28	231	231
CH4000	18	169	157	1.45	233	233	108	1.28	234	234
CH4250	23	170	161	1.45	242	242	111	1.28	243	243
CH4500	25	170	164	1.44	248	248	113	1.28	249	249
CH4750	26	168	162	1.45	243	243	112	1.28	243	243
CH5000	27	163	160	1.47	235	235	110	1.30	235	235
CH5250	26	159	155	1.48	225	225	107	1.31	225	225
CH5500	21	155	148	1.50	210	210	102	1.33	210	210
CH5750	13	152	139	1.51	177	177	95	1.34	191	191
CH6000	9	147	131	1.53	166	166	90	1.37	176	176
CH6250	17	142	133	1.55	172	172	91	1.38	174	174
CH6500	17	139	131	1.56	171	171	90	1.39	170	170
CH6750	15	138	128	1.57	167	167	88	1.40	165	165
CH7000	16	135	127	1.58	166	166	87	1.41	161	161
CH7250	14	135	125	1.58	163	163	86	1.41	157	157
CH7500	13	132	121	1.59	159	159	84	1.43	150	150
CH7750	13	135	124	1.58	161	161	85	1.41	155	155
CH8000	10	138	124	1.57	160	160	85	1.40	159	159
CH8250	8	142	126	1.56	160	160	86	1.39	164	164
CH8500	7	147	129	1.54	163	163	89	1.37	172	172
CH8750	10	148	133	1.53	169	169	91	1.36	179	179
CH9000	14	148	136	1.52	174	174	94	1.36	184	184
CH9250	14	150	138	1.52	176	176	95	1.35	188	188
CH9500	13	146	133	1.53	171	171	92	1.37	178	178
CH9750	12	151	136	1.52	173	173	94	1.35	187	187
CH10000	13	148	136	1.52	174	174	93	1.36	184	184

Stewarton North Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH250	24	113	115	1.69	159	159	79	1.52	129	129
CH500	23	180	170	1.41	265	265	117	1.25	266	266
CH750	18	189	174	1.39	277	277	120	1.22	279	279
CH1000	18	193	178	1.38	286	286	122	1.21	289	289
CH1250	13	200	178	1.37	293	293	123	1.20	296	296
CH1500	11	202	179	1.36	295	295	123	1.20	298	298
CH1750	14	170	154	1.45	229	229	106	1.28	230	230
CH2000	14	127	118	1.62	157	157	81	1.45	142	142
CH2250	15	122	115	1.64	154	154	79	1.47	134	134
CH2500	14	125	116	1.63	155	155	80	1.46	138	138
CH2750	11	125	114	1.63	150	150	78	1.46	134	134
CH3000	12	133	122	1.59	159	159	84	1.42	151	151
CH3250	12	148	134	1.53	171	171	92	1.36	182	182
CH3500	13	182	164	1.41	254	254	113	1.25	256	256
CH3750	14	68	69	2.07	107	107	47	1.90	89	89

Stewarton South Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH250	24	59	69	2.18	113	113	48	2.02	98	98
CH500	15	126	118	1.62	157	157	81	1.45	142	142
CH750	18	120	116	1.65	156	156	80	1.48	135	135
CH1000	21	114	113	1.68	155	155	77	1.52	125	125
CH1250	19	106	105	1.73	146	146	72	1.56	118	118
CH1500	24	102	106	1.76	150	150	73	1.59	123	123

Tannyfoil Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH500	22	78	84	1.95	127	127	58	1.78	106	106
CH750	14	87	84	1.88	122	122	58	1.71	99	99
CH1000	12	89	85	1.86	122	122	58	1.69	98	98
CH1250	25	83	91	1.90	136	136	63	1.73	114	114
CH1500	24	107	109	1.72	153	153	75	1.56	125	125
CH1750	19	102	102	1.76	143	143	70	1.59	116	116
CH2000	14	109	104	1.71	142	142	71	1.54	114	114
CH2250	18	99	98	1.78	139	139	68	1.61	113	113
CH2500	15	107	102	1.73	141	141	70	1.56	113	113
CH2750	15	111	106	1.70	145	145	73	1.53	116	116
CH3000	15	119	112	1.66	151	151	77	1.49	129	129
CH3250	18	116	112	1.67	153	153	77	1.50	122	122
CH3500	15	121	114	1.65	153	153	79	1.48	133	133
CH3750	14	117	110	1.67	148	148	75	1.50	124	124
CH4000	14	122	114	1.64	153	153	79	1.47	134	134
CH4250	14	124	115	1.63	153	153	79	1.47	135	135
CH4500	14	125	116	1.63	155	155	80	1.46	138	138
CH4750	18	131	125	1.59	165	165	86	1.43	156	156
CH5000	17	129	122	1.61	162	162	84	1.44	150	150
CH5250	15	135	126	1.58	165	165	87	1.41	160	160
CH5500	15	134	125	1.58	164	164	86	1.42	157	157
CH5750	14	131	121	1.60	159	159	84	1.43	150	150

South Ballamoo Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH750	81	180	318	1.41	365	365	271	1.24	367	367
CH1000	74	190	309	1.38	375	375	260	1.21	378	378
CH1250	53	199	263	1.36	357	357	211	1.19	360	360
CH1500	56	214	282	1.32	395	395	226	1.16	399	399
CH1750	59	224	299	1.30	422	422	241	1.14	427	427
CH2000	71	220	325	1.31	434	434	267	1.14	438	438
CH2250	63	221	306	1.31	423	423	249	1.14	427	427
CH2500	58	219	291	1.31	409	409	233	1.15	413	413
CH2750	52	200	261	1.36	357	357	208	1.19	360	360
CH3000	59	185	267	1.40	338	338	219	1.23	340	340
CH3250	45	203	209	1.35	352	352	143	1.18	355	355
CH3500	66	173	273	1.43	322	322	228	1.26	323	323
CH3750	58	174	255	1.43	310	310	209	1.26	312	312
CH4000	50	165	226	1.46	278	278	183	1.29	279	279
CH4250	76	148	279	1.51	263	279	240	1.35	290	290
CH4500	60	156	245	1.49	277	277	204	1.32	277	277

Kenmare Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH500	49	82	153	1.91	169	169	132	1.74	147	147
CH750	49	106	174	1.73	189	189	146	1.56	161	161
CH1000	53	110	187	1.70	198	198	158	1.53	169	169
CH1250	38	124	136	1.62	189	189	94	1.46	175	175

North Marshmead Void

ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH750	24	145	142	1.53	186	186	98	1.36	193	193
CH1000	26	150	148	1.51	194	194	102	1.34	207	207
CH1250	41	146	156	1.53	210	210	108	1.36	221	221
CH1500	58	139	224	1.55	229	229	188	1.38	238	238
CH1750	66	125	234	1.62	229	234	201	1.45	225	225
CH2000	70	129	246	1.60	238	246	213	1.43	239	239
CH2250	79	135	276	1.57	256	276	240	1.40	269	269
CH2500	88	134	297	1.57	268	297	262	1.40	284	284
CH2750	88	140	303	1.55	273	303	267	1.38	295	295
CH3000	74	163	285	1.46	317	317	243	1.29	318	318
CH3250	84	156	307	1.49	323	323	266	1.32	322	322
CH3500	95	151	329	1.50	292	329	290	1.34	331	331
CH3750	97	152	336	1.50	339	339	296	1.33	338	338
CH4000	87	163	319	1.46	341	341	277	1.29	342	342
CH4250	83	173	317	1.43	354	354	271	1.26	355	355
CH4500	78	176	309	1.42	353	353	262	1.25	355	355
CH4750	74	185	305	1.40	364	364	256	1.23	366	366
CH5000	70	196	304	1.37	380	380	253	1.20	383	383
CH5250	72	199	311	1.36	389	389	259	1.19	392	392

South Marshmead Void

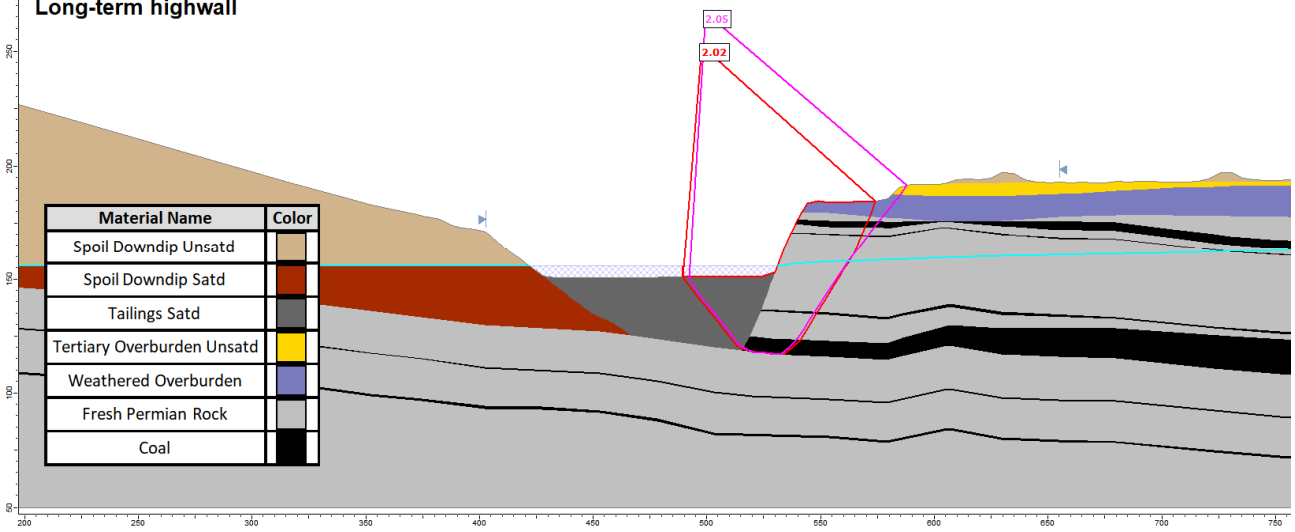
ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH500	54	104	184	1.74	194	194	157	1.57	167	167
CH750	61	111	209	1.69	210	210	180	1.52	181	181
CH1000	63	118	221	1.65	220	221	190	1.48	208	208
CH1250	66	125	235	1.61	230	235	202	1.45	227	227
CH1500	76	125	260	1.62	244	260	227	1.45	244	244
CH1750	82	124	273	1.62	251	273	241	1.45	253	253

Kennedy West Void

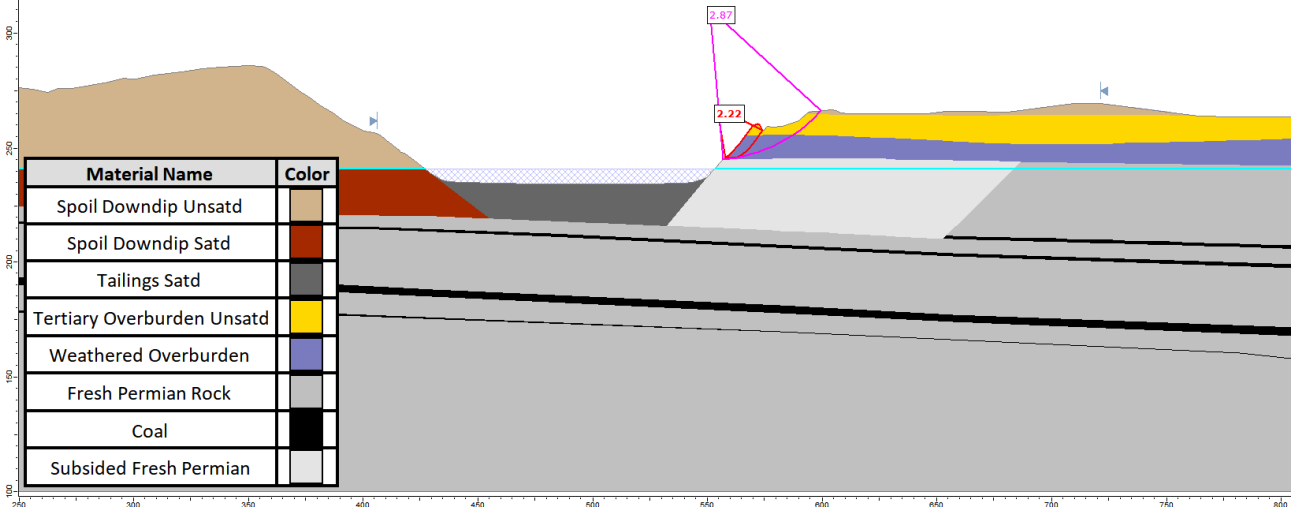
ID	D_{TW}	D_P	A_p=50°				A_p=60°			
			S_1	FoS_P	S_P	Set-back from toe (m)	S_1	FoS_P	S_P	Set-back from toe (m)
CH250	41	126	140	1.61	195	195	97	1.45	183	183
CH500	37	121	132	1.64	184	184	91	1.47	166	166
CH750	34	115	124	1.67	174	174	86	1.51	144	144
CH1000	31	111	119	1.70	168	168	82	1.53	139	139
CH1250	29	106	113	1.73	160	160	78	1.56	132	132
CH1500	28	99	106	1.77	153	153	73	1.60	127	127
CH1750	28	86	95	1.87	142	142	66	1.71	119	119
CH2000	28	79	89	1.94	135	135	61	1.78	115	115
CH2250	29	74	87	1.99	134	134	60	1.82	114	114
CH2500	31	64	79	2.11	127	127	55	1.94	111	111
CH2750	31	68	83	2.06	132	132	57	1.90	114	114
CH3000	31	63	78	2.13	126	126	54	1.96	110	110
CH3250	34	60	78	2.18	128	128	54	2.01	112	112
CH3500	33	57	76	2.21	125	125	52	2.05	110	110
CH3750	38	57	79	2.22	132	132	55	2.06	117	117
CH4000	41	65	89	2.10	143	143	61	1.93	126	126
CH4250	41	69	92	2.05	147	147	64	1.88	129	129
CH4500	43	79	103	1.93	158	158	71	1.77	137	137
CH4750	43	84	106	1.89	162	162	73	1.72	140	140
CH5000	35	88	103	1.86	154	154	71	1.69	131	131
CH5250	32	87	100	1.87	149	149	69	1.70	126	126
CH5500	31	89	101	1.85	149	149	69	1.68	126	126

APPENDIX B RESULTS FROM BESPOKE STABILITY ANALYSES

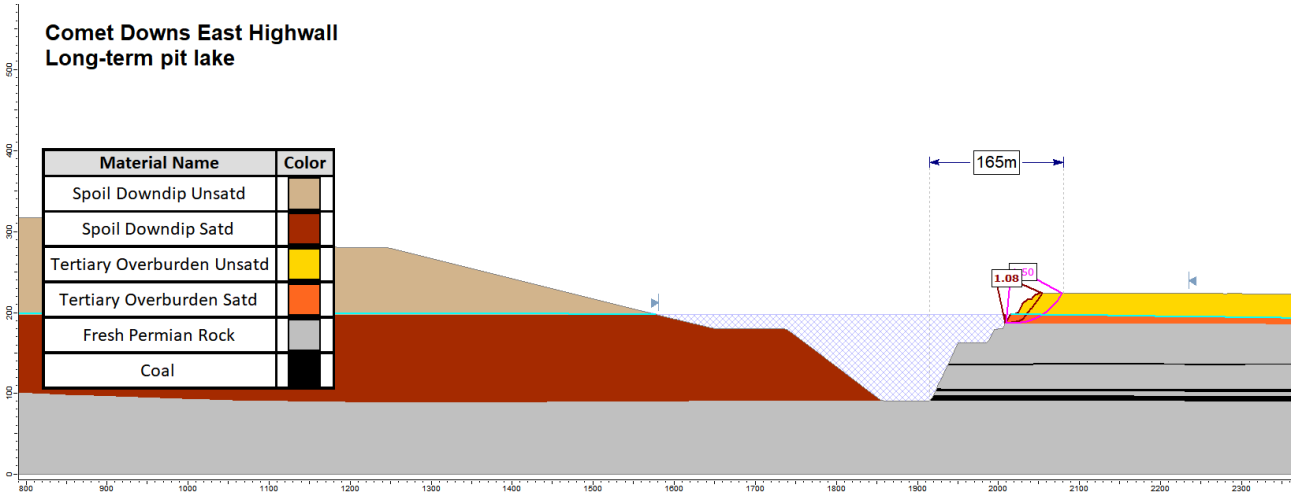
Bonnie Doon CH500
Long-term highwall



Laleham R74 CH1900
Long-term highwall



Comet Downs East Highwall
Long-term pit lake



WHITEHAVEN COAL LIMITED

Assessment of Geotechnical Stability of LF#4.4 Residual Void Lowwalls at Blackwater Mine

May 2026

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L I S T O F F I G U R E S

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1. INTRODUCTION

Dr Sue Henderson (RPEQ 4952) of Henderson Geotech Pty Ltd was requested to provide assessment of pit lowwall geotechnical stability for inclusion in void closure plans for Blackwater Mine. The work, for the proposed final landform LF4.4 and associated land uses, was undertaken in the April-May 2026.

The assessments described in this report were made in accordance with the principles of the Guidelines for Assessment of Geotechnically Safe and Stable Post-Mining Landforms (Simmons et al, 2024).

1.1 Limitation

This report has been prepared by Henderson Geotech Pty Ltd for Whitehaven Coal Limited (Client) for the purpose of supporting preparation of Progressive Rehabilitation and Closure Plan for Blackwater Mine. It shall not be used or relied on for any other purpose. No parties other than the Client and the Department of Environment, Tourism, Science, and Innovation (DETSI) are authorised to rely on this report without the prior written consent of Henderson Geotech Pty Ltd.

This report is, in part, based on information provided by the Client or by other parties on behalf of the Client (Client-supplied information) in addition to data collected by Henderson Geotech Pty Ltd from the public domain. Henderson Geotech Pty Ltd has not always verified the accuracy of such information and makes no representations regarding its accuracy. Henderson Geotech Pty Ltd is not responsible for the consequences of any error or omission in Client-supplied information.

Henderson Geotech Pty Ltd has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same specialist field for projects of a similar nature and at the time and in the jurisdiction where the services were rendered. Henderson Geotech Pty Ltd makes no warranty, express or implied.

2. STATEMENT OF LANDFORM DESIGN INTENT

This assessment of geotechnical stability for residual void lowwalls at Blackwater Mine was undertaken to support an amendment to Blackwater Mine's Progressive Rehabilitation and Closure Plan, to demonstrate that the final voids can be rehabilitated as non-use management areas (NUMAs) that will not adversely impact nearby woodland and grazing PMLUs for at least 60 years.

The geotechnical stability analyses and assessment described in this report are applicable only to the scenarios and inputs also described herein. A new assessment will be required if there are:

- Non-trivial changes to the location or geometry of the planned residual voids;
- Changes to proposed post-mining land uses of the voids or adjoining lands;
- Substantial changes to the understanding of stratigraphy or geotechnical properties; or

- Substantial changes to the understanding of end-of-mining and long-term groundwater levels or long-term pit lake levels.

3. GEOTECHNICAL MODEL

A topographic model of the proposed final landform included fourteen NUMA voids. The features considered most likely to affect lowwall stability - height of spoil; dip of the mined floor; and depth of the final pit lake – are summarised in Table 3-1.

Table 3-1: Geometric characteristics of voids

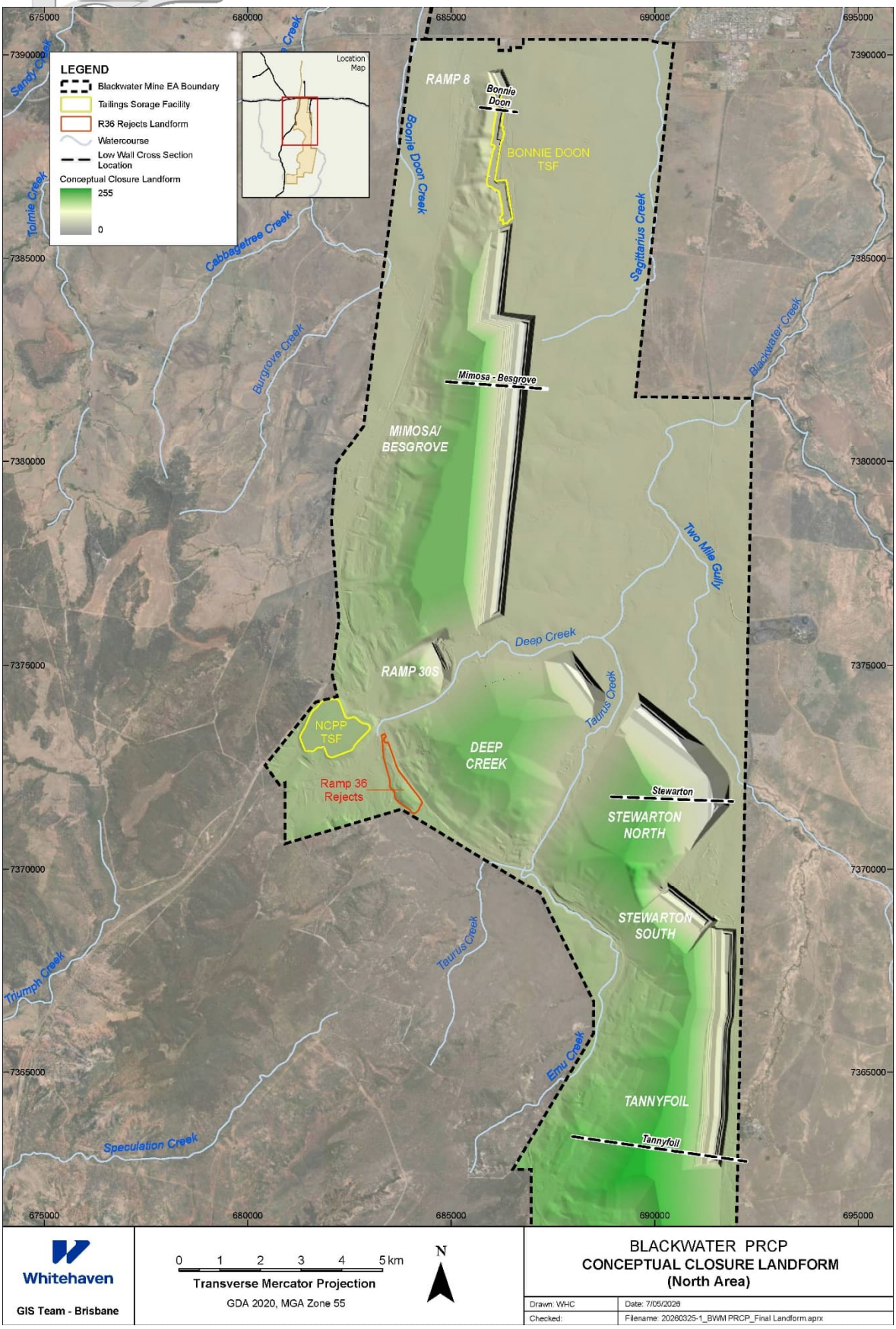
Void name	Approx. length (km)	Max. spoil height (m)	Max floor dip[a] (deg)	Long-term pit lake depth[b] (m)
Ramp 8	0.7	100	6	45
Bonnie Doon	2.8	80	10	2 (& tailings)
Mimosa/Besgrove	9.3	332	4	55
Deep Creek	1.4	306	2	84
Ramp 30	0.8	136	4	10
Stewarton North	3.7	384	3	75
Stewarton South	1.4	244	4	10
Tannyfoil	5.8	174	5	24
South Ballamoo	4.4	280	4	53
Kenmare	0.8	230	4	54
Ramp 74 / Laleham	1.7	60	3	3 (& tailings)
North Marshmead	5.3	350	3	68
South Marshmead	1.6	265	6	66
Kennedy	5.5	315	2	64
Comet Downs East	0.6	230	1	112

[a] plans showing contours of floor dip angle provided by Whitehaven Coal Limited 5/11/2025
[b] long term pit lake surface elevations provided in SLR (2026 b)

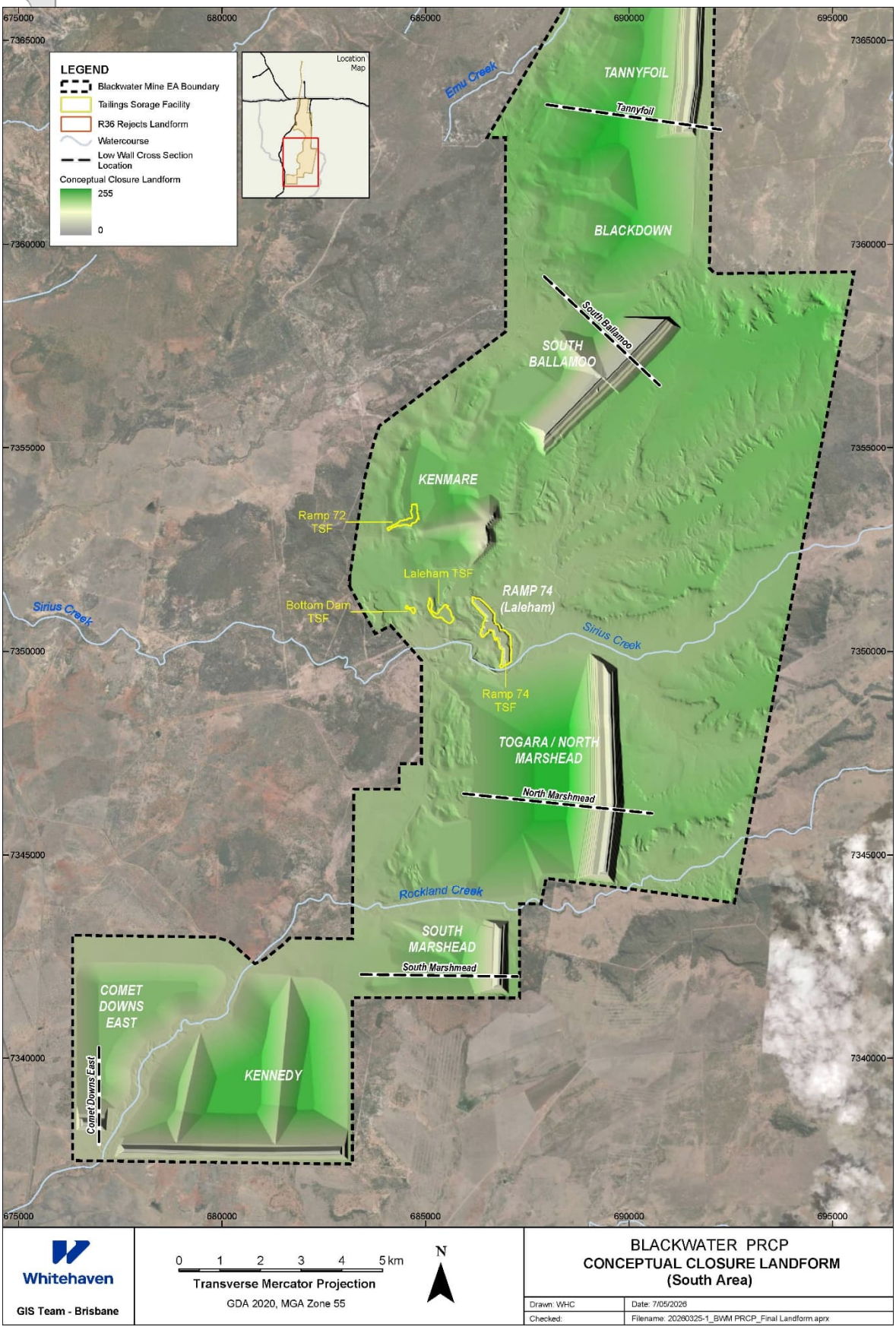
Eight cross-sections were selected for stability analysis, covering highest spoil, steepest floor dig, and deepest long-term pit lake, as well as large voids with 'typical' characteristics, and one of the in-pit TSFs.

Figure 3-1: Location of cross-sections analysed

a) Northern area



b) Southern area



3.1 Strata and Properties

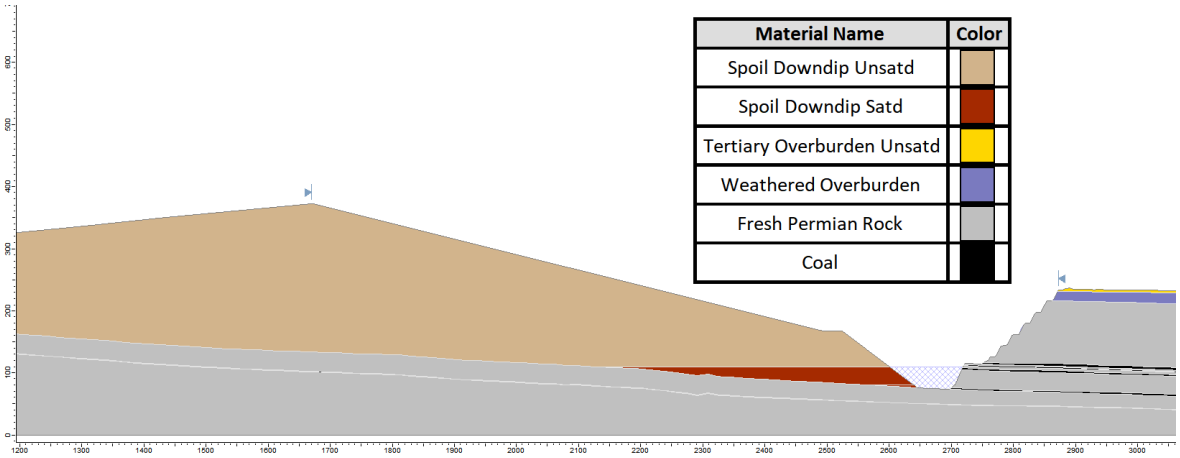
For each cross-section, the Client provided base of Tertiary overburden, base of weathering, coal seam roofs and floors, mined pit shell, and final landform surface.

Strength properties were sourced from BHP (September 2020), Table 6. The coefficient of permeability of the spoil was based on industry experience and is typical of silt-sand/gravel mixtures. Coefficients of permeability for coal and overburden were adapted from calibrated average values reported in SLR (2026 a). Strength and hydraulic properties are summarised in Table 3-2. An example of a cross-section set up for stability analysis is included as Figure 3-2.

Table 3-2: Geotechnical parameters used in stability analyses

Material	Weight kN/m^3	Cohesion kPa	Friction Angle degree	Coeff. of Permeability m/s	k_v/k_h
Unsaturated spoil (down dip spoil)	18	40	30	5e-5	0.25
Saturated spoil (down dip spoil)	20	23	25	5e-5	0.25
Unsaturated Tertiary overburden	20	50	30	7.1e-7	0.01
Saturated Tertiary overburden	20	15	30	7.1e-7	0.01
Weathered Permian overburden	24	75	30	4.5e-6	0.02
Fresh Permian over/interburden	24	450	42	1.9e-9	0.01
Fresh coal	15	30	35	1.1e-7	0.01
Saturated Tailings	14	15	0		

Figure 3-2: Example cross-section for analysis



3.2 Groundwater Pressure Model

Piezometric heads at the ends of each cross-section were provided by the Client based on hydrogeological modelling (SLR, 2026 b) and were applied as total head boundaries at the edges of each cross-section. Long-term pit lake levels were provided in the same reference.

Three groundwater scenarios were applied in geotechnical stability analyses for each cross-section, namely:

- end-of mining;
- long-term equilibrium post-mining, and
- interim condition, with pit lake half the long-term depth and total head boundaries mid-way between end-of-mining and long-term.

Water pressures throughout the sections were then obtained by finite element analyses. Obviously, groundwater conditions change over time after the end of mining; however. the rate of such change is slow enough that steady state analysis was considered sufficiently accurate.

3.3 Potential Geotechnical Instability Mechanisms

Aside from the mined pit floor and coal seams below that, the geological model did not indicate dominant structural features that would affect lowwall stability. Dragline spoil dumps often contain coarse and finer zones; however these are implicitly allowed for in the adopted strength properties, which were partly based on back-analysis of historic spoil slopes and slips.

In this context, 2D circular and non-circular slip surfaces were considered. Circular slips are typical of fine grained spoil and sedimentary rock masses while non-circular slips dominate in granular materials and might be dictated by material interfaces such as the pit floor and the interface between saturated and unsaturated spoil.

On lowwalls, rainfall runoff will mainly flow straight down the batters, with vegetation in the grazing and woodland PMLUs limiting the quantity of such runoff. On these bases, it was concluded that erosion is not likely to materially affect long-term geotechnical stability.

The open porous character of dumped spoil may allow physical weathering, such as slaking, to some depth, however, the associated strength reduction is already accommodated in the adopted strength parameters, in particular those for saturated spoil.

WMR (2025) modelled flows in the various creek catchments that traverse Blackwater Mine and found that none of the voids would be inundated in floods up to 1:1000 AEP events.

Flood modelling was also undertaken for a probable maximum flood (PMF) event. This conceptual flood is applicable to dam design, specifically dams with major or catastrophic failure consequence (ANCOLD, 2000), and flood emergency management planning (Geoscience Australia, 2019). The consequences of geotechnical instability of landforms at Blackwater Mine range from negligible to low (refer Section 4) and therefore PMF is not an appropriate design standard to apply in this assessment.

The hydrogeological assessment and modelling simulated a period of 1,900 years, and the resultant long-term pit lake levels were included in each cross-section analysed. In summary, the effects of severe hydrological events appropriate to the consequences of void geotechnical instability have been addressed in this assessment.

3.4 Statement of Model Uncertainty

The stability assessment methodology described in Simmons et al (2024) includes a matrix to consider and score the confidence in the geotechnical model, based on the quality of input data for various aspects of the model. This subsidiary assessment is included as Appendix A. In summary. the combined geotechnical and groundwater pressure model has a reliability score of 52/100 and is therefore ranked near the margin of Medium to High Uncertainty.

As outlined in Simmons et al (2024), the model uncertainty rating is not a reflection on the reliability of the geotechnical assessment process. Rather, it is a tool to guide selection of appropriate Design Acceptance Criteria (refer Section 5).

4. CONSEQUENCE ASSESSMENT

A consequence assessment, also undertaken in accordance with Simmons et al (2024), is included as Appendix B. Although woodland habitat is the proposed post-mining land use for lowwalls outside the non-use management area voids, and in fact for most of the spoil landforms, for completeness grazing was considered as a potential land use in the assessment. The outcomes are summarised in Table 4-1.

Table 4-1: Consequence category assessment for geotechnical instability

Scenario	Consequence of Geotechnical Instability
Lowwall instability that extends into grazing PMLU	Low
Lowwall instability that extends into woodland PMLU	Low
Lowwall instability that does not extend outside NUMA	Negligible

5. DESIGN ACCEPTANCE CRITERIA

Instability along potential slip surfaces is most commonly assessed using limit equilibrium analyses. Results are expressed as Factor of Safety, with the typical range in factor of safety adopted for slope design being 1.2 to 1.5. In a particular stability assessment, the target values of Factor of Safety that are adopted as Design Acceptance Criteria depend on both model uncertainty and consequences of instability – the high end of the range is appropriate for higher model uncertainty and higher consequence. Consideration of the geotechnical model as Medium Uncertainty in conjunction with the consequence levels listed in Section 4, led to selection of the minimum factors of safety set out in Table 5-1.

Table 5-1: Adopted design acceptance criteria

Scenarios	Minimum Factor of Safety
Instability extending into grazing PMLUs	1.50
Instability extending to watercourses or flood protection structures	1.50
Instability extending into woodland PMLU	1.35
Instability contained wholly within NUMA	1.20

6. STABILITY ANALYSES

The cross-sections were analysed using Slide2 Modeler, 2D Limit Equilibrium Analysis for Slopes. The analytical methods used initially were Morgenstern/GLE - Vertical Slices - Circular Surfaces and Sarma - Vertical Slices - Non-Circular Surfaces, both with Auto Refine Search Method. Initial assessment found that the Sarma method produced lower minimum Factors of Safety because it was better able to generate potential slip surfaces with sliding faces in saturated spoil adjoining the pit floor.

The long-term pit lake scenario produced the lowest factor of safety, except for Mimosa/ Besgrove and Comet Downs East, for which the lowest result occurred with the half-depth pit lake. Significant results are presented in Appendix C and summarised in Table 6-1. Except for Bonnie Doon, Stewarton North and South Ballamoo, the minimum factor of safety was lower than the design acceptance criterion adopted for NUMA voids. The reason for this was that the landform design left the final batters within the NUMAs as-dumped (at angle of repose) and these segments did not have acceptable stability when saturated strength properties were applied to the spoil below the pit lake level. When each pit approaches its final location, more detailed spoil category assessment and observation may justify changes to the conservative strength parameters applied in the stability analyses reported herein. That would be the appropriate stage to refine void design details, for example, benching or flattening the lowwall slope to a design acceptance criterion appropriate to the consequences of instability.

However, the design acceptance criterion for woodland was always achieved at a lower elevation than the opposite highwall crest, and the design acceptance criterion for grazing was always achieved in front of the lowwall crest. As seen from the result images in Appendix C, when there was a wide bench behind the as-dumped segment, those acceptance criteria were met on the bench but where the bench was narrow or absent, they were achieved further up the lowwall slope.

In summary, with the proviso of revising the geotechnical model and/or the slope geometry within the NUMA as each pit approaches its final strip, void lowwalls can meet design acceptance criteria for geotechnical stability.

Table 6-1: Geotechnical stability results for lowwall cross-sections

Section	Minimum FoS	Location of FoS ≥1.35 on lowwall	Position of FoS ≥1.35 relative to highwall crest	Position of FoS ≥1.5 relative to lowwall crest
Bonnie Doon	1.31	on slope	below	in front
Mimosa/Besgrove	0.91	on slope	below	in front
Stewarton North	1.36	on bench	below	in front
Tannyfoil	1.06	on bench	below	in front
Sth Ballamoo	1.78	No FoS<1.5		
Nth Marshmead	0.94	on bench	below	in front
Sth Marshmead	0.95	on slope	below	in front
Comet Downs East	0.91[a]	on slope	below	in front

a minimum factor of safety occurred for pit lake at half final depth.

7. SAFETY ASSESSMENT

Simmons et al (2024) requires a qualitative safety risk assessment to be undertaken for the designed slopes, to identify further risk reduction measures aligned with the ALARP principle. That is, even though compliance with the Design Acceptance Criteria achieves an appropriate level of risk, further mitigative measures should be considered if the cost and difficulty are “reasonable” in the context of the incremental reduction in safety risk.

The safety risk assessment is included as Appendix D. In essence, the recommended additional measures consist of exclusion bunds on the highwall, exclusion fencing all around the NUMA, and explanation of the function of the bunds and fences in the Land Management Plan that will be attached to the land when leases are relinquished.

8. CONCLUSIONS

For the final landform geometry provided, geotechnical stability of void lowwalls meet appropriate Design Acceptance Criteria for post-mining land uses adjacent to the NUMA voids. Within the NUMA, some lowwall profiles may require revision at the detailed design stage.

9. REFERENCES

ANCOLD, March 2000, Guidelines on Selection of Acceptable Flood Capacity for Dams, Australian National Committee on Large Dams Incorporated.

BHP, September 2020, Geotechnical Design, Operating and Monitoring Manual, company internal document

Geoscience Australia, 2019, Australian Rainfall and Runoff – a Guide to Flood Estimation version 4.2, Commonwealth of Australia.

Simmons J, Henderson S and Kennedy G, June 2024, Guidelines for Assessment of Geotechnically Safe and Stable Post-Mining Landforms, ACARP C34028 project report.

SLR, 2026 a, Blackwater North Extension Project Groundwater Modelling Technical Report.

SLR, 2026 b, Blackwater Mine Transitional PRC Plan Hydrogeology Assessment Revision 3, report prepared for Whitehaven Coal Limited.

WRM, 2025, Blackwater Mine Progressive Rehabilitation and Closure Plan Final Landform Flood Assessment, report prepared for Whitehaven Coal Limited.

APPENDIX A MODEL RELIABILITY STATEMENT

Model Element	**Max.**		**Uncertainty Level**	**and Weighting**		**Score**
	Score	Introductory	High	Medium	Low	
		0.0	0.2	0.6	1.0	
Strata & landform profile information	10	Basic surfaces with unreliable or absent data	Assessment based on 'typical' regional conditions.	Geological surfaces extracted from site geological model.	Use of information such as drill logs and field mapping to define sub geotechnical units within broader geological units.	6
Structural Model	15	No information	Structure assumed typical of the region	Structure broadly understood from observation and experience at the site	Either no dominant structure OR structure well understood from mapping and drilling	15
Strata Complexity	5	No information	Strata or structure are highly variable with distance OR properties are greatly affected by moisture content.	Strata and structure do not vary rapidly with distance, AND properties not greatly affected by moisture content changes.	Strata quite uniform in thickness and properties AND structure clearly defines slip surfaces	3
Strength Properties	10	No information	Derived from published data for the material classifications, without specific regional data.	Derived from tests on key strata sampled from sites within the region.	Derived from site specific tests on key strata	6
Deformation Properties	5	No information, or not considered in stability assessment	Derived from published data for the material classifications, without specific regional data.	Derived from tests on key strata sampled from sites within the region.	Derived from site specific tests on key strata	0
Groundwater Pressure Model	20	No site measurements; conceptual hydrogeological assessment only	Pre-mining groundwater study OR sensitivity analyses included in stability analyses	>2 years measurement for site groundwater network, with interpretation.	>2 years measurement of at least 2 piezometers at the slope in question, with associated groundwater analysis	12

Method of Analysis	10	No quantitative analyses	Able to accurately represent the failure mechanism BUT there is limited industry experience interpreting the results	Able to approximately represent the failure mechanism AND there is wide industry experience in interpreting the results	Able to accurately represent the failure mechanism AND there is wide industry experience in interpreting the results	10
Reported field performance observations	25	<2 years visual observation of the slope in question.	2-5 years visual observation of the slope in question.	>5 years visual observation or > 2 years movement measurement	> 5 years movement measurement	0

TOTAL = 52

Rating	**Ranking**	**Safety and Stability Implications**
80 - 100	Low Uncertainty	Risk management to an ALARP standard is possible with due allowances for model elements ranked as medium or high uncertainty level
50 - 79	Medium Uncertainty	Risk management to an ALARP standard may not be possible without some combination of improvements to the model, significant increases in design acceptance criteria, or uncertainty allowances in observational stability acceptance criteria
< 50	High Uncertainty	Risk management to an ALARP standard is not likely to be possible. Assessment must be qualified accordingly, or significant improvements made to the model, significant increases in design acceptance criteria, or uncertainty allowances in observational acceptance criteria prior to finalising assessment.

APPENDIX B CONSEQUENCE CATEGORY ASSESSMENT

Consequence Category Levels and Thresholds

	N/A or Negligible	Low	Medium	High
Harm to Humans				
	People are not routinely present in the impacted area or only injuries requiring first aid are likely	Loss of life is not expected and only short-term disabling injuries are expected.	Single loss of life or long-term disabling injuries are expected	Multiple loss of life expected
Environmental Harm				
	Minor, temporary impact to the environment	Measurable impact to an area ≤ 1km^2; where remediation of damage is likely to take ≤ 1 year	Impact to an area ≤ 5km^2; where remediation of damage is likely to take ≤ 5 years	Impact to an area > 5km^2; where remediation of damage is likely to take > 5 years
Property Loss & Damage				
	Minor, temporary community impact that recovers with little intervention; Damage to property or compensation or repair costs < $0.5M	Measurable but limited community impact lasting less than six months; Damage to property or compensation or repair costs $0.5M - $10M	Serious impact on community lasting up to 12 months; Damage to property or compensation or repair costs $10M - $50M	Severe impact on community lasting more than 12 months; Damage to property or compensation or repair costs > $50M

Assessment for Blackwater Mine Lowwalls

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Crest Zone							
Woodland PMLU	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of vegetation would take <1year	**Low**	No repair or compensation costs	Negl.
Grazing PMLU	A small number of people likely to access the area due to cattle grazing operations Grassland habitat with some shade trees, suitable for managed grazing Property such as fencing and water troughs may be present	Only short-term disabling injuries expected	**Low**	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of grassland would take <1year	**Low**	Costs to replace damage property expected to be <$0.5M	Negl.
Within NUMA	People will not routinely access NUMA Low value habitat on slope No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl	No repair or compensation costs	Negl.

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Body of Slope							
Woodland PMLU	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of vegetation would take <1year	**Low**	No repair or compensation costs	Negl.
Grazing PMLU	A small number of people likely to access the area due to cattle grazing operations Grassland habitat with some shade trees, suitable for managed grazing Property such as fencing and water troughs may be present	Only short-term disabling injuries expected	**Low**	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of grassland would take <1year	**Low**	Costs to replace damage property expected to be <$0.5M	Negl.
Within NUMA	People will not routinely access NUMA Low value habitat on slope No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl	No repair or compensation costs	Negl.
Toe Zone							
Within NUMA	People will not routinely access NUMA Low value habitat in pit lake No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl.	No repair or compensation costs	Negl.

Negligible consequence for geotechnical instability in NUMA

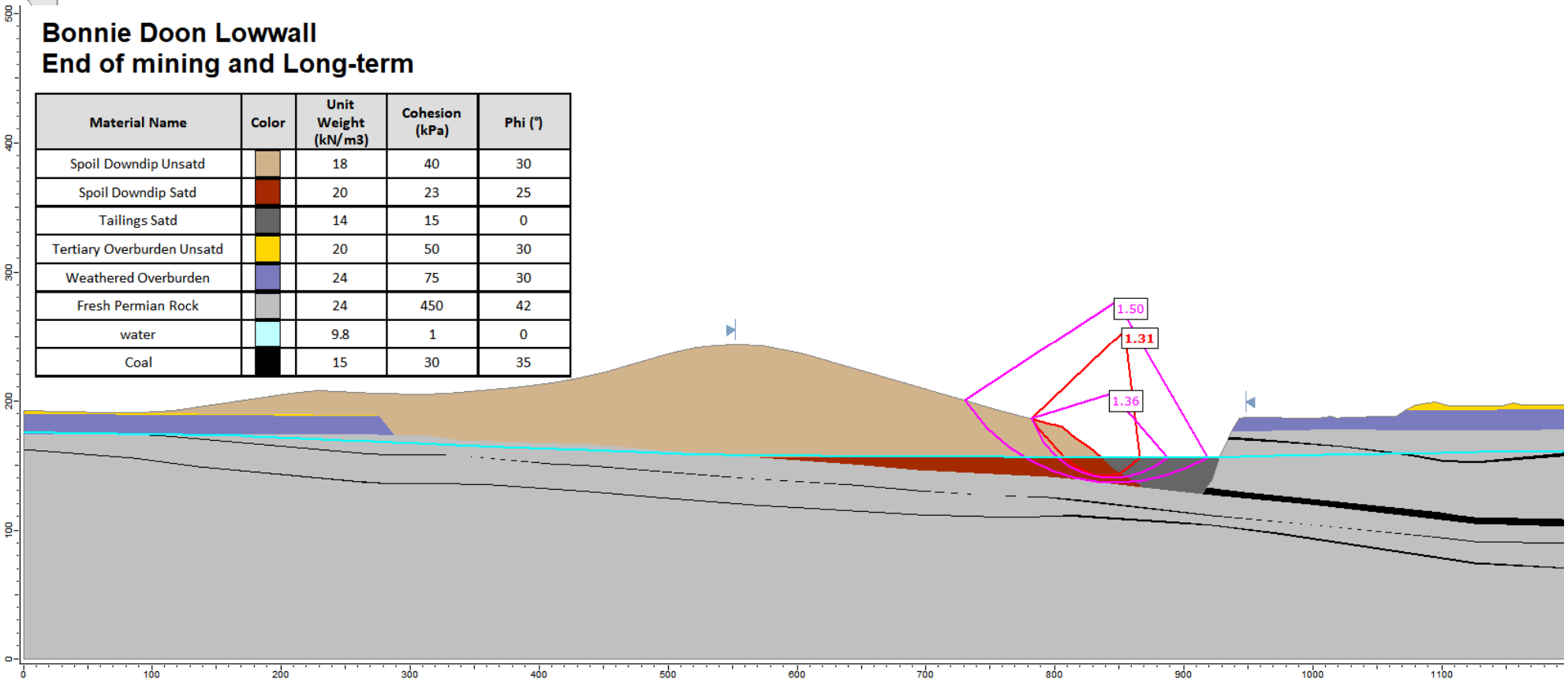
Low consequence for geotechnical instability that extends into Woodland PMLU

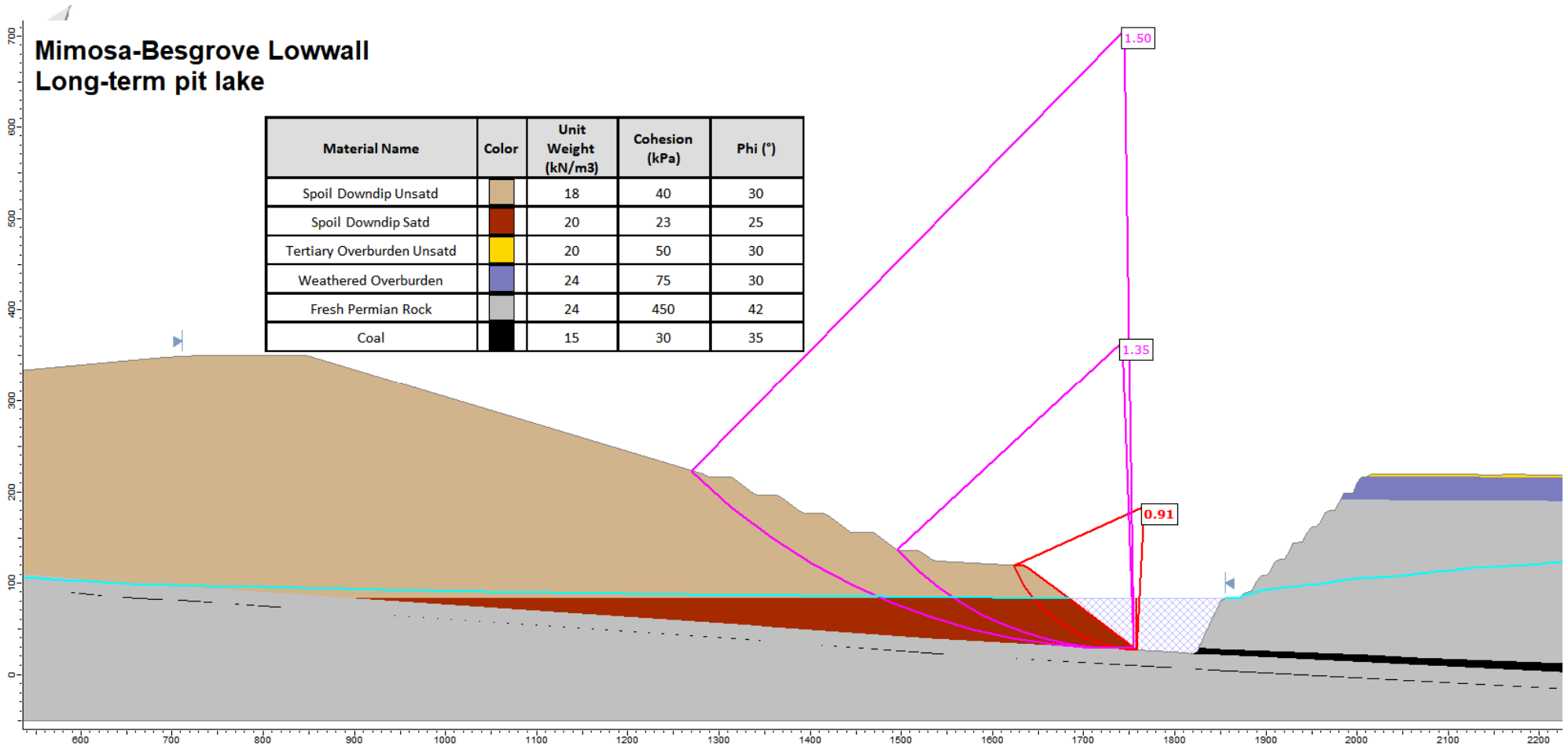
Low consequence for geotechnical instability that extends into Grazing PMLU

APPENDIX C STABILITY ANALYSES

Bonnie Doon Lowwall
End of mining and Long-term

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tailings Satd		14	15	0
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
water		9.8	1	0
Coal		15	30	35

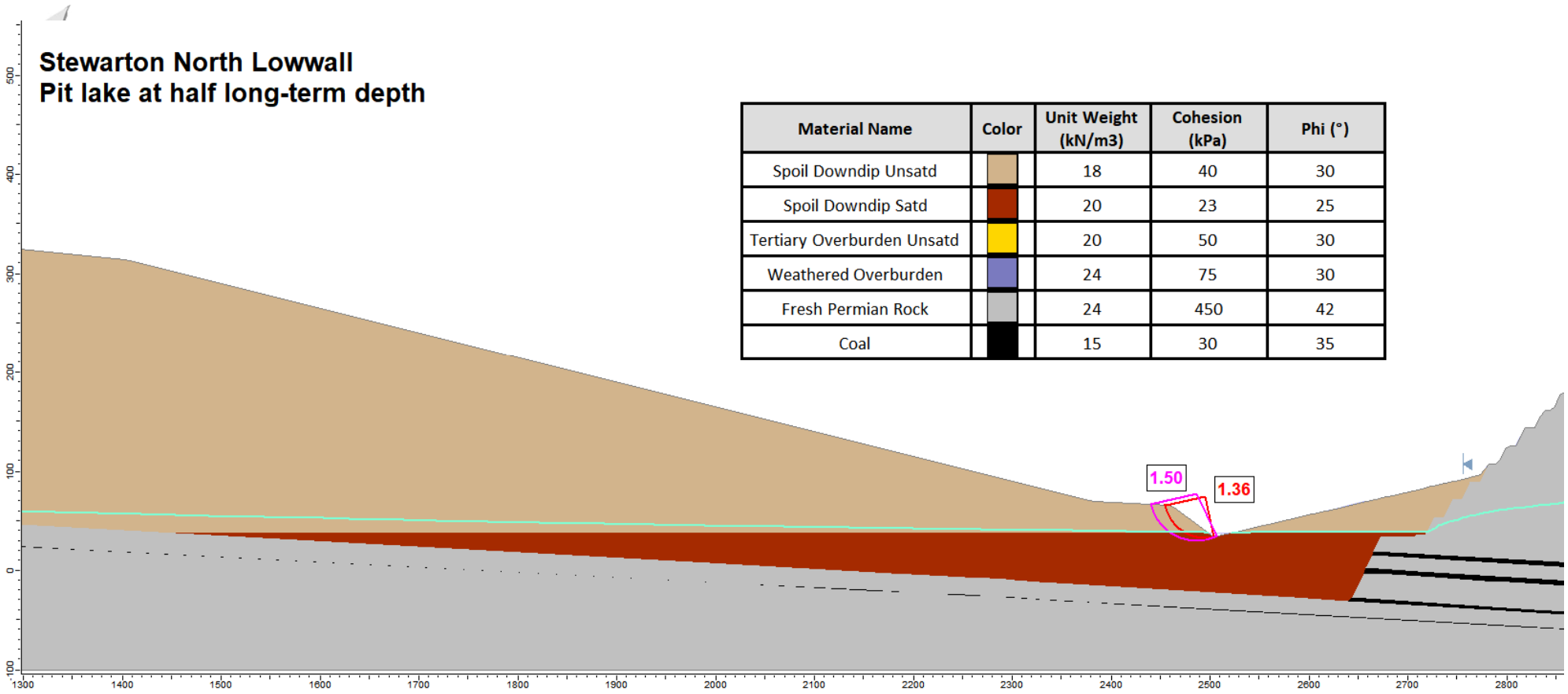




Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

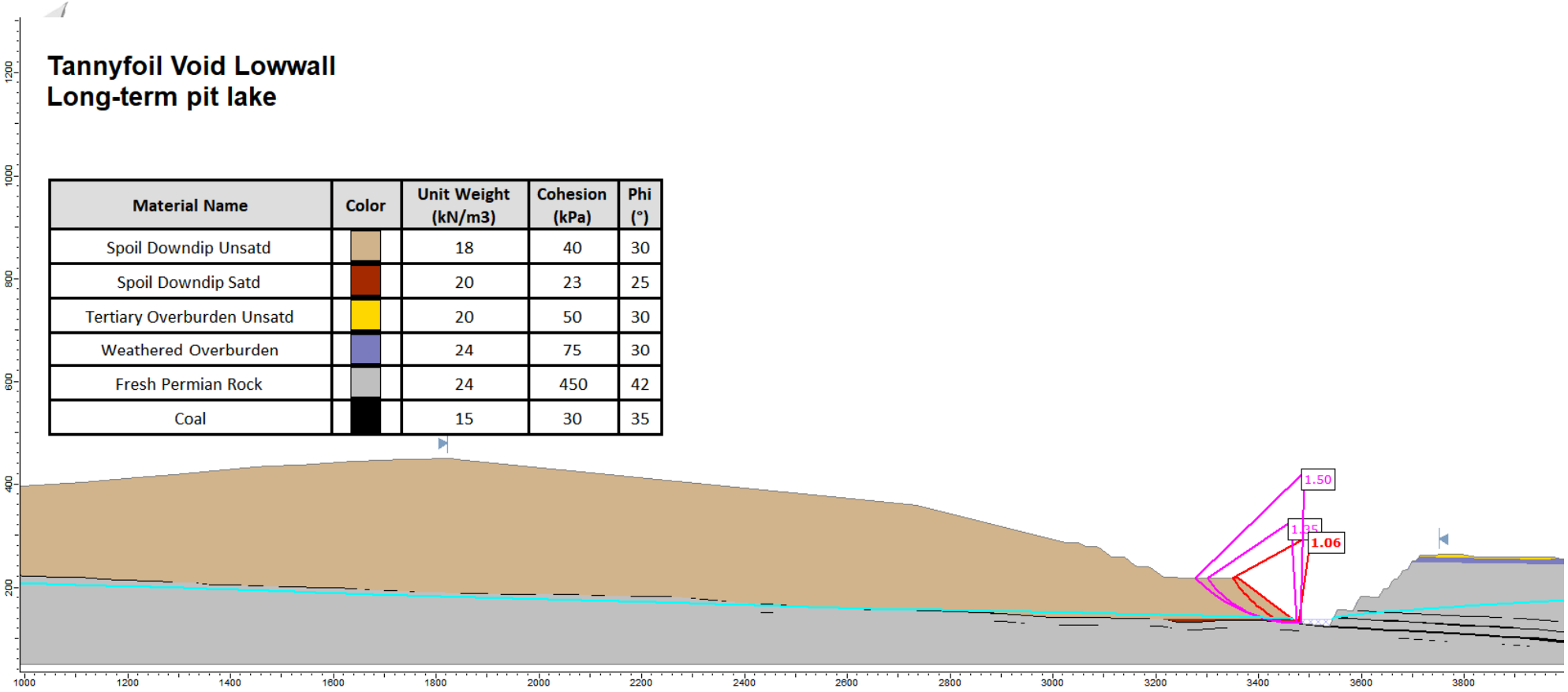
Stewarton North Lowwall
Pit lake at half long-term depth

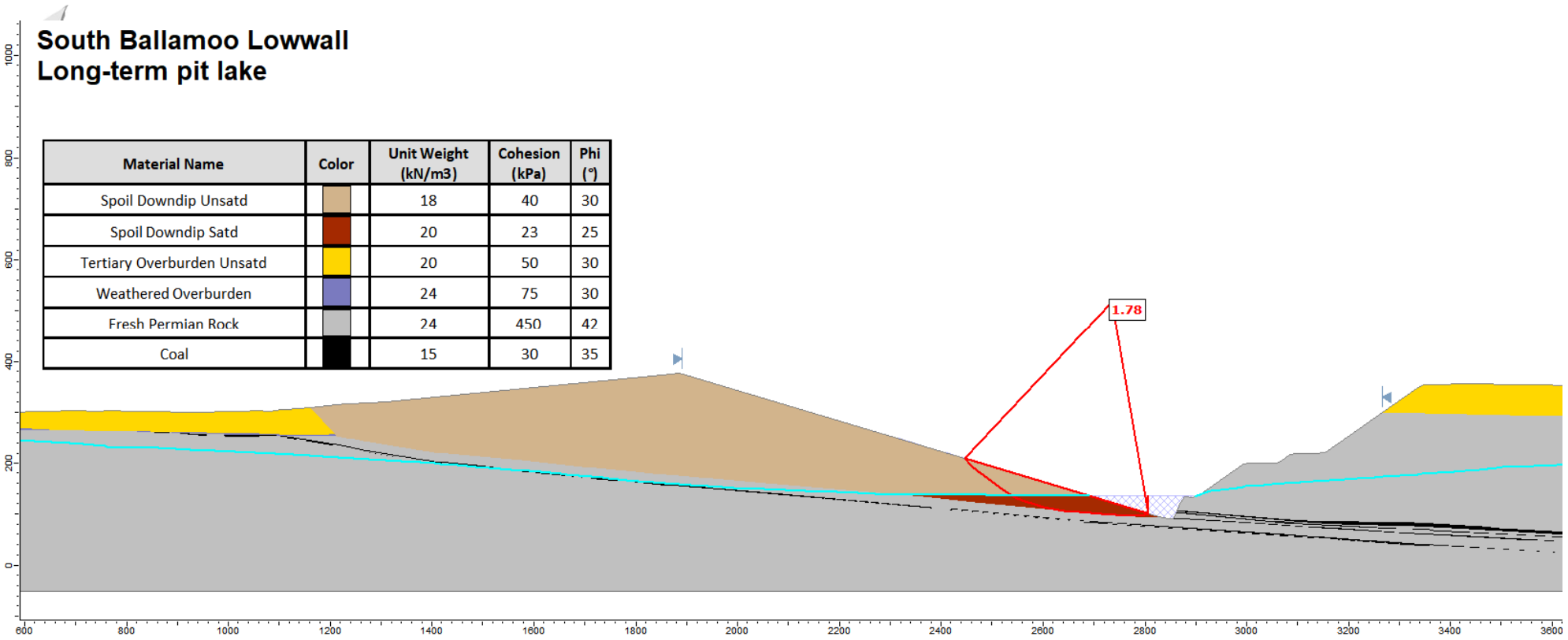
Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35



Tannyfoil Void Lowwall
Long-term pit lake

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

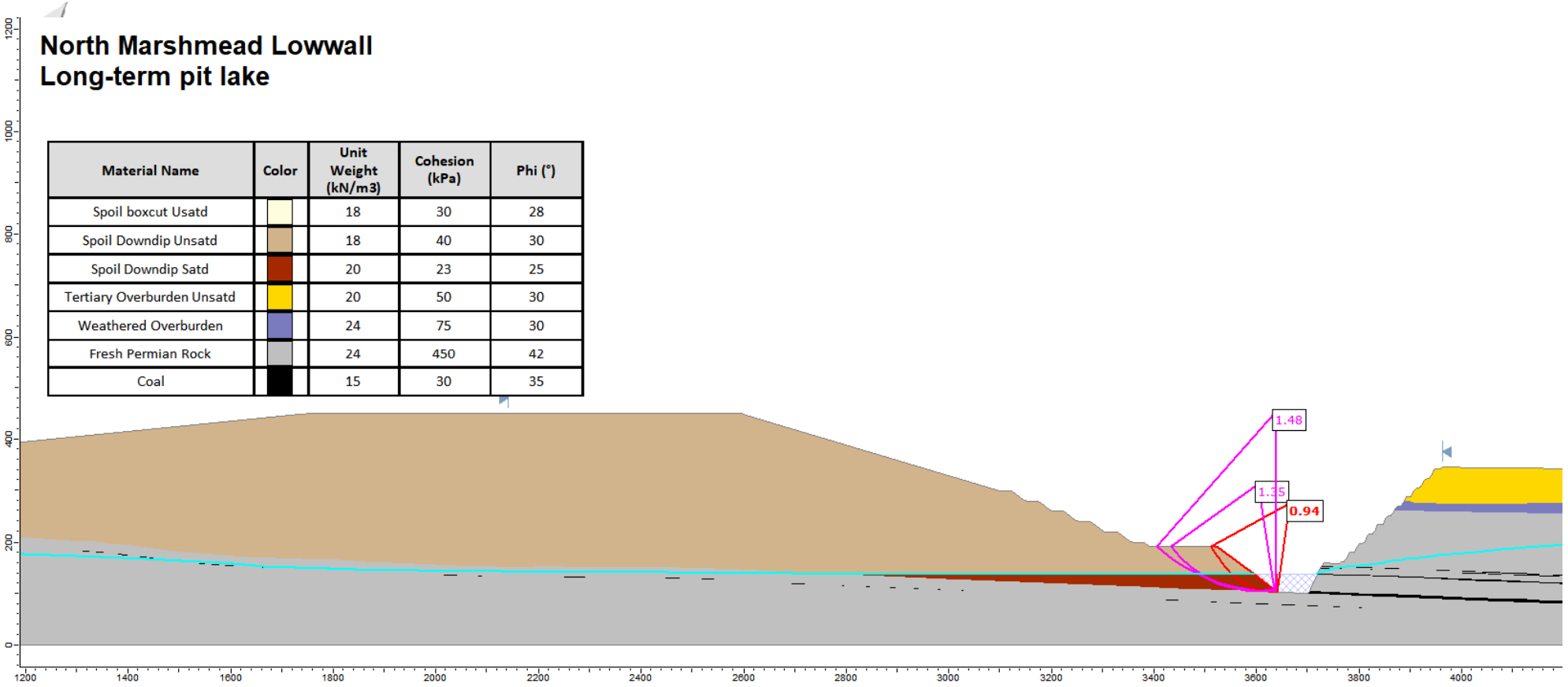


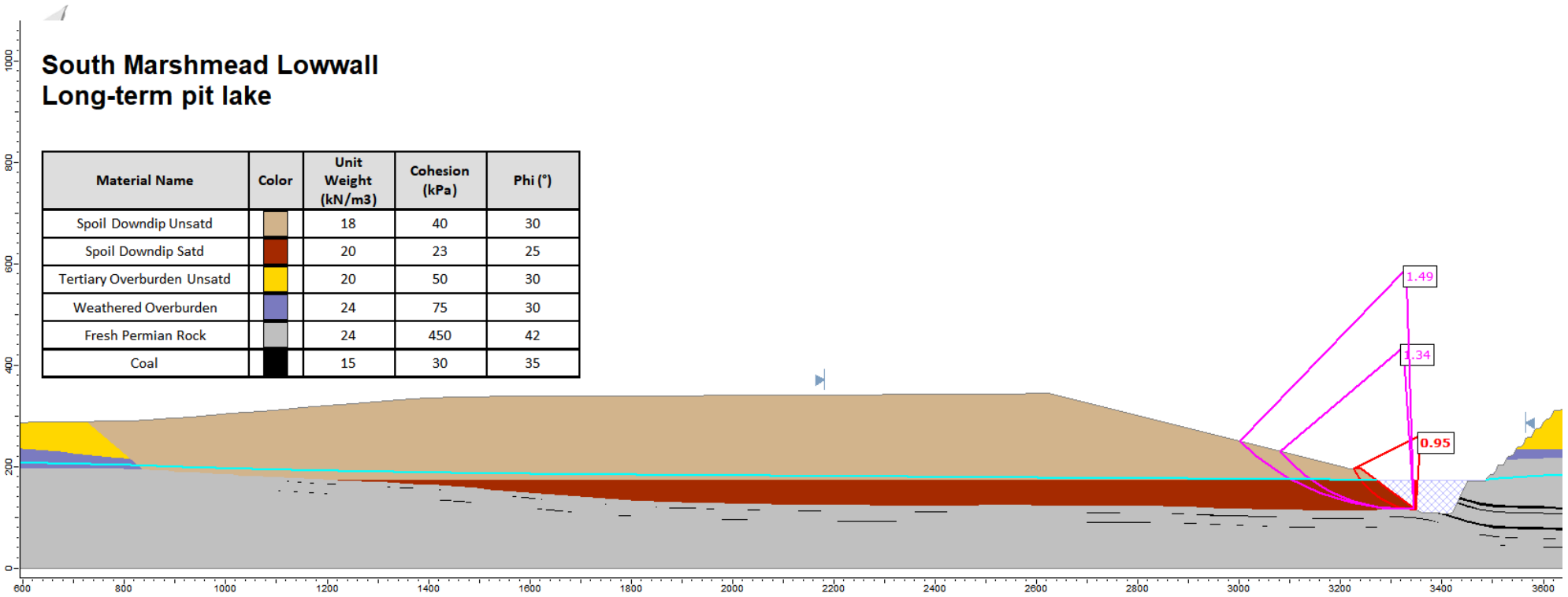


Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

North Marshmead Lowwall
Long-term pit lake

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil boxcut Usatd		18	30	28
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

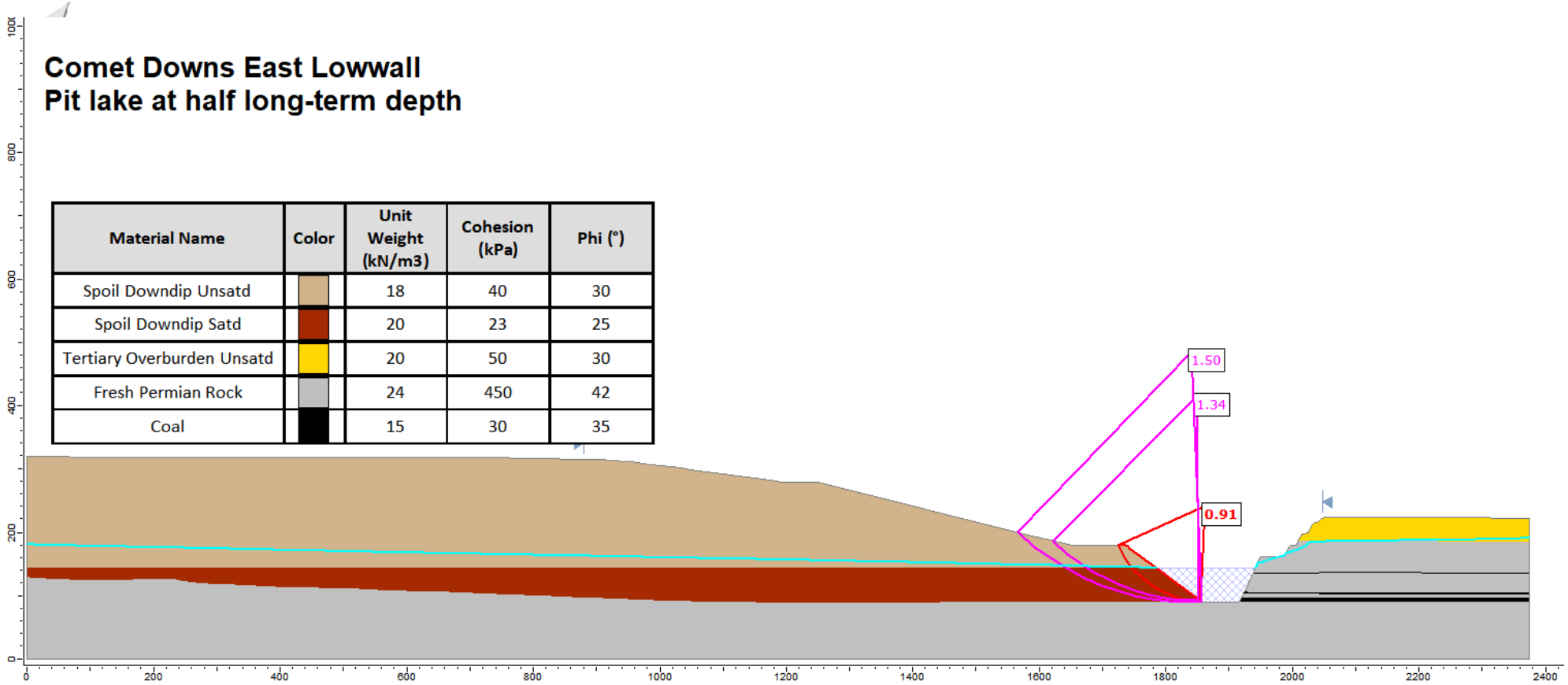




Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Weathered Overburden		24	75	30
Fresh Permian Rock		24	450	42
Coal		15	30	35

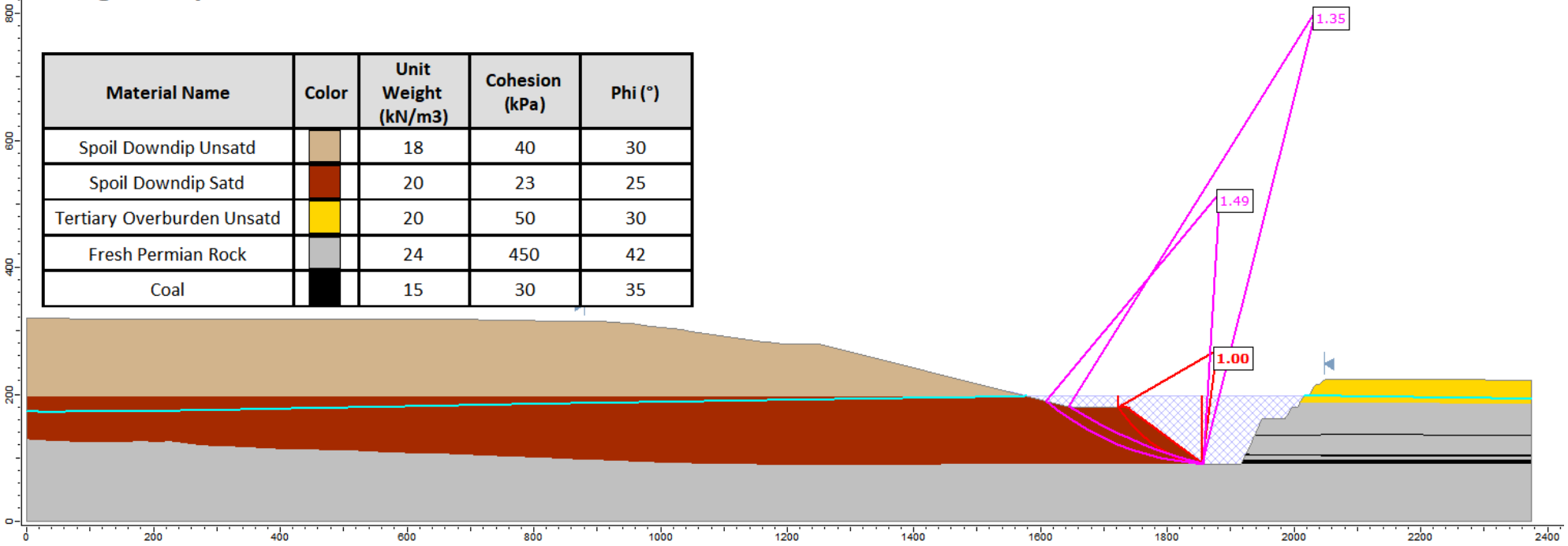
Comet Downs East Lowwall
Pit lake at half long-term depth

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Fresh Permian Rock		24	450	42
Coal		15	30	35



Comet Downs East Lowwall
Long-term pit lake

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)
Spoil Downdip Unsatd		18	40	30
Spoil Downdip Satd		20	23	25
Tertiary Overburden Unsatd		20	50	30
Fresh Permian Rock		24	450	42
Coal		15	30	35



APPENDIX D SAFETY RISK ASSESSMENT

Safety (Risk) Assessment Matrix (from Simmons et al, 2024)

		Consequence		
		High	Medium	Low
Likelihood	High	High Risk	Medium Risk	Medium Risk
	Medium	Medium Risk	Medium Risk	Low Risk
	Low	Medium Risk	Low Risk	Low Risk

Hazard	Potential consequence	Factors affecting likelihood	Risk rating of design	Additional mitigation measures
Arc- or wedge- slip instability of lowwall	Person falls on rough ground that is not steeply sloping (medium-term injury)	Unauthorised person might access lowwall side of void	L-L = Low	Fence NUMA on all sides to prevent unauthorised access. Locate lowwall fences outside the extent of the long term pit-lake Note function of exclusion fencing in Land Management Plan
	Damage to fencing		L-L = Low	
	Damage to vegetation		L-L = Low	Rely on natural recovery processes

Note: Lowwall slopes outside the long-term pit lake level are not steep enough to generate a rockfall hazard.

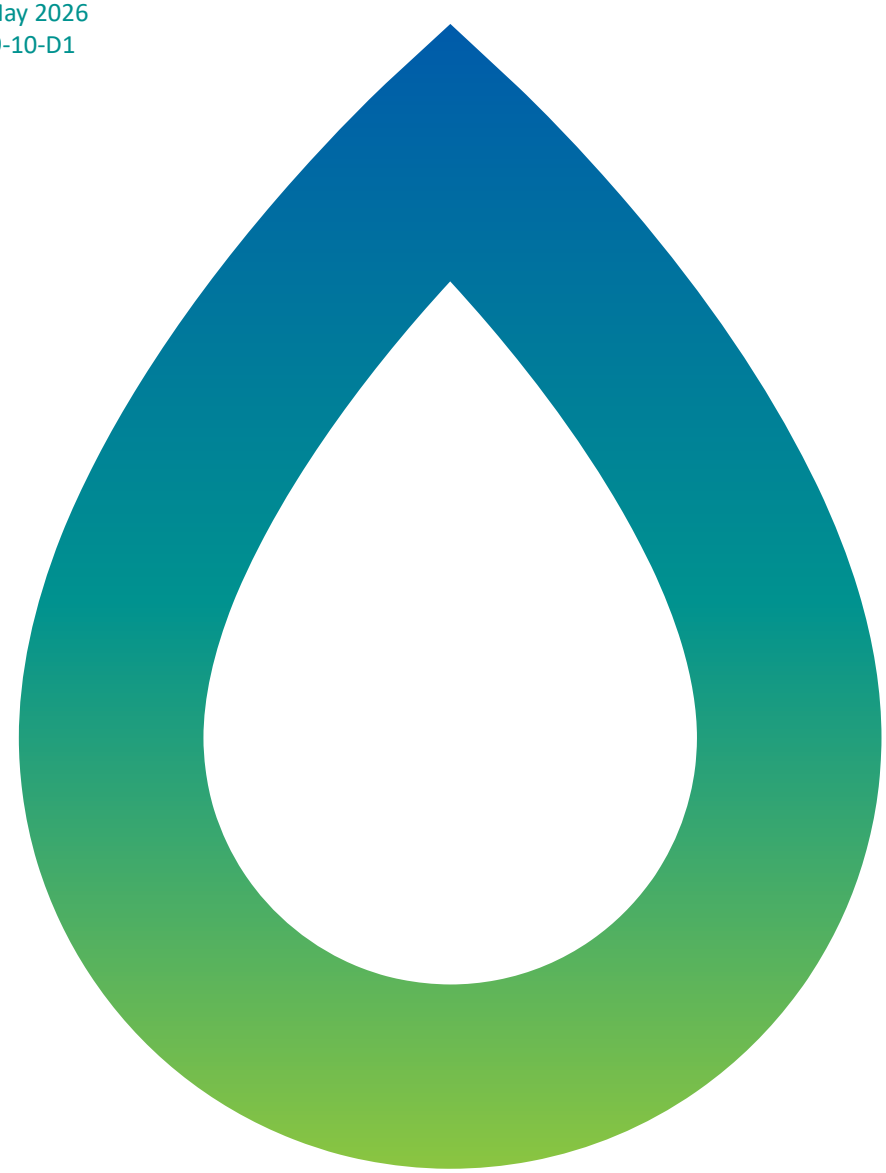
PROGRESSIVE REHABILITATION AND CLOSURE PLANNING – BLACKWATER MINE

Final Void Water Balance

Whitehaven Coal Limited

20 May 2026

1559-10-D1



DETAILS

Report Title	Progressive Rehabilitation and Closure Planning – Blackwater Mine, Final Void Water Balance
Client	Whitehaven Coal Limited

THIS REVISION

Report Number	1559-10-D1
Date	20 May 2026
Author	JG
Reviewer	GR

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1 INTRODUCTION

Whitehaven Coal Limited, owner of Blackwater Mine (BWM), commissioned WRM Water & Environment Pty Ltd to undertake a water balance assessment to support the mine's Progressive Rehabilitation and Closure Plan (PRCP). The PRCP is required under Environmental Authority EPML00717813 and relevant Queensland and Commonwealth legislation, including the *Environmental Protection Act 1994* and the *Environment Protection and Biodiversity Conservation Act 1999*.

The closure plan incorporates a series of residual final voids, classified as Non-use Management Areas (NUMAs), which require detailed assessment to demonstrate long-term hydrological stability, environmental protection, and public safety following mine closure.

Water levels within the final voids are expected to vary over time in response to prevailing climatic conditions and the balance between evaporation losses and inflows from rainfall, surface runoff, and groundwater.

HydroBalance (2026) conducted a final void water balance assessment using the GoldSim software platform. This report summarises the final void assessment approach and modelling results.

2 PROPOSED FINAL VOIDS

2.1 FINAL VOID CONFIGURATION

The proposed final landform layout is presented in Figure 2.1 to Figure 2.3 and comprises fifteen (15) residual final voids:

- Ramp 8 (R8);
- Bonnie Doon (BD);
- Mimosa/Besgrove (MB);
- Ramp 30 (R30);
- Deep Creek (DC);
- Stewarton North(ST-N);
- Stewarton South(ST-S);
- Tannyfoil (TF);
- South Ballamoo (SB);
- Kenmare (KM);
- Ramp 74 (R74);
- Togara/North Marshmead (TNM);
- South Marshmead (SM);
- Kennedy (KE); and
- Comet Downs East (CDE).

2.2 FINAL VOID GEOMETRY

The proposed BWM final landform incorporates 15 residual voids that span across the reaches of the Blackwater Creek, Taurus Creek, Deep Creek, Two Mile Creek and Burngrove Creek catchments.

This final landform would form during mining, including the in-pit backfilled spoil surface sitting atop a mined pit shell. A digital elevation model (DEM) of the proposed final landform design surface "20251104 BWM PRCP Rev3 LF4.2 1x1m grid" (Rev3 final landform) was provided by BWM in November 2025.

A summary of the final void geometries is provided in Table 2.1, including the year that the works commence.

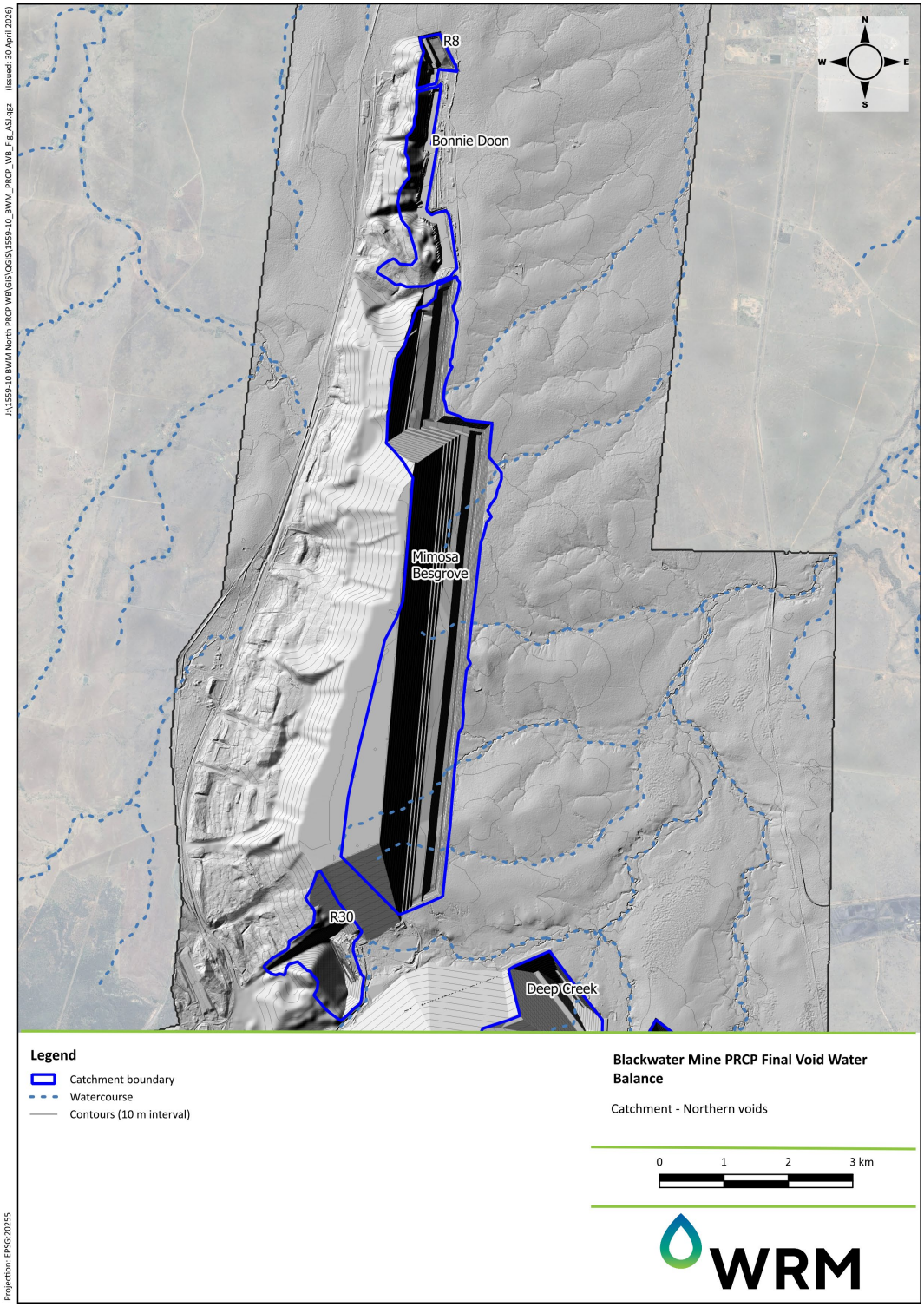

J:\1559-10 BWM North PRCP WB\GIS\QGIS\1559-10_BWM_PRCP_WB_Fig_ASI.qgz (Issued: 30 April 2026)
R8
Bonnie Doon
Mimosa
Besgrove
R30
Deep Creek
N
W
E
S
Legend
Catchment boundary
Watercourse
Contours (10 m interval)
Blackwater Mine PRCP Final Void Water Balance
Catchment - Northern voids
0
1
2
3 km
WRM
Projection: EPSG:20255

Figure 2.1 Final void catchment/land uses – Northern voids

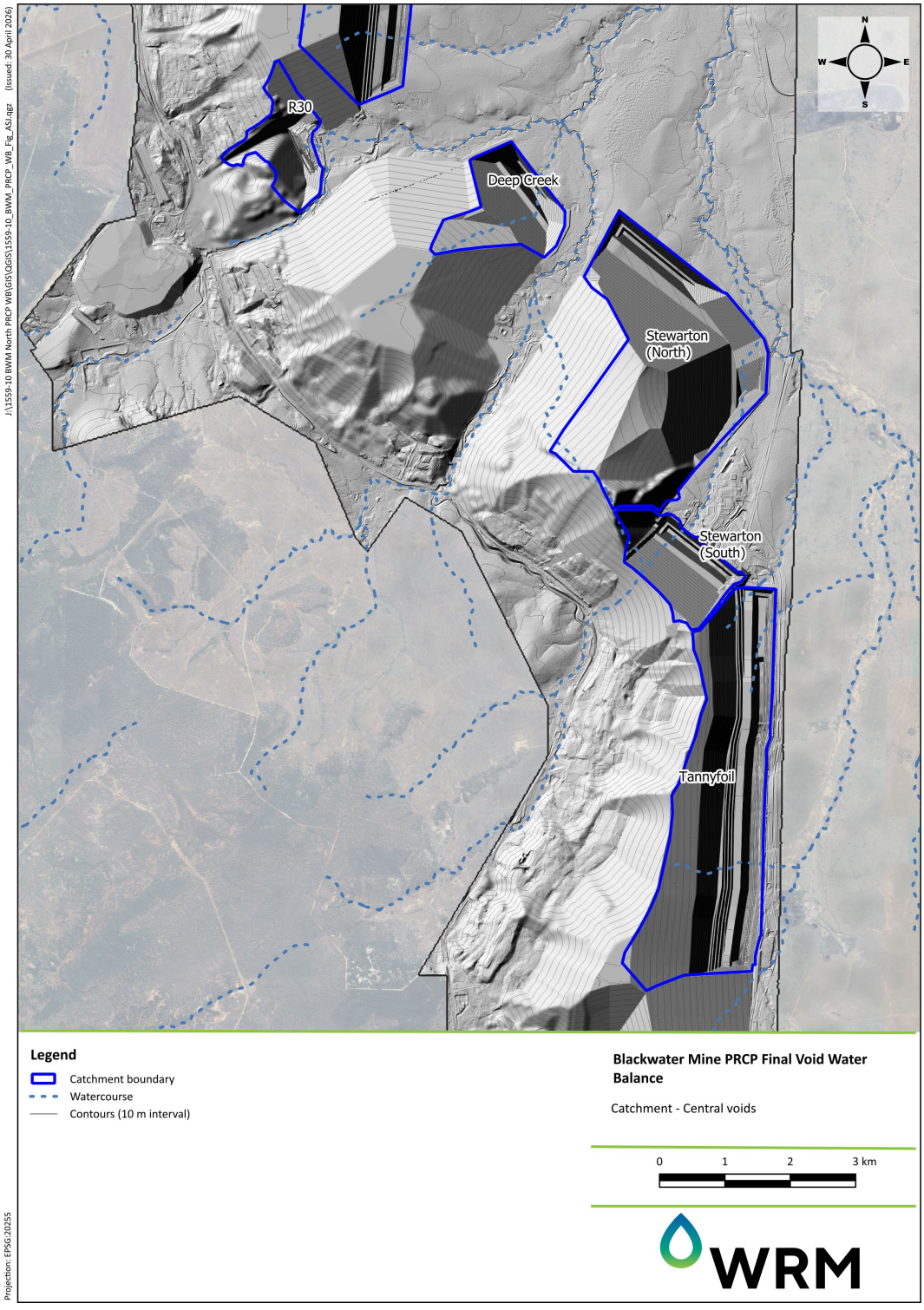


Figure 2.2 Final void catchment/land uses – Central voids

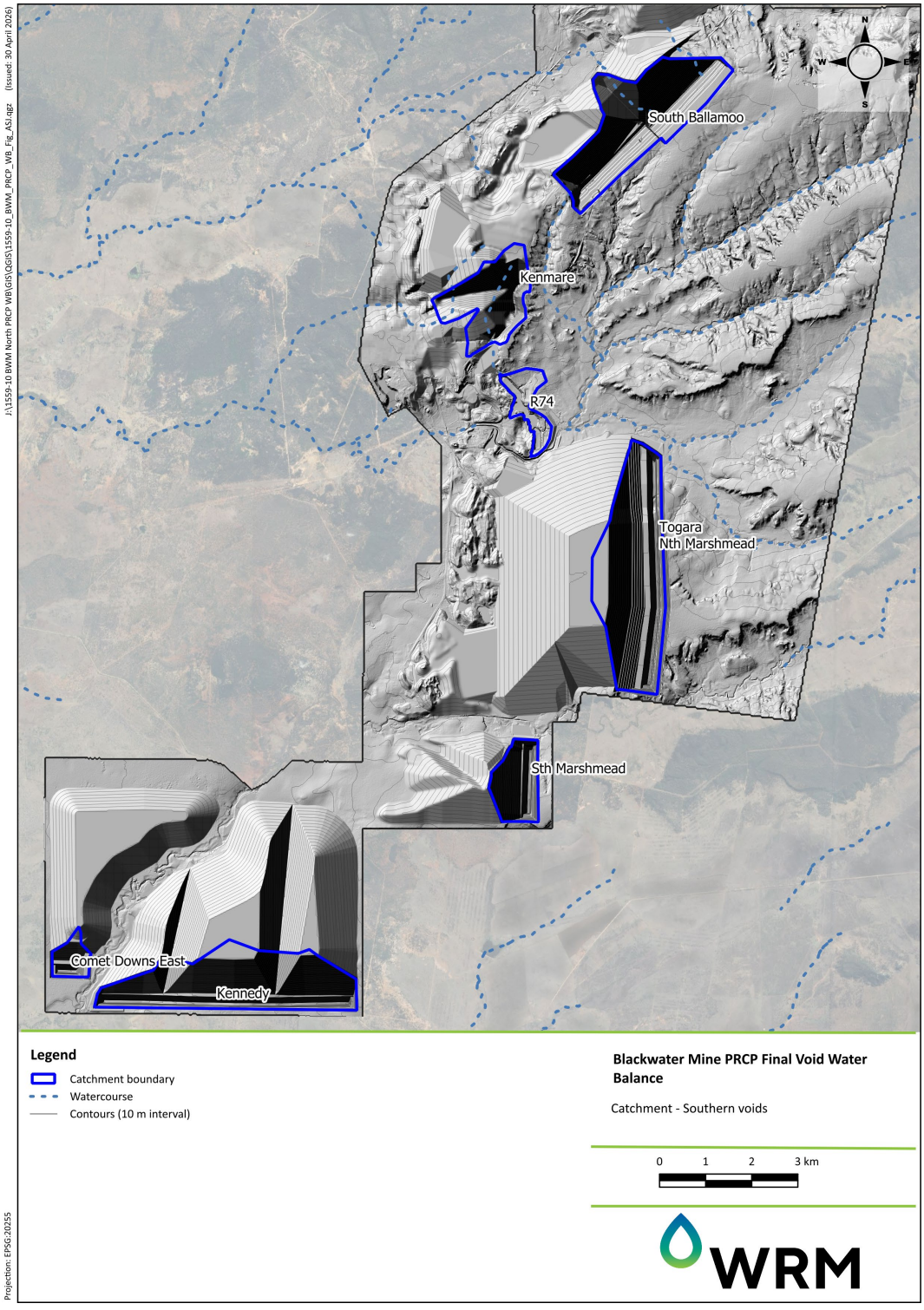


Figure 2.3 Final void catchment/land uses – Southern voids

Table 2.1 Final void geometries

Void	Floor level (mAHD)	Crest level (mAHD)	Depth (m)	Volume to crest (ML)	Surface area at crest (ha)
R8	109	175*	66	6,528	21
BD	150	175*	26	3,633	30.3
MB	24	200	176	374,878	597.2
R30	139	217	78	16,316	59.7
DC	52	202	150	54,895	109.4
ST-N	-4	204	208	302,582	380.1
ST-S	92	232	140	42,632	82.5
TF	115	237	122	160,141	303.2
SB	84	290	206	376,755	447.9
KM	161	297	136	51,258	116.4
R74	234	266	32	9,954	60.5
TNM	69	271	202	292,542	363.8
SM	108	270	162	74,727	112.8
KE	99	221	122	93,791	192.8
CDE	90	222	132	20,377	41.7

Note: * This value represents the internal crest level between R8 and BD

Note: # R8 and BD overflow to the receiving environment at 188mAHD

3 MODEL CONFIGURATION

3.1 MODELLING APPROACH

HydroBalance (2025 and 2026) assessed the long-term hydrological behaviour of these voids over a 1,000-year post-closure period using the GoldSim software platform.

The GoldSim model was used to simulate the water volume within the final void on a daily time-step. The volume of water in the voids was calculated at each time step as the sum of direct rainfall to the void surface, catchment runoff, and groundwater flux, less evaporation losses.

Key components of the model are summarised in the following sub-sections, including descriptions of key model inputs and assumptions.

3.2 CLIMATE DATA

The Australian Government Consistent Climate Scenarios (CCS) project was used to generate climate change adjusted rainfall and evaporation data, which transformed historical climate data from the period 1960 to 2024 (64 years). The CCS project provides climate projections as a daily time series across Australia on a 0.05-degree grid. The grid point closest to the centre of BWM was used for this assessment.

The Shared Socioeconomic Pathway SSP2-4.5 was selected as the emission pathway for the Intergovernmental Panel on Climate Change (IPCC) assessment report AR5, with a base case global warming sensitivity for the Year 2070. The Year 2070 was selected as it represents a general mid-point for the varying void commencement dates.

SSP2-4.5 assumes that global development and environmental policies will continue along their current trajectories, and represents a moderate path where social, economic and technological trends do not shift markedly from historical patterns. It leads to moderate greenhouse gas emissions and radiative forcing of 4.5 W/m^2 by 2100.

The climate data was selected according to the following climate sensitivity and climate change model composites:

- Climate warming sensitivity assumed to fall in the medium category; and
- The representative future climate cluster was selected as HP, which represents a high level of global warming.

The 64 years of historical climate data adjusted rainfall and evaporation data was looped to create a long-term (1,000-year) climate sequence.

Figure 3.1 shows the long -term monthly averages for the rainfall data and pan evaporation.

Pan evaporation has been converted to Morton's Lake (mLake) and Morton's Wet (mWet) evapotranspiration to account for evapotranspiration losses from the pit lake and catchment as follows:

- Pan evaporation to mLake factor: 0.883 – applied to the evaporation acting on the surface of the pit lake.
- Pan evaporation to mWet factor: 0.845 – applied to the evaporation.

3.3 CATCHMENT RUNOFF

3.3.1 Catchment areas

The final landform catchment area was delineated from the final landform surface provided by BWM. The land use of the void floor has been characterised as spoil. Figure 2.1 to Figure 2.3 show the catchment boundary adopted for the final void water balance. The catchment and land use values (HydroBalance, 2025 and 2026) are provided in Table 3.1.

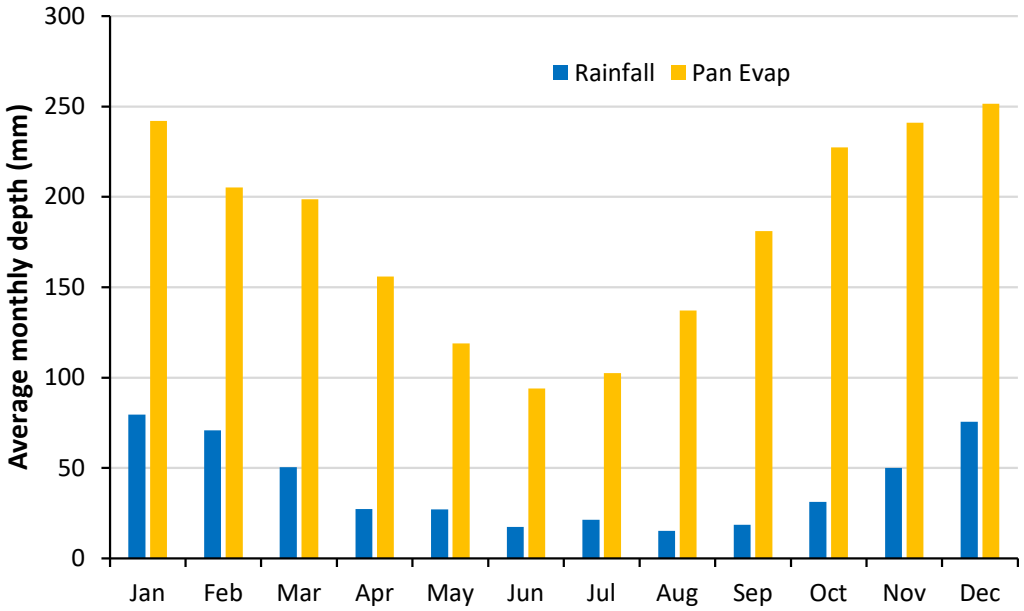


Figure 3.1 Distribution of monthly CCS rainfall and pan evaporation (1960 - 2024) [HydroBalance, 2026]

Table 3.1 Final void catchment and land use areas

Void	Contributing Catchment (ha)			
	Undisturbed	Spoil	Rehabilitated spoil	Total
R8	33.7	22	21.8	77.5
BD	98.1	84.1	184.4	366.6
MB	39.1	596.5	622.4	1258
R30	0	24.1	149.2	173.3
DC	0	52.9	167.3	220.2
ST-N	0	195.2	678.1	873.3
ST-S	0	50.9	150.3	201.2
TF	0	388.1	458.6	846.7
SB	0	365	267.4	632.4
KM	0	146.1	236	382.1
R74	10.1	58.3	112.9	181.3
TNM	7.4	458	249.1	714.5
SM	0	119.4	80.3	199.7
KE	0	188.6	481.1	669.7
CDE	8.9	27.7	69.4	106

3.3.2 AWBM parameters

Table 3.2 shows the adopted rainfall runoff parameters for each catchment land use. Catchment runoff was modelled using the Australian Water Balance Model (AWBM). The long-term volumetric runoff coefficient (Cv) for each land use calculated using the parameters is also shown.

Table 3.2 Adopted AWBM rainfall runoff parameters

Parameter	Natural	Spoil	Rehab (& partial rehab)	Tailings	Hardstand/ pit	Disturbed
C1 (mm])	30	100	20	5	10	10
C2 (mm)	180	200	120	15	40	60
C3 (mm)	250	300	180	25	50	100
A1	0.134	0.134	0.134	0.134	0.3	0.3
A2	0.433	0.433	0.433	0.433	0.4	0.4
A3	0.433	0.433	0.433	0.433	0.3	0.3
C_{av}	190.2	229.9	132.6	18.0	34.0	57.0
BFI	-	0.8	0.35	-	-	-
K_{base}	-	0.98	0.98	-	-	-
K_{surf}	-	0.1	0.1	-	-	-
Cv (%)	4.2	1.6	6.5	32.2	23.3	18.2

Notes: C1/C2/C3 – Surface storage capacities
A1/A2/A3 – Partial area fraction
C_{av} – Catchment averaged surface storage capacity
BFI – Baseflow index
K_{base} – Baseflow recession constant
K_{surf} – Surface flow recession constant
C_v – Long-term coefficient of runoff

Cv for spoil is low, reflecting high infiltration of rehabilitated spoil. Infiltration from spoil was accounted for in the groundwater inflows as described in Section 3.3.3.

3.3.3 Groundwater inflows

Groundwater inflows into the 15 voids were provided by SLR (2026) as a time series over the 1,000-year simulation. Seepage interaction between spoil and voids was included in the groundwater flow rates to simulate the groundwater table based on the estimated void water levels. The hydrological behaviour of the voids was simulated iteratively to achieve convergence with the predicted groundwater flow rates and void water levels.

SLR (2026) confirms that the residual voids form evaporative sinks and that void water levels stabilise (reach equilibrium) below the regional groundwater table.

4 FINAL VOID RESULTS

4.1 OVERVIEW

The final voids were modelled using the assumptions outlined in Section 3 and the results are outlined in Section 4.2. In addition, analysis of the final void behaviour for extreme rainfall events was undertaken as outlined in Section 4.3.

4.2 FINAL VOID MODEL RESULTS

The final void modelled water levels for the 15 voids are presented in Figure 4.1 to Figure 4.15. The following is of note regarding this result:

- Ramp 8 (R8) void stabilises at an average water level of approximately 146.5 mAHD at around 200 years post-mining. This is 28.5 m below the level at which R8 would overflow to Bonnie Doon (175 mAHD) and 41.5 m below the pit crest level (188 mAHD). The internal overflow level between Ramp 8 and Bonnie Doon (175 mAHD) is not reached under average conditions, and no inter-void spill is expected.
- Bonnie Doon (BD) void stabilises within an average water level of approximately 154.5 mAHD at around 150 years post-mining. This is 20.5 m below the overflow level to R8 (175 mAHD) and 33.5 m below the pit crest level (188 mAHD), indicating no overtopping occurs.
- Mimosa/Besgrove (MB) void stabilises within around 200 years post-closure at an average water level of approximately 83.7 mAHD, which is 116.3 m below the pit crest level (200 mAHD).
- Ramp 30 (R30) void stabilises within around 150 years post-closure at an average water level of approximately 143.3 mAHD, which is 73.7 m below the pit crest level (217 mAHD).
- Deep Creek (DC) void stabilises within around 300 years post-closure at an average water level of approximately 134.5 mAHD, which is 67.5 m below the pit crest level (202 mAHD).
- Stewarton North (ST-N) void stabilises within around 200 years post-closure at an average water level of approximately 74.0 mAHD, which is 130.0 m below the pit crest level (204 mAHD).
- Stewarton South (ST-S) void stabilises within around 100 years post-closure at an average water level of approximately 103.9 mAHD, which is 128.1 m below the pit crest level (232 mAHD).
- Tannyfoil Creek (TF) void stabilises within around 250 years post-mining at an average water level of approximately 144.7 mAHD, which is 92.3 m below the pit crest level (237 mAHD).
- South Ballamoo (SB) void stabilises within around 300 years post-mining at an average water level of approximately 141.5 mAHD, which is 148.5 m below the pit crest level (290 mAHD).
- Kenmare (KM) void stabilises within around 150 years post-mining at an average water level of approximately 218.0 mAHD, which is 79.0 m below the pit crest level (297 mAHD).
- Ramp 74 (R74) void stabilises within around 100 years post-mining at an average water level of approximately 234.1 mAHD, which is 31.9 m below the pit crest level (266 mAHD), indicating no overtopping occurs.
- Togara North/Marshmead (TNM) void stabilises within around 300 years post-mining at an average water level of approximately 165.7 mAHD, which is 105.3 m below the pit crest level (271 mAHD).
- South Marshmead (SM) void stabilises within around 300 years post-mining at an average water level of approximately 171.1 mAHD, which is 98.9 m below the pit crest level (270 mAHD).
- Kennedy (KE) void stabilises within around 400 years post-mining at an average water level of approximately 166.4 mAHD, which is 54.6 m below the pit crest level (221 mAHD).
- Comet Downs East (CDE) void stabilises within around 450 years post-mining at an average water level of approximately 191.2 mAHD, which is 30.8 m below the pit crest level (222 mAHD), indicating no overtopping occurs.

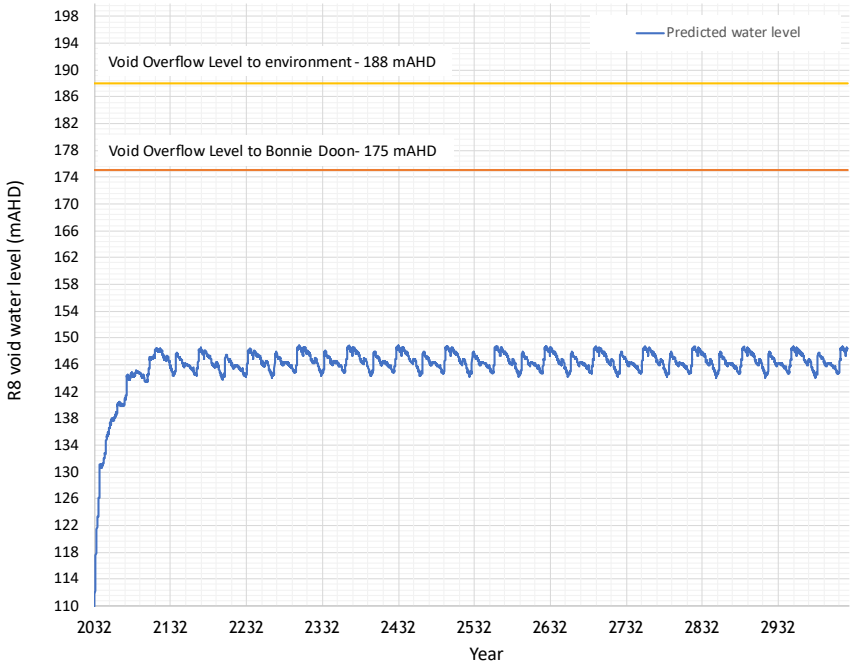


Figure 4.1 Ramp 8 void - long-term predicted void water level (HydroBalance, 2026)

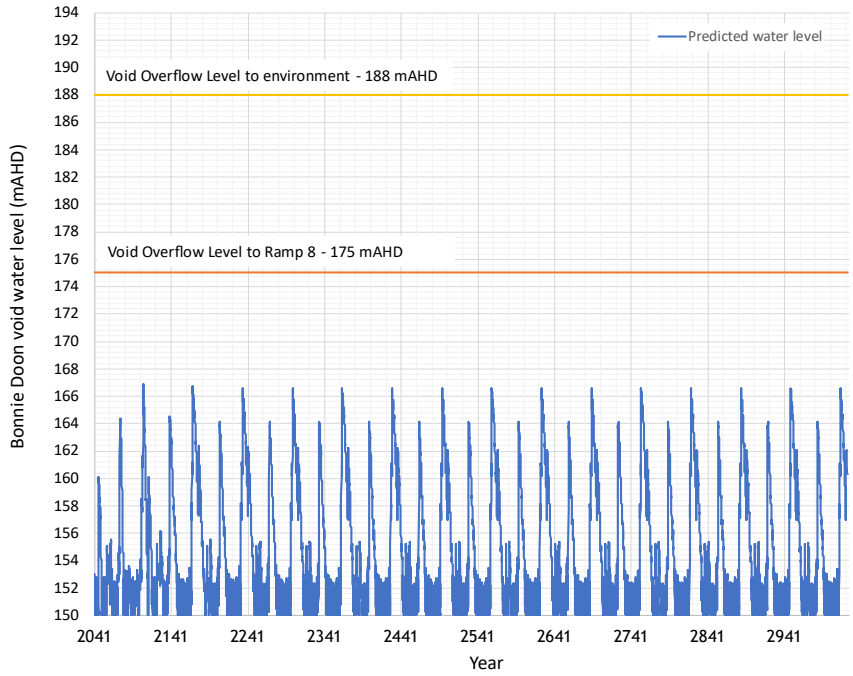


Figure 4.2 Bonnie Doon void - long-term predicted void water level (HydroBalance, 2026)

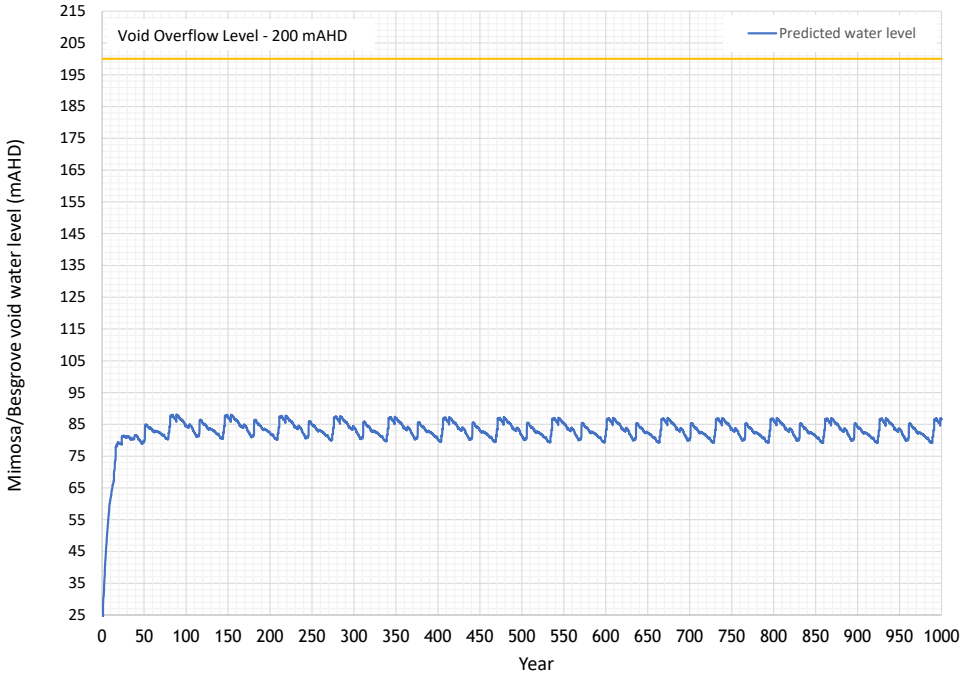


Figure 4.3 Mimosa/Besgrove void – long term predicted final void water level (HydroBalance, 2026)

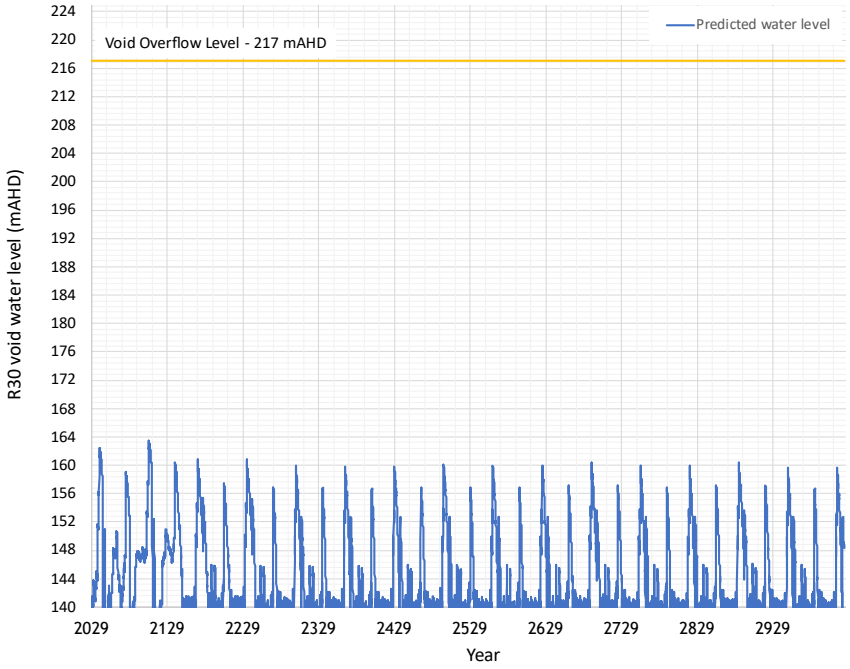


Figure 4.4 Ramp 30 void – long term predicted final void water level (HydroBalance, 2026)

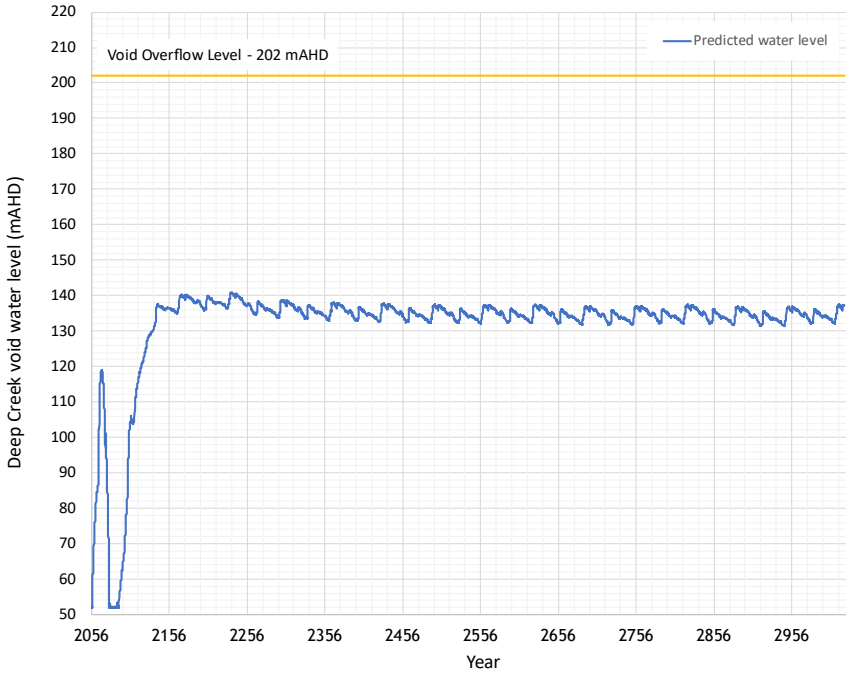


Figure 4.5 Deep Creek void – long term predicted final void water level (HydroBalance, 2026).

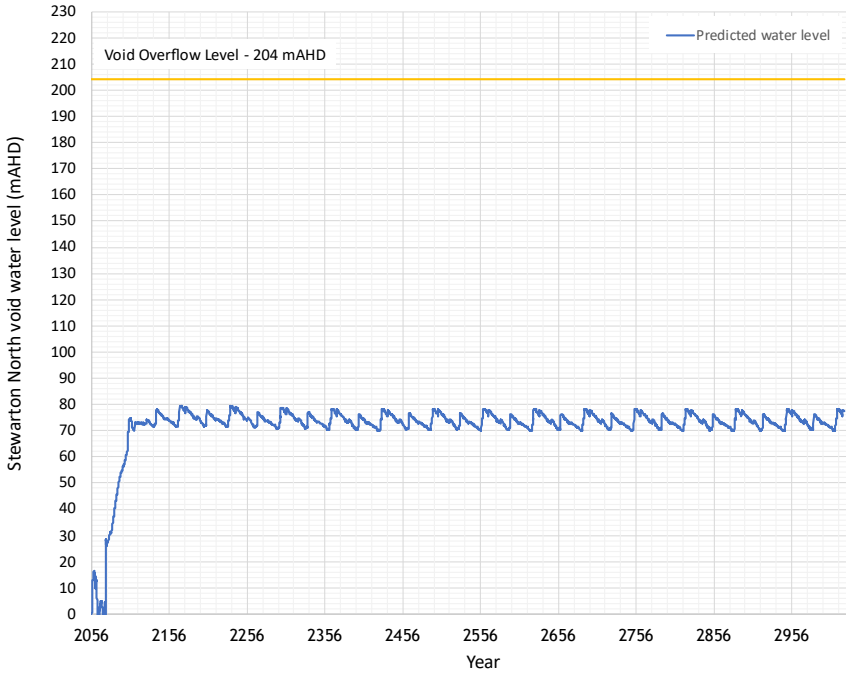


Figure 4.6 Stewarton North void – long term predicted final void water level (HydroBalance, 2026)

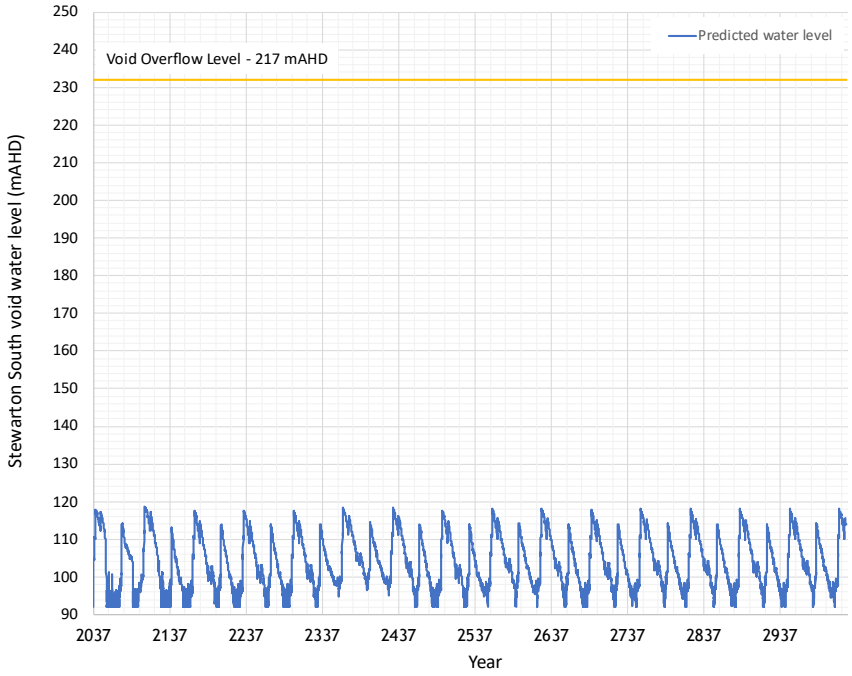


Figure 4.7 Stewarton South void – long term predicted final void water level (HydroBalance, 2026)

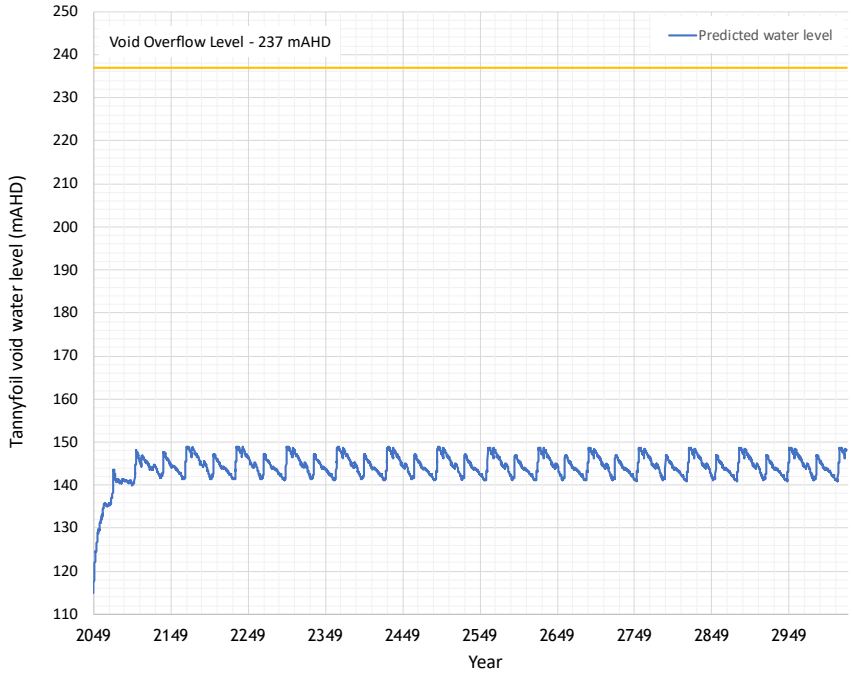


Figure 4.8 Tannyfoil Creek void - long-term predicted void water level (HydroBalance, 2026)

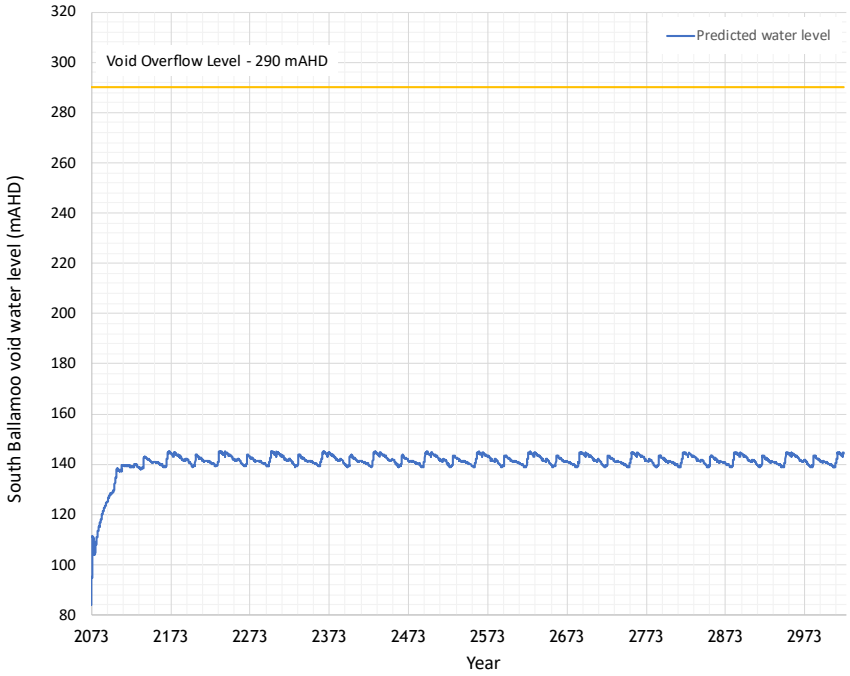


Figure 4.9 South Ballamoo void - long-term predicted void water level (HydroBalance, 2026)

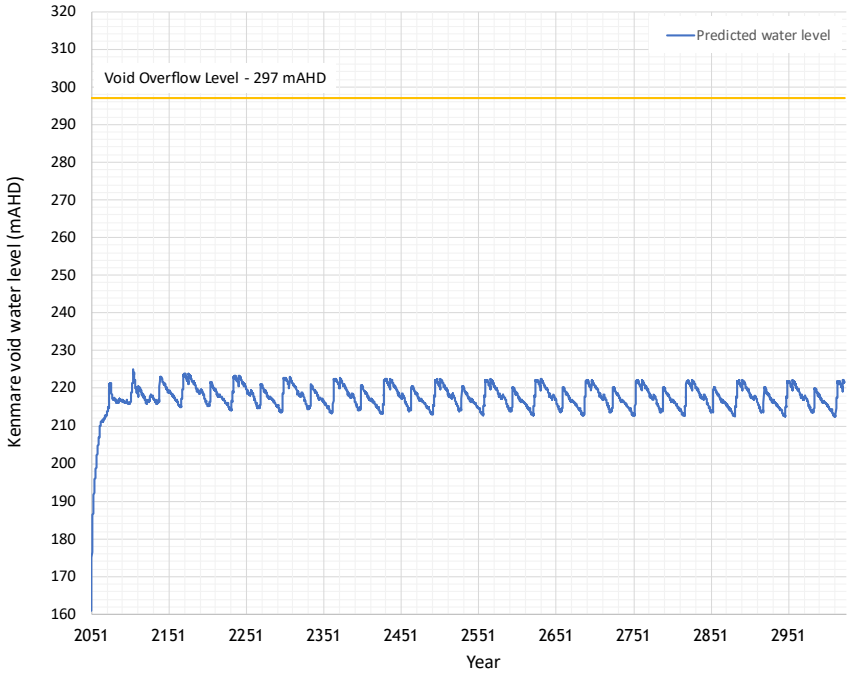


Figure 4.10 Kenmare void - long-term predicted void water level (HydroBalance, 2026)

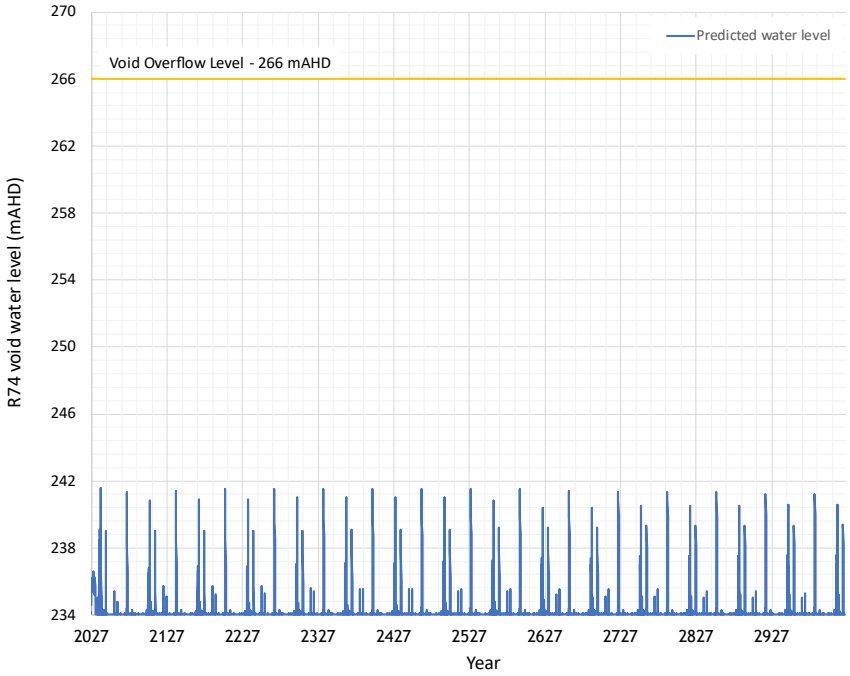


Figure 4.11 Ramp 74 void - long-term predicted void water level (HydroBalance, 2026)

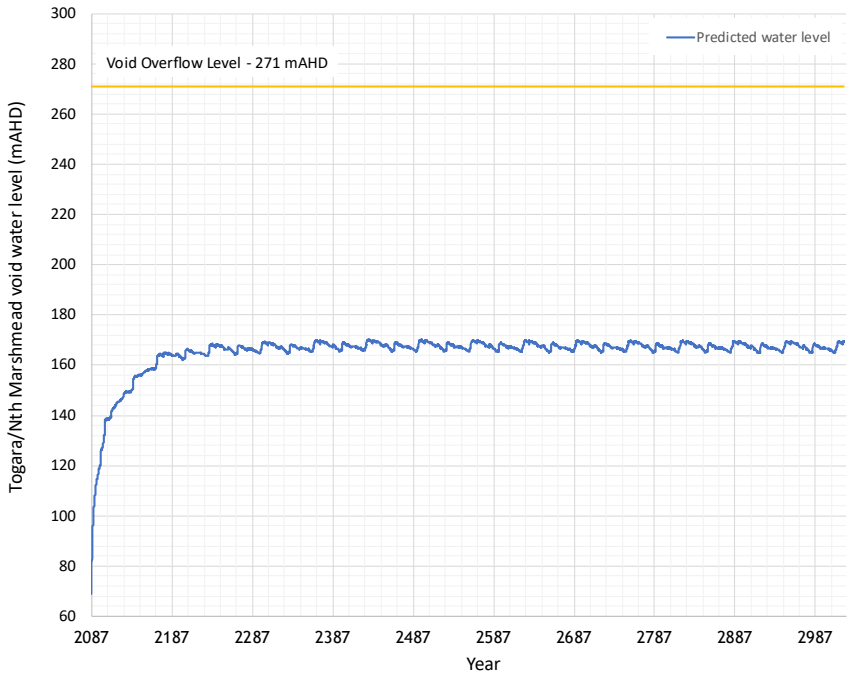


Figure 4.12 Togara North/Marshmead void - long-term predicted void water level (HydroBalance, 2026)

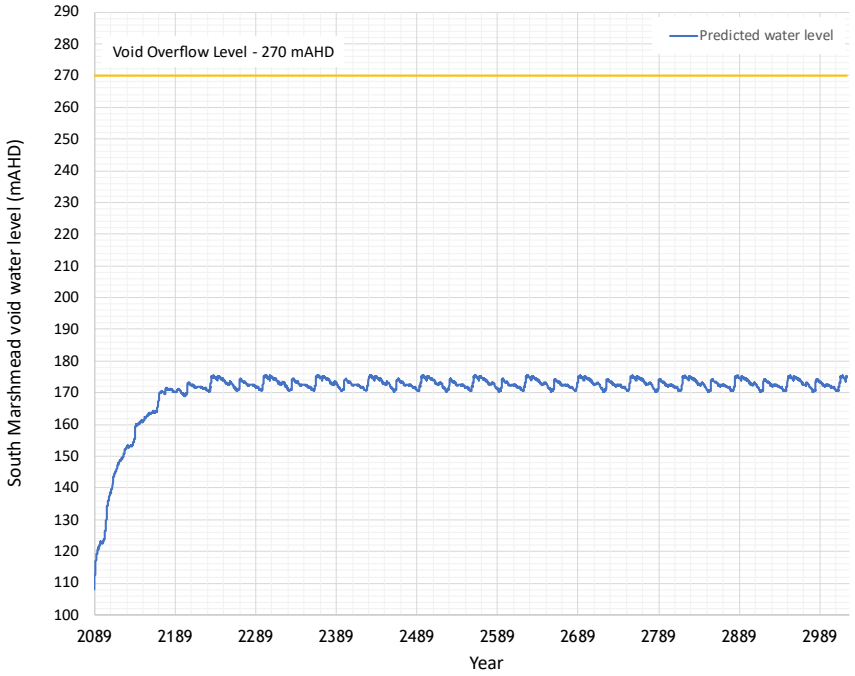


Figure 4.13 South Marshmead void - long-term predicted void water level (HydroBalance, 2026)

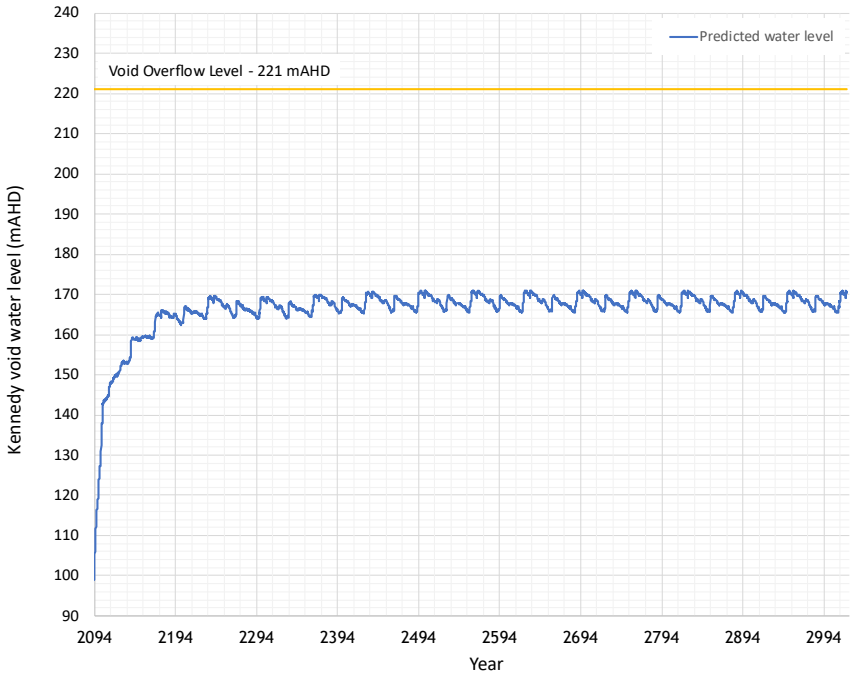


Figure 4.14 Kennedy void - long-term predicted void water level (HydroBalance, 2026)

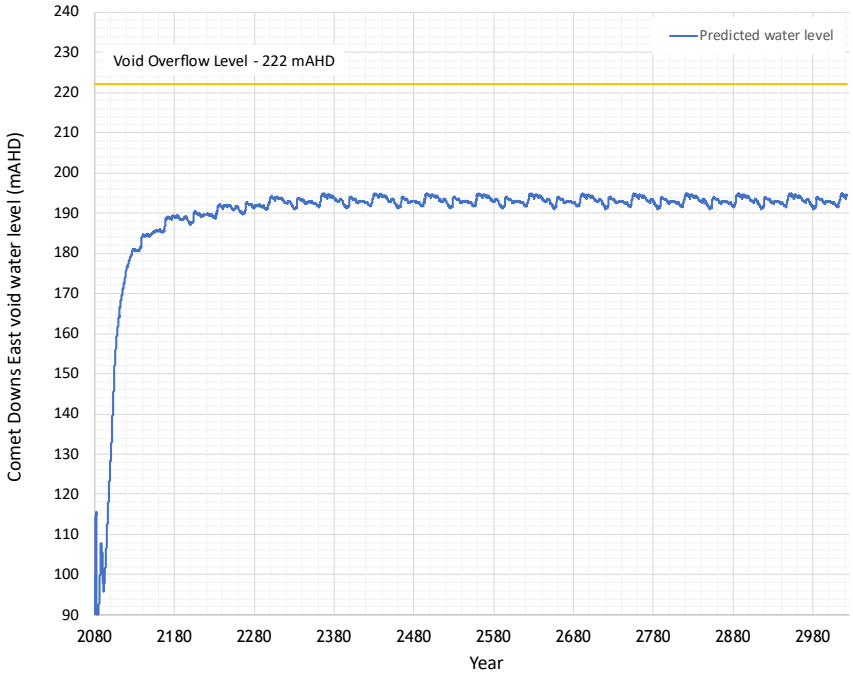


Figure 4.15 Comet Downs East void - long-term predicted void water level (HydroBalance, 2026)

4.3 EXTREME STORM EVENT WATER STORAGE

4.3.1 Method

An assessment of the impact of extreme storm events on the water levels in the final voids has been undertaken. The potential for discharge of void water during a large storm was assessed for the 1 in 1,000 AEP (or 0.1% AEP) 72-hour (3 day) design storm. The method assumes initial water levels are consistent with the average modelled long-term water levels.

Design rainfall depths for the above events were estimated using standard procedures in Australian Rainfall and Runoff (ARR) (Ball et al., 2019). The runoff generated from the storm events has been conservatively calculated assuming 100% of runoff reports to the voids (i.e. no losses) from the surface catchment reporting to the voids.

4.3.2 Results

The results of the storm event analysis are presented in Table 4.1. These results show that, even during extreme short duration storm events, the pit crest would not be overtopped for any of the final voids.

Table 4.1 Storm event modelling results

Void	Runoff Volume (ML)	Water level increase (m)	Final volume (ML)	Final level (mAHD)	Pit crest level (mAHD)	Freeboard (m)
R8	221	2.2	2,180	148.7	188*	39.3
BD	1,045	5.3	1,430	159.8	188*	21.2

Void	Runoff Volume (ML)	Water level increase (m)	Final volume (ML)	Final level (mAHD)	Pit crest level (mAHD)	Freeboard (m)
MB	3,585	4.4	25,763	88.1	200	111.9
R30	494	19.3	892	162.6	217	54.4
DC	628	2.6	9,741	137.1	202	64.9
ST-N	2,489	4.5	59,120	78.5	204	125.5
ST-S	573	11.6	732	115.5	232	116.5
TF	2,413	3.6	11,023	148.3	237	88.7
SB	1,802	2.8	14,952	144.3	290	145.7
KM	1,089	3.5	6,152	221.5	297	75.5
R74	517	10.2	795	244.3	266	21.7
TNM	2,036	2	39,873	167.7	271	103.3
SM	569	2.9	10,211	174.0	270	96.0
KE	1,909	2.4	26,516	168.8	221	52.2
CDE	302	1.8	10,334	193.0	222	29.0

Note: * This value represents the internal crest elevation between Ramp 8 and BD

5 SUMMARY AND CONCLUSIONS

A GoldSim water balance model was developed to assess the long-term water level behaviour at the proposed BWM final voids. The proposed BWM final landform includes 15 residual voids, all of which are designated as NUMAs. The final voids were modelled for a 1,000-year period following mine closure.

The final void model results for BWM void show the following:

- All voids reach an equilibrium within 100 to 500 years after closure.
- The modelled water level for all 15 voids is below the pit void overflow levels, and there are no modelled spills to the receiving environment for any voids over the 1,000-year simulation.

The extreme storm event assessment demonstrates that, even if the voids received inflows from a 0.1% AEP 72-hour storm event (with zero losses), they would not overflow to the receiving environment.

The assessment demonstrates that the risk of surface overtopping to the receiving environment from the 15 voids is extremely low. All voids function as terminal evaporative sinks, consistent with groundwater modelling outcomes (SLR, 2026).

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HydroBalance, 2026	HydroBalance, 2026, Blackwater North Extension Project: Water Balance Assessment Report, Whitehaven Coal, Doc. Ref.: WHC-037-C1_DRAFT, 10 March 2026, HydroBalance Environmental and Mine Water Management Solutions.
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BYRNES GEOTECHNICAL

BMA

Geotechnical considerations for closure of underground mines at BMA Blackwater.

REPORT: BMA-10 BLACKWATER PRCP

Date: 11/03/2024

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Executive Summary

The purpose of this report is to fulfill the requirements of the PRCP guideline pertaining to UG mines and identifies geo-technical hazards and provides recommendations which are secondary to any requirements under Queensland mining legislation.

Most of the workings in Laleham and Kenmare should now be in a stable condition given that the end of underground mining was more than 20 years ago. There is a negligible hazard of pot-hole subsidence in the future.

Surface damage in the form of rib parallel tensile cracking is present above both Laleham and Kenmare. The cracks are typically 200 mm wide and several metres deep. Where Quaternary sediments are present at the surface, the cracking that developed during pillar extraction at Laleham has been naturally remediated by slumping associated with rainfall.

The portal entries for Sirius Creek No 2 and Clutha should be rehabilitated by removing the existing steel sets and lagging boards and then backfilling. No earth works are recommended for Sirius Creek No 1.

These recommendations are provided for the purpose of planning closure and rehabilitation of Blackwater mines and further and more specific guidance is to be obtained to the specific areas/mines before conducting any operational activities which may be required as a part of these closure recommendations.

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1 Introduction

The guidelines for Progressive Rehabilitation and Closure Plans (PRCP) as they relate to underground mining require a geotechnical study that must include:

- an assessment of post closure stability of the workings
- proposed methods for sealing-off of surface access to the workings
- the extent of post-closure subsidence
- subsidence modelling to inform rehabilitation strategies and milestones.

The long-term closure impacts are primarily changes in surface topography. Most of these will develop within 1-2 years after mining and need to be considered for progressive rehabilitation.

After mining there will be recovery of the groundwater levels as the ground water stabilises back into the underground voids and reaches equilibrium. This will then represent a significant change in the geotechnical environment within the underground workings and may lead to additional deformations at the surface.

This report has been compiled for the use within the PRCP and presents the underground related geotechnical issues that require consideration for the legacy and abandoned underground mines within the Blackwater Mine operations.

There are multiple underground mines located within the Blackwater mining leases, all of which were never operated by BMA (Figure 1). They are located within the area known as “South Blackwater” and include:

- Kenmare 1 & 2.
- Laleham Mine.
- Sirius Creek No 1 & No 2.
- Ballamoo Mine.
- Clutha Trial Mine.

The area known as the Clutha trial mine in this report has been known under many names in the history of the site. For all purposes in this document, it will be maintained as Clutha Trial mine.

The operations that resulted in surface subsidence are Kenmare (longwall) and Laleham (bord and pillar and pillar extraction). Both mines extracted coal from the Aries Seam and the underlying Pollux Seam (Figure 2).

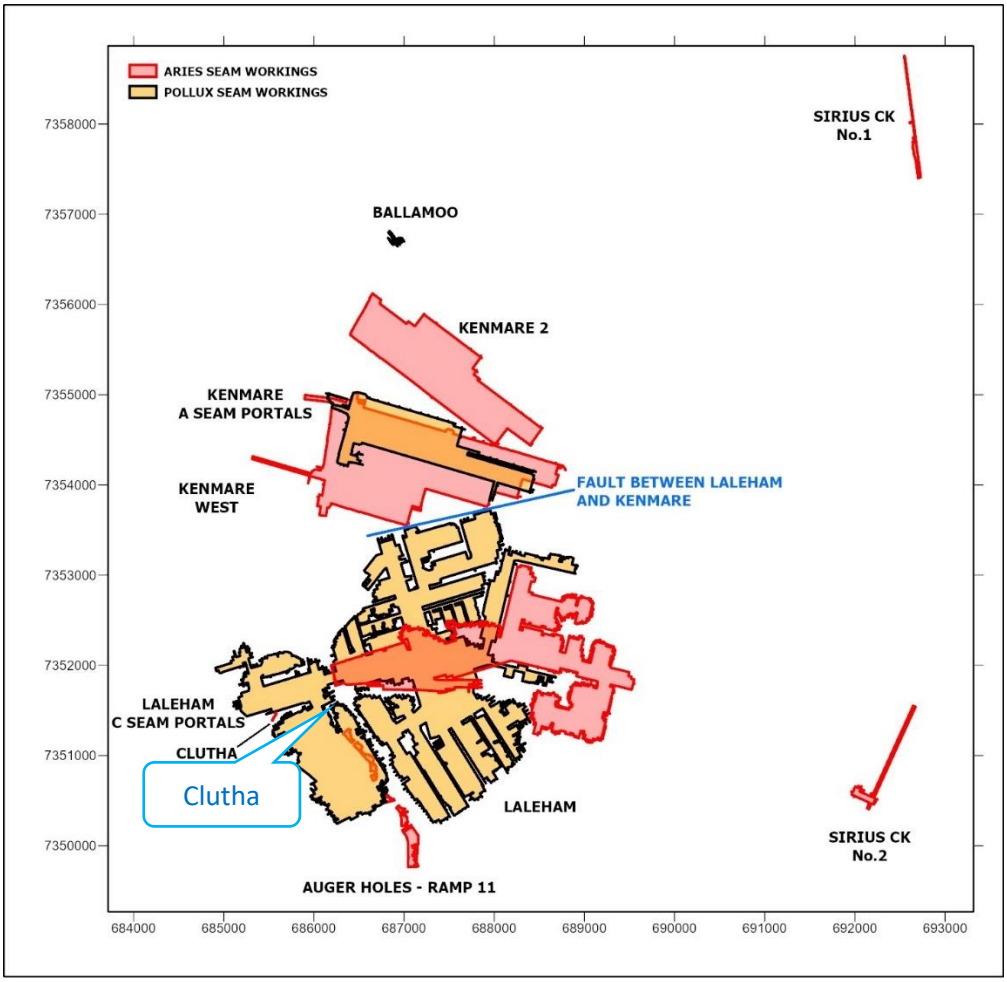


Figure 1 Mine plans for Laleham and Kenmare undergrounds.

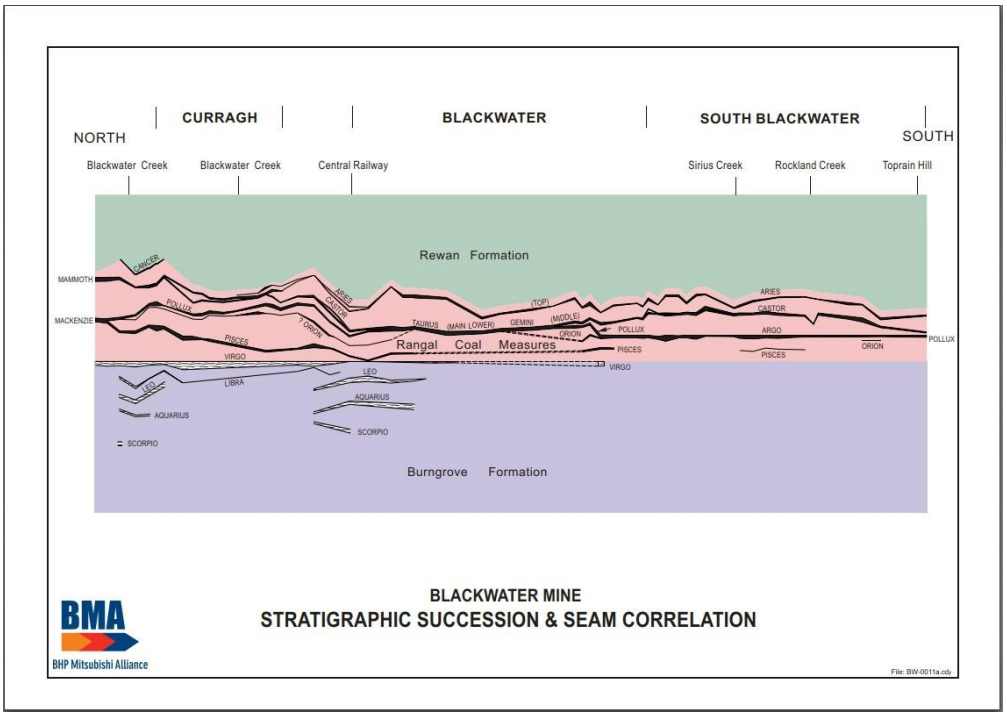


Figure 2 Seam Correlation Diagram of Blackwater Area.

2 Surficial geology

The impact of mine subsidence deformations on post-mining land use depends in part on the nature of the geological materials at the surface. Maps of the surface geology/soils (Figure 3 and Figure 4) indicate the presence of 5 different units.

- Qrc – Quaternary, colluvium and or residual deposits, talus, scree, sheet wash, boulder, gravel, sand.
- Czl – Cainozoic, Ferruginous duricrust, laterite, may include massive to pisolitic subsoil, mottled clays.
- Czoem – Eocene, Emerald Formation – fluviatile and lacustrine claystone and siltstone, quartzose sandstone, pebbly sandstone, gravel, lignite, oil shale, interbedded basalt, all deeply weathered.
- Rsr – Triassic Rewan Group, Lithic sandstones, green to reddish brown mudstone.
- Pok – Permian Blackwater Group, coal measures.

The ability for subsidence cracks to "self-heal" after rainfall depends on the surface geology and topography. It has been observed throughout BMA sites that where there is a loose surface soil, it becomes more easily rehabilitated and soil can settle into the cracks naturally during rain events. However, where there is a duricrust or rock at the surface (for example Czl), it is less likely that natural self-healing will occur over time, and the rain may increase the erosion risks in these areas.

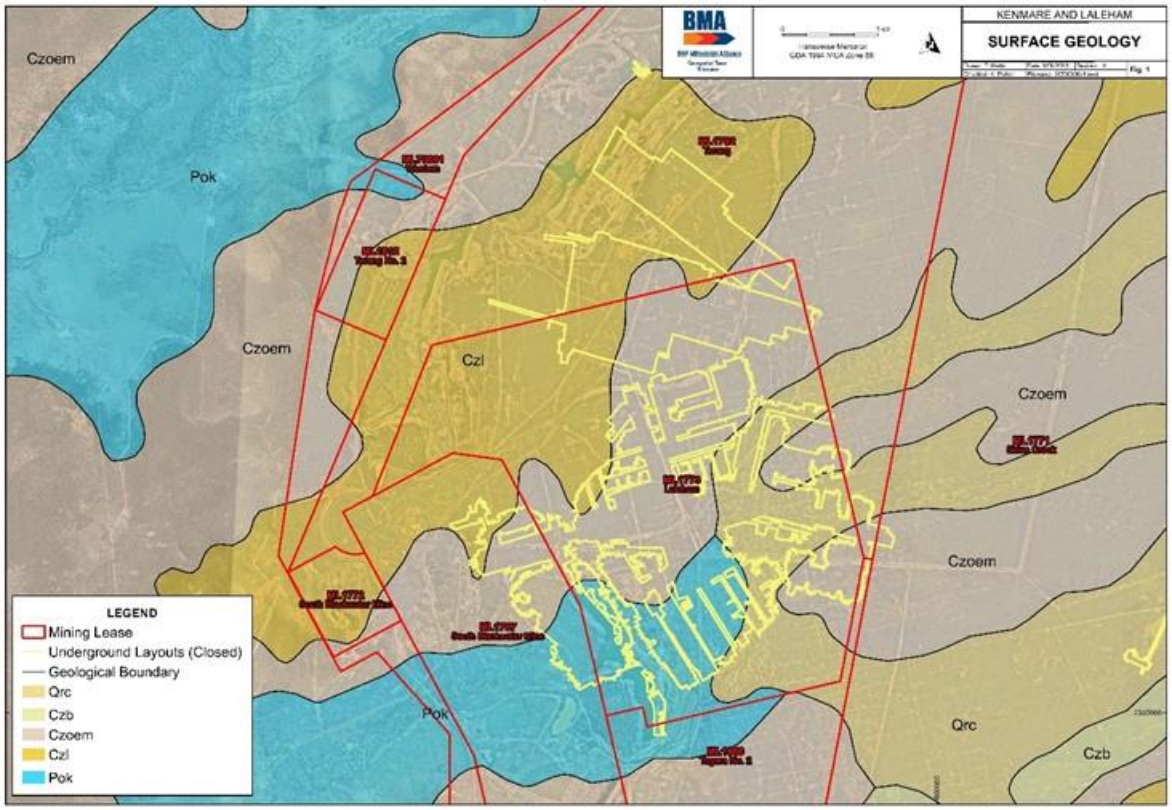


Figure 3 Surface geology – Laleham and Kenmare.



Figure 4 Surficial geology - Sirius Creek No 1 No 2.

3 Underground Mining Operations

A number of different underground mining methods were utilised at BWM:

- Kenmare 1 & 2 – Longwall
- Laleham Mine – Pillar extraction and bord and pillar
- Sirius Creek No 1 & No 2 – Bord and pillar
- Ballamoo – Bord and pillar (headings only)
- Clutha Trial Mine – (single 80m heading in Laleham area)

3.1 Longwalls

3.1.1 General comments

Inherent in safe and productive longwall mining is the collapse of the rock mass above the extracted coal. This collapse may extend to the surface if the width of the extraction relative to the depth of mining exceeds about 0.5. The width:depth ratio for the Kenmare longwall mine means that substantial vertical subsidence developed progressively as the longwall retreated. Maximum subsidence likely developed above the extraction within about 100 m of the retreating face, there would also have been a lesser amount of vertical subsidence above the chain pillars that developed independently of that above the extraction (Figure 5).

When the underground workings are flooded there may be a small amount of additional vertical subsidence related to the softening of the caved rock above the extracted coal in the presence of water. This flooding can occur as a direct result of the mine being purposefully flooded, or over time as the ground water recovers from dewatering. The subsidence above the chain pillars is unlikely to increase when the groundwater recovers.

The situation with the mains pillars and roadways is different. These are designed to be stable during the operations – both in terms of roof collapse in the roadways and stability of the pillars. Over time, the roof will likely collapse as the support/reinforcement steel members degrade either in the humid mine air or as the mine floods. The possibility that such collapses could extend to the surface at

shallow depths of cover needs to be considered. The mains pillars are typically designed with high stability factors such that failure over the long term is unlikely. Flooding of the mine may temporarily reduce the stability of the pillars, but eventually their stability will be increased due to a buoyancy effect reducing the loads on the pillars.

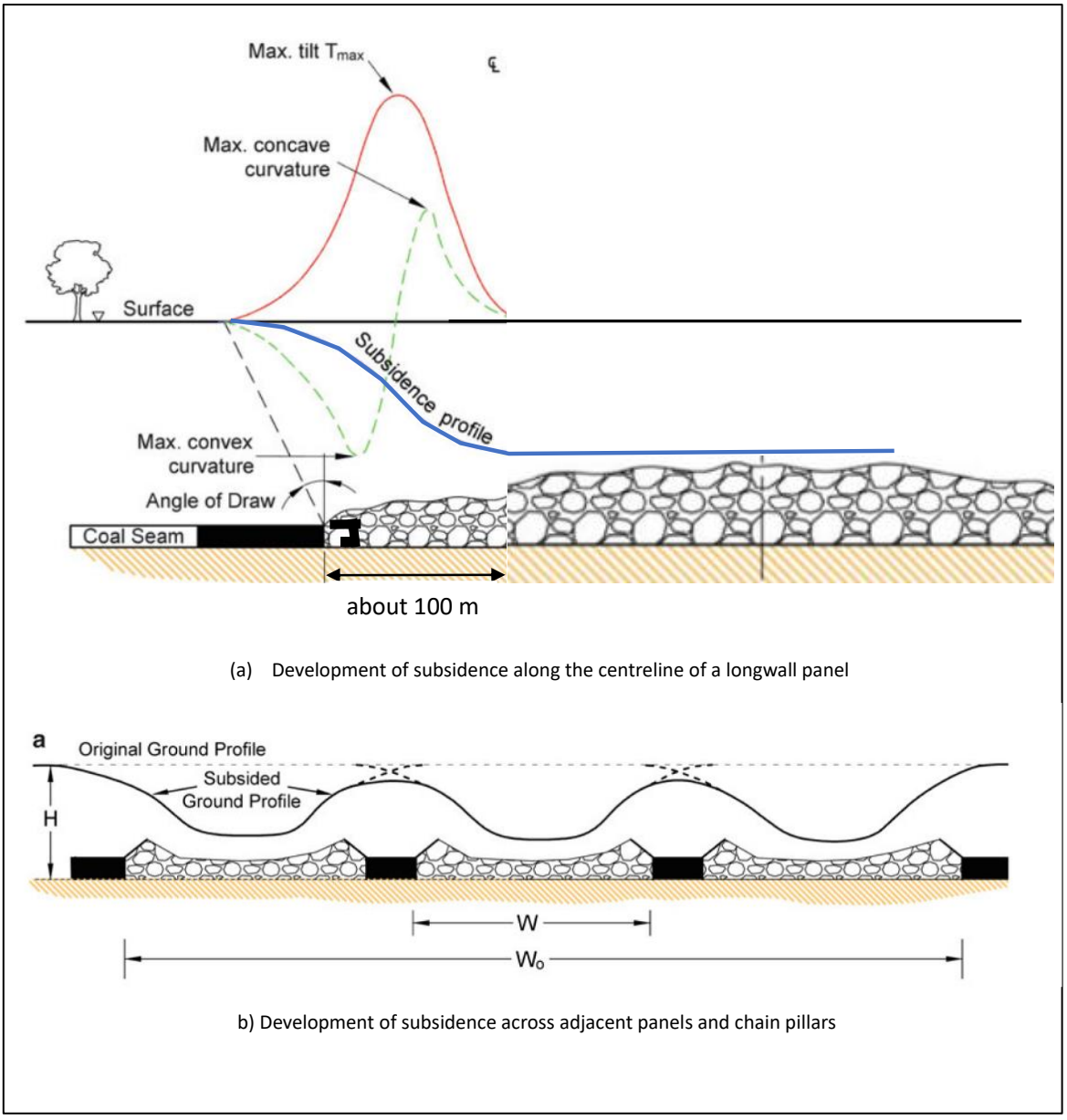


Figure 5 General nature of longwall subsidence[1].

3.1.2 Kenmare

Underground drivEage at Kenmare, accessing the Aries Seam from South Blackwater Ramp 66 South, began in November 1994 and the first longwall panel was extracted between November 1996 and April 1997. Longwall panels were about 203 m wide (Figure 6).

Based on discussions with previous mining and geotechnical engineers based at the underground mines prior to abandonment, there was a large amount of historical monitoring information regarding subsidence above both Laleham and Kenmare. However, it is unable to be located, and

[1] Galvin JM 2016. Ground Engineering: Principles and Practices for Underground Coal Mining. Springer.

hence no subsidence information can be used to validate subsidence predictions. This is not seen as a limitation to a Blackwater PRCP as the major identified hazard is subsidence cracking and the predictions are adequate to locate areas of interest. Some information on rock strengths from the Kenmare operation is available for use[2], but it is minimal.

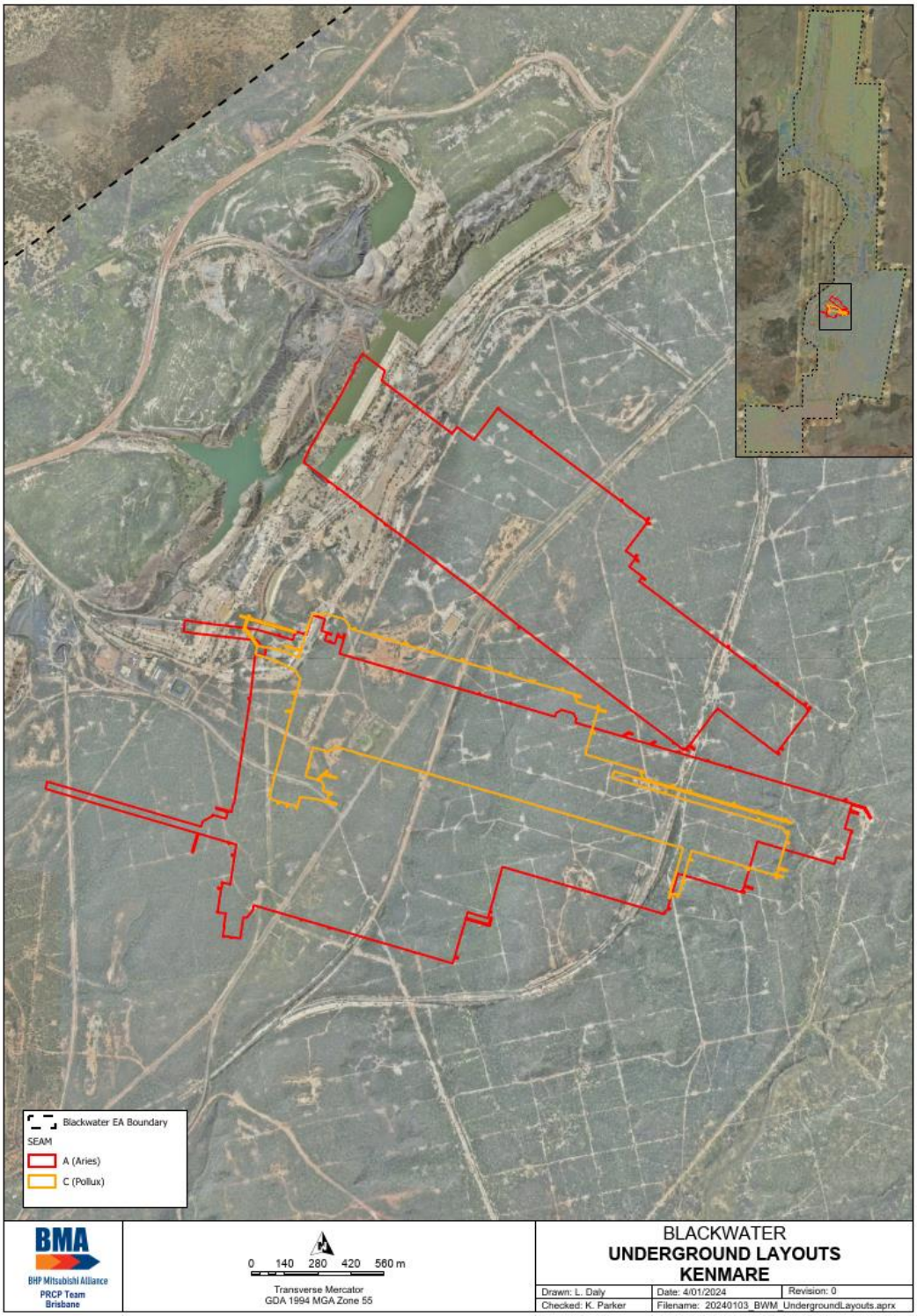


Figure 6 Layouts of longwall extraction by mined seam (insert shows location relative to lease boundary).

[2] Coutts, R. 2001. Kenmare2 - Longwall2, Hazard management exploration programme, Results of Phase 1 & 2

3.2 Pillar extraction mines

3.2.1 General comments

Legacy pillar extraction mines have mains pillars designed similarly to those for longwalls and also have some areas where pillars may have lesser stability and some areas where the pillars have been extracted. Where the pillars have been extracted surface subsidence may have developed in the same way as for longwalls. There is a possibility that in some areas where the pillars have been extracted the extracted width was insufficient to cause complete subsidence to the surface – such areas may collapse over time.

There may be cases where very high/narrow pillars were formed during the extraction operation resulting in pillars with low stability and the possibility of collapse within a 100-year time frame. Whether such a collapse could extend to the surface needs to be examined.

3.2.2 Laleham

At Laleham, pillar extraction was conducted in the Pollux Seam and only bord and pillar operations were conducted in the Aries Seam (Figure 7).

The Laleham underground bord and pillar mine began in the Pollux Seam in 1969 and was accessed by two drifts, approximately 150 m long. Various methods of pillar extraction were carried out, mostly using timber as ground support, but towards the completion of mining in the Pollux Seam, breaker line supports (BLS) were utilised in a Wongawilli layout (Figure 8) which results in a layout somewhat analogous to a longwall.

At around the same time that Kenmare began operations, Laleham accessed the Aries Seam with an interseam drift from the Pollux Seam and successfully mined several bord and pillar panels using place-change development systems with no pillar extraction.

3.3 Bord and pillar mines

Legacy bord and pillar mines such as the Sirius Creek operations (Figure 9) can be considered in the same context as mains pillars in the longwall mines with regards to stability.

Flooding of the bord and pillar workings will have the same effects as for longwalls.

3.3.1 Sirius Creek Mines

Sirius Creek No 1 (Figure 10a) was a 900 m single entry until it intersected the Aries Seam at about 300 m depth where a line of 18 m wide pillars were formed. Being a single row of pillars, their stability is very high – it is assessed that these will never collapse and there will be no associated surface subsidence.

Sirius Creek No 2 (Figure 10b) utilised 2 of 6 m wide roadways with a 15.2 m wide pillar until it intersected pit bottom at about 200 m depth, at which point pillars were formed on 30 m centres (24 m solids). The limited lateral extent of the pillars, together with their width means that they have high levels of stability – it is assessed that these will never collapse and there will be no associated surface subsidence. The site inspection revealed a pothole has developed through the fill material placed above the original portal canopy.



Figure 7 Underground mining by seam at Laleham.

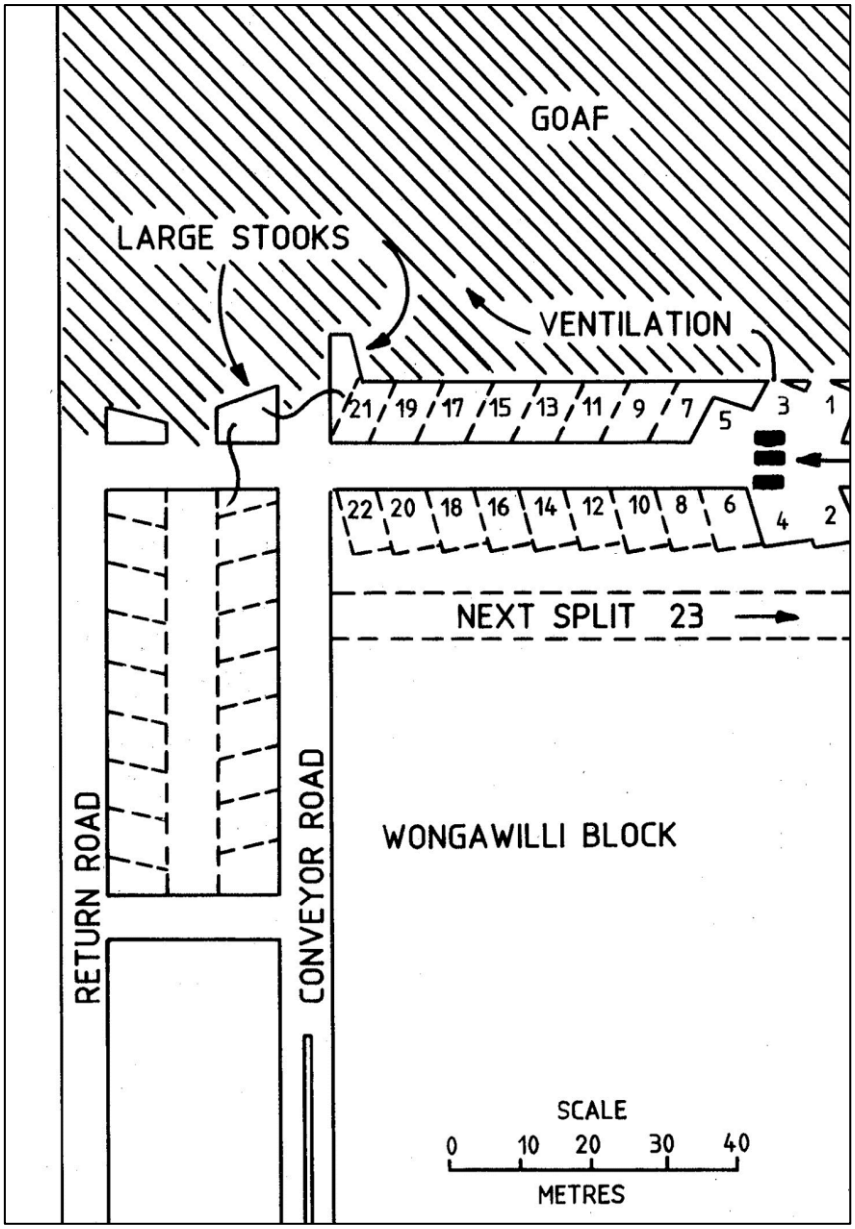
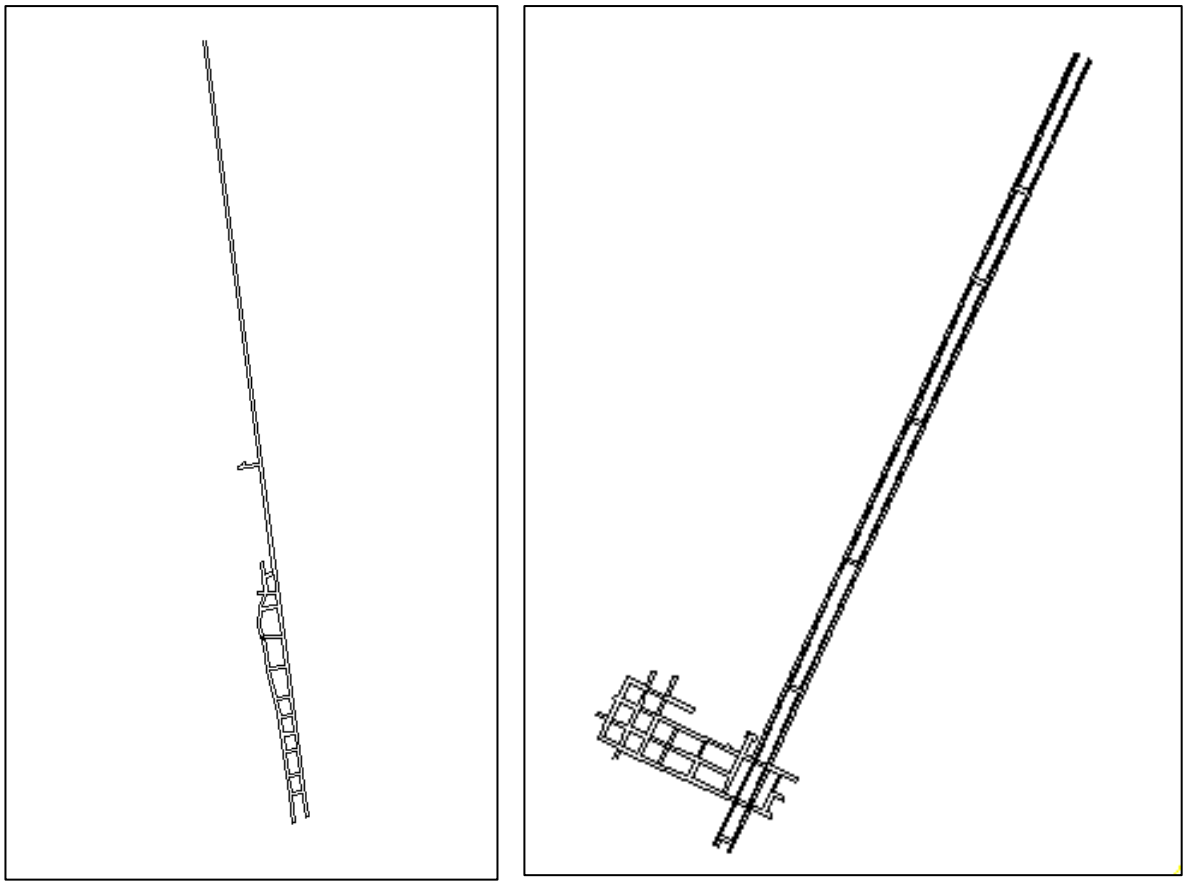


Figure 8 Plan view image of a Wongawilli pillar extraction layout with double sided lifting and BLS units (source Galvin: op. cit.).



Figure 9 Underground layouts by seam for Sirius Creek Undergrounds.



Sirius Creek No 1 Sirius Creek No 2

Figure 10 a) Layouts for Sirius Creek No 1 (pit bottom at 320 m depth) and b) No 2 (pit bottom at 200 m depth).

3.3.2 Ballamoo Mine

The Ballamoo mine extended about 190 m from the Ballamoo highwall and involved 5 headings: no pillars were formed (Figure 11). The headings were located on 30 m centres with 7 m wide roads. The current closure plan is that they will be buried with backfill. The maximum mining depths were in the order of 50 m, no pillar instability is anticipated even when they are buried by backfill.

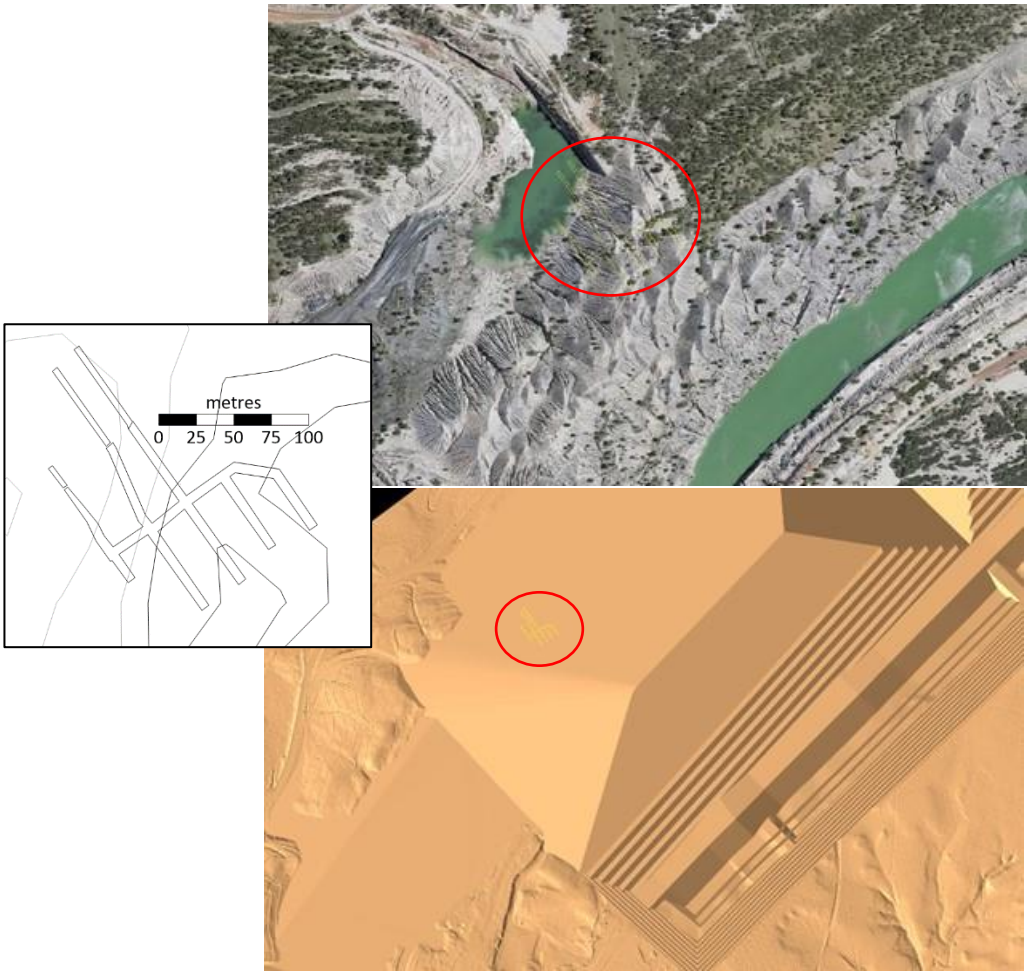


Figure 11 Ballamoo pit and underground workings will be buried by backfill.

4 Stability assessment

An assessment of the current and ongoing stability of the underground workings is critical to understanding the subsidence risk at closure. Specifically, there is a need to consider possible impacts on the post mining land use related to further pillar collapse or further roof collapse.

For operational reasons the pillars in the main access roadways (Mains pillars) were designed with high levels of stability and a design life in excess of 50 years. Typically, Mains pillars are dimensioned with a factor of safety in excess of 2.0 and there is an industry conjecture that the probability of failure is better than 1:1 000 000. It is valid to conclude that these Mains pillars have not and will not collapse.

In both legacy pillar mines and the longwall mines there are pillars that were designed to collapse as an integral part of the mining system, for example longwall chain pillars and some pillars in pillar extraction mines. These will have already collapsed and any associated surface subsidence developed.

There are also pillars that have intermediate levels of stability. Typically, during mining operations the heuristics applied to pillar stability relate to a ratio of pillar strength: pillar load. Typical thresholds used for mine design are presented in Table 1:

Table 1 Pillar stability thresholds

Stability	Factor of Safety	Implied probability of collapse within a nominal 50-year periods
Immediate collapse	<1.0	1:1
Short term	>1.2	1:10
Pillar formed on advance	>1.6	1:1 000
Long term	>2.11	1:1 000 000

It is important to emphasise that these factors of safety are derived from a statistical analysis of small databases (n<100) in which there are no collapse cases with a pillar width to height ratio greater than 5.0.

From a rock mechanics perspective, the ultimate strength of a pillar relates to the frictional restraint that can be developed once any cohesive strength is lost (for example by overstressing or weathering). If a very much lower-bound frictional strength of 12° is adopted for coal it would follow that the width to height ratio of a coal pillar would need to be 4.7 for the pillar to completely collapse (by lateral displacement) assuming that the loading is purely vertical; this is similar to the upper bound in the database of failed pillars. From this discussion, our assessment is that for the for bord and pillar workings at Laleham and Kenmare long term stability will be present if the Factor of Safety is greater than 1.6 and/or the aspect ratio of the pillars is in excess of 4.7.

4.1 Laleham pillars

There are pillars at Laleham with stability factors less than 2.0, therefore based on the previous discussion there could be a risk of further collapse. These pillars are located in production panels where only first workings development (beyond the Mains) or pillar splitting was undertaken (Figure 1213). A series of pillar stability analyses have been conducted on these pillars. The pillars examined in the stability analysis, are located in either the Aries or Pollux seams with their specific locations shown in Figure 12. Seam thickness in both the Aries and Pollux Seams ranged from 3.4 m – 3.8 m. A roadway height of 3.6 m has been assumed for this analysis.

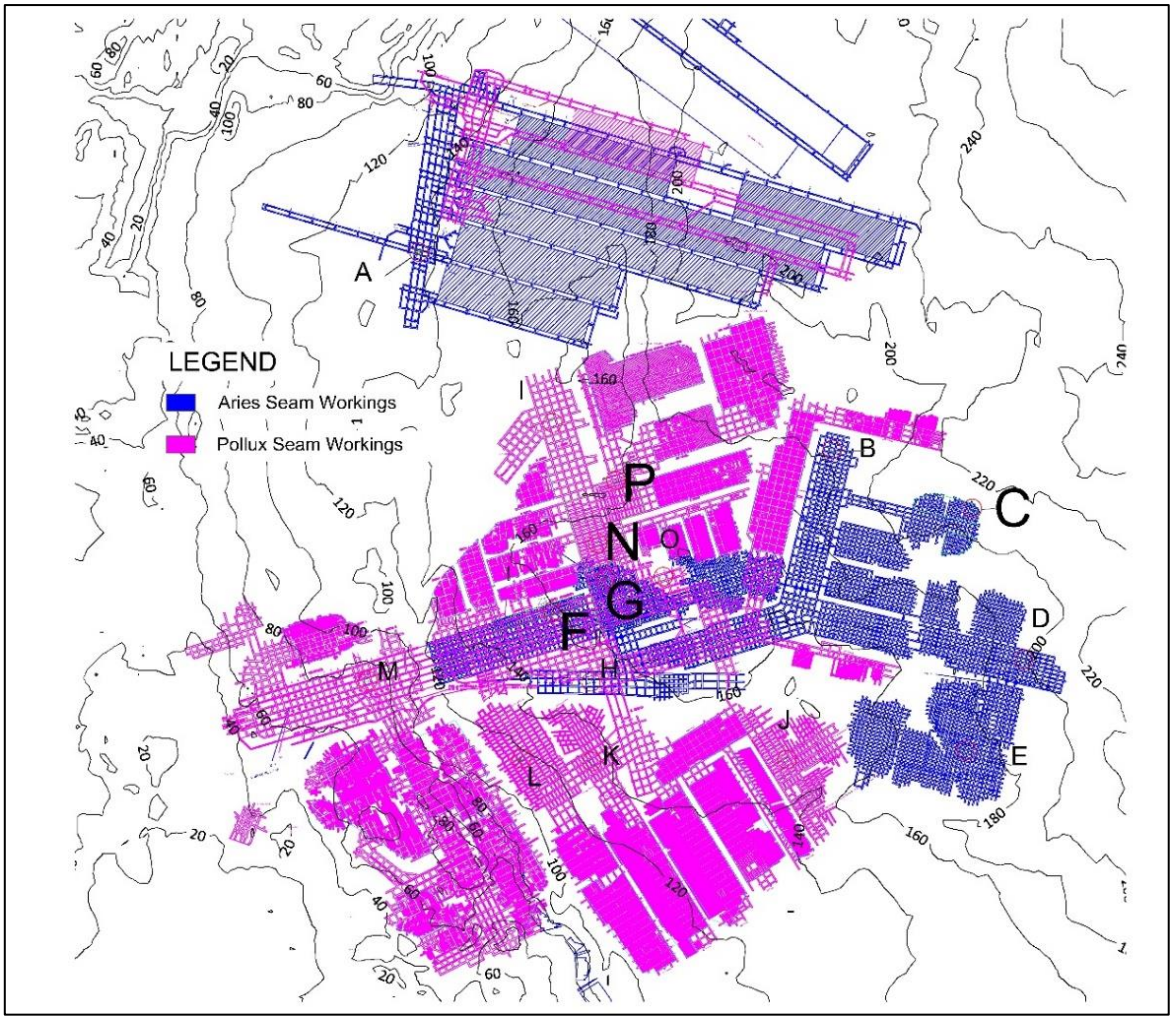


Figure 12 Depth to Pollux Seam and location of pillar stability analyses (larger fonts indicate pillars of marginal stability).

The stability of these pillars has been assessed using either the UNSW power (width to height ratio <5) or UNSW squat (width to height ratio >5) pillar formulae (Table 2). Pillar's C, F, G, N, and P have marginal long-term stability as indicated by low factors of safety results as shown in Table 2. These results indicate that there may be a hazard of further subsidence in these areas within a nominal time frame of 100 years (Section 5.4).

Table 2 Kenmare and Laleham Pillar Stability Analyses

Location	Depth (m)	Width to Height Ratio	Factor of Safety
Pillar A Kenmare Mains	110	5.5	3.58
Pillar B Laleham Aries First Workings 1	150	5.0	2.19
Pillar C Laleham Aries First Workings 2	**170**	**3.1**	**1.14**
Pillar D Laleham Aries First Workings 3	160	4.4	1.70
Pillar E Laleham Aries First Workings 4	140	3.9	1.69
Pillar F Laleham Aries First Workings 5	**120**	**2.8**	**1.58**
Pillar G Laleham Aries First Workings 6	**130**	**2.5**	**1.27**
Pillar H Laleham Aries Mains	130	9.2	5.08
Pillar I Laleham Pollux 1 North Mains	170	9.0	3.48
Pillar J Laleham Pollux 303 Panel Split Pillars	150	3.8	1.69
Pillar K Laleham Pollux 3 South Panel Split Pillars	140	3.8	1.99
Pillar L Laleham Pollux 4 South Panel	120	3.8	2.30
Pillar M Laleham Pollux East Headings	80	8.1	6.13
Pillar N Laleham Pollux 111 Panel Split Pillars	**165**	**3.5**	**1.39**
Pillar O Laleham Pollux 1 East	170	8.1	3.03
Pillar P Laleham Pollux 100 Panel Split Pillars	**160**	**2.8**	**1.16**

Due to the depths of cover being mostly in excess of 30 m for both the Laleham and Kenmare 2 portal areas, pot-hole risk is highly unlikely to occur. There is only a small section of Kenmare 1 that has a lower depth of cover than this (Figure 13) which means that there is a hazard of pot holing occurring near the mine's entrance and this should be addressed in the plans for the surface mine void.

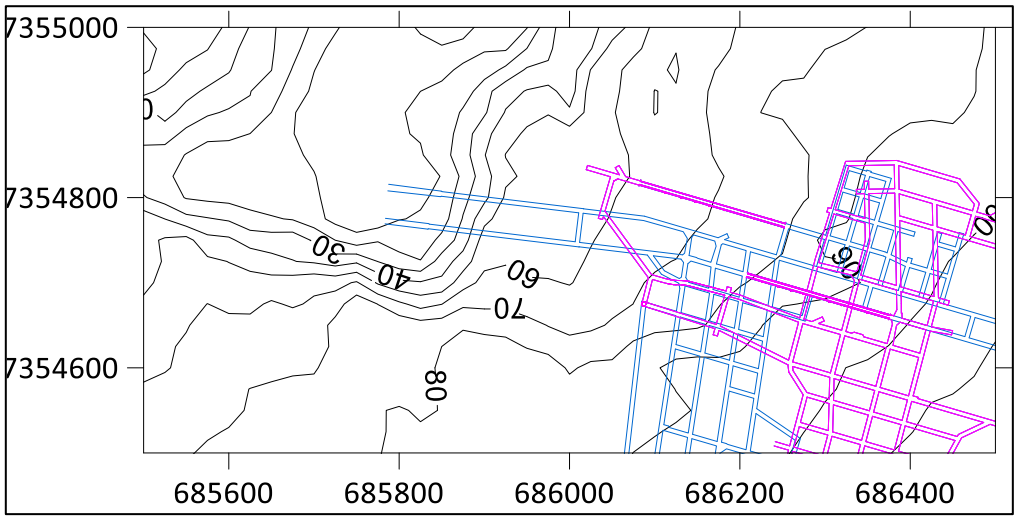


Figure 13 Depth to Aries Seam roadways near the entry to Kenmare 1.

4.2 Flooding Impacts on pillar stability

In the laboratory there is a measurable decrease in uniaxial compressive strength on saturation of coal measure rocks (about 20%). The impact of this on the stability of narrow pillars is in the order of 11% for pillars with width to height ratios of less than four but has not been studied for wider pillars. It is assessed that this strength loss will not add materially to the consideration for the stability of the pillars in Laleham.

There is a possibility of reduction in the floor strength of the roadways which would result in a reduction in the bearing strength of the pillar floor system (Figure 16). The reduction in roadway floor strength may be relatively small so the impact on pillar stability will be minor unless the impacted layer is very thick and initial floor stability was low. The available information on the Aries and Pollux seams[3] suggests that the floor strengths are well in excess of those that could be associated with this type of failure mechanism.

In contrast to these reductions in strength, there will be an overall trend for an increase in stability related to a buoyancy effect as the water level rises above the coal seam. The result is that any decrease in stability will be temporary while the material at or below seam level softens and the water level is such that there is no buoyancy effect. Over time as the water level rises above the coal seam level, buoyancy will dominate and stability will increase beyond that at mine closure. It is valid to include consideration of buoyancy when using the available method to estimate pillar loading.

5 Surface deformations

Mining subsidence results in the following deformation and associated impacts at the surface:

- Downward vertical movements.
- Change in surface slope angles.
- Vertical steps and compression humps.
- Surface cracking.

It is noted that the remediation of vertical steps, humps, and cracking is addressed as part of progressive rehabilitation and forms a part of the operational mining activities.

5.1 Subsidence prediction and visualisation

There are many tools for visualising the distribution of vertical subsidence, tilt, and curvature, all require a prediction of the maximum vertical subsidence which can only be derived from surveys of mines in the same geological regime. In this report the SDPS influence function method[4] has been used.

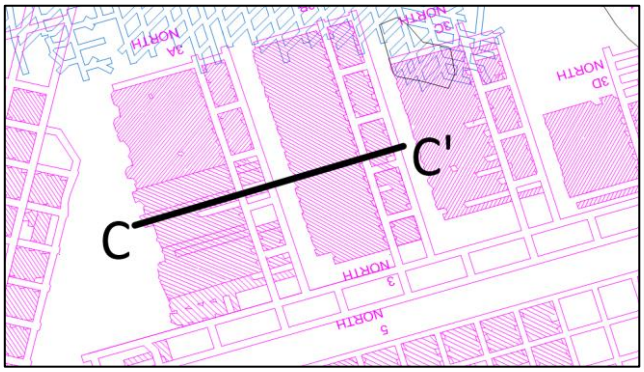
Documented subsidence information has been located, related to a 110-125 m wide pillar extraction panel at Laleham mine at a nominal 150 m depth[5]. This survey was conducted before Panel B was fully extracted; the information from Panel A is consistent with other subsidence results in the

[3] Gordon N. Optimisation of strata reinforcement at Kenmare Colliry. Coutts R 2001. Kenmare 2 – Longwall 2. Hazard Management Exploration Programme, Results of Phase 1 & 2.

[4] Surface Deformation Prediction System (SDPS) Software | Office of Surface Mining Reclamation and Enforcement (osmre.gov)

[5] Wardle, LJ. 1993. The use of numerical modelling for underground coal mine design. Chapter 28 in Volume 2, Analysis and Design Methods, Comprehensive Rock Engineering, pp 733-948

Bowen Basin allowing more recently derived generic parameters to be applied when predicting these values.



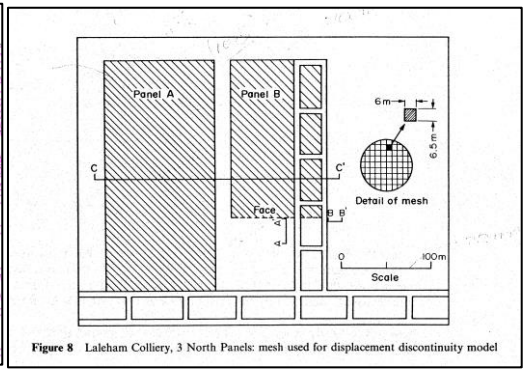


Figure 8 Laleham Colliery, 3 North Panels: mesh used for displacement discontinuity model

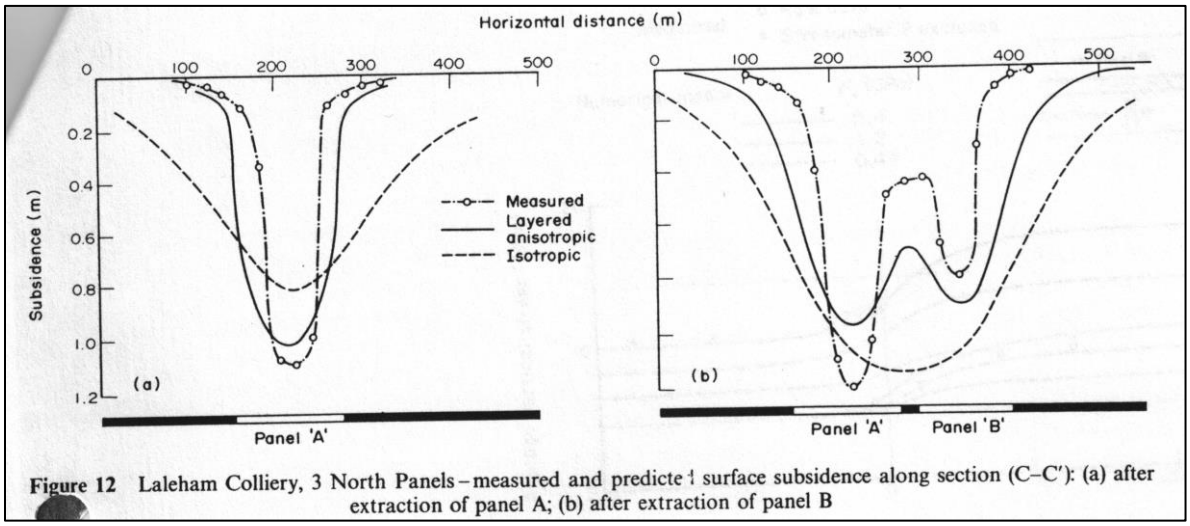


Figure 12 Laleham Colliery, 3 North Panels – measured and predicted surface subsidence along section (C–C'): (a) after extraction of panel A; (b) after extraction of panel B

Figure 14 Subsidence information from a pillar extraction panel at Laleham Colliery (from Wardle 1993).

5.2 Mining subsidence

The modelled distribution of vertical subsidence is shown in Figure 15 and the horizontal strains shown in Figure 16. For the Laleham Pollux Seam workings it was necessary to make assumptions on the collapse of some of the shallower (early) panels where extensive extraction of bord and pillars workings was completed and likely to have been sufficient to cause surface subsidence.

The maximum vertical subsidence is 2.5 m for single seam extraction and 3.5m for dual seam extraction. The 3.5 m applies only to a small area of Kenmare 1 where mining of both the Aries and Pollux seam was undertaken.

For the vertical subsidence, a cut-off deformation of 20 mm was adopted to define the onset of displacement. Using this definition, there is an estimated area of 3.2 km^2 subsided ground above Laleham and 2.9 km^2 above Kenmare.

For horizontal strain (Figure 16), the presented contours are those in excess of 5 mm/m in either tension or compression to give an insight into areas where visible localised surface deformations may be seen (cracking).

Figure 17 presents frequency plots of the level of vertical subsidence, change in slope, and tensile/compressive strains expressed relative to the area defined by the 20 mm vertical subsidence level. The maximum change in slope is 4.8° (8%). It is anticipated that 20% of the subsided area may

have tensile strains in excess of 5 mm/m and a similar percentage will have compressive strains in excess of 5 mm/m.

The modelling of horizontal strain and inferences on surface deformations was validated by the observed cracking during the May 2023 site inspection.

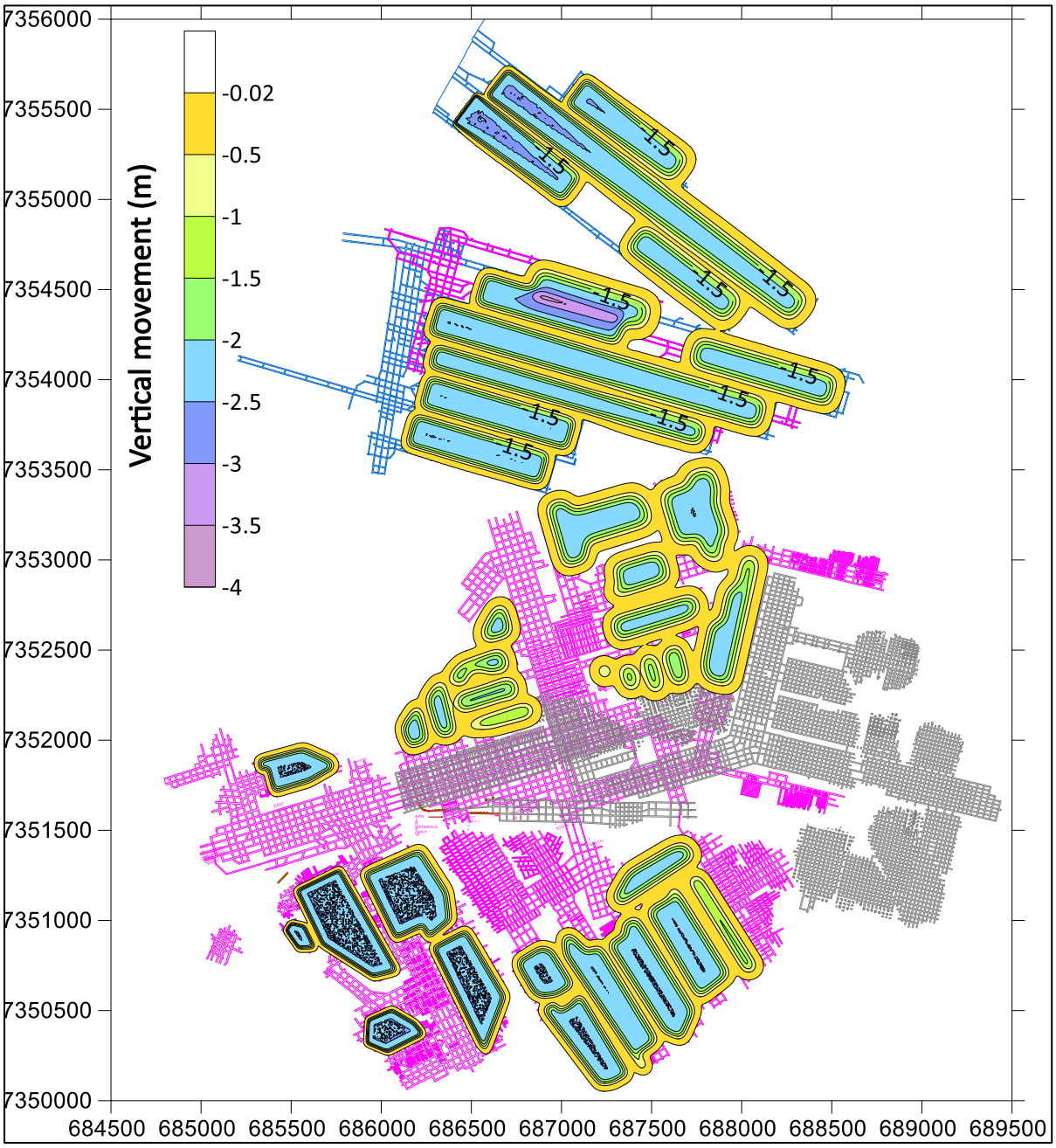


Figure 15 Visualisation of vertical subsidence at Laleham and Kenmare.

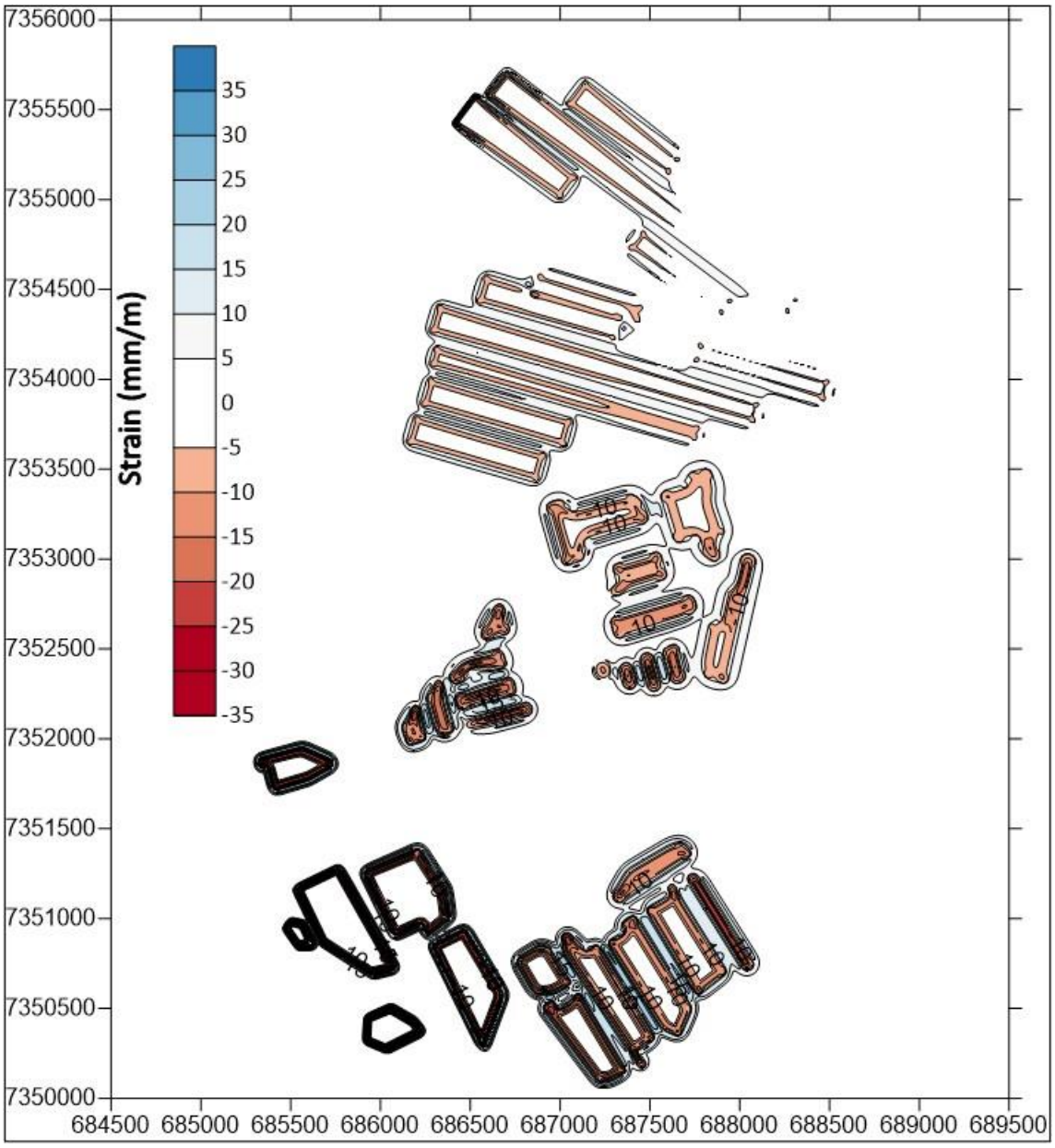


Figure 16 Visualisation of likely horizontal strain at Laleham and Kenmare..

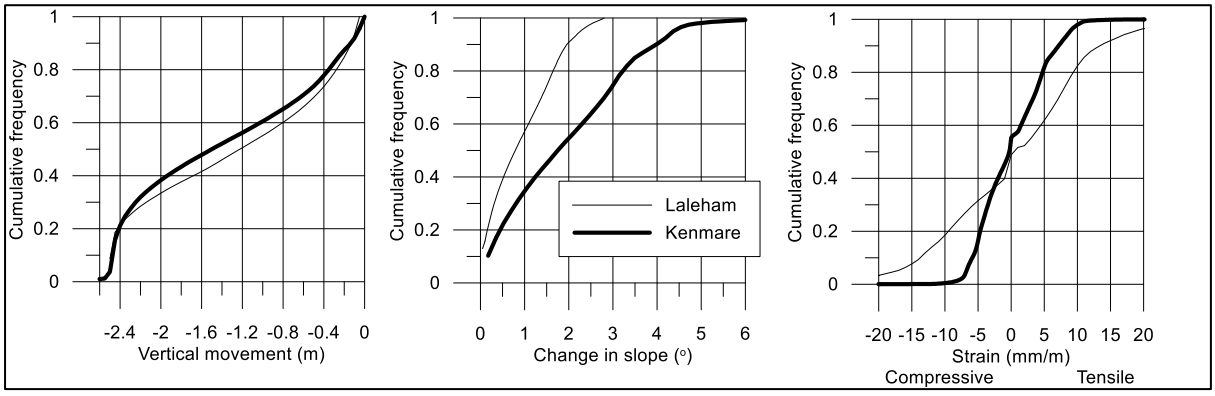


Figure 17 Frequency statistics on total area exposed to mine subsidence as defined by a prediction of vertical subsidence in excess of 20 mm..

5.3 Surface cracking

High levels of tensile strain can lead to the onset of cracking at the surface. There are two end members of cracking – ribs-parallel tensile cracking and face-parallel/arcuate steps (Figure 19).

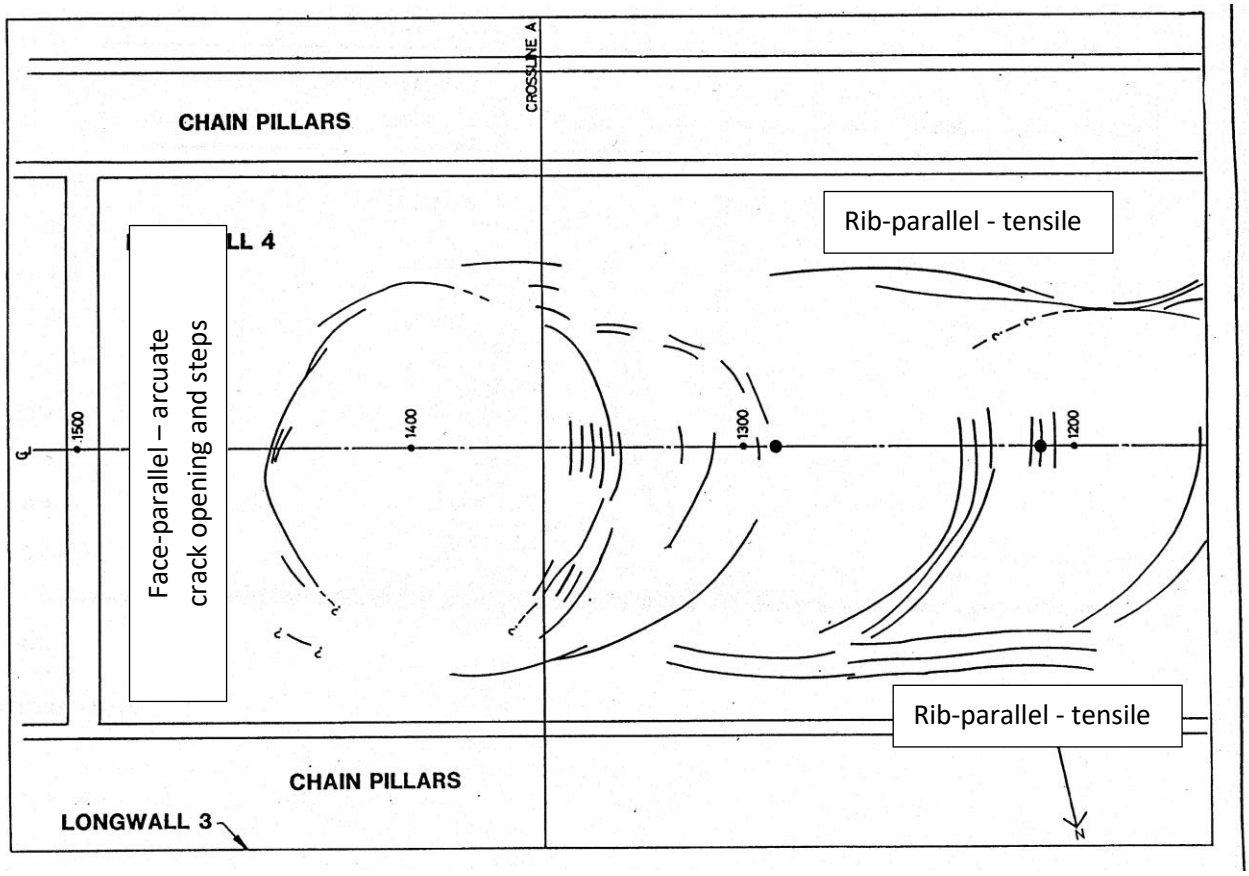


Figure 18 Typical areal distribution of surface cracking, dots indicate noticeable compressive humps (LW4 Cook Colliery ACARP C1311).

The rib-side cracking is perhaps the most obvious and is typically the focus of progressive rehabilitation regimes on most mine sites. Rib cracking is the result of overburden blocks' rotation at the edge of the extraction panel (Figure 19). Both a tensile opening and a compression strain associated with block rotation is experienced. The tensile opening (crack) becomes easily visible at the surface, where the compression strain is usually not clearly discernible.

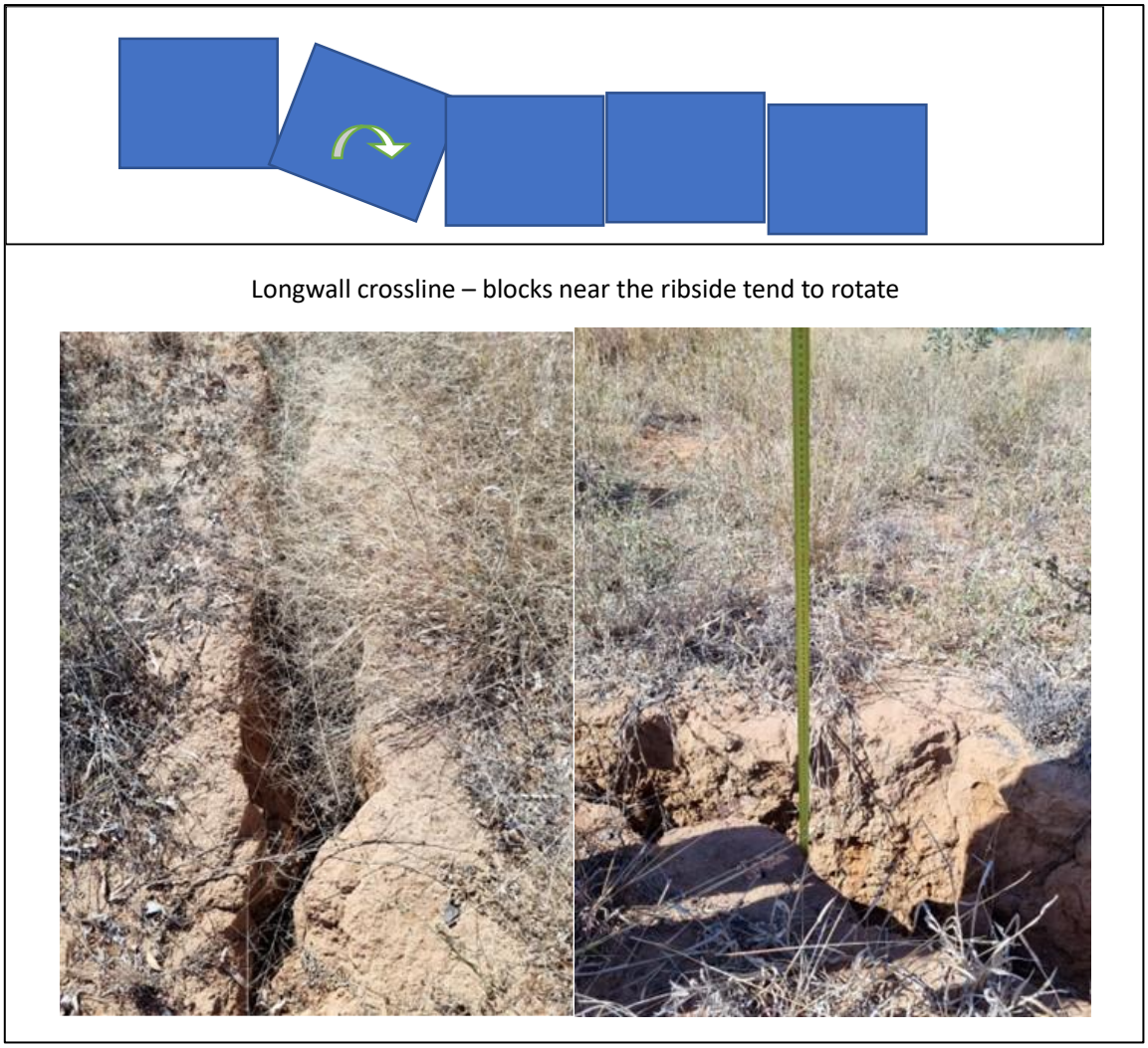
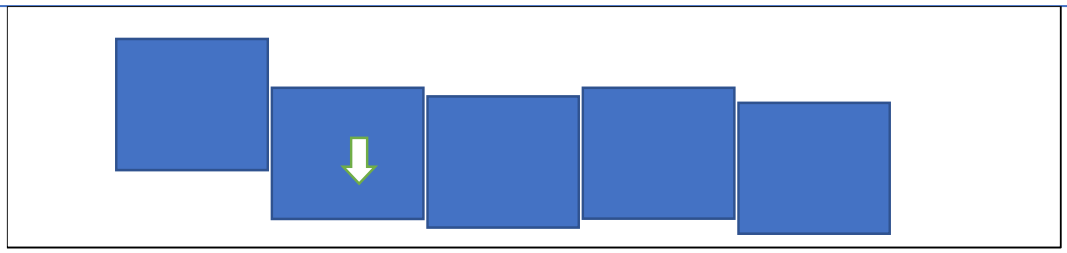


Figure 19 Mechanism and examples of rib parallel cracks.

The face-parallel deformations are related to periodic vertical collapse (Figure 20) with the collapse somewhat akin to the periodic weighting events experienced at the longwall mining face but at a much smaller scale. As the longwall face retreats the rocks near the surface may temporarily "hang up" but then collapse vertically. The roughness of the interface between the blocks will mean that the blocks will not match perfectly - hence the steps and some opening. As for the rib-parallel cracks, the face-parallel deformations will be apparent through the soil cover but may be ameliorated by rainfall.



Longwall centreline – blocks move downwards (and to a lesser degree sideways) at discrete intervals



Figure 20 Mechanism and examples of face parallel cracking.

Rehabilitation of rib-parallel cracks and face-parallel cracks near the longwall end lines is standard practice at mines in the Bowen Basin.

A reconnaissance survey of subsidence cracking was conducted in May 2023 by inspecting areas of predicted high visualised tensile strain that could be readily accessed on foot. Figure 21 shows the location of observed cracking relative to the visualised tensile strain and the surface geology.

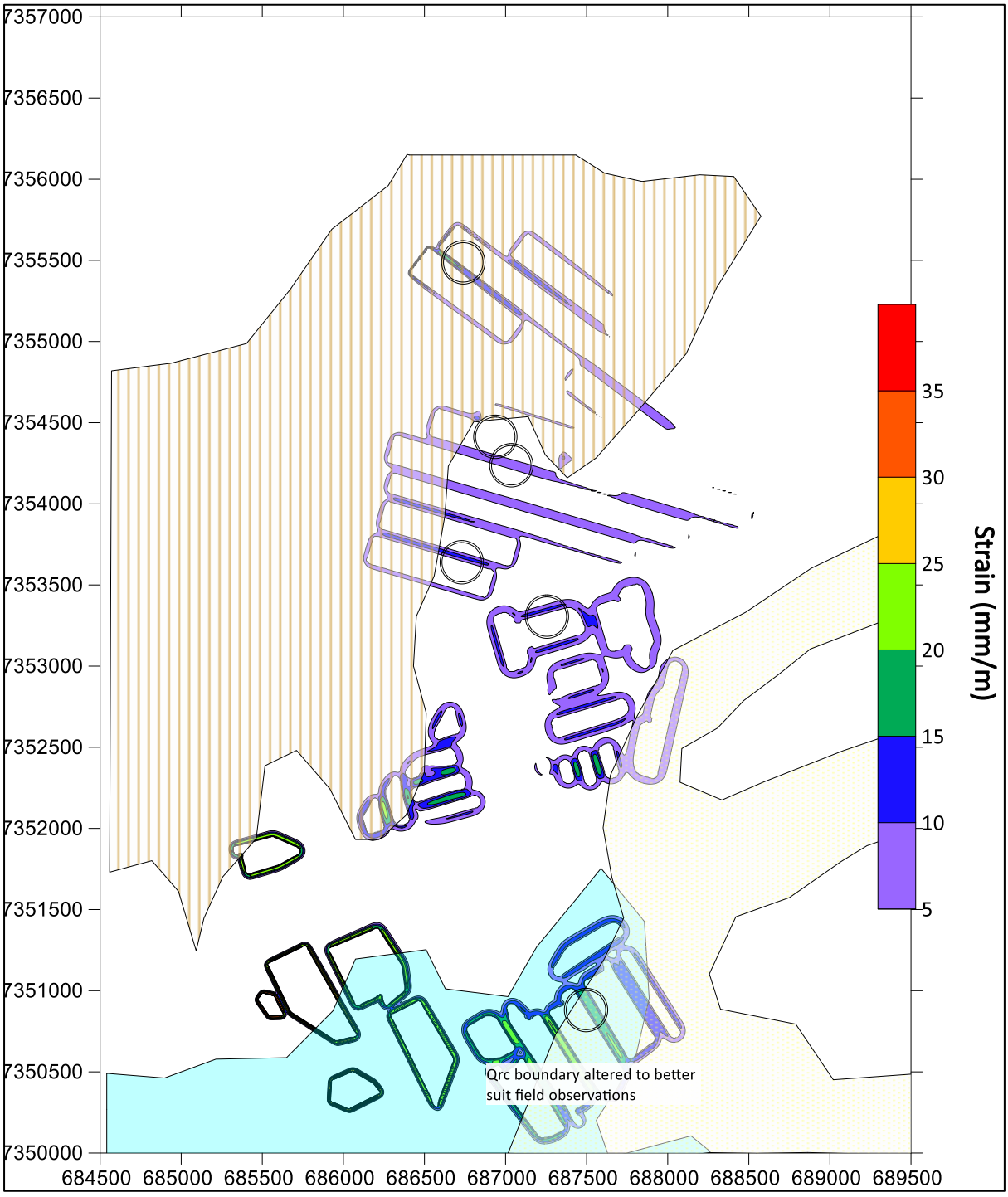


Figure 21 Location of sites inspected in May 2023 relative to the prediction of tensile strain and the surface geology (Qrc boundary moved to better represent observations).

The nature of the rib parallel cracking associated with both, longwall and pillar extraction show cracks up to 200 mm – 250 mm wide with depths sometimes in excess of 2 m.

It was observed during the inspection that the cracking does not appear to have adversely impacted vegetation growth. The mining was concluded in excess of 20 years ago but there is no obvious natural remediation of the cracking; this is attributed to the surface geology – duricrust (Czl) or sandstone/mudstones of the Emerald Formation (Czoem).

The surface above Laleham extraction panels where the surface geology appears to be Quaternary (Qrc) are shallow linear "trenches" which are interpreted to have been large tensile cracks that have "self-healed" over the years through rainfall and sediment migration. Note that the Qrc boundary presented in Figure 21 has been moved to reflect the observations made in May 2023.

5.4 Possibility of post-closure subsidence

Most of the workings in Laleham and Kenmare should now be in a stable condition given that the end of underground mining was more than 20 years ago. Figure 22 indicates the potential for additional vertical subsidence that may develop if additional pillars within the Laleham Aries seam workings collapse (Section 4.1).

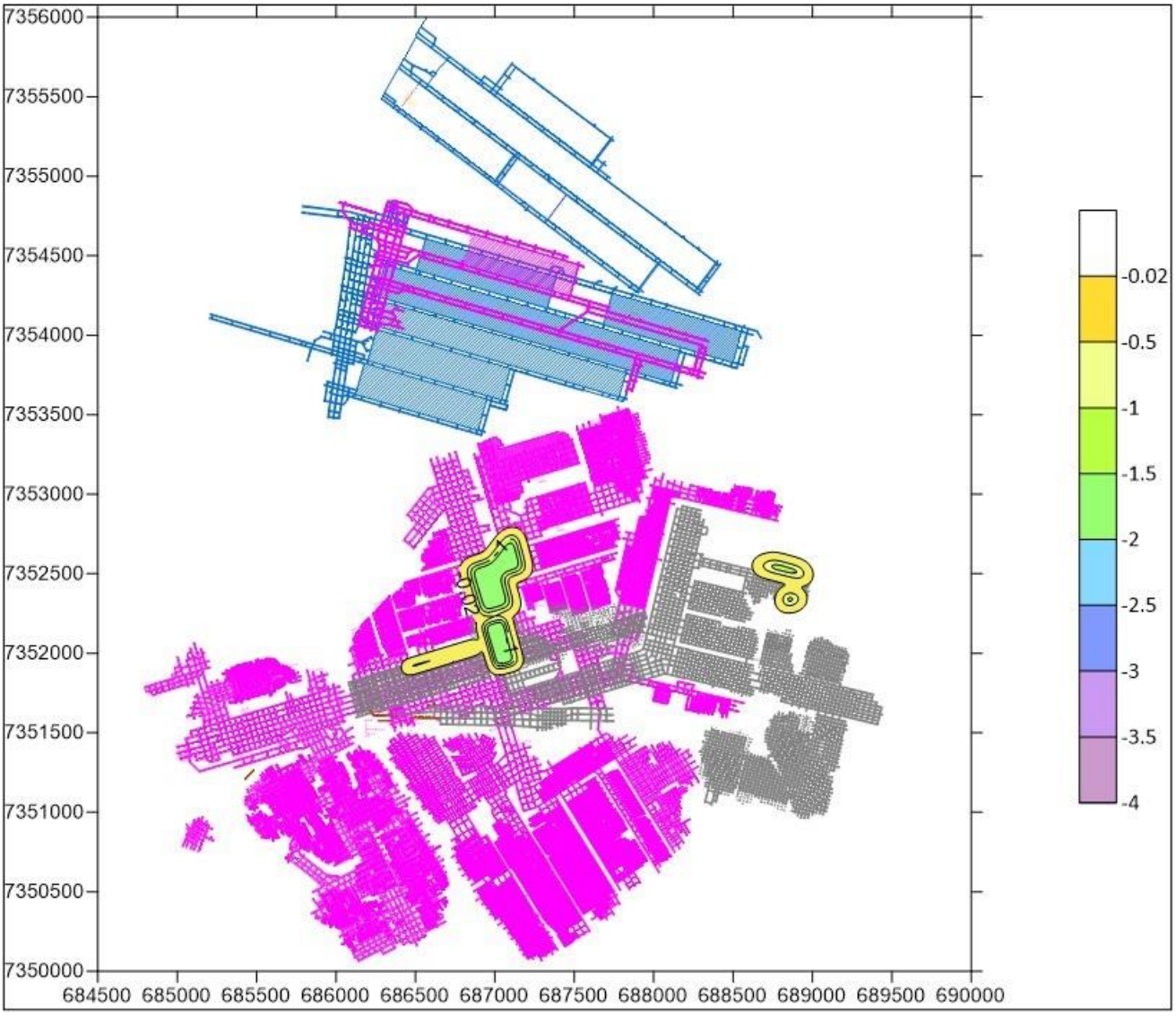


Figure 22 Possible additional subsidence if pillars collapse.

6 Groundwater

6.1 Current water level

In the first week of September 2023, the water level recorded in the pump hole at the inbye end of Kenmare 1 Aries Seam workings (Figure 23) was 21 m below the top of the casing and at an RL of 277.5 m. Assuming that the standing water level is horizontal and that the two seams are interconnected either by longwall caving or cross measure drifts, the standing water level is 3 m below and 37 m east of the Kenmare 1 portal. MB16 is located above the Laleham workings and the water level in this hole is 37.76m below the top of the casing indicating that these working are flooded. From a geotechnical perspective this means that any strength losses due to inundation have already developed and hence no hazard off additional collapses.

Kenmare K2 retreated into an existing surface mine void and there was no attempt to create a hydraulic seal between the surface and underground voids. The minimum separation between K1 and K2 is in the order of 18 m (at E687878, N7354266). It is assessed that K2 can be considered to be flooded.

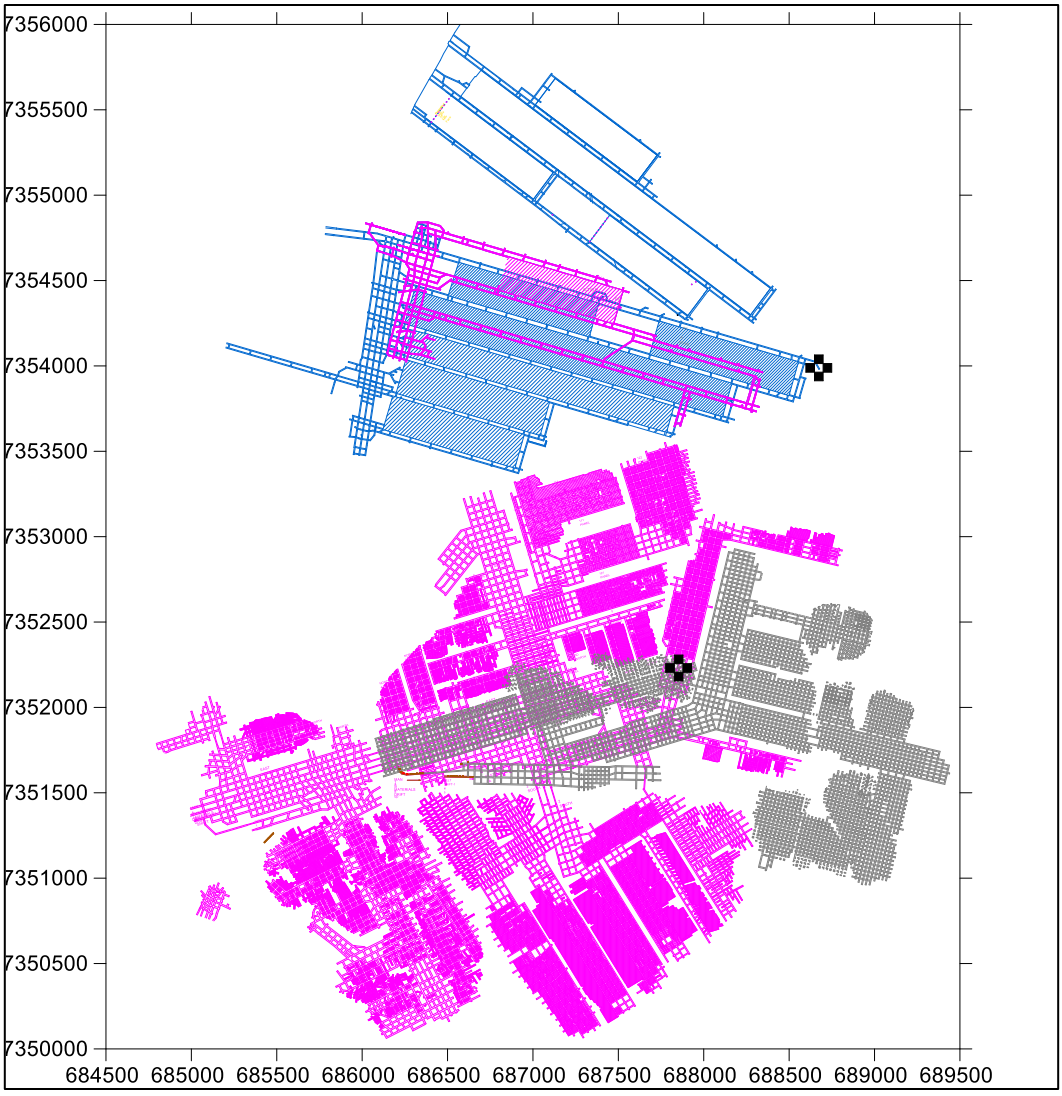


Figure 23 Location of holes monitoring groundwater in Laleham and Kenmare 1.

No standing water data is available for the Sirius Creek, Clutha or Ballamoo mines but it is assessed that they are now flooded to the regional groundwater level. It is noted that there is no pillar collapse hazard in these mines as they had no or very few pillars.

6.2 Flooding of undergrounds

Flooding an underground mine will result in the saturation of the bottom of the goaf (the Potential Consolidation or Caved Zone in Figure 24) and this will cause a softening of the fragmented immediate roof with consequent consolidation. This consolidation may be reflected in additional surface subsidence. Based on the discussion above, it is assessed that this softening and consolidation has already developed.

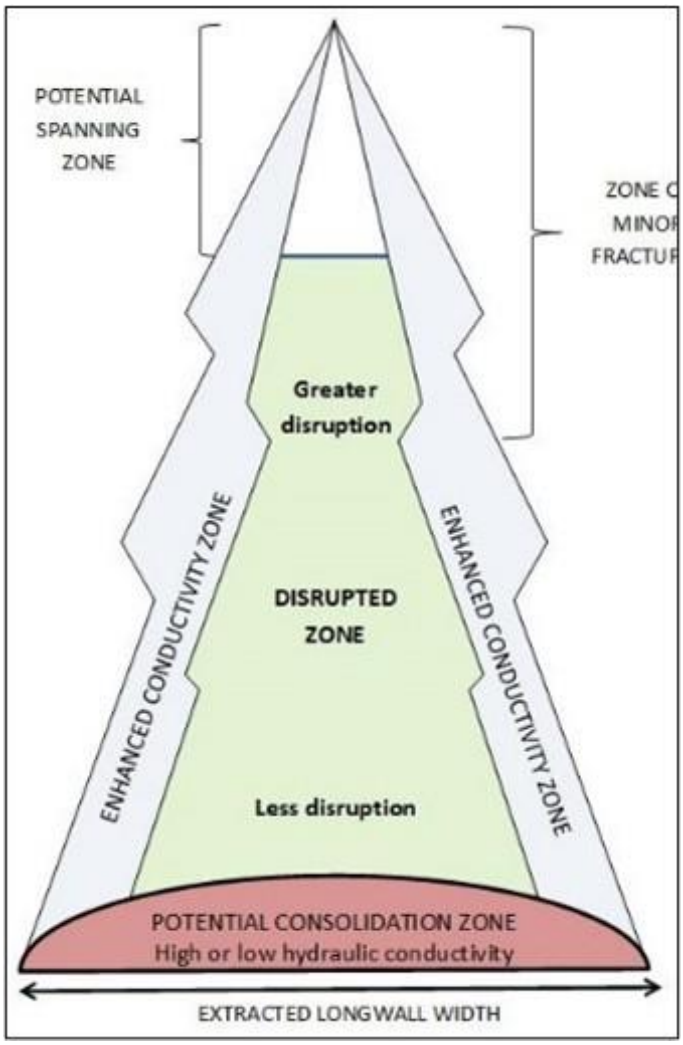


Figure 24 Framework of the geotechnical model for fracturing.

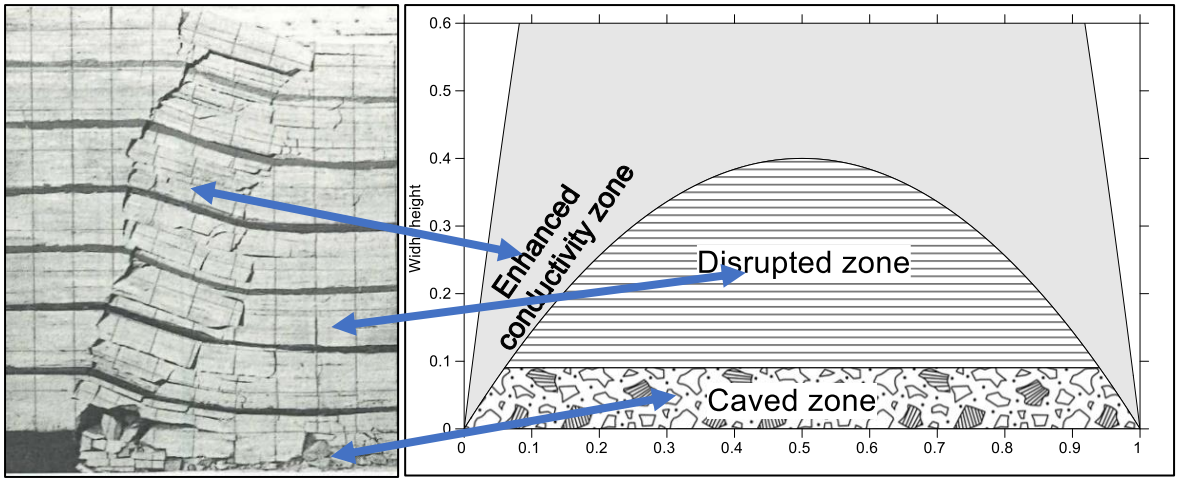


Figure 25 Physical and conceptual models for fracturing between seam and surface.

6.3 Hydraulic conductivity

Collapse or fracturing of the rock mass above the extracted coal is an intrinsic feature of extraction or longwall mining, except in some specific geological environments. Subsidence results in large scale fracturing of the overburden and subsequently, disruption to the overburden above the mined seam. This means that groundwater systems are unlikely to be returned to pre-mining condition. Importantly, if the differential surface subsidence above any extraction panel is in excess of about 500 mm there will be fracturing through to the surface.

Following work done at Crinum Mine, then owned by BMA in 2014, there has been a revision in the model for longwall fracturing and hydraulic conductivity. The largest changes in hydraulic conductivity are now recognised to be in the "Enhanced Conductivity Zones" (Figure 24 and Figure 25).The Impact on the overburden above the extracted area is not homogenous in its extents. An estimate of the resulting hydraulic conductivity (based on one scenario of how cracking develops in the overburden) is presented in Figure 26.

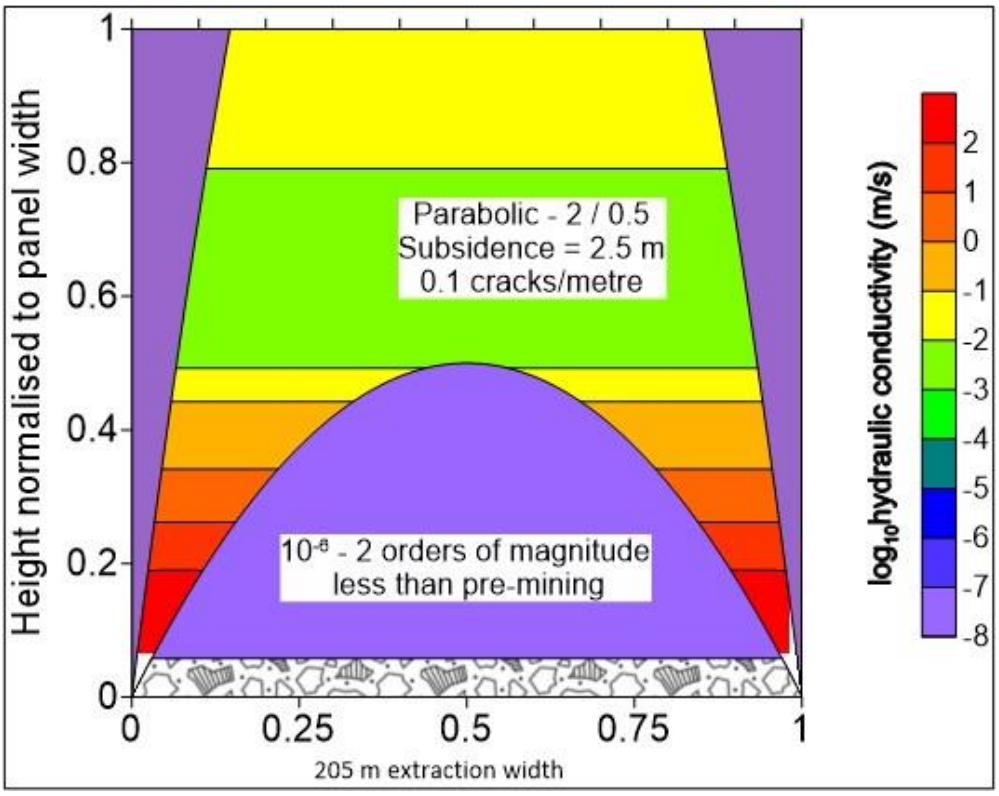


Figure 26 Hydrogeology model – fracturing.

7 Rehabilitation strategies

7.1 Rib parallel cracks

Up to 20 % of the subsided ground may be exposed to rib parallel cracks. Areas of high predicted tensile strain (Figure 21) indicate likely locations. Any cracking that has occurred in the Qrc surface geological will show evidence of self-healing, and no further subsidence or cracking is expected.

If rehabilitation is considered for the cracking in the non Qrc area, then earthworks to flatten the sides will be required or material will need to be imported. The general strategy of rehabilitation for this type of movement should be based on removing the slip/trip hazard at the surface by ripping/breaking the vertical faces to a 1 m depth and then compacting/grading (Figure 27). A nominal 3 m wide rounded gutter shape will result.

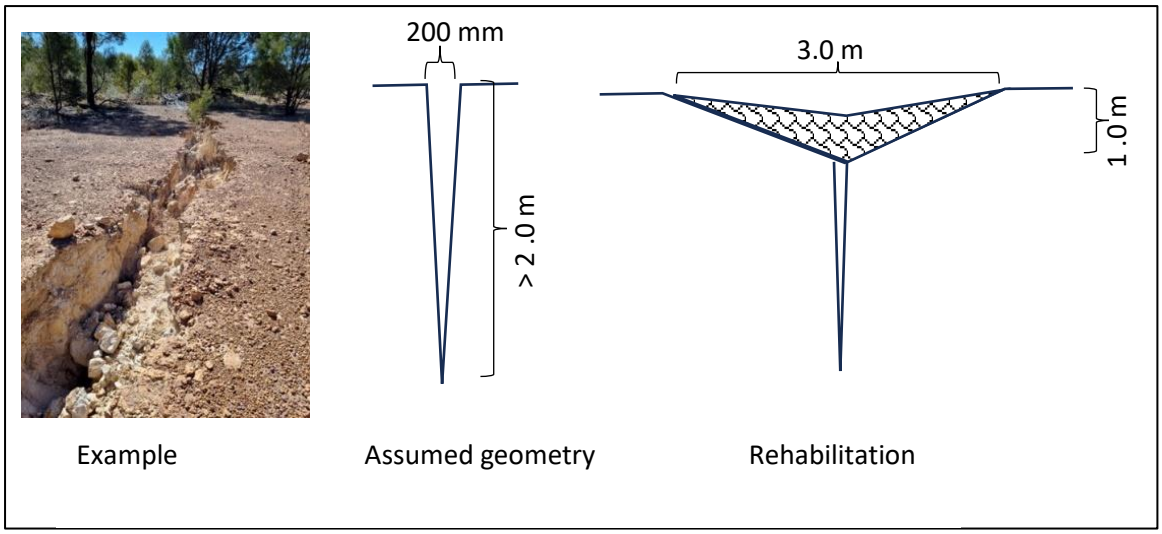


Figure 27 Schematic of general strategy to remove safety hazard associated with subsidence cracks in duricrust.

7.2 Face parallel or arcuate cracking

Face parallel cracking was not observed during the site reconnaissance. It should be assumed that these cracks may be present where the surface subsidence is greater than 2.0 m (Figure 28).

Rehabilitation would be to remove the edge with a grader or similar.

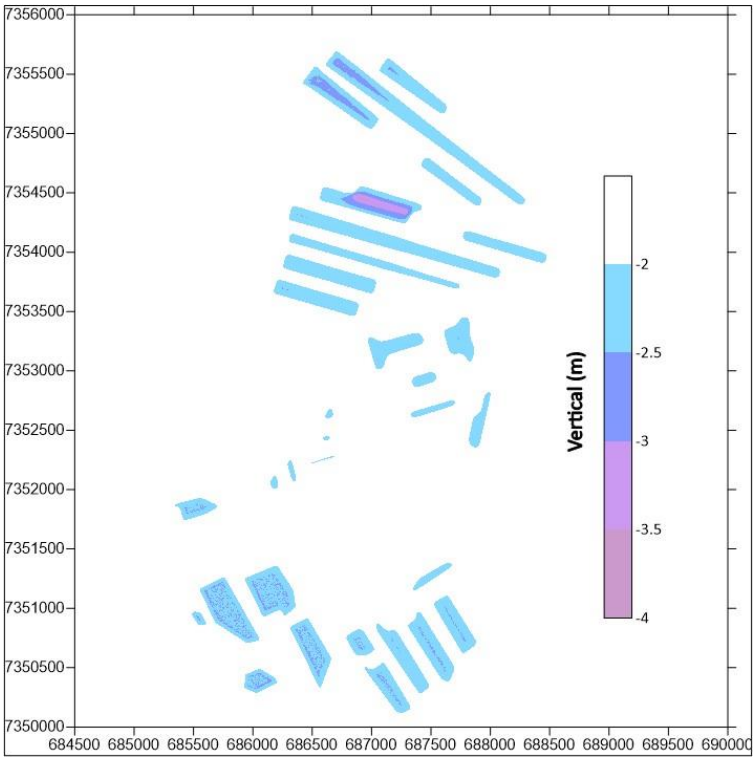


Figure 28 Possible areas of face parallel subsidence fractures in the Kenmare and Laleham areas as defined by subsidence greater than 2.0m.

7.3 Seals and Bulkheads

Mine seals are used to manage or limit water and gas flows as well as to control physical access to parts of the mine.

7.3.1 Kenmare 1

The Statutory Mine Plan (Plan of Abandonment) submitted to the Mines Department in 2001 shows seals at about 142 m from the portal entrance in both the "Man & Materials" & "Conveyor" drifts. A survey of the "Man & Materials" drift that was conducted on 19th of October 2023 showed that the drift has filled (floor to roof) with silt to a distance of about 70m from the entrance (Figure 29).

The current landform designs for closure of the surface mine has the Kenmare pit backfilled to surface.

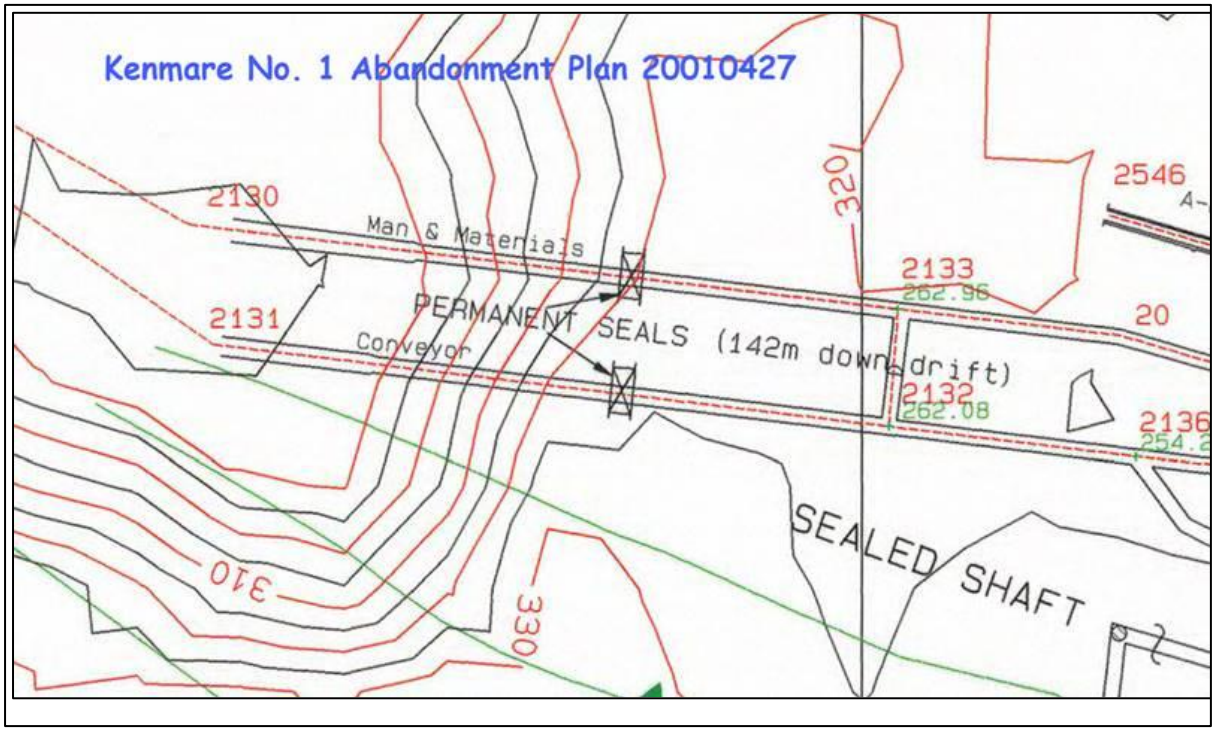


Figure 29 Kenmare Aries portal.

7.3.2 Kenmare 2

Kenmare 2 retreated the longwall face into an existing surface excavation which has since been incorporated into the surface operation.

7.3.3 Laleham

The Laleham portals have been either dozed-in or dumped-over.

7.3.4 Sirius Creek No 1

Sirius Creek No 1 was closed soon after opening and the portal entries are not visible. Re-excavation is not recommended. The current surface should be regraded and revegetated.

7.3.5 Sirius Creek No 2

Permanent seals appear to have been installed at about 1150m from portal entrance in both the Man & Materials and Conveyor drifts. The symbols appear to indicate an "Explosion Proof Stopping" on the statutory mine plans submitted to the Mines Department in 1976.

There has been a recent collapse at the Sirius Creek # 2 portal. It is assessed that timber lagging bords and/or the steel arches have deteriorated over time and a pothole has developed

A solution for closure would be to excavate the steel arches and lagging bords and backfill with a coarse-grained fill. An indicative specification would be:

- UCS>30 MPa
- 150 mm topsize
- 20 mm minimum size
- free draining
- not acid forming.

It is noted that a potential for remote installation of a grout seal may be required. This is also relevant for Clutha below.

7.3.6 Clutha

The Clutha portal is located at the outcrop of the Aries Seam. It was a single entry only, approximately 80 m long. Recommendations for closure include removal of the arches and lagging bords and then backfill using fill sourced from the immediate area.

7.4 Shafts

The main ventilation shaft for Kenmare 1 is annotated as sealed on the statutory mine abandonment plan and there is a plaque glued to the concrete plug on top of the shaft (Figure 30).



Figure 30 Kenmare 1 ventilation shaft.

Shafts should be fully backfilled with any locally sourced material. The shaft collar should be removed to allow removal of weathered/soil like material and then backfilled and compacted.

7.5 Exploration Holes

All open exploration holes previously completed as part of the exploration works of the mine development will require, as per legislation, the hole to be located, the casing to be removed and the hole to be cleaned out and grouted to surface.

7.6 Underground service holes (drop holes, pump holes)

Open holes to surface that are not defined as geological in nature will also need to be grouted to surface and sealed. All mine plans should be reviewed for these holes to ensure that no open access to the underground workings is maintained at closure.

8 Mine Closure Requirements

Mine subsidence results in permanent changes in the relative level of the surface and the generation of small-scale disruptions to the surface (cracks, steps, and humps).

The tensile cracks and steps discussed in Section 8 present a hazard to fast moving vehicles and possibly to wildlife. Over time there would be a lesser hazard if the surficial geology allows “self-healing” during rainfall events but where there are duricrusts or rock exposures the hazards will continue to exist for an unspecified duration.

Specific rehabilitation strategies should only be developed after an appropriate risk assessment is conducted based on the final land use and its impacts.

9 Monitoring

No further monitoring of the undergrounds at Blackwater Mine is recommended once it is established that the mines are flooded.

Where flooding has not occurred, there is potential for an additional subsidence of up to 250 mm; this is unlikely to change the current surface conditions.

Monday, 18 August 2025

REF: Blackwater - 05

Sahar Donner,
Superintendent – Group Approvals,
Whitehaven Coal Limited,
Level 31, 12 Creek Street,
Brisbane, Queensland 4001.

Dear Sahar,

Re: Auguring Ramp 8.

In an email dated 8 August 2025, you supplied more details of some auguring conducted by South Blackwater Mine in Ramp 8 (Figure 1). Their location indicates that this augering was not highwall augering as it is understood nowadays but was conducted for other purposes early in the pit development – possibly to obtain large samples for coal quality testing.

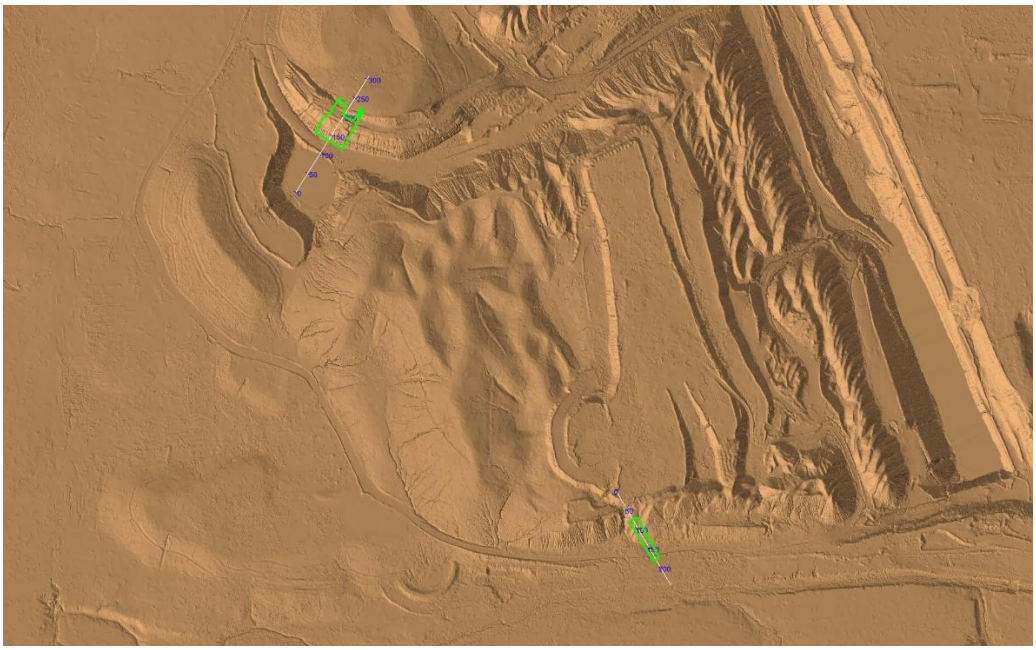


Figure 1 Location of augering in Ramp 8 - in access ramp or side wall, not highwall

Your surveyors and mine planners have determined that the augering was conducted at about 25 m – 30 m below the pre-mining surface and hence very early in the mining operation. The augering was in the Pollux Seam. The geometry of the 2 areas is summarised below.

RLs	Floor of coal	Top of coal	Premining topo	Current max topo
Northern R82	247.1	250.6	283.7	302.1
Southern R84S	224.2	229.0	260.4	289.7

Figure 2 is the R82 area reproduced at a larger scale. I interpret the steps and peaks in the green line as indicating the extent of each auger and this indicates that the augers were located at 4.5 m centres. Given the likely age of the augering, I assess that the auger diameter would have been 1.2 m.

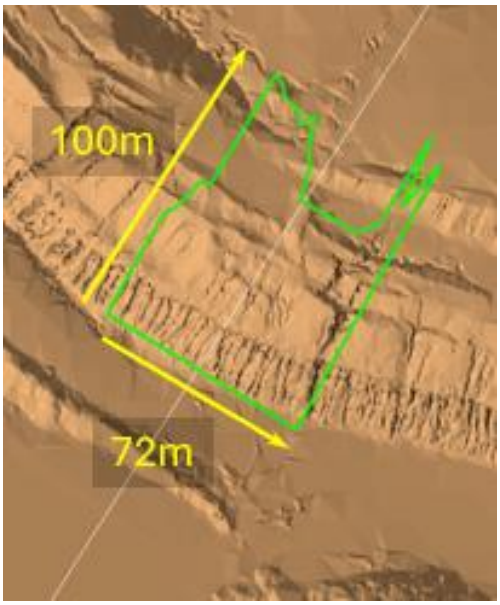


Figure 2Enlargement of the R82 area

A simple geotechnical model for "pillar stability" is shown in Figure 3. The coal "pillars" would be 1.2 m high and 3.3 m wide and the maximum depth is now 50-60m. Stability analysis indicates a pillar strength of 8.5 MPa and a pillar load of 2 MPa giving a factor of safety in excess of 4. Collapse of the auger holes themselves would induce bulking in the immediate overburden such that caving would progress to a maximum of about 5 m above the base of the auger.

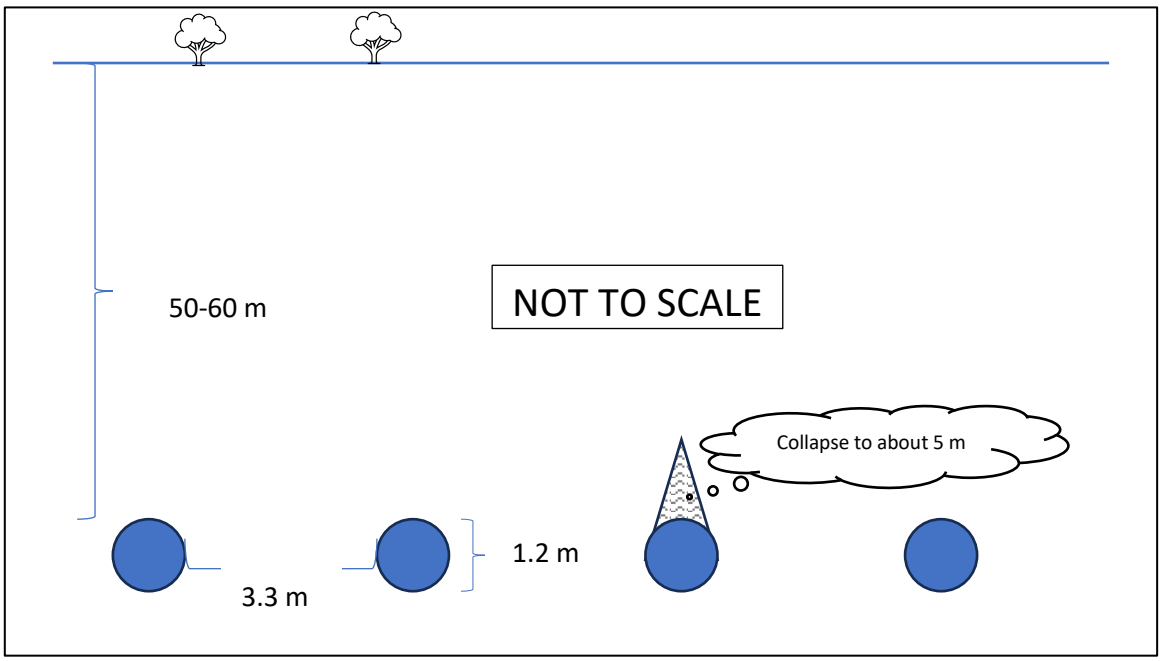


Figure 3 Geotechnical model for stability of the augering.

On the basis of these comments, I make the following assessments

1. The auguring in Ramp 8 was not highwall augering – it was not in a highwall and was not designed for high resource recovery.
2. The auger layout involved holes at 4.5 m centres resulting in high levels of overall stability.
3. Any collapse of the auger holes will extend to a maximum of 5 m height.

From this I conclude that this augering does not present a surface subsidence hazard for mine closure.

Yours truly



Ross Seedsman
FAusIMM, CP, RPEQ.

Prepared for Blackwater Coal Mine (BWM)

Blackwater Coal Mine Underground Mining Surface Cracks and Sinkholes: Assessment of Impacts to Vegetation and Habitat



Final 20/11/2025

LYNGCO ENVIRONMENTAL CONSULTING

DOCUMENT VERSION HISTORY

Project Name	Blackwater Coal Mine Underground Mining Surface Cracks and Sinkholes: Assessment of Impacts to Vegetation and Habitat
Project Number	WHC028
Project Manager	Steve Lyngcoln
Report Authors	Laura Harms
Version - Date	Final – 20/11/2025

INTENDED USE: Lyngco Environmental Consulting (LEC) has prepared this report for Blackwater Coal Mine (BWM) to determine if surface cracks caused by subsidence have had a significant impact to vegetation and habitat in areas of historic underground mining. Information and recommendations contained herein are purpose and project specific and LEC accepts no liability for the use or interpretation of any information contained in this report for any other purposes other than intended.

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EXECUTIVE SUMMARY

The purpose of this Blackwater (BWM) underground mining surface cracks assessment is to provide a field-based technical assessment of the potential impacts to vegetation and habitat from surface cracks and sinkholes as a result of subsidence from historical underground mining on BWM in response to a request for more information (RFI) from the Department of the Environment, Tourism, Science and Innovation (DETSI).

The approach to the assessment included an initial desktop analysis followed by field surveys comparing the vegetation and habitat value of sites affected by subsidence surface cracks, and nearby reference sites in the same regional ecosystems. Vegetation and habitat value included vegetation structure and composition, remnant status of vegetation, and habitat suitability for fauna and flora, including species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Nature Conservation Act 1992* (NC Act).

This assessment found no evidence of significant impacts to vegetation or fauna habitat due to subsidence cracking or sinkholes. One site (Crack 11) had evidence of minor canopy tree dieback that was potentially associated with the subsidence crack. A tertiary vegetation assessment (Cr11Ter) confirmed that any impact to tree canopy cover did not affect the remnant status of the vegetation (refer Table 15).

Bertya opponens (Vulnerable under the EPBC Act) was identified at most subsidence sites associated with remnant or high value regrowth (HVR) vegetation (refer Table 16). Potential habitat was also present at many sites (refer Table 16) for the following fauna:

- Squatter pigeon (*Geophaps scripta scripta,* Vulnerable under the EPBC and NC Acts)
- Yakka skink (*Egernia rugosa*, Vulnerable under the EPBC and NC Acts)
- Short-beaked echidna (*Tachyglossus aculeatus*, Special Least Concern under the NC Act).

Habitat suitability for these fauna was not affected by subsidence cracking or sinkholes.

From an ecological standpoint, amelioration of subsidence-caused cracking and sinkholes is not recommended. If BWM decides to undertake amelioration of cracks for geotechnical or safety reasons, a Significant Impact Assessment (SIA) would be required for all sites containing *Bertya opponens.* Refer to Table 16 for specific recommendations for each site.

DEFINITIONS AND ABBREVIATIONS

Acronym Term	Definition
BWM	Blackwater Coal Mine
DETSI	Department of Environment, Tourism, Science and Innovation
EDL	Ecologically Dominant Layer
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
HVR	High Value Regrowth
LEC	Lyngco Environmental Consulting
MNES	Matter of National Environmental Significance
MSES	Matter of State Environmental Significance
NC Act	*Nature Conservation Act 1992*
RE	Regional Ecosystem
RFI	Request For Information
SIA	Significant Impact Assessment

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Table 18: Fauna species recorded within the Survey Area. 41

1. Introduction and Purpose

The purpose of this Blackwater (BWM) underground mining surface cracks assessment is to provide a field-based technical assessment of the potential impacts on vegetation and habitat from surface cracks and sinkholes as a result of subsidence from historical underground mining on BWM in response to a request for more information (RFI) from the Department of the Environment, Tourism, Science and Innovation (DETSI).

The approach to the assessment included an initial desktop analysis followed by field surveys comparing the vegetation and habitat value of sites affected by subsidence surface cracks, and nearby reference sites in the same regional ecosystems. Vegetation and habitat value included vegetation structure and composition, remnant status of vegetation, and habitat suitability for fauna and flora, including species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Nature Conservation Act 1992* (NC Act). The 'Survey area' refers to all areas identified via desktop analysis as potential surface cracks and/or sinkhole areas as provided to LEC by BWM.

Table 1 summarises the surface crack sites, sinkhole sites and reference sites and their corresponding regional ecosystems. Note that the sinkhole site should be considered a potential sinkhole, however further geotechnical assessment would be required to discern if this site is a sinkhole or excavated pit. Figure 1 depicts the Survey area including the historic underground mining footprint.

Table 1: Summary of subsidence, reference and mapped subsidence sites and corresponding regional ecosystems.

Feature ID	Regional ecosystem and condition
Reference sites	
Reference Site 1	11.7.2 Remnant
Reference Site 2	11.7.6 Remnant
Field-verified subsidence crack or sinkhole	
Potential Sinkhole 1	11.7.2 High Value Regrowth
Crack 1	Non-remnant
Crack 2	Non-remnant
Crack 3	11.7.2 Remnant
Crack 4	Non-remnant
Crack 5	11.7.2 Remnant
Crack 6	11.7.2 Remnant
Crack 7	11.7.2 Remnant
Crack 8	11.7.2 Remnant
Crack 9	11.7.2 Remnant
Crack 10	11.7.2 Remnant
Crack 11	11.7.2 Remnant

Feature ID	Regional ecosystem and condition
Crack 12	Non-remnant
Crack 12b	11.7.2 High Value Regrowth
Crack 13	Non-remnant
Crack 14	11.7.6 Remnant
Crack 15	11.7.2 Remnant
Crack 16	11.7.2 Remnant
Crack 17	11.7.2 Remnant
Crack 18	11.7.6/11.7.2 Remnant
Crack 19	11.7.2 Remnant
Crack 20	11.7.2 Remnant
Crack 21	11.7.2 Remnant
Crack 22	11.7.2 High Value Regrowth
Crack 23	11.7.2 High Value Regrowth
Crack 24	11.7.2 High Value Regrowth
Crack 25	11.7.2 Remnant
No field evidence of subsidence crack or sinkhole	
Mapped Crack 1	11.7.2 High Value Regrowth
Mapped Crack 2	11.7.2 Remnant
Mapped Crack 3	11.7.2 Remnant
Mapped Crack 4	11.7.2 Remnant
Mapped Crack 5	11.7.2 Remnant
Mapped Crack 6	11.7.2 Remnant

Figure 1: Survey Area Overview.

685000

690000

7360000

7355000

7350000

ML 1862

ML 1762

ML 1792

ML 1812

ML 70091

ML 1773

ML 1771

ML 1772

ML 1767

ML 1860

ML 1829

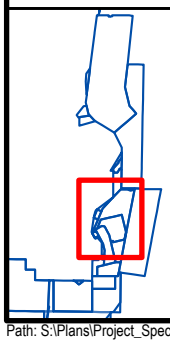
GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 200 400 600 800 1,000

m



- BWM Mining Lease
- Area of Interest
- Kenmare
- Laleham

LYNGCO ENVIRONMENTAL CONSULTING

Drawn By:	C Schlebusch
Requested by:	S Lyngcoln
Date:	10/09/2025

Figure 1

Overview

RTPL_LE_BMRM001_WHC028_MAP0002_A

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2. Methods

2.1. Appropriately qualified persons

The desktop and field assessments were undertaken by two appropriately qualified persons (AQP) - Principal Ecologist Stephen Lyngcoln and Graduate Ecologist Laura Harms. Their experience and roles within the assessment are summarised below in Table 2.

Table 2: Appropriately qualified persons.

Ecologist and Role	Experience
• Steve Lyngcoln – Vegetation and flora field assessment – Report review	Steve has over 20 years' experience in environmental management in Queensland including experience specialising in terrestrial ecology. Steve specialises in vegetation ecology including survey and mapping of regional ecosystems and threatened ecological communities, threatened flora surveying and mapping, rehabilitation monitoring, revegetation planning and management, environmental offsets planning and management. Steve has over 15 years specific experience working in the coal mining industry for coal mining companies working on several coal mine environmental impact assessments, undertaking rehabilitation monitoring and has prepared a number of associated rehabilitation plans and offset strategies. He has formal postgraduate qualifications with a Master of Environmental Science from the University of New England (UNE) specialising in vegetation ecology and ecosystem rehabilitation.
• Laura Harms – Desktop assessment – Fauna field assessment – Report writing	Laura is a Graduate Ecologist. She holds a Bachelor of Advanced Science (First Class Honours) majoring in Ecology from the University of Queensland. Laura has a well-rounded base of experience in terrestrial ecology and has worked on projects ranging from Significant Impact Assessments and Rehabilitation Monitoring Reports for mining clients, to pre-clear habitat assessments for civil construction clients. Laura has experience with various flora and fauna monitoring methods, including BioCondition surveys, camera trapping, acoustic monitoring, live trapping and active searches.

2.2. Survey timing

The field assessment was undertaken in fine environmental conditions and weather on the 4th and 5th of September 2025. Due to the size and scope of the survey, habitat assessments and opportunistic fauna surveys were utilised in the field assessment. No fauna trapping, camera trapping or extended fauna survey techniques were employed during the field assessment.

2.3. Desktop assessment

Desktop assessments included searches of the following databases:

- EPBC Act Protected Matters Search Tool, to identify MNES relevant to the Proposed action within a search area extending 15 km from the Survey area (DCCEEW, 2025)
- MSES and Regional Ecosystems reports (DETSI, 2025)
- Queensland WildNet Database (DETSI, 2025)
- Atlas of Living Australia (ALA, 2025)
- Vegetation management Regional Ecosystem map (versions 11 and 12) to identify vegetation communities and fauna habitats that are likely to occur (DoR, 2024)
- Regional Ecosystem (Queensland Herbarium 2019) and Broad Vegetation Group (BVG) descriptions (Neldner, et al., 2023)

2.4. Field assessment

The field assessment comprised of:

- 32 Quaternary level vegetation assessment sites (Neldner, et al., 2023)
- 4 Tertiary level vegetation assessment sites – 2 reference sites and 2 subsidence sites (V.J. Neldner, 2022)
- 36 habitat assessments
- Opportunistic searches for Endangered, Vulnerable and Near Threatened (EVNT) flora and fauna species.

The reference sites were located on areas of BWM outside the footprint of underground mining, in corresponding regional ecosystems to those of the subsidence sites. Tertiary level vegetation assessments (Neldner, et al., 2023) were conducted at reference sites, as well as subsidence sites with evidence of tree dieback where a more comprehensive assessment was required to determine any effect on canopy cover and the remnant status of the vegetation. The survey effort undertaken within the Survey area is illustrated in Figure 2.

2.5. Ground-truthed regional ecosystem mapping

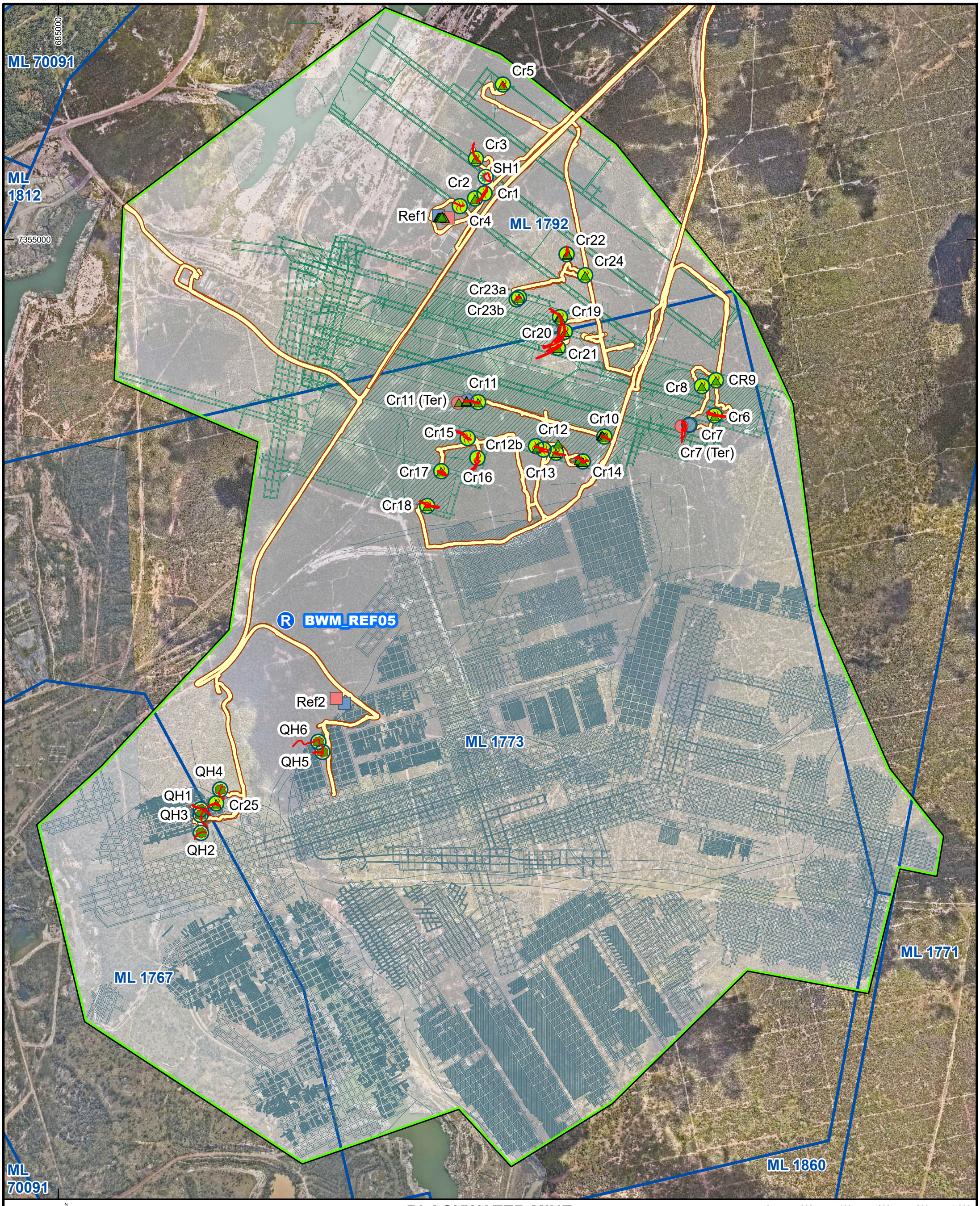
Ground-truthed regional ecosystem mapping was developed within the AOI using the following datasets and methods:

- Initial ground-truthed regional ecosystem was updated based on field survey results from Quaternary and Tertiary site data associated with sites that were cracking and adjacent areas not affected (refer Section 3.2)
- Non-remnant areas were defined using the latest BWM disturbance data
- The initial ground-truthed regional ecosystem mapping was intersected with the BWM disturbance layer to give one dataset where each area contains the BWM disturbance attributes and the ground-truthed regional ecosystem attributes.

- The ground-truthed regional ecosystem mapping condition was changed based on the Disturbance attribute.

It is important to note the ground-truthed regional ecosystem mapping was developed for the purpose of comparing areas impacted by cracking versus adjacent areas not affected by cracking. Additional survey effort and additional mapping using up-to-date imagery would be required to develop a more detailed ground-truthed regional ecosystem map for the entire AOI.

Figure 2: Survey Effort.



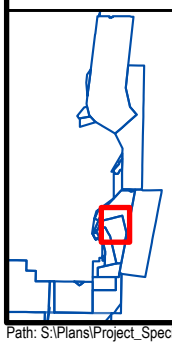
GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 200 400 600 800 1,000

m



- BWM Mining Lease
- Area of Interest
- Kenmare
- Laleham
- Recorded Track
- BWM Rehab. Monitoring Reference Site
- Crack / Sinkhole
- Fauna Habitat Assessment Site
- *Bertya opponens* sighting
- Quaternary Habitat - Cracks observed
- Quaternary Habitat - No cracks observed
- Quaternary Habitat - Sinkhole observed
- Reference Site - Start
- Reference Site - End
- Tertiary Site - Start
- Tertiary Site - End

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Requested by: S Lyngcoln

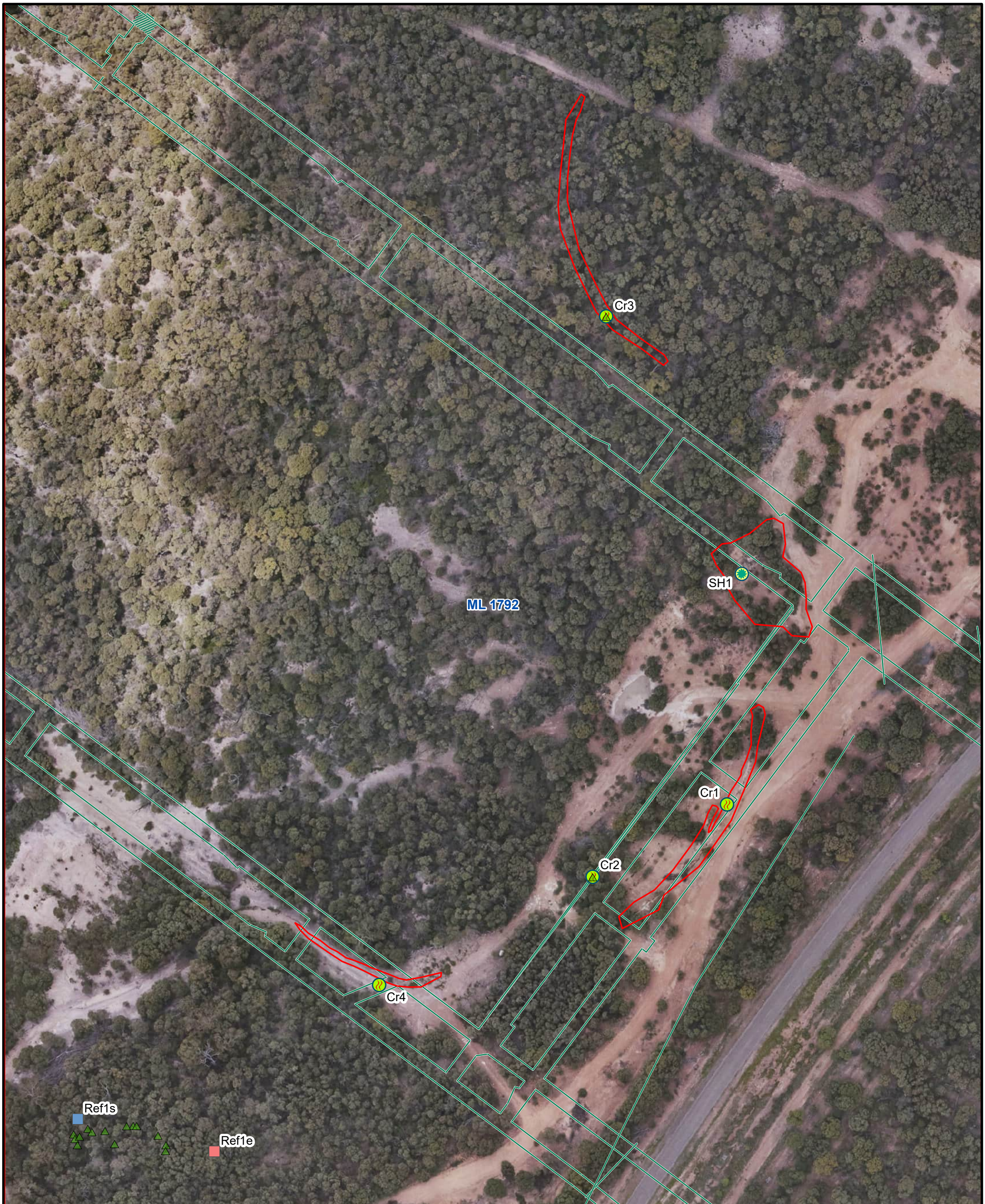
Date: 26/09/2025

Figure 2

Survey Effort

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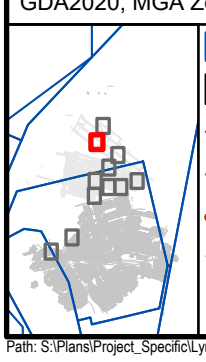


GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 10 20 30 40 50
m



- BWM Mining Lease
- Area of Interest
- Kenmare
- Laleham
- Recorded Track
- Crack / Sinkhole
- Fauna Habitat Assessment Site
- *Bertya opponens* sighting
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- Reference Site - Start
- Reference Site - End
- Tertiary Site - Start
- Tertiary Site - End

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Drawn By:	C Schlebusch
Requested by:	S Lyngcoln
Date:	20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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ML 1792

Cr5

GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 10 20 30 40 50

m

BWM Mining Lease
Area of Interest
Kenmare
Laleham
Recorded Track
Crack / Sinkhole

Fauna Habitat Assessment Site
Bertya opponens sighting
Quaternary Habitat - Cracks observed
Quaternary Habitat - No cracks observed
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Reference Site - Start

Reference Site - End
Tertiary Site - Start
Tertiary Site - End

LYNGCO ENVIRONMENTAL CONSULTING

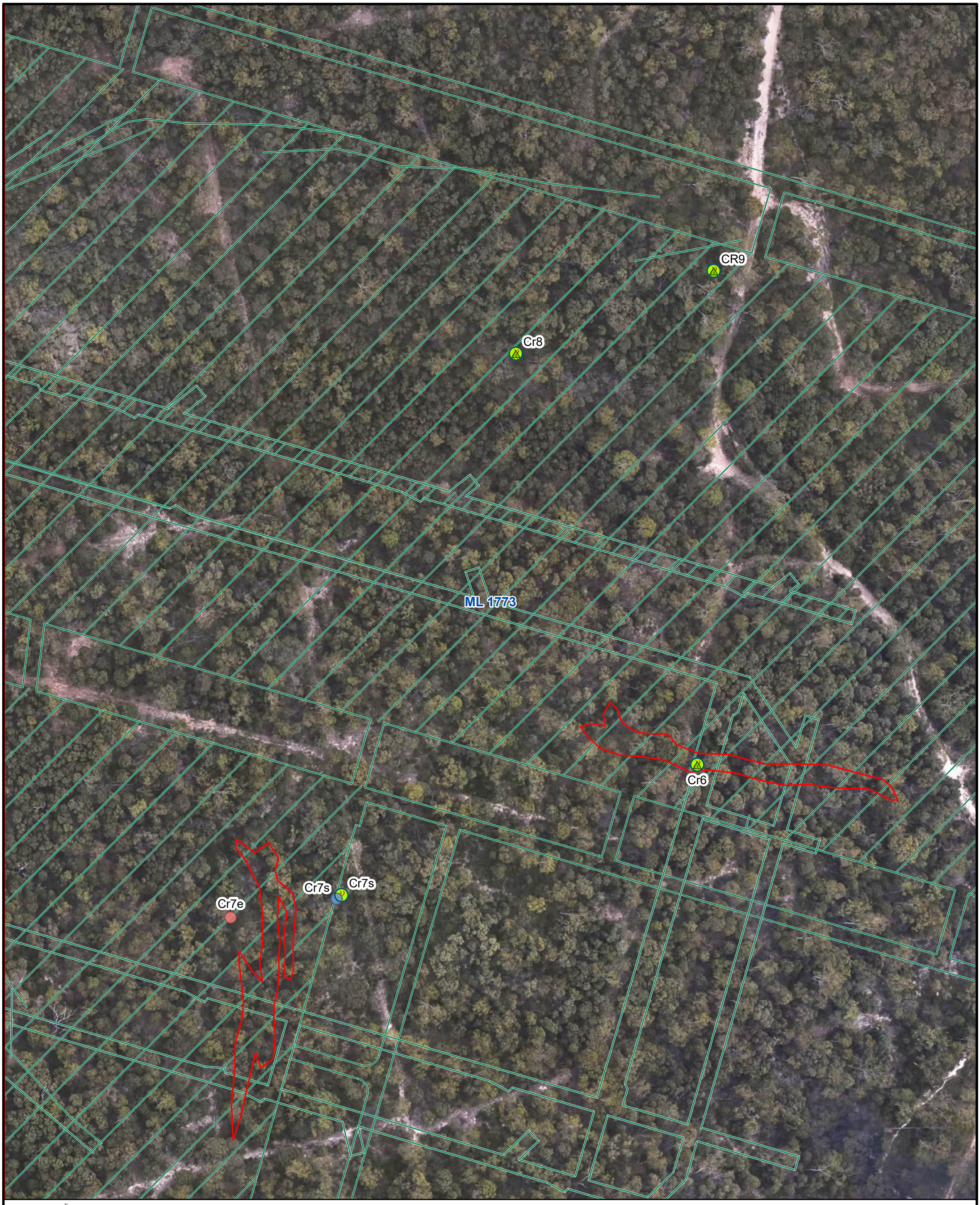
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Requested by:	S Lyngcoln
Date:	20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 10 20 30 40 50
m

BWM Mining Lease
Area of Interest
Kenmare
Laleham
Recorded Track
Crack / Sinkhole

Fauna Habitat Assessment Site
Bertya opponens sighting
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Tertiary Site - End

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Requested by: S Lyngcoln
Date: 20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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ML 1773

Cr10

Cr14

GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

0 10 20 30 40 50

m

BWM Mining Lease
Area of Interest
Kenmare
Laleham
Recorded Track
Crack / Sinkhole

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Reference Site - End
Tertiary Site - Start
Tertiary Site - End

LYNGCO ENVIRONMENTAL CONSULTING

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Requested by: S Lyngcoln

Date: 20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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ML 1773

Cr12b

Cr12

Cr13

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 10 20 30 40 50
m

BWM Mining Lease
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Kenmare
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Figure 2b

Survey Effort
Crack and Sinkhole Detail

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ML 1792

Cr11s

Cr11

Cr11e

ML 1773

Cr15

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 10 20 30 40 50

m

BWM Mining Lease
Area of Interest
Kenmare
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Date: 20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 10 20 30 40 50
m

BWM Mining Lease
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LYNGCO ENVIRONMENTAL CONSULTING

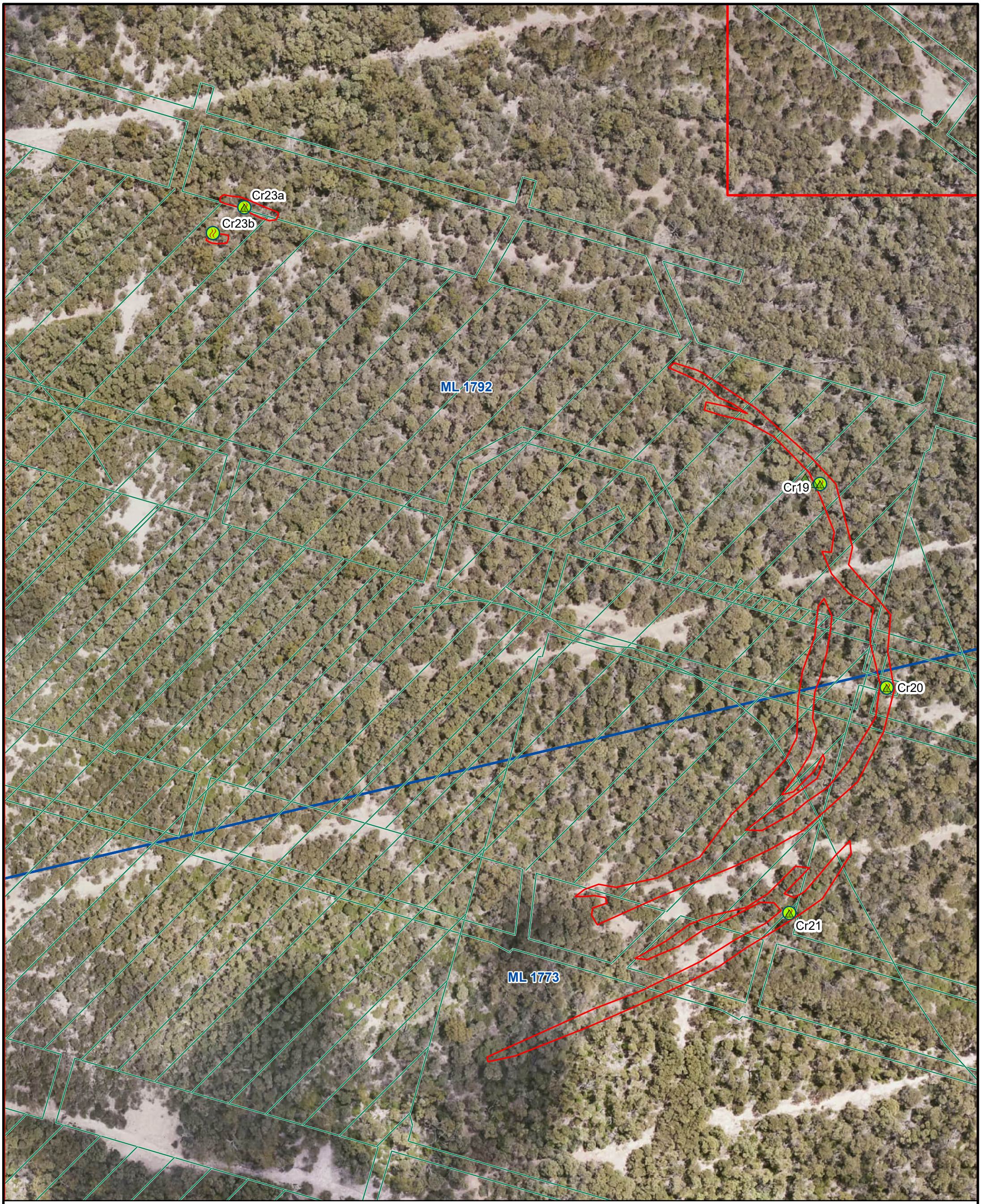
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Requested by: S Lyngcoln
Date: 20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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GDA2020, MGA Zone 55

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

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Cr22

ML 1792

Cr24

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

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Figure 2b

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Crack and Sinkhole Detail

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QH4

ML 1773

Cr25

QH1

QH3

ML 1767

QH2

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 10 20 30 40 50

m

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LYNGCO ENVIRONMENTAL CONSULTING

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Requested by: S Lyngcoln

Date: 20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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GDA2020, MGA Zone 55

BLACKWATER MINE

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LYNGCO ENVIRONMENTAL CONSULTING

Drawn By:	C Schlebusch
Requested by:	S Lyngcoln
Date:	20/11/2025

Figure 2b

Survey Effort
Crack and Sinkhole Detail

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3. Results

3.1. Desktop results

Database searches returned the following MNES and MSES as having been previously recorded or having the potential to occur within 15 km of the Survey area (see Appendix A).

- 35 MNES threatened and/or migratory fauna species
- 1 MSES special least concern fauna species (*Tachyglossus aculeatus*, short-beaked echidna)
- 11 MNES threatened flora species
- 2 MSES threatened flora species
- 6 Threatened Ecological Communities (TECs), including:
  - Weeping Myall Woodlands
  - Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin
  - Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions
  - Poplar Box Grassy Woodland on Alluvial Plains
  - Brigalow (*Acacia harpophylla* dominant and co-dominant)
  - Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions

Based on a desktop assessment of species records within the locality and vegetation mapped within the Survey area, a Likelihood of Occurrence assessment was conducted to categorise MNES and MSES species as 'unlikely to occur', 'potential to occur', 'likely to occur' or 'known to occur' within the Survey area. The criteria for the Likelihood of Occurrence assessment is summarised in Table 3.

Table 3: Likelihood of occurrence assessment criteria.

Likelihood of Occurrence	Criteria for Threatened Flora and Fauna	Criteria for Threatened Ecological Communities
Unlikely to occur	The Disturbance footprint does not comprise suitable habitat for the species or is outside of the species known distribution.	State mapped Regional Ecosystems within the Disturbance footprint do not correspond with the TEC.
Potential to occur	The Disturbance footprint is within the species known distribution and suitable habitat to support the species is present; however, the species has not previously been recorded within the desktop search extent; and/or suitable habitat is degraded or of limited extent, thereby reducing the likelihood of the species occurrence.	N/A
Likely to occur	Suitable habitat to support the species is present and the species has previously been recorded within 20 km of the Disturbance footprint (the desktop search extent).	State mapped Regional Ecosystems corresponding to the TEC have been identified by the desktop assessment within Disturbance footprint

Likelihood of Occurrence	Criteria for Threatened Flora and Fauna	Criteria for Threatened Ecological Communities
Known to occur	Has been recorded within the Disturbance footprint previously.	The TEC has been recorded within the Disturbance footprint previously.

Table 4 and Table 5 detail the results from the desktop Likelihood of Occurrence assessment, showing fauna and flora species with potential to occur and /or that are 'likely to occur' or 'known to occur'. The desktop assessment informed the MNES and MSES to be targeted during the field assessment. Five threatened or listed fauna species and five threatened flora species were determined as having the 'potential to occur' or being 'likely to occur' within the Survey area.

No TECs were determined as being 'likely to occur', as the Survey area did not contain any mapped remnant or high value regrowth vegetation corresponding to a TEC.

The full desktop Likelihood of Occurrence assessment is available in Appendix A.

Table 4: Desktop MNES and MSES fauna likelihood of occurrence assessment within the survey area.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Birds						
Squatter Pigeon (southern)	*Geophaps scripta scripta*	V	V	Occurs from the Burdekin-Lynd Divide in north Queensland to the Border Rivers in northern New South Wales and inland to Hughenden to Charleville. They are found in remnant, regrowth and modified open-forest and wooded communities dominated by Eucalyptus, Corymbia, Acacia or Callitris species and within 3 km of water bodies. They require patchy understory with tussocks where vegetation is generally below 33% on well-draining, gravelly, sandy, or loamy soils. Breeding occurs within 1km of a suitable, permanent waterbody (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15km, the survey area contains mapped potentially suitable habitat.
Mammals						
Greater Glider (southern and central)	*Petauroides volans*	E	E	Occurs from Proserpine in Queensland south through New South Wales to Blackwood in Victoria in Eucalypt forests and woodlands below 1200 m above sea level. Tall, montane and moist forests tend to be preferred, though they can be found in drier habitats, and they favour forests with a diversity of Eucalypt species with seasonal growth variation for year-round foraging. They require large, old trees with hollows for dens (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory)	*Phascolarctos cinereus*	E	E	For the combined population considered here, occurs from the Wet Tropics in Queensland south to the New South Wales and Victoria border, and inland to up to approximately 600 km, including the Australian Capital Territory. The distribution is not continuous and isolated populations are often in low density. The species is restricted to Eucalypt sclerophyll forest and woodlands where preferred food trees occur (*Eucalyptus, Lophostemon, Melaleuca, Angophora, Corymbia sp*). They prefer habitats with higher tree species richness in proximity to creek lines (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Short-beaked Echidna	*Tachyglossus aculeatus*	-	SL	Occurs across most of Australia, except for inland Western Australia where there are fewer records. They are habitat generalists, found in forests, woodlands, shrublands and grasslands, rocky outcrops and agricultural lands where there are enough ants and/or termites for foraging (Atlas of Living Australia, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Reptiles						
Yakka Skink	*Egernia rugosa*	V	V	The Yakka Skink is commonly found in cavities under and between partly buried rocks, logs or tree stumps, root cavities and abandoned animal burrows. The species often takes refuge in large hollow logs and has been known to excavate deep burrow systems, sometimes under dense ground vegetation. In cleared habitat, this species can persist where there are shelter sites such as raked log piles, deep gullies, tunnel erosion/sinkholes and rabbit warrens. The species has also been found sheltering under sheds and loading ramps. This species is not generally found in trees or rocky habitats (Department of Sustainability Environment Water Population and Communities 2011).	Potential	Records are not within 15 km however the survey area contains suitable mapped habitat.

Table Key: SL – Special Least Concern, LC – Least Concern, Ma – Marine, M – Migratory, V – Vulnerable, E – Endangered, CE – Critically Endangered

Table 5: Desktop MNES and MSES flora likelihood of occurrence assessment within the survey area.

Scientific Name	Common Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Solanum dissectum	NA	E	E	*Solanum dissectum* has a restricted distribution in central Queensland. It has mainly been found in the area bounded by Banana, Dululu, Moura and Thangool but has also been recorded 40 km south of Blackwater. *Solanum dissectum* occurs in open forest and woodland of brigalow (*Acacia harpophylla*) or *Eucalyptus thozetiana* on solodic clay soils (Department of Environment and Science, 2012).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Solanum elachophyllum	NA	-	E	*Solanum elachophyllum* is endemic to Queensland and confined to the central subcoastal part of the state, from Middlemont to Theodore. The species occurs within Junee State Forest and Taunton National Park. *Solanum elachophyllum* grows on fertile cracking-clay soils in open forest of *Eucalyptus thozetiana, Acacia harpophylla*, with understorey of *Geijera parviflora, Casuarina cristata, Macropteranthes leichhardtii, Eucalyptus cambageana*, or woodland of *E. crebra* and *E. tenuipes* (Department of Environment and Science, 2012).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Cadellia pentastylis	Ooline	V	V	*Cadellia pentastylis* is now restricted in distribution from near Duaringa west of Rockhampton to the NSW border in Queensland, and on the western edge of the North West Slopes north of Gunnedah in northern New South Wales. It occurs in a range of vegetation types including semi-evergreen vine thicket, brigalow-belah, poplar box and bendee communities. Ooline often occurs on the edges of sandstone and basalt escarpments, 200 to 500 m above sea level. In most areas of its range, ooline grows on the moderately fertile soils preferred for agriculture and pasture development (Department of Environment and Science, 2009).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Bertya opponens	NA	V	LC	*Bertya opponens* has been recorded growing in a variety of community types including mixed shrubland, lancewood woodland, mallee woodland, eucalypt/Acacia open forest with shrubby understorey, eucalypt/Callitris open woodland and semi-evergreen vine-thicket. The soils are recorded as generally shallow sandy loams or red earths associated mostly with sandstone, but also with rhyolite, shale and metasediments (Department of Environment and Science, 2012)	Likely	Records are within 15 km and the survey area contains suitable mapped habitat.
***Cerbera* dumicola**	NA	-	NT	*Cerbera dumicola* occurs across a range of habitats in central and southern Queensland. Associated vegetation and species include: sandstone hills in open *E. umbra subsp. carnea*; on plateaus, in woodland of *Acacia shirleyi* with *Corymbia dolichocarpa*; acidic soils in mine rehabilitation area; woodland of *A. catenulata* and *A. shirleyi* with *E. thozetiana* on a slope of sand/clay soil; semi-deciduous notophyll-microphyll vine forest of *Brachychiton australis*, *Gyrocarpus americanus, Flindersia australis, Pleiogynium timorense, Drypetes deplanchei* and *Sterculia quadrifida* on rhyolite hillslopes; open-woodland of *E. melanophloia* with occasional *Acacia shirleyi, E. populnea* and *E. brownii*; semi-evergreen vine thicket with *Corymbia citriodora* and *Corymbia aureola* emergents; woodland of *A. rhodoxylon* on brown, sandy loam; and in *Corymbia tessellaris - Acacia aneura* open woodland (Department of Environment and Science, 2012).	Likely	Records are within 15 km and the survey area contains suitable mapped habitat.

Table Key: LC – Least Concern, NT – Near Threatened, V – Vulnerable, E – Endangered, CE – Critically Endangered

3.2. Field results

3.2.1. Overview of subsidence crack and sinkhole sites

Table 6 below provides a summary of results from all field sites, including:

- reference sites
- field-verified subsidence crack and sinkhole sites – including mapped and unmapped sites.
- mapped crack sites where no evidence of subsidence was observed in the field.

Refer to Figure 2 for the locations of all field sites. Crack 8, Crack 9 and Crack 24 were discovered whilst traversing the Survey area (i.e. were not identified via desktop mapping). Mapped Cracks 1-6 had no evidence of subsidence caused cracks or sinkholes. The topography of these areas appeared consistent with the natural landscape, including drainage lines and rocky slopes. Identification of subsidence or lack thereof was based on an ecological understanding of natural landscape topography, and does not substitute for a geotechnical assessment. Note that the sinkhole site should be considered a potential sinkhole, however further geotechnical assessment would be required to discern if this site is a sinkhole or excavated pit.

Table 6: Summary of field sites including regional ecosystem and condition, evidence of subsidence, maximum crack depth and width, and corresponding assessment sites.

Feature ID	Regional ecosystem and condition	Evidence of subsidence	Maximum depth (m)	Maximum width (m)	Relevant assessment sites*
Reference sites					
Reference Site 1	11.7.2 Remnant	NA	NA	NA	Ref1, HA5
Reference Site 2	11.7.6 Remnant	NA	NA	NA	Ref2, HA6
Field-verified subsidence crack or sinkhole					
Potential Sinkhole 1	11.7.2 High Value Regrowth	Yes	1.5	30	SH1, HA3
Crack 1	Non-remnant	Yes	1	1	Cr1, HA1
Crack 2	Non-remnant	Yes	3	1.5	Cr2, HA2
Crack 3	11.7.2 Remnant	Yes	0.5	0.75	Cr3, HA4
Crack 4	Non-remnant	Yes	0.6	0.5	Cr4, HA6
Crack 5	11.7.2 Remnant	Yes	3	2	Cr5, HA7
Crack 6	11.7.2 Remnant	Yes	1	2.5	Cr6, HA8
Crack 7	11.7.6 Remnant	Yes	1.5	0.6	Cr7Ter, HA9
Crack 8	11.7.2 Remnant	Yes	1	0.5	Cr8, HA10
Crack 9	11.7.2 Remnant	Yes	3	0.5	Cr9, HA11

Feature ID	Regional ecosystem and condition	Evidence of subsidence	Maximum depth (m)	Maximum width (m)	Relevant assessment sites*
Crack 10	11.7.2 Remnant	Yes	3.3	0.5	Cr10, HA12
Crack 11	11.7.2 Remnant	Yes	2	0.5	Cr11, Cr11Ter, HA13
Crack 12	Non-remnant	Yes	6	0.3	Cr12, HA15
Crack 12b	11.7.2 High Value Regrowth	Yes	0.9	0.3	Cr12b, HA16
Crack 13	Non-remnant	Yes	3.9	0.5	Cr13, HA17
Crack 14	11.7.6 Remnant	Yes	21	0.3	Cr14, HA18
Crack 15	11.7.2 Remnant	Yes	2.5	0.5	Cr15, HA19
Crack 16	11.7.2 Remnant	Yes	2	1	Cr16, HA20
Crack 17	11.7.2 Remnant	Yes	1.2	0.6	Cr17, HA21
Crack 18	11.7.6/11.7.2 Remnant	Yes	4.5	0.5	Cr18, HA22
Crack 19	11.7.2 Remnant	Yes	1	0.6	Cr19, HA23
Crack 20	11.7.2 Remnant	Yes	2	0.5	Cr20, HA24
Crack 21	11.7.2 Remnant	Yes	2	0.5	Cr21, HA25
Crack 22	11.7.2 High Value Regrowth	Yes	2.5	0.5	Cr22, HA26
Crack 23	11.7.2 High Value Regrowth	Yes	1.2	1	Cr23, HA27
Crack 24	11.7.2 High Value Regrowth	Yes	0.3	0.2	Cr24, HA28
Crack 25	11.7.2 Remnant	Yes	1.2	1.1	Cr25, HA32
No field evidence of subsidence crack or sinkhole					
Mapped Crack 1	11.7.2 High Value Regrowth	No	NA	NA	QH1, HA29
Mapped Crack 2	11.7.2 Remnant	No	NA	NA	QH2, HA30
Mapped Crack 3	11.7.2 Remnant	No	NA	NA	QH3, HA31
Mapped Crack 4	11.7.2 Remnant	No	NA	NA	QH4, HA33
Mapped Crack 5	11.7.2 Remnant	No	NA	NA	QH5, HA35
Mapped Crack 6	11.7.2 Remnant	No	NA	NA	QH6, HA36

*Table Key: Ref – Reference Site Tertiary Assessment, HA – Fauna Habitat Assessment site, Cr – Crack Quaternary Assessment, SH – Sinkhole Quaternary Assessment, Cr_Ter – Crack Tertiary Assessment, QH – Quaternary Assessment (no subsidence)

3.2.2. Reference site results – vegetation and habitat

Two reference sites were established as a part of this field assessment on areas on Blackwater Mine with no historic underground mining. These included Reference Site 1 in remnant vegetation analogous with Regional Ecosystem 11.7.2, and Reference Site 2 in remnant vegetation analogous with Regional Ecosystem 11.7.6. Existing reference site BWM_REF05 (LEC, 2025) is also included in this report as it provides an additional reference site in Regional Ecosystem 11.7.2. Table 7 to Table 9 summarise the results of the reference sites, including vegetation and relevant MNES and MSES flora and fauna species.

Table 7: Reference Site 1 Summary.

Reference Site 1: Regional Ecosystem 11.7.2.	
Vegetation Community Description:	*Acacia shirleyi* woodland on ironstone jump-ups.
Fauna habitat type	*Acacia* woodland on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	Remnant
Vegetation structure:	Mid-high
Ecological Dominant Layer:	Tree 1
EDL height (range)	6-12 m
Tree canopy cover (%)	89.4
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam
Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice, and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	0%
Emergent layer dominant species	*Blakella citriodora* (D)
Tree 1 layer dominant species	*Acacia shirleyi (D), Alphitonia excelsa, Eucalyptus exserta*
Shrub layer	*Bertya opponens* (C), *Acacia shirleyi* (C), *Dodonaea oxyptera, Everistia vacciniifolia*, *Erythroxylon australe*
Ground layer dominant species	*Entolasia stricta* (D), *Lomandra confertifolia, Aristida caput-medusae, Cyperus sp., Aristida calycina, Eragrostis sp., Dinebra decipiens, Opuntia sp., Sida sp., Parsonsia straminea, Abutilon sp.*
Disturbance notes	None.



Table Key: D – Dominant, C – Co-dominant.

Table 8: Reference Site 2 Summary.

Reference Site 2: Regional Ecosystem 11.7.6.	
Vegetation Community Description:	*Blakella citriodora* woodland with *Eucalyptus crebra* on ironstone jump-ups.
Fauna habitat type	Lemon-scented gum woodland with scattered ironbarks on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	Remnant
Vegetation structure:	Mid-high
Ecological Dominant Layer:	Tree 1
EDL height (range)	12-24 m
Tree canopy cover (%)	96.6
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam
Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice, and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Blakella citriodora* or *Eucalyptus crebra* woodland on Cainozoic lateritic duricrust.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	0%
Tree 1 layer dominant species	*Blakella citriodora* (D), *Eucalyptus crebra* (A)
Tree 2 layer dominant species	*Acacia shirleyi* (D), *Blakella citriodora, Eucalyptus crebra, Grevillea striata*
Shrub layer	*Hibiscus heterophyllus* (C), *Phebalium glandulosum subsp. glandulosum* (C), *Alstonia constricta, Psydrax odorata, Dodonaea oxyptera, Myoporum acuminatum*
Ground layer dominant species	*Aristida calycina* (C), *Cymbopogon refractus* (C), *Entolasia stricta, Aristida caput-medusae, Ancistrachne uncinata*
Disturbance notes	None.



Table Key: D – Dominant, C – Co-dominant, A – Associated.

Table 9: Reference Site BWM_REF05 Summary.

Reference Site BWM_REF05: Regional Ecosystem 11.7.2.	
Vegetation Community Description:	*Acacia shirleyi* woodland on ironstone jump-ups.
Fauna habitat type	*Acacia* woodland on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	Remnant
Vegetation structure:	Mid-high
Ecological Dominant Layer:	Tree 1
EDL height (range)	6-12 m
Tree canopy cover (%)	52.2%
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam



Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone.
EPBC Act threatened ecological community type	NA.
Tree 1 layer dominant species	*Acacia shirleyi* (D), *Blakella citriodora subsp. citriodora, Eucalyptus crebra*
Shrub layer	*Everistia vacciniifolia, Eucalyptus shirleyi, Psydrax oleifolia, Geijera parviflora, Bertya opponens, Croton phebalioides.*
Ground layer dominant species	*Aristida calycina, Digitaria sp, Aristida sp., Eragrostis sp., Aristida caput-medusae, Entolasia stricta, Ancistrachne uncinulata, Cenchrus ciliaris, Cenchrus pennisetiformis*
Disturbance notes	None.

Table Key: D – Dominant.

3.2.3. Subsidence crack and sinkhole sites – vegetation and flora

The results of the ecological assessment showed that the Survey area occurred across both remnant, high value regrowth (HVR) and non-remnant areas. There was evidence of minor canopy tree dieback potentially associated with Crack 11, which did not affect the remnant vegetation status of this site whereby when compared to reference site 1 for RE11.7.2 the vegetation maintained 70% of the height and at least 50% of the overall canopy cover. Scattered minor canopy tree dieback occurred at Crack 17 and Cracks 19, 20, 21 and 22, however this was widespread throughout the general area and therefore was determined to not be associated with the subsidence cracking. There was evidence of selective logging in some areas (refer to Appendix C for images). EPBC Act listed Vulnerable plant *Bertya opponens* occurred closely at many subsidence crack sites. Figure 4 shows *Bertya opponens* sightings and habitat within the Survey area. No other threatened flora species were identified during the field assessment.

A list of all flora species recorded in the Survey area has been provided in Appendix B.

Vegetation analogous with remnant and HVR regional ecosystems 11.7.2 and 11.7.6 was identified throughout the Survey area (refer Figure 3).

Table 10 - Table 13 summarise the results of the subsidence crack and sinkhole sites, including vegetation and relevant MNES and MSES flora and fauna species.

Figure 3: Ground-truthed regional ecosystems within the Survey area.

685000

7355000

ML 70091

ML 1812

ML 1792

ML 1773

ML 1767

ML 1771

ML 1860

ML 70091

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 200 400 600 800 1,000

m

BWM Mining Lease
Area of Interest
Kenmare
Laleham
Crack / Sinkhole

11.7.2, Remnant
11.7.2, HVR
11.7.2, Non-remnant
11.7.2/11.7.6 (80%/20%), Remnant
11.7.2/11.7.6 (80%/20%), Regrowth
11.7.2/11.7.6 (80%/20%), Non-remnant
11.7.6, HVR
Non-remnant

LYNGCO ENVIRONMENTAL CONSULTING

Drawn By: C Schlebusch

Requested by: S Lyngcoln

Date: 14/10/2025

Figure 3

Ground-truthed Regional Ecosystems

RTPL_LE_BMRM001_WHC028_MAP0004_A

Path: S:\Plans\Project_Specific\LyngcoEnvironmental\BlackwaterMine\WHC028 Subsidence and Cracking\RTPL_LE_BMRM001_WHC028_MAP0004_A BWM Subsidence and Cracking Kenmare and Laleham GTRE.aprx

Figure 4: *Bertya opponens* habitat within the Survey area.

685000

7355000

ML 70091

ML 1812

ML 1792

ML 1773

ML 1771

ML 1767

ML 1860

ML 70091

BLACKWATER MINE

Kenmare and Laleham Underground Subsidence Crack Monitoring

GDA2020, MGA Zone 55

0 200 400 600 800 1,000

m

- BWM Mining Lease
- Area of Interest
- Kenmare
- Laleham
- Crack / Sinkhole
- *Bertya opponens* sighting
- *Bertya opponens* habitat

LYNGCO ENVIRONMENTAL CONSULTING

Drawn By:	C Schlebusch
Requested by:	S Lyngcoln
Date:	14/10/2025

Figure 4

***Bertya opponens* habitat**

RTPL_LE_BMRM001_WHC028_MAP0004_A

Path: S:\Plans\Project_Specific\LyngcoEnvironmental\BlackwaterMine\WHC028 Subsidence and Cracking\RTPL_LE_BMRM001_WHC028_MAP0005_A BWM Subsidence and Cracking Kenmare and Laleham Bertya opponens habitat.aprx

Table 10: Subsidence crack and sinkhole sites: Regional ecosystem 11.7.2 (Remnant).

Subsidence crack and sinkhole sites: Regional ecosystem 11.7.2 (Remnant).	
Vegetation Community Description:	*Acacia shirleyi* woodland on ironstone jump-ups.
Fauna habitat type	*Acacia* woodland on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	Remnant
Vegetation structure:	Mid-high
Ecological Dominant Layer:	Tree 1
EDL height (range)	6-14 m
Tree canopy cover (%)	81
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam
Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice, and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	0%
Emergent layer dominant species	*Blakella citriodora* (D)
Tree 1 layer dominant species	*Acacia shirleyi (D), Eucalyptus exserta*
Shrub layer	*Everistia vacciniifolia* (C), *Croton insularis, Erythroxylon australe, Bertya opponens, Geijera parviflora, Acalypha eremorum*
Ground layer dominant species	*Entolasia stricta* (C), *Ancistrachne uncinata* (C), *Enteropogon ramosus, Parsonsia straminea*
Disturbance notes	Selective logging.
Relevant sites	Crack 3, Cracks 5 & 6, Cracks 8-11, Cracks 15-21*, Crack 25, Mapped Cracks 2-6.



Table Key: D – Dominant, C – Co-dominant.

*Crack 18 was associated with an ecotonal area of RE 11.7.6/11.7.2 vegetation.

Table 11: Subsidence crack and sinkhole sites: Regional ecosystem 11.7.2 (High Value Regrowth).

Subsidence crack and sinkhole sites: Regional ecosystem 11.7.2 (High Value Regrowth).	
Vegetation Community Description:	*Acacia shirleyi* woodland on ironstone jump-ups.
Fauna habitat type	*Acacia* woodland on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	High Value Regrowth
Vegetation structure:	Low
Ecological Dominant Layer:	Tree 1
EDL height (range)	4-10 m
EDL cover density	Mid-dense (50-80%)
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam
Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice, and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	0%
Emergent layer dominant species	*Blakella citriodora* (D)
Tree 1 layer dominant species	*Acacia shirleyi (D), Eucalyptus exserta* (A)
Shrub layer	*Bertya opponens* (S), *Dodonaea oxyptera* (A), *Everistia vacciniifolia* (A)
Ground layer dominant species	*Entolasia stricta* (S), *Dinebra decipiens* (S), *Ancistrachne uncinata* (A)
Disturbance notes	None.
Relevant sites	Sinkhole 1, Crack 12b, Cracks 22-24, Mapped Crack 1.



Table Key: D – Dominant, S – Sub-dominant, C – Co-dominant, A – Associated.

Table 12: Subsidence crack and sinkhole sites: Regional Ecosystem 11.7.6 (Remnant).

Subsidence crack and sinkhole sites: Regional Ecosystem 11.7.6 (Remnant).	
Vegetation Community Description:	*Blakella citriodora* woodland on ironstone jump-ups.
Fauna habitat type	Lemon-scented gum woodland on ironstone jump-ups.
Relevant MNES and MSES fauna species	Squatter pigeon (breeding) Yakka skink (breeding) Short-beaked echidna (breeding)
Relevant MNES and MSES flora species:	*Bertya opponens*
Remnant status:	Remnant
Vegetation structure:	Mid-high
Ecological Dominant Layer:	Tree 1
EDL height (range)	12-24 m
Tree canopy cover (%)	52
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam
Fauna habitat type description	This fauna habitat type has the potential to provide foraging habitat for the squatter pigeon as it is comprised of woodland on suitable well-draining soil. Breeding habitat is present in areas <1 km from a waterbody. This habitat type may provide breeding habitat for the yakka skink as it is situated on a land zone known to provide yakka skink habitat as per the Conservation advice, and contains coarse woody debris including hollow logs. This habitat type may provide breeding habitat for the short-beaked echidna as it provides suitable woodland habitat with coarse woody debris and termite mounds. Generally, this habitat type provides habitat for reptiles, woodland birds, small mammals and macropods as it contains woodland with habitat and foraging features such as coarse woody debris, leaf litter, seeding grasses, and rocky areas.
RE short description:	*Blakella citriodora* or *Eucalyptus crebra* woodland on Cainozoic lateritic duricrust.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	4%
Tree 1 layer dominant species	*Blakella citriodora* (D), *Acacia shirleyi* (C)
Tree 2 layer dominant species	*Acacia shirleyi* (D), *Alphitonia excelsa* (S)
Shrub layer	*Acacia macradenia* (C), *Phebalium glandulosum subsp. glandulosum, Alstonia constricta, Cassia brewsteri, Geijera salicifolia*
Ground layer dominant species	*Enneapogon pallidus, Bothriochloa bladhii, Cenchrus ciliaris, Melinis repens, Cymbopogon refractus, Aristida calycina, Dinebra decipiens, Sida sp., Gossypium sturtianum*
Disturbance notes	Selective logging.
Relevant sites	Crack 7, Crack 14, Crack 18*



Table Key: D – Dominant, S – Sub-dominant, C – Co-dominant, A – Associated.

*Crack 18 was associated with an ecotonal area of RE 11.7.6/11.7.2 vegetation.

Table 13: Subsidence crack and sinkhole sites: non-remnant areas.

Subsidence crack and sinkhole sites: non-remnant areas.	
Vegetation Community Description:	Cleared or young regrowth non-remnant areas.
Fauna habitat type	Cleared or young regrowth non-remnant areas.
Relevant MNES and MSES fauna species	None.
Relevant MNES and MSES flora species:	*Bertya opponens* at Crack 2.
Remnant status:	Non-remnant
Vegetation structure:	NA.
Ecological Dominant Layer:	NA.
EDL height (range)	NA.
EDL canopy cover (%)	NA.
Geology	Ironstone jump-ups
Landform	Upper slope
Soil type	Loam/Gravel
Fauna habitat type description	This fauna habitat type consists of cleared and/or young regrowth vegetation. This habitat type does not provide any foraging or breeding habitat for relevant MNES or MSES fauna species.
RE short description:	NA.
EPBC Act threatened ecological community type	NA.
Total exotic ground cover (%)	NA.
Tree 1 layer dominant species	*Acacia shirleyi* (D)
Shrub layer	*Bertya opponens**
Ground layer dominant species	*Paspalidium caespitosum* (D)
Relevant sites	Cracks 1, 2, 4, 12 and 13.



Table Key: D – Dominant, C – Co-dominant, A – Associated.

**Bertya opponens* present at non-remnant site Crack 2.

3.2.4. Subsidence cracks and sinkholes – fauna

The field assessment recorded a total of 12 native fauna species including 11 bird species and 1 mammal species. No threatened fauna species were detected during the field survey. A complete fauna list is presented in Appendix B.

Table 14 below summarises the fauna habitats present in the Survey area. Refer to Table 10 - Table 13 for detailed descriptions of each fauna habitat type.

Table 14: Summary of fauna habitat types within the Survey area.

Fauna Habitat Type	Regional Ecosystem and Condition	Vegetation Survey Sites	Habitat Assessment Sites	Relevant threatened or listed fauna species
Acacia woodland on ironstone jump-ups.	11.7.2 Remnant and HVR	SH1, Cr3, Cr5, Cr6, Cr8-11, Cr12b, Cr15-25*, QH1-6.	HA3, HA4, HA7, HA8, HA10-13, HA16, HA19-36.	Squatter pigeon Yakka skink Short-beaked echidna
Lemon-scented gum woodland on ironstone jump-ups.	11.7.6 Remnant	Cr7Ter, Cr14, Cr18*.	HA9, HA18, HA22.	Squatter pigeon Yakka skink Short-beaked echidna
Cleared or young regrowth non-remnant areas.	Cleared or young regrowth non-remnant areas	Cr1, Cr2, Cr4, Cr12, Cr13.	HA1, HA2, HA6, HA15, HA17.	None

Table Key: HA – Fauna Habitat Assessment site, Cr – Crack Quaternary Assessment, SH – Sinkhole Quaternary Assessment, Cr_Ter – Crack Tertiary Assessment, QH – Quaternary Assessment (no subsidence).
*Crack 18 was associated with an ecotonal area of RE 11.7.6/11.7.2 vegetation.

Potential habitat was present for the following MNES and MSES fauna species within the survey area:

- Squatter pigeon (*Geophaps scripta scripta,* listed as Vulnerable under the EPBC and NC Acts)
- Yakka skink (*Egernia rugosa*)
- Short-beaked echidna (*Tachyglossus aculeatus,* listed as Special Least Concern under the NC Act)

There was no habitat for the following threatened species within the survey area:

- Koala (*Phascolarctos cinereus*)
- Greater glider (*Petauroides volans*)

There was no koala habitat within the survey area as there were no suitable vegetation communities dominated or co-dominated by locally important koala tree species (LIKT) for the Brigalow Belt as per *A review of koala habitat assessment criteria and methods* (Youngentob, Marsh, & Skewes, 2021).
There was no greater glider habitat within the survey area, as whilst feed trees were present (*Blakella citriodora*), there were insufficient tree hollows to support the shelter and breeding requirements of the species (Kerswell, Kaveney, Evans, & Appleby, 2020).

3.3. Impact Analysis

This assessment found no evidence of significant impacts to vegetation or fauna habitat due to subsidence cracking or sinkholes.

Five subsidence cracking sites were in non-remnant areas and hence cracking did not impact any protected vegetation. Twenty sites had no evidence of any impact to vegetation growth or structure caused by subsidence cracking or sinkholes. One site (Crack 11) had evidence of minor canopy tree dieback that was potentially associated with the subsidence crack. A tertiary vegetation assessment (Cr11Ter) confirmed that any impact to tree canopy cover did not affect the remnant status of the vegetation (refer Table 15). The tree canopy cover for Crack 11 was >100% of the BioCondition benchmark for RE 11.7.2 and was > 50% of the canopy cover value for Reference Site 1. The T1 tree canopy height for Crack 11 was >85% of the BioCondition benchmark and greater than the tree height of Reference Site 1.

Non-native species cover was also not notably different between the reference sites and the subsidence sites, with tertiary sites recording between 0 and 4% non-native cover (refer Table 15). Native species richness was similar between the reference sites and tertiary subsidence sites. For RE 11.7.6, both Reference Site 1 and Crack 7 recorded a total native species richness of 15 tree, shrub, grass and forb species. For RE 11.7.2, the Crack 11 site featured 70% of the total native species richness of corresponding Reference Site 2, and a similar number to BWM_REF05 (refer Table 15).

Table 15: Comparison of representative subsidence sites with reference sites – canopy cover, non-native species cover and native species richness.

Site ID	Regional ecosystem and status	Tree Canopy Cover (%)	Tree Canopy Cover (%) - BioCondition Benchmark	T1 Canopy Height (m)	T1 Canopy Height – BioCondition Benchmark	Non-native species cover (%)	Native species richness (trees, shrubs, grasses and forbs)
Crack 11	11.7.2 Remnant	81	60	12	14	0	13
Reference Site 1	11.7.2 Remnant	89.4	60	11	14	0	19
Reference Site BWM_REF05	11.7.2 Remnant	52.2	60	NA	14	NA	13
Crack 7	11.7.6 Remnant	52	47	19	25	4	15
Reference Site 2	11.7.6 Remnant	96.6	47	22	25	0	15

Habitat suitability for fauna was also not significantly affected by subsidence cracks or sinkholes. The subsidence cracks and sinkholes did not affect key components of squatter pigeon habitat. These include a

suitable waterbody for drinking water within 3 km, suitable well-draining soil, and areas of patchy ground cover including bare ground for dust-bathing (Kerswell, Kaveney, Evans, & Appleby, 2020). Suitable grasses for foraging were present at both the reference and subsidence sites.

Yakka skink habitat is broadly defined in the Conservation advice (DoE, 2014), and hence the species may not occur in many areas defined as potential yakka skink habitat. Nonetheless, habitat suitability for the yakka skink was similar in both the reference sites and subsidence sites. Coarse woody debris for shelter was present across all sites. Subsidence cracking may provide additional habitat amenity for the yakka skink, as the species is known to use rock crevices and tunnel erosion for shelter (Kerswell, Kaveney, Evans, & Appleby, 2020).

Subsidence did not affect habitat suitability for the short-beaked echidna. Habitat features including coarse woody debris and termite nests were present across both reference and subsidence sites.

In general, the subsidence cracks may pose minor movement barriers to terrestrial fauna. In some cases, cracks had steep sides which may impede escape for any fauna that enter the crack. However, depth varied within each crack (refer to photos in Appendix C), providing shallower areas where fauna could more easily escape. There was no evidence of trapped fauna in the surveyed cracks.

From an ecological perspective, amelioration of subsidence-caused cracking and sinkholes is not recommended. Table 16 outlines each subsidence-caused crack or sinkhole, the ecological constraints associated with each (including *Bertya opponens* presence and fauna habitat), and subsequent recommendations.

Table 16: Summary of subsidence crack and sinkhole sites, including impact to vegetation or fauna, presence of *Bertya opponens* and MNES and MSES fauna habitat, and subsequent recommendations.

Subsidence site	Regional ecosystem and condition	Subsidence impact on vegetation and/or fauna	*Bertya opponens* presence	Relevant MNES or MSES fauna habitat	Recommendations
Potential Sinkhole 1	11.7.2 High Value Regrowth	No significant impact	Yes	Squatter pigeon, Yakka skink, Short-beaked echidna.	Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 1	Non-remnant	No significant impact	No	None.	No constraints, fill crack if necessary.
Crack 2	Non-remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 3	11.7.2 Remnant	No significant impact	Yes	Squatter pigeon, Yakka skink, Short-beaked echidna.	Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 4	Non-remnant	No significant impact	No	None.	No constraints, fill crack if necessary.
Crack 5	11.7.2 Remnant	No significant impact	Yes	Squatter pigeon, Yakka skink, Short-beaked echidna.	Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 6	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 7	11.7.2 Remnant	No significant impact	No		Monitor. Remnant RE.
Crack 8	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 9	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 10	11.7.2 Remnant	No significant impact	Adjacent		Monitor. Avoid adjacent *Bertya opponens* and remnant vegetation if filling crack.

Subsidence site	Regional ecosystem and condition	Subsidence impact on vegetation and/or fauna	*Bertya opponens* presence	Relevant MNES or MSES fauna habitat	Recommendations
Crack 11	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 12	Non-remnant	No significant impact	Adjacent	None.	No constraints in cleared non-remnant area. Fill crack if required. Adjacent area of HVR 11.7.2 contains *Bertya opponens*.
Crack 12b	11.7.2 High Value Regrowth	No significant impact	Yes	Squatter pigeon, Yakka skink, Short-beaked echidna.	Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 13	Non-remnant	No significant impact	No	None.	No constraints in cleared non-remnant area. Fill crack if required. Adjacent area of HVR 11.7.2 contains *Bertya opponens*.
Crack 14	11.7.6 Remnant	No significant impact	Yes	Squatter pigeon, Yakka skink, Short-beaked echidna.	Monitor. Fill accessible areas that avoid impact to *Bertya opponens* or undertake SIA.
Crack 15	11.7.2 Remnant	No significant impact	No		Monitor. Remnant RE 11.7.2 recommend do not disturb.
Crack 16	11.7.2 Remnant	No significant impact	No		Monitor. Remnant RE 11.7.2 recommend do not disturb.
Crack 17	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 18	11.7.6/11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 19	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.

Subsidence site	Regional ecosystem and condition	Subsidence impact on vegetation and/or fauna	*Bertya opponens* presence	Relevant MNES or MSES fauna habitat	Recommendations
Crack 20	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 21	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 22	11.7.2 High Value Regrowth	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 23	11.7.2 High Value Regrowth	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 24	11.7.2 High Value Regrowth	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.
Crack 25	11.7.2 Remnant	No significant impact	Yes		Monitor. SIA required if disturbed due to *Bertya opponens* presence.

Table Key: SIA – Significant Impact Assessment

4. Recommendations and Conclusions

The purpose of this BWM underground mining surface cracks assessment was to provide a field-based technical assessment of the potential impacts to vegetation and habitat from surface cracks and sinkholes as a result of subsidence from historical underground mining on BWM in response to a request for more information (RFI) from the Department of the Environment, Tourism, Science and Innovation (DETSI).

This assessment found no evidence of significant impacts to vegetation or fauna habitat due to subsidence cracking or sinkholes. One site (Crack 11) had evidence of minor canopy tree dieback that was potentially associated with the subsidence crack. A tertiary vegetation assessment (Cr11Ter) confirmed that any impact to tree canopy cover did not affect the remnant status of the vegetation (refer Table 15).

Bertya opponens (Vulnerable under the EPBC Act) was identified at most subsidence sites associated with remnant or HVR vegetation (refer Table 16). Potential habitat was also present at many sites (refer Table 16) for the following fauna:

- Squatter pigeon (*Geophaps scripta scripta,* Vulnerable under the EPBC and NC Acts)
- Yakka skink (*Egernia rugosa*, Vulnerable under the EPBC and NC Acts)
- Short-beaked echidna (*Tachyglossus aculeatus*, Special Least Concern under the NC Act).

Habitat suitability for these fauna was not affected by subsidence cracking or sinkholes.

From an ecological standpoint, amelioration of subsidence-caused cracking and sinkholes is not recommended. If BWM decides to undertake amelioration of cracks for geotechnical or safety reasons, a Significant Impact Assessment would be required at all sites containing *Bertya opponens.* Refer to Table 16 for specific recommendations for each site.

Finally, if BWM consider to ameliorate surface cracks in areas of cleared non-remnant vegetation it is recommended that adjacent areas of remnant and/or HVR vegetation and areas mapped as habitat for *Bertya opponens* (Figure 4) are demarcated and avoided. No ecological constraints were otherwise recorded in non-remnant vegetation (Figure 3).

Appendix A Desktop Assessment

Table 1: Desktop Threatened Fauna Likelihood of Occurrence assessment within the Survey area.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Birds						
Curlew Sandpiper	*Calidris ferruginea*	CE, M, Ma	CE	Occurs around the coasts of Australia and is widespread inland in smaller numbers. In Queensland there are scattered records occurring in the Gulf of Carpentaria, with widespread records along the coast south of Cairns. Habitat generally consists of intertidal mudflats in sheltered coastal areas, though is known to occur around non-tidal swamps, lakes, and ephemeral water bodies. They roost on beaches, sandspits, islets and occasionally dunes. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain any mapped wetland habitat.
Australian Painted Snipe	*Rostratula australis*	E	E	Occurs across Australia though is more common in eastern Australia. They inhabit permanent and ephemeral wetlands, preferably freshwater though occasionally brackish, that typically have emergent, fringing vegetation. They will sometimes use areas lined with trees. Required breeding habitat is shallow freshwater wetlands (often islands within wetlands) with wet mud, dense low cover, and upper and canopy cover nearby (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain any mapped wetland habitat.
Red Goshawk	*Erythrotriorchis radiatus*	E	E	Occurs from the Kimberly in Western Australia to the Cape York Peninsula in Queensland, with records in south-east Queensland becoming increasingly scant since 2010. The species inhabits open forests, woodlands, wooded riparian zones that transect tropical savannas, and rainforest ecotones along coastal and sub-coastal regions. They prefer intact environments with a mosaic of vegetation types and permanent water. They require trees over 20 m tall with an open limb and canopy structure for nesting (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	Records are not within 15 km and the survey area does not contain mapped suitable habitat.
Southern Black-throated Finch	*Poephila cincta cincta*	E	E	Occurs in grassy woodland dominated by eucalypts, paperbarks or acacias where there are seeding grasses and water. Nests in tree hollows or builds domed nests in trees (Garnett, 2000).	Unlikely	The survey area is not within the current known distribution of the species (DCCEEW, 2025).
Star Finch (eastern), Star Finch (southern)	*Neochmia ruficauda ruficauda*	E	E	The Star Finch occurs mainly in grasslands and grassy woodlands that are located close to bodies of fresh water. It also occurs in cleared or suburban areas such as along roadsides and in towns (Ausgrid 2011).	Unlikely	This species is likely extinct.
Diamond Firetail	*Stagonopleura guttata*	V	V	Occurs from very southern Queensland to the Eyre Peninsula, South Australia, and up to 300km inland. They inhabit woodlands, open forests and other lightly timbered habitats dominated by Eucalypts, Acacias and/or Casuarinas. They exhibit a preference for high grass coverage, low tree density and low coarse woody debris and litter (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	Records are not within 15 km and the survey area does not contain mapped suitable habitat.
Latham's Snipe	*Gallinago hardwickii*	V, M, Ma	V	Occurs from the Cape York Peninsula in Queensland south to South Australia, and inland west of the Great Dividing Range. They inhabit various wetlands, permanent and ephemeral, of varying salinity, though they prefer freshwater with low, dense vegetation. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	Records are not within 15 km and the survey area does not contain mapped suitable habitat.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Squatter Pigeon (southern)	*Geophaps scripta scripta*	V	V	Occurs from the Burdekin-Lynd Divide in north Queensland to the Border Rivers in northern New South Wales and inland to Hughenden to Charleville. They are found in remnant, regrowth and modified open-forest and wooded communities dominated by Eucalyptus, Corymbia, Acacia or Callitris species and within 3 km of water bodies. They require patchy understory with tussocks where vegetation is generally below 33% on well-draining, gravelly, sandy, or loamy soils. Breeding occurs within 1km of a suitable, permanent waterbody (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15km, the survey area contains mapped potentially suitable habitat.
Black-breasted Button-quail	*Turnix melanogaster*	V	V	Occurs in the coastal and subcoastal from Byfield in Queensland to the New South Wales tablelands. The species is predominantly found in rainforests and forests with a dense understorey and fertile soil, where annual rainfall is between 770-1200 mm. They can occasionally be found in low, dense acacia thickets and in vegetation behind sand dunes, and rarely in Eucalypt forests (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Painted Honeyeater	*Grantiella picta*	V	V	Occurs sporadically from south-eastern Australia to north-western Queensland and across to eastern Northern Territory. They are found in Eucalypt, Melaleuca, Acacia and Casuarina forests and woodlands that have an abundance of mature trees with mistletoes present, which is their primary food source. They prefer larger sections of intact habitat over strips of remnant vegetation (such as road reserve) though exceptions have been recorded when mistletoes are present in particularly high abundance. Nesting also occurs where mistletoes are abundant (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Grey Falcon	*Falco hypoleucos*	V	V	Occurs in inland Australia in arid and semi-arid conditions, including Murray-Darling Basin, Eyre Basin, central Australia, and Western Australia where annual rainfall is below 500 mm. It appears to be absent east of the Great Dividing Range. They are found in lightly wooded plains with a preference for Acacia woodlands with vegetated watercourses. They require abandoned nests in tall trees for nesting (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
White-throated Needletail	*Hirundapus caudacutus*	V, M, Ma	V	Occurs from northern Queensland through to south-eastern Australia and inland to the west of the Great Dividing Range, and in Tasmania. The species is nearly exclusively aerial. They are found above a variety of ecosystems, though there appears to be preference for open forests, rainforest, and heathlands, and less often over woodland and treeless areas. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	This species is nearly exclusively aerial.
Sharp-tailed Sandpiper	*Calidris acuminata*	V, M, Ma	V	Occurs along the coastline of Queensland, New South Wales, and Victoria, with scattered records inland and in other states. The species occurs in freshwater/brackish wetlands that have muddy edges with sedges, grass, saltmarsh, or other low vegetation. They can be attracted to aquatic vegetation such as algae mats and water weeds. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable wetland habitat.
Oriental Cuckoo	*Cuculus optatus*	M	SL	Occurs along the coastline of Northern Territory, Queensland, and New South Wales. The species often inhabits rainforest, vine thickets, wet sclerophyll forest and open woodlands. The species spends the non-breeding season (spring and summer) in Australia (iNaturalist, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Fork-tailed Swift	*Apus pacificus*	M, Ma	SL	Occurs across all Australia, though the species is nearly exclusively aerial. The species generally occur over inland plains, sometimes coastal areas. The species spends the non-breeding season	Unlikely	This species is nearly exclusively aerial.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
				(spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).		
Pectoral Sandpiper	*Calidris melanotos*	M, Ma	SL	Occurs around the Cairns region in Queensland, widespread in New South Wales, and in southern Victoria, with isolated records throughout the rest of Australia. The species prefers shallow fresh or saline wetlands, generally coastal or near coastal, with muddy edges and low, fringing, or emergent vegetation. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable wetland habitat.
Osprey	*Pandion haliaetus*	M, Ma	SL	Generally a coastal species, occurring in estuaries, bays, inlets, islands and surrounding waters, coral atolls, reefs, lagoons, rock cliffs and stacks. Sometimes ascends larger rivers to far inland. Builds nests high in tree, on pylon or on ground on islands. Feeds on fish (Pizzey and Knight 2007).	Unlikely	The survey area does not contain suitable mapped coastal or riverine habitat.
Common Sandpiper	*Actitis hypoleucos*	M, Ma	SL	Occurs along all coastlines of Australia and found in many inland areas where freshwater or saltwater wetlands are present. The species exhibits a preference for mangroves, muddy margins and or rocky shores, and is rarely found on mudflats. They have been recorded in estuaries, deltas, banks, lakes, reservoirs, dams, and occasionally piers and jetties. Roosting habitat is generally rocks or roots/branches of vegetation, particularly mangroves. The species spends the non-breeding season (spring and summer) in Australia (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable wetland habitat.
Yellow Wagtail	*Motacilla flava*	M, Ma	SL	This species occurs in a range of habitats including estuarine habitats such as sand dunes, mangrove forests and coastal saltmarshes. This species also occurs in open grassy areas including disturbed sites such as sports grounds and has been recorded on the edges of wetlands, swamps, lakes and farm dams. This species migrates from Asia to Australia in spring-summer. It has been recorded in the estuarine areas of the Hunter River in Newcastle NSW and in QLD and the north of NT and WA (Birds Australia, 2007).	Unlikely	The species is rare and the survey area does not contain suitable estuarine habitat.
Mammals						
Greater Glider (southern and central)	*Petauroides volans*	E	E	Occurs from Proserpine in Queensland south through New South Wales to Blackwood in Victoria in Eucalypt forests and woodlands below 1200 m above sea level. Tall, montane and moist forests tend to be preferred, though they can be found in drier habitats, and they favour forests with a diversity of Eucalypt species with seasonal growth variation for year-round foraging. They require large, old trees with hollows for dens (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Northern Quoll	*Dasyurus hallucatus*	E	LC	Occurs from Mt Morgan to Weipa inland towards Carnarvon Gorge in Queensland, with some records south to Sunshine Coast hinterland. In Northern Territory they are restricted to the Top End. In Western Australia they are within the Pilbara, on a number of islands, and scattered from Derby to Wyndham. The species is found in a variety of habitats ranging from rocky areas, Eucalypt forests, woodlands, rainforests, beaches, shrublands, grasslands and desert. They favour high-relief areas with shallow soils, high boulder cover and low fire frequency close to permanent water. Dens are often in rocky areas with surrounding vegetation and can be crevices, tree holes or termite mounds (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	No records within 15 km, the species is rare within the surrounding areas, and no suitably connected mapped habitat is present.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Large-eared Pied Bat	*Chalinolobus dwyeri*	E	E	Occurs sporadically from Shoalwater Bay in Queensland south to Ulladulla in New South Wales and up to 400 km inland, with most records occurring in New South Wales. They are predominantly found within several kilometres of cliff lines or rocky terrain, particularly sandstone cliffs near fertile woodland valleys. They prefer woodlands that are dominated by box gums with a riparian corridor present. Roosting occurs in abandoned mine shafts, caves, and overhangs, and has been recorded using abandoned nests, and potentially tree hollows (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory)	*Phascolarctos cinereus*	E	E	For the combined population considered here, occurs from the Wet Tropics in Queensalnd south to the New South Wales and Victoria border, and inland to up to approximately 600 km, including the Australian Capital Territory. The distribution is not continuous and isolated populations are often in low density. The species is restricted to Eucalypt sclerophyll forest and woodlands where preferred food trees occur (*Eucalyptus, Lophostemon, Melaleuca, Angophora, Corymbia sp*). They prefer habitats with higher tree species richness in proximity to creek lines (Department of Climate Change, Energy, the Environment and Water, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Corben's Long-eared Bat	*Nyctophilus corbeni*	V	V	Inhabits a variety of vegetation types, including mallee, bulloke (*Allocasuarina leuhmanni*) and box eucalypt dominated communities, but it is distinctly more common in box/ironbark/cypress-pine vegetation that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland. (Department of Environment and Heritage Protection 2020)	Unlikely	The survey area does not contain mapped suitable habitat.
Yellow-bellied Glider (south-eastern)	*Petaurus australis australis*	V	V	Occurs disjunctly from Mackay in Queensland through New South Wales and to far south-eastern South Australia. The species is generally along the coastline, with some isolated populations inland along the western slopes of the Great Dividing Range in parts of New South Wales and Queensland. The species is found in woodlands and wet and dry sclerophyll forests dominated by Eucalypts, with a preference for old growth forests that have seasonal growth variation for year-round foraging and an abundance of winter-flowering and smooth-barked Eucalypts. They require large hollows, generally over one metre wide, in old trees for dens (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Short-beaked Echidna	*Tachyglossus aculeatus*	-	SL	Occurs across most of Australia, except for inland Western Australia where there are fewer records. They are habitat generalists, found in forests, woodlands, shrublands and grasslands, rocky outcrops and agricultural lands where there are enough ants and/or termites for foraging (Atlas of Living Australia, 2023).	Potential	Whilst records are not within 15 km, the survey area contains potentially suitable mapped habitat.
Reptiles						
Southern Snapping Turtle	*Elseya albagula*	CE	CE	The white-throated snapping turtle is only found in the Burnett, Fitzroy, Raglan and Mary river drainages of south-east Queensland. It prefers permanent flowing water habitats where there are suitable shelters and refuges (e.g. fallen trees). (Department of Environment and Heritage Protection 2014)	Unlikely	The survey area does not contain suitable mapped habitat.
Grey Snake	*Hemiaspis damelii*	E	E	Occurs from the coastal areas of Rockhampton in Queensland down to the eastern then central interior of New South Wales to the southern state border. The species has a fragmented range, and the core area is the Brigalow Belt between Dalby and Glenmorgan. The species floodplains and ephemeral wetlands with *Acacia harpophylla* (Brigalow) and *Casuarina cristata* (Belah) woodlands with logs and rocks. Grasslands over alluvial plains with cracking soil can also be utilised and cracking soils are required for foraging (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.

Common Name	Scientific Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Fitzroy River Turtle	*Rheodytes leukops*	E	E	The Fitzroy River Turtle is found in rivers with large deep pools with rocky, gravelly or sandy substrates, connected by shallow riffles. Preferred areas have high water clarity, and are often associated with Ribbonweed (*Vallisneria sp.*) beds (Cogger et al. 1993). Common riparian vegetation associated with the Fitzroy River Turtle includes Blue Gums (*Eucalyptus tereticornis*), River Oaks (*Casuarina cunninghamiana*), Weeping Bottlebrushes (*Callistemon viminalis*) and Paperbarks (*Melaleuca linariifolia*) (Tucker et al. 2001).	Unlikely	The survey area does not contain suitable mapped habitat.
Adorned Delma, Collared Delma	*Delma torquata*	V	V	Occurs sporadically in Queensland with known locations including Bunya Mountains, Blackdown Tablelands National Park, Expedition National Park, Western Creek, Toowoomba Ranges, and the western suburbs of Brisbane. The species inhabits Eucalypt-dominated woodlands and open forests on Land Zones 3, 9 and 10, and is associated with RE's 11.3.2, 11.9.10, 11.10.1, and 11.10.4. The species requires rocks, coarse woody debris, bark and leaf litter (generally 30–100 mm thick) (Department of Climate Change, Energy, the Environment and Water, 2023).	Unlikely	The survey area does not contain mapped suitable habitat.
Ornamental Snake	*Denisonia maculata*	V	V	The species is known only from the Brigalow Belt North and parts of the Brigalow Belt South biogeographical regions. The core of the species' distribution occurs within the drainage system of the Fitzroy and Dawson Rivers. The Ornamental Snake's preferred habitat is within, or close to, habitat that is favoured by its prey - frogs. The species is known to occur in RE 11.4.3, 11.4.6, 11.4.8, 11.4.9, 11.3.3, and 11.5.16 (Department of the Environment 2020).	Unlikely	The survey area does not contain mapped suitable habitat.
Yakka Skink	*Egernia rugosa*	V	V	The Yakka Skink is commonly found in cavities under and between partly buried rocks, logs or tree stumps, root cavities and abandoned animal burrows. The species often takes refuge in large hollow logs and has been known to excavate deep burrow systems, sometimes under dense ground vegetation. In cleared habitat, this species can persist where there are shelter sites such as raked log piles, deep gullies, tunnel erosion/sinkholes and rabbit warrens. The species has also been found sheltering under sheds and loading ramps. This species is not generally found in trees or rocky habitats (Department of Sustainability Environment Water Population and Communities 2011).	Potential	Records are not within 15 km however the survey area contains suitable mapped habitat.

Table Key: SL – Special Least Concern, LC – Least Concern, Ma – Marine, M – Migratory, V – Vulnerable, E – Endangered, CE – Critically Endangered

Table 2: Desktop Threatened Flora Likelihood of Occurrence assessment within the Survey area.

Scientific Name	Common Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
Homoranthus decumbens	NA	E	V	*Homoranthus decumbens* is endemic to Queensland, where it is known from two areas: Blackdown Tableland and Barakula State Forest (Queensland Herbarium, 2009). The extent of occurrence is 3 km2 and area of occupancy is estimated to be less that 1 km2 (Queensland Herbarium 2009). The species is found in tall shrubland or heath up to 800 m in altitude	Unlikely	The survey area does not contain suitable mapped habitat.
Solanum dissectum	NA	E	E	*Solanum dissectum* has a restricted distribution in central Queensland. It has mainly been found in the area bounded by Banana, Dululu, Moura and Thangool but has also been recorded 40 km south of Blackwater. Solanum dissectum occurs in open forest and woodland of brigalow (*Acacia harpophylla*) or *Eucalyptus thozetiana* on solodic clay soils (Department of Environment and Science, 2012).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Solanum elachophyllum	NA	-	E	*Solanum elachophyllum* is endemic to Queensland and confined to the central subcoastal part of the state, from Middlemont to Theodore. The species occurs within Junee State Forest and Taunton National Park. *Solanum elachophyllum* grows on fertile cracking-clay soils in open forest of *Eucalyptus thozetiana, Acacia harpophylla*, with understorey of *Geijera parviflora, Casuarina cristata, Macropteranthes leichhardtii, Eucalyptus cambageana*, or woodland of *E. crebra* and *E. tenuipes* (Department of Environment and Science, 2012).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Macrozamia platyrhachis	cycad	E	E	*Macrozamia platyrhachis* is scattered and locally abundant in eucalypt woodland or open forest at altitudes between 300-780m above sea level. The mid- and under-stories of the vegetation may be quite dense, but this is variable depending on fire history. The species grows on deep sandy soils, derived from sandstone (Department of Environment and Science, 2009).	Unlikely	The survey area does not contain suitable mapped habitat.
Cadellia pentastylis	Ooline	V	V	*Cadellia pentastylis* is now restricted in distribution from near Duaringa west of Rockhampton to the NSW border in Queensland, and on the western edge of the North West Slopes north of Gunnedah in northern New South Wales. It occurs in a range of vegetation types including semi-evergreen vine thicket, brigalow-belah, poplar box and bendee communities. Ooline often occurs on the edges of sandstone and basalt escarpments, 200 to 500 m above sea level. In most areas of its range, ooline grows on the moderately fertile soils preferred for agriculture and pasture development (Department of Environment and Science, 2009).	Potential	Records are within 15 km and the survey area contains limited suitable mapped habitat.
Daviesia discolor	NA	V	V	*Daviesia discolor* is known from three widely disjunct localities in Queensland, near Blackwater on the Blackdown Tableland, in the Mount Walsh area near Biggenden (Crisp, 1991) and north of Mount Playfair within Carnarvon National Park (Queensland Herbarium specimen records). On the Blackdown Tableland, *D. discolor* occurs on sandy soil derived from sandstone and on lateritic clay, at altitudes of 600 to 900 m, in open eucalypt forest dominated by species such as Blackdown Stringybark (*Eucalyptus sphaerocarpa*) and Black Stringybark (*Eucalyptus nigra*) (Crisp, 1991). In the Mount Walsh area, *D. discolor* grows in very tall open forests of Bloodwood (*Corymbia trachyphloia*) and White Mahogany (*Eucalyptus acmenoides*) on hillcrests and slopes at 500 to 580 m altitude on well-drained, shallow sandy loam to sandy clays (Halford, 1998). The population in Carnarvon National Park occurs on brown sandy loam of creek banks, in mixed shrubland with scattered *Triodia sp.* hummocks and *Angophora sp.* trees (CANB collection details, 1993).	Unlikely	The survey area does not contain suitable mapped habitat.
Polianthion minutiflorum	NA	V	V	*Polianthion minutiflorum* is known from five areas in east Queensland, from Redcliffe Vale, about 110 km west of Mackay, south to Kingaroy, covering a distance of approximately 800 km (BRI collection records, n.d.). It grows in forest and woodland on sandstone slopes and gullies	Unlikely	The survey area does not contain suitable mapped habitat.

Scientific Name	Common Name	Status		Habitat Description	Likelihood of Occurrence	Justification
		EPBC Act	NC Act			
				with skeletal soil, or deeper soils adjacent to deeply weathered laterite (Kellermann et al., 2006).		
Arthraxon hispidus	Hairy-joint Grass	V	V	Occurs north from Gibraltar Range where it grows on the edges of rainforest and in wet sclerophyll forest. It prefers moist shady sites and is often found near creeks or swamps (Harden, 1993; NSW National Parks and Wildlife Service, 2002)	Unlikely	The survey area does not contain suitable mapped habitat.
Dichanthium setosum	bluegrass	V	LC	Occurs from southern New South Wales to northern Queensland, often on black soil and red-brown loamy soil. The species has a wide, disjunct distribution and can be locally common. Habitat can include woodlands or open woodlands dominated by Acacia and/or Eucalypt species, grasslands and previously cleared areas such as road reserve and pasture (Office of Environment and Heritage, 2023).	Unlikely	The survey area does not contain suitable mapped habitat.
Dichanthium queenslandicum	King Blue-grass	E	V	*Dichanthium queenslandicum* occurs from near Dalby north to about 90 km north of Hughenden and west as far as Clermont. The main concentration of populations in central Queensland in the Emerald region. *Dichanthium queenslandicum* occurs on black cracking clay in tussock grasslands on undulating plains mainly in association with other species of blue grasses *(Dichanthium spp.* and *Bothriochloa spp.*) but also with other grasses restricted to this soil type (Department of Environment and Science, 2012).	Unlikely	The survey area does not contain suitable mapped habitat.
Bertya opponens	NA	V	LC	*Bertya opponens* has been recorded growing in a variety of community types including mixed shrubland, lancewood woodland, mallee woodland, eucalypt/Acacia open forest with shrubby understorey, eucalypt/Callitris open woodland and semi-evergreen vine-thicket. The soils are recorded as generally shallow sandy loams or red earths associated mostly with sandstone, but also with rhyolite, shale and metasediments (Department of Environment and Science, 2012)	Likely	Records are within 15 km and the survey area contains suitable mapped habitat.
Aristida annua	NA	V	V	*Aristida annua* is restricted to central Queensland in the Emerald and Springsure districts (BRI, undated.; Simon, 1984; 1992). The species is very poorly understood, there is no information on the population size of *Aristida annua* and there appears to be no survey data. *Aristida annua* occurs in eucalypt woodland (BRI collection records, n.d.; Simon, 1984; 1992). It is restricted to black clay soils (Simon, 1984), basalt soils and possibly disturbed sites.	Unlikely	The survey area does not contain suitable mapped habitat.
Cerbera dumicola	NA	-	NT	Cerbera dumicola occurs across a range of habitats in central and southern Queensland. Associated vegetation and species include: sandstone hills in open *E. umbra subsp. carnea*; on plateaus, in woodland of *Acacia shirleyi* with *Corymbia dolichocarpa*; acidic soils in mine rehabilitation area; woodland of *A. catenulata* and *A. shirleyi* with *E. thozetiana* on a slope of sand/clay soil; semi-deciduous notophyll-microphyll vine forest of *Brachychiton australis*, *Gyrocarpus americanus, Flindersia australis, Pleiogynium timorense, Drypetes deplanchei* and *Sterculia quadrifida* on rhyolite hillslopes; open-woodland of *E. melanophloia* with occasional *Acacia shirleyi, E. populnea* and *E. brownii*; semi-evergreen vine thicket with *Corymbia citriodora* and *Corymbia aureola* emergents; woodland of *A. rhodoxylon* on brown, sandy loam; and in *Corymbia tessellaris - Acacia aneura* open woodland (Department of Environment and Science, 2012).	Likely	Records are within 15 km and the survey area contains suitable mapped habitat.

Table Key: LC – Least Concern, NT – Near Threatened, V – Vulnerable, E – Endangered, CE – Critically Endangered

Table 3: Desktop Threatened Ecological Communities Likelihood of Occurrence assessment within the Survey area.

Threatened Ecological Community	EPBC Act Status	Description	Likelihood of Occurrence	Justification
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Semi-arid to humid subtropical woodland where coolibah (*Eucalyptus coolibah subsp. coolibah*) and/or black box (*Eucalyptus largiflorens*) are the dominant canopy species and where the understorey tends to be grassy. The ecological community is associated with the floodplains and drainage areas.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Ten of 15 types of SEVT community described for the Brigalow Belt (North and South) Bioregion (Sattler and Williams 1999) are included in the EPBC Act listed SEVT EC - RE 11.2.3, 11.3.11, 11.4.1, 11.5.15, 11.8.3, 11.8.6, 11.8.13, 11.9.4, 11.9.8, 11.11.18.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	This TEC is located west of the Great Dividing Range, and is typically associated with the Brigalow Belt bioregions. In South East Queensland, it coincides with one Regional Ecosystem, RE 12.3.10.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.
Brigalow (*Acacia harpophylla* dominant and co-dominant)	Endangered	In Queensland, the ecological community coincides with 16 Regional Ecosystems: 11.2.1, 11.4.3, 11.4.7, 11.4.8, 11.4.9, 11.4.10, 11.5.16, 11.9.1, 11.9.5, 11.9.6, 11.11.14, 11.12.21, 12.8.23, 12.9-10.6, 12.12.26, 6.4.2. All 16 REs are listed as endangered under the VM Act 1999 as at Oct 2013.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.
Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin	Endangered	Corresponds closest to these Regional Ecosystems in Queensland: 11.3.21, 11.4.4, 11.4.11, 11.8.11, 11.9.3, 11.9.12, 11.11.17.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.
Weeping Myall Woodlands	Endangered	This TEC occurs on the inland alluvial plains west of the Great Dividing Range. The Weeping Myall Woodlands occurs within RE 11.3.2 and 11.3.28. The proportion of these regional ecosystems that comprose Weeping Myall Woodlands is at most 5%.	Unlikely	The survey area does not contain any mapped regional ecosystems which correspond with this TEC.

Australian Government

Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 19-Sep-2025

Summary

Details

- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat

Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	6
Listed Threatened Species:	36
Listed Migratory Species:	10

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	18
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	2
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	11
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text	Buffer Status
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area	In feature area
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Community may occur within area	In buffer area only
Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin	Endangered	Community likely to occur within area	In feature area
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	Community likely to occur within area	In feature area
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Community likely to occur within area	In feature area
Weeping Myall Woodlands	Endangered	Community likely to occur within area	In feature area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat likely to occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In feature area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat known to occur within area	In feature area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Neochmia ruficauda ruficauda Star Finch (eastern), Star Finch (southern) [26027]	Endangered	Species or species habitat likely to occur within area	In feature area
Poephila cincta cincta Southern Black-throated Finch [64447]	Endangered	Species or species habitat may occur within area	In feature area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area	In feature area
Stagonopleura guttata Diamond Firetail [59398]	Vulnerable	Species or species habitat may occur within area	In feature area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat may occur within area	In buffer area only
MAMMAL			

Scientific Name	Threatened Category	Presence Text	Buffer Status
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Endangered	Species or species habitat may occur within area	In buffer area only
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area	In feature area
Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area	In feature area
Petauroides volans Greater Glider (southern and central) [254]	Endangered	Species or species habitat likely to occur within area	In feature area
Petaurus australis australis Yellow-bellied Glider (south-eastern) [87600]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Endangered	Species or species habitat likely to occur within area	In feature area
PLANT			
Aristida annua [17906]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Arthraxon hispidus Hairy-joint Grass [9338]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Bertya opponens [13792]	Vulnerable	Species or species habitat known to occur within area	In feature area
Cadellia pentastylis Ooline [9828]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Daviesia discolor [3567]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Dichanthium queenslandicum King Blue-grass [5481]	Endangered	Species or species habitat may occur within area	In feature area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat may occur within area	In feature area
Homoranthus decumbens a shrub [55186]	Endangered	Species or species habitat may occur within area	In buffer area only
Macrozamia platyrhachis cycad [3412]	Endangered	Species or species habitat likely to occur within area	In buffer area only
Polianthion minutiflorum [82772]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Solanum dissectum [75720]	Endangered	Species or species habitat known to occur within area	In feature area
REPTILE			
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Denisonia maculata Ornamental Snake [1193]	Vulnerable	Species or species habitat known to occur within area	In feature area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area	In feature area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat may occur within area	In feature area
Hemiaspis damelii Grey Snake [1179]	Endangered	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Rheodytes leukops			
Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver [1761]	Endangered	Species or species habitat likely to occur within area	In feature area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Apus pacificus			
Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Terrestrial Species			
Cuculus optatus			
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area	In feature area
Hirundapus caudacutus			
White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Motacilla flava			
Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Migratory Wetlands Species			
Actitis hypoleucos			
Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Calidris acuminata			
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea			
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Calidris melanotos			
Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area
Gallinago hardwickii			
Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Pandion haliaetus](#) Osprey [952]		Species or species habitat may occur within area	In feature area

Other Matters Protected by the EPBC Act

Listed Marine Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
[Anseranas semipalmata](#) Magpie Goose [978]		Species or species habitat may occur within area overfly marine area	In feature area
[Apus pacificus](#) Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
[Bubulcus ibis as Ardea ibis](#) Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area overfly marine area	In feature area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area overfly marine area	In buffer area only
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area overfly marine area	In buffer area only
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area overfly marine area	In feature area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Rhipidura rufifrons			
Rufous Fantail [592]		Species or species habitat may occur within area overfly marine area	In buffer area only
Rostratula australis as Rostratula benghalensis (sensu lato)			
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area	In feature area

Extra Information

State and Territory Reserves			[Resource Information]
Protected Area Name	Reserve Type	State	Buffer Status
Blackdown Tableland	National Park	QLD	In buffer area only
Kenmare	Nature Refuge	QLD	In buffer area only

EPBC Act Referrals				[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Blackwater Mine ? North Extension Project	2023/09723		Assessment	In buffer area only
Blackwater Mine South Coking Coal Project	2022/09279		Assessment	In buffer area only
Coal Seam Gas Field Development for Natural Gas Liquefaction Park, Curtis Island	2008/4059		Post-Approval	In buffer area only
Comet Ridge Mahalo North Coal Seam Gas Project	2023/09689		Assessment	In buffer area only
rail track to link the proposed MIM Rolleston coal mine to existing rail network	2002/637		Post-Approval	In feature area
Controlled action				
Future Gas Supply Area Project	2012/6357	Controlled Action	Completed	In buffer area only
Norwich Park & Blackwater CSG Fields & supporting infrastructure Bowen Basin	2011/6032	Controlled Action	Completed	In buffer area only
Santos GLNG Gas Field Development Project, QLD	2012/6615	Controlled Action	Post-Approval	In buffer area only

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Controlled action				
ZeroGen Integrated Gasification Combined Cycle Power Plant and CO2 Capture, Transport and Storage	2009/5195	Controlled Action	Completed	In feature area
Not controlled action				
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
Not controlled action (particular manner)				
Blackwater to Rolleston 132 kV transmission line	2002/880	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data is available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on the contents of this report.

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions when time permits.

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded breeding sites; and
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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WN Taxon ID	Kingdom	Class	Family	Scientific name	Common name	NCA status	EPBC status	Superseded	Conservation significant	Establishment	Sensitive species	Sighting records	Specimen records	Sighting summary
8936	Plantae	Equisetopsida	Apocynaceae	Cerbera dumicola		NT		No	Yes	NTQ	No	2	2	2
36488	Plantae	Equisetopsida	Campanulaceae	Wahlenbergia capillaris		SL		No	Yes	NTQ	No	1	0	1
11323	Plantae	Equisetopsida	Euphorbiaceae	Bertya opponens		C	V	No	Yes	NTQ	No	2	2	2
6198	Plantae	Equisetopsida	Solanaceae	Solanum dissectum		E	E	No	Yes	NTQ	No	3	3	3
13541	Plantae	Equisetopsida	Solanaceae	Solanum elachophyllum		E		No	Yes	NTQ	No	1	1	1
17796	Plantae	Equisetopsida	Sterculiaceae	Brachychiton australis	broad-leaved bottle tree	SL		No	Yes	NTQ	No	1	0	1
13670	Plantae	Equisetopsida	Surianaceae	Cadellia pentastylis	ooline	V	V	No	Yes	NTQ	No	2	2	2

Queensland Government

Department of the Environment, Tourism, Science and Innovation

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest

Longitude: 148.8385853576 Latitude: -23.91220309238 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 2020). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and a field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@detsi.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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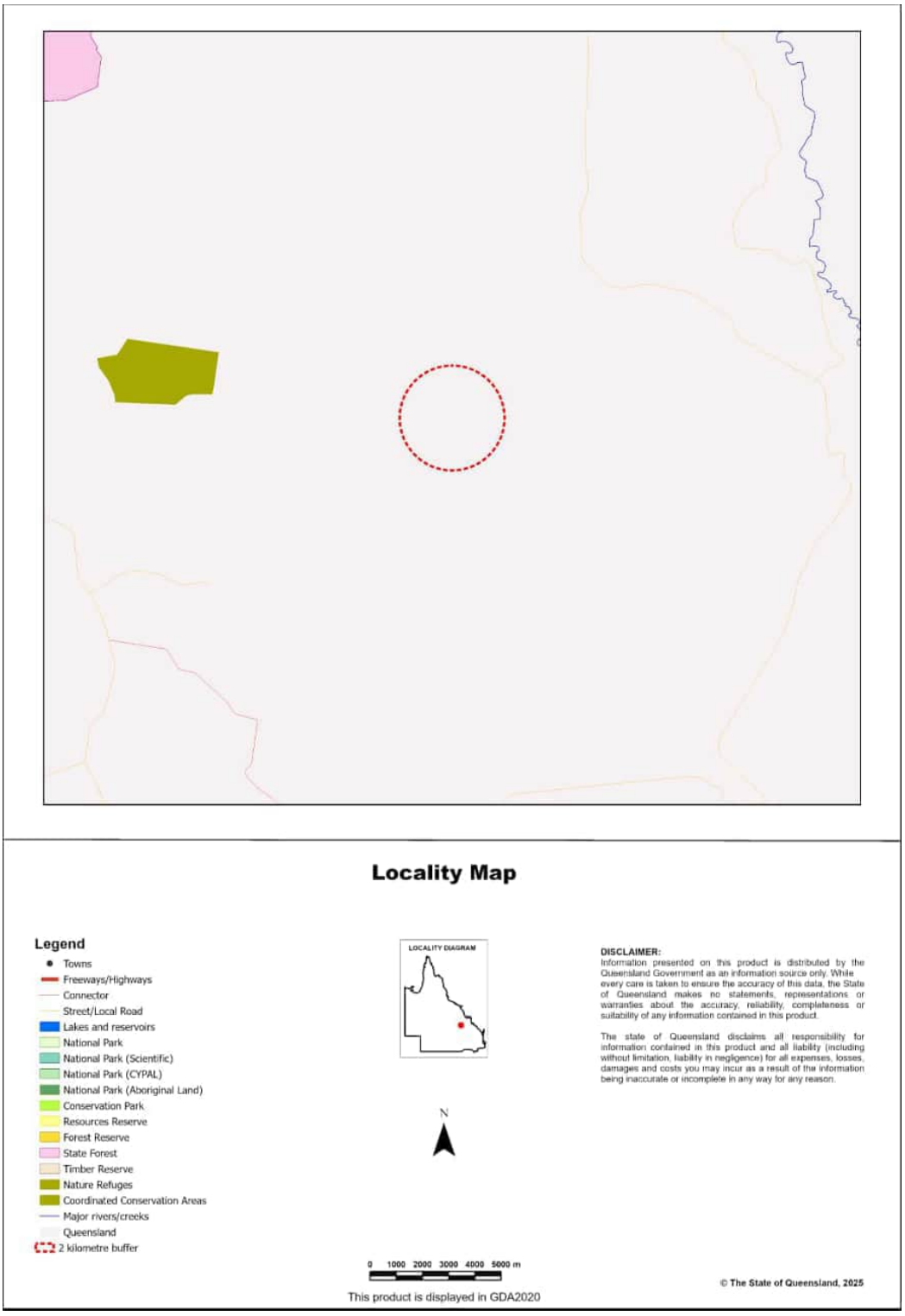
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI: Longitude: 148.8385853576 Latitude: -23.91220309238 with 2 kilometre radius, with area 1256.64 ha

Local Government(s)	Catchment(s)	Bioregion(s)	Subregion(s)
Central Highlands Regional	Fitzroy	Brigalow Belt	Isaac - Comet Downs



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992;*

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the Marine Parks Act 2004 ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- *Threatened wildlife under the Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

  - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
  - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
  - Category R areas on the regulated vegetation management map;
  - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;
  - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;
- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0 ha	0.0%
1b Protected Areas- nature refuges	0 ha	0.0%
1c Protected Areas- special wildlife reserves	0 ha	0.0%
2 State Marine Parks- highly protected zones	0 ha	0.0%
3 Fish habitat areas (A and B areas)	0 ha	0.0%
4 Strategic Environmental Areas (SEA)	0 ha	0.0%
5 High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values	0 ha	0.0%
6a High Ecological Value (HEV) wetlands	0 ha	
6b High Ecological Value (HEV) waterways	0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	259.23 ha	20.6%
7b Special least concern animals	0 ha	0.0%
7c i Koala habitat area - core (SEQ)	0 ha	0.0%
7c ii Koala habitat area - locally refined (SEQ)	0 ha	0.0%
7d Sea turtle nesting areas	0 km	Not applicable
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	258.97 ha	20.6%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0 ha	0.0%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	2.95 ha	0.2%
8d Regulated Vegetation - Essential habitat	298.76 ha	23.8%
8e Regulated Vegetation - intersecting a watercourse	9.2 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0 ha	0.0%
9a Legally secured offset areas- offset register areas	0 ha	0.0%
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0 ha	0.0%

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(No results)

1b. Protected Areas - nature refuges

(No results)

1c. Protected Areas - special wildlife reserves

(No results)

2. State Marine Parks - highly protected zones

(No results)

3. Fish habitat areas (A and B areas)

(No results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(No results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

(no results)

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Not applicable

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

7d. Wildlife habitat (sea turtle nesting areas)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii	Keys boronia	V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	Core
Euastacus bindal	Mount Elliot crayfish	CR	None
Euastacus binzayedi		CR	None
Euastacus eungella		E	None
Euastacus hystricosus		E	None
Euastacus jagara	Jagara hairy crayfish	CR	None
Euastacus maidae		CR	None
Euastacus monteithorum		E	None
Euastacus robertsi		E	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Macadamia integrifolia		V	None
Melaleuca irbyana	swamp tea-tree	E	None
Macadamia ternifolia		V	None
Macadamia tetraphylla	bopple nut	V	None
Petrogale penicillata	brush-tailed rock-wallaby	V	None
Petrogale coenensis	Cape York rock-wallaby	E	None
Petrogale purpureicollis	purple-necked rock-wallaby	V	None
Petrogale sharmani	Sharmans rock-wallaby	V	None
Petrogale xanthopus celeris	yellow-footed rock-wallaby (Qld subspecies)	V	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Phascolarctos cinereus	Koala - outside SEQ*	E	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Xeromys myoides	Water Mouse	V	None

*For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.

Threatened (endangered or vulnerable) wildlife species records

(No results)

Special least concern animal species records

(No results)

Shorebird habitat (critically endangered/endangered/vulnerable)

Not applicable

Shorebird habitat (special least concern)

Not applicable

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:

https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals** and **Map 3b - MSES - Species - Koala habitat area (SEQ)** and **Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:

https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:

https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.4/11.3.2/11.4.9a/11.3.25	E-subdom	rem_end
11.4.8/11.4.9b/11.5.15	E-dom	rem_end
11.7.2/11.4.9b/11.5.15	E-subdom	rem_end

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Regulated vegetation map category	Map number
R	8650

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

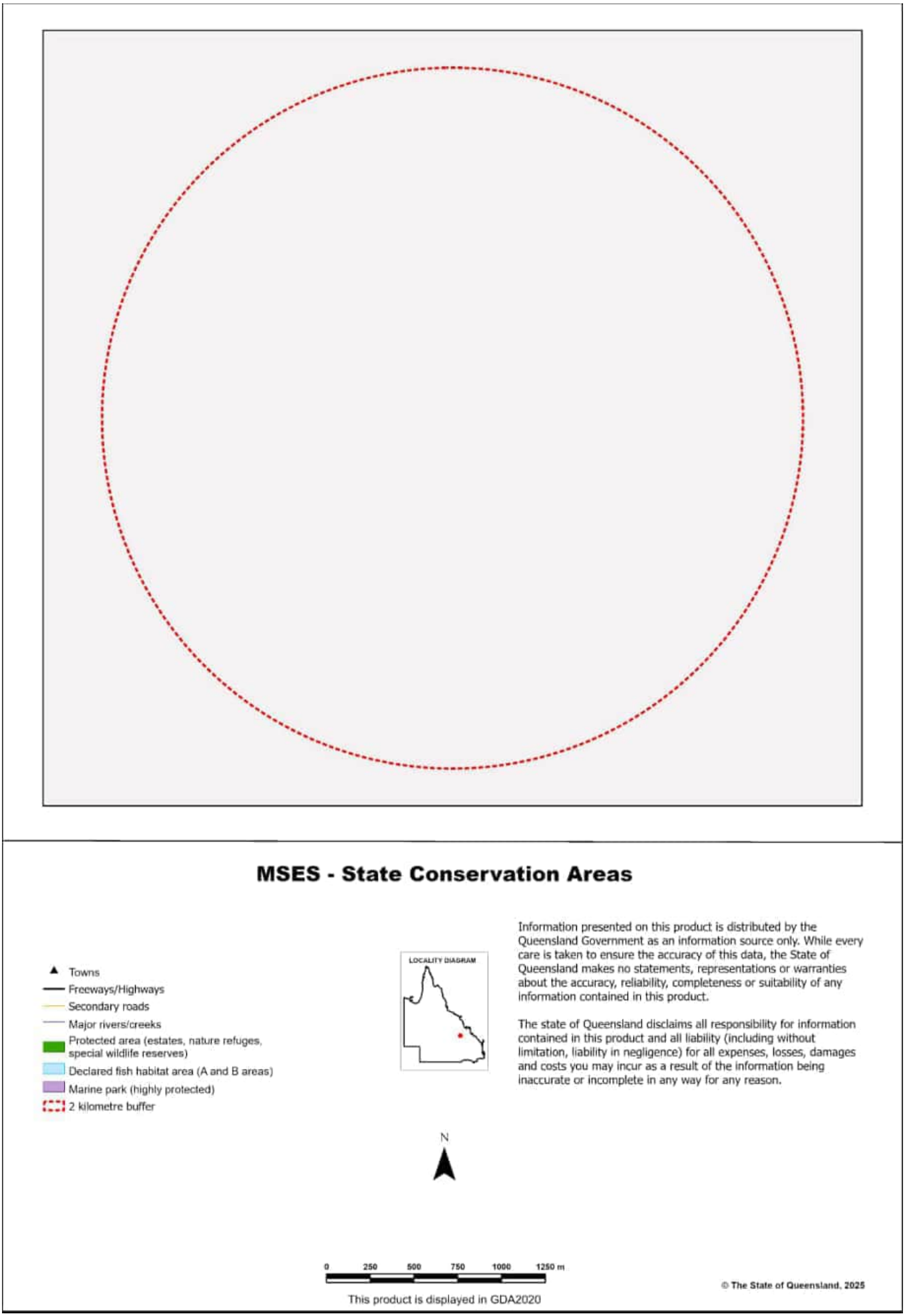
(No results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

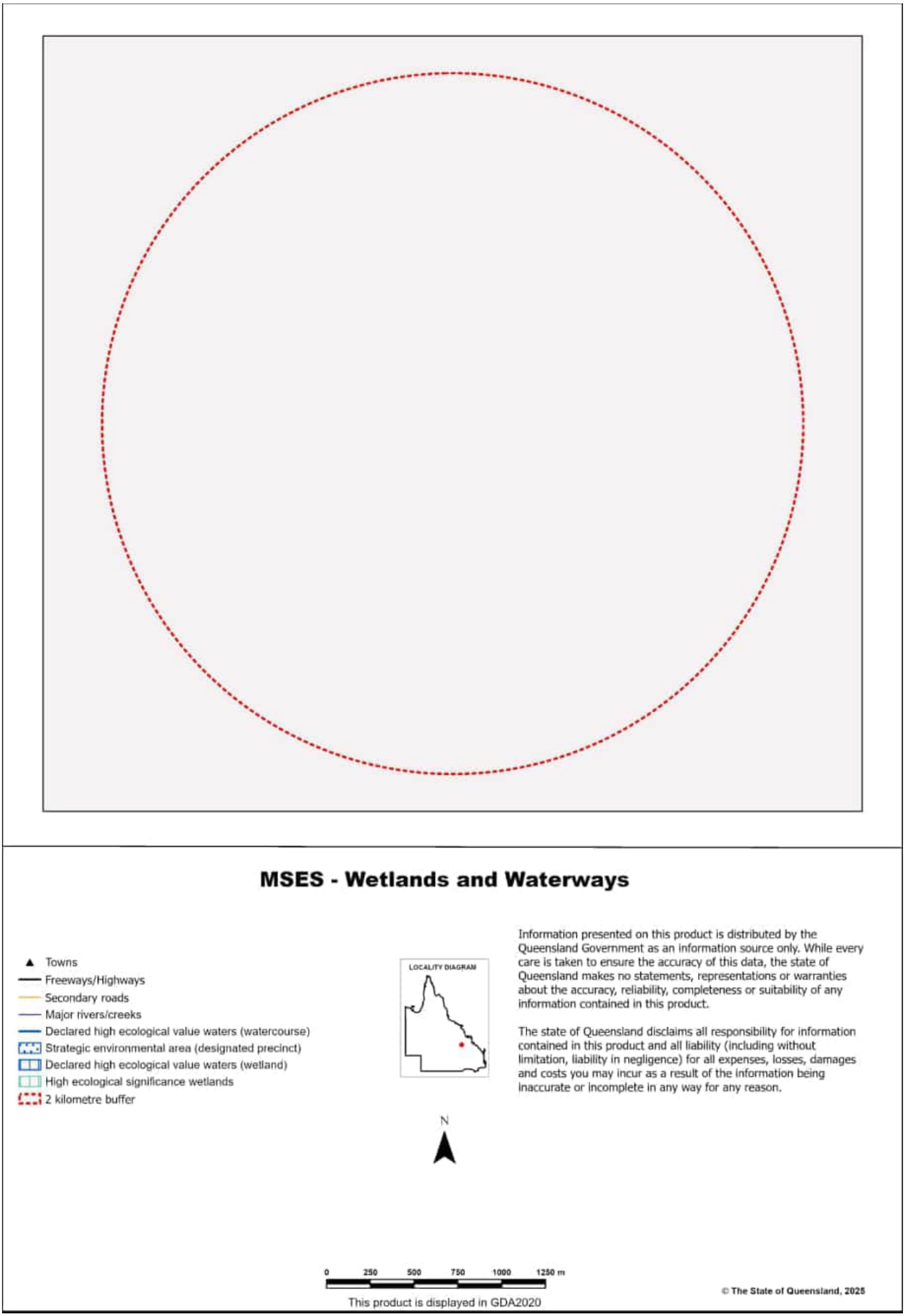
(No results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

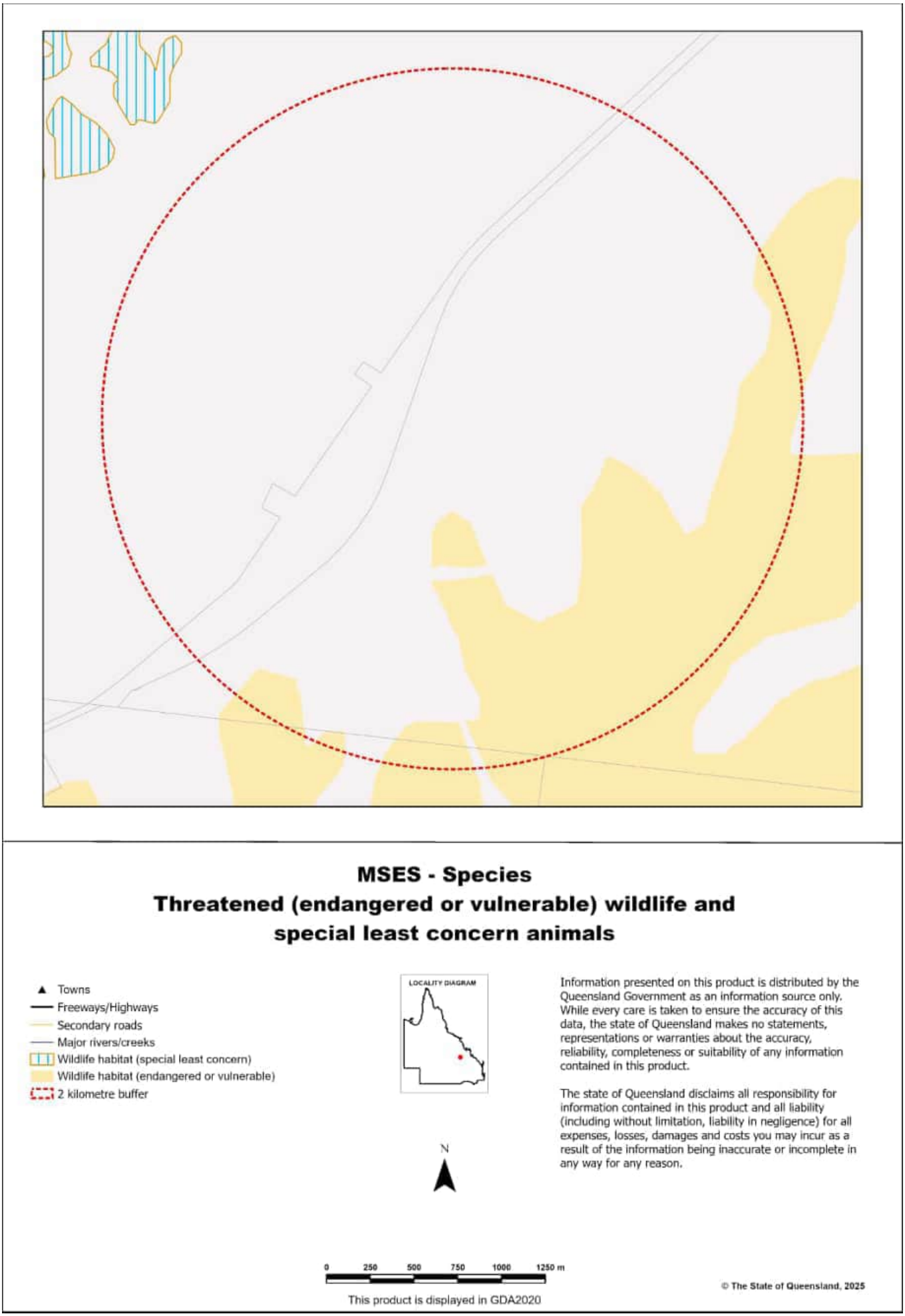
Map 1 - MSES - State Conservation Areas



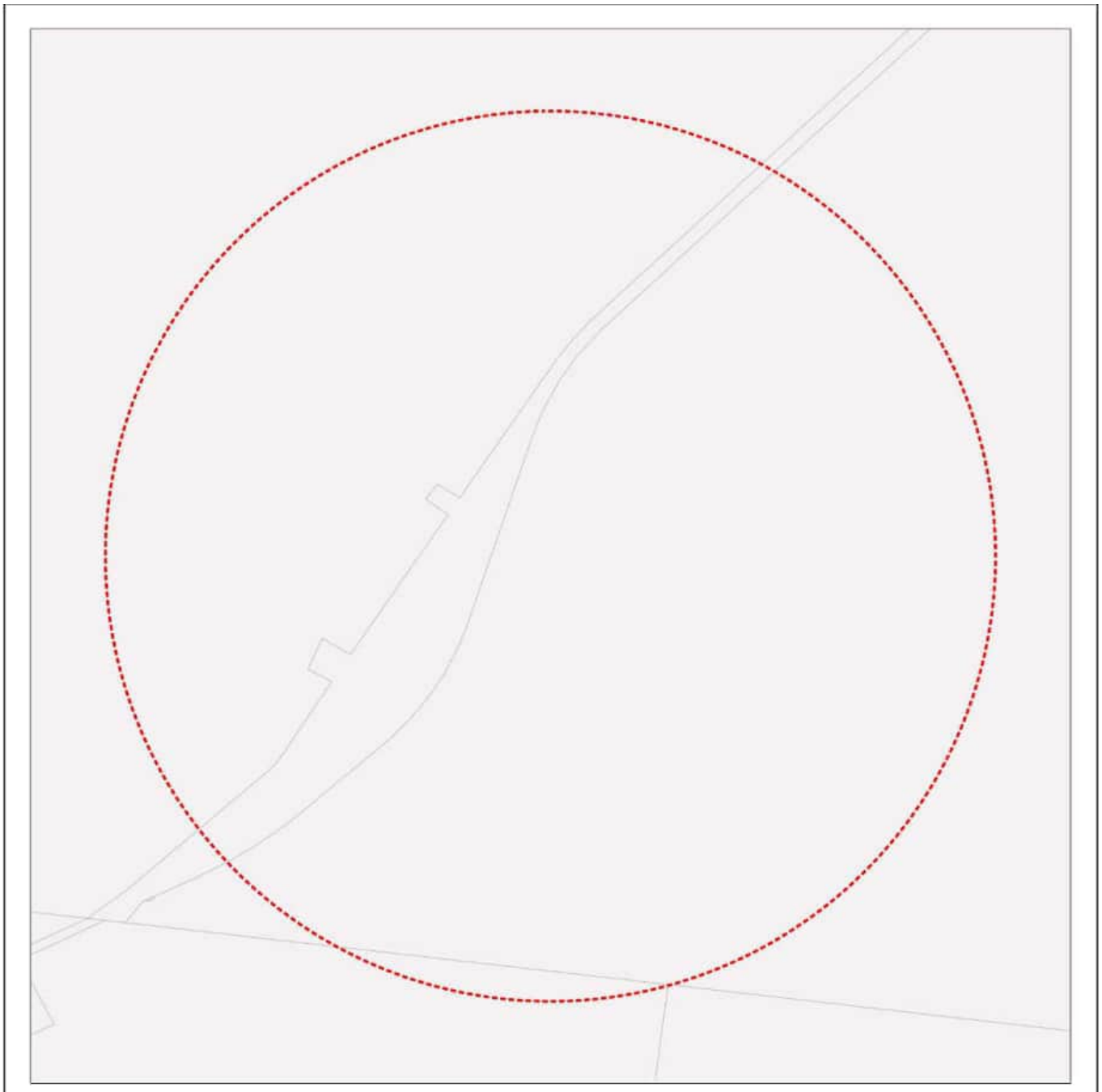
Map 2 - MSES - Wetlands and Waterways



Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



Map 3b - MSES - Species - Koala habitat area (SEQ)



MSES - Species
Koala habitat area (SEQ)

- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)
- 2 kilometre buffer

LOCALITY DIAGRAM



While every care is taken to ensure the accuracy of this product, the Department of the Environment, Tourism, Science and Innovation acting on behalf of the State of Queensland makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which you might incur as a result of the data being inaccurate or incomplete in any way and for any reason. Due to varying sources of data, spatial locations may not coincide when overlaid.

The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

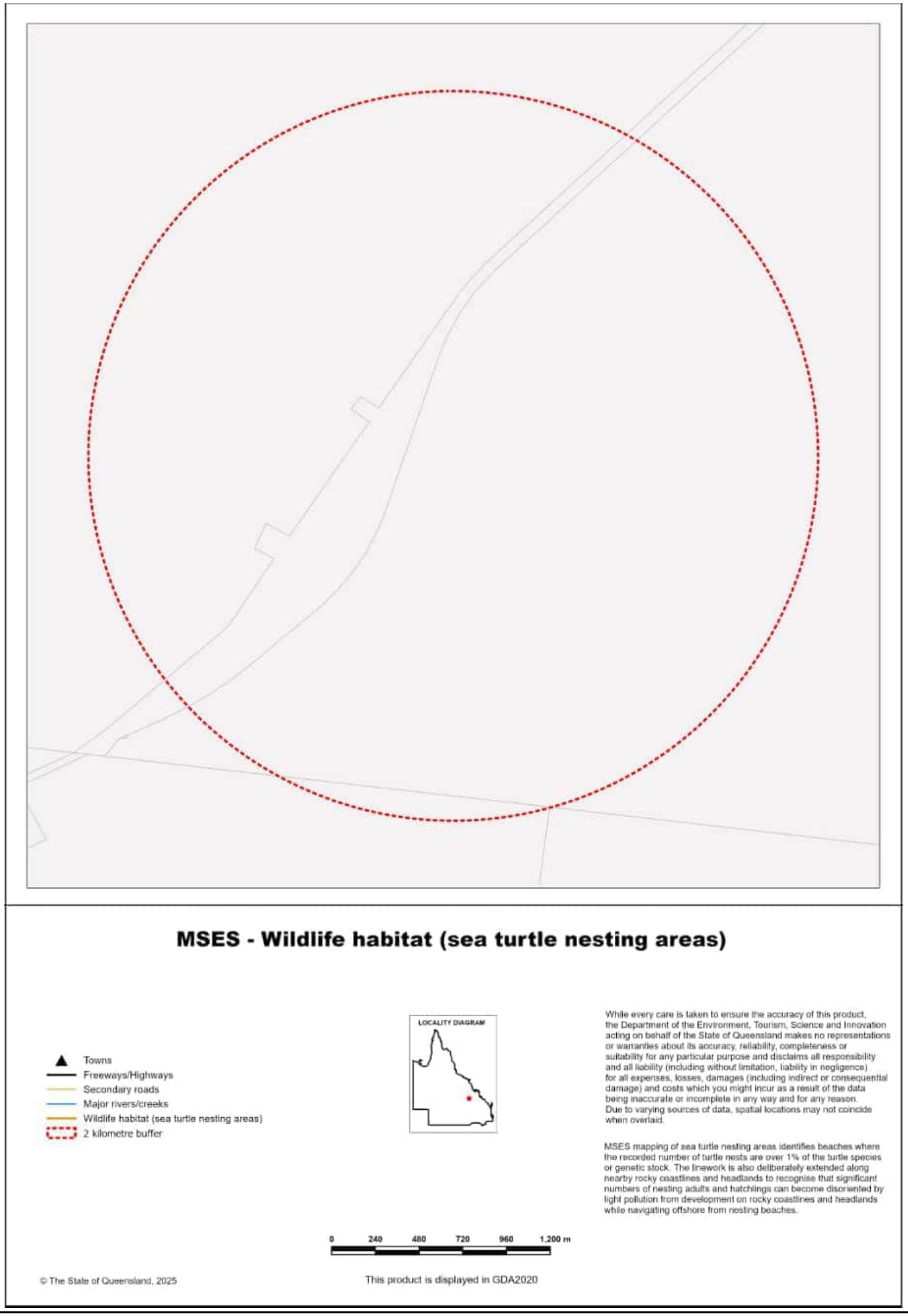
The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

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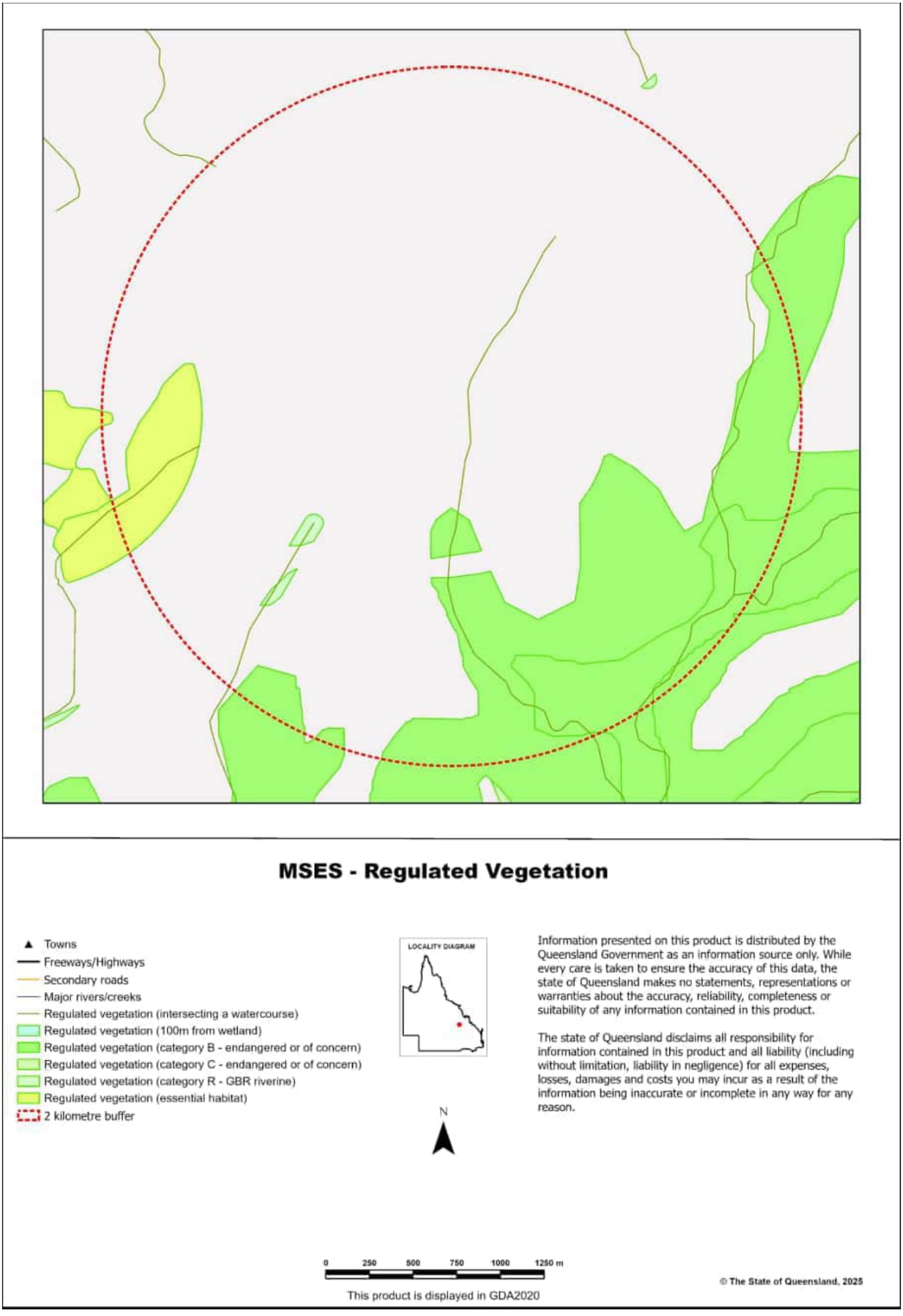
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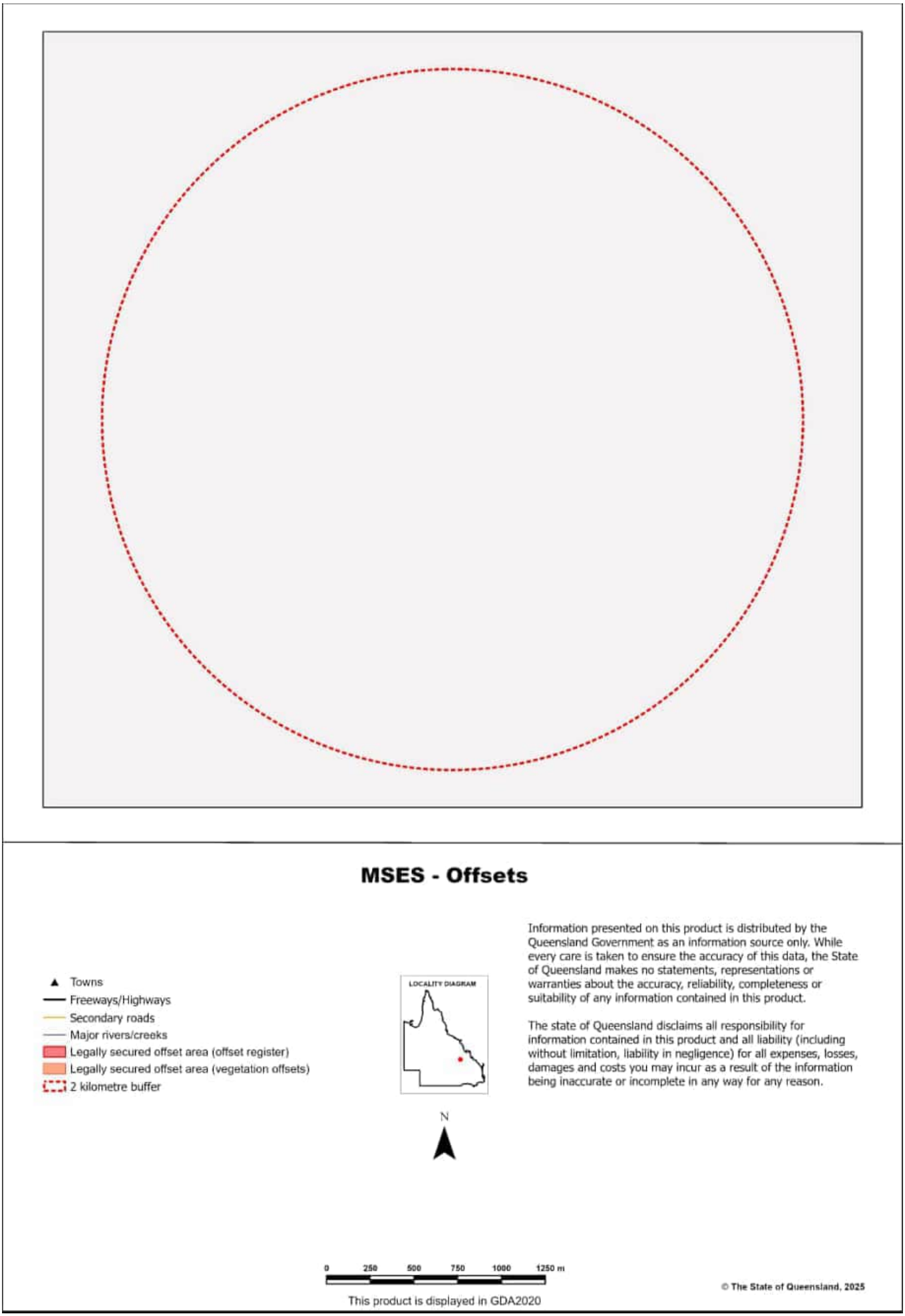
Map 3c - MSES - Species - Wildlife habitat (sea turtle nesting areas)



Map 4 - MSES - Regulated Vegetation



Map 5 - MSES - Offset Areas



Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). Its primary purpose is to support implementation of the SPP biodiversity policy.

MSES mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations.

MSES mapping does not determine whether state or local development assessment is required. For state assessment triggers refer to the Development Assessment Mapping System (DAMS). For local assessment triggers, refer to the relevant local planning scheme.

The Queensland Government's "Method for mapping - matters of state environmental significance can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DETSI
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DETSI	- Department of the Environment, Tourism, Science and Innovation
EP Act	- Environmental Protection Act 1994
EPP	- Environmental Protection Policy
GDA2020	- Geocentric Datum of Australia 2020
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- Nature Conservation Act 1992
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- Vegetation Management Act 1999

Queensland Government

Department of the Environment, Tourism, Science and Innovation

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
Longitude: 148.8385853576 Latitude: -23.91220309238 with 2 kilometre buffer

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 2020). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium & Biodiversity Science's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium & Biodiversity Science's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development website https://www.nrmmrrd.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Details for area of interest:
Longitude: 148.8385853576 Latitude: -23.91220309238 with 2 kilometre buffer, with area 1256.64 ha

Local Government(s)	Catchment(s)	Bioregion(s)	Subregion(s)
Central Highlands Regional	Fitzroy	Brigalow Belt	Isaac - Comet Downs

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	194.75	15.50
Of concern	55.44	4.41
No concern at present	521.02	41.46
Total remnant vegetation	771.22	61.37

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and may be distinguished by differences in structure or sub-dominant species in the ecologically dominant layer. Vegetation communities with different dominant species in the ecologically dominant layer may be amalgamated in to a regional ecosystem if they are not mappable and predictable in the landscape at 1:100 000 scale. Vegetation communities may be mappable at a scale larger than 1:100 000. Vegetation communities within a regional ecosystem are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2023) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium & Biodiversity Science's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development website https://www.nrmmrrd.qld.gov.au/.

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 percent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 percent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (<1000 ha); or patch size (<100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

*****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.*

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
11.10.1	Blakella citriodora woodland on coarse-grained sedimentary rocks	No concern at present	62.49	4.97
11.3.2	Eucalyptus populnea woodland on alluvial plains	Of concern	18.48	1.47
11.3.25	Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines	Of concern	6.16	0.49
11.3.4	Eucalyptus tereticornis and/or Eucalyptus spp. woodland on alluvial plains	Of concern	30.80	2.45
11.4.8	Eucalyptus cambageana woodland to open forest with Acacia harpophylla or A. argyrodendron on Cenozoic clay plains	Endangered	102.35	8.14
11.4.9a	Acacia harpophylla shrubby woodland with Terminalia oblongata on Cenozoic clay plains	Endangered	6.16	0.49
11.4.9b	Acacia harpophylla shrubby woodland with Terminalia oblongata on Cenozoic clay plains	Endangered	76.44	6.08
11.5.15	Semi-evergreen vine thicket on Cenozoic sand plains and/or remnant surfaces	Endangered	9.81	0.78
11.5.9b	Eucalyptus crebra and other Eucalyptus spp. and Corymbia spp. woodland on Cenozoic sand plains and/or remnant surfaces	No concern at present	2.42	0.19
11.7.2	Acacia spp. woodland on Cenozoic lateritic duricrust. Scarp retreat zone	No concern at present	456.11	36.30
non-remnant	None	None	484.59	38.56

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the AOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.10.1	Pre-clearing 981000 ha; Remnant 2023 848000 ha	10a	Not a Wetland	High
11.3.2	Pre-clearing 1872000 ha; Remnant 2023 482000 ha	17a	Contains Palustrine	Low
11.3.25	Pre-clearing 842000 ha; Remnant 2023 541000 ha	16a	Riverine	Low
11.3.4	Pre-clearing 680000 ha; Remnant 2023 177000 ha	16c	Not a Wetland	Low
11.4.8	Pre-clearing 730000 ha; Remnant 2023 67000 ha	25a	Contains Palustrine	Low
11.4.9a	Pre-clearing 989000 ha; Remnant 2023 88000 ha	25a	Not a Wetland	Low
11.4.9b	Pre-clearing 989000 ha; Remnant 2023 88000 ha	25a	Not a Wetland	Low
11.5.15	Pre-clearing 43000 ha; Remnant 2023 14000 ha	7a	Not a Wetland	Low
11.5.9b	Pre-clearing 371000 ha; Remnant 2023 242000 ha	18b	Not a Wetland	Low
11.7.2	Pre-clearing 549000 ha; Remnant 2023 358000 ha	24a	Not a Wetland	Low
non-remnant	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
11.10.1	11.10.1: Potential habitat for NCA listed species: Acacia argentina, Acacia calantha, Acacia handonis, Acacia islana, Acacia pedleyi, Acacia sp. (Ruined Castle Creek P.I.Forster+ PIF17848), Apatophyllum teretifolium, Calytrix islensis, Capparis humistrata, Cerbera dumicola, Cryptandra ciliata, Eucalyptus beaniana, Homoranthus tricolor, Livistona nitida, Macrozamia crassifolia, Melaleuca groveana, Melaleuca irbyana, Micromyrtus rotundifolia, Ozothamnus eriocephalus, Pomaderris coomingalensis, Pseudanthus pauciflorus subsp. arenicola, Rutidosis crispata, Samadera bidwillii, Sannantha brachypoda, Zieria inexpectata.
11.3.2	11.3.2: Habitat for threatened flora species Homopholis belsonii. This ecosystem is also known to provide suitable habitat for koalas (Phascolarctos cinereus).
11.3.25	11.3.25: Shown to be associated with a high fauna species richness in the Taroom area (Venz et al. 2002). Within parts of the Fitzroy catchment, this RE is known habitat for the threatened freshwater turtle Rheodytes leukops. Known to be important habitat for other riparian freshwater turtle species. This ecosystem is also known to provide suitable habitat for koalas (Phascolarctos cinereus).
11.3.4	11.3.4: Potential habitat for NCA listed species: Acacia pedleyi, Callicarpa thozetii, Cycas megacarpa, Cycas ophiolitica, Digitaria porrecta, Eriocaulon carsonii subsp. orientale, Livistona nitida, Rhaponticum australe, Samadera bidwillii, Sannantha brachypoda. This ecosystem is also known to provide suitable habitat for koalas (Phascolarctos cinereus).
11.4.8	11.4.8a: Larger gilgai provides ephemeral wetland habitat.
11.4.9a	11.4.9: Potential habitat for NCA listed species: Cadellia pentastylis, Solanum adenophorum, Solanum dissectum, Solanum elachophyllum, Solanum johnsonianum, Xerothamnella herbacea.
11.4.9b	11.4.9: Potential habitat for NCA listed species: Cadellia pentastylis, Solanum adenophorum, Solanum dissectum, Solanum elachophyllum, Solanum johnsonianum, Xerothamnella herbacea.
11.5.15	11.5.15: Habitat for threatened plant species including Fontainea fugax, Pomaderris clivicola and Cadellia pentastylis and the near threatened species Macropteranthes leiocaulis; a wide range of flora and fauna species with disjunct distributions.
11.5.9b	11.5.9: Potential habitat for NCA listed species: Cerbera dumicola, Cossinia australiana, Cycas ophiolitica, Solanum elachophyllum.
11.7.2	11.7.2: Habitat for threatened plant species including Acacia wardellii.
non-remnant	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at: https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	484.59	38.56
10a	Dry woodlands to open woodlands dominated by Blakella citriodora (spotted gum).	62.49	4.97
16a	Open forest and woodlands dominated by Eucalyptus camaldulensis (river red gum) (or E. tereticornis (blue gum)) and/or E. coolabah (coolabah) (or E. microtheca (coolabah)) fringing drainage lines. Associated species may include Melaleuca spp., Blakella tessellaris (carbeen), Angophora spp., Casuarina cunninghamiana (riveroak). Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded.	6.16	0.49
16c	Woodlands and open woodlands dominated by Eucalyptus coolabah (coolabah) or E. microtheca (coolabah) or E. largiflorens (black box) or E. tereticornis (blue gum) or E. chlorophylla on floodplains. Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded.	30.80	2.45
17a	Woodlands dominated by Eucalyptus populnea (poplar box) (or E. brownii (Reid River box)) on alluvium, sand plains and footslopes of hills and ranges.	18.48	1.47
18b	Woodlands dominated Eucalyptus crebra (sens. lat.) (narrow-leaved red ironbark) frequently with Corymbia or Blakella spp. or Callitris spp. on flat to undulating plains.	2.42	0.19
24a	Low woodlands to tall shrublands dominated by Acacia spp. on residuals. Species include A. shirleyi (lancewood), A. catenulata (bendee), A. microsperma (bowyakka), A. clivicola, A. sibirica, A. rhodoxylon (rosewood) and A. leptostachya (Townsville wattle).	456.11	36.30
25a	Open forests to woodlands dominated by Acacia harpophylla (brigalow) sometimes with Casuarina cristata (belah) on heavy clay soils. Includes areas co-dominated with A. cambagei (gidgee) and/or emergent eucalypts.	184.95	14.72
7a	Semi-evergreen vine thickets on wide range of substrates.	9.81	0.78

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See: http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium & Biodiversity Science's QBEIS database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2023 (PDF)* section 3.3 of: https://www.qld.gov.au/__data/assets/pdf_file/0033/459186/methodology-mapping-surveying-v7.pdf

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community. http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

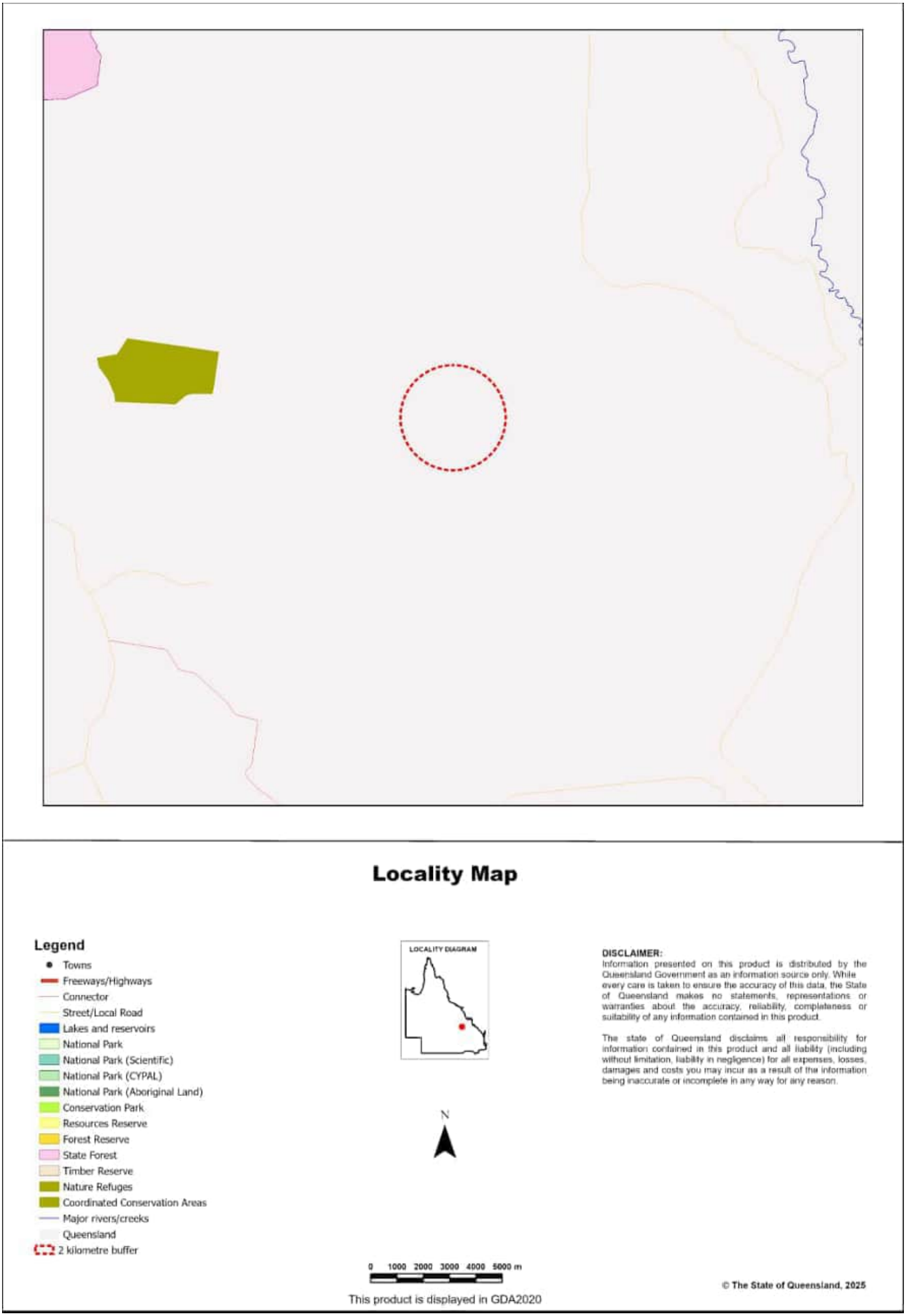
Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

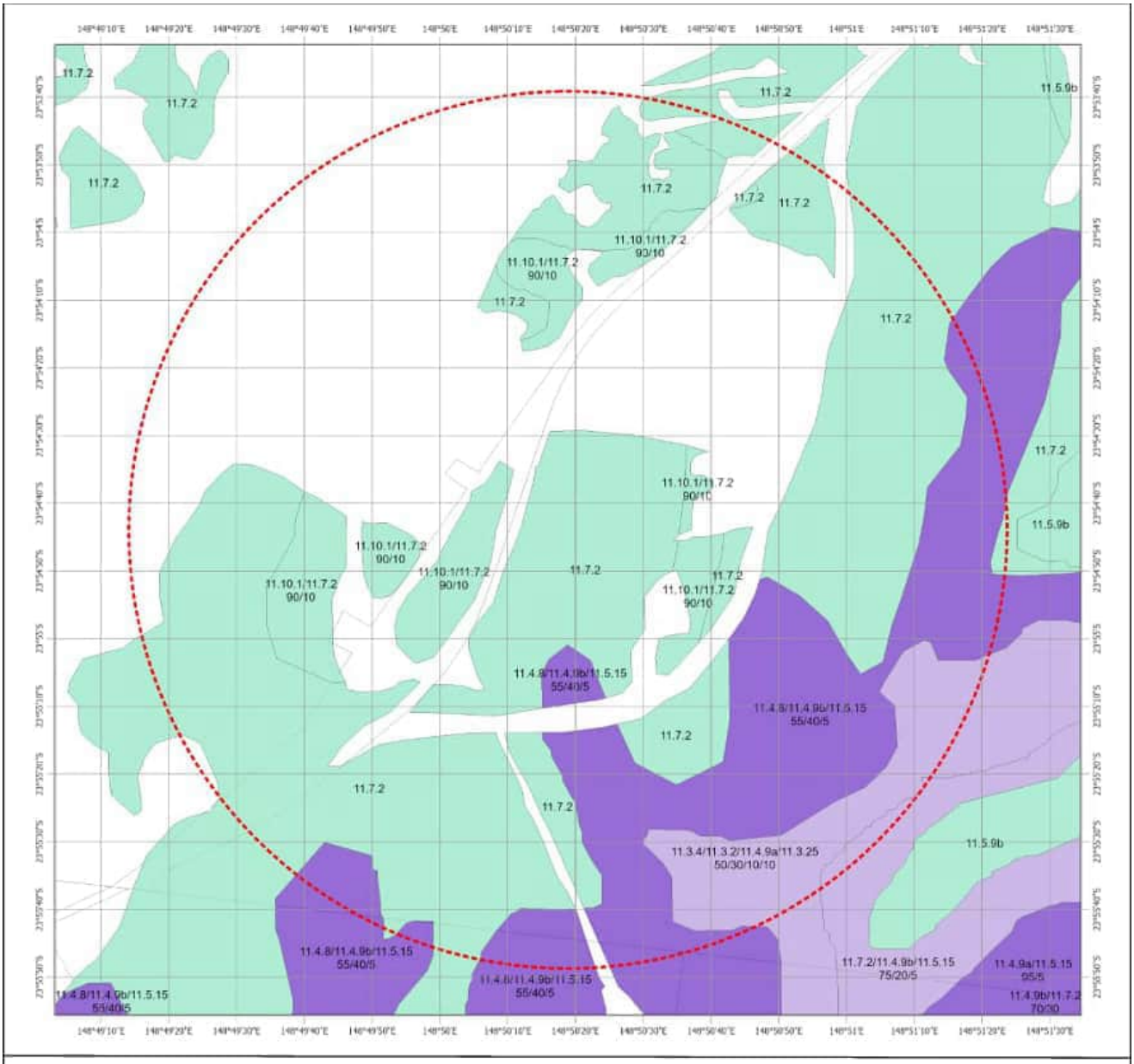
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
11.10.1	Available	Available
11.3.2	Available	Available
11.3.25	Available	Available
11.3.4	Available	Available
11.4.8	Available	Available
11.4.9a	Available	Not currently available
11.4.9b	Available	Not currently available
11.5.15	Available	Available
11.5.9b	Available	Available
11.7.2	Available	Available
non-remnant	Not currently available	Not currently available

Maps

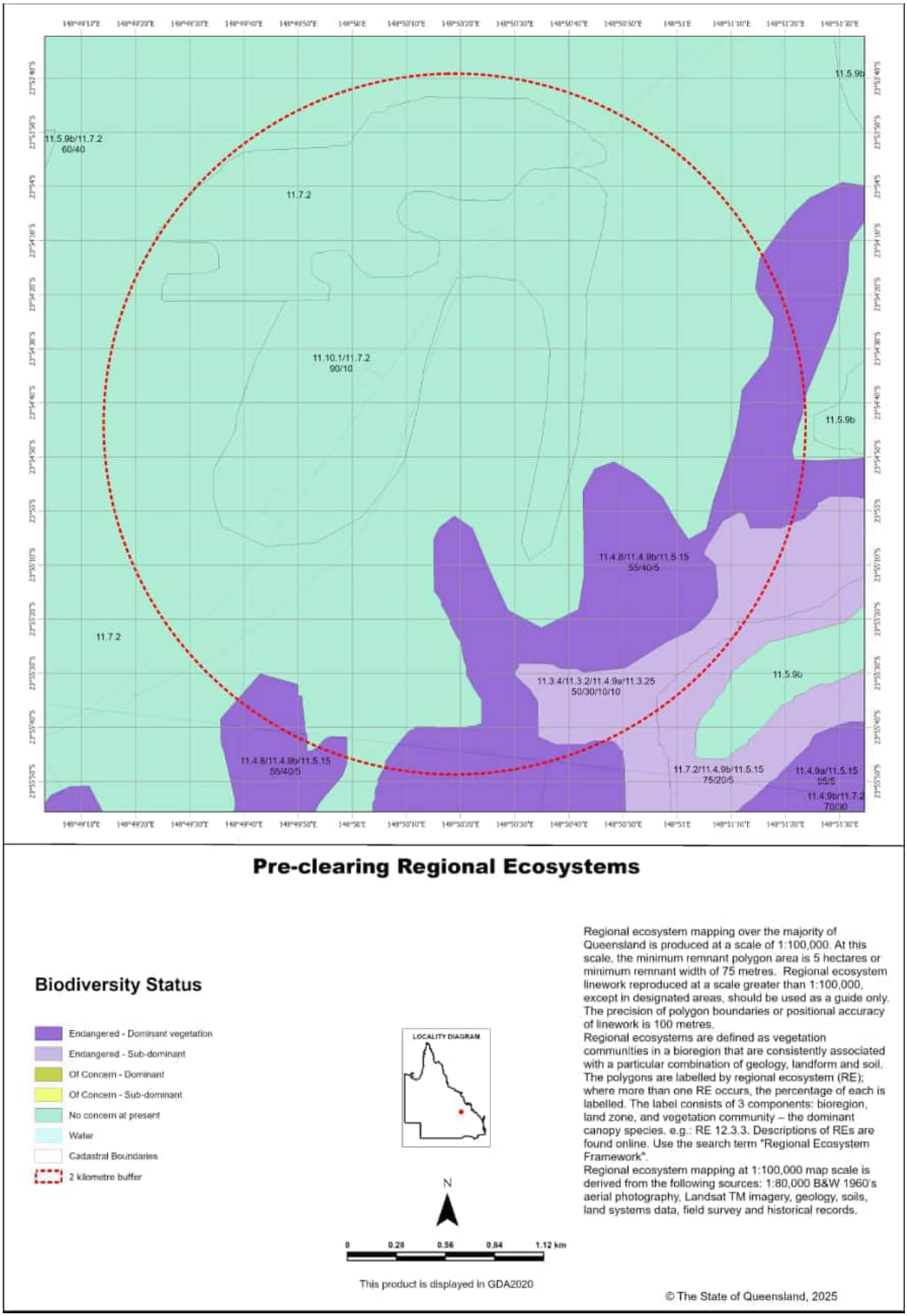
Map 1 - Location



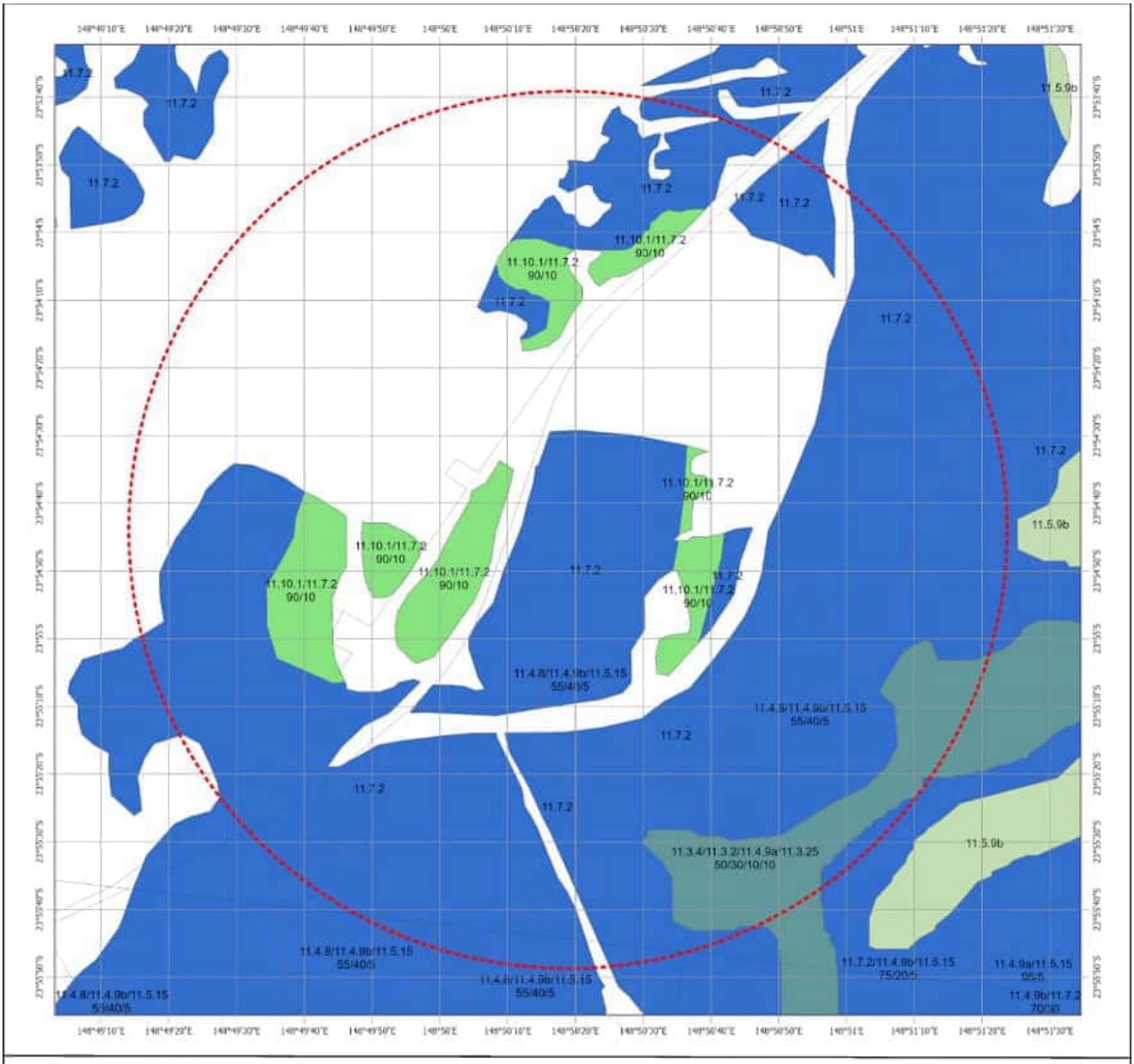
Map 2 - Remnant 2021 regional ecosystems



Map 3 - Pre-clearing regional ecosystems



Map 4 - Remnant 2021 regional ecosystems by BVG (5M)



Remnant 2021 Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups
BVG5M Description (BVG1M codes)

- 1. Rainforests and scrubs (1-7b)
- 2. Wet eucalypt open forests (8-8b)
- 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 7. Callitris woodland - open forests (20a)
- 8. Melaleuca open woodlands on depositional plains (21-22c)
- 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 12. Other coastal communities or heaths (28-29b)
- 13. Tussock grasslands, forblands (30-32b)
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Non-remnant vegetation, cultivated or built environment
- Water
- Cadastral Boundaries
- 2 kilometre buffer

LOCALITY DIAGRAM

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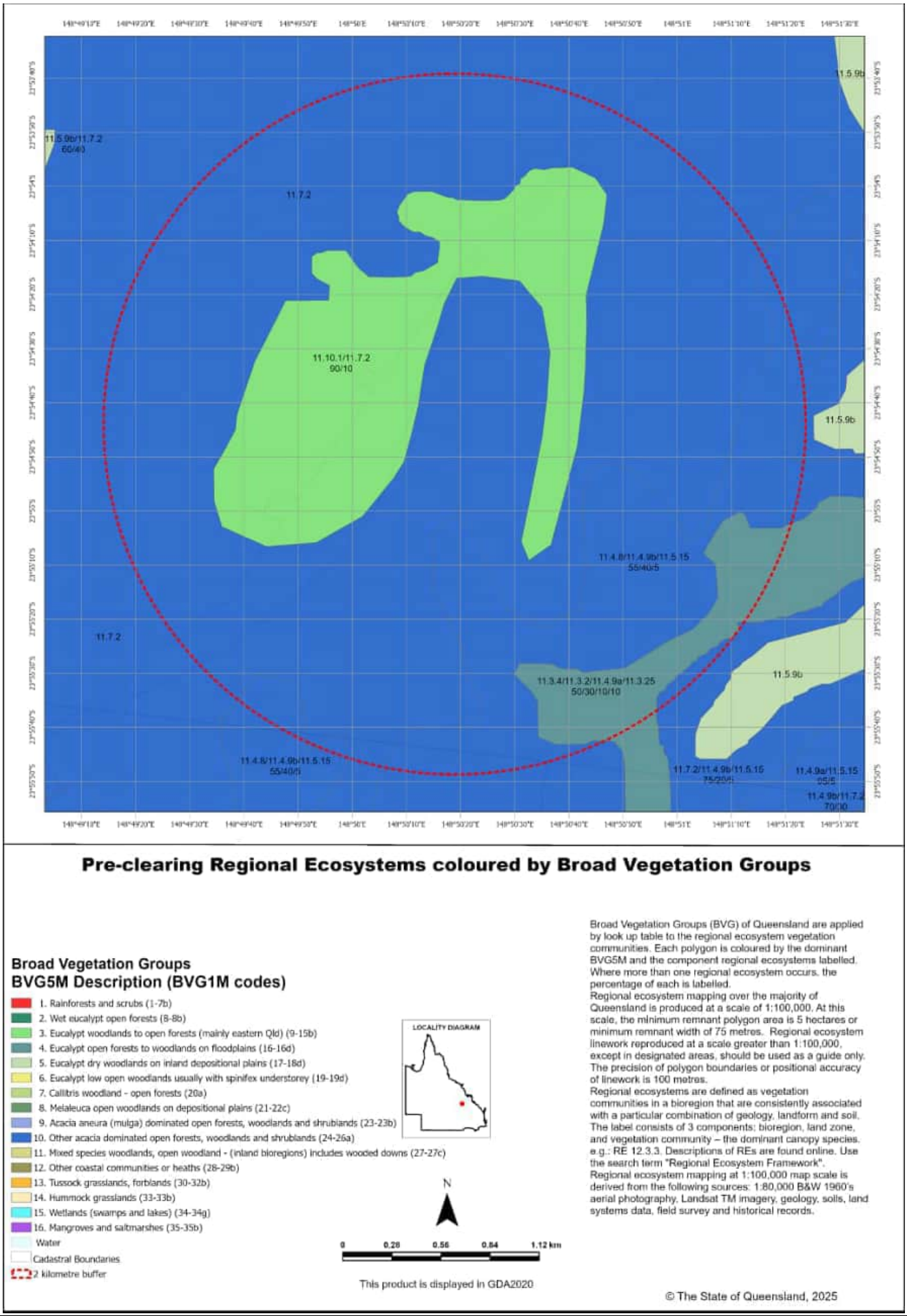
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This product is displayed in GDA2020

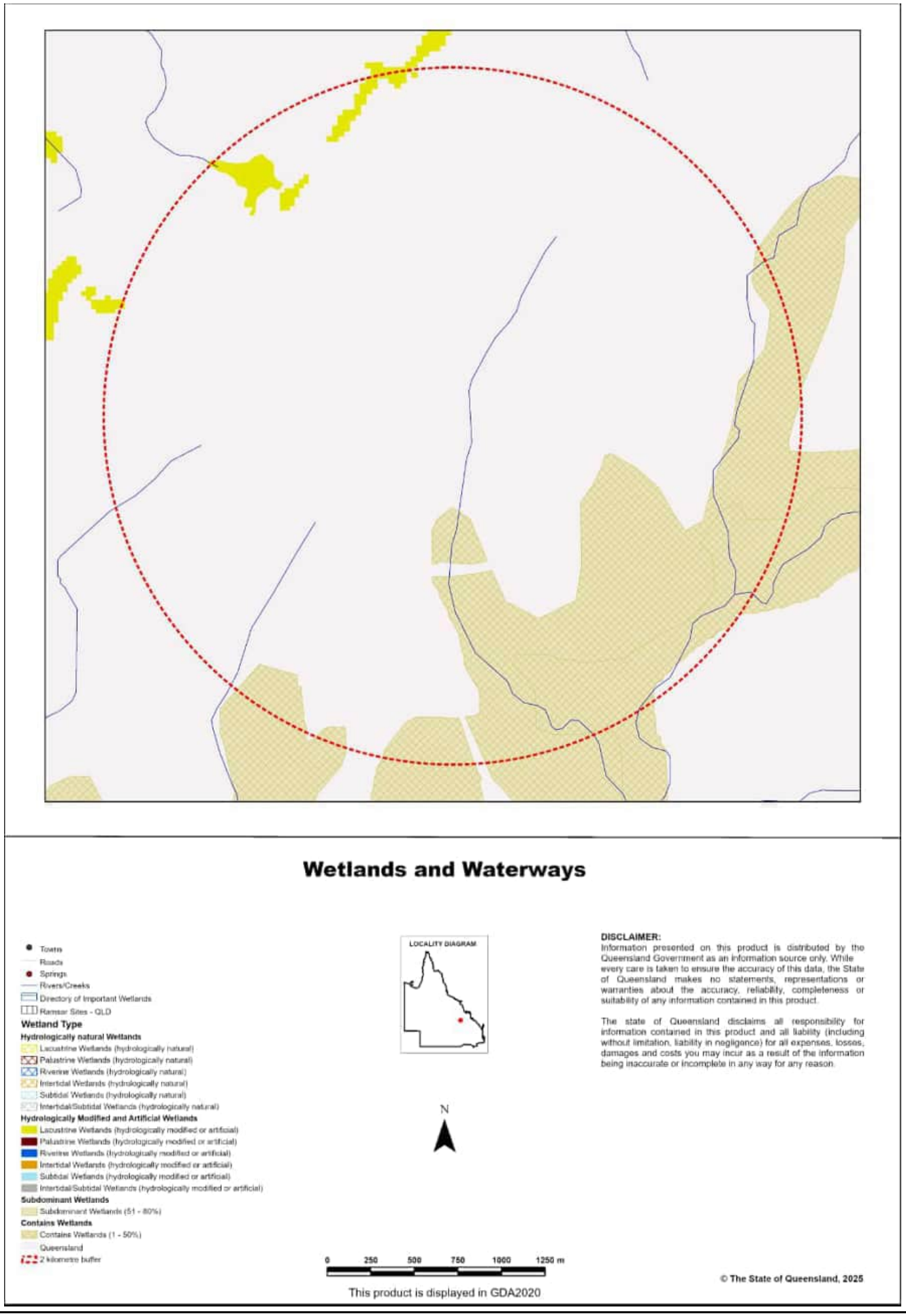
Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.
Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.
Non-remnant vegetation includes regrowth and disturbed native vegetation.

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Map 5 - Pre-clearing regional ecosystems by BVG (5M)



Map 6 - Wetlands and waterways



Links and Other Information Sources

The Department of the Environment, Tourism, Science and Innovation's Website - http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/ provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from: https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/broad-vegetation

The methodology for mapping regional ecosystems can be downloaded from: https://www.qld.gov.au/__data/assets/pdf_file/0033/459186/methodology-mapping-surveying-v7.pdf

Technical descriptions for regional ecosystems can be obtained from: http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from: http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Spatial Catalogue, Queensland Spatial Catalogue : Queensland Government (information.qld.gov.au)

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link: https://qldglobe.information.qld.gov.au/

References

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F., Ford, A.J. and Accad, A. (2023). The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 6.0. Queensland Herbarium, Department of Environment and Science. (https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086)

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Richter,D., Addicott, E.P. and Appelman, C.N. (2023) Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 7.0. Updated December 2023. Queensland Herbarium, Queensland Department of Environment, Science and Innovation, Brisbane. (https://www.qld.gov.au/__data/assets/pdf_file/0033/459186/methodology-mapping-surveying-v7.pdf).

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:
http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

The datasets listed below are available for download from:
Queensland Spatial Catalogue : Queensland Government (information.qld.gov.au)

- Biodiversity status of pre-clearing and 2021 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas
- Pre-clearing broad vegetation groups of Queensland
- Remnant 2021 broad vegetation groups of Queensland

Appendix 2 - Acronyms and Abbreviations

AOI - Area of Interest
GIS - Geographic Information System
RE - Regional Ecosystem
REDD - Regional Ecosystem Description Database
VMA - *Vegetation Management Act 1999*

Appendix B Flora and Fauna Lists

Table 17: Flora species recorded within the Survey area.

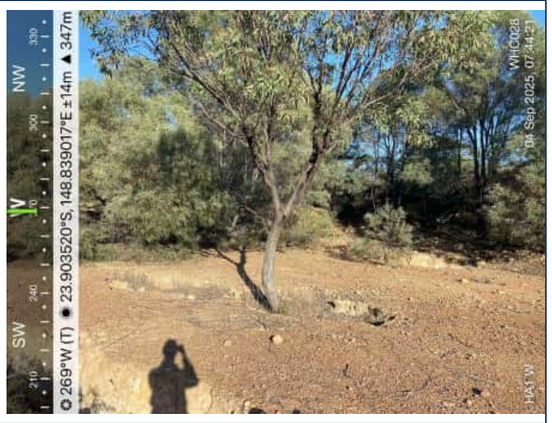
Scientific Name	Common Name
Acacia macradenia	Zig-Zag Wattle
Acacia rhodoxylon	Rosewood
Acacia shirleyi	Lancewood
Acalypha eremorum	Soft Acalypha
Alphitonia excelsa	Soap Tree, Red Ash
Alstonia constricta	Bitterbark, Quinine Bush
Ancistrachne uncinulata	Hooked-Hairy Panic Grass
Aristida calycina	Dark Wiregrass
Aristida caput-medusae	Many-Headed Wiregrass
Bertya opponens	-
Blakella citriodora	Lemon-scented Gum
Bothriochloa bladhii	Forest bluegrass
Callitris glaucophylla	White Cypress Pine
Carissa ovata	Currantbush
Cassia brewsteri	Leichhardt Bean, Bean Tree
Cenchrus ciliaris	Buffel Grass
Cenchrus pennisetiformis	Buffel Grass
Croton insularis	Silver Queensland Cascarilla
Cymbopogon refractus	Barbed-wire Grass
Dinebra decipiens	Slender Canegrass
Dodonaea oxyptera	Hop Bush
Enneapogon pallidus	Conetop Nineawn
Enteropogon ramosus	Spider Grass, Curly Windmill Grass
Entolasia stricta	Wiry Panic
Eragrostis sp.	-
Erythroxylum australe	Cocaine Tree
Eucalyptus crebra	Narrow-leaved Ironbark
Eucalyptus exserta	Queensland Peppermint
Eucalyptus populnea	Poplar Box
Everistia vacciniifolia	Small-leaved Canthium

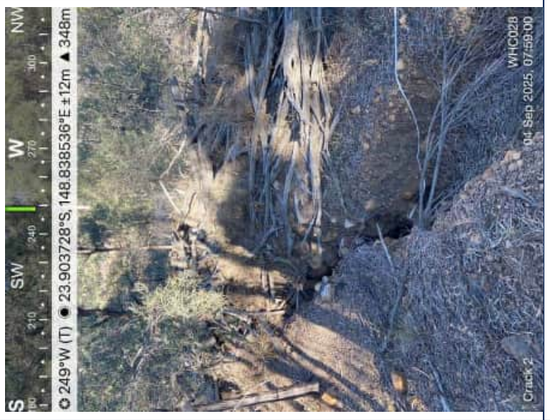
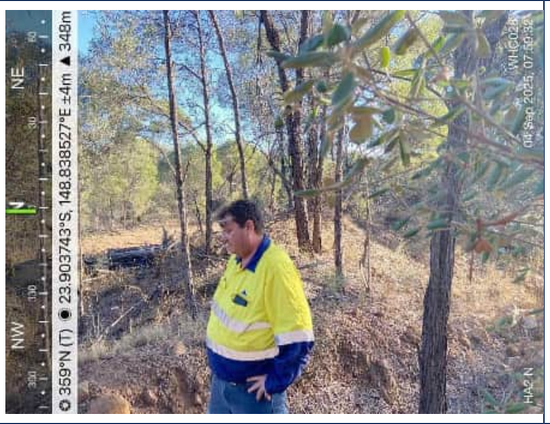
Scientific Name	Common Name
Geijera parviflora	Wilga, Dogwood
Geijera salicifolia	Brush Wilga
Gossypium sturtianum	Sturt's Desert Rose
Harrisia martinii	Harrisia Cactus
Hibiscus heterophyllus	Native Hibiscus, Native Cottonwood
Hovea sp.	-
Melinis repens	Red Natal Grass
Parsonsia straminea	Monkey Rope
Paspalidium caespitosum	Brigalow Grass
Phebalium glandulosum subsp. glandulosum	Desert Phebalium
Sida sp.	-

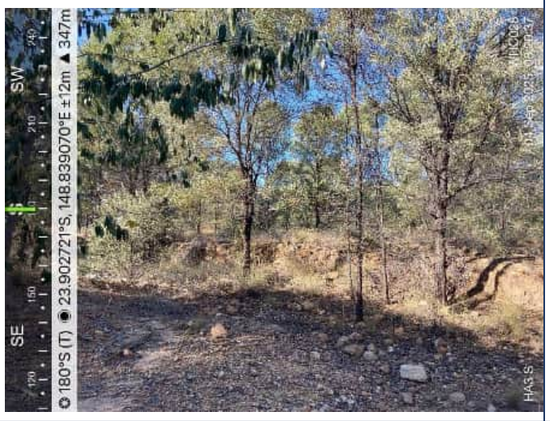
Table 18: Fauna species recorded within the Survey Area.

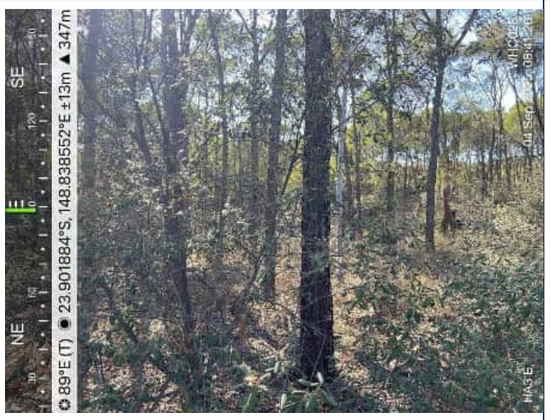
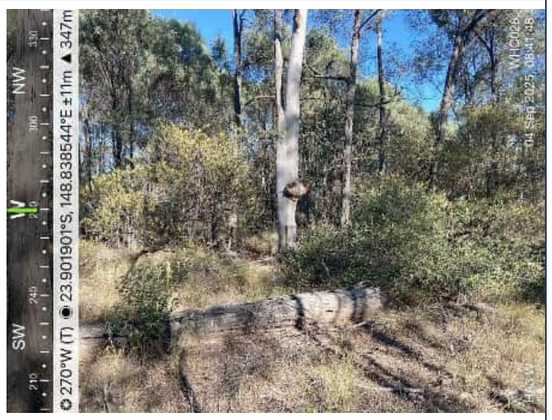
Scientific Name	Common Name
Corvus orru	Torresian Crow
Dacelo novaeguineae	Laughing Kookaburra
Grallina cyanoleuca	Magpie-lark
Gymnorhina tibicen	Australian Magpie
Haliastur sphenurus	Whistling Kite
Macropus giganteus	Eastern Grey Kangaroo
Malurus melanocephalus	Red-backed Fairy Wren
Manorina melanocephala	Noisy Miner
Pheasant Coucal	Pheasant Coucal
Rhipidura albiscapa	Grey Fantail
Strepera graculina	Pied Currawong
Struthidea cinerea	Apostlebird

Appendix C Site Photos

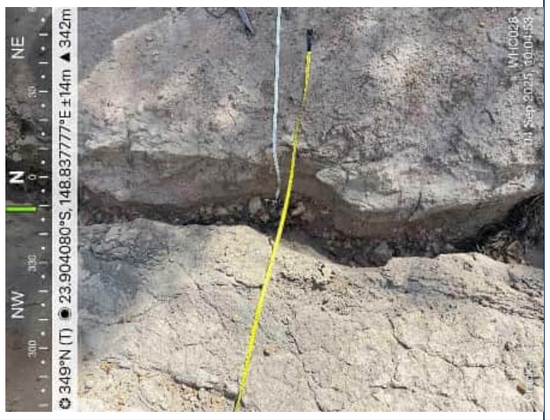
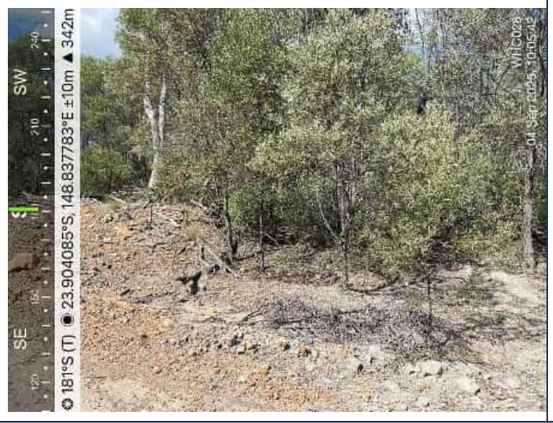
Crack 1 – Habitat Assessment 1			
			
Photo 1: Crack 1	Photo 2: Crack 1		
			
Photo 3: HA1 North	Photo 4: HA1 East	Photo 5: HA1 South	Photo 6: HA1 West

Crack 2 – Habitat Assessment 2			
			
Photo 7: Crack 2	Photo 8: Crack 2		
			
Photo 9: HA2 North	Photo 10: HA2 East	Photo 11: HA2 South	Photo 12: HA2 West

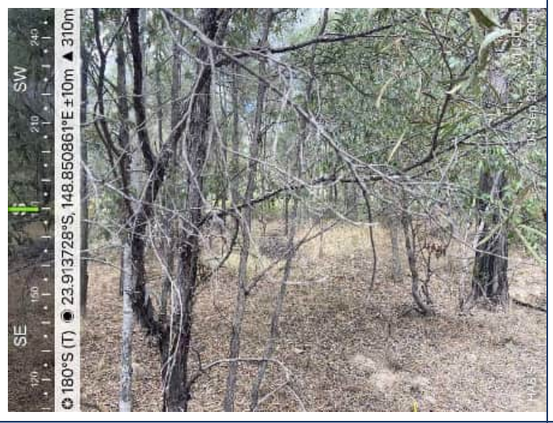
Sinkhole 1 – Habitat Assessment 3			
			
Photo 13: Sinkhole 1	Photo 14: Sinkhole 1		
			
Photo 15: HA3 North	Photo 16: HA3 East	Photo 17: HA3 South	Photo 18: HA3 West

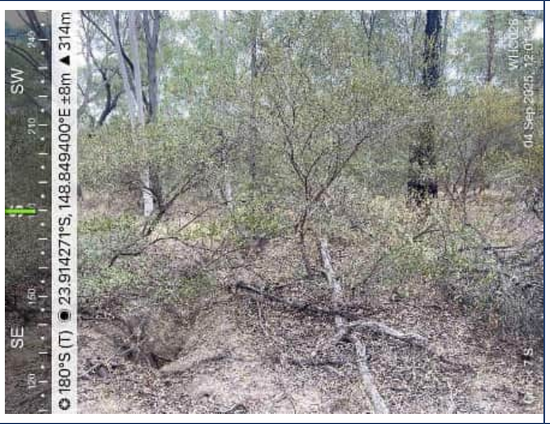
Crack 3 – Habitat Assessment 4			
			
Photo 19: Crack 3	Photo 20: Crack 3		
			
Photo 21: HA4 North	Photo 22: HA4 East	Photo 23: HA4 South	Photo 24: HA4 West

Reference Site 1 – Habitat Assessment 5			
			
Photo 25: HA5 North	Photo 26: HA5 East	Photo 27: HA5 South	Photo 28: HA5 West

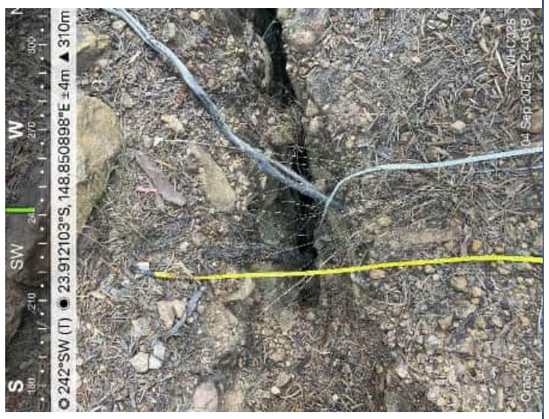
Crack 4 – Habitat Assessment 6			
			
Photo 29: Crack 4	Photo 30: Crack 4		
			
Photo 31: HA6 North	Photo 32: HA6 East	Photo 33: HA6 South	Photo 34: HA6 West

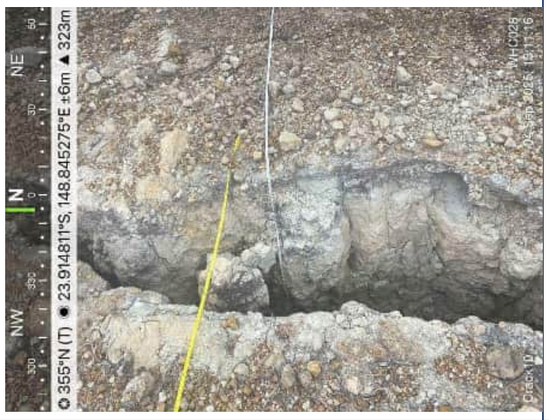
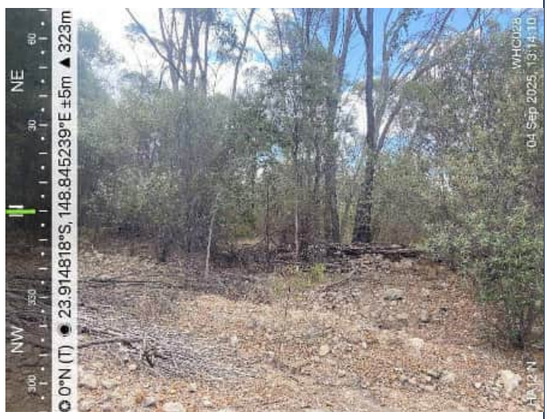
Crack 5 – Habitat Assessment 7			
			
Photo 35: Crack 5	Photo 36: Crack 5	Photo 3: Crack 5	
			
Photo 37: HA7 North	Photo 38: HA7 East	Photo 39: HA7 South	Photo 40: HA7 West

Crack 6 – Habitat Assessment 8			
			
Photo 41: Crack 6	Photo 42: Crack 6		
			
Photo 43: HA8 North	Photo 44: HA8 East	Photo 45: HA8 South	Photo 46: HA8 West

Crack 7 Tertiary Site – Habitat Assessment 9			
			
Photo 47: Crack 7	Photo 48: Crack 7		
			
Photo 49: HA9 North	Photo 50: HA9 East	Photo 51: HA9 South	Photo 52: HA9 West

Crack 8 – Habitat Assessment 10			
			
Photo 53: Crack 8	Photo 54: Crack 8		
			
Photo 55: HA10 North	Photo 56: HA10 East	Photo 57: HA10 South	Photo 58: HA10 West

Crack 9 – Habitat Assessment 11			
			
Photo 59: Crack 9	Photo 60: Crack 9		
			
Photo 61: HA11 North	Photo 62: HA11 East	Photo 63: HA11 South	Photo 64: HA11 West

Crack 10 – Habitat Assessment 12			
			
Photo 65: Crack 10	Photo 66: Crack 10		
			
Photo 67: HA12 North	Photo 68: HA12 East	Photo 69: HA12 South	Photo 70: HA12 West

Crack 11 Tertiary Site – Habitat Assessment 13 & 14



Photo 71: Crack 11

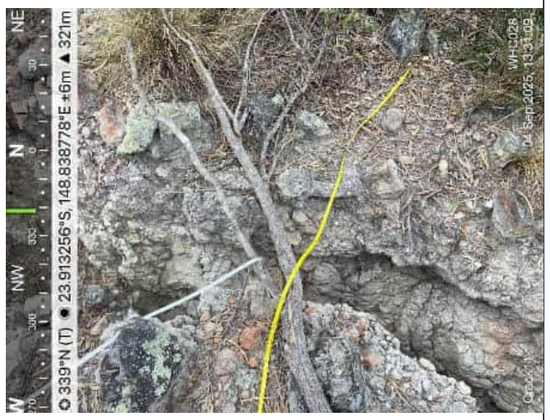


Photo 72: Crack 11



Photo 3: Evidence of dieback Crack 11

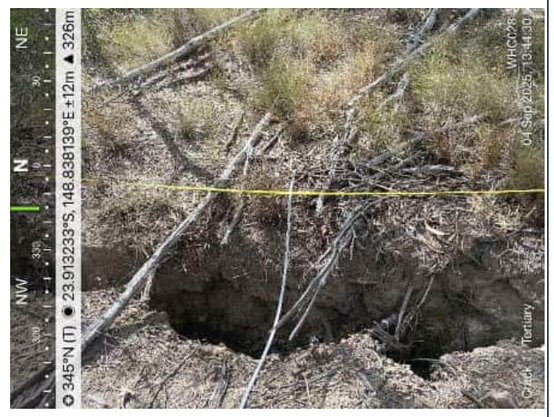


Photo 4: Crack 11



Photo 73: HA13 North

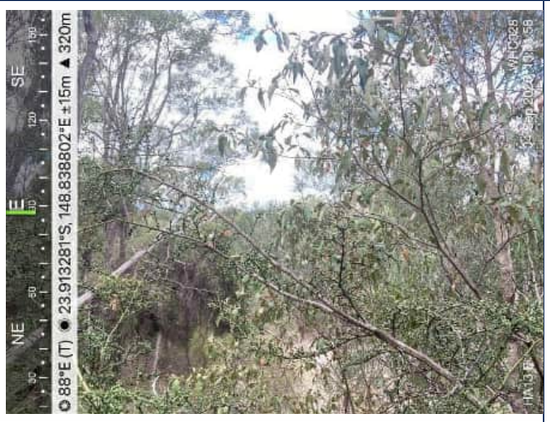


Photo 74: HA11 East

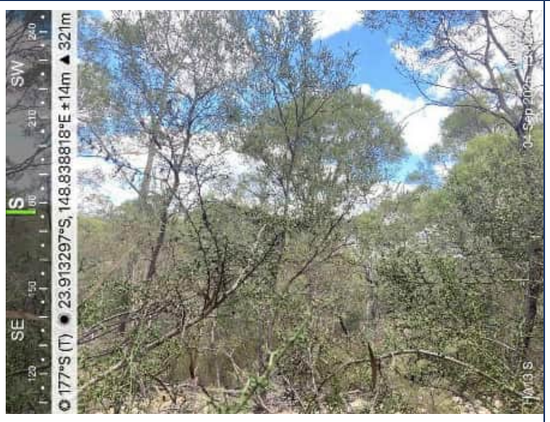


Photo 75: HA11 South



Photo 76: HA11 West

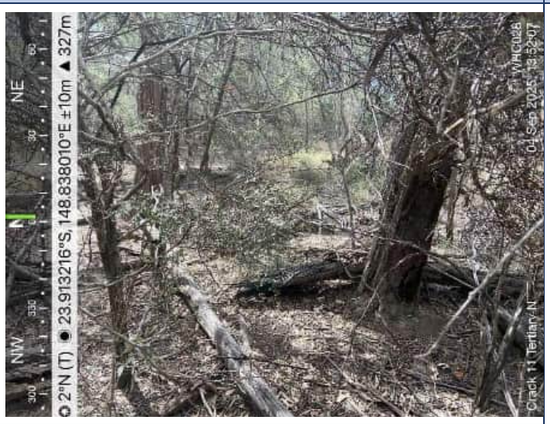


Photo 77: HA11 North



Photo 78: HA11 East

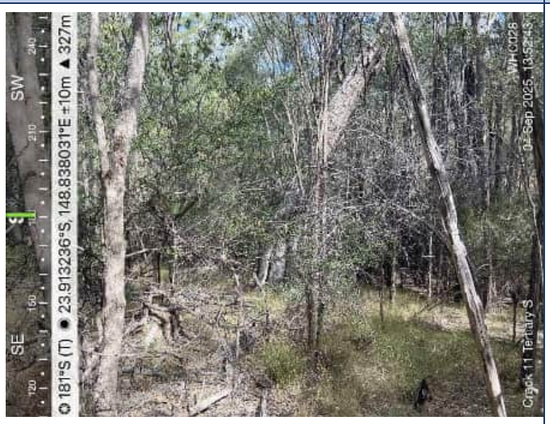


Photo 79: HA11 South

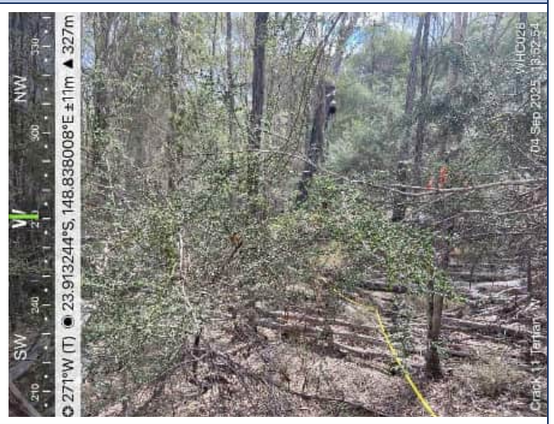


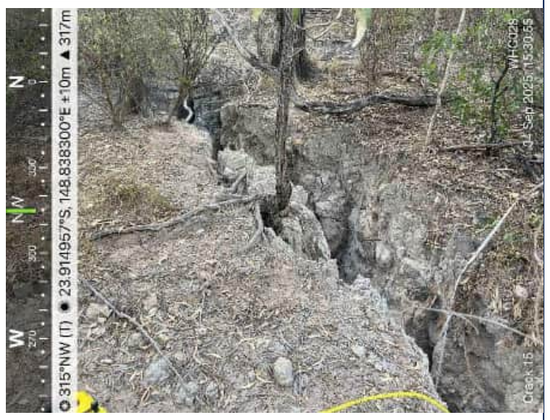
Photo 80: HA11 West

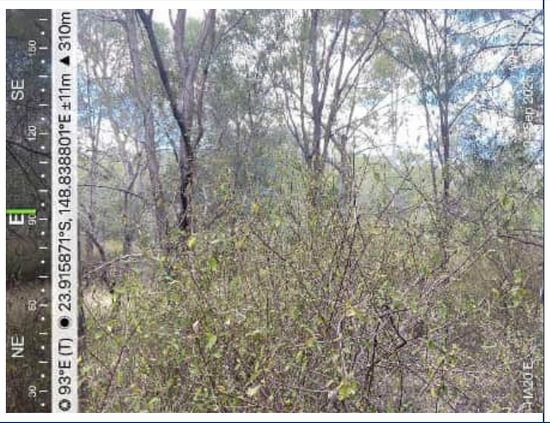
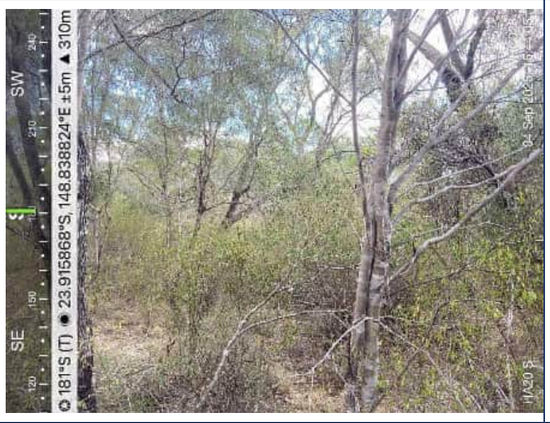
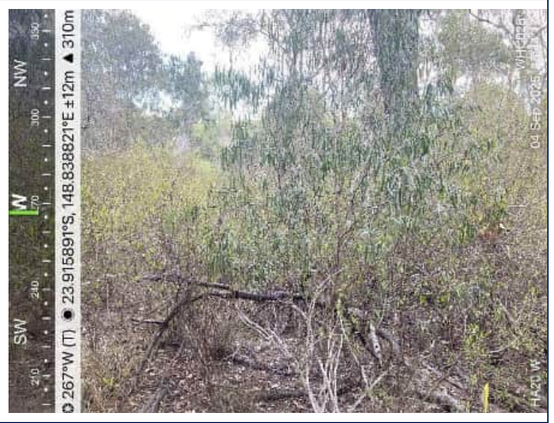
Crack 12 – Habitat Assessment 15			
			
Photo 81: Crack 12	Photo 82: Crack 12		
			
Photo 83: HA15 North	Photo 84: HA15 East	Photo 85: HA15 South	Photo 86: HA15 West

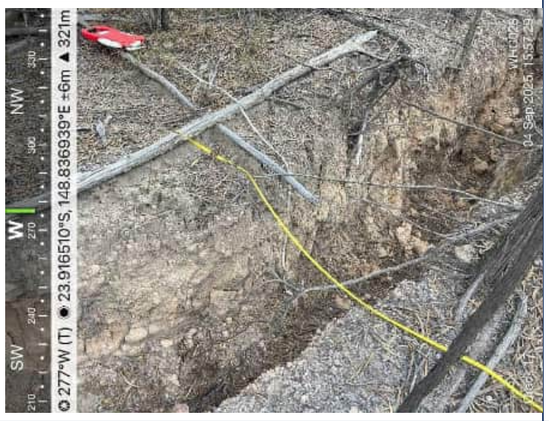
Crack 12b – Habitat Assessment 16			
			
Photo 87: Crack 12b	Photo 88: Crack 12b		
			
Photo 89: HA16 North	Photo 90: HA16 East	Photo 91: HA16 South	Photo 92: HA16 West

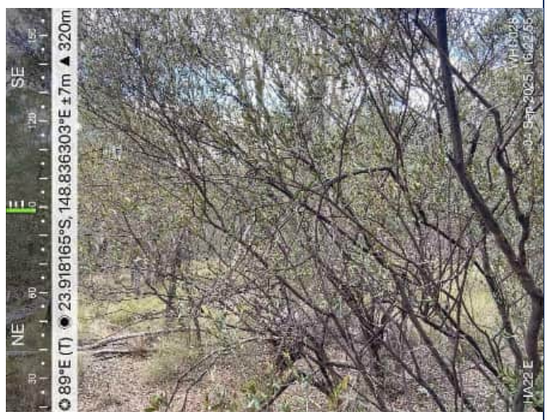
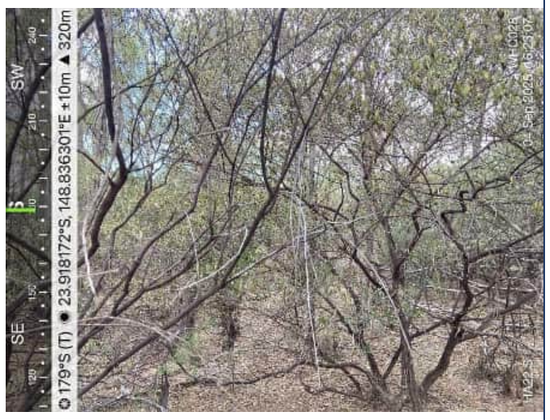
Crack 13 – Habitat Assessment 17			
			
Photo 93: Crack 13	Photo 94: Crack 13	Photo 3: HA17	

Crack 14– Habitat Assessment 18			
			
Photo 95: Crack 14	Photo 96: Crack 14		
			
Photo 97: HA18 North	Photo 98: HA18 East	Photo 99: HA18 South	Photo 100: HA18 West

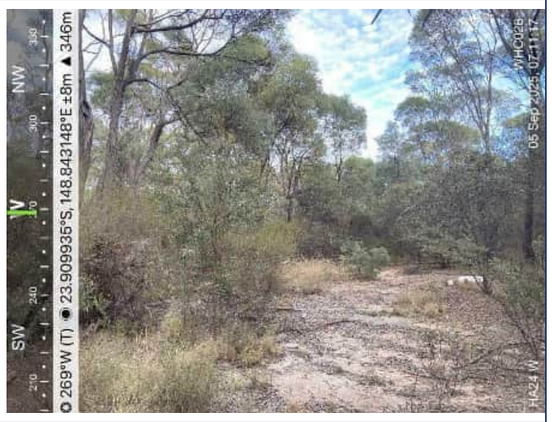
Crack 15 – Habitat Assessment 19			
			
Photo 101: Crack 15	Photo 102: Crack 15		
			
Photo 103: HA19 North	Photo 104: HA19 East	Photo 105: HA19 South	Photo 106: HA19 West

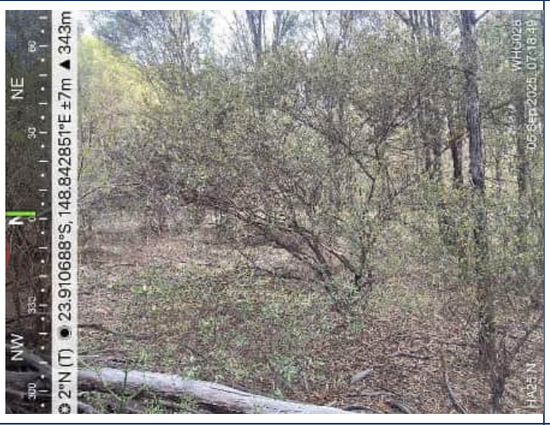
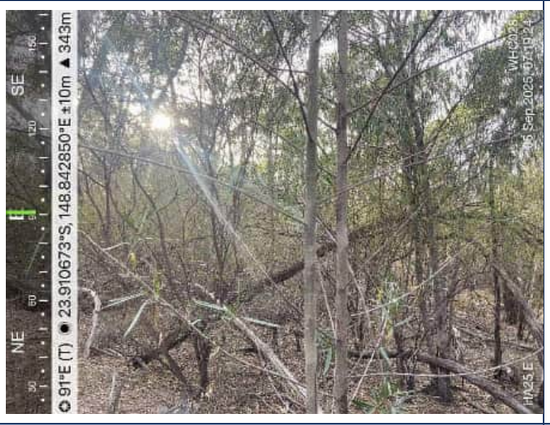
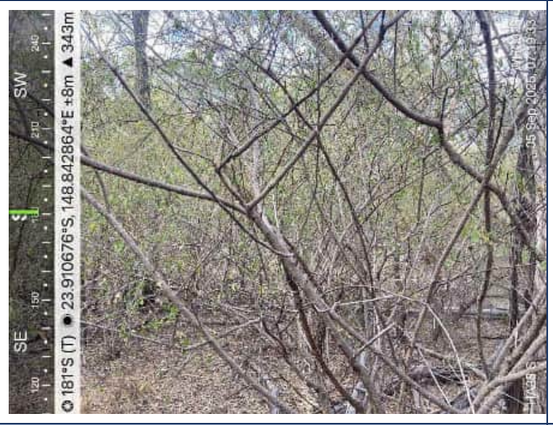
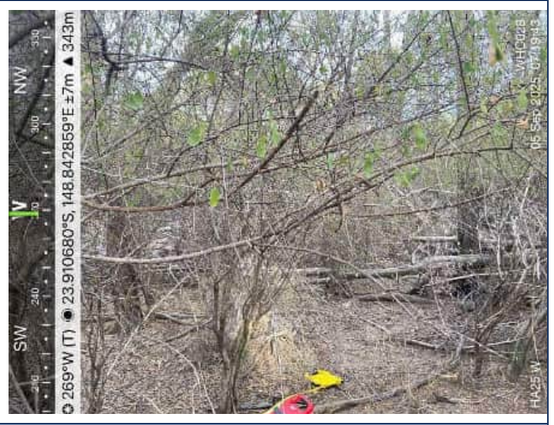
Crack 16 – Habitat Assessment 20			
			
Photo 107: Crack 16	Photo 108: Crack 16		
			
Photo 109: HA20 North	Photo 110: HA20 East	Photo 111: HA20 South	Photo 112: HA20 West

Crack 17 – Habitat Assessment 21			
			
Photo 113: Crack 17	Photo 114: Crack 17	Photo 3: Crack 17 Evidence of Logging	
			
Photo 115: HA21	Photo 116: HA21	Photo 117: HA21	Photo 118: HA21

Crack 18 – Habitat Assessment 22			
			
Photo 119: Crack 18	Photo 120: Crack 18	Photo 3: Crack 18 Evidence of Logging	
			
Photo 121: HA22 North	Photo 122: HA22 East	Photo 123: HA22 South	Photo 124: HA22 West

Crack 19 – Habitat Assessment 23			
			
Photo 125: Crack 19	Photo 126: Crack 19		
			
Photo 127: HA23 North	Photo 128: HA23 East	Photo 129: HA23 South	Photo 130: HA23 West

Crack 20 – Habitat Assessment 24			
			
Photo 131: Crack 20	Photo 132: Crack 20		
			
Photo 133: HA24 North	Photo 134: HA24 East	Photo 135: HA24 South	Photo 136: HA24 West

Crack 21 – Habitat Assessment 25			
			
Photo 137: Crack 21	Photo 138: Crack 21		
			
Photo 139: HA25 North	Photo 140: HA25 East	Photo 141: HA25 South	Photo 142: HA25 West

Crack 22 – Habitat Assessment 26



Photo 143: Crack 22



Photo 144: Crack 22



Photo 3: Crack 22 Evidence of Logging



Photo 145: HA26 North



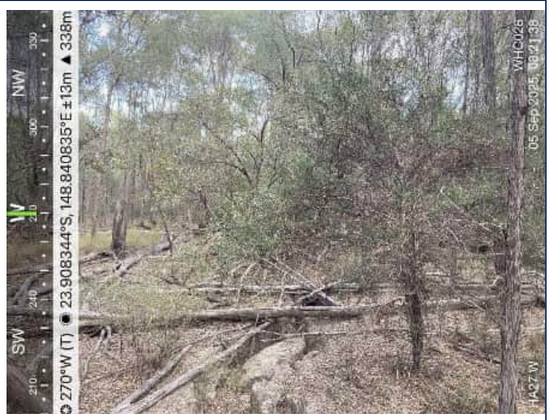
Photo 146: HA26 East



Photo 147: HA26 South



Photo 148: HA26 West

Crack 23 – Habitat Assessment 27			
			
Photo 149: Crack 23	Photo 150: Crack 23	Photo 3: Crack 23 Evidence of Logging	
			
Photo 151: HA26 North	Photo 152: HA26 East	Photo 153: HA26 South	Photo 154: HA26 West

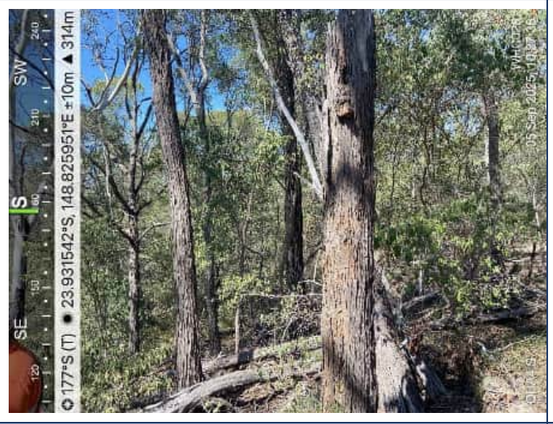
Crack 24 – Habitat Assessment 28			
			
Photo 155: Crack 24	Photo 156: Crack 24		
			
Photo 157: HA28 North	Photo 158: HA28 East	Photo 159: HA28 South	Photo 160: HA28 West

Mapped Crack 1 – Habitat Assessment 29			
			
Photo 161: Mapped Crack 1 – Drainage Line	Photo 162: Mapped Crack 1 – Drainage Line		
			
Photo 163: HA29 North	Photo 164: HA29 East	Photo 165: HA29 South	Photo 166: HA29 West

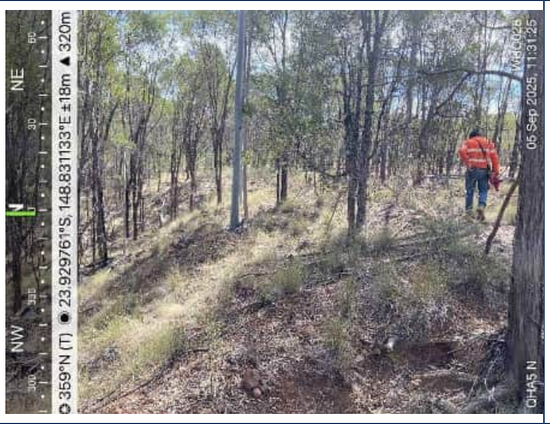
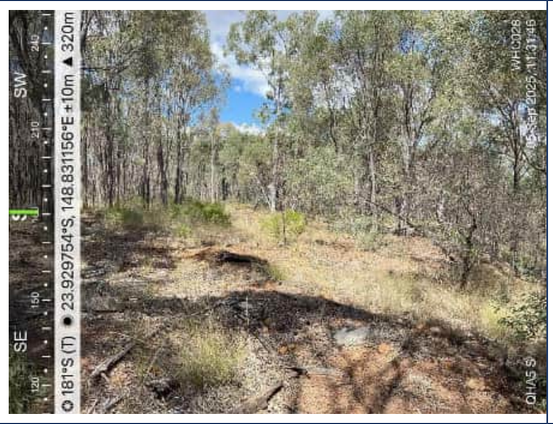
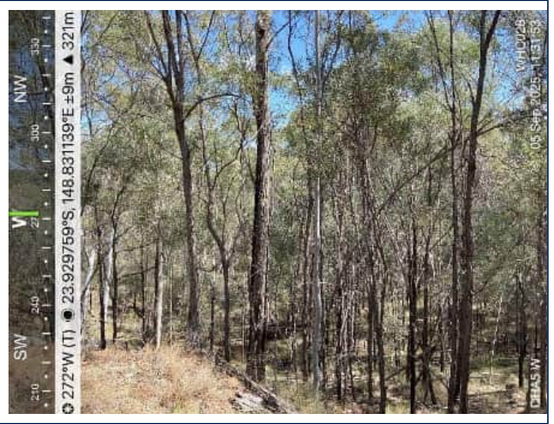
Mapped Crack 2 – Habitat Assessment 30			
			
Photo 167: Mapped Crack 2 – Escarpment Cliff Line			
			
Photo 168: HA30 North	Photo 169: HA30 East	Photo 170: HA30 South	Photo 171: HA30 West

Mapped Crack 3 – Habitat Assessment 31			
			
Photo 172: Mapped Crack 3 – Escarpment Cliff Line			
			
Photo 173: HA31 North	Photo 174: HA31 East	Photo 175: HA31 South	Photo 176: HA31 West

Crack 25 – Habitat Assessment 32			
			
Photo 177: Crack 25	Photo 178: Crack 25		
			
Photo 179: HA32 North	Photo 180: HA32 East	Photo 181: HA32 South	Photo 182: HA32 West

Mapped Crack 4 – Habitat Assessment 33			
			
Photo 183: Mapped Crack 4 – Escarpment Cliff Line			
			
Photo 184: HA29 North	Photo 185: HA29 East	Photo 186: HA29 South	Photo 187: HA29 West

Reference Site 2 – Habitat Assessment 34			
			
Photo 188: HA34 North	Photo 189: HA34 East	Photo 190: HA34 South	Photo 191: HA34 West

Mapped Crack 5 – Habitat Assessment 35			
			
Photo 192: Mapped Crack 5 – Escarpment Slope			
			
Photo 193: HA35 North	Photo 194: HA35 East	Photo 195: HA35 South	Photo 196: HA35 West

Mapped Crack 6 – Habitat Assessment 36			
			
Photo 197: Mapped Crack 6 – Gully	Photo 2: Mapped Crack 6 - Gully		
			
Photo 198: HA36 North	Photo 199: HA36 East	Photo 200: HA36 South	Photo 201: HA36 West


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ENVIRONMENTAL CONSULTING

CONSIDERATIONS AND INITIAL RISK EVALUATION							CONTROL INPUT AND RESIDUAL RISK EVALUATION				Action Program	
	Risk Event	Cause & Impact		Assessment of Risk without controls in place			Control Input	Assessment of Risk with controls in place				
Ref / ID # A value must be entered for every row	Hazard or Risk	How could it happen? (Causes)	What Could Happen (Impacts)	Inherent Likelihood	Inherent Consequence	Inherent Risk Assessment	Control Name	Residual Consequence	Residual Likelihood	Current Risk Assessment	Is Action Required?	PRC Plan Reference to Action Program
PMLU 1	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **Landform Failure**	1. Erosional instability 2. Geotechnical instability 3. Inadequate or inappropriate geotechnical assessment 4. Ineffective placement of spoil material 5. Differential settlement - ineffective and or inappropriate placement of spoil material (including backfilled dams) 6. Insufficient materials to achieve design (rock, growth media) 7. Unsuitable spoil used on final landform surface 8. Flooding 9. Not achieving design 10. Inappropriate modelling and design 11. Selection of inappropriate PMLU 12. Fire	- Failure of vegetation (vegetated cover) - Failure of water management / drainage - Failure of growth media - Erosion resulting in gully erosion - Slumping and settlement - Mass movement of landform - Inability to meet surface water quality criteria (due to exposure of problematic underlying materials) - Ecosystem impacts - Fire destroys revegetated areas and compromises landform stability	Almost Certain	Minor	M	Preventative Controls: - Landform design appropriate for PMLU, designed by an AQP, and implemented in accordance with PRCP Schedule requirements. - All major earthworks (including reshaping, pushing, trimming etc) undertaken in accordance with the design specifications provided by an Appropriately Qualified Person (AQP). - Ongoing materials characterisation - Closure landform design, growth media and spoil assessment by AQP to determine ameliorant and fertiliser requirements. - Review the topsoil and rock material balance periodically during operations to ensure sufficient volumes for the rehabilitation needs - Selective handling of materials for placement - No contour banks 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 - Construction governance (work packs) - Bushfire management plan to prevent / mitigate fire risk - Flood modelling to validate velocity of < 2.5 m/s against rehab for the 0.1% AEP Mitigating Controls: - Monitoring of landform stability and rehabilitation success to be undertaken post-rehabilitation - Identify requirements for rectification works - Complete maintenance - Verified rehabilitation performance that already demonstrates criteria achievement (over time)	Minor	Possible	L	Yes	PRC Plan Section 3.7.1.3
PMLU 2	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **Altered hydrogeological conditions (to modelled/assumed conditions), based on interaction of groundwater with spoil dumps. (For all areas, excluding TSFs (PMLU11 & 12))**	1. Release of contaminants to groundwater (percolation through spoil, or toe seepage interacting with shallow aquifer) 2. Change in groundwater flow, recharge and/or discharge characteristics resulting in changes to the hydrogeological system 3. Hydrogeologic conditions that are different to groundwater modelling outcomes	- 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 reporting to shallow and deep groundwater systems - Reduction of groundwater height within surrounding extraction bores - Degradation of terrestrial and aquatic groundwater dependant ecosystems (GDEs)	Possible	Medium	M	Preventative Controls: - 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 (maintenance of the void as a sink in perpetuity) - Groundwater modelling to validate particle tracking from spoils to voids - Regular, ongoing monitoring (re-assessing and calibration of groundwater model, resulting in refined design, as needed) (accounting for climate predictability) - Pre-defined backfill planning aligned to site-wide source-sink retention - 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 - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Landforms constructed to minimise the potential for flooding of the residual voids - Groundwater condition assessment integrated into mine planning constraints Mitigating Controls: - Assessment and remediation of impacted material, where appropriate - Re-establishment of impacted ecosystems - Decommissioning of impacted supply bores and re-instatement in suitable location	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3
PMLU 3	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **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 (including climate change) 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 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	Likely	Medium	H	Preventative Controls: - All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Appropriate management, placement, and monitoring of waste (spoil, rejects) during operations - Mine affected water dams and industrial sites 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 - Rehabilitation of disturbed areas will be undertaken as soon as possible after land becomes available - Rehabilitation and monitoring of disturbed reaches of creeks undertaken - Appropriate management, placement, and monitoring of waste (spoil, tailings, rejects) during operations - Landforms and creek diversions designed and constructed (AQP) to minimise the potential for flooding of the residual voids - Erosion and sediment control systems installed per detailed rehabilitation design specifications Mitigating Controls: - 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 additional controls/measures that reduce the potential for surface water impacts and/or re-establishment of impacted ecosystems where appropriate - Rehabilitated landforms and creek diversions/watercourses that do not attain a stable state to be repaired and revegetated - Ongoing geochemical testing to continue to verify potential contaminants reporting to surface water	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3

CONSIDERATIONS AND INITIAL RISK EVALUATION							CONTROL INPUT AND RESIDUAL RISK EVALUATION				Action Program	
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Ref / ID # A value must be entered for every row	Hazard or Risk	How could it happen? (Causes)	What Could Happen (Impacts)	Inherent Likelihood	Inherent Consequence	Inherent Risk Assessment	Control Name	Residual Consequence	Residual Likelihood	Current Risk Assessment	Is Action Required?	PRC Plan Reference to Action Program
PMLU 4	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **Creek diversions not achieving closure objectives**	1. Inadequate or inappropriate diversion design 2. Hydrologic characteristics of surface water and groundwater systems not representative of natural reaches 3. Hydraulic characteristics not representative of natural reaches 4. Geomorphic instability (bank erosion) 5. Seepage to/from residual voids or spoil dumps impacting on stability 6. Sediment transport regime is not in equilibrium with and/or representative of the natural reaches 7. Poor riparian vegetation diversity and cover 8. High percentage of weeds/ invasive species 9. Poor water quality from runoff from surrounding landforms and rehabilitated areas 10. Failure of landforms impacting the performance of the diversion 11. Failure of rehabilitation along creek diversion	- Sediment regime impacts within diversion and downstream reaches resulting in changes to hydraulic properties - Surface water chemistry altered rendering it not suitable for PMLU - Degradation of downstream ecosystems and land uses connected to surface water flows and floodplains - Surface water quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the mine is located - accelerated rates of erosion and instability within diversion embankments and surrounding the diversion causing landform instability, damage to rehabilitation areas and alteration of diversion hydraulics - changes to environmental flows and flood regimes impacting on surrounding land users and environmental receptors - Rehabilitation failure along length of creek diversion - Unstable diversion channel erodes into adjacent void	Almost Certain	Medium	H	Preventative Controls: - Functional design and as constructed plans prepared by an AQP as per the guideline: *"Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000 (OSW/2019/4599) (DNRME 2019)", or the latest revision of that guideline* - Creek diversion monitoring to relevant IDC standard and maintenance implemented during the operational phase - Disturbed natural watercourse bed and banks are rehabilitated and returned to a stable profile - Growth media and spoil assessment by AQP to determine ameliorant and fertiliser requirements - Revegetation species aligned to growth media, landforms and PMLU - Surface water drainage infrastructure that interacts with the creek diversions during operations will be removed prior to closure (e.g. watercourse crossing and culverts) - Rehabilitation of surrounding landforms. Mitigating Controls: - Rehab undertaken during dry season - Surface water monitoring data to be collected. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Rehabilitated landforms that do not attain a stable state to be investigated, repaired, revegetated and/or redesigned	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3
PMLU 5	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **Contaminated land impacting on environmental receptors, rehabilitation and attainment of PMLUs**	1. Discharges and accumulation of hazardous contaminants (including emerging contaminants) from operational activities. 2. Deterioration of retained built infrastructure in mining industrial areas, from lack of maintenance	- 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 - Degradation of terrestrial and aquatic groundwater dependant ecosystems (GDEs) - Contamination of surface water runoff affecting integrity of local catchments	Likely	Major	H	Preventative Controls: - Contaminated land assessments as required to identify and verify sources - Hazardous substance assessment and approval process - Environmental Authority conditions and Australian Standards govern hazardous substance use, storage and management requirements - Cleaning up of spills upon identification - Remediation or management of residual contamination - Ongoing surface water and groundwater monitoring providing an earlier indication of contamination - Management of operational activities to limit any potential contamination - All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Infrastructure inspections and ongoing maintenance of plant, measures and equipment Mitigating Controls: - Investigate and remediate contamination incidents - At the completion of operations all stored hazardous materials and infrastructure within the MIA and CHPP, that have the potential to release contaminants to environmental receptors, will be either remediated in-situ, disposed of on-site as authorised under the Environmental Authority, or removed and disposed of at an approved landfill, with waste tracking information recorded and submitted. - Contaminated Land Investigation completed in accordance with the Environmental Protection Act 1994, including a site investigation report, and where required, a Validation Report and/or a draft Site Management Plan. - Removal of primary or secondary sources - Restrict site usage - Undertake ongoing monitoring to manage contaminated land risks	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3
PMLU 6	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **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 - Failure of the landform into the creek, altering its geomorphology - 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 - Fire destroys revegetated areas and compromises landform stability	Almost Certain	Medium	H	Preventative Controls: - Flood modelling for 0.1% Annual Exceedance Probability (AEP) informing landform design - Establishment of landforms that are stable and provide appropriate level of flood protection to the residual voids (0.1% AEP flood event) - Removal of surface water drainage infrastructure from watercourses (crossings and culverts), 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 - Energy dissipation measures (e.g. rock lining) installed in areas where high-energy flows (≥2.5m/s) are determined by an AQP Mitigating Controls: - 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	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3

CONSIDERATIONS AND INITIAL RISK EVALUATION							CONTROL INPUT AND RESIDUAL RISK EVALUATION				Action Program	
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PMLU 7	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **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. 4. Environmental flows impacted due to incorrect runoff coefficients	- 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	Almost Certain	Major	C	Preventative Controls: - Removal of surface water drainage infrastructure that would adversely interfere with stream hydraulics (crossings and culverts) and decommissioning of dams - Establishment of landforms that are stable and provide appropriate level of flood protection to the residual voids (0.1% AEP flood event (extremely conservative) - Undertake monitoring and maintenance works where required to maintain landforms - Landform design with consideration of water balance and catchment size - Reduction of catchment with landform and rehabilitation - Flood modelling for 0.1% AEP informing landform design - Energy dissipation measures (e.g. rock lining) installed in areas where high-energy flows (≥2.5m/s) are determined by an AQP - Ongoing environmental monitoring in accordance with the PRCP Schedule. Mitigating Controls: 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.	Major	Rare	M	Yes	PRC Plan Section 3.7.1.3
PMLU 8	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of: **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 vegetative groundcover (poor vegetation growth or incorrect vegetation affecting PMLU)	Almost Certain	Catastrophic	C	Preventative Controls: - Growth media surveys and mapping (growth media management system) - Review the growth media and rock resource quantities periodically during operations to ensure sufficient volumes for the rehabilitation needs (material balance for mine and rehab planning) - Implement rehabilitation execution including amelioration to address requirements for growth media, rock, seed and management for the PMLU (work packs) - Management of topsoil and rock stockpiles and application during rehabilitation. - Execution governance (compliance to plan work packs) Mitigating Controls: - Monitoring of 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.	Major	Possible	H	Yes	PRC Plan Section 3.7.1.3
PMLU 9	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as a result of **Inadequate and/or inappropriate management of mineral waste in general spoil landforms.**	1. Inadequate or incorrect geochemical characterisation and assessment of landform materials. 2. Management strategy adopted was inadequate or inappropriate to manage the AMD hazards of the waste materials. 3. Incorrect or inappropriate mine planning processes to account for management (spatial and temporal) for adverse materials in landform. 4. Poor final landform execution (e.g. poor/incorrect landform reshaping, resulting in exposure of adverse material)	- Contamination of surface water and/or groundwater by AMD or other contaminants. - Impact to flora (vegetation failure) - Impact to fauna (aquatic)	Possible	Medium	M	Preventative Controls: - Material characterisation through exploration drilling and ongoing geochemical testing - Mine planning strategy for life of mine mineral waste management (placement and cover requirements) - Mine planning haulage model (including material categorisation) for life of mine mineral waste management - Material placement tracking system (Corvus) - 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) - Post-capping QA/QC Mitigating Controls: - Material characterisation (outcomes to be stored into GeoBank) in line with Whitehaven Materials Standards - Remove and / or cover undesirable materials - 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 - Ongoing geochemical testing to continue to verify low likelihood of AMD or other contaminants reporting to surface water	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3
PMLU 10	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as result of: **Inadequate and/or inappropriate revegetation**.	1. Unfavourable climatic conditions and/or weather events 2. Incorrect species mix 3. Poor seed quality 4. Weed contaminated seed 5. Poor quality growth media or seed bed preparation 6. Erosion 7. Land contaminants 8. Incorrect agronomy and amelioration advice 9. Poor planning and execution	- Exposed soils due to poor vegetation establishment and growth, resulting in enhanced erosion rates. - Increased weed establishment and growth. - Reduction in land capability of PMLU (woodland habitat and/or grazing) - Need for ongoing corrective action - Additional soil sampling and analysis, amelioration and re-vegetation.	Almost Certain	Major	C	Preventative Controls: - Landform design - Growth media and spoil assessment by AQP to determine ameliorant and fertiliser requirements - Revegetation species selection aligned to growth media, landforms and PMLU - Management of seed selection, provenance and quality control implemented as per PRCP Schedule requirements. - Plant at optimal time of year. - Post execution governance (compliance to plan work packs) Mitigating Controls: - 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.	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3

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PMLU 11	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as result of: **Failure of TSF and rejects rehabilitation (landform and function).**	1. Inadequate or incorrect geochemical characterisation and assessment of landform materials. 2. Management strategy adopted was inadequate or inappropriate to manage the AMD hazards of the waste materials. 3. Incorrect or inappropriate mine planning processes to account for management (spatial and temporal) for adverse materials in landform. 4. Poor final landform execution (e.g. poor/incorrect landform reshaping, resulting in exposure of adverse material) 5. Geotechnical instability including foundation failure and slope failure 6. Erosional instability including surface water quality to receiving environment not meeting target criteria, failure of vegetative cover and ineffective erosion protection elements	- Financial cost of rectification and remediation - Reputational damage - Loss of containment - Contamination of surface and groundwater sources - Failure of achievement of PMLU - Contamination of surface and groundwater sources	Likely	Catastrophic	C	Preventative Controls: - Material characterisation to understand short-term and long-term geochemical behaviour - Mine planning strategy for life of mine mineral waste management (placement and cover requirements) - Mine planning haulage model (including material categorisation) for life of mine mineral waste management - Material placement tracking system (Corvus) - TSF and reject cover systems designed by an AQP to be erosional stable, geotechnically stable, supportive of the PMLU and effective in mitigating the potential for migration of contaminants to the receiving environment. - Ongoing periodic monitoring by appropriately qualified persons to ensure alignment with rehabilitation milestones and PMLU requirements - Remediation works where evidence through ongoing monitoring suggests that PMLU requirements may not be achieved - Surface and groundwater monitoring - In situ geochemical monitoring - TSF closure management plan Mitigating Controls: - Material characterisation (outcomes to be stored into GeoBank) in line with Whitehaven Materials Standards - Remove and / or cover undesirable materials - Response (maintenance, remediation, increased monitoring, notification to any affected stakeholders) to performance indicators not being met. - 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 - Ongoing geochemical testing to continue to verify low likelihood of AMD or other contaminants reporting to surface water	Major	Rare	M	Yes	PRC Plan Section 3.7.1.3
PMLU 12	Stable condition (safe, stable, non-polluting and sustainable) for land described as a PMLU (cattle grazing, woodland habitat, watercourse) is not achieved as result of: **Failure of TSF and rejects cover system resulting in ongoing seepage (NCPP, Laleham and Bottom Dam TSFs; R36 rejects)**	1. Inadequate or incorrect geochemical characterisation and assessment of landform materials. 2. Management strategy adopted was inadequate or inappropriate to manage the AMD hazards of the waste materials. 3. Incorrect or inappropriate mine planning processes to account for management (spatial and temporal) for adverse materials in landform. Inadequate cover placement 4. Inappropriate cover material 5. Inadequate cover design 6. Cover doesn't function as designed 7. Cover deterioration over time	- AMD seepage impact on surrounding water values (surface and groundwater)	Almost Certain	Medium	H	Preventative Controls: - Material characterisation to understand short-term and long-term geochemical behaviour - Mine planning strategy for life of mine mineral waste management (placement and cover requirements) - Mine planning haulage model (including material categorisation) for life of mine mineral waste management - Material placement tracking system (Corvus) - TSF and reject cover systems designed by an AQP to be erosional stable, geotechnically stable, supportive of the PMLU and effective in mitigating the potential for migration of contaminants to the receiving environment. - NUMAs are acting as sinks for groundwater - Cover design based on trials - Material characterisation - Water balance and groundwater modelling to validate the TSF is a sink - Out of pit TSFs and out of pit reject dumps report to groundwater sink - Monitoring of the cover after significant rainfall during operation of the mine Mitigating Controls: - Groundwater monitoring with TARP - Surface water monitoring with TARP - Material characterisation (outcomes to be stored into GeoBank) in line with Whitehaven Materials Standards - Remove and / or cover undesirable materials - Appropriate material placement and selective handling during operations	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3
NUMA 1	NUMA does not achieve safe, structurally stable condition or causes environmental harm as a result of: **Void walls not achieving geotechnical stability**	1. Increase/decrease in predicted void water levels 2. Use of inaccurate geological model (geotechnical parameters) 3. Poor low-wall and high-wall design (compliance to plan) 4. Erosional instability 5. Non-conformance to design 6. Inappropriate modelling and design	- Failure of void walls leads to instability beyond NUMA extent -Failure of landform protecting final void from flooding	Almost Certain	Major	C	Preventative Controls: - Geotechnical assessment to be completed by AQP taking into consideration failure zones and proximities to public infrastructure and mining lease boundaries, and floodwaters against creek-side batters (where relevant) - Pit wall designs based on geotechnical assessments and flood modelling (as required) - Pit walls are constructed per AQP designs, using non-dispersive materials - 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. - Water balance and groundwater modelling to validate the pit lake is below the zone of weathering Mitigating Controls: - Geotechnical monitoring - Identify requirements for rectification works.	Major	Unlikely	H	Yes	PRC Plan Section 3.7.1.3
NUMA 2	NUMA does not achieve safe, structurally stable condition or causes environmental harm as a result of: **Uncontrolled access to NUMA areas**	1. Inappropriate design, management and construction of safety bund 2. Inadequate/poorly maintained fencing and signage	- Unmanaged access to NUMA by people or livestock	Likely	Major	H	Preventative Controls: - Safety bund, fencing and signage placed at FoS limit, where required. Mitigating Controls: - Compliance checks as part of monitoring	Major	Rare	M	Yes	PRC Plan Section 3.7.1.3

CONSIDERATIONS AND INITIAL RISK EVALUATION							CONTROL INPUT AND RESIDUAL RISK EVALUATION				Action Program	
	Risk Event	Cause & Impact		Assessment of Risk without controls in place			Control Input	Assessment of Risk with controls in place				
Ref / ID # A value must be entered for every row	Hazard or Risk	How could it happen? (Causes)	What Could Happen (Impacts)	Inherent Likelihood	Inherent Consequence	Inherent Risk Assessment	Control Name	Residual Consequence	Residual Likelihood	Current Risk Assessment	Is Action Required?	PRC Plan Reference to Action Program
NUMA 3	NUMA does not achieve safe, structurally stable condition or causes environmental harm as a result of: **Uncontrolled flooding into residual voids**	1. Flood mitigation (backfill and/or landforms) is not constructed or installed correctly, or included as part of future mine planning 2. Inaccurate flood modelling 3. Erosion/piping failure of flood protection landform	- 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	Almost Certain	Major	C	Preventative Controls: - Flood modelling completed by an AQP, confirms the landform design prevents the inundation of floodwaters into the residual void, up to and including the 0.1% AEP event - Pit wall designs are based off geotechnical assessments which considers floodwaters against creek-side batter/s (where relevant) - Landform is thick enough to prevent seepage from flood water though the landform, based on duration of wetting the landform by 0.1% AEP - Flood mitigation designed to correct flood event and outside of the predicted failure slope assessed with a suitable factor of safety - Energy dissipation measures (e.g. rock lining) installed in areas where high-energy flows (≥2.5m/s) are determined by an AQP for the 0.1% AEP - Regular, ongoing monitoring (re-assessing and calibration of groundwater model, resulting in refined design, as needed, accounting for climate change) - Flood mitigation (partial backfill and/or landforms) Mitigating Controls: - Compliance checks as part of monitoring - Review flood modelling following flood events to refine model	Medium	Rare	L	Yes	PRC Plan Section 3.7.1.3
NUMA 4	NUMA does not achieve safe, structurally stable condition or causes environmental harm as a result of: **Water in the void causes environmental harm outside of the mining tenure (due to pit lake)**	1. Groundwater outflow seepage not identified by groundwater modelling 2. Poor water quality 3. Overtopping or interconnection of the void lake with shallow groundwater water units 4. Groundwater significantly above model forecast/predications 5. Contributing catchment to the void is larger due to changes to landform or failure to divert clean water catchments	- Pit lake level elevated, turning it into a source - 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	Likely	Major	H	Controls: - Maximum area of each NUMA is limited to the extents defined in the approved PRCP Schedule - Clean water diversions included in landform design - Ongoing groundwater modelling to validate predicted flows - Ongoing water balance modelling to validate predicted lake levels - Water quality modelling completed by AQP - Catchment area minimised where possible and practical to do so - Flood mitigation (partial backfill and/or landforms) designed to provide protection for a 0.1% AEP event - 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 - TSF cover systems designed by an AQP to be erosionally stable, geotechnically stable and effective in mitigating the potential for migration of contaminants to the receiving environment. Mitigating Controls: - Rectification works on impacted ecosystems or bores - Installation of engineering controls to limit potential for ongoing impacts	Medium	Unlikely	M	Yes	PRC Plan Section 3.7.1.3