# BHP Iron Ore Pty Ltd
# Marillana Creek (Yandi) Closure Plan

## May 2025, Revision 6

Site code: S0001524, S0223585, S0233696

Tenements: M270SA, G47/12 to G47/19, L47/118, L47/667 and L47/771

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# Document amendment record

| Version | Change Effected | Date of Change |
|---|---|---|
| Revision 4 | Marillana Creek (Yandi) Mine Closure Plan supersedes Marillana Creek (Yandi) Mine Decommissioning and Final Rehabilitation Plan (DFRP), Revision 3, 2011 and Progressive Rehabilitation Management Plan, Revision 2, 2011. | 2016 |
| Revision 5 | Update to the 2016 Yandi Mine Closure Plan including alignment to the DEMIRS Statutory guidelines for Mine Closure Plans (DMIRS, 2020a). | 2020 |
| Revision 6 | Update to the 2020 Yandi MCP in accordance with Ministerial Statement (MS) 679 Conditions 5 and 6 (as amended by MS 1039) and in support of the *Marillana Creek* (Yandi) *Life of Mine Proposal Significant Amendment* Environmental Review Document. | 2025 |

# Submission details

| Company Name: | BHP Iron Ore |
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# Executive summary

The Marillana Creek (Yandi) mine (herein referred to as "Yandi") is located approximately 100 kilometres north-west of Newman in the Pilbara Region of Western Australia. The operation is situated within Mining Lease 270SA, General Purpose Leases 47/12 to 47/19, Miscellaneous Licences 47/118, 47/667 and 47/771, and Crown Lease K843924. The underlying tenure comprises predominantly pastoral leases with a small area of vacant crown land in the north-western and south-western corners of the Yandi development envelope. The mine operates on the lands of the Banjima people and BHP takes into consideration the views and feedback of the Banjima people as part of the closure planning process. This Mine Closure Plan (MCP) facilitates engagement on closure outcomes with the Banjima People, supported by Banjima Native Title Aboriginal Corporation (BNTAC) and its consultants / technical advisers. Copies of this plan have been provided to BNTAC (and their technical advisers) and the Banjima people for their review and comment along with in-person briefings.

Yandi mining operations commenced in 1991. The orebody is a near-surface Channel Iron Deposit (CID) which, for mining purposes, has been sub-divided into a series of mine pit areas; Western (W) 1 to 6, Central (C) 1 to 6[1] and Eastern (E) 1 to 8. Approval is currently being sought for the E8 mining area via the *Marillana Creek (Yandi) Life of Mine Proposal Significant Amendment* Environmental Review Document (ERD). Mining at Yandi (including E8) is expected to be complete around 2032, although options are currently under internal consideration for mining remnant ore, and utilising Yandi infrastructure as a regional processing hub for satellite ore bodies beyond cessation of current mining activities.

BHP Iron Ore[2] is the manager for the Yandi Joint Venture, which owns the Yandi operation. The Joint Venture partners for Yandi are:

- BHP Minerals Pty Ltd - 85%;
- Itochu Minerals and Energy of Australia Pty Ltd - 8%; and
- Mitsui Iron Ore Corporation Pty Ltd - 7%.

This Mine Closure Plan (MCP) outlines BHP's current closure strategy for Yandi (noting that further engagement with the Banjima people is required), and the technical studies and other knowledge base parameters that have informed the strategy. The MCP is being submitted to the Department of Water and Environmental Regulation (DWER):

- As an update to the 2020 Yandi MCP in accordance with Ministerial Statement (MS) 679 Conditions 5 and 6 (as amended by MS 1039 – refer to Section 3.1 for further details).
- To support the *Marillana Creek (Yandi) Life of Mine Proposal Significant Amendment* ERD.

The MCP describes how the Yandi operation, will be rehabilitated and closed in a manner that addresses:

- Condition 5 of MS 679 (as amended by MS 1039) and the information on progressive rehabilitation required by Condition 6 of MS 679.
- The Department of Energy, Mines, Industry Resources and Safety (DEMIRS) Statutory Guidelines for Mine Closure Plans (DMIRS, 2020a) and Mine Closure Plan Guidance (DMIRS, 2020b);
- BHP corporate standards and procedures;
- Feedback from regulators (DEMIRS and DWER) on the 2020 MCP (Revision 5); and
- Feedback from the Banjima people.

Map E 1 and Table E 1 outline the key closure domains and features of the Yandi mine.

[1] Note the C6 pit is named Yandi C2/3 in MS 679 but has been renamed for operational purposes and is referred to as C6 throughout this document.

[2] Several terms have been used to refer to the company in this document:
- BHP refers to the BHP group of companies under parent entities BHP Group Limited and BHP Group Plc
- BHP Western Australia Iron Ore (WAIO) refers to the local Western Australian operation
- BHPIO Iron Ore Pty Ltd (BHPIO) is the legal company name for licences and approvals

**Table E 1 Yandi closure domains**

| Domain | Sub-domain type | Feature |
|---|---|---|
| Mine Voids | Mine Void | W1, W2, W3, W4, W5, W6, C1/2, C4/5, C6, E1-6, E7, E8 (proposed) |
| Ex-pit areas | Overburden Storage Areas (OSAs) / Run-of Mine (ROM) / stockpiles | Rehabilitated OSAs C1 and E2. |
| | | Other OSAs and associated stockpiles and ROM pads. |
| | Infrastructure | Roads, laydown areas and service corridors. |
| | | Rail lines. |
| | | Ore Handling Plant (OHP) 1, OHP 2 and OHP 3, workshops, non-process infrastructure, fuel storage facilities and camps. |
| | | Western and Central landfills. |
| Surface water infrastructure | Surface water infrastructure | Flood channels, flood bunds, Marillana Creek diversions (E1 and E4), Herbert's Creek land bridge and W3, C1/2, C5, E3/5/6, E7, W2 and W5 diversions. |
| Infrastructure jointly owned with Rio Tinto Iron Ore (RTIO)* | Infrastructure roads and rail | Airport and road to the airport. |

*Note: While the Yandi Joint Venture (JV) holds the tenure for the Yandi airport and road to the airport, the infrastructure is 50% owned by RTIO. The timing for the closure of this infrastructure will, therefore, be subject to the needs of both parties.

A key consideration in planning for the closure of the Yandi mine is the potential influence of other mining areas on the closure outcomes at Yandi. In particular, RTIO's neighbouring Yandicoogina mine, which lies to the east and immediately downstream of BHP's Yandi mine, influences pit lake and groundwater outcomes, as the mine is extracting ore from the same CID aquifer as the Yandi mine.

The information in this MCP represents a significant advance on the information presented in the last (2020) MCP and has been generated through BHP's study process which comprises:

- An Identification Phase Study (IPS; closure readiness study) which explores alternatives for closure and selects the preferred alternative(s).
- A Selection Phase Study (SPS) which optimises all aspects of the preferred alternative(s).
- A Definition Phase Study (DPS) which advances the development of the project and planning for execution. Execution follows completion of the DPS.

This MCP represents the knowledge base and designs developed through the partial completion of the Yandi closure SPS. The SPS has been put on hold following a request by BNTAC and the Banjima people to halt the progression of the SPS to the DPS until BNTAC and Banjima have:

- Reviewed technical studies to gain a full understanding of the process and rationale for the preferred closure strategy identified by the IPS; and
- Discussed and workshopped post-mining land use(s) and closure outcomes with BHP.

This means that the knowledge base and designs in this MCP are at different levels of maturity depending on the studies available at the time of writing. In addition, several of the SPS studies were executed concurrently so the findings of some studies may not yet have been integrated into the findings of others.

While the Yandi closure study has significantly advanced the knowledge base for closure and refined design options, there are still knowledge gaps that require further study and assessment as the closure design matures. Of significance, is the ongoing engagement with the Banjima Traditional Owners who have expressed an aversion to permanent saline pit lakes.

In addition to the iterations associated with closure planning studies, changes to mine plans, including the extent to which low grade ore will be mined / recovered, also need to be factored into the closure study over time.

Given the variables outlined above, the knowledge base and designs in this MCP represent a snapshot in time and will be updated as consultation with the Banjima people and subsequent design studies progress. These updates will be progressively reported in future updates to the MCP.

BHP is committed to environmental stewardship. The BHP Charter is the overarching document that articulates the corporate vision and values and what BHP stands for. The first value in the Company Charter is:

> *Sustainability: putting health and safety first, being environmentally responsible and supporting our communities.*

The WAIO closure and rehabilitation objective is to:

> *Develop a safe, stable, non-polluting and sustainable landscape that is consistent with key stakeholder agreed social and environmental values and aligned with creating optimal business value.*

To guide the development and implementation of mine closure and rehabilitation for the Pilbara operations, BHP has established a set of closure guiding principles. The principles address post-closure land use, land management, safety, landforms, mine planning, ecosystem sustainability, water, decommissioning, contaminated sites, human resources and community assets.

The WAIO-wide closure objective and guiding principles have been supplemented by the Yandi -specific closure objective derived from MS 679 as amended by MS 1039:

*Ensure that the mine is decommissioned and rehabilitated in an ecologically sustainable manner.*

As outlined in the 2016 MCP, there is insufficient overburden to backfill all mine voids to 5 m above the pre-mining water table to enable a groundwater throughflow system to be re-established and prevent the establishment of pit lakes which will become hypersaline over time. Studies have shown that Fortescue Marsh and riparian vegetation along Marillana Creek are reliant on surface water flows and, therefore, closure designs have focused on maintaining surface water flows to support these ecosystems. To achieve groundwater throughflow, surface water would need to be diverted to the pits which would reduce the amount of water available to recharge the Marillana Creek alluvial aquifer and Fortescue Marsh. Furthermore, RTIO's Mungadoo Pit (adjacent to E7 Pit) is expected to be a long-term saline pit lake post-closure as RTIO also has insufficient material to backfill its entire Yandicoogina mine to above the recovered water table (Rio Tinto, 2014). The pit lake in Mungadoo, would inhibit movement of any groundwater flows from Yandi beyond this pit, and consequently, groundwater throughflow off-tenement would add very little benefit to the overall outcomes to be achieved in closure.

Given this context, the guiding principles outlined in Table E 2 were developed for the closure of Yandi[3]. Since 2016, a key principle for Yandi closure designs has been to prioritise Marillana Creek surface water flow regime (water resource, hydraulic conditions and fluvial system) over groundwater throughflow.

**Table E 2 Yandi closure guiding principles**

| Regional environmental outcomes maintained (Fortescue Marsh, Weeli Wolli Creek, Marillana Creek)<br>Local mine void outcomes informed by further options assessment and stakeholder consultation | | |
|---|---|---|
| **Land** | **Water** | **Heritage** |
| • Post-mining land use will be determined in consultation with key stakeholders;<br>• Residual mine voids will be left in a geotechnically stable state;<br>• Overburden will be used to partially fill and profile mine voids to achieve beneficial local ecosystem outcomes; and<br>• Mine landforms will be revegetated to establish local native vegetation appropriate for the area. | • Fortescue Marsh and Weeli Wolli Creek regional outcomes will be maintained by committing to a sustainable Marillana Creek surface water flow regime; and<br>• Local groundwater outcomes will be informed by collaboration with key stakeholders including adjacent mines and Banjima People. | • The Banjima People will be engaged to inform the rehabilitation program consistent with the obligations and aspirations of the Banjima Comprehensive Agreement; and<br>• The integrity of, and access to, places of cultural significance will be maintained in the closure design to the greatest extent practicable. |

Several studies, including water balance modelling, have been conducted to inform the current closure concept which has been chosen to minimise the footprint of hyper-salinity in the landscape through the partial backfill of selected pits (Map E 1 and Figure E 1). This backfill strategy results in permanent pit lakes at W2, W3, C4/5 and E7 which will become hypersaline over time due to evapo-concentration. The E7 Pit is adjacent to RTIO's Mungadoo Pit and there are plans to mine the pillar of CID between the two pits. RTIO also has insufficient material to backfill all the Yandicoogina pits to above the water table, and the current closure plan for Mungadoo Pit is that it will also become a permanent pit lake. BHP acknowledges the Banjima people's stated aversion to pit lakes and has committed to ongoing engagement with BNTAC and the Banjima people. BHP and RTIO have also recognised the interdependencies between their operations and have a closure / water data sharing agreement to facilitate closure planning to optimise regional outcomes. There have been several meetings between RTIO and BHP and a joint BHP / RTIO meeting with BNTAC to discuss water and closure-related matters. BHP and RTIO have committed to continuing to work together to progress their respective closure strategies in consultation with BNTAC and the Banjima people.

With the exception of C6 and proposed E8 Pit, the partially backfilled pits are predicted to have seasonal expressions of non-saline water. C6 and E8 will be backfilled to above the recovered water level and are not expected to have expressions of water.

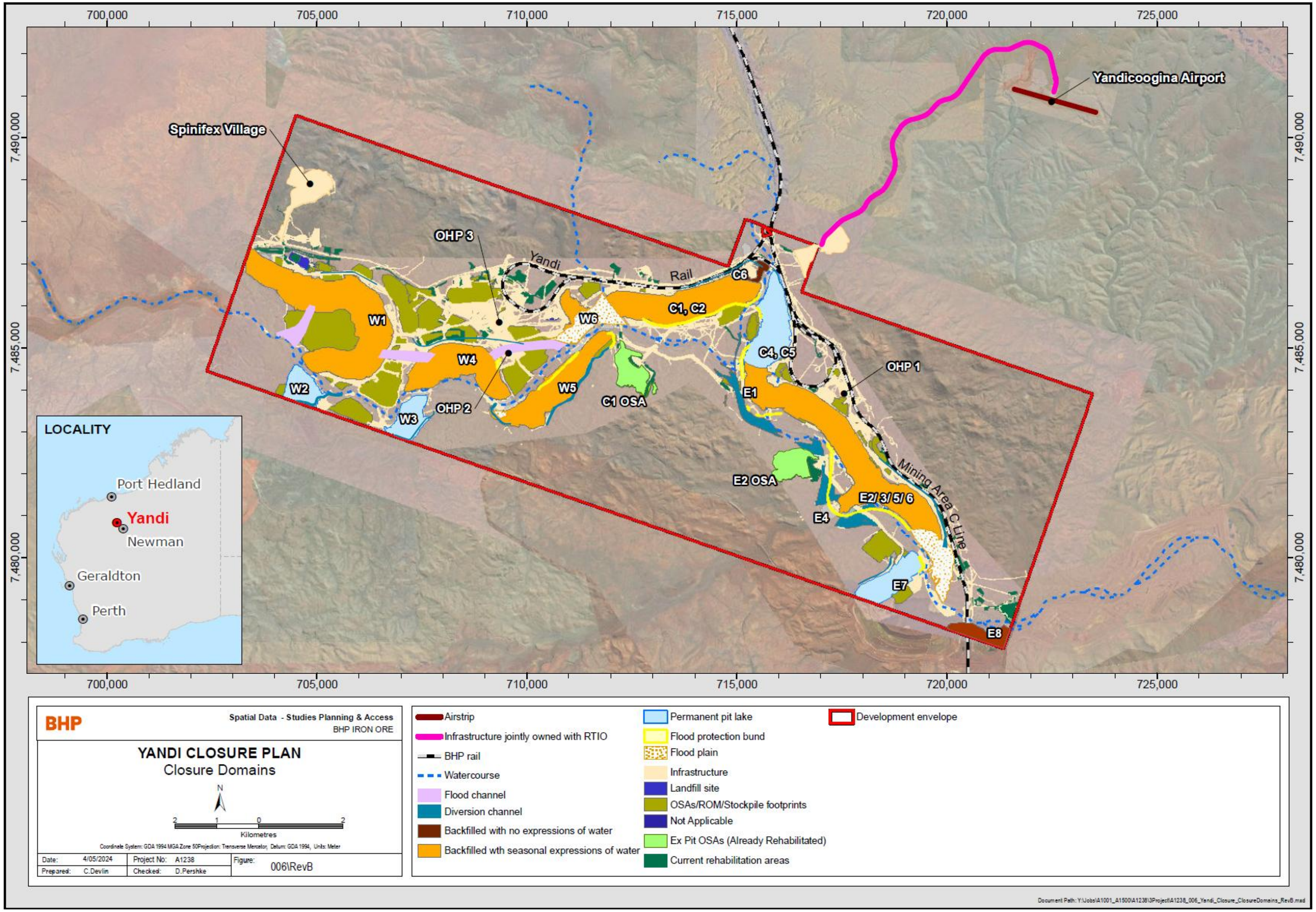
To achieve the current closure concept, all ROM pads, stockpile bases and OSAs (except C1 and E2) will be rehandled back to the Yandi pits as part of the backfill design. C1 and E2 OSAs will remain in the landscape as they have already been rehabilitated, and landform evolution modelling and rehabilitation monitoring have shown that they will be stable in the long-term and vegetation is progressing towards completion criteria. The additional volume of overburden in these OSAs will not enable substantially different outcomes to be achieved if rehandled to the pits and maintaining them as ex-pit OSAs provides a buffer of material that can be used to supplement backfill areas if monitoring indicates this is required.

3 BHP acknowledges the recent receipt (late March 2025) of the Banjima Mine Closure Objective, Principles and Outcomes which will be used to inform future discussions with the Banjima people and updates to the MCP.

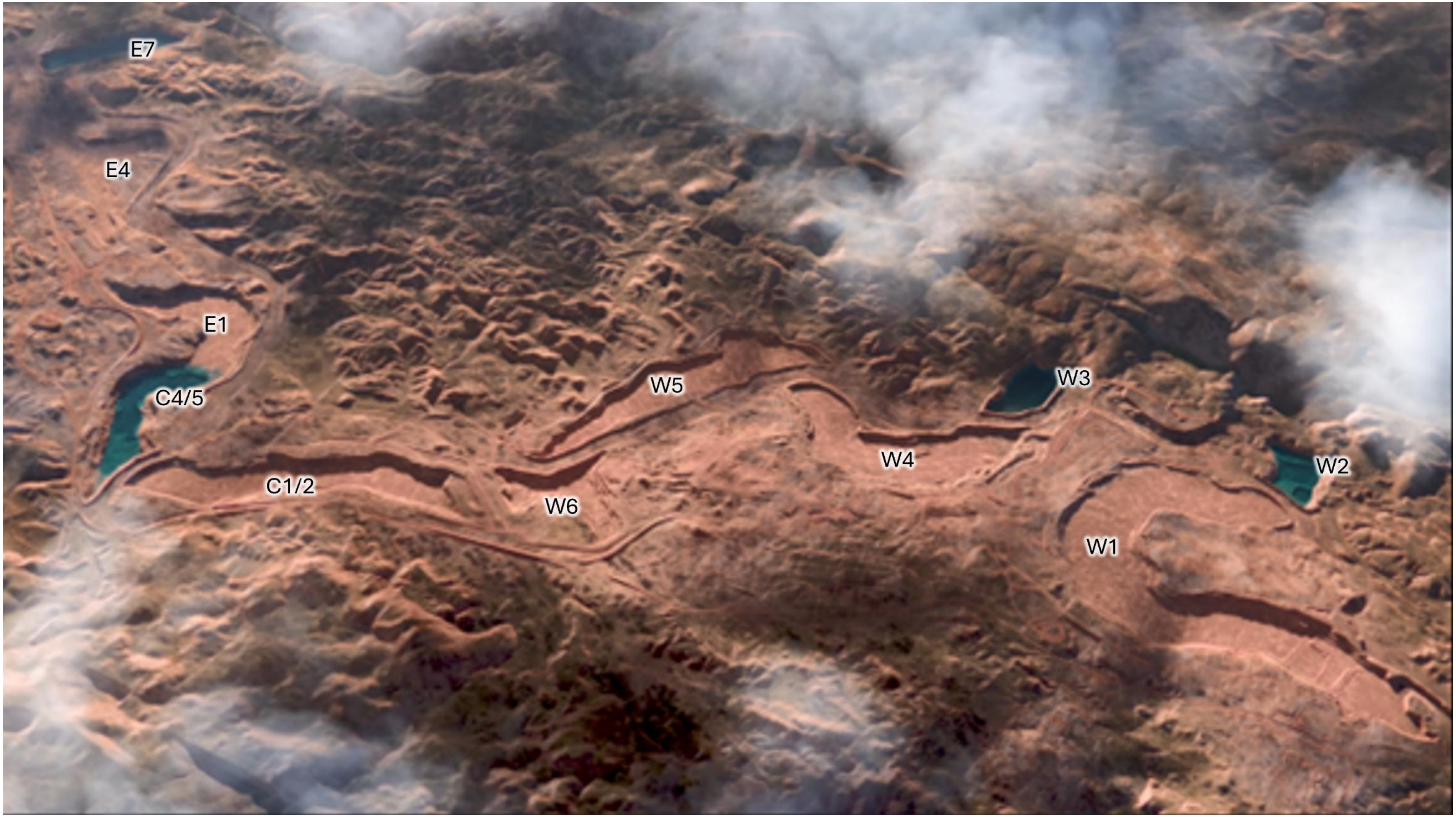
To prevent the capture of Marillana Creek by the pits, a series of surface water management measures have been designed including creek diversions, flood bunds, floodplains and flood channels. The flood channels will allow Marillana Creek to overflow in a controlled manner:

- Into W1 Pit (via flood channel W1-SP0);
- From W1 Pit into W4 Pit (via W1-SP3); and
- From W4 Pit back to Marillana Creek (in a 1:10,000 Annual Exceedance Probability (AEP) event via W4-SP4).

The flood channels will be activated during rare post-closure rainfall events and prevent erosion or damage to diversions / flood bunds / floodplains or uncontrolled overtopping of downstream pit crests. In addition, while the E8 Pit backfill design has yet to be finalised, BHP intends to backfill the pit to the level of the Marillana Creek invert (defined as the level of the low flow channel) to prevent creek capture.




**Map E 1 Closure domains**




Notes: This visualisation was created before floodplain landforms were introduced into the closure design
Visualisation looks north / south with significant vertical exaggeration

**Figure E 1 Visualisation of the Yandi closure design concept incorporating permanent pit lakes at W2, W3, C4/5 and E7**

BHP commenced the investigation of post-mining land uses in 2019 with a strategic opportunity assessment of its central and eastern Pilbara operations. Since that time, several other studies have been conducted and consultation with BNTAC and the Banjima people about land use planning for Yandi has commenced. Since post-mining land use planning is an ongoing discussion, the Yandi closure study has taken the approach of working towards interim land uses that are consistent with the underlying tenure (pastoral) but has used the outcomes of studies conducted to date, to develop closure designs that do not preclude potentially viable land uses. The interim land uses are:

- For all ex-pit areas within the development envelope - *relatively natural environments for pastoral grazing purposes*.
- For mine voids - *Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.*

Table E 3 provides a summary of key closure information by domain including:

- The interim post-mining land uses.
- Key closure outcomes. These outcomes provide the overarching objectives that guide the more detailed closure criteria presented within the body of this MCP.
- Key closure risks. This column provides a brief summary of the key closure risks associated with each domain. Further information on causes and potential impacts is provided within the body of this MCP. Very low inherent risks (i.e. risks prior to the application of controls) have not been included in this table.
- The main controls that are being, or will be, implemented to achieve the key outcomes and mitigate the closure risks.
- A summary of knowledge gaps that are still to be addressed.
- The forward work program to address the outstanding knowledge gaps and enable closure planning to be refined and progressed towards execution.

**Table E 3 Summary of key risks and management approaches**

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| **General - applicable to all domains** | **Ex- pit areas**<br>*Relatively natural environments for pastoral grazing purposes.*<br>**Surface water infrastructure**<br>*Relatively natural environment not inconsistent with pastoral use.*<br>**Mine voids**<br>*Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 1 | • Post-closure land use has been informed by consultation with relevant stakeholders.<br>• Infrastructure has been decommissioned and removed where transfer to a third party is not agreed.<br>• Long-term land management requirements have been addressed. | • Land / infrastructure condition is not suited to the post-mining land use | • Consultation / collaboration will continue with BNTAC, the Banjima people and other relevant stakeholders to define post-mining land uses for Yandi. This will include defining post-mining land use performance objectives which will inform the refinement of completion criteria.<br>• Stakeholders including government and BNTAC / Banjima will be consulted on requirements for infrastructure prior to demolition.<br>• Where infrastructure is to be transferred, infrastructure condition will be assessed, and the condition included in stakeholder agreements, along with responsibilities for maintenance.<br>• Post-closure land management and maintenance requirements will be tracked through the post-closure monitoring program and, where requirements exceed those of surrounding land, arrangements will be made in consultation with key stakeholders for ongoing management post-relinquishment. | • Post-mining land uses.<br>• Long term post-completion land management requirements.<br>• Stakeholder requirements for infrastructure that would otherwise be demolished / removed. | • Consultation will be conducted with key stakeholders, including BNTAC / Banjima people, regarding post-mining land uses at Yandi and domain-specific completion criteria.<br>• Post-closure land management requirements will be identified through the post-closure monitoring and maintenance program.<br>• Government and stakeholder consultation will be conducted to identify requirements for infrastructure prior to Stage 2 demolition. |
| | | ES 2 | • Protection of cultural values, and access to sites of cultural importance has been incorporated into mine closure planning following consultation with the Traditional Owners.<br>• Visual amenity of constructed landforms is compatible with that of local Pilbara landforms. | • Impact to Traditional Owner cultural values from aspects of the closed mine other than saline pit lakes (discussed in further detail in ES 9 below).<br>• Impact to heritage sites as a result of additional disturbance required to execute closure. | • Consultation with BNTAC and the Banjima people will continue to inform the closure strategy and outcomes for Yandi.<br>• All OSAs except C1 and E2 will be rehandled to the pits as backfill and the ex-pit area returned to an approximation of the pre-mining topography.<br>• The backfill design incorporates features to make the backfill surface more natural looking.<br>• Marillana Creek E1 and E4 diversions have been constructed to resemble analogue reaches of Marillana Creek.<br>• Minor and intermediate diversion designs will be optimised to include consideration of the potential to develop more natural looking systems which support riparian vegetation.<br>• The W1-SP0 energy dissipator will be designed to resemble a natural analogue system and will comprise a rocky channel with features similar to those at Flat Rocks such as uneven ground, bumps, small drops and irregularities.<br>• BHP has a suite of standard rehabilitation procedures which will be implemented to establish target vegetation communities and manage weeds. These procedures and the revegetation strategy for Yandi are informed by research and trials. A land rehabilitation partnership between BHP and the Banjima people is being used to research the production of materials for use in revegetation programs at Yandi. Seed mixes contain culturally significant species.<br>• If any new disturbance is required as a result of closure activities, archaeological and ethnographic surveys are conducted and BNTAC and the Banjima people are consulted to identify any heritage sites or sites of cultural significance.<br>• Any disturbance required for closure execution activities will be approved through BHP's Project Environmental and Aboriginal Heritage Review (PEAHR) process prior to ground disturbing activities commencing. | • Final mine closure strategy / outcomes.<br>• Detailed designs for final closure strategy.<br>• Detailed rehabilitation strategy. | • Further consultation on mine closure designs and outcomes will be undertaken with BNTAC and the Banjima people.<br>• Depending on the final closure strategy, the following matters will be considered in the development of detailed designs:<br>- Optimisation of backfill, creek diversion, floodplain and flood channel designs to manage impacts on heritage sites and cultural values.<br>- Options to achieve more natural looking systems, erosion and deposition processes and establishment of riparian vegetation in creek diversions.<br>- Options for incorporating measures for safe access and egress into designs.<br>- The vegetation communities and species mix to be assigned to each domain<br>• Further research and trials will be conducted to inform the revegetation strategy for backfilled pits.<br>• A research program is currently being planned to investigate fauna habitat and the return of fauna to rehabilitated areas, including consideration of key species of significance to Traditional Owners. |
| | | ES 3 | • Contaminated sites have been documented and managed to achieve a classification commensurate with the post-mining land use.<br>• Groundwater quality is acceptable at key receptors.<br>• Surface water quality is acceptable at key receptors. | • Identified areas of contamination have not been managed during operations or the contaminated sites classification under the *Contaminated Sites Act 2003* is not suitable for the agreed post-mining land use. | • Pre-closure monitoring enables groundwater and surface water contamination to be identified and remediated, if required.<br>• BHP has a contaminated sites register and a risk-based schedule for investigation and remediation of contamination during operations.<br>• Any contamination remaining at closure will be investigated and remediated to a standard commensurate with the post-closure land use, as required by the *Contaminated Sites Act 2003*.<br>• Demolition and decommissioning plans will be developed which address the management of hydrocarbons and other potential contaminants during closure execution. | • Contamination assessment and remediation is incomplete for known and suspected sites. | • Suspected contaminated sites will be investigated.<br>• Known contamination will be remediated, if required. |

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| Ex-pit areas (excluding creek diversions) | *Relatively natural environments for pastoral grazing purposes.* | ES 4 | • Materials with poor chemical properties do not compromise rehabilitation (landform stability and revegetation) or water quality[4].<br>• The constructed surface is stable and showing no signs of significant erosion or release of sediment beyond design criteria which causes adverse impacts to drainage lines.<br>• A suitable growth medium has been identified to facilitate plant establishment and growth.<br>• Vegetation is suited to the final landform and post-closure land use.<br>• Demonstrated capacity of the site to recover from fire, drought and other disturbances.<br>• Department of Biodiversity Conservation and Attractions (DBCA) priority list weed species to be managed so as not to cause unacceptable risk to surrounding environments.<br>• Total weed cover to be typical for each site and landform and reflect final land use.<br>• Vegetated areas provide fauna habitat. | • Revegetation of ex-pit domains (excluding creek diversions) does not meet ecological completion criteria. | • BHP has a range of rehabilitation standards and procedures that it uses to guide rehabilitation and manage weeds. Monitoring has shown that the rehabilitated OSAs C1 and E2 are progressing towards completion criteria indicating that rehabilitation techniques for ex-pit areas can establish target vegetation communities.<br>• A revegetation strategy has been developed for Yandi, and this will be refined as closure designs progress.<br>• Topsoil is stockpiled and available volumes are reconciled with volumes required for rehabilitation. There is a topsoil deficit at Yandi. To address this deficit, overburden types have been analysed to assess their suitability for use as growth media. A rehabilitation trial is planned for FY25 to assess different growth media mixes (various proportions of topsoil and CID), seed mixes, seeding techniques, and fertiliser treatments. The outcomes of this trial will be used to refine the Yandi revegetation strategy.<br>• BHP continues to support research on a range of factors influencing rehabilitation success including seed collection, storage, processing and use, alternate growth media, and rehabilitation techniques. This research informs updates to BHP's rehabilitation practices and procedures.<br>• The seed list for Yandi includes species of cultural significance to the Banjima people.<br>• Local provenance seed is used in rehabilitation.<br>• Opportunities to provide habitat for fauna are considered during rehabilitation.<br>• Monitoring of the success of progressive rehabilitation will be used to inform future rehabilitation practices. | • Detailed revegetation strategy for Yandi including the allocation of topsoil to make the best use of the limited resource. | • Topsoil stockpiles will be tested for a range of physical and chemical parameters that influence plant growth.<br>• A growth media trial is planned for FY25 and will be used to refine revegetation strategies.<br>• A watching brief will be maintained on emerging research associated with the use of out of provenance seed sources to increase genetic diversity to provide resilience to climate change.<br>• A research program is currently being planned to investigate fauna habitat and the return of fauna to rehabilitated areas. |
| Mine voids - permanent pit lakes & backfilled | *Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 5 | • There are no unsafe areas where members of the general public could gain inadvertent access and residual risks are consistent with natural hazards in the surrounding area.<br>• Constructed landforms are safe and geotechnically stable. | • Inadvertent access to unsafe areas causes injury or fatality | • Preliminary pit wall stability assessments have been conducted, and a study was in progress at the time of writing to update this information but was not available for inclusion in the MCP.<br>• Where failure of pit walls may impact nearby infrastructure (e.g. safety bunds, flood bunds, diversions), slopes may be buttressed or reprofiled to achieve a lower slope angle to improve stability and achieve a Factor of Safety (FoS) ≥1.5 (static) and ≥1.0 (seismic).<br>• The backfill design improves pit wall stability.<br>• Geotechnical assessments and hydraulic modelling have informed surface water infrastructure designs and their potential to impact on pit wall stabilities. Surface water infrastructure design modifications required to protect pit wall stability have either been identified or a forward work program developed to enable appropriate design modifications to be determined.<br>• Safety bunds will be constructed around pits in accordance with DEMIRS guidance (DoIR, 1997) to prevent inadvertent access.<br>• Any potentially fibrous materials encountered during regrading or recovery for mine void backfill are placed at least 1 m below inert non-fibrous overburden. | • Detailed designs for pit wall stabilisation and access control. | • Pit wall stability analyses will be conducted, and designs of safety bunds and pit wall stabilisation measures will be developed and refined as pit wall and closure designs evolve.<br>• Following cessation of mining, a final check of pit wall stabilities will be conducted to confirm stability assessments based on as constructed pit geometries, where required.<br>• Further geotechnical assessments will be conducted to inform flood channel, flood bund and diversion designs. |

[4] Geochemical studies have shown that the overburden at Yandi has a low risk of acid or neutral metalliferous or saline drainage.

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| *Mine voids - permanent pit lakes & backfilled continued* | *Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 6 | • Constructed landforms are safe and geotechnically stable.<br>• The constructed surface is stable and showing no signs of significant erosion.<br>• Rehabilitation drainage patterns have been established, and impacts on natural surface water flows are acceptable at key receptors. | • Overtopping of pit crests in extreme / rare rainfall event, or failure of existing flood bunds or remnant CID results in capture of Marillana Creek causing impacts to downstream riparian vegetation | • Hydraulic modelling, geotechnical assessments and various optimisation studies have informed flood bund designs along Marillana Creek including:<br>- Required flood bund heights to accommodate a 1 in 10,000-year event.<br>- Rock armour specifications<br>- Depth of scour protection required.<br>• Flood bund closure designs are generally geotechnically stable and achieve FoS ≥1.5 (static) and ≥1.2 (seismic). In most cases, the bunds manage seepage risks to stability, but mitigation may be required for W5, E1 and E4 flood bunds where the alluvium intersects the pit wall.<br>• To manage the risks of seepage at W5, the floodplain adjacent to the mid-section of W5 Pit will be widened to reduce flow velocities in this region and enable the flood bund to be offset from the pit edge.<br>• Flood channels have been designed to direct portions of rare flood events (up to a 1 in 10,000 AEP) to W1 and W4 pits to attenuate downstream flows and prevent damage to surface water infrastructure / remnant CID.<br>• Floodplains have been designed for constrained sections of Marillana Creek between W5-W6, W4-W5 and E6-E7 to reduce the risks of erosion, lateral channel migration and / or overtopping of the CID / flood bunds.<br>• E8 (if approved) will be backfilled to the Marillana Creek invert level to prevent creek capture.<br>• Modelling for a climate change scenario has indicated that the flood protection freeboard allowances prevent flooding from entering pits in a 1 in 10,000-year flood scenario. | • Detailed designs for flood bunds and floodplain landforms. | • Further geotechnical inspections / investigations and analysis of flood bund foundations (CID, alluvium, Oakover Formation), and floodplains will be conducted, where required.<br>• The suitability of in-situ CID material along pit crests to retain a 1 in 10,000-year flood event will be assessed.<br>• Following cessation of mining, a final check of pit wall stabilities will be conducted, where required.<br>• A detailed investigation and assessment will be conducted of existing minor flood bunds.<br>• Further hydraulic analysis and scour modelling will be used to:<br>- Optimise flood bund designs including the tie in of flood bunds with existing creek and floodplain surfaces.<br>- Optimise floodplain designs.<br>- Inform options to manage the interaction of the W6 floodplain landform with Herbert's Creek land bridge design for closure.<br>• Further assessment of overburden settlement rates will be conducted to inform floodplain designs.<br>• The need for erosion protection for the backslope (downstream slope) of bunds will be assessed. |
| | | ES 7 | • Impacts to groundwater dependent receptors from water levels in the CID / alluvium are acceptable.<br>• Regional groundwater levels are acceptable at key receptors. | • Change to groundwater levels in the CID which impacts groundwater levels in the alluvium where it intersects the CID and impacts riparian vegetation beyond that accepted via project approvals[5]<br>• Cumulative drawdown that impacts the Ministers North aquifer and Yandicoogina Gorge[6] | • The backfill strategy minimises the area of permanent pit lakes which will act as sinks and depress groundwater levels post-closure. Groundwater levels will recover post-backfill (albeit to a lower level than pre-mining groundwater levels), but the extent to which this may influence regional groundwater levels has not yet been modelled.<br>• The current backfill design is for W1 Pit to be partially backfilled with seasonal expressions of water to reduce the effects of drawdown upstream at Flat Rocks post-closure.<br>• The impacts at Flat Rocks are currently being managed via the Marillana Creek Water Resource Management Plan (BHP, 2022b)[7]. If any of the options require action at closure, these will be incorporated into future iterations of the MCP, as required.<br>• The closure design for the proposed E8 Pit represents a potential opportunity to support riparian vegetation in this area. The feasibility of this opportunity is currently being explored in consultation with Traditional Owners, and if feasible, will be incorporated into future updates to this MCP. | • The permeability of backfill remains uncertain.<br>• There are several factors that could change the post-closure water balance.<br>• Residual regional drawdown post-closure has yet to be modelled.<br>• The need for long-term mitigation measures for Flat Rocks to be integrated into the MCP has yet to be defined.<br>• The potential for a connection between dewatering in the CID and Ministers North aquifer requires investigation. | • Further permeability testing of backfill materials will be conducted to increase the spatial distribution of test locations.<br>• Water balance modelling will be updated based on:<br>- The outcomes of consultation with BNTAC and the Banjima people.<br>- Revisions to permeability assumptions (if required).<br>- Data sharing with RTIO.<br>- Further assessment of overburden settlement rates.<br>- Pit wall stability and floodplain designs.<br>• Closure conditions will be incorporated into the regional groundwater model and the inputs and outputs of the regional numerical model and GoldSim water balance model will be aligned.<br>• An assessment / mapping of the influence of post-mining groundwater levels in the CID on riparian vegetation within the Yandi lease will be updated.<br>• Following the study into long-term mitigation measures for groundwater decline at Flat Rocks conducted in accordance with the Marillana Creek Water Resource Management Plan, relevant management measures will be incorporated into the MCP, if required.<br>• Complete investigations to assess potential for a connection between dewatering in the CID and Ministers North aquifer to the south. |

5 Impacts to riparian vegetation at Flat Rocks (upstream of Yandi) have already been detected and are being managed via the Marillana Creek Water Resource Management Plan. Within the Yandi mining lease, mature tree health decline has been observed in proximity to areas where groundwater levels in the CID have declined and the alluvium directly overlies the CID and / or intersects mine voids. The principal riparian tree species most likely to be impacted is *Melaleuca argentea*. The major riparian Eucalypt species are likely to be more resilient to lowered water tables if the surface water regime supporting regular vadose-zone replenishment is maintained. However, some areas that historically supported stands of *Melaleuca argentea* may not remain viable for this species. The impacts to riparian vegetation within the Yandi lease area have been highlighted and accepted in approval submissions (BHP Iron Ore, 1995; EPA, 2005). Currently high-density riparian vegetation is being supported to the north of the proposed E8 pit by discharge of dewatering water which has created an artificial pool. Following cessation of discharge, riparian vegetation communities will change to a new equilibrium commensurate with the post-mining availability of water.

6 Groundwater levels in the Ministers North aquifer have been observed to decline since 2018. This is likely due to declining rainfall, but dewatering of Yandi and third-party mining operations may be a contributing factor. Further investigations are required to determine the contribution, if any, of dewatering to the observed decline. This risk reflects this uncertainty.

7 An updated (2025) version of the Marillana Creek Water Resource Management Plan has been drafted to support the Significant Amendment ERD and continues to include actions for investigating / implementing short and long-term management options for impacts at Flat Rocks.

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| Mine voids - permanent pit lakes | *Aquatic (safe and stable) system not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 8 | • There are no unsafe areas where members of the general public could gain inadvertent access and residual risks are consistent with natural hazards in the surrounding area.<br>• Constructed landforms are safe and geotechnically stable.<br>• Materials with poor chemical properties do not compromise water quality.<br>• Permanent pit lakes should have no unacceptable impacts to people and fauna. | • Public access to pit lakes impacts human health and safety[8]<br>• Access to pit lakes impacts wildlife health[6] | • As well as the control measures for inadvertent access outlined above (ES 5), backfill surfaces that intersect the C4/5 pit lake, will be graded to form shallow beaches to reduce the potential for steep drop offs to lead to drowning. | • Changes to backfill designs may change hydrogeochemical modelling outputs.<br>• The pit lake risk assessment requires an update to consider hydrogeochemical modelling outputs.<br>• Geochemical characteristics of final pit walls[9].<br>• Presence of PAF materials within flood diversion channels. | • Once pit shell designs have been finalised, including consideration of any pit wall stabilisation measures (e.g., buttressing, pit wall re-profiling), the geochemical characteristics of pit wall exposures will be reassessed.<br>• Drilling and characterisation of materials within the flood channels will be conducted to assess the potential for exposing PAF materials.<br>• The pit lake hydrogeochemical model will be updated, if required, following the update of backfill designs.<br>• The pit lake risk assessment will be refined based on the outcomes of modelling. |
| | | ES 9 | • Protection of cultural values, and access to sites of cultural importance has been incorporated into mine closure planning following consultation with the Traditional Owners. | • Traditional Owners do not accept permanent saline pit lakes in the environment | • The proposed backfill strategy was selected as it minimises the footprint of hyper-salinity in the landscape with only W2, W3, C4/5 and E7 becoming permanent saline pit lakes.<br>• The backfill strategy has been informed by:<br>- Water balance modelling and sensitivity testing including climate change scenarios.<br>- Permeability testing.<br>- Data sharing agreement with RTIO.<br>• Excluding C1 and E2 OSAs from the backfill design provides a source of materials for supplementing backfill in areas where settlement may be more than predicted.<br>• Measures have been incorporated into the backfill strategy to minimise the potential for erosion (and hence changes to the water balance) including gentle slopes, ramp landings to dissipate energy from surface water run-off from ramps and an energy dissipation apron at the toe of the W1-SP0 flood channel.<br>• Surface water management infrastructure has been designed to manage ingress of water to pits. | • The permeability of backfill remains uncertain.<br>• There are several factors that could change the post-closure water balance.<br>• Further consultation with Traditional Owners is required.<br>• The final backfill strategy has yet to be defined. | • Further permeability testing of backfill materials will be conducted to increase the spatial distribution of test locations.<br>• GoldSim and regional groundwater model inputs and outputs will be aligned.<br>• The backfill strategy will be refined based on:<br>- Further consultation and post-mining land use planning with BNTAC and the Banjima people.<br>- Continued data sharing with RTIO.<br>- Further assessment of overburden settlement rates.<br>- Pit wall stability and floodplain designs.<br>- Updated modelling including any revisions to permeability assumptions.<br>- Updated material balance. |
| | | ES 10 | • Constructed landforms are safe and geotechnically stable.<br>• Materials with poor chemical properties do not compromise water quality.<br>• The constructed surface is stable and showing no signs of significant erosion.<br>• Groundwater quality is acceptable at key receptors. | • Pits become temporary throughflow systems which impact downstream groundwater quality and associated receptors | • Surface water management designs for closure prevent uncontrolled discharge of surface water to pits (and hence for temporary throughflow to occur) and have been based on hydraulic modelling, geomorphic and geotechnical assessments and various optimisation studies.<br>• Flood channels have been designed to direct portions of rare flood events up to 1 in 10,000 AEP to W1 and W4 pits to attenuate downstream flows and prevent damage to surface water infrastructure. However, the current closure design maintains groundwater sinks in strategic locations to prevent impacts to surrounding groundwater quality, and water balance modelling indicates that these pits are maintained as sinks during controlled discharges of flood waters to W1 and W4 Pits. Water balance modelling also shows that maximum water levels do not intersect the alluvial aquifer based on the backfill strategy.<br>• An initial review of the potential for pit lake stratification indicates that the risk of density driven flow is low.<br>• Modelling for a climate change scenario has indicated that the flood protection freeboard allowances prevent flooding from entering pits in a 1 in 10,000-year flood scenario. | • Surface water management infrastructure designs require finalisation.<br>• The potential for density driven flow requires further investigation. | • Surface water management infrastructure designs will be further investigated and optimised, as outlined for ES 6, ES 14, ES 16 and ES 17.<br>• The potential for the Yandi pit lakes to stratify and result in density driven flow will be investigated in further detail. |

8 Hydrogeochemical modelling indicates that there may be elevated levels of sulphate, boron, fluoride and selenium while salinity is in the tolerable range for livestock (which has been used as a proxy for identifying the palatability of water for drinking). An initial pit lake risk assessment has concluded that the risks to human health and wildlife are low because of the high salinity (and unpalatability of the water) and limited exposure risk. Pit lakes will represent poor wildlife habitat with low ecosystem diversity and abundance.

9 The Yandi deposit has a low risk of acid or neutral metalliferous and /or saline drainage. The pit shells may intersect stratigraphies that have been identified as having a slightly higher sulphur content from the total assay database, but the mining model for the W1, C4/5 and E7 pit shells shows that the overburden blocks intersected are non-acid forming (AMD0). Once the final pit shell designs have been developed (including pit wall stabilisation measures such as laybacks and buttresses) a further assessment will be conducted to confirm the low risk.

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| *Mine voids - permanent pit lakes continued* | *Range of aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 11 | • Constructed landforms are safe and geotechnically stable.<br>• Materials with poor chemical properties do not compromise water quality.<br>• Surface water quality is acceptable at key receptors. | • Uncontrolled surface water flows into pits causes uncontrolled overtopping of pit lakes into Marillana Creek and impacts to surface water quality and downstream receptors | • Surface water management designs for closure prevent uncontrolled discharge of surface water to pits and have been based on hydraulic modelling, geomorphic and geotechnical assessments and various optimisation studies.<br>• W4-SP4 flood channel has been designed as a controlled discharge to Marillana Creek once W4 Pit is full.<br>• Modelling of the W4 controlled discharge concluded that the W4 flood would only be expected to be activated in a very rare (1 in 10,000-year event) and only short term (<30 hours), modest exceedances of some water quality guideline values (nitrate, salinity, sulphate, nickel and zinc depending on the modelled scenario) could occur in the mixing zone. | • Final surface water management infrastructure designs. | • Surface water management infrastructure designs will be further investigated and optimised, as outlined for ES 6, ES 14, ES 16 and ES 17.<br>• Should changes to closure designs or associated knowledge base warrant, the implications for pit lake water release to Marillana Creek will be reviewed and modelling updated, if required. |
| Mine voids - partially backfilled with seasonal expressions of water, or no water | *Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids.* | ES 12 | • There are no unsafe areas where members of the general public could gain inadvertent access and residual risks are consistent with natural hazards in the surrounding area.<br>• Constructed landforms are safe and geotechnically stable. | • Controlled access to backfilled pits post-closure results in injury or fatality | • As well as the control measures for inadvertent access outlined above (ES 5):<br>- Where pits are designed for controlled access, pit walls will be designed to achieve a FoS consistent with natural hazards in the surrounding area.<br>- Boulders may be placed at the top of access ramps to restrict vehicle access.<br>- The backfill design includes:<br>▪ Slopes to direct water away from pit walls to avoid ponding which causes geotechnical instability.<br>▪ Perimeter benches to provide an elevated surface for pit access when conditions are unsuitable on the remainder of the pit backfill surface. | • Detailed access designs for backfilled pits. | • Following confirmation of the backfill strategy, options will be considered for incorporating measures for safe access and egress into designs. |
| | | ES 13 | • The constructed surface is stable and showing no signs of significant erosion beyond design criteria.<br>• A suitable growth medium has been identified to facilitate plant establishment and growth.<br>• Vegetation is suited to the final landform and post-closure land use.<br>• Demonstrated capacity of the site to recover from fire, drought and other disturbances.<br>• DBCA priority list weed species to be managed so as not to cause unacceptable risk to surrounding environments.<br>• Total weed cover to be typical for each site and landform and reflect final land use.<br>• Vegetated areas provide fauna habitat | • Revegetation of backfilled pits does not meet ecological completion criteria | • As well as the measures implemented for ex-pit domains to support achievement of completion criteria (ES 4):<br>- Modelling and sensitivity testing has been used to inform the backfill strategy.<br>- Measures have been incorporated into the backfill strategy to minimise the potential for erosion including gentle slopes, ramp landings to dissipate energy from surface water run-off from ramps and an energy dissipation apron at the toe of the W1-SP0 flood channel<br>- Contouring of the backfill is proposed to collect seasonal water in low points. Modelling indicates that salt build up in the low points will likely be flushed to deeper levels in the backfill profile and that development of sodicity is likely to be limited. | • Final backfill strategy (see ES 9). | • Refer to ES 9 for forward work program to develop final backfill strategy.<br>• The significance of backfill permeability and surface topography to salt accumulation will be investigated as backfill designs are refined.<br>• Research and trials will be conducted to inform the species mix to be used in backfilled pits including floodplains, buttresses and pit laybacks. |
| Flood channels | *Relatively natural environment not inconsistent with pastoral use.* | ES 14 | • Constructed landforms are safe and geotechnically stable.<br>• The constructed surface is stable and showing no signs of significant erosion or release of sediment beyond design criteria which causes adverse impacts to drainage lines.<br>• Rehabilitation drainage patterns have been established and impacts on natural surface water flows are acceptable at key receptors. | • Failure of W1-SP0 flood channel constructed for closure results in capture of Marillana Creek causing impacts to downstream riparian vegetation[10] | • The design of the flood channels has been informed by geotechnical investigations and hydraulic modelling.<br>• Given the distance of the creek to the flood channel outlet, and the dolerite along the alignment, the risk of creek capture is considered to be low. | • Geotechnical conditions along the eastern part of the W1-SP0 flood channel.<br>• Final design for the W1-SP0 flood channel. | • Further geotechnical investigations and analyses will be conducted for the eastern part of the W1-SP0 flood channel.<br>• Optimisation of W1-SP0 flood channel design based on geotechnical data and additional hydraulic modelling. |

[10] Note the W1-SP3 flood channel is designed to transfer water from W1 Pit to W4 Pit and hence is not considered to be a significant risk to Marillana Creek, and the W4-SP4 flood channel will only transfer water from the pit to Marillana Creek when the pit is full and hence will not present a significant risk of head cutting and creek capture as there will be no hydraulic head between the W4-SP4 flood channel outlet and Marillana Creek.

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| *Flood channels continued* | *Relatively natural environment not inconsistent with pastoral use.* | ES 15 | • There are no unsafe areas where members of the general public could gain inadvertent access and residual risks are consistent with natural hazards in the surrounding area. | • Access to flood channels results in injury or fatality from steep drops or access to fibrous materials | • The energy dissipator for the W1-SP0 has been designed to represent an analogue system and incorporates shallow steps and irregularities which minimises the potential for inadvertent access to steep drops.<br>• Fibrous material exposures in W1-SP0 are expected to pose similar hazards to natural occurrences at Flat Rocks and other places locally, but a 1.5 m cut has been designed at the entrance to the W1-SP0 flood channel to deter access.<br>• W1-SP3 has been designed with stepped energy dissipators (10 m high), but the accessibility of the flood channel from ex-pit areas is limited as it connects the W1 and W4 pits.<br>• The W4-SP4 flood channel has been designed as a sloped system (no steps) but further work is required to consider prevention of inadvertent access to the W4 Pit from the channel. | • Risk from fibrous material exposures in flood channels requires further investigation.<br>• Detailed designs for flood channels. | • A more detailed risk assessment will be conducted for the potential fibrous material exposures in the W1-SP0 flood channel in comparison to natural analogues and review of mitigation options, if required.<br>• Where there is safe access following construction, fibrous materials exposures will be mapped to enable confirmation (or otherwise) that the assumptions used in risk assessments are valid.<br>• Flood channel designs will include consideration of the safety / access control measures required. |
| E1 & E4 Marillana Creek diversions | *Relatively natural environment not inconsistent with pastoral use.* | ES 16 | • The constructed surface is stable and showing no signs of significant erosion or release of sediment beyond design criteria which causes adverse impacts to drainage lines.<br>• A diversity of habitats is established that supports representative flora and fauna species and provides ecological function and connectivity through the system.<br>• Total weed cover to be typical for each site and landform and reflect final land use.<br>• Major creek diversions function similarly to pre-development conditions (hydraulics, sediment transport, geomorphology) and do not exhibit substantial long-term geomorphological change that could destabilise the landform. | • Revegetation of creek diversions with a morphology suitable to revegetation establishment does not meet ecological completion criteria<br>• Failure of E1 or E4 diversions leads to reduction of surface water flows to Marillana Creek resulting in impacts to downstream receptors (riparian vegetation)[11]. | • The morphology of the E1 and E4 creek diversions has been designed to support vegetation, and an engineered aquifer has been provided within the diversions. Monitoring has shown that vegetation is re-establishing, but time is required for it to mature.<br>• Modelling for a climate change scenario indicates that flooding does not enter pits in a 1 in 10,000-year flood event, but velocity increases of up to 1 m/s may be experienced at E1 and E4 diversions. Further study is required to determine whether additional controls may be required. | • The E1 & E4 creek diversions have only been recently conducted, and the vegetation communities have not yet matured.<br>• The need for upgrades to E1 and E4 diversions to accommodate climate change requires further study. | • Monitoring will continue until the vegetation communities mature.<br>• The need for upgrades to E1 and E4 diversions to accommodate a climate change scenario will be investigated. |
| Creek diversions - intermediate (Herberts Creek & W3) & minor | *Relatively natural environment not inconsistent with pastoral use.* | ES 17 | • Constructed landforms are safe and geotechnically stable.<br>• The constructed surface is stable and showing no signs of significant erosion or release of sediment beyond design criteria which causes adverse impacts to drainage lines.<br>• Vegetation is suitable to the geomorphology and function of the surface water structure.<br>• Demonstrated capacity of the site to recover from fire, drought and other disturbances.<br>• DBCA priority list weed species to be managed so as not to cause unacceptable risk to surrounding environments.<br>• Total weed cover to be typical for each site and landform and reflect final land use.<br>• Vegetated areas provide fauna habitat.<br>• Rehabilitation drainage patterns have been established and impacts on natural surface water flows are acceptable at key receptors. | • Failure of existing diversions leads to reduction of surface water flows to Marillana Creek resulting in impacts to downstream receptors (riparian vegetation).<br>• Revegetation of creek diversions with a morphology suitable to revegetation establishment does not meet ecological completion criteria. | • Hydraulic modelling (including climate change scenarios), geomorphological and geotechnical assessments have been used to inform the closure designs for creek diversions.<br>• Upgrades will be made to the intermediate diversions (Herbert's Creek and W3) to accommodate a 1 in 1,000-year event.<br>• The upgrades required for the Herbert's Creek land bridge diversion require further investigation. The W6 floodplain landform has the potential to dissipate flows from Herbert's Creek on to the land bridge and reduce the potential for erosion, however, further assessment of this interaction is required during the upgrade design review.<br>• Current design studies for the W3 diversion indicate that even if the creek is widened to 140 m where tenement and pit edge constraints allow, velocities will remain high at the existing flood bund and where the diversion turns north around the pit. In a climate change scenario, these velocities could increase by up to 1 m/s. Further study is required to identify appropriate design measures.<br>• Upgrades will be made to minor diversions to reduce the potential for scour / erosion and deposition to compromise the function of the diversion in the design event (1 in 100 AEP). Upgrades typically include widening of the diversions, but further investigation of design solutions is required for diversions that intersect potentially erodible materials.<br>• Modelling for a climate change scenario indicates that flooding does not enter pits in a 1 in 10,000-year flood event. | • Final closure designs for intermediate and minor diversions. | • Geotechnical investigation and analysis will be conducted for:<br>- Herbert's Creek land bridge including an analysis of the interaction with the backfill design and proposed W6 floodplain.<br>- W3 closure design.<br>- Minor diversion closure designs.<br>• An assessment will be conducted of the need for a geosynthetic liner across the Herbert's Creek land bridge and the risks associated with tree growth and long-term stability.<br>• Hydraulic modelling and geomorphic assessments will be conducted to:<br>- Inform the upgrade of the Herbert's Creek land bridge for closure.<br>- Manage the interaction of the W6 floodplain landform with the Herbert's Creek land bridge design for closure.<br>- Inform the closure designs for the W3 and minor diversions.<br>• Diversion designs will be optimised including consideration of:<br>- Additional measures to manage erosion and increase capacity at W3, W2, W5 East, C5 diversions.<br>- Manage the risk of lateral channel migration.<br>- The tie in of the W4 diversion with the W4-SP4 flood channel.<br>- The W1 diversion (south of W1) tie-in with W1-SP0.<br>- The configuration of C1/2 diversion as the backfill designs for C6 are progressed.<br>- The potential to achieve more natural looking systems, erosion and deposition processes and establishment of riparian vegetation.<br>• Following cessation of mining, a final check of pit wall stabilities will be conducted, where required. |

[11] The E1 and E4 creek diversions have been constructed, and monitoring has shown that they are performing to design and, therefore, present a very low inherent risk of creek capture.

| Domain | Post-mining land use | ID | Key outcomes | Key closure risks | Controls (treatment) | Key knowledge gaps | Forward work program |
|---|---|---|---|---|---|---|---|
| Infrastructure | *Relatively natural environments for pastoral grazing purposes.* | ES 18 | • There are no unsafe areas where members of the general public could gain inadvertent access. | • Inadvertent access to unsafe areas causes injury or fatality | • Stakeholders including government and BNTAC / Banjima will be consulted on requirements for infrastructure prior to demolition.<br>• Where infrastructure is to be transferred, infrastructure condition will be assessed, and the condition included in stakeholder agreements, along with responsibilities for maintenance.<br>• Unused infrastructure will be demolished and the footprint re-profiled and rehabilitated. | • Stakeholder requirements for infrastructure that would otherwise be demolished / removed. | • Government and stakeholder consultation will be conducted to identify requirements for infrastructure prior to Stage 2 demolition.<br>• Decommissioning and demolition plans will be developed for Stage 2 demolition. |

# Contents

## Appendices

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# Abbreviations

| Abbreviation | Description |
|---|---|
| ABA | Acid Base Accounting |
| ABCC | Acid Buffering Characteristic Curves |
| ACARP | Australian Coal Industry's Research Program |
| ADWG | Australian Drinking Water Guidelines |
| AEP | Annual Exceedance Probability |
| AER | Annual Environmental Report |
| Ag | Silver |
| AGR | Acid Generation Rate |
| AHD | Australian Height Datum |
| Al | Aluminium |
| ALARP | As Low as Reasonably Practicable |
| AMD | Acid and Metalliferous Drainage |
| ANC | Acid Neutralising Capacity |
| ANFO | Ammonium Nitrate Fuel Oil |
| ANZMEC | Australian and New Zealand Minerals and Energy Council |
| ARI | Average Recurrence Interval |
| As | Arsenic |
| AS/NZS ISO | Australian and New Zealand International Standards Organisation |
| B | Boron |
| Ba | Barium |
| BAM Act | *Biosecurity and Agriculture Management Act 2007 (WA)* |
| BC Act | *Biodiversity Conservation Act 2016 (WA)* |
| Be | Beryllium |
| BFA | Batter Face Angle |
| BG | Basal Conglomerate |
| BHPIO | BHP Iron Ore Pty Ltd |
| Bi | Bismuth |
| BIF | Banded Iron Formation |
| BK | Basal Clay |
| BOM | Bureau of Meteorology |
| BNTAC | Banjima Native Title Aboriginal Corporation |
| BTEX | Benzene Toluene Ethylbenzene Xylene |
| Ca | Calcium |
| $CaCO_3$ | Calcium carbonate |
| CAP | Corporate Alignment Planning |
| Cd | Cadmium |
| CEC | Cation Exchange Capacity |
| CEO | Chief Executive Officer |
| CFD | Computational Fluid Dynamics |
| CID | Channel Iron Deposit |
| Cl | Chloride |
| Co | Cobalt |
| Cr | Chromium |
| CRD | Critical Rock Diameter |
| Cs | Caesium |
| CS Act | *Contaminated Sites Act 2003 (WA)* |

| Abbreviation | Description |
|---|---|
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| Cu | Copper |
| d | Day |
| DAA | Department of Aboriginal Affairs (now DPLH) |
| DAMO | Denitrifying Anaerobic Methane Oxidation |
| DBCA | Department of Biodiversity Conservation and Attractions |
| DBH | Diameter at Breast Height |
| DEC | Department of Environment and Conservation (now DWER) |
| DEMIRS | Department of Energy Mines Industry Regulation and Safety |
| DER | Department of Environment Regulation (now DWER) |
| DI | De-ionised |
| DISER | Department of Industry, Science, Energy and Resources |
| DJTSI | Department of Jobs Tourism Science and Innovation |
| DMP | Department of Mines and Petroleum (now DEMIRS) |
| DNRA | Dissimilatory Nitrate Reduction |
| DPaW | Department of Parks and Wildlife (now DBCA) |
| DPIRD | Department of Primary Industries and Regional Development |
| DMIRS | Department of Mines Industry Regulation and Safety (now DEMIRS) |
| DoIR | Department of Industry and Resources (now DEMIRS) |
| DoL | Department of Lands (now DPLH) |
| DoP | Department of Planning (now DPLH) |
| DoW | Department of Water (now DWER) |
| DPLH | Department of Planning Lands and Heritage |
| DPS | Definition Phase Study |
| DWER | Department of Water and Environmental Regulation |
| DSI | Detailed Site Investigation |
| EIA | Environmental Impact Assessment |
| EC | Electrical Conductivity |
| ECEC | Effective Cation Exchange Capacity |
| EK | Eastern Clay |
| EMP | Environmental Management Plan |
| EP Act | *Environmental Protection Act 1986 (WA)* |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* |
| EPS | Environmental Protection Statement |
| EPA | Environmental Protection Authority |
| ERD | Environmental Review Document |
| ESP | Exchangeable Sodium Percentage |
| F | Fluoride |
| Fe | Iron |
| FNU | Formazin Nephelometric Unit (turbidity) |
| FoS | Factor of Safety |
| FY | Financial Year |
| GAI | Geochemical Abundance Indices |
| GARD | Global Acid Rock Drainage |
| GCL | Geosynthetic Clay Liner |
| GDE | Groundwater Dependent Ecosystem |
| GIS | Geographic Information System |
| GL | Gigalitre |
| GTSMR | Generalised Tropical Storm Method |
| ha | Hectare |
| HAC | Heritage Advisory Council |

| Abbreviation | Description |
|---|---|
| $HCO_3$ | Bicarbonate |
| HE | Weeli Wolli Dolerite |
| HFO | Hydrous Ferric Oxides |
| Hg | Mercury |
| HJ | Weeli Wolli BIF |
| IBRA | Interim Biogeographic Regionalisation for Australia |
| ICMM | International Council on Mining and Minerals |
| IDC | Index of Diversion Condition |
| IFD | Intensity Frequency Duration |
| INAP | International Network for Acid Prevention |
| INSAR | Interferometric Synthetic Aperture Radar |
| IPCC | Intergovernmental Panel on Climate Change |
| IPS | Identification Phase Study |
| IQR | Interquartile Range |
| IRA | Inter-Ramp Angle |
| ISA | In-pit Storage Area |
| JV | Joint Venture |
| K | Potassium |
| KL | Kilolitre |
| KNAC | Karlka Nyiyaparli Aboriginal Corporation |
| L | Litre |
| LCID | Lower Channel Iron Deposit |
| Li | Lithium |
| LiDAR | Light Detection and Ranging |
| LOA | Life of Asset |
| LOM | Life of Mine |
| LOR | Limit of Reporting |
| m | Metre |
| mAHD | Metres Above Australian Height Datum |
| mRL | Metre Reduced Level |
| MAR | Mandatory Audit Report |
| MCA | Minerals Council of Australia |
| MCP | Mine Closure Plan |
| MCWRMP | Marillana Creek Water Resource Management Plan |
| Mg | Magnesium |
| mg | Milligrams |
| ML | Mineral Lease or Megalitre |
| Mn | Manganese |
| Mo | Molybdenum |
| MPA | Maximum Potential Acidity |
| MRF | Mining Rehabilitation Fund |
| mRL | Metres Reduced Level |
| MS | Ministerial Statement |
| N | Nitrogen |
| Na | Sodium |
| Ni | Nickel |
| $NO_3$ | Nitrate |
| NAF | Non-Acid Forming |
| NAG | Net Acid Generation |
| NAGR | Net Acid Generation Rate |
| NAPP | Net Acid Production Potential |

| Abbreviation | Description |
|---|---|
| NMD | Neutral Metalliferous Drainage |
| NPR | Neutralisation Potential Ratios |
| NTU | Nephelometric Turbidity Unit |
| OC | Organic Carbon |
| OCR | Oxygen Consumption Rate |
| OEPA | Office of the Environmental Protection Authority |
| OHP | Ore Handling Plant |
| OK | Ochreous Clay |
| ORP | Oxidation-Reduction Potential |
| OSA | Overburden Storage Area |
| P | Phosphorous |
| PAF | Potentially Acid Forming |
| Pb | Lead |
| PEAHR | Project Environmental and Heritage Review |
| PEC | Priority Ecological Community |
| PFAS | Per- and poly-fluoroalkyl substances |
| PGA | Peak Ground Acceleration |
| PMF | Probable Maximum Flood |
| PMP | Probable Maximum Precipitation |
| PSD | Particle Size Distribution |
| PSI | Preliminary Site Investigation Program |
| RAP | Remediation Action Plan |
| Rb | Rubidium |
| RGBI | Red Green Blue Intensity |
| RIWI | *Rights in Water and Irrigation Act 1914 (WA)* |
| RL | Reduced Level |
| ROM | Run-Of-Mine |
| RTIO | Rio Tinto Iron Ore |
| RULSE | Revised Universal Soil Loss Equation |
| S | Sulphur |
| SAP | Sampling and Analysis Plan |
| Sb | Antimony |
| Se | Selenium |
| SGWMP | Surface and Groundwater Management Plan |
| $SiO_2$ | Silicon dioxide |
| Sn | Tin |
| $SO_4$ | Sulphate |
| SMDD | Standard Maximum Dry Density |
| SPL | Species Protection Limit |
| SPS | Selection Phase Study |
| Sr | Strontium |
| SRE | Short Range Endemic |
| SWOT | Strengths Weaknesses Opportunities Threats |
| Ta | Tantalum |
| TBA | To be Advised |
| TDS | Total Dissolved Solids |
| TEC | Threatened Ecological Community |
| Th | Thorium |
| Tl | Thallium |
| TPH | Total Petroleum Hydrocarbons |
| TRH | Total Recoverable Hydrocarbons |

| Abbreviation | Description |
|---|---|
| TSS | Total Suspended Solids |
| U | Uranium |
| UCID | Upper Channel Iron Deposit |
| UCS | Unconfirmed Compressive Strength |
| V | Vanadium |
| VAR | Voluntary Audit Report |
| W | Tungsten |
| WA | Western Australia |
| WABSI | Western Australian Biodiversity Science Institute |
| WAIO | BHP Western Australia Iron Ore |
| WEPP | Water Erosion Prediction Project |
| XRF | X-Ray Fluorescence |
| Yr | Year |
| ZOI | Zone of Instability |
| Zn | Zinc |

# 1 Introduction

BHP Iron Ore[12] operates the Marillana Creek (Yandi) mine which is located approximately 100 kilometres north-west of Newman in the Pilbara Region of Western Australia (Map 1-1). The Yandi operation is situated within Mining Lease 270SA, General Purpose Leases 47/12 to 47/19, Miscellaneous Licences 47/118, 47/667 and 47/771, and Crown Lease K843924. The underlying tenure comprises predominantly pastoral leases with a small area of vacant crown land in the north-western and south-western corners of the Yandi development envelope (refer to Section 2.5 for further information).

Yandi mining operations commenced in 1991. The orebody is a near-surface Channel Iron Deposit (CID) which, for mining purposes, has been sub-divided into a series of mine pit areas; Western (W) 1 to 6, Central (C) 1 to 6[13] and Eastern (E) 1 to 8 (see Section 2 for further information). Approval is currently being sought for the E8 mining area via the *Marillana Creek (Yandi) Life of Mine Proposal Significant Amendment* Environmental Review Document (ERD). Mining at Yandi (including E8) is expected to be complete around 2032, although options are currently under internal consideration for mining remnant ore, and utilising Yandi infrastructure as a regional processing hub for satellite ore bodies beyond cessation of current mining activities.

## 1.1 Purpose of plan

This Mine Closure Plan (MCP) outlines BHP's current closure strategy for Yandi (noting that further engagement with the Banjima people is required, as outlined in Section 1.4), and the technical studies and other knowledge base parameters that have informed the strategy. The MCP is being submitted to the Department of Water and Environmental Regulation (DWER):

- As an update to the 2020 Yandi MCP in accordance with Ministerial Statement (MS) 679 Conditions 5 and 6 (as amended by MS 1039 – refer to Section 3.1 for further details).
- To support the *Marillana Creek (Yandi) Life of Mine Proposal Significant Amendment* ERD.

The MCP facilitates engagement on closure outcomes with the Banjima People, supported by Banjima Native Title Aboriginal Corporation (BNTAC) and its consultants. It describes how the Marillana Creek (Yandi) operation (herein referred to as "Yandi") will be rehabilitated and closed in a manner that addresses:

- Condition 5 of MS 679 (as amended by MS 1039) and the information on progressive rehabilitation required by Condition 6 of MS 679.
- The Department of Energy Mines Industry Resources and Safety (DEMIRS) Statutory Guidelines for Mine Closure Plans (DMIRS, 2020a) and Mine Closure Plan Guidance (DMIRS, 2020b);
- BHP corporate standards and procedures;
- Feedback from regulators (DEMIRS and DWER) on the 2020 MCP (Revision 5); and
- Feedback from the Banjima people.

This MCP will be used by BHP Western Australia Iron Ore (WAIO)[12] and its contractors in the implementation of appropriate rehabilitation and mine closure strategies at the Yandi operation, inclusive of proposed modifications.

The plan will be revised at intervals of three years in accordance with Condition 5 of MS 679 (as amended by MS 1039). This revision timeline is consistent with the DEMIRS guidelines (DMIRS, 2020a; 2020b), and with BHP's strategic approach to closure planning across its Pilbara assets.

This plan describes closure planning activities and outcomes across the life of mine planning horizon, including progressive activities previously completed, near term planned activities, and long-term activities focused on final closure of the operation.

Copies of this plan have been provided to BNTAC (and their technical advisers) and the Banjima people for their review and comment along with in-person briefings.

[12] Several terms have been used to refer to the company in this document:
- BHP refers to the BHP group of companies under parent entities BHP Group Limited and BHP Group Plc
- BHP Western Australia Iron Ore (WAIO) refers to the local Western Australian operation
- BHPIO Iron Ore Pty Ltd (BHPIO) is the legal company name for licences and approvals

[13] Note the C6 pit is named Yandi C2/3 in MS 679 but has been renamed for operational purposes and is referred to as C6 throughout this document.


See Appendix Q for a pdf version of this map

**Map 1-1 Yandi regional location**

## 1.2 MCP scope

The scope of this MCP includes:

- The Yandi iron ore deposits (Western (W) 1 to 6, Central (C) 1 to 6 (refer to footnote 13) and Eastern (E) 1 to 8) and associated Overburden Storage Areas (OSAs) and infrastructure within the development envelope for Yandi (Map 1-2).
- The Yandi village and access road which lie just outside the Yandi development envelope (Map 1-2).
- The airport and associated access road (Map 1-2) which also lie outside the development envelope and are jointly owned by Rio Tinto Iron Ore (RTIO).

Excluded from the scope of this plan are:

- The power line running through the Miscellaneous Licence L47/92 and Mining Area C rail line which runs through L47/95 (Map 1-2). While these traverse the Yandi tenure, they are used to service other operations and will not be closed until these operations cease.
- Infrastructure owned by RTIO on L42/108 and L42/182 (Section 2.5).

## 1.3 Document history

In late 1998, BHP prepared and submitted an initial Decommissioning Plan for the Yandi Mine in accordance with Condition 5 of MS 405 (issued in February 1996 and now superseded by MS 679 and MS 1039). The initial plan addressed closure of the E2, C1, C2 and C5 mine areas and associated infrastructure once these pits were completed.

As part of a Life of the Mine (LOM) planning process, BHP revised the Yandi closure plan in 2004. The revised plan (renamed the Decommissioning and Final Rehabilitation Plan) was prepared as a supporting document to the Yandi LOM Proposal Environmental Protection Statement (EPS) (BHP Billiton Iron Ore, 2005) and provided details on the closure and rehabilitation planning processes applied at the mine. The 2004 Decommissioning and Final Rehabilitation Plan was prepared with a whole-of-lease perspective, rather than on the pit-by-pit basis adopted in the previous plan. The 2004 Decommissioning and Final Rehabilitation Plan was approved by the Department of Environment and Conservation (DEC – now DWER) in 2006.

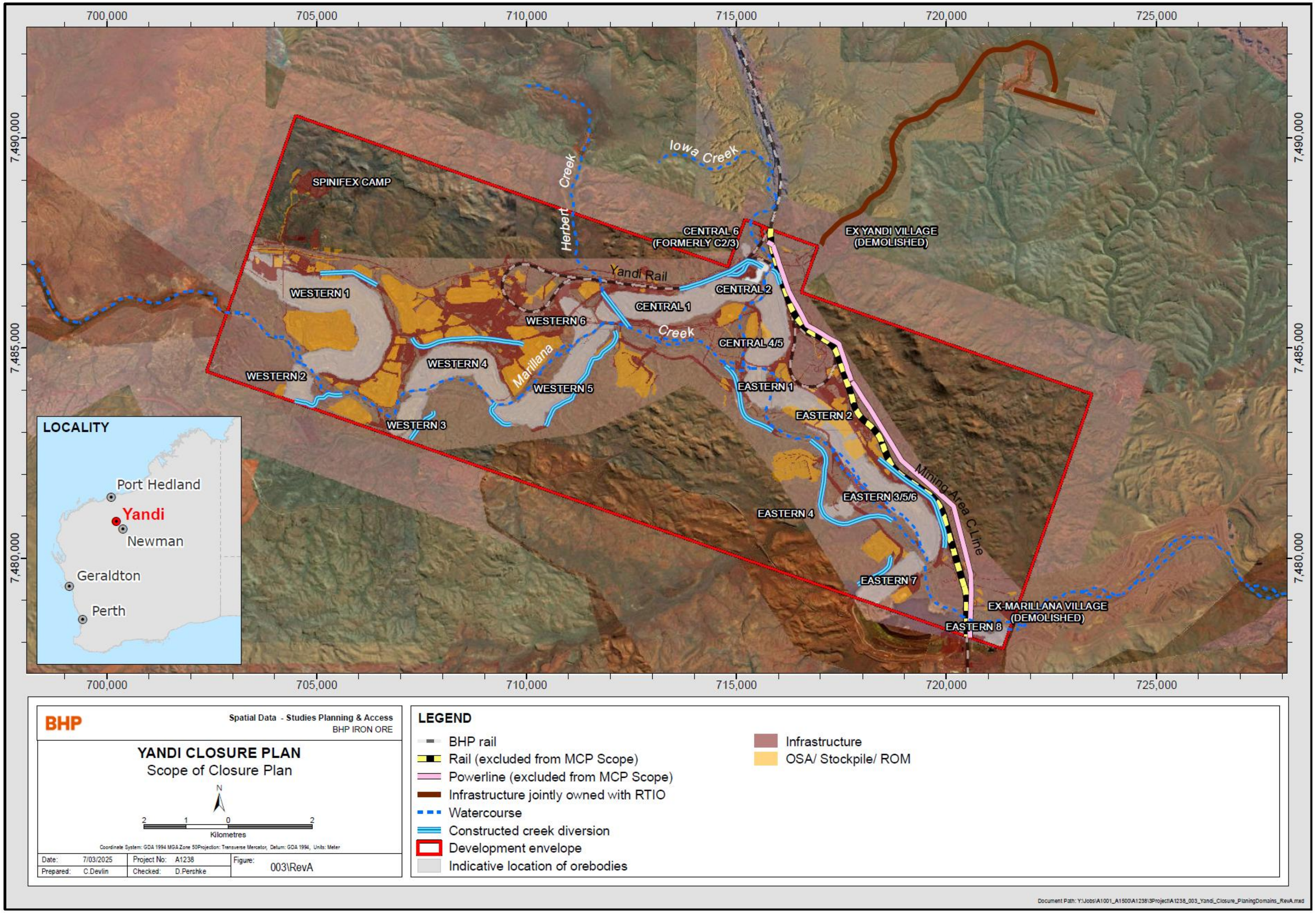
In 2011, the content of the Decommissioning and Final Rehabilitation Plan was updated to reflect changes in environmental management practices that had occurred since the previous revision. The level of detail included in the plan also increased as the plan transitioned from a conceptual plan to a more detailed plan.

Between 2011 and 2016, a review of the overall closure strategy, and in particular the mine void closure designs, was undertaken as a result of:

- An improved understanding of physical system behaviour in the area, particularly regarding the respective influences of surface water and groundwater on ecological functions, and the need to account for activities and approaches proposed by third party operators downstream in the catchment.
- The limited overburden volumes available due to the low ore to overburden strip ratio and mining of the Lower Channel Iron Deposit (LCID).

The revised strategy was presented in the 2016 MCP (Revision 4) and was approved by the Office of the Environmental Protection Authority (OEPA, now DWER) in 2017. Revision 5 (submitted in September 2020) represented a major update to the MCP and further developed the approved 2016 closure strategy. At the time that the 2020 MCP (Revision 5) was being prepared, a Closure Identification Phase (IPS) study was in progress for Yandi (see Section 1.4 for explanation of study phases). While the Yandi Closure IPS had not been completed at the time of the 2020 MCP, several technical studies to support the IPS had been completed and were included in Revision 5 of the plan.

The Yandi closure study has now progressed to a Selection Phase Study (SPS) (refer to Section 1.4). This revision of the plan (Revision 6) incorporates further information from the IPS and some information from the SPS, noting that the SPS is only partially complete.




See Appendix Q for a pdf version of this map

**Map 1-2** **Scope of Yandi MCP**

## 1.4 Closure planning maturity

According to the BHP Global Standard for Capital Projects (BHP, 2023d), an Identification Phase Study IPS forms the first phase of detailed closure execution planning (closure readiness studies) for a mine. The purpose of the IPS is to explore alternatives for closure and select the preferred alternative(s). Once the preferred alternative(s) have been selected, a SPS is conducted which optimises all aspects of the preferred alternative(s). A Definition Phase Study (DPS) follows to advance the development of the project and planning for execution. Execution follows completion of the DPS.

This MCP represents the knowledge base and designs developed through the partial completion of the Yandi closure SPS. The SPS has been put on hold following a request by the Banjima Native Title Aboriginal Corporation (BNTAC) and the Banjima people to halt the progression of the SPS to the DPS until BNTAC and Banjima have:

- Reviewed technical studies to gain a full understanding of the process and rationale for the preferred closure strategy identified by the IPS; and
- Discussed and workshopped post-mining land use(s) and closure outcomes with BHP.

This means that the knowledge base and designs in this MCP are at different levels of maturity depending on the studies available at the time of writing. In addition, several of the SPS studies were executed concurrently so the findings of some studies may not yet have been integrated into the findings of others.

Planning for closure is not a linear process. As the knowledge base matures and assumptions are tested, changes are made to closure designs to respond to new information. These changes may, in turn, require further assessment / modelling iterations to identify potential implications for closure outcomes and other aspects of the closure designs to inform optimisation processes. The Yandi closure study has significantly advanced the knowledge base for closure and refined design options, but there are still knowledge gaps that require further study and assessment as the closure design matures. Of significance, is the ongoing engagement with the Banjima Traditional Owners who have expressed an aversion to permanent saline pit lakes (Section 4).

In addition to the iterations associated with closure planning studies, changes to mine plans, including the extent to which low grade ore will be mined / recovered, also need to be factored into the closure study over time.

Given the variables outlined above, the knowledge base and designs in this MCP represent a snapshot in time and will be updated as consultation with the Banjima people and subsequent design studies progress. These updates will be progressively reported in future updates of the MCP.

## 1.5 BHP business guidance

BHP is committed to environmental stewardship. The BHP Charter is the overarching document that articulates the corporate vision and values and what BHP stands for. The first value in the Company Charter is:

> *Sustainability: putting health and safety first, being environmentally responsible and supporting our communities.*

This commitment provides the starting point from where the mine closure and rehabilitation policy and procedures begin. The remaining values are integrity, respect, performance, simplicity and accountability.

A series of Global Standards (previously *Our Requirements* documents) that underpin the Charter have been developed which describe the performance requirements and accountabilities for definitive business obligations, processes, functions and activities. Compliance with these documents ensures minimum standards are met for all BHP operations.

The Global Standards considered relevant to Mine Closure include:

- **Closure and Legacy Management** – as stewards of the land on which we operate and members of the communities which host us, we have a responsibility to leave a sustainable, positive legacy for host communities, the environment and future land users. In line with Our Purpose and Our Charter, delivering optimised closure outcomes and objectives supports our licence to operate, our commitment to social value and our aspiration to build a better world. BHP's closure management process manages closure risks throughout the entire lifecycle of a site by considering BHP's values, external expectations, safety and costs, while addressing legal obligations and public commitments (BHP, 2023c).
- **Environment and Climate Change Standards** – we acknowledge that the nature of our operations can have adverse or positive environmental impacts, and that climate change can amplify the sensitivities of our natural systems. We identify and assess environment and climate related risks and aim to minimise impacts through every stage of our operations and contribute to resilience of, and positive impact to, the natural environment. We also recognise that our environmental performance and management of our environmental impacts on our host communities is an important part of our contribution to social value (BHP, 2023e; 2023i).
- **Risk Management** – through the delivery of best-in-class risk management, we protect what BHP has today and grow value for tomorrow. The identification and management of risks is central to achieving our strategic objectives. An essential element of effective risk management is to have an enterprise view so that the full risk exposure can be prioritised, and the aggregate impact from cumulative risks can be understood. As such, BHP operates to one Risk Framework for all risks (BHP, 2023f).
- **Corporate Alignment Planning** – the Corporate Alignment Planning (CAP) process is fundamental to creating alignment across the organisation; it guides the development of plans, targets and budgets to help us decide where best to deploy capital and invest resources with the fundamental aim of delivering sector leading operational performance, financial returns and social value. The CAP process has two discrete phases: it starts with directional planning to understand strategic

options and growth plans to maximise the long-term value of our assets; then moves into delivery planning, which focuses on short and medium-term plans to deliver against the agreed strategic objectives. We regularly review our strategy against the constantly changing external environment to capture the risks and opportunities presented and cascade any changes through our planning processes. The intent of the CAP process and deliverables is to facilitate robust discussion, informed decision-making and disciplined delivery of quality planning outcomes (BHP, 2023b).

- **Global Investment Process and Capital Projects** – our investments are governed by a single process which is structured in phases so that appropriate levels of work and associated reviews can be done to support the business case and a decision on whether an investment should progress. These requirements are designed to make sure that investments and capital projects have gone through the appropriate level of study, critical thinking and planning so that they are aligned with BHP's strategy and values, are technically achievable and maximise financial and social value (BHP, 2023d; 2023g).
- **Community and Indigenous Peoples and Social Value and Sustainability Standards** – working openly with the communities in which we operate and with government contributes to economic and social development and social licence to operate (BHP, 2023h; 2023j).

From the Charter and Global Standards flow various business level documents and procedures that provide a framework for the application of the corporate vision and values with respect to mine closure planning and rehabilitation. These include for example:

- Minerals Australia Closure Planning Standard (BHP, 2021b);
- Rehabilitation Standard 0001074 (WAIO, 2023c);
- Closure Provision and Life of Asset Cost Procedure 0005144 (WAIO, 2017a);
- Mined Materials Management Standard (BHP, 2021a);
- Acid and Metalliferous Drainage Management Standard 0096370 (WAIO, 2022a);
- Biodiversity Strategy 0120098 (WAIO, 2018);
- Environment and Climate Change Management Procedure (WAIO, 2019);
- Mines Closure Design Guidance Technical Process Instruction (WAIO, 2022f); and
- Water Management (WAIO, 2022g).

It should be noted that the procedures and standards referenced in this document are periodically updated and where there is a difference between the procedure referenced in this plan and the controlled version in BHP's document system, the version in the document system takes precedence.

## 1.6 Navigating this document

The pdf of this document has been saved with bookmarks that can be used to quickly navigate between sections and appendices (Figure 1-1). To access these bookmarks, the navigation pane will need to be opened. The location of this pane is dependent on the browser used but typically can be identified from a bookmark icon similar to that shown circled in red in Figure 1-1.

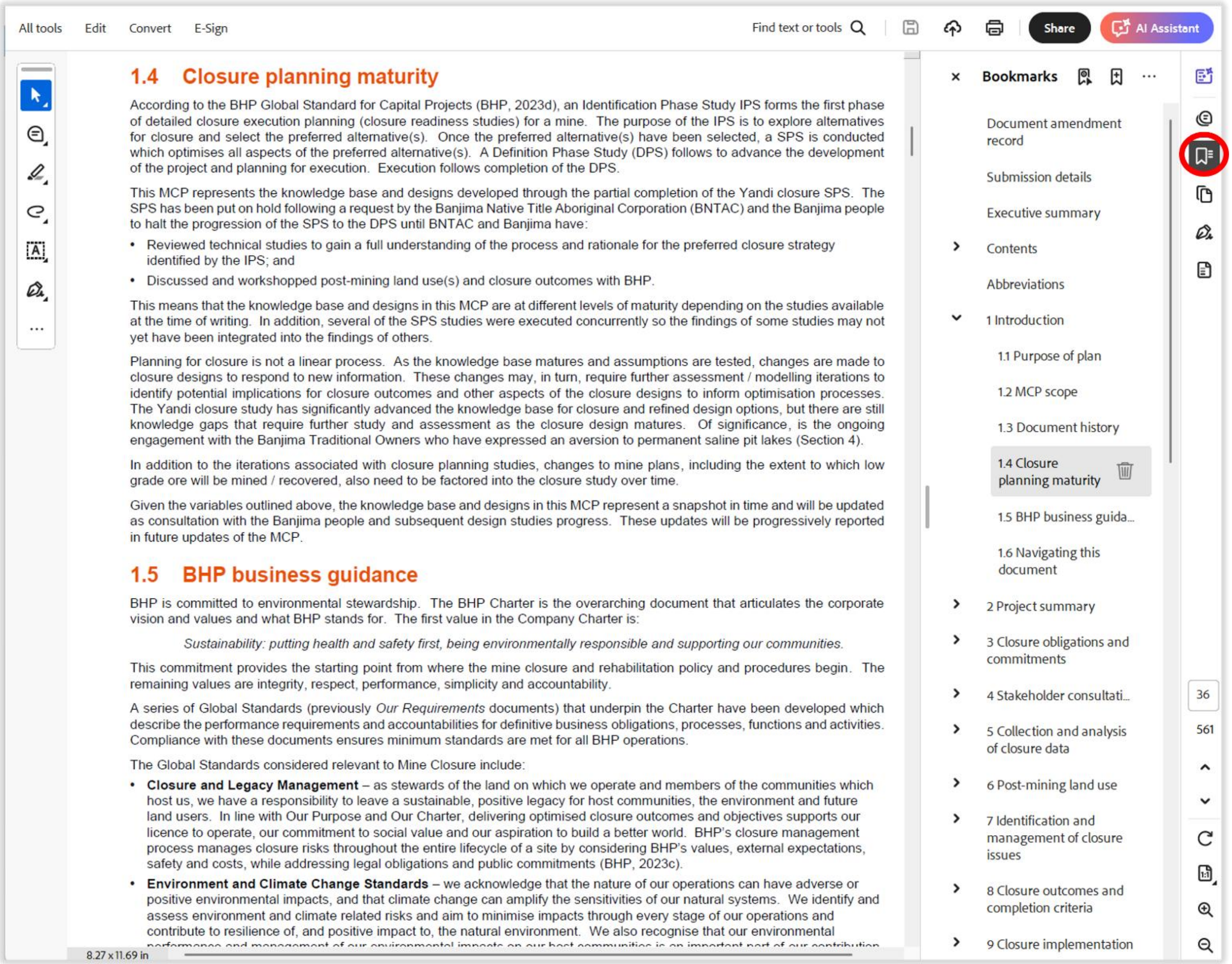



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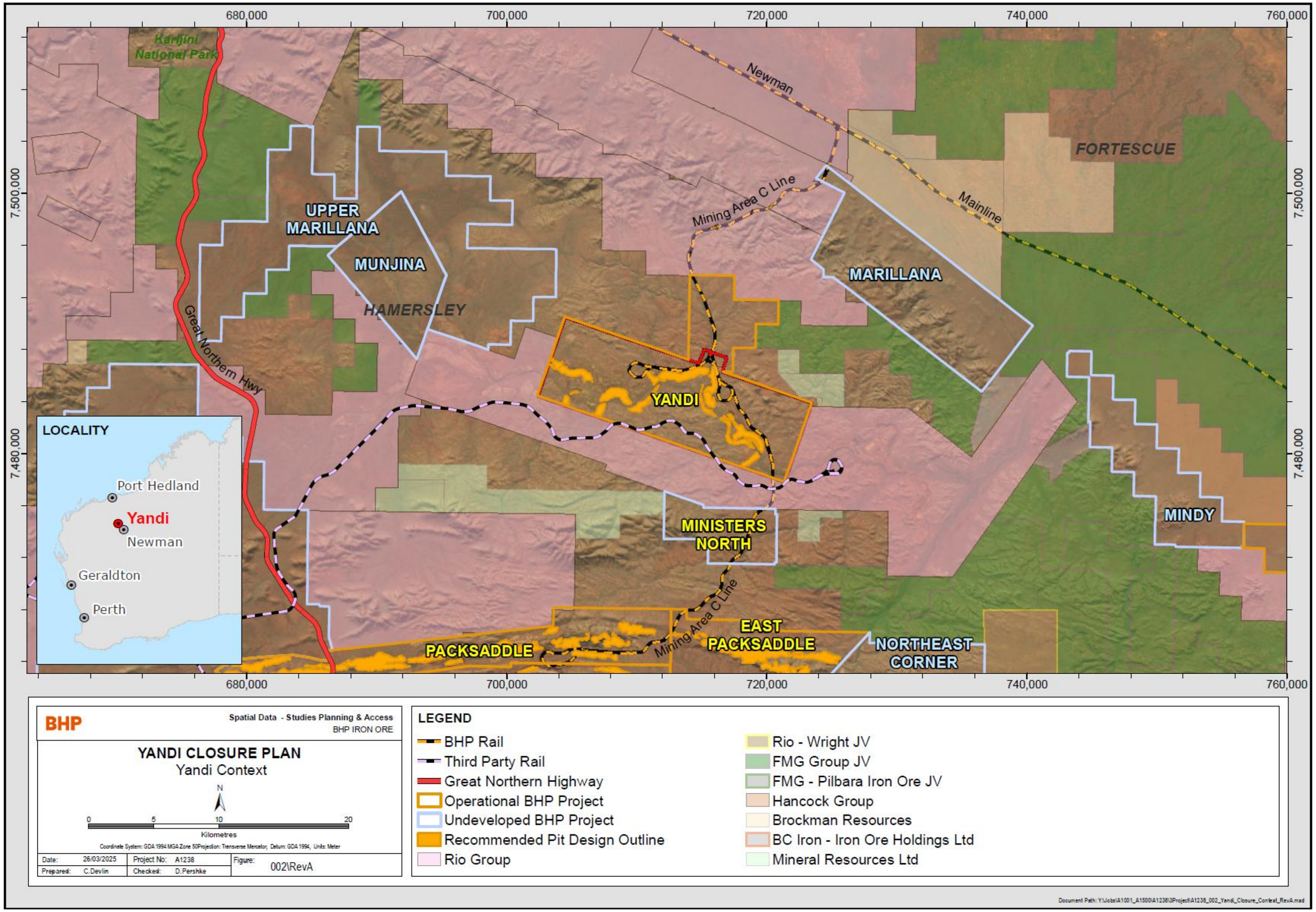
**Figure 1-1 Snapshot showing pdf browser navigation pane with bookmarks**

# 2 Project summary

## 2.1 Context for Yandi mine

A key consideration in planning for the closure of the Yandi mine is the potential influence of other mining areas on the closure outcomes. In particular, RTIO's neighbouring Yandicoogina mine, which lies to the east and immediately downstream of BHP's Yandi mine, influences pit lake and groundwater outcomes, as the mine is extracting ore from the same CID aquifer as the Yandi mine (Map 2-1). A key principle in selecting closure alternative(s) for the Yandi mine to date has, therefore, been to select alternatives where the closure outcomes will be least affected by neighbouring operations over which BHP has no control. However, BHP and RTIO have recognised the interdependencies between the two mines and have a closure / water data sharing agreement to facilitate closure planning to optimise regional outcomes.

The Yandi mine is being considered as a hub for processing ore from adjacent BHP satellite mines which, if approved, will extend the use of the processing and associated infrastructure for decades beyond the life of mining at Yandi. One near term option being considered is the transport of ore from Ministers North (potential new mining area) to Yandi for processing at Yandi Ore Handling Plant (OHP) 3 which would require partial backfill of W5 Pit to provide a land bridge to support transport infrastructure. While approval for the satellite mining areas (including Ministers North) has not yet been sought, the mine closure options and demolition / rehabilitation timing for Yandi have been developed so that they do not preclude the use of infrastructure by these developments in the future.




See Appendix Q for a pdf version of this map

**Map 2-1** **Yandi context**

## 2.2 Overview of operations

Mining at Yandi is conducted by conventional open-cut mining methods, including drill and blast, load and haul and processing through Ore Handling Plants (OHPs). Ore is blended into stockpiles and railed to BHP's shipping facilities at Port Hedland for export. BHP plans to use the same open cut mining techniques, ore processing methods, and predominantly the same supporting mine infrastructure over the remaining life of the Yandi mine.

The development and concurrent mining of several pits within the Yandi orebody is necessary to allow for blending of the ore at a rate that enables BHP to meet production and ore quality commitments. As individual pits are mined out, the voids are partially infilled with overburden materials from other pits within the lease.

A key characteristic of the proposal approved under MS 679 was diversion of sections of Marillana Creek in order to maximise resource use in the W5 mine area and the E1 to E6 mine areas. Two of these diversions have been constructed (E1 and E4). In addition to the diversions of Marillana Creek, there are diversions of intermediate and minor creeks that have been constructed for operational purposes and will need to be upgraded for closure.

The main components of the Yandi mining operation are as follows:

- Open cut mining of overburden and ore from the CID;
- Dewatering of the orebody during mining operations;
- Placement of overburden in mined-out voids and out of pit Overburden Storage Areas (OSAs);
- Processing, loading and rail transportation of ore;
- Supply and distribution of power and raw water to meet operational demands; and
- Service infrastructure (e.g., access roads, workshops, administration areas, accommodation village, airstrip).

## 2.3 Yandi layout and key features

Map 2-2 shows the areas of disturbance to date by Mining Rehabilitation Fund (MRF) category, and Map 2-3 the area of predicted disturbance at the end of operations by closure domain. The key features of the operation comprise:

- Mine voids. A number of the orebodies have been mined to form contiguous pits. At the end of mining, there will be fourteen individual pits defined as:
  - Western pits W1, W2, W3, W4, W5, W6.
  - Central pits C1/2, C4/5, C6.
  - Eastern pits E1, E2/3/4/5/6, E4, E7 and E8 (should approval for E8 be granted).
- OSAs, stockpiles and Run of Mine (ROM) pads including topsoil stockpiles and two OSAs that have been completely rehabilitated; C1 and E2.
- In-pit Storage Areas (ISAs) where overburden has been placed into pits at W1, W5, C1/2, C4/5, E1 and E2/3/4/5/6.
- Surface water management infrastructure which includes the Lamb Creek diversion, Herbert's Creek land bridge, Marillana Creek E1 and E4 diversions, and several other minor operational diversions and flood bunds.
- Yandi Joint Venture (JV) owned infrastructure which includes:
  - Three OHPs.
  - Workshops and fuel storage areas.
  - Non process infrastructure such as administration buildings, power generation, water and wastewater treatment and storage.
  - Two rail loops.
  - Spinifex camp and associated potable water bores. Yandi camp has been recently demolished, but the footprint has yet to be rehabilitated.
- Two landfill sites; Central and Western.
- Transport and service corridors including roads, haul roads, tracks and pipeline / powerline corridors.
- Laydown areas.
- Infrastructure jointly owned with RTIO which comprises Yandi airport and road. It should be noted that while the Yandi JV holds the tenure for the Yandi airport and road to the airport (see Section 2.5), the infrastructure is 50% owned by RTIO. The timing for the closure of this infrastructure will, therefore, be subject to the needs of both parties.

The area of disturbance occupied by existing and proposed mine features is summarised in Table 2-1.

**Table 2-1 Yandi mine features and areas of disturbance**

| Domain | MRF[14] Description | MRF Category | Current Footprint (ha)[1] | Indicative Future Footprint (ha) | Area Rehabilitated (ha) |
|---|---|---|---|---|---|
| OSAs / ROM pad / stockpiles | Overburden stockpile (Class 1) | A | 129.66 | Ex-pit OSAs remaining post-closure ~ 116 ha<br>Footprints of landforms relocated to pits as backfill ~958 ha | 15.85 |
| | Overburden stockpile (Class 2) | B | 462.87 | | 214.65 |
| | Low-grade ore stockpile (Class 1) | B | 79.06 | | - |
| | Low-grade ore stockpile (Class 2) | C | 156.91 | | - |
| | ROM pad | C | 165.04 | | - |
| | Topsoil stockpile | E | 80.17 | | - |
| Mine voids | Voids (≥5 m deep) above water table | C | 153.69 | Void with no backfill ~357 ha<br>Void with backfill ~ 1,676 ha[3] | - |
| | Voids (≥5 m deep) below water table | B | 1,594.36 | | - |
| Infrastructure | Plant site | B | 71.07 | Infrastructure footprint ~1,117 ha[4] | 4.79 |
| | Processing equipment or stockpile associated with basic raw material extraction | C | 2.99 | | - |
| | Workshop | B | 15.05 | | - |
| | Fuel storage facility | B | 6.6 | | - |
| | Evaporation pond | A | 2.04 | | - |
| | Dam fresh water | B | 7.67 | | - |
| | Sewage pond | C | 12.77 | | - |
| | Building (other than workshop) or camp site | C | 63.21 | | 12.11 |
| | Laydown or hardstand area | C | 67.37 | | - |
| | Landfill site | B | 11.18 | | - |
| | Other | C | 105.04 | | - |
| | Transport or infrastructure corridor | C | 837.97 | | 33.34 |
| | Borrow pit (<5 m deep) | C | 36.16 | | - |
| | Borefield | C | 1.73 | | - |
| RTIO / BHP owned infrastructure | Airstrip and access road[2] | C | 77 | 77[5] | |
| Surface water infrastructure | Diversion drain or channel | B | 335.18 | 451[6] | 54.25 |
| **Total disturbance** | | | **4,474.79** | **4,752** | |
| **Total rehabilitated land** | | | | | 334.99 |

Notes: 1. Disturbance and rehabilitation data reported for FY24 in the 2024 Annual Environmental Report (AER) excluding exploration clearing which is regulated separately

2. Infrastructure owned jointly with RTIO and reported separately to the data in the 2024 AER

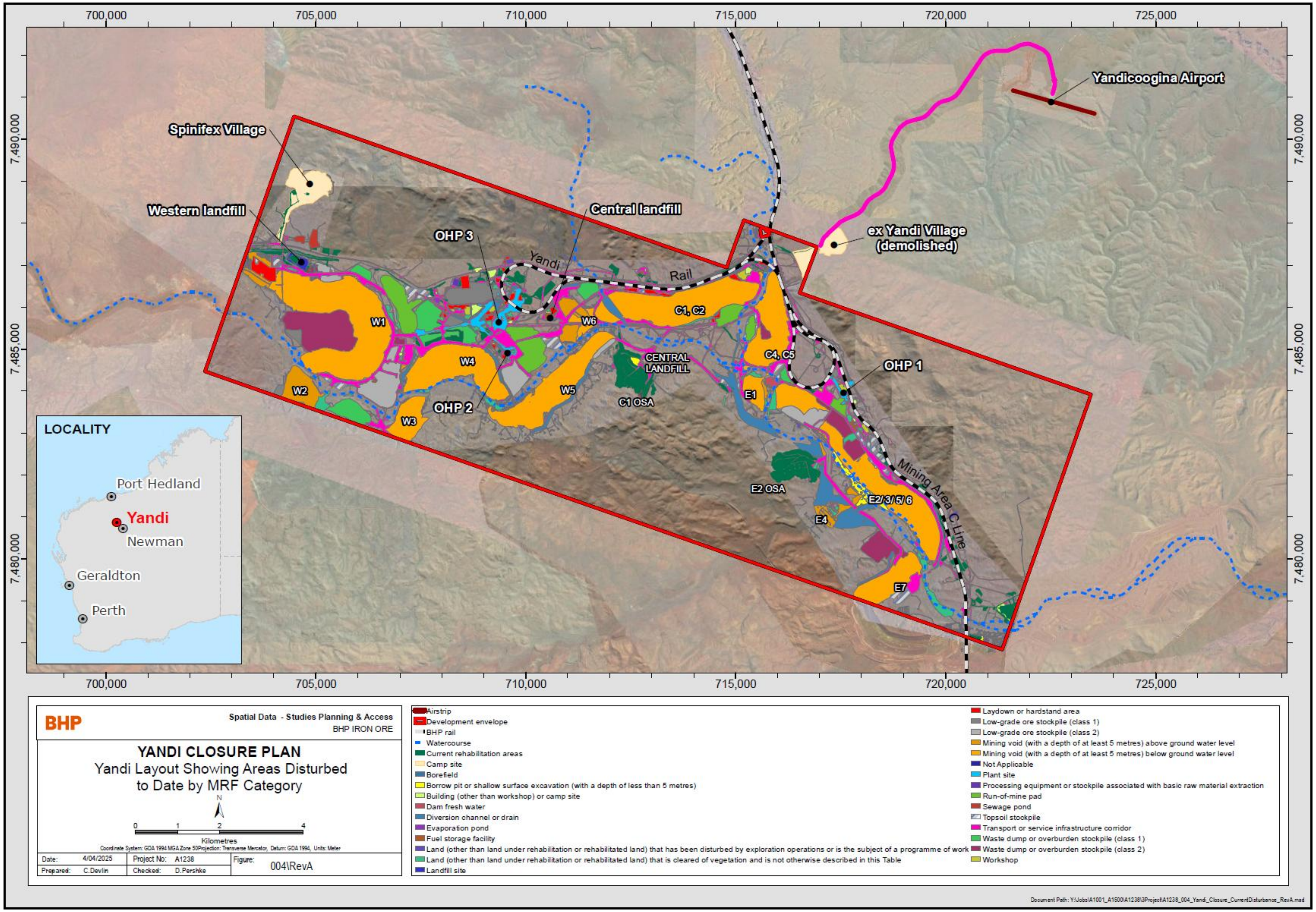
3 Includes floodplain landforms

4 Note some areas currently classified as infrastructure will be reclassified as the mine develops / progresses towards closure e.g. as new surface water infrastructure is developed

5 Note the infrastructure jointly owned by RTIO / BHP falls outside the Yandi development envelope and clearing has been approved separately to MS 679

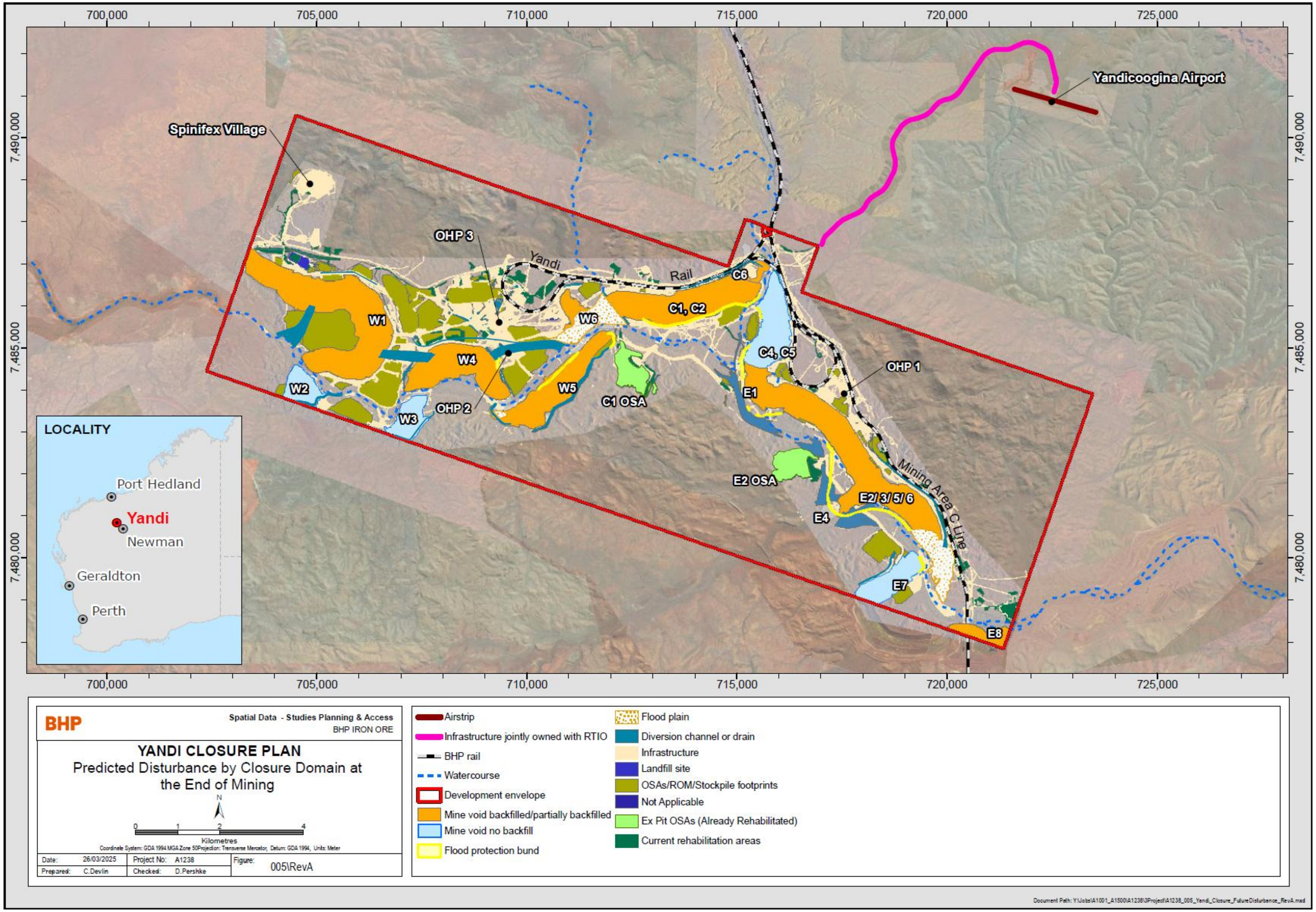
6 Note a separate approval will be sought for additional clearing required for closure designs prior to execution

14 Mining Rehabilitation Fund




See Appendix Q for a pdf version of this map

**Map 2-2 Yandi layout showing areas disturbed to date by MRF category**




See Appendix Q for a pdf version of this map

**Map 2-3 Predicted disturbance by closure domain at the end of mining**

## 2.4 Closure features and domains

To facilitate effective mine closure planning, the features outlined in Table 2-1 have been divided into several physically distinct domains that have similar revegetation requirements. These domains are further sub-divided into domains that have separate closure planning requirements. The OSAs / ROM / stockpile sub-domain has been further divided into two feature types; rehabilitated OSAs (C1 and E2) and other OSAs / ROM / stockpiles. This is because all features except for C1 and E2 OSAs will be relocated to the pits as backfill during closure. Similarly, the infrastructure features have been categorised separately as they have slightly different closure requirements.

Following closure, surface water management infrastructure (flood channels[15], diversions and flood bunds) will be necessary to maintain surface water flows in Marillana Creek and minimise the potential for permanent diversion of creeks to the pits (creek capture). Once closure has commenced, it is proposed that flood channels be cut between Marillana Creek and the mine voids to allow some floodwater to pass safely and in a controlled manner into pits to protect downstream diversions and flood bunds from erosion and minimise the risk of unplanned creek capture by mine voids. This infrastructure forms a separate domain (Table 2-2, Map 2-3).

As discussed in Section 2.3, the airport and road to the airport are jointly owned by the Yandi JV and RTIO. Since the timing for the closure of this infrastructure is independent of the closure timeframe for Yandi, it has been allocated to a separate domain (Table 2-2, Map 2-3).

**Table 2-2 Domains and features of the operations**

| Domain | Sub-domain type | Feature |
|---|---|---|
| Mine Voids | Mine Void | W1, W2, W3, W4, W5, W6, C1/2, C4/5, C6, E1-6, E7, E8 (proposed) |
| Ex-pit areas | OSAs / ROM / stockpiles | Rehabilitated OSAs C1 and E2. |
| | | Other OSAs and associated stockpiles and ROM pads. |
| | Infrastructure | Roads, laydown areas and service corridors. |
| | | Rail lines. |
| | | OHP 1, OHP 2 and OHP 3, workshops, non-process infrastructure, fuel storage facilities and camps. |
| | | Western and Central landfills. |
| Surface water infrastructure | Surface water infrastructure | Flood channels, flood bunds, Marillana Creek diversions (E1 and E4), Herbert's Creek land bridge and W3, C1/2, C5, E3/5/6, E7, W2 and W5 diversions. |
| Infrastructure jointly owned with RTIO | Infrastructure roads and rail | Airport and road to the airport. |

Yandi mining operations (including E8) are currently planned to be completed around 2032, with options currently under internal consideration for mining remnant ore and utilising Yandi infrastructure beyond 2032 as a regional ore processing hub.

## 2.5 Tenure and ownership

The Yandi development envelope is situated on the tenure outlined in Table 2-3 and shown on Map 2-4.

BHP Iron Ore is the manager for the Yandi Joint Venture, which owns the Yandi operation. The Joint Venture partners for Yandi are:

- BHP Minerals Pty Ltd - 85%;
- Itochu Minerals and Energy of Australia Pty Ltd - 8%; and
- Mitsui Iron Ore Corporation Pty Ltd - 7%.

[15] Previously referred to as spillways in the 2020 MCP.

**Table 2-3 Yandi tenure**

| Lease | Description | Grant date | Expiry date | Purpose | Legislation Under Which Tenure Granted |
|---|---|---|---|---|---|
| M270SA | Mining Lease 270SA | 04/09/1991 | 03/09/2033 | Mining & exploration and ancillary activities | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* & *Mining Act 1978 (WA)* |
| G47/12 to G47/19 | General Purpose Leases 47/12 to 47/19 | 08/05/1991 | 07/05/2033 | Accommodation village and supporting infrastructure | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* & *Mining Act 1978 (WA)* |
| L47/118 | Miscellaneous Licence 47/118 | 20/02/2002 | 19/02/2044 | Aerodrome and road | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* & *Mining Act 1978 (WA)* |
| L47/667 | Miscellaneous Licence 47/667 | 17/11/2017 | 16/11/2038 | Bore, communications facility, powerline, road, taking water | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* |
| L47/771 | Miscellaneous Licence 47/771 | 29/05/2017 | 28/05/2038 | Bore, borefield, pipeline, power line, pump station, road, search for groundwater, water management facilities and taking water | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* |
| K843924 | Crown Lease K843924 | 01/07/2007 | 03/09/2033 | Railway spur line, access roads and ancillary activities | *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* & *Land Administration Act 1997 (WA)* |

The tenure of the land underlying the Yandi leases comprises (Map 2-4):

- Vacant crown land in the north-western and south-eastern corners of the Yandi development envelope.
- Marillana pastoral lease (owned by BHP and subleased to the Karlka Nyiyaparli Aboriginal Corporation [KNAC]) in the eastern portion of the development envelope.
- Juna Downs pastoral lease (owned by a subsidiary of the Rio Tinto Group) in the western portion of the development envelope.

The mine operates on the lands of the Banjima People [Determination No. WCD2014/001], with their connection to the land stretching back over 40,000 years (see Section 3.3.3 for further details).

The contact details for BHP Iron Ore are:

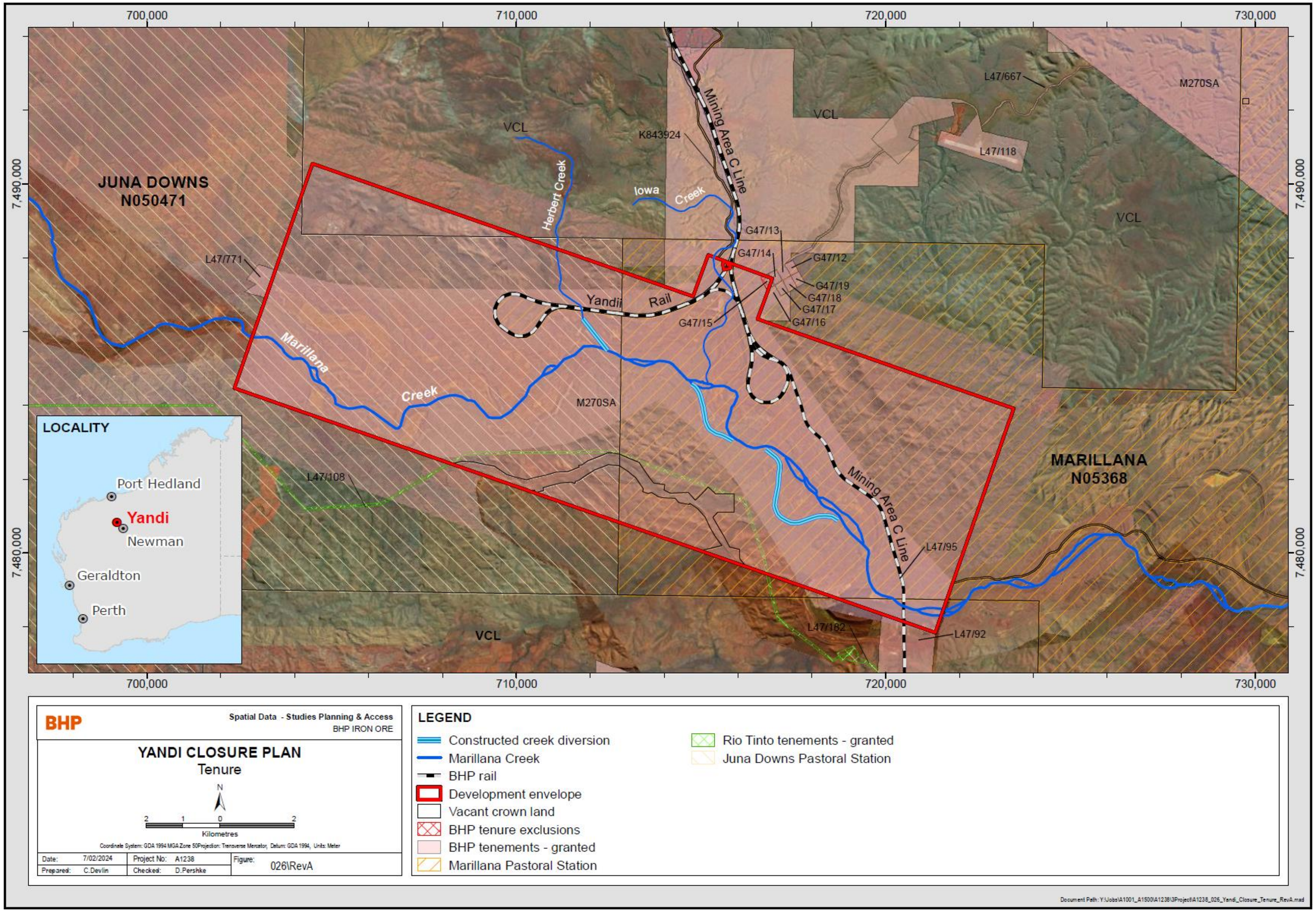
BHP Iron Ore Pty Ltd

City Square

125 St Georges Terrace

PERTH WA 6000

Phone: 08 6321 6000




See Appendix Q for a pdf version of this map

**Map 2-4 Yandi tenure overview**

# 3 Closure obligations and commitments

The management measures contained within this MCP have been developed with reference to State Government rehabilitation requirements, policies and guidance statements, which are summarised below.

## 3.1 Environmental Protection Act 1986 (Part IV) Approvals

Part IV of the *Environmental Protection Act, 1986* (EP Act) establishes provisions for the Environmental Protection Authority (EPA) to carry out formal environmental impact assessments of proposals which may have a significant impact on the environment and the setting of statutory conditions by the Minister for the Environment.

A summary of the history of Part IV approvals at Yandi is as follows:

- Mining at Yandi from the E2 Pit, with an initial installed capacity of 5 Mtpa, was first approved by the Minister for the Environment in May 1988. Mining commenced under this approval in 1991, with the first ore railed in January 1992. Subsequent incremental expansions of installed capacity were approved in May 1992 (10 Mtpa) and April 1994 (15 Mtpa).
- An additional proposal was approved in February 1996 to develop the Yandi C1/2 deposit at an initial installed capacity of 5 Mtpa, to be expanded to 15 Mtpa as ore demand increased.
- In September 1999, approval to develop Yandi C5 at an installed capacity of 12.5 Mtpa was granted.
- In June 2004, the Minister for the Environment granted approval to develop the C4 and W4 orebodies. In July 2004, the Minister for State Development also granted approval for the proposal under the Marillana State Agreement (Section 3.3.1). The approvals included a minor increase in installed capacity from 40 Mtpa to 45 Mtpa.
- In April 2005, BHP Iron Ore submitted a proposal for the conceptual Life of Mine for the Marillana Creek (Yandi) operation. A key characteristic of the proposal was permanent diversion of Marillana Creek to maximise resource use in the W5 mine area and the E1 to E6 mine area. The EPA's assessment and recommendations were issued in Bulletin 1166 (April 2005). MS 679 was subsequently issued by the Minister for the Environment on 6 July 2005. The conditions of this statement superseded those of Statements 029, 259, 357 and 405 that were previously relevant to Yandi.
- Subsequent increases in installed capacity were approved in December 2007 (from 45 Mtpa to 65 Mtpa) and September 2008 (from 65 Mtpa to 87 Mtpa), with approval to mine the W1 orebody also granted in June 2008.
- Substantial infrastructure projects were undertaken following the mining approval amendment in 2008. These were associated with the Rapid Growth Project 5 (RGP5) and included the construction of OHP 3 and the Spinifex Camp. These projects were completed in August 2011.
- In September 2013, BHP Iron Ore submitted a proposal to increase the mining disturbance area from 3,450 ha to 4,050 ha and increase the water usage from 10,200 $m^3$ per day to an annualised figure of 10 GL/year. Approval of the changes (including removal of water usage from the key characteristics table) was granted by the EPA in December 2013 under section 45C of the EP Act.
- In May 2016, approval under Section 45C of the EP Act was granted to increase the "total area disturbed" for vegetation clearing at Yandi from 4,050 ha to 4,558 ha. The request also amalgamated the 'mining disturbance area' and 'infrastructure disturbance area' into one consolidated category. Changes to disturbance areas are summarised as follows:
  - Increase the disturbance area for mining and infrastructure from a combined total of 3,802 ha to 4,147 ha (representing an additional 345 ha); and
  - Replace the 230 ha allocation associated with 'diverting Marillana Creek' with 393 ha to correctly represent the actual spatial area of the 'Conceptual Creek Diversion'.
- Most recently, in 2016, an amendment of MS 679 was approved under Section 46 of the EP Act to update the Closure Condition requirement to achieve consistency with contemporary approval conditions. The revised conditions are detailed in Section 3.1.1. As a result of this amendment, a new Ministerial Statement (1039) was issued that replaces the relevant mine closure conditions in MS 679.

Closure-relevant statements made in submissions to government are recorded in Appendix A.2 along with a summary of how the statements are addressed in this MCP.

### 3.1.1 Ministerial Statement Conditions

Closure conditions and commitments for the Yandi mine from MS 679 (as amended by MS 1039) are detailed in (Table 3-1).

Condition 5 relates to the development and implementation of a MCP that conforms to the Guidelines for Preparing Mine Closure Plans (DMIRS, 2020a). This plan conforms to those guidelines.

Condition 6 requires the preparation of a Progressive Rehabilitation Management Plan. This plan has been designed to address this requirement. Appendix A.1provides a summary of where each requirement of Condition 6 is addressed in this plan.

Condition 7 relates to the preparation of a Marillana Creek Diversion Management Plan. This MCP is not intended to replace the Marillana Creek Diversion Management Plan, rather it includes a summary of information on the Marillana Creek Diversion which is relevant to closure and completion criteria.

Condition 9 specifies pit lake salinity requirements. A substantial amount of work has been undertaken since the 2016 closure plan to investigate mine void closure strategies to optimise closure outcomes. Further work (as outlined in the forward work program – Section 13.3) and additional consultation with stakeholders is required to inform the preferred closure strategy. This plan summarises the current state of knowledge regarding mine void closure. Following additional technical studies and stakeholder consultation, Condition 9 of MS679 will be reviewed and BHP may seek an update to align with the mine void closure strategy developed in response to this information.

**Table 3-1 Ministerial conditions related to closure and rehabilitation**

| Applicable MS | Condition No. | Closure Condition |
|---|---|---|
| **Conditions relating to closure planning and rehabilitation** | | |
| 1039 (replaces Condition 5 of MS679) | 5-1 | The proponent shall ensure that the proposal is decommissioned and rehabilitated in an ecologically sustainable manner, through the implementation of the Mine Closure Plan referred to in condition 5-2. |
| | 5-2 | The proponent shall implement the Mine Closure Plan (Revision No. 3, November 2011). |
| | 5-3 | The proponent shall review and revise the Mine Closure Plan referred to in condition 5-2, on the advice of the Department of Mines and Petroleum [now DEMIRS] and to the satisfaction of the CEO, in accordance with the Guidelines for Preparing Mine Closure Plans, May 2015 and any updates, at intervals not exceeding three years from the issue of this Statement, or as otherwise agreed in writing by the CEO. |
| | 5-4 | The proponent shall implement the latest revision of the Mine Closure Plan, which the CEO has confirmed by notice in writing, satisfies the requirements of condition 5-1. |
| 679 | 6-1 | Within 12 months following the formal authority issued to the decision-making authorities under section 45(7) of the *Environmental Protection Act 1986*, the proponent shall prepare a Progressive Rehabilitation Management Plan to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority and the Department of Conservation and Land Management.<br>The objectives of this Plan are to:<br>• establish rehabilitation completion criteria;<br>• carry out successful rehabilitation works; and<br>• establish a monitoring programme to demonstrate whether the criteria are being achieved.<br>This Plan shall include:<br>1. Progressive rehabilitation works (i.e. new areas) and rehabilitation management activities (i.e. maintenance of existing areas);<br>2. A description of how the planned works and activities have been developed with consideration and incorporation (where practicable, and having regard for site conditions) of:<br>- the characteristics of the pre-mining ecosystems within the mining leases (through research and / or baseline surveys);<br>- the performance of previously rehabilitated areas within the mining lease;<br>- the performance of rehabilitation areas at the proponent's other operations in the Pilbara; and<br>- best practice rehabilitation techniques used elsewhere in the mining industry.<br>3. A description of the process and timing for developing rehabilitation performance objectives, parameters and completion criteria;<br>4. Rehabilitation performance objectives, parameters and completion criteria once they have been developed;<br>5. Rehabilitation monitoring (i.e. Ecosystem Function Analysis or an equivalent long-term systems-based monitoring programme) which will be used to assess the performance of all rehabilitated areas against the completion criteria; and<br>6. Reporting of rehabilitation and monitoring results. |
| | 6-2 | The proponent shall implement the Progressive Rehabilitation Management Plan required by condition 6-1. |
| | 6-3 | The proponent shall review and revise the Progressive Rehabilitation Management Plan required by condition 6-1 at intervals not exceeding five years. |
| | 6-4 | The proponent shall make the Progressive Rehabilitation Management Plan required by condition 6-1 publicly available. |

| Applicable MS | Condition No. | Closure Condition |
|---|---|---|
| **Marillana Creek Diversion** | | |
| 1039 (replaces Condition 7 of MS679) | 7-1 | At least six (6) months prior to diversion construction of any section of Marillana Creek, the proponent shall prepare a Marillana Creek Diversion Management Plan to the requirements of the CEO on advice of the Department of Parks and Wildlife [now DBCA] and the Department of Mines and Petroleum [now DEMIRS].<br>The objective of this Plan is to ensure that diverted sections of Marillana Creek function as a fluvial system in a similar manner to the existing creek system.<br>The plan shall include:<br>1. design details and specifications of the planned diversion(s), associated diversion cut-off levee(s) and high flow by-pass spill-out channel(s);<br>2. design details for creating appropriate transitional gradients to minimise the potential for scouring at the confluence of tributaries and the creek diversion;<br>3. design options for the section of Marillana Creek to be diverted. Independent technical peer review will be required:<br>- to compare the various design options;<br>- to ensure that the option selected is the most suitable and practicable, consistent with current best practice; and<br>- to ensure that at each diversion there is continuous improvement, based on adaptive management and benchmarking against similar projects in Australia and internationally;<br>5. baseline information on water flow, water quality, geomorphology, fauna, vegetation and flora on the section of Marillana Creek to be diverted;<br>6. revegetation for the diversion channel using suitable riparian species and alluvial sediment sourced from the diverted section of Marillana Creek;<br>7. management of Aboriginal heritage matters within the planned disturbance area and vicinity of the planned diversion;<br>8. weed management within the planned disturbance area and vicinity of the planned diversion;<br>9. performance criteria for water flow, water quality, ecology and geomorphology for the creek diversion;<br>10. monitoring of water flow, water quality, vegetation, flora, fauna and ecological and geomorphologic integrity of the creek diversion and downstream of the creek diversion during operations and post-closure;<br>11. inspection and maintenance of the creek diversion and revegetation works during operations and until the objective is met;<br>12. findings of hydrological and hydraulic modelling, groundwater modelling, research programmes, and monitoring results to show whether the planned diversion satisfies the objectives of the Mine Closure Plan referred to in condition 5-2;<br>13. water quality management of Marillana Creek which is consistent with the *State Water Quality Management Strategy, 2000* or the approved equivalent; and |
| | 7-2 | The proponent shall implement the Marillana Creek Diversion Management Plan required by condition 7-1, employing the most suitable design option referred to in 7-1 (3). |
| **Conditions relating to pit lake salinity** | | |
| 679 | 9-1 | At all times up to the relinquishment of the leases by the proponent, the proponent shall not cause or allow the Total Dissolved Solids concentration in any pit lake to exceed the "critical" level of 8,000 milligrams per litre on one or more occasion in each of three consecutive years. |
| | 9-2 | In the event that groundwater monitoring shows the concentration of Total Dissolved Solids to be in excess of the "target" level of 6,500 milligrams per litre on one or more occasion in each of two consecutive years, the proponent shall prepare a Pit Lake Salinity Contingency Plan which incorporates corrective management measures including the time to be taken, to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.<br>The objectives of this Plan are to:<br>• reduce the Total Dissolved Solids concentration in the pit lake to below the "target" level; and<br>• maintain this reduced level for at least three years thereafter.<br>The abovementioned management measures shall be one or more of the following:<br>1. backfilling of the pit lake to above the water table;<br>2. diversion of surface water flow into the pit lake; or<br>3. any other appropriate remedial measures. |
| | 9-3 | In the event that groundwater monitoring shows the concentration of Total Dissolved Solids to be in excess of the "target" level of 6,500 milligrams per litre on one or more occasion in the next year following the two consecutive years referred to in condition 9- 2, the proponent shall immediately implement the Pit Lake Salinity Contingency Plan required by condition 9-2. |
| | 9-4 | The proponent shall make the Pit Lake Salinity Contingency Plan required by condition 9-2 publicly available. |

| Applicable MS | Condition No. | Closure Condition |
|---|---|---|
| 679 | 9-5 | In the event that the proponent implements option 2 of condition 9-2, and surface waters are diverted into a pit lake and hypersaline water is allowed to flow out of the pit lake into adjoining water courses, the proponent shall prepare a Hypersaline Waters Diversion Management Plan, to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.<br>This Plan shall address potential impacts on Marillana Creek and include the following:<br>1. monitoring;<br>2. management; and<br>3. reporting on the impacts. |
| | 9-6 | The proponent shall implement the Hypersaline Waters Diversion Management Plan required by condition 9-5 |
| | 9-7 | The proponent shall make the Hypersaline Waters Diversion Management Plan required by condition 9-5 publicly available |

### 3.1.2 Management plans

Several management plans have been prepared to meet the requirements of Ministerial Statement conditions (BHP Billiton, 2016; BHP, 2021e; 2022b)[16]. A Social Cultural Heritage and Environmental Management Plan has also been prepared in consultation with BNTAC and the Banjima people to support the Significant Amendment ERD.

The role of the environmental management plans is to guide the monitoring and control of environmental impacts to an agreed level during operations. Performance against these plans is reported in Annual Environmental Reports (AERs). Generally, any exceedances of agreed levels occurring during operations will be dealt under these management plans, unless there are specific actions that need to be taken in closure. These actions will be incorporated into the MCP as appropriate.

Some of the plans contain objectives that will continue to be relevant to closure and these are briefly summarised in Table 3-2 along with a synopsis of key operational management measures. Where relevant, measures that require action at closure will be integrated into this MCP at the appropriate time.

Management plans are revised from time to time, and where there are differences between the management plan provisions summarised in this MCP and the management plan in force at the time, the management plan will take precedence.

**Table 3-2 Management plans with relevance to closure and rehabilitation**

| Section / Schedule | Objectives | Status |
|---|---|---|
| **Surface and Groundwater Management Plan (SGWMP), re-named Marillana Creek Water Resource Management Plan (MCWRMP), to satisfy Condition 8 of MS 679** | | |
| Section 2<br>Tables 7 & 8 | • Sets thresholds for:<br>- Groundwater levels upstream of Yandi mining area and identifies contingency actions in the event the groundwater levels fall below threshold.<br>- Riparian vegetation condition and contingency measures if the threshold is exceeded.<br>• Commits to:<br>- Investigating measures for establishing the feasibility a man-made engineering option to protect areas upstream from groundwater drawdown.<br>- Establishing groundwater levels corresponding to active tree health monitoring sites on tenure.<br>- Surface water monitoring at the Marillana Creek discharge point.<br>- No decline in riparian vegetation at the discharge point due to changes in surplus water quality.<br>- Reporting performance via AERs. | SGWMP Rev 3 superseded by MCWRMP Rev 1.2 submitted July 2022 |
| **Yandi Biodiversity Environmental Management Plan (EMP) to satisfy Conditions 11 & 12 of MS 679** | | |
| Section 1.4.2<br>Tables 3 & 4 | Biodiversity EMP objectives / management targets:<br>• Maintain the abundance, diversity, geographic distribution, conservation status and productivity of flora and fauna.<br>• No new weeds (introduced flora species) are introduced within the development envelope that are attributable to the proposal. | Version 0 endorsed 16/04/2021 |

16 Note: revised draft management plans are being submitted to EPA with the Significant Amendment ERD, and once approved, will be referenced in future updates to the MCP.

| Section / Schedule | Objectives | Status |
|---|---|---|
| Section 2<br>Table 2 | Commits to:<br>• Undertaking:<br>  - Weed mapping annually to monitor the presence / absence and intensity of weeds.<br>  - Control and eradication measures in high priority and / or risk areas at least annually prior to the end of June.<br>• Reporting performance in AERs and a five yearly weed performance report. | |
| **Marillana Creek Diversion Management Plan to satisfy Condition 7 of MS 1039** | | |
| Section 1.2 | Objective of plan:<br>• Diverted sections of Marillana Creek function as a fluvial system in a similar manner to the existing creek system. | Rev 0 endorsed 30/03/2017 |
| Sections 5 to 7 | Summarises design studies. Those studies that are relevant to closure have also been summarised in this MCP (Section 5.15.3.1 and Appendix N.1). | |
| Section 8 | Specifies management targets and monitoring which are relevant to the completion criteria and post-closure monitoring sections of this MCP (Sections 8.3 and 10, respectively) and have been reproduced in those sections. | |
| **Social Cultural Heritage and Environmental Management Plan** | | |
| Section 2, Table 4 | Sets objectives for:<br>• Minimising impacts to riparian vegetation and culturally significant areas.<br>• Exploring options for minimising pit lakes and collaborating with the Banjima people on post-mining land use options.<br>• Ongoing engagement with Banjima people on management plans.<br>• Providing the Banjima people with the opportunity to be involved in and undertake environmental monitoring, surveys and rehabilitation activities.<br>• Sharing environmental monitoring data.<br>• Maintaining ongoing access to Country.<br>Commits to:<br>• Identifying and implementing mitigation options(s) for tree health decline at Flat Rocks Spring, Yandicoogina Gorge and Marillana Creek and collaborating with RTIO to achieve these aims.<br>• Backfilling E8 to pit crest[17] to create a free draining landform back towards Marillana Creek.<br>• Engaging with the Banjima people on closure planning for Yandi including pit lakes and post-mining land use planning.<br>• Providing regular update of planned environmental monitoring and surveys and environmental monitoring data.<br>• Enabling safe access to Country in accordance with the land access protocol. | September 2024 |

## 3.2 Environmental Protection Act 1986 (Part V)

Yandi has a licence under Part V of the EP Act for its mining, processing and ancillary operations (L6168/1991/11). The licence was amended in 2023 to allow for the establishment (and capping) of three new inert landfills for disposal of the inert concrete waste from the decommissioning of the Yandi camp.

Licence conditions that may have relevance to closure and closure execution (including those associated with the landfills to accommodate concrete from decommissioning) are outlined in Table 3-3. Otherwise, most of the conditions relate to operational matters including surplus water discharge (from dewatering operations) to Marillana Creek.

17 For clarity, the proposed E8 pit is located on a hillslope and hence the pit crest will be different elevations at different points around the pit. The intent of this commitment is to prevent capture of the nearby Marillana Creek and hence, the pit will be backfilled to at least the level of the Marillana Creek invert which coincides with the level of the northern pit crest.

**Table 3-3 Environmental licence conditions with relevance to closure execution**

<table>
<tr><th>Condition No</th><th>Aspect</th><th colspan="3">Licence Condition</th></tr>
<tr><td rowspan="6">2</td><td rowspan="6">Decommissioning</td><td colspan="3">The Licence Holder shall only accept waste on to the landfill if:<br>(a) it is of a type listed in Table 2;<br>(b) the quantity accepted is below any quantity limit listed in Table 2; and<br>(c) it meets any specification listed in Table 2.</td></tr>
<tr><td colspan="3">Table 2</td></tr>
<tr><td>Waste type</td><td>Quantity limit</td><td>Specification</td></tr>
<tr><td>Inert Waste Type 1</td><td rowspan="2">Combined total of up to 15,000 tonnes per annual period.</td><td>None specified includes inert concrete and pipework</td></tr>
<tr><td>Inert Waste Type 2</td><td>Tyres, conveyor belts and plastic only</td></tr>
<tr><td>Putrescible Waste</td><td>Combined total of up to 31,800 tonnes per annual period</td><td>None specified</td></tr>
<tr><td>4</td><td>Decommissioning</td><td colspan="3">Following up to 10,000 m$^3$ of inert concrete material, from the decommissioning of the Yandi Camp, placed into up to three Inert Landfills, excavated soil shall be used to cap the facility to a depth of 0.5 m when deposition of the waste concrete is complete.</td></tr>
<tr><td>8.</td><td>Decommissioning</td><td colspan="3">Land farm facilities will be constructed with the following requirements:<br>• Synthetic Lined to achieve a permeability of 1 x 10$^{-9}$ m/s;<br>• Stormwater run-off diverted so as not to flow onto the treatment facility;<br>• Designed so that any potentially contaminated runoff from the treatment cells is contained;<br>• Within the prescribed premises<br>• Not to be constructed within 5 0 m of surface water courses;<br>• Adequately fenced or positioned to prevent public access; and<br>• Appropriate signage warning of contamination placed.</td></tr>
<tr><td>20</td><td>Decommissioning</td><td colspan="3">No specific condition for closure, but a limit of 15 mg/L for total recoverable hydrocarbons is placed on the discharge from the OHP 3 oily wastewater ponds. This may have some relevance during decommissioning activities.</td></tr>
<tr><td>22</td><td>Monitoring</td><td colspan="3">Monitoring of ambient surface water quality will be conducted in accordance with the licence (see Section 10.1.8 for further details).</td></tr>
</table>

## 3.3 Other regulatory mechanisms

### 3.3.1 State Agreement Act

The Yandi tenure is held pursuant to the *Iron Ore (Marillana Creek) Agreement Act 1991 (WA)* (Marillana State Agreement), *Mining Act 1978 (WA)* and *Land Administration Act 1997 (WA)*. Where the Yandi operations take place on State Agreement Act tenure, these works are implemented pursuant to approved proposals under the Marillana State Agreement which must include *an environmental management program as to measures to be taken, in respect of the Company's activities under this Agreement, for rehabilitation and the protection and management of the environment (*Clause 7 (1)(m)).

Under Clause 14(1) of the Marillana State Agreement, BHP is required to carry out a continuous program, including monitoring to ascertain the effectiveness of rehabilitation and the protection and management of the environment, and report to the Minister from time to time. The Minister must be notified of any changes or additions to approved proposals required to more effectively rehabilitate, protect or manage the environment (Clause 14(2)).

Provision of workforce accommodation is outlined in the Marillana State Agreement. Under Clause 21(2), BHP is required to confer with the Minister with respect to future accommodation requirements of the mine workforce.

In addition, on the cessation or determination of the Marillana State Agreement, should BHP wish to remove any fixed or movable plant and equipment, the State must be notified in writing and provided the right or option to purchase such plant or equipment at a fair and agreed valuation (Clause 35(3)).

### 3.3.2 Tenement conditions

The key tenement conditions that may have relevance to closure are outlined in Table 3-4.

**Table 3-4 Key closure related tenement conditions**

| Tenement No. | Condition Number | Closure Condition |
|---|---|---|
| M270SA | 4 | At least six months prior to decommissioning the project, or part thereof, the lessee submitting a decommissioning programme to the State Mining Engineer for his approval in consultation with the Environmental Protection Authority. |
| G47/12, G47/13, G47/14, G47/15, G47/16, G47/17, G47/18, G47/19 | 5 | At least six months prior to decommissioning of the accommodation facilities the lessee submitting a program for the decommissioning of the facilities for approval by the State Mining Engineer. |
| L47/667 | 2 & 3 | The rights of ingress to and egress from Exploration Licence 47/1539 and Miscellaneous Licence L47/118 will at all times be preserved to the holder and there will be no interference with the purpose or installations connected with E47/1539 or L47/118. |
| L47/667, L47/771 | 5 or 7 | All topsoil that may be removed ahead of pipe laying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum [now DEMIRS]. |
| L47/771 | 4 | The rights of ingress to and egress from Mining Lease 274SA will at all times be preserved to the holder and there will be no interference with the purposes or installations connected with Mining Lease 274SA. |
| L47/771 | 15 | All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the licence area prior to or at the termination of exploration program |
| L47/667, L47/771 | Endors 7 | Measures such as drainage controls and stormwater retention facilities are to be implemented to minimise erosion and sedimentation of adjacent areas, receiving catchments and waterways. |
| L47/667, L47/771 | Endors 08 | All activities to be undertaken so as to avoid or minimise damage, disturbance or contamination of waterways, including their beds and banks, and riparian and other water dependent vegetation. |

### 3.3.3 Native Title and cultural heritage

The Yandi Mining Lease 270SA is located within the boundary of the Banjima Native Title determination [WCD2014/001].

As outlined in BHP's Indigenous Peoples Policy Statement, BHP has ambitions to create long-term relationships with Indigenous Peoples, based on trust and mutual benefits. The foundation of this relationship with the Banjima people is formalised through the Comprehensive Agreement signed by BHP and BNTAC in 2015, and associated registered Indigenous Land Use Agreement (ILUA). This Comprehensive Agreement includes a heritage protocol supporting the identification of Aboriginal cultural heritage and cultural values within the determination area and the management of BHP's activities to minimise impacts on Aboriginal cultural heritage and protect Aboriginal cultural heritage values from significant harm.

It also includes the following commitments relevant to closure and rehabilitation:

- Traditional Owners will be engaged to inform the rehabilitation programme based on their holistic understanding of 'healthy country'.
- The integrity of, and access to, places of cultural significance will be maintained in the closure design – including and encompassing the restoration and rehabilitation of cultural values and landscapes after mine closures.
- Salvaged artefacts will be returned to Country post-closure as per the wishes of the relevant Traditional Owner group.

Representatives of both BHP and Banjima meet throughout the year, including at the Heritage Advisory Council (HAC). The HAC forum is an important part of the relationship between BHP and the Banjima people, which enables sharing of information, feedback from recent engagements and identification and discussion of concerns and decision-making in relation to Aboriginal cultural heritage and environment matters.

During the mining operations, cultural material has been salvaged as part of ministerial approvals. The material is currently stored in our Banjima cultural material keeping place and will be repatriated back to suitable locations within Yandi in consultation with the Banjima People.

Where there is the potential for closure works to impact on sites of cultural significance, the provisions of the current Aboriginal Heritage legislation will also apply.

BHP is committed to continued consultation with the Banjima People on the closure of the Yandi mine. Consultation with Traditional Owners on closure and post-closure land-use is undertaken through the ongoing stakeholder engagement process (Section 4).

### 3.3.4 Rights in Water and Irrigation Act 1914

Yandi abstracts water in accordance with Groundwater Licence 89501(11) issued under the *Rights in Water and Irrigation Act 1914 (WA)* (RIWI Act). There are no specific conditions relevant to closure within the licence, but the licence specifies that Yandi operations must comply with the Groundwater Operating Strategy for Yandi (WAIO, 2022d) which is approved by DWER. The groundwater operating strategy outlines the current groundwater monitoring program (Section 10.1.10). The results from this program are used to calibrate groundwater models and help to inform completion criteria. There are no other closure-related commitments.

### 3.3.5 Contaminated Sites Act 2003

The *Contaminated Sites Act 2003 (WA)* (CS Act), regulates the reporting, management and remediation of contaminated sites. Under the Act, remediation of contaminated sites is the responsibility of the polluter or current site owner. Reporting and management of contaminated sites occurs throughout operations, and BHP has reported known and suspected contamination targets at Yandi to DWER in accordance with the Act (Section 5.10). BHP also provides regular updates to DWER as sites are investigated and remediated (Section 4.2). Section 5.10, Table 5-43, summarises the current status of Yandi contamination targets and Section 9.1.10 provides further details of BHP's processes for management of contaminated sites.

### 3.3.6 Rail Safety National Law WA Act 2015

The *Rail Safety National Law WA Act 2015* and associated *Rail Safety National Law (WA) Regulations 2015* govern the safe operation and decommissioning of railway infrastructure and rolling stock. Under the Act and associated regulations, there must be a documented set of operational procedures and engineering and safety standards and procedures, for *inter alia*, decommissioning or disposal of rail infrastructure and rolling stock.

## 3.4 Closure guidelines and industry standards

BHP governs closure planning, on a corporate level, through the Corporate Alignment Planning Global Standard (BHP, 2023b). The purpose of this document is to ensure closure planning is included in the business planning processes throughout the lifecycle of a project.

This MCP has been prepared to satisfy the relevant components of BHP's Corporate Alignment Planning and closure planning processes and has been finalised for external review in line the DEMIRS Statutory Guideline (DMIRS, 2020a). In addition, this MCP incorporates relevant aspects from other closure guidelines and industry standards including:

- *Mine Closure Plan Guidance - How to prepare in accordance with part 1 of the Statutory Guidelines for Mine Closure Plans* (DMIRS, 2020b);
- *Integrated Mine Closure: Good Practice Guide* (ICMM, 2019);
- *Strategic Framework for Mine Closure* (Minerals Council of Australia, and the Australian and New Zealand Minerals and Energy Council (ANZMEC & MCA, 2000);
- *Mine Closure and Completion* (DISER, 2016a);
- *Mine Rehabilitation* (DISER, 2016b);
- *Preventing Acid and Metalliferous Drainage* (DISER, 2016c);
- *Evaluating Performance Monitoring and Auditing* (DISER, 2016d);
- *Technical Guidance - A framework for developing mine-site completion criteria in Western Australia* (Young, et al., 2019);
- *Mine Closure Completion Guideline – for demonstrating completion of a mine closure in accordance with an approved mine closure plan* (DMIRS, 2021);
- *Safety Bund Walls Around Abandoned Open Pit Mines* (DoIR, 1997); and
- *Ground Control in Western Australian Mining Operations* (DMIRS, 2019).

# 4 Stakeholder consultation

## 4.1 Objectives

BHP recognises the importance of engaging with relevant stakeholders. The ability to build relationships and work collaboratively and transparently with our host communities is critical to the Company's long-term success. BHP has established a comprehensive consultation program to support ongoing, effective dialogue with stakeholders potentially impacted by, or interested in, the implications of the Company's operations. This approach is consistent with BHP's Charter that states a commitment to supporting communities and the BHP Code of Business Conduct that articulates how this underpins how the Company does business:

> *"Our ability to build relationships and work collaboratively and transparently with our host communities is critical to our long-term success. Our aim is to be the company of choice, valued and respected by the communities in which we operate. We do this by engaging regularly, openly and honestly with people affected by our operations, and by taking their views and concerns into account in our decision-making"*

BHP has an ongoing consultation program relating to its Yandi mining operations with government agencies (both state and local), Traditional Owners and other landowners based on interest and proximity to the project location. The objectives of the program are to provide information and the opportunity to comment to government agencies and other stakeholders who may potentially be interested in activities (including closure and rehabilitation) at Yandi and to:

- Identify key issues and concerns regarding closure designs and management;
- Discuss objectives for the development of Yandi and its ultimate rehabilitation and closure;
- Periodically provide updated information and results of closure planning studies and processes as more information comes to hand; and
- Allow for adjustments to the design and / or management of any proposed activities to accommodate concerns or issues, where relevant.

## 4.2 Consultation program

BHP's locally based Community and Indigenous Affairs team are active members of Pilbara communities and through continued community engagement they have established:

- Supportive working relationships between BHP and the Pilbara communities (Port Hedland and Newman);
- An environment conducive to productive dialogue;
- An understanding of key issues and concerns of the community in relation to developments in the area; and
- An avenue to share key project information as it becomes available.

As part of the broad consultation program for Yandi, BHP consults with identified stakeholders on closure related issues during each project phase (pre-approval, operations, rehabilitation and post-closure) to ensure that legal requirements, risks and internal and external stakeholder expectations for closure at Yandi are considered at an appropriate time and as far as practicable.

In line with DEMIRS guidelines (DMIRS, 2020a), BHP considers key stakeholders at Yandi to be post-mining owners or managers, including Traditional Owners and relevant regulators. The current focus of the closure consultation for the Yandi mining operations is primarily with the key stakeholders Traditional Owners (Banjima People and BNTAC), DEMIRS, DWER and neighbouring mining companies (RTIO). Consultation undertaken to date is recorded in Section 4.3, and has included developing a data-sharing agreement with RTIO to aid water and closure planning.

As Yandi approaches the completion of mining, closure-specific consultation will increase with broader stakeholder groups such as those listed below.

***Landowners and managers:***

- Traditional landowners Banjima People;
- RTIO (Yandicoogina);
- Other mining companies (where relevant);
- Pastoral station managers (Marillana Creek and Juna Downs); and
- Department of Planning Lands and Heritage (DPLH) (administers crown land).

***State Government agencies:***

- DEMIRS;
- Department of Biodiversity Conservation and Attractions (DBCA);
- EPA;
- DWER;
- Department of Jobs Tourism Science and Innovation (DJTSI);
- Department of Planning;

- Main Roads Western Australia;
- Department of Health;
- Heritage Council of WA;
- Department of Primary Industries and Regional Development (DPIRD); and
- Pilbara Development Commission.

***Local Governments and politicians:***

- Shire of East Pilbara;
- Local Member for the Pilbara;
- Minister for Environment; Water;
- Minister for Mines and Petroleum;
- Minister for Heritage; Local Government; and
- Minister for Regional Development.

***Local and regional groups:***

- Newman Community Consultative Group;
- Newman Chamber of Commerce and Industry;
- Wildflower Society of WA;
- Tourism Operators;
- Greening Australia; and
- Conservation Council of WA.

***Other***

- Employees and Contractors.

The Yandi mining operations consultation program has been developed based on the continuity of operations in this area through the utilisation of processing and supporting infrastructure. The focus is, therefore, on sharing information and gaining feedback following advances in mine closure design studies and progressing post-mining land use discussions.

BHP acknowledges that mine closure and rehabilitation are critical issues for the Banjima people, and closure matters are considered via several different engagement forums (see Table 4-1). This program is being refined during progressive engagement with the Banjima People. Social surrounds workshops conducted as part of environmental approvals also consider closure issues.

An indicative stakeholder consultation program for the Yandi mining operations in advance of the next closure plan update (three-yearly cycle) is shown in Table 4-1.

**Table 4-1 Stakeholder consultation program**

| Stakeholders | Timing | Communications |
|---|---|---|
| BNTAC and Banjima people[18] | Two days twice per year plus special meetings to address urgent matters if required | **Implementation committee meetings**<br>Address Banjima comprehensive agreement implementation including employment, business development, closure and health / wellbeing of Banjima community as well as a number of other matters. |
| | Subject to business needs, but recently has been two days quarterly | **Heritage Advisory Committee**<br>Forum to discuss heritage related matters and projects, including Cultural Heritage Management Plans. This would include matters such as repatriation of cultural artefacts post-closure. |
| | Associated with environmental approval submissions | **Social surroundings workshops**<br>On country workshop that enables on-ground survey work and two-way engagement with Banjima on their values in relation to flora, fauna and the land. |
| | MCP review | MCPs are provided for review as they are updated. |

[18] It should be noted that there are high demands on Banjima time for consultation with several different proponents in the Pilbara. Engagement on closure matters for Yandi is subject to the constraints of the BNTAC / Banjima calendars.

| Stakeholders | Timing | Communications |
|---|---|---|
| *BNTAC and Banjima people owners continued* | Other engagements, subject to study progress and BNTAC / Banjima availability | Closure-specific workshops are periodically conducted to discuss closure-specific issues in further detail with the aim of informing relevant amendments to the Yandi closure approach. At a recent engagement in October 2024 (Table 4-2), BHP and BNTAC agreed that there would be regular dedicated sessions on closure.<br>Engagements will include:<br>• Mine void final landform options (backfill design) and sustainability of surface water flows at closure.<br>• Visual amenity.<br>• Post-mining land uses and requirements for safe access, including access to sites of cultural significance.<br>• Progressive demolition of infrastructure not being transferred to a third-party post-closure.<br>• Likely post-closure groundwater and vegetation outcomes.<br>• Completion criteria.<br>Given the interrelationships between the closure approaches / outcomes at BHP's Yandi mine and RTIO's Yandicoogina mine, a plan is being progressed to hold some workshops as a joint session with RTIO. |
| Pastoral Station Land Managers | As part of regular stakeholder consultation, as required. | Key topics may include:<br>• Mine void final landform options and sustainability of surface water flows at closure.<br>• Post-mining land use and completion criteria.<br>• Requirements for post-closure access.<br>• Progressive demolition of infrastructure not being transferred to a third-party post-closure. |
| RTIO | As required. | Mine void final landform options and potential to manage surface water and groundwater impacts through closure designs.<br>Continue to progress information sharing with RTIO. |
| DWER (Contaminated Sites Branch) | Ongoing as part of regular stakeholder consultation and, as required, to discuss the findings of contaminated sites investigations. | Update on contaminated sites management (WAIO-wide). |
| EPA, DEMIRS, DWER | Ongoing as part of regular stakeholder consultation.<br>At a minimum for the revised MCP and nominally with any new development proposals. | MCP technical studies update briefing including:<br>• Mine void final landform closure options and potential impacts to groundwater levels and pit lake quality<br>• Surface water regime continuity at closure<br>• Stakeholder consultation progress update |
| DBCA, DPLH | Ongoing as part of regular stakeholder consultation and nominally with key revisions to post-mining land uses and completion criteria. | Post-mining land use and completion criteria. |
| DJTSI | Prior to demolishing infrastructure / executing final closure | Progressive demolition of infrastructure not being transferred to a third-party post-closure. |
| Newman Stakeholder Engagement Group | As required | High level update as the impact to the Newman community is low because Yandi has a predominantly Fly-in Fly-out workforce and is not near a major town centre. |

## 4.3 Consultation undertaken to date

Since the 2020 MCP, there has been a significant amount of consultation with BNTAC and the Banjima people which has included several meetings to provide closure updates, and a workshop focused on closure issues including a joint workshop with RTIO. During these meetings the Banjima people stated that they are not supportive of pit lakes in general, and saline pit lakes in particular. In July 2023, BNTAC requested summaries of the post-mining land use planning studies conducted by BHP to date, and the decision-making process behind the closure options outlined in this plan. The documents provided in response to this request are provided in Appendices J.1 and J.2. A request was also made to halt the progression of the SPS to DPS until BNTAC and the Banjima people have reviewed technical studies and workshopped post-mining land uses and outcomes with BHP. As discussed in Section 1.4, the SPS is currently on hold until the BNTAC and the Banjima people have progressed their review of information provided, and future mining options have been finalised.

Table 4-2 summarises the key issues discussed with stakeholders and comments received relating to mine site rehabilitation and closure during consultation conducted to date.

**Table 4-2 Stakeholder consultation summary**

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
|---|---|---|---|---|---|
| **Department of Energy Mines Industry Regulation and Safety** | | | | | |
| 5 November 2009 | Face-to-face meeting | Department of Mines and Petroleum (DMP) (now DEMIRS) | DMP requested that BHP considers adopting 10 m high lifts, as it is easier for the batters to be re-shaped and flattened to their final angle. | BHP uses OSA lifts of between 10 and 20 m at its existing Pilbara operations, with the actual height used dependent on the characteristics of the overburden, location of the stockpile, operational requirements at the mine, and the site's rehabilitation and mine closure objectives. In general terms, BHP agrees that it is easier for batters to be re-shaped and flattened to their final angle if OSA lifts are 10 m high, and as a result, where practicable, OSA lifts at BHP's contemporary Pilbara mining areas are on the lower end of the range. There are, however, occasions where higher lifts are suitable and can still be successfully and progressively rehabilitated. The height of OSA lifts is therefore decided on a case-by-case basis as part of the LOM planning process. | No response |
| 25 March 2013 | Rehabilitation update meeting | DMP (now DEMIRS) | Development of ecological completion criteria including rehabilitation strategy, seed management, growth media, rehabilitation monitoring, timeline to developing completion criteria including planned milestones. | DMP supportive of strategy. Interested in changes to the monitoring program especially in relation to defining progress and use towards developing completion criteria. Keen to be kept up to date as work progresses. | **BHP Response**<br>Progress to be reported in Annual Environmental Reports (AERs). |
| 16 December 2013 | Meeting to provide closure and rehabilitation update | DMP (now DEMIRS) | Closure and Rehabilitation Regional Management Strategy.<br>BHP engagement with DMP regarding MCP submissions. | Supportive of Strategy. Could not see any gaps.<br>DMP expressed a desire to be provided with an update on the MCPs prior to submission through a brief update presentation (not a full draft MCP). A schedule of when the updates are due would help manage DMP resources. | **BHP Response**<br>Provide schedule for near term MCP updates and coordinate update sessions in advance of the MCP submissions. |
| 17 March 2014 | Meeting to discuss closure planning update | DMP (now DEMIRS) | Provided hard copy (pdf soft copy by email) of the Draft Closure and Rehabilitation Management Strategy for DMP consultation.<br>Provided look ahead for next 12 month of closure plans that are anticipated to be submitted to EPA / DMP | Agreed to provide feedback to BHP Closure Manager by approx. end March 14.<br>Noted upcoming items.<br>Advised that the July 14 revision to the guidelines will not be significant. The main changes will be more detailed guidance in Table 1 and guidance on how to submit a revised closure plan to enable more efficient processing by DMP. | **BHP Response**<br>Likely Closure Guideline changes noted. |
| 3 December 2014 | Rehabilitation update meeting | DMP (now DEMIRS) | Discussion held over potential for misalignment on targets defined in 2014 Annual Environmental Report (AER) where hectares planned for rehabilitation could be interpreted as being completed during FY2015.<br>Review of ecological completion criteria development meeting summary (from 26 March 2013).<br>Discussion of progress to date on achievements and challenges in the development of ecological completion criteria and alignment on new target date for defining agreed draft criteria now 2020. | Concern was raised over BHP's ability to complete earthworks to an acceptable standard when using production fleet to execute bulk earthworks (regrade); concern alleviated by BHP engaging rehabilitation contractor to complete the works.<br>DMP expressed interest in development of execution tolerances for rehabilitation earthworks; were supportive that growth media requirements are embedded in planning process for rehabilitation projects; acknowledged that delays in executing project works had resulted in push back in the delivery date for agreed draft completion criteria; and were interested in development of an alternative rehabilitation monitoring approach using remote sensing / photogrammetry.<br>Overall DMP were supportive of proposed approach and keen to be kept up to date as work progresses. | **BHP Response**<br>Progress to be reported in AER. |
| 12 September 2016 | Yandi closure plan update technical content and OEPA submission timing. | DMP (now DEMIRS) | Yandi closure plan update technical briefing. | BHP provided a technical overview of Yandi closure plan update across (1) scope and closure timing, (2) Yandi closure guiding principles with priority to sustain Marillana Creek surface water flow from eastern boundary through to Weeli Wolli Creek and Fortescue Marsh (3) Yandi closure risks as understood, with further management actions required. | **DMP Response**<br>Noted the mine void backfill configuration options were still under internal assessment requiring Banjima People consultation before inclusion within the next 3-yearly Yandi closure plan update.<br>Interested to see the details on safety bund assessment relative to floodplain and status of existing ex-pit OSAs.<br>Will review in association with Marillana Creek Diversion Management Plan submission. |
| 6 March 2019 | Completion criteria | DMIRS (now DEMIRS) & DBCA | BHP presented and discussed the sustainability section of the draft BHP rehabilitation completion criteria | Meeting attendees generally happy with the approach proposed and the detail. During the meeting, it was noted that weeds will require addressing. | **BHP Response**<br>BHP has incorporated weeds into criteria. |
| 6 February 2020 | Safety bunds | DMIRS (now DEMIRS) | BHP discussed safety bunds with DMIRS in relation to the Mount Goldsworthy site, but the principles of the conversation are relevant to other sites | OSAs may be considered to form part of safety bunds on a case-by-case basis, but OSAs with slopes of 20° are not sufficient to be a deterrent to the public and will not control void access.<br>Staggered large boulders have been used in creek beds. | **BHP Response**<br>Incorporate principles of safety bund discussion into safety bund planning for all sites. |
| 3 September 2021 | Decommissioning | DMIRS (now DEMIRS) | Letter - Notification of Progressive Decommissioning | Notification of partial decommissioning at Marillana Creek (Yandi) under M270SA condition 4 and G47/12, G47/13, G47/14, G47/15, G47/16, G47/17, G47/18, G47/19 condition 5. | **DMIRS Response - letter dated 21 July 2022**<br>If the next submission of the revised MCP for Yandi adequately addresses the points raised by DEMIRS in relation to the decommissioning sections of the 2020 MCP, the updated MCP would be considered to satisfy the requirements of the conditions imposed under the *Mining Act 1978,* and a separate Decommissioning Program would not be required.<br>**BHP Response**<br>The 2024 MCP has been amended to address DEMIRS comments as outlined in Section 13.2. |
| 14 September 2021 | Sterilisation reports | DMIRS (now DEMIRS) | Emails seeking clarification from DMIRS on 'sterilisation report submission form for in-pit waste / tailings disposal proposals'. | Request to DMIRS for clarification on process for submitting 'sterilisation report submission form for in-pit waste / tailings disposal proposals' with respect to State Agreement Act tenure. | **DMIRS Response**<br>Sterilisation reports are required for State Agreement Act tenure (or where there is no associated Mining Proposal). |

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
|---|---|---|---|---|---|
| 21 March 2022 | Closure & approvals program | DMIRS (now DEMIRS) | Briefing and feedback from DMIRS on current closure and environment upcoming approvals | Noted upcoming changes to legislation, upcoming approvals and MCP updates and priorities. | **DMIRS Response**<br>BHP to provide a list of MCPs currently under review and a priority list for assessment, with reasons for priorities.<br>**BHP Response**<br>Priority list provided and meeting organised. |
| 13 March 2023 | Quarterly meeting | DMIRS (now DEMIRS) | Briefings on several MCPs and overarching approach to closure outcomes and completion criteria | BHP provided an overview of:<br>• BHP's closure vision and guiding principles which are consistent across all sites<br>• Closure outcomes and post-closure land uses with the primary land use(s) generally being a natural outcome of native vegetation for pastoral use or managed resource protection. It was noted that BHP is currently working with Traditional owners to progress further detail in MCPs as they mature.<br>• Provided an overview of typical criteria and how they are linked to the landform, post-mining land use and closure risks and how the criteria are spilt into performance indicators and completion criteria. | **DMIRS Response**<br>BHP is following the right process with respect to development of completion criteria and DMIRS likes the approach but requires clarity on what they are actually being asked to approve.<br>**BHP Response**<br>Consider presentation of completion criteria in MCPs. |
| 25 July 2023 | Telephone call | DMIRS (now DEMIRS) | Site codes and MCP cover page information | Request to provide site codes on the front page of MCPs and instead of providing other details required by the Statutory Guidelines for Mine Closure Plans on the following page, move these to the first cover page. | **BHP Response**<br>Cover page changed. |
| 19 December 2024 | Meeting | DEMIRS | Meeting was focused on closure of GNA, but topics relevant to other WAIO sites (site security, abandonment bund placement and infrastructure removal depth) have been captured here. | **Abandonment Bunds**<br>DEMIRS provided in-principle acknowledgement that abandonment bunds tied into OSAs could be considered by DEMIRS using a risk based approach, provided that they are not trafficable by vehicles.<br>**Infrastructure Removal Depth**<br>DEMIRS acknowledged that a risk-based approach to the depth of infrastructure removal could be considered providing that:<br>• The post-mining land use is stable.<br>• There is no unearthing of below ground services / infrastructure.<br>• Stakeholders such as Traditional Owners have been consulted. | No response. |
| **Department of Jobs Tourism Science and Innovation** | | | | | |
| 3 September 2021 | Decommissioning | DJTSI | Letter - Notification of Progressive Decommissioning | Notification of partial decommissioning at Marillana Creek (Yandi) under M270SA condition 4 and G47/12, G47/13, G47/14, G47/15, G47/16, G47/17, G47/18, G47/19 condition 5 | No response. |
| **Office of Environmental Protection Authority** | | | | | |
| 6 July 2016 | Yandicoogina Creek diversion and closure strategy update briefing | OEPA | Marillana Creek Diversion Management Plan and Yandi Closure Plan update | BHP provided (1) detailed Marillana Creek diversion overview, including design features and monitoring and (2) Yandi Closure Plan update approach to align with Diversion Management Plan submission. | **OEPA Response**<br>Acknowledged the significant amount of technical detail gone into the diversion study, look forward to seeing all the detail. |
| 3 September 2021 | Decommissioning | EPA | Letter - Notification of Progressive Decommissioning | Notification of partial decommissioning at Marillana Creek (Yandi) under M270SA condition 4 and G47/12, G47/13, G47/14, G47/15, G47/16, G47/17, G47/18, G47/19 condition 5 | No response. |
| **Department of Water and Environmental Regulation** | | | | | |
| 17 November 2009 | Face-to-face meeting | DEC (Environmental Management Branch) (now DWER) | Closure plan briefing | DEC requested that BHP provides further information on the closure risks (e.g. final void water quality and native fauna). | **BHP Response**<br>A risk assessment has been completed and is provided in Section 7 and further technical detail on pit lake quality and risks are provided in Section 5.14. |
| 8 April 2014 | BHP Contaminated sites debrief | Department of Environmental Regulation (DER; now DWER) Contaminated Sites Branch | Management of contaminated sites | Discussed the risk-based management approach adopted by BHP for its suspected and known contaminated sites at its Pilbara operations. | **BHP Response**<br>Continue to apply contaminated sites management framework including research. |
| 14 April 2014 | Meeting to discuss Closure Planning update | Department of Water (DoW; now DWER) | Provided an overview of the Closure and Rehabilitation Regional Management Strategy | Supportive of the regional strategic approach and the alignment with the Pilbara Water Resource Management Strategy. | No response. |
| 9 August 2016 | Yandicoogina Creek diversion and closure strategy update briefing | DoW (now DWER) | Marillana Creek Diversion Management Plan and Yandi Closure Plan update | BHP provided (1) detailed Marillana Creek diversion overview, including design features and monitoring and (2) Yandi Closure Plan update approach to align with Marillana Creek Diversion Management Plan submission.<br>BHP committed to return to DoW with more detailed briefing on Yandi Closure Plan prior to submission of update to OEPA. | **DoW Response**<br>Acknowledged the significant amount of technical detail gone into the diversion study, look forward to seeing all the detail.<br>Acknowledged the receipt of Yandi closure plan in coming months to review in tandem with the Marillana Creek Diversion Management Plan |
| 12 September 2016 | Yandi closure plan update technical content and OEPA submission timing | DoW (now DWER) | Yandi closure plan update technical briefing | BHP provided technical overview of Yandi closure plan update across (1) scope and closure timing, (2) Yandi closure guiding principles with priority to sustain Marillana Creek surface water flow from eastern boundary through to Weeli Wolli Creek and Fortescue Marsh (3) Yandi closure risks as understood, with further management actions required. | **DoW Response**<br>Comfortable with groundwater modelling approach using GoldSim water balance model with inputs from regional numerical model.<br>Will review in association with Marillana Creek Diversion Management Plan submission. |

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
|---|---|---|---|---|---|
| 9 December 2021 | Letter | DWER | Yandi MCP approval | The 2020 MCP was approved for implementation on the basis that further work required (as outlined in attachments) is addressed in the next iteration of the MCP. | **BHP Response**<br>Requests for further work have been addressed in this MCP submission (Section 13.2). |
| 22 September 2022 | Letter | DWER | Request for deferral of MCP submission. | Request to delay the submission of the Yandi MCP to enable further studies to be completed and consultation with Banjima people to occur following various delays (including the effects of Covid-19 management measures). | **DWER Response (letter dated 26 October 2022)**<br>Approval was given the defer submission. |
| 23 October 2024 | Letter | DWER | Request for deferral of MCP submission. | Request to delay submission of the Yandi MCP based on the timing of the Yandi E8 Deposit (mining) referral. | **DWER Response (letter dated 15 January 2025)**<br>Approved. BHP has until 30 June 2025 to submit the MCP, with a referral or otherwise. |
| **Department of Biodiversity Conservation and Attractions** | | | | | |
| 6 March 2019 | Completion criteria | DMIRS (now DEMIRS) & DBCA | BHP presented and discussed the sustainability section of the draft BHP rehabilitation completion criteria | Meeting attendees generally happy with the approach proposed and the detail. During the meeting, it was noted that weeds will require addressing. | **BHP Response**<br>BHP has incorporated weeds into criteria. |
| **Traditional Owners[19]** | | | | | |
| 14 September 2016 | Yandi closure discussion forum | Banjima People environment & heritage sub-committee | Yandi final landform closure options and Banjima People end land use requirements | BHP provided introductory overview of Yandi closure plan update scope and closure timing and indicated that the company is seeking to work together on the Yandi closure strategy for Banjima People end land use requirements. | **BHP Response**<br>First step to more consultation. Look forward to more detailed discussions in near future and following years to develop final closure end land use strategy. |
| 19 October 2017 | Yandi closure discussion forum | Banjima People environment & heritage sub-committee | Yandi closure planning update and further consultation | Seeking preliminary ideas / preferences related to mine voids, revegetation, repatriation of cultural artifacts and Marillana Creek. | **Banjima People Response**<br>Elders needed to be present in future meetings to make any decisions of cultural material to be repatriated and potentially other decisions.<br>No decisions can be solely made by the Banjima People committee members present in the room and further discussions are needed. Therefore, the ideas discussed by Banjima People are to be considered preliminary preferences only at this time.<br>The group requested forming a specific subcommittee (with Elders) to address Yandi mine closure with next meeting to be with this subcommittee and completed on country. The group also added that information about Yandi closure plans could be included in the Banjima Seasons roadshow in the community (visiting Elders).<br>Committee members preliminary preferences summary:<br>• Where possible pit walls should have flat / smooth gradients.<br>• Where possible the pit lakes should be fresh water and not salty / saline.<br>• Would prefer seasonal pools over permanent or no pools as this is more natural and animals that come back into the area would adapt to this better.<br>• Areas along Marillana Creek must have the most stable walls to ensure the creek does not fail. |
| 3 August 2018 | Yandi closure discussion forum | Banjima People environment & heritage sub-committee | Yandi closure planning update and further consultation | Recapped on Banjima People preliminary preferences from October-17 meeting.<br>Outlined:<br>• Yandi year plan ramp down timing.<br>• Further site utilisation studies underway.<br>• BHP process for making Banjima People aware of unwanted non-process infrastructure reuse options.<br>Requested Banjima People preference for timing of next site-based consultation | **Banjima People Response**<br>Agreement with preliminary preferences from October-17. Further discussion on revegetation plant mix (bush tucker) and access to land post-mining (who will control the land following lease extinguishment). Expressed potential interest in the camp facilities and gatehouse post-closure.<br>**BHP Response**<br>All options / concepts by Banjima People can be evaluated which is the primary reason for BHPs desire to routinely meet and work with Banjima People on Yandi closure and rehabilitation |

19 It should be noted that early engagements with Traditional Owners did not have the benefit of technical support. Since 2023, technical support has been provided to the Banjima people and consequently, feedback from more recent sessions provides a more informed response.

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
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| 21 May 2019 | Yandi Site Tour | Banjima People Environment & Heritage Sub-committee | On-country discussion of closure of the Yandi mine. | Recapped on discussions in previous session.<br>Toured and discussed:<br>• Marillana Creek Land Bridge Diversion.<br>• Rehabilitation Areas (Radio Hill Lookout).<br>• Eastern 8 discharge point where the Banjima members were impressed at the clarity of the water and the amount of fish present.<br>Questions / comments included:<br>• Whether the landscape would be "flat and level" after closure.<br>• Whether remaining pit lakes would be accessible.<br>• Concerns that wildlife would not return to the area.<br>• Concern about tree deaths at Flat Rocks Spring and assurance that this would not happen again.<br>• Importance of water to a heathy Country and that Banjima People are very keen to work with BHP to ensure the Country stays healthy.<br>• The Banjima Rangers are very keen to get skilled up and be part of the closure process. | **BHP Responses**<br>There is not enough fill to backfill the pits entirely and therefore there will be pit lakes – likely 12.<br>Some of the pit lakes would be accessible and BHP will work with Banjima People to ensure this would be the case where possible.<br>A lot has been learnt from work at Yarrie where wildlife is already returning to rehabilitated areas.<br>Provided an overview of the research to be conducted to determine how to best manage the discharge of water into the creek.<br>A Banjima trainee program has been initiated in conjunction with the seed production area and tree nursery (Section 5.15.6).<br>**Banjima People Response**<br>Pit lakes are particularly important for young people who may wish to use them as a resource, however, safety concerns should be taken in to account to ensure nobody is hurt. |
| 12 November 2019 | Yandi closure discussion | Banjima People Agreement Implementation Committee | Discussion on Yandi closure IPS and other business | Progress update on Yandi mine planning and Yandi closure study. Discussed the desire to engage on conceptual closure design elements and sought guidance on the appropriate group / forum for this engagement. | **Banjima People Response**<br>Update was well received and appreciated. Further engagement with the sub-committee recommended.<br>**BHP Response**<br>BHP to continue to engage through the environment & heritage sub-committee meetings. |
| 1 April 2021 | Update on closure planning | Banjima People Agreement Implementation Committee | Update on closure planning activities | Update on key aspects of closure study. | BHP to engage through environment sub-committee at next meeting |
| 27 July 2021 | Update on closure planning | Banjima People Agreement Environment Sub-committee | Update on closure planning activities | Discussions on:<br>• Recommencing the collaborative approach to closure.<br>• Ranger program.<br>• Tree planting.<br>Questions / comments included:<br>• How riparian health will be protected through closure (i.e., long term fix for tree mortality along Marillana Creek).<br>• Importance of maintaining surface water flows and having access to surface water in pits (ponds / lakes etc) as part of being on country.<br>• Request for inclusion of bush foods and medicines in rehabilitation.<br>• Concerns about macro fauna populations, e.g., kangaroos and decline in the environment due to grazing pressures.<br>• Request to use limited topsoil resources in a smart way, e.g., "putting high in landscape so it can wash down, not low in the landscape where it can wash away". | **Banjima People Response**<br>Expressed interest in:<br>• Being part of the process for collaborating on closure concepts / designs.<br>• The Ranger program and the tree planting projects.<br>• Having access to assets as part of the disposal process.<br>• Participating in rehabilitation execution through Banjima contracting companies.<br>**BHP Response**<br>BHP to follow up on consultation and future engagements via subcommittee and Implementation Committee meetings |
| 28 July 2021 | Update on closure planning | Banjima People Agreement Implementation Committee | Update on closure planning activities | Follow on and completion of discussions arising from the environment subcommittee meeting on 27 July 2021 including discussion of future mining areas, progressive rehabilitation and the contracting strategy for rehabilitation works. | **BHP Response**<br>BHP to follow up on consultation and future engagements via subcommittee and Implementation Committee meetings. |
| 2 August 2021 | Update on closure planning | Banjima People Heritage Advisory Committee | Brief update on closure planning | High level briefing provided on closure outcomes at Yandi. | No response. |
| 3 September 2021 | MCP provided | BNTAC on behalf of the Banjima people | 2020 MCP provided to BNTAC for review | Review of MCP requested again in July 2023. | **Banjima People Response**<br>No response had been received at the time of writing. |
| 14 March 2022 | Implementation Committee Meeting | Banjima representatives / BNTAC | Inform on closure planning activities | An update on was provided on closure planning processes at Yandi and a request was made to the committee for time to discuss Yandi -specific closure outcomes. Specific values / requirements noted by BHP from previous engagements were:<br>• Support for walls so they don't fall.<br>• Safey for people and animals.<br>• Preferences for seasonal fresh water and the ability to access these areas.<br>• Prioritise bush tucker for people and animals.<br>• Employ Banjima in rehabilitation works and monitoring after mining.<br>• Elders to be involved in cultural repatriation decisions. | No response. |

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| 22 November 2022 | Heritage Advisory Committee | Banjima representatives / BNTAC | E8 proposal | BHP provided a project overview on identification of existing values, potential impacts and proposed environmental management to the committee members. | **BNTAC / Banjima**<br>Banjima representatives identified water as significant cultural value for BHP to draw focus to.<br>**BHP response**<br>Committed to inviting water experts to next consultation and providing further information on current modelling. |
| 23 November 2022 | Implementation Committee Meeting | Banjima representatives / BNTAC | Inform on closure planning activities | The meeting included an overview of:<br>• The BHP study process.<br>• Progress of the Yandi landform and infrastructure studies.<br>• An overview of the backfill strategy and pit lake locations.<br>• The expression of interest for Yandi camp buildings.<br>• A proposed outline of a program of closure engagements.<br>• Rehabilitation target areas and involvement of Banjima trainees. | **BNTAC / Banjima**<br>Acknowledgement that further discussion of Yandi closure strategies is required and that this will be key topic in upcoming social surrounds to support Part IV approval at Yandi. |
| 22 March 2023 | Heritage Advisory Committee | Banjima representatives / BNTAC | Discussion of Flat Rocks Spring impacts and remediation, E8 proposal, Yandicoogina Gorge and closure planning. | Key points discussed included:<br>• The E8 proposal and the need to move the surplus water discharge point. Cessation of discharge of surplus water will result in tree health decline.<br>• Change to water levels at Yandicoogina Gorge.<br>• Status of Yandi closure planning including:<br>- An overview of the Yandi closure study.<br>- An overview of the closure concept which proposes permanent pit lakes at W2, W3, C4/5 and E7 which will become saline over time.<br>- Backfilling of W1 to maintain groundwater gradient so water is maintained upstream.<br>- Timeline for completion of backfill and closure ~2035 with remaining infrastructure to support ore from satellite mines.<br>- Status of infrastructure removal and the expression of interest for receiving donation of camp buildings. | **BNTAC / Banjima People Response**<br>• Requested:<br>- Further details on infrastructure that will be left to support satellite mines.<br>- 3D model so everyone can see what the land will look like in the future, as well as infrastructure that will be left.<br>- A copy of all the previous MCPs to see history and information base.<br>- Site visit with Senior Elders, BHP General Managers and relevant Subject Matter Experts to discuss management of impacts to water on country.<br>**BHP Response**<br>• Requested documented feedback on water values and what BHP needs to consider.<br>• Provided 2016 and 2020 MCPs and technical appendices (see 29 March and 4 July 2023).<br>• A fly-through, interactive tool is being developed and will be provided (See 12 - 16 June 2023).<br>• Committed to an on-country consultation as requested (see 12 - 16 June ). |
| 29 March 2023 | Email from BHP to BNTAC and consultants | BNTAC (on behalf of the Banjima people) and consultants | Provision of technical documents. | As requested during meeting of 22 March 2023, copies of 2016 and 2020 MCPs provided for review via external link. | No response |
| 18 April 2023 | Letter from BNTAC to BHP | BNTAC on behalf of the Banjima people | Outcomes of internal BNTAC Heritage Advisory Committee meeting to discuss matters raised at the meeting with BHP on 22 March | An internal meeting was held to discuss items arising from the Heritage Advisory Committee meeting on 22 March and the following requests were made to BHP as a result:<br>• Facilitate an on-Country visit to Flat Rock Spring and Yandi.<br>• Organise a water workshop between BHP, BNTAC and advisors.<br>• Implement the stakeholder engagement strategy as outlined in the MCP.<br>• Provide closure documents and environmental data.<br>• Address closure at Yandi in stand-alone consultation sessions as the depth of information is substantial.<br>• Provide further information on the infrastructure that will and will not remain to support satellite mining operations. | **BHP Response by email 11 May 2023**<br>• Committed to:<br>- Facilitating on-Country visits (see 12 - 16 June)<br>- Convening a water workshop (see 11 - 12 July, 25 August and 2 November 2023)<br>• BHP is fully committed to the stakeholder engagement strategy in the MCP and has presented closure related topics at most Implementation Committee meetings (agenda time permitting) since the submission of the 2020 MCP, starting in April 2021 and gradually covering the topics outlined in Table 4-1 of the 2020 MCP. A half day closure planning workshop was held in November 2021 specifically focused on the background of the Yandi closure strategy and future engagement topics. BHP is looking forward to ongoing engagements on Yandi closure strategies and would welcome any feedback on further engagement that BNTAC and or Banjima representatives would like.<br>• BHP is seeking opportunities to engage on closure related topics in greater depth and would like to participate in additional, closure-specific discussions if this is supported by the relevant Banjima committees. In addition to Yandi closure focused discussions that will occur as part of upcoming Social Surroundings consultation, BHP would like to take the time to work through this detail with committee members, including hosting an on-Country session later in 2023.<br>• BHP supplied the 2020 MCP and technical appendices to BNTAC on 29th March 2023. Prior to the next social surrounds meeting, BHP will provide to BNTAC and supporting consultants, additional technical documents relevant to the pit lake closure strategies (see 4th July).<br>• BHP has decommissioned Ore Handling Plant (OHP) 1, OHP 2, Train Load Out (TLO) 1 and Yandi Camp (currently under demolition). There are also numerous small facilities and buildings around the site e.g. old gate house, communication structure or storage areas that will be included in future demolition projects. The timing of future demolition projects is under assessment and will be discussed with Banjima as part of ongoing consultation.<br>• BHP proposes to continue to use OHP 3, TLO 2, administration buildings, heavy vehicle maintenance workshop, stores, spinifex camp, access road and airport (shared with RTIO). |

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| 12 - 16 June 2023 | Yandi Social Surrounds | Banjima representatives / BNTAC and their consultants | Banjima led social surroundings on-Country engagement including E8 project overview.<br>The site visit and associated discussions were documented in a report by Australian Cultural Heritage Management which was delivered on 18 June 2023. | Locations visited as per Banjima request were Flat Rock Spring, and stockyards located at E7 Pit.<br>A closure fly through video was shown which explains the formation of pit lakes (including the evolution of salinity) and the current closure concept for Yandi (and a copy was sent to BNTAC by email on 17 July 2023).<br>Key discussion points relevant to closure are as follows:<br>• Water was the environmental element of most concern. From the Banjima people's perspective, water the life blood of the land and the essential life force of the Banjima people themselves. Consequently, the Fortescue River and all of its tributaries are of central importance. All underground, surface and ephemeral waterways are equally important and anything that impedes the warlu's (water serpent creation ancestor) movement through Country is dangerous to the Country and the Banjima people. The Banjima people have a very keen sense of their cultural responsibility to maintain the Fortescue River system, including its tributaries, to ensure lore and culture are maintained. They also have a responsibility to neighbouring groups, to ensure no detrimental impacts on neighbouring groups downstream.<br>• The Banjima and their consultants stated that they would not be willing to accept saline pit lakes as an impact.<br>• To protect Banjima's interests appropriately, water management requires the co-operation of all operating mining companies, particularly neighbouring operations that involve dewatering.<br>• Banjima representatives discussed ideas for the final landform design for pits, including smoothing off pit benches and taking pit edges further out to generate more fill to cover the recovered groundwater level and prevent the formation of pit lakes. It was acknowledged that this would increase the overall area disturbed, but this was preferred to permanent saline pit lakes on Country, as the disturbance can be rehabilitated. The long-term outcome would look more natural.<br>• The principal issue for Banjima is that the land needs to be returned to as close as possible its natural state.<br>• The management, storage and disposal of potentially contaminating materials (such as non-putrescible wastes, medical waste, hydrocarbons, asphalt, and contaminated soils) was discussed.<br>• The Banjima representatives were impressed by the Yandi nursery facility. However, it was noted that it is still in its infancy will need to be expanded given the size of the closure task ahead.<br>• The northern edge of the proposed E8 Pit is located approximately 150 m south of Marillana Creek. Concerns were raised about the proximity of this proposed pit to the creek for multiple reasons, including dewatering impacts on the creek and groundwater-dependent ecosystems and vegetation, other direct and indirect disturbance (dust, noise, vibration, visual) and potential downstream impacts. | **BNTAC / Banjima People Response**<br>• Key issues raised included:<br>- Saline pit lakes.<br>- Impacts to Yandicoogina Gorge and Flat Rocks Spring.<br>- Proximity of the proposed E8 pit to Marillana Creek.<br>• The following requests were made:<br>- BHP to determine an alternative to saline pit lakes.<br>- Establish a joint water working group with regular meetings to discuss water management issues on Banjima Country.<br>- Establish a dedicated mine closure group to commence detailed discussions about mine closure on Banjima Country.<br>- Infrastructure no longer in use is removed and the land rehabilitated.<br>- Potentially contaminating waste is not disposed of on Banjima Country as Banjima people do not want to inherit Country that is contaminated.<br>- Include culturally important species in assessments with other listed species in environmental impact assessments. Examples of such species are the Hill kangaroo or Euro (*Osphranter robustus*), goanna (Varanus spp.), Emu (*Dromaius novaehollandiae*), Bush turkey or Australian bustard (*Ardeotis australis*) and native honeybee (*Trigona* and *Austroplebeia* spp.).<br>- BHP to consider establishing an environmental monitoring data portal.<br>- Involvement of Banjima people in environmental monitoring for BHP and consider opportunities to incorporate traditional ecological knowledge into monitoring programs wherever possible.<br>- Backfill the E8 Pit to the original ground level at closure.<br>**BHP Response**<br>Plan a further closure- and water-specific engagement sessions in conjunction with BNTAC. |

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| 23 June 2023 | Heritage Advisory Committee | Banjima representatives / BNTAC | BHP provided a summary of the Social Surroundings consultation that took place a week prior and responded to comments / concerns raised by Banjima during the Social Surroundings consultation. | BHP provided:<br>• An overview of feedback from the June Social Surroundings engagement.<br>• An update on Flat Rocks Spring including the results of monitoring showing rebound of groundwater levels following decrease in abstraction from W0, and tree health monitoring indicating that tree health had been stable.<br>• An update on infrastructure as follows:<br>- Decommissioning of OHP 1, OHP 2, IOWA Crusher, TLO 1 and Yandi Camp (currently under demolition).<br>- Timing of future demolition projects is under assessment and will be discussed with Banjima as part of ongoing consultation.<br>- BHP proposes to continue to use the following infrastructure areas for mining and future ore processing; OHP 3, TLO 2, administration buildings, heavy vehicle maintenance workshop, stores, Spinifex Camp, access road and airport (shared with RTIO).<br>- A program for demolition of small facilities and buildings will be developed as they are assessed as no longer necessary to ongoing operations.<br>• Update on progressive closure activities (backfilling, rehabilitation, demolition of Yandi camp).<br>With reference to a dedicated session on the Yandi Closure strategy and pit lake outcomes, BHP:<br>• Requested that Banjima provide feedback at the session on:<br>- How the Banjima people would like to use the land after mining.<br>- How Banjima water values can be incorporated into closure outcomes.<br>- How Banjima landscape values can be incorporated into closure outcomes.<br>• Presented the proposed agenda for the session including:<br>- The outcomes of closure studies.<br>- Update on progressive closure activities and opportunities to participate.<br>- Outcomes of rehabilitation activities. | **BHP Response**<br>Committed to:<br>• Backfilling E8 to above water table.<br>• An implementation strategy to mitigate impacts at Yandicoogina Gorge, including continued engagement with Banjima throughout implementation.<br>• Facilitating a “Water Workshop” between BNTAC and BHP, focusing on water management across Banjima country<br>Requested:<br>• Review and comment on 2020 MCP with a specific focus on the closure strategy and pit lake outcomes. |
| 4 July 2023 | Email from BHP to BNTAC with technical documents | BNTAC (on behalf of the Banjima people) and consultants | Provision of technical documents | Provided 2020 MCP files and the GoldSim modelling report completed post the 2020 MCP<br>Formal request for feedback on the MCP | No response |
| 11 - 12 July 2023 | Flat Rocks & Yandi Closure Strategy | Banjima representatives / BNTAC and consultants | Flat Rocks tree health decline and closure workshop | Discussed issues around the tree health decline in the Flat Rocks area including the BHP mitigation plan.<br>Provided an introduction to the Yandi MCP and closure strategy, in follow up to the Social Surrounds meeting in June 2023. This workshop was to progress discussions and develop common knowledge about the pit lake strategy. | **BNTAC / Banjima People Response**<br>• Banjima Elders are not supportive of pit lakes - especially saline ones.<br>• Banjima want more consultation and an opportunity to allow consultation to catch up before a final closure alternative is chosen.<br>• Banjima want joint consultation with BHP and RTIO to understand the cumulative post-closure landscape.<br>• BNTAC will issue a letter summarising concerns about the Yandi closure strategy.<br>**BHP Response**<br>BHP will work with BNTAC to hold a joint meeting with RTIO on the Yandi closure strategy. |
| 22 July 2023 | Email from BNTAC to BHP on Yandi Post Mining Land Use paper | BNTAC on behalf of the Banjima people / BHP | Post-mining land use paper | BNTAC requested that BHP supply internal documents relating to the process around determining Post Mining Land Use opportunities for Yandi. | **BHP Response**<br>The following information was provided:<br>• The location within the MCP where a summary of the internal reports was provided.<br>• A paper produced by Pershke Consulting around the process to investigate post-mining land uses that made reference to BHP as a case study without providing the details of investigation outcomes. |
| 25 July 2023 | Letter to BNTAC from BHP | BNTAC on behalf of the Banjima people | Flat Rocks Spring | Letter committing to working collaboratively and constructively with the Banjima people to find a solution for Flat Rocks Spring including:<br>• Evaluation of long-term management options for Flat Rocks Spring and incorporation of any relevant measures for closure into the MCP.<br>• Workshop to discuss remediation options. | See workshop on 25 August |

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| 28 July 2023 | Letter from BNTAC to BHP on Yandi Closure | BNTAC on behalf of the Banjima people | Follow up to workshop on 11 - 12 July 2023. | Letter recognising the effort that BHP staff put into delivering the content of the closure workshops, as well as the progression of a remedial groundwater strategy for Flat Rock Springs. The letter identified a need for:<br>• BHP and BNTAC to explore potential post-mining land uses and to consult with the Banjima Traditional Owners on alternative uses.<br>• Joint BNTAC / BHP / RTIO water workshops to discuss Flat Rock Springs and broader water issues on Banjima Country and to explore possible approvals pathway for a remediation strategy at Flat Rock Springs.<br>Requests were made to:<br>• Provide further technical study information arising from the IPS.<br>• Provide a high-level document outlining the decision-making process behind closure options to date.<br>• Halt progression from the SPS to the DPS until BNTAC and Banjima have reviewed technical studies and workshopped Banjima requirements for post-mining land use.<br>• Acknowledge the broader context of water on Banjima Country as it relates to Yandi closure and post-mining land use opportunities. | **BHP Response**<br>A joint meeting on closure strategies was held between BNTAC, RTIO and BHP on the 25th August.<br>A publicly available paper on the process used to investigate land uses was provided on 31 July 2023.<br>Summaries were prepared of:<br>• Post-mining land use investigations which included relevant information in the report prepared in 2019 and subsequent work<br>• The decision-making process behind closure options to date.<br>These documents were provided on 16th January 2024 (see below). |
| 25 August 2023 | Joint meeting on closure strategies | BNTAC on behalf of the Banjima people / RTIO / BHP | Closure strategies for Yandi and Yandicoogina. The purpose of the workshop was to discuss options that could be brought to the Banjima Traditional Owners for their consideration. | Items discussed included:<br>• BHP Flat Rocks mitigation and RTIO involvement. No fatal flaws were identified for the Flat Rocks Springs remediation.<br>• BHP Yandi closure landforms including the E7 (water filled void) and E8 (backfilled to above returning water table) closure strategies.<br>• RTIO Yandicoogina closure landforms.<br>• Interfaces between RTIO and BHP.<br>• Marillana Creek land bridge between E6 and E7 near the stockyards was originally a semi-permanent pool with a Melaleuca community in the land bridge location. The current condition is that there is no pool due to voids on either side, which result in under draining and the Melaleucas dying. The discharge point currently provides the closest to what was there historically.<br>• Banjima may prefer to have a clearance of land to create borrow pit to minimise or eliminate pit lakes or saline pit lakes. | **BNTAC Response**<br>• The scope of work discussed for Flat Rocks Spring was generally supported for subsequent discussion with the Banjima people.<br>• The historic semi-permanent pool is desired to be re-instated as part of closure in some locations along Marillana Creek.<br>• Banjima are not supportive of pit lakes and particularly saline pit lakes.<br>• Consider reviewing the closure landforms and use of the available fill (and more broadly from the mines in the region) across the RTIO / BHP operations to optimise solutions that consider Banjima people's preferences.<br>**BHP Response**<br>BHP will develop actions and share with BNTAC and RTIO. Actions to include:<br>• Data Sharing<br>• Establishment of a hydrogeology technical working group.<br>• Establishment of an environmental approvals working group.<br>• Establishment of a closure landform planning technical working group.<br>BHP will develop more details around strategies for closure of E8. |
| 26 - 27 September 2023 | Heritage Advisory Committee | Banjima representatives / BNTAC | BHP provided a closure planning update and project overview of Yandi E8 including identification of existing values, potential impacts and proposed environmental management to the committee members. | The session included:<br>• An overview of the outcomes of the:<br>  - BNTAC / BHP closure meeting on 14th July.<br>  - BNTAC / RTIO / BHP meeting on 25th August.<br>• Proposed next steps:<br>  - Development of technical group (BNTAC / RTIO / BHP) to discuss:<br>    ▪ Closure design opportunities.<br>    ▪ E8 and adjacent RTIO Mungadoo Pit closure strategies.<br>  - Ongoing BNTAC / BHP consultation on closure strategies for:<br>    ▪ Flat Rocks.<br>    ▪ Stock Yards.<br>    ▪ Post mining land uses.<br>  - Provision of closure strategy for E8 at the next Social Surrounds meeting. | No response. |
| 2 November 2023 | Martidja Banjima Consultation / Workshop | Banjima representatives / BNTAC | Yandi landscape consultation on closure / Flat Rocks and Yandicoogina Gorge remediation strategies / E8 | Meeting discussed:<br>• Impacts at:<br>  - Yandicoogina Gorge and proposals for short term operational mitigations.<br>  - Flat Rocks and mitigation plans (incorporated into the Marillana Creek Water Resource Management Plan and proposed Integrated Management Plan for Flat Rocks Spring).<br>• E8 proposal including the proposed plan to backfill the pit to above the water table (not pit crest) and predicted groundwater drawdown during operations.<br>BHP presented information on the seed production area and tree nursery and noted that seedlings will be used to supplement rehabilitation where seeding has not resulted in the outcomes expected. BNTAC proposed that a commercial arm could be developed as a Banjima project.<br>BNTAC suggested that an online monitoring portal be established.<br>BNTAC requested BHP remove all infrastructure at closure, rather than leaving footings in place. | Through co-development of the Social Cultural Heritage and Environmental Management Plan for the Proposal, BHP and BNTAC committed to ongoing engagement in relation to rehabilitation. This may include inclusion of bush tucker species in rehabilitation seed mixes where practicable and creation of fauna habitats during closure.<br>BHP noted the request to remove footings and the request for an online monitoring portal. The portal may not be possible, but data will be shared at future Heritage Advisory Council (HAC) meetings. |

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| 6 - 7 December 2023 | Heritage Advisory Committee | Banjima representatives / BNTAC | BHP provided an overview of the engagement between Banjima and BHP to date for the E8 proposal, including issues raised by the Banjima people and recommendations/ commitments made by BHP. | BHP committed to:<br>• Identify and implement mitigation option(s) to mitigate tree health decline at Flat Rock Spring, Yandi and Marillana Creeks.<br>• Provide the opportunity for Banjima people to be involved in, and undertake environmental monitoring, surveys and rehabilitation activities.<br>• Share key environmental data metrics which can be monitored through time by Banjima people. | No response |
| 16 January 2024 | Email from BHP to BNTAC | BNTAC on behalf of the Banjima people | Post-mining land use and closure IPS option evaluation summary | In response to requests from BNTAC, BHP provided two memos summarising:<br>• Post-mining land use investigations which also proposed an approach to working with BNTAC / Banjima to define post-mining land uses for Yandi.<br>• The decision process forming the basis of the current design concept. | **BNTAC response**<br>BNTAC expressed appreciation for the information and noted that the organisation is working on a more formal response / proposal that will feed into the 'next steps' proposed by BHP.<br>BNTACs intention over 2024 is to produce an internal document articulating 'Banjima Principles in Mine Closure and Post Mining Land Use'. This document is intended to be the basis on which all Banjima consultations on individual mine closures / post-mining land uses stem from.<br>BNTAC will use social surroundings consultations with all proponents throughout 2024 to engage Banjima Traditional Owners on closure and post-mining land use principles to help facilitate the production of the document.<br>BNTAC will also engage with BHP on Yandi -specific Traditional Owner consultations on closure / post-mining land use workshops in 2024, as per BHPs 'next steps' proposal to gain alignment on a post-mining future at Yandi. |
| 8 February 2024 | Email from BNTAC to BHP | BNTAC and their technical advisers on behalf of the Banjima people | Feedback on the E7 Mungadoo water balance | Feedback was provided on the AQ2 (2023a) E7 Mungadoo water balance report by Pentium Water on behalf of BNTAC. A summary of comments follows:<br>• The proposed presence of saline pit lakes following closure is unacceptable to the Banjima people and further options for avoiding permanent saline pit lakes be considered, potentially including diversion of surface water into pits.<br>• Combing the Mungadoo and E7 water balance models highlights deficiencies and risks associated with isolated modelling which reduces confidence in modelling outcomes. A recommendation was made for a combined water balance model to be developed for the entire length of the BHP and RTIO Yandi operations and for sensitivity analyses to be conducted, including an understanding of the worst-case scenario. | **BHP / RTIO Response**<br>BHP and RTIO have committed to working together to improve their understanding of the cumulative effects of the closure plans for their respective mines.<br>Further consultation will be conducted with BNTAC and the Banjima people and their consultants to provide context to the plans developed to date, and the consequences of diversion of surface water into pits (including the potential impacts to riparian vegetation). |
| 20 May 2024 | Preliminary Ethnobotanical Survey - Banjima People | Banjima people and ethnoecologist | Survey completed in the Ministers North area and report prepared for Banjima participants. | At least 126 cultural or heritage plant species have been found or are likely to occur in the Ministers North area and vicinity. These plants were identified in a desk top survey and a 3-day on-ground reconnaissance with five Banjima women plus BHP staff and the ethnoecology consultant. Twenty-one useful plants were found on the reconnaissance and the remaining 112 plants were identified from books and reports relevant to the area. | **BHP Response**<br>Several species of cultural significance are currently included in seed mixes (Appendix I.1) and consideration will be given to how a greater diversity of culturally significant species can be included in future rehabilitation programs. |

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
|---|---|---|---|---|---|
| 30 August 2024 | Meeting with BNTAC and their consultant | BNTAC on behalf of the Banjima people and consultant | Meeting to discuss the review of the MCP and provide feedback from BNTAC | Detailed feedback from BNTAC is presented as Appendix J.3 along with BHP's responses to the feedback which have been incorporated into this MCP, as appropriate. A summary of the key points raised is as follows:<br>• Saline pit lakes post-closure are not acceptable to Banjima and the residual risk remains high.<br>• Requirement for connections between heritage and cultural sites along song lines and cultural access pathways to be restored.<br>• The purpose of the MCP to include reference to engagement with Banjima with a view to gaining free, prior and informed consent.<br>• Further details of the Indigenous Land Use and Comprehensive Agreements requested.<br>• The request to halt the progression of the SPS was to allow BNTAC and Banjima to review technical studies and to fully understand the process and rationale for outcomes of the IPS. This includes achieving agreement on post-mining land use and shared closure principles.<br>• BNTAC acknowledged BHP's commitment to work collaboratively with the Banjima on several topics including visual amenity, saline pit lakes and post-mining land use and stated that it expects that information from these sessions and changes to the closure strategy will be incorporated in future iterations of the MCP. Further detail on post-mining land use investigations was requested.<br>• BNTAC is working with Banjima to identify specific expected closure outcomes that reflect Banjima's expectations and values and expect that this is reflected in the next iteration of the MCP.<br>• Further detail was requested to be provided on the spiritual and cultural knowledge held by the Banjima people.<br>• Collaborative engagement with Banjima was requested on completion criteria, supported by independent technical reviews.<br>• Request for the MCP to provide further information on the management of post-relinquishment risk and liability. | **BHP Response**<br>BHP has made several amendments to the MCP in response to BNTAC's comments (refer to Appendix J.3 for further details) including:<br>• Update to the residual risk of impacts to Banjima cultural values from saline pit lakes (Section 7.4).<br>• Reference to songlines and post-closure access in Section 5.12.3 and the forward work program (Section 13.3).<br>• Acknowledgement that part of the purpose of the MCP is to facilitate consultation with the Banjima people (Section 1.1).<br>• Further detail on Indigenous Land Use and Comprehensive Agreements (Section 3.3.3).<br>• Updates to Section 1.4 on reasons for BNTAC requesting the halt to the SPS.<br>• BHP has committed to continuing to work with the Banjima people on post-mining land uses via closure workshops and forums (Section 6).<br>• BNTAC recently (21 March 2025) provided BHP with a copy of the Banjima Mine Closure Objective, Principles and Outcomes. The objective, principles and outcomes will inform future discussions and updates to the MCP.<br>• Some minor updates have been included in Section 5.12, but in recognition that this MCP is a publicly available document and that there may be sensitivities in sharing certain information, advice is sought on the information that the Banjima people would be willing to share publicly. This can be incorporated into the MCP.<br>• Ongoing discussions on post-mining land uses and Banjima closure principles and values will shape the closure outcomes for Yandi, which in turn will require the development of supporting completion criteria. Peer reviews of selected criteria will be conducted as appropriate and summarised in updates to the MCP (Section 8.3).<br>• The forward work program has been updated to reference the need for a residual post-relinquishment risk and liability assessment and management strategy (Section 13.3). |
| 23 - 29 September 2024 | Ministers North Social Surroundings Engagement | Banjima representatives / BNTAC | While this meeting was focused on the Ministers North Part IV application, some information relevant to Yandi closure was discussed. | Discussions relevant to the Yandi MCP included the following:<br>• Banjima people raised the possibility of the overburden at Ministers North to be utilised in the backfill of Yandi.<br>• Banjima have a preference for traditional "bush medicine" plants to be incorporated into rehabilitation. | **BHP Response**<br>BHP agreed to consider the feedback provided and evaluate options. |
| 30 October 2024 | Banjima Closure Principles Workshop #1 | Banjima representatives / BNTAC and consultants | First engagement with Banjima representatives, BNTAC and their consultants on closure principles and outcomes. | BNTAC provided a presentation on preliminary Banjima closure objectives, principles and outcomes. These have been developed for the purpose of socialising with the Banjima people and their key stakeholders. Following sufficient engagement, the objectives, principles and outcomes will be finalised and formally communicated for consideration by proponents within their planning and applications. Key aspects covered by the closure objectives, principles and outcomes were:<br>• Ideas for collaborative engagement on closure including quantification and communication of risks and liabilities.<br>• Consideration of cumulative impacts and opportunities within the Banjima Native Title Determination area including prioritisation of repurposing of existing disturbed land for future development rather than disturbance of new land.<br>• Communication of long-term planning for mining operations.<br>• Maintaining surface water quality and no saline pit lakes.<br>• Visual amenity.<br>• Post-closure access and management of cultural materials and sites.<br>• Ex-pit storage of overburden.<br>• Management of waste and contaminated sites.<br>• Return of environmental diversity, Mandu (bush meats) and medicine and bush tucker plants.<br>• Flexibility of land capability to support future economic development.<br>BNTAC expressed the need for earlier engagement in mine planning, development and study timing, with BNTAC and Banjima engagements to occur during IPS.<br>BHP provided a presentation on BHP's approach to closure planning and post mining land use principles which include considerations of land capability, compatibility with surrounding land uses and mine plans, supporting infrastructure and economic sustainability of a land use and pathways to relinquishment | **BHP Response**<br>BHP:<br>• Acknowledged the presentation of the preliminary principles and outcomes for consideration and further future discussion.<br>• Committed to sharing the Life of Asset plan with Banjima and BNTAC in future engagements.<br>**BHP / BNTAC Responses**<br>• The conversation was beneficial, and that the momentum should not be lost on the topic.<br>• Regular (twice a year with Banjima) dedicated sessions on closure. |

| Date | Description of Engagement | Stakeholders | Topic | Engagement Summary | Response |
|---|---|---|---|---|---|
| 20 November 2024 | Banjima Closure Principles Workshop #2 | Banjima representatives / BNTAC and consultants | Second engagement with Banjima representatives, BNTAC and their consultants on closure principles and outcomes.<br><br>This was a follow up meeting to the workshop on 20th October and included:<br>• Sharing BHPs Life of Asset plan across Banjima country and a discussion on timing of the developments and how the mines will be developed.<br>• Discussion on the ongoing routines to talk through closure principles.<br>• Initial discussions on post mining land uses preferred by the Banjima people. | Key points raised which are relevant to the closure of Yandi are as follows:<br>• BNTAC consultants presented their ideas for potential post-mining land uses associated with water and power.<br>• The Banjima people expressed a strong view on the need for the restoration of natural and cultural values post mining, but did not express a strong position on other post mining land use outcomes.<br>• Transition land uses should be targeted and support restoration towards post mining land use. These land uses could include recycling opportunities (tyres, belts scrap), and rehabilitation project work to support closure outcomes. | **BNTAC Consultant Response**<br>Appreciated the information shared on Life of Asset planning.<br>**BHP / BNTAC Responses**<br>There was general agreement that the next engagement should be on site to review rehabilitation and discuss closure landforms. |
| 21 March 2025 | Email to BHP | BNTAC on behalf of Banjima representatives | Banjima Board and HAC endorsed Banjima Mine Closure Objective, Principles and Outcomes | A final version of the of the Banjima Mine Closure Objective, Principles and Outcomes was provided to key BHP representatives. | **BHP Response**<br>BHP acknowledges the finalised Banjima closure principles which will inform future discussions and updates to the MCP. |
| **Shire of East Pilbara** | | | | | |
| 22 August 2022 | Infrastructure | Shire of East Pilbara Joint Technical Working Group | Provide information on Yandi surplus infrastructure donation expression of interest | Provided information on BHP's intention to request expressions of interest from not-for-profit community groups and organisations within Shire of East Pilbara for receiving donations of surplus infrastructure from the Yandi camp.<br>Requested information on Shire requirements of applicants (e.g., building approvals, development applications etc). | **Shire Response**<br>Expressed appetite to support the process and committed to providing BHP with a 'pack' including all of the relevant detail around development applications, building permits etc. which can be attached to the expression of interest. The Shire enquired about the opportunity to review final expression of interest.<br>**BHP Response**<br>Provide the expression of interest for Shire review once complete. |
| **Other mining companies** | | | | | |
| 14 April 2016 | Yandi Closure – hydrological data sharing | RTIO | BHP's Yandi E7 and RTIO's Yandicoogina Oxbow dewatering information sharing | RTIO to share with BHP Oxbow [now named Mungadoo] pit lake's predicted water levels and water quality, and groundwater numerical model assumptions which underpin prediction of aforementioned parameters, such as: recharge, hydraulic conductivity, porosity, evaporation, surface water interaction (pit inflow and creek seepage) and outflow from BHP's Yandi operations.<br>BHP to share with RTIO the predicted groundwater throughflow at the eastern lease boundary of its Yandi operations and its quality, and details of the hydrological assumptions used for BHP's numerical groundwater model such as recharge, evaporation, hydraulic conductivity, porosity, surface water interaction (pit inflow and creek seepage). | **BHP / RTIO Response**<br>Both parties approved data sharing. |
| 22 February 2018 | Yandi Closure – hydrological data sharing | RTIO | Information on the companies' respective closure strategies | Both companies shared their current closure strategies and provided a high-level overview of completion criteria for surface and groundwater and the outcomes of some of the associated technical studies. | **BHP / RTIO Response**<br>Both parties agreed once data sharing agreement signed off to catch up again, with first focus being on surface water hydrology.<br>Future discussions to include:<br>• Final land use and landforms and opportunities to work to the same goal.<br>• Potential for a single model for surface water that covers both sites. |
| 22 October 2020 | Coordination of closure planning & closure outcomes | RTIO | Mine Closure Planning update - Yandi and Yandicoogina | Meeting included:<br>• An update on closure planning strategy and objectives for RTIO and BHP for the Yandi and Yandicoogina operations.<br>• BHP activities and update to MCP in September 2020.<br>• RTIO activities and update to MCP in April 2020.<br>• Reinvigorating the data sharing agreement.<br>• Developing a routine meeting between the two parties.<br>• Proposal to meet with pastoral station management for both parties. | BHP and RTIO shared the most recent versions of their respective MCPs. |
| 28 March 2023 | Closure strategies | RTIO | Closure strategies for Yandi and Yandicoogina | Meeting included:<br>• Update on BHP Yandi Closure Strategy and Outcomes.<br>• Update on RTIO closure strategy and outcomes.<br>• Data Sharing. | No formal response required. |
| 11 August 2023 | Closure strategies | RTIO | Closure strategies for Yandi and Yandicoogina | Meeting included:<br>• Update on BHP Yandi Closure Strategy and Outcomes.<br>• Update on RTIO closure strategy and outcomes.<br>• Data Sharing.<br>• Discussions of outcomes of recent engagements with Traditional Owners on pit lakes. | Data to be shared. |

# 5 Collection and analysis of closure data

Consistent with the adaptive management approach in the Guidelines for Mine Closure (DMIRS, 2020b), BHP has commissioned several studies to inform relevant considerations for mine closure planning. As discussed in Section 1.4, closure studies and trials are iterative as many closure considerations are interlinked. This is particularly true at Yandi where there are strong links between several variables, including surface water infrastructure designs, backfill designs and surface water / groundwater / pit lake outcomes. This section provides a snapshot in time of the current knowledge base and design considerations, noting that the SPS has only been partially completed. This means that studies described in this section are the most current for a particular knowledge area but may have been completed at different times to other studies and consequently may not reflect the current state of knowledge for those study areas. Section 13.3 outlines the forward work programs aimed at addressing the knowledge gaps identified in this section.

The proposed closure management of Yandi presented in Section 9 of this plan has been based on our current understanding of the surrounding environment and closure design approaches as summarised in the following sections:

- Local climatic conditions and projected future climate change for the area (Section 5.1);
- Geology, soils and overburden characterisation including geochemical properties, soil and overburden structure and stability (e.g. erodibility), backfill hydraulic properties and growth medium type (Sections 5.2 and 5.3);
- Seismicity and pit wall geotechnical and erosional stability analyses (Section 5.4);
- Landforms, land systems and local and regional information on flora, fauna, ecology, communities and habitats (Sections 5.5 to 5.8);
- Hydrology and hydrogeology baseline conditions (Section 5.9); and
- Contaminated sites, visual amenity, cultural heritage and local land use (Sections 5.10 to 5.13).

Following the DEMIRS Guidelines (2020a; 2020b), studies informing closure and rehabilitation designs are also presented in this section (Sections 5.14 and 5.15), including:

- Mine void backfill option evaluation and design process (Sections 5.14.1 and 5.14.2).
- Pit lake water quality modelling and risk assessments (Sections 5.14.3 to 5.14.6).
- Surface water infrastructure design studies (Sections 5.14.7 to 5.14.10).
- Mine void stabilisation options (Section 5.14.11).
- Preliminary materials balance (Section 5.14.12).
- Sustainable yield assessment which investigated the potential for water from Yandi pits to be used to support a broadscale irrigated agriculture project (Section 5.14.13).
- Rehabilitation research and progressive rehabilitation performance (Section 5.15).

Section 7.3 provides a summary of the cumulative changes to the environment following the closure of Yandi.

## 5.1 Climate

### 5.1.1 Existing climate

The Yandi mine is located in the Pilbara region of Western Australia where the climate is semi-arid to arid and characterised by irregular rainfall and hot summers. Tropical lows and cyclones dominate the Pilbara's climate in the summer wet season. Cyclonic systems deliver widespread rain across the region, with rainfall occurring mostly between December and March (Table 5-1). However, southern cold fronts can also extend north to the Pilbara in late autumn, winter, and early spring, bringing rains to the region, most commonly to western parts (CSIRO, 2015a).

The dominant growing season is from December to March. When winter rainfall occurs, it supports the growth of shrubs and cool season ground covers (Golder, 2020b).

**Table 5-1 Rainfall at Marillana rainfall station**

| Statistic | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 79.1 | 68.9 | 49.5 | 23.6 | 21.2 | 20.4 | 14.0 | 5.6 | 3.1 | 5.3 | 10.4 | 27.8 |
| Highest Daily | 255.0 | 129.5 | 171.7 | 72.0 | 57.2 | 84.6 | 91.0 | 55.9 | 35.0 | 26.4 | 63.0 | 86.0 |

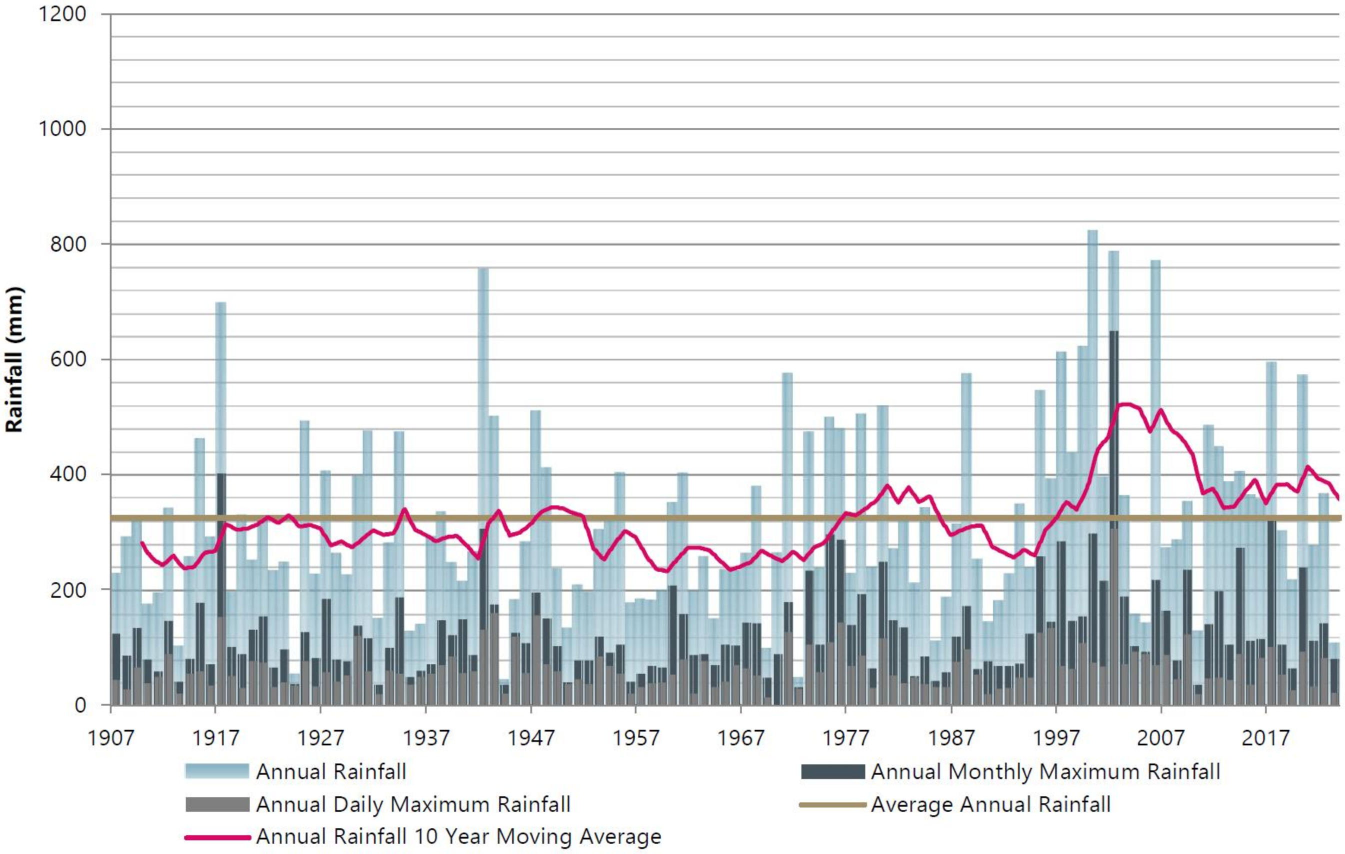
Source: Bureau of Meteorology (BOM) (2020)

Average annual rainfall within the Marillana Creek catchment ranges from 450 mm in the west of the catchment to just over 300 mm near the confluence with Weeli Wolli Creek in the east. The long-term average annual rainfall recorded at the Marillana rainfall station (BOM ID 5009) is 329 mm (BOM, 2020). The rainfall station opened in 1936 and is located approximately 32 km away from Yandi. The long-term average annual rainfall (1967-2020) at the Flat Rocks stream gauging station (DoW ID 708001), located approximately 300 m upstream of the Yandi lease boundary, is 383 mm.

Annual rainfall is highly variable and extended periods of low rainfall are common. This is supported by BoM's index of variability, with the variability of annual rainfall classified as high, whilst variability in the wettest months (January to March, producing approximately 60% of annual rainfall) reaches very high in the lower Marillana Creek catchment areas. The variability of rainfall is demonstrated in Figure 5-1 and Figure 5-2 for the Bonney Downs and Mulga Downs sites respectively. These are the closest long-term rainfall data sites available (on average, both approximately 100 km from Yandi mine). In some years, large daily events almost reach the long term annual average rainfall and similarly, particularly wet months can comprise a significant portion of the yearly total and easily exceed the long term annual average (e.g., December 2002 at Bonney Downs and December 1975 at Mulga Downs which was responsible for the largest flood on record at Flat Rocks) (Advisian, 2023c).

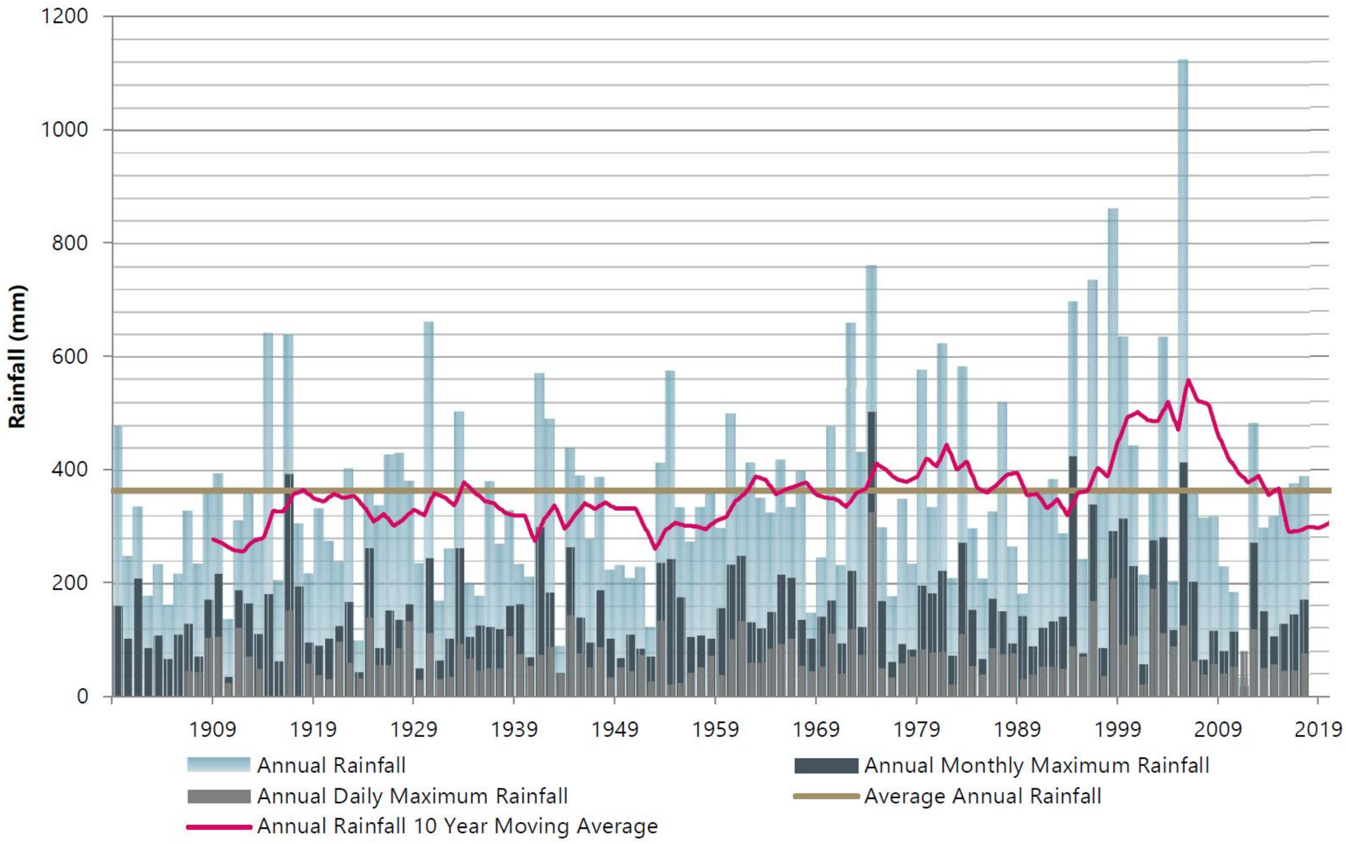
Both the Bonney Downs and Mulga Downs sites (Figure 5-1 and Figure 5-2) show trends towards increased annual rainfall over the last approximately 25 years, with wetter than usual periods throughout the late 1990s and early 2000s. The late 2000s trend back to drier than average conditions. Recorded annual daily maxima which are a reasonable meteorological indicator of a likely flood-inducing event seemingly remain more consistent, albeit following similar trends, highlighting the link between discrete intense events and the annual total (Advisian, 2023c).

The Intensity Frequency Duration (IFD) data used in surface water modelling by Advisian (2023c) are provided in Appendix D.1.




Source: Advisian (2023c)

**Figure 5-1 Bonney Downs historical rainfall summary**




Source: Advisian (2023c)

**Figure 5-2 Mulga Downs historical rainfall summary**

Temperatures measured at Newman Aero (BOM ID 007176), approximately 100 km from Yandi, indicate that mean maximum temperatures in the summer months from November to February exceed 37°C and maximum temperatures above 42°C are common. Mean maximum and minimum temperatures in winter (June to August) are between 23 to 26°C and 6 to 8°C, respectively (Table 5-2).

**Table 5-2 Temperature at Newman Aero**

| Statistic | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean maximum (°C) | 39.0 | 37.4 | 35.4 | 32.1 | 27.2 | 23.0 | 23.1 | 26.1 | 30.5 | 35.3 | 37.6 | 39.3 | 32.2 |
| Mean minimum (°C) | 25.1 | 24.1 | 22.1 | 17.6 | 11.9 | 7.4 | 6.4 | 7.9 | 12.2 | 17.9 | 21.1 | 24.1 | 16.5 |

Source: BOM (2020)

Annual average evaporation potential is far in excess of the annual average rainfall, as are evaporation potentials in all individual months. Mean Class A pan evaporation at Jigalong and Newman are 4,066 and 3,733 respectively, which is an order of magnitude higher than the average annual rainfall (MWH, 2016a; Luke, Burke, & O'Brien, 1987). As a result, there is commonly a large moisture deficit in the environment.

### 5.1.2 Climate change

BHP accepts the Intergovernmental Panel on Climate Change's (IPCC) current view that warming is unequivocal, human influence is clear, and physical impacts have occurred and will continue to intensify (IPCC, 2023). BHP believes the world must pursue the aims of the Paris Agreement with increased levels of national and global ambition to limit the impacts of climate change. BHP's Climate Transition Action Plan (BHP, 2021d) sets out the strategic approach to achieving our long-term greenhouse gas emissions reduction goals, and the Climate Change Global Standard (BHP, 2023i) focuses on climate change risk management and strategies. These strategies include operational greenhouse gas emissions reduction by using and investing in low emissions technology, supporting emissions reduction in our value chain, promoting product stewardship and increasing our resilience to physical climate change impacts.

Climate change is a complex issue, with inherent uncertainty about the timing, pace, and severity of possible impacts. Risks from climate change to the stability of landforms, mobilisation of contaminants and re-vegetation are some of the identified vulnerabilities considered in closure planning.

We have worked with the CSIRO to obtain regional analyses of climate change science and understand that climate change will amplify existing risks in BHP's mining and associated port and rail operations in the Pilbara region. CSIRO (2015a) forecasted Pilbara region climate conditions for 2030 and 2050 under various emissions scenarios and concluded that:

- Conditions would be hotter (both averages and extremes) with higher potential evaporation:
  - Forecast temperature changes were 1.5 to 1.6°C for 2030 and 2.1 to 2.9°C for 2050.
  - Projected changes to evaporation ranged from annual increases of 3% to 4% for 2030 and from 4% to 7% for 2050.
- Tropical cyclones may decrease in number but increase in intensity and duration over the same period.
- There may be more unpredictable characteristics of other climate-related hazards, including flooding, storm surges and wildfires, e.g. in 2050 CSIRO forecasted up to 100% increase in days with extreme forest fire danger index (up to 44 days per year) from the current average of 23 days per year.

Climate models indicate that there could be wetter or drier conditions with models predicting wet conditions indicating rainfall increases of 3.2% by 2030 under an intermediate emissions scenario and 7.8% by 2050 under a high emissions scenario. Models predicting dry conditions indicate a decrease in rainfall from 4.2% by 2030 under an intermediate emissions scenario and 17% by 2050 under a high emissions scenario (CSIRO, 2015a). Given the high level of uncertainty associated with the direction and likely magnitude of rainfall change, BHP conducts sensitivity analyses to understand the impacts of changes in rainfall to proposed closure designs where this may be critical to the design (e.g. flood protection bunds).

### 5.1.3 Knowledge gaps & forward work program

BHP is in the process of updating climate change projections to 2090 based on the latest generation of climate models. Relevant data will be incorporated into future revisions of the MCP.

## 5.2 Overburden characteristics

Materials at BHP sites are characterised based on their, geochemical, and physical characteristics. This characterisation process allows BHP to identify material types and manage their placement appropriately, including segregation and selective disposal of Potentially Acid Forming (PAF) overburden and selective placement of beneficial overburden. This approach is consistent with the Leading Practice Sustainable Development Program for the Mining Industry *Mine Closure* and *Preventing Acid and Metalliferous Drainage* handbooks (DISER, 2016a; 2016c).

### 5.2.1 Geological overview

#### 5.2.1.1 Regional geology

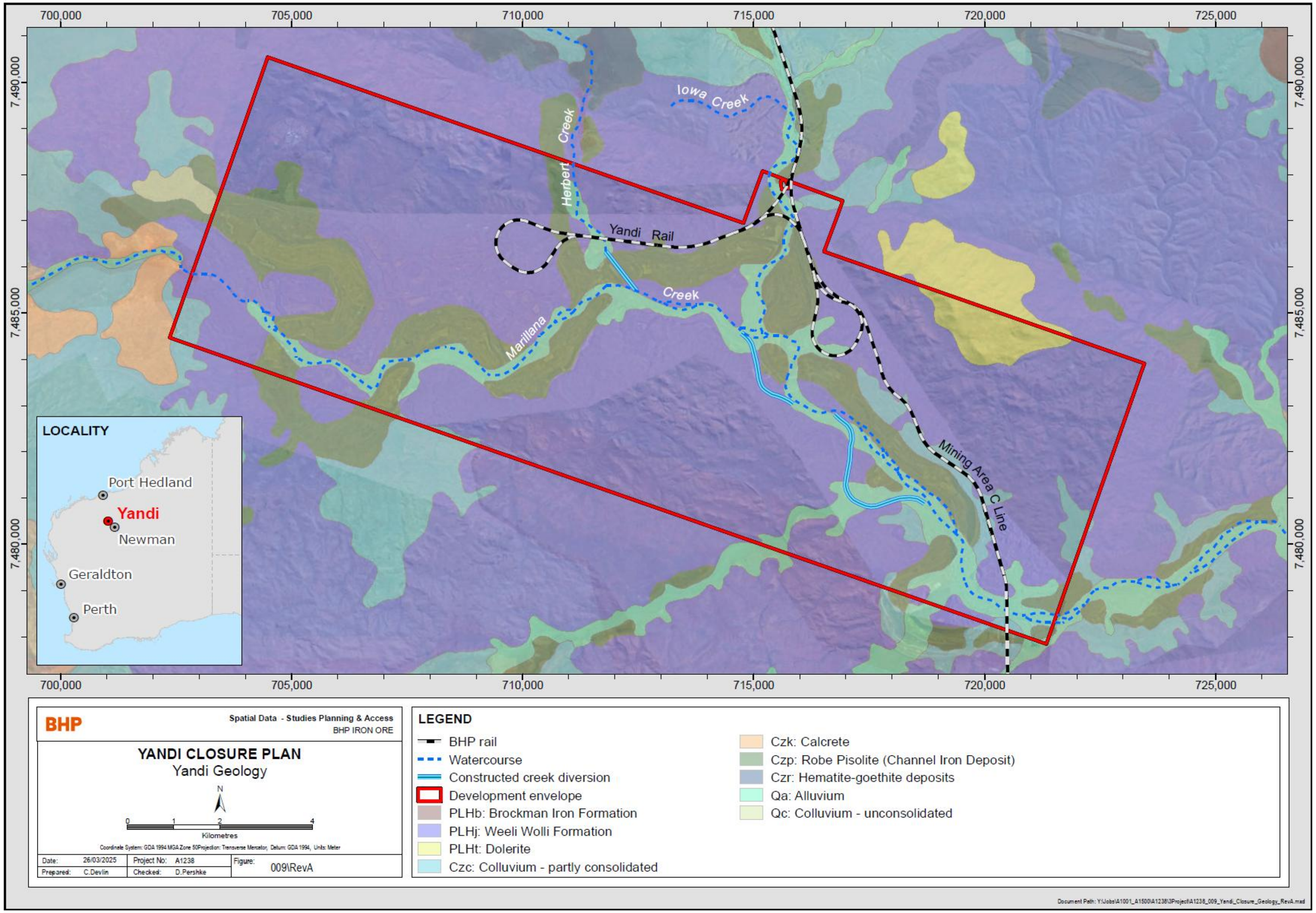
The Hamersley Province, which covers an area of approximately 80,000 km$^2$, has a long geological history. The geology broadly comprises late Archaean and Lower Proterozoic (2800 to 2300 Ma) sediments and metasediments situated between Archaean granitoid rocks of the Yilgarn and Pilbara blocks.

The regional geology has been described and mapped by the Geological Survey of Western Australia at a scale of 1:250,000 (Tyler, Hunter, & Williams, 1991). The geology within the development envelope for Yandi belongs to the Hamersley Group of the Hamersley Basin, a late Archaean to early Proterozoic (2765-2470 Ma) basin which occurs over the southern part of the Pilbara Craton (Thorne & Tyler, 1997).

#### 5.2.1.2 Local geology

The geology of Yandi is broadly classified into four units (Map 5-1), following Thorne & Tyler (1997) (listed from youngest to oldest):

- **Quaternary Alluvium:** Recent alluvial deposits line the banks and floodplains of Marillana Creek within the development envelope for Yandi.
- **Cainozoic Colluvium:** The south-western corner of the project area is covered in partially cemented Cainozoic valley-fill deposits containing boulders of limonite.
- **Cainozoic Robe Pisolite:** This formation constitutes the main iron-ore deposits within the mining lease and is closely associated with the presence of a meandering band of CID 'mesas' within the Marillana Creek palaeochannel. CID is composed of pisolitic limonite deposits with fossil wood fragments and is heavily secondarily weathered and porous.
- **Weeli Wolli Formation:** The Weeli Wolli Formation is typically composed of jaspilitic iron-formations, together with shale and chert. The formation has been intruded by several dolerite dykes and sills, giving a distinctive, broadly striped appearance to the outcrops. The most prominent of these dykes and sills intrude into the upper part of the Weeli Wolli Formation in the Marillana Creek area (e.g. at the “Three Sisters”, and the “Flat Rocks” areas).




See Appendix Q for a pdf version of this map

**Map 5-1 Yandi geology**

In the Marillana Creek catchment, Tertiary deposits infill older erosion features, including broad valleys, with clays and calcretes of lacustrine origin or channel-fill deposits in what remain the main drainage lines. The geological units at Yandi comprise (refer to Figure 5-3) (Golder, 2020c; Advisian, 2019) (from youngest to oldest):

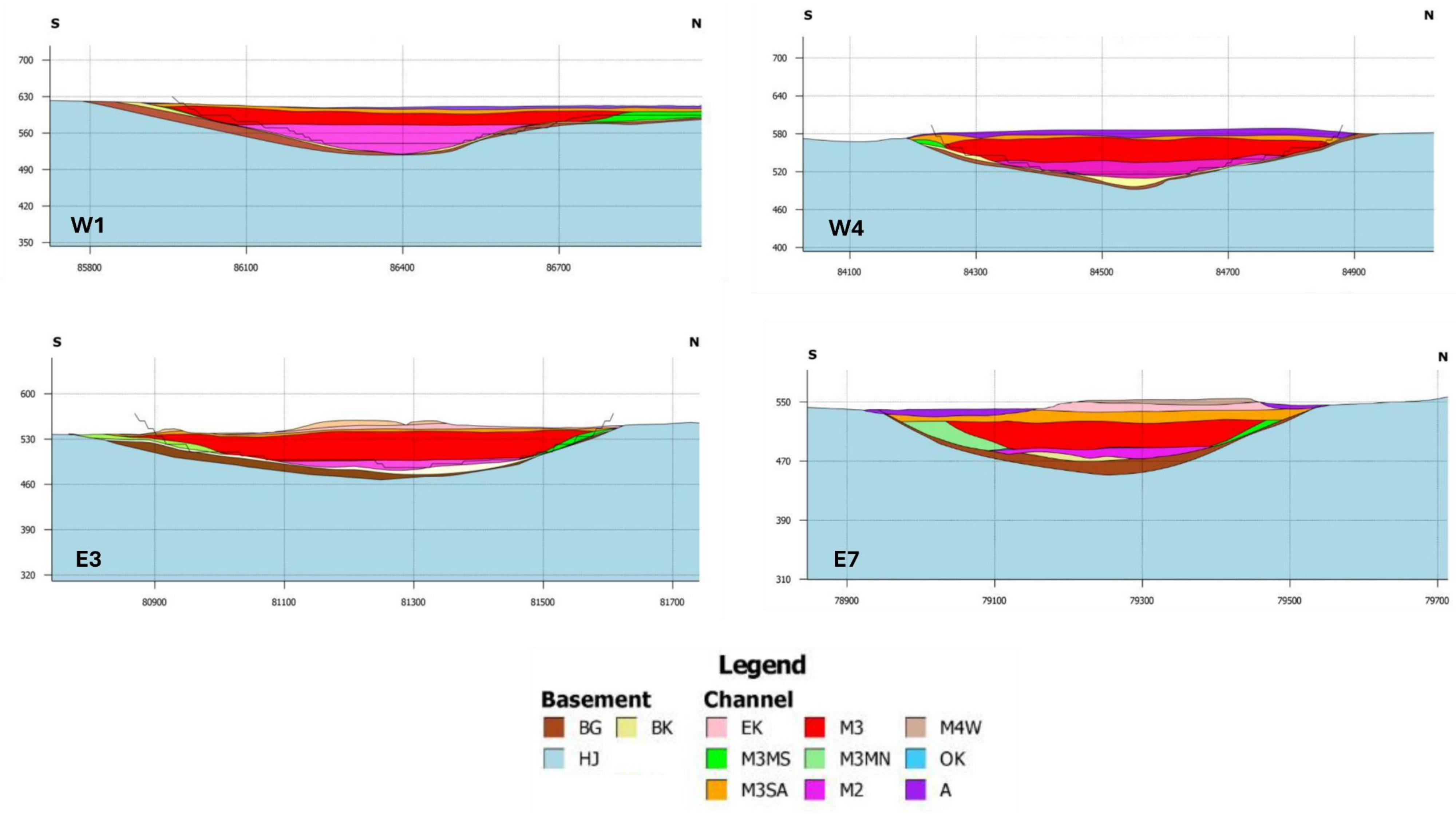
- **Alluvium (A):** unconsolidated fragments of chert, Banded Iron Formation (BIF), shale, minor dolerite, and occasional CID clasts in a matrix of red-brown clayey sand and sandy clay.
- **Eastern CID (M4):** this unit represents the youngest preserved CID occurrence in the present channel. It occurs almost exclusively as a weathered capping to the ore deposits in the eastern part of the Yandi development envelope and shows a lack of CID texture and vughs.
- **Eastern Clay (EK):** thin, mottled, white-brown to yellow, locally indurated clay. Typically, elastic or conglomeratic at the base, with a gradation change into an upper massive kaolinitic to goethitic clay.
- **Upper CID (UCID or M3):** primarily comprises red brown goethitic CID, (pisolitic iron deposits) with a thickness of up to 70 m. Discontinuous clay pods occur within this unit, varying from 0.1 to 1 m in thickness and occurring at random intervals. Zones of silicification also occur. It is extremely weak to strong with very close to widely spaced joints.
- **Ochreous Clay (OK):** pale yellow (sometimes pinkish), soft to firm, thin, flat clay horizon separating upper and lower CID units. It is generally seen as the marker bed but does not occur everywhere.
- **Lower CID (LCID or M1/2)**: the ore-bearing unit below the water table. Its parent mineralogy is identical to M3 but affected by groundwater with limonite and limonitic clay coated fractures. It comprises denatured CID, CID and Ochreous clay. The unit can be sub-divided into a lower zone (M1 - with consistently harder CID) and an upper denatured zone (M2 - variable hardness, characterised by increased ochreous goethite). In central parts of the channel, the ore is pisolitic and comprises goethite and limonite. It is highly variable in strength, some areas with low strength and clay horizons, some with high silica and goethite alteration destroying original pisolitic texture.
- **Basal Clay (BK):** intercalated clays and CID, often with some conglomerate lenses. It is not mined and is transitional to the UCID or LCID units above. It is possible that the increased clay content of this zone was derived from nearby dolerite sills. It is a highly plastic clay with or without clasts and lines the base of the paleochannel.
- **Basal Conglomerate (BG):** goethite or a siliceous clay matrix- to clast-supported conglomerate of BIF, shale, weathered dolerite and angular to rounded chert clasts. The basal conglomerate is not mined at Yandi. It blankets the walls of the paleochannel and is considered to be a weak to medium strength rock. Joints are generally rough and very widely spaced. Where weathered, the material is weaker and more friable.
- **Weeli Wolli BIF (HJ):** basement unit of BIF with shale. Anisotropic with distinct bedding fabric throughout. It varies from extremely weathered to slightly weathered with dolerite intrusions.
- **Weeli Wolli Dolerite (HE):** intruded into BIF. Extremely weak to strong. Dolerite found immediately adjacent to the palaeochannel is generally extremely weathered. The dolerite rock fabric is preserved, but the material is weathered to a silt clay or clayey silt of low plasticity. At some locations away from the channels, however, the dolerite shows as a fresh rock with high to extremely high strength.

Erosion of less competent, weathered BIF has left the more resistant CID material as mesas standing above the level of the modern valley floor. During this period, the modern Marillana Creek was incised into the current land surface.

The Marillana catchment area is relatively simple structurally. It can be described as a shallow, easterly plunging syncline that is bound to the north, south and west by outcropping Brockman Iron Formation, with a core of Weeli Wolli Formation consisting of BIF, shale and dolerite (sills and dykes) (Figure 5-4). By definition, the sills are concordant with bedding and the dolerite dyke sets are north-east to south-west trending, with a more or less orthogonal set of dykes trending north-west to south-east. The dyke sets occur in both the Brockman Iron and Weeli Wolli Formations, and do not appear to be folded. Minor, smaller scale folds trending in the same direction as the broad syncline (which defines the catchment) have been mapped within the southern flank of the Brockman Iron Formation and to a lesser extent in the Weeli Wolli Formation, within the catchment's eastern limit.

The Yandi deposit occurs within the Marillana palaeochannel network and comprises a 28 km stretch of a single, continuous, high grade, low phosphorus, pisolitic goethite orebody which is over 70 km long. The CID itself consists of detritus formed by the erosion of intensely weathered bedrock, subsequent transport by sheetwash, and ultimately, deposition in the ancient Marillana Creek drainage system. The palaeochannels are typically 450 to 750 m in width and can be up to 100 m deep in the centre.

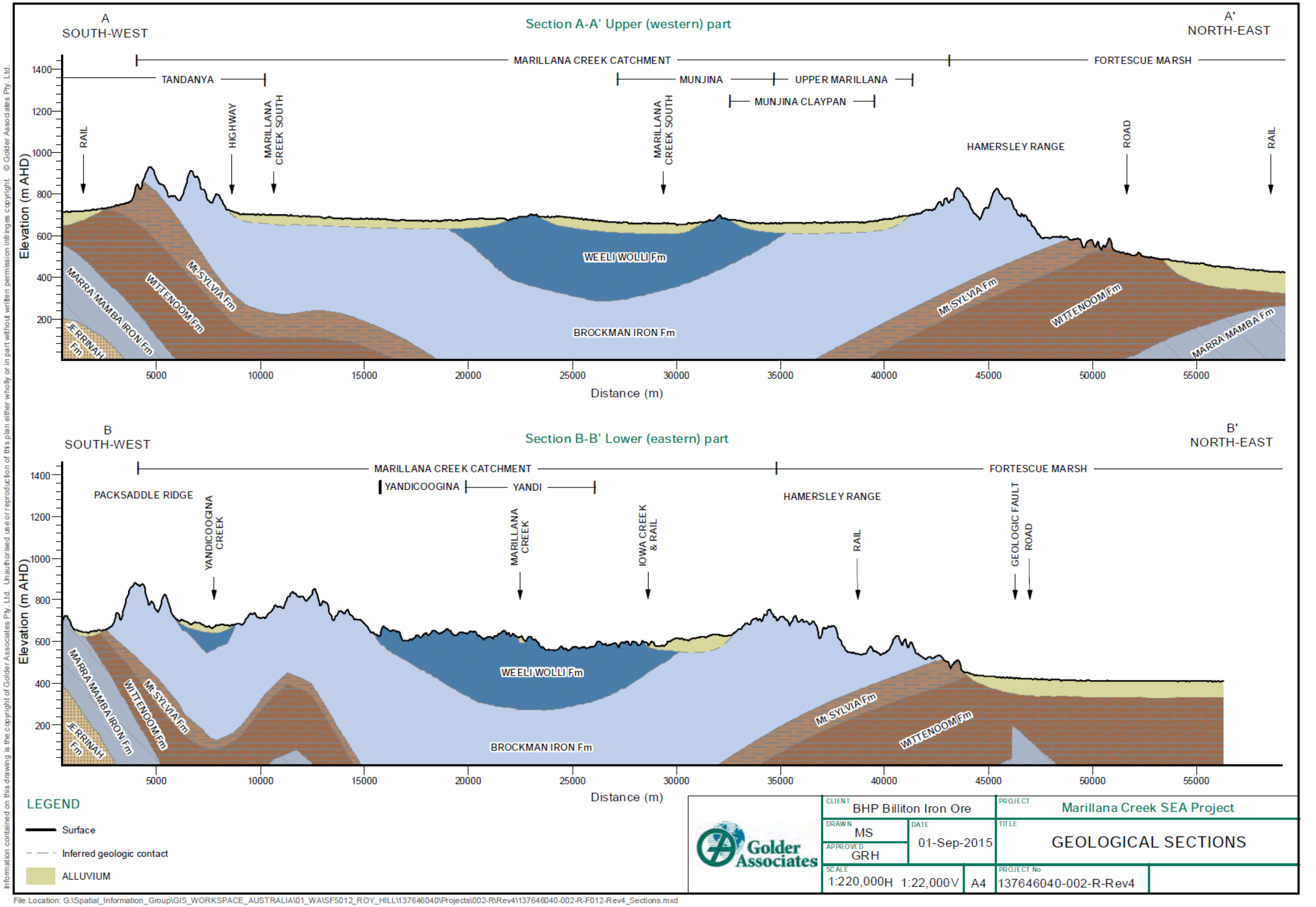
The Yandi ore deposit is composed of masses of cemented concretionary iron oxides occurring as irregular, sub-rounded goethitic clasts of up to 3 mm diameter. The iron oxides are separated by a loose matrix, a subsequent brown to grey, sub-vitreous to vitreous goethite cement, or are just densely packed. The ore comprises goethite-hematite pelletoids in the upper part of the Marillana Formation (UCID), with increasing peloid content towards the base and margins of the channel (LCID) in the Western area of the tenement.




NOT TO SCALE

Note: vertically exaggerated

**Figure 5-3 Example geological cross sections of Yandi pits**




Source: Golder (2015b)

**Figure 5-4 Regional geological cross-sections**

#### 5.2.1.3 Projected overburden proportions by stratigraphy

Based on the Yandi mining models, the majority (63%) of the overburden comprises units of the Marillana Formation (Upper and Lower CID; M3 and M2 stratigraphies respectively). Other key overburden units are the Iowa Member – Eastern Clay (13.2%), Tertiary sediments (7.5%), Eastern CID Weathered (5.7%) and Alluvials (5.4%) (Table 5-3).

**Table 5-3 Projected life of mine overburden proportions by stratigraphic unit**

| Strat. | Units | % Total Volume |
|---|---|---|
| M3 | 7350 – Upper CID High Silica High Alumina | 24.9 |
| | 7370 – Upper CID Weathered | 18.5 |
| | 7300 – Barimunya Member – Upper CID | 6.7 |
| | 7320 – Southern Marginal zone | 1.7 |
| | 7330 – Northern Marginal Zone | 1.5 |
| | **M3 TOTAL** | **53.4** |
| EK | 7410 – Iowa Member – Eastern Clay | 13.2 |
| M2 | 7120 – Barimunya Member – Lower CID | 9.9 |
| T | 8100 – Tertiary Sediments | 7.5 |
| M4W | 7420 – Eastern CID Weathered | 5.7 |
| A | 8160 – Alluvials | 5.4 |
| BG | 7030 – Munjina Member – Basal Conglomerate | 1.6 |
| OK | 7130 –Barimunya Member, Ochreous Clay | 1.1 |
| BK | 7050 – Munjina Member – Basal Clay | 1.0 |
| SZ | 8150 – Surface Scree | 0.9 |
| HJ | 6110 – Weeli Wolli Iron Formation | 0.5 |
| OTHER | | <0.5 |
| **TOTAL** | | **100** |

Source: Mine Waste Management (2022a)

### 5.2.2 Overburden classification system

BHP classifies overburden to inform the management of different overburden types according to their physical and geochemical properties using two interconnected classifications; Acid and Metalliferous Drainage (AMD) class and physical property (WMAT) class (Table 5-4). These classifications have been devised to support informed management of beneficial and problematic overburden during mine planning. The preliminary classifications are included into mining and geological models, with classifications confirmed though analysis and inspection of blast cone chips prior to mining. Furthermore, targeted test work is also conducted, as required, to validate AMD classification assumptions and physical materials properties (Sections 5.2.3 and 5.2.4).

**Table 5-4 Geochemical and physical classification categories**

| Classification | Geochemical / Physical Stability Stratigraphy | Description |
|---|---|---|
| AMD0 | **Geochemically inert:**<br>NAPP <3 kg $H_2SO_4$/t: | AMD0 overburden is segregated based on its physical properties into WMAT 1, WMAT 2 and WMAT 3 material types (see below). |
| AMD1 | **Geochemically problematic**:<br>All stratigraphies below water table, NAPP ≥3 kg$H_2SO_4$/tonne | **Adverse AMD overburden** for containment within OSAs following specific dumping guidance due to the adverse geochemical properties leading to AMD.<br>**Management recommended**<br>AMD1: Paddocked dumped and encapsulated.<br>AMD2 / AMD3: Encapsulated by at least 10 m of geochemically stable material**.** |
| AMD2 | **Geochemically problematic**:<br>All stratigraphies above water table, NAPP ≥3 kg$H_2SO_4$/tonne | |
| AMD3 | **Geochemically problematic**:<br>All non-bedrock stratigraphies, i.e. Detritals.<br>NAPP ≥3 kg$H_2SO_4$/tonne; includes alluvial, Scree and Tertiary Detritals (TD1, TD2, and TD3) | |
| WMAT1 | **Geochemically inert:**<br>AMD0, NAPP <3<br>**AND**<br>**Physically inert:**<br>Upper CID, Eastern CID, Hard cap, Northern and Southern marginal zone, Weeli Wolli BIF and undifferentiated | **Beneficial competent and inert overburden** for placement on outer OSA surfaces due to inherent hardness, mean rock size (rockiness) and physical properties that promote a stable landform surface.<br>**Management recommended**<br>To be used on final surface with a minimum thickness of 1 m. |
| WMAT2 / WMAT3 | **Geochemically inert:**<br>AMD0, NAPP < 3<br>**AND**<br>**Physically problematic**:<br>Tertiary Sediments, Ochreous Clay, Eastern Clay, Lower CID, Alluvials, Munjina Member undifferentiated, Basal Clay, Basal Conglomerate, weathered Weeli Wolli Dolerite | **Potential (WMAT2) and Certain (WMAT3) geochemically inert but physically problematic overburden** for placement within OSAs, beneath outer surface material due to the unfavourable physical properties (dispersive, fine grained) that promote a highly erosive and unstable landform surface.<br>**Management recommended**<br>Avoid placement on final surface. To be placed below WMAT1. |

Notes: NAPP – Net Acid Production Potential (see below for explanation)

Further detail on the geochemical and physical classification systems summarised in Table 5-4 is provided in the relevant sub-sections below.

#### 5.2.2.1 Geochemical classification

**Introduction to AMD**

AMD is used to describe low-quality seepage or drainage that has been affected by the oxidation of sulphide minerals (primarily pyrite), and / or by the dissolution of acid generating sulphate minerals (such as jarosite, alunite, melanterite etc.).

AMD may be produced when sulphide minerals are exposed to oxygen and water, or when acid sulphate salts are leached. Oxidation of sulphide minerals and / or leaching of acid sulphate salts may result in the production of sulphate ($SO_4^{-2}$), acid (H+), release of metals (Mg, Ca, Fe, Al, Mn, Zn, Cu, Ni, As, etc.) and salinity ($SO_4^{-2}$, Ca, Mg, $HCO_3^-$, $Cl^-$) depending on mineralogy. For AMD to occur, a sample must contain sulphides or acid generating sulphates. If a sample does not contain reactive sulphur, then AMD reactions cannot occur.

AMD can be acidic, pH circum-neutral, alkaline or saline (INAP, 2014; DISER, 2016c). Whether contact water is acidic and metalliferous (acid drainage), neutral / alkaline and metalliferous (neutral metalliferous drainage) or just saline (high sulphate, saline drainage) largely depends on the relative proportion of sulphide minerals (acid generating) and carbonate minerals (acid neutralising) in the source materials.

Acidic drainage is generated when the acid generating capacity of a material exceeds its acid buffering capacity (Acid Neutralising Capacity; ANC). In this case, the drainage is acid, contains elevated metal concentration and is saline (mostly sulphate salinity).

Neutral metalliferous drainage is formed when the acid generating capacity of a material is less than its ANC. In this case, the drainage is near neutral / alkaline (around pH 6-8) and can contain low levels of metals that are soluble at higher pH if they are present (manganese, cobalt, zinc, arsenic). Salinity is dominated by sulphate, calcium, magnesium and bicarbonate.

Saline drainage (oxidative) occurs when the acid buffering capacity of a system far exceeds its acid generating capacity; in this case, drainage pH is alkaline (>pH 8) and saline (mostly sulphate, calcium, magnesium, carbonate salinity) and has limited (potentially manganese) or no metals in solution.

The hazard for metalliferous and saline drainage associated with AMD reactions is linked to total sulphur (and specifically sulphide sulphur) concentrations. The higher the sulphur and ANC concentrations in Non-Acid Forming (NAF) materials, the higher the potential to generate neutral metalliferous and saline drainage. It is generally accepted that neutral metalliferous and saline drainage are generally of concern for materials characterised by total sulphur concentration above 1 wt.%.

Distinct from AMD reactions, other potential processes that may release salinity and metals are associated with the dissolution of readily soluble mineral groups such as salts, some sulphates (gypsum, epsomite), and carbonates (non-oxidative metalliferous and saline drainage). Some of these mineral groups may contain impurities and / or metals absorbed on their surface that may impact the quality of contact water upon mineral dissolution. However, based on the mineralogy of the stratigraphic units mined across BHP deposits, these minerals are not expected to be present in large quantities. Thus, it is not expected that non-oxidative metalliferous and saline drainage will be a key process impacting on contact water quality. Leach test data can assist with understanding the impacts on contact water quality associated with oxidative and non-oxidative processes.

Use of competent rock (WMAT 1, which is rocky and hard) on the final landform surface will minimise the potential for mobilisation of salts / metals associated with non-oxidative weathering in run-off and contact water.

#### BHP's geochemical classification system

BHP has historically identified Potentially Acid Forming (PAF) material in geological and mine planning block models based on total sulphur (S) content, degree of weathering and lithology, and the focus was on material known to have a high acid generating potential (i.e. unweathered black shales). However, since 2015, improvements have been made to procedures for identifying and coding PAF that may contribute to AMD in geological and mine planning block models. These improvements are possible based on the collection of extensive geochemical characterisation data across BHP's operations, and learnings from preliminary AMD risk assessments and research studies.

BHP now classifies PAF according to the Net Acid Production Potential (NAPP) system. The NAPP classification evaluates the balance between the acid generating and acid neutralising potential of a sample or overburden block. The pre-mining water table is used as a geochemical boundary, above which, material is assumed to be completely weathered (oxidised sulphur) and below which, the material is assumed to be partially or completely unweathered (reduced sulphur). Where unweathered (un-oxidised) material is assessed as having a NAPP ≥3 kg $H_2SO_4$/t, it is classified AMD1. Weathered and detrital material having a NAPP ≥3 kg $H_2SO_4$/t is classed as AMD2 or AMD3, respectively (Table 5-4). AMD1, AMD2 and AMD3 overburden are PAF and are managed according to their geochemical hazard. Thus, the current AMD classification manages geochemical risk associated with sulphide oxidation (pyrite) and acid sulphate salts leaching (acid generating sulphates).

The classification uses primary assay data to estimate the acid generating and acid neutralisation capacity of a sample. Regardless of the acid generating mineral (i.e. sulphides or sulphates), the classification embedded in the geological and mining models assumes that all sulphur is associated with pyrite, which it is usually not, and thus is especially conservative for AMD2 and AMD3 overburden types. All mined materials are classed into inert (AMD0) or reactive (AMD1, AMD2, AMD3) groups based a NAPP cut-off value of 3 kg $H_2SO_4$/t, as follows:

- **NAPP <3 kg $H_2SO_4$/t:**
  - **AMD0**: inert overburden which is then segregated based on its physical properties into WMAT1, WMAT2 and WMAT3 material types (see below).
- **NAPP ≥3 kg $H_2SO_4$/t:**
  - **AMD1**: geochemically reactive overburden associated with fresh material (i.e. overburden located below the water table and assumed to contain pyrite).
  - **AMD2**: potentially geochemically reactive overburden located above the water table.
  - **AMD3**: associated with detrital lithologies and containing potentially geochemically reactive overburden.

AMD1 overburden is likely to contain fresh sulphides (i.e. pyrite) and thus, poses the highest risk to water quality. AMD2 materials are unlikely to contain sulphide minerals, however, they may contain acid sulphate minerals such as, alunite, jarosite, Na-alum. AMD3 materials may contain fresh sulphides (pyrite) particularly in the lignite horizons associated with Tertiary Detritals 2 (TD2), while other stratigraphies within the Detritals may contain acid sulphate minerals. AMD1, AMD2 and AMD3 overburden can generate water of poor quality and thus require management. However, acid sulphate salts minerals are sparingly soluble and pose a much lower risk to water quality compared to AMD1 type overburden, as recently determined from on-going AMD studies conducted by BHP.

#### 5.2.2.2 Physical classification

The WMAT classification manages physical property risks associated with how AMD0 material responds to weathering. AMD0 overburden is segregated into three classes based on the propensity of each of the mined stratigraphic units to withstand erosion (Table 5-4):

- **WMAT1**: comprises stratigraphies that are blocky, competent and resistant to erosion. This material is recommended for emplacement on the final surface with a minimum thickness of 1 m and used for armouring of final landforms. WMAT1 is considered an asset, and should be differentially handled, stockpiled and / or placed on landforms in strategic locations.
- **WMAT2**: is potentially problematic overburden, with properties to be confirmed during mining. WMAT2 material requires management and is to be placed at least 1 m below the final surface of OSAs.
- **WMAT3**: comprises known non-competent stratigraphies and is to be placed at least 1 m below the final surface of OSAs.

### 5.2.3 Geochemical characterisation

This section provides:

- An overview of the scope of the geochemical studies conducted at Yandi and a summary of their key findings (Section 5.2.3.1).
- A summary of the geochemical testing results for stratigraphies at Yandi (Section 5.2.3.2).
- An assessment of the source hazard posed by Yandi overburden and residual mine voids (Section 5.2.3.3).
- An assessment of PAF material associated with the Marillana Creek diversion (Section 5.2.3.4).
- A summary of geochemical knowledge gaps that are still to be addressed (Section 5.2.3.5).

**Summary**

Several studies have been conducted to assess the geochemical risk at Yandi and the resulting geochemistry dataset has provided the basis for assessment of the AMD source hazards. This data set is appropriate to the current stage of closure planning and comprises:

- BHP assay data of around 9 million total sulphur analyses as well as estimated ANC and total elemental concentrations.
- Acid Base Accounting (ABA) data for the stratigraphies that represent 93% of the total estimated overburden volume.
- Leach testing for the key stratigraphies representing the bulk of the total overburden volume (66%) and pit wall surface exposures (estimated to be 90% or greater). Leach testing has included static (de-ionised water and saline), multi-stage unsaturated and saturated test work. This range of testing has been conducted to assess leaching under the various conditions to which pit backfill may be subjected.

Using a combination of extensive assay datasets and validating assay-derived inferences through laboratory testing is consistent with leading practice for AMD hazard assessment (Mine Waste Management, 2022a).

The stratigraphies mined at Yandi have been classified as NAF, but some PAF material was intersected by the excavation for the E1-E4 section of the Marillana Creek diversion. Summaries of the mining area and creek diversion source hazard assessments are provided separately below.

*Mining area source hazard assessment*

An assessment by Mine Waste Management (2022a) of the AMD source hazards associated with the mining area concluded that the risk of acid, neutral metalliferous and saline drainage from overburden and pit wall exposures at Yandi is low. SRK (2022a) conducted a peer review of the assessment and concurred with these findings.

- The statistical assessment of the primary assay data showed that all Yandi deposits are very low in sulphur with 99.95% of the samples assessed having total S < 0.2 wt.%. Mean and median total S concentrations were equal to 0.01 wt.%S across all deposits. Together the sulphur assay and ABA data support the conclusion that the stratigraphies mined at Yandi possess low acid generation potential. The Munjina Member Basal Conglomerate and the Weeli Wolli Iron Formation have been identified as having a relatively higher risk of AMD than other geological formations due to slightly higher S grades observed in the primary assay data and NAPP block model assessment. These stratigraphies represent approximately 2% of the total overburden volume, however, the geological blocks intercepted by mining (overburden and pit walls) within these stratigraphic units are shown to contain low sulphur and have been classified as AMD0.
- As neutral metalliferous and saline drainage originate from the oxidation of sulphide minerals followed by neutralisation by *in situ* carbonates, the low total sulphur content of the Yandi deposit suggests that the generation of neutral metalliferous or saline drainage resulting from sulphide oxidation is unlikely. The hazard associated with neutral metalliferous drainage derived from mined materials that do not contain sulphides or associated hydroxysulphate minerals (i.e., through mineral weathering and dissolution within post-mine landforms) was scrutinised using a combination of static and kinetic leachate testing on key overburden stratigraphies that typify the mineralogical characteristics of the site. All samples tested, generated non-saline leachate and low dissolved concentrations of potentially environmentally significant metals / metalloids and salts in leachates, suggesting a low risk of neutral metalliferous or saline drainage from overburden and pit wall exposures associated with non-oxidative processes.
- Static leachate testing (de-ionised water) of samples obtained from OSAs suggest that there is some potential for leaching of nitrate from overburden potentially associated with dissolution of ammonium-nitrate based explosive residues. This has been considered in pit lake modelling and source-pathway-receptor assessments outlined in Section 5.14.

*Marillana Creek diversion source hazard assessment*

Twenty samples were collected from the Weeli Wolli Formation, during a geotechnical investigation for the Marillana Creek Diversion Project in 2015 and were submitted for ABA test work. Seven samples were also later submitted for total elemental analysis and static leach testing. Together, the results were interpreted as indicative of the low risk of the exposed materials generating adverse acidic, neutral metalliferous or saline drainage.

High sulphur materials were later identified by BHP in some of the 270 samples obtained from blast holes drilled in the Weeli Wolli BIF as part of excavations for the E1 - E4 section of the diversion. Geological mapping of the area showed that pyritic material is mostly confined to dolerite and black shale with some disseminated pyrite present in BIF schist. These materials are located within discrete zones resulting in the exposure of approximately 350 $m^2$ of PAF material.

Kinetic geochemical testing of the high sulphur (PAF) samples from the creek diversion concluded that the normalised acidity generation / release rate is small, ranging from 0.0003 - 0.038 kg $H_2SO_4/m^2/wt.\% FeS_2/year$. The 350 $m^2$ wall rock exposure may, therefore, generate approximately <0.1 - 14 kg $H_2SO_4$ acidity per year. Even assuming a surface roughness and fracture density of wall rock exposures to be 100 times greater than that of the samples tested in the laboratory, the acidity generation rates predicted for the wall rock exposure would still be low (only be 11 to 1,400 kg $H_2SO_4$ acidity per year) and can be managed through the soluble alkalinity in Marillana Creek water and available ANC in the alluvium.

The BHP classification identified approximately 0.1 Mt of overburden from the diversion with potential for AMD and requiring selective mining and management during the excavation of the E1 and E4 creek diversions. The excavated material was managed in accordance with WAIO's Acid and Metalliferous Drainage Management Technical Process Instruction (2022a) and placed in the E2 ISA. Subsequent testing conducted on blast hole samples (270 samples) indicated that the BHP classification system was overly conservative and that only a few thousand tonnes of the material placed in the E2 ISA was actually PAF.

Test work on dolerite excavated as part of the creek diversion found that the material was NAF and may offer erosion control benefits.

#### 5.2.3.1 Overview of geochemical studies

Several studies have been conducted to assess the geochemical risk at Yandi:

- Preliminary AMD risk assessment (GHD, 2014);
- A review of Yandi environmental geochemical test work data to validate the BHP AMD classification system and more broadly validate GHD (2014) findings (Mine Waste Management, 2020);
- Collation of relevant environmental geochemistry data (including data collected since the 2020 MCP) and assessment of geochemical source hazards at Yandi (Mine Waste Management, 2022a);
- Peer review of Mine Waste Management geochemical modelling inputs (SRK, 2022a); and
- An assessment of the potential risk of acidity generation in the Marillana Creek diversion and properties of dolerite (Earth Systems, 2019a; 2019b), summarised in Marillana Creek Diversion – AMD hazard Assessment (WAIO, 2020a).

Together the available geochemistry data from these studies are sufficient for the purposes of AMD source hazard assessment and closure planning. The suite of data available to support the source hazard assessment includes an extensive assay database containing in the order of 9 million total sulphur data as well as estimated ANC and total elemental concentrations. As a minimum, ABA data are available for the stratigraphies that represent 93% of the total estimated overburden volume, and leachate testing has been completed for the key stratigraphies representing the bulk of the total overburden volume (66%) and pit wall surface exposures (estimated to be 90% or greater) (Mine Waste Management, 2022a).

A summary of the focus and conclusions of each study follows. Further details of the assessments are provided in Sections 5.2.3.2 to 5.2.3.4.

**GHD (2014) preliminary AMD assessment**

GHD's (2014) preliminary AMD assessment was based on an analysis of ~9 million x-ray fluorescence (XRF) primary assay results, from exploration and resource definition drilling at Yandi, and the potential for AMD was assessed for the following areas:

- Western CID pits (W1 to W6);
- Central CID pits (C1 to C5);
- Eastern CID pits (E1 to E8); and
- The Marillana Creek diversion creek alignment sections proposed at that time.

The assessment expanded beyond the mining pit shell and included stratigraphic units that were not included in the mining plan. The classification threshold adopted by GHD for PAF materials was a NAPP[20] >6.1 kg $H_2SO_4$/tonne (equivalent to 0.2 wt.% total S with no neutralising capacity). Material with NAPP values ranging from 0 to 6.1 kg $H_2SO_4$/tonne was classified as having an uncertain AMD risk, and NAPP <0 kg $H_2SO_4$/tonne was classified as Non-Acid Forming (NAF), or acid consuming if NAPP <-50 kg $H_2SO_4$/t. The study concluded that geological materials at the Yandi site represent a relatively low AMD risk. Some PAF material (<1%) was identified from the total assay sample database but was not located within the proposed pit shells. While the GHD classification was slightly different from the current BHP classification system in that the NAPP cut-off was higher and the methodology for estimating ANC from primary assay data was different, subsequent assessments (see sections below) have confirmed GHD's assessment of the low AMD risk at Yandi. The material identified as PAF by GHD was restricted to the Weeli Wolli Formation and the Munjina Basal Conglomerate, neither of which were planned to be mined or dewatered at the time of the

[20] NAPP was estimated from total S and calcium assay data, assuming that all S was associated with pyrite and all calcium was associated with calcite

assessment. Since that time, subsequent pit wall stratigraphy work indicates that both the Munjina and the Weeli Wolli Formations have been intersected by the pits[21]

#### Mine Waste Management (2020) review of Yandi geochemical test work

Subsequent to GHD's (2014) assessment, BHP collected Acid Base Accounting (ABA) data on 81 samples sourced from exploration drilling activities within the Yandi mining area. The ABA data supported the BHP AMD classification system applied to the Yandi mining model (Section 5.2.2.1), and the GHD (2014) conclusion that the Yandi geology is generally low in sulphur, and therefore, low in acid generation potential. Mine Waste Management (2020) also inferred that sulphide based neutral metalliferous and saline drainage is unlikely due to the very low total sulphur content of the Yandi deposit.

#### Mine Waste Management (2022a) assessment of geochemical source hazard of Yandi mining area

Further to the Mine Waste Management (2020) review, an additional 31 samples were collected from drilling of the Yandi E8 deposit and 14 composites during an OSA drilling program. These samples were subjected to geochemical testing to support the AMD source hazard characterisation. The source hazard assessment encompassed a review of all geochemical data collected to date and:

- Assessment of stratigraphies exposed on all pit walls at the completion of mining.
- Interrogation of mining models to determine volumes of stratigraphies mined, and therefore, approximate composition of OSAs and / or backfilled pits.

The study concluded that, based on all data gathered to date for Yandi, the likelihood of generating acidic drainage as the result of sulphide mineral oxidation or the dissolution of hydroxysulphate minerals (e.g., jarosite and alunite), is low. The results also indicated that the risk of neutral metalliferous or saline drainage generation from non-sulphide bearing overburden is low.

The available geochemistry data (126 samples; see Appendix B.2) were considered by Mine Waste Management (2022a) to be sufficient for the purposes of AMD source hazard assessment for Yandi closure planning.

#### SRK (2022a) peer review of the geochemical source hazard of Yandi mining area

SRK reviewed the Mine Waste Management (2022a) geochemical source hazard assessment as part of a peer review of the hydrogeochemical modelling reported in Section 5.14.3 and concurred with the conclusions of the assessment that the risk of long-term poor-quality drainage from rock mined at Yandi is low. SRK (2022a) stated that "*the negligible to low sulphur contents suggest a low potential for the generation of acidic conditions and the mineralogy of the waste rock was shown to largely comprise iron oxides / hydroxides, quartz and kaolinite - all of which are expected to be stable and un-reactive at near-neutral pH*".

#### AMD hazard of Marillana Creek diversion

Twenty samples were collected from the Weeli Wolli Formation, during a geotechnical investigation for the Marillana Creek Diversion Project in 2015 and were submitted for ABA test work. Seven samples were also later submitted for total elemental analysis and static leach testing. Together, the results were interpreted as indicative of the low risk of the exposed materials generating adverse acidic, metalliferous or saline drainage (Mine Waste Management, 2020).

High sulphur materials were later identified by BHP in some of the 270 samples obtained from blast holes drilled in the Weeli Wolli BIF as part of excavations for the E1 - E4 section of the diversion. These samples represented potential PAF exposures in drainage channel surfaces and were investigated by Earth Systems (2019a; 2019b). Based on kinetic testing undertaken by Earth Systems (2019a; 2019b) and further AMD hazard assessment (WAIO, 2020a), it was determined that the identified sulphidic material had low reactivity and, therefore, ultimately presented a low level of risk.

### 5.2.3.2 Geochemical test results

#### GHD analysis of primary assay data

GHD (2014) evaluated the AMD hazard for Yandi using a number of geochemical variables, including:

- Total S distribution.
- NAPP values estimated from total S and calcium assay data, assuming that all S was associated with pyrite and all calcium was associated with calcite.

Data interpretation did not take account of whether the overburden was oxidised or fresh. The key outcomes from GHD's (2014) study are as follows:

- The statistical assessment of the primary assay data showed that all Yandi deposits are very low in sulphur with 99.95% of the samples assessed having total S <0.2 wt.%. A very small subset of data (n=4,040 samples or 0.05%) had total S concentrations above 0.2 wt.%S, with a maximum value of 2.36 wt.%. This subset of elevated total S samples was associated with the Weeli Wolli Formation located below the W5N Pit floor.

[21] Collectively, the Munjina Member of the Marillana Iron Formation and Weeli Wolli Formation stratigraphies represent ~15% of the surface area of C4/5 and ~6% of the final pit surface area of W1 and E7.

- Mean and median total S concentrations were equal to 0.01 wt.%S across all deposits.
- Aside from the Weeli Wolli Formation below the W5N Pit floor, maximum S grades >0.1 wt.%S were observed at C1 (1.08 wt.%S), C4 (0.14 wt.%S) and C5 (1.3 wt.%S) (Appendix B.1).
- All lithologies within the Yandi geological setting had average and median total S concentrations of 0.01 wt.%S. The Munjina Member Basal Conglomerate and the Weeli Wolli Formation showed the highest maximum concentrations of total S of 1.3 wt.%S and 2.36 wt.%S, respectively (Appendix B.1). At the time of the GHD study, there were no plans to actively mine these materials, although subsequent pit wall stratigraphy work indicates that both the Munjina and the Weeli Wolli Formations have been intersected by the pits (Section 5.2.3.3) and the Weeli Wolli Formation was intercepted during construction of the Marillana Creek diversion channels (Section 5.2.3.4).
- Assessment of the NAPP estimated from the primary assay data suggested that 0.01% of samples had a NAPP >6.1 kg $H_2SO_4$/t and were, therefore, classified as PAF, 5% of samples were classified as uncertain based on NAPP values ranging from 0 to 6.1 kg $H_2SO_4$/t, while the remainder were classified as NAF (i.e., NAPP <0 kg $H_2SO_4$/t). GHD stated that the positive NAPP values were due to low calcium in the samples assessed, and by extension low ANC, rather than due to elevated sulphur.
- In addition, approximately 2% of samples were predicted to be potentially acid consuming (i.e., NAPP <-50 kg $H_2SO_4$/t). These ANC rich samples were from the C1, C5, E1, E2, E3/5/6, E4, E7, and W1N areas within the Barimunya Member UCID, Munjina Member Basal Conglomerate, Weeli Wolli Formation and some unknown material.
- Block modelling of the total S and ANC values (and associated NAPP variable) indicated that overburden within the pit shells was dominated by NAF materials (88%) with a small number of blocks classed as uncertain (12%).
- GHD concluded that the small volume of PAF overburden predicted via the resource definition model and assessment of the primary assay data was located below the base of the W5N Pit, C1 Pit and E1 Pit within the Munjina Member Basal Conglomerate and the Weeli Wolli Formations. The W5N area of the resource definition model contained the largest number of PAF blocks. All predicted PAF material was below the pit shells.

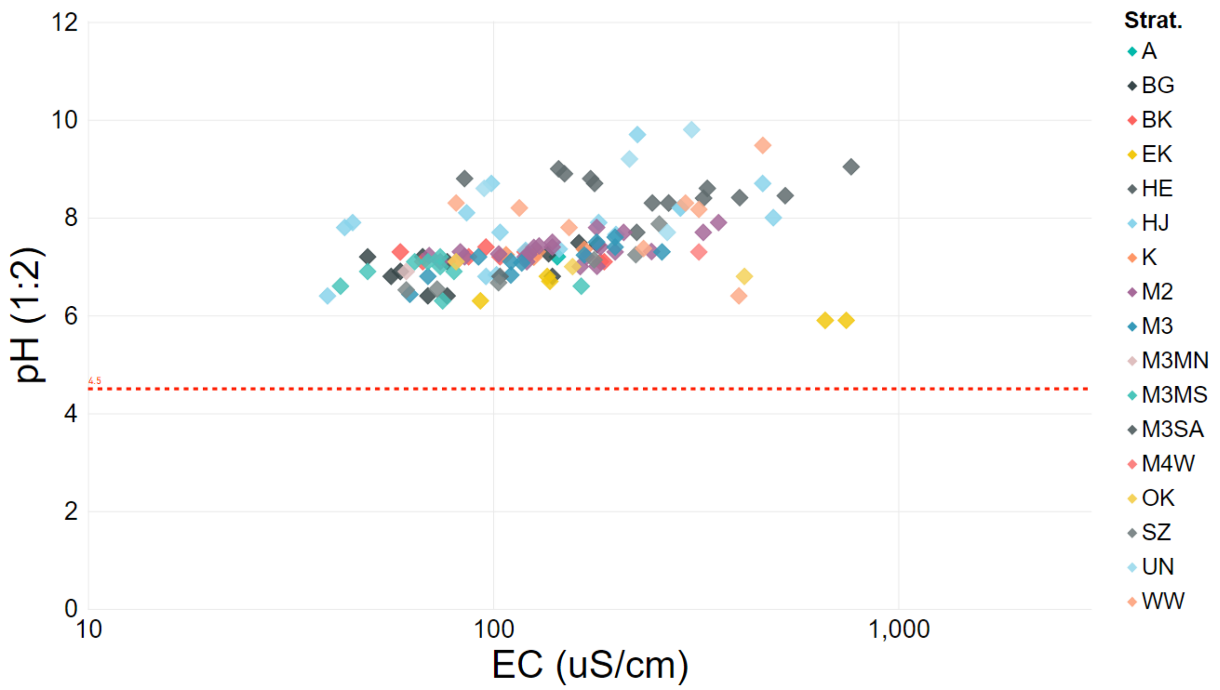
### Acid base accounting

ABA results are provided in Appendix B.3 and can be summarised as follows (Mine Waste Management, 2022a):

- Paste pH for all samples (pH 5.9 - 9.8) was greater than pH 5.5 (Figure 5-5), which is typically used as a cut off for assessing the inherent acidity in a sample. Only two samples recorded a paste pH of 5.9.
- Paste Electrical Conductivity (EC) data (Figure 5-5) suggest there is a low risk for saline drainage to be generated. All samples were classified as non-saline (39 - 765 µS/cm EC; 25 - 490 mg/L Total Dissolved Solids; TDS).

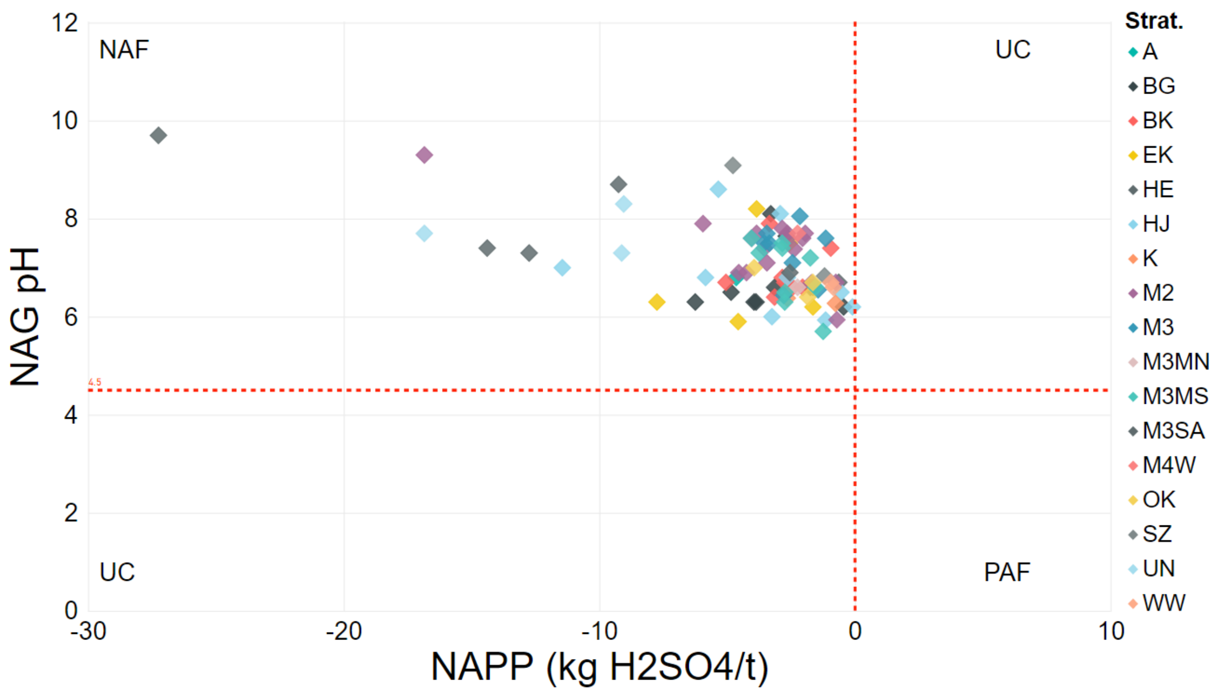
All samples submitted for environmental test work were classified as NAF (AMD0) based on a combination of the AMIRA (2002) (NAPP vs. Net Acid Generation; NAG pH) (Figure 5-6) and Price (2009) (ANC vs. Maximum Potential Acidity; MPA) (Figure 5-7) classification systems.

- All Marillana Formation samples (n=73) were characterised by very low S (<0.05 wt.%) with Maximum Potential Acidities (MPAs) ≤1.5 kg $H_2SO_4$/t. Whilst ANC values were also low (0.6 - 17 kg $H_2SO_4$/t), all samples attained negative NAPP values (-17 to -0.4 kg $H_2SO_4$/t) and Neutralisation Potential Ratios (NPR) exceeding 3 (4 to 111). NAG testing of 64 out of 73 samples produced NAG pH values between 5.7 and 9.3, confirming the NAF (AMD0) classification of all samples.
- The Alluvium stratigraphy sample from Pit E7 contained negligible total S (<0.01 wt.%) and low ANC (4.8 kg $H_2SO_4$/t). NAG pH of 6.8 confirmed the NAF (AMD0) classification of this sample.
- Six Surface Scree samples were characterised by very low S (≤0.01 wt.%) with MPAs ≤0.5 kg $H_2SO_4$/t. ANC values (0.8 to 4.9, median 1.7 kg $H_2SO_4$/t) in excess of MPA provided negative NAPP values for all samples (- 4.8 to -0.7 kg $H_2SO_4$/t) and NPR values exceeding 5. NAG pH results of 6.8 to 9.1 confirmed the NAF (AMD0) classification of all samples.
- Four Dyke / Sill samples contained negligible total S (<0.01 wt.%) with MPAs <0.3 kg $H_2SO_4$/t. Whilst ANC results were low (0.5 to 2.8 kg $H_2SO_4$/t), all samples attained negative NAPP (-2.7 to -0.3 kg $H_2SO_4$/t) and NPR values exceeding 3 (3.2 to 18). Classification for all samples was NAF (AMD0).
- All but one of the 38 samples representing the Weeli Wolli Formation contained very low S (<0.05 wt.%) with MPAs <1.5 kg $H_2SO_4$/t. A single sample of Weeli Wolli dolerite contained total S of 0.13 wt.% (MPA 4 kg $H_2SO_4$/t). Relative to other Yandi Formations, ANC is highest in the Weeli Wolli Formation (<0.5 - 326 kg $H_2SO_4$/t). Moderate median ANC values of 18 and 5.5 kg $H_2SO_4$/t were observed for the Weeli Wolli dolerite and Weeli Wolli Iron Formation sub-units, respectively, whilst the undifferentiated Weeli Wolli samples had lower ANC (median of 2.3 kg $H_2SO_4$/t). All samples attained an NPR of >2 apart from one (NPR 1.5), which contained negligible total S (0.03 wt.%) and reported a NAG pH of 5.7. Therefore, all Weeli Wolli Formation samples can be classified NAF (AMD0).
- Four samples of unknown stratigraphies contained variable total S (<0.01 - 0.16 wt.%) with MPAs <0.3 to 4.9 kg $H_2SO_4$/t. These samples had highly variable ANC, with 3 samples reporting 9.2 - 17 kg $H_2SO_4$/t and a single sample (0.16 wt.% S; MPA 4.9 kg $H_2SO_4$/t) reporting 208 kg $H_2SO_4$/t. Based on negative NAPP values (-9 to -203 kg $H_2SO_4$/t) and circum-neutral to alkaline NAG pH (7.3 – 10.4), all samples were classified NAF (AMD0).



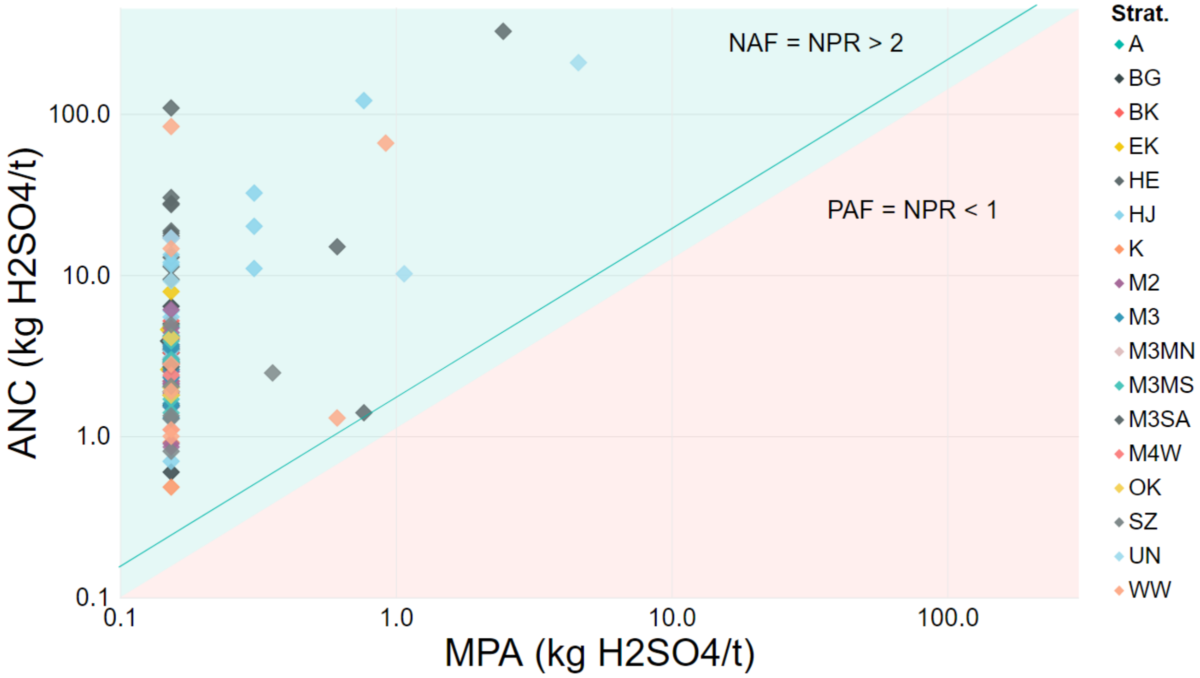

Source: Mine Waste Management (2022a)

**Figure 5-5 Paste pH and EC data for all Yandi samples**




Notes: two NAF Weeli Wolli samples not shown due to highly negative NAPP values of -120 and -323 kg $H_2SO_4$/t.
Source: Mine Waste Management (2022a)

**Figure 5-6 AMIRA classification - NAPP and NAG pH data for all Yandi samples**




Source: Mine Waste Management (2022a)

**Figure 5-7 MPA and ANC data for all Yandi samples**

## Elemental analysis and enrichment

Total elemental analysis and elemental enrichment assessment was completed for 52 samples (including 7 samples from the Marillana Creek diversion). Appendix B.2 details the stratigraphic units analysed. Of the 52 samples, 43 produced one or more instances of Geochemical Abundance Indices (GAI) ≥3[22]. The elements most frequently enriched in the samples were arsenic, antimony, boron, iron, molybdenum and selenium. Elements enriched less frequently included manganese and mercury. Total elemental data is also available for fourteen Weeli Wolli Formation samples from other BHP mines and generally correlated with the reported total elemental data for Yandi (Mine Waste Management, 2022a).

## Mineralogical composition

Semi-quantitative mineralogical analysis was completed for 21 samples comprising 14 samples from the E8 deposit and 7 samples collected as part of a parallel OSA drilling program. The dominant minerals in most samples were iron oxides / hydroxides (goethite, hematite and minor magnetite) with smaller proportions of gibbsite (aluminium hydroxide) detected in samples of M3 and M2 from the E8 deposit. Kaolinite clay was detected in 19 of 21 samples and quartz was detected in all samples. Materials lacking a clearly identifiable crystal lattice (amorphous materials) comprised up to 23 wt.% of the samples (Mine Waste Management, 2022a).

Neither sulphide minerals nor carbonate minerals were detected in any of the samples analysed, which reflects the low S concentrations and typically low ANC values obtained for the samples (Mine Waste Management, 2022a).

Overall, the mineralogical results are consistent with the overburden being highly weathered, dominated by iron oxides / hydroxides and containing little or no reactive minerals with the capacity to generate or neutralise acidity (Mine Waste Management, 2022a).

## Static leach testing

Static leach testing was conducted using both de-ionised (DI) water and saline water to provide an understanding of the leaching that may occur under a range of conditions that may be experienced in the Yandi pits.

### *DI leach testing results*

Static leach testing using DI water was undertaken on 52 samples, including 31 samples collected from E8, 14 composite samples collected from OSAs, and 7 samples previously collected and analysed as part of the Marillana Creek diversion project. The data did not suggest any particular stratigraphy had a higher potential to release dissolved metal / metalloids than other stratigraphies.

22 Generally, a GAI of 3 or greater signifies enrichment that warrants further examination such as leachate testing. It is also important to note that elemental enrichment is not unexpected in samples from mineralised areas and that enrichment does not necessarily mean that specific elements will be environmentally mobile and bioavailable (Mine Waste Management, 2022a).

Whilst samples from some stratigraphies appeared to mobilise more metal(oid)s than others, the concentrations were still relatively insignificant (Table 5-5). A summary of the results follows (Mine Waste Management, 2022a):

- Leachates were circum-neutral to moderately alkaline (pH 6.7 - 9.5) and non-saline (EC <700 µS/cm, TDS 34 - 447 mg/L). Total leachate alkalinity ranged between 7 and 206 mg/L as $CaCO_3$ (median 35 mg/L). Concentrations of major contributors to salinity (chloride, sulphate and major cations) were low (<110 mg/L), consistent with the low EC of the leachates.
- Low concentrations of key nutrients were detected. Nitrate (0.02 - 8.3 mg/L) was detected in 38 of 46 samples, whereas phosphate (0.02 - 0.13 mg/L) was detected in only 5 of the samples. Extractable nitrate concentrations were typically higher in the OSA composite samples (0.2 - 8.3 mg/L, median 3.1 mg/L) compared with samples from elsewhere (<0.01 - 0.86 mg/L, median 0.13 mg/L), which potentially represents residues from blasting with ammonium nitrate (i.e., 'ANFO').
- Numerous analytes were present near to, or below, the detection limit (<0.001 mg/L) in all leachates (e.g., Be, Bi, Cd, Cs, Cu, Sn, and Tl). Others were only detected in isolated samples and / or at concentrations only marginally exceeding their detection limit (e.g., As, Co, Pb, Rb, Ta, Th and U).
- There were detectable but relatively low concentrations of several elements including Ba (<0.001 - 0.35 mg/L), Cr (<0.001 - 0.01 mg/L), Li (<0.001 - 0.16 mg/L), Ni (0.002 - 0.05 mg/L), Sr (<0.001 - 0.17 mg/L), V (<0.001 - 0.016 mg/L), W (<0.001 - 0.014 mg/L) and Zn (0.001 - 0.066 mg/L), across multiple stratigraphies.
- Fluoride concentrations were <0.01 - 2.3 mg/L with a median of 1.1 mg/L.
- Iron was detected at elevated levels (0.14 - 1 mg/L) in leachate from 6 samples. Given that these leachates were neutral to alkaline (pH 7 - 9.4), the iron is considered colloidal and not present as the dissolved species.
- For the elements (excluding iron) found to be frequently enriched (GAI ≥3) in the samples (B, Mn, Mo, Sb, Se, and less frequently Hg), leached concentrations were consistently low for B (<0.01 - 0.27 mg/L), Mn (<0.001 - 0.18 mg/L), Mo (<0.001 - 0.026 mg/L), Sb (<0.001 - 0.002 mg/L), and Se (<0.001 - 0.016 mg/L). Mercury (Hg) was not present at detectable concentrations (<0.001 mg/L) in any leachate.

**Table 5-5 Stratigraphies with highest median water leachate concentrations**

| Element | Stratigraphy | Median for stratigraphy | Median for all samples* |
|---|---|---|---|
| Ba | BG | 0.14 | 0.033 |
| | SZ | 0.11 | |
| Li | BG | 0.012 | <0.001 |
| Mn | BG | 0.062 | 0.004 |
| | SZ | 0.015 | |
| Mo | BG | 0.007 | <0.001 |
| | HJ | 0.005 | |
| Ni | M3 | 0.007 | 0.002 |
| Zn | SZ | 0.027 | 0.001 |

Source: Mine Waste Management (2022a)

Notes: Table summarises median concentrations by metal / metalloid and stratigraphy, where the stratigraphy median was greater than the median for all samples by a factor of at least 3.

*Median concentrations include half Laboratory Limit of Reporting (LOR) values substituted for samples containing <LOR.

*Saline leach testing results*

Static leach testing was completed for 31 samples collected from E8 using saline water with a salinity approaching that which may be expected in pit lakes. The results showed that although saline water enhanced the dissolution of six elements of interest (Ba, Co, Li, Rb, Sr and Zn), the saline elemental leachate concentrations remained relatively low (Table 5-6). The overall impact on potential pit lake concentrations is not expected to be significant given that groundwater inflow is the primary driver of pit lake hydrochemistry (Section 5.14.3) (Mine Waste Management, 2022a).

None of the elements found to be frequently enriched (GAI ≥3) in the solid samples were present at significant concentrations in saline leachates (Mine Waste Management, 2022a).

**Table 5-6 Summary of salinity - enhanced dissolution in short-term leachate tests**

| Element | Concentration Factor vs. DI Water | Saline leachate concentration range | Comments |
|---|---|---|---|
| Ba | 2 - 190 | 0.029 - 3.8 mg/L | - |
| Co | 1 - 13 | <0.001 - 0.013 mg/L | <0.001 mg/L in 9 of 14 saline leachates |
| Li | 1 - 6 | <0.001 - 0.23 mg/L | - |
| Rb | 3 - 24 | 0.004 - 0.024 mg/L | - |

| Element | Concentration Factor vs. DI Water | Saline leachate concentration range | Comments |
|---|---|---|---|
| Sr | 2 - 194 | 0.03 - 1 mg/L | - |
| Zn | 1 - 11 | <0.001 - 0.08 mg/L | <0.001 mg/L in 8 of 14 saline leachates |

Source: Mine Waste Management (2022a)

### Multi-stage leach testing

Multi-stage leach testing[23] was performed to determine the potential for solute release from backfilled overburden or exposed pit walls under unsaturated conditions (i.e., by percolating rainwater or runoff). Six samples were tested, including three composite samples, representing each of the stratigraphies available for testing from the E8 deposit (Appendix B.5). The results of the multi-stage leachate test are provided in Appendix B.5 and are summarised below. Overall, results indicate that there is limited potential for seepage or runoff to contain significantly elevated concentrations of salts, nutrients and most metals / metalloids (Mine Waste Management, 2022a):

- All leachates were circum-neutral to slightly alkaline (pH 6.5 - 8) and non-saline (EC <1,300 µS/cm) with consistently declining EC with successive leaching. Total leachate alkalinity was typically between 30 and 90 mg/L as $CaCO_3$. Rapidly declining concentrations of chloride, sulphate, magnesium, sodium, and potassium with successive leaches are consistent with the trend for declining EC, and these trends are consistent with the depletion of soluble mineral sources (i.e., source-controlled dissolution).
- Nitrate concentrations showed a similar trend. Initial moderate levels (0.33 - 9.81 mg/L) declined to <0.001 mg/L for all samples except for the M3 composite (0.06 mg/L) after the second leaching. Leachate phosphate (P) concentrations were consistently <0.01 mg/L.
- Many analytes were typically below or around the Laboratory Limit of Reporting (LOR - 0.001 mg/L) or were only detected in the first leachate (e.g., As, Be, Bi, Cd, Co, Cr, Cs, Ni, Pb, Se, Sn, Ta, Th, Tl, U, V and W).
- For the elements found to be enriched (GAI ≥3) in the solid samples (B, Fe, Sb and infrequently Hg):
  - Leachate boron (B) concentrations were either consistently between 0.05 and 1 mg/L or declined from up to 0.25 mg/L to <0.1 mg/L between the initial and final leaches.
  - Dissolved total iron (Fe) concentrations were typically between 0.001 and 0.07 mg/L. Two anomalously high values (0.89 - 1.1 mg/L) were detected in leachates from the M3 composite sample, which have been attributed to colloidal iron capable of passing the sample filtration apparatus (iron is highly insoluble at circum-neutral pH). This was also observed for the M2 composite subjected to saturated leach testing.
  - Antimony (Sb) and mercury (Hg) were not present at detectable concentrations (<0.001 mg/L) in any leachate.
- Fluoride (F) concentrations in the initial leachate were elevated (3 - 11 mg/L), decreasing with successive leaches to around 1 mg/L or less, except for the M3 composite which decreased to ~2 mg/L. This reflects the presence of low to moderate fluoride concentrations (0.62 - 2.3 mg/L) in short-term water leachates for samples representing all stratigraphies assessed.
- Concentrations of several analytes (Cu, Li, Rb, Sr, Zn) declined with successive leaches consistent with source-controlled dissolution.
- As observed for boron and fluoride, concentrations of barium and molybdenum in selected samples (Barimunya Member and Weeli Wolli Iron Formation) indicate more complex dissolution behaviour, potentially reflecting the presence of a sparingly soluble mineral phase source (i.e., solubility-controlled dissolution).

### Saturated column leach testing

Saturated column leachate testing (using a kinetic column leach method[24]) was performed to identify the potential for solute release from backfilled overburden, and pit walls inundated by pit lakes that may form after mine closure. Testing was completed over 12 weeks, on composite samples from the stratigraphies which represent the majority of overburden produced and exposed on pit walls at closure (Appendix B.6).

Overall, the saturated leachate test results (Appendix B.6) indicated that the materials tested have limited intrinsic potential to release significantly elevated concentrations of salts, nutrients and metals / metalloids under saturated, low oxygen conditions. These conditions reflect those that may be encountered by sub-aqueous overburden. A summary of the results follows (Mine Waste Management, 2022a):

[23] Using a modified AMIRA (2002) Free Draining Leach Column Test Procedure. Refer to Mine Waste Management (2022a) for further information.

[24] USEPA Leaching Environment Assessment Framework (LEAF) 1314 test method (USEPA, 2017) was adapted to use nitrogen-sparged de-ionised water (<0.5 mg/L dissolved oxygen) as the eluent.

- Leachates were circum-neutral to alkaline (pH 7.8 - 9.3) and consistently non-saline (EC 80 - 750 µS/cm). Concentrations of primary contributors to salinity (chloride, sulphate and sodium) either declined significantly during the first four weeks of the trial and remained low, or consistently decreased throughout the trial, reflecting the trend for EC.
- Leachate alkalinity peaked in week 5 of the trial for both composites, increasing from 61 to 160 mg/L as $CaCO_3$ for the M2 composite and from 180 to 230 mg/L as $CaCO_3$ for the M3 composite. From week 6 of the trial, leachate alkalinity for the two samples converged and steadily declined to approximately 50 mg/L as $CaCO_3$. Corresponding trends for dissolved calcium and magnesium suggest that the fluctuation in alkalinity may be related to dissolution of trace[25] amounts of dolomite ($CaMg(CO_3)_2$) or a similar mineral present within the composites.
- The Oxidation-Reduction Potential (ORP) of the leachates ranged between 40 and 128 mV and dissolved oxygen concentrations were relatively stable (0.4 - 1.7 mg/L), reflecting mildly oxidising conditions. The absence of reducing conditions may be partially attributed to limitations of the testing process, but more likely reflects limited biotic activity within the sample material itself.
- Nitrate and phosphate / phosphorus concentrations were low, particularly from week two onward. After the initial leachate (up to 0.19 mg/L), nitrate concentrations ranged between <0.005 mg/L and 0.19 mg/L whilst phosphate (as P) concentrations were predominantly <0.005 mg/L. Note that these samples did not reflect the potential influence of blasting residue present in the samples collected from OSAs as they were collected from drill hole samples from the E8 area which has not yet been mined.
- Many analytes were typically at or below the limit of reporting (0.001 mg/L for most analytes) or were only detected in the first leachate (Ag, As, Be, Bi, Cd, Co, Cr, Cs, Fe(II), Hg, Mo, Ni, Pb, Se, Sn, Ta, Te, Th, Tl, U and W).
- For the elements found to be enriched (GAI ≥3) in solid samples of M2 and M3 stratigraphies (B, Fe, and Sb):
  - Boron (B) was present at relatively stable concentrations in leachates from M2 (0.1 - 0.2 mg/L) until week 9 of the trial and then declined to 0.05 mg/L thereafter. In the M3 composite, dissolved boron gradually decreased throughout the trial, from 0.3 to 0.1 mg/L.
  - Antimony (Sb) concentrations were below the limit of reporting in all leachates except for M2 week 5 (0.002 mg/L).
  - Total dissolved iron (Fe) concentrations for M2 were typically at or below 0.1 mg/L apart from a 'spike' in leachate concentration (>1 mg/L) during week 3, matched by elevated aluminium (4.2 mg/L) and titanium (0.17 mg/L), which has been attributed to colloidal material passing through the sample filtration apparatus. A minor increase was also observed in week twelve (0.24 mg/L). For M3, concentrations were < 0.1 mg/L between weeks 1 and 6 and increased to 0.19 - 0.37 mg/L during weeks 7 to 12. Similar trends for aluminium are consistent with the release of iron and aluminium colloids.
- Fluoride concentrations from both composites were relatively stable (0.5 - 1 mg/L), suggesting the presence of fluoride within a sparingly soluble mineral within the M2 and M3 composite samples. This reflects the presence of low to moderate fluoride concentrations (0.62 - 2.3 mg/L) in short-term water leachates for samples representing all stratigraphies assessed.
- There were isolated detections of copper at up to 0.01 mg/L in leachates from both composites during the first 5 weeks of the trial, after which, concentrations were consistently <0.001 mg/L. Similarly, vanadium (0.011 mg/L) and chromium (0.002 mg/L) were detected in a single leachate sample from the M2 composite at week 4.
- Barium was detected at low and relatively steady concentrations for much of the trial, at around 0.01 mg/L for M2 and 0.03 mg/L for M3. Zinc was detected at low concentrations (up to 0.004 mg/L after week 1) in leachate from both composites, peaking at week 5 - 6 of the trial and then declined to ≤0.001 mg/L thereafter. Lithium was only consistently detected in leachate from the M2 composite, at very low concentrations throughout the trial (0.001 - 0.006 mg/L).

#### 5.2.3.3 Source hazard assessment (overburden & mine voids)

##### Overburden AMD hazard

Mine Waste Management (2022a) assessed the overburden source hazard using the entire suite of geochemical test results reported in Section 5.2.3.2 and an interrogation of the projected overburden volumes from the Yandi mining models (Section 5.2.1.3).

The suite of data available to support the source hazard assessment includes an extensive assay database containing in the order of 9 million total sulphur data as well as geochemical test data for all significant overburden units except for Tertiary Sediments. As a minimum, ABA data are available to represent materials comprising 93% of the total overburden volume. Relying on a combination of extensive assay datasets and validating assay-derived inferences through laboratory testing is consistent with leading practice for AMD hazard assessment (Mine Waste Management, 2022a).

In addition to ABA, elemental analysis and leachate testing data are available for the major overburden units (M2 and M3 stratigraphies), which comprise around two thirds of the overburden volume (Section 5.2.1.3), as well as the Weeli Wolli Iron Formation (HJ), which represents 0.5% of overburden volumes but a relatively higher risk AMD compared to other stratigraphies (Section 5.2.3.2). Four stratigraphies (EK, T, M4W and A) which together comprise 32% of the overall overburden volume (Section 5.2.1.3) have not been submitted for environmental geochemical testing. However, given the low overall total S concentration

[25] The absence of detectable carbonates using XRD suggests a trace presence at no more than 1 wt.%

(from the primary assay database) in these stratigraphic units, the risk profile presented by the available environmental geochemistry dataset and low variability of leachate concentrations between stratigraphies tested (Section 5.2.3.2), the absence of ABA test work for these stratigraphies is not considered to be a critical data gap (Mine Waste Management, 2022a).

*Acidic drainage potential*

Together the sulphur assay and ABA data (Section 5.2.3.2) support the conclusion that the stratigraphies mined at Yandi generally possess low acid generation potential and all 112 samples sourced from Yandi were classified as NAF (AMD0) (Mine Waste Management, 2022a).

While GHD (2014) identified the Munjina Member Basal Conglomerate and the Weeli Wolli Iron Formation as having a higher risk of AMD than other geological formations (Section 5.2.3.2) (Mine Waste Management, 2022a):

- These stratigraphies represent only ~2% of the total overburden volume associated with the current mine plan.
- The overburden blocks intercepted by the current pit shells contain low sulphur and have been classified as AMD0 based on BHP's primary assay database.

*Neutral metalliferous, saline, and nitrate drainage potential*

As neutral metalliferous and saline drainage originate from the oxidation of sulphide minerals followed by neutralisation by *in situ* carbonates, the low total sulphur content of the Yandi deposit suggests the generation of neutral metalliferous or saline drainage resulting from sulphide oxidation is unlikely. The hazard associated with neutral metalliferous drainage derived from mined materials that do not contain sulphides or associated hydroxysulphate minerals (i.e., through mineral weathering and dissolution within post-mine landforms) was scrutinised using a combination of static and kinetic leachate testing on key overburden stratigraphies that typify the mineralogical characteristics of the site. All samples tested generated non-saline leachate and low dissolved concentrations of potentially environmentally significant metals / metalloids and salts in leachates (Section 5.2.3.2), suggesting a low risk of non-oxidative neutral metalliferous and saline drainage (Mine Waste Management, 2022a).

Static leachate testing (DI water) of samples obtained from OSAs suggest that there may be some potential for nitrate dissolution from overburden associated with ammonium-nitrate based explosive residues. This has been considered in pit lake modelling and source-pathway-receptor assessments outlined in Section 5.14.

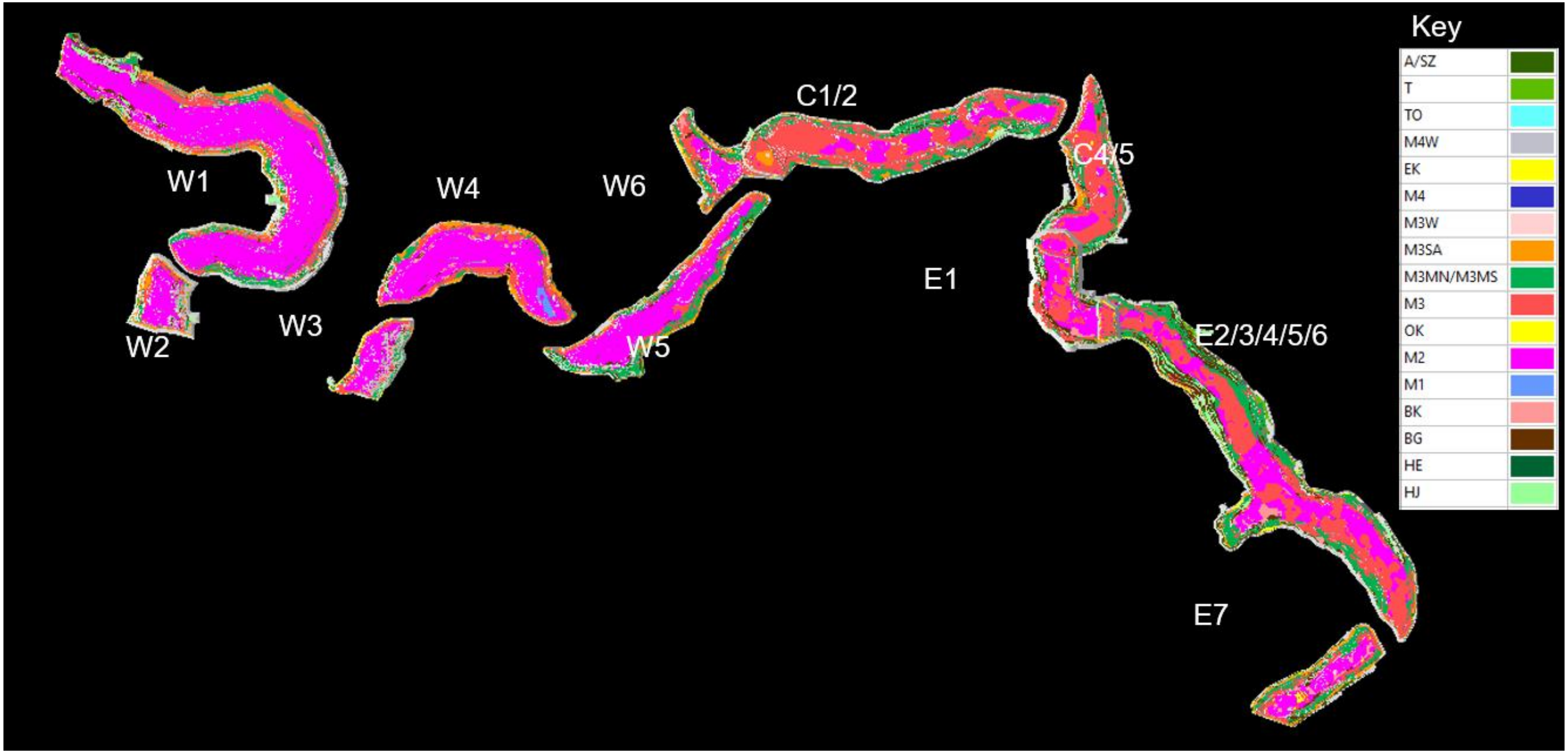
**Mine void AMD hazard**

Mine Waste Management (2022a) conducted an assessment of pit wall exposures of each stratigraphic unit at closure by combining the mining models with the final pit shell wireframe models (Table 5-7 and Figure 5-8). In summary, the stratigraphic assessment indicates that, in addition to primary assay data (including total S) for thousands of samples from each stratigraphic unit, 90% or more of the surface area of the Yandi pits is represented by ABA, elemental analysis, and short-term leachate data. The most important stratigraphies (M2, M3, BG, and HJ) are also represented by more sophisticated leachate data including multi-stage unsaturated leach testing and saturated column leach testing which have indicated a low risk of acid, neutral metalliferous and saline drainage.

**Table 5-7 Summary of stratigraphies present on final pit surface**

| Stratigraphy | Description | W1 | W2 | W3 | W4 | W5 | W6 | C1/2 | C4/5 | E1 | E2-6 | E7 | E8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Alluvials | | | X | X | X | | | X | X | X | X | X |
| SZ | Surface scree | | | | | X | X | | | | X | | |
| T | Tertiary sediments - undivided | X | X | | | X | X | | X | X | | | |
| TO | Oakover Formation | | | | | | X | | | | | | |
| M4W | Marillana Formation Iowa Member - Eastern Clay - WEATHERED | | | | | X | | | X | X | X | X | X |
| EK | Marillana Formation Iowa Member - Eastern Clay | | | X | | X | X | X | X | X | X | X | X |
| M3W | Marillana Formation Barimunya Member - Upper CID - WEATHERED | | | | X | | X | X | X | X | | | |
| M3SA | Marillana Formation Barimunya Member - Upper CID -High Silica High Alumina | X | X | X | X | X | X | X | X | X | X | X | X |
| M3MN | Marillana Formation Barimunya Member - Upper CID - Northern Marginal Zone | X | X | X | X | X | X | X | X | X | X | X | |
| M3MS | Marillana Formation Barimunya Member - Upper CID - Southern Marginal zone | X | X | X | | X | X | X | X | X | X | X | |
| M3 | Marillana Formation Barimunya Member - Upper CID | X | X | X | X | X | X | X | X | X | X | X | X |
| OK | Marillana Formation Barimunya Member - Ochreous | X | X | X | X | X | X | X | X | X | | X | X |
| M2 | Marillana Formation Barimunya Member - Lower CID | X | X | X | X | X | X | X | X | X | X | X | X |
| M1 | Marillana Formation Barimunya Member - Lower CID | | | | X | X | | | | | | | |
| BK | Marillana Formation Munjina Member - Basal Clay | X | X | X | X | X | X | X | X | X | X | X | |
| BG | Marillana Formation Munjina Member - Basal | X | X | X | X | X | X | X | X | X | X | X | |
| HE | Weeli Wolli Dolerite | | | | X | X | | | | | X | | |
| HJ | Weeli Wolli Iron Formation (PHj) (interbedded BIF & shale) | X | X | X | X | X | X | X | X | X | X | X | |

Source: Mine Waste Management (2022a)




Source: Mine Waste Management (2022a)
Refer to Appendix B.7 for more larger images of each pit

**Figure 5-8 Stratigraphy of Yandi pit surfaces**

A quantitative assessment was also conducted of the pit wall exposures of different stratigraphies in the E7, W1 and C4/5 pits (Table 5-8). Based on this analysis, the BG and HJ stratigraphies represent around 15% of the surface area of C4/5 Pit and around 6% of the final pit surface area of W1 and E7. Although these stratigraphies have been identified as slightly higher sulphur content from the total assay database (Section 5.2.3.2), the overburden blocks assigned to these two stratigraphies in the mining model contain low sulphur concentrations and are classified AMD0 (Mine Waste Management, 2022a). It is expected that the remaining pits with exposures of BG and HJ stratigraphies would represent similarly low risk, based on similar stratigraphic location within the pit shell. Once pit shell designs have been finalised, including consideration of any pit wall stabilisation measures (e.g., buttressing, pit wall re-profiling), the geochemical characteristics of pit wall exposures will be reassessed.

**Table 5-8 W1, C4/5 & E7 pit wall exposures of stratigraphic units**

| Strat. Number | Strat. Code | W1 | | C4/5 | | E7 | |
|---|---|---|---|---|---|---|---|
| | | Surface Area ($m^2$) | % Total Area | Surface Area ($m^2$) | % Total Area | Surface Area ($m^2$) | % Total Area |
| 8160 | A | - | - | 3,233 | 0.2 | 33,229 | 3.3 |
| 8100 | T | 53,828 | 1.1 | 21,345 | 1.5 | - | - |
| 7420 | M4W | - | - | 455 | <0.1 | 3,090 | 0.3 |
| 7410 | EK | - | - | 5,760 | 0.4 | 10,052 | 1 |
| 7370 | M3W | - | - | 39,230 | 2.8 | - | - |
| 7350 | M3SA | 229,624 | 4.8 | 67,199 | 4.8 | 113,465 | 11 |
| 7330 | M3MN | 288,493 | 6.1 | 145,935 | 10 | 96,876 | 9.7 |
| 7320 | M3MS | 114,818 | 2.4 | 113,594 | 8.2 | 135,730 | 14 |
| 7300 | M3 | 671,291 | 14 | 351,365 | 25 | 193,986 | 19 |
| 7130 | OK | 7,852 | 0.2 | 2,909 | 0.2 | 15,641 | 1.6 |
| 7120 | M2 | 3,014,241 | 63 | 432,146 | 31 | 287,841 | 29 |
| 7050 | BK | 120,646 | 2.5 | 45 | <0.1 | 50,975 | 5.1 |
| 7030 | BG | 143,384 | 3 | 135,847 | 9.8 | 54,061 | 5.4 |
| 6110 | HJ | 122,875 | 2.6 | 73,642 | 5.3 | 6,538 | 0.7 |

Source: Mine Waste Management (2022a)

Notes: Blue shading indicates stratigraphies that are not represented by total elemental analysis and leachate testing data and yellow shading indicates where the proportion of the stratigraphy represents more than 2% of the total pit surface area (i.e., significant surface exposures).

Golder (2020d) conducted an assessment of the potential for pit wall failure to expose PAF materials based on the outcomes of the GHD (2014) AMD study and the results of the stability analysis work described in Section 5.4.2.2. This assessment concluded that the risk of AMD generation as a result of pit wall failure was low. This is because failure through the BIF layer was not considered to be a credible slope instability mechanism, and consequently the in situ PAF materials, if any, underlying the detrital layer would be unlikely to be exposed (Golder, 2020d).

#### 5.2.3.4 Marillana Creek diversion AMD assessment

During work associated with the channel alignment for the Marillana Creek E1 and E4 diversions, and routine primary assay assessments, a number of PAF samples were identified within the stratigraphic unit encountered in the diversion. Environmental geochemical investigation and analyses were conducted to verify the AMD hazard of material exposed and excavated during the construction of the diversion channel. The findings of these studies are outlined below.

**AMD wall rock assessment at E1**

Geological mapping identified seven discrete sulphidic wall rock lithologies in the E1 reach of the Marillana diversion (Table 5-9) which were associated with a dome (hill) that had to be partially removed to allow excavation of the diversion (Figure 5-9). Each lithology was sampled and subjected to geochemical testing.

**Table 5-9 Marillana Creek E1 sulphidic wall rock lithologies**

| Sample No | Lithology | AMD classification - Total S (wt.%) |
|---|---|---|
| 1 | Altered BIF with no visible of pyrite | NAF - 0.05 |
| 2 | Weathered BIF with no visible pyrite | NAF - <0.01 |
| 3 | Slightly altered BIF | PAF - 0.99 |
| 4 | Altered dolerite (chlorite + stilpnomelane + pyrite cubes) | PAF - 0.95 |
| 5 | Schistose BIF | PAF - 10.9 |

| Sample No | Lithology | AMD classification - Total S (wt.%) |
|---|---|---|
| 6 | Fresh dolerite | NAF - 0.28 |
| 7 | Fresh BIF | NAF - 0.21 |
| 8 | Dolerite (not from E1 construction but assessed for suitability as geochemical ameliorant) | NAF - 0.03 |

Source: Earth Systems (2019a)

The total sulphur content of all samples was found to be relatively low, varying from <0.01 to 0.99 wt.%, except Sample 5 (10.9 wt.%). Data indicated that most of the sulphur was associated with sulphides. The total carbon content of all samples was low, and the ANC of all samples was low to moderate, varying from 8 to 35 kg $H_2SO_4$/t.

Following an analysis of ABA, NAG and NAG leachate chemistry data, Earth Systems (2019a) concluded:

- Four of seven wall rock types (1, 2, 6 & 7) were classified as NAF, being characterised by negative NAPP values (-8 to -30 kg $H_2SO_4$/t) and NAG pH greater than 4.5. All these samples had low total S values of <0.2 wt.% and generally moderate ANC at values greater than 20 kg $H_2SO_4$/t.
- Three samples were identified as PAF (3, 4 & 5) with potential for acid generation ranging from low to high. Samples 3 and 5 had positive NAPP values (18.4 kg $H_2SO_4$/t and 295 kg $H_2SO_4$ /t respectively). Sample 4 had a negative NAPP, but NAG testing results were inconsistent with this result, and the sample was given a preliminary classification of PAF. All samples classed as PAF had total S close to, or greater than, 1 wt.%.
- NAF samples did not display any significant mobile component in the NAG leachate (i.e., fully oxidised samples, worst case water quality) suggesting low potential for neutral metalliferous or saline drainage, however, Earth Systems speculated that NAF samples with total S >1 wt.% might generate neutral metalliferous drainage. Some metal mobilisation was observed, as expected, in the NAG leachate of PAF samples (Appendix B.8). The mobile aqueous components in the NAG leachate for the PAF samples included sulphate, aluminium, iron, manganese, arsenic, chromium, cobalt, copper, lead, nickel, selenium, and zinc.
- All samples were considered unlikely to generate salinity except Sample 5, which had a high potential for salinity due to its high reactive sulphide content.

*Acidity generation rates*

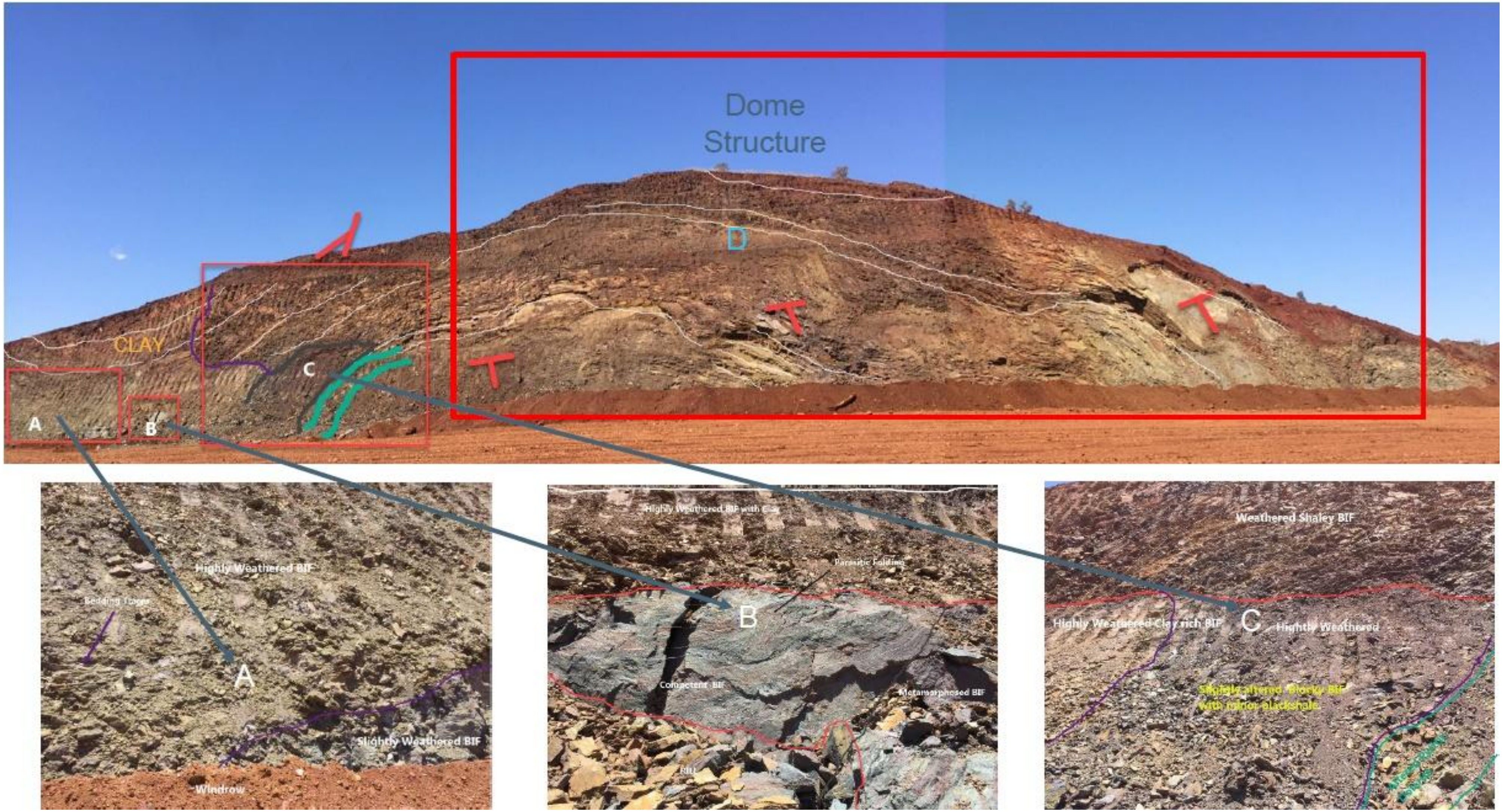
Kinetic test work (Earth Systems, 2019a) was conducted to estimate the acidity generation rates of the samples exposed on the diversion wall and assess the AMD hazard of the wall exposure. Samples 1 and 2 were excluded from the kinetic test work as they were largely weathered and contained little or no sulphur. The remaining five samples were subjected to oxygen consumption tests (Table 5-10) which confirmed the geochemical characteristics of the samples established through static test work (Earth Systems, 2019a).

Once the acid neutralising capacity of the samples is accounted for (refer to Net Acid Generation Rate in Table 5-10), Earth Systems (2019a) concluded that the normalised acidity generation / release rate from PAF samples 3, 4 and 5 is small, ranging from 0.0003 - 0.038 kg $H_2SO_4/m^2$/wt.% $FeS_2$/year. For a 1,000 $m^2$ wall rock exposure of sample 3, 4, or 5 containing an average of 1 wt.% pyrite, these acidity generation rates translate to only 0.3 - 40 kg $H_2SO_4$ per annum.

**Table 5-10 Oxygen consumption, acidity generation and normalised acidity generation rates**

| Parameter | Unit | Sample No. | | | | |
|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 |
| Oxygen Consumption Rate (OCR) | mol/$m^2$/year | 0.128 | 0.153 | 0.113 | 0.365 | 0.055 |
| Acid Generation Rate (AGR) | kg $H_2SO_4/m^2$/year | 0.007 | 0.008 | 0.006 | 0.020 | 0.003 |
| Normalised AGR | kg $H_2SO_4/m^2$/wt.% $FeS_2$/year | 0.004 | 0.004 | 0.0003 | 0.038 | 0.007 |
| Net Acid Generation Rate (NAGR) | kg $H_2SO_4/m^2$/ wt.% $FeS_2$/year | 0.004 | 0.004 | 0.0003 | 0 | 0 |

Source: Earth Systems (2019a)




Source: WAIO (2020a)

**Figure 5-9 Geology and structure of the dome exposed by excavation of the diversion channel at E1**

The approximate surface area of the dome is 1,200 $m^2$, however, geological mapping (Figure 5-9) shows that only a small proportion of this exposure is associated with pyrite bearing rock. Geological mapping identified the following key stratigraphic and geotechnical zones (WAIO, 2020a):

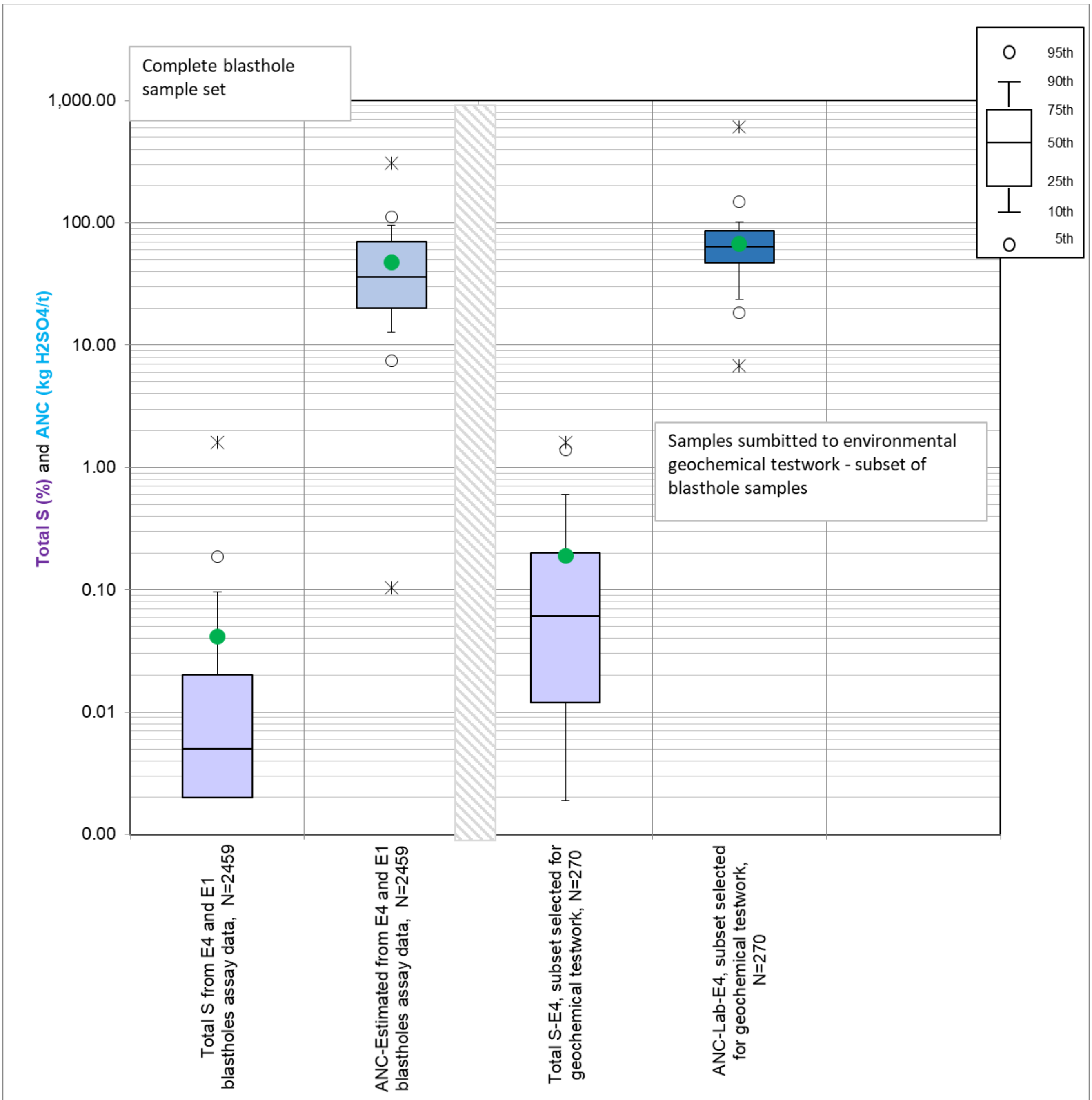
- Zone A is interpreted to be associated with highly weathered to weathered shaly BIF. No pyritic material was identified by the field geologist (similar to Samples 1 and 2, Table 5-9). Based on Earth Systems (2019a), this section of the dome is likely NAF.
- Zone B is interpreted to include clay rich shaly-BIF which includes semi-fresh metamorphosed (schist) Weeli Wolli Iron Formation (BIF - HJ), similar to Sample 5 (Table 5-9). Pyrite is associated with the BIF Schist within this zone (bottom right section of insert B in Figure 5-9). Based on Earth Systems (2019a), this section of the dome is likely PAF.
- Zone C is interpreted as to include Shaly BIF, slightly altered block BIF with minor black shale, clay rich BIF and altered dolerite, similar to Samples 3, 4 and 6 (Table 5-9). Pyrite has been observed in the black shale and in fresh and altered dolerite. Based on Earth Systems (2019a), this section of the dome is likely mostly PAF.
- Zone D is interpreted to include BIF with shale interbeds, variably weathered and including blocky BIF, similar to Sample 7 (Table 5-9). Pyrite or black shale was not observed in this zone. Based on Earth Systems (2019a), this section of the dome is likely NAF.

Geological mapping of the dome showed that pyritic material is mostly confined to dolerite and black shale, however, some disseminated pyrite was also identified in altered BIF (BIF schist). These materials are located within Zone B and Zone C. Thus, based on the geological map shown in Figure 5-9, potential PAF exposures associated with the dome amount to approximately 350 $m^2$. Using Earth Systems (2019a) acidity generation rate estimate, it is expected that the wall rock exposure may generate approximately <0.1 - 14 kg $H_2SO_4$ acidity per year. Even assuming a surface roughness and fracture density of wall rock exposures to be 100 times greater than that of the samples tested in the laboratory by Earth Systems (2019a), the acidity generation rates predicted for the wall rock exposure would still only be 11 - 1,400 kg $H_2SO_4$ acidity per year. The upper limit is associated with materials similar to Sample 6 (weathered dolerite), which is one of the lithologies exposed within Zone C on Figure 5-9. These net acidity generation rate values remain relatively low and can be managed through the soluble alkalinity in Marillana Creek water (Section 5.9.3.2) and available ANC in the alluvium (Section 5.2.3.2) (Earth Systems, 2019a; WAIO, 2020a).

#### Assessment of excavated rock at E1 and E4

The primary assay data for 2,651 blasthole samples from the excavation of E1 and E4 were assigned an AMD classification based on the BHP AMD classification system (Appendix B.9). Figure 5-10 shows the total S and the estimated ANC distribution of the full blasthole sample dataset and indicates that, overall, material excavated from the E1 and E4 diversion has low total S concentrations with median and 95$^{th}$ percentile values of 0.005 wt.% and 0.18 wt.% respectively. Only 13 samples had total S greater than 1.0 wt.%. Estimated ANC values suggest that material excavated from the diversion has moderate to elevated ANC with a median of approximately 35 kg $H_2SO_4$/t and 95$^{th}$ percentile value in excess of 100 kg $H_2SO_4$/t (WAIO, 2020a).

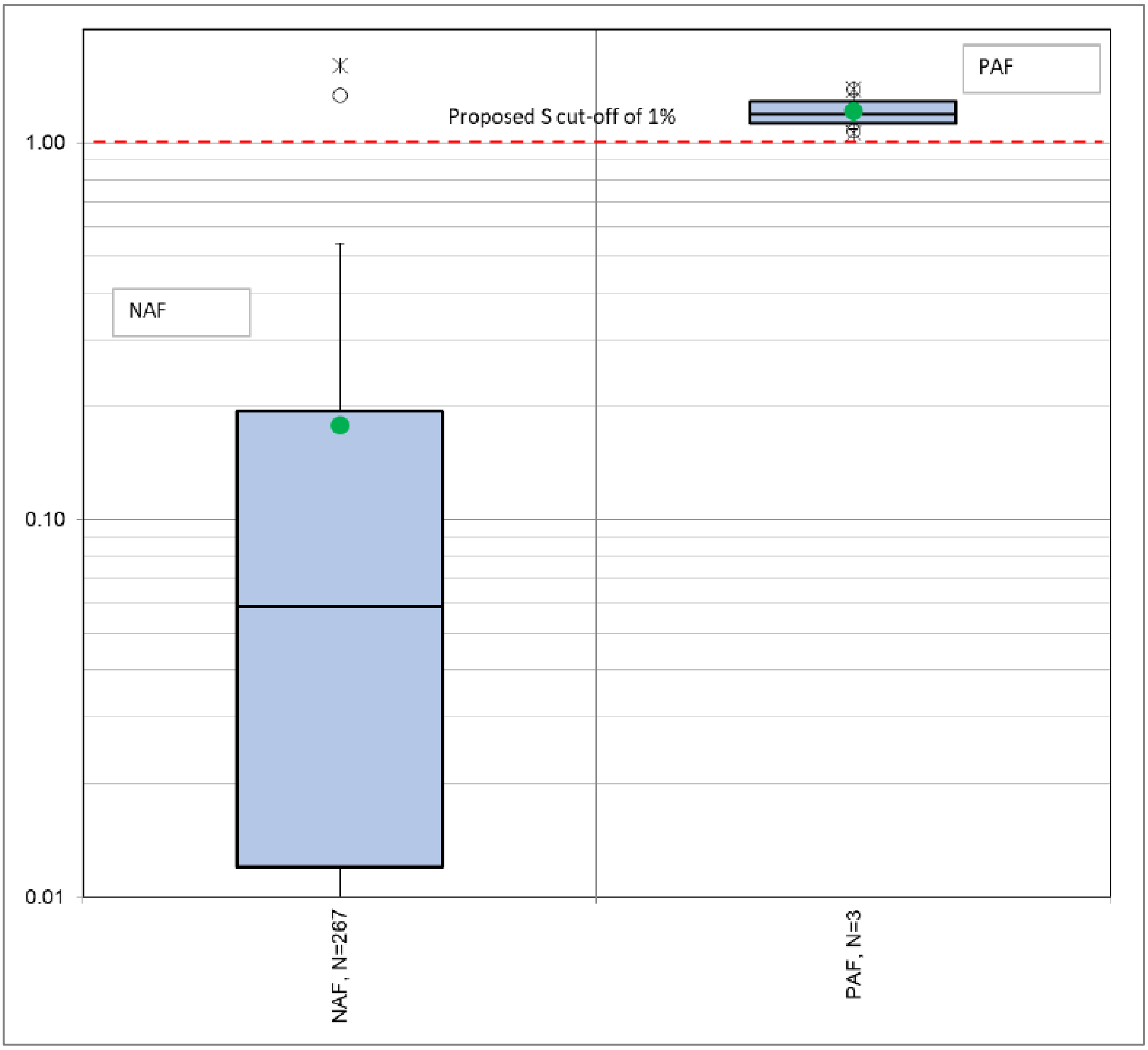
The BHP classification system identified approximately 0.1 Mt of overburden with the potential for AMD (AMD2) and these materials were selectively excavated and managed as PAF in accordance with WAIO's Acid and Metalliferous Drainage Management Technical Process Instruction (2022a). Excavated material was placed in the E2 ISA. To better understand the geochemical properties of the materials mined from the diversion and validate the BHP classification system, 270 blasthole pulp samples were submitted for geochemical test work by Earth Systems (2019a; 2019b). The samples were selected based on total S values and estimated ANC, as determined from the primary assay data, and were biased towards samples at higher S concentrations (Figure 5-10), as these represent the materials with greater potential for AMD. AMD classifications were assigned to each of the samples based on the test work results and AMIRA (2002) classification, and BHP's AMD classification system, respectively (Appendix B.9). This test work indicated that BHP's AMD classification system is conservative as of 270 samples, only three samples were classified as PAF, compared to 72 samples initially classified PAF by BHP. More importantly, only one PAF sample was erroneously classified as NAF by BHP. Based on the results of the test work, only a small proportion of the material excavated from the diversion actually has the potential for AMD generation (Figure 5-11) compared to that estimated using the current WAIO AMD classification system. Figure 5-11 shows that the PAF classification corresponds to a S cut-off value of 0.95 wt.%. When using this cut-off, less than 0.5% of the blasthole samples have the potential for AMD (which represents only a few thousand tonnes), compared to a prediction of approximately 10% (or 0.1 Mt) when using the overly conservative BHP AMD classification system (WAIO, 2020a).




Source: WAIO (2020a)

Note: Total S measured ANC (ANC-Lab) for the samples submitted for environmental test work and sourced from the E4 diversion excavations (right) and Total S and ANC-Estimated from the primary assay data of all blasthole samples for the E1 and E4 diversions submitted to bulk chemistry determination (primary assay) - left. Stars represent minimum and maximum values. Green dot represents average values

**Figure 5-10 Total S and ANC distribution for material from the E1 and E4 diversion**




Source: WAIO (2020a)

**Figure 5-11 Summary of S distribution as a function of AMD class**

A summary of the results of the test work results follows (Earth Systems, 2019a; 2019b; WAIO, 2020a):

- The samples from the diversion have elevated measured ANC with median values of 63 kg $H_2SO_4$/t, and a 5th percentile value of 18 kg $H_2SO_4$/t. The Acid Buffering Characteristic Curve (ABCC) test work data showed that calcite was the key acid neutralising mineral in most samples (7 out of 10 tested), with a field availability averaging 60%. This means that in a field setting, most of the ANC measured in the laboratory is available for acid buffering reactions.
- Median and average total S values were low at 0.06 wt.%S and 0.19 wt.%S, respectively.
- Sulphur speciation test work suggested that, in fresh samples from the creek diversion (i.e., Wolli Weeli Formation), most sulphur was associated with sulphidic minerals.
- AMD classification of the 270 samples submitted for geochemical test work using the AMIRA (2002) protocol resulted in only 1% of the samples tested being classified as PAF, with two samples having a low potential for acid generation (i.e., $NAG_7$ <15 kg $H_2SO_4$/t) and one having a moderate potential for acid generation. All these samples had total S concentrations >1 wt.%, and ANC / MPA ratios <1.15. All other samples were classed as NAF.
- Thirteen samples with total S values close to, or more than, 0.95 wt.%S were classed as NAF. These samples had ANC / MPA ratios ranging from 1.1 to 40. To better define the geochemical nature of high sulphur samples, three samples with ANC / MPA ratio <2 were submitted for sequential NAG tests. This test has the objective of pushing high sulphur samples towards complete oxidation through staged NAG tests. Following completion of the test work, none of the samples submitted for sequential NAG tests changed classification, i.e., the NAG pH remained above 4.5.
- Approximately 50% of the samples submitted for test work showed NAPP values <-50 kg $H_2SO_4$/t and total S <0.2 wt.%. These materials are generally considered NAF with potential for acid consumption.
- The geochemical environmental test work suggests that materials from the E1 and E4 diversions can be classed as having the potential for AMD when total S concentrations are close to, or more than, 1 wt.%S. This S cut-off accounts for both PAF material with the potential to generate acid drainage and for NAF material with the potential to generate neutral metalliferous drainage associated with sulphide oxidation and neutralisation reactions.

#### Dolerite assessment

Test work on dolerite excavated as part of the creek diversion process found that it was NAF and that it may offer erosion control benefits (Earth Systems, 2019a).

#### 5.2.3.5 Knowledge gaps & forward work program

The forward work program includes the following activities:

- Drilling and test work will be conducted prior to construction of flood channels to confirm low risk of exposing PAF.
- Monitoring of the E1 PAF exposure will be conducted to determine whether any further management action is required.
- Once pit shell designs have been finalised, including consideration of any pit wall stabilisation measures (e.g., buttressing, pit wall re-profiling), the geochemical characteristics of pit wall exposures will be reassessed.

### 5.2.4 Physical characterisation

Several physical characterisation studies have been conducted to inform the Yandi closure planning, including assessments of the:

- Erodibility of overburden materials at Yandi (Section 5.2.4.1).
- Hydraulic properties of alluvium and blasted rock to determine the potential to use blasted rock as an engineered aquifer in creek diversions (Section 5.2.4.2).
- Hydraulic properties of overburden to inform the permeability assumptions used in water balance modelling studies that guide the backfill strategy for Yandi (Section 5.2.4.3).
- Settlement characteristics of overburden to inform backfill and other closure strategies (Section 5.2.4.4).
- Fibrous materials identified during drilling for the W1-SP0 flood channel (Section 5.2.4.5).

Forward work programs to address remaining knowledge gaps are outlined in Section 5.2.4.6.

**Summary**

*Erosion assessment*

Material characterisation and erosion modelling has been undertaken on the stratigraphies at Yandi which represent the highest proportion of overburden (Eastern CID (M4), UCID (M3) and LCID (M2)). The UCID alone represents ~53% of the overburden. Water Erosion Prediction Project (WEPP) modelling concluded that:

- The UCID (M3) material was the most erosionally stable and would allow 40 m high linear batters with slopes of up to 12° - 18°.
- The LCID (M2) material was the most erodible. A 20 m high 15° batter may be possible due to its high critical shear, however, once rills are initiated, this material will readily detach and produce quite high erosion rates.
- The Eastern CID (M4) material would allow 20 m high batters with up to 18° slopes and 30 m high batters with potentially up to 10° to 12° slopes.
- Higher rock contents could reduce erosion to acceptable levels for 30 m batters for all materials.
- The M4 material (west sample) was the most durable of the overburden materials tested. Other overburden materials are likely to be durable, but their high water absorption value could indicate that they may weather more rapidly over time than more BIF dominated overburden.

*Alluvium / engineered aquifer assessment*

There are two types of natural alluvium: fine-grained alluvium and typical coarse-grained alluvium. The fine-grained alluvium has a fine fraction of 18% to 60% by weight, whereas the fine fraction in the typical coarse-grained alluvium comprises less than 14% of the entire sample. Testing of two materials that could potentially be used in engineered aquifers concluded that:

- Blasted BIF rock had:
  - A similar fines content to the typical coarse-grained alluvium, however, the 90% coarse fraction was preferentially coarser than the natural alluvium (predominantly cobbles rather than grading from sand to cobbles).
  - Hydraulic properties were similar to the typical coarse-grained alluvium from Marillana Creek.
- Blasted weathered dolerite had:
  - A similar fines fraction to the fine-grained alluvium, but did not have any material greater than 2 mm.
  - Similar hydraulic properties to the fine-grained alluvium from the creek.
- Both types of blasted rock could, therefore, be used to replicate the natural aquifer conditions where the ground is permanently saturated.
- The unsaturated hydraulic properties and moisture content of alluvium and the blasted rock were similar for the soil matric potential range in which the riparian trees operate and could support riparian vegetation under unsaturated conditions.
- Because the overall grading of blasted rock (from fine-grained to coarse-grained) is different to alluvium, it will have different sediment mobilisation characteristics during flow events and should, therefore, be incorporated in designs for engineered aquifers in creek diversions below the estimated depth of scour.

*Hydraulic properties of backfill*

Although drill holes targeted both LCID and UCID (based on aerial-photo interpretation), most were logged as UCID. Except for the "logged LCID", the permeability distributions of all other materials sampled followed similar log-normal distributions (in the range of 2 to 3 m/d). Logged LCID had a mean permeability of 0.2 m/d but material with a high "yellow clay" content was targeted during logging which may have led to less clayey material that would routinely form part of the LCID mass, being incorrectly allocated to UCID or the analysis of logged LCID focusing on the lower end of the range in particle size. The adopted base case for modelling was, therefore, that UCID, LCID and mixed overburden has the same effective permeability (3 m/d). Given the sensitivity of water balance modelling to permeability (see Section 5.14.1), further testing that increases the spatial distribution of test locations will be conducted to support future modelling.

*Settlement analysis*

A high-level assessment of likely backfill settlement conducted by BHP in 2015, concluded that based on the expected material type and placement process, settlement of backfill in Yandi pits would be in the order of 3.5% of placed height. However, it was noted that greater settlements could be expected if there is a large presence of clay or silt layers within the overburden and material is exposed to vibrations from machinery and traffic, or where there are large fluctuations in live loads and variable actions. A further review of the post-construction settlement performance of backfill across a variety of other Pilbara sites conducted by Advisian in 2023 concluded that:

- Conservative post-construction settlement estimates, up to 10 years post-construction, could be expected to be between 4% and 10% of backfill height, where little to no compaction is adopted.
- A reduction in post-construction settlements is likely where conventional or impact rolling methods are implemented. Reductions could be an order of magnitude, where premium construction methods, materials and control are adopted.

Settlement rates will have a significant bearing on the mine void closure outcomes and the effectiveness of floodplain landforms. Further assessment of settlement rates will, therefore, be conducted to inform detailed closure designs.

*Fibrous materials*

Naturally occurring fibrous (asbestiform - actinolite) materials have been detected within bores drilled in the dolerite that will be intersected by W1-SP0 flood channel. The length / continuity of seams is unknown (random and unpredictable), but they are expected to be lenticular. The total thickness of the fibrous material intersected by drilling seams amounts to 0.648 m, i.e. 0.068% of core drilled at W1-SP0.

#### 5.2.4.1 Erosion assessment

Landloch (2016) conducted erosion testing and modelling of three overburden materials (Eastern CID (M4), UCID (M3) and LCID (M2)) from six locations at Yandi (Table 5-11) to understand their erosion characteristics. These stratigraphies represent ~69% of the total overburden at Yandi, with the UCID representing the highest proportion (~53%) (Section 5.2.1.3).

**Table 5-11 Overburden materials tested for erosional stability (Landloch, 2016)**

| Overburden Type | Sample No | Sample Location |
|---|---|---|
| M4 - upper most overburden from the Iowa Eastern CID | M4 West | Western pits. |
| | M4 East | Eastern pits |
| M3 - overburden / ore from the UCID | M3 East | Eastern pits |
| | M3 West | Western pits |
| M2 - from the LCID of the Barimunya Member | M1/2 East | Eastern pits |
| | M1/2 West | Western pits |

Adapted from Landloch (2016)

The results of laboratory analyses of the materials in Table 5-11 are presented in Appendix B.10. In summary, M2 East and M2 West materials may present a dispersion risk as they have (Landloch, 2016a):

- Exchangeable Sodium Percentage (ESP) >6%;
- Exchangeable sodium >0.3 meq/100g;
- Effective Cation Exchange Capacity (ECEC) >3 meq/100g; and
- Clay content >10%.

However, the amount of rock in the M2 East and M2 West materials lowers the risk of structural decline and the potential for tunnel erosion (Landloch, 2016).

Laboratory testing included simulation of rainfall and overland flow using predicted rainfall events derived from local rainfall data. Testing of overland flow under a range of simulated rainfall conditions and gradients has enabled the quantification of:

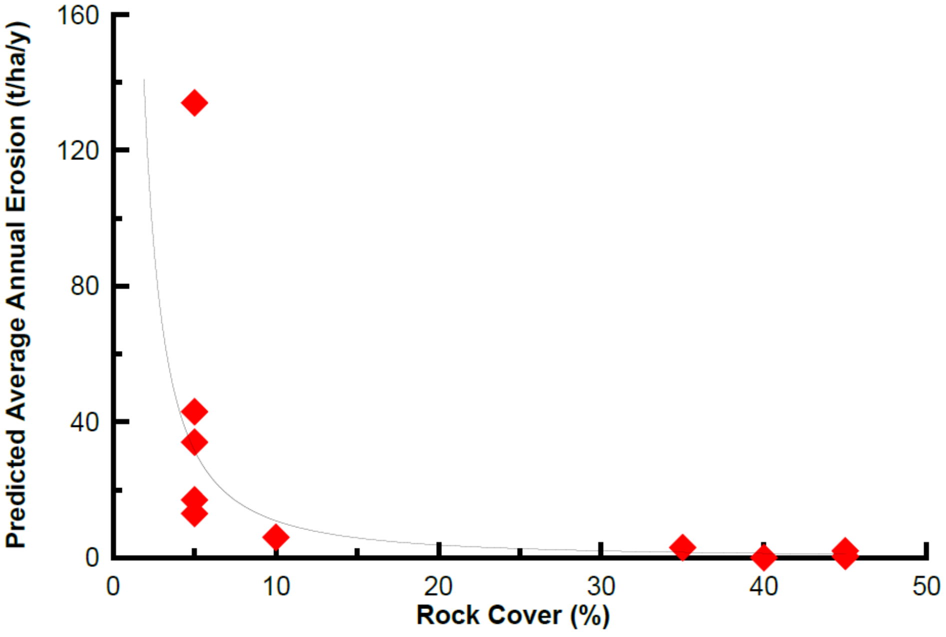
- Interrill erodibility.

- Rill erodibility.
- Critical shear.
- Effective hydraulic conductivity.

Landloch (2016) used these data in Water Erosion Prediction Project (WEPP) modelling to assess the erosion potential of each material for linear batter heights ranging from 10 to 40 m and gradients of 10° to 18° (Table 5-12). Cells shaded in red indicate batter configurations that have predicted erosion rates that exceed the thresholds set for this project. Cells shaded in green indicate batter configurations that have predicted erosion rates that are lower than the thresholds set for this project[26].

The results of the WEPP modelling (Table 5-12) show that the M3 West material was the most erosionally stable with 40 m high linear batters possible. The M2 East material was the most erodible. The pattern of erosion for M2 showed that a 20 m high 15° batter may be possible due to its high critical shear, however, once rills are initiated, this material will readily detach and produce quite high erosion rates (Landloch, 2016).

For the arid Pilbara region, the rockiness of a material strongly controls its erosion resistance. The higher the rock content, the higher the erosion resistance. Augmentation of rock into the materials will increase their erosion resistance and enable construction of taller batter profiles. The relationship between rock cover and erosion is shown in Figure 5-12 for a 10 m high 15° single linear batter slope (Landloch, 2016).




Source: Landloch (2016)

**Figure 5-12 Relationship between rock cover and erosion for 10 m high linear slope with a 15° gradient**

[26] Landforms designed with a predicted long term average annual erosion rate (averaged over the whole slope) less than 6 t/ha/yr, together with a predicted maximum long term average annual erosion rate (at any point on the slope) less than 10 t/ha/yr exhibit a low tendency to rill. These erosion threshold values were adopted in this report to differentiate between acceptable and unacceptable slope options (Landloch, 2016; 2018).

**Table 5-12 WEPP erosion predictions**

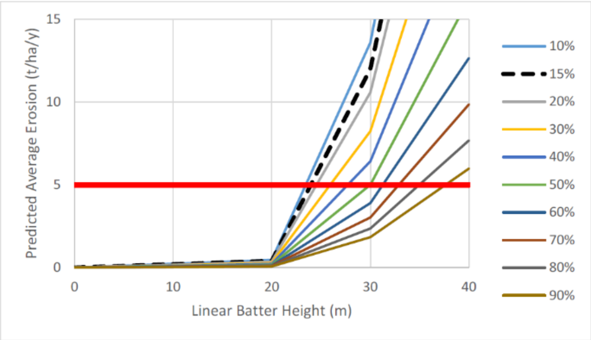
| Batter Configuration | | | Long-term Annual Erosion Predictions (t/ha/y) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M2 East | | M2 West | | M3 East | | M3 West | | M4 East | | M4 West | |
| Height (m) | Gradient (°) | Footprint (m) | Avg | Peak | Avg | Peak | Avg | Peak | Avg | Peak | Avg | Peak | Avg | Peak |
| 10 | 10 | 80.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 |
| 10 | 12 | 47.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 |
| 10 | 15 | 37.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 |
| 10 | 18 | 30.8 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 |
| 20 | 10 | 113.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.5 | 0.1 | 0.2 |
| 20 | 12 | 94.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.3 | 1.1 | 0.1 | 1.6 |
| 20 | 15 | 74.6 | 0.4 | 5.2 | 0.2 | 1.0 | 0.2 | 0.8 | 0.1 | 0.1 | 0.4 | 2.4 | 0.4 | 4.5 |
| 20 | 18 | 61.6 | 1.7 | 17 | 0.4 | 2.7 | 0.2 | 1.5 | 0.1 | 0.1 | 0.6 | 3.8 | 0.8 | 8.9 |
| 30 | 10 | 170.0 | 1.5 | 25 | 0.4 | 4.1 | 0.2 | 2.3 | 0.1 | 0.1 | 0.7 | 5.1 | 1.0 | 9.5 |
| 30 | 12 | 141.0 | 4.8 | 58 | 0.9 | 9.1 | 0.5 | 4.4 | 0.1 | 0.1 | 1.2 | 8.3 | 2.0 | 16 |
| 30 | 15 | 112.0 | 12 | 107 | 2.0 | 17 | 1.0 | 7.3 | 0.1 | 0.3 | 2.0 | 13 | 3.9 | 26 |
| 30 | 18 | 92.3 | 19 | 144 | 3.1 | 23 | 1.4 | 9.7 | 0.2 | 0.5 | 2.7 | 16 | 5.4 | 34 |
| 40 | 10 | 227.0 | 12 | 104 | 2.1 | 18 | 0.9 | 6.2 | 0.1 | 0.2 | 2.1 | 13 | 2.9 | 17 |
| 40 | 12 | 188.2 | 22 | 158 | 3.9 | 29 | 1.7 | 9.7 | 0.1 | 0.6 | 3.3 | 18 | 5.2 | 26 |
| 40 | 15 | 149.3 | 39 | 217 | 6.7 | 41 | 2.7 | 14 | 0.3 | 1.7 | 4.9 | 24 | 8.6 | 35 |
| 40 | 18 | 123.1 | 52 | 264 | 9.0 | 50 | 3.7 | 18 | 0.4 | 2.6 | 6.3 | 29 | 12 | 44 |

Landloch (2016)

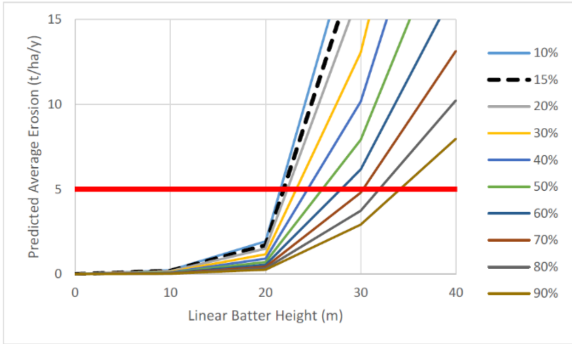
Notes: cells shaded green have a predicted long term average annual erosion rate (averaged over the whole slope) less than 6 t/ha/yr and a maximum (peak) long term average annual erosion rate (at any point on the slope) less than 10 t/ha/yr. Cells shaded red exceed these thresholds.

Figure 5-13 shows the effect of adding rock to the more erodible Yandi overburden types (M2 East, M2 West, M4 East, and M4 West) that could not be used to construct a 30 m high batter for all the gradients assessed (Table 5-12). The graphs in Figure 5-13 show the predicted average annual erosion rates for calculated rock cover values ranging from 10% to 90%. Higher rock contents could reduce erosion to acceptable levels for 30 m batters for all materials.

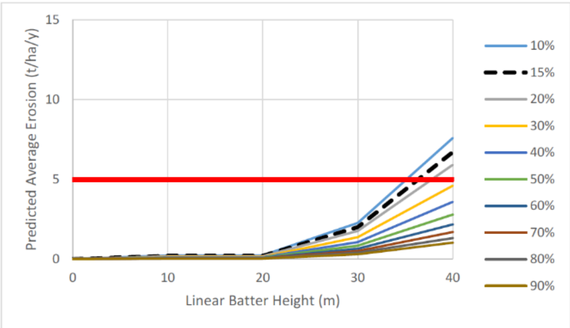
**M2 East 15° linear batter slope**



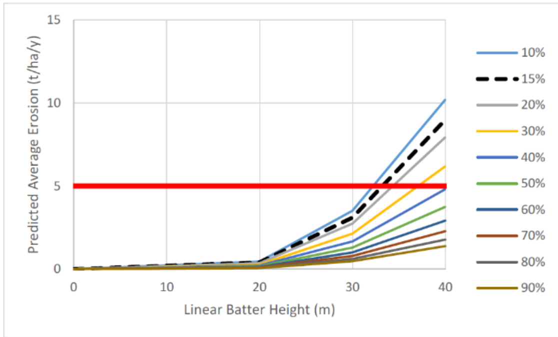

**M2 East 18° linear batter slope**



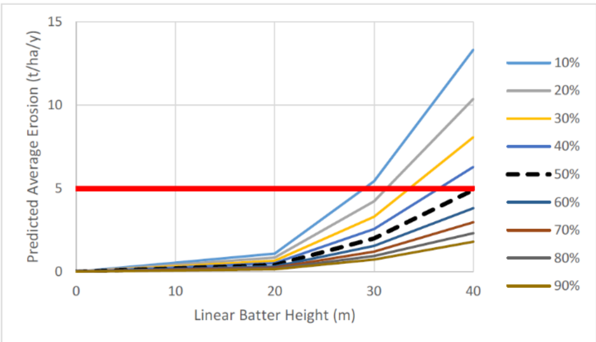

**M2 West 15° linear batter slope**



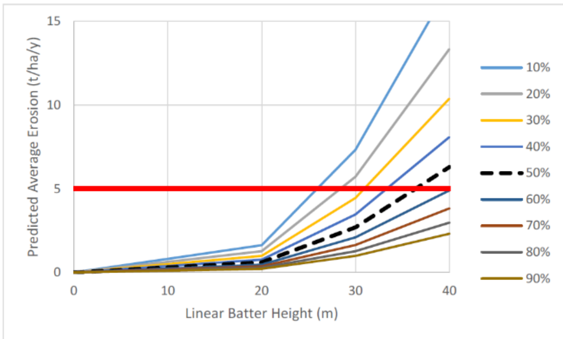

**M2 West 18° linear batter slope**



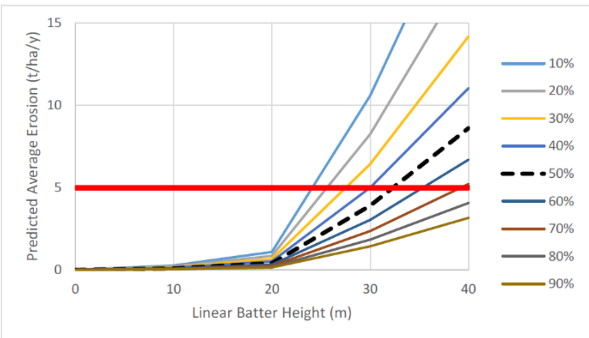

**M4 East 15° linear batter slope**



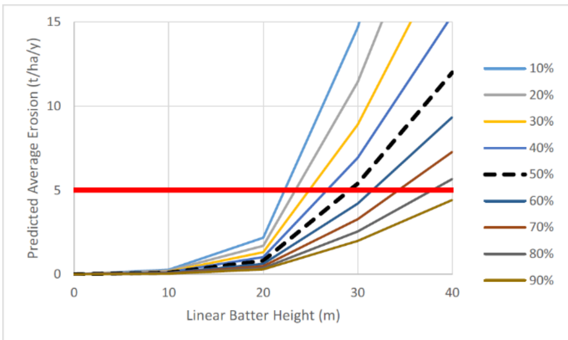

**M4 East 18° linear batter slope**




**M4 West 15° linear batter slope**




**M4 West 18° linear batter slope**




Notes: Inherent rock cover level is shown in the black dashed lines
Source: Landloch (2016)

**Figure 5-13 Erosion profiles showing the effect of rock addition**

Materials that have a rock density >2.7 g/cm$^3$ are classed as 'excellent' for use in hydraulic structures (CIRIA, 2007) and materials with water absorption results <2% are classified as 'good'. All six materials have a rock density of >2.7 g/cm$^3$, however, none of the materials have water absorption results <2% (Table 5-13). A high rock density and the lowest water absorption indicate that the M4 West material is the most durable of the overburden materials tested. Other overburden materials are likely to be durable, but their high water absorption value could indicate that they may weather more rapidly over time than more BIF dominated overburden (Landloch, 2016).

**Table 5-13 Rock characteristics**

| Analyses | Unit | M2 East | M2 West | M3 East | M3 West | M4 East | M4 West |
|---|---|---|---|---|---|---|---|
| Rock Particle Density | g/cm$^3$ | 2.7 | 2.8 | 2.8 | 3.1 | 2.7 | 3.4 |
| Rock Water Absorption | % | 19.6 | 8.9 | 7.9 | 4.7 | 9.1 | 3.9 |
| Rock Diameter $D_{50}$ | mm | 42 | 39 | 40 | 45 | 30 | 35 |
| Rock Diameter $D_{max}$ | mm | 100 | 70 | 80 | 85 | 100 | 80 |

Source: Landloch (2016)

Materials vary in their resistance to gullying due to variations in the proportions of coarse particles that resist entrainment by concentrated flows. Fine grained materials have little resistance to gully development and will not stabilise over time, whereas gullies formed in materials with a significant component of coarse fragments have considerably greater potential to stabilise over time (Landloch, 2018).

To be effective, the coarse particles need to be of a diameter and density such that their critical shear for entrainment by flow is seldom, if ever, exceeded. Based on a range of simulations for Pilbara sites and materials, critical rock particle diameters (CRD) ($D_{50}$) have been developed for a range of batter slope options (Landloch, 2018) (Table 5-14).

**Table 5-14 Critical rock diameters ($D_{50}$) for 18° batter under Pilbara conditions**

| Lift height (m) | Critical Rock Diameter (CRD) (mm)[1] |
|---|---|
| 60 | 125 |
| 20 | 70 |
| 10 | 55 |
| 5 | 45 |

Source Landloch (2018)

[1]Note: assumes a rock wet density of 2.8 g/cm$^3$

The likelihood of active and persistent gully development is assessed as (Landloch, 2018):

- Likely where material has competent rock with a $D_{50}$ <50% of CRD.
- Possible where material has competent rock with a $D_{50}$ between 50% and 99% of CRD.
- Unlikely where material with competent rock has a $D_{50}$ ≥CRD.

The $D_{50}$ of the blasted and trucked overburden at Yandi is relatively uniform, ranging from 35 - 45 mm (Landloch, 2016) which falls within the range of between 50% and 90% of CRD for lifts less than 20 m and batter slopes of 18°.

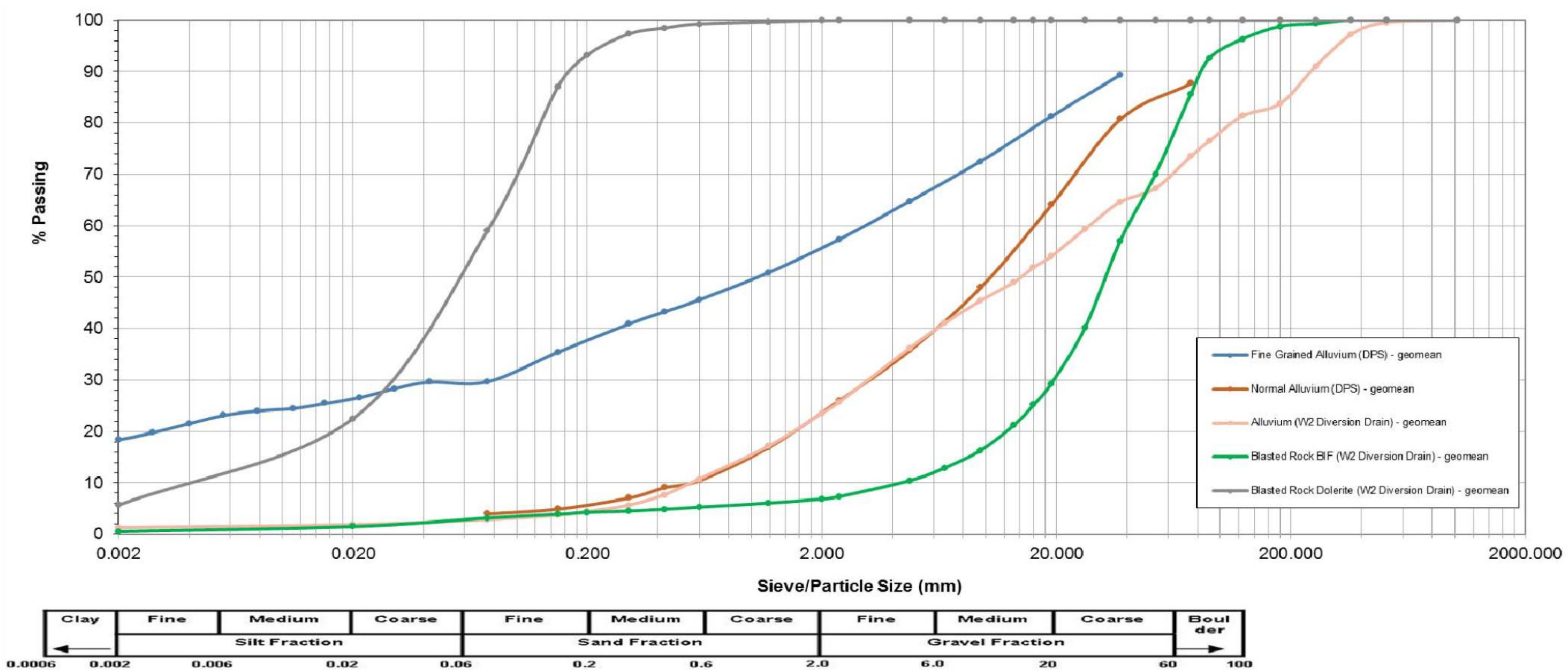
#### 5.2.4.2 Alluvium hydraulic properties assessment

To support the design of the engineered aquifer for the Marillana Creek diversions (Section 5.15.3), AQ2 (2017) conducted an assessment of natural alluvium and blasted rock to determine whether blasted rock, left in-situ, would have similar hydraulic properties to the natural alluvium. Samples of blasted rock (BIF and weathered dolerite) from the W2 and Creek 24 diversion drains were analysed and compared with analyses of Marillana Creek alluvium. The results of the analysis are summarised below.

**Particle size distribution**

There are two types of natural alluvium: fine-grained alluvium and typical coarse-grained alluvium. The fine-grained alluvium has a fine fraction (<0.075 mm sieve size) of 18% to 60% by weight, whereas the fine fraction in the typical coarse-grained alluvium comprises less than 14% of the entire sample. Drilling indicated that the alluvium in Marillana Creek does not generally increase in fines with depth (AQ2, 2017).

Figure 5-14 shows how the particle size distribution of natural fine grained (blue line) and coarse grained (dark brown line) alluvium compares to alluvium from the W2 creek diversion (light brown line), blasted BIF rock (green line) and blasted dolerite (grey line). The blasted BIF rock has a similar fines content to the typical coarse-grained alluvium; both are in the range 10% or less (for <2 mm). However, the 90% coarse fraction for blasted rock is preferentially coarser than the natural alluvium (predominantly cobbles rather than grading from sand to cobbles). The blasted weathered dolerite has a similar fines fraction to the fine-grained alluvium but does not have any material greater than 2 mm (AQ2, 2017).




Source: AQ2 (2017)

**Figure 5-14 Representative overall cumulative particle size distribution**

It is only the sand fraction and finer (i.e. <2.3 mm) that contributes to unsaturated moisture retention. Thus, for natural alluvium or blasted rock, in the unsaturated zone, only a small component of the overall mass of material contributes to plant-available water storage (AQ2, 2017).

#### Moisture retention

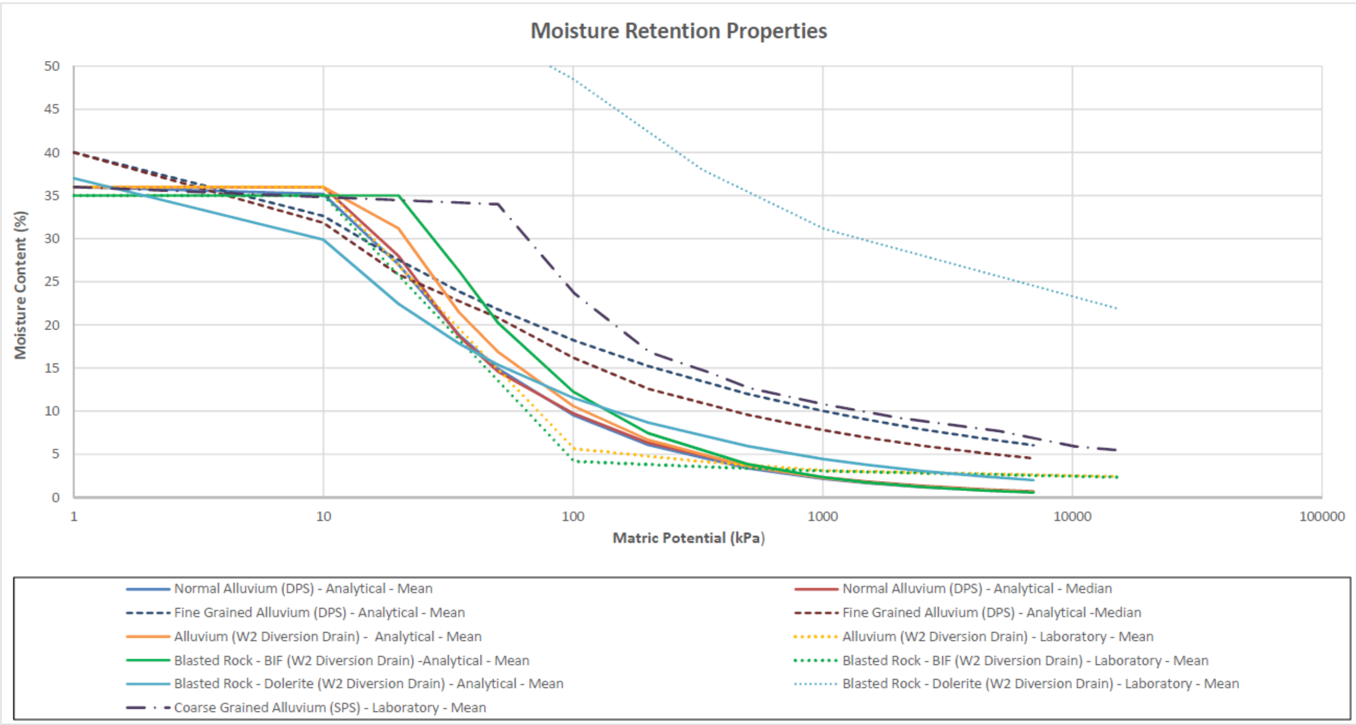
Moisture retention curves for the natural alluvium compared to blasted rock are shown in Figure 5-15. The results show that (AQ2, 2017):

- In-situ blasted BIF has similar hydraulic properties to the typical coarse-grained alluvium from Marillana Creek.
- In-situ blasted weathered dolerite (derived from the analytical mean) has similar hydraulic properties to the fine-grained alluvium from the creek. The full saturated porosity derived from laboratory data is most likely erroneous as a result of the disturbed / de-compacted nature of the sample.

Both types of blasted rock could, therefore, be used to replicate the natural aquifer conditions where the ground is permanently saturated (AQ2, 2017).

The unsaturated hydraulic properties and moisture content of alluvium and the blast samples for the W2 diversion are similar for the soil matric potential range in which the riparian trees operate (refer to Section 5.6.3). Thus, blasted rock (with a particle size distribution at least as "fine-grained" as the W2 blast) could support riparian vegetation under unsaturated conditions (AQ2, 2017).

There is a caveat on the use of blasted rock for engineered aquifer fill. The fine-grained components of alluvium and blasted rock are sufficiently similar to result in similar hydraulic properties. However, the overall grading (from fine-grained to coarse-grained) is different. The natural alluvium has a more progressive distribution whereas the blasted rock tends to have fine-grained material and very coarse-grained material. This difference will result in different sediment mobilisation characteristics during flow events. As such, blasted rock should be incorporated in designs for engineered aquifers in creek diversions below the estimated depth of scour (AQ2, 2017).




Source: AQ2 (2017)

**Figure 5-15 Moisture retention curves**

##### 5.2.4.3 Backfill hydraulic properties assessment

A preliminary laboratory assessment of Yandi CID materials was undertaken by Soil Water Group (2016) to determine its hydraulic properties for use in water balance modelling used to inform the backfill strategy. This concluded that where coarser aggregates accumulate, the permeability of backfilled material will remain high (i.e. >10 - 20 m/day) but if there is a substantial reduction in particle size or an appreciable increase in the fines content, then the permeability of the backfill would be expected to be low at <1 m/day. To increase the confidence in the hydraulic conductivity values used in water balance modelling (Section 5.14.1), and reduce the uncertainty around backfill volumes required to achieve defined environmental outcomes, seven holes were drilled at three ISA and four OSA locations (refer to Appendix B.12 for spatial location). Drill holes were completed nominally to the base of overburden using the Dual Rotary drilling method. Selected samples from the drill holes were analysed for particle size distribution, and several failing head tests were conducted during drilling. Permeabilities were then estimated from the falling head tests and particle size distribution for comparison (AQ2, 2022a).

### Drill hole data

Although drill holes targeted both LCID and UCID (based on aerial-photo interpretation), most were logged as UCID. This implies that there is either:

- Limited difference between the overburden types and all samples represent a "composite"; or
- The air-photo interpretation, and therefore testing, may not be representative of actual available overburden (i.e., skewed to UCID) as there were few samples that targeted LCID (AQ2, 2022a).

### Falling head tests

The results from the permeability tests show a wide range in values (Table 5-15) with the minimum value being 0.01 m/d, and the maximum 228 m/d. Because permeability naturally varies spatially within a formation, it is necessary to upscale individual point estimates to a value that is representative of the formation as a whole. The permeability at any specific location, within a given formation, generally follows a log-normal distribution. In an isotropic granular formation (i.e., one with the same properties in all directions), the mean value derived from the log-normal distribution can be used as the value that is representative of overall formation behaviour. This can also be approximated by the geometric mean of the non-log-normal values (AQ2, 2022a).

The log-normal distributions for several scenarios representing different interpretations of the UCID / LCID data are provided in Figure 5-16 as follows:

- The overburden types are as per the targets that were generated from the aerial photography interpretation (which implies some actual LCID overburden has been logged as UCID during drilling because either fines were lost during sample collection or because the LCID includes material that looks predominantly like UCID).
- The overburden types are as per the field logging (which implies the majority of tests undertaken were in UCID overburden, the targets generated from the aerial photography interpretation were incorrect, and LCID is poorly represented in the test results).
- The overburden types can be considered as a single material type.

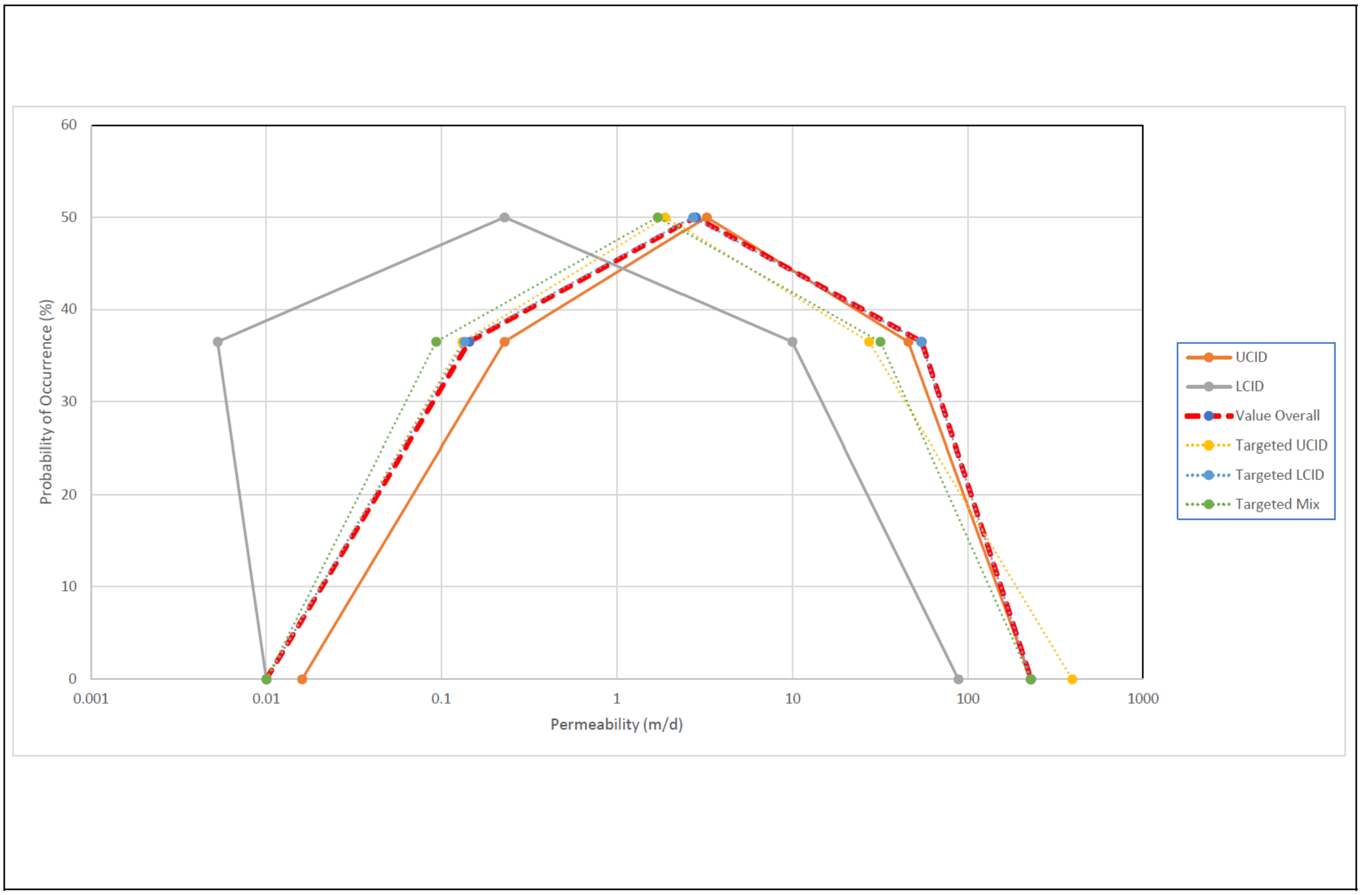
Except for the "logged LCID" material, the distributions of estimated permeability follow similar log-normal distributions, both when the results are assigned to either the material as logged, the material as targeted or a mixed single overburden type (Figure 5-16). If logged LCID results are excluded, permeability is in the range of 2 to 3 m/d. Logged LCID has the lowest mean permeability of 0.2 m/d but material with a high "yellow clay" content was targeted during logging which may have led to:

- Less clayey material that would routinely form part of the LCID mass, being incorrectly allocated to UCID; or
- The analysis of logged LCID has focussed on the lower end of the range in particle size of material that would comprise LCID.

**Table 5-15 Estimates of permeability by overburden type (from falling head test results)**

| Estimate | Min | -1 Std Dev | Mean | +1 Std Dev | Max |
|---|---|---|---|---|---|
| Overall | 0.01 | 0.1 | 2.8 | 54.4 | 228 |
| Logged UCID | 0.02 | 0.2 | 3.2 | 45.6 | 228 |
| Logged LCID | 0.01 | 0.0 | 0.2 | 10.0 | 88.1 |
| Targeted UCID | 0.01 | 0.1 | 1.9 | 27.3 | 11.8 |
| Targeted LCID | 0.01 | 0.1 | 2.7 | 53.9 | 228 |

Source: AQ2 (2022a)




Source: AQ2 (2022a)

**Figure 5-16 Estimated log-normal permeability distributions**

## Particle size distribution

Permeability was estimated from particle size distribution using two methods (Table 5-16). The magnitude and range in estimated permeability is consistent with the range derived from the analysis of falling head tests outlined above.

**Table 5-16 Estimates of permeability derived from the particle size distribution analysis**

| Sample type | Hydraulic Conductivity (m/d) | |
|---|---|---|
| | Saxton Rawls[1] | Devlin[2] |
| LCID | 0.248 | 0.46 |
| UCID | 0.234 | 60.9 |
| UCID | 0.252 | 6.12 |
| UCID | 0.458 | 3.36 |
| UCID | 0.328 | 3.41 |
| UCID | 0.177 | 0.14 |
| UCID | 0.368 | 5.65 |

Source: AQ2 (2022a)

Notes: [1] Estimates fine fraction only and where material has a large coarser fraction, commonly underestimates permeability by 1 - 2 orders of magnitude (AQ2, 2022a).

[2] Accounts for coarse fraction and is likely to give more reliable estimate for Yandi overburden (AQ2, 2022a).

## Adopted base case

The magnitude and range of permeabilities estimated from particle size distribution data are consistent with the permeabilities estimated from falling head tests. Falling head test analyses show that, other than when the four "logged LCID" samples are considered separately, the permeability of the overburden material follows a similar log-normal distribution. As such, the adopted base case for modelling is that UCID, LCID and mixed overburden has the same effective permeability (3 m/d).

### 5.2.4.4 Settlement assessment

A high-level assessment of likely backfill settlement was conducted (BHP Billiton, 2015) using assumed material properties based on overburden material characteristics derived from E7 drill core data (Table 5-17) and an assumption that the proportion of these materials in backfill comprises 66% M3 and 33% M2. This concluded that given the expected material type and placement process, settlement of backfill in Yandi pits would be in the order of 3.5% of placed height, although it was noted that greater settlements could be expected if:

- There is a large presence of clay or silt layers within the overburden; and
- Material is exposed to vibrations from machinery and traffic, or where there are large fluctuations in live loads and variable actions.

Advisian (2023f) conducted a further review of the post-construction settlement performance of backfill across a variety of other Pilbara sites and concluded that:

- Conservative post-construction settlement estimates, up to 10 years post-construction, could be expected to be between 4% and 10% of backfill height, where little to no compaction is adopted. It was noted that settlements in the order of 6% have been noted within relatively short post-construction timeframes.
- A reduction in post-construction settlements are likely where conventional or impact rolling methods are implemented. Reductions could be an order of magnitude, where premium construction methods, materials and control are adopted.

**Table 5-17 Overburden material characteristics**

| Strat Unit | Range of Strengths | Modal Strength Class | Nominal Equivalent UCS* (MPa) | Weighted Average UCS* (MPa) | Unit Weight kN/m$^3$ | Moisture Content (%) | Soil Classification | Uniformity Coefficient |
|---|---|---|---|---|---|---|---|---|
| **M3** | CVSO (soil) - strong | Weak | 5 - 25 | 22.52 | 27 | 36 | SAND with gravel and silt | 11800 Well graded |
| **M2** | CSO - strong | Weak | 5 - 25 | 11.11 | 26 | 64 | Silty SAND with gravel pockets of clay Sandy silty CLAY | 175 Well graded |

Source: BHP Billiton (2015)

Notes: *Unconfirmed Compressive Strength

### 5.2.4.5 Fibrous materials

Naturally occurring fibrous (asbestiform - actinolite) materials have been detected within bores drilled in the dolerite that will be intersected by W1-SP0 flood channel (Table 5-18 and Map 5-2) (Advisian, 2023e).

Drill core analysis indicated that the fibrous materials were typically found locally between defects in the dolerite. Defects were typically widely spaced and planar to undulating, slightly rough to rough and clean. All fibrous seams noted were within, or in immediate vicinity of, coarser grained grey dolerite which is thought to have been intruded into the finer grained darker grey dolerite encountered. The length / continuity of seams is unknown (random and unpredictable), but they are expected to be lenticular (Advisian, 2023e).

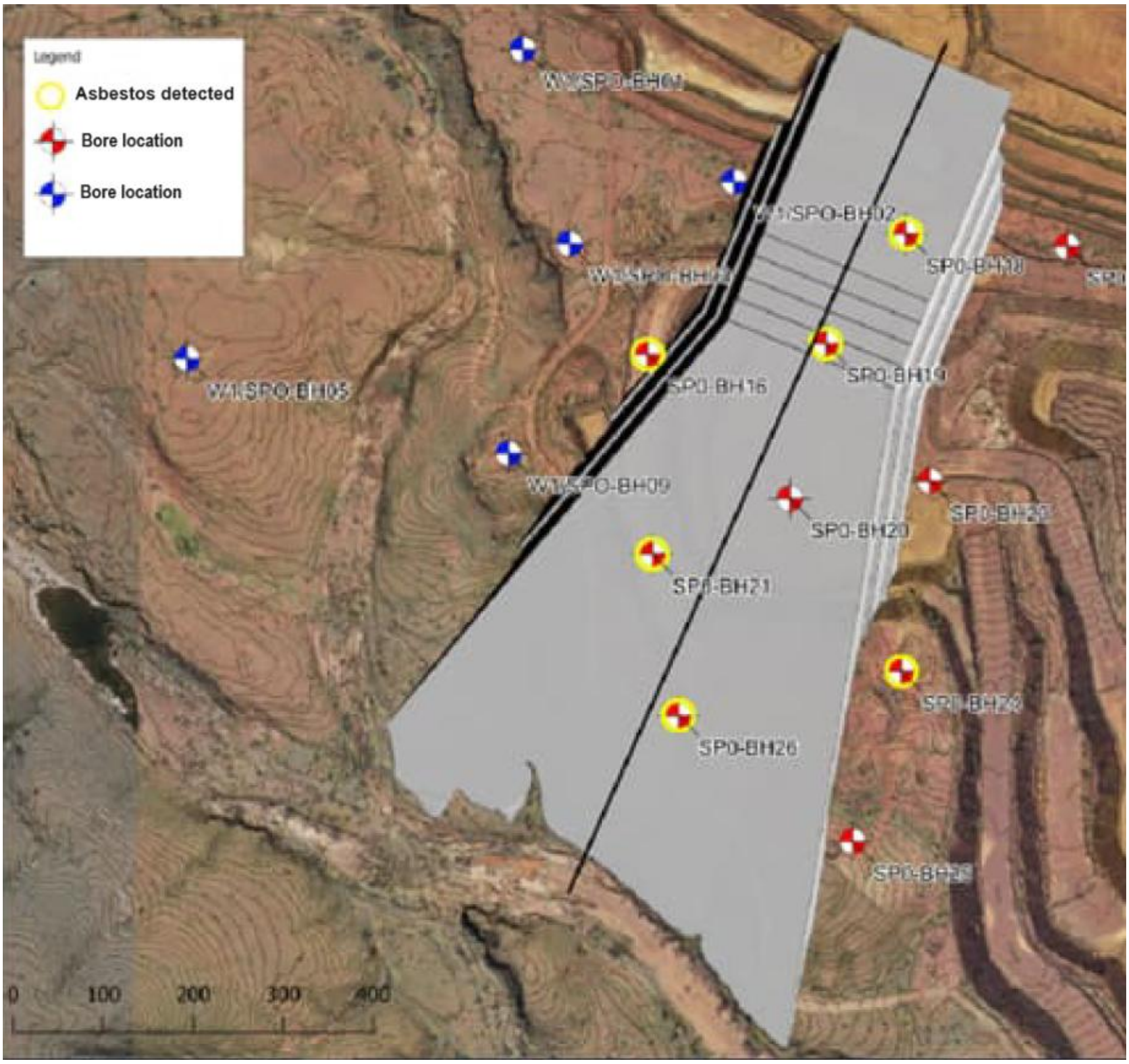
There have been 959.9 m of drilling at, or within the immediate vicinity of the W1-SP0 flood channel, and 74 individual seams of fibrous materials have been logged, ranging in thickness from 1 mm to 50 mm. The total thickness of the fibrous material seams amounts to 0.648 m, i.e. 0.068% of core drilled at W1-SP0 (Advisian, 2023e).

A qualitative assessment of the risks associated with this material in connection with the W1-SP0 flood channel location is discussed in Section 5.14.7.5.

**Table 5-18 Naturally occurring fibrous materials detected during drilling of W1-SP0 flood channel**

| Borehole | Depth (mbgs) / Description |
|---|---|
| W1/SP0-BH03 | 37.2 m (discontinuous seam of potential fibrous materials up to ~ 100 mm thick at base of run) |
| W1/SP0-BH18 | 50.7 to 51.5 m (three potential fibrous seams between 1 mm and 10 mm thick) |
| W1/SP0-BH19 | 61.7 to 61.9 m (80 mm thick fibrous seam) |
| W1/SP0-BH21 | 41.4 to 43.9 m (three potential fibrous seams up to 10 mm thick) |
| W1/SP0-BH24 | 27.9 to 49.05 m (numerous seams of fibrous material ranging from 1 - 50 mm thick) |
| W1/SP0-BH26 | 29.90 to 30.15 m (two 2 mm thick fibrous material seams) |

Source: Advisian (2023e)




Source: Advisian (2023e)

**Map 5-2 Locations of fibrous materials detected at W1-SP0**

#### 5.2.4.6 Knowledge gaps & forward work program

The following forward work programs have been identified to support refinement of Yandi closure designs:

- Given the sensitivity of water balance modelling to permeability (see Section 5.14.1), further testing that increases the spatial distribution of test locations will be conducted to support future modelling.
- Settlement rates will have a significant bearing on the mine void closure outcomes and the effectiveness of floodplain landforms. Further assessment of settlement rates will, therefore, be conducted to inform detailed closure designs.
- Mapping of fibrous materials exposures in flood channels will be conducted, where there is safe access following construction, to enable confirmation (or otherwise) that the assumptions used in risk assessments are valid (refer to Section 5.14.7.9).

### 5.2.5 Volume and availability

The 2020 MCP categorised available (as mined in 2020) overburden into material groups with different proportions of UCID and LCID based on aerial photography. Since that study, AQ2 (2022a) completed permeability testing on the materials classified as UCID and LCID by aerial photography (Section 5.2.4.3), and determined that:

- The permeability of the materials could not be estimated on the basis of these classifications.
- When considered in aggregate, the material could be classified as a mixed material with the same effective permeability.

Except for materials yet to be mined, re-estimates of overburden volumes to include new mine planning data, topsoil bases and haul roads, therefore, do not distinguish between different material types (Table 5-19).

**Table 5-19 Overburden volume estimates**

| Category | Feature | Volume $Mm^3$ |
|---|---|---|
| Reclaimable OSAs, ROM & topsoil base | Western, Central, Eastern | 84.1 |
| Rehabilitated OSAs to remain post-closure | C1 and E2 | 25.9 |
| ISAs | E2, E3, E5, E6, W4 | 75.8 |
| Overburden to be mined WMAT 1 | W1, W2, W3, W5, W6, C1, C3, C6, E1, E3, E4, E7, E8 (proposed) | 2 |
| Overburden to be mined WMAT 3 | | 3.7 |
| Haul roads | W1, W4, W5, W6, C1, E2, E3, E4, D7, | 11.7 |
| **Total** | | **203.2** |

# 5.3 Soil characteristics

**Summary**

Temperature and soil moisture are inter-related and influence germination and establishment. Most Pilbara species will germinate over a wide temperature range (10 to 35°C), but require ample moisture, which is characteristic of cyclone rain events (with at least 4 rain events occurring within a 10-day period). Germination for most species, therefore, occurs in spring and summer (December to March) in correspondence with the highest moisture levels in the Pilbara.

There are ~2.3 $Mm^3$ of stockpiled topsoil at Yandi. Assuming an application of 150 mm topsoil across all disturbed domains there is a deficit of ~2.2 $Mm^3$ topsoil for rehabilitation. A rehabilitation trial is proposed to assess the effectiveness of mixing different proportions of topsoil with CID to address this deficit (Section 5.15.7).

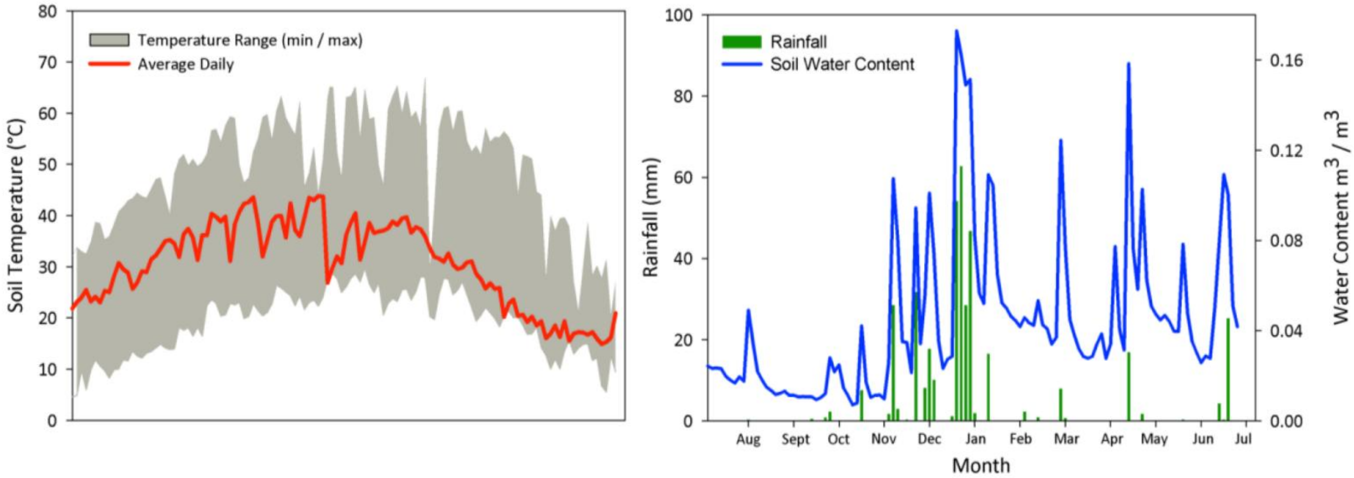
Several Yandi overburden types have been tested to assess their potential for use as growth media. Test results indicated that:

- In terms of pH and EC, all materials would likely be suitable for native plant growth without amendment.
- Total nitrogen, plant available phosphorous, sulphur and organic carbon were generally consistent with those in the region. Available potassium was lower than topsoils in the region but was considered unlikely to inhibit vegetation establishment.
- Wet Basal Clay was slightly sodic with an ESP of 9, due to the lack of exchangeable calcium and magnesium compared with other samples. All other materials were not sodic (ESP <6%).
- Wet basal clay, basal clay, LCID, UCID and Eastern CID all indicated the potential to be 'hard setting' which may restrict seedling emergence and root penetration into the soil matrix and will require strategies to ensure good germination of reintroduced target species.
- In terms of chemical properties, the Ochreous Goethitic Clay was identified as the most suitable topsoil substitute. However, due to the clayey nature of the material and the low percentage of rocks, the use of Siliceous Hard Cap material in conjunction with the Ochreous Goethitic Clay would be important as the high proportion of rocks in the material would provide surface stability, while the Ochreous Goethitic Clay would store water and nutrients.
- The Poddy Clay could also be used in conjunction with Siliceous Hard Cap material as surface materials on OSAs, as it was chemically benign and appeared to have low potential to hard set.

## 5.3.1 Pilbara soil environment

The Pilbara soil environment is as follows:

- Soil temperatures range from a low of 5°C during winter to over 65°C during summer (Figure 5-17).
- Soils experience intermittent periods of wetting and drying, which occurs more frequently during the summer months (December to March) (Figure 5-17).
- During intense summer rainfall events soil temperatures drop with the influx of soil moisture (for example, from 65°C to 25°C when fully saturated).
- Following a large rainfall event, due to high evaporation rates, soil dries quickly (with soil moisture rarely persisting in the top 5 cm of the soil profile beyond one week) (Figure 5-17).
- Lower evaporation rates from May to August mean that smaller rainfall events that occur during this time can lead to relatively high soil moisture levels, but these increases in soil moisture are short-lived due to evaporation (Figure 5-17).




Notes: Recorded during 2013/2014 at a depth of 3-5 cm below the soil surface at a site in the Pilbara near Newman, WA
Source: Erickson, Barrett, Symons, Turner, & Merritt (2016)

**Figure 5-17 Relationship between soil temperature, rainfall and soil moisture content**

Temperature and soil moisture are inter-related and influence germination and establishment in the field. Most species will germinate over a wide temperature range (10 to 35°C), but require ample moisture, which is characteristic of cyclone rain events (with at least 4 rain events occurring within a 10-day period). Germination for most species occurs in spring and summer (December to March) in correspondence with the highest moisture levels in the Pilbara (Restoration Seedbank Initiative, 2020a; 2020b; 2020c).

## 5.3.2 Soil characteristics

Yandi lies within a large region of soils that have been classified by Bettenay et al. (1967). The dominant soil types covering the project area are coherent and porous loamy soils with weak pedologic development. These soils are generally associated with spinifex steppes and a tree overstorey of *Eucalyptus leucophloia*.

In the hills and mesas that represent the surface expression of the Robe Pisolite, extensive areas without soil cover occur, and those soils that do occur are shallow and skeletal. Here, rocks weather very slowly and any soil which does form, tends to be transported into the surrounding valleys and plains because of the sparse vegetation cover and erosional force of heavy rains derived from thunderstorms and cyclones (Beard J. S., 1975). Consequently, it is the geology rather than the soil type which is correlated with the vegetation type in the hills and ridges of the Yandi region. Despite this, the soils of the hills and mesas tend to possess a duplex texture profile of medium texture with a uniform profile.

The soils on slopes, although having had more time to develop than the soils of adjacent ridges, are still influenced by the parent rock, and may be sands or loams and are often shallow and stony. These soils are generally unfavourable for plant growth due to their low soil moisture holding capacity and poor nutrient status (Beard J. S., 1975).

On pediments, older pediplains and alluvial plains, the soil has had considerable time to develop. Here, deeper hard alkaline red loamy soils tend to be dominant and can probably be considered as the regional mature soil type (Beard J. S., 1975). The surface of these areas may carry a layer of small gravels, which are derived from the more resistant rocks in the area, particularly quartz and jaspilite. Incoherent sands occur in the active streams which drain the region.

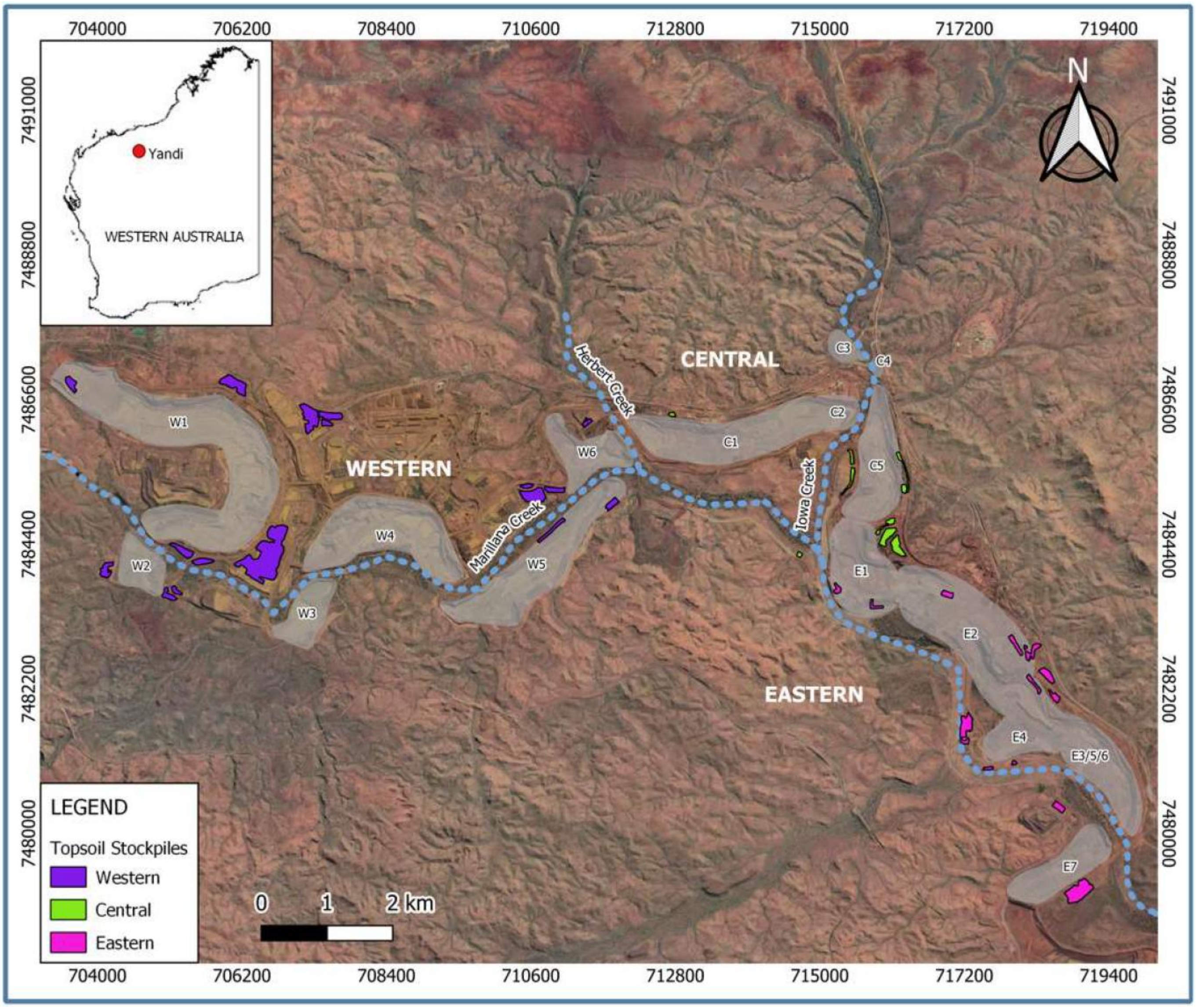
The soil type in the main drainage channel of Marillana Creek consistently tends to be alluvial sands with a combination of alluvial sands and duplex soils forming creek banks (Ecologia, 1998). Soils of minor drainage lines (i.e. tributaries of Marillana Creek) are consistently composed of duplex soils.

## 5.3.3 Topsoil

There are several topsoil stockpiles at Yandi (Table 5-20 and Figure 5-18). Recent survey data indicate that there are 2.3 $Mm^3$ of topsoil stockpiled. A program is planned to test topsoil stockpiles for a range of physical and chemical parameters influencing plant growth. This information will inform the planned rehabilitation trials and revegetation strategy for Yandi (Sections 5.15.7 and 9.3). Data from the testing program will be included in future iterations of this MCP.

**Table 5-20 Summary of topsoil stockpile inventory**

| Zone | Number of Topsoil Stockpiles | Volume ($Mm^3$) |
|---|---|---|
| Western | 16 | 1.46 |
| Central | 8 | 0.26 |
| Eastern | 14 | 0.57 |
| **Total** | **38** | **2.30** |




Source: Okane (2024b)

**Figure 5-18 Topsoil stockpiles**

Golder (2020b) assessed the topsoil required for revegetation of Yandi, assuming the application of 150 mm topsoil across all disturbed domains in accordance with the *Management of Growth Media for Rehabilitation Technical Process Instruction* (WAIO, 2022c). This information has been used to develop a topsoil balance for Yandi (Table 5-21) which indicates that there is a deficit of approximately 2.2 $Mm^3$. The proposed rehabilitation trial (Section 5.15.7) aims to assess the effectiveness of mixing different proportions of topsoil with CID to address this deficit.

Typically topsoil deficits occur due to:

- The greater surface area of three-dimensional landforms (OSAs) compared the original landform;
- Some areas of the pre-mining surface may not have had topsoil, whereas the recreated landforms do require growth media;
- Losses incurred during stripping, storage and relocation to rehabilitation areas.

**Table 5-21 Yandi topsoil balance**

| Component | Volume (Mm$^3$) |
|---|---|
| Current topsoil stockpiles | 2.3 |
| Backfilled pit topsoil requirements (@ 150mm) | 1.6 |
| Ex-pit topsoil requirements (@ 150mm) | 2.9 |
| ***Total topsoil requirement*** | ***4.5*** |
| **Total deficit** | **2.2** |

Source: Okane (2024b); Golder (2020b)

### 5.3.4 Alternate growth media

The suitability of overburden materials at Yandi as growth media has been considered by Outback Ecology (2005) and Landloch (2016). The analytical data derived from these studies are presented in Appendix B.10 and B.13 respectively. The materials tested during the respective studies are outlined in Table 5-22.

**Table 5-22 Alternate growth media sampling locations**

| Overburden Type | Sample Location | Sample No | Source of Data |
|---|---|---|---|
| M4 - upper most overburden from the Iowa Eastern CID | Western pits | M4 West | Landloch (2016) |
| | Eastern pits | M4 East | |
| M3 - overburden / ore from the UCID | Eastern pits | M3 East | |
| | Western pits | M3 West | |
| M2 - LCID of the Barimunya Member | Eastern pits | M1/2 East | |
| | Western pits | M1/2 West | |
| UCID Siliceous Hard Cap | Southern End C5 A | MC1 | Outback Ecology (2005) |
| | Southern End C5 B | MC2 | |
| Poddy Clay | C1 546 A | MC3 | |
| | C1 546 B | MC4 | |
| LCID Ochreous Goethitic Clay | C5 510 Bench A | MC5 | |
| | C5 510 Bench B | MC6 | |
| Wet Basal Clay | C1 546 A | MC7 | |
| | C1 546 B | MC8 | |
| Basal Clay | C5 West Wall A | MC9 | |
| | C5 West Wall B | MC10 | |

Source: Landloch (2016); Outback Ecology (2005); Golder (2020a)

Both Landloch (2016) and Outback Ecology (2005) found that the pH of materials tested was generally in the range of slightly acidic to slightly alkaline. EC was also found to be low in all samples. In terms of pH and EC, it was considered likely that all materials would be suitable for native plant growth without amendment.

Soils and overburden materials from the Pilbara are typically low in total Nitrogen (N) and Organic Carbon (Landloch, 2016). Outback Ecology (2005) noted that all materials analysed had similar or higher N concentrations to the topsoils of the region and Landloch (2016) indicated that the total N and organic carbon values were consistent with those in the region. Despite these similarities, Landloch (2016) recommended that the M2, M3 and M4 materials be amended to increase N if they were to be used in rehabilitation activities.

Of the other nutrients, the plant available Phosphorus (P) levels were very low to moderate and available Potassium (K) was very low (Landloch, 2016). Outback Ecology (2005) noted that all materials had similar or higher P and S concentrations to the topsoils of the region, but lower K concentrations which were considered unlikely to be an issue for vegetation establishment.

Wet Basal Clay (MC8) was considered to be slightly sodic with an ESP of 9, due to the lack of exchangeable Ca and Mg compared with other samples. All other materials analysed by Outback Ecology (2005) were not sodic with ESP values below 6%.

The Wet Basal Clay (MC7 and MC8) and Basal Clay (MC9 and MC10) materials recorded crust strength values in the MoR test which suggested that they have the potential to be 'hard setting' (Outback Ecology, 2005). Landloch (2016) similarly noted that the most likely structural issues for materials M2 - M4 would be hard setting surfaces. Restricted seedling emergence and root penetration into the soil matrix is a likely consequence of a hard setting surface and will require strategies to ensure good germination of reintroduced target species. Outback Ecology (2005) concluded that the Wet Basal Clay and Basal Clay would not be ideal for surface soils on OSAs.

In terms of chemical properties, the Ochreous Goethitic Clay would be most suitable as a topsoil substitute, as sample MC6 reported the highest Cation Exchange Capacity (CEC), as well as high N and K. However, due to the clayey nature of the material and the low percentage of rocks, the use of Siliceous Hard Cap material in conjunction with the Ochreous Goethitic Clay would be important as the high proportion of rocks in the material would provide a high degree of surface stability, while the Ochreous Goethitic Clay would store water and nutrients. The Poddy Clay could also be used in conjunction with Siliceous Hard Cap material as surface materials on OSAs, as it was chemically benign and appeared to have low potential to hard set (Outback Ecology, 2005).

### 5.3.5 Knowledge gaps & forward work program

A program is planned to test topsoil stockpiles for a range of physical and chemical parameters that influence plant growth.

At the time of writing, a planning process was underway for implementing rehabilitation trials to test different growth media mixes (Section 5.15.7).

## 5.4 Slope stability and seismicity

**Summary**

A probabilistic seismic hazard assessment conducted for the Yandi area concluded that the peak ground acceleration values estimated from the study correspond to a low to moderate seismic hazard. Peak ground accelerations based on a 10% probability of exceedance in 50 years were estimated to be up to 0.074 g.

Slope stability was modelled for several pit sections which were chosen to capture the variability of material distribution and thickness along the paleochannel. This work was reported in the 2020 MCP. Further work was being conducted at the time of writing but was not available for inclusion in this MCP. A summary of the work reported in the 2020 MCP follows. Criteria adopted to assess acceptable stability were Factor of Safety (FoS) ≥1.5 under static conditions and FoS ≥1.0 for seismic conditions (assuming a peak ground acceleration of 0.12 g):

- Most areas met the slope stability criterion of FoS ≥1.50 for an overall slope scale instability except some sections in W1 to W4 pits and Section EA’ in East Pit where a multi-batter scale failure mechanism was identified.
- Sections AC to AF in W5 Pit adjacent to the Marillana Creek had FoS >1.70.
- Slope failure mechanisms were found to be within the CID sequence and no critical mechanisms were identified in the Weeli Wolli (HJ) BIF. Failure mechanisms in the CID were considered likely to result in a relaxed slope profile over time through natural slope degradation processes rather than failure as a single mass which was considered unlikely.
- End walls have been designed and constructed to an operational FoS (>1.20), which is lower than that required for closure. End walls will require either a flatter final slope angle or buttressing to achieve a FoS ≥1.50.
- All sections were above the minimum FoS ≥1.0 for seismic conditions.

In addition to geotechnical failure mechanisms, the potential for erosion to impact pit walls was also evaluated using SIBERIA modelling. The model was designed to evaluate erosion of the W1 Pit wall, but the outputs can be used as a proxy for other pits which share similar benched profiles. The model predictions should be viewed as qualitative due to the lack of erosion data by which to calibrate the model, the expansive areas covered by multiple pits, and the potential variability in pit wall materials. However, the results provide a supporting tool in the development of final designs. Key conclusions arising from the modelling are:

- Pit walls with minimal ex-pit catchments are unlikely to cut far back into ex-pit areas due to the inherent stability of the UCID material.
- Erosion features tend to develop more extensively where bench and ex-pit catchments are larger. However, over the 1,000-year modelling period no areas of the W1 Pit were predicted to erode to an extent that would cause capture of Marillana Creek.
- Head cutting of gullies into the surrounding terrain may occur where the pit catchment is large and concentrates surface water flows. This can be mitigated by using bunds to compartmentalise ex-pit catchments, limiting the volume of surface water runoff discharging down pit walls.

### 5.4.1 Seismic hazard analysis

In 2012, a probabilistic seismic hazard assessment was conducted on selected BHP operations in the Pilbara, including Yandi (Meynink Engineering Consultants, 2012). The assessment was based on area seismic sources as no evidence of recent fault activity was recognised close to the BHP operations in the Pilbara during the preliminary neotectonic observations. The observations showed that an inferred segmented fault system appears to run across the area; however, there was no indication of recent fault activity (Meynink Engineering Consultants, 2012).

The Meynink (2012) study estimated peak ground acceleration values at Yandi for different types of material and different probabilities of exceedance (Table 5-23) at a representative location.

**Table 5-23 Estimated peak ground acceleration values**

| Representative Location | Probability of Exceedance in 50 years | Peak Ground Acceleration (g) | | | |
|---|---|---|---|---|---|
| | | Tertiary Sediments ($vs^{30}$ 500 m/s) | Moderately Weathered Rock ($vs^{30}$ 760 m/s) | Shale ($vs^{30}$ 865 m/s) | Fresh BIF ($vs^{30}$ 1800 m/s) |
| Central 1 | 2%[1] | 0.214g | 0.195g | 0.188g | 0.137g |
| Central 1 | 5%[2] | 0.119g | 0.105g | 0.101g | 0.074g |
| Central 1 | 10%[3] | 0.074g | 0.065g | 0.062g | 0.045g |

Notes: [1]equivalent to 2475 years return period
[2]equivalent to 975 years return period
[3]equivalent to 475 years return period
Source: Meynink Engineering Consultants (2012)

Since the Meynink study, recent observations at Area C have confirmed a significant fault structure traversing the north wall of C Pit, showing clear cross cutting relationships and displacement of the Detritals sequence. This fault traverses the entire Detritals stratigraphic sequence (>100 metres in thickness) and breaks through the Quaternary Detrital surface colluvium unit at the current surface, where recent tension cracking as a result of mine site blasting activities, can also be observed. This implies relatively recent re-activation of basement fault structures in the Pilbara region that affect the youngest Quaternary aged deposits (<2 Ma).

In the Australian context, Meynink Engineering Consultants (2012) concluded that the peak ground acceleration values estimated from the study correspond to a low to moderate seismic hazard. Recent observations have not given BHP reason to believe that the seismic hazard is significantly higher.

## 5.4.2 Slope stability analysis

Golder (2020c) conducted a stability analysis to inform closure designs. This comprised:

- A review of instability mechanisms (Section 5.4.2.1).
- Modelling of slope stability under static and seismic conditions assuming no backfill (Section 5.4.2.2).
- Sensitivity analysis of slope stability modelling (Section 5.4.2.3).

The criteria adopted to assess whether slopes are acceptably stable were:

- Factor of Safety (FoS) ≥1.5 for static conditions; and
- FoS ≥1.0 for seismic conditions.

### 5.4.2.1 Instability mechanisms

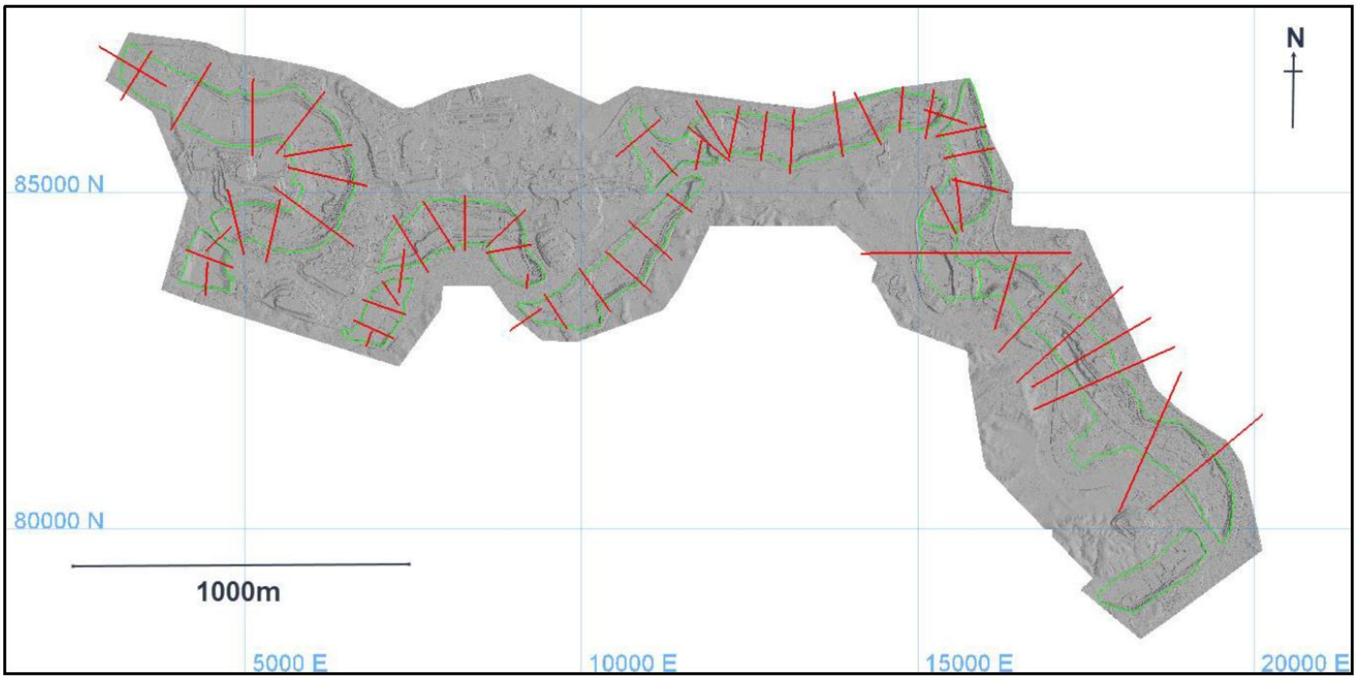
The geological models show a horizontally stratified CID deposited within a competent BIF paleochannel (Section 5.2.1). The contact between the BIF and CID is between ~15° and ~26° on the paleochannel flanks. The BIF is too competent to fail with such a low angle slope, even at the upper end of ~26°, should it be fully exposed. The less competent CID has the potential to fail through the rock mass and along weak basal conglomerate and clay deposits. Failure in the CID is, therefore, considered to be the dominant slope instability mechanism (Golder, 2020c).

### 5.4.2.2 Slope stability modelling

Slope stability was modelled for several pit sections (Map 5-3) which were chosen to be normal to the paleochannel slope and through the pit ends, and to capture variability of material distribution and thickness along the paleochannel. The stability analyses were based on the following assumptions (Golder, 2020c):

- The ultimate pit design was used to represent the condition with maximum slope height exposed, greatest pore pressure condition, and highest level of instability risk.
- No consideration was made for any backfilling of the pits, either actual or planned, or for any variation of excavation from the design.
- A disturbance factor of D=0.7 was used as the base case for all analyses.
- Tension cracks were introduced into the model to reduce the effect of tensile interslice forces within the model. Tension crack depths were constrained by the depth to the bottom of the slice where tensile interslice forces are present.

A seismic analysis was also conducted for the critical base case model for all sections. A peak ground acceleration of 0.12 g was adopted for the assessment from the National Seismic Hazard Assessment Map (Geoscience Australia, 2018) based on a 10% probability of exceedance in 50 years (Golder, 2020c). This is more conservative than the peak ground acceleration values identified by Meynink for the Yandi site (Section 5.4.1). A seismic coefficient of 0.06 g was used in the model based on the Hynes-Griffin (1984) method, which considers the seismic coefficient to be 50% of peak ground acceleration (Golder, 2020c).

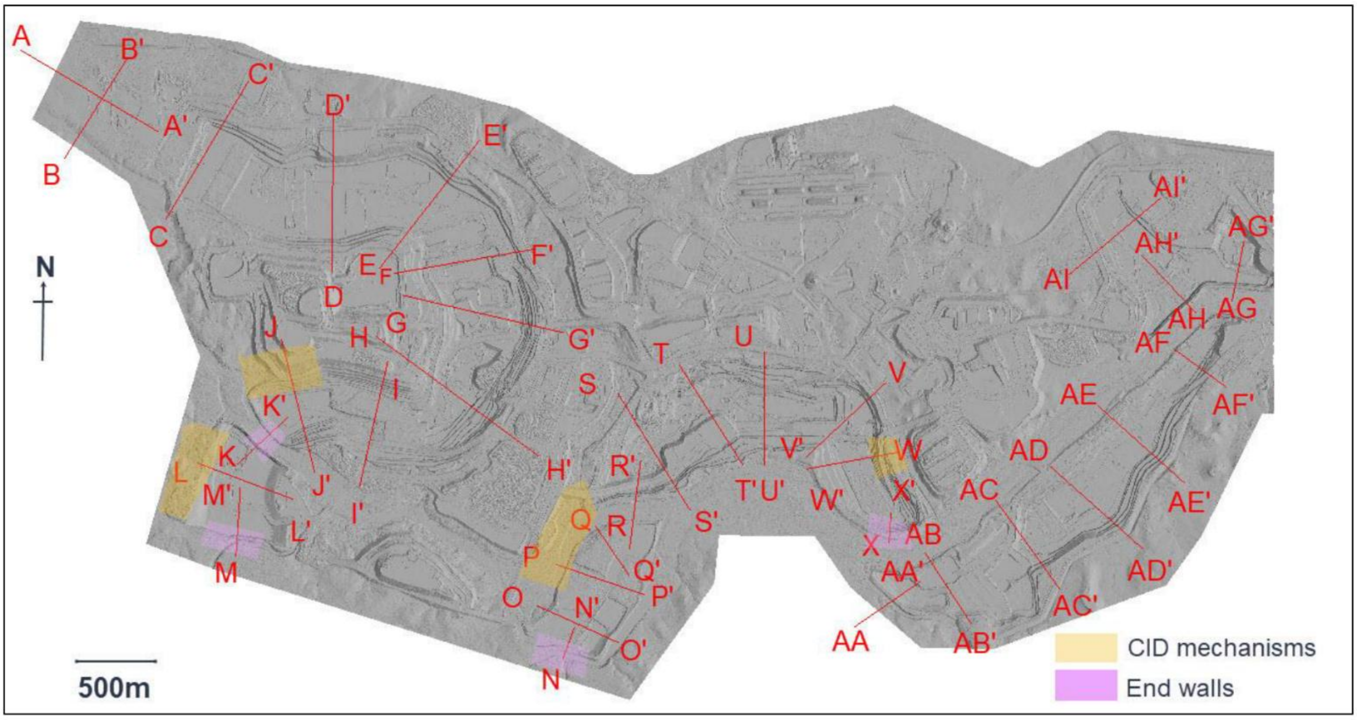



Notes: Pit design outline in green and slope stability section locations in red
Source: Golder (2020c)

**Map 5-3 Pit sections modelled for stability**

Golder (2020c) concluded that:

- Most areas met the slope stability criterion of FoS ≥1 .50 for an overall slope scale instability. Areas that did not meet this criterion were largely in the west pits (W1 to E4) (Map 5-4 and Table 5-24). A multi-batter scale failure mechanism was also identified in the east pit (E1) for Section EA' where the upper slope had a FoS of 1.23 (Map 5-5 and Table 5-25).
- Sections AC to AF in W5 Pit are all adjacent to the Marillana Creek (Map 5-4). While they all show FoS >1.70, they should be reviewed against the final closure design to ascertain if there is a change in risk profile and whether controls are required (e.g. slope profiling or strategic backfill placement).
- Slope failure mechanisms were found to be within the CID sequence and no critical mechanisms were identified in the Weeli Wolli (HJ) BIF. Failure mechanisms in the CID were considered likely to result in a relaxed slope profile over time through natural slope degradation processes rather than failure as a single mass which was considered unlikely.
- There are no geotechnical constraints on closure design options. Areas with FoS <1.50 should be reviewed against preferred closure designs to assess any change in risk profile and to apply controls if required. Such controls may include slope reprofiling or strategic backfill placement.
- End walls have been designed and constructed to an operational FoS (>1.20), which is lower than that required for closure. As a consequence, multiple end wall results did not meet the closure criterion of FoS ≥1.50. End walls will require either a flatter final slope angle or buttressing to achieve a FoS ≥1.50.
- All sections showed lower FoS for a seismic scenario, but all were above the minimum FoS ≥1.0 for seismic conditions. The lowest value returned was FoS of 1.07. All results with FoS <1.25 were mechanisms where significant CID thickness was left on the slope or in end walls.



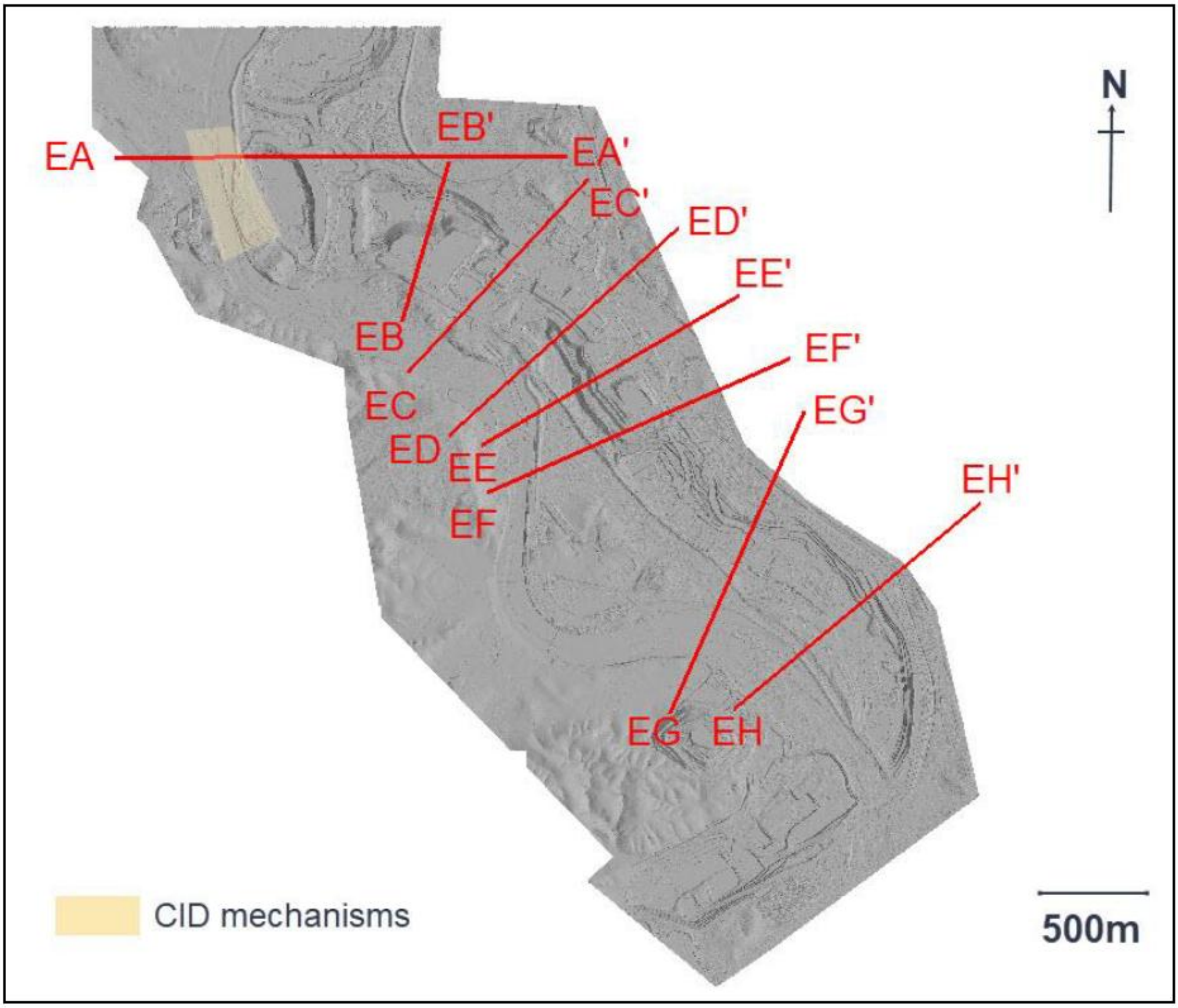

Areas that do not meet FoS ≥1.5 are shown by shading.
Source: Golder (2020c)

**Map 5-4 West Pit area stability results with FoS <1.5**

**Table 5-24 West Pit area stability results with FoS <1.5**

| Section | Wall | FoS | Comment |
|---|---|---|---|
| Yandi_West_J | J | 1.43 | Upper slope inter-ramp failing on BK |
| Yandi_West_K | K | 1.31 | End wall in CID |
| | K | 1.33 | End wall in CID |
| Yandi_West_L | L | 1.20 | Overall slope in CID failing on BK |
| Yandi_West_M | M | 1.42 | End wall in CID |
| Yandi_West_N | N | 1.30 | End wall in CID |
| Yandi_West_P | P | 1.32 | Overall slope in CID failing on BK |
| Yandi_West_Q | Q | 1.44 | Overall slope in CID failing on BK |
| Yandi_West_W | W | 1.30 | Overall slope in CID failing on BK |
| Yandi_West_X | X | 1.35 | End wall in CID |

Source: Golder (2020c)

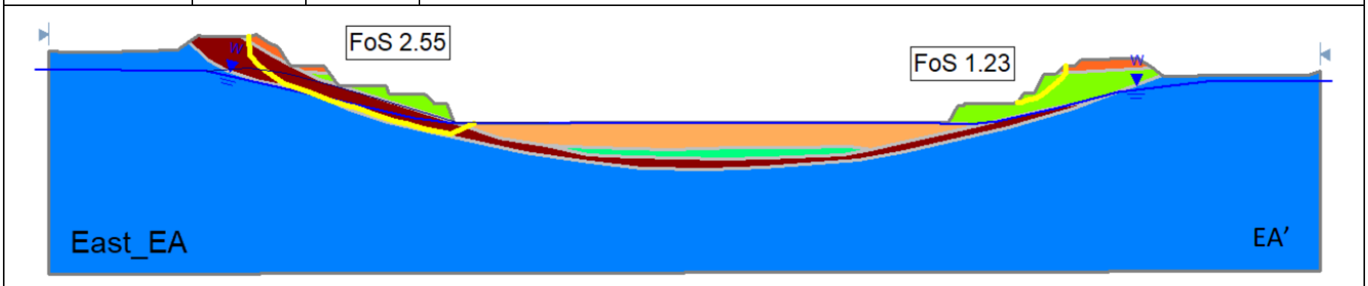



Areas that do not meet FoS ≥1.5 are shown by shading.
Source: Golder (2020c)

**Map 5-5 East Pit area stability results with FoS <1.5**

**Table 5-25 East Pit area stability results with FoS <1.5**

| Section | Wall | FoS | Comment |
|---|---|---|---|
| Yandi_East_EA | EA | 1.23 | Upper slope multi-batter failing in EK. Mechanism is not overall slope scale and there is a large step out below the mechanism. |




Source: Golder (2020c)

#### 5.4.2.3 Sensitivity analysis

A sensitivity analysis was conducted by Golder (2020c) on selected representative sections to assess slope performance under a variety of conditions that would be likely to reduce the resulting FoS:

- Elevated water tables to simulate water, and associated uplift from pore pressure, closer to the slope face.
- Weaker material at the base of the CID sequence in the basal clays and basal conglomerate.
- Weaker material within the UCID and LCID.
- Weaker Weeli Wolli BIF.

Based on the outcomes of the assessment, Golder (2020c) concluded that:

- Under an elevated water table:
  - All side wall sections showed lower FoS for the lower strength basal clay condition, but they still achieved a FoS >1.50.
  - The end wall sections all showed a reduction in FoS, as did the section in East Pit (EA) with the potential for a multi-batter instability. Further stability assessments should be conducted for these areas once a closure design has been confirmed.
- Stability is not sensitive to lower Weeli Wolli BIF (HJ) strengths.
- There is some sensitivity to weaker materials in the CID, UCID and LCID. Where the lower bound strengths for BG and BK were used as input parameters for the CID and lower bound strengths for M2 and M3 as inputs for UCID and LCID:
  - Side wall slopes showed a reduced FoS, but all remained above FoS 1.50.
  - End wall sections showed a reduction in FoS, and further stability assessments should be conducted for these areas once a closure design has been confirmed.

### 5.4.3 Pit wall erosion

As well as geotechnical failure mechanisms, erosion has the potential to impact pit walls in the long-term. Okane (2023b), therefore, conducted SIBERIA modelling of the W1 Pit wall with the objective of gaining an indication of where erosion may manifest and whether continued erosion could lead to capture of Marillana Creek. This modelling can be used as a proxy model for other pits, which share similar benched profiles.

#### 5.4.3.1 Approach to modelling

The W1 Pit SIBERIA model was developed using the ultimate pit design geometry outlined in Section 9.2, including the backfilled floor, removal of the surrounding OSAs, and flood channels. Safety bunds were not included in the model, which is a conservative assumption, as the presence of safety bunds limits surface water flows from ex-pit catchments which would otherwise add to erosion of the pit walls (Okane, 2023b).

Pit wall materials have undergone less disturbance and inherently possess greater erosional stability compared to overburden stored in OSAs. However, quantitative erosion data for pit walls were not available as an input to the SIBERIA model, so the erosion parameters for UCID overburden determined by Landloch (2016) through testing and WEPP modelling (Section 5.2.4.1) were used as a conservative 'bookend' assumption (Okane, 2023b).

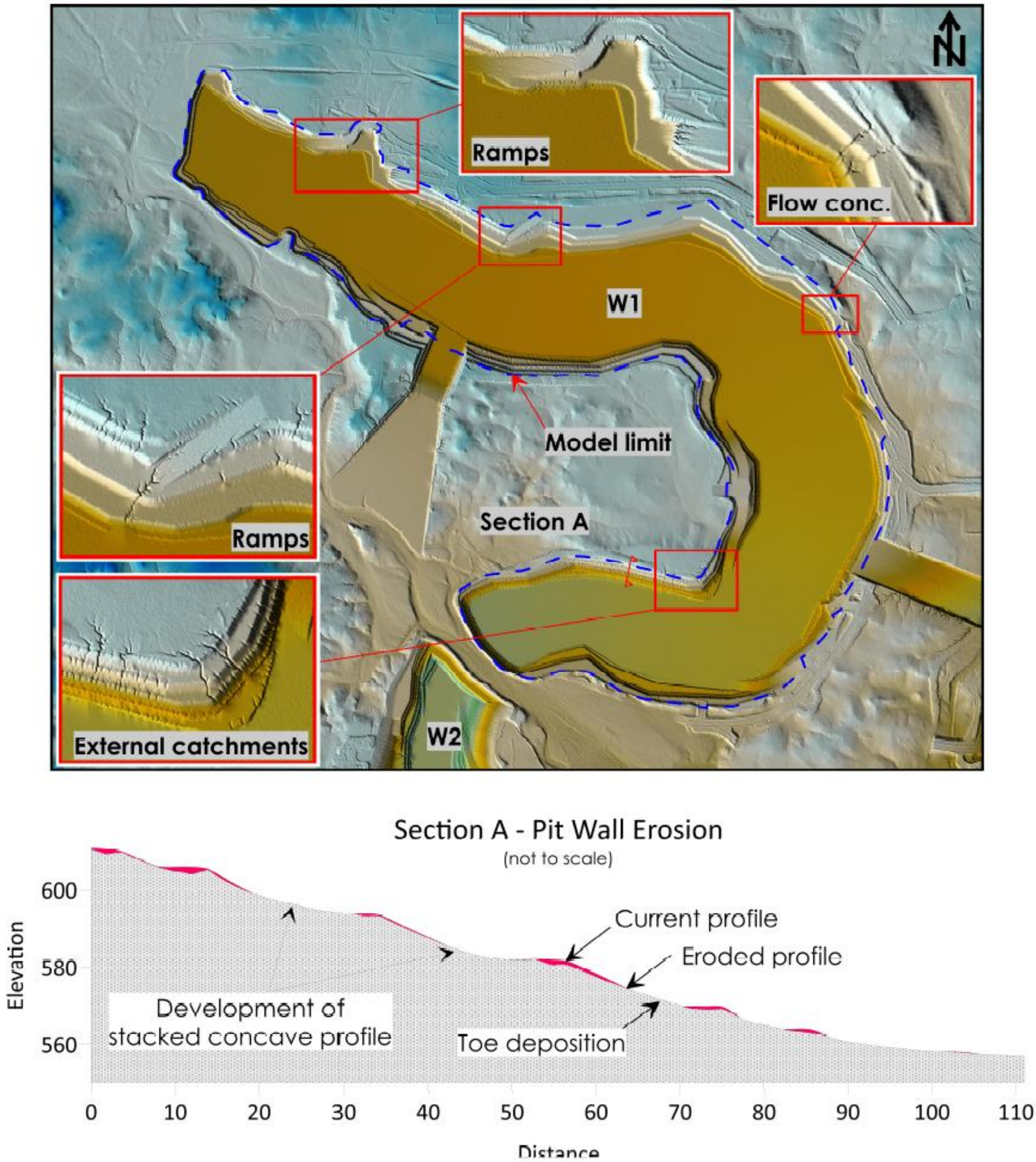
Rainfall conditions for the SIBERIA model were derived from 2090 predictions using the Climate Change Australia Projections Tool (CSIRO and Bureau of Meteorology, 2023) for the nearest rainfall station (Wittenoom Gorge), to account for climate change (assuming the maximum increase in annual rainfall of 5%) (Okane, 2023b).

A period of 1000-years was modelled to enable potential long-term morphological changes to be identified (rather than a 100-year period which is used to return an annualised erosion rate for OSAs) (Okane, 2023b).

#### 5.4.3.2 SIBERIA modelling outputs

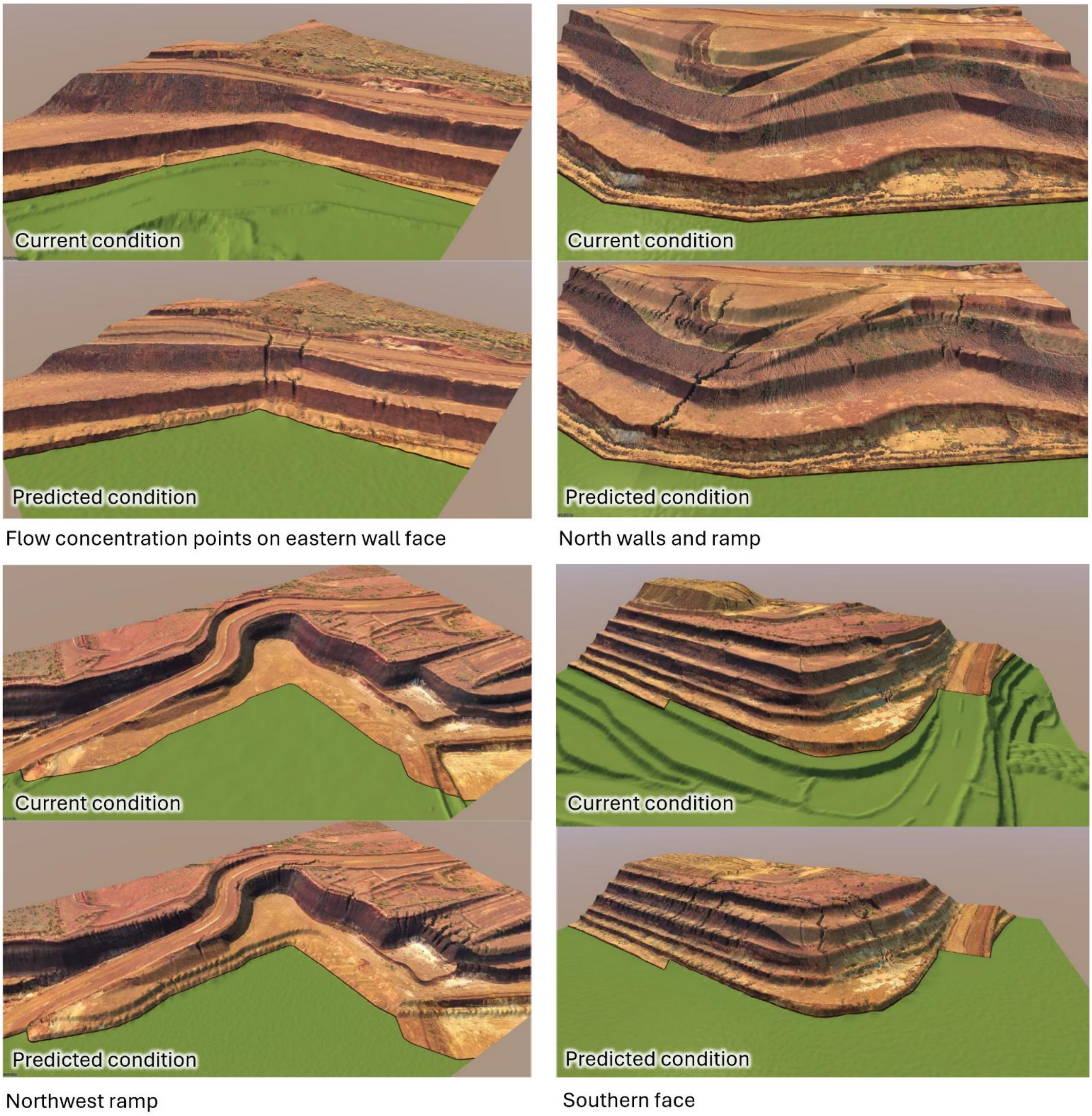
Based on the outputs of the SIBERIA model (Figure 5-19 and Figure 5-20), Okane (2023b) concluded that the modelling forecasted tolerable erosion, which would not cause capture of Marillana Creek over the 1000-year term of the model. This was attributed to the stable UCID materials and limited extent of the catchments surrounding the pits. Further analysis is provided below:

- Erosion features were predicted to develop more extensively where bench and ex-pit catchments were larger.
- The pit walls with minimal ex-pit catchments tended to evolve with regularly spaced gullies forming at the relief points along benches. In these areas the as-mined pit wall configuration tended to erode at the crest, with deposition occurring at the toe, generating a stacked-concave profile (Figure 5-19). Generally, the erosion at the pit crests was not predicted to cut far back into ex-pit areas and this is largely attributed to the inherent stability of the UCID material.
- Head cutting of gullies into the surrounding terrain was predicted to occur where the catchment was unbounded and concentrated surface water flows (Figure 5-19 and Figure 5-20). Development of these types of erosion features can be mitigated using bunds to compartmentalise ex-pit catchments, limiting the volume of surface water runoff discharging down pit walls.
- Larger continuous incisive gullies developed with time and the expanding catchment area in areas where there are substantial ex-pit catchments, such as ramps and roads. These progressed further back into ex-pit areas in certain locations, though not into the Marillana Creek area.




Source: Okane (2023b)

**Figure 5-19 Visualisation of W1 Pit after 1,000 years**




Source: Okane (2023b)

**Figure 5-20 W1 Pit wall current versus predicted condition after 1,000 years**

The predictions outlined in this section should be viewed as qualitative due to the lack of erosion data by which to calibrate the model, the expansive areas covered by multiple pits, and the potential variability in pit wall materials. However, the results provide a supporting tool in the development of final designs.

### 5.4.4 Knowledge gaps & forward work program

Further stability analyses are in progress to support pit wall stabilisation measures and safety bund designs. These analyses will be updated, as required, as pit wall and closure designs evolve. Updated information will be provided in future revisions of the MCP.

Following cessation of mining, a final check of pit wall stabilities will be conducted to confirm stability assessments based on as constructed pit geometries.

## 5.5 Landforms and land systems

**Summary**

The Yandi mining area is surrounded to the north, east and west by escarpments, and rounded hills and ranges dominate the landscape. The flat valley floors consist of Cainozoic sediments.

The dominant pre-disturbance land system represented within the Yandi mining area is the McKay land system, which is composed of hills, ridges, plateaux remnants and minor breakaways of sedimentary rocks with relief of up to 100 m. Pre-mining, the CID formed part of the Robe land system. Since the CID has been removed by mining, this land system will not be re-created during rehabilitation. The River land system, defined as active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands, is representative of the ephemeral Marillana Creek.

Key characteristics of the McKay landform associations relevant to the rehabilitation and revegetation of Yandi include the predominance of *Triodia* spp. hummock grasslands, shallow topsoils on elevated areas, beneficial pH and EC values, low palatability vegetation for livestock, and the erosion protection provided by the widespread stony surface mantles, or cryptogams when stony materials are absent.

The River land system is represented along sections of the current Marillana Creek and consists of unvegetated minor and major channels with banks of fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix*, *Melaleuca argentea* (cadjeput), *M. glomerata*, *Sesbania Formosa* (white dragon tree), *Acacia coriacea* (river jam) with an understorey of sedges and grasses including *Cyprus vaginatus*, *Cenchrus ciliaris* and *Triodia pungens*. While the minor and major channels landform accounts for only 20% of the overall River land system, it is considered the key relevant landform for determining appropriate rehabilitation and revegetation approaches for the Marillana Creek closure domain.

### 5.5.1 Topography

The Hamersley Range, the Fortescue Valley, and the Chichester Plateau and Range are the major physiographic features of the region. The east-west trending Fortescue Valley separates the Hamersley Range (to the south) and Chichester Range (to the north) (MWH, 2016a).

The Yandi mining area is located on the Hamersley Plateau which lies within the Hamersley Range. The Hamersley Range is an extensive mountainous area including peaks of over 1,250 m above Australian Height Datum (mAHD). The ridgelines and peaks are characterised by steep slopes, with well-developed drainage incisions in the major valleys. At the base of the ranges, the topography transitions to gentle, undulating slope surfaces. The dominant drainage lines emanating from the Hamersley Range exit the northern margin of the range into a series of alluvial fans and deltaic areas which permeate into the Fortescue Valley (MWH, 2016a).

The Yandi mining area is surrounded to the north, east and west by escarpments, and rounded hills and ranges dominate the landscape. The flat valley floors consist of Cainozoic sediments.

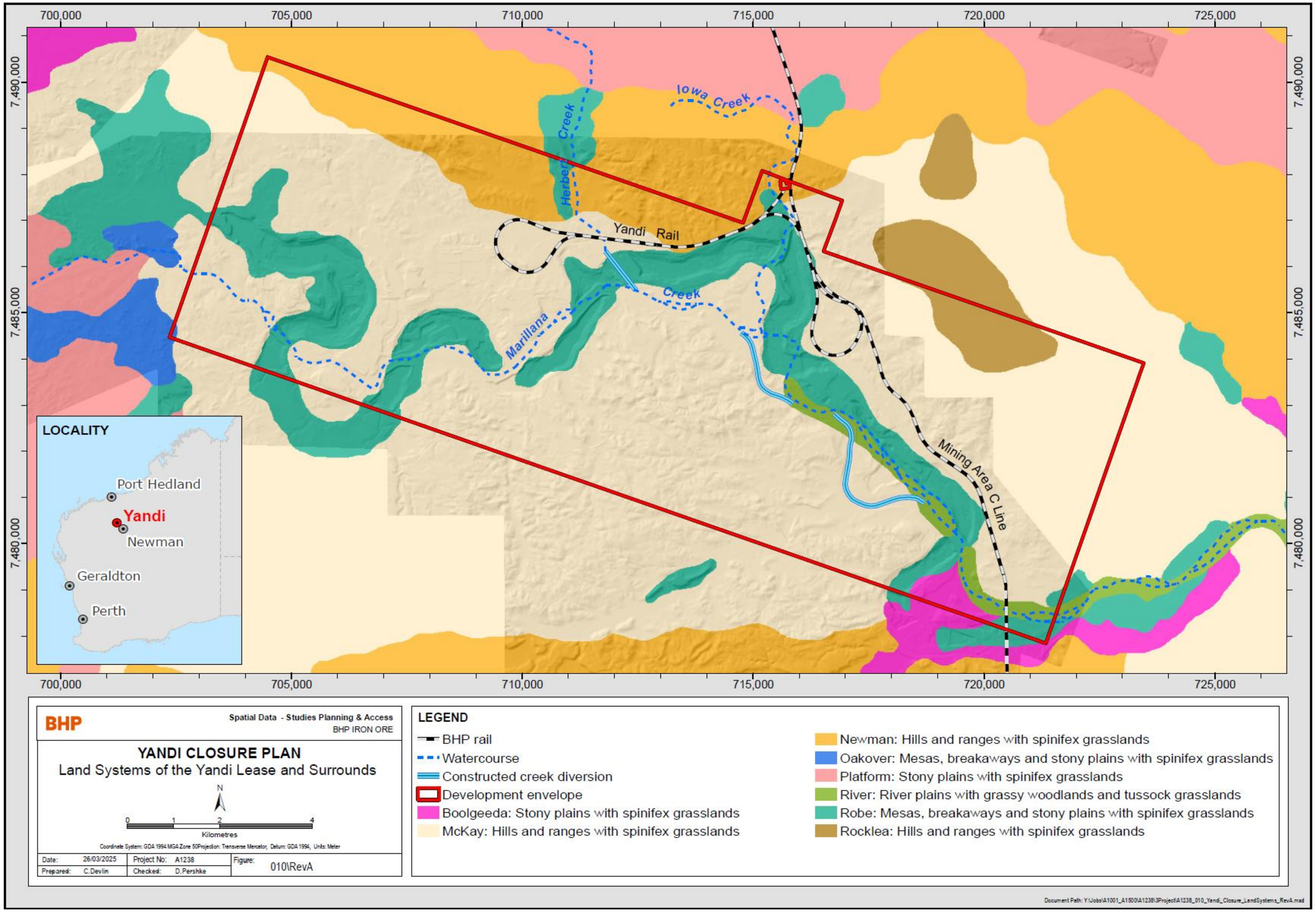
### 5.5.2 Land systems

Land systems across much of the grazing and pastoral lands of WA were surveyed, described and categorised during a series of surveys conducted by the Department of Agriculture. The Yandi mine lies within the Pilbara Region, which was surveyed in the period between 1995 and 1999, by van Vreeswyk et al. (2004), with the results published in Technical Bulletin No. 92. The descriptions of the land systems below are consistent with those described in Technical Bulletin No. 92.

A total of 102 land systems were defined in the Pilbara at a scale of 1:250,000 (van Vreeswyk, Leighton, Payne, & Henning, 2004), with seven land systems occurring within the Yandi lease area (Table 5-26 and Map 5-6).

**Table 5-26 Land systems occurring within the Yandi development envelope**

| Land System | Description |
|---|---|
| Robe | Conspicuous chains of limonite mesas and buttes with steep breakaway faces. Source of iron ore as pisolitic limonite. Relief up to 50 m. |
| Newman | Rugged high mountains, ridges and plateaux with near vertical escarpments of jaspilite, chert and shale. The second largest system in the survey area and prominent in southern parts (e.g. Ophthalmia Range, Hamersley Range). Relief up to 450 m. |
| River | Narrow floodplains and major channels. |
| McKay | Hills, ridges, plateaux remnants and minor breakaways of sedimentary and meta sedimentary rocks. Relief up to 100 m. |
| Oakover | Prominent plateaux, mesas and buttes of calcrete with lower plains with highly calcareous soils. Relief up to 60 m. |
| Rocklea | Rough hill and mountain tracts predominantly of basalt. The largest land system in the survey area and widespread throughout. Relief up to 110 m. |
| Boolgeeda | Stony lower slopes, level stony plains and narrow sub-parallel drainage floors. Relief up to 20 m. A common system in shallow valleys below hill systems such as Newman and Rocklea. |




See Appendix Q for a pdf version of this map

**Map 5-6 Land systems of the Yandi lease and surrounds**

The dominant pre-disturbance land system represented within the Yandi mining area is the McKay land system, which is composed of hills, ridges, plateaux remnants and minor breakaways of sedimentary rocks with relief of up to 100 m (van Vreeswyk, Leighton, Payne, & Henning, 2004). The relative positions of these landforms are shown in Figure 5-21.

1) Hill, ridge, and plateau remnants
2) Breakaway
3) Lower foot slope
4) Stony plain
5) Drainage floor

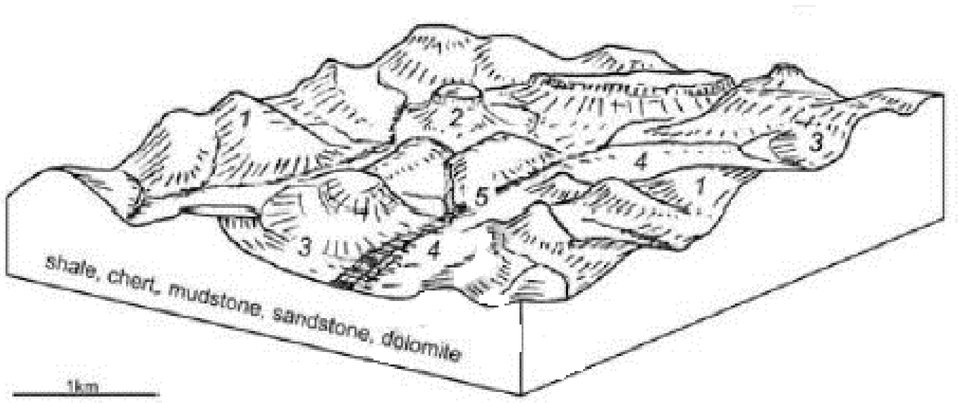



**Figure 5-21 Landforms of the McKay land system (van Vreeswyk, Leighton, Payne, & Henning, 2004)**

The River land system which is defined as active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands, is representative of the ephemeral Marillana Creek (Golder, 2020b).

Pre-mining, the CID formed part of the Robe land system. Since mining has removed the CID, this land system will not be re-created as part of the site rehabilitation (Section 9.2) and consequently is not discussed further. Similarly, the Boolgeeda land system is not discussed further given its low representation within the Yandi development envelope and the Newman, Rocklea and Oakover land systems do not lie within areas disturbed by mining (Golder, 2020b). Details of the soil, vegetation and landform associations of the McKay and River land systems are provided in Sections 5.5.3 and 5.5.4 respectively.

### 5.5.3 McKay land system

The broad soil, vegetation, and landform associations of the McKay land system are provided in Table 5-27. Area percentages indicate the estimated proportion of each landform represented in the Pilbara region. Outstanding characteristics of the landform associations relevant to the rehabilitation and revegetation of Yandi include the predominance of *Triodia* spp. hummock grasslands, shallow topsoils on elevated areas, beneficial pH and EC values, low palatability vegetation for livestock, and the erosion protection provided by the widespread stony surface mantles, or cryptogams when stony materials are absent (Golder, 2020b).

**Table 5-27 Soil, vegetation, and landform associations of McKay land system**

| Unit | Landform and Description | Area of Total Land System within Pilbara | Soil | Vegetation |
|---|---|---|---|---|
| 1. | **Hills, ridges and plateaux remnants**<br>Rounded hill and ridge crests, level to gently inclined plateaux surfaces, moderately inclined to very steep upper slopes; surface mantles rock outcrop; relief up to 100 m. | 60% | Stony Soils | Hummock grasslands of *Triodia lanigera*, *T. wiseana* (hard spinifex) with isolated to scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* (snappy gum) trees. |
| 2. | **Breakaways**<br>Indurated mesa caps of ironstone or laterite with vertical faces up to 15 m high over weathered parent rock and with short, moderate to steep slopes | 2% | Stony Soils | Very scattered to scattered shrublands with *Acacia aneura* (mulga) or other *Acacia* and *Triodia* spp. (spinifex) understorey. Also, *Triodia* spp. hummock grasslands. |
| 3. | **Lower foot slopes**<br>Very gently inclined slopes extending for up to 500 m below unit 1, mantles of very abundant pebbles of mixed lithology. | 10% | Red shallow loams | Hummock grasslands of *Triodia* spp. (hard spinifex) with isolated to scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* trees. Less frequently with *Triodia pungens* (soft spinifex). |
| 4. | **Stony plains**<br>Level to undulating plains and interfluves extending for up to 2 km below units 1, 2 and 3; mantles of abundant pebbles of chert, shale, dolomite and other rocks. | 20% | Red deep loamy duplex soils<br>Red shallow sandy duplex soils<br>Minor presence of red shallow loams | Hummock grasslands of *Triodia wiseana*, T. spp. (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs and occasional eucalypt trees. Occasionally hummock grasslands of *Triodia pungens* (soft spinifex). |

| Unit | Landform and Description | Area of Total Land System within Pilbara | Soil | Vegetation |
|---|---|---|---|---|
| 5. | **Drainage floors**<br>Dendritic floors less than 100 m wide with channels incised in narrow valleys in upper parts of system becoming broader (up to 250 m wide) with channels up to 50 m wide further downstream. | 8% | Red loamy earths<br>Riverbed soils in channels | Scattered tall shrublands / woodlands with *Acacia* and *Eucalyptus* spp. and hummock grass *Triodia* spp. understorey. |

Source: van Vreeswyk et al. (2004)

### 5.5.4 River land system

The broad soil, vegetation, and landform associations of the River land system are provided in Table 5-28. The River land system at Yandi is represented along sections of the current Marillana Creek (Map 5-6), and consists of unvegetated minor and major channels with banks of fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix*, *Melaleuca argentea* (cadjeput), *M. glomerata*, *Sesbania formosa* (white dragon tree), *Acacia coriacea* (river jam) with an understorey of sedges and grasses including *Cyprus vaginatus*, *Cenchrus ciliaris* and *Triodia pungens* (Golder, 2020b).

While the minor and major channels landform accounts for only 20% of the overall River land system, it is considered the key relevant landform for determining appropriate rehabilitation and revegetation approaches for the Marillana Creek closure domain (Golder, 2020b).

**Table 5-28 Soil, vegetation, and landform associations of River land system**

| Unit | Landform and Description | Area of Total Land System within Pilbara | Soil | Vegetation |
|---|---|---|---|---|
| 1. | **Sandy levees and sand sheets**<br>Narrow (generally <300 m wide), ill-defined sandy levees flanking upper terraces and channels and raised up to 5 m (occasionally higher) above floodplains and lower terraces; also, as broader sandy sheets, moundy surfaces. | 15% | Red deep sands<br>Red sandy earths<br>Red loamy earths<br>Riverbed soils | Hummock grasslands of *Triodia pungens* (soft spinifex) with very scattered to moderately close shrubs such as *Acacia trachycarpa* (miniritchie) and *A. inaequilatera* (kanji).<br>Tussock grasslands of *Cenchrus ciliaris* (buffel grass), *Eragrostis eriopoda* (woolly butt) with very scattered to scattered acacia shrubs and trees or open eucalypt woodlands with grass understorey of *C. ciliaris*. |
| 2. | **Upper terraces**<br>Level, upper terraces marginally higher (1 - 2 m) than floodplains and lower terraces, up to 500 m wide, surface mantle absent or few to many water worn pebbles; subject to occasional flooding. | 5% | Red deep sands | Hummock grasslands of *Triodia* spp. (hard spinifex) or *T. pungens* (soft spinifex) frequently with no shrubs, occasionally isolated to very scattered *Acacia* spp. shrubs and trees such as *Hakea subarea* (corkwood). |
| 3. | **Floodplains and lower terraces**<br>Level floodplains and terraces flanking single and multiple channels of the major rivers, commonly 300 - 800 m wide but up to 2 km in lower reaches, often with moundy surfaces; subject to fairly regular flooding. | 50% | Deep red / brown non-cracking clays<br>Red loamy earths | Tussock grasslands of *Cenchrus ciliaris* (buffel grass) or hummock grasslands mainly of *Triodia pungens* (soft spinifex). Also scattered to moderately close *Eucalyptus victrix* (coolibah) or acacia woodlands / tall shrublands with prominent tussock grass understorey of *C. ciliaris, Chrysopogon fallax* (ribbon grass), *Eulalia aurea* (silky brown top) and others, or hummock grass understorey of *Triodia pungens*. |
| 4. | **Stony plains**<br>Level to very gently inclined plains up to 500 m in extent with surface mantles of common to very abundant pebbles and water worn cobbles; some are active flood areas over old cobble beds between minor and major channels, others are raised above general flood levels. | 10% | Red shallow loams<br>Red shallow sands | Hummock grasslands of *Triodia* spp. (soft and hard spinifex) with very scattered to scattered acacia shrubs. Also, woodlands / tall shrublands with *Eucalyptus victrix, Acacia* spp. and tussock and hummock grasses. |
| 5. | **Minor and major channels**<br>Channels 30 - 1,000 m wide between sandy banks 1 - 10 m above channel beds, bed loads of sand, gravel, pebbles and stones. | 20% | Riverbed soils | Channels - no vegetation.<br>Banks - close or closed fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix, Melaleuca argentea* (cadjeput), *M. glomerata, Sesbania formosa* (white dragon tree), *Acacia coriacea* (river jam) with understorey of sedges and grasses including *Cyprus vaginatus, Cenchrus ciliaris* and *Triodia pungens*. |

Source: van Vreeswyk et al. (2004)

### 5.5.5 Knowledge gaps & forward work program

No knowledge gaps have been identified.

## 5.6 Vegetation

**Summary**

The Yandi mine is located within the Hamersley subregion (PIL3) of the Pilbara bioregion and is characterised by mountainous areas of Proterozoic sedimentary ranges (ironstone ranges) and plateaux dissected by gullies and gorges. Mulga low woodland over bunch grasses on fine-textured soils dominates in valley floors, while skeletal soils of the ranges are dominated by snappy gum over *Triodia brizoides.*

A total of 42 vegetation associations, classified under 17 broad floristic formations, have been described and mapped within the Yandi development envelope, and none have any affiliation with Federal or State listed Threatened Ecological Communities (TEC's), or State listed Priority Ecological Communities (PEC's).

The dominant vegetation association of the development envelope is *Triodia* hummock grassland on hill crests. Fourteen riparian vegetation associations have been mapped, and eleven are aligned with a DBCA defined 'ecosystem at risk', as they represent vegetation associated with a major ephemeral water course. Two of these vegetation associations are highly likely to be groundwater dependent, as they contain *Melaleuca argentea* and a further two are likely to be groundwater dependent, because they contain *Eucalyptus camaldulensis* and *E. victrix* and occur in the creek bed and / or areas with shallow water tables.

*Melaleuca argentea* is an obligate phreatophyte associated with shallow groundwater and / or permanent pools of surface water and, therefore, has the highest degree of groundwater dependence. However, even this species is likely to have some capacity to extract soil-water when available at high enough matric potentials (approximately ≥ -2,000 kPa).

*Eucalyptus camaldulensis* and *Eucalyptus victrix* are facultative phreatophytes that draw on groundwater in times of drought but also utilise surface water and soil moisture reserves. Monitoring indicates that *E. camaldulensis var. refulgens* and *E. victrix* can extract water from relatively dry soils with matric potentials ≥ -3,500 kPa and >-4,500 kPa, respectively.

In areas where there is direct hydraulic connection between the alluvial aquifer and the CID (i.e. where Marillana Creek intersects the CID), tree-deaths of *Melaleuca argentea* have occurred in response to dewatering of the CID. Areas where riparian vegetation health has declined include a site upstream of the Yandi development envelope at Flat Rocks. These impacts are being managed in accordance with the Marillana Creek Water Resource Management Plan[27] and are reported on annually via the AER. Should any investigations conducted under the management plan indicate the need for measures to be implemented during closure, these will be integrated into future iterations of this MCP.

In areas where the alluvial aquifer does not directly intersect the CID, stands of *Melaleuca argentea* appear less vulnerable to drawdown effects as they are more reliant on rainfall and stream flow to provide seasonal replenishment of groundwater to the creek alluvium.

Yandicoogina Gorge is located 4 km south of Yandi mine on Yandicoogina Creek at the convergence of surface and groundwater flows from the upstream catchment. Where groundwater intercepts the surface, a series of seeps and pools extend for approximately 3.4 km within the gorge. These areas support vegetation associations that have been identified to have affinities with the Priority 2 ecological community '*Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara Region*'.

No threatened flora species listed under the *Biodiversity Conservation Act 2016 (WA)* (BC Act), or the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act) have been recorded in the Yandi development envelope, but eight DBCA listed priority flora species have been recorded.

Twenty-seven introduced flora species have been recorded from the Yandi lease. None of which are 'declared plants' under the *Biosecurity and Agriculture Management* (BAM) *Act 2007 (WA)* or are species on the DBCA's Pilbara Region Priority Alert list. BHP manages introduced flora species at the Yandi mine in accordance with the Yandi Biodiversity Environmental Management Plan (BHP, 2021e) and Weed Management Procedure (WAIO, 2020c).

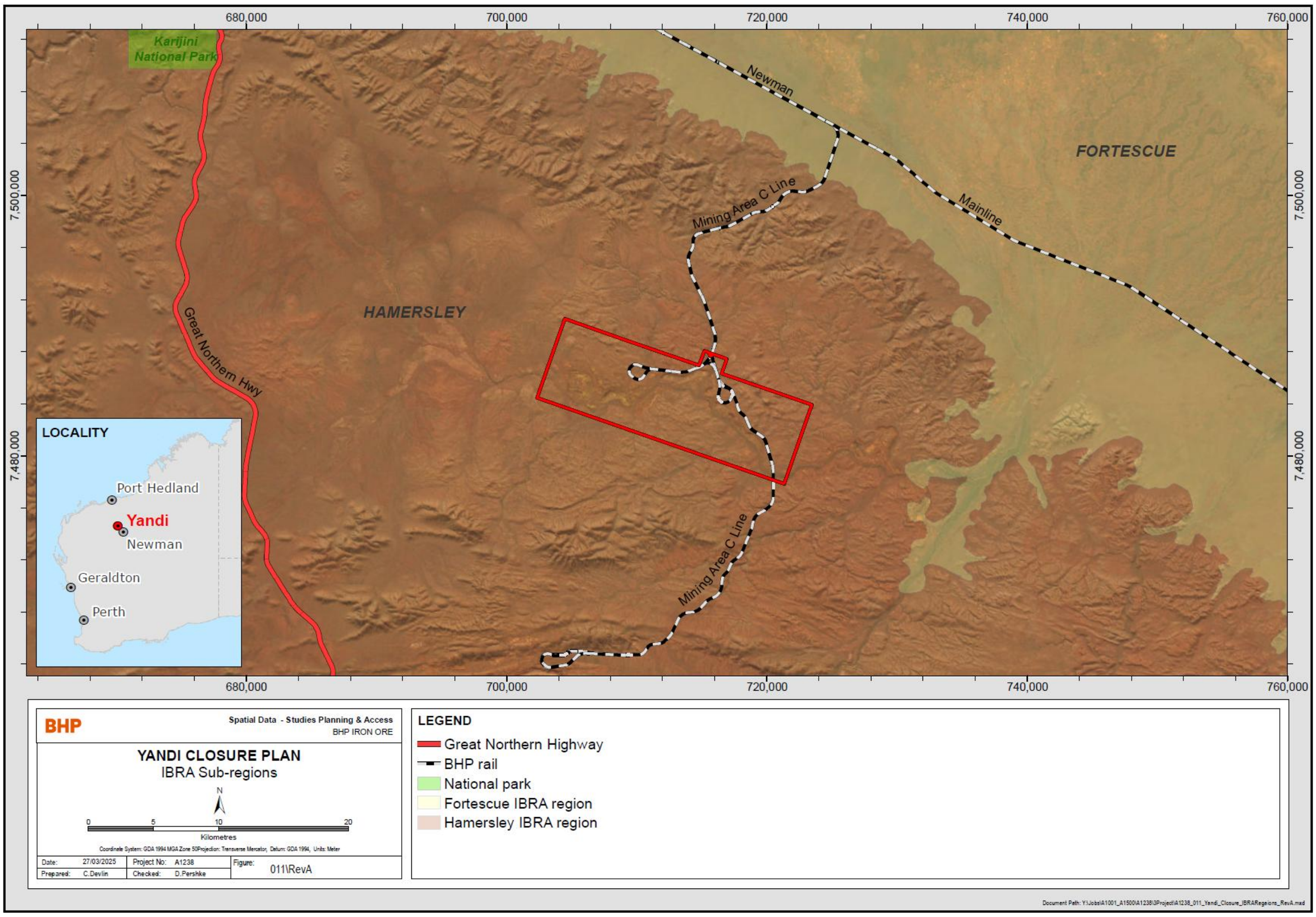
### 5.6.1 Regional flora and vegetation

The Yandi mine is located within the Hamersley subregion (PIL3) of the Pilbara bioregion as classified by the Interim Biogeographic Regionalisation of Australia (IBRA) (Department of Environment and Energy, 2012) (Map 5-7). The Hamersley subregion is characterised by mountainous areas of Proterozoic sedimentary ranges (ironstone ranges) and plateaux dissected

[27] Both the 2022 version of the plan (BHP, 2022b) and current (2025) draft prepared to support the Significant Amendment ERD contain actions for investigating long-term mitigation measures for drawdown at Flat Rocks.

by gullies and gorges. Mulga low woodland over bunch grasses on fine-textured soils dominates in valley floors, while skeletal soils of the ranges are dominated by snappy gum over *Triodia brizoides* (Kendrick, 2002).

Original vegetation mapping undertaken by Beard (1975) was refined by Shepherd et al. (2002), who confirmed the two vegetation associations present within the Yandi lease as hummock grasslands, low tree steppe; snappy gum over *Triodia wiseana* and low woodland of mulga (*Acacia aneura*).




See Appendix Q for a pdf version of this map

**Map 5-7 IBRA sub-regions**

## 5.6.2 Local vegetation

A total of 42 vegetation associations, classified under 17 broad floristic formations, have been described and mapped within the Yandi development envelope (Map 5-8 and Table 5-29). None of the vegetation associations mapped at Yandi have any affiliation with Federal or State listed Threatened Ecological Communities (TEC's), or State listed Priority Ecological Communities (PECs) (BHP, 2025).

The dominant vegetation association of the development envelope is *Triodia* hummock grassland on hill crests (HC Tw AiAb InrSeao) (Map 5-8 and Table 5-29).

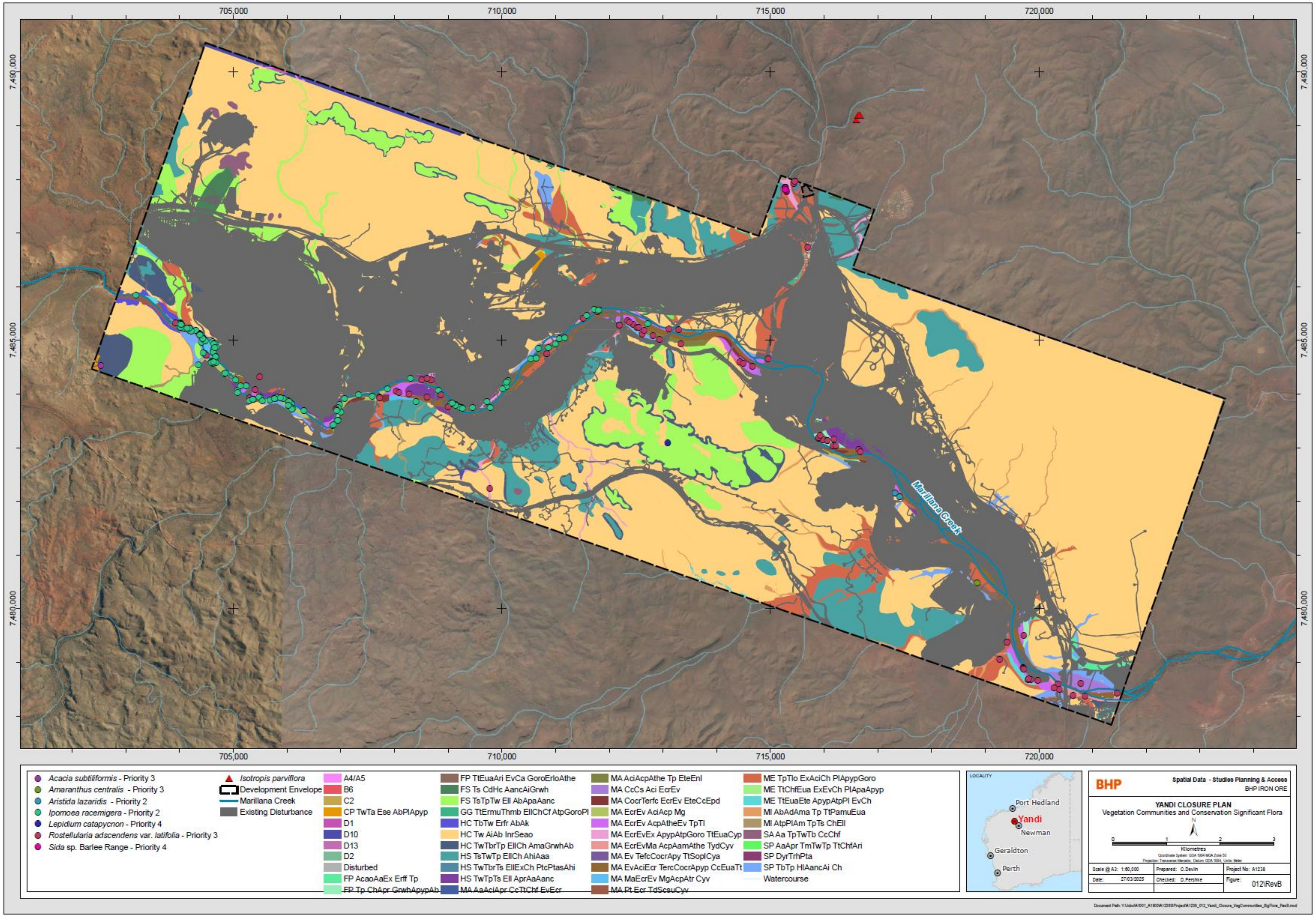
Given the age of the Yandi site, contemporary vegetation mapping does not exist across the entire development envelope. Historical vegetation mapping exists for the now cleared areas of the development envelope, but mapping was conducted at differing levels of detail to meet previous survey requirements which makes alignment of new and old vegetation association mapping problematic. The best representation of pre-mining vegetation is, therefore, the Beard vegetation associations (Map 5-9).

**Table 5-29 Yandi vegetation associations**

| Broad Floristic Formation | Vegetation Code | Vegetation Association Description |
|---|---|---|
| Other areas historically mapped and not integrated into recent consolidated mapping - collectively these areas account for <1% of the database | A4/A5 | Not available |
| | B6 | Mixed tall shrubs over *Triodia pungens.* |
| | C2 | Scattered Eucalypt species over mixed shrubs and dense *Triodia pungens.* |
| | D1 | *Triodia basedowii* steppe with sparse emergents including *Corymbia deserticola* and *Eucalyptus leucophloia*. |
| | D10 | *Acacia inaequilatera* over *Triodia wiseana*. |
| | D13 | *Triodia brizoides / T. wiseana* steppes. |
| | D2 | *Triodia wiseana* steppe with sparse emergents including *Eucalyptus leucophloia*. |
| Acacia Low Open Forest | MA AaAciApr CcTtChf EvEcr | Low Open Forest of *Acacia aptaneura, Acacia citrinoviridis* and *Acacia pruinocarpa* very Open Tussock Grassland of **Cenchrus ciliaris, Themeda triandra* and *Chrysopogon fallax* with Open Woodland of *Eucalyptus victrix* and *Eucalyptus camaldulensis* subsp. *refulgens* on brown loamy sand on major drainage lines with broad and deeply incised drainage channels. |
| | SA Aa TpTwTb CcChf | Low Open Forest of *Acacia aptaneura* over Open Hummock Grassland of *Triodia pungens, Triodia wiseana* and *Triodia basedowii* over Open Tussock Grassland of **Cenchrus ciliaris* and *Chrysopogon fallax* on red brown sandy loam on sandy plains and undulating low hills |
| | SP AaApr TmTwTp TtChfAri | Low Open Forest of *Acacia aptaneura* and *Acacia pruinocarpa* over Open Hummock Grassland of *Triodia melvillei, Triodia wiseana* and *Triodia pungens* over Tussock Grassland of *Themeda triandra, Chrysopogon fallax* and *Aristida inaequiglumis* on red brown loam on stony plains |
| Acacia Low Woodland | FP AcaoAaEx Erff Tp | Low Woodland of *Acacia catenulata* subsp. *occidentalis, Acacia aptaneura* and *Eucalyptus xerothermica* over Open Shrubland of *Eremophila forrestii* subsp. *forrestii* over Open Hummock Grassland of *Triodia pungens* on red sandy loam on floodplains |
| | MA AciAcpAthe Tp EteEnl | Low Woodland of *Acacia citrinoviridis, Acacia coriacea* subsp. *pendens* and *Atalaya hemiglauca* with Open Hummock Grassland of *Triodia pungens* and Open Tussock Grassland of *Eriachne tenuiculmis* and *Enneapogon lindleyanus* on brown loam on raised levee banks of major drainage line |
| Acacia Open Scrub | MI AtpPlAm TpTs ChEll | Open Scrub of *Acacia tumida* var. *pilbarensis, Petalostylis labicheoides* and *Acacia monticola* over Open Hummock Grassland of *Triodia pungens* and *Triodia* sp. Shovelanna Hill (S.van Leeuwen 3835) with Low Open Woodland of *Corymbia hamersleyana* and *Eucalyptus leucophloia* subsp. *leucophloia* on red brown sandy loam on minor drainage lines |
| Acacia Shrubland | MI AbAdAma Tp TtPamuEua | Shrubland of *Acacia bivenosa, Acacia dictyophleba* and *Acacia maitlandii* over Open Hummock Grassland of *Triodia pungens* over Open Tussock Grassland of *Themeda triandra, Paraneurachne muelleri* and *Eulalia aurea* on brown sandy loam on minor drainage lines |
| Cenchrus Closed Tussock Grassland | MA CcCs Aci EcrEv | Closed Tussock Grassland of **Cenchrus ciliaris* and **Cenchrus setiger* with Low Open Forest of *Acacia citrinoviridis* and Scattered Low Trees of *Eucalyptus camaldulensis* and *Eucalyptus victrix* on banks and floodplains of major drainage line with brown sandy loam |
| Corchorus Low Open Heath | MA CocrTerfc EcrEv EteCcEpd | Low Open Heath of *Corchorus crozophorifolius* and *Tephrosia rosea* var. Fortescue creeks (M.I.H. Brooker 2186) with Scattered Trees of *Eucalyptus camaldulensis* and *Eucalyptus victrix* and Scattered Tussock Grasses of *Eriachne tenuiculmis*, **Cenchrus ciliaris* and *Eriachne pulchella* subsp. *dominii* on creek bed of major drainage line with brown clay loam |
| Dysphania Herbs | SP DyrTrhPta | Herbs of *Dysphania rhadinostachya, Tribulus hirsutus* and *Ptilotus aervoides* on brown clay on undulating stony plains |

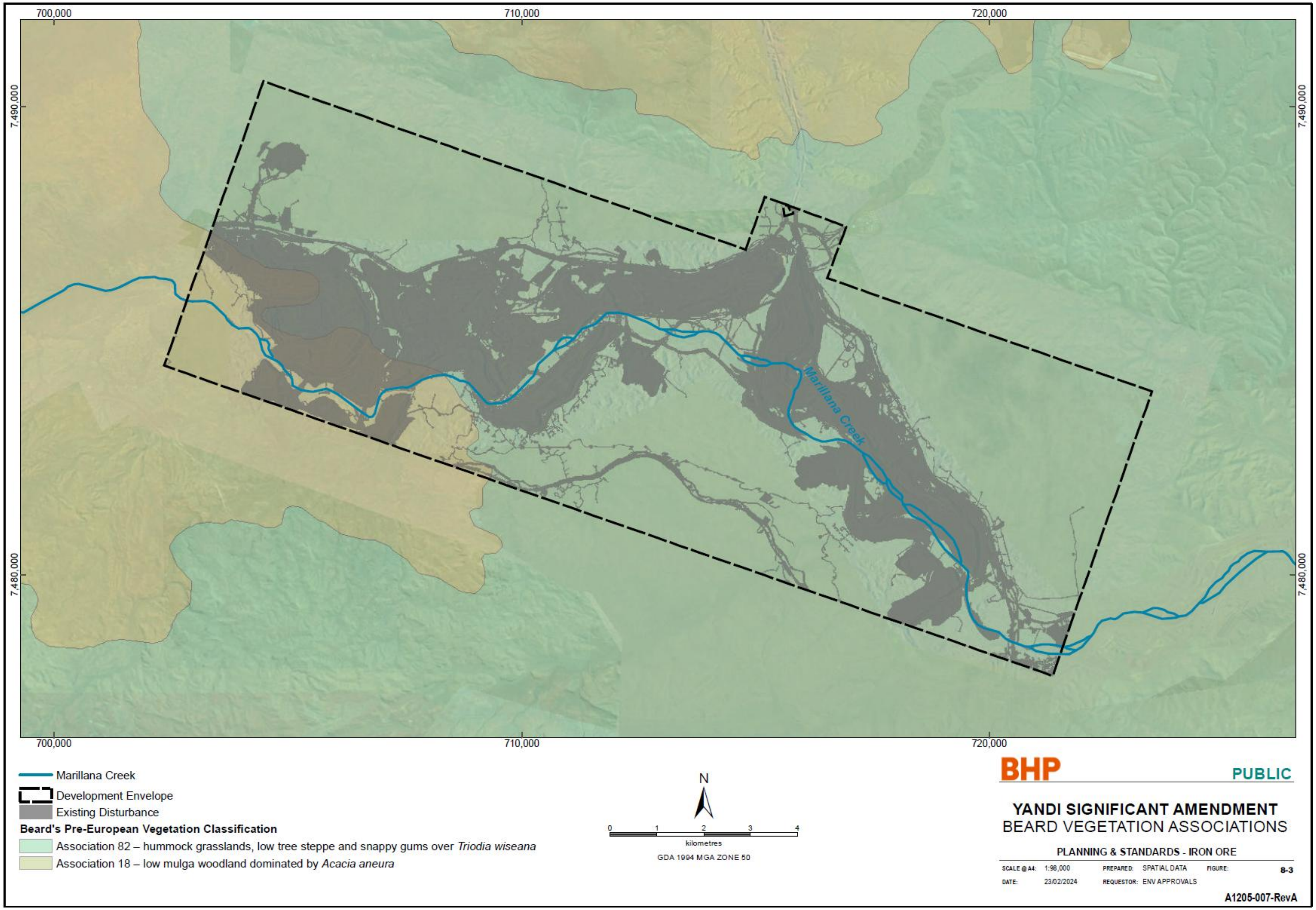
| Broad Floristic Formation | Vegetation Code | Vegetation Association Description |
|---|---|---|
| Eucalyptus Low Open Forest | MA EcrEvEx ApypAtpGoro TtEuaCyp | Low Open Forest of *Eucalyptus camaldulensis* subsp. *refulgens, Eucalyptus victrix* and *Eucalyptus xerothemica* over High Shrubland of *Acacia pyrifolia* var. *pyrifolia, Acacia tumida* var. *pilbarensis* and *Gossypium robinsonii* over Open Tussock Grassland of *Themeda triandra, Eulalia aurea* and *Cymbopogon procerus* on red brown clay loam on major drainage lines |
| Eucalyptus Low Woodland | MA Ev TefcCocrApy TtSoplCya | Low Woodland of *Eucalyptus victrix* over Low Shrubland of *Tephrosia rosea* var. Fortescue creeks (M.I.H. Brooker 2186), *Corchorus crozophorifolius* and *Acacia pyrifolia* over Open Tussock Grassland of *Themeda triandra, Sorghum plumosum* and *Cymbopogon ambiguus* on brown sand on major drainage lines. |
| Eucalyptus Open Forest | MA EcrEvMa AcpAamAthe TydCyv | Open Forest of *Eucalyptus camaldulensis* var. *refulgens, Eucalyptus victrix* and *Melaleuca argentea* over Low Open Forest of *Acacia coriacea* subsp. *pendens, Acacia ampliceps* and *Atalaya hemiglauca* over Open Sedges of *Typha domingensis* and *Cyperus vaginatus* on brown sandy clay loam along major rivers with permanent water |
| Eucalyptus Open Woodland | MA EcrEv AciAcp Mg | Open Woodland of *Eucalyptus camaldulensis* and *Eucalyptus victrix* over Low Open Woodland of *Acacia citrinoviridis* and *Acacia coriacea* subsp. *pendens* over High Open Shrubland of *Melaleuca glomerata* on riverbed with brown sand |
| Eucalyptus Woodland | MA EcrEv AcpAtheEv TpTl | Woodland to Open Woodland of *Eucalyptus camaldulensis* and *Eucalyptus victrix* over Low Woodland of *Acacia coriacea* subsp. *pendens, Atalaya hemiglauca* and *Eucalyptus victrix* over Open Hummock Grassland of *Triodia pungens* and *Triodia longiceps* on brown sandy loam on levees and channel islands of major drainage lines |
| | MA EvAciEcr TercCocrApyp CcEuaTt | Woodland of *Eucalyptus victrix, Acacia citrinoviridis* and *Eucalyptus camaldulensis* subsp. *refulgens* over Low Open Shrubland of *Tephrosia rosea var. clementii, Corchorus crozophorifolius* and *Acacia pyrifolia* var. *pyrifolia* over Very Open Tussock Grassland of **Cenchrus ciliaris, Eulalia aurea* and *Themeda triandra* on brown loamy sand on channels of major drainage lines |
| Melaleuca High Open Forest | MA MaEcrEv MgAcpAtr Cyv | High Open Forest of *Melaleuca argentea, Eucalyptus camaldulensis* var. *refulgens* and *Eucalyptus victrix* over High Open Shrubland of *Melaleuca glomerata, Acacia coriacea* subsp. *pendens* and *Acacia trachycarpa* over Very Open Sedges of *Cyperus vaginatus* on alluvial gravelly soils on major drainage channels with seasonal pools |
| Potamogeton Open Herbs | MA Pt Ecr TdScsuCyv | Open Herbs of *Potamogeton tricarinatus* with Open Woodland of *Eucalyptus camaldulensis* and Very Open Sedges of *Typha domingensis, Schoenoplectus subulatus* and *Cyperus vaginatus* on brown light clay on dolerite platforms of major drainage lines |
| Themeda Tussock Grassland | FP TtEuaAri EvCa GoroErloAthe | Tussock Grassland of *Themeda triandra, Eulalia aurea* and *Aristida inaequiglumis* with Open Woodland of *Eucalyptus victrix* and *Corymbia aspera* and High Open Shrubland of *Gossypium robinsonii, Eremophila longifolia* and *Atalaya hemiglauca* on brown sandy loam on plains |
| | GG TtErmuThmb EllChCf AtpGoroPl | Tussock Grassland of *Themeda triandra, Eriachne mucronata* and *Themeda* sp. Mt Barricade with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia, Corymbia hamersleyana* and *Corymbia ferriticola* over High Shrubland of *Acacia tumida* var. *pilbarensis, Gossypium robinsonii* and *Petalostylis labicheoides* on red brown sandy loam on narrowly incised rocky drainage lines |
| | ME TtEuaEte ApypAtpPl EvCh | Tussock Grassland of *Themeda triandra, Eulalia aurea* and *Eriachne tenuiculmis* with High Shrubland of *Acacia pyrifolia* var. *pyrifolia*, *Acacia tumida* var. *pilbarensis* and *Petalostylis labicheoides* and Open Woodland of *Eucalyptus victrix* and *Corymbia hamersleyana* on red brown silty loam on medium drainage lines and floodplains |
| | ME TtChfEua ExEvCh PlApaApyp | Tussock Grassland of *Themeda triandra, Chrysopogon fallax* and *Eulalia aurea* with Low Open Woodland of *Eucalyptus xerothermica, Eucalyptus victrix* and *Corymbia hamersleyana* and Shrubland of *Petalostylis labicheoides, Acacia pachyacra* and *Acacia pyrifolia* var. *pyrifolia* on red sandy loam on medium drainage lines. |
| Triodia Closed Hummock Grassland | HC TbTw Erfr AbAk | Closed Hummock Grassland of *Triodia brizoides* and *Triodia wiseana* with Shrubland of *Eremophila fraseri* and High Open Shrubland of *Acacia bivenosa* and *Acacia kempeana* on brown silty loam on high dolerite hills |

| Broad Floristic Formation | Vegetation Code | Vegetation Association Description |
|---|---|---|
| Triodia Hummock Grassland | CP TwTa Ese AbPlApyp | Hummock Grassland of *Triodia wiseana* and *Triodia angusta* with Open Mallee of *Eucalyptus socialis* subsp. *eucentrica* and Open Shrubland of *Acacia bivenosa, Petalostylis labicheoides* and *Acacia pyrifolia* var. *pyrifolia* on light brown clay loam on calcrete plains and rises |
| | FP Tp ChApr GrwhApypAb | Hummock Grassland of *Triodia pungens* with Scattered Low Trees of *Corymbia hamersleyana* and *Acacia pruinocarpa* over Open Shrubland of *Grevillea wickhamii* subsp*. hispidula, Acacia pyrifolia* var. *pyrifolia* and *Acacia bivenosa* on brown loamy sand on floodplains |
| | FP Tp ChHallEv TefcApy | Open Hummock Grassland of *Triodia pungens* with Low Open Woodland of *Corymbia hamersleyana, Hakea lorea* subsp*. lorea* and *Eucalyptus victrix* over Low Open Shrubland of *Tephrosia rosea* var. Fortescue creeks (M.I.H. Brooker 2186) and *Acacia pyrifolia* on brown sandy loam on floodplains and drainage lines. |
| | FS Ts CdHc AancAiGrwh | Hummock Grassland of *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835) with Low Open Woodland of *Corymbia deserticola* subsp. *deserticola* and *Hakea chordophylla* over Open Shrubland of *Acacia ancistrocarpa, Acacia inaequilatera* and *Grevillea wickhamii* subsp. *hispidula* on red brown sandy loam on footslopes and stony plains |
| | FS TsTpTw Ell AbApaAanc | Hummock Grassland of *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835), *Triodia pungens* and *Triodia wiseana* with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia* and Open Shrubland of *Acacia bivenosa, Acacia pachyachra* and *Acacia ancistrocarpa* on red brown loam on footslopes, low undulating hills and stony plains |
| | HC Tw AiAb InrSeao | Hummock Grassland of *Triodia wiseana* with High Open Shrubland of *Acacia inaequilatera* and *Acacia bivenosa* over Low Open Shrubland of *Indigofera rugosa* and *Senna artemisioides* subsp. *oligophylla* on red silty loam on dolerite hill crests |
| | HC TwTbrTp EllCh AmaGrwhAb | Hummock Grassland of *Triodia wiseana, Triodia brizoides* and *Triodia pungens* with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia* and *Corymbia hamersleyana* over High Open Shrubland of *Acacia maitlandii, Grevillea wickhamii* subsp*. hispidula* and *Acacia bivenosa* on red brown sandy loam on hill crests and upper hill slopes |
| | HS TsTwTp EllCh AhiAaa | Hummock Grassland of *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835), *Triodia wiseana* and *Triodia pungens* with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia* and *Corymbia hamersleyana* over Low Open Shrubland of *Acacia hilliana* and *Acacia adoxa* var*. adoxa* on red brown sandy loam on hill slopes |
| | HS TwTbrTs EllExCh PtcPtasAhi | Hummock Grassland of *Triodia wiseana, Triodia brizoides* and *Triodia* sp. Shovelanna Hill with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia, Eucalyptus xerothermica* and *Corymbia hamersleyana* over Low Open Shrubland of *Ptilotus calostachyus, Ptilotus astrolasius* and *Acacia hilliana* on brown loam on hill crests and upper hill slopes |
| | HS TwTpTs Ell AprAaAanc | Hummock Grassland of *Triodia wiseana, Triodia pungens* and *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835) with Low Open Woodland of *Eucalyptus leucophloia* subsp. *leucophloia* over Open Shrubland of *Acacia pruinocarpa, Acacia aptaneura* and *Acacia ancistrocarpa* on red brown loam on plains and low hills |
| | ME TpTlo ExAciCh PlApypGoro | Hummock Grassland of *Triodia pungens* and *Triodia longiceps* with Low Woodland of *Eucalyptus xerothermica, Acacia citrinoviridis* and *Corymbia hamersleyana* over High Shrubland of *Petalostylis labicheoides, Acacia pyrifolia* var. *pyrifolia* and *Gossypium robinsonii* on red brown clay loam on medium drainage lines and surrounding floodplains |
| | SP TbTp HlAancAi Ch | Hummock Grassland of *Triodia basedowii* and *Triodia pungens* with High Open Shrubland of *Hakea lorea* subsp. *lorea, Acacia ancistrocarpa* and *Acacia inaequilatera* and Scattered Low Trees of *Corymbia hamersleyana* on red brown loamy sand on stony plains |




See Appendix Q for a pdf version of this map

**Map 5-8 Vegetation communities and conservation significant flora**




See Appendix Q for a pdf version of this map

**Map 5-9** **Beard vegetation associations**

A total of fourteen riparian vegetation associations have been mapped and eleven of these are aligned with a DBCA defined ‘ecosystem at risk’, as they represent vegetation associated with a major ephemeral water course (Marillana Creek) (Map 5-10 and Table 5-29) (BHP, 2025):

- Themeda Tussock Grassland (FP TtEuaAri EvCa GoroErloAthe and ME TtEuaEte ApypAtpPl EvCh).
- Cenchrus Closed Tussock Grassland (MA CcCs Aci EcrEv).
- Corchorus Low Open Heath (MA CocrTerfc EcrEv EteCcEpd).
- Eucalyptus Low Open Forest (MA EcrEvEx ApypAtpGoro TtEuaCyp).
- Eucalyptus Open Forest (MA EcrEvMa AcpAamAthe TydCyv).
- Eucalyptus Woodland (MA EcrEv AcpAtheEv TpTl and MA EvAciEcr TercCocrApyp CcEuaTt).
- Eucalyptus Open Woodland (MA EcrEv AciAcp Mg).
- Melaleuca High Open Forest (MA MaEcrEv MgAcpAtr Cyv).
- Potamogeton Open Herbs (MA Pt Ecr TdScsuCyv).

Two of these vegetation associations are highly likely to be groundwater dependent as they contain *Melaleuca argentea* (MA EcrEvMa AcpAamAthe TydCyv and MA MaEcrEv MgAcpAtr Cyv). Two other associations are also likely to be groundwater dependent (MA EvAciEcr TercCocrApyp CcEuaTt and MA EcrEv AcpAtheEv TpTl) as they contain *Eucalyptus camaldulensis* and *E. victrix*, and occur in the creek bed and / or areas with shallow water tables (refer to Section 5.6.3 for further information) (BHP, 2025).

One vegetation association (SA Aa TpTwTb CcChf) is potentially aligned with the ‘Valley Floor Mulga’ ecosystem at risk. However, this vegetation association only occurs sparsely within the development envelope. It is not considered to represent an ecosystem at risk because the importance of the ‘Valley Floor Mulga’ ecosystem, within the northern extent of the Hamersley subregion, is related to large occurrences of vegetation dominated by Mulga occurring on valley floors or broad plains, rather than the sparse occurrences at Yandi (BHP, 2025).

Vegetation condition has been rated as good to very good for the majority of the lease outside of approved disturbance areas (BHP, 2025). Condition declines within drainage lines and floodplains associated with cattle grazing and the introduction of weeds (Buffel grass).

### 5.6.3 Groundwater dependent vegetation

This section describes the groundwater dependent vegetation associations:

- Along Marillana Creek which are representative of both the associations within the Yandi tenure, and those located upstream at Flat Rocks.
- At Yandicoogina Gorge which is located 4 km south of Yandi.

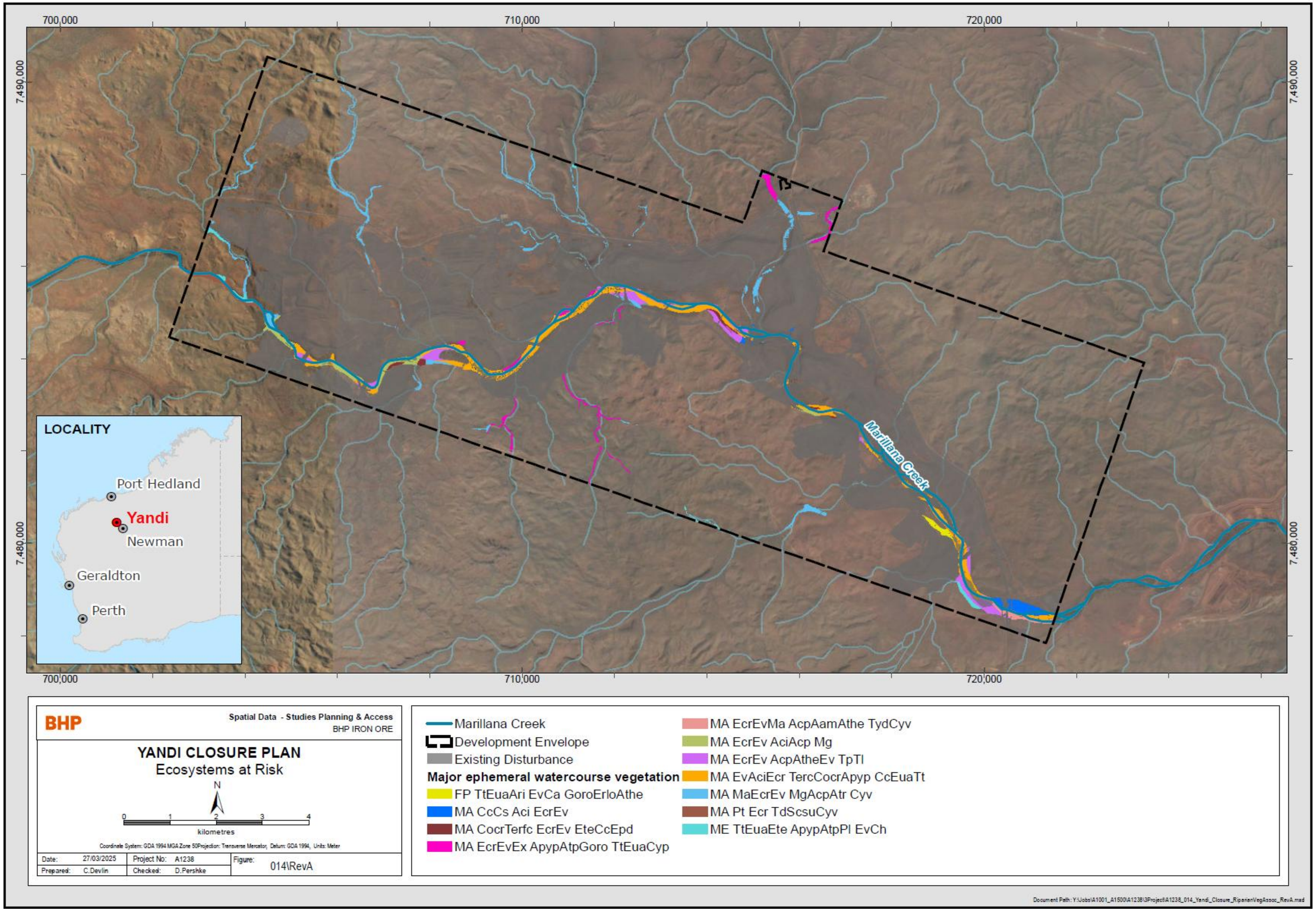
#### 5.6.3.1 Marillana Creek

The riparian zones associated with Marillana Creek comprise an incised drainage channel surrounded by levee banks and small floodplains. Dominant tree species of the riparian zone are *Eucalyptus camaldulensis*, *Eucalyptus victrix* and *Melaleuca argentea*. *Eucalyptus camaldulensis* and *Eucalyptus victrix* are facultative phreatophytes that draw on groundwater in times of drought but also utilise surface water and soil moisture reserves. *Melaleuca argentea* is an obligate phreatophyte associated with shallow groundwater and / or permanent pools of surface water at points along the creek (Onshore Environmental, 2015).

Of the riparian species in Marillana Creek, *Melaleuca argentea* is likely to have the highest degree of groundwater dependence. However, even this species is likely to have some capacity to extract soil-water when available at high enough matric potentials (approximately ≥ -2,000 kPa). Leaf water potential measurements collected by BHP from multiple sites in the Pilbara as a component of operational monitoring programs, indicate that *E. camaldulensis var. refulgens* and *E. victrix* can extract water from relatively dry soils (i.e. with matric potentials approximately ≥ -3,500 kPa and > -4,500 kPa respectively) (AQ2, 2017).

Based on riparian vegetation mapping of Marillana Creek completed by Onshore Environmental (2015) the dominant species and vegetation associated with the main landform types of the creek can be summarised as (BHP Billiton, 2016):

- Stream bed of major channels - Open forest to open woodland of tall riverine eucalyptus (*Eucalyptus victrix, E. Camaldulensis* subsp. *refulgens*) and cajeput (*Melaleuca argentea*) over variable understorey of small trees or tall shrubs (*Acacia citrinoviridis, Acacia coriacea* subsp. *pendens, Melaleuca glomerata* and *Melaleuca bracteata*) over open low shrubs or heath (*Corchorus crozophorifolius, Tephrosia rosea* var. Fortescue creeks (M.I.H. Brooker 2186)) and perennial tussock grasses (*Eriachne* species).
- Stream banks - Open woodland of riverine eucalyptus (*Eucalyptus victrix, E. camaldulensis* subsp. *refulgens*) over low woodland (*Acacia coriacea* subsp. *pendens, Atalaya hemiglauca, Acacia citrinoviridis, Acacia pruinocarpa, Corymbia hamersleyana*) with low shrubs (*Corchorus crozophorifolius, Acacia pyrifolia*) over hummock grasses (*Triodia species*) and tussock grasses (*Eriachne tenuiculmis* and *Enneapogon lindleyanus*).




See Appendix Q for a pdf version of this map

**Map 5-10 Ecosystems at risk**

In areas where there is direct hydraulic connection between the alluvial aquifer and the CID (i.e. where Marillana Creek intersects the CID), tree-deaths of *Melaleuca argentea* have occurred in response to dewatering of the CID. Areas where riparian vegetation health has declined include a site upstream of the Yandi development envelope at Flat Rocks. These impacts are being managed in accordance with the Marillana Creek Water Resource Management Plan and are reported on annually via the AER. Should any investigations conducted under the management plan indicate the need for measures to be implemented during closure, these will be integrated into future iterations of this MCP.

In areas where the alluvial aquifer does not directly intersect the CID, stands of *Melaleuca argentea* appear less vulnerable to drawdown effects as they are more reliant on rainfall and stream flow to provide seasonal replenishment of groundwater to the creek alluvium.

#### 5.6.3.2 Yandicoogina Gorge

Yandicoogina Gorge is located 4 km south of Yandi mine on Yandicoogina Creek at the convergence of surface and groundwater flows from the upstream catchment. Where groundwater intercepts the surface, a series of seeps and pools extend for approximately 3.4 km within the gorge. These areas support vegetation associations that have been identified to have affinities with the Priority 2 ecological community '*Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara Region*' but are not recognised as a confirmed Priority Ecological Community (PEC). The vegetation associations with affinities to the Priority 2 PEC have the following characteristics (BHP, 2025):

- *Eucalyptus victrix* ecotype (Ev-type). This ecotype comprises a low woodland of *Eucalyptus victrix* at low to moderate basal area. These areas are characterised by a grass understory.
- *Eucalyptus camaldulensis* ecotype (Ec-type). This ecotype comprises a mid-woodland with *Eucalyptus camaldulensis* as the primary species. *Eucalyptus victrix* forms a subordinate species at its upstream margins while *Melaleuca argentea* is a subordinate species at its downstream margins. This ecotype includes *Acacia tumida* and *A. coriacea* as mid storey species. Extensive *Gossypium robinsonii* occurs in slightly elevated areas on the margin of the creek.
- *Melaleuca argentea* ecotype (Ma-type). This ecotype comprises a high woodland to open forest of *Melaleuca argentea* with subordinate *Eucalyptus camaldulensis*. The ecotype includes *Acacia tumida* and *A. coriacea* as mid storey species and extensive *Typha domingensis* in areas of both permanent and transient pools. *Extensive Gossypium robinsonii* occurs in slightly elevated areas on the margin of the creek.

### 5.6.4 Flora of conservation significance

No threatened flora species listed under the *Biodiversity Conservation Act 2016 (WA)* (BC Act), or the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act) have been recorded in the Yandi development envelope[28].

Seven priority flora species currently listed by DBCA have been recorded within the undisturbed area of Yandi (Table 5-30 and Map 5-8).

*Goodenia nuda* was previously listed as Priority 4 but has since been delisted (DBCA, 2022).

**Table 5-30 Priority flora species recorded within the Yandi mining lease**

| Scientific Name | Priority Status [1] |
|---|---|
| *Aristida lazaridis* | P2 |
| *Ipomoea racemigera* | P2 |
| *Acacia subtiliformis* | P3 |
| *Amaranthus centralis* | P3 |
| *Rostellularia adscendens* var. *latifolia* | P3 |
| *Lepidium catapycnon* | P4 |
| *Sida sp.* Barlee Range | P4 |

Sources: WAIO (2024b); [1]DBCA (2022)

P1 - Priority 1 (poorly known species); P2 - Priority 2 (poorly known species); P3 - Priority 3 (poorly known species); P4 - Priority 4 (rare, near threatened and other species in need of monitoring)

### 5.6.5 Weeds and declared plants

No 'declared plants' listed under the *Biosecurity and Agriculture Management* (BAM) *Act 2007 (WA)* have been recorded within the Yandi area. There are also no weeds on the DBCA's Pilbara Region Priority Alert list (DBCA, 2019).

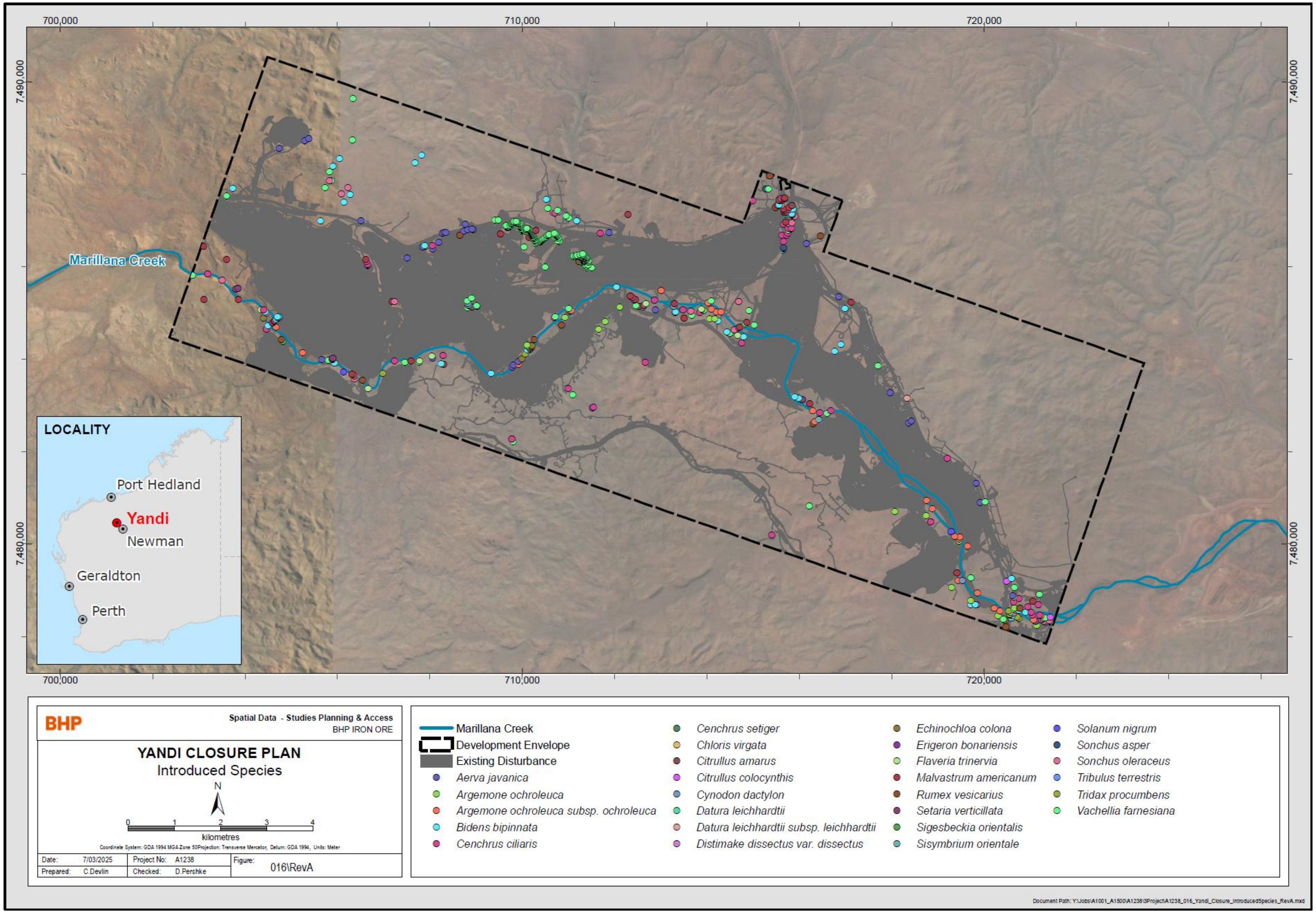
[28] One species has been recorded (*Seringia exastia*) which was in the process of being delisted as a Threatened species at the time of writing (BHP, 2025).

Twenty-seven, introduced flora species have been recorded from the Yandi lease (Table 5-31) (Map 5-11). Weed occurrences are concentrated around areas of disturbance, particularly along linear infrastructure including the rail line and roads. The most commonly recorded species in the development envelope are **Vachellia farnesiana* (Mimosa Bush), **Malvastrum americanum* (Spiked Malvastrum), **Bidens bipinnata* (Bipinnate Beggartick) and **Cenchrus ciliaris* (Buffel Grass). Since 2015, two new weed species have been recorded and treated within the Yandi area: *Flaveria trinervia* (speedy weed) and *Sonchus asper* (rough sowthistle). Two weed species have not been recorded in the project area but have the potential to occur in the future: *Alternanthera pungens* (khaki weed) and *Polypogon mospeliensis* (annual beardgrass) (BHP, 2021e).

BHP manages introduced flora species at the Yandi mine in accordance with the Yandi Biodiversity Environmental Management Plan (BHP, 2021e) and Weed Management Procedure (WAIO, 2020c).

### 5.6.6 Knowledge gaps & forward work program

Vegetation communities have a role in providing habitat for fauna, and research is currently being planned on fauna habitat for key species (see Section 5.7.7).




See Appendix Q for a pdf version of this map

**Map 5-11 Introduced species at Yandi**

**Table 5-31 Introduced flora species recorded within the Yandi mining lease area**

| Scientific Name | Common Name | Ecological Impact | Invasiveness | Notes |
|---|---|---|---|---|
| **Aerva javanica* | Kapok Bush | High | Rapid | A common weed in the Pilbara rangelands, preferring deeper soils and disturbance. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Argemone ochroleuca*<br>**Argemone ochroleuca subsp. Ochroleuca* | Mexican Poppy | Unknown | Rapid | Widespread, particularly creek edges, riverbanks, roadsides. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Bidens bipinnata* | Bipinnate Beggartick | Unknown | Rapid | Commonly observed in association with Mulga vegetation and creek lines in the Pilbara. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Cenchrus ciliaris* | Buffel Grass | High | Rapid | Widespread in Pilbara. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Cenchrus setiger* | Birdwood Grass | High | Rapid | Is closely related to Buffel grass, also introduced as a fodder species and grows in similar habitats. Permitted under S 11 of the BAM Act (DPIRD, 2023) |
| **Chloris virgata* | Feathertop Rhodes Grass | High | Rapid | Annual grass preferring clay or sandy soils. Responds rapidly to rainfall events. Recorded in two locations in the Jimblebar development envelope, in close proximity to the rail line. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Citrullus amarus* | Wild Melon | Not listed | Not listed | Not listed under the BAM Act or by DBCA (2019). |
| **Citrullus colocynthis* | Colocynth / Bitter apple | Unknown | Moderate | Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Cynodon dactylon* | Couch | High | Rapid | Perennial, rhizomatous grass, resistant to drought, waterlogging and fire. Capable of reducing growth and germination of other species. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Datura leichhardtii*<br>*Datura leichhardtii subsp. Leichhardtii* | Native Thornapple | Unknown | Unknown | Native to the Mediterranean, this species is very hardy and persists in arid conditions. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Distimake dissectus var. dissectus* | White convolvulus creeper | Not listed | Not listed | Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Echinochloa colona* | Awnless Barnyard Grass | High | Rapid | Tufted annual grass. Widespread throughout Kimberley and Pilbara near watercourses and swamps. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Erigeron bonariensis* | Flax-leaf fleabane | Not listed | Not listed | Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Flaveria trinervia* | Speedy Weed | Not listed | Not listed | An annual daisy common in the Pilbara and occurs in drainage and disturbed areas. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Malvastrum americanum* | Spiked Malvastrum | High | Rapid | Typically occurs in Mulga vegetation, drainage areas and floodplains and can also be recorded on steep hill slopes and rock piles. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Rumex vesicarius* | Ruby Dock | High | Rapid | Common within disturbed areas in the arid zone. Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Setaria verticillata* | Whorled Pigeon Grass | High | Rapid | Widespread, loosely tufted annual grass. Permitted under S 11 of the BAM Act (DPIRD, 2023). |

| Scientific Name | Common Name | Ecological Impact | Invasiveness | Notes |
|---|---|---|---|---|
| **Sigesbeckia orientalis* | Indian Weed | Unknown | Rapid | Annual herb preferring rocky gullies, limestone ranges, creek beds.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Sisymbrium orientale* | Indian Hedge Mustard | Low | Unknown | Erect annual or biennial herb, widespread in disturbed areas.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Solanum nigrum* | Black Berry Nightshade | Low | Rapid | Short lived perennial herb typically occurs in Mulga vegetation, drainage lines and on floodplains.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Sonchus asper* | Rough sowthistle | Not listed | Not listed | An erect robust, spiny annual or biennial herb.  This species favours dunes, valleys, seasonally wet areas, watercourses, lakes, wetlands and disturbed sites.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Sonchus oleraceus* | Common sowthistle | Low | Rapid | Common and widespread in disturbed areas.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Tribulus terrestris* | Caltrop | Unknown | Moderate | Found widely throughout WA.  Grows rapidly and produces sharp, spiny burrs with up to 20 000 seeds produced on each plant that can remain dormant for up to 5 years.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Tridax procumbens* | Tridax daisy | Not listed | Not listed | Perennial herb occurring in north-west Western Australia in wet and disturbed ground.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |
| **Vachellia farnesiana* | Mimosa bush | High | Rapid | Thicket forming thorny shrub isolated occurring along drainage systems and in adjacent low-lying areas.  Permitted under S 11 of the BAM Act (DPIRD, 2023). |

Sources: WAIO (2024b); DBCA (2019); DPIRD (2023)

## 5.7 Fauna

**Summary**

Fourteen vertebrate fauna habitat types have been described and mapped at Yandi. Most of the fauna habitats are broadly distributed and well represented across the Pilbara bioregion, and support fauna assemblages which are generally common and widespread. The wetland habitat is relatively uncommon in the Pilbara and has limited extent within the Yandi development envelope.

Nine of the mapped fauna habitats are considered to be high or moderate value for terrestrial vertebrate fauna as they provide critical and / or supporting habitat for conservation significant fauna species; specifically, wetland, major drainage line, breakaway / cliff, medium drainage line, hardpan plains, mulga woodland, drainage area / floodplain, stony plain and sandy / stony plain. Three of these habitat types may provide critical habitat for Ghost Bat, but only where they occur within 12 km of critical roosting habitat (drainage area / floodplain, sandy / stony plain and stony plain). One Category 4 Ghost Bat cave has been recorded and identified as a potential nocturnal roost.

Two permanent / semi-permanent (MC1 and MC2) natural water features / pools have been mapped at Yandi in association with Marillana Creek. Several persistent pools are also located upstream of the Yandi development envelope, at Flat Rocks.

252 vertebrate fauna species have been recorded including five amphibians, 81 reptiles, 127 birds and 39 mammals. These include five conservation significant fauna:

- Fauna listed under the EPBC and / or BC Act and their conservation status:
  - Pilbara Olive Python (*Liasis olivaceus barroni*) (Vulnerable).
  - Northern Quoll (*Dasyurus hallucatus*) (Endangered).
  - Common Sandpiper (*Actitis hypoleucos*) (Migratory).
  - Peregrine Falcon (*Falco peregrinus*) (Other specially protected species).
- Western Pebble-mouse (*Pseudomys chapmani*) which is classified as a Priority 4 species by the DBCA.

There are also other highly mobile conservation significant fauna that have not been recorded to date, but are likely to occur:

- Fauna listed under the EPBC and / or BC Act and their conservation status:
  - Vulnerable - Ghost Bat (*Macroderma gigas*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantius* [Pilbara form]) and Grey Falcon (*Falco hypoleucos*).
  - Endangered - Australian Painted Snipe (*Rostratula australis*).
  - Migratory - the Common Greenshank (*Tringa nebularia*), Glossy Ibis (*Plegadis falcinellus*) and Fork-tailed Swift (*Apus pacificus*).
- Priority species listed by DBCA:
  - Priority 2 - Pilbara Barking Gecko (*Underwoodisaurus seorsus*) and Unpatterned Robust Slider (Robertson Range) (*Lerista macropisthopus remota*).
  - Priority 4 - Brush-tailed Mulgara (*Dasycerus blythi*) and Letter-winged Kite (*Elanus scriptus*).

Introduced fauna recorded include Cow (*Bos taurus*), Red Fox (*Vulpes vulpes*), Dingo / Dog (*Canis familiaris*), Donkey (*Equus asinus*), Camel (*Camelus dromedarius*), Cat (*Felis catus*) and House Mouse (*Mus musculus*).

Permanent / semi-permanent pools support diverse invertebrate fauna (microinvertebrates, hyporheos fauna and macroinvertebrates). Most species are common and widespread throughout the Pilbara, and none are specifically listed under state or national legislation. At Yandicoogina Gorge, a relatively high percentage of stygobitic taxa (19%) has been recorded compared to other hyporheic zones in the Pilbara (5%), including five potentially restricted stygofauna species. Three troglofauna species have also been recorded in the hyporheic zone in the gorge.

Three common, widespread freshwater fish species have been recorded at Yandi and at reference sites; the western rainbowfish (*Melanotaenia australis*), spangled perch (*Leiopotherapon unicolor*) and Pilbara tandan (*Neosilurus* sp.).

The aquifers at Yandi (Sections 5.9.2 and 5.9.3) represent suitable habitat for subterranean fauna as they are relatively shallow with low salinity:

- The superficial alluvial systems of Marillana Creek are known to support a diverse stygofauna fauna community. At least 56 stygofauna taxa have been recorded in and around the development envelope and groundwater drawdown area including specimens that could not be identified to species level. Of the stygofauna species recorded, a total of six species are currently known only from the groundwater drawdown area. The remaining species are either widespread or have linear ranges that extend outside the groundwater drawdown area. None are listed or recognised as conservation priorities under state or federal legislation.
- At least 35 troglofauna taxa are known from the Yandi development envelope including 194 specimens attributable to 33 taxa recorded during recent surveys (reported in 2024 and 2025). Fifteen species are known only from the Yandi development envelope. However, none of the troglofauna taxa, nor the communities recorded in the development envelope, are listed or recognised as conservation priorities under state or federal legislation.

The stygofauna assemblage at Ministers North is considered relatively depauperate, likely due to groundwater depths > 40 m.

All habitat types are prospective for Short Range Endemic Fauna (SREs) (i.e., contain microhabitats, levels of shade and / or humidity, or suitable soils for burrowing). Habitat types:

- That retain moisture such as drainage lines, drainage area / floodplain, south-facing slopes within hillcrest / hillslope habitats, breakaway / cliff and wetland habitats are particularly prospective for SREs that require high humidity (e.g., millipedes, molluscs and SREs that live amongst leaf litter and vegetation such as pseudoscorpions).
- Such as stony plain, hardpan plain and sand plain may be prospective for mygalomorph spiders and scorpions.

Based on recent (2023) and historical Short Range Endemic (SRE) surveys, three Confirmed, 19 Potential and 25 Uncertain SREs have been recorded within the development envelope. None are listed as Threatened under the EPBC or BC Act. Three Confirmed SREs, six Potential SREs and six Uncertain SREs are all known from outside the development envelope and / or have linear ranges that extend beyond the boundaries of the development envelope. Thirteen potential SREs and six Uncertain SREs were either collected for the first time in the 2023 survey or are data deficient with unknown distributions.

Marillana Creek is considered to be an important dispersal conduit for SREs due to the relatively continuous corridor of dense vegetation and the periodic influence of flooding. Establishing a diversity of habitats that support representative flora and fauna species and provide ecological function and connectivity through the system is a design objective specified in the Marillana Creek Diversion Management Plan (BHP Billiton, 2016) and incorporated into the completion criteria in Section 8.3.

### 5.7.1 Fauna habitats

Fourteen fauna habitat types have been described and mapped within the development envelope (Table 5-32 and Map 5-12). Most of the fauna habitats are broadly distributed and well represented across the Pilbara bioregion and surrounding regions, and support fauna assemblages which are generally common and widespread. The wetland habitat is relatively uncommon in the Pilbara and has limited extent within the development envelope.

Nine of the mapped fauna habitats are considered to be high or moderate value for terrestrial vertebrate fauna as they provide critical and / or supporting habitat for conservation significant fauna species, specifically wetland, major drainage line, breakaway / cliff, medium drainage line, hardpan plains, mulga woodland, drainage area / floodplain, stony plain and sandy / stony plain (Table 5-32). Three of these habitat types may provide critical habitat for Ghost Bat, but only where they occur within 12 km of critical roosting habitat (drainage area / floodplain, sandy / stony plain and stony plain). The remaining habitats are considered moderate to low or low value for vertebrate fauna due to containing low vegetation complexity and/or a lack of microhabitats or features utilised by fauna.

All of the habitat types are prospective for Short Range Endemic (SRE) fauna (Section 5.7.6) since they contain microhabitats, levels of shade and / or humidity, or suitable soils for burrowing. Habitat types that retain moisture such as drainage lines, drainage area / floodplain, south-facing slopes within hillcrest / hillslope habitats, breakaway / cliff and wetland habitats are particularly prospective for SREs that require high humidity such as millipedes and molluscs, as well as SREs that live amongst leaf litter and vegetation (e.g., pseudoscorpions), whereas habitats such as stony plain, hardpan plain and sand plain may be prospective habitat types for mygalomorph spiders and scorpions.

Two permanent / semi-permanent (MC1 and MC2) natural water features / pools have been mapped within the Yandi development envelope in association with Marillana Creek (Map 5-12). The observed number of distinct pools has varied in reporting over biodiversity and water monitoring surveys due to seasonal and temporal fluctuations of the hydrology of the pools. Several persistent pools are also located upstream of the Yandi development envelope, at Flat Rocks (Section 5.9.4.2) (BHP, 2025).

One Category 4 Ghost Bat cave has been recorded within the development envelope and has been identified as a potential nocturnal roost for Ghost Bat (BHP, 2025).

### 5.7.2 Vertebrate fauna

During historical and recent (2023) surveys, 252 vertebrate fauna species have been recorded within the development envelope. These include five conservation significant fauna (Section 5.7.3) (BHP, 2025).

Introduced fauna recorded include Cow (**Bos taurus*), Red Fox (**Vulpes vulpes*), Dingo / Dog (**Canis familiaris*), Donkey (**Equus asinus*), Camel (**Camelus dromedarius*), Cat (**Felis catus*) and House Mouse (**Mus musculus*).

The recorded fauna assemblage is considered typical of the Pilbara bioregion, and more specifically the Hammersley subregion. The number of species recorded is comparative to other fauna assessments in the subregion (BHP, 2025).

**Table 5-32 Fauna habitats**

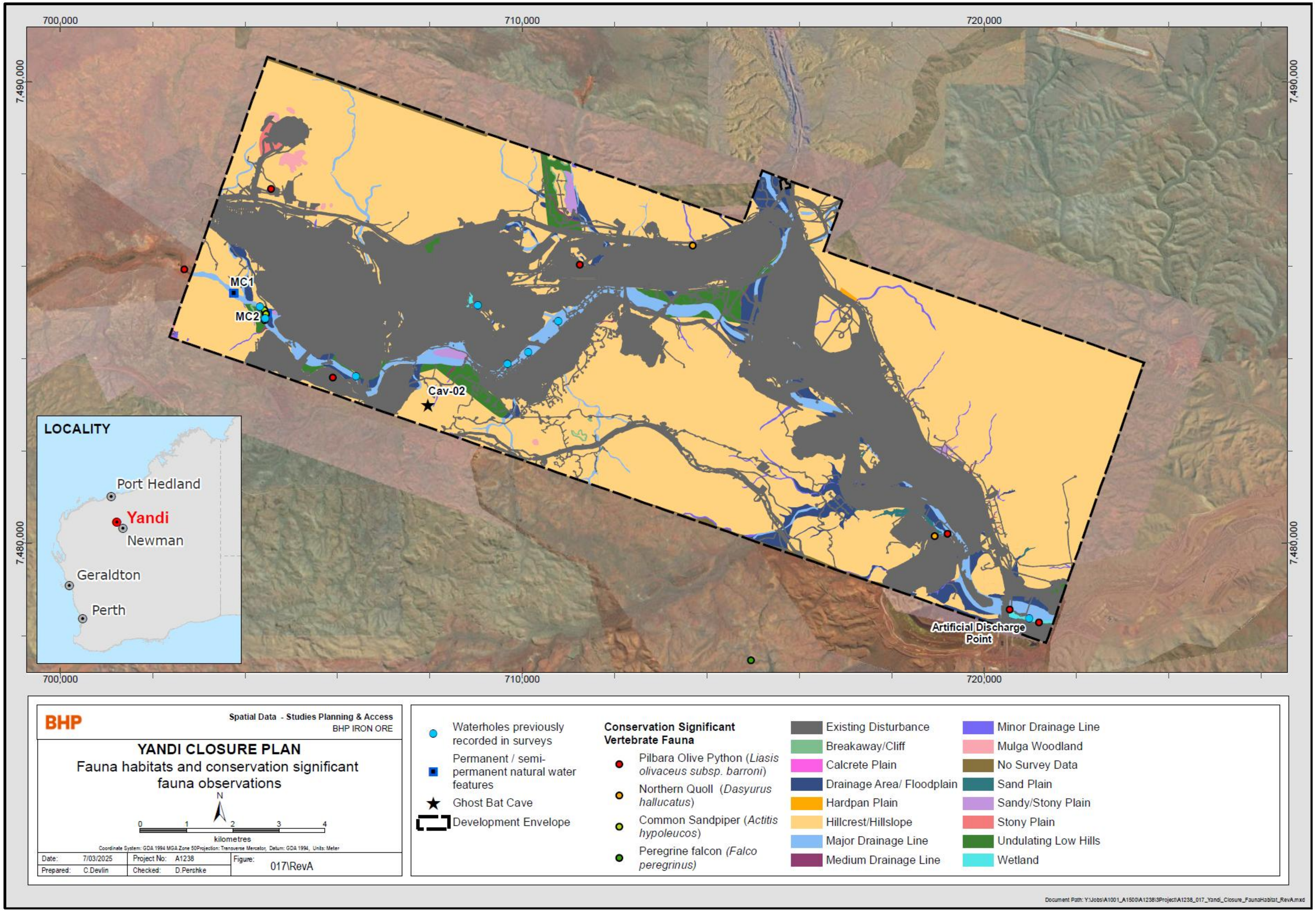
| Habitat Type | Description | Value to conservation significant fauna[29] | Value to Short Range Endemic (SRE) fauna |
|---|---|---|---|
| Wetland | Wetland habitats differ from permanent / semi-permanent pools as they are generally a larger water body that supports their own distinct ecosystem and aquatic fauna assemblages (waterfowl, fish etc.).<br>This habitat includes Flat Rocks; a section of the creek on the western side of the development envelope which widens and holds permanent water and is surrounded by rocky habitat. | Provides **critical foraging habitat** for Pilbara Olive Python and **supporting habitat** for Northern Quoll. Also provides suitable habitat for some Migratory listed bird species. | Wetland habitats are similar to drainage lines in terms of suitability for SREs. The major difference is that wetland habitats tend to be isolated within the broader landscape; accordingly, moisture dependent SREs may not have distribution corridors away from wetlands.<br>*Acacia* provides bark and leaf litter at this site, and rocks provide sheltered microhabitats for invertebrates. |
| Major Drainage Line | This fauna habitat type consists of large drainage channels over 10 m wide, typically lined with mature *Eucalyptus / Corymbia* and *Melaleuca* species. It exhibits a moderate diversity of microhabitats, with some tree hollows and woody debris (logs and leaf litter). Within the Yandi area, buffel grass (**Cenchrus ciliaris*) was present in the ground storey vegetation, reducing floral diversity. Permanent or semi-permanent water bodies were identified in multiple sections of the survey area. Flat Rocks is considered a larger permanent body of water. | Provides **critical habitat** for the Grey Falcon (breeding, foraging and dispersal), the Pilbara Olive Python (foraging and dispersal) and Ghost Bat (foraging) when within 12 km of critical roosting habitat.<br>Provides **supporting habitat** for Northern Quoll, Ghost Bat (if outside the 12 km radius) and Pilbara Leaf-nosed Bat. | Contains vegetation providing microhabitats under bark and / or in leaf litter for invertebrates. Sandy soils further away from the watercourse at the survey sites provide suitable habitat for burrowing invertebrates such as mygalomorph spiders. Residual seasonal moisture from drainage lines provides elevated humidity suitable for gastropods, isopods, and millipedes. |
| Breakaway / Cliff | Breakaway / cliff habitat is characterised by large rocky outcrops that are not cave forming with little vegetation and limited soft soil, leaf litter and dense vegetation. Contains large rock fragments and more rock outcropping than other fauna habitats; however, is generally unsuitable for many fauna species due to the lack of soft soil, leaf litter and / or dense vegetation. | Provides **supporting habitat** for Northern Quoll, Ghost Bat, Pilbara Olive Python, Pilbara Leaf-nosed Bat.<br>May provide **critical habitat** for Pilbara Olive Python but only where it occurs in proximity to a water source.<br>This habitat type is generally not cave or shelter forming within the development envelope and, therefore, is not considered critical habitat for the Ghost Bat unless it occurs within 12 km of critical roosting habitat. | Often rocky, with higher humidity at the base of declivities which hosts various plant species and humidity-dependent SRE Groups such as millipedes and isopods. Often contains vegetation providing bark and leaf litter microhabitats.<br>Gorges and gullies tend to be isolated habitat types. |
| Medium Drainage Line | This habitat type typically consists of small drainage channels with eucalypt woodlands growing in the riparian zone. A moderate diversity of microhabitats occurs with some seasonal presence of pools, tree hollows and woody debris (logs and leaf litter). Buffel grass was often present in the ground storey vegetation, reducing floral diversity. | Provides **critical habitat** for Ghost Bat where it occurs within 12 km of critical roosting habitat. Otherwise, provides **supporting habitat** for Northern Quoll, Pilbara Olive Python, Ghost bat and Pilbara Leaf-nosed Bat. | As for major drainage line. |

29 Value to conservation significant fauna relates to those species that have been recorded, or which are considered to have a high or moderate likelihood of occurrence, within the development envelope

| Habitat Type | Description | Value to conservation significant fauna[29] | Value to Short Range Endemic (SRE) fauna |
|---|---|---|---|
| Hardpan Plains | Consists of mainly alluvial, silty to sandy clay loam floodplains associated with drainage lines and comprises clay-based soils, both cracking and non-cracking in low lying areas that have slight to no gradient.<br>Exhibits a moderate diversity of microhabitats, with some tree hollows and logs and deep sandy soils suitable for burrowing. | Provides **critical habitat** for Ghost Bat where it occurs within 12 km of critical roosting habitat. Otherwise, provides **supporting habitat** for Northern Quoll, Ghost bat and Grey Falcon. | Leaf litter from *Acacia* and *Eucalyptus* provided suitable microhabitat for invertebrates at this site. Hardpan plains are highly prospective for mygalomorphs in the genus *Conothele*, which often prefer to burrow in claypan. Centipedes, including the SRE-rich families *Geophilidae* and *Cryptopidae*, are also often more abundant in this habitat type. |
| Mulga Woodland | Comprises stands of mulga (*Acacia aneura*) over clay or stony substrates. Differs from other plains by having a monoculture of mulga compared to a diversity of other *Acacia* species. | May provide important habitat for a range of fauna species in general. May provide **critical foraging habitat** for Ghost Bat (where <12 km to critical roosting habitat). | Leaf litter from *Acacia* provides suitable microhabitat for invertebrates at this site. May be prospective for species which prefer to burrow in claypan such as *Conothele*. |
| Drainage Area / Floodplain | Lower lying plain often subjected to sheet flow following large rainfall events. Vegetation and substrates of this habitat are variable, often comprising scattered *Eucalyptus* over *Acacia* and / or *Grevillea* shrubs with an understorey dominated by *Triodia* hummock grasses and / or mixed tussock grasses on alluvial substrates, often comprising heavy clays and gravel. | Provides microhabitats for many fauna species including reptiles and mammals.<br>Provides **critical habitat** for Ghost Bat where it occurs within 12 km of critical roosting habitat. Otherwise, provides **supporting habitat** for Northern Quoll, Ghost bat and Grey Falcon. | As for major drainage line. |
| Sandy / Stony Plain | Characterised by large hummock *Triodia* grasses or stands of *Acacia* or other shrubs over clay or stony substrates. Common throughout the Pilbara region and has value to a wide spectrum of fauna species. Contains logs, tree hollows, thick undergrowth, leaf litter, soft soil (burrows), and old *Triodia*. | Provides suitable burrowing and foraging habitat for a number of fauna species.<br>Provides **critical habitat** for Ghost Bat where it occurs within 12 km of critical roosting habitat. Otherwise, provides **supporting habitat** for Northern Quoll, Ghost bat and Grey Falcon. | Provides burrowing habitat for SREs requiring firmer soils as well as areas containing loose soil more suitable for species such as *Urodacus* scorpions and anamid mygalomorphs lacking a rastellum. Some areas contain rocks and vegetation which provides suitable microhabitat for *Lychas* scorpions, centipedes, millipedes, and pseudoscorpions, and areas with vegetation may also retain enough humidity to support isopods. |
| Stony Plain | Comprises flat to low undulating areas and low hills with vegetation dominated by *Triodia* hummock grasses of various life stages with scattered eucalypts and patches of various small to medium shrub species on gravelly clay loam substrates. In some low-lying areas, isolated patches of sandy substrate occur. | Provides **critical habitat** for Ghost Bat where it occurs within 12 km of critical roosting habitat. May also provide **supporting habitat** for other species that may utilise it for occasional foraging and / or dispersal such as the Pilbara Leaf-nosed Bat, Northern Quoll, and Grey Falcon. Also provides suitable habitat for Western Pebble-mound Mouse. | Stony plains typically provide habitat for burrowing SREs requiring firmer soils (e.g. most mygalomorph spiders) but not for burrowing SREs requiring looser soils (e.g. some *Urodacus* scorpions). The presence of rocks and vegetation throughout stony plains provides suitable microhabitat for *Lychas* scorpions, centipedes, millipedes, and pseudoscorpions, which may occur beneath rocks, under bark, and / or in leaf litter. Rocks and vegetation may also retain enough humidity to support isopods. |
| Hillcrest / Hillslope | Comprises rocky outcrops, ridges and stony plains on the tops of ranges, supporting *Triodia* hummock grassland with scattered *Eucalyptus* and *Acacia*. Such areas are not highly complex and generally have skeletal soils and sparse open vegetation that can provide pockets of protection from exposure. | Provides suitable habitat for the Western Pebble-mound Mouse. | South-facing slopes within this habitat type are highly prospective for SREs as they have higher humidity than other aspects and are at least partially sheltered from sunlight. Millipedes, anamid mygalomorphs, and *Lychas* scorpions are all likely to occur in south-facing slopes in the Pilbara. Hillslopes hosting *Acacia* species often provide bark and leaf litter for pseudoscorpions as well. |

| Habitat Type | Description | Value to conservation significant fauna[29] | Value to Short Range Endemic (SRE) fauna |
|---|---|---|---|
| Undulating Low Hills | Undulating low hills, footslope, hillslope, hillcrest / upper hillslope, ironstone outcrops, with scattered eucalypts over open *Acacia* shrubland over *Triodia* hummock grassland over gravelly silty or sandy clay loam. This habitat is widespread and common throughout the Pilbara region and exhibits low vegetation complexity and low diversity of microhabitats. | May provide some habitat for species such as the Grey Falcon. | Undulating low hills provide different microhabitats for a variety of SREs including burrowing species or those found beneath rocks, under bark, and / or in leaf litter. Rocks and vegetation may also retain enough humidity to support isopods. |
| Minor Drainage line | Located within the minor gullies and depressions, generally through the hillcrest / hillslope habitat. Consists primarily of *Acacia* low shrubland. The understorey generally lacks density and often consists solely of sparse tussock grassland, often including the weed Buffel Grass where it has been introduced. The substrate can be sandy in places but generally consists of a skeletal loam gravel or stone. | Due to the general lack of tall, hollow-bearing trees, most minor drainage lines are not commonly used for nesting. Some species may utilise this habitat transiently as corridors during dispersal. However, this habitat generally has low vegetation complexity and microhabitat diversity and is considered of low value for fauna. | As for major drainage line. |
| Calcrete Plain | This habitat type is mostly low in the landscape. The vegetation occurring on calcrete differs from that of the surroundings, largely due to the differences in soil type. The substrate is white and consists of skeletal soil, gravel and small jagged pebbles. Trees are isolated and the shrub layer tends to be sparse, with a low hummock grassland (*Triodia* sp.) dominant. | Overall value to fauna is low; however, the Western Pebble-mound Mouse is known to build mounds in this habitat type. | Scattered *Corymbia* trees and *Acacia* shrubs may provide leaf litter and shade for some SREs but is generally devoid of other microhabitats. |
| Sand Plain | Sand plain habitat is characterised by relatively deep sandy soils supporting dense spinifex grasslands and sparse shrubs. This habitat often occurs as terraces along major drainage lines. | May provide suitable burrowing habitat for a number of fauna species but does not support any significant species that occur within Yandi. | Sand plains with loose soil are suitable for *Urodacus* scorpions and anamid mygalomorphs lacking a rastellum.<br>Mygalomorph spiders, centipedes, millipedes, pseudoscorpions, and isopods were collected from this habitat type during the survey, demonstrating that this habitat provides suitable habitat for SREs, despite limited vegetation. |

Source: BHP (2025)




See Appendix Q for a pdf version of this map

Note: the location of the Peregrine Falcon sighting is not shown on this map as it was not recorded at the time of the survey in 1995

**Map 5-12 Fauna habitats and conservation significant fauna observations**

### 5.7.3 Conservation significant terrestrial fauna

Conservation significant fauna species recorded within the Yandi development envelope are listed in Table 5-33. Other highly mobile conservation significant fauna that have not been recorded to date, but are likely to occur include (BHP, 2025):

- Fauna listed under the EPBC and / or BC Act with the conservation status:
  - Vulnerable - Ghost Bat (*Macroderma gigas*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantius* [Pilbara form]) and Grey Falcon (*Falco hypoleucos*).
  - Endangered - Australian Painted Snipe (*Rostratula australis*).
  - Migratory - the Common Greenshank (*Tringa nebularia*), Glossy Ibis (*Plegadis falcinellus*) and Fork-tailed Swift (*Apus pacificus*).
- Priority species listed by DBCA:
  - Priority 2 - Pilbara Barking Gecko (*Underwoodisaurus seorsus*) and Unpatterned Robust Slider (Robertson Range) (*Lerista macropisthopus remota*).
  - Priority 4 - Brush-tailed Mulgara (*Dasycerus blythi*) and Letter-winged Kite (*Elanus scriptus*).

**Table 5-33 Conservation significant fauna species recorded within the Yandi lease**

| Species | Conservation status | | Preferred habitat | Comments |
|---|---|---|---|---|
| | EPBC Act | BC Act / DBCA | | |
| Pilbara Olive Python (*Liasis olivaceus barroni*) | VU | VU | Prefers rocky outcrops, escarpments, and gorges, often in close proximity to water holes (including man-made) which attract suitable sized prey species. Microhabitat preferences include rock piles, on top of rocks or underneath spinifex. | There are six records of Pilbara Olive Python within the development envelope. In addition, there are at least 23 regional records within a 40 km radius. The breakaway / cliff fauna habitat located close to the Flat Rocks water pools and the major drainage line habitats provide critical habitat for the Pilbara Olive Python, with medium drainage line, and wetland habitat types also providing supporting habitat for this species. |
| Northern Quoll (*Dasyurus hallucatus*) | EN | EN | Rocky habitats which provide diversity of microhabitats, retain water, and provide protection from predators.<br>Gorge / gully and breakaway habitats are particularly important for Northern Quoll, as they provide denning sites for breeding and shelter, and diverse microhabitats for foraging. | The species has been recorded in the development envelope twice. In addition, there are almost 500 regional records of Northern Quoll within 20 km. Although there is no critical habitat present, 'supporting' habitat (i.e. foraging and dispersal only) occurs in most of the habitats present within the development envelope. |
| Common Sandpiper (*Actitis hypoleucos*) | MI | MI | Prefers wetland habitats with steep shorelines, in particular along mangrove-lined creeks, muddy areas with rocky outcrops, steep sided dams, and sewage ponds. | The species was recorded eight times during a recent (2023) field survey and there are three historical records in the wider development envelope. Suitable habitat for this species occurs within the wetland habitat and some of the major drainage line habitat. |
| Western Pebble-mouse (*Pseudomys chapmani*) | - | P4 | Occur on stony hillsides with hummock grassland and shelter in complex burrow systems under a mound which they construct on the surface using pebbles collected in the vicinity. | There are 1,039 records of this species across the development envelope. Seven mounds were recorded during a recent (2023) survey including three active mounds, three recently inactive mounds, and one historical inactive mound. The stony plain, undulating low hills and hillcrest / hillslope habitats provide suitable habitat for this species. |
| Peregrine Falcon (*Falco peregrinus*) | n/a | OS | Hunts in any habitat and nests on rocky ledges in tall, vertical cliff faces and tall trees associated with drainage lines. | Has historically been recorded in the development envelope* and regional records exist approximately 5 km south and east. Suitable habitat occurs within the major and medium drainage line fauna habitats. |

Source: BHP (2025)

Notes: EPBC and BC Act Classifications: EN - Endangered, VU - Vulnerable, MI - Migratory, OS - Other Specially Protected Species; DBCA classification P4 - Priority 4 (rare, near threatened and other species in need of monitoring)

*The Peregrine Falcon was recorded in the development envelope from a survey in 1995, but the precise location was not captured and, therefore, this record is not shown on Map 5-12.

### 5.7.4 Aquatic fauna

#### 5.7.4.1 Marillana Creek

WRM (2015; 2018) conducted aquatic fauna surveys of Marillana Creek within the Yandi development envelope at the locations shown on Map 5-13. Yandi sampling sites were generally dominated by transmissive gravel and sand substrates and characterised by submerged macrophyte and algal habitats. Sites MC1 and MC2, were considered to be of some importance as they are the only long-term pools within the Yandi development envelope (WRM, 2018).

A diverse invertebrate fauna (microinvertebrates, hyporheos fauna and macroinvertebrates) was recorded during both the 2014 and 2017 surveys with the sites upstream of MC7 (i.e. upstream of Yandi's dewatering discharge) supporting the highest number of all faunal components, as well as the greatest number of significant species (short range endemics and / or Pilbara endemics). The differences in aquatic invertebrate communities upstream and downstream of MC7 are considered largely flow-related and include lower species richness, abundance and differing species assemblage composition downstream of the discharge outlet, compared to upstream and in reference creeks. Most the invertebrate species recorded are common and widespread throughout the Pilbara. None are specifically listed under state or national legislation (DBCA Priority Fauna or EPBC Act) (WRM, 2018).

Three common, widespread freshwater fish species were recorded from within the Yandi development envelope and at reference sites. These were the western rainbowfish (*Melanotaenia australis*), spangled perch (*Leiopotherapon unicolor*) and Pilbara tandan (*Neosilurus* sp.) (WRM, 2018).

#### 5.7.4.2 Yandicoogina Gorge

Recent aquatic ecosystem sampling (reported in 2023 and 2024) has recorded a relatively high percentage of stygobitic taxa (19%) compared to other hyporheic zones in the Pilbara (5%), including five potentially restricted stygofauna species (BHP, 2025):

- *Gomphodella* `sp. Biologic-OSTR077 – a potentially new species of ostracod currently not known from elsewhere.
- *Bathynellidae* sp. BES7547, *Atopobathynella* `sp. Biologic-PBAT042` and *Bathynellidae* `sp. Biologic-BATH019` which are potentially new species of syncarid that are currently not known from elsewhere.
- *Pygolabis* `sp. Biologic-ISOP035` - potentially restricted isopod currently not known from elsewhere.

In addition, three troglofauna taxa were recorded from the hyporheic zone including the pseudoscorpion *Chthoniidae* `sp. Biologic-PSEU083`, the dipluran *Projapygidae* `sp. Biologic-DIPL053`, and the symphylan *Hanseniella* `sp. Biologic-SYMP054`. All troglofauna taxa were recorded in the wet season from sites which do not always have an inundated hyporheic zone and would likely represent a humid, subterranean environment, that is not often inundated (BHP, 2025).

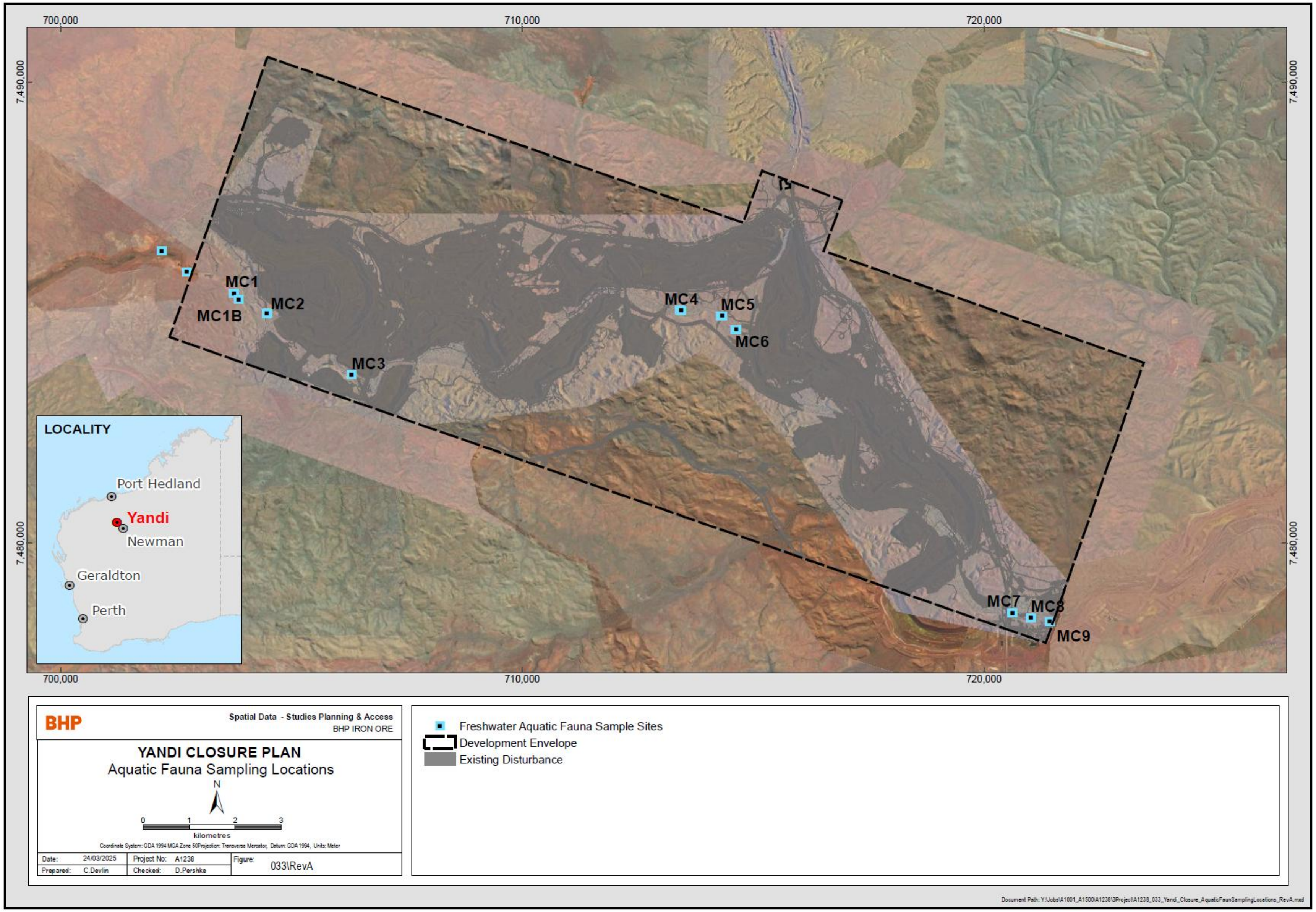
### 5.7.5 Subterranean fauna

The types of geology known to support stygofauna include calcretes; alluvial formations, particularly when associated with alluvial or palaeochannel aquifers; fractured rock aquifers, and karst limestone, whereas troglofauna are likely to be present in karst, CID, BIF, alluvium / colluviums in valley-fill areas, and weathered or fractured sandstone (BHP, 2025).

The Yandicoogina palaeovalley (which incorporates the Marillana Creek palaeochannel) overlaps several areas of the development envelope and connects to the north-east with the much larger Robe palaeovalley, which is a globally significant subterranean fauna habitat. Stygofauna and troglofauna records are often associated with palaeovalleys, with stygofauna generally occurring more centrally in the valley and troglofauna on the slopes (BHP, 2025).

Stygofauna prefer shallow groundwater (less than 30 mbgl) in aquifers with higher transmissivity and fresh / low salinity water (although some species can tolerate higher salinities). The aquifers at Yandi (Sections 5.9.2 and 5.9.3) represent potential habitat for subterranean fauna as they are relatively shallow with low salinity. The CID and superficial alluvial systems of Marillana Creek are known to support a diverse subterranean fauna community. The CID and detritals form highly suitable subterranean fauna habitats, especially where secondary weathering and fracturing of CID provide frequent and well-developed cavities, vugs, and pore spaces, while the alluvial deposits provide suitable subterranean fauna habitat where sufficient pore spaces occur between variably textured material. The Weeli Wolli Formation which is a fractured-rock aquifer along the basement of the Marillana / Yandicoogina palaeovalley system is considered lower yielding for subterranean fauna compared to the CID and alluvial aquifers but may still provide some suitable habitat in areas of sufficiently weathered / fractured cherty or shaly BIF (BHP, 2025).

Based on the surface geology, hydrogeology and occurrence of the Yandicoogina palaeovalley, the subterranean habitats throughout the development envelope are likely to extend beyond the boundaries of the development envelope. Habitat modelling of the Eastern mining area indicates that a thin layer of CID remains intact around pit shells and under the benches and consequently, the current extent of suitable subterranean fauna habitat throughout the study area is well-connected and continuous, with no major habitat barriers (BHP, 2025).




See Appendix Q for a pdf version of this map

**Map 5-13 Aquatic fauna sampling locations**

#### 5.7.5.1 Stygofauna

The stygofauna assemblage within the Yandi Hub is considered to be relatively rich. At least 56 stygofauna taxa have been recorded in and around the development envelope and groundwater drawdown area including specimens that could not be identified to species level. Copepods were the most diverse and abundant stygofauna group (at least 12 species and 597 specimens), however, amphipods, annelids, ostracods, syncarids, roundworms, and one species of isopod were also collected. Of the stygofauna species recorded, a total of six species are currently known only from the groundwater drawdown area including *Dussartcyclops* 2222 `BCY095`, *Pilbaranella* `BSY372`, *Candonopsis* `BOS1831`, *Elaphoidella* sp. S02, *Haplotaxidae* sp. S01 and *Darwinulidae* sp. The remaining species are either widespread or have linear ranges that extend outside the groundwater drawdown areas (BHP, 2025).

The stygofauna assemblage at Ministers North is considered relatively depauperate, likely due to groundwater depths > 40 m. During a survey reported in 2024, 117 stygofauna specimens belonging to six species were collected from 11 different holes (BHP, 2025).

None of the stygofauna taxa, nor the communities recorded in the groundwater drawdown area, are listed or recognised as conservation priorities under state or federal legislation (BHP, 2025).

#### 5.7.5.2 Troglofauna

At least 35 troglofauna taxa are known from the Yandi development envelope including 194 specimens attributable to 33 taxa recorded during recent surveys (reported in 2024 and 2025). Myriapoda (millipedes) were the most abundant troglofauna group (five species; 42 specimens), but araneomorph spiders, beetles, centipedes, cockroaches, diplurans, dipterans, hemipterans, pauropods, pseudoscorpions, schizomids, silverfishes, and symphylans have also been collected. Fifteen troglofauna species are known only from the Yandi development envelope. However, none of the troglofauna taxa, nor the communities recorded in the development envelope, are listed or recognised as conservation priorities under state or federal legislation (BHP, 2025).

### 5.7.6 Short range endemic species

Based on recent (2023) and historical SRE surveys, three Confirmed, 19 Potential and 25 Uncertain SREs have been recorded within the development envelope. None are listed as Threatened under the EPBC or BC Act. Three Confirmed SREs, six Potential SREs and six Uncertain SREs are all known from outside the development envelope and / or have linear ranges that extend beyond the boundaries of the development envelope. Thirteen Potential SREs and six Uncertain SREs were either collected for the first time in this survey or are data deficient with unknown distributions (Table 5-34).

**Table 5-34 SRE species only known from within the development envelope**

| Order / taxa | SRE status | Habitat types |
|---|---|---|
| **Mygalomorphae spiders** | | |
| *Conothele* `BMYG220` | Potential | Hillcrest / hillslope |
| **Pseudoscorpiones** | | |
| *Austrochthonius* `BPS507` | Uncertain | Minor drainage, gorge / gully, hillcrest / hillslope |
| *Austrochthonius* sp. | Uncertain | Hillcrest / hillslope, gorge / gully, major drainage line |
| *Oratemnus* `BPS502` | Potential | Major drainage line |
| *Oratemnus* `BPS503` | Potential | Major drainage line |
| Cheliferidae `BPS504` | Potential | Major drainage line |
| *Synsphyronus* `BPS511`(lathrius?) | Potential | Minor drainage line |
| *Synsphyronus* `paradoxus complex` | Uncertain | Major drainage line, gorge / gully |
| *Austrohorus* `BPS508` | Uncertain | Major drainage line, gorge / gully, hillcrest / hillslope |
| *Austrohorus* `BPS509` | Potential | Gorge / gully |
| *Beierolpium* 8/2 `BPS521` | Uncertain | Hardpan plain |
| Olpiidae `BPS510` | Potential | Drainage area / floodplain |
| *Afrosternophorus* `BPS506` | Uncertain | Major drainage line |
| Xenolpium `PSE120` | Potential | Major drainage line |
| **Scorpions** | | |
| *Lychas* `BSCO088` `pilbara1 group` | Potential | Drainage area / floodplain |

| Order / taxa | SRE status | Habitat types |
|---|---|---|
| **Isopods** | | |
| *Acanthodillo* `BIS523` | Potential | Waterhole |
| *Acanthodillo* `BIS524` | Potential | Stony plain |
| *Buddelundia* `BIS521` | Potential | Hillcrest / hillslope, stony plain |
| **Myriapods (centipedes)** | | |
| Geophilidae sp. B01 | Potential | Hillcrest / hillslope and gorge / gully |

Source: BHP (2025)

Marillana Creek is considered to be an important dispersal conduit for SREs due to the relatively continuous corridor of dense vegetation and the periodic influence of flooding. Establishing a diversity of habitats that support representative flora and fauna species and provide ecological function and connectivity through the system is a design objective specified in the Marillana Creek Diversion Management Plan (BHP Billiton, 2016) and incorporated into the completion criteria in Section 8.3.

### 5.7.7 Knowledge gaps & forward work program

The extent to which subterranean fauna species may recolonise backfilled mine voids has not been established in the Pilbara. The closure of pits at Yandi may present an opportunity to monitor subterranean fauna colonisation of backfilled pit areas post-closure.

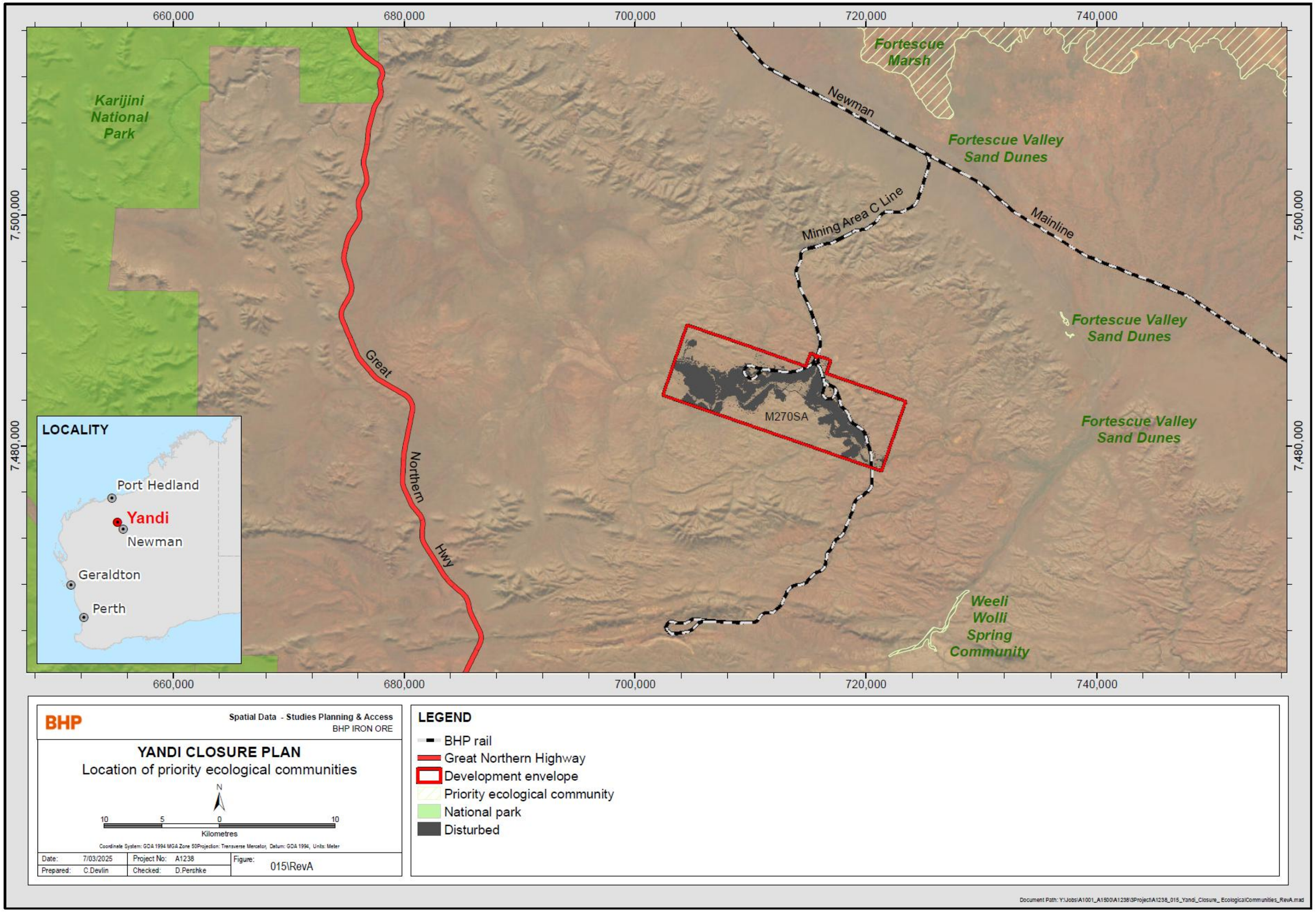
Research is being planned to investigate fauna habitat attributes of importance for conservation significant species and also some of the key species of significance to Traditional Owners.

## 5.8 Threatened or Priority Ecological Communities

No Threatened Ecological Communities (TECs) occur within or adjacent to the Yandi development envelope. However, the following Priority Ecological Communities (PECs) are located in the general Yandi region (DBCA, 2023) (Map 5-14):

- The Priority 1 Weeli Wolli Spring PEC occurs approximately 9 km south-east of the mine.
- The Priority 1 Fortescue Marsh PEC is located approximately 30 km to the north-east of the mine.
- The Priority 3 Vegetation of Sand Dunes of the Hamersley Range / Fortescue Valley (formerly known as Fortescue Valley Sand Dunes) PEC is located approximately 15 km to the north-east.
- The Priority 2 Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara Region PEC which is currently known to occur sporadically throughout the Pilbara, with several occurrences in Karijini National Park.

In addition, several vegetation associations at Yandicoogina Gorge have affinities with the Priority 2 ecological community '*Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara Region*' (Section 5.6.3.2), although are not recognised as a confirmed PEC. DBCA (2023) describes this PEC as "*including flora with restricted distributions or populations that are highly disjunct or are major range extensions from northern and eastern Australia. These include Imperata cylindrica, Cladium procerum, Schoenus falcatus and Fimbristylis sieberiana (P3). In the Pilbara these taxa are almost exclusively restricted to the riparian zones of permanent wetlands with high soil moisture maintained by groundwater flows. Occurrences are disjunct with sites typically associated with groundwater discharge in gorge and valley wetlands that are often coupled with significant shading.*"




See Appendix Q for a pdf version of this map

**Map 5-14 Location of Priority Ecological Communities**

## 5.9 Water

This section provides a summary of the hydrological (Section 5.9.1) and hydrogeological (Section 5.9.2) regimes at Yandi. As there are interactions between surface water and groundwater at Yandi, surface water and groundwater qualities have been discussed together in Section 5.9.3. Ecohydrological assets are discussed in Section 5.9.4.

### 5.9.1 Hydrology

**Summary**

The Yandi operation is located within the Marillana Creek catchment (~2,050 km$^2$ in area) which forms part of the broader Upper Fortescue River Catchment (area of 16,281 km$^2$). Marillana Creek flows to the east, with major tributaries contributing to flow including (moving from west to east) Lamb Creek, Herbert's Creek and Iowa Creek. Downstream of Yandi, Marillana Creek passes through RTIO's lease where Phil's Creek and Yandicoogina Creek enter the creek prior to its confluence with Weeli Wolli Creek. Weeli Wolli Creek flows in a northerly direction for approximately 40 km before discharging into the Fortescue Marsh.

Fortescue Marsh is the drainage terminus of the Fortescue River Catchment, and is a brackish to saline wetland, extending for about 100 km along the Fortescue Valley with a width of between 3 and 10 km. The Fortescue Marsh water balance is dominated by surface water inputs. Weeli Wolli Creek contributes approximately 18% of mean annual inflow. Records from the Waterloo Bore stream flow gauge in Lower Weeli Wolli Creek (~7.5 km north of the Marillana Creek confluence) suggest that significant infiltration losses are experienced along Weeli Wolli Creek upstream from the gauge. Therefore, only very large flow events carry through into the Fortescue Valley.

Marillana Creek has an ephemeral flow regime, primarily driven by periodic cyclonic storm events and high evaporation rates. While the creek is naturally ephemeral, there are a number of semi-permanent and permanent pools known throughout the area including several persistent pools in the lower sub-catchment that are sustained by localised storage in the surrounding alluvium. Persistent pools occur in the vicinity of Flat Rocks gauging station where groundwater ponds behind, and flows over, basement rock at the surface.

Within the Yandi area, Marillana Creek follows the same valley in which the CID palaeochannel has developed, and cuts across the CID in places. The 25 km reach of Marillana Creek running through the Yandi lease area is characterised by a low sinuosity, bedrock controlled, anabranching channel and has the following geomorphic and vegetation characteristics:

- Floodplains: which are usually vegetated with spinifex with sparse, small trees.
- The active channel: which is divided into three types:
  - Incised - Category 1: which has no vegetation in the broad primary channel, but the marginal benches contain trees.
  - Incised - Category 2: is the same as incised Category 1 but with scattered large trees growing in the channel bed.
  - Anabranching: where the active channel is made up of the following areas:
    - Low flow channel: This is the lowest part of the active channel and is made up of gravel or bedrock sections without vegetation in the channel. The channel banks are vegetated.
    - Vegetated anabranches: These are the narrow, elongate, treed, ridges that run parallel to the channel.
    - Marginal benches: These are benches that form on the edges of channels, beside bedrock banks of the channel (note that they do not form beside floodplains).

A number of creek diversions have been constructed at Yandi. The major creek diversions are the Marillana Creek diversions at E1 and E4. There are two intermediate creek diversions at W3 (Lamb Creek) and Herbert's Creek (which is a diversion constructed through a mine void via a land bridge structure), and a number of other minor diversions. Several other water management structures will need to be constructed for closure (flood channels, creek diversions and flood bunds). These are discussed further in Sections 5.14.7 to 5.14.9.

As there have been updates to the Australian Rainfall and Runoff Guide to Flood Estimation, BoM design rainfalls and modelling techniques since the last comprehensive assessment of design flows (in 2014), updated modelling of hydrological conditions has been completed to inform closure designs as they progress towards detailed design. Design events were simulated in a RORB model. For events greater than the 1 in 2,000 Annual Exceedance Probability (AEP) (i.e., the 1 in 10,000 AEP design event), interpolation was undertaken between very rare design rainfall estimates from BoM and those obtained from the Probable Maximum Precipitation (PMP) rainfall estimate. PMP was estimated using recommended methods for Australia (Ball, et al., 2019) which include the Revised Generalised Tropical Storm Method (GTSMR) for the Pilbara.

A sensitivity analysis was conducted to assess the potential impacts of climate change on hydrologic predictions. The assessment showed that the predicted increase in rainfall intensity for the 2075 design horizon (11%) resulted in increases in peak flows of:

- Between 35% and 25% at Flat Rocks for the 10% AEP and 1% AEP events, respectively and 10% for the 1 in 10,000 AEP scenario.
- Between 13% and 14% in the three major tributaries contributing to the Marillana Creek for the 1 in 1,000 AEP event.

2D (TUFLOW) hydrodynamic flood modelling was conducted to provide an understanding of the 2022 operational landform performance with respect to the updated design flows. The outputs of the flood model indicate that in the 1 in 10,000 AEP

event, the 2022 operational mining landform would allow significant ingress of flood water into a number of pits due to the large flow magnitudes associated with this design event. Closure designs have been developed to control these inflows (refer to Section 5.14).

Advisian (2017a) conducted hydraulic modelling assessments for Marillana Creek within the Yandi lease boundary to characterise the existing hydraulic behaviour. This resulted in a series of S-Curves representing the velocity, bed shear and stream power frequency. The modelled behaviour of surface water closure designs has been compared with these S Curves. Sediment transport modelling has also been conducted to provide a high-level understanding of sediment transport conditions to facilitate creek diversion design. Modelling results indicated that the existing system is generally in equilibrium (i.e. the bed level variations balance out between erosion and deposition).

#### 5.9.1.1 Regional overview

**Catchments**

The Yandi operation is located within the Marillana Creek catchment which occupies an area of about 2,050 km$^2$ and forms part of the broader Upper Fortescue River Catchment which has a catchment area of 16,281 km$^2$ and for which Fortescue Marsh is the drainage terminus (Map 5-15). Fortescue Marsh is a brackish to saline wetland, extending for about 100 km along the Fortescue Valley with a width of between 3 and 10 km.

The Marillana Creek catchment consists of upper and lower sub-catchments with different hydrological characteristics. The upper sub-catchment includes a broad alluvial plain (Munjina Flats) flanked by high-relief areas with elevations up to 1,200 mAHD. The broad, gently sloping Munjina Flats provide considerable water storage capacity, which attenuate some surface water flows prior to discharging into the lower sub-catchment. This mechanism reduces peak discharge associated with smaller rainfall events and delays the time to peak runoff in the lower catchment. It also results in the storage of sediment upstream of the Yandi operation which is located within the lower sub-catchment. The lower sub-catchment comprises an extensive basement outcrop of moderate relief into which the Marillana Creek is incised (BHP Billiton, 2016).

Table 5-35 provides the catchment characteristics for Marillana Creek Upstream of Yandi and at the downstream boundary of Yandi, along with those of the larger tributaries within the Yandi lease area.

**Table 5-35 Marillana Creek and tributary catchment characteristics**

| Catchment Name | Area (km²) | Mainstream Length (km) |
|---|---|---|
| Marillana Creek to Flat Rocks | 1,375 | 75.97 |
| Marillana Creek to BHP Rail Crossing | 1,839* | 100.64 |
| Lamb Creek | 91 | 21.01 |
| Herbert's Creek | 29 | 10.21 |
| Iowa Creek | 100 | 15.82 |

Source: Advisian (2023c)

*Notes: excludes pit areas from total

**Marillana Creek overview**

Marillana Creek flows to the east, with major tributaries contributing to flow including (moving from west to east) Lamb Creek, Herbert's Creek and Iowa Creek. Downstream of Yandi, Marillana Creek passes through RTIO's lease where Phil's Creek and Yandicoogina Creek enter the creek prior to its confluence with Weeli Wolli Creek (Map 5-16). Weeli Wolli Creek flows in a northerly direction for approximately 40 km before discharging into the Fortescue Marsh (BHP Billiton, 2016).

A number of creek diversions have been constructed at Yandi. The major creek diversions are the Marillana Creek diversions at E1 and E4. There are two intermediate creek diversions at W3 (Lamb Creek) and Herbert's Creek (which is a diversion constructed through a mine void via a land bridge structure), and a number of other minor diversions have either been constructed or are planned to be constructed for closure (see Section 9.2.4 for further details). Iowa Creek has not been diverted, however pits have been mined on either side creating a natural land bridge that has reduced the maximum flow capacity of the creek.

Marillana Creek has an ephemeral flow regime, primarily driven by periodic cyclonic storm events and high evaporation rates. The majority of stream flow occurs during the summer months of December through to March. Large stream flows are typically associated with rain-bearing depressions of high intensity rainfall. The only gauging station within the catchment is Flat Rocks (DoW ID 708001) which is located near the western edge of the Yandi mine and measures surface water flow from the upper sub-catchment (Golder, 2015b). Analysis of data from this gauging station between 1967 and 2014 indicates a historical average of four flow events per year with a range of zero to thirteen occurring in a given year.

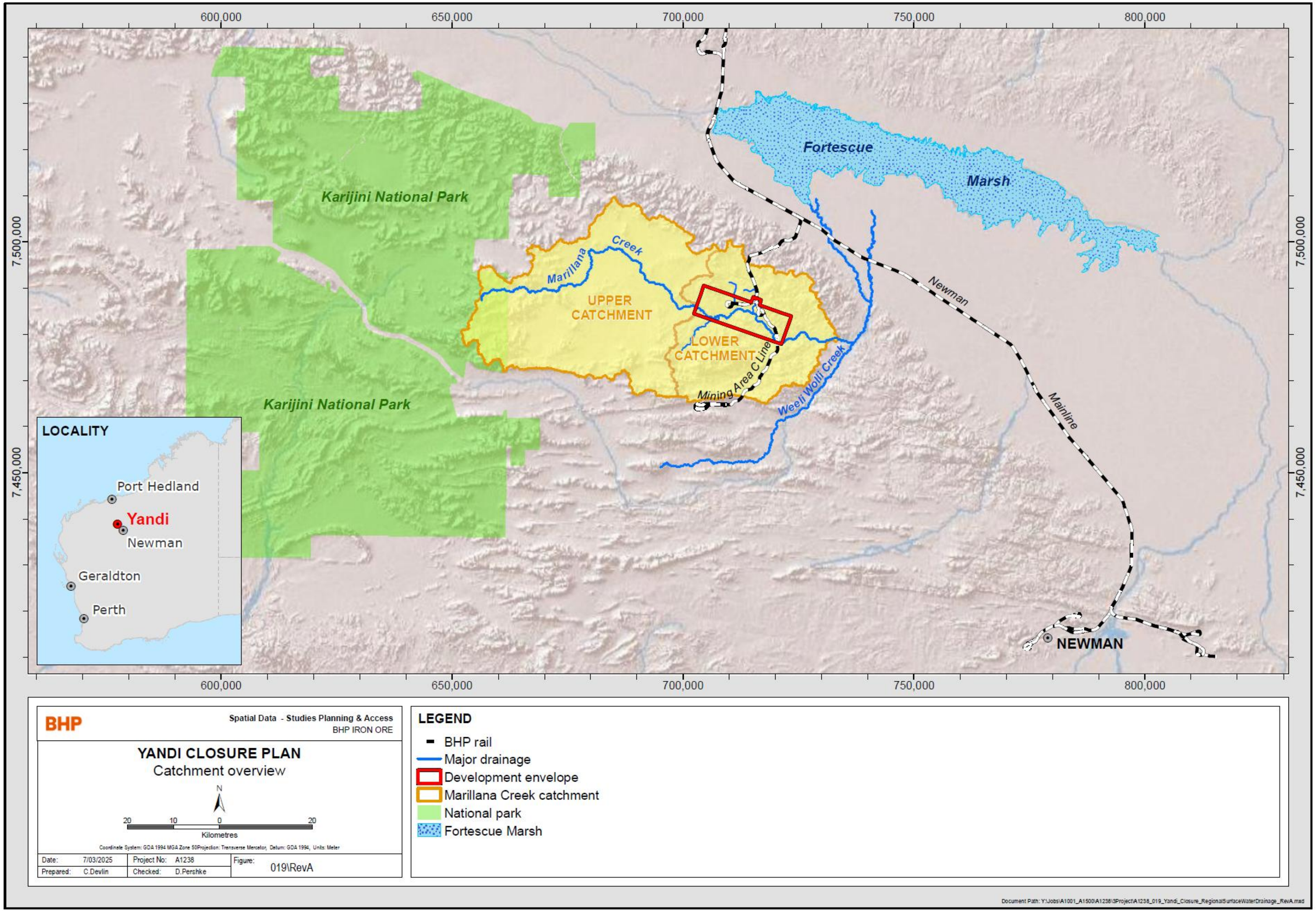
Flow events in Marillana Creek tend to be "flashy" with steep rises in the flood hydrograph followed by a relatively quick recession. The largest discharge in the gauging record, with a peak hourly discharge of 1,322 m$^3$/s, resulted from heavy rainfall associated with tropical cyclone Joan which passed the catchment on 9 December 1975 (BHP Billiton, 2016).

While the Marillana Creek is naturally ephemeral, there are several semi-permanent and permanent pools known throughout the area including several persistent pools in the lower sub-catchment that are sustained by localised storage in the surrounding alluvium. Persistent pools occur in the vicinity of Flat Rocks gauging station where groundwater ponds behind, and flows over, basement rock at the surface (refer to Section 5.9.4.2 for further details) (Golder, 2015b).

### Fortescue Marsh

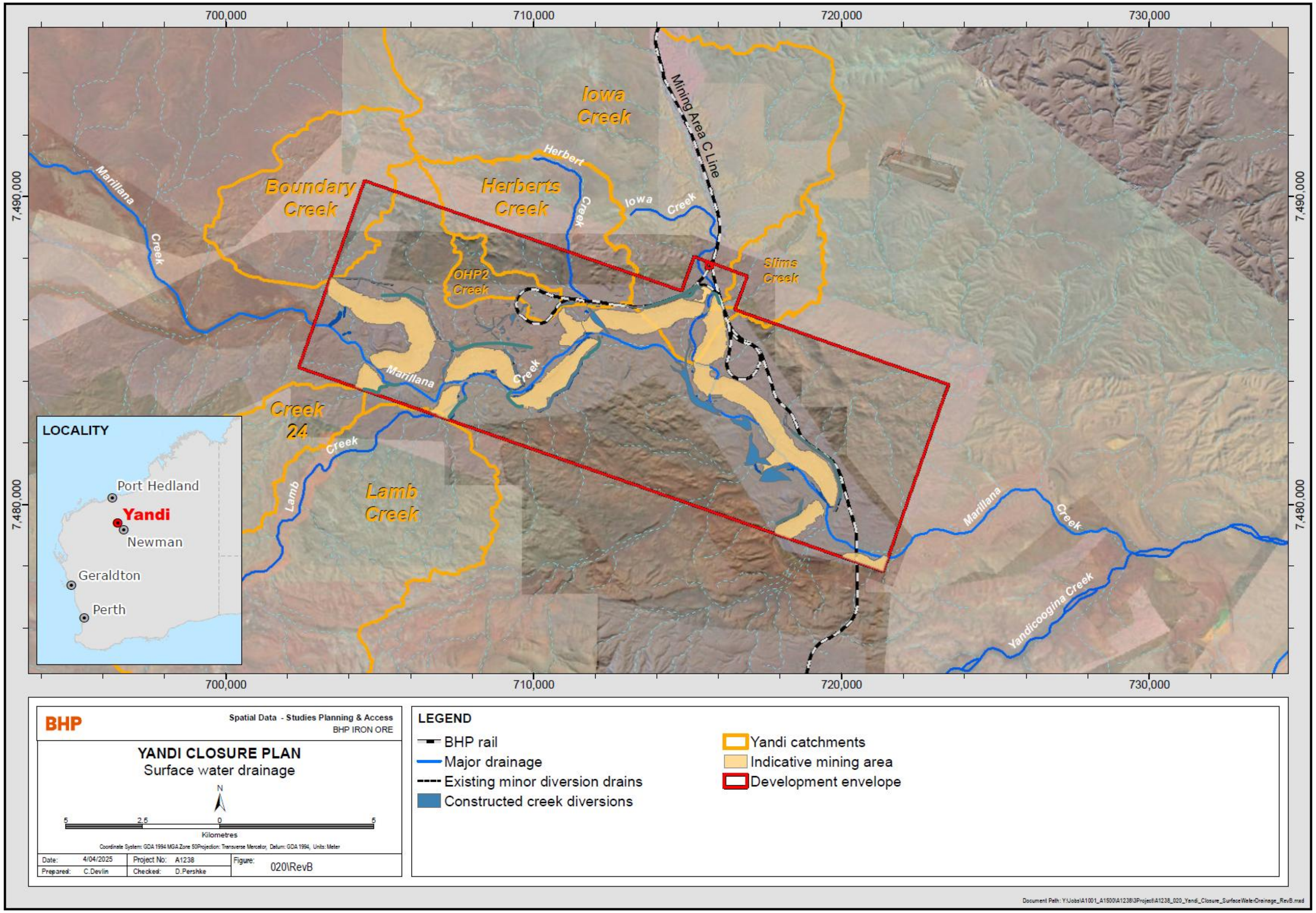
The Fortescue Marsh water balance is dominated by surface water inputs. The largest source of surface water inflow to Fortescue Marsh is the Fortescue River which contributes on average 42% of inflow. Weeli Wolli Creek contributes approximately 18% of mean annual inflow to Fortescue Marsh, and the Marillana Creek catchment accounts for approximately half of the Weeli Wolli catchment contribution. Approximately 8% of total input to Fortescue Marsh is, therefore, sourced from the catchment area defined at the downstream extent of the Yandi lease boundary (MWH, 2016a). Records from the Waterloo Bore stream flow gauge in Lower Weeli Wolli Creek (DoW ID 708013; located approximately 7.5 km north of the Marillana Creek confluence) suggest that significant infiltration losses are experienced along Weeli Wolli Creek upstream from the gauge (MWH, 2015). Therefore, only very large flow events carry through into the Fortescue Valley.

Annual inflow volumes to Fortescue Marsh vary widely, with the median inflow as low as 61 GL/yr and maximum inflow greater than 1,400 GL/yr (Skrzypek, Dogramaci, & Grierson, 2013). Flooding of Fortescue Marsh is generally associated with cyclonic rainfall and runoff in the summer months, with large-scale inundation events estimated to occur every five to seven years on average, during which more than 20% of the Marsh is inundated. Floodwaters may persist for several months providing breeding and foraging habitat for waterbirds and other biota before evaporating - leading to salt accumulation (BHP Billiton Iron Ore, 2016).




See Appendix Q for a pdf version of this map

**Map 5-15 Catchment overview**




See Appendix Q for a pdf version of this map

**Map 5-16 Surface water drainage**

#### 5.9.1.2 Surface water flows

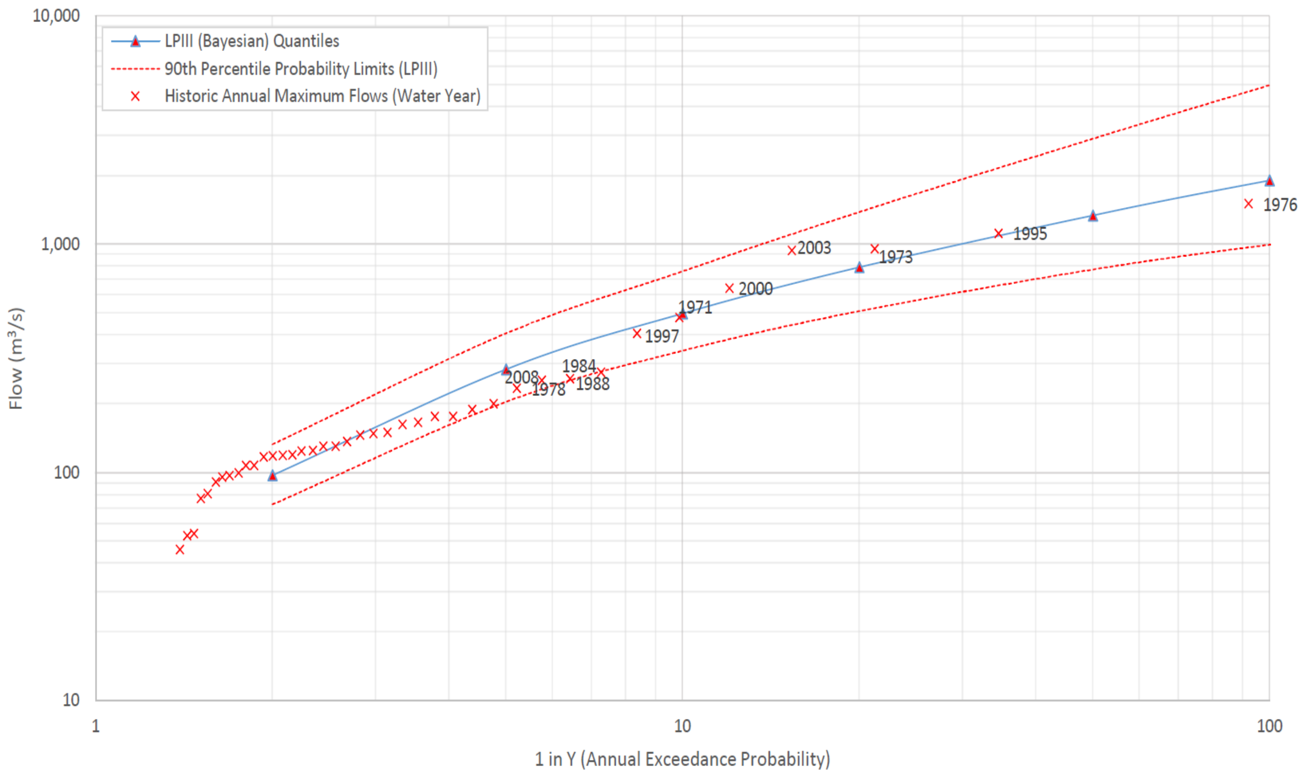
Since the last comprehensive assessment of design flows at Yandi (in 2014), there have been updates to the Australian Rainfall and Runoff Guide to Flood Estimation, BoM design rainfalls and modelling techniques. As part of the Yandi closure study, Advisian (2023c), therefore, conducted a review of the baseline hydrology of Marillana Creek and associated tributaries to update design flow events which will enable closure designs to be refined as they progress towards detailed design. The review encompassed:

- Development of a rainfall run-off model to enable design peak flow rates to be estimated for Marillana Creek and major tributaries.
- Assessment of the sensitivity of peak flow rates to climate change.
- Modelling of flood extents and peak velocities based on the 2022 operational Yandi landform.

Key elements of the review are summarised in the following sub-sections.

**Model development**

During the development of the revised surface water model for Yandi, Advisian (2023c) conducted a review of the flow data recorded from Flat Rocks gauging station to assess the data's suitability for use in the modelling update. As a result of the review, Advisian derived new rating curves for the gauging station (Appendix D.2). The flood frequency analysis for the Flat Rocks gauging station using the rating curves derived by Advisian is provided as Figure 5-22, and was used in the updated flood modelling.




Source: Advisian (2023c)

**Figure 5-22 Flood frequency analysis at Flat Rocks gauging station using Advisian derived ratings**

MWH (2016b) noted poor correlation of rainfall and run-off data at the Flat Rocks gauging station. For example, very large events, even those that occurred later in the season with nearly saturated catchment conditions, sometimes resulted in very little flow at the stream gauging sites, while relatively high discharge rates have been observed to occur at the stream gauging sites following relatively small rainfall events at Flat Rocks. The lack of correlation may be related to surface water storage in the claypan, extreme variations in temporal and spatial rainfall patterns relative to the catchment shape and drainage paths, large variations in antecedent moisture conditions, high variability in channel infiltration, or a number of other factors (MWH, 2016b). Advisian (2023c) addressed these factors as outlined below.

Design flows for Marillana Creek and its major tributaries were estimated using a rainfall-runoff model (RORB) developed for the entire Marillana Creek catchment to the downstream extent of the BHP mine lease (the BHP rail crossing being considered representative of this location for the study). Given the large study area (and that design rainfalls are typically derived for a single point of interest) (Advisian, 2023c):

- Two individual design rainfall input datasets were developed for the catchments contributing to the upstream (Flat Rocks site) and downstream (BHP rail crossing) extents of the BHP mine lease.

- Discrete RORB models were developed for the major tributary inflows to Marillana Creek to accurately define peak design flows from these systems, rather than using the predicted inflows from the model parameterised to represent Marillana Creek as this would have under-estimated peak flows from these systems:
  - Lamb Creek.
  - Herbert's Creek.
  - Iowa Creek.

All key parameters within the model were calibrated / validated to either the derived flood frequency analysis quantiles at Flat Rocks or to detailed 2D hydraulic modelling (Advisian, 2023c).

The impact of Munjina Flats in the upper catchment on peak flow estimates, was validated using 2D modelling and topographic data to define the reach-storage effects in this area. A key observation from the validation works was that peak flows observed at Flat Rocks were not typically dominated by the peak runoff from the large headwater areas being routed through Munjina Flats. This is due to timing of catchment response through the system and the effects of the storage within Munjina Flats. Expansive floodplain flows from headwaters contributing from the southwest of Munjina Flats in conjunction with storage take up, results in a delayed runoff response from this upper catchment compared to lower regions of the catchment where the landforms are more typical of Pilbara waterways (Advisian, 2023c).

Design events were simulated in the RORB model according to the procedures outlined by Ball et. al., (2019). For events greater than the 1 in 2,000 AEP (i.e., the 1 in 10,000 AEP design event[30]), interpolation was undertaken between very rare design rainfall estimates from BoM and those obtained from the Probable Maximum Precipitation (PMP) rainfall estimate. PMP was estimated using recommended methods for Australia (Ball, et al., 2019) which include the Revised Generalised Tropical Storm Method (GTSMR) for the Pilbara (Advisian, 2023c).

The adopted design flow rates are provided in Table 5-36 and Table 5-37. A comparison of these flow rates and those identified in previous studies and the 2020 MCP is provided in Appendix D.5.

**Table 5-36 Design flows - Marillana Creek mainstream**

| Location | AEP event | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10% ($m^3/s$) | 5% ($m^3/s$) | 2% ($m^3/s$) | 1% ($m^3/s$) | 1 in 200 ($m^3/s$) | 1 in 500 ($m^3/s$) | 1 in 1,000 ($m^3/s$) | 1 in 2,000 ($m^3/s$) | 1 in 10,000 ($m^3/s$) |
| Flat Rocks | 493 | 849 | 1,398 | 1,898 | 2,457 | 3,345 | 4,055 | 4,825 | 7,244 |
| Lamb Creek confluence | 508 | 929 | 1,573 | 2,129 | 2,736 | 3,698 | 4,469 | 5,296 | 7,978 |
| Herbert's Creek confluence | 513 | 956 | 1,634 | 2,209 | 2,833 | 3,820 | 4,612 | 5,459 | 8,232 |
| Iowa Creek confluence | 523 | 1,016 | 1,769 | 2,387 | 3,046 | 4,087 | 4,925 | 5,813 | 8,785 |
| Unnamed Creek confluence | 528 | 1,047 | 1,840 | 2,480 | 3,158 | 4,227 | 5,088 | 5,998 | 9,074 |
| BHP Rail | 532 | 1,071 | 1,895 | 2,553 | 3,245 | 4,335 | 5,214 | 6,140 | 9,297 |

Source: Advisian (2023c)

**Table 5-37 Design flows - major tributaries of Marillana Creek**

| Location | AEP event | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10% ($m^3/s$) | 5% ($m^3/s$) | 2% ($m^3/s$) | 1% ($m^3/s$) | 1 in 200 ($m^3/s$) | 1 in 500 ($m^3/s$) | 1 in 1,000 ($m^3/s$) |
| Lamb Creek outlet | 156 | 265 | 384 | 484 | 616 | 776 | 893 |
| Herbert's Creek outlet | 92 | 138 | 205 | 248 | 276 | 332 | 375 |
| Iowa Creek outlet | 244 | 374 | 534 | 646 | 811 | 981 | 1,109 |

Source: Advisian (2023c)

30 As discussed in Section 9.1.2, BHP uses a 1:10,000 ARI event as the basis of design for extreme post-closure rainfall conditions, as the Probable Maximum Flood (PMF) method produces flood estimates significantly larger than those contained in the palaeo record of any Australian River when adjusted for catchment area (Appendix D.4).

### Sensitivity to climate change

A sensitivity analysis was conducted to assess the potential impacts of climate change on hydrologic predictions. The analysis used the rainfall factoring procedure defined in Appendix D.3 and suggested approaches in Ball et. al., (2019). The assessment showed that the predicted increase in rainfall intensity for the 2075 design horizon (11%) resulted in increases in peak flows:

- At Flat Rocks of between 35% and 25% for the 10% AEP and 1% AEP events, respectively and 10% for the 1 in 10,000 AEP scenario (refer to Appendix D.6 for further details).
- For the three major tributaries contributing to the Marillana Creek of between 13% and 14% for the 1 in 1,000 AEP[31] event (Appendix D.6).

### Flood modelling results

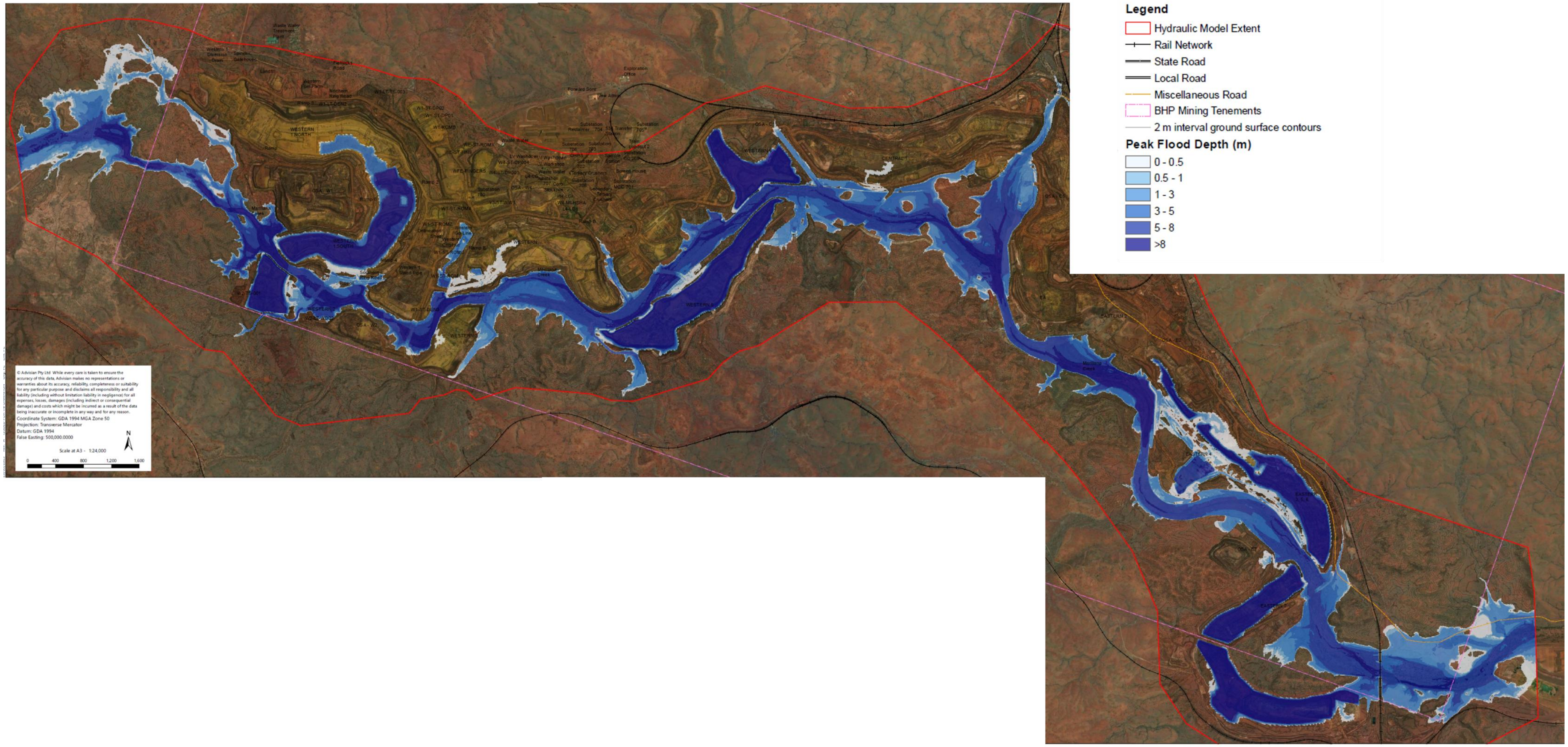
2D hydrodynamic flood modelling was conducted to provide an understanding of the 2022 operational landform performance with respect to the updated design flows reported above. Modelling of the Marillana Creek system and tributaries was undertaken using TUFLOW HPC (version 2023-03-AA). The outputs of the flood model are provided in Map 5-17 to Map 5-18. The 2022 operational mining landform allows significant ingress of flows from Marillana Creek into a number of pits during a 1 in 10,000 AEP event due to the large flow magnitudes associated with this design event. Table 5-38 provides indicative ingress volumes for each pit based on the 2022 mine landform.

**Table 5-38 Approximate flood ingress volumes (1 in 10,000 AEP - 2022 operational landform)**

| Pit ID | 1 in 10,000 AEP flood ingress volume (GL) |
|---|---|
| Western 1 South (north of creek) | 17.0 |
| Western 1 South (south of creek) | 5.2 |
| Western 3 | <0.1 |
| Western 4 | <0.1 |
| Western 5 | 27.4 |
| Western 6 | 12.5 |
| Central 1 | <0.1 |
| Eastern 4 | 10.0 |
| Eastern 3,5,6 | 1.9 |
| Eastern 7 | 7.9 |

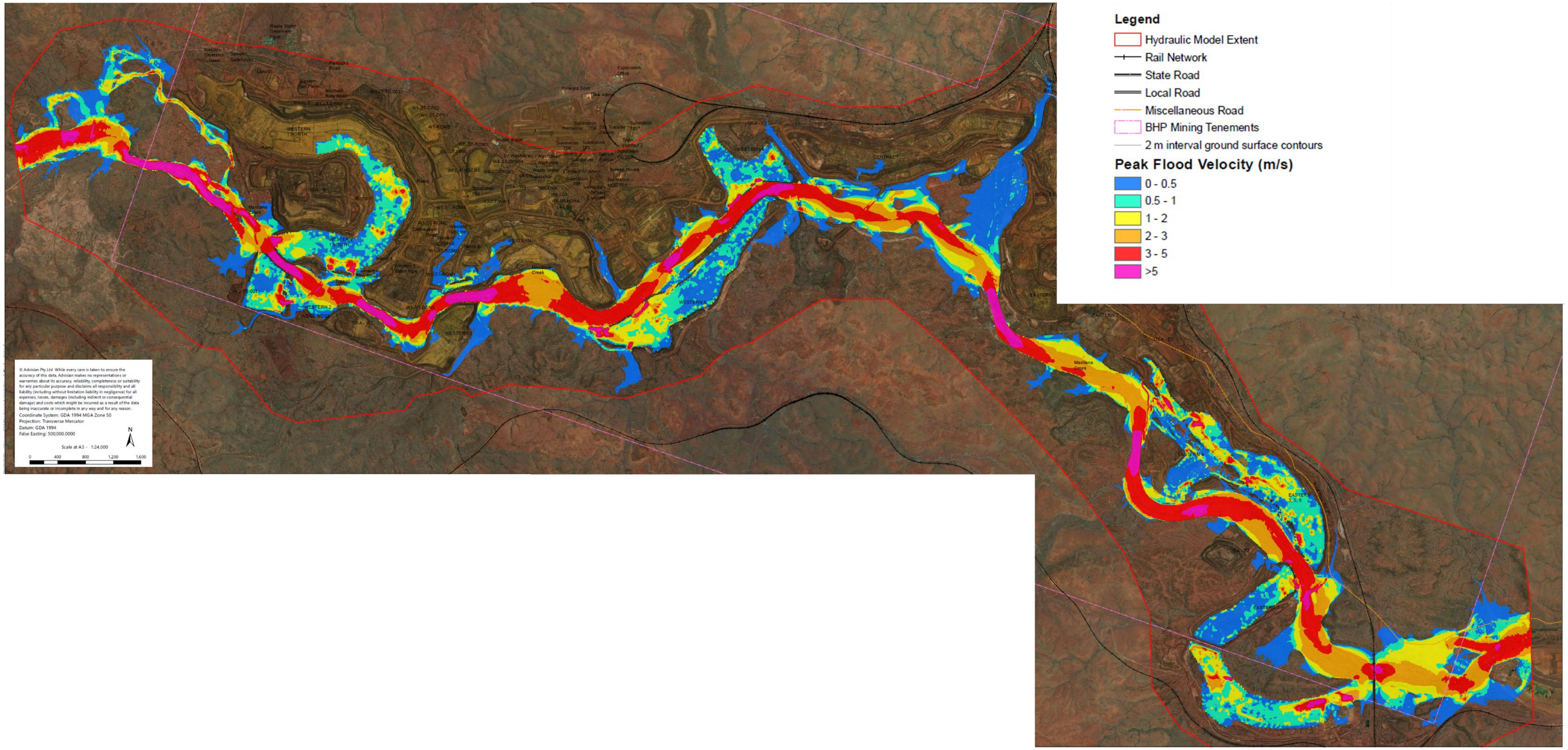
Source: Advisian (2023c)

31 As discussed in Section 9.1.2, BHP uses a risk-based approach to defining design rainfall events for surface water management structures.




Source: Advisian (2023c)

**Map 5-17 Modelled 1 in 10,000 AEP peak flood depths (for 2022 operational landform)**




Source: Advisian (2023c)

**Map 5-18 Modelled 1 in 10,000 AEP peak flood velocities (for 2022 operational landform)**

### 5.9.1.3 Marillana Creek characteristics

Marillana Creek characteristics were defined to inform the design of creek diversions.

#### Geomorphology

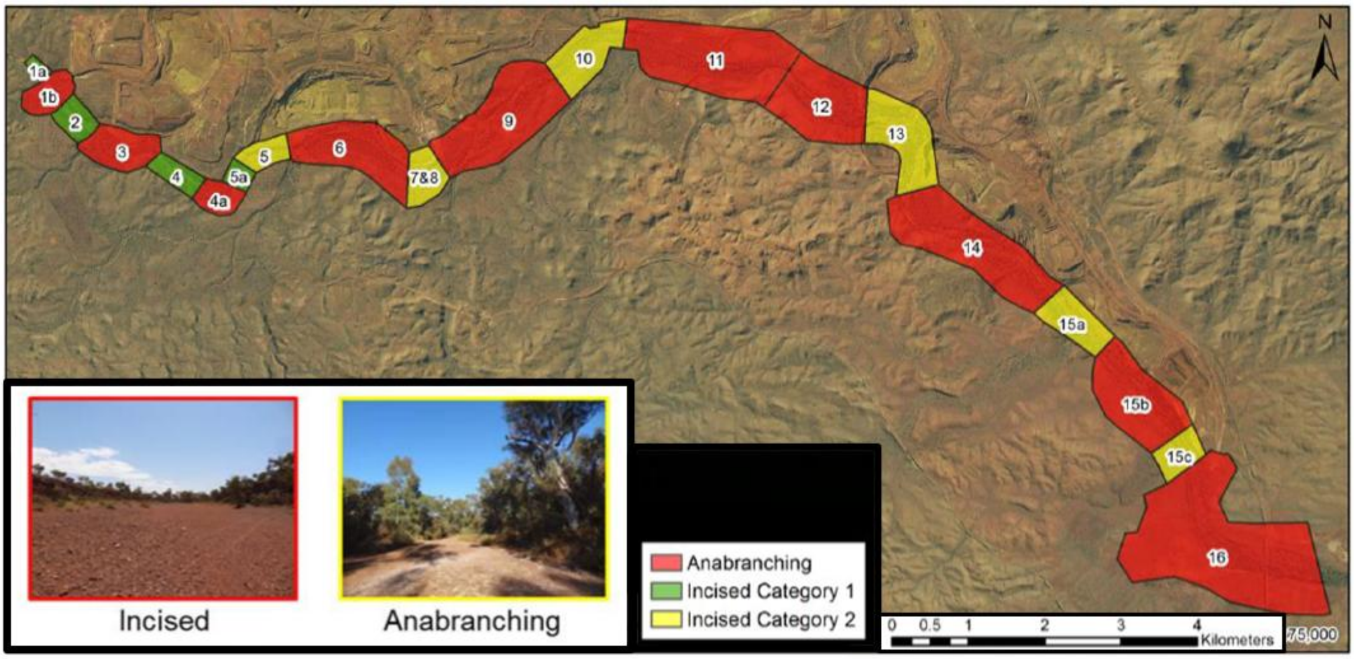
Within the Yandi area, Marillana Creek follows the same valley in which the CID palaeochannel has developed, and cuts across the CID in places. The 25 km reach of Marillana Creek running through the Yandi lease area is characterised by a low sinuosity, bedrock controlled, anabranching channel. All geomorphic measures along the creek are highly variable, but the average dimensions and ranges are as follows (BHP Billiton, 2016):

- Channel width varies from 30 to 340 m, with an average of 153 m.
- Channel depth ranges from 1.2 to 3.4 m, with an average of 2.1 m.
- Slope varies between 0.002 and 0.003 m/m.
- Sinuosity ranges between almost straight (1.05 - 1.07) to winding (1.16).

While the geomorphic characteristics in Marillana Creek are highly variable, the creek at Yandi has the following geomorphic and vegetation characteristics (Advisian, 2017b):

- **Floodplains:** These are gently sloping areas defined as surfaces that are inundated between about the 2-year and 5-year AEP floods and are fully inundated by the 10-year AEP flood. They are usually vegetated with spinifex with sparse, small trees.
- **The active channel:** This is the portion of the channel that experiences regular transport of bed material (sands and gravels). It is the area of the bed that is covered by the 2-year AEP flood. The active channel is divided into three types (Map 5-19):
  - **Incised - Category 1:** has no vegetation in the broad primary channel but the marginal benches contain trees. The width of Category 1 reaches is defined by the cliffs bounding each side of the active channel.
  - **Incised - Category 2:** is the same as incised Category 1 but with scattered large trees growing in the channel bed.
  - **Anabranching:** reaches of the creek where the active channel is made up of the following areas:
    - Low flow channel: This is the lowest part of the active channel and is made up of gravel or bedrock sections without vegetation in the channel. The channel banks are vegetated.
    - Vegetated anabranches: These are the narrow, elongate, treed, ridges that run parallel to the channel. These tend to be just inundated at the one-year flood and submerged at the 2-year flood.
    - Marginal benches: These are benches that form on the edges of channels, beside bedrock banks of the channel (note that they do not form beside floodplains). They are just inundated at the one-year flood and submerged at the 2-year flood.

The characteristics of these reaches are summarised in further detail below. A third reach type, characterised by exposed bedrock, is located directly upstream of Yandi at Flat Rocks.




Source: BHP Billiton (2016); Advisian (2017a)

**Map 5-19 Reach types present in Marillana Creek**

**Characteristics of anabranching reaches**

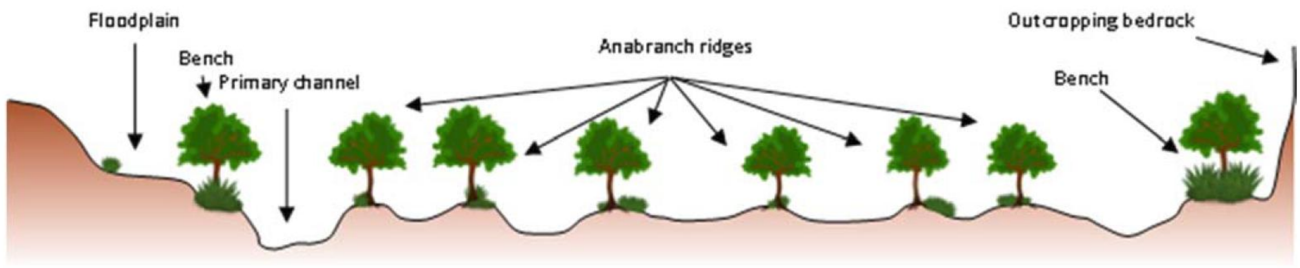
Rivers with multiple channels characterised by vegetated or otherwise relatively stable, elongated alluvial bars that divide flows at discharges up to bank-full are classified as *anabranching* (BHP Billiton, 2016).

A conceptual cross section of an anabranching reach is presented in Figure 5-23**.** The primary channel in anabranching reaches is relatively narrow, typically ranging between 20 m and 30 m wide. The median bed sediment size is fine gravel, but there is a wide range of bed-material sizes up to large boulders with clasts dominated by the local geology; CID, BIF and dolerite. The bounds of the primary channel are defined by the presence of anabranch ridges and / or a marginal bench (BHP Billiton, 2016; Advisian, 2017b).

The general elevation of the crest of the anabranch ridges at Yandi is almost always coincident with the elevation of benches at the channel margin. Marginal benches are formed along most of the length of Marillana Creek, although not always on both sides of the channel. Bench widths are typically 20 to 30 m wide, consist of fine-grained silt to sand, and are characteristically well vegetated. The streamward edges of the benches are usually close to vertical where they are undercut by lower flows. There are occasionally small secondary flood channels at the rear of the bench adjacent to outcropping bedrock or at the floodplain margin (BHP Billiton, 2016; Advisian, 2017b).

There is a well-defined, discontinuous floodplain along the anabranching sections of Marillana Creek that is typically 2 to 6 m higher in elevation than the active channel bed level. The surface of the floodplain has small channels and ridges of less than 0.5 m amplitude and is typically covered by hummock grass. The floodplain is longitudinally discontinuous and tends to occur on the inside of channel bends (BHP Billiton, 2016).

A feature of Marillana Creek also evident throughout the anabranching reaches is the development of intermittent pools. Scour in the primary channel leads to the formation and maintenance of permeable pools following discharge events (BHP Billiton, 2016).




Source: BHP Billiton (2016)

**Figure 5-23 Conceptual cross-section of an anabranching channel reach in Marillana Creek**

**Characteristics of incised reaches**

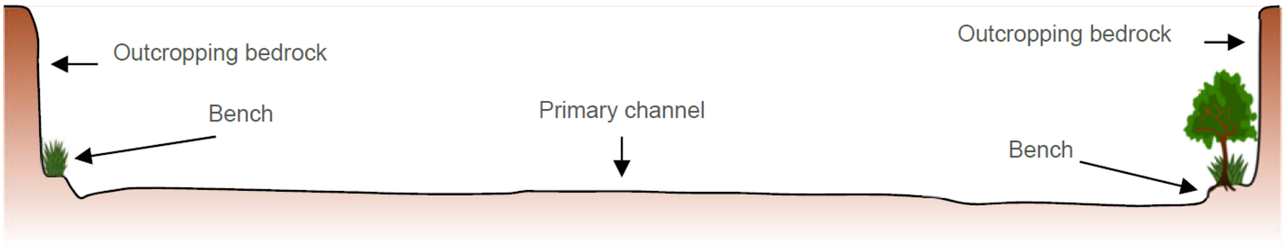
Incised channel reaches are characterised by vertical cliffs of outcropping bedrock up to 20 m high through which Marillana Creek passes. A conceptual cross section of an incised reach is presented in Figure 5-24. The channel is characteristically broad (more than 100 m wide) and single-threaded. The channel bed is composed of sand and gravels ranging in size from pebbles to cobbles. The channel bed profile is characterised as “featureless”, with only slight changes in bed elevation noted between the thalweg[32] and the remainder of the channel (BHP Billiton, 2016).

The bounds of the channel are defined by the presence of marginal benches composed of fine-grained silt to sand. Bench widths range in size from several metres up to 20 m wide. In contrast to the channel, which has very little vegetation, marginal benches are typically well vegetated. Benches are confined by the outcropping bedrock characteristic of this reach type. A small secondary flow channel is occasionally seen at the back of the bench running along the toe of the outcropping bedrock. Valley floor width, defined by the separation distance of outcropping bedrock, appears to be a key control on the formation of either incised or anabranching channel forms. For example, where valley widths increase to approximately 200 m or greater, anabranching occurs despite the presence of CID cliffs on either side of Marillana Creek (BHP Billiton, 2016).

Outcropping bedrock at the margins of incised reaches confines flow during large discharge events, thereby increasing stage heights and shear stresses relative to those seen in anabranching reaches. As a result, vegetation is scoured from the channel reach (to varying degrees depending on whether the reach is incised Category 1 or 2) and bedload sediments are readily mobilised. The more competent flow in the incised channel reaches transports sediment to anabranching reaches where it is deposited on ridges, benches and, in the case of larger events, the floodplain. It is important to note, however, that incised reaches of Marillana Creek have a lower slope than anabranching reaches. This indicates that sediment behaviour through

[32] Line of lowest elevation

incised reaches is not simply limited to erosion and conveyance (which would result in relatively steeper slopes), but a phase of aggradation (deposition) also occurs. It is likely that this occurs at a point on the waning limb of the flood hydrograph where the unit stream power in anabranching reaches exceeds that in incised reaches. This occurs when low flow volumes are confined to a relatively small primary channel in anabranching reaches whereas they are dissipated across a broad channel in planar reaches (BHP Billiton, 2016).




Source: BHP Billiton (2016)

**Figure 5-24 Conceptual cross-section of an incised channel reach in Marillana Creek**

### Hydraulics

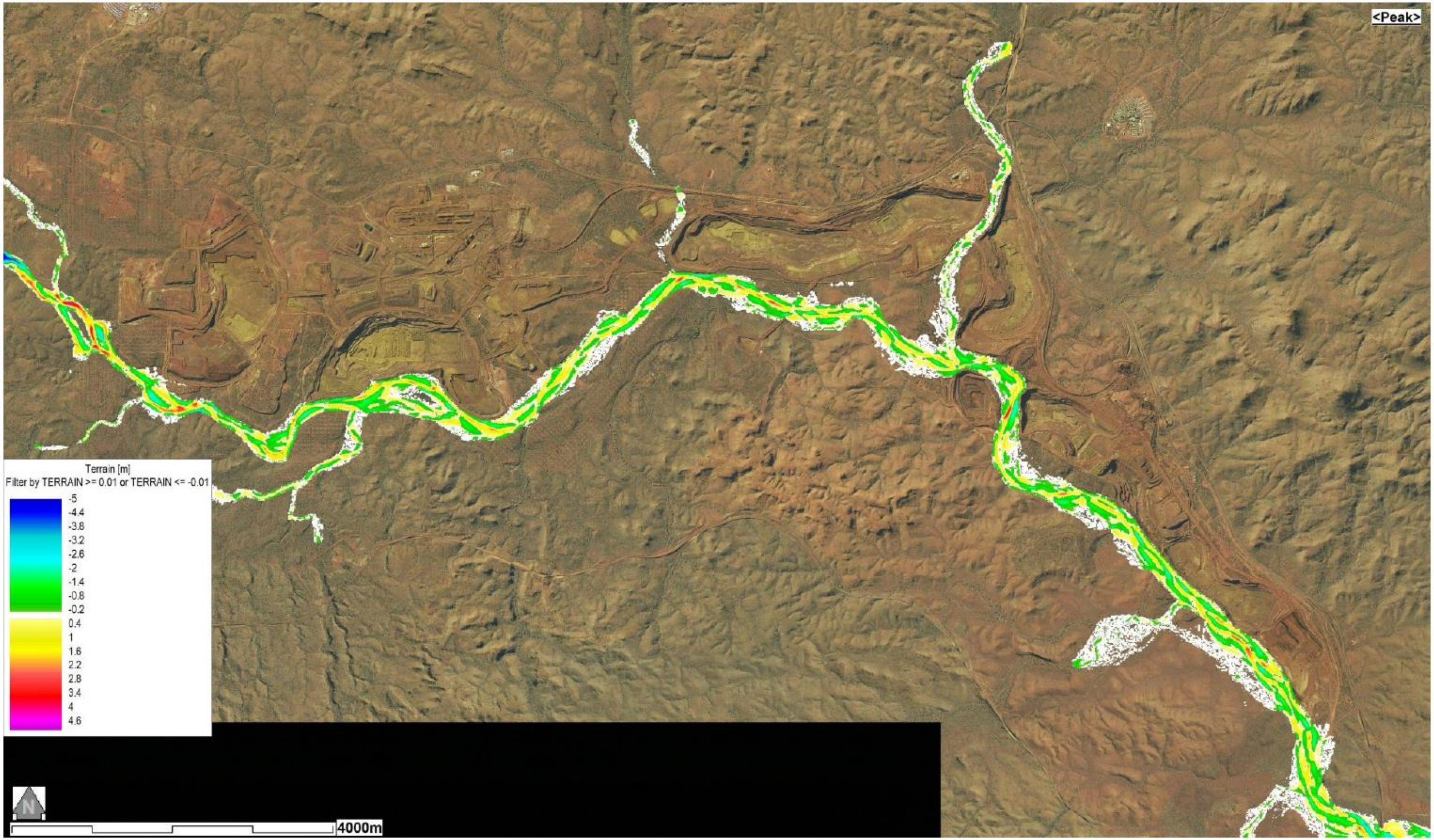
Advisian (2017a) conducted hydraulic modelling assessments for Marillana Creek within the Yandi lease boundary to characterise the existing hydraulic behaviour. This resulted in a series of S-Curves representing the velocity, bed shear and stream power frequency (Appendix N.1.9). The modelled behaviour of surface water closure designs has been compared with these S Curves (refer to Appendix N.1.9).

### Sediment transport

Sediment transport modelling was conducted by Advisian (2017c) to provide a high-level understanding of sediment transport conditions to facilitate creek diversion design. The focus of the event-based sediment transport modelling was the 100-year Average Recurrence Interval (ARI) event as this event has a greater ability to mobilise sediment than more frequent, lower magnitude events. Sediment transport modelling results for the 100-year ARI event indicated that the existing system is generally in equilibrium (i.e. the bed level variations balance out between erosion and deposition) (Figure 5-25). The modelled behaviour of surface water closure designs has been compared to this sediment transport modelling (Appendix N.1.10).

#### 5.9.1.4 Knowledge gaps & forward work program

No knowledge gaps identified.




Source: Advisian (2017c)

**Figure 5-25 Modelled bed-level change following a 1:100-year ARI event**

### 5.9.2 Hydrogeology

**Summary**

The Yandi mine is located roughly in the central eastern part of a CID deposit that stretches over 50 km. The RTIO Yandicoogina mine is directly to the east and BHP's Ministers North mining area (yet to be developed) to the south. RTIO's Mungadoo Pit lies between the E7 and proposed E8 pits and the RTIO Junction South West Pit lies to the east of E8.

Since the 2020 MCP, a new regional numerical groundwater model has been developed which considers the cumulative influences of the Yandi mine (including the proposed E8 Pit) and the adjacent RTIO Mungadoo and Junction South West pits. An update to the conceptual model has informed the modelling and is summarised below:

- There are three recognised aquifers at Yandi:
  - A shallow aquifer in the Marillana Creek bed and floodplain alluvium.
  - The palaeochannel which hosts the CID comprises three members:
    - Eastern Member which is unsaturated in the area.
    - Barimunya Member which is the major ore-bearing member and consists of the LCID, overlain in part by unnamed ochreous clay and the UCID. In general terms the UCID thickens to the east and the LCID thins in that direction.
    - Munjina Member which comprises an indurated basal conglomerate, which may have low permeability, and is situated at the base of the palaeochannel.
  - The Weeli Wolli Formation which surrounds the CID and presents extremely variable hydraulic characteristics.
- The Ministers North aquifer lies directly to the south of the E7, E8 and Mungadoo deposits and is composed of mineralised rocks from the Brockman Iron Formation with moderate to high permeability. This aquifer is assumed to support the Yandicoogina Gorge Groundwater Dependent Ecosystem (GDE) (refer to Section 5.9.4.5).
- Groundwater movement is generally towards the lowest parts of the catchment, i.e., to the CID deposit, Marillana Creek, and its major tributaries. The pre-mining groundwater levels indicate that groundwater flows were from west to east with an average hydraulic gradient of 0.2%. Data suggest that there are no major flow barriers perpendicular to the flow direction / CID strike throughout this entire area.
- The CID aquifer facilitates groundwater throughflow from the Marillana Creek catchment to the Fortescue River catchment via the Weeli Wolli Creek valley. Groundwater inflows to Fortescue Marsh are negligible due to an extremely low hydraulic gradient of 0.001 in the sediments of the Fortescue Valley surrounding the marsh.
- The alluvial aquifer is recharged by direct infiltration of rainfall and variably through surface water flow in channels and creek beds. When recharge events occur soon after one another, then the combined recharge volume is sufficient to fully saturate the alluvium, even where it has been dewatered due to mining.
- Throughflow is small in the alluvial aquifer and vertical fluxes dominate, including recharge from infiltration during creek flow, losses from the alluvial aquifer as seepage into the underlying CID, and evapotranspiration.
- The hydraulic connection between the alluvium and CID is variable depending on the thickness of the alluvium, proximity to the CID and presence of finer material in deeper horizons. Marillana Creek generally follows the direction of the palaeochannel but crosses it in several places. The alluvial aquifer and the CID aquifer are in hydraulic connection where Marillana Creek and other major creeks cross the CID. Conversely, the lower hydraulic conductivity of the bedrock (Weeli Wolli Formation) may restrict the hydraulic connection between the alluvium and CID where the creek bed alluvium is not adjacent to the CID.
- Prior to mining, the alluvium and CID were probably in equilibrium. At this time groundwater levels along Marillana Creek were sustained for long periods between rainfall events as water was able to discharge from the CID and into the creek bed.
- In some locations, the saturated Marillana Creek alluvium is truncated by shallow bedrock, for example at Flat Rocks, resulting in near-permanent baseflow at low rates.

Dewatering to support below water table mining at Yandi has significantly impacted the water level in the CID and has:

- Reduced groundwater levels in the alluvium. As a result, the patterns of recession following rainfall / streamflow recharge are most likely more rapid than would have occurred prior to dewatering, and more often result in complete drying of the alluvium.
- Extended into the CID upgradient of W0 (western end of W1 Pit) resulting in vegetation loss at Flat Rocks. This is being managed during operations via the Marillana Creek Water Resource Management Plan required under Condition 8 of MS 679, although any implications for closure will be integrated into future iterations of the MCP, if required (Section 9.2.3.2). There has been a recovery of water levels adjacent to W0 since November 2022 in response to a recent reduction in abstraction in W0.
- Resulted in a variable response in the Weeli Wolli Formation. In some places, most notably the four bores east of E2/3/4/5/6, the Weeli Wolli has responded very strongly to dewatering, with water levels falling several metres.

Ministers North has not been developed for mining, however since 2018, water levels in the aquifer have declined. The driving force for the falling water levels could be:

- Climate variability (below average rainfall); or
- A combination of both climate variability and regional dewatering activities.

Without good baseline data for the Ministers North aquifer and Yandicoogina Gorge, or in the areas between these and the dewatering operations, it is not possible to definitively answer this question. Investigations are planned to fill key data gaps.

Numerical modelling has been conducted of the cumulative drawdown from all BHP Yandi pits and nearby mining operations prior to commencement of backfill. Given the uncertainty associated with the contribution of dewatering to observed drawdown in the Ministers North aquifer, the model has been based on the precautionary assumption that there is a diffuse hydraulic connection between the Yandi CID and the Ministers North aquifers. The model predicts drawdown:

- Of up to 60 m in the CID with at least 1 m drawdown extending ~10 km within the CID to the west of the development envelope, although it should be noted that this does not take into account mitigation measures implemented in accordance with the Marillana Creek Water Resource Management Plan.
- In the basement (i.e. the Weeli Wolli Formation) that surrounds the CID is variable. In places, the 1 m drawdown contour extends less than 1 km from the CID and in others much further (more than 4 km) from the CID.
- Of approximately 5 to 10 m may extend into the Ministers North aquifer with approximately 5 to 6 m decline at Yandicoogina Gorge by the end of mining (investigations are ongoing to test this conservative assumption). The modelled contribution of E8 shows that drawdown from this pit is not predicted to reach Yandicoogina Gorge.

Due to the extreme heterogeneity of the alluvium and limited monitoring data, the numerical groundwater model could not reproduce historical groundwater levels in the alluvium.

As dewatering ceases and the backfill strategy at Yandi is implemented, groundwater levels will rebound as described in Section 5.14.1 which would be expected to reduce the extent and magnitude of drawdown. Further modelling to gain an understanding of the residual drawdown following backfill will be required as an input to the refinement of the Yandi backfill strategy as stakeholder consultation and other technical closure studies progress.

#### 5.9.2.1 Regional setting

The Yandi mine is located roughly in the central eastern part of a CID deposit that stretches over 50 km. The RTIO Yandicoogina mine is located directly to the east and BHP's Ministers North mining area (not yet developed) to the south (Map 5-20). RTIO's Mungadoo Pit lies between the E7 and proposed E8 pits (to the south of E7 and west of E8) and the RTIO Junction South West Pit lies to the east of E8 (Map 5-20).

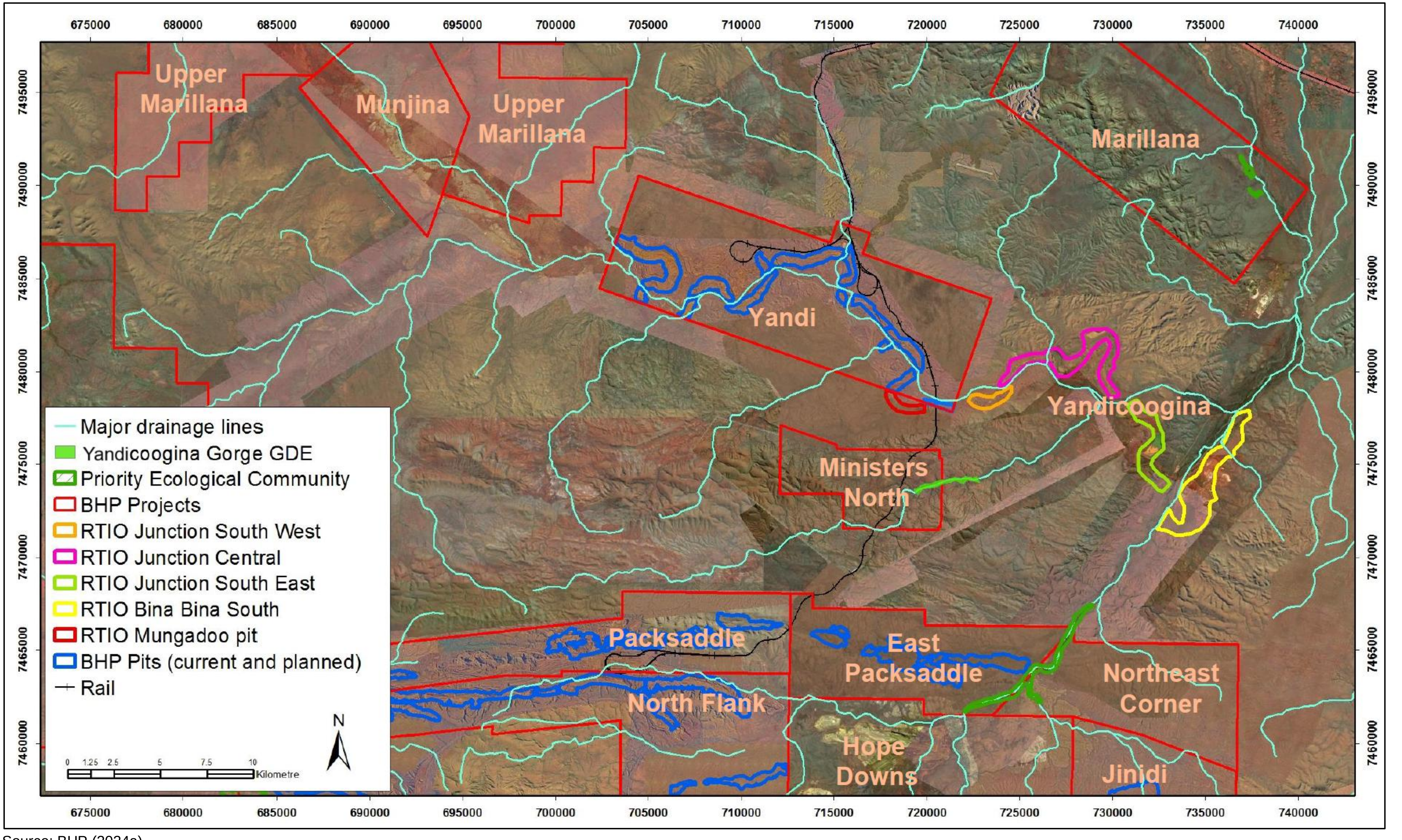
The palaeochannel, which hosts the CID deposits, was incised into an older landscape comprising mostly unmineralised BIF of the Weeli Wolli Formation, with dolerite intrusions. Marillana Creek follows the same broad valley in which the palaeochannel developed. In some locations, the creek flows alongside the palaeochannel and in other locations, it crosses the CID deposit. In locations where the creek is remote from the CID, the creek is incised into BIF bedrock and may, in places, be underlain by recent alluvial material (Map 5-21).

#### 5.9.2.2 Aquifers

There are three recognised aquifers at Yandi (BHP, 2024a; INTERA, 2024):

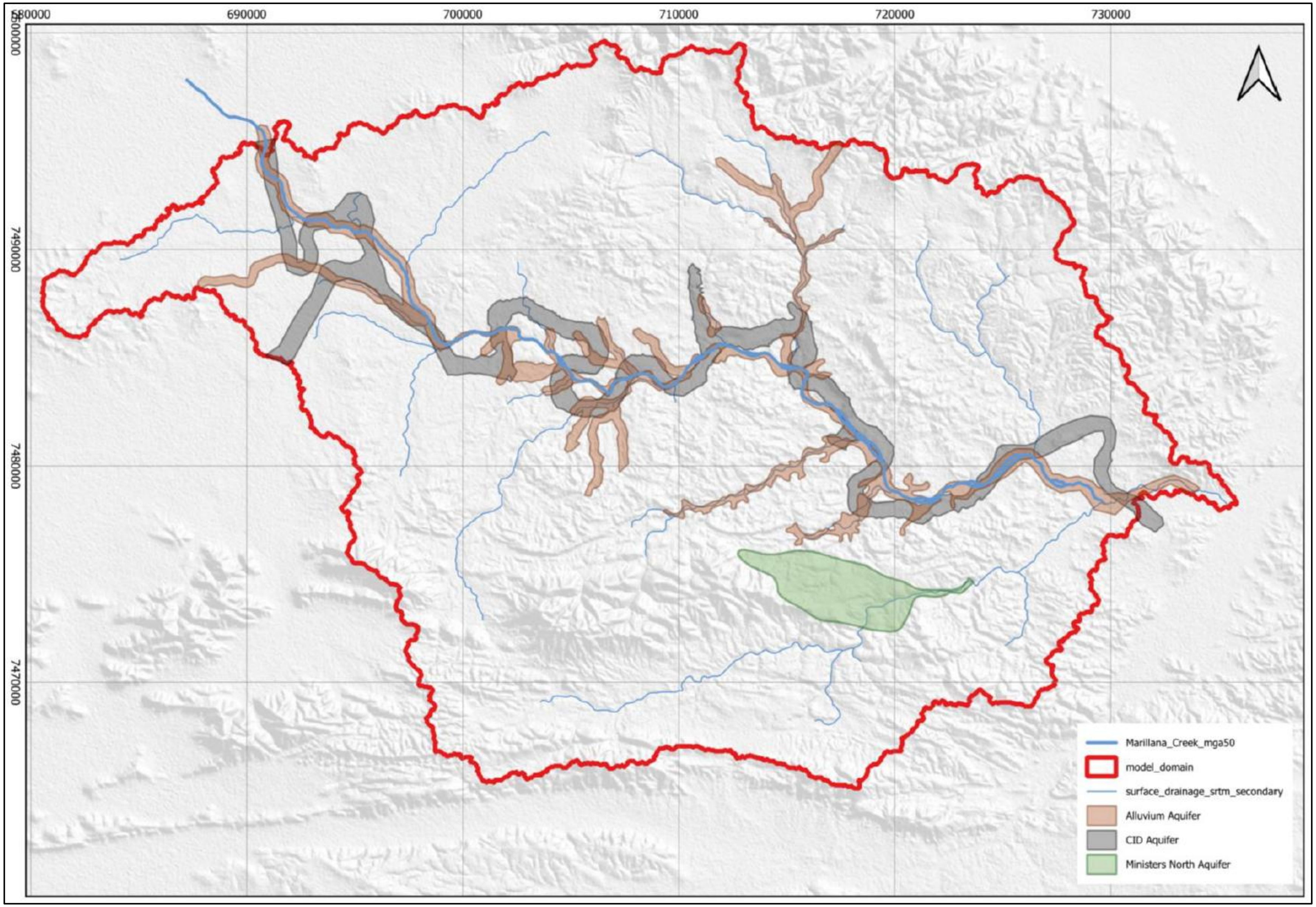
- A shallow aquifer in the Marillana Creek bed and floodplain alluvium. The alluvium is discontinuous along the western part of the deposit; there is no alluvium at Flat Rocks, but it increases in thickness to approximately 20 m at Yandi's most easterly deposits and likely greater than 20 m at the confluence of Marillana Creek with Weeli Wolli Creek. As discussed in Section 5.2.4.2, the alluvium comprises a mixture of coarse and finer grained materials. It has low to high permeability.
- The palaeochannel which hosts the CID comprises three members:
  - Eastern Member which is unsaturated in the area.
  - Barimunya Member which is the major ore-bearing member and consists of the LCID, overlain in part by unnamed ochreous clay and the UCID. The LCID is different to the UCID, and it contains a larger proportion of fines, and hence is likely to have a lower hydraulic conductivity. In general terms the UCID thickens to the east and the LCID thins in that direction:
    - The thickness of the UCID increases from west to east (downstream) and is about 10 to 30 m thick in western deposits and about 50 to 70 m thick in the central and eastern deposits.
    - The thickness of the LCID decreases from west to east and is 40 to 50 m thick in the western deposits and about 10 to 20 m thick in the central and eastern deposits.
  - Munjina Member which comprises an indurated basal conglomerate, which may have low permeability, and is situated at the base of the palaeochannel. The unit seems to occur throughout the palaeochannel length and along the palaeochannel sides. Basal clays also occur sporadically along the base of the palaeochannel.
- The Weeli Wolli Formation surrounds the CID and presents extremely variable hydraulic characteristics. Immediately beneath and adjacent to the CID it is likely that the Weeli Wolli Formation presents an elevated hydraulic conductivity due to weathering. However, beyond this zone, the hydraulic conductivity may range from very low to moderate, whereas the storage is low.

The Ministers North aquifer lies directly to the south of the E7, E8 and RTIO Mungadoo deposits (Map 5-21) and is hosted in the mineralised Dales Gorge Member of the Brockman Iron Formation. The aquifer presents very high transmissivity and moderate to low storage and is assumed to support the Yandicoogina Gorge Groundwater Dependent Ecosystem (GDE) (BHP, 2024a) (refer to Section 5.9.4.5).




Source: BHP (2024a)

**Map 5-20 Regional setting**




Source: INTERA (2024)

**Map 5-21 Hydrogeological setting**

#### 5.9.2.3 Groundwater levels

**Alluvium**

The shallow alluvial aquifer in Marillana Creek is characterised by a depth to groundwater of 0 to 3 m below ground level (bgl). The alluvium at most locations records rapid increases in water levels following rainfall / creek flow events. These approach and sometimes exceed the ground elevation. Depending on the location, the increases range from approximately 3 to 12 m. Once wet season rains subside, groundwater levels in the alluvium also subside (BHP, 2024a).

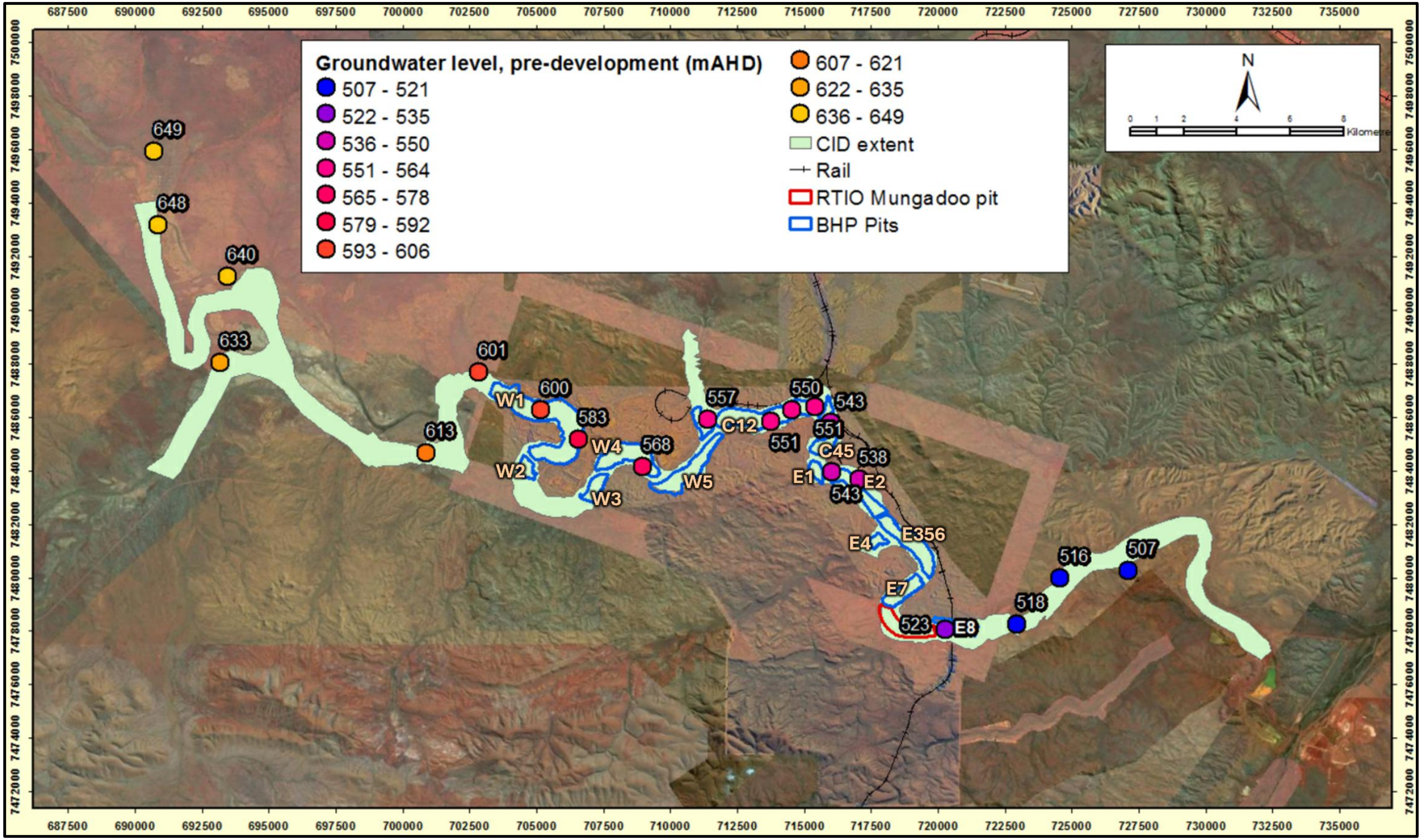
**CID**

The CID is relatively weathering resistant and the palaeochannel is elevated above the surrounding landscape as a sinuous mesa. The pre-mining depth to groundwater from the top of the CID mesa was 20 to 30 mbgl and ranged from approximately 613 mAHD in the west (to the west of Flat Rocks) to approximately 507 mAHD in the east (6 km east of E8) (Map 5-22). The gradient was very consistent from west to east, falling 106 m over 48 km (2.2 m/km) (BHP, 2024a). Table 5-39 summarises pre-mining water levels in each deposit (also refer to Map 5-22).

**Table 5-39 Estimates of the pre-mining water table depth in the Yandi lease area**

| Mine Area | Approx. Pre-mining Water Table (mRL)[33] |
|---|---|
| W1 | 580 to 600 |
| W2 | 580 |
| W3 | 570 |
| W4 | 565 to 570 |
| W5 | 557 |
| W6 | 557 |
| C1 | 550 to 555 |
| C5 | 545 to 550 |
| E2 | 536 |
| E3/5/6 | 536 |
| E7 | 532 |
| E8 (proposed) | 523 |

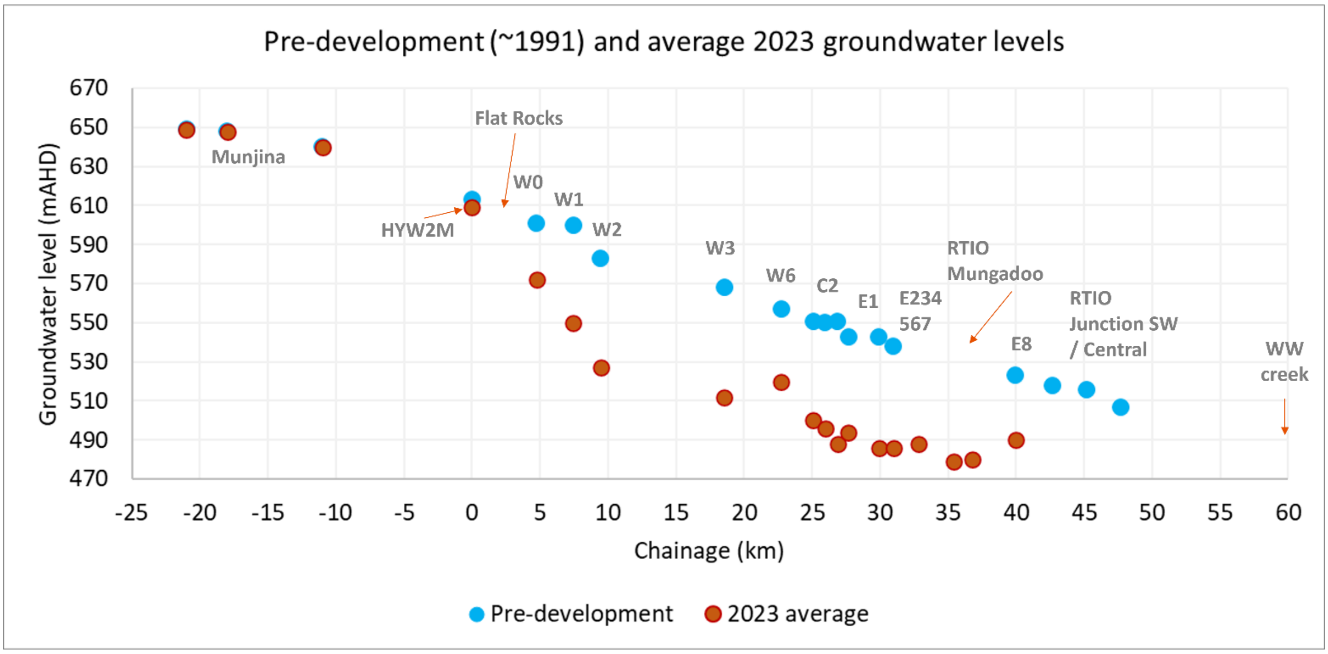
[33] Used synonymously with mAHD




Source: BHP (2024a)

**Map 5-22 Yandi pre-mining groundwater levels**

Dewatering to support below water table mining at Yandi has significantly impacted the water level in the CID (Figure 5-26) and has extended into the CID upgradient of W0 (western end of W1 Pit) resulting in vegetation loss at Flat Rocks (Section 5.9.4.2). This is being managed during operations in accordance with the Marillana Creek Water Resource Management Plan required under Condition 8 of MS 679. Should investigations conducted in accordance with the plan identify any long-term measures that need to be implemented for closure, these will be incorporated into future iterations of the MCP (Section 9.2.3.2).

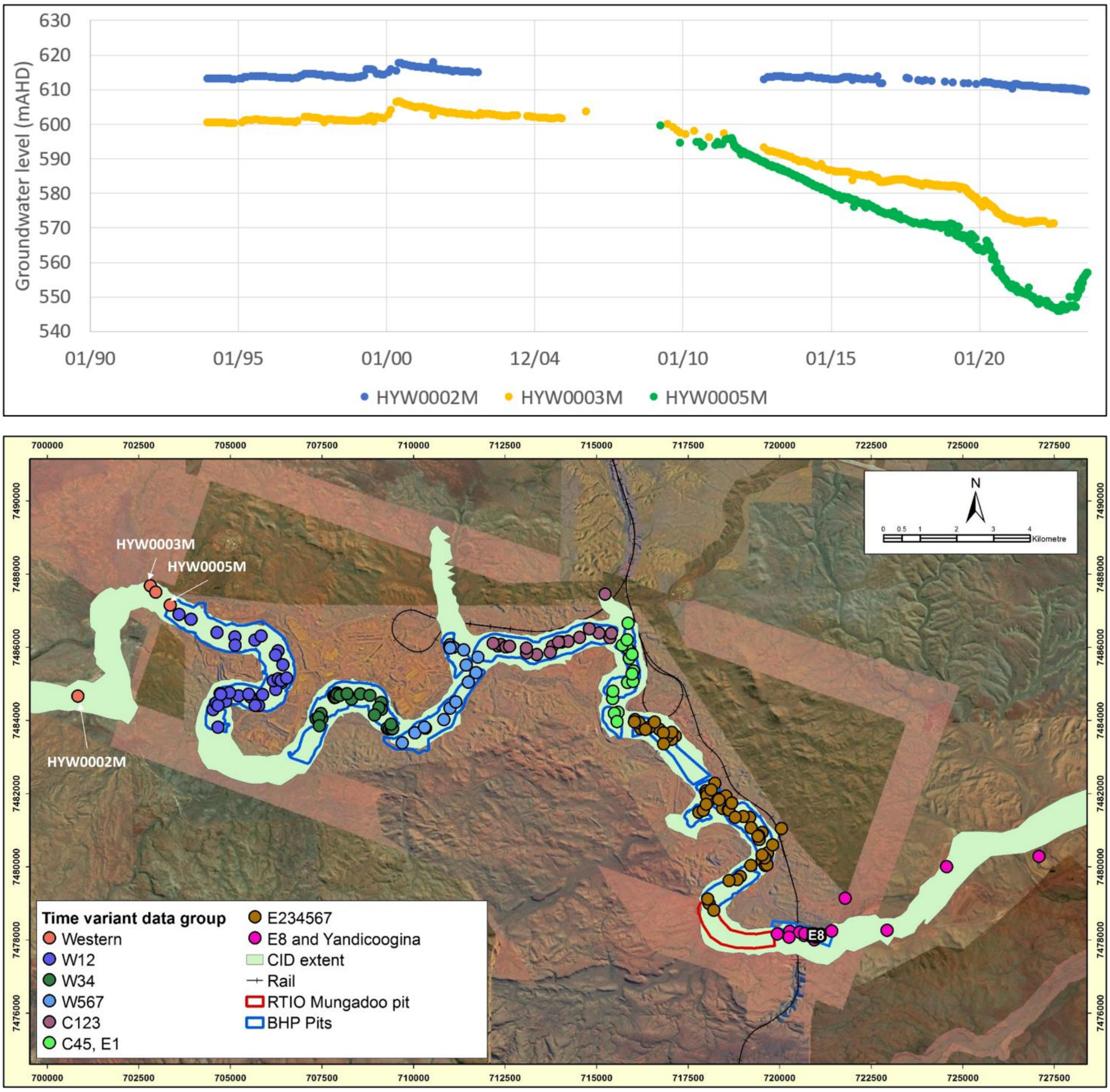



Source: BHP (2024a)

**Figure 5-26 Pre-development and 2023 groundwater levels along the CID**

Based on the observed water level in 1995, the drawdown observed at the most westerly Yandi bore (HYM0002M) was 3.6 m in August 2023. Over almost the same period, the drawdown at HYW0003M (just to the west of W0) was 29 m (up to July 2023) (Figure 5-26). Between November 2022 and April 2024, there has been a recovery of water levels (546 - 562 mAHD) adjacent to W0 (in HYW0005M) in response to a recent reduction in abstraction in W0 (Figure 5-27) (BHP, 2024a).

In the east of the development envelope, groundwater levels were not impacted directly by dewatering until approximately 2013. Since that time, groundwater levels in the vicinity of E8 have declined to approximately 500 mAHD (from ~523 mAHD) (BHP, 2024a).




Source: BHP (2024a)

**Figure 5-27 Water levels in bores upgradient of W0 (western end of W1 Pit)**

### Weeli Wolli

There are no observations of the Weeli Wolli Formation water levels prior to mining. A review of Weeli Wolli groundwater level data (from bores drilled in 2015 and 2016) in relation to the groundwater levels in the CID has shown that the response to dewatering in the Weeli Wolli Formation is very variable. In some places, most notably the four bores east of E2/3/4/5/6, the Weeli Wolli has responded very strongly to dewatering, with water levels falling several metres. In other locations, such as between W2 and W3, the Weeli Wolli Formation is less than 1,000 m from the nearest dewatered CID deposit and appears to be unaffected by dewatering (BHP, 2024a).

### Ministers North aquifer

Ministers North has not yet been developed for mining and there is limited data on the groundwater levels in Ministers North aquifer before 2018. Since 2018, the water levels have declined by almost 3.5 m (as of February 2023). Two changes have occurred in the hydrological / hydrogeological systems surrounding Ministers North that could have the potential to produce this groundwater level decline (BHP, 2024a):

- Lower than average rainfall. The area has experienced lower than average rainfall since 2018 which correlates exactly with the timing and duration of the observed decline in the Ministers North aquifer groundwater levels. The groundwater monitoring at Ministers North between 2002 and 2018 confirms that the aquifer water levels have varied by at least two metres in response to previous rainfall conditions (where dewatering is very unlikely to have played a part).

- Dewatering to support mining in nearby aquifers. Dewatering to support mining is occurring within 15 km to the north, south and east of the Ministers North aquifer. The closest of these being the Yandi / Yandicoogina mines less than 3 km directly to the north.

The historic fluctuations in groundwater levels prior to the potential influence of dewatering indicate that the Ministers North aquifer is sensitive to variations in rainfall. Therefore, while dewatering may be a contributing factor, the lower than average rainfall observed since 2018 is almost certainly the cause of either all, or a proportion, of the observed groundwater level decline over the same period. Without good baseline data for the Ministers North aquifer and Yandicoogina Gorge, or in the areas between these and the dewatering operations, it is not possible to determine the contribution of dewatering (if any) to groundwater decline. Investigations are planned to fill key data gaps (Section 5.9.2.8) (BHP, 2024a).

#### 5.9.2.4 Groundwater flows

Groundwater movement is generally towards the lowest parts of the catchment, i.e. to the CID deposit, Marillana Creek, and its major tributaries (Figure 5-28 and Figure 5-29). The pre-mining groundwater levels indicate that groundwater flows were from west to east with an average hydraulic gradient of 0.2% (Map 5-22). The data suggest that there are no major flow barriers perpendicular to the flow direction / CID strike throughout this entire area (BHP, 2024a).

The CID units are highly transmissive (hydraulic conductivity 10 - 100 m/d), whilst the clay layers within the sequence may function as aquitards. The estimated throughflow for the CID aquifer prior to mining is 4,000 - 5,000 KL/d (AQ2, 2020b).

The CID aquifer facilitates groundwater throughflow from the Marillana Creek catchment to the Fortescue River catchment via the Weeli Wolli Creek valley. Groundwater inflows to the marsh are constrained by low hydraulic gradients (MWH, 2015) and the overall groundwater component of catchment discharge is extremely small, being approximately 1 GL/yr when compared with 868 GL/yr of annual average rainfall (about 0.1%) (Golder, 2015b). A water balance reconciliation based on chloride mass balance and hydrograph data indicated that the aquifer storage capacity at the mouth of Fortescue Valley is many times greater than the upstream influx (Dogramaci, Firmani, Hedley, Skrzypek, & Grierson, 2015).

The alluvium associated with Marillana Creek is characterised as a local aquifer and estimates for aquifer transmissivity and specific yield are 5 - 20 $m^2$/d and 6 - 18% respectively. Throughflow is small in the alluvial aquifer and vertical fluxes dominate including recharge from infiltration during creek flow, losses from the alluvial aquifer as seepage into the underlying CID, and evapotranspiration (AQ2, 2017). Prior to mining, groundwater in the alluvium and CID was probably in equilibrium. At this time, groundwater levels along Marillana Creek were sustained for long periods between rainfall events as water was able to discharge from the CID and into the creek bed (BHP, 2022b). While monitoring of the alluvium did not commence until after dewatering of the CID, available data indicate that (BHP, 2024a):

- Groundwater levels in the alluvium have been reduced by dewatering of the CID.
- The observed patterns of recession following rainfall / streamflow recharge are most likely more rapid than would have occurred prior to dewatering and more often result in complete drying of the alluvium.

The hydraulic connection between the alluvium and CID is variable depending on the thickness of the alluvium, proximity to the CID and presence of finer material in deeper horizons. The alluvial aquifer and the CID aquifer are in hydraulic connection where Marillana and other major creeks cross the CID (Map 5-21 and Figure 5-28). Conversely, where the bedrock (Weeli Wolli Formation) is of lower hydraulic conductivity, this may restrict the hydraulic connection between the alluvium and CID where the creek bed alluvium is not adjacent to the CID (Figure 5-29). Similarly, the lower hydraulic conductivity of finer material in deeper horizons of the alluvium may also limit the vertical hydraulic connection although does not prevent lateral connections where the alluvium is incised more deeply along the edge of the CID (e.g., the eastern deposits at Yandi) (Golder, 2015b; BHP, 2024a).

Dewatering of the CID has reduced groundwater levels throughout the Yandi mine site. Dewatering of the RTIO Yandicoogina mine CID has had the same effect. There is some cumulative drawdown from both operations at the eastern end of Yandi and the western end of RTIO's Yandicoogina mine (BHP, 2024a).

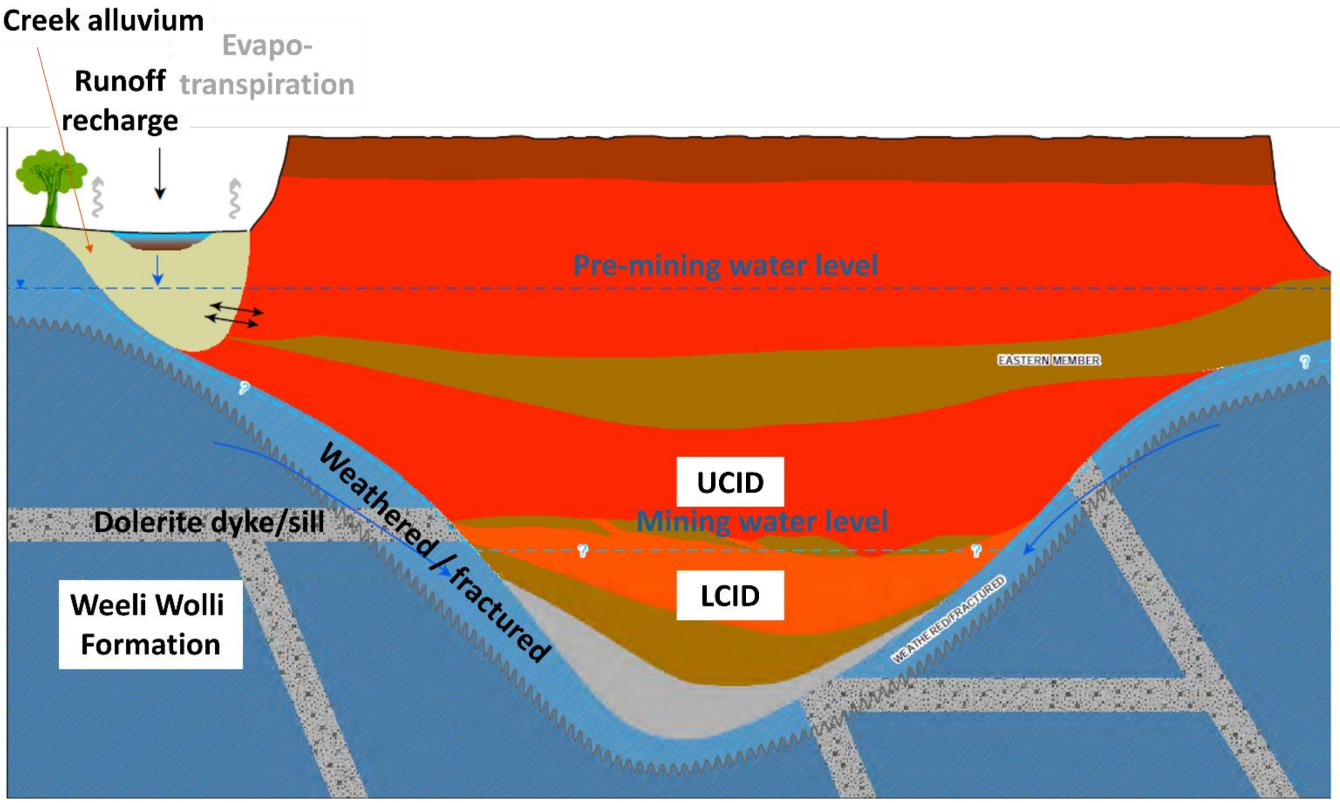
The CID palaeochannel aquifer units occupy the lowest part of the landscape and act as linear drains for the regional fractured rock groundwater system. Groundwater is, therefore, expected to discharge into the CID aquifer from the bedrock aquifer (Figure 5-28 and Figure 5-29). As discussed above, monitoring data show that the hydraulic conductivity of the Weeli Wolli Formation is variable and, therefore, drawdown in the CID extends further into the Weeli Wolli Formation in some areas than others, or not at all (BHP, 2024a).

The connection between the Ministers North aquifer and Weeli Wolli regional units is complex. The conventional view of the hydrogeology of the region does not support a connection between Yandicoogina Gorge and regional below water table mining in the CID. However, BHP has explored the causes of decline through the development of two groundwater numerical models:

- The Ministers North aquifer numerical model (BHP, 2024b). This model includes only the Ministers North aquifer and the material immediately surrounding it. Water enters the system via rainfall recharge and leaves the system via discharge at the Gorge. There is no hydraulic connection to the Yandi CID and therefore no influence from dewatering drawdown in this model. The model was calibrated to transient conditions between 2000 and 2024 and replicates the observed decline in groundwater levels between 2018 and 2024. The modelling results present a sound basis for the hypothesis that climate variability could be the key driver for the observed groundwater decline.
- The BHP Yandi E8 groundwater model (INTERA, 2024) is a regional model that includes the entire Yandi groundwater catchment (which incorporates the Ministers North aquifer). The simulated water balance at Ministers North is much the same as the smaller model described above, but in this case, the model incorporates the precautionary assumption of a diffuse hydraulic connection to the Yandi CID allowing drawdown to migrate from there to the Ministers North aquifer. This model was calibrated to transient conditions between 1991 and 2023 and incorporates BHP and third party dewatering of the

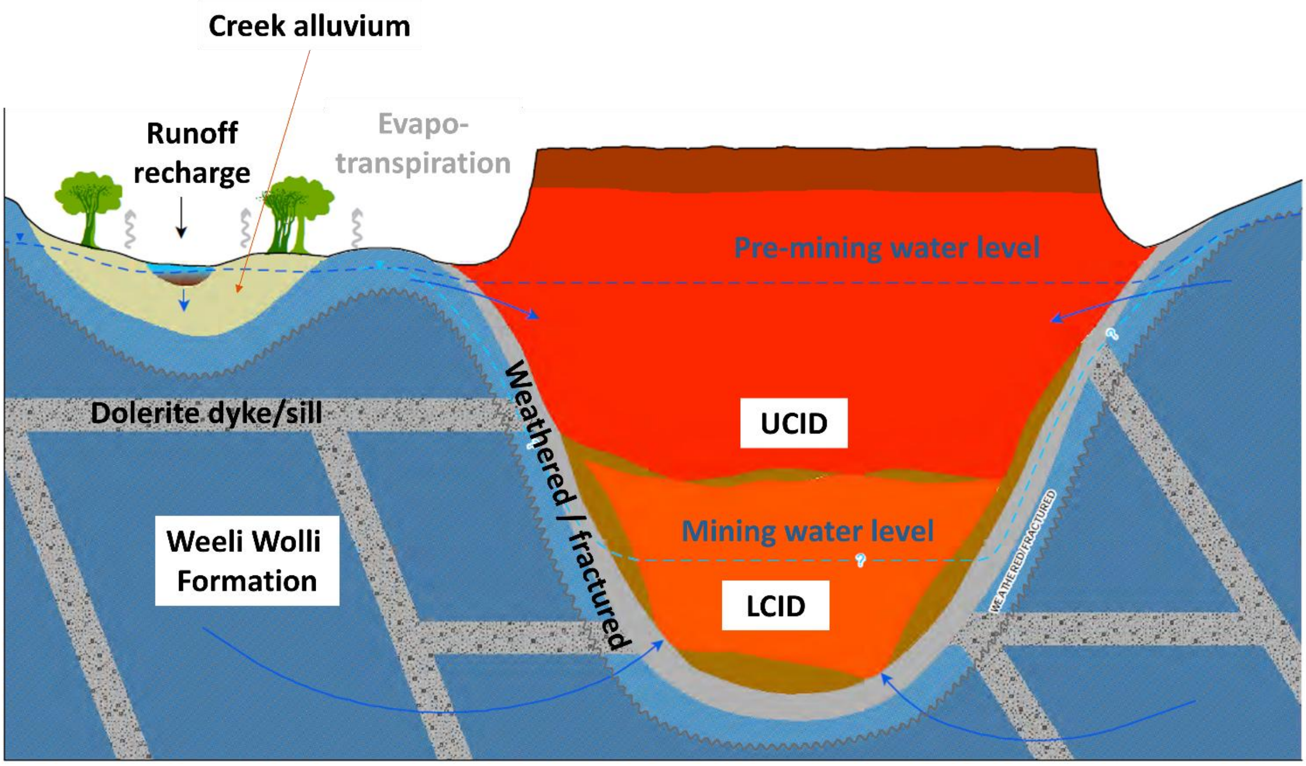
CID. The model can replicate the observed decline in Ministers North groundwater levels between 2018 and 2023. The decline in this model is derived from a combination of climate variability and cumulative drawdown from dewatering the CID. The model therefore shows that cumulative drawdown from the Yandi CID directly to the north of the Ministers North aquifer could contribute to the observed declines.

In summary, a successful calibration was achieved for both scenarios and provided a good correlation to the observed groundwater decline in the Minister's North Aquifer. Both scenarios incorporated the below average rainfall conditions experienced at the site, which suggests that dewatering may not be a critical factor in observed groundwater level decline. However, BHP has commenced investigations in collaboration with RTIO, to refine the groundwater conceptualisation and determine if there is a potential for a hydraulic connection between the Weeli Wolli and Ministers North aquifers.




Source: BHP (2024a)

**Figure 5-28 Yandi conceptual groundwater model - creek & alluvium in contact with CID**




Source: BHP (2024a)

**Figure 5-29 Yandi conceptual groundwater model - creek & alluvium remote from CID**

### 5.9.2.5 Recharge and discharge

#### Recharge

The groundwater systems are recharged episodically, not seasonally, so are typically in recession most of the time.

*Alluvial aquifer recharge*

The alluvial aquifer is recharged by direct infiltration of rainfall and variably through surface water flow in channels and creek beds. AQ2 (2017) estimated an average recharge rate of 2,050 to 6,175 kL/day over the area of the alluvial aquifer (calculated to be 625 ha based on a length of 25 km and an active recharge zone of 250 m). Using the median and mean estimates of specific yield, annual average recharge to the alluvial aquifer is estimated to be around 4,000 kL/day. Replenishment of the vadose zone will also occur from rainfall infiltration in areas where the moisture content has fallen below field capacity due to evapotranspiration.

An analysis of short-term hydrographs for the period 2012 - 2014 indicated that, in areas where the alluvial aquifer was not substantially affected by mining related drawdown, the water level rise associated with each recharge event ranged between 0.5 and 3 m, and the alluvial aquifer appeared to have been fully saturated following recharge. In areas where water levels in the alluvial aquifer were affected by mining, the largest individual rise from one recharge event was around 8 m, following creek flow in December 2013. This is consistent with the 10 m maximum rise observed in the long-term data. When recharge events occur soon after one another, then the combined recharge volume is sufficient to fully saturate the alluvium, even where it has been dewatered due to mining (AQ2, 2017).

The unsaturated hydraulic properties of the alluvium are important with respect to the ecohydrology of the system and these are summarised in Table 5-40 as the moisture content at the following matric potentials:

- -33 kPa which represents the matric potential and moisture content as unsaturated conditions first prevail (i.e. after gravity drainage following a recharge event).
- -2500 kPa which represents the matric potential and moisture content at the point *Melaleuca argentea* begin to experience severe drought stress.
- -4500 kPa which represents the matric potential and moisture content at the point *Eucalyptus victrix* begin to experience severe drought stress.

**Table 5-40 Vadose parameters for Marillana Creek alluvium**

| | Median | -1 Std Dev | Mean | +1 Std Dev |
|---|---|---|---|---|
| Moisture Content at -33 kPa (%) | 19.91 | 16.54 | 20.21 | 24.69 |
| Moisture Content at -2500 kPa (%) | 1.93 | 0.74 | 2.16 | 6.26 |
| Moisture Content at -4000 kPa (%) | 1.39 | 0.48 | 1.58 | 5.21 |

Notes: For all moisture content parameters, the percentages refer to the entire alluvial mass, i.e. including the coarse fraction that would typically be screened off prior to laboratory analysis

Source: AQ2 (2017)

*CID aquifer recharge*

The main sources of recharge are from (BHP, 2024a):

- Throughflow from the upstream CID.
- Leakage from the alluvium where it crosses or abuts the CID (Figure 5-28). This is enhanced during Marillana Creek flow events, although these events are sporadic with significant flows in response to high rainfall events but little or no flow in extended dry periods. It is also enhanced by discharge of surplus dewatering water directly to the creek during operations (managed in accordance with the Marillana Creek Water Resource Management Plan and EP Act Part V Environmental Licence L6168/1991/11).

A smaller amount of recharge to the CID is also likely to come from direct infiltration of rainfall and from groundwater flow from the surrounding Weeli Wolli Formation. Direct infiltration of creek water may also occur when exceptionally high water levels in the creek, from runoff and discharge of surplus mine water flood areas beyond the alluvium, result in direct infiltration to the CID (Golder, 2015b; BHP, 2024a).

*Recharge rates*

The rate of recharge to the groundwater systems is low as a proportion of average annual rainfall. Recent modelling allowed recharge rates to vary between 0.001 and 0.15% of annual rainfall.

### Discharge

Natural groundwater discharge occurs mostly through lateral groundwater movement out of the catchment, and by evapotranspiration losses. In pre-mining conditions, shallow groundwater in the alluvium and CID could discharge to Marillana and Weeli Wolli creeks after a flood event. However, dewatering now represents the largest outflow at Yandi and there are no longer any flows from the CID to the creek in the mining area. In some locations, the saturated Marillana Creek alluvium is truncated by shallow bedrock, for example at Flat Rocks, resulting in near-permanent baseflow at low rates (Golder, 2015b; BHP, 2024a).

Evapotranspiration is concentrated in areas of abundant vegetation consisting of woodland communities. Specific transpiration rates of vegetation in the Pilbara vary with vegetation type and distribution within the creek systems. Higher evapotranspiration rates are associated with riparian vegetation communities consisting of *Eucalyptus camaldulensis*, *Eucalyptus victrix*, and *Melaleuca argentea* and lower evapotranspiration rates with vegetation communities consisting of *Acacia* species (e.g. Mulga), shrublands and grasslands of the alluvial plains (Golder, 2015b). Several independent studies of tree water use by riparian eucalypts in the Pilbara have found similar relationships between tree size and tree water use (AQ2, 2017):

- Pfautsch et al. (2011) reported annual water use of 405 mm/year in a dense woodland of *E. victrix* (tree densities of 180 to 200 trees/ha) growing with unrestricted access to shallow groundwater near Millstream. The largest tree at this site (Diameter at Breast Height (DBH) 58 cm) transpired up to 8,000 L/month (equivalent to about 270 L/day); whilst average sized trees (DBH 20 to 40 cm) transpired in the order of 30 to 100 L/tree/day.
- Pfautsch et al. (2014) reported daily transpiration in the order of 10 to 240 L/tree/day for *E. victrix* trees spanning a DBH range of approximately 20 to 75 cm growing along the lower Weeli Wolli Creek system. The water use of trees with perennial access to abundant moisture was more than double that of trees growing in drier settings, indicating the effect of site conditions on water use regulation behaviour.
- Rio Tinto (2011) reported water use of up to 135 L/tree/day for *E. victrix* trees growing in woodlands at the Mount Bruce Flats. Average tree water use was strongly related to tree size / sapwood area.
- Astron (2014) reported water use rates for *E. victrix* trees growing in woodlands at Coondewanna Flats in the range of 20 to 200 L/tree/day. Average tree water use was strongly related to tree size / sapwood area.

These results are generally consistent with multiple tree water use studies from around Australia (AQ2, 2017).

Other discharges of groundwater may occur through anthropogenic processes such as groundwater abstraction for pastoral use (Golder, 2015b).

#### 5.9.2.6 Groundwater / surface water interactions

As discussed above, Marillana Creek may both discharge into groundwater during flood events and receive recharge from the saturated alluvium aquifers after flooding.

There is limited information available to provide an estimate of Marillana Creek seepage losses through the CID and into mine voids. However, the likely seepage rate is expected to fall between the following range of estimates (AQ2, 2020a):

- CSIRO (2015b) completed some estimates of creek seepage within sub-catchments of the Upper Fortescue River including Weeli Wolli Creek, Marillana Creek and the Upper Fortescue River near Newman. Results were typically in the order of 2 ML/km/d (during creek flow periods), which is the equivalent of 44,000 $m^3$/d over a 22 km mine length. BHP considers these estimates an underestimate, as they do not fully reflect the impact of mine void developments adjacent to Marillana Creek.
- BHP has developed a function to estimate the seepage rate from the alluvium into the CID:
  - If creek flow is greater than 100,000 $m^3$/hr, then total seepage would be 2,254,000 $m^3$/d.
  - If creek flow is greater than 10,000 $m^3$/hr, then total seepage would be 790,00 0$m^3$/d.
  - If creek flow is less than 10,000 $m^3$/hr, then total seepage would be 0 $m^3$/d.

Groundwater inflows to Fortescue Marsh are negligible due to an extremely low hydraulic gradient of 0.001 in the sediments of the Fortescue Valley surrounding the marsh (Skrzypek, Dogramaci, & Grierson, 2013).

In addition to natural flows, excess dewatering water is discharged to Marillana Creek. Two main locations have been used; one in the Central area (now decommissioned) and the other down gradient of the Eastern area. Another discharge location was adjacent to the W3 Pit (used only in exceptional circumstances), has only been used to discharge minimal amounts of water. Total discharge to the creek averaged 20 ML/d between 1997 and 2021, with a peak of 47 ML/d at the end of 2014. The Central location has seen about 20% of the discharge and the Eastern location the rest. Recirculation of the discharged water via seepage from the creek into the CID is likely when the Central discharge point is used. The Central discharge location has not been used consistently since 2013 (BHP, 2024a; INTERA, 2024). These discharges are managed through the Marillana Creek Water Resource Management Plan.

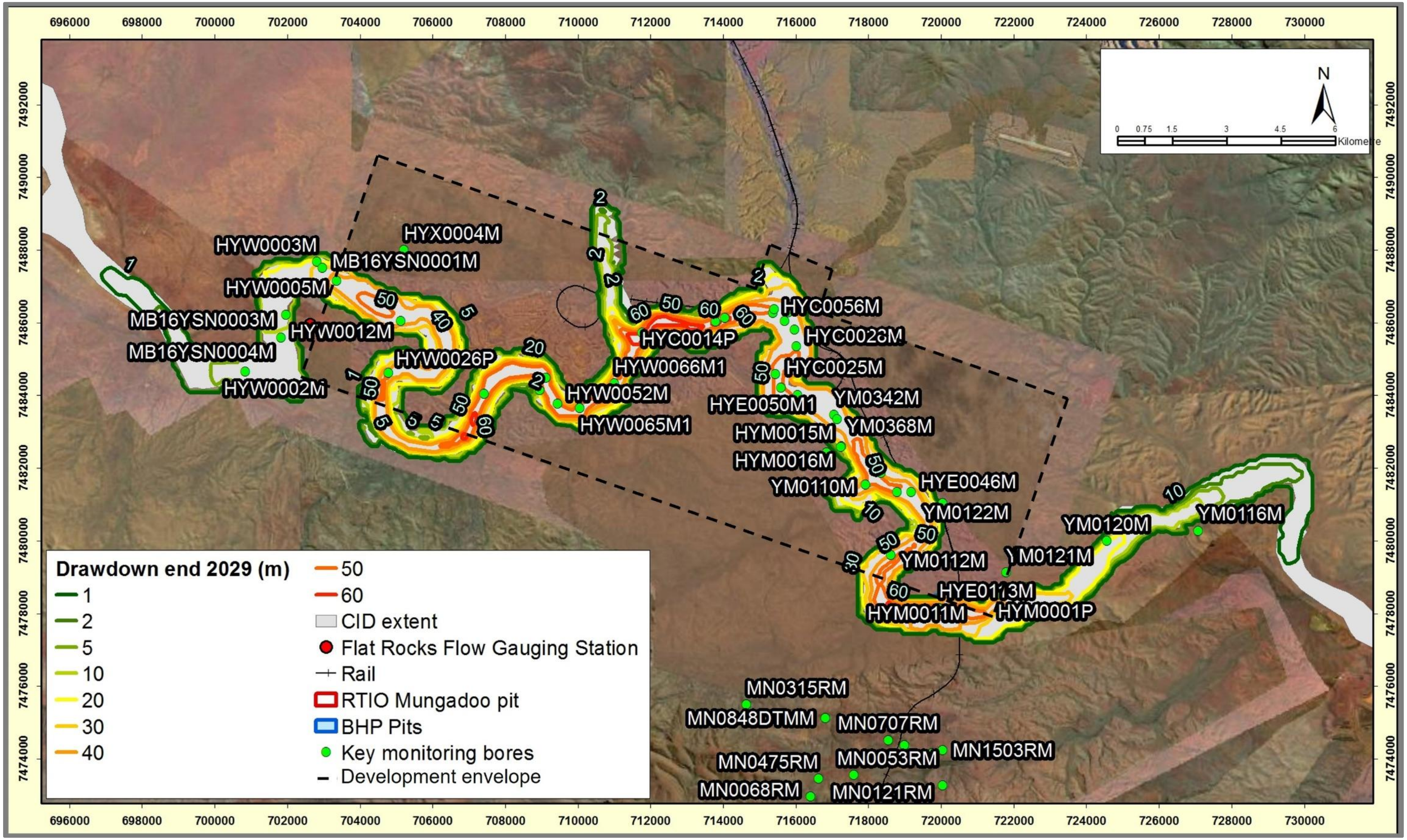
#### 5.9.2.7 Groundwater modelling

As discussed in the introduction to Section 5, closure studies are interlinked and often iterative. This is particularly true of Yandi mine voids, as changes to one or combination of several factors can influence closure outcomes. A new regional numerical groundwater model has recently been developed for Yandi based on the conceptual model outlined in BHP (2024a) (Sections 5.9.2.3 to 5.9.2.6). This new model has been used to assess the potential impacts of the proposed E8 Pit dewatering on groundwater levels, and to inform the closure strategy for E8 (described in Section 9.2.3.1). This section summarises the outcomes of this modelling which also considers the cumulative influences of the entire Yandi mine and selected third party pits. The modelling presents an assessment of cumulative drawdown prior to commencement of backfill. As dewatering ceases and the backfill strategy at Yandi is implemented, groundwater levels will rebound as described in Section 5.14.1 which would be expected to reduce the extent and magnitude of drawdown. Further modelling, to gain an understanding of the residual drawdown following backfill, will be required as an input to the refinement of the Yandi backfill strategy as stakeholder consultation and other technical closure studies progress.

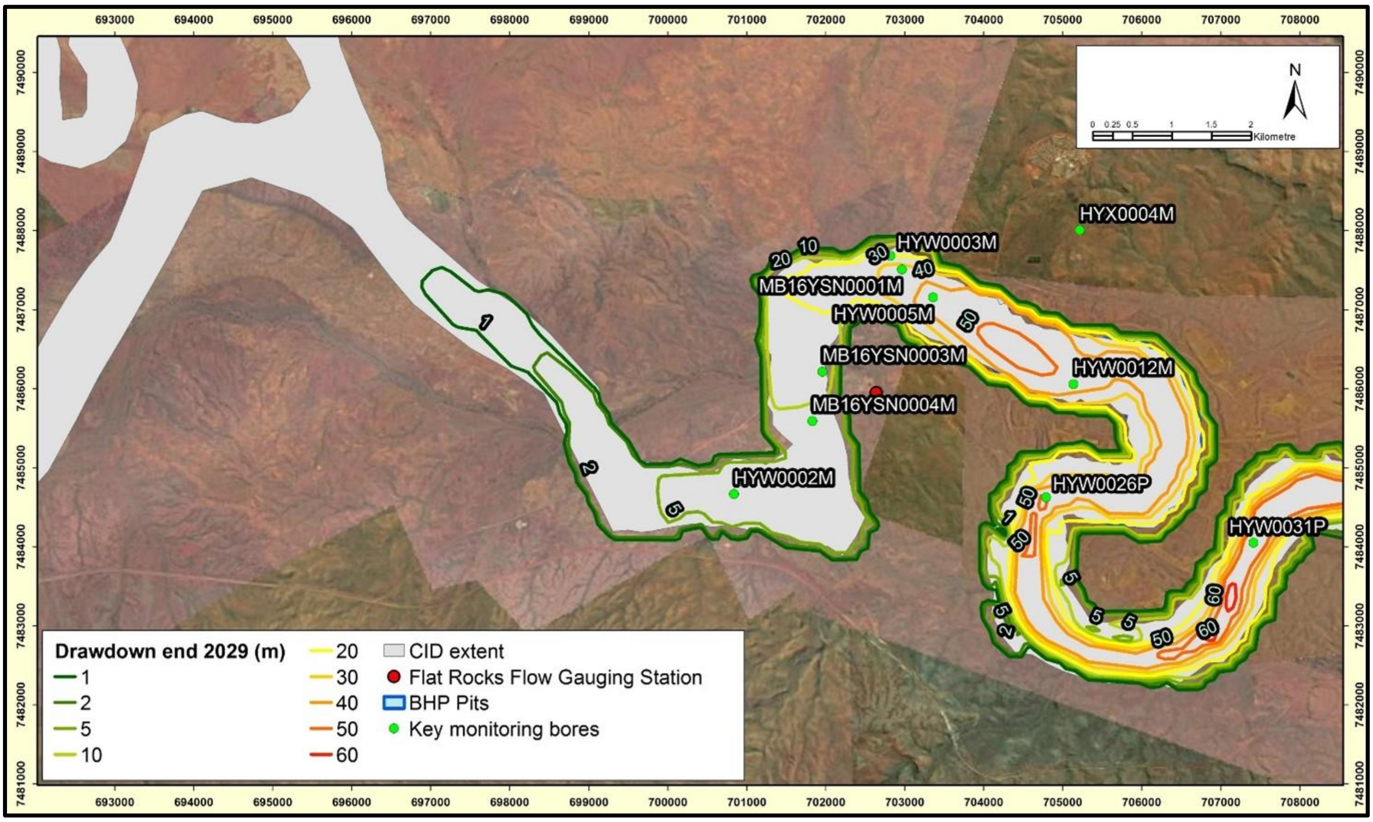
Modelling was conducted by INTERA (2024) to 2029 which was assumed to be the end of mine life at the time of modelling. The modelled future groundwater levels at the third-party pits were based on observed levels at E7 and proposed E8 Pit. The modelled future groundwater levels at the BHP pits were based on dewatering plans and the conservative assumption that groundwater levels at all pits would be maintained at the lowest final level until 2029. This was to incorporate the uncertainty around the timing of closure (backfilling) (BHP, 2024c).

Predicted drawdown was calculated from the start of BHP dewatering (1991). The study was undertaken by running many hundreds of distinct models, each with different parameter settings but each also producing an acceptable fit between observed and simulated water levels at the hundreds of monitoring bores around Yandi (most of which are in the CID). The model could reproduce historical groundwater levels in the CID and basement (Weeli Wolli Formation), but due to the extreme heterogeneity of the alluvium and limited monitoring data, it could not reproduce historical groundwater levels in the alluvium. The median results of the CID and basement runs are outlined below (BHP, 2024c).

By 2029, drawdown of up to 60 m is predicted in the CID (Map 5-23) and at least 1 m drawdown is predicted to extend approximately 10 km within the CID to the west of the development envelope (Map 5-24). However, this does not take into account mitigation measures implemented in accordance with the Marillana Creek Water Resource Management Plan (BHP, 2024c).



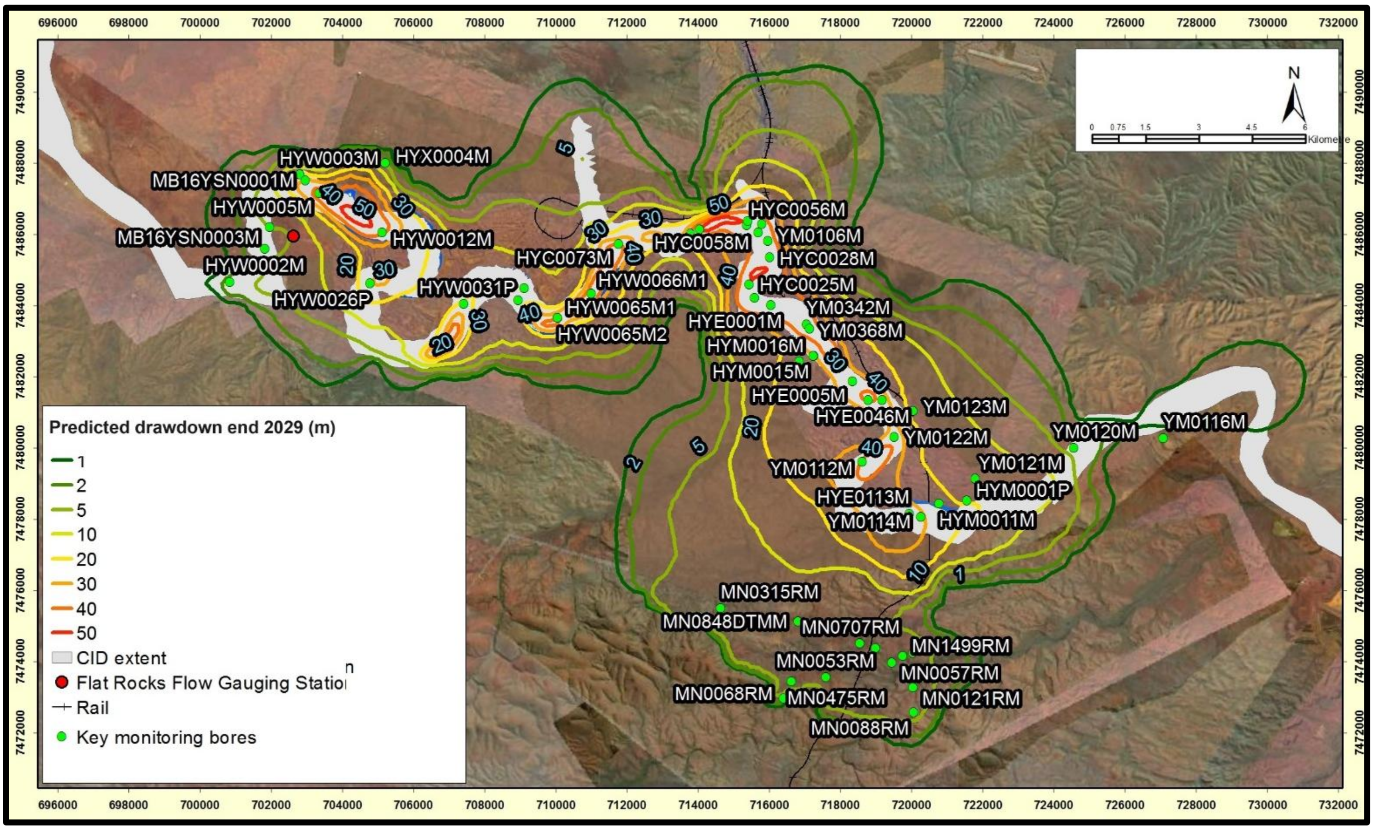

**Map 5-23** **Modelled cumulative CID drawdown to the end of 2029**




Source: BHP (2024c)

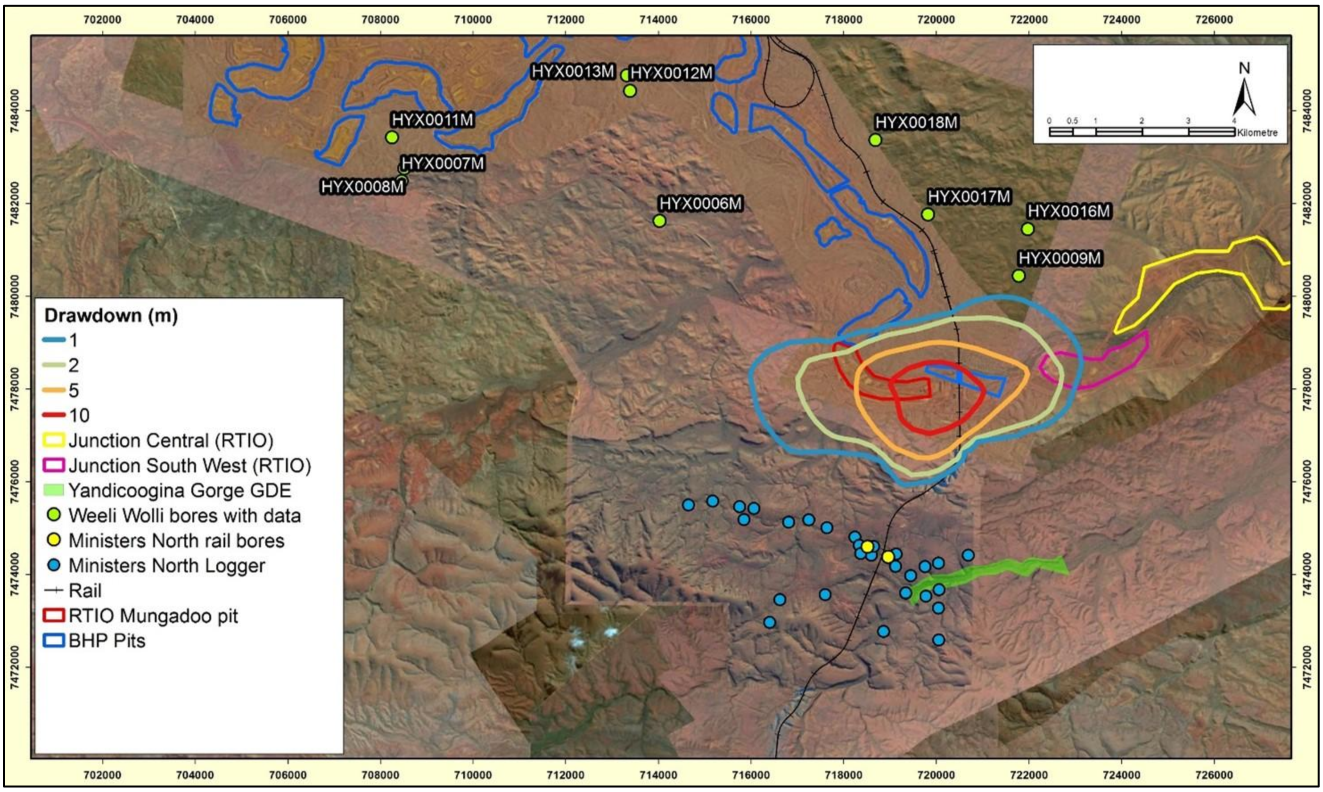
**Map 5-24 Modelled cumulative CID drawdown to the end of 2029 - Yandi western end**

Modelled drawdown in the basement (i.e. the Weeli Wolli Formation) that surrounds the CID is variable. In places, the 1 m drawdown contour extends less than 1 km from the CID and in others, it extends much further, potentially more than 4 km from the CID (Map 5-25) (BHP, 2024c).




**Map 5-25 Modelled cumulative drawdown in Weeli Wolli and Ministers North aquifers to the end of 2029**

As outlined in Section 5.9.2.3, the INTERA (2024) model has been based on the precautionary assumption that there is a diffuse hydraulic connection between the Yandi CID and the Ministers North aquifers. Based on this assumption, the model predicts that, by the end of 2029, drawdown of approximately 5 to 10 m may extend into the Ministers North aquifer with approximately 5 to 6 m decline at Yandicoogina Gorge[34] The modelled contribution of the proposed E8 Pit to the drawdown in the Weeli Wolli Formation is shown in Map 5-26. Drawdown is predicted to reach just over 10 m directly beneath E8 and up to 1 m is predicted to extend between 2.5 km (north south) and 4.5 km (east west) from the dewatering. Drawdown from E8 alone is not predicted to reach Yandicoogina Gorge (BHP, 2024c).




Source: BHP (2024c)

**Map 5-26 Modelled contribution of E8 to drawdown in the Weeli Wolli Formation to the end of 2029**

#### 5.9.2.8 Knowledge gaps & forward work program

The following forward work programs will be used to inform closure designs:

- Integration of regional groundwater and GoldSim modelling (Section 5.14.1) to assess regional post-closure groundwater levels.
- Investigation of the cause of groundwater decline in the Ministers North aquifer.

### 5.9.3 Water quality

Hydro Geochem Group (2022) conducted a review of surface water and groundwater quality data from Yandi to:

- Identify any trends in water quality that may be associated with impacts from mining activities to receptors.
- Evaluate current monitoring programs for their suitability to inform closure planning and completion criteria and provide appropriate data post-mining to support completion reporting.

The work comprised:

- Development of a conceptual site model that identifies the likely sources of constituents of potential concern and transport pathways to receptors (Section 5.9.3.1).
- Identification of spatial and temporal trends in water quality (Section 5.9.3.2).
- Identification of processes controlling water quality (Section 5.9.3.3).
- Review of monitoring programs (Section 5.9.3.4).

[34] Note: this is just one modelled scenario, and investigations are ongoing to validate the inputs to the model.

**Summary**

Hydro Geochem Group (2022) developed a conceptual water quality source-pathway-receptor model for Yandi:

- Key sources considered were exposed PAF material in Marillana Creek diversion, neutral metalliferous and / or saline drainage from overburden (OSAs / ISAs), pit wall exposures leading to acid, neutral metalliferous and / or saline drainage, potential for nitrate releases from explosive residue, and saline water from pit lakes. Except for explosive residue, all sources were considered unlikely to impact surface water or groundwater.
- Key pathways considered were:
  - Surface water flow in Marillana Creek and groundwater flow in the associated alluvial aquifer.
  - Groundwater flow in the CID aquifer (which will be influenced by the residual mineralised material in the pits and the final backfill strategy).
  - Overflow from W4 Pit in a 1 in 10,000 year event.

  Given the relatively low permeability of the Weeli Wolli aquifer, flows in the bedrock aquifer were not considered a key pathway.
- Potentially sensitive receptors include riparian vegetation communities, subterranean fauna communities in the CID aquifer, downstream users of groundwater and surface water, including the Fortescue Marsh and associated samphire-dominated vegetation communities, groundwater fed persistent pools that support aquatic invertebrates, and fauna accessing pit lakes (post-closure).
- The spatial temporal review of surface water and groundwater quality data concluded that:
  - Yandi groundwater and surface water are characterised by circum-neutral pH and show no impact due to AMD, consistent with the NAF classification of materials.
  - Acid, neutral metalliferous and / or saline drainage is unlikely to be a process affecting water chemistry at Yandi.
  - Nitrate is widespread in surface water and groundwater at Yandi with no clear evidence of persistent point sources. This is an indication that Ammonium Nitrate Fuel Oil (ANFO) residue from blasted rock and pit walls could be the source of nitrate. Available data indicate no elevation in nitrate concentrations in Marillana Creek downstream of Yandi and no site-wide increase in groundwater concentrations over time.
  - Dewatering due to mining has accelerated the downstream movement of older groundwater in the CID aquifer. This has been partially replaced by infiltration from the alluvial aquifer and rainfall, which has changed the proportions of major ions and resulted in modest decreases in salinity and bicarbonate alkalinity.
  - After closure, the CID aquifer at Yandi will be partly composed of pit backfill. Salinity from evapo-concentration of seasonal expressions of water is predicted to be flushed to groundwater (Section 5.14.3.2). The salinity of the mining-modified backfill / CID aquifer at Yandi is, therefore, likely to increase and evolve towards a more Na-Cl - type groundwater in response to this discharge and because fresh recharge will mostly be diverted down the post-closure Marillana Creek surface water system.
- A review of the groundwater and surface water monitoring programs identified some areas for improvement which have been incorporated into the forward work program (Section 13.3) and proposed improvements to monitoring noted in Sections 10.1.8 and 10.1.10. Improvements include:
  - Establishment of:
    - Additional reference sites.
    - Monitoring locations along the linear pathway identified in the conceptual model.
    - Monitoring locations that can detect changes arising from specific sources or the contribution of water from tributaries feeding Marillana Creek.
  - Regularly spaced monitoring events at consistent locations and installation of continuous samplers to optimise the probability of collecting viable surface water samples given the episodic nature of creek flow.
  - Analysis of a consistent suite of parameters that can be rationalised over time to focus on constituents of potential concern.

#### 5.9.3.1 Conceptual model

The movement of both surface water and groundwater at Yandi is essentially linear; from upstream in the Marillana Creek and CID palaeochannel to downstream. Runoff from the Marillana Creek catchment flows into the creek channel. A portion of the runoff recharges the Weeli Wolli fractured rock aquifer (noting that the Weeli Wolli aquifer has a hydraulic conductivity at least an order of magnitude lower than the CID and alluvial aquifers - refer to Section 5.9.2).

The Marillana Creek flows over the top of and adjacent to the CID deposits of the Marillana Formation. Flow in the creek channel recharges the alluvial aquifer associated with Marillana Creek. This in turn recharges the CID aquifer. The CID aquifer also receives recharge from direct rainfall infiltration and from the surrounding Weeli Wolli fractured rock aquifer.

The linear geometry of Yandi constrains potential surface water impacts to the Marillana Creek channel and associated alluvial aquifer. It also constrains potential groundwater impacts to the CID aquifer.

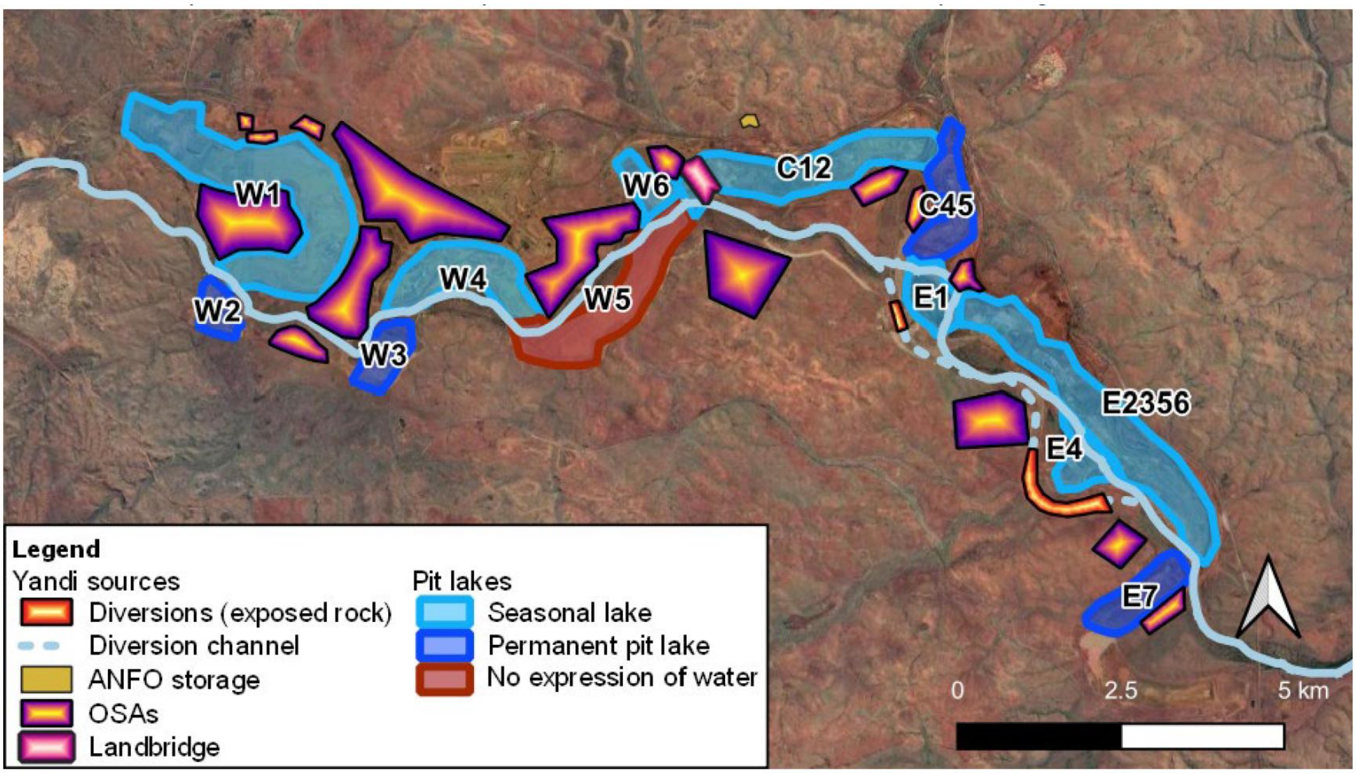
## Sources

The key sources of constituents of potential concern considered are summarised in Table 5-41 and represented spatially in Figure 5-30.

**Table 5-41 Sources of constituents of potential concern considered**

| Source | Constituents of potential concern | Likelihood of release |
|---|---|---|
| **Marillana Creek diversion**<br>Excavations into the Weeli Wolli shale, dolerite, and other bedrock lithologies are known to have exposed PAF materials with the potential for AMD (Section 5.2.3.4). | Associated with AMD including acidity, sulphate, iron, and trace metals | Unlikely<br>AMD risk is low due to low reactivity, high neutralisation capacity and small exposures (Section 5.2.3.4). |
| **Overburden**<br>Classified as NAF. NAF overburden is a potential source of neutral metalliferous or saline drainage (Section 5.2.3). | Associated with neutral metalliferous and saline drainage including pH, sulphate, and salinity | Unlikely<br>Geochemical testing indicates limited potential for metal and salinity mobilisation from Yandi overburden associated with oxidative and non-oxidative processes (Section 5.2.3). |
| **Pit wall exposures**<br>Residual CID material in pit walls is classified as NAF. Munjina Member and Weeli Wolli Formation materials have been identified as having slightly higher sulphur concentrations from the total assay database. These stratigraphies represent around 15% of the surface area of C4/5 and 6% of W1 and E7, however, the overburden blocks assigned to these two stratigraphies in these pits are classified NAF (Section 5.2.3.3). | Associated with acid and neutral metalliferous / saline drainage including acidity, pH, sulphate, iron, trace metals and salinity | Unlikely<br>Geochemical testing indicates (Section 5.2.3):<br>• Limited sulphur concentrations and potential for AMD.<br>• Limited potential for metal and salinity mobilisation. |
| **Explosive residue**<br>The Ammonium Nitrate Fuel Oil (ANFO) explosive used in mine activity leaves a residue after blasting. | Nitrate and ammonium | Likely<br>Explosive residues are readily soluble and may be flushed from overburden and pit walls. |
| **Pit lakes**<br>Seasonal and permanent pit lakes will become saline (Section 5.14.3). | The key contributors to salinity are the major ions (K, Na, Ca, Mg, Cl, $SO_4$). Concentrations of metals and metalloids that remain in solution at neutral pH may also increase in response to evaporative concentration (Section 5.14.3). | Unlikely - groundwater<br>Saline pits may become sources of saline impacts to the CID aquifer. However, the pits are predicted to become sinks and the potential for density driven flow is unlikely (Section 5.14.5).<br>Unlikely - surface water<br>The W4 Pit is the only pit which is predicted to overtop to Marillana Creek (in a 1 in 10,000-year event). However, this is unlikely to cause significant impacts (Section 5.14.4). |

Source: Hydro Geochem Group (2022)




Source: Hydro Geochem Group (2022)

Notes: Shows the location of current conceptual sources considered as well as the mine void sources associated with closure Scenario B.1.

**Figure 5-30 Location of conceptual sources considered**

### Pathways

Key pathways of mining-related impact on water quality include:

- Surface water flow in Marillana Creek and groundwater flow in the associated alluvial aquifer.
- Groundwater flow in the CID aquifer (which will be influenced by the residual mineralised material in the pits and the final backfill strategy).
- Overflow from W4 Pit in extreme rainfall events.

Given the relatively low permeability of the Weeli Wolli aquifer, flows in the bedrock aquifer were not considered to be a key pathway.

### Receptors

Ecohydrological assets (Section 5.9.4) that are potentially sensitive to changes in regional groundwater and / or surface water, include:

- Riparian vegetation communities of Marillana Creek and the associated alluvial aquifer.
- Subterranean fauna communities in the CID aquifer.
- Groundwater / surface water users downstream of Yandi, including the Fortescue Marsh and associated samphire-dominated vegetation communities.
- Persistent pools where groundwater ponds behind shallow basement rock and daylights at surface. These support aquatic invertebrate assemblages.
- Fauna accessing pit lakes (post-closure).

## 5.9.3.2 Monitoring data review

The monitoring locations included in the Yandi water quality monitoring dataset are shown in Figure 5-31.

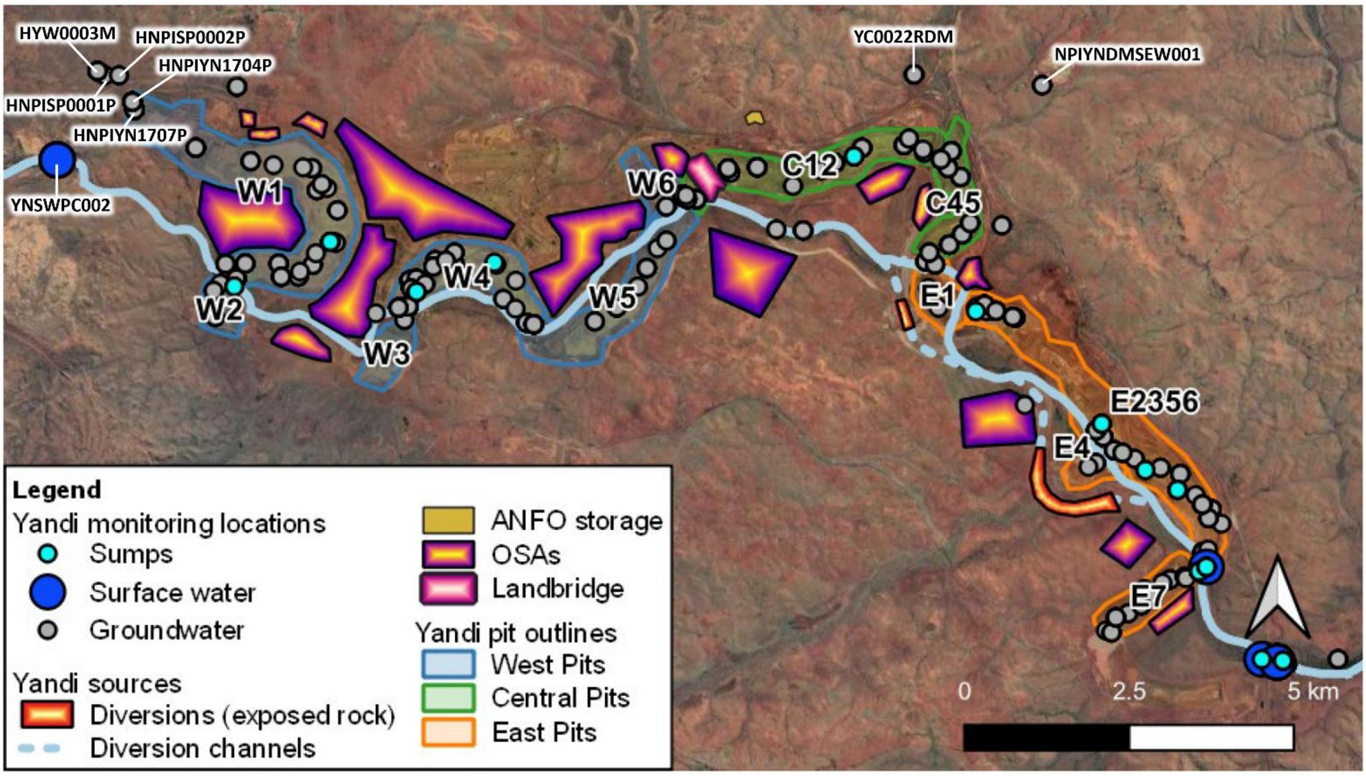
### Reference locations

#### *Groundwater*

Bores HYW0003M, HNPIYN1704P, HNPIYN1707P, YC0022RDM, HNPISP0001P, and HNPISP0002P (Figure 5-31) are located outside the inferred zone of influence of mining activities and may indicate the range of background concentrations of selected parameters in groundwater. They were, therefore, designated "reference bores" for the purposes of the water quality assessment. Hydro-stratigraphic information indicates that three of the bores are screened in the CID aquifer (HYW0003M, HNPISP0001P, and HNPISP0002P) but no information was available to show where the other three bores have been screened.

*Surface water*

Sampling location YNSWPC002 (Figure 5-31) is the single surface water reference location at Yandi.




Source: Hydro Geochem Group (2022)

Notes: reference sites are shown with sampling location numbers

**Figure 5-31 Yandi water quality sampling locations**

## Screening

To assist in identifying the parameters for the spatial temporal review, water quality results were screened against five criteria (Appendices E.2 and E.5). Screening criteria used were (Hydro Geochem Group, 2022):

- Guideline values for 95% species protection (95% SPL) for freshwater ecosystems (ANZECC & ARMCANZ, 2000).
- Australian Drinking Water Guidelines (ADWG) - Health-related guideline values of the National Health and Medical Research Council (NHMRC, 2011).
- ADWG - Aesthetic guideline values (NHMRC, 2011).
- Livestock Guideline Value (ANZECC & ARMCANZ, 2000).
- Site specific trigger values (Golder, 2015a) set for groundwater only.

Key findings were (Hydro Geochem Group, 2022):

- There were no exceedances of the groundwater site specific trigger value for pH. Of the exceedances of the trigger values in groundwater:
  - Nitrate was exceeded most often (561 of 626 measurements, 90%).
  - Boron was the next most frequent exceedance (164 of 413 measurements, 40%).
  - EC exceeded the trigger value in 147 of 712 measurements (21%).
- There were no exceedances of the surface water 95% SPL guideline value for pH. Of the exceedances of guideline values for surface water:
  - EC was exceeded most often (73 of 80 measurements, 91%).
  - Nitrate was the next most frequent exceedance (68 of 83 measurements, 82%).
  - Copper exceeded the 95% SPL in 18 of 81 measurements (22%).

## Spatial temporal review

Based on the conceptual site model and the criteria screening, a spatial and temporal assessment was conducted for ten key parameters; pH, alkalinity, sulphate, EC, nitrate, boron, zinc, copper, barium, iron. This comprised a statistical analysis of data and comparison to reference site behaviour. Table 5-42 provides the reference site concentrations for each parameter along with commentary on the observed spatial and temporal trends across the full data set. The conclusions arising from the assessment are summarised below (Hydro Geochem Group, 2022):

- Yandi groundwater and surface water are characterised by circum-neutral pH and show no impact due to AMD, consistent with the NAF classification of materials (Section 5.2.3).
- Bicarbonate alkalinity in:
  - Surface water is low; generally less than 150 mg/L (as $CaCO_3$).
  - Groundwater exceeds 350 mg/L (as $CaCO_3$) in reference bores. In non-reference bores, it is in the range 150 to 350 mg/L (as $CaCO_3$) due to displacement of older higher alkalinity groundwater with lower alkalinity rainfall recharge. Alkalinity appears to be declining in some bores in the Western area, but this process is likely to be a result of dewatering due to mining activities, rather than a leading indicator of AMD.
- Sulphate concentrations are generally low and suggest AMD is not impacting water quality at Yandi.
- EC in:
  - Surface water at Yandi appears in the order of 150 µS/cm[35].
  - Groundwater has two modes of distribution (~850 µS/cm and ~1,150 µS/cm). The higher EC mode appears to characterise background CID groundwater while the lower EC mode is likely to be associated with recharge by low salinity groundwater / rainwater in response to mining-associated dewatering[36].
- Nitrate is widespread in surface water and groundwater at Yandi, with no clear evidence of persistent nitrate point sources. This is an indication that Ammonium Nitrate Fuel Oil (ANFO) residue from blasted rock and pit walls could be the source of nitrate. Available data indicate no elevation in nitrate concentrations in Marillana Creek downstream of Yandi and no site-wide increase in groundwater concentrations over time. While concentrations in groundwater are elevated, the lack of a robust background groundwater quality dataset makes it difficult to indicate how elevated
- Estimated background boron concentration in groundwater at Yandi is significantly higher than surface water. Elevated downstream concentrations in Marillana Creek may have been associated with discharge of dewatered groundwater to the creek. Exceedances of the site-specific trigger value in groundwater may be associated with natural variation in concentrations. There is no clear evidence of persistent boron point sources in the available data.
- The estimated upper limit of zinc concentrations in background groundwater exceeds the 95% SPL (0.008 mg/L) by approximately one order of magnitude. Therefore, exceedances of the 95% SPL are frequent in monitoring data and spatially distributed throughout the site. There appears to be no indication of point sources of zinc contamination.
- Exceedances of the copper 95% SPL and site-specific trigger value are sporadic and appear unrelated to point sources.
- Barium concentrations have not been analysed for Marillana Creek samples. In groundwater, exceedances of the barium site specific trigger values are sporadic and appear unrelated to point sources.
- Iron is largely insoluble under oxidising and pH neutral conditions. Under these conditions significant iron concentrations are generally associated with colloidal matter in a sample. The Yandi iron concentrations are sporadic with no temporal and spatial trends. Exceedances are likely to be anomalies associated with colloidal material in the monitoring samples.

#### 5.9.3.3 Processes controlling water quality

The spatial / temporal assessment of Yandi water quality data identified one process controlling water quality and one potential source of impact. Analysis of a Piper plot of Yandi water quality samples showed that acid and neutral metalliferous and / or saline drainage is unlikely to be a process affecting water chemistry at Yandi (Hydro Geochem Group, 2022).

**Process**

The process of dewatering of the CID aquifer removes older, more saline, more alkaline (Ca-Mg-Na-Cl-$HCO_3$ - type) groundwater to allow mining of the CID ore bodies. This results in an increased recharge of the CID aquifer from the alluvial aquifer and rainfall infiltration. The recharge is less saline and has lower alkalinity resulting in a change in chemical signature to a more Ca-Mg-$HCO_3$ – type groundwater in the dewatered CID aquifer (Hydro Geochem Group, 2022).

After closure, residual mine voids and partially backfilled pits will mostly replace the original CID aquifer, which will have been largely mined out. Salinity from evapo-concentration of seasonal expressions of water is predicted to be flushed to groundwater (Section 5.14.3.2). The salinity of the mining-modified backfill / CID aquifer at Yandi is, therefore, likely to increase and evolve towards a more Na-Cl - type groundwater in response to this discharge and because fresh recharge will mostly be diverted down the post-closure Marillana Creek surface water system (Hydro Geochem Group, 2022).

[35] Pre-mining surface water quality data from Flat Rocks Gauging Station has recorded EC ranging between 136 and 1,805 µS/cm and neutral to slightly alkaline pH (6.10 to 8.70) (BHP, 2022b).

[36] Baseline groundwater analyses provided in the Initial Project Public Review (BHP Utah, 1987) reported TDS concentrations of ~ 500 mg/L (equivalent to EC ~770 µS/cm based on a water chemistry dominated by calcium and bicarbonate).

**Table 5-42 Spatial temporal review of constituents of potential concern against reference concentrations**

| Parameter | Medium | Concentrations at reference locations | | | Comments on data from within the Yandi mining area |
|---|---|---|---|---|---|
| | | Range | Median | No. Analyses | |
| pH (pH units) | Groundwater | 6.8 - 8.4 | 7.8 | 26 | 223 pH groundwater field measurements were within the range pH 5 - 6 (generally between 2014 and 2015). This appears to be related to above average rainfall in the 2013-2014 wet season. Rainfall generally has a lower pH than local groundwater due to equilibrium with atmospheric carbon dioxide and therefore is the cause of a widespread decline in groundwater pH during this period. No low pH signature due to AMD is evident which is consistent with AMD testing of Yandi mine overburden indicating material is NAF (Section 5.2.3). |
| | Surface water | 7.0 - 8.1 | 7.5 | 9 | |
| Alkalinity (mg/L as $CaCO_3$) | Groundwater | 88 - 451 | 412 | 25 | Bicarbonate alkalinity exceeding 350 mg/L as $CaCO_3$ tends to be in reference bores and the western area of the Yandi mining area. Mining at Yandi commenced in the eastern and central areas and older, higher alkalinity groundwater would have been dewatered in these areas and the aquifers recharged by lower alkalinity rainwater. This process would have left a longer monitoring history of older, higher alkalinity groundwater in the reference bores (unaffected by dewatering) and the western area where dewatering occurred later. This is supported by statistically significant declines in bicarbonate alkalinity in several production bores in the western area at Yandi. |
| | Surface water | 31 - 140 | 62 | 9 | Bicarbonate alkalinity in surface water is generally less than 150 mg/L as $CaCO_3$. |
| Sulphate (mg/L) | Groundwater | 3 - 71 | 59 | 28 | Data from two bores in the central area show modest upward trends with maximum sulphate concentrations of 81 mg/L in 2020 and 52 mg/L in 2018, respectively. These two bores do not appear to be associated with an identified sulphate source. Three bores in the western area show downward trends in sulphate concentration from 60-70 mg/L to about 50 mg/L. This may be a response to dewatering of old, higher sulphate groundwater and recharge by low sulphate groundwater from the alluvial aquifer and / or rainfall. |
| | Surface water | 5 - 31 | 10 | 9 | - |
| EC (µS/cm) | Groundwater | 410 - 1,600 | 1,175 | 28 | The distribution of EC measured in the field and in the laboratory indicates two modes; ~850 µS/cm and ~1,150 µS/cm. The inferred background groundwater EC is ~1,150 µS/cm. The ~850 µS/cm groundwater may be associated with mining dewatering of the CID aquifer and recharge with low salinity groundwater from the alluvial aquifer and / or rainfall. This is supported by statistically significant decreases in EC in several bores throughout the Yandi pits over time. Higher salinity measurements are generally associated with the western area of Yandi which may be because mining, dewatering and associated recharge with low salinity waters commenced in eastern and central areas first. |
| | Surface water | 95 - 530 | 150 | 9 | Surface water at Yandi appears to be associated with EC in the order of 150 µS/cm. |
| Nitrate (mg/L as $NO_3$) | Groundwater | <0.01 - 16 | 14 | 47 | Median background nitrate concentration in groundwater is around 14 mg/L as $NO_3$. Groundwater in pit bores has a median concentration of about 9 mg/L as $NO_3$ with a scatter of at least four orders of magnitude (0.03 mg/L to 240 mg/L). While some bores indicate significant upward or downward trends in nitrate concentration, the data do not suggest a site-wide increase in nitrate over time. |
| | Surface water | 02 - 6.3 | 1.7 | 9 | Background nitrate concentrations in surface water are estimated at less than 6.3 mg/L. Available data do not indicate elevated nitrate concentrations in Marillana Creek downstream of Yandi. |
| Boron (mg/L) | Groundwater | 0.11 - 0.55 | 0.43 | 24 | The data review generally indicates no significant temporal trends in boron concentration and considerable scatter in concentrations from <LOR to 0.91 mg/L. Exceedances of the boron site specific trigger value are distributed throughout the site. |
| | Surface water | <0.005 - 0.17 | 0.08 | 9 | Boron concentrations in surface water reference samples are lower than groundwater concentrations. Downstream boron samples in Marillana Creek show elevated boron concentrations prior to 2020 in a concentration range consistent with boron in background groundwater which suggests discharge of dewatered groundwater in the creek. |
| Zinc (mg/L) | Groundwater | <0.005 - 0.076 | 0.005 | 28 | While 164 of 617 (27%) measurements exceed the 95% SPL for zinc (0.008 mg/L), 368 measurements (60%) indicated zinc <LOR. Monitoring data indicate that exceedances of zinc guidelines are sporadic. Temporal trends in the data are generally poorly defined. Exceedances of the zinc 95% SPL are distributed throughout the site. Exceedances of the site-specific trigger value are limited to three locations in C3 (not mined) and one location in E7. |
| | Surface water | <0.005 | <0.005 | 9 | |
| Copper (mg/L) | Groundwater | <0.001 - 0.035 | 0.001 | 28 | Generally, exceedances of copper threshold values are sporadic and significant temporal trends are not apparent in the data. Spatially, copper exceedances are generally scattered throughout the site. A cluster of exceedances of the site-specific trigger value is apparent in the W4 Pit. However, these do not occur simultaneously and do not appear to be associated with meaningful temporal trends. |
| | Surface water | <0.001 - 0.002 | 0.001 | 9 | |
| Barium (mg/L) | Groundwater | 0.044 - 0.33 | 0.089 | 28 | Generally, no temporal trends in barium concentrations are apparent in the data. The exception is HYW0029P which shows a statistically significant decrease in barium concentrations over time. This may be related to dewatering. The few measured exceedances of the barium site specific trigger value appear to be mostly located in the W1 Pit. However, they do not occur simultaneously, and do not appear to be associated with meaningful temporal trends. |
| | Surface water | No data | No data | 0 | - |
| Iron (mg/L) | Groundwater | <0.005 - 23 | 0.05 | 28 | There are 36 exceedances (6% of measurements) of the iron site specific trigger value of 0.07 mg/L. None of these exceedances are associated with significant temporal trends in Marillana Creek or in groundwater. Spatially, iron exceedances are scattered throughout the site. No significant point sources of iron are apparent in the spatial data. |
| | Surface water | 0.005 - 0.77 | 0.028 | 9 | |

Source: adapted from Hydro Geochem Group (2022)

Notes: LOR - Limit of Reporting

**Source of impact**

ANFO explosive residue could be a diffuse source of impact on Yandi surface water and groundwater quality. Although individual blasting events are conducted in a relatively small area and might be considered a point source, these sources are widely dispersed throughout the site over the period of mining operations. Wind is also expected to disperse dust containing explosive residue. Nitrate and ammonium are easily flushed from the blasted rock, which can rapidly diffuse a water quality impact over a larger area (Hydro Geochem Group, 2022).

#### 5.9.3.4 Review of monitoring programs

Hydro Geochem Group (2022) identified several gaps in the Yandi water monitoring program in terms of the program's suitability to inform completion criteria and provide appropriate data post-mining to support completion reporting. These are summarised below:

- Groundwater:
  - There appears to be scope for extending the monitoring program to include additional upstream and downstream monitoring locations for the alluvial and Weeli Wolli aquifers. Recent downstream groundwater quality data is also required for the CID aquifer.
  - There are limited monitoring bores located in proximity to potential sources of post-closure solute loads.
  - There is a general lack of regularly-spaced monitoring events at consistent locations in the Yandi dataset. Sampling frequency is an important consideration for the evaluation of temporal trends.
  - The parameter list for groundwater samples generally includes the constituents of potential concern that are relevant to identified Yandi sources. However, not all parameters were measured for all samples.
- Surface water:
  - Continued monitoring of surface water will be required upstream of Yandi and upstream and downstream of the Marillana Creek discharge point.
  - There are no antimony, barium, cobalt, molybdenum, uranium, vanadium, or phosphorous analyses for surface water, and limited analyses for lead and tin.

Based on the gaps outlined above, Hydro Geochem Group (2022) made several recommendations for improvements to the groundwater and surface water monitoring quality programs. These are captured in Sections 5.9.3.5, 10.1.8 and 10.1.10.

#### 5.9.3.5 Knowledge gaps & forward work program

Key elements of the forward work program arising from the Hydro Geochem Group (2022) review of the Yandi water monitoring program are:

- Confirm reference bores for groundwater quality which between them represent all three main aquifers at Yandi (alluvial, CID, Weeli Wolli).
- Identify a set of bores for routine groundwater monitoring that acknowledge the linear source-pathway-receptor context of the site and will facilitate the validation of various modelling studies conducted to inform closure planning at Yandi.
- Analyse a consistent suite of parameters including missing or under-represented parameters in groundwater and / or surface water analyses (such as antimony, barium, cobalt, lead molybdenum, phosphorous, tin, uranium, vanadium and zinc). This can be rationalised over time to focus on key constituents of concern.

### 5.9.4 Ecohydrological receptors

Ecohydrology provides an understanding of relationships between hydrological regimes and ecosystems. An ecological asset which has a degree of regional water dependency is referred to as an ecohydrological receptor. An ecohydrological receptor might be sensitive to changes in regional groundwater and / or surface water. In contrast, ecological assets are defined as areas which do not have a regional water dependency, such as ecological systems which rely on direct rainfall or local perched aquifer systems away from mining areas and will not be affected by the mining activities.

**Summary**

Ecological receptors to activities at Yandi mine are outlined below

**Riparian vegetation communities of Marillana Creek and its major tributaries**

The riparian vegetation communities of Marillana Creek and its major tributaries are characterised by the presence / absence of the following overstorey species:

- *Melaleuca argentea* which requires permanently moist soil and occurs in areas with shallow groundwater.
- *Eucalyptus camaldulensis* subsp. *refulgens* and *E. victrix* which can use groundwater opportunistically when available but are capable of extracting water from moderately dry soils and can subsist on vadose zone water replenished by rainfall and floods.

In the natural creek system, zones of higher mature tree density (>20 trees/ha) occur on alluvial terraces, usually within 2 m elevation change from the invert level of the low flow channel and always within 3 m. The vegetation structure is strongly linked to the frequency and quantum of vadose-zone replenishment and groundwater recharge during overbank flow with high tree density (20 to 40 mature trees/ha) observed in channel areas within the 2-year AEP flooding zone, and low tree density (10 to 20 mature trees/ha) in floodplain areas above the 2-year AEP flooding zone.

Other factors affecting the establishment of riparian vegetation include:

- Plant available water within the alluvial profile. The volume of plant available water storage is greater where the alluvium is deep, providing a larger reservoir during protracted inter-flood periods.
- Shear stress. Areas with higher velocity flows, including some incised channel sections, appear to hinder the establishment and persistence of riparian trees. By way of contrast, in anabranching sections, trees are able to trigger the development of, and progressively colonise, the anabranch ridges.
- Persistent shallow groundwater. Mature *Melaleuca argentea* trees tend to cluster in areas where the alluvial aquifer overlies the CID. In these areas (in the absence of mining disturbance), the CID aquifer contributes to sustaining the alluvial aquifer during inter-flood periods.

**Persistent pools and riparian vegetation at Flat Rocks**

Persistent pools and riparian vegetation at Flat Rocks occur along a 2.5 km stretch of the Marillana Creek riverbed 1 km upstream of the Yandi development envelope. Stands of high value Melaleuca trees are supported by the groundwater in these areas. These pools could also potentially function as refugia for some aquatic fauna species during dry phases.

Tree health decline and deaths have been observed at tree health monitoring Site 8, where the groundwater level in the downstream intersection with the CID is much lower than the creek bed (due to dewatering) and, therefore, seasonal water availability to the trees in this area has been compromised. At the upstream intersection of the CID (near tree health Site 9), groundwater levels are much closer to the creek bed and, therefore, still support tree health through water availability. Tree health monitoring Site 7 is interpreted to lie between two intersections of the CID and, therefore, the impact of dewatering is limited by the topography of the base of the creek alluvium (surface of the Weeli Wolli Formation). Vegetation decline at Flat Rocks is being managed via the Marillana Creek Water Resource Management Plan, although any implications for closure will be incorporated into future iterations of the MCP, if required (Section 9.2.3.2).

**Other persistent pools**

A number of persistent pools occur in sections of the Marillana Creek which may support aquatic invertebrate assemblages. In times of high flow in Marillana Creek all pools are connected by the waterway. As flows decline, some depressions will retain water permanently or semi-permanently. Generally, pools in the upper reaches are driven by the geology and discharge from the underlying aquifer, and pools in the lower reaches by the presence of water in flat sections of the creek bed and rainfall. There are no natural pools present in the stretch of Marillana Creek downstream of the development area.

**Stygofauna habitat**

The shallow interconnected groundwater system provides habitat for a diverse stygofauna assemblage, however, no taxa, nor communities are listed or recognised as conservation priorities under state or federal legislation. Most species encountered are either widespread or have linear ranges >15 km, although eight species are currently only known from the Yandi development envelope (Section 5.7.5). The flooding regime and aquifer recharge processes linked to major flow events are likely to aid in broad scale stygofauna dispersal.

**Riparian vegetation communities within Yandicoogina Gorge**

Yandicoogina Gorge is a valley incised into the Hancock Range by the Yandicoogina Creek which is a tributary of Marillana Creek. Within the gorge, the groundwater appears to intercept the surface, forming a series of seeps and pools that extend for approximately 3.5 km. Numerous expressions of the groundwater can be seen throughout this section of the creek and groundwater dependent vegetation is present along its length. At least one permanent pool is present, which is likely maintained partially by aspect (against a cliff face), but is also likely groundwater fed. As discussed in Section 5.8, the gorge hosts vegetation associations with characteristics similar to the Priority 2 Pilbara Pools ecological community, although is not recognised as a confirmed PEC. It also supports a diverse range of aquatic fauna and provides habitat for conservation significant species including Ghost Bat and the Pilbara Flat-headed Blind Snake. The gorge is of cultural significance to Banjima Traditional Owners.

At a regional level, ecological assets are:

- Riparian vegetation and persistent pools associated with Marillana Creek.
- Riparian woodlands of Weeli Wolli Creek, downstream from the Marillana Creek confluence. In this area the alluvium is deep (tens of meters) and the depth to groundwater is greater. *Melaleuca argentea* does not naturally occur in this area and Eucalypt dominated vegetation communities are likely to be more dependent on surface water inputs.
- The integrated CID and alluvium groundwater system, which hosts a stygofauna community including several taxa not currently known outside the development envelope.
- The vegetation communities at Yandicoogina Gorge with affinity to the Priority 2 PEC Pilbara Pools communities.
- The Fortescue Marsh Priority 1 PEC. The ephemeral water body and diverse samphire dominated vegetation communities are dependent on the surface water regime. The Fortescue Marsh is a regionally important conservation asset with multiple ecological and cultural values.

Ecological receptors to activities at Yandi mine are (Map 5-27):

- The riparian vegetation communities of Marillana Creek and its major tributaries.
- Persistent pools and riparian vegetation at Flat Rocks.
- Other persistent pools.
- The groundwater system comprising stygofauna habitat.
- Riparian vegetation communities within Yandicoogina Gorge.

Sections 5.9.4.1 to 5.9.4.5 provide details of each receptor and, where relevant, ecohydrological conceptualisations.

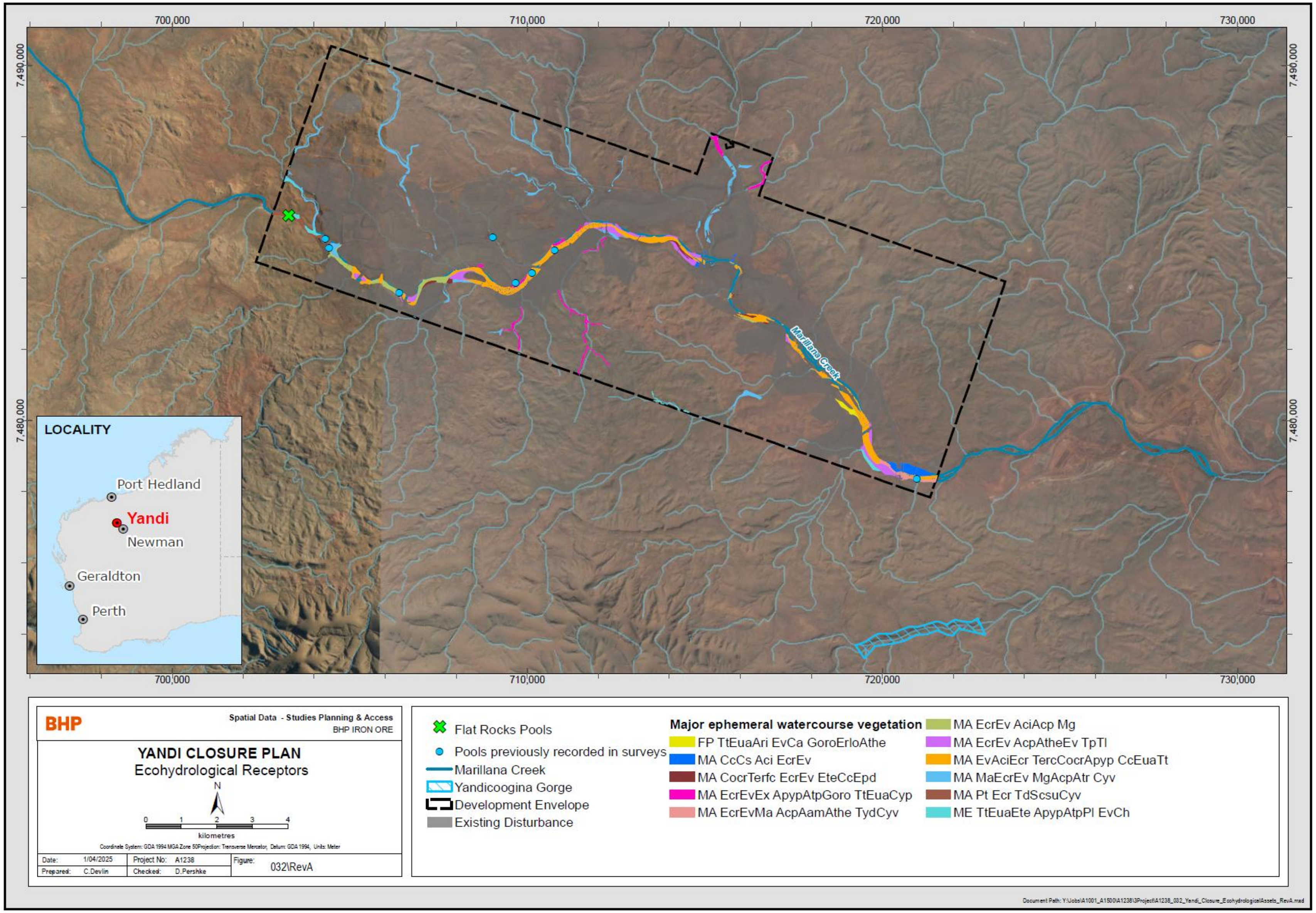
#### 5.9.4.1 Marillana Creek riparian vegetation

An ecohydrological conceptualisation of Marillana Creek is schematically depicted in Figure 5-32 and Figure 5-33. Areas where the river channel overlies the CID are distinguishable from areas where the channel is disjunct from the CID, as this has a controlling effect on ecological water availability. The major system elements include:

- The variably connected alluvial and CID groundwater systems.
- The unsaturated alluvium of the creek bed and floodplain (i.e. the vadose zone).
- The riparian woodland and open forest vegetation communities, characterised by the presence / absence of the following overstorey species:
  - *Melaleuca argentea* which requires permanently moist soil. In Marillana Creek it occurs in areas with shallow groundwater and is phreatophytic.
  - *Eucalyptus camaldulensis* subsp. *refulgens* and *E. Victrix* which can use groundwater opportunistically when available but are capable of extracting water from moderately dry soils and can subsist on vadose zone water replenished by rainfall and floods. Under prolonged drought conditions these species reduce canopy leaf density to regulate water use.

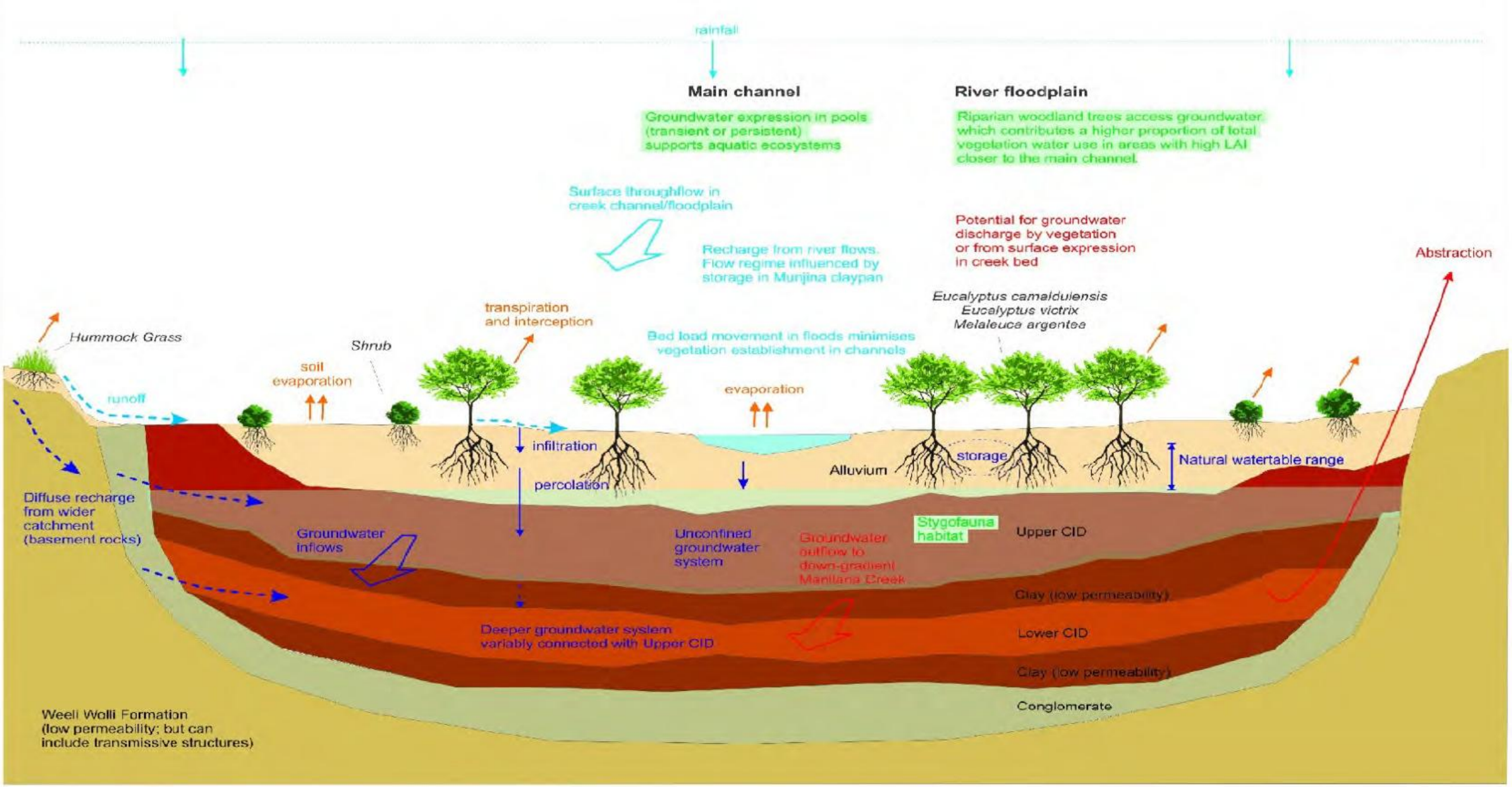
The key ecohydrological processes operating in Marillana Creek system are summarised as follows:

- Water replenishment in the Marillana Creek riparian system is from direct infiltration deriving from incident rainfall and infiltration from creek flow events. Both are influenced by natural climate variation, but locally, creek flow is also influenced by dewatering discharge from Yandi and RTIO’s Yandicoogina mine. This has resulted in a greater density of riparian vegetation in these areas.
- The alluvial aquifer is recharged principally by large creek flow events, which on average, occur about seven out of ten years (approximately 2-year AEP flood event). Recharge events are typically sufficient to fully replenish the aquifer and bring groundwater levels close to the surface, especially when rest water levels are less than 3 mbgl.



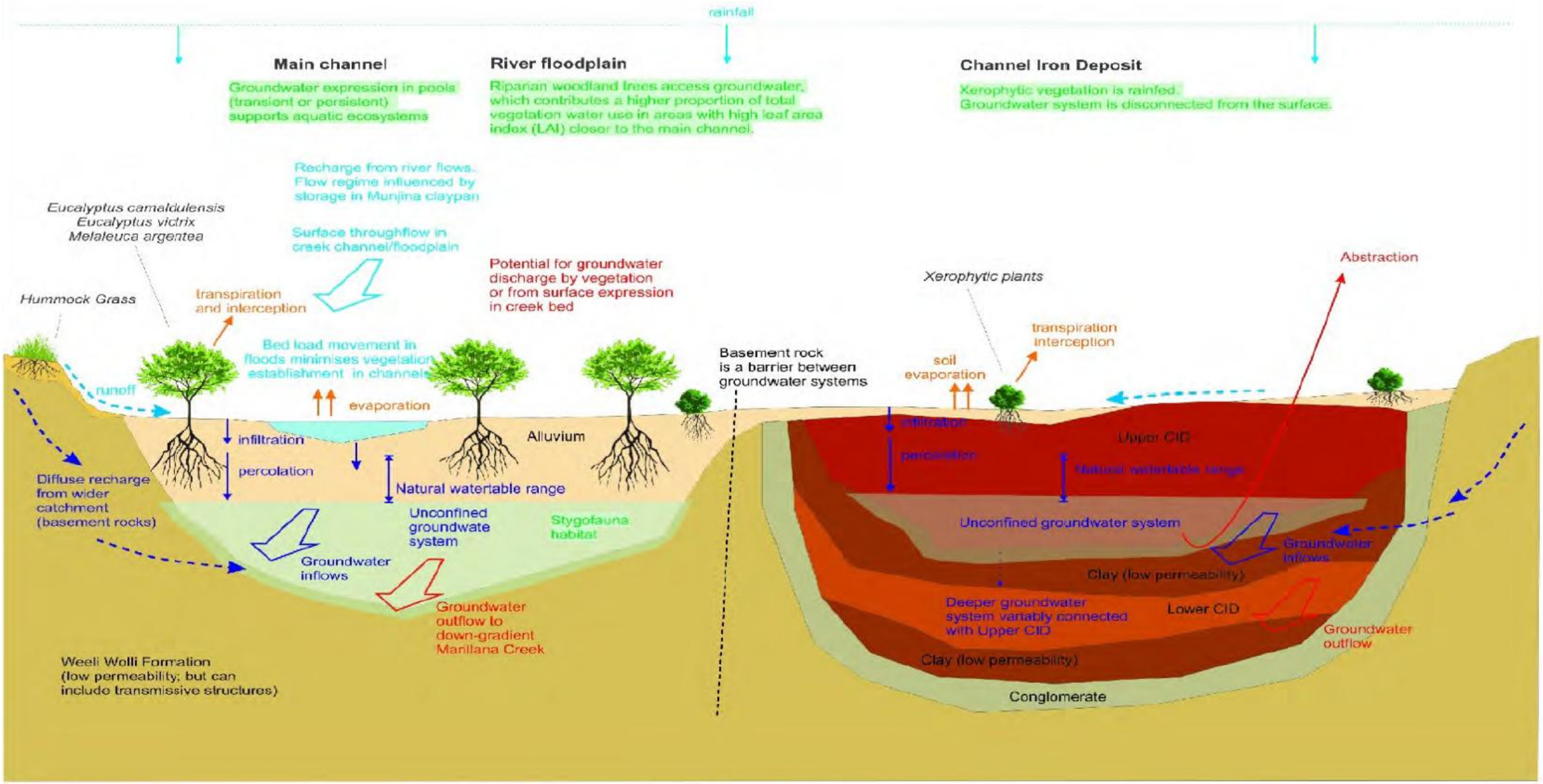

See Appendix Q for a pdf version of this map

**Map 5-27 Ecohydrological receptors**




Source: Golder (2015b)

**Figure 5-32 Ecohydrological conceptualisation for Marillana Creek where the river channel overlies the CID**




Source: Golder (2015b)

**Figure 5-33 Ecohydrological conceptualisation for Marillana Creek where the river channel is disjunct from the CID**

The amount of water storage is determined by the vadose-zone depth and physical properties of the alluvial sediments, which may vary over local scales. As part of the shallow aquifer design for the Marillana Creek diversion, AQ2 (2017) investigated the density and distribution of trees within Marillana Creek. In the natural creek system, zones of higher mature tree density (>20 trees/ha) occur on alluvial terraces, usually within 2 m elevation change from the invert level of the low flow channel and always within 3 m. Zones of high and low riparian mature tree density were delineated from aerial photograph interpretation assuming a mean basal area of mature trees of 0.20 $m^2$/tree which is broadly consistent with plot level observations (Onshore Environmental, 2015; AQ2, 2017):

- High tree density was observed in channel areas within the 2-year AEP flooding zone, supporting 20 to 40 mature trees/ha equating to a stand basal area range of 4 to 8 $m^2$/ha; and
- Low tree density in floodplain areas above the 2-year AEP flooding zone, supporting 10 to 20 mature trees/ha equating to a stand basal area range of 2 to 4 $m^2$/ha.

The vegetation structure is strongly linked to the frequency and quantum of vadose-zone replenishment and groundwater recharge during overbank flow. Where the channel is wide and flat, a larger area is inundated by flooding and the trees may occur over a wider area; however, this is not ubiquitous. Thus, topographic elevation (above the low flow channel) and the associated effect on inundation and recharge, is the major control on riparian tree distribution rather than channel width (AQ2, 2017).

Additional controls on riparian tree distribution identified in Marillana Creek include (AQ2, 2017):

- Plant available water within the alluvial profile. The volume of plant available water storage is greater where the alluvium is deep, providing a larger reservoir during protracted inter-flood periods. This may enable trees to maintain higher (less negative) leaf water potentials during droughts. Conversely, areas of very shallow alluvium are unable to support riparian tree species.
- Shear stress. Areas with higher velocity flows, including some incised channel sections, appear to hinder the establishment and persistence of riparian trees. By way of contrast, in anabranching sections, trees are able to trigger the development of, and progressively colonise, the anabranch ridges. Processes of tree establishment and senescence are dynamic, reach specific and mediated, in particular, by infrequent large-scale flooding events.
- Persistent shallow groundwater. *Melaleuca argentea* is not ubiquitous in riparian vegetation communities, with mature trees tending to cluster in areas where the alluvial aquifer overlies the CID. In these areas (in the absence of mining disturbance), the CID aquifer contributes to sustaining the alluvial aquifer during inter-flood periods. Thus, the root systems of trees in these areas may avoid exposure to extended periods of dry soil (in particular with matric potential below about -2,500 kPa).

#### 5.9.4.2 Persistent pools and riparian vegetation at Flat Rocks

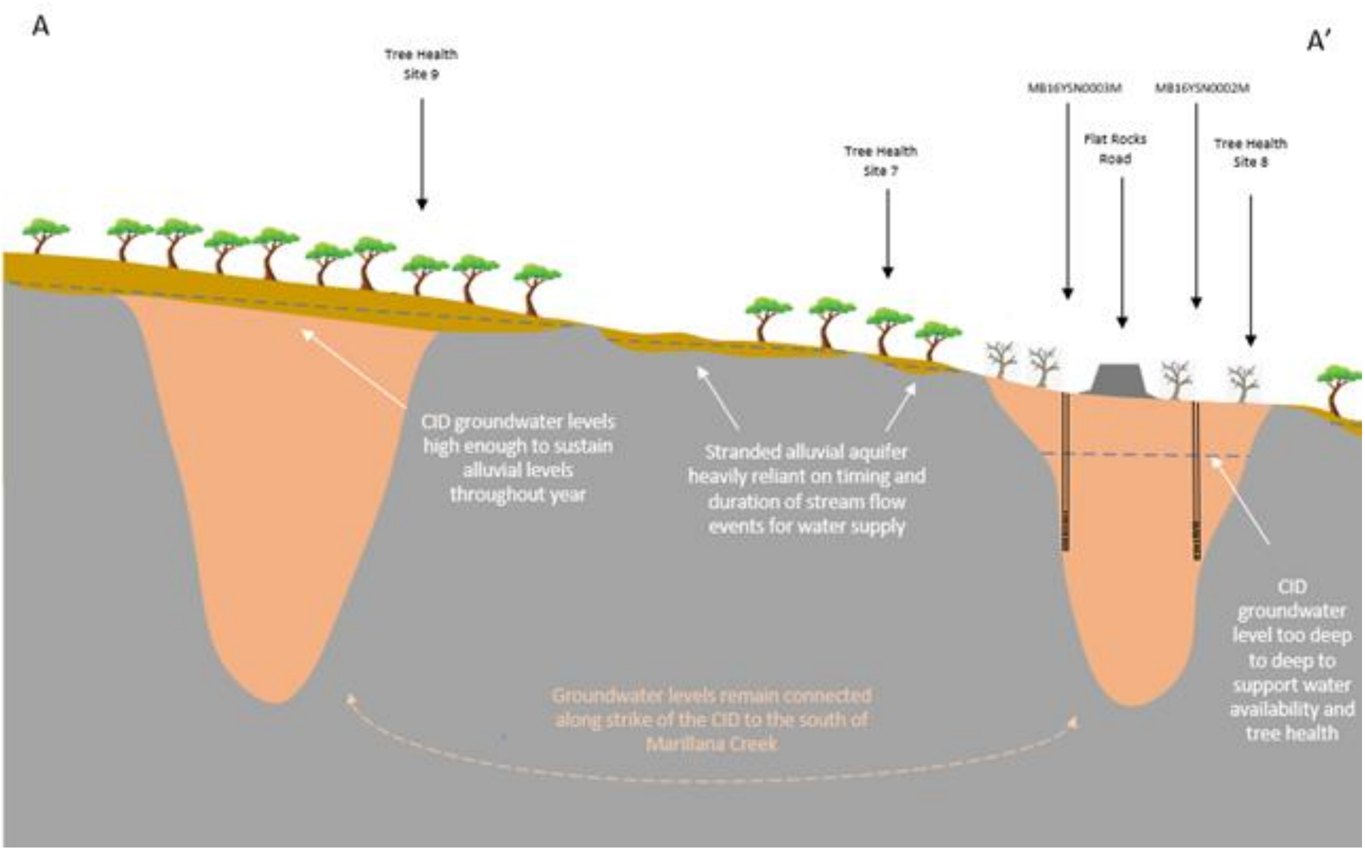
Several persistent pools, referred to collectively as Flat Rocks Pools occur along a 2.5 km stretch of the Marillana Creek riverbed 1 km upstream of the Yandi development envelope extending to downstream of Flat Rocks Road and the western side of BHP's existing Yandi operations (Map 5-27). The observed number of distinct pools has varied in reporting over biodiversity surveys and water monitoring, due to seasonal and temporal fluctuations of the hydrology of the pools. Stands of high value Melaleuca trees are supported by the groundwater in these areas and the geology is likely to be suitable for both stygofauna and troglofauna (BHP, 2022b; BHP, 2025). The pools are of cultural and archaeological significance to the Banjima people.

Tree health decline and deaths have been observed at tree health monitoring Site 8, where Flat Rocks Road crosses Marillana Creek. Groundwater drawdown has extended to this area. Groundwater monitoring shows that the groundwater level in the downstream intersection with the CID is much lower than the creek bed and therefore seasonal water availability to the trees in this area has been compromised (Figure 5-34) (BHP, 2022b; BHP, 2025).

Recent monitoring data indicate that groundwater levels at the upstream intersection of the CID (near tree health Site 9) are much closer to the creek bed and, therefore, still support tree health through water availability. This suggests that whilst dewatering of the W1 pits has caused groundwater level drawdown to extend to tree health monitoring Site 8, it has not reached Site 9 (Figure 5-34) (BHP, 2022b; BHP, 2025).

Tree health monitoring Site 7 is interpreted to lie between two intersections of the CID and, therefore, the impact of dewatering is limited by the topography of the base of the creek alluvium (surface of the Weeli Wolli Formation). Field observations along this area indicate that there are several bedrock outcrops within the creek bed which act to interrupt the continuity of groundwater flow along the creek alluvium. These bedrock outcrops effectively result in the intermittent 'damming; of groundwater which prevents it from being drawn into the adjacent dewatered CID and therefore is allowed to persist for much longer periods following rain events. This area is, therefore, heavily dependent on rainfall and streamflow to maintain water availability for riparian vegetation and is unlikely to be impacted by the continued decline in groundwater levels beneath the downstream crossing with the CID (Figure 5-34) (BHP, 2022b).

The tree health decline is being managed via the Marillana Creek Water Resource Management Plan. Should investigations conducted in accordance with the plan identify any long-term measures that need to be implemented for closure, these will be incorporated into future iterations of the MCP (Section 9.2.3.2)




Source: BHP (2022b)

**Figure 5-34 Flat Rocks conceptual ecohydrological model**

### 5.9.4.3 Other persistent pools

A number of other persistent pools occur in sections of the Marillana Creek which may support aquatic invertebrate assemblages. In times of high flow in Marillana Creek all pools are connected by the waterway. As flows decline, some depressions will retain water permanently or semi-permanently. The presence and extent of water in pools is influenced by several factors to differing degrees depending on location including:

- Rainfall and associated creek flow;
- Geomorphology and grade of the creek bed; and
- Interactions with underlying aquifers (CID, alluvial and calcrete sections).

Generally, pools in the upper reaches are driven by the geology and discharge from the underlying aquifer, and pools in the lower reaches by the presence of water in flat sections of the creek bed and rainfall. There are no natural pools present in the stretch of Marillana Creek downstream of the development area. An artificial pool is located immediately north of the proposed E8 Pit due to the discharge of surplus water from the site.

### 5.9.4.4 Groundwater system containing stygofauna habitat

The shallow interconnected groundwater system provides habitat for a diverse stygofauna assemblage, however, no taxa, nor communities are listed or recognised as conservation priorities under State or Federal legislation. Most species encountered are either widespread or have linear ranges that extend outside the development envelope, although six species are currently only known from the groundwater drawdown area (Section 5.7.5).

Dewatering and mining of the CID (as approved via Part IV EP Act processes) results in the removal of stygofauna habitat in localised areas. However, despite the observed groundwater drawdown throughout the development envelope, a rich stygofauna assemblage continues to persist with at least 35 species having been recently recorded. Stygofauna habitat modelling in the Eastern mining area of Yandi indicates that CID habitat persists around the pit shells and under the benches and consequently, habitat is well connected through this area (BHP, 2025). As groundwater levels recover post-mining, it is, therefore, expected that species will gradually recolonise previous habitat outside of mine voids but within groundwater drawdown areas from the surrounding Marillana catchment. Some stygobitic taxa are sensitive to water salinity and may be negatively impacted by changes in water quality in the CID between pits.

The current closure designs aim to preserve flows in Marillana Creek which regularly recharge the alluvium and CID providing habitat for stygofauna. The flooding regime and aquifer recharge processes linked to major flow events are likely to aid in broad scale stygofauna dispersal.

The closure of Yandi provides the opportunity to investigate the extent to which stygofauna and troglofauna might recolonise backfilled pits, and the influence of water quality on these communities.

#### 5.9.4.5 Yandicoogina Gorge

Yandicoogina Gorge is a valley incised into the Hancock Range by the Yandicoogina Creek which is a tributary of Marillana Creek. Within the gorge, the groundwater appears to intercept the surface, forming a series of seeps and pools that extend for approximately 3.5 km. Numerous expressions of the groundwater can be seen throughout this section of the creek and groundwater dependent vegetation is present along its length. At least one permanent pool is present, which is likely maintained partially by aspect (against a cliff face), but is also likely groundwater fed.

The gorge is of cultural significance to the Banjima people and, as discussed in Section 5.8, the gorge hosts vegetation associations with characteristics similar to the Priority 2 Pilbara Pools ecological community. It also supports a diverse range of aquatic fauna including troglofauna and a relatively high percentage of stygobitic taxa compared to other hyporheic zones in the Pilbara (Section 5.7.4.2).

The gorge supports major drainage line and gorge / gully fauna habitats and at least four potentially suitable Ghost Bat caves have been recorded within gorge / gully habitat associated with Yandicoogina Creek. Evidence of the Ghost Bat (scats) has been recorded in caves in proximity to Yandicoogina Gorge and it is likely that the species utilises the gorge for foraging, with habitats present likely to represent critical habitat. The gorge also provides suitable habitat for a number of Priority listed species such as the Pilbara Flat-headed Blind Snake (*Anilios ganei*) which has previously been recorded in the gorge, as well as providing habitat for migratory birds.

Monitoring of the pools in Yandicoogina Creek in the 2019 dry season and 2020 wet season indicated that the water quality within the pools was generally good and characterised by fresh (355 mg/L to 425 mg/L TDS), clear waters, with low dissolved oxygen saturation, neutral pH (6.8 - 7.7) and generally low dissolved metals concentrations (Appendix E.4). A number of water quality characteristics confirmed the connection of the pools with groundwater, including ionic composition dominated by calcium cations and hydrogen carbonate anions, as well as a lack of seasonal variation in EC.

#### 5.9.4.6 Knowledge gaps & forward work program

The closure of pits at Yandi may present an opportunity to monitor subterranean fauna colonisation of backfilled pit areas post-closure.

## 5.10 Site contamination

There are a number of suspected contaminated targets at Yandi (Table 5-43 and Map 5-28), which are managed in accordance with BHP's contaminated sites management practices and the CS Act. An inspection schedule is maintained across site for inspection of these targets on a periodic basis (the frequency determined by risk posed) and the contamination is controlled. The management and investigation of these targets is based on risk and timing for decommissioning of infrastructure.

**Table 5-43 Suspected contaminated targets**

| Location | | Potential Contaminants | Comments / Status |
|---|---|---|---|
| YN01 | Eastern Workshops and Associated Facilities | Hydrocarbons and PFAS | Last investigated in 2023. Detailed Site Investigation (DSI) planned for 2025 to close residual data gaps. |
| YN02 | Eastern Washdown bay and Evaporation Pond | Hydrocarbons and PFAS | Last investigated in 2023. DSI planned for 2025 to close residual data gaps. |
| YN03 | Eastern Fuel Farm | Hydrocarbons and PFAS | DSI completed in 2022 and site management plan developed in 2023. |
| YN04 | Power Station | Hydrocarbons and PFAS | DSI completed in 2022. Site identified as low risk. |
| YN05 | Mobile equipment workshop | Hydrocarbons and PFAS | Last investigation completed in 2023. DSI planned for 2025 to close residual data gaps. |
| YN06 | Central workshops and associated facilities | Hydrocarbons and PFAS | DSI completed in 2022 and site management plan developed in 2023. |
| YN08 | Putrescible landfill | Leachate | Site is considered low risk. |
| YN09 | Land farm eastern and central | Hydrocarbons and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN10 | Sewerage irrigation areas - Yandi and Marillana | Sewage and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN11 | Fibrous materials | Asbestos | Potential asbestos forming material in overburden - identified at several locations within mining lease. |
| YN12 | AN facility | Ammonium nitrate | Site is considered low risk. |
| YN13 | Sewerage ponds - Spinifex | Sewage and PFAS | Preliminary PFAS investigation in 2023. Site identified as low risk. |
| YN14 | OHP 3 OWW retention ponds | Hydrocarbons and PFAS | Preliminary PFAS investigation in 2023. Site identified as low risk. |

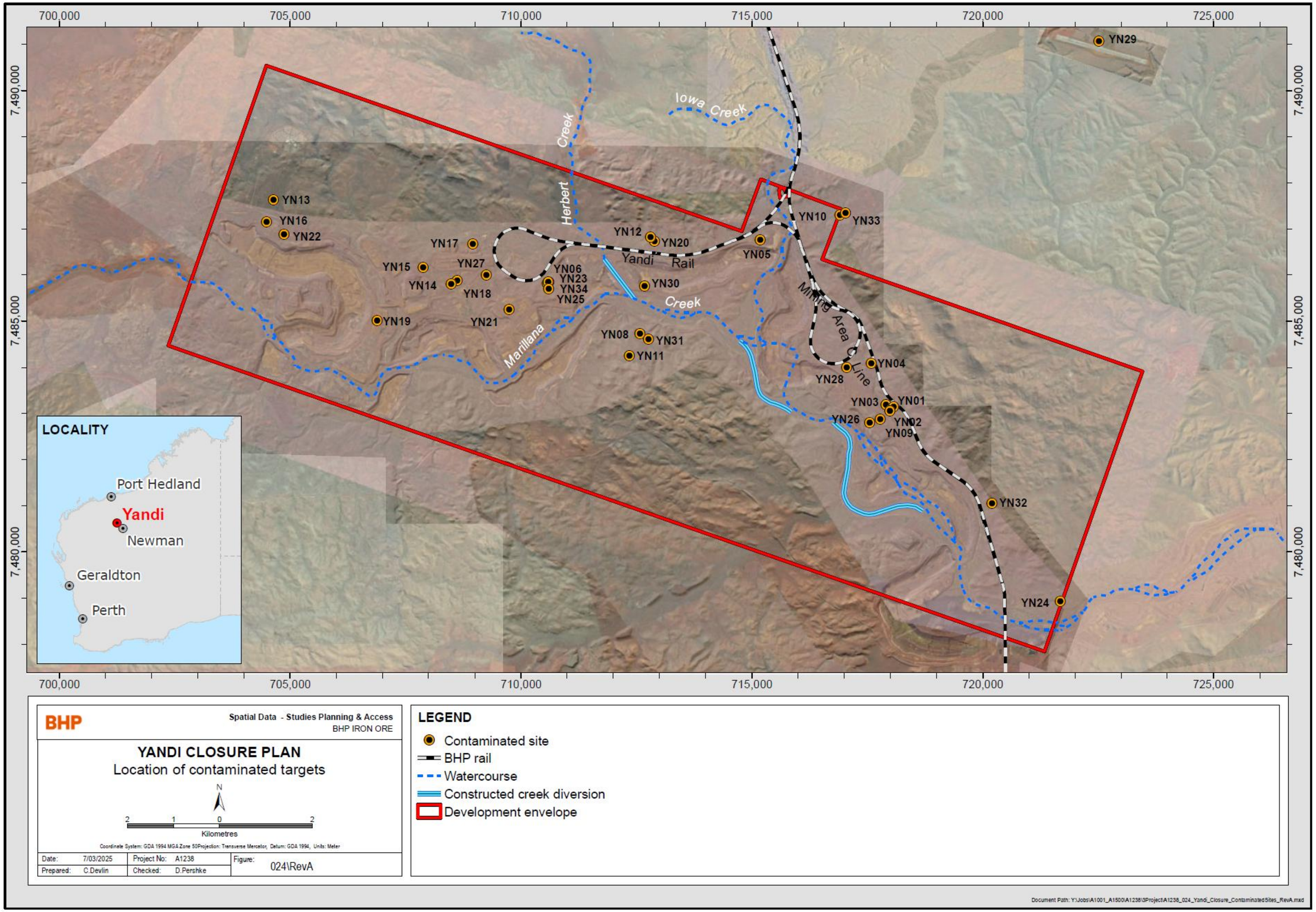
| Location | | Potential Contaminants | Comments / Status |
|---|---|---|---|
| YN15 | OHP 3 WWTP evaporation ponds | Sewage and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN16 | Landfill | Hydrocarbons and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN17 | Batch Plant Bulk Diesel | Hydrocarbons | Site is considered low risk. |
| YN18 | Western workshop and associated facilities | Hydrocarbons and PFAS | Last investigation completed in 2023. DSI planned for 2025 to close residual data gaps. |
| YN19 | Western 4 fuel pod | Hydrocarbons | Site is considered low risk. |
| YN20 | AN facility fuel pod | Hydrocarbons | Site is considered low risk. |
| YN21 | Y2 fuel pod | Hydrocarbons | Site is considered low risk. |
| YN22 | Western 1 fuel pod | Hydrocarbons | Site is considered low risk. |
| YN23 | Western 6 fuel pod | Hydrocarbons | Site is considered low risk. |
| YN24 | Sewerage irrigation area | Sewage and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN25 | Land farm central | Hydrocarbons and PFAS | Last investigated in 2023. DSI planned for 2025 to close residual data gaps. |
| YN26 | E2 Inert Dump (Rubber) | Inert | Site is considered low risk. |
| YN27 | Fixed plant maintenance OWW pond | Hydrocarbons and PFAS | Last investigation in 2023. Site identified as low risk. |
| YN28 | Eastern Crib Hut Fuel Bowser | Hydrocarbons and PFAS | Site is considered low risk. |
| YN29 | Barimunya airport | PFAS | Last investigation in 2023. DSI planned for 2025 to close residual data gaps. |
| YN30 | Central 1 bench fire training area | PFAS | Last investigation in 2023. DSI planned for 2025 to close residual data gaps. |
| YN31 | Central 1 OSA fire training area | PFAS | Last investigation in 2023. Site identified as low risk. |
| YN32 | Flat Rocks Road fire training area | PFAS | Last investigation in 2023. DSI planned for 2025 to close residual data gaps. |
| YN33 | Yandi Camp fire training area | PFAS | Last investigation in 2023. DSI planned for 2025 to close residual data gaps. |
| YN34 | Central bunded storage area | Hydrocarbons and PFAS | Site is considered low risk. |

Notes: PFAS - per- and poly-fluoroalkyl substances

Should any further suspected contaminated targets be identified in future, investigation will be prioritised in accordance with risk, as discussed with the DWER.

### 5.10.1 Knowledge gaps & forward work program

As closure planning progresses, detailed site investigations will be progressively carried out in accordance with the timeframes outlined in Table 5-43 to determine optimum management and remediation programs for contaminated sites.




See Appendix Q for a pdf version of this map

**Map 5-28 Location of suspected contamination targets**

## 5.11 Visual amenity

A landscape and visual impact assessment conducted by GHD and 360 Environmental (2015) concluded that there are limited sites within the Yandi area that represent key viewpoints. The region is largely undeveloped and primarily used for pastoral purposes, mining, and some transport (via the rail access road being used as an alternate route to the Great Northern Highway). No areas were found during the study where there was a significant risk of visual amenity impacts. The only viewpoint identified during the study with relevance to the Yandi mining operation was Munjina Water Hole which is located within the Marillana Creek upstream of the Yandi mine.

It should be noted that the GHD and 360 Environmental (2015) review focused on viewpoints that are readily accessible to the public and did not specifically consider landscape views relevant or significant to the Banjima People. Further work is required to consider visual impacts in a closure context and aspects of importance to the Banjima People.

Since the GHD and 360 Environmental study, Golder (2020b) identified The Three Sisters as a potentially sensitive viewpoint. This is a hill which lies approximately 4 km to the east of Yandi and is a site of ethnographic significance.

### 5.11.1 Knowledge gaps & forward work program

The GHD and 360 Environmental study (2015) did not specifically consider landscape views relevant or significant to the Banjima People. Consultation with the Banjima People is ongoing and includes consideration of the visual characteristics of landform designs.

## 5.12 Cultural heritage & values

**Summary**

Comprehensive archaeological and ethnographic surveys have been undertaken over Yandi and BHP is aware of the location and extent of all known Aboriginal heritage sites within the footprint covered by the closure plan. Protection and management of heritage sites is conducted in compliance with relevant legislation.

A review of the *Banjima Yurlubajagu Strategic Plan* and consultation with BNTAC and the Banjima people has identified the following values / issues of importance to the Banjima people in the closure of Yandi:

- Water is of key significance. Surface water flows should be maintained and Banjima people have expressed a clear preference for the avoidance of permanent pit lakes at closure and, in particular, oppose saline pit lakes. However, where there is surface water in pits, the Banjima people expressed a preference for seasonal fresh water and the ability to access these areas. Rehabilitation of Flat Rock Spring and Yandicoogina Gorge / Marillana Creek to return water and biodiversity to these culturally significant places is important.
- Ability to introduce appropriate fire regimes to produce a mosaic of unburnt and burnt patches that protect cultural heritage places, bring fresh plants and replenish food and medicines on-Country.
- Access to Country.
- Protection of cultural assets. Heritage values extend beyond discrete identified heritage places and are embedded in a combination of values which come together to form a landscape.
- Plants and animals of cultural significance. A request has been made for plant species of cultural significance (bush tucker and medicinal plants) to be documented and used in rehabilitation seed mixes.
- Infrastructure no longer in use should be removed and the land rehabilitated.
- Where possible pit walls should have flat / smooth gradients.

### 5.12.1 Heritage

Comprehensive archaeological and ethnographic surveys have been undertaken over Yandi. The Banjima people have worked with BHP for over 40 years on identifying and managing cultural heritage and cultural values. As a result of the surveys, heritage sites have been recorded at different locations within the Yandi lease. Out of respect for the wishes of Traditional Owners, the locations of the recorded Aboriginal heritage sites are not shown in this closure plan.

BHP is aware of the location and extent of all known Aboriginal heritage sites within the footprint covered by the closure plan and manages and protects Aboriginal heritage in compliance with relevant legislation.

### 5.12.2 Values

Information in this section has been drawn from:

- Publicly available information.
- Various surveys conducted over the life of the Yandi mine (refer to BHP (2025)) during which the Banjima people have shared their deep knowledge of the ecological, cultural and spiritual nature of the Yandi landscape gained over tens of thousands of years of occupation. These surveys have been captured in a variety of reports, several of which are confidential.
- Consultation with BNTAC and Banjima people in relation to closure plans for Yandi.

Noting the confidential nature of several reports and potential sensitivities with publicly sharing cultural information, this section briefly summarises key points arising from engagements and publicly available information. As discussed in Section 4, consultation with the BNTAC and the Banjima people on closure outcomes is ongoing and will inform the refinement of closure approaches and designs.

Banjima cultural values identified from a review of the *Banjima Yurlubajagu Strategic Plan* (BNTAC, 2019) include:

- **Water.**
  - It is an important cultural responsibility to keep water in Country pure.
  - Permanent water (*yinda),* which is otherwise scarce in the region, is of particular importance and *yinda* water and gorge springs are culturally significant places of the highest order. Milimbirinha is an important *yinda* where Wirlawali (Weeli Wolli Creek) meets the Manggurdu (Fortescue River and floodplain) and from where that water goes underground to Jindawirrinha (Millstream). Banjima believe that if the Milimbirinha is harmed the water would dry up.
  - An important cultural responsibility is for Banjima to protect Manggurdu (Fortescue River and floodplain) health, condition, water flows, *yinda* waters and gorge springs which connect saltwater people, freshwater people and red water (claypan) people, including the Martu desert people to the east with Nyiyaparli, Banjima and Yindjibarndi.
  - Jilbana means places where food can grow strong on Banjima country. Jilbanas are known to flourish around the *yindas* and throughout Karijini.
- **Fire.** Appropriate fire regimes are important to produce a mosaic of unburnt and burnt patches that protect cultural heritage places, bring fresh plants and replenish food and medicines on-Country.
- **Access to Country** is critical to enable Banjima people to manage Country and maintain culture.
- **Cultural assets**. Throughout the Fortescue catchment, there are cultural assets such as middens, burial sites, petroglyphs, medicinal plants, fishing and food gathering sites and lore grounds.
- **Plants and animals of cultural significance.** The *Banjima Yurlubajagu Strategic Plan* identifies several plants of cultural significance which are listed in Appendix I.2 along with information from BHP's internal ethnobotanical database. Animals of cultural significance identified in the strategic plan are outlined in Table 5-44 along with their Latin names where these have been identified from social surrounds engagements.

**Table 5-44 Animals of importance to Banjima people**

| Banjima name | Translation / common name | Latin name |
|---|---|---|
| *Bardagurra or thurrgi* | Bush turkey / Australian bustard | *Ardeotis australis* |
| *Garlaya* | Emu | *Dromaius novaehollandiae* |
| *Gangguru*, *birrunmarra* | Types of kangaroo | - |
| *Bajarri* | Hill kangaroo | - |
| *Bajiwanarra / barlgarranyungu* | Euro | *Macropus robustus* |
| *Yujurli*, *gurrumanthu* | Goanna | *Varanus* spp. |
| *Gardandarri* | Ducks | - |
| *Gulhamba* | Freshwater perch | - |
| - | Native honeybee | *Trigona* and *Austroplebeia spp*. |

Source: BNTAC (2019); BHP (2025)

The values outlined in the *Banjima Yurlubajagu Strategic Plan* were echoed in engagements with BNTAC and the Banjima people during social surrounds engagements and those focused on the Yandi closure plans. Values articulated during these engagements include:

- Heritage values extend beyond discrete identified heritage and ethnographic places and are connected by songlines and cultural access pathways embedded in a combination of values which come together to form a landscape.
- Water is the life blood of the land, and the essential life force of the Banjima people themselves. All underground, surface and ephemeral waterways are equally important and anything that impedes the warlu's (water serpent creation ancestor) movement through Country is dangerous to the Country and the Banjima people. The Banjima people have a very keen sense of their cultural responsibility to maintain the Fortescue River system, including its tributaries, to ensure lore and culture are maintained. They also have a responsibility to neighbouring groups, to ensure no detrimental impacts on neighbouring groups downstream. The Banjima people have expressed a clear preference for the avoidance of pit lakes at closure and, in particular, oppose saline pit lakes. However, where there is surface water in pits, the Banjima people expressed a preference for seasonal fresh water and the ability to access these areas.
- Flat Rocks, Yandicoogina Gorge and Marillana Creek are culturally important places and rehabilitation of Flat Rock Spring and Yandicoogina Gorge / Marillana Creek to return water and biodiversity to these places is important.
- Caring for plants and animals is part of the Banjima's role and responsibility as Traditional Owners. A request has been made for plant species of cultural significance (bush tucker and medicinal plants) to be documented and used in rehabilitation seed mixes (refer to Appendices I.1 and I.2).
- The closed landform should be natural looking and safe for people and animals.

- Infrastructure no longer in use should be removed and the land rehabilitated.

BNTAC recently (late March 2025) provided BHP with a copy of the Banjima Mine Closure Objective, Principles and Outcomes (Table 4-2, Section 4.3). The objective, principles and outcomes will inform future discussions and updates to the MCP.

The Banjima People have expressed a strong interest in rehabilitation and environmental monitoring. BHP is committed to working with the relevant Traditional Owners to investigate how they might be engaged in rehabilitation and land management and monitoring activities.

### 5.12.3 Knowledge gaps & forward work program

The forward work program includes ongoing engagement with BNTAC and the Banjima people on closure designs and outcomes for Yandi including repatriation of cultural artefacts, songlines and safe access post-closure.

## 5.13 Local land use

Mining and pastoral activities are the main land uses in the Yandi area. BHP operates the Yandi and Mining Area C / South Flank mines in this area and RTIO operates the nearby Yandicoogina mine. There is some tourism in the region, with the Karijini National Park located approximately 50 km to the east of Yandi and the Warlu Way (a 400 km driving trail connecting the coast to Newman) passing within 50 km of the mine.

The current land use for areas not directly affected by mining in the vicinity of Yandi operations area is low intensity grazing on areas of pastoral lease.

The mine itself is located on the land of the Banjima People (Section 3.3.3) who have historically used this area for a range of traditional uses and continue to do so.

### 5.13.1 Knowledge gaps & forward work program

No knowledge gaps have been identified.

## 5.14 Design option studies and analyses

Several design studies have been progressed since the 2020 MCP and have informed the closure approaches and designs presented in Section 9 of this MCP. The outcomes of the studies are summarised in this section along with information arising from some studies reported in the 2020 MCP. Design processes are iterative and while studies have progressed, there are still knowledge gaps to address, including further consultation with BNTAC and the Banjima people. These knowledge gaps have been captured in the forward work program outlined in Section 13.3.

The information in this section represents a snapshot in time and some of the studies discussed below were progressed concurrently or have not yet been updated to reflect the findings of other studies. Future design processes will address outstanding knowledge gaps and optimise designs to integrate the findings of all studies. The studies outlined in this section include:

- An evaluation of mine void backfill options (Section 5.14.1).
- Processes followed to develop the backfill design outlined in Section 9.2.3.1 (Section 5.14.2).
- Pit lake water quality hydrogeochemical modelling (Section 5.14.3).
- An assessment of the potential impacts associated with a controlled release of pit lake water from W4 Pit to Marillana Creek (Section 5.14.4).
- An initial review of the potential for density driven flow from permanent pit lakes (Section 5.14.5).
- An initial pit lake risk assessment which informed the backfill option selection process (Section 5.14.6).
- Further optimisation of flood channel locations and designs, based on hydraulic modelling and geotechnical assessments (Section 5.14.7).
- Further investigation of flood bund designs and development of floodplain landform concepts (Section 5.14.8).
- Further investigation of minor and intermediate diversions and update of designs (Section 5.14.9).
- An assessment of the performance of Herbert's Creek land bridge to gain an understanding of the upgrades that may be required for closure. This included landform evolution modelling to determine the long term erosional stability of the landform (Section 5.14.10).
- An assessment of mine void stabilisation options (Section 5.14.11).
- A preliminary materials balance based on the outcomes of the other design studies (Section 5.14.12).
- A sustainable yield assessment to provide an indication of the amount of water that may be available from mine voids to support a post-mining land use (Section 5.14.13).

### 5.14.1 Mine void backfill option evaluation

As originally outlined in the 2016 MCP, there is insufficient overburden at Yandi to backfill all the mine voids to 5 m above the water table. BHP has, therefore, been conducting studies to evaluate different closure options for the mine voids to optimise closure outcomes since 2015. The studies have been progressively refined over time to incorporate new information and mine plans. A GoldSim model (Section 5.14.1.3) has been used to model pit lake water balances under different backfill scenarios. This process has been iterative, and several different combinations of backfill and model input parameters have been assessed over time. Section 5.14.1.1 provides a brief history of the studies and the key decisions leading to the currently preferred backfill alternative (Section 9.2.3.1), noting that the backfill strategy is under review following the outcomes of consultation with the Banjima people (Section 4.3) and changes to the mine plan. Sections 5.14.1.2, 5.14.1.3 and 5.14.1.4 summarise the evaluation framework for backfill option assessment, the backfill / pit lake modelling approach and model outputs, respectively. Section 5.14.1.5 outlines the remaining knowledge gaps and forward work program.

**Summary**

The modelling reported in the 2020 MCP was for two backfill scenarios and a reference case (assuming no backfill):

- A three-sink model with sinks at W1, C4/5 and E7.
- A four-sink model with sinks at W4, W5, C4/5 and E7.

Further to the 2020 model, a pit lake risk assessment was conducted (Section 5.14.6.4) which identified that it would be preferential to backfill W4. There was also a preference to maintain backfill in W5 to support a land bridge to be used for future transport of ore from satellite mines. Modelling was, therefore, conducted of two additional scenarios:

- Sinks at W2, W3, C4/5 and E7 (Scenario B).
- Sinks at W1, C4/5 and E7 (Scenario C).

An evaluation of Scenarios B and C concluded that Scenario B was more favourable because:

- The footprint of hyper-salinity in the landscape is almost half that of Scenario C.
- Backfilling of W1:
  - Reduces the hydraulic gradient and drawdown at the areas of riparian vegetation at Flat Rocks.
  - Eliminates the potential for mixing of permanent (evapo-concentrated) pit lake water with freshwater discharged through the W1-SP0 flood channel into the pit, and reduces the salt load discharged to W4 Pit.
  - Reduces the risk of geotechnical failure associated with the flood channels.

Subsequent to this work, BHP and RTIO explored the potential to mine the pillar of CID between the E7 and Mungadoo pits to create a single mine void. The combined water balance model for this work resulted in a predicted water level at E7 significantly lower (in the order of 15 - 20 m) than previously predicted (with and without the CID pillar). This resulted in an adjustment to the assumed downstream water levels at the boundary of the Yandi model which was incorporated into the most recent modelling by AQ2 (2024). The modelling also concluded that when the pillar of CID is removed, the salinity in E7 increases due to the higher salinity of the Mungadoo Pit which is influenced by the significant amount of surface water runoff (and associated salinity) from the external catchment area reporting to the pit. The salinity / water level classifications of the remaining RTIO and BHP pits were unaffected.

Modelling for Scenario B.1 (sinks at W2, W3, C4/5 and E7, and the salinity at all other pits of ≤4,000 mg/L) was updated by AQ2 (2024) and included:

- C6 Pit (which was previously excluded from modelling).
- Revised pit shells based on updated mine planning data.
- A revised assumption for the downstream water levels in the RTIO Mungadoo Pit based on the joint BHP / RTIO modelling.

This concluded:

- The addition of the C6 Pit to the assessment did not cause any significant impacts to the predicted results.
- If the backfill permeability is:
  - Lower than the modelled base case (1 m/d instead of 3 m/d) ~14% more backfill would be required.
  - Higher than the modelled base case (8.2 m/d) ~15% less backfill would be required.
- Neither the wet nor dry climate change scenarios resulted in changes to the salinity classifications of the pits, although it was noted that the wet scenario (8% increase in rainfall and 7 % increase in evaporation) generally resulted in greater salt concentrations in the pits than the base case model.

To date, the proposed E8 Pit has not been incorporated into the GoldSim model, but current plans are to backfill the pit to above the water table (Section 9.2.3.1), and this would be expected to result in a minimal net impact to groundwater levels in this location (i.e., post-closure groundwater levels would be influenced by other pits rather than E8).

During the various different iterations of the model, several sensitivity analyses have been conducted and have concluded that the model is most sensitive to:

- Assumed hydraulic conductivity values for the backfill. More permeable backfill generally reduces the average predicted water levels and salinity along the mine path. Since the 2020 MCP, an analysis of the permeability of backfill values has been conducted (Section 5.2.4.3) and the results incorporated into the 2022 and 2024 modelling.
- Increased rainfall as, while rainfall is a low salinity input:
  - Additional water inputs to the pits also results in an increased salt load. The associated higher salt mass can lead to higher salinity when evaporation / evapotranspiration removes water from the system but leaves salt behind.
  - The constraints on the amount of salinity that can leave the mine path through groundwater outflows and over topping do not change.

Further modelling will be conducted to inform the refinement of the backfill strategy, as required.

#### 5.14.1.1 Study history

In 2016, water balance modelling was conducted to determine the backfill levels required at Yandi to enable a throughflow system to be re-established. This modelling concluded that there was insufficient overburden to backfill each pit to above the recovered water level and consequently, pit backfill would need to be prioritised to optimise pit lake water quality outcomes across the mine. It was also established that RTIO's Mungadoo Pit (adjacent to E7 Pit) would be a long-term saline pit lake post-closure as RTIO also has insufficient material to backfill its entire Yandicoogina mine to above the recovered water table (Rio Tinto, 2014). The pit lake in Mungadoo, would inhibit movement of any groundwater flows from Yandi beyond this pit and consequently, a decision was made that groundwater throughflow off-tenement would add very little benefit to the overall outcomes to be achieved in closure. This decision was also informed by the following considerations:

- The higher importance of surface water flow to Fortescue Marsh compared to groundwater contribution. As discussed in Sections 5.9.1.2 and 5.9.2.6, groundwater inflows to Fortescue Marsh are negligible and consequently the marsh ecosystem is reliant on surface water inputs.
- The significant role that surface water plays in recharging the alluvial aquifer of the Marillana Creek system during flood events and supporting riparian vegetation (Section 5.9.2.5).
- A focus on achieving groundwater throughflow when there is insufficient backfill would involve diverting additional surface water to the pits which would reduce the amount of water available to recharge the Marillana Creek alluvial aquifer and Fortescue Marsh.

Subsequent studies have, therefore, focused on refining the backfill strategy to optimise the mine void closure outcomes that can be achieved within the Yandi mining area with consideration to managing upstream impacts at Flat Rocks (Section 5.9.2.3). Various permutations of pit backfill scenarios have been modelled over the years and the scenarios have been evaluated in accordance with the ecohydrological evaluation tool outlined in Section 5.14.1.2. This tool identified the various ecosystem values that may develop in the closed mine environment, and enabled hydrological thresholds to be developed to distinguish the various wetland ecosystem types that might establish in the mine voids.

Various learnings from the modelling conducted between 2016 and 2020 were summarised in the 2020 MCP and are reproduced in Appendix F.1.2. Below is a history of some of the key decisions that have been made in determining the currently preferred option which was the subject of the modelling outlined in Section 5.14.1.4.

- An early decision was the selection of E7 as one of the sinks (permanent saline lakes) to isolate the closure outcomes at Yandi from closure decisions made for the downstream (RTIO) pits. However, it was noted that if the water levels in RTIO's pits at closure are below the base of E7 Pit, this advantage would be negated. With E7 as a sink, a secondary sink is required to be located at C4/5.
- In 2020, two backfill scenarios and a reference case (assuming no backfill) were evaluated. The two backfill scenarios evaluated were a three-sink model with sinks at W1, C4/5 and E7, and a four-sink model with sinks at W4, W5, C4/5 and E7.
- Further to the 2020 model, a pit lake risk assessment was conducted and W4 was identified as a pit that would be preferential to backfill (Section 5.14.6.4). There was also a preference to maintain backfill in W5 to support a land bridge to be used for future transport of ore from satellite mines. Modelling was, therefore, conducted of two additional scenarios in 2022 (see Appendix F.1.3) which assessed sinks at W2, W3, C4/5 (Scenario B) and E7, W1, C4/5, E7 (Scenario C). These scenarios were compared to a reference case (Scenario D - no backfill).
- An evaluation of the Scenarios B and C concluded that Scenario B was more favourable because:
  - The footprint of hyper-salinity in the landscape is almost half that of Scenario C. Scenario B results in a 245 hectare (ha) direct hypersaline footprint compared with 480 ha attributed to Scenario C.
  - Backfilling of W1:
    - Reduces the hydraulic gradient and drawdown at the areas of riparian vegetation at Flat Rocks.
    - Eliminates the potential for mixing of permanent (evapo-concentrated) pit lake water with freshwater discharged from the W1-SP0 flood channel into the pit and reduces the salt load discharged to W4 Pit.
    - Reduces the risk of geotechnical failure associated with the flood channels.
- Two sub-sets of Scenario B were modelled to assess the backfill levels required to maintain water salinity in the backfilled pits to either less than 4,000 mg/L (B.1) or less than 8,000 mg/L (B.2) (Appendix F.1.3). Scenario B.1 is the currently preferred option described in Section 9.2.3.1.

- An analysis of the potential for recovered water levels in Scenario B.1 to intersect the alluvial aquifer where Marillana Creek crosses the CID along the mine path (AQ2, 2023b) indicated that the entire alluvial aquifer will be unsaturated for average water level conditions, but maximum predicted pit water levels will bring groundwater in the CID into contact with the base of the alluvial aquifer in some locations (Figure 5-35). However, maximum groundwater levels are associated with the activation of the W1 flood channel and subsequent flow into W4 Pit which has a return period of 500 years.
- Subsequent to the modelling conducted in 2022, BHP and RTIO explored the potential to mine the pillar of CID between the E7 and Mungadoo pits to create a single mine void which resulted in an adjustment to the assumed downstream water levels at the boundary of the Yandi model (Section 5.14.1.4).
- Modelling for Scenario B.1 was updated by AQ2 (2024) and is summarised in Section 5.14.1.4. The update included:
  - C6 Pit (which was previously excluded from modelling).
  - Revised pit shells based on updated mine planning data.
  - A revised assumption for the downstream water levels in the RTIO Mungadoo Pit based on the work outlined in Section 5.14.1.4.

To date, the proposed E8 Pit has not been incorporated into the model, but current plans are to backfill the pit to the level of the Marillana Creek invert (above the recovered water table) (Section 9.2.3.1) and consequently, the pit would be expected to have minimal net impact on the groundwater levels in the CID post-closure (i.e., post-closure groundwater levels would be influenced by other pits rather than E8).

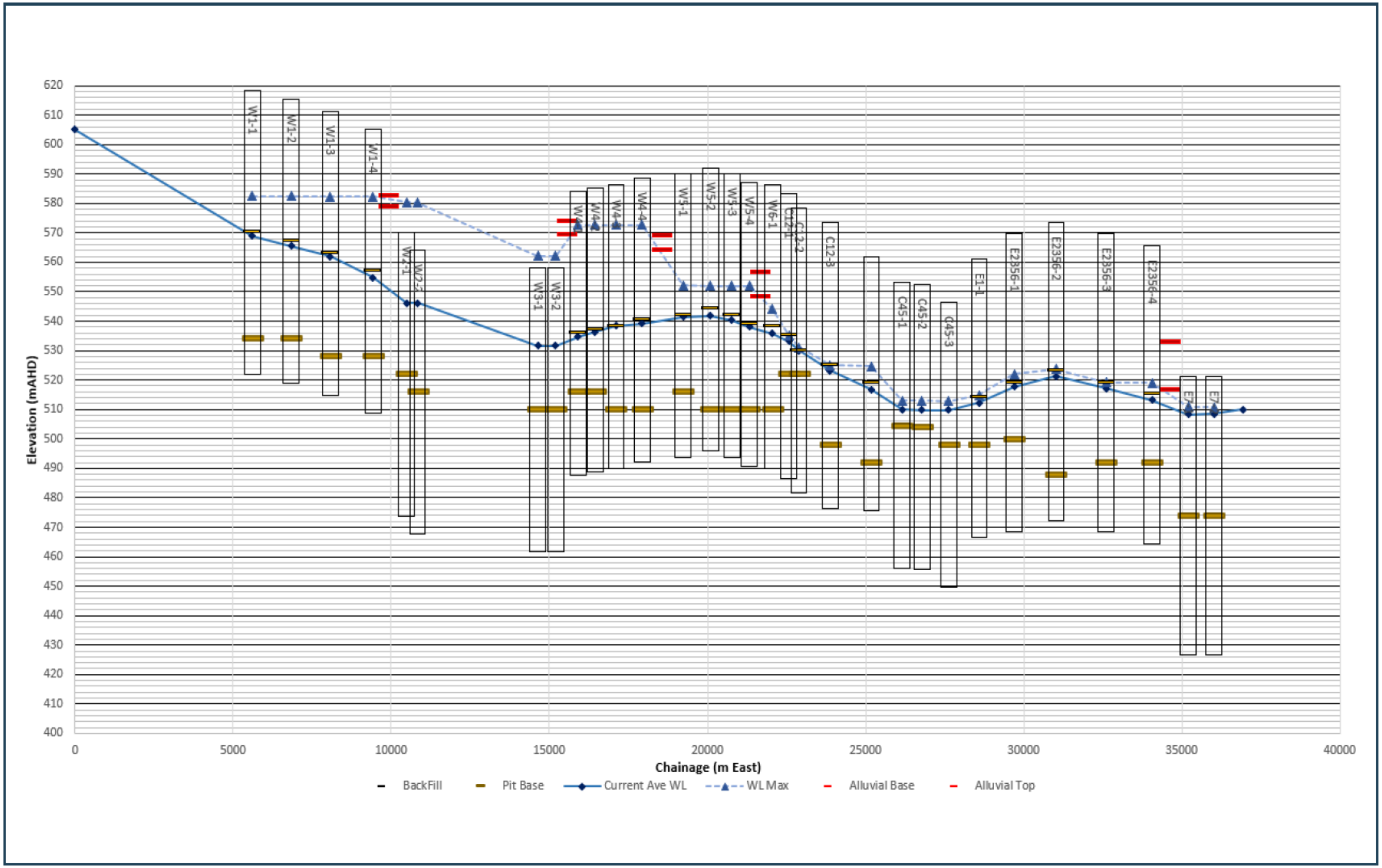
During the various different iterations of the model, several sensitivity analyses have been conducted (Table 5-45) and have concluded that the model is most sensitive to:

- Assumed hydraulic conductivity values for the backfill
- Increased rainfall as, while rainfall is a low salinity input:
  - Additional water inputs to the pits also results in an increased salt load. The associated higher salt mass can lead to higher salinity when evaporation / evapotranspiration removes water from the system but leaves salt behind.
  - The constraints on the amount of salinity that can leave the mine path through groundwater outflows and over topping do not change.

Since the 2020 MCP, an analysis of the permeability of backfill values has been conducted (Section 5.2.4.3) and the results incorporated into the modelling reported in Sections 5.14.1.4 and Appendix F.1.3.

An analysis conducted in 2020, and reported in the 2020 MCP, concluded that backfill uncertainty could not be overcome by adding 10 m fixed additional depth of backfill across all of the pits, and that a variable additional overburden thicknesses would be required to achieve the same water quality outcomes.

Further sensitivity analyses to those reported in Table 5-45 were conducted on the currently preferred scenario to determine the backfill levels that would be required to respond to different backfill permeabilities, and the sensitivity of the backfill design to climate change conditions. These analyses are reported in Section 5.14.1.4.




Source: AQ2 (2023b)

**Figure 5-35 Post-closure groundwater levels and alluvial aquifer thickness where Marillana Creek crosses the CID along the mine path**

**Table 5-45 Sensitivity analyses**

| Date | Study | Sensitivity analysis | Outcomes |
|---|---|---|---|
| 2020 | Reported in 2020 MCP | Reduce hydraulic conductivity to 0.15 m/d (from 15 m/d) in the CID and 0.5 m/d (from 5 m/d) in the backfill | Non-saline pits decreased from the base case of 10 to 3 and brackish and saline pits both increased (4 brackish and 5 saline compared to 0 brackish and 2 saline in the base case). |
| | | Reduce upstream boundary from 605 mRL to 567 mRL to model a scenario where mining may occur upstream of Yandi. | No difference to number of saline / non-saline pits. |
| | | Reduce downstream boundary (at Mungadoo) from 521 mRL to 500 mRL | |
| | | Increase upstream boundary (at Mungadoo) from 521 mRL to 530 mRL | Only a minor difference to outcomes - non-saline pits decreased from 10 to 9 and saline pits increased to 3 (from 2). |
| | | Future pit 3rd party pit between W2 and W3 not backfilled | |
| | | Future pit 3rd party pit between W2 and W3 backfilled | No difference to number of saline / non-saline pits. |
| | | Half the creek inflow from flood channels | No difference to number of saline / non-saline pits, but a reduction in the frequency of inundation of some pits. |
| | | Double the creek inflow from flood channels | No difference to number of saline / non-saline pits, but an increase in the frequency of inundation of some pits. |
| | | Cumulative decrease in water:<br>• Half direct creek inputs from flood channels<br>• Reduced upstream boundary condition (567 mRL)<br>• Reduced downstream boundary condition (500 mRL)<br>• Reduced hydraulic conductivity (backfill 0.5 m/d, CID 1.5 m/d) | Reduction in non-saline pits from the base case of 10 to 5 and increase in brackish and saline pits (2 brackish and 5 saline compared to 0 brackish and 2 saline in the base case). |
| | | Cumulative salt increase:<br>• Double direct creek inputs.<br>• Downstream boundary conditions increased to 530 mRL. | No difference to number of saline / non-saline pits, but an increase in the frequency of inundation of some pits. |
| 2022 | AQ2 (2022a) | Increase backfill permeability from 3 m/d used in the base case to 10 m/d | Does not change the water quality designations of pits and generally reduces average predicted water levels and salinity along the mine path. |
| | | Decrease backfill permeability from 3 m/d to 0.5 m/d | Significant increase in salinity with 9 pits being designated as either brackish or saline compared with 3 in the base case. |
| | | Increase daily rainfall by 30% | |
| | | Decrease daily rainfall by 30% | Does not change the water quality designation of the pits, but salinity overall is lower compared to the base case. |
| | | Increase in daily evaporation (and evapotranspiration) by 10% | Does not change the water quality designation of the pits compared to the base case. |
| | | Decrease in daily evaporation (and evapotranspiration) by 10% | |
| | | Increase (double) alluvial seepage resulting from creek flow events | Does not change the water quality designation of the pits but predicted salinities are marginally higher compared to the base case. |
| | | Decrease (halve) alluvial seepage resulting from creek flow events | Does not change the water quality designation of the pits but predicted salinities are marginally lower compared to the base case. |
| | | Combined increase in evaporation (+7%) and rainfall (+8%) consistent with the 2050 climate change scenario in Section 5.1.2. | Increased salinity throughout the model but only changed the designation of 2 pits from non-saline to brackish. |
| | | Combined decrease in rainfall (-17%) and increased evaporation (+7%) consistent with the 2050 climate change scenario in Section 5.1.2. | Reduced salinity through the model due to the reduced salt volumes entering via rainfall processes. |

#### 5.14.1.2 Backfill option evaluation framework

AQ2 & Equinox (2016) conducted a literature review (Appendix M.2) that informed the ecohydrological characterisation of the Yandi mine voids and defined the ecosystem benefits and values that may develop in the closed-mine environment based on the various mine void closure concepts outlined in Appendix F.1.1. This information was used in the development of an ecohydrological evaluation tool enabling comparison of the ecological values of different backfill configurations. This tool provides an analytical framework for linking different combinations of biophysical elements (e.g. surface water body, engineered fill, aquatic and terrestrial vegetation) to ecosystem services (e.g. habitat provision) and to utilities based on human values (e.g. aesthetic appeal, conservation of biodiversity, future use potential) - refer to Figure 5-36.

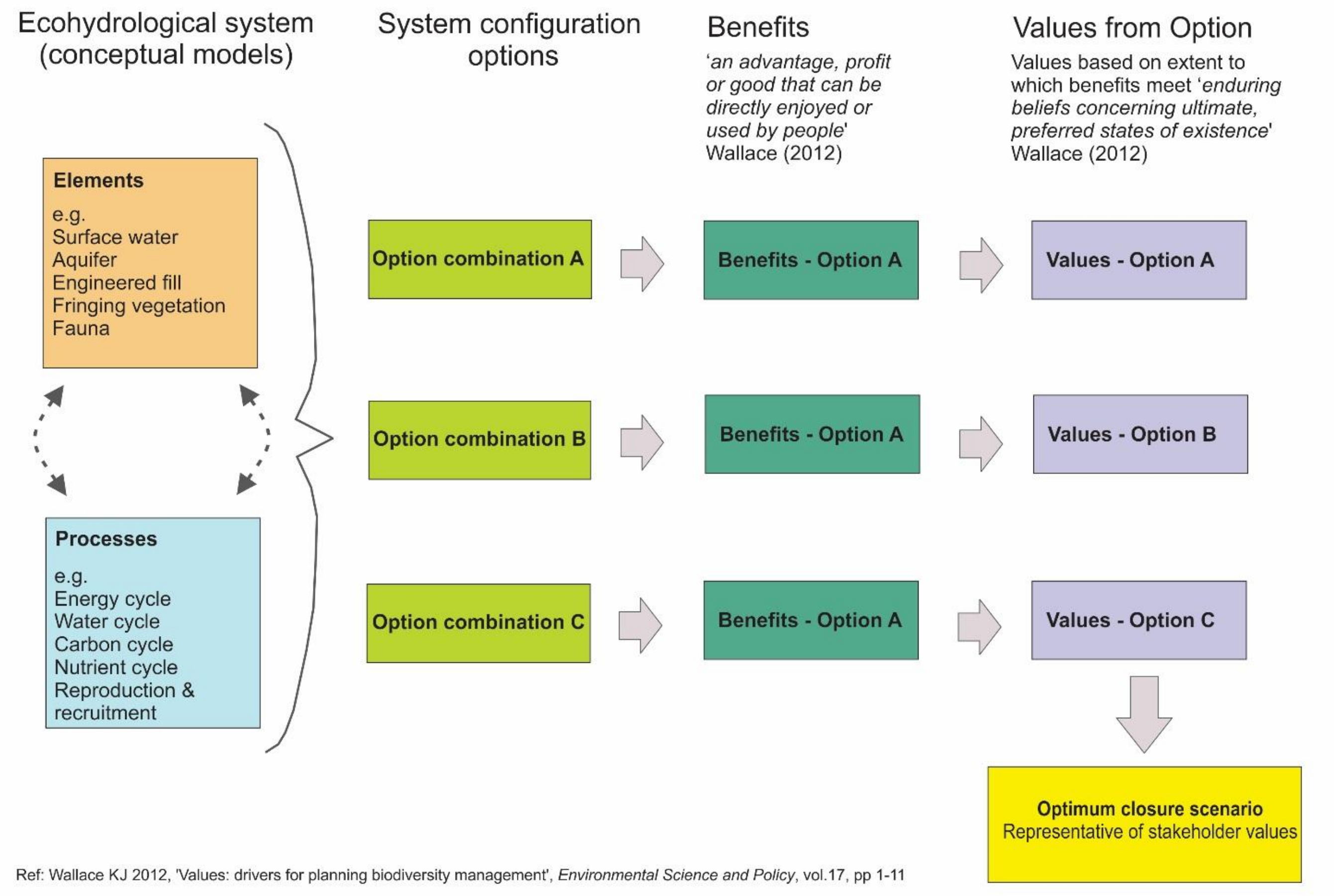



**Figure 5-36 Ecohydrological evaluation framework**

From this work, hydrological thresholds for distinguishing wetland ecosystem types in mine voids were developed (AQ2, 2020a), which include the criteria outlined in Table 5-46.

**Table 5-46 Mine void assessment criteria**

| Category | Criteria | Commentary |
|---|---|---|
| Water level | >10m below surface | Water levels more than 10 m below surface (upon which a terrestrial ecosystem could develop). Where groundwater elevations are more than 10 m below the backfill elevation in a cell, it will be difficult to develop vegetation required to support high ecohydrological value (i.e. the vegetation will be sparse and xerophytic). However, the vegetation is likely to be salinity independent. |
| | Between 10 m below the surface and 1 m above the surface | Water levels upon which a riparian ecosystem could develop. The rationale in including water levels up to 1 m above the surface is that areas of ponds and alluvial terraces could easily be formed with limited contouring of the backfill surface. Note that in reality, a water surface that was consistently marginally above or below the ground surface would likely not support riparian vegetation growth. However, the water level ranges are being used in the backfill studies study to select which pits may be able to ecohydrologically support a riparian ecosystem with engineered backfill contours. |
| | Permanent water body | A permanent pond of water may allow a lake ecosystem to develop, which may be a satisfactory ecohydrological outcome for the closure option. |

| Category | Criteria | Commentary |
|---|---|---|
| Inundation frequency | Inundation more frequent than once every 100 years | Frequent inundation means that a sustainable riparian system may not develop, and the environment may be more akin to an alluvial flat or salt marsh (depending on water quality). A high frequency of ponding in the pit will waterlog vegetation and result in an unsatisfactory ecohydrological outcome. |
| | Inundation (water ponding >1 m above surface for more than 90 consecutive days) is less frequent than once every 100 years | Infrequent inundation means that a riparian ecosystem could potentially develop. |
| Salinity<br>Based on thresholds identified by Coughran et al (2013) | Non-saline (<4,000 mg/L) | Taken as the highest salinity that freshwater ecosystems can tolerate (non-saline) from Coughran et al (2013). |
| | Saline (4,000 mg/L to 8,000 mg/L) | 8,000mg/L is the stock water guideline and also the threshold for vegetated saline ecosystems[1]. Water salinity in this range can still support future agricultural (stock) activities (brackish water). |
| | Extremely saline (>8,000 mg/L) | Above the stock water guideline limit (saline water). |

Source: adapted from AQ2 (2020a)

[1]Notes: Coughran et al (2013) define thresholds in key water-quality parameters for the health and persistence of ecosystem types. These were 4,000 mg/L for non-saline, 12,000 mg/L for brackish and anything above 12,000 mg/L was saline. However, the majority of Coughran's identified saline ecosystems were characterised by a salinity of less than 8,000 mg/L. Additionally, 8,000 mg/L is also the salinity limit for stock water. Thus, conservatively, we adopted 4,000 mg/L and 8,000 mg/L for the thresholds for non-saline, brackish and saline ecosystem potential for this evaluation framework.

Feedback from Traditional owners in 2017 (Section 4.3), indicated that where possible, pit lakes should be fresh, and that seasonal pools were preferred over permanent pools as these are more natural. This was interpreted to mean that a seasonally wet riparian environment that is readily accessible would afford the most value (AQ2, 2020a).

The combination of hydrological characteristics considered to support the highest value rehabilitated ecosystem was, therefore (AQ2, 2020a):

- Non-saline water quality (<4,000 mg/L).
- Pit water levels that are higher than 10 m below the backfill surface, but with ponding events above the backfill occurring with an average recurrence interval greater than 100-years (i.e. less than 10 occurrences in a 1,000-year model run).

A second acceptable outcome (but with lower ecohydrological value) was for the pit to have:

- A salinity of less than 4,000 mg/L.
- A permanent pond of water.

Within a pit, a combination of these two environments would have the highest ecohydrological value (i.e. both a terrestrial riparian and aquatic zone within the pit). A closure scenario that generated some non-saline pits (even when the remainder of the pits were classified as extremely saline) was estimated to provide more cumulative environmental value than a scenario where all of pits were brackish to saline (AQ2, 2020a).

#### 5.14.1.3 Backfill / pit lake modelling approach

This section outlines in the sub-sections below:

- The general modelling approach adopted to assess mine void backfill options.
- The scope of a joint BHP / RTIO study into the Mungadoo pit lake (AQ2, 2023a).
- The scope of the most recent (AQ2, 2024) model.

Modelling results are discussed in Section 5.14.1.4.

**General modelling approach**

GoldSim modelling has been conducted since 2016 to simulate hydrological conditions within each of the pits, post mine closure, to enable different closure options to be assessed. GoldSim is a Monte Carlo simulation software that allows users to create customised models based on built-in functions within the software. The model has been progressively refined over time as new information has become available and increasing sophistication is required to support backfill option decision-making.

In 2016, the model was peer reviewed by Golder (2016) who concluded that it represented a reasonable conceptual model of the system that is consistent with the defined study objective. Some recommendations for improvement were made in relation to rainfall sequences used in the model and verification of the assumption that all salt entering the vadose zone would be flushed to the groundwater (AQ2, 2020b). The rainfall sequences were adjusted based on the Golder (2016) recommendations, and HYDRUS modelling was conducted to assess the validity of the assumption that all salt in the vadose zone would be flushed to groundwater. The modelling concluded that the GoldSim model approximation of unsaturated zone processes appeared to be consistent with those predicted by HYDRUS modelling. In particular, the HYDRUS modelling predictions indicate that salt is regularly flushed to the saturated zone and does not build up in the unsaturated zone over large periods of time (AQ2, 2020a). This is consistent with the literature review of natural salt lake behaviour conducted by Mine Waste Management (2023b) (see Section 5.14.3.2). Given the sensitivity of the model to backfill permeability, the hydraulic properties of the backfill were investigated in 2022 (Section 5.2.4.3) and the permeability used in the model was adjusted based on these findings. The most recent model was refined to adjust the evaporation reduction factor to account for increasing water salinity on the evaporation rate from open water bodies. The downstream boundary condition was also updated to reflect a recent joint BHP / RTIO study for water levels in Mungadoo Pit (AQ2, 2024).

An overview of the conceptual model is shown in Figure 5-37. Each of the Yandi pits is modelled as a series of "cells" where groundwater and surface water inflows and outflows are balanced with changes in the storage volume of the cell at each time step. The GoldSim model predicts the water level in each cell at each time step using the defined stage / storage relationship for each pit, and the sum of all groundwater and surface water inflows and outflows. The cells form a grid over each pit (one cell wide with variations to the number of cells depending on the length of the pit (AQ2, 2024).

Each cell within the model consists of two water volume balancing sub-cells. One sub-cell covers the water stored in the saturated groundwater zone, the other in the unsaturated vadose zone. Water levels that are reported are all based on the water level in the saturated groundwater sub-cell. When groundwater levels rise above the ground surface, the vadose zone sub-cell is effectively turned off in the model. The water balance can be summarised by the following list of inflows and losses (AQ2, 2024):

- Water inflows:
  - Direct rainfall to the mine void over each cell footprint.
  - Rainfall recharge from the vadose zone (rainfall recharge from the vadose zone sub-cell to the saturated zone sub-cell occurs when the moisture content in the vadose zone exceeds the soil field capacity).
  - External catchment runoff.
  - Creek overflow into the pit (assumed to occur as direct recharge to the saturated zone).
  - Creek seepage (assumed to occur as direct recharge to the saturated zone when the creek is flowing).
  - Groundwater inflow (from the upstream CID).
  - Groundwater inflow (from the surrounding Weeli Wolli Formation).
- Water losses:
  - Evapotranspiration from bare soil and vegetation.
  - Evaporation from pit lakes.
  - Pit overflow.
  - Groundwater outflow (to downstream).

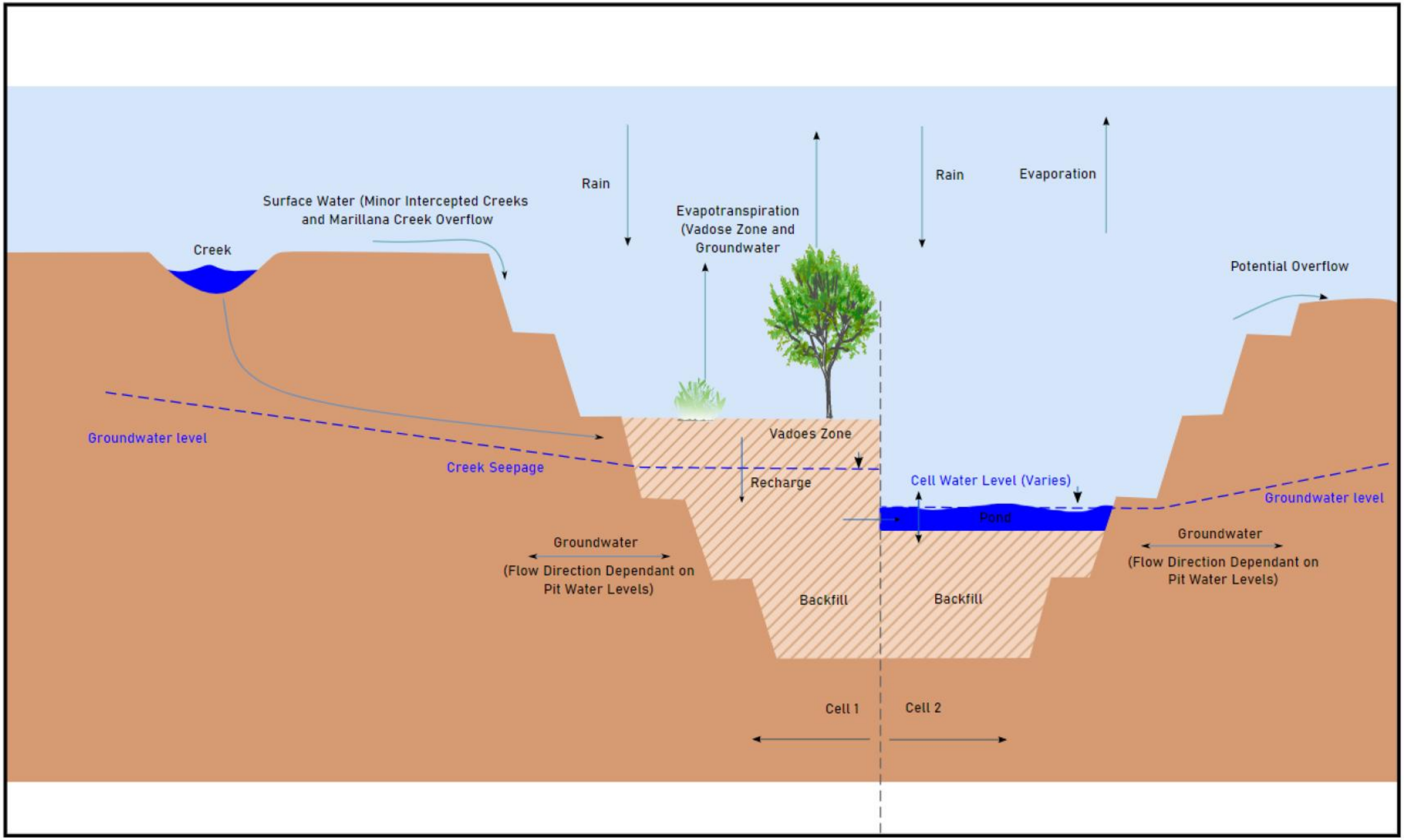
The GoldSim model allows groundwater flow through the CID Formation between successive pits, and between the assumed upstream boundary and the upstream pit (W1) and the downstream boundary (RTIO's Mungadoo Pit water level) and the downstream pit (E7). Groundwater flow also occurs through overburden used to backfill the pits. The condition at the upstream boundary of the model was taken as a constant pre-mining water table elevation upstream of W1 Pit (AQ2, 2024).

Note that, a constant inflow rate with time for groundwater seepage from the Weeli Wolli basement formation to the cells was assumed (regardless of pit water levels) (AQ2, 2024).

Marillana Creek crosses the CID Formation in several locations in proximity to the pits that are being modelled. When the creek is flowing, a hydraulic gradient is formed between the creek bed and the pit water level which results in seepage into the pit. The pit seepage inflow simulation in the model is simplified to only occur on the day that the rainfall and creek flow is simulated to occur. The seepage rate that was adopted was part way between Pilbara creek loss rates estimated by CSIRO (which likely underestimate seepage) and rates developed by BHP (provided in Section 5.9.2.6, which may overestimate seepage) (AQ2, 2024).

The GoldSim model approximates water levels over a 1,000-year period on a daily time-step, such that all calculations are updated every day of the simulated period. The model uses rainfall data based on a synthetic 1,000-year rainfall record generated using the e-water program Stochastic Climate Library based on a combination of BoM and SILO rainfall data for Marillana weather station (AQ2, 2024).

The conceptual salt balance model is that salt moves in and out of the model cell with each of the water fluxes, with the exception of evapotranspiration, which is assumed to result in no salt flux (removal of salt). A constant value of salinity was adopted for each of the external water inputs to each cell, and a salt mass balance model was used for each cell to estimate the mass of salt within the cell, and therefore the salt concentration (salinity) of stored water within the cell at each time step (assuming full mixing). The simulated groundwater salinity at each time step was applied to each water loss component from the pit to complete the salt balance model (except for evapotranspiration which is assumed to result in no salt flux loss) (AQ2, 2024).




Source: AQ2 (2024)

**Figure 5-37 GoldSim conceptual water balance model**

While climate change has not specifically been modelled, a sensitivity analysis was conducted in 2022 and 2024 to assess the impact of climate change on the modelled options (Sections 5.14.1.1 and 5.14.1.4).

Key data inputs to the model are outlined in Table 5-47.

**Table 5-47 Key GoldSim model inputs**

| Model parameter | | Value | Basis |
|---|---|---|---|
| Permeability of the in-situ remnant CID aquifer | | 15 m/d | Consistent with values used in groundwater modelling for LCID. |
| Permeability of the overburden material | | 3 m/d | 2022 site investigation (Section 5.2.4.3) |
| Salinity of rainwater | | 5 mg/L | Nominal / assumed value |
| Salinity of creek seepage | | 100 mg/L | Within the range of surface water samples (Section 5.9.3) |
| Salinity of in situ groundwater | | 500 mg/L | Within the range of groundwater samples (Section 5.9.3) |
| Overburden porosity | | 15% | Derived from soil moisture retention curves calculated from Particle Size Distribution (PSD) data (Section 5.2.4.3) using Saxton & Rawls (2006) |
| Overburden field capacity | | 7% | |
| Bare Soil evapotranspiration soil moisture content cut-off | | 2.7% | |
| Riparian zone evapotranspiration soil moisture content cut-off | | 1.6% | Reflect the respective turgor-loss points of the characteristic vegetation and the likely soil-matric pressures that will result at these moisture contents (refer to Section 5.6.3.1). |
| Understorey zone evapotranspiration soil moisture content cut-off | | 0.5% | |
| Rainfall | Median | 309.1 mm | Marillana Rainfall Station (BoM records 1936 - 2016) and SILO enhanced climate database. |
| Rainfall | Mean | 324.0 mm | |
| Rainfall | Maximum | 1,124.8 mm | |
| Rainfall | Minimum | 0.3 mm | |
| Rainfall | 90th percentile | 546.9 mm | |
| Rainfall | 75th percentile | 413.5 mm | |
| Rainfall | 25th percentile | 209.5 mm | |
| Rainfall | 10th percentile | 124.2 mm | |
| Pond evaporation | | Various | Based on a CSIRO (McJannet, et al., 2016) model for evaporation from a mine void and adjusted to account for increasing salinity[37]. |
| Creek inflows | | Various | Hydrographs from surface water modelling conducted by Advisian to inform surface water management designs (Section 5.14.7). |
| Creek seepage | | 200,000 $m^3$/d across mine length | Derived from CSIRO (2015b) and BHP estimates (Section 5.9.2.6). |
| Weeli Wolli inflow | | 6,000 $m^3$/d over simulated mine path | Consistent with values from groundwater modelling. |
| CID upstream boundary conditions | | 605 mRL | Groundwater level data (Section 5.9.2.3). |
| CID inflow | | 2,000 $m^3$/d | Consistent with values from groundwater modelling. |
| CID downstream boundary | | 495 mRL | Joint BHP / RTIO study for water levels in Mungadoo Pit AQ2 (2023a) (Section 5.14.1.4). |

Source: AQ2 (2024)

37 CSIRO (McJannet, et al., 2016) conducted a study of pit lake evaporation at Mount Goldsworthy and developed a transferable evaporation model for use in predicting evaporation from other pit lakes. The model includes:

- Corrections to adjust for the sheltering effect of the pit on solar radiation inputs and wind speed.
- The influence of pit lake salinity and pit lake size on evaporation.

### Scope of E7 / Mungadoo pit lake model

The scope of the E7 / Mungadoo pit lake model was to assess the impact on water levels and water quality of removing the pillar of CID between RTIO and BHP's pits. RTIO and BHP have separate GoldSim pit closure water balance models. A combined pit closure water balance model has been created to simulate the impact of removing the E7 / Mungadoo CID pillar on the water quality and water levels in the closed pits (E7, Mungadoo and adjacent pits) (AQ2, 2023a).

The backfill elevations used in the model were based on BHP's Scenario B.1 (as modelled by AQ2 (2022a)) and RTIO's model Scenario 1. Two model scenarios were considered (AQ2, 2023a):

- Scenario A (With Pillar) - the CID pillar remains between the E7 and Mungadoo pits, with the pits operating as separate mine voids.
- Scenario B (Without Pillar) - the CID pillar has been mined between the E7 and Mungadoo, with the pits becoming a single void.

The model extent was chosen to cover an area bounded by the closest significant groundwater sinks upstream and downstream of the E7 / Mungadoo pit area (Map 5-29). These groundwater sinks were predicted in previous modelling activities which were completed for the BHP and RTIO mine sites independently (AQ2, 2023a).

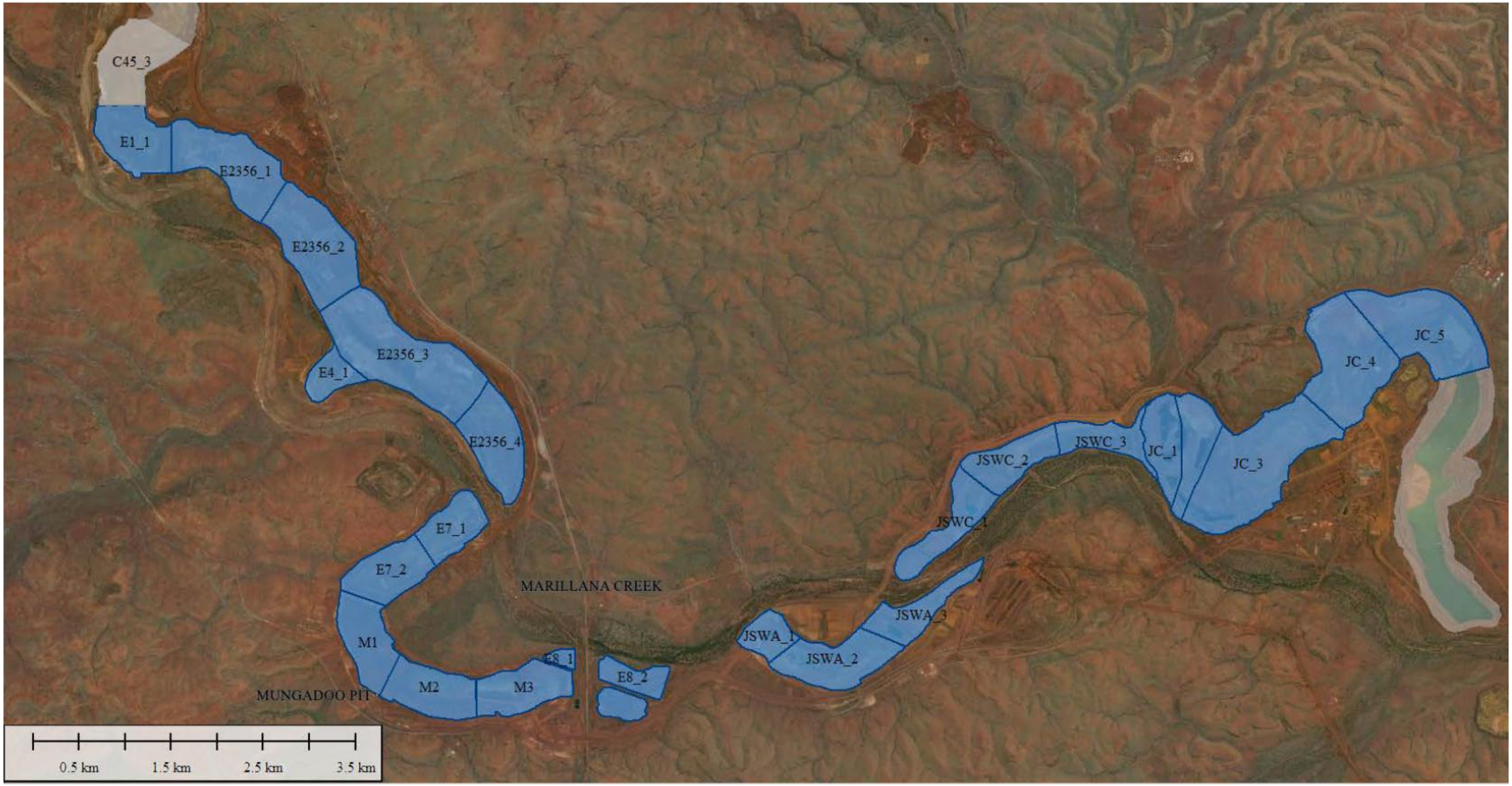
Both the RTIO and BHP GoldSim models are based on the concept outlined in Figure 5-37 (Section 5.14.1.3). The model operation and assumptions are broadly the same as those outlined in Section 5.14.1.3, although some assumptions were adjusted to account for differences in the approach taken by RTIO and BHP. Key differences are (AQ2, 2023a):

- A creek seepage inflow rate to the pit of 10 ML/km/d was adopted for the duration that Marillana Creek flows, consistent with previous assessments completed for RTIO.
- Evaporation was estimated from the evaporation data sourced from SILO at the Marillana weather station with a pan factor of 0.63 applied (as per Department Agriculture 1987, for Mt Newman). The average annual evaporation rate was estimated to be 3,200 mm, which equates to 2,028 mm when the assumed pan factor is applied.
- Backfill porosity - 10%.
- An annual evapotranspiration rate of 600 mm/y was adopted.
- Catchment runoff was assigned a salinity of 50 mg/L.
- Creek overflow was assigned a salinity of 50 mg/L.

### Scope of AQ2 (2024) model for Yandi

The aim of the AQ2 (2024) model was to:

- Incorporate revisions to the mine plan including:
  - Adding C6 Pit to the model.
  - Buttressing and layback of pit walls.
  - Revised final pit shells.
- Update the downstream boundary condition based on the findings of the combined E7 / Mungadoo modelling (Section 5.14.1.4).
- Update the salinity function to account for the impact of salinity on pit evaporation rates and the volume of water in the pits.
- Conduct a sensitivity analysis of the required backfill volume to meet similar environmental outcomes to Scenario B.1 from the AQ2 (2022a) study (which involves designated pit lakes in W2, W3, C4/5 and E7, with groundwater salinity in the mine voids outside of these pit lakes typically <4,000 mg/L) (Appendix F.1.3) due to:
  - Different backfill permeabilities.
  - Climate change.




Source: AQ2 (2023a)

**Map 5-29 E7 / Mungadoo model extent**

#### 5.14.1.4 Modelling results

The results from the Mungadoo and AQ2 (2024) Yandi water balance models are reported separately in the sub-sections below.

**E7 / Mungadoo pit lake model**

The predicted recovered pit water levels from the combined E7 / Mungadoo model were compared to the predictions from the previous BHP and RTIO models, and generally, the combined model showed similar predicted water levels with one significant exception; the water levels predicted in E7 and Mungadoo were significantly lower than those predicted in the separate models. This is because the constant water level boundary conditions assumed for E7 (in the RTIO model) and Mungadoo (in the BHP model) resulted in a sustained higher ponded water level in the respective model sink. When both sinks are considered in a combined model, the water level in the E7 and Mungadoo pits is predicted to be substantially (in the order of 15 - 20 m) lower than the previous model predictions (AQ2, 2023a).

The water loss from the E7 and Mungadoo pits is dominated by the evaporative loss function in both Scenarios A and B (AQ2, 2023a).

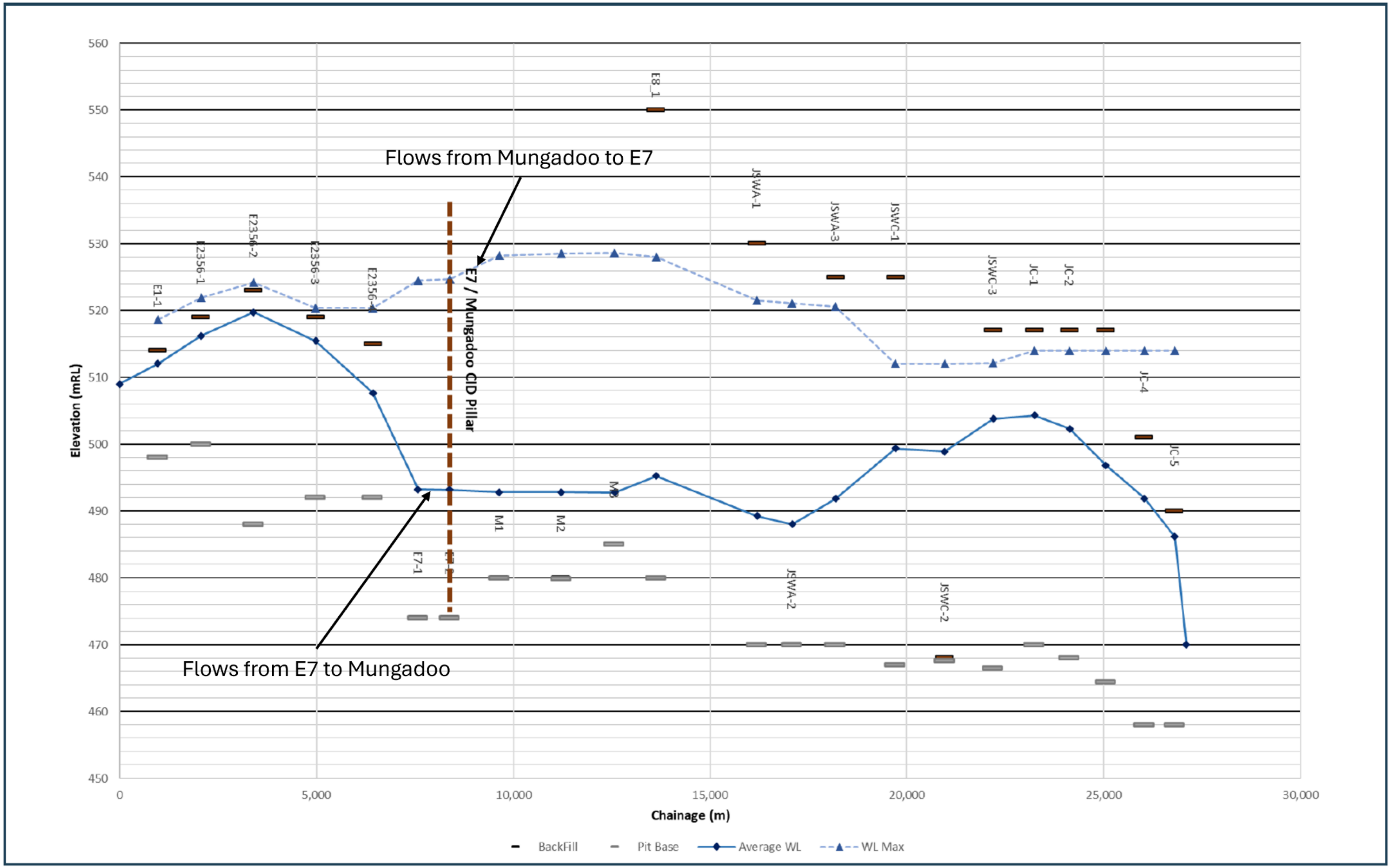
With the pillar in place (Scenario A):

- The average predicted water levels in E7 are marginally (~0.3 m) higher than the water levels in Mungadoo Pit, such that there will generally be groundwater outflow from E7 to Mungadoo (Figure 5-38 and Figure 5-39). However, under peak water level conditions, there is predicted to be groundwater flow from Mungadoo to E7 (Figure 5-38). Mungadoo Pit is predicted to have a higher maximum pit lake water level, as it receives a significant amount of inflow from an external catchment reporting to the pit (Figure 5-39). This catchment is proposed to continue to report to the pit post-closure.
- The flow from the E7 pit lake to the Mungadoo pit lake under average conditions results in a lower pit lake salinity in the E7 pit lake than has been previously predicted (AQ2, 2023a).

The predicted impact of mining the pillar between the pits (Scenario B) is unlikely to have a meaningful impact on the water levels or quality of the recovering pit lake in the combined mine void. The predicted impacts of mining the pillar are (AQ2, 2023a):

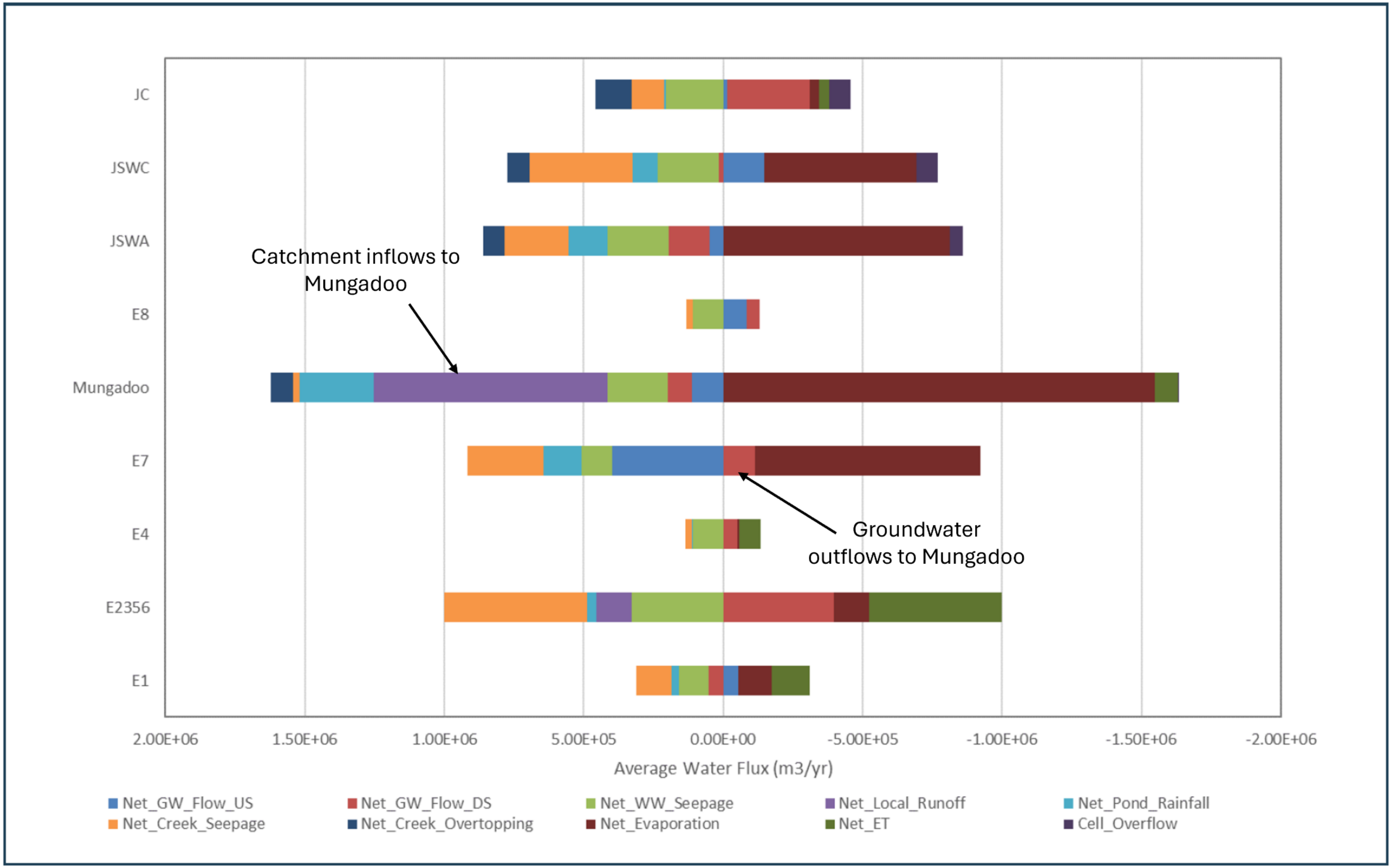
- The average water levels across the E7 / Mungadoo pit lake will be identical (as opposed to E7 being slightly higher than Mungadoo in Scenario A) (Figure 5-40).
- Lower maximum water levels in the Mungadoo Pit, as the surface water inflow can spread across both pits (Figure 5-40).
- Higher salinity in the E7 pit lake due to the higher salinity in the Mungadoo Pit. While the outputs of the water balance model predict different salinity in each of the model cells covering the combined E7 / Mungadoo pit lake, the salinity across the pit lake is expected to be similar and in the order of 50,000 mg/L (Figure 5-41).

The removal of the pillar in the E7 / Mungadoo pit is not predicted to impact the predicted closure outcomes of any of the other pits upstream or downstream of E7 / Mungadoo (Figure 5-40 and Figure 5-41).



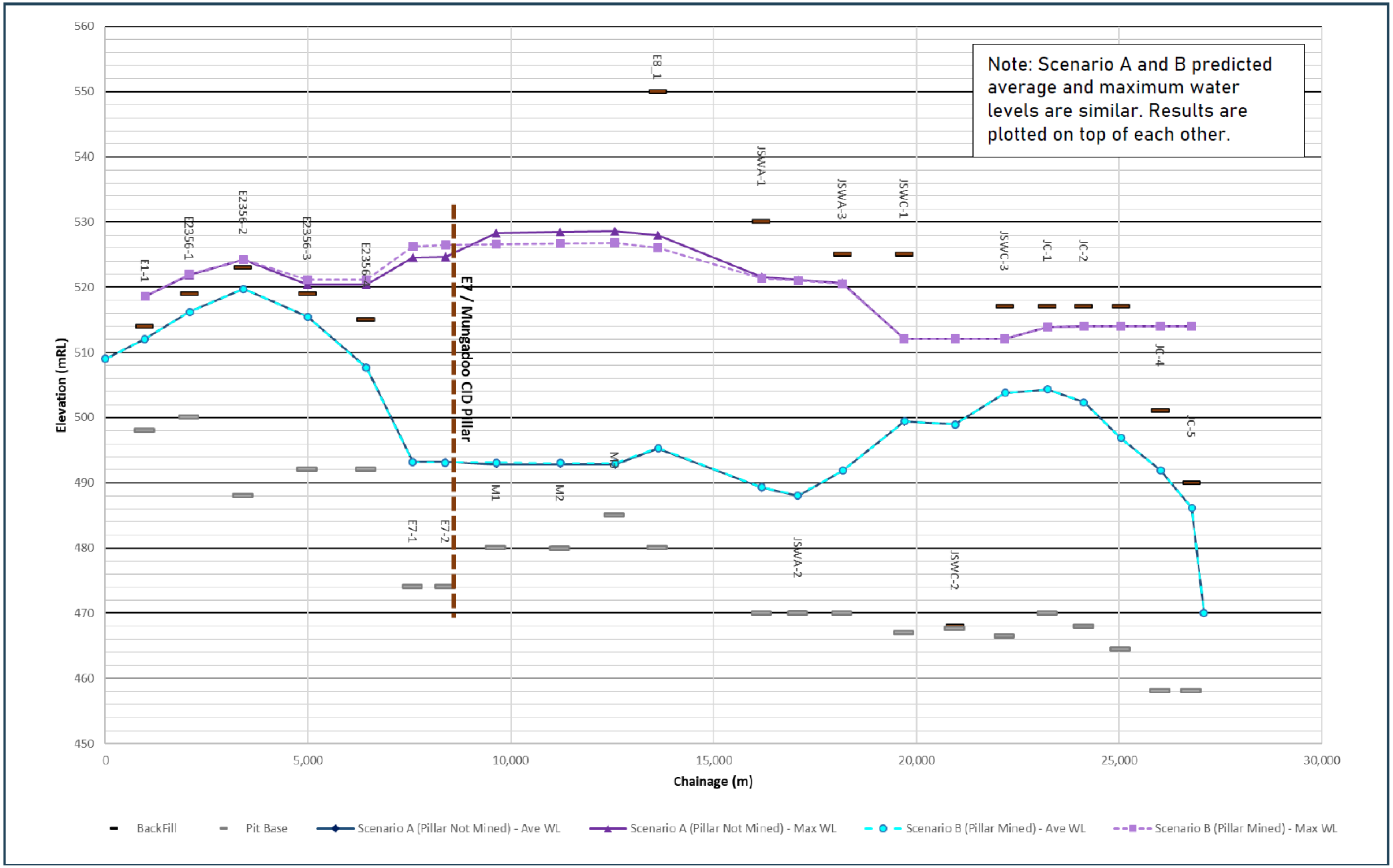

Source: AQ2 (2023a)

**Figure 5-38 Average water levels with pillar in place (Scenario A)**



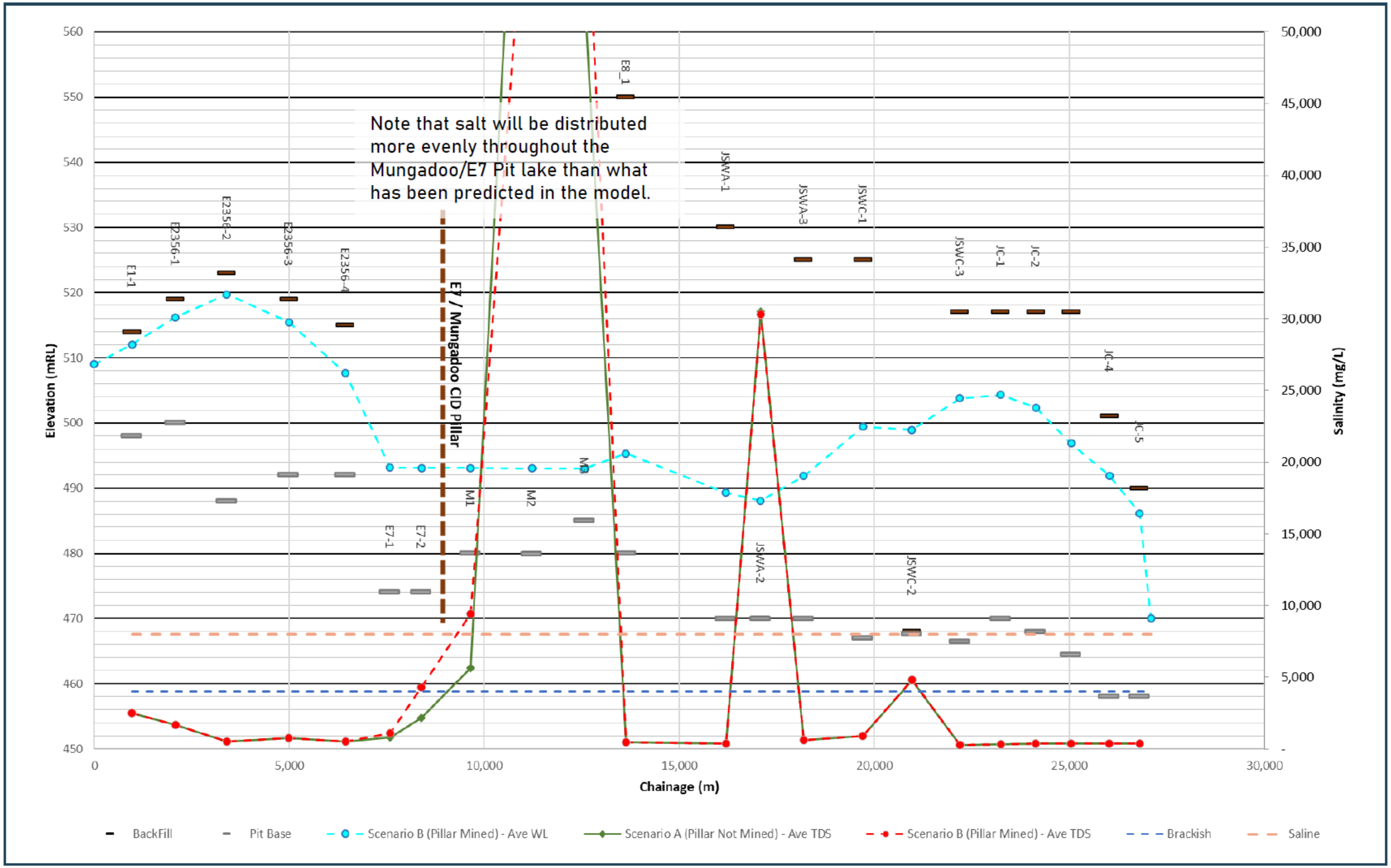

Source: AQ2 (2023a)

**Figure 5-39 Average water fluxes with pillar in place (Scenario A)**




Source: AQ2 (2023a)

**Figure 5-40 Comparison of predicted water levels with (Scenario A) and without (Scenario B) pillar in place**




Source: AQ2 (2023a)

**Figure 5-41 Comparison of predicted salinity with (Scenario A) and without (Scenario B) pillar in place**

### AQ2 (2024) model for Yandi

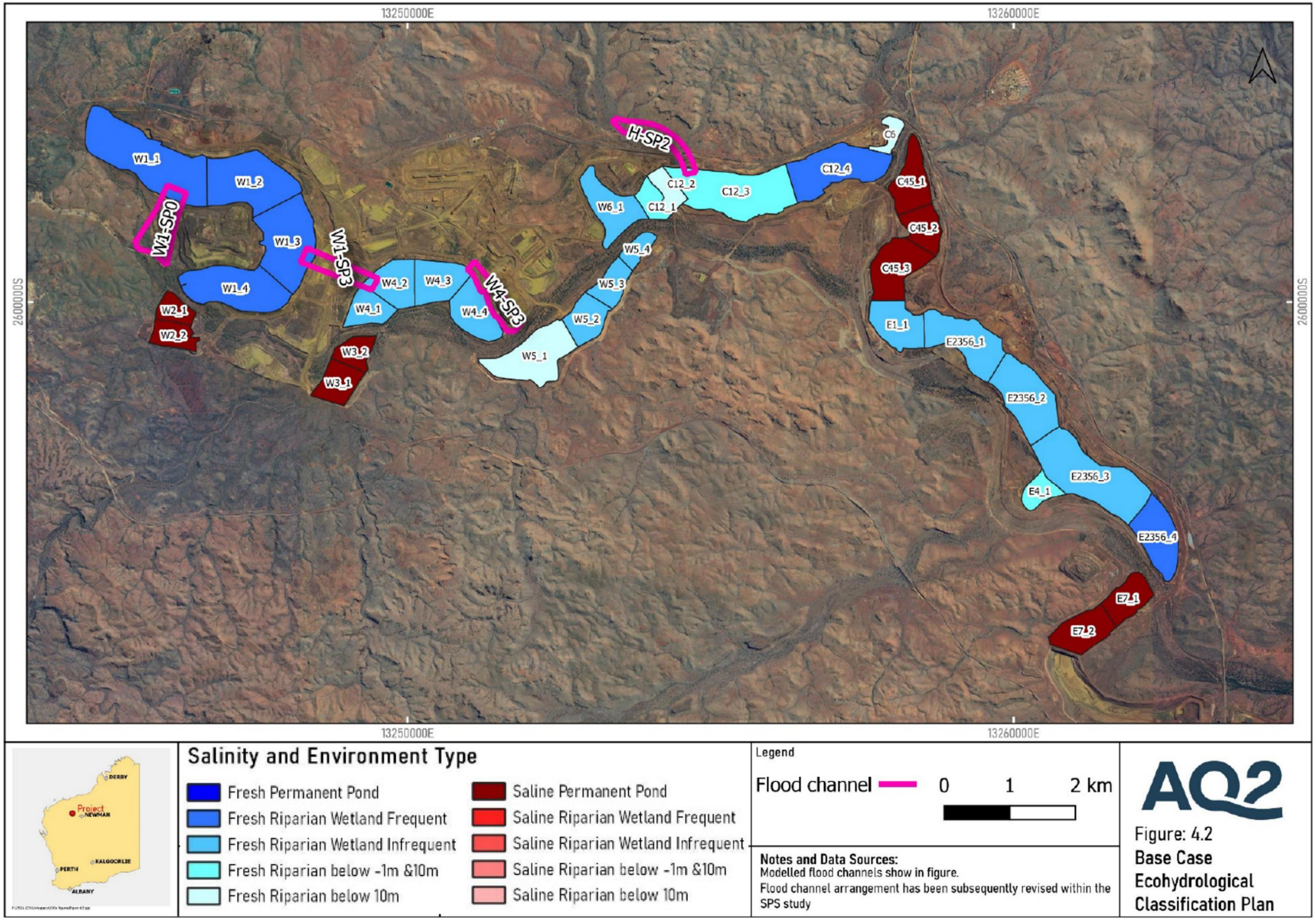
Using the new mine planning data, downstream boundary conditions and salinity function, AQ2 (2024) modelled various backfill scenarios until the 2022 Scenario B.1 outcomes (see Appendix F.1.3) were achieved. The resulting water levels and pit classifications are provided in Figure 5-42 and Figure 5-43, and the required backfill elevations to achieve these outcomes in Table 5-48 (AQ2, 2024).

The addition of the C6 Pit to the assessment did not cause any significant impacts to the predicted model results. This was expected given that the current C6 Pit is located on a tributary to the main Yandi CID aquifer and is required to be backfilled to a level above the predicted water levels in the adjacent C1/2 Pit (AQ2, 2024).

**Table 5-48 Modelled backfill elevations required to achieve Scenario B.1**

| Pit | Cell | Cell Base | Scenario B.1 |
|---|---|---|---|
| W1 | 1 | 534 | 570 |
| | 2 | 534 | 567 |
| | 3 | 528 | 563 |
| | 4 | 528 | 557 |
| W2 | 1 | 528 | 528 |
| | 2 | 528 | 528 |
| W3 | 1 | 510 | 510 |
| | 2 | 510 | 510 |
| W4 | 1 | 516 | 536 |
| | 2 | 516 | 537 |
| | 3 | 510 | 538 |
| | 4 | 510 | 540.5 |
| W5 | 1 | 516 | 542 |
| | 2 | 510 | 544 |
| | 3 | 510 | 542 |
| | 4 | 510 | 539 |
| W6 | 1 | 510 | 538 |
| C1/2 | 1 | 522 | 535 |
| | 2 | 522 | 530 |
| | 3 | 498 | 525 |
| | 4 | 492 | 518.75 |
| C6 | 1 | 522 | 560 |
| C45 | 1 | 504.6 | 504.6 |
| | 2 | 504 | 504 |
| | 3 | 498 | 498 |
| E1 | 1 | 498 | 514 |
| E2356 | 1 | 500 | 519 |
| | 2 | 488 | 523 |
| | 3 | 492 | 519 |
| | 4 | 492 | 515 |
| E4 | 1 | 498 | 520 |
| E7 | 1 | 480 | 480 |
| | 2 | 480 | 480 |

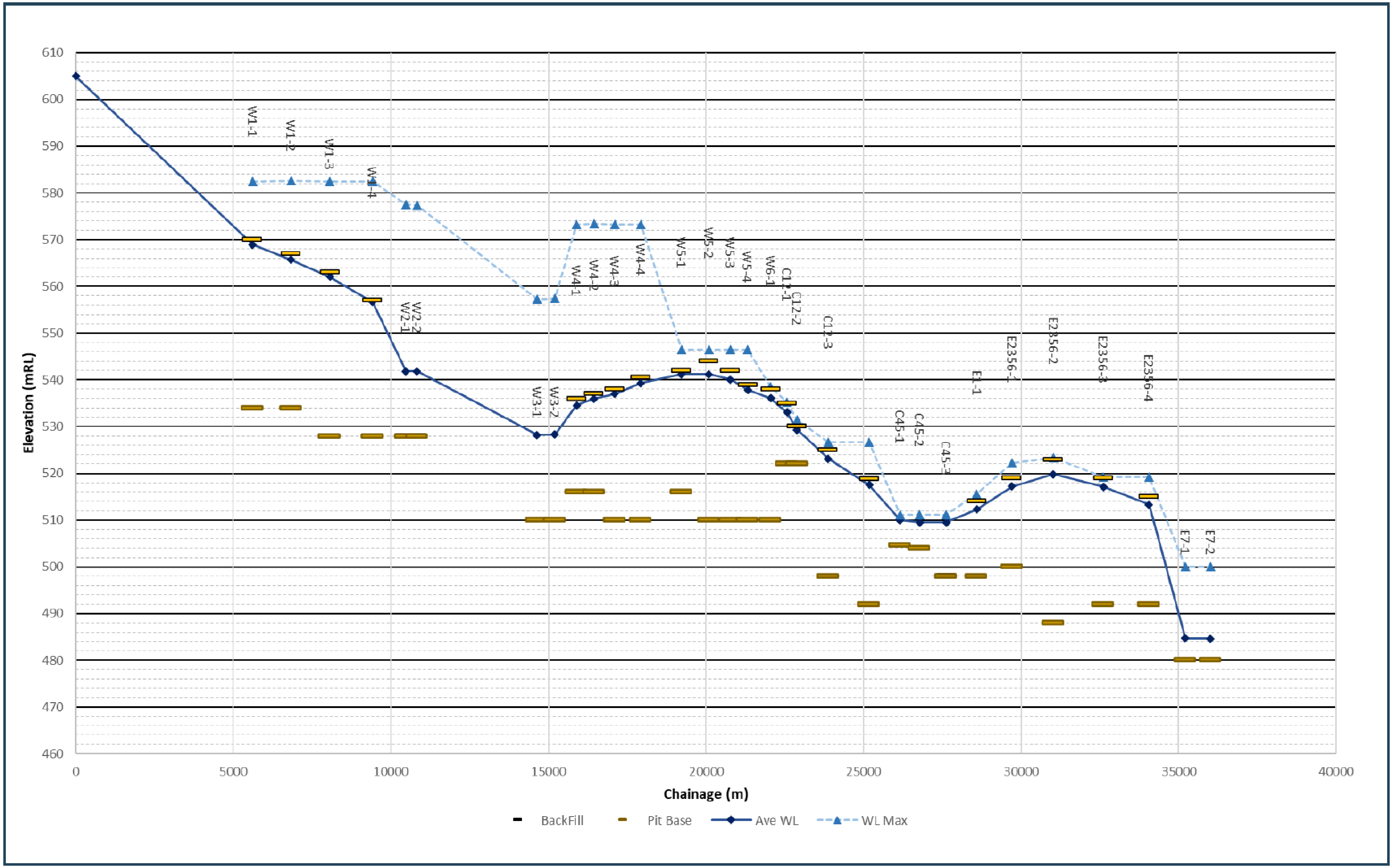
Source: AQ2 (2024)




Source: AQ2 (2024)

Note: Flood channels have not been updated to reflect current designs. The GoldSim model still simulates an inflow to C1/2 Pit, but this is a relatively small water flus into the pit overall and therefore unlikely to have a significant impact on model results (AQ2, 2024)

**Figure 5-42 Scenario B.1 predicted pit classifications (from 2024 modelling)**




Source: AQ2 (2024)

**Figure 5-43 Scenario B.1 predicted average water levels (from 2024 modelling)**

*Sensitivity analyses*

In addition to the sensitivity analyses outlined below, AQ2 (2024) noted that the model results for Scenario B.1 are sensitive to the aquifer characteristics simulated between pits W2 and W3. W2 and W3 are separated by approximately 3 km of remnant CID aquifer with unknown geometry and aquifer properties. A nominal flow area perpendicular to the flow direction within the remnant CID was used to estimate the hydraulic connection between W2 and W3. When a greater connection was simulated between these two pits, the backfill required through pits W4 to C1/2 to keep the pits non-saline increased.

**Permeability**

A sensitivity analysis was conducted to assess the effect of different backfill permeabilities on the model results. The base case assumed 3 m/d based on the average values from the analysis of falling head test data (Section 5.2.4.3). The sensitivity analysis tested upper and lower permeability values of 8.2 m/d and 1.0 m/d, respectively, which represent the 99% confidence level values of bulk permeability from the normal distribution fitted to the field test data (Section 5.2.4.3).

The results of the analysis indicated that ~14% more backfill would be required in the low permeability case, and ~15% less backfill would be required in the high permeability case.

**Climate change**

Two climate change scenarios were assessed based on the 2050 climate change scenarios outlined in Section 5.1.2:

- 8% increase in rainfall and 7% increase in evaporation.
- 17% decrease in rainfall and 7% increase in evaporation.

Neither the wet nor dry model sensitivity tests resulted in changes to the salinity classifications of the pits, although it was noted that the:

- Wet sensitivity test generally resulted in greater salt concentrations in the pits than the base case model.
- Dry sensitivity test resulted in reduced salinity through the model (due to the reduced salt volumes entering via rainfall processes).

#### 5.14.1.5 Knowledge gaps & forward work program

The following additional studies have been identified as required to enable the backfill strategy for Yandi to be optimised:

- Further consultation with BNTAC and the Banjima people as outlined in Section 4.
- Continued data sharing with RTIO.
- Incorporate modelling of closure conditions into the regional groundwater model described in Section 5.9.2.7 and align GoldSim and regional groundwater model inputs and outputs. This will enable better estimates of the regional groundwater recovery levels and recovery timeframes and improve confidence in the estimated inflows to the GoldSim model.
- Update water balance modelling, as required, to inform the refinement of the backfill strategy.
- Additional permeability testing that increases the spatial distribution of test locations.

### 5.14.2 Backfill design

Okane (2024a) developed a preliminary backfill design for Scenario B.1 (Appendix F.1.3) based on:

- The outcomes of AQ2's (2022a) water level modelling.
- Final mine pit designs (current in March 2023).
- An analysis of the reclaimable overburden from OSAs and ISAs, excluding C1 and E2 OSAs that have already been rehabilitated and will remain post-closure.
- The W5 land bridge design.

The preliminary pit backfill design has incorporated key characteristics of similar areas to those that might be expected to return in backfilled pits which were identified during a site inspection conducted by Okane (2023c). Section 5.14.2.1 summarises the outcomes of this inspection. An overview of the key elements of the design process are outlined in Section 5.14.2.2. The design itself is presented in Section 9.2.3, noting it is subject to change due to changes in mine plans and following further consultation with BNTAC and the Banjima people. The preliminary material balance to achieve the design is outlined in Section 5.14.12.

**Summary**

During consultation with BNTAC and the Banjima people, various preferences for closure have been expressed including:

- Seasonal expressions of water rather than permanent water bodies.
- Natural looking landforms.
- Establishment / retention of riparian trees in surface water designs.

While ideal native analogues do not exist for the heavily modified nature of backfilled pits, inspections were undertaken of natural areas that could provide ideas for the design of backfill profiles that address some of the preferences articulated by the Banjima people to date. Features on which design concepts could be based included:

- The well-vegetated, anabranching channels and alluvial bars in Marillana Creek which provide diverse habitats for flora and fauna, and could serve various purposes in the backfill design, including mitigating scour from the infrequent operation of the flood channels, potentially lowering local groundwater levels, providing flood refuge, offering habitat, and enhancing overall amenity.
- The incised sections of the Marillana Creek channel which show steep walls and low, flat marginal benches that are well vegetated, and provide a proxy for buttresses.

Following observation of materials in OSAs, the site inspection also identified the potential to use gravity segregation of overburden to enhance the permeability of backfill by utilising higher (~20 m+) tip heads during backfilling to facilitate bulk sorting of materials. As discussed in Section 5.14.1.4, a higher permeability reduces groundwater levels and salinity, and hence the requirement for backfill.

The design process considered safety, development of landforms consistent with the surrounding landscape and efficient placement of materials. Where practicable, all material within an OSA (except for C1 and E2) was allocated to pit backfill and the OSA footprint returned to pre-mining topography to retain the natural catchment.

The backfill design will be further developed following consultation with BNTAC and the Banjima people, and subsequent iterations of modelling.

#### 5.14.2.1 Design site inspection

During consultation with BNTAC and the Banjima people, various preferences for closure have been expressed including:

- Seasonal expressions of water rather than permanent water bodies.
- Natural looking landforms.
- Establishment / retention of riparian trees in surface water designs.

Inspections were, therefore, undertaken of natural areas that could provide ideas for the design of backfill profiles that address some of the preferences articulated by the Banjima people to date.

The site inspection also reviewed potential opportunities for establishing higher permeability zones during construction as this is favourable to mine void closure outcomes (Section 5.14.1.4).

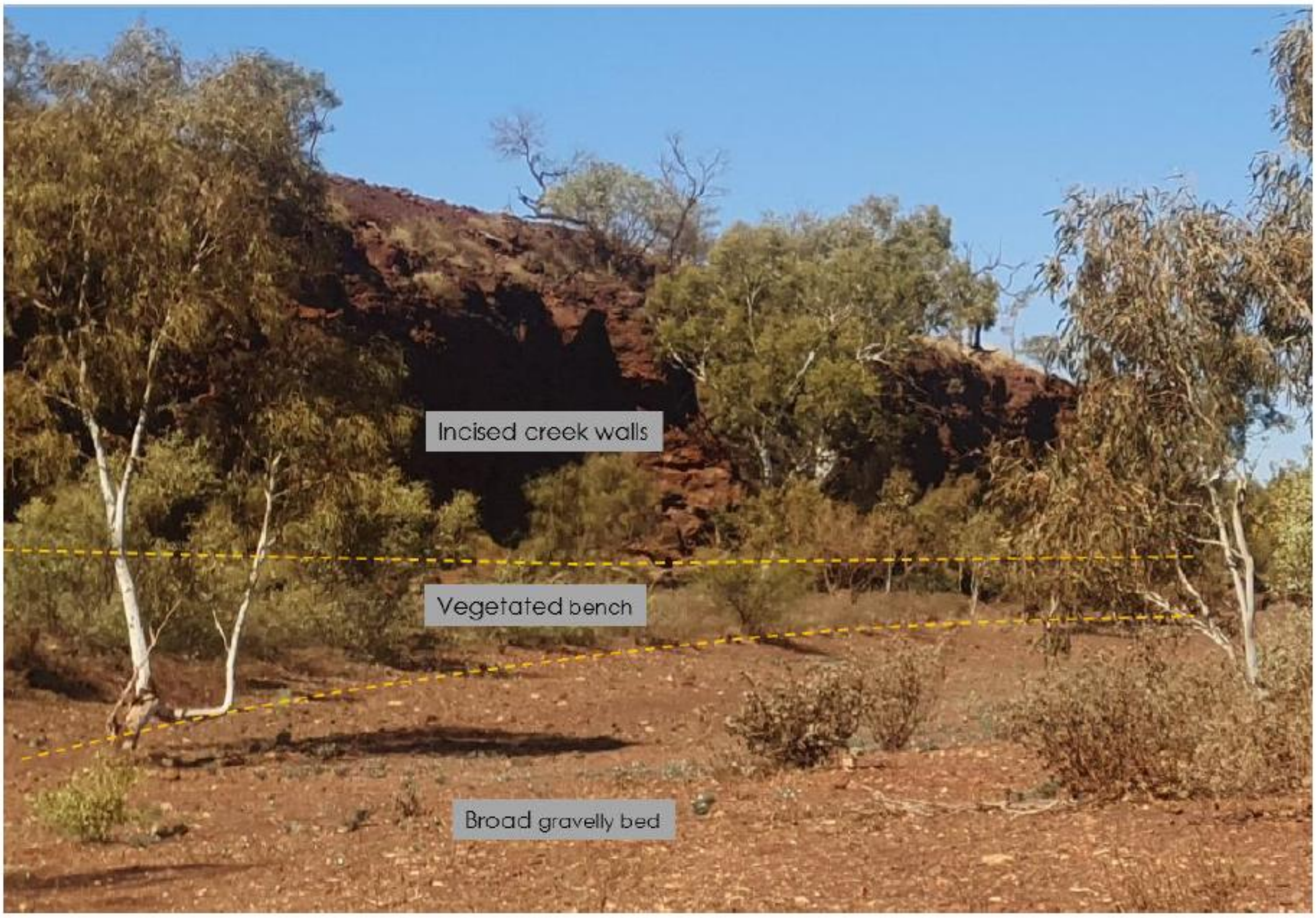
The outcomes of the inspections are summarised in the sub-sections below.

**Backfill design potential analogue features**

Given the heavily modified nature of the planned backfilled pits, ideal native analogues do not exist. However, observations made in Marillana Creek identified opportunities for natural topographic features that could be incorporated into the pit backfill design to achieve various functional and aesthetic design objectives.

The well-vegetated, anabranching channels, and alluvial bars in Marillana Creek (Figure 5-45) provide diverse habitats for flora and fauna and could serve various purposes in the backfill design, including mitigating scour from infrequent operation of the flood channels, potentially lowering local groundwater levels, providing flood refuge, offering habitat, and enhancing overall amenity.

The pit backfill plan is to primarily retain pit walls in their as-mined configuration (where geotechnically stable). If geotechnical design criteria are not met, buttressing, or reprofiling (laybacks) may be implemented. The incised sections of the Marillana Creek channel (Figure 5-44) show steep walls and low, flat marginal benches that are well vegetated, providing a suitable proxy for buttresses.




Source: Okane (2023c)

**Figure 5-44 Site observations of Marillana Creek incised reach features**


Source: Okane (2023c)

**Figure 5-45 Site observations of Marillana Creek anabranching reach features**

### Backfilling strategy

As outlined in Section 5.14.1.4, the permeability of the backfill has a significant influence over closure outcomes with backfill layers having higher conductivity resulting in lower groundwater levels and less salinity, and hence less requirement for backfill. The permeability testing outlined in Section 5.2.4.3 indicated that stockpiled material is mixed and unlikely to have a significant range of hydraulic conductivity. Therefore, selective placement of LCID / UCID / mixed backfill in the mine voids appears unlikely to be practical or to make a difference in how groundwater moves within the backfilled material. However, the Okane site investigation identified the potential for significant gravity segregation in OSAs (Figure 5-46) which presents opportunities for separating finer and coarse fractions by utilising higher (~20 m+) tip heads during backfilling to facilitate bulk sorting (Okane, 2023c).


Source: Okane (2023c)

**Figure 5-46 West W1 OSA exhibiting segregation of materials**

#### 5.14.2.2 Design process

The design process considered safety, development of landforms consistent with the surrounding landscape and efficient placement of materials. Where practicable, all material within an OSA was allocated to pit backfill and the OSA footprint returned to pre-mining topography to retain the natural catchment. Given the results of the permeability testing outlined in Section 5.2.4.3, overburden was considered to be homogeneous for the purpose of pit backfill design and there was no selective placement of materials based on classification (Okane, 2023c).

The following parameters were applied in development of the pit backfill design (Okane, 2023c):

- Backfill design slopes were kept within +/- 1% gradient wherever possible, to allow water run-off while minimising erosion and safety impacts.
- Ramp toe landings were designed at the base of all ramps which may nominally remain available for pit access, to dissipate the energy of surface water run-off (down the ramp) and to assist with egress. The gradient applied at the ramp toes was between 0.25% to 0.75%, in semi-circle projected up from backfill surface to create a gentle “dome” type shape.
- The pit backfill depth above returning groundwater level was designed to be between 1 m and 5 m above the anticipated groundwater level modelled by AQ2 (2022a). Yearly average anticipated groundwater levels over a period of 1000 years were provided by AQ2 for each cell. To allow for recovery of groundwater levels, the average groundwater level was calculated for years 200 to 1000, for each cell.
- Design surfaces were back-sloped at +/- 1% gradient where low points occurred at pit end walls and land bridge toes, with the aim of preventing water from ponding against structure toes and thereby reducing geotechnical risk.
- Where backfill surfaces and pit lakes intersect, the backfill surface was tapered down to the pit lake floor at a gradient of up to 2%, to transform the vertical drop-off into a “beach” to improve safety. To maintain the size of the C4/5 permanent pit lake and the resulting surface area for evaporation so that the pit remains a sink, the slope of the backfill surface towards the C4/5 pit was initiated at the northern end of the E1-cell 1 / western edge of the C3 cell at maximum gradient of 2%
- To avoid ponding against pit walls and to assist with egress and geotechnical stability, the backfill surfaces were back-sloped away from pit walls at between 2 and 3%.

#### 5.14.2.3 Knowledge gaps & forward work program

The backfill design will be further developed following consultation with BNTAC and the Banjima people, data sharing with RTIO, and subsequent iterations of modelling. Further work is required to:

- Incorporate:
  - Pit wall stability designs (e.g., buttresses, pit wall re-profiling / laybacks).
  - Floodplain landforms for surface water control.
- Confirm pit access locations / designs.
- Assess settlement rates and adjust designs to account for settlement.
- Update inputs to the materials balance.

### 5.14.3 Pit lake water quality modelling

Since the 2020 mine closure plan, hydrogeochemical modelling of pit lake qualities has commenced. To date, the following studies have been completed:

- In 2022, Mine Waste Management completed pit lake water quality modelling for the C4/5 Pit as a proxy for the Yandi pit lakes in general. This pit was chosen as it is expected to capture flows from adjacent backfilled pits, behave as a terminal hydraulic sink and has the potential for significant evapo-concentration influences. The predictions for C4/5 should have, therefore, provided a conservative approximate indication of long-term water quality in the Yandi pit lakes after closure. SRK (2022a) conducted a peer review of the hydrogeochemical model inputs and approaches, and the 2022 modelling approach was updated by Mine Waste Management (2023a) to address recommendations made by SRK and to extend the modelling to all the permanent pit lakes in Scenario B.1 (Section 5.14.1).
- An assessment of the soluble salt build-up in seasonal water bodies was completed by Mine Waste Management (2023b) which evaluated the:
  - Potential for “first-flush” re-dissolution of previously precipitated salts after significant rainfall events.
  - Potential for the formation of sodic soils and impacts to vegetation within backfilled pits.
  - Influence of soluble salt build up in seasonal lakes on permanent pit lake water quality.
- Conceptual assessment of the nitrogen dynamics in Yandi pit lakes conducted by Mine Lakes Consulting (2023).

The permanent pit lake hydrogeochemical modelling is summarised in Section 5.14.3.1 along with SRK’s (2022a) observations on the inputs and approach. The assessment of soluble salt build up in seasonal water bodies is summarised in Section 5.14.3.2 and the conceptualisation of the nitrogen dynamics in Section 5.14.3.3. Outstanding knowledge gaps and proposed forward works are outlined in Section 5.14.3.4.

As previously discussed in Section 1.4, the final pit basement levels (and hence unmined thickness of the CID aquifer remaining) are subject to changes to mine plans. Changes to the unmined CID aquifer thickness influences water balance outcomes and hence changes to the mine plan will also influence the hydrogeochemical modelling results presented in this section which rely extensively on the water balance results as inputs. Modelling will, therefore, need to be updated as mine plans change.

#### 5.14.3.1 Permanent pit lake hydrogeochemical modelling

The final configuration and characteristics of pit lakes is still under review, however, Scenario B.1 (Section 5.14.1) was used as the basis for the hydrogeochemical modelling study to provide a conceptual understanding of potential pit lake qualities. Under this scenario, there will be four permanent pit lakes (W2, W3, C4/5 and E7). Three of these lakes (W3, C4/5 and E7) are expected to behave as terminal hydraulic sinks with the potential for significant evapo-concentration, and the fourth lake (W2) is expected to behave as a throughflow system with groundwater outflows to W3 Pit[38] (Mine Waste Management, 2023a).

**Summary**

Hydrogeochemical modelling was conducted using PHREEQC to model geochemical processes and the AQ2 (2022a) water balance (Section 5.14.1) to determine the mixing proportions of pit lake inflows and outflows at each model time step. This approach enabled the primary drivers of lake water chemistry to be modelled including:

- Solute mass loading from groundwater inflows (basement inflow, inflow from upgradient backfilled pits and seepage from Marillana Creek alluvial aquifer).
- Solute mass release from backfill in adjacent upgradient pits, which is flushed into the permanent pit lakes with inflowing groundwater.
- Evapo-concentration, which drives the accumulation of solutes over long timescales.

38 The remaining pits will be partially backfilled and will either be dry of have seasonal expressions of water. They have not been considered further in this section as it focuses on permanent pit lake water quality modelling.

- Precipitation / dissolution of secondary mineral phases, particularly dolomite and magnesite which constrains dissolved concentrations of calcium, magnesium, sulphate, fluoride, barium, aluminium, and iron.

Predicting the water qualities of complex systems through modelling requires many assumptions. To assess the potential impact of selected assumptions / inputs on modelled pit lake water quality, three model cases were run:

- Base case - based on median water balance outputs and assuming 'as expected' climate and hydraulic parameters.
- 'Low K' case - based on median water balance outputs where backfill permeability was reduced from 3 m/d (base case assumption) to 0.5 m/d.
- Climate change case - based on median water balance outputs where average rainfall (+8%) and evaporation rates (+7%) were increased consistent with the 2050 climate change scenario (Section 5.1.2).

A further sensitivity analysis was also conducted to assess the potential influence of elevated dissolved $CO_2$ on water quality.

Key model outputs are outlined below. Due to various assumptions and uncertainties, model outputs should be viewed as first-order approximations with more emphasis placed on modelled trends in chemistry, rather than precise concentrations or timeframes.

- The largest contributors to solute load in the pit lakes are the groundwater inflows from upstream and downstream.
  - W2 receives the largest solute load from upstream, reflecting significant inflows from W1 and the solute contribution from the backfill in W1.
  - W3 receives roughly equal proportions of solute load from downstream backfill (in W4 and W5) and from W2, which is upstream of W3.
  - C4/5 receives little solute load from downstream. The greatest proportion is obtained from the upstream backfill in the W5, W6, and C1/2 pits, and the groundwater inflows from the Weeli Wolli Formation.
  - E7 receives the largest load from downstream sources (from RTIO's Mungadoo Pit, based on assumed conditions for this pit).
- The projected pH for all pit lakes was neutral to alkaline and varied by less than 0.5 pH units between model cases. Except for W2, a declining pH trend was noted in all pit lakes which is consistent with natural hypersaline lakes where pH in the range pH 6 - 8 declines with increasing salinity.
- Modelled maximum TDS concentrations ranged from 7,000 to around 250,000 mg/L in both the base case and climate change case. The 'Low K' case typically presented higher TDS concentrations. Since the hydrogeochemical model allows for mineral precipitation, the predicted TDS concentration is significantly lower than that predicted by the water balance model. Modelled TDS of the pit lakes does not exceed the halite saturation of 360,000 mg/L for long periods, before decreasing due to rainfall and groundwater inflows. In contrast to the steady increase in salinity of the other pit lakes, W2 salinity varied within a consistent range (about 1,000 mg/L to 7,000 mg/L for both the base and climate change cases) as salinity increases in this pit are diluted by the significant upstream water input from W1 and the salinity outflow to W3.
- Selected major ion (sodium, chloride, sulphate, magnesium, potassium) concentrations tended to follow the trend of TDS for each pit. Other observations were:
  - Sodium and chloride concentrations tended to be highest as these ions behave conservatively (not affected by mineral precipitation within the modelled timeframe) and, therefore, concentrations are driven by evapo-concentration.
  - Sulphate was a major component of the solute assemblage. Concentrations can be limited by gypsum precipitation, but except for W3, conditions were generally not favourable for gypsum precipitation in the model, as the water did not reach saturation with respect to this mineral.
  - Modelled magnesium concentrations were constrained by precipitation of magnesite and dolomite.
  - Potassium concentrations were the lowest of the major ions, which reflects the low inflow concentrations.
- Modelled calcium and alkalinity concentrations varied significantly between pit lakes with concentrations influenced by the solute loading from backfill, evapo-concentration, dilution with rainfall events and precipitation of calcium bearing mineral phases (dolomite, gypsum, fluorite). Dolomite and magnesite were the most significant contributors to the removal of dissolved alkalinity.
- Salinity (TDS) is a primary control on water quality risk from a toxicological perspective as it determines the palatability of the water for drinking, and potential for aquatic species to live in lakes and accumulate contaminants. Salinity tolerance varies by species, but in general, TDS concentrations of 4,000 - 8,000 mg/L are tolerable to livestock, and above this range can lead to a decline in health.
- No exceedances of ANZECC & ARMCANZ (2000) livestock drinking water guideline values were projected over the modelled timeframe for calcium, aluminium, arsenic, lead or zinc. Key predicted exceedances over the modelled timeframe and the salinity at the time the exceedance occurred were:
  - W2 - sulphate, boron, and fluoride. Exceedances were predicted to occur in the short term (0 - 100 years) for boron and fluoride, and medium term (100 - 500 years) for sulphate while salinity is in the 'tolerable' TDS range (4,000 - 8,000 mg/L).
  - W3 - sulphate, boron, fluoride, and selenium. Exceedances were predicted to occur in the short term while salinity is in the 'tolerable' TDS range.
  - C4/5 - sulphate, boron, fluoride, and selenium in the short term while salinity is in the 'tolerable' TDS range and nickel in the long term when salinity approaches 180,000 mg/L.

- E7 - sulphate (in the medium term) and fluoride (in the short term) while salinity is in the ‘tolerable’ TDS range and boron (in the medium term) when salinity exceeds 8,000 mg/L.
- Nitrate concentrations in the short to medium term in W2, W3 and C4/5 while salinity is in the ‘tolerable’ TDS range. However, these are overestimates as the model did not allow for biochemical nitrate cycling processes. Conceptualisation of the nitrogen cycle (refer to Section 5.14.3.3) suggests that nitrate concentrations are expected to diminish, not increase over time.

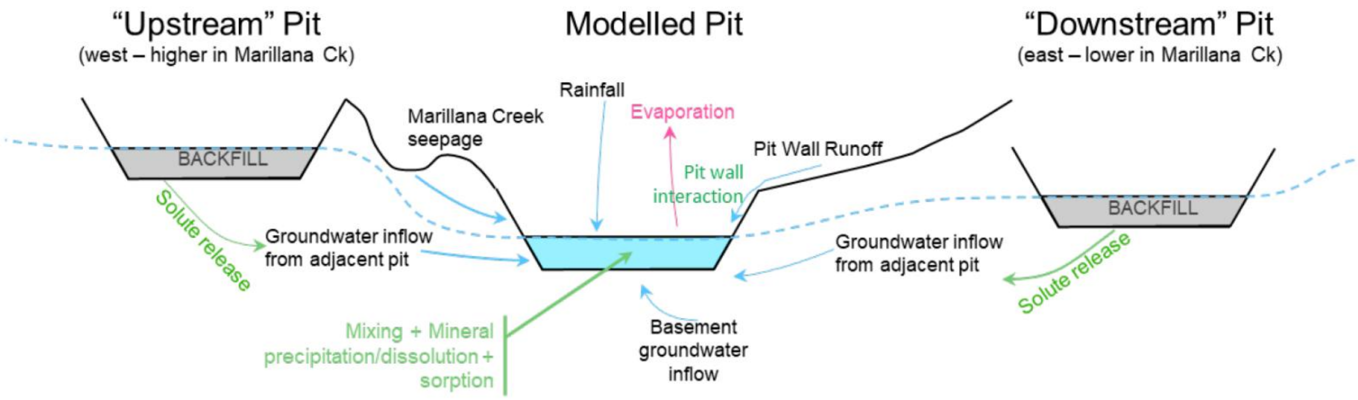
Whilst modelled pit water quality trends for the base case and climate change cases were consistent, the Low K model case shortened the time before nickel values exceeded guideline values in C4/5 and led to an exceedance of selenium in W2 (as well as W3 and C4/5).

- A sensitivity analysis to assess the potential water quality influences of elevated dissolved $CO_2$ in the deeper pit lakes, reflecting a hypothetical presence of suboxic / anoxic water due to seasonal stratification, concluded that:
  - As expected, the parameters most affected were alkalinity and pH:
    - pH was predicted to be lower (by approximately 0.25 pH units) with increased dissolved $CO_2$.
    - Alkalinity was predicted to be higher (in the order of 100 mg/L) for the higher dissolved $CO_2$.
  - Projected concentrations of metals / metalloids and other solutes were relatively insensitive to variations in dissolved $CO_2$ concentrations and no additional constituents of potential concern were identified. The parameters most affected were zinc and nickel, with a slight (insignificant) increase in projected dissolved concentrations (less than 4%) which is within the likely error of the model.

### Conceptual model

A generic conceptual hydrogeochemical model was developed to guide water quality modelling of the permanent pit lakes (Figure 5-47) (Mine Waste Management, 2023a). This was based in part on the conceptual hydrological model and water balance outputs (AQ2, 2022a) reported in Appendix F.1.3.

The generic conceptual model (Figure 5-47) shows inflows (blue), evaporation outflows (pink) and geochemical processes occurring on the pit wall and within the pit backfill and pit lake (green) (Mine Waste Management, 2023a). This model addresses a recommendation by SRK (2022a) that the model include solute concentrations from backfilled pits. In all other respects, SRK (2022a) concluded that the conceptual model is fit for purpose.




Source: Mine Waste Management (2023a)

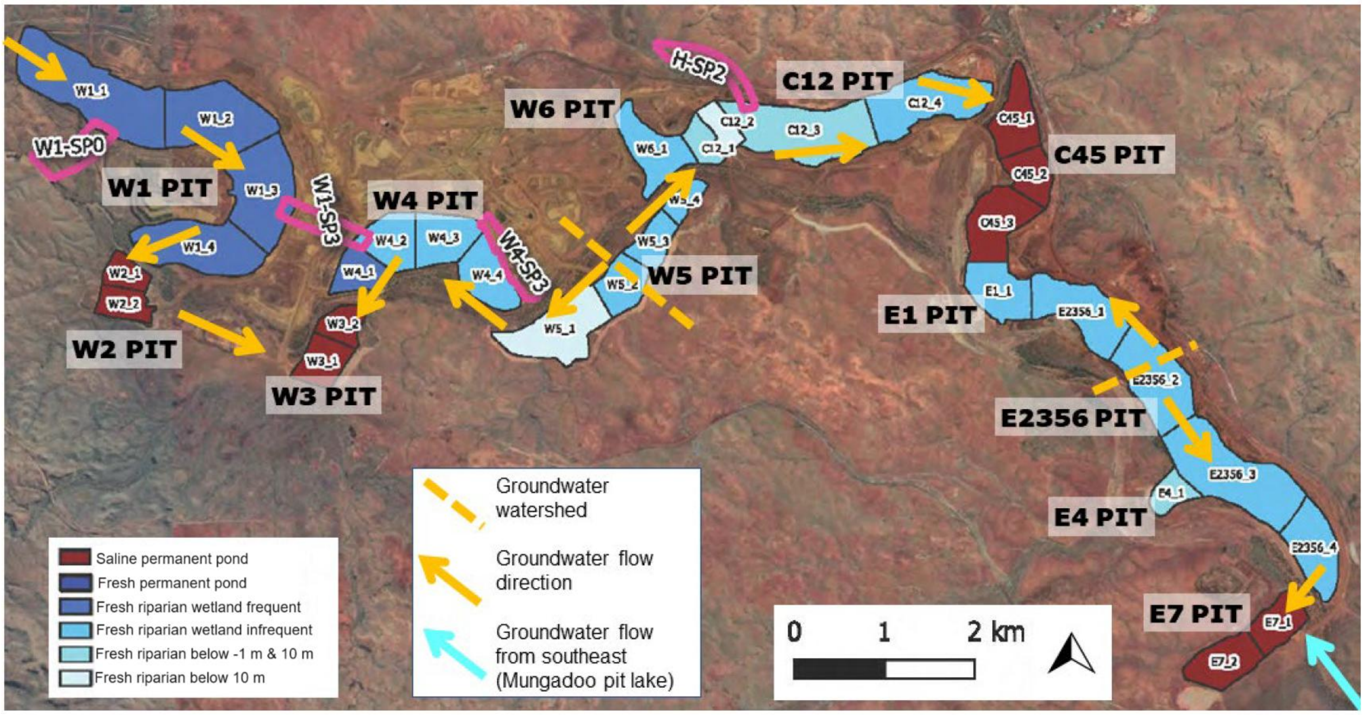
**Figure 5-47 Generic geochemical conceptual model**

The generic conceptual model (Figure 5-47) is not directly applicable to all four modelled pit lakes. Differences to the generic model relate to groundwater inflow and backfill solute release, which varies according to each pit (Figure 5-48 and Table 5-49). As shown in Figure 5-48, groundwater flows do not consistently trend ‘downstream’ (eastwards) as the terminal sinks are situated at local low points in the elevation profile and may receive inflows from pits either side. Some pits are hydraulically down-gradient of multiple pits (e.g., W3 is down-gradient of both W2 and W1) (Mine Waste Management, 2023a).

**Table 5-49 Similarity / variance of each permanent pit lake from the conceptual model**

| Permanent pit lake | Immediate upstream pit | Immediate downstream pit |
|---|---|---|
| W2 | W1 (partially backfilled) | None |
| W3 | W2 (no backfill) | W4 (partially backfilled) |
| C4/5 | C1/2 (partially backfilled) | E1 (partially backfilled) |
| E7 | E2/3/5/6 (partially backfilled) | Groundwater inflow assumed controlled by the Mungadoo Pit Lake (formerly Oxbow Pit) at RTIO’s Yandicoogina operation. |

Source: AQ2 (2022a) & Mine Waste Management (2023a)




Source: AQ2 (2022a) & Mine Waste Management (2023a)

Notes: Areas outlined in pink (e.g., W1-SP0) represent flood channels proposed at the time of the study. The configuration has changed and will be updated in any future modelling.

**Figure 5-48 Modelled groundwater flow directions**

## Modelling approach

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013). The AQ2 (2022a) water balance (Section 5.14.1) was used to determine the mixing proportions of pit lake inflows and outflows at each model time step. For each time step represented in the pit lake water balance, the hydrogeochemical model simulated (Mine Waste Management, 2023a):

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the water balance;
- Effect of evapo-concentration, as predicted by the water balance, on the resulting mixed lake water by removal of pure water; and
- Geochemical speciation modelling of the mixed, evapo-concentrated water to account for geochemical processes including:
  - Equilibration with atmospheric gases ($O_2$ and $CO_2$);
  - Precipitation of secondary minerals, principally hydrated oxides, if predicted to be oversaturated in the mixed lake water; and
  - Adsorption of dissolved metals and metalloids to Hydrous Ferric Oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

SRK (2022a) noted that the model accounts for mineral solubility and sorption controls, as well as equilibration of oxygen and carbon dioxide in air, and concluded that the adopted mineral suite and key input assumptions are reasonable. A recommendation was made to assess the sensitivity of the model to changes in redox conditions / dissolved $CO_2$. This has been addressed by Mine Waste Management (2023b) and the outcomes of the analysis are reported in the model outputs sub-section below.

### *Key assumptions and limitations*

Key assumptions and limitations relating to the hydrogeochemical model included (Mine Waste Management, 2023a):

- Complete instantaneous mixing of the groundwater plus solute load component and other inflows to the permanent pit lake.
- Pit lake stratification effects in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential are ignored. This is considered appropriate given the current level of uncertainty and level of sophistication of the model plus the long projection period.
- The pit lake will remain oxic (high Eh/ORP). A pe value of 10 was applied for all source terms and equilibrium between the lake and the atmosphere ($O_2$ and $CO_2$) was assumed. This is consistent with the complete mixing. Note that further to a recommendation by SRK (2022a), a sensitivity analysis was undertaken to assess the potential influence of increased $CO_2$ saturation in pit lakes, reflecting seasonal stratification.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium is attained. Kinetically limited reactions were not accounted for.
- Reaction of exposed pit walls in contact with the pit lake water was not considered. Pit wall solute inputs were limited to the pit wall runoff source term.

- Biochemical processes are not considered in the model (e.g., nitrate cycling).
- High ionic strength solutions (or high salinity) can cause increased calculation errors, since thermodynamic databases rely on experimental data typically involving solutions of low ionic strength. Whilst the use of a Pitzer thermodynamic database can minimise this type of error, results should be interpreted as relative approximations and trends.
- The water balance model includes external catchments for three pits, none of which are to become permanent pit lakes (AQ2, 2022a); hence, there is no ex-pit runoff component in the hydrogeochemical model.

*Uncertainties*

All models estimate future conditions by reducing complex systems to a limited number of significant, often simplified, processes. Predicting the water qualities of complex systems requires many assumptions. Even a rigorous sampling and analysis program cannot precisely determine all the physical, chemical, and geological characteristics of the system. Nor can they precisely indicate how these characteristics might change over time. Even though assumptions are informed by data they include an inherent level of uncertainty. Table 5-50 summarises the key uncertainties associated with the Yandi pit lake models. To assess the potential impact of selected assumptions / inputs on modelled pit lake water quality, three model cases were run:

- **Base Case** - based on median water balance outputs (Scenario B1 of AQ2 (2022a)). The water balance assumed 'as expected' climate and hydraulic parameters.
- **'Low K' Case** - based on median water balance outputs where backfill permeability was reduced from 3 m/d (base case assumption) to 0.5 m/d.
- **Climate Change Case** - based on median water balance outputs where average rainfall (+8%) and evaporation rates (+7%) were increased consistent with the 2050 climate change scenario (Section 5.1.2).

As outlined above, a further sensitivity analysis was conducted to assess the potential influence of elevated dissolved $CO_2$ on water quality.

**Table 5-50 Uncertainties associated with the Yandi pit lake models and input data**

| Item | Limitation | Uncertainty |
|---|---|---|
| 1 | Predicting field-scale water quality from lab scale test results is an approximation | Leaching of salts and metals at the field scale is variable in time and controlled by factors not fully applied at the lab scale. Amongst others, these factors include temperature, nature of the leaching solution, the solution to solid ratio, solution-solid contact time, and particle size / surface area of the solid leached. The quality of water due to interaction with material such as overburden, and pit walls as presented in this report, are therefore, informed estimates. |
| 2 | The compositions of input waters are constant | The quality of water sources, such as groundwater, surface water, and rainwater, are the results of other complex systems (aquifer, catchment, atmosphere). While water composition can be determined in the laboratory with some accuracy, it requires a statistically relevant number of samples to establish inherent variability due to factors such as seasons, sediment movement, changes in gradient, etc. The required number of samples is only rarely obtained in practice. |
| 3 | The geochemical database is relevant to the system being modelled | Hydrogeochemical modelling uses the inherently uncertain laboratory results and water qualities as inputs. These are processed using thermodynamic data determined in the laboratory on ideal materials and solutions. The laboratory determined constants may not be directly applicable to the materials, solutions, and chemical context of the pits. |
| 4 | The modelling assumes thermodynamic equilibrium in the model system. | In the field, all chemical components are subject to kinetic variation and the system might, at most, be in a state of quasi-equilibrium. This may suggest that attempts to simulate or predict the state of these complex systems have questionable value. However, geochemical evaluations of natural and mine waters over the last few decades have shown that the equilibrium assumption is a powerful tool that in many circumstances produces results that accurately describe the general chemistry of such waters. |
| 5 | The water balance model includes a range of assumptions | AQ2 (2022) and associated reports document the assumptions and uncertainties inherent in the water balance model. Since the pit lake hydrogeochemical model uses mixing volumes and proportions of different source waters from the water balance, the uncertainties in the water balance are propagated, at least in part, to the hydrogeochemical model. These uncertainties include (amongst others): porosity characteristics of pit backfill, groundwater inflow rates, groundwater levels upstream and downstream of the Yandi system, constant climate characteristics over 1,000 years, etc. |

Source: Mine Waste Management (2023a)

**Source terms**

*Rainfall & pit wall run-off quality*

The water qualities used for rainfall and pit wall run-off are provided in Appendix F.2.1 (Mine Waste Management, 2023a):

- Direct rainfall water quality was derived from a rainfall composition monitoring network established by CSIRO (Crosbie, et al., 2012) and 27 samples collected at the Meekatharra station in Western Australia from May 2007 to Jun 2011.
- Pit wall run-off quality was derived from the results of the de-ionised water leachate tests on Yandi materials (Section 5.2.3.2). This is a conservative assumption as:

- The liquid : solid ratio of the leach test is likely to be much lower than pit wall run-off resulting in higher element concentrations.
- The use of crushed sample material for leach tests results in a larger ratio of surface area to leaching solution than might be expected under pit wall runoff conditions, resulting in an over-estimated solute release.
- The pit wall runoff source term is assumed to be constant. That is, there is no systematic decrease in element concentrations in pit wall run-off with time, as might be expected over 1,000 years of leaching due to exhaustion of the readily soluble salts / mineral phases.

While SRK (2022a) notes that small finite quantities of readily soluble salt may mean that pit wall run-off quality may change over time, and that pit wall liquid to solid ratios might be different than the 2:1 used in leach tests, they concluded that, the current modelling approach is acceptable as:

- Run-off from the pit wall represents a small proportion of overall solute loadings to the pit lake.
- It is challenging to estimate an appropriate contact ratio during a rainfall / runoff event - the concentrations in run-off may be higher or lower than the current estimate.
- Pit wall weathering and continued development of talus could be used as an argument for continued exposure of 'new' salt sources.

*Initial pit lake water quality*

The water balance for each of the pit lakes starts with an initial lake volume because the water balance model simulation period starts after groundwater rebound has occurred following cessation of dewatering (Mine Waste Management, 2023a).

The solute composition assigned to these initial lakes was based on the inference that interactions between rainfall / runoff and the pit walls would be the primary influence on water quality at this early stage of lake development (i.e., before basement groundwater inflows dominate). The composition was based on the pit wall runoff source term (Appendix F.2.1), adjusted to account for evapo-concentration (Mine Waste Management, 2023a).

The initial pit lake water quality was assumed to be the same for every pit lake, reasonably assuming that the exposed rock of the pit walls is similar, and that the original source term reflects the consistent geology throughout the Yandi orebody. Nominating consistent initial water quality for each pit lake is unlikely to significantly affect longer-term projections of pit lake water quality, given their minor volumetric contribution to steady-state permanent pit lakes (Mine Waste Management, 2023a).

*Basement groundwater inflows & creek seepage*

**Basement groundwater inflows**

The composition used for groundwater inflowing from the basement aquifers is provided in Appendix F.2.3, and was derived from groundwater bores screened in the various aquifers contributing to basement groundwater flow (CID, Weeli Wolli Formation, dolerite and basal conglomerate) (Mine Waste Management, 2023a).

A median groundwater composition was ascertained by filtering the water quality monitoring dataset for samples within ±10% of the median of major parameters in the following order: EC, total alkalinity, chloride, sodium, calcium, magnesium, sulphate, and potassium (because these are the major ions contributing to salinity). This yielded a groundwater analysis from bore HYC0005P (11/04/2018) as representing the major ion composition approximating the median Yandi groundwater composition. Where a trace element concentration in sample HYC0005P (11/04/2018) was less than the median of the same trace element in all samples, it was replaced by the median from all samples (Mine Waste Management, 2023a).

**Creek seepage**

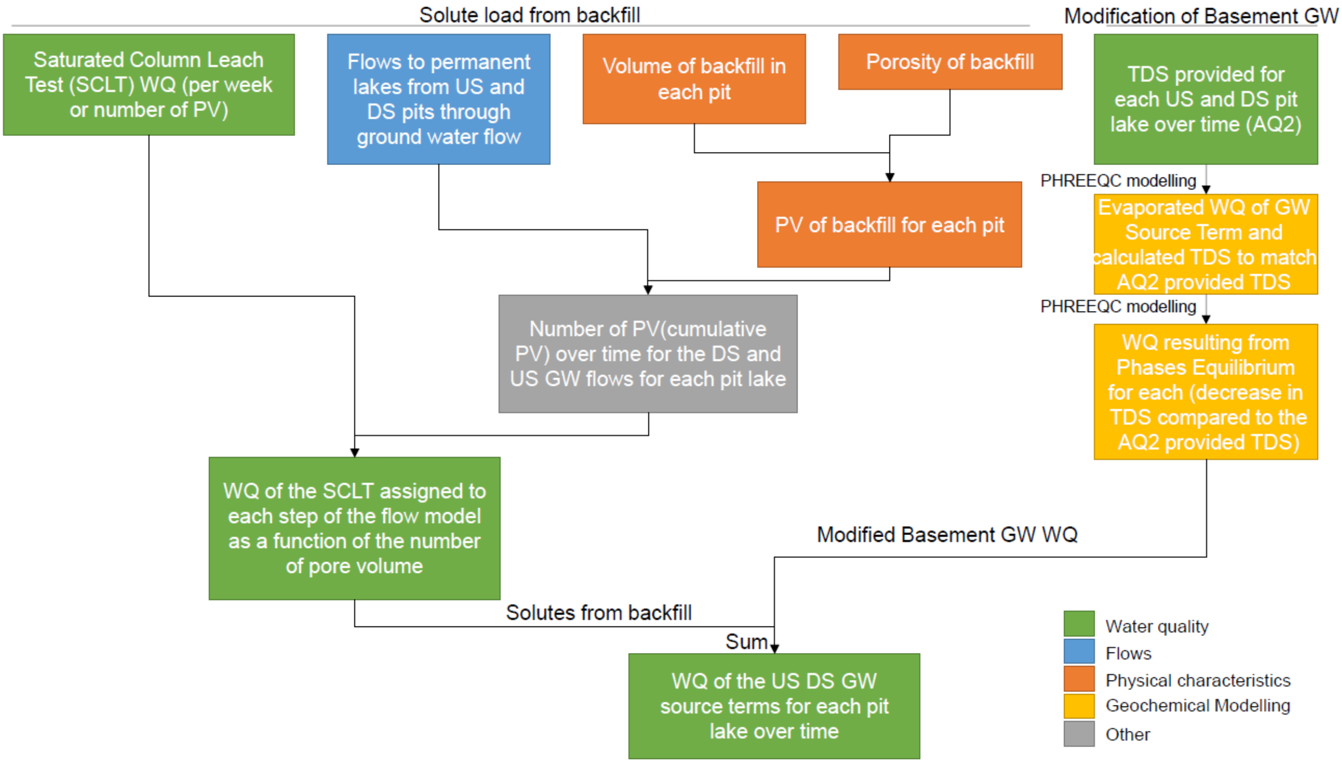
Groundwater in the alluvium associated with the Marillana Creek represents the chemical composition of potential seepage from the creek into the permanent pit lakes. Of fifteen samples from bores screened in the alluvium, element concentrations in sample HYM0011M (04/02/2015) were closest to the median for all 15 samples and was selected as the source term (Appendix F.2.3) (Mine Waste Management, 2023a).

*Groundwater inflows from adjacent pit lakes*

The chemical composition of groundwater inflows from adjacent pit lakes comprised two components:

- The source term for basement groundwater inflows modified at each time step to match the salinity (as TDS) calculated by the AQ2 (2022a) water balance model.
- Solute load from backfill.

The modelling approach is shown in Figure 5-49 and described in the following subsections. It addresses SRK's (2022a) recommendation that backfill should be represented as a source of salinity or trace parameters and that the salt balance should be reviewed to determine if the influence of a short-term flush of saline water from inundated backfill has a material effect on outcomes.




Source: Mine Waste Management (2023a)

Notes: WQ - Water quality; US - upstream; DS - downstream; SCLT - saturated leach column test; PV - pore volume; GW - groundwater

**Figure 5-49 Process to define groundwater inflow source terms for each pit lake**

#### Modification of basement groundwater

The composition of groundwater inflows from backfilled pits was extrapolated from the basement groundwater inflow modified via a PHREEQC evaporation model to adjust the groundwater composition to account for evapo-concentration and the influences of secondary mineral precipitation and dissolution, and atmospheric gas exchange in the temporary lakes over the 1,000 year projection period (Appendix F.2.4) (Mine Waste Management, 2023a). This component accounts for the contribution of salts to groundwater from the unsaturated / vadose sections of the backfill.

#### Solute load from backfill

Results from the saturated leach column testing reported in Section 5.2.3.2 were used as the primary basis for the backfill solute source term to account for the contribution from the proportion of backfill under saturated conditions. The tests were performed on composite samples of the M2 (Barimunya Member - Lower CID) and M3 (Barimunya Upper CID and Marginal Zone units) stratigraphies which represent the majority of pit backfill material and pit wall exposures. The test results indicate the relationship of element mass release to the number of pore volumes of de-ionised water moving through the column-packed overburden sample (Appendix F.2.4). While composite overburden samples used for the column experiments were obtained from resource definition diamond drill core and do not directly represent blasted overburden, the aggressive leaching of freshly crushed (to <3 mm) rock is sufficiently representative of solute release from the fine particle size fraction of groundwater-inundated backfill.

The number of backfill pore volumes represented by groundwater inflowing to the permanent pit lakes at each timestep were calculated based on the mass and nominal porosity (15%) of backfill (Section 5.14.1.3) up-gradient of the permanent pit lakes. The corresponding backfill solute mass release was then extrapolated from the column test results, for the equivalent pore volume[39] (maximum values for both composites) and added to the modified basement groundwater composition. The final solution composition, reflecting groundwater with additional solutes released from backfill, was then mixed with the permanent pit lake water in proportions reflecting groundwater inflows at each timestep (Appendix F.2.4).

### Model outputs

Modelling provides an informed estimate of future conditions to support decision-making. Given the model assumptions and uncertainties outlined in the sub-sections above, the reported concentrations in this section should be viewed as first-order

39 The saturated leach column tests were stopped at 12 pore volumes. As the number of pore volumes through the backfill increased beyond 12 during the 1,000-year model simulation, the solute mass release from the final (12th) pore volume in the laboratory tests was conservatively used to determine backfill solute release for subsequent pore volumes and may overestimate elements sourced from a finite quantity of salt.

approximations with more emphasis being placed on the modelled trends in chemistry, rather than precise concentrations or timeframes.

*Solute loads*

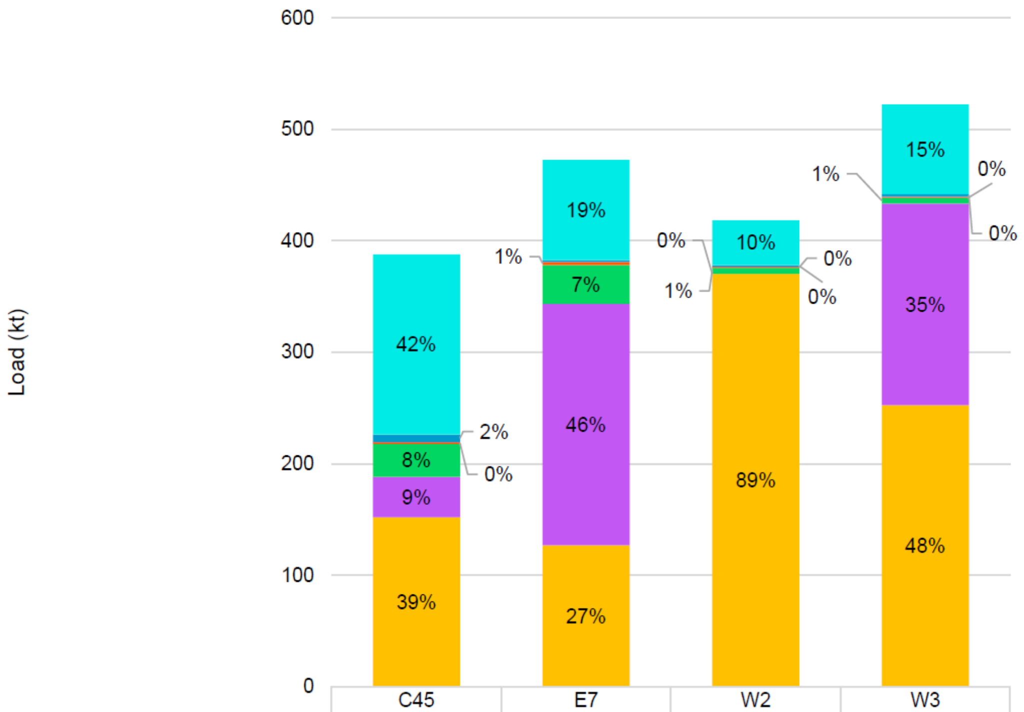
Analysis of the solute loads addresses SRK's (2022a) recommendation that a matrix of solute sources and sinks be prepared so that it is possible to highlight which components of the solute load balance contribute most to the predicted distribution and behaviour of key elements within the integrated landform.

The largest contributors to solute load[40] are the groundwater inflows to the permanent pit lakes from upstream and downstream (Figure 5-50) (Mine Waste Management, 2023a).

W2 receives the largest solute load from upstream, reflecting the significant inflows of groundwater from W1 and the associated solute contribution from the backfill mass in W1. There is no solute load from W3, which is downstream of W2, as the net groundwater flow is from W2 to W3. W3 receives roughly equal proportions of solute load from downstream backfill (in W4 and W5 pits) and from W2, which is upstream of W3 (Mine Waste Management, 2023a).

C4/5 receives little solute load from downstream. The greatest proportion is obtained from the upstream backfill in the W5, W6, and C1/2 pits, and the groundwater inflows from the Weeli Wolli Formation (Mine Waste Management, 2023a).

E7 receives the largest load from downstream sources. In this case, the source is the inferred solute load from RTIO's Mungadoo pit lake[41]. The groundwater quality inflowing from RTIO's Mungadoo Pit, is assumed to be fixed at 500 mg/L of TDS (AQ2, 2022a). The composition was derived from the basement groundwater source term, normalised to 500 mg/L (Mine Waste Management, 2023a).




| | C45 | E7 | W2 | W3 |
|---|---|---|---|---|
| Net_WW_Seepage (Basement) | 161 | 89.9 | 40.3 | 80.7 |
| Pit_Wall_Runoff_Total | 7.1 | 1.5 | 1.4 | 2.2 |
| Pond_Direct_Rainfall_Total | 1.5 | 2.7 | 0.9 | 0.9 |
| Net_Creek_Seepage | 29.7 | 35.0 | 5.5 | 5.2 |
| Net_GS_Flow_DS | 36.2 | 217 | 0.0 | 181 |
| Net_GS_Flow_US | 152 | 127 | 370 | 253 |

Source: Mine Waste Management (2023a)

Notes: Units are in thousands of tonnes (kt); GS - groundwater solute; DS - downstream; US - upstream

**Figure 5-50 Base case cumulative solute balance after 1,000 years for each permanent pit lake**

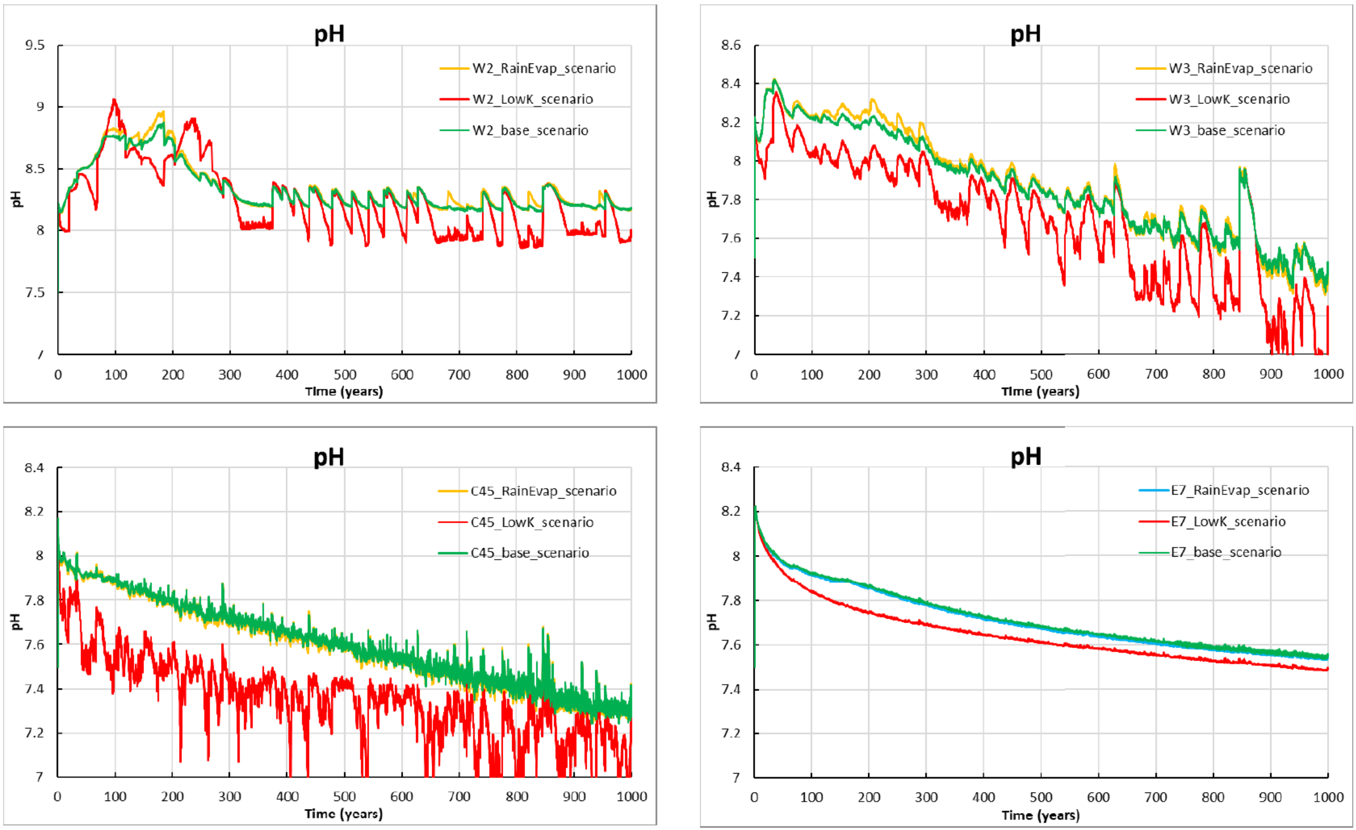
40 Solute loads do not relate directly to solute concentrations in the lakes, which are substantially influenced by evapo-concentration (see sub-sections below).

41 Note: the E7 / Mungadoo water balance model had not been completed at the time of this study.

*pH*

The projected pH for all pit lakes was neutral to alkaline (Figure 5-51) and varied by less than 0.5 pH units between model cases. The 'Low K' (permeability) case generally resulted in lower pit lake pH which was attributed to a lower alkalinity contribution from the reduced backfill solute load. The declining pH trend noted in pits W3, C4/5 and E7 is consistent with observational data for hypersaline lake settings where there is a correlation between increasing salinity and decreasing pH in the same range (pH 6-8) (Mine Waste Management, 2023a).

The modelled broad peak of alkaline pH (>8.5) in W2 from year 0 to ~300 was due to the significant alkalinity load predicted from the backfill in W1 at low pore volumes. The peaks and troughs in pH predictions for pits W2, W3 and C4/5 were attributed to periodic alkalinity contributions from backfill which gradually decreased through dolomite precipitation. The peaks and troughs were significantly muted in E7 as this pit contains >10 times more water than the other three pit lakes (Mine Waste Management, 2023a).




Source: Mine Waste Management (2023a)

**Figure 5-51 Modelled pH in permanent pit lakes over 1,000 years (case comparison)**

*TDS*

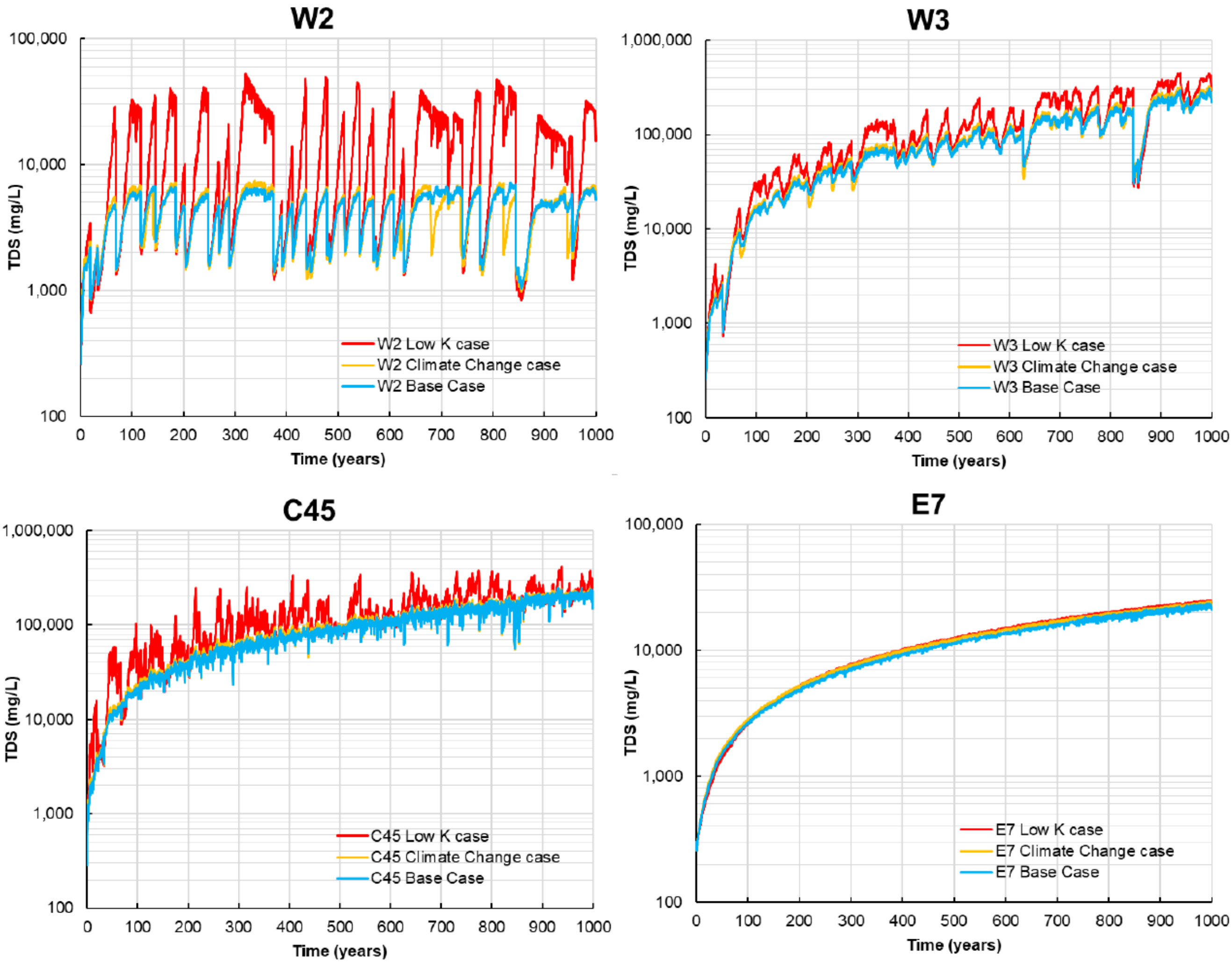
Modelled maximum TDS concentrations ranged from 7,000 to around 250,000 mg/L for the lakes under both the base case (Table 5-51) and climate change case (Figure 5-52). The 'Low K' case typically presented higher TDS concentrations compared to these cases (Figure 5-52). TDS maxima were peaks associated with extended periods of evapo-concentration that tended to be truncated by rainfall events. The TDS concentration of the pit lakes did not exceed the halite saturation of 360,000 mg/L for long periods, before rainfall and groundwater inflow decreased the concentration. In contrast to the steady increase of the other pit lakes, W2 salinity varied within a consistent range (about 1,000 mg/L to 7,000 mg/L for the base and climate change cases) which suggests that salinity in W2 is diluted by the significant upstream water input from W1 and the salinity outflow to W3 (Mine Waste Management, 2023a).

**Table 5-51 Pit lake TDS concentrations after 1,000 years (base case)**

| W2 | W3 | C4/5 | E7 |
|---|---|---|---|
| Saline<br>up to ~7,000 mg/L | Brine<br>up to ~240,000 mg/L | Brine up to<br>~200,000 mg/L | Highly saline<br>up to ~23,000 mg/L |

Source: Mine Waste Management (2023a)

Notes: Salinity classifications according to "Understanding Salinity" Department of Water and Environmental Regulation (DWER). https://www.water.wa.gov.au/water-topics/water-quality/managing-water-quality/understanding-salinity, accessed 07/02/2023.

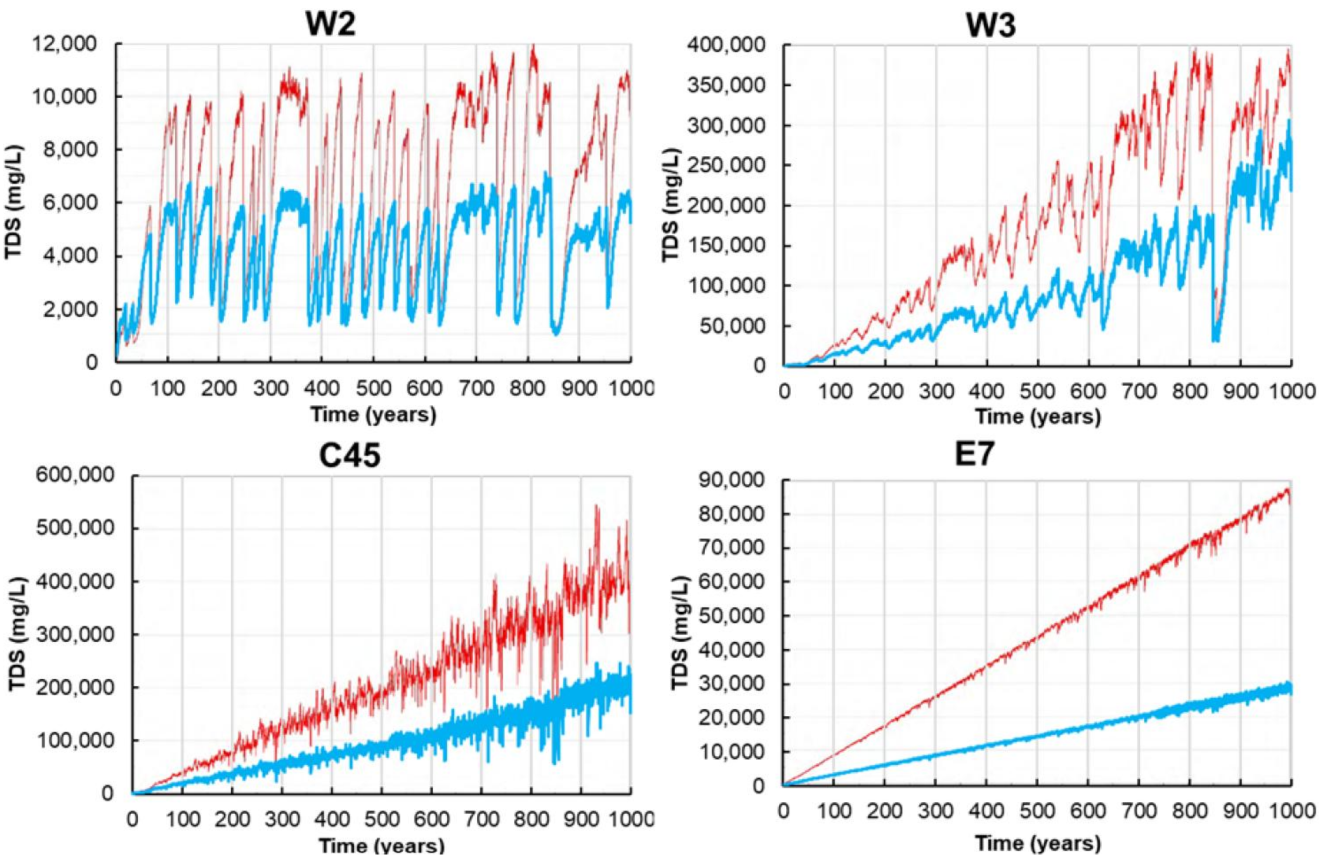



Source: Mine Waste Management (2023a)

Note the difference in the scale of the vertical axes for the W2 and E7 pit lakes

**Figure 5-52 Modelled TDS in permanent pit lakes over 1,000 years (case comparison)**

Since the hydrogeochemical model allows for mineral precipitation, solute mass is lost from the pit lake water column, resulting in lower TDS concentrations than predicted by the water balance (Figure 5-53). The difference is significant with more than half of the conservative AQ2 (2022a) water balance solute mass redistributed to precipitated mineral mass in the hydrogeochemical model (Mine Waste Management, 2023a).




Source: Mine Waste Management (2023a)

Note the difference in the scale of the vertical axes

**Figure 5-53 Comparison of water balance TDS (red) and hydrogeochemical model TDS (blue) (base case)**

*Major ions*

Selected major ion (sodium, chloride, sulphate, magnesium, potassium) concentrations tended to follow the trend of TDS for each pit (Figure 5-54). Other observations were (Mine Waste Management, 2023a):

- Sodium and chloride concentrations tended to be highest as these ions behave conservatively (not affected by mineral precipitation within the modelled timeframe) and, therefore, concentrations were driven by evapo-concentration.
- Sulphate was a major component of the solute assemblage. Concentrations can be limited by gypsum precipitation, but except for W3, conditions were generally not favourable for gypsum precipitation in the model.
- Modelled magnesium concentrations were constrained by precipitation of magnesite and dolomite.
- Potassium concentrations were the lowest of the major ions, which reflects the low inflow concentrations.

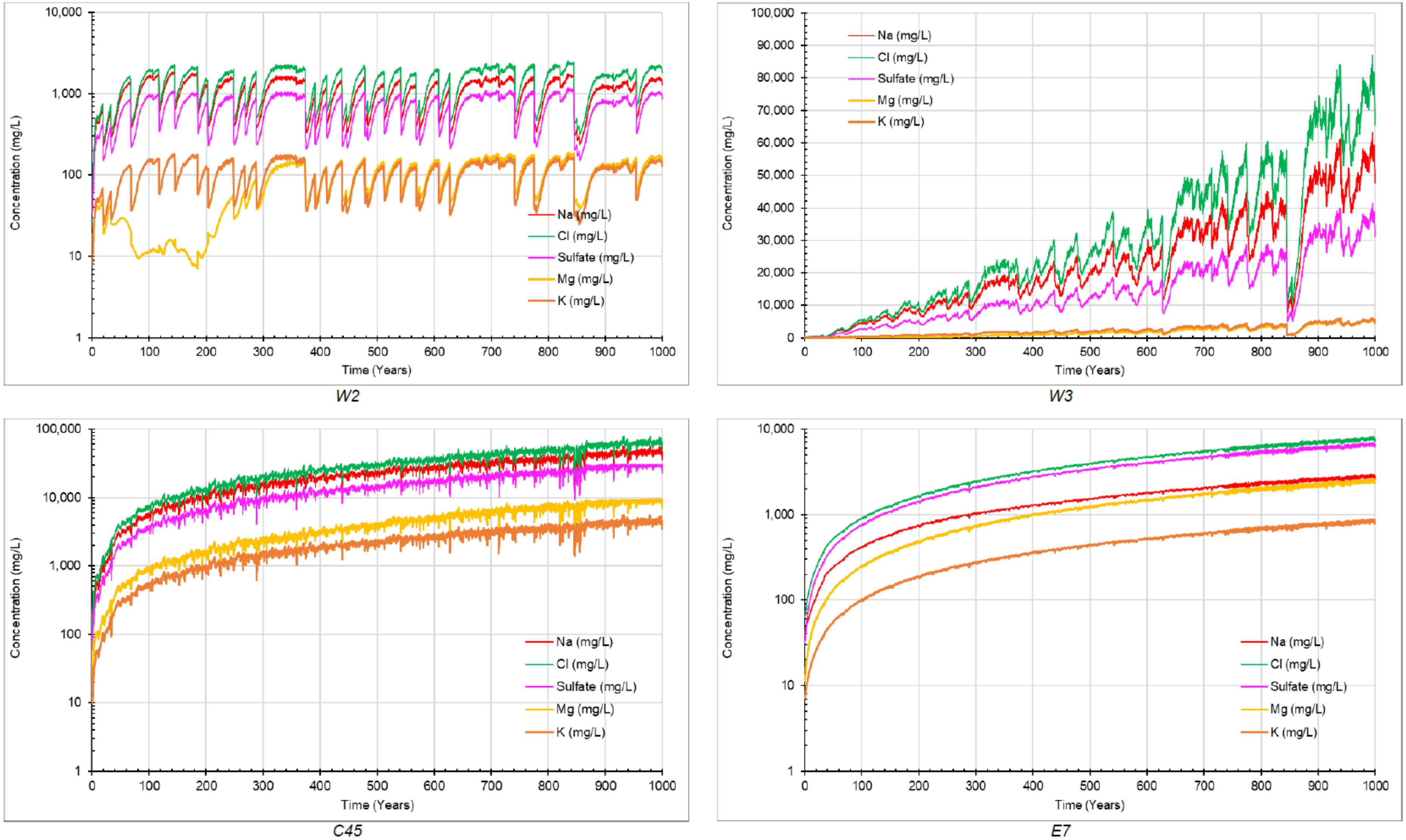
Modelled calcium and alkalinity concentrations varied significantly between pit lakes with concentrations influenced by the solute loading from backfill, evapo-concentration, dilution with rainfall events and precipitation of calcium bearing mineral phases (dolomite, gypsum, fluorite) (Figure 5-55). Dolomite and magnesite were the most significant contributors to the removal of dissolved alkalinity (Mine Waste Management, 2023a).

Calcium concentrations were lowest in W2, suggesting all available calcium was precipitated in calcium-bearing mineral phases, and alkalinity peaked around year 200 due to the solute load from backfill (Mine Waste Management, 2023a).

In W3 there was an increasing trend in calcium concentrations due to backfill solute loading and evapo-concentration. Alkalinity increased to a peak around year 250 and then was controlled within a range of about 80 to 130 mg/L, likely due to equilibrium with atmospheric $CO_2$ (Mine Waste Management, 2023a).

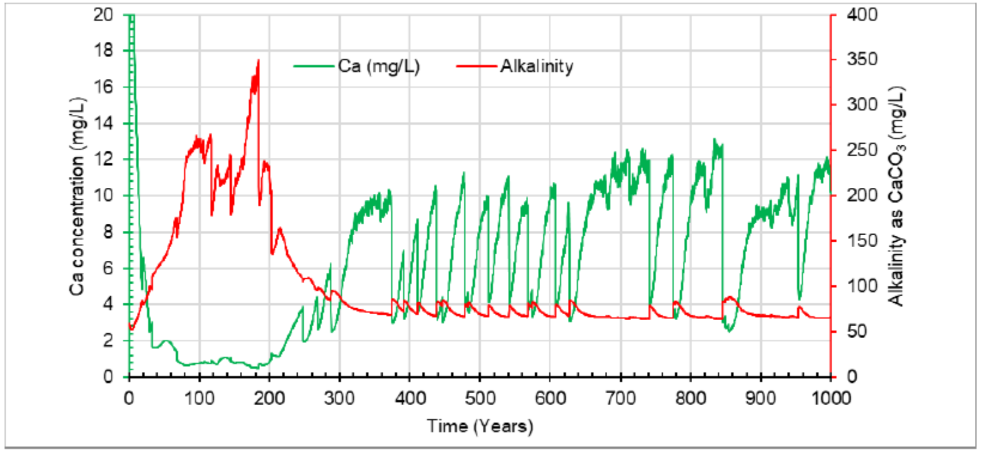
In C4/5, calcium concentrations increased due to evapo-concentration, and alkalinity increased steeply in the first 100 years due to solute loading from upstream backfill, but then increased at a lower rate as evapo-concentration became the dominant influence on water quality. The rate of increase was moderated by the consumption of alkalinity through precipitation of dolomite.

In E7, calcium concentrations started low, due to dolomite precipitation, before the rate of increase steepened in about year 200 due to evapo-concentration. Alkalinity fell rapidly from year 0 and levelled off around year 150, likely as a result of initial loading from backfill driving precipitation of minerals such as dolomite. After year 150 alkalinity declined, trending towards a long-term equilibrium of about 25 mg/L as $CaCO_3$ by year 1,000 (Mine Waste Management, 2023a).

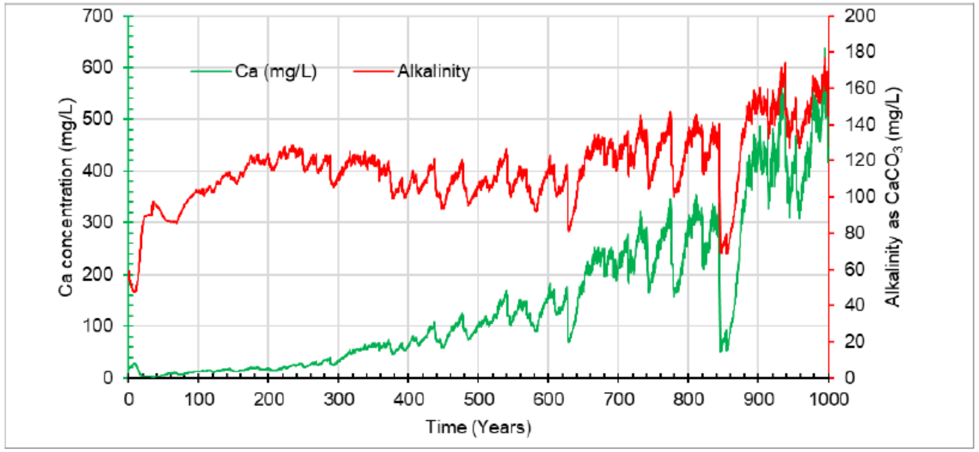



Mine Waste Management (2023a)

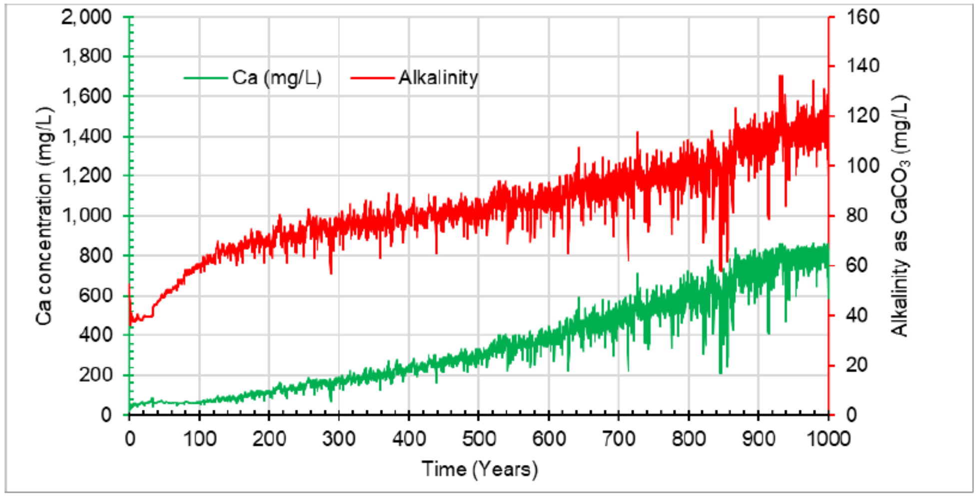
**Figure 5-54 Modelled major ion concentrations (base case)**



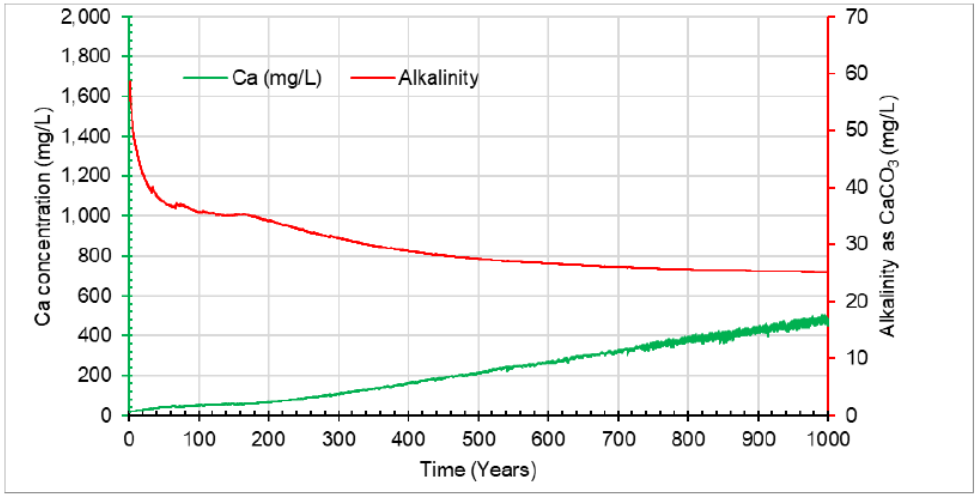

*W2*




*W3*




*C45*




*E7*

Mine Waste Management (2023a)

**Figure 5-55 Modelled calcium and alkalinity (base case)**

*Constituents of potential concern*

Salinity is a primary control on water quality risk from a toxicological perspective as it determines the palatability of the water for drinking and potential for aquatic species to establish / live in lakes and accumulate contaminants. Salinity tolerance varies by species, but in general, TDS concentrations of 4,000 - 8,000 mg/L are tolerable to livestock, and above this range can lead to a decline in health. Table 5-52 shows the broad timeframe in which selected parameters were predicted to exceed livestock drinking guideline values in the base case[42] and the predicted salinity at the time the guideline value for that parameter was exceeded (Mine Waste Management, 2023a).

There are no livestock drinking water guidelines for manganese and barium, but (Mine Waste Management, 2023a):

- Maximum concentrations of manganese were predicted to be in the order of 18 mg/L in C4/5 with other lakes being significantly lower. Manganese is not strongly constrained by adsorption to HFO surfaces or secondary mineral precipitation. Concentrations are driven mainly by adopted source term concentrations and effects of evapo-concentration and dilution.
- Barium concentrations were maintained at <0.15 mg/L due to precipitation of barite.

**Table 5-52 Modelled timeframe to exceed livestock drinking guideline values & corresponding TDS (base case)**

| Parameter Threshold | W2 | | W3 | | C45 | | E7 | |
|---|---|---|---|---|---|---|---|---|
| | Timescale | TDS (mg/L) | Timescale | TDS (mg/L) | Timescale | TDS (mg/L) | Timescale | TDS (mg/L) |
| Ca (1,000 mg/L) | No exceedance projected | | | | | | | |
| *$NO_3$ (400 mg/L) | short | 4,000 | short | 5,000 | short | 7,000 | medium | 10,000 |
| $SO_4$ (1,000 mg/L) | medium | 6,000 | short | 6,000 | short | 6,000 | medium | 3,000 |
| Al (5 mg/L) | No exceedance projected | | | | | | | |
| As (0.5 mg/L) | No exceedance projected | | | | | | | |
| B (5 mg/L) | short | 5,000 | short | 5,000 | short | 7,000 | medium | 10,000 |
| Cu (0.5 mg/L) | No exceedance projected | | | | | | | |
| F (2 mg/L) | short | 300 | short | 300 | short | 300 | short | 300 |
| Pb (0.1 mg/L) | No exceedance projected | | | | | | | |
| Ni (1 mg/L) | - | - | - | - | long | 180,000 | - | - |
| Se (0.02 mg/L) | - | - | short | 7,000 | short | 8,000 | - | - |
| Zn (20 mg/L) | No exceedance projected | | | | | | | |

Source: Mine Waste Management (2023a)

Notes: Short term: 0-100 years, medium term: 100-500 years, long term: 500-1,000 years.

TDS has been rounded to the nearest 1,000 mg/L TDS to reflect model uncertainty.

* Nitrate concentrations do not account for biochemical processes and are considered to be substantially overestimated (see Section 5.14.3.3).

No exceedances were projected over the modelled timeframe for calcium, aluminium, arsenic, lead or zinc. Gibbsite precipitation removes aluminium from the water column and calcium is precipitated in calcium-bearing mineral phases. While precipitation of gypsum may control concentrations of sulphate, conditions were not generally favourable for this to occur in the model, and sulphate guideline values were exceeded. Fluoride guidelines were also predicted to be exceeded despite precipitation of fluorite (Mine Waste Management, 2023a).

Key predicted exceedances were (Mine Waste Management, 2023a):

- W2 - sulphate, boron, and fluoride while salinity was in the ‘tolerable’ TDS (4,000 - 8,000 mg/L) range.
- W3 - sulphate, boron, fluoride, and selenium while salinity was in the ‘tolerable’ TDS range.
- C4/5 - sulphate, boron, fluoride, and selenium while salinity was in the ‘tolerable’ range and nickel when salinity approached 180,000 mg/L.
- E7 - sulphate and fluoride while salinity was in the ‘tolerable’ range and boron when salinity exceeded 8,000 mg/L.

As previously noted, nitrate concentrations were overestimated by the model since microbially mediated reactions that decrease nitrate concentrations were not simulated. The conservative model results suggest that nitrate concentrations may exceed the

[42] Selected as wild animals obtain water from several sources as they range which may limit the duration of exposure relative to stock animals.

livestock drinking water guideline value in W2, W3 and C4/5 while salinity is in the 'tolerable' 4,000 - 8,000 mg/L range. Section 5.14.3.3 provides further discussion of nitrogen dynamics in pit lakes (Mine Waste Management, 2023a).

Whilst modelled pit water quality trends for the base case and climate change cases were consistent, the Low K model case shortened the time before nickel values exceeded guideline values in C4/5 and led to an exceedance of selenium in W2 (as well as W3 and C4/5) (Mine Waste Management, 2023a).

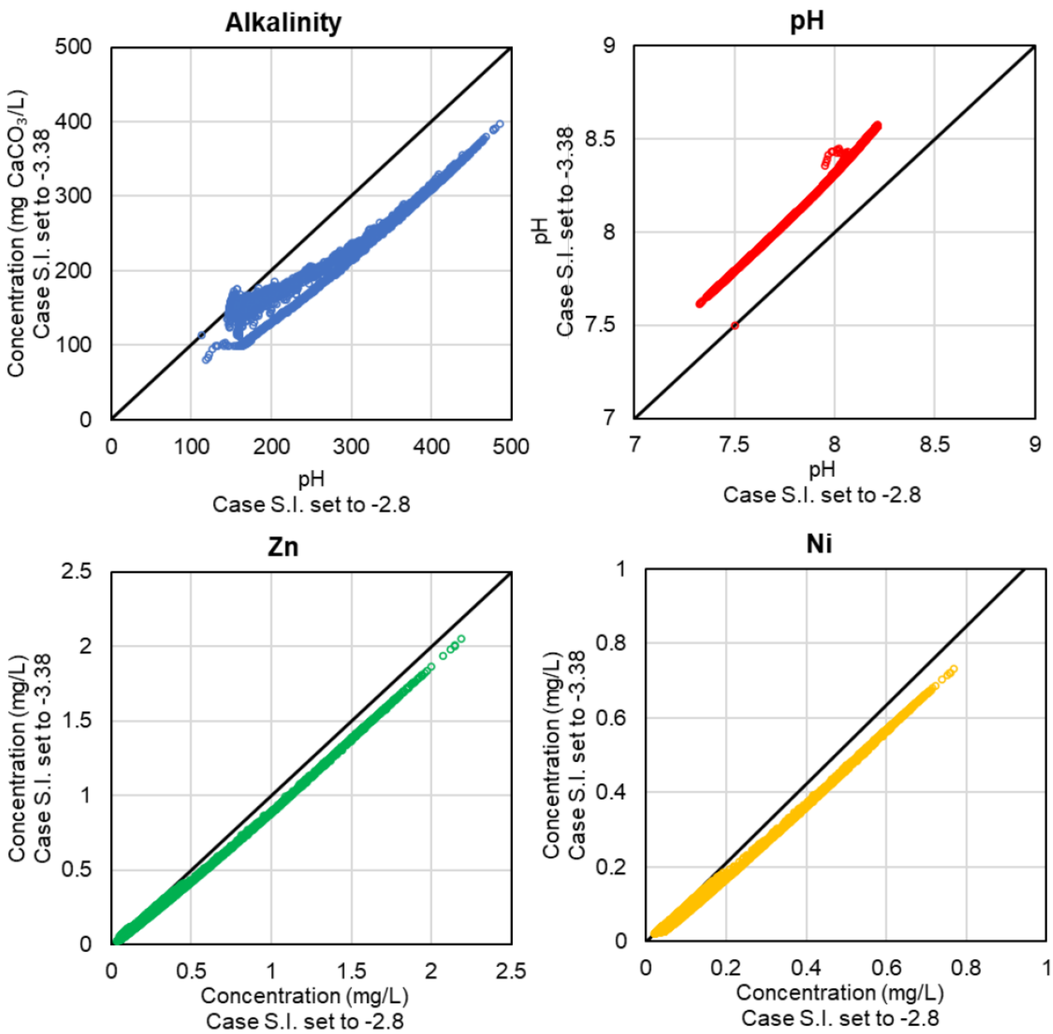
*Sensitivity analysis for $CO_2$ saturation*

As recommended by SRK (2022a), Mine Waste Management (2023a) conducted a sensitivity analysis to assess the potential water quality influences of elevated dissolved $CO_2$ in the deeper pit lakes, reflecting a hypothetical presence of suboxic / anoxic water due to seasonal stratification. The analysis was conducted on the C4/5 pit lake model, which is strongly evapo-concentrated and, therefore, likely to reveal additional constituents of potential concern in response to altered solubility constraints. A saturation index (-log of $pCO_2$) of -2.8 was adopted, which allows for higher dissolved $CO_2$ concentrations compared to the value adopted for the three model cases (-3.38). The value adopted in the model cases (-3.38) represents complete interaction with the atmosphere (~400 ppm $CO_2$), while -2.8 was nominated to represent groundwater conditions (equivalent to equilibration with atmospheric concentrations in the order of 1,600 ppm $CO_2$) (Mine Waste Management, 2023a).

As expected, the parameters most affected were alkalinity and pH (Mine Waste Management, 2023a):

- pH was predicted to be lower (by approximately 0.25 pH units) with increased dissolved $CO_2$ (Figure 5-56).
- Alkalinity was predicted to be higher (in the order of 100 mg/L) for the higher dissolved $CO_2$ (Figure 5-56).

Projected concentrations of metals / metalloids and other solutes were relatively insensitive to variations in dissolved $CO_2$ concentrations and no additional constituents of potential concern were identified. The parameters most affected were zinc and nickel, with a slight increase in projected dissolved concentrations equivalent to less than 4% (Figure 5-56). However, since this increase likely falls within the error of the model, it is not considered to be significant. Other metals showed a similar pattern, with smaller differences that were not reported and were not considered significant (Mine Waste Management, 2023a).




Source: Mine Waste Management (2023a)

Notes: The x-axis of the figure shows the results of the C4/5 pit lake model for the CO2(g) S.I. at -3.38, while the y-axis shows the results for -2.8

**Figure 5-56 Comparisons between the saturation index of CO2 set to -2.8 and -3.38 in the C4/5 pit lake**

#### 5.14.3.2 Assessment of the soluble salt build-up in seasonal water bodies

As discussed in Section 5.14.1, several backfilled pits have the potential to develop seasonal surface water expressions (temporary pit lakes) which subsequently drain / evaporate. Mine Waste Management (2023b) assessed the potential for salt accumulation in these temporary pit lakes and the implications for vegetation and downstream pit lake quality. This assessment addresses SRK's (2022a) recommendation (following a peer review of the 2022 Mine Waste Management hydrogeochemical model for C4/5 Pit) that the salt balance be reviewed to determine if the influence of a short-term flush of saline water from inundated backfill has a material effect on outcomes.

W4 Pit was used as the basis for this study since this is the only pit with an overflow into the surface water environment under Scenario B.1 (see Section 5.14.1). However, the assumptions adopted for the estimate are applicable to all the temporary pit lakes considered in the water balance model and, therefore, the conclusions reached for W4 are expected to be applicable to the other temporary pit lakes at Yandi (Mine Waste Management, 2023b).

**Summary**

To inform the conceptual model for the assessment, Mine Waste Management (2023b) conducted a literature review of naturally occurring saline lakes. Based on this review, a conservative conceptual model was chosen that allows for some of the precipitated salt mass from evaporation to be temporarily retained through formation of a salt crust at the base of temporary pit lakes or in the vadose zone. The remainder of the salt is transferred from pit to pit along the palaeochannel aquifer towards permanent pit lakes that form terminal sinks and prevent further migration of salt downstream. This model is conservative as available information from the literature review suggests that salt build-up in temporary pit lakes is unlikely because most, if not all, precipitated salt will be flushed into the groundwater.

PHREEQC modelling was used to simulate the composition of precipitated mineral salts in the Yandi temporary pit lakes, and a spreadsheet model was used to simulate the mass of precipitated salts.

Modelling concluded that:

- Precipitated salts would likely comprise:
  - Around 50 - 80% carbonate minerals (calcite, magnesite, rhodochrosite, and potentially others not considered in the model).
  - Between 8 and 33% halite.
  - About 10% silica (or minerals containing silicon).
- Widespread salt crust generation in backfilled Yandi pits is unlikely since precipitated salts are expected to be flushed into the backfill subsurface during rainfall events due to the higher permeability of backfill compared with natural soils and salt lake sediments.
- Some localised salt crusts (in the order of 0.01 - 0.15 m thick after 1,000 years of evapo-concentration) may form in zones of lower permeability and topographic depressions across the backfill surface, however, it is unlikely that large masses of salt will be available for re-dissolution in ponded water.
- Given the conservative assumptions adopted for the modelling, the likelihood of highly saline temporary pit lakes forming in backfilled pits is low. A coarse estimate of first flush salt mobilisation suggested that temporary pit lake TDS may range up to ~75 times the groundwater TDS concentration but would be less than 8,000 mg/L for greater than 90% of events.
- Salt accumulation in seasonal / temporary pit lakes may, for a time, reduce the mass of salt moving downgradient towards permanent pit lakes and, therefore, reduce the salinity of those lakes. However, since most accumulated salts in temporary lakes are expected to eventually be flushed into the groundwater, the movement of salt mass towards permanent pit lakes is delayed, not prevented. In the long-term, transient salt storage in backfilled pits is not likely to significantly change the quality of permanent pit lakes forming groundwater sinks.
- Due to the likely flushing of salts into deeper levels of the backfill profile, the potential for development of sodicity in the upper levels appears to be limited. However, as the permeability of the backfill profile at surface is not likely to be uniform, the formation of sodic profiles in the upper levels of backfill cannot be excluded but are likely to be limited to localised depressions where salts are more likely to accumulate.

**Conceptual model development**

*Literature review*

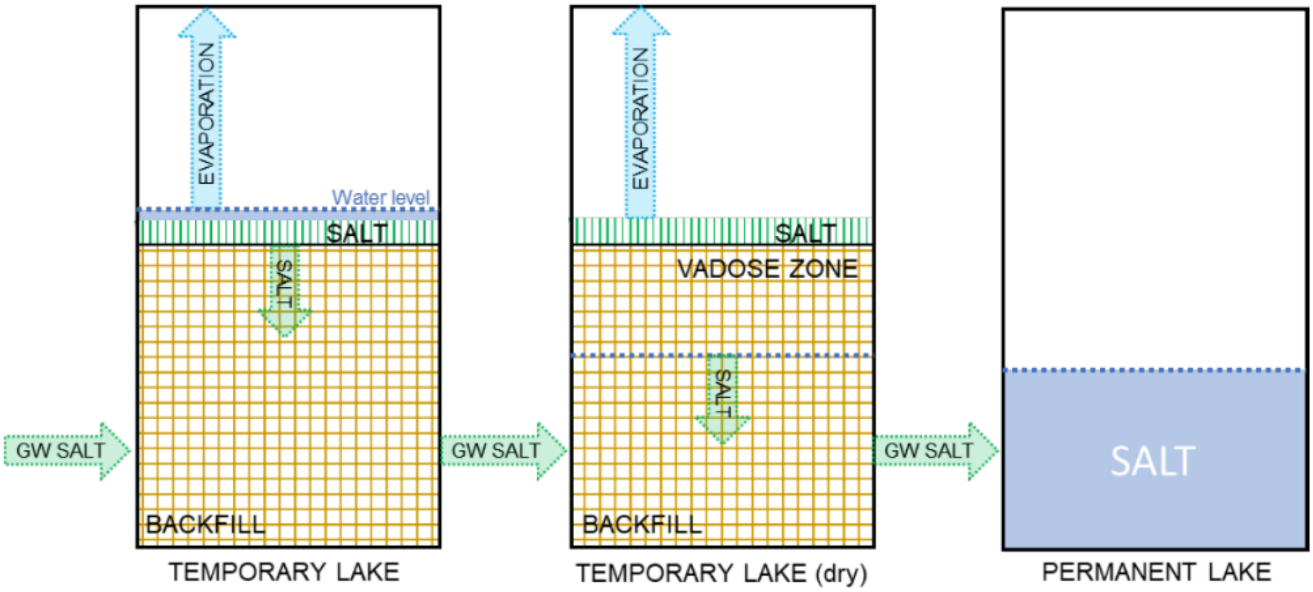
To inform the conceptual model for the assessment, Mine Waste Management (2023b) conducted a literature review of naturally occurring saline lakes which concluded that:

- In the arid Western Australian climate, 50% of naturally occurring lakes are temporary saline lakes. The salinity in these natural lakes fluctuates and follows a trend from hypersaline during dry season / drought periods to diluted (variably less saline) during and after significant rainfall events. They become hypersaline again during extended periods without significant rainfall events.

- Pit lakes generally have higher relative depths[43] (10% to 40%) compared to naturally formed Australian lakes, which have relative depths of 0.4% to 7%, and pit lake catchment sizes are typically less than a tenth of natural lake systems.
- The formation of accumulated salts ("salt crust") is a feature of both natural saline lakes and pit lakes, and case studies indicate that a maximum of approximately 20 - 25% of the salt mass associated with saline water discharged to natural lakes accumulates at surface. The remainder is flushed into the material underlying the water body.
- The potential for surface accumulated salts to be significantly mobilised into surface flow by a single rainfall event appears to be low. Based on published observations, it appears that accumulated salt on the surface does not dissolve rapidly on exposure to fresh water (although this is likely to vary depending on the mineralogy of the salt and its age; older salts would be more consolidated with fewer voids and slower rates of dissolution).
- The flushing of surface accumulated salts into the material underlying the water body is likely to lead to build up of salinity in the underlying vadose zone and groundwater. The extent of this salinity accumulation depends on the permeability of the sub-surface material. Observations of natural lakes indicate they are underlain by low permeability sediments, which suggests perched water tables close to surface. In contrast, soil moisture modelling (Section 5.2.4.3) suggests that Yandi backfill is sufficiently permeable to limit significant salt accumulation in the vadose zone profile of backfilled pits and, instead, salt is flushed into the groundwater.

*Conceptual model*

A conservative conceptual model was chosen that allows for some of the precipitated salt mass from evaporation to be temporarily retained through formation of a salt crust at the base of temporary pit lakes or in the vadose zone. The remainder of the salt is transferred from pit to pit along the palaeochannel aquifer towards permanent pit lakes that form terminal sinks and prevent further migration of salt downstream (Figure 5-57). This model is conservative as available information from the literature review suggests that salt build-up in temporary pit lakes is unlikely because most, if not all, precipitated salt will be flushed into the groundwater (Mine Waste Management, 2023b).




Source: Mine Waste Management (2023b)

**Figure 5-57 Conceptual model of salt build up in temporary pit lakes**

Key features and assumptions of the model are (Mine Waste Management, 2023b):

- The salt mass associated with evaporating water mass is retained at the base of temporary pit lakes (the backfill surface above the vadose zone).
- For estimating the maximum salt mass theoretically accumulated or available for transfer to the surface water environment, salt mass in evaporated water is retained in the partially backfilled pits without remobilisation during the 1,000-year modelling duration.
- Salt mass associated with evaporated water is retained, regardless of whether there is bare soil above the groundwater level (i.e., no influence from vegetation). This is a conservative simplification.
- The salt mass consists of a mixture of mineral phases based on the chemistry of the evaporating groundwater / ponded water.

43 Relative depth is the ratio of the maximum depth to the lake diameter, expressed as a percentage.

- A portion of the salt mass is available for remobilisation by incident rainfall or rising groundwater elevation.
- While the Yandi closure water balance model considers various evaporation rates for open water, bare soil, vegetation cover, etc., this conceptual model assumes salt mass is retained only from direct evaporation.

**Modelling approach and inputs**

PHREEQC modelling (Parkhurst & Appelo, 2013) was used to simulate the composition of precipitated mineral salts in the Yandi temporary pit lakes, and a spreadsheet model was used to simulate the mass of precipitated salts (Mine Waste Management, 2023b). Each approach is described in further detail below.

*Composition of precipitated salts*

As discussed in Section 5.14.3.1, the most significant salt mass originates from groundwater. Two indicative (maximum and median) groundwater compositions were selected (Appendix F.2.5) from the groundwater monitoring data set compiled by Hydro Geochem Group (2022) (see Section 5.9.3) (Mine Waste Management, 2023b).

Model conditions included equilibrium atmospheric partial pressures for carbon dioxide ($CO_2$, 0.00039 mg/L) and model runs were conducted that simulated the evaporation of the two water compositions to the point where >99.5% of water was removed (Appendix F.2.5) (Mine Waste Management, 2023b).

*Salt mass modelling*

The conceptual model assumes that the salt load associated with evaporating water precipitates as a salt mass ("crust") at the surface of the backfill. Cumulative evaporation loss from W4 is 99.47 GL over the 1,000-year simulation period. Complete evaporation of 99.47 GL of the median and maximum Yandi groundwater compositions leads to precipitated salt masses of 6.6 - 107 kg and 9.7- 107 kg, respectively (Mine Waste Management, 2023b).

The conceptual model assumes a salt crust of consistent thickness over the entire area of the backfill surface (which is assumed to be level in the Yandi water balance model). However, if a salt crust forms, it will more likely be localised by factors such as (Mine Waste Management, 2023b):

- Backfill topography. Low-lying areas may favour the development of ponds, evaporation, and precipitation of salts.
- Backfill permeability. Lower permeability areas with less vertical recharge to groundwater may favour salt crust formation.

An analysis was conducted to assess the potential salt crust properties of variable proportions of the W4 surface area to reflect the potential spatial variability arising from backfill topography and permeability (Mine Waste Management, 2023b).

A coarse estimate was made of the potential "first flush" mobilisation of salt resulting from redissolution of a salt crust within W4 Pit following a significant rainfall event. This estimate was based on the closure water balance results (Section 5.14.1) as follows (Mine Waste Management, 2023b):

- A pond was assumed to exist on the backfill surface for those time steps when the water storage volume in the pit exceeded the median storage volume (approximating periods of surface water expression). The volume of the pond was obtained from the difference between the two storage volumes.
- The cumulative salt mass was calculated for each time step.
- If a pond existed in a time step, it was assumed that 25% of the accumulated salt mass was mobilised into the pond. The accumulated salt mass was reduced by 25% for the next time step.
- The mobilised salt mass was divided by the pond volume to estimate the TDS added to the pond by the "first flush" salt mass in that time step.
- Salt mass "flushed" into the pond was assumed to pass into the groundwater system as a permanent loss from the pit, i.e., salt mass was retained in the pit for a period before progressing towards the W3 Pit terminal sink. The period of retention was determined by the gap between successive rainfall events, as defined in the water balance model.

**Model outputs**

Modelled evaporation of Yandi groundwater (median and maximum TDS compositions) to near complete dryness indicated that precipitated salts would likely comprise (Mine Waste Management, 2023b):

- Around 50 - 80% carbonate minerals (calcite, magnesite, rhodochrosite, and potentially others not considered in the model).
- Between 8 and 33% halite.
- About 10% silica (or minerals containing silicon).

Widespread salt crust generation in backfilled Yandi pits is considered unlikely since precipitated salts are expected to be flushed into the backfill subsurface during rainfall events. This is primarily due to the higher permeability of overburden backfill compared with natural soils and salt lake sediments, which favours flushing of salts deeper into the profile. This inference is applied in the solute accounting approach used for the closure water balance (Section 5.14.1). However, zones of lower permeability and topographic variations across the backfill surface may encourage ponding and reduce flushing. Therefore, the localised development of salt crusts cannot be entirely excluded as a possibility at this stage. An analysis of the potential for localised salt crusts to form over variable areas of W4 Pit (Table 5-53) indicated that the mass of salt accumulated after 1,000 years of evapo-concentration could form a crust in the order of 0.01 - 0.15 m thick, depending on factors such as the surface area over which the crust forms, the mineralogy of the salt, and the extent of salt consolidation (Mine Waste Management, 2023b).

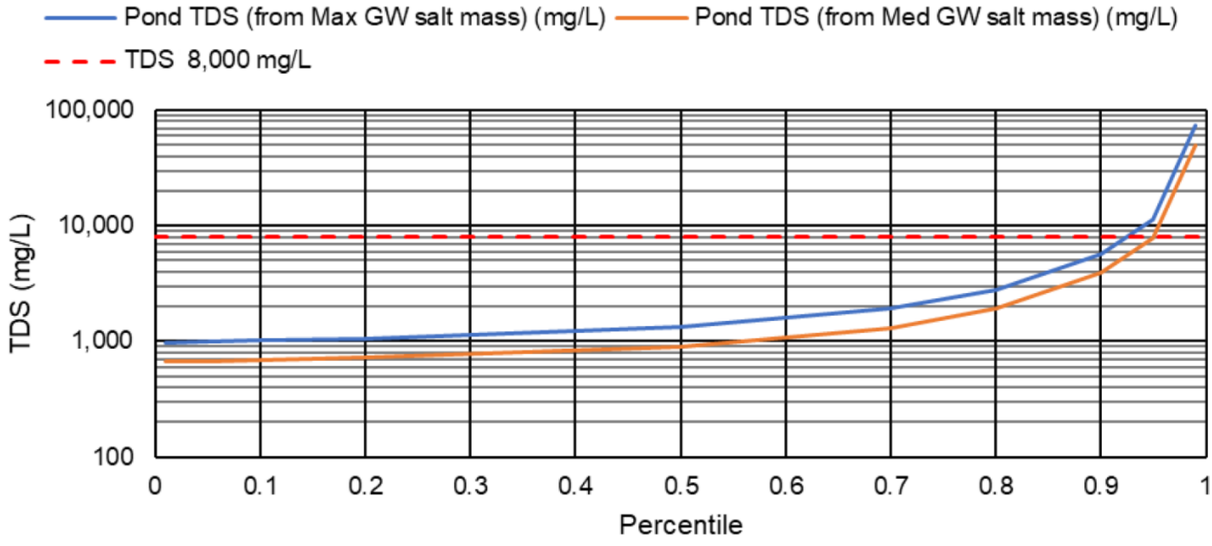
**Table 5-53 Estimated salt crust thickness over variable surface areas**

| W4 area ($m^2$) | $1.17\times10^6$ | | | |
|---|---|---|---|---|
| Proportion of W4 area subject to salt buildup | 1.0 | 0.5 | 0.25 | 0.1 |
| Salt precipitation area ($m^2$) | $1.17\times10^6$ | $5.85\times10^5$ | $2.93\times10^5$ | $1.17\times10^5$ |
| Total salt mass precipitated over 1,000 years (kg) (assuming maximum Yandi groundwater composition) | $9.68\times10^7$ | | | |
| Proportion salt mass not flushed to subsurface | 0.25 | | | |
| Resulting salt mass at surface (kg) | $2.42\times10^7$ | | | |
| Assumed salt density ($kg/m^3$)[A] | 1,350 - 2,700 | | | |
| Maximum salt crust volume ($m^3$) | $1.79\times10^4$ | | | |
| Minimum salt crust volume ($m^3$) | $8.96\times10^3$ | | | |
| **Maximum salt crust thickness (m)** | **0.02** | **0.03** | **0.06** | **0.15** |
| **Minimum salt crust thickness (m)** | **0.01** | **0.02** | **0.03** | **0.08** |

Source: Mine Waste Management (2023b)

Notes: Calcite density 2,700, Halite density 2,160. Assumed 75 - 100% density of calcite to allow for halite content and density-decreasing formation of voids in the salt crust during precipitation.

The coarse estimate of first flush salt mobilisation from redissolution of the crust suggested that temporary pit lake TDS concentrations may range up to ~75 times the groundwater TDS concentration, but would be less than 8,000 mg/L for greater than 90% of events (Figure 5-58) (Mine Waste Management, 2023b).




Source: Mine Waste Management (2023b)

Notes: Estimated mobilisation of salt mass precipitated from evaporation (based on the water balance for Scenario B1 of the Yandi closure water balance

**Figure 5-58 Estimated frequency of TDS in W4 ponds over 1,000 years from 'first flush' salt mobilisation**

### Conclusions

Given the conservative assumptions adopted for the modelling, the likelihood of highly saline temporary pit lakes forming in backfilled pits is low. Further, the potential for formation of significant salt crusts in backfilled pits is also low and it is, therefore, unlikely that large masses of salt will be available for re-dissolution in ponded water (Mine Waste Management, 2023b).

Salt accumulation in seasonal / temporary pit lakes may, for a time, reduce the mass of salt moving downgradient towards permanent pit lakes and, therefore, reduce the salinity of those lakes. However, since most accumulated salts in temporary lakes are expected to eventually be flushed into the groundwater, the movement of salt mass towards permanent pit lakes is delayed, not prevented. In the long-term, transient salt storage in backfilled pits is not likely to significantly change the quality of permanent pit lakes forming groundwater sinks (Mine Waste Management, 2023b).

Due to the likely flushing of salts into deeper levels of the backfill profile, the potential for development of sodicity in the upper levels appears to be limited. However, the permeability of the backfill profile at surface in W4 is not likely to be uniform and the efficiency of salt flushing into the subsurface is likely to be less than 100%. Therefore, the local formation of sodic profiles in the upper levels of the W4 backfill, especially over long periods of time, cannot be excluded, but is likely to be limited to localised depressions where salts are more likely to accumulate (Mine Waste Management, 2023b).

#### 5.14.3.3 Conceptualisation of nitrogen dynamics

As discussed in Section 5.14.3.1, nitrate concentrations have been overestimated by the hydrogeochemical model, as microbially mediated reactions that decrease nitrate concentrations were not considered. To gain an understanding of likely Yandi pit lake nitrate concentration trends over time, Mine Lakes Consulting (2023) conducted a conceptual assessment of nitrogen dynamics in the pit lakes. The emphasis of the study was on nitrate concentrations in saline and hyper-saline pit lakes, to reflect the expected long-term water quality in Yandi mine voids. Acidity was ignored as Yandi pit lakes are all expected to be neutral to alkaline. The assessment was informed by a literature review. The literature review and conceptualisation are summarised in the relevant sub-sections below.

**Summary**

The conceptual assessment informed by the literature review concluded that:

- In-pit and ex-pit waters with elevated nitrate concentrations from dissolution of blasting agents are likely to represent the highest nitrate inputs to pit lakes along with groundwater inflows from aquifers with elevated nitrate concentrations.
- Pit lake nitrate loss processes tend to be dominated by microbial denitrification and ammonification of nitrate and other nitrogen compounds similar to a natural lake's nitrogen cycle.
- Case studies of pit lakes have found that nitrate appears to undergo net removal over time, relative to concentration. Therefore, although Yandi pit lakes are modelled to contain elevated concentrations of nitrate initially, nitrate concentrations are expected to diminish and not increase over time as the empirical modelling in Section 5.14.3.1 has suggested. This is due to the biogeochemical processes likely to be established in the pit lake.

**Literature review of nitrogen dynamic processes**

The aquatic nitrogen cycle refers to the inter-conversion between dissolved nitrogen (N), nitrite ($NO_2^-$) nitrate ($NO_3^-$) ammonia ($NH_3$), and ammonium ($NH_4^+$) in the aquatic environment. Nitrate ($NO_3^-$) is the end product of the oxidation of elemental nitrogen (N), ammonium ($NH_4^+$) and / or nitrite ($NO_2^-$) and is an extremely soluble form of nitrogen that readily moves through different chemical and biological compartments. It does not bind with the surfaces of clay minerals like other macro nutrients such as phosphorus (P) nor does it form insoluble compounds with other elements that it encounters when moving through aquatic and terrestrial ecosystems. There is limited knowledge of the sources and environmental behaviour of nitrate in pit lakes. A literature review was, therefore, conducted on nitrogen dynamics in natural lakes (and the applicability of this to pit lakes) as well as available information on pit lakes, specifically. The outcomes of the review are summarised briefly in Table 5-54 and focused on (Mine Lakes Consulting, 2023):

- Nitrogen inputs and losses from the aquatic ecosystem.
- Nitrogen incorporation and loss from pit lake storage pools.
- Change to other nitrogen species.
- Salinity, sulphate and mixing (oxic / anoxic) geochemical interactions.
- Overall long-term accumulation of nitrogen in pit lakes due to evapo-concentration.

**Table 5-54 Brief summary of literature review of nitrogen dynamics in natural and pit lakes**

| Aspect | Literature findings | Relevance to Yandi |
|---|---|---|
| **Nitrogen inputs** | | |
| Blasting explosives residues | Explosive residues of nitrate may remain in overburden or within the mine void where N-based explosives such as ANFO have been used. Consequently, residual ammonia and nitrate salts are commonly flushed from pit walls by rainfall and in conjunction with exposure to oxygen are converted to nitrate during the first few years of pit lake development.<br>Explosive residues remaining within overburden may enter the pit lake environment through groundwater seepage or surface flow. | Nitrate-based explosives have been used at Yandi and elevated concentrations of nitrate have been detected in surface water and groundwater samples (Section 5.9.3). |
| Nitrogen fixation | Nitrogen fixation ($N_2$ fixation) is the conversion of nitrogen gas into ammonia. Lake ecosystem primary $N_2$ fixers are cyanobacteria and anaerobic bacteria; including methanogenic, sulphate ($SO_4^{2-}$) reducers, and fermenters. | Nitrification rates are poorly understood, but nitrogen fixation is likely an important source of lake N inputs and, while of much less consequence relative to ANFO blasting residues, is likely to be the major contribution to pit lake nitrate concentrations over-longer time scales (e.g., centuries), as microbial biomass and nutrient concentrations increase in the lakes. |
| Ammonification | Ammonification releases organic forms of nitrogen as ammonia / ammonium and is coupled to nitrate / nitrite reduction. Ammonification requires high organic matter loads which pit lakes rarely demonstrate with their small catchment sizes, especially in the absence of riverine flow-through. | The current closure strategy for Yandi does not include riverine flow-through in the pit lakes, so the pit lakes are unlikely to demonstrate high ammonia loads at any time. |
| Nitrification | Nitrification is the conversion of ammonium to nitrite and nitrate and occurs in the presence of nitrifying bacteria, incorporating oxygen from the atmosphere. | Ammonium may be at a high concentration over the short term (decades) in anoxic Yandi pit lake waters through ammonification of biomass which has incorporated nitrate e.g., flooded terrestrial vegetation and waterlogged organic soils (see above). However, ammonium is not likely to be a sustained source of nitrate through nitrification, as the ammonium budget decreases over time. |
| Geological weathering | Sedimentary and volcanic lithologies such as greenstone and slate, typically contain high levels of elemental nitrogen which can be released as nitrate in normal geological processes such as erosion, desertification and soil formation. Unweathered nitrogen-containing minerals in the bedrock come into contact with water and the atmosphere upon being exposed during mining excavations. | Geological weathering at Yandi is not likely to yield high concentrations of nitrate as natural occurrence of nitrate is typically low in sediment sources of iron ore. |
| Groundwater inflows | Pit lakes can be a receiving environment of contamination through solutes such as nitrate in groundwater inflows especially with a water terminal balance and no net solute losses. | Naturally highly elevated nitrate concentrations can occur in some regional aquifers such as those that the Yandi mine intersects. Local differences in ecological tolerances may exist in these areas. |
| **Nitrogen outputs** | | |
| Denitrification | Microbial denitrification and N removal is generally dominated by denitrification in natural pit lakes. Denitrification is a redox reaction that occurs during microbial metabolism under anaerobic conditions, where nitrate is reduced to nitrogen gas ($N_2$) through several intermediate steps. However, intermediate oxidation steps of nitrite ions can temporarily accumulate if denitrification conditions are not conducive e.g., an inadequate supply of organic carbon (OC), low pH or oxic redox. Nitrite is more toxic than nitrate.<br>Denitrification is generally controlled by availability and type of organic matter, however, some nitrate reducers are able to oxidise reduced inorganic compounds such as ammonium. Denitrification can begin quickly and is often accompanied by a decrease in organic carbon from lake benthic sediments. There is a well-established positive linear relationship between nitrate and denitrification rates implying that pit lakes will lose nitrate at faster rates when nitrate concentrations are higher. Degradation of organic matter also consumes oxygen which further enhances denitrification rates.<br>The composition of dissolved organic matter is strongly correlated with water residence times in lakes and short residence time systems have a dissolved organic matter composition reflecting the surrounding catchment. Pit lakes typically have long residence times. As hydraulic residence times increase, terrestrial nutrient ratios are increasingly lost and internal carbon sources such as aquatic microbes and aquatic plants have a greater influence. | Denitrification is expected to be the short and long-term dominant process for nitrate loss from Yandi pit lakes. |
| Biological assimilation | Most aquatic organisms cannot fix nitrogen directly and instead accumulate ammonium directly, or through reducing nitrate to ammonium (nitrate assimilation). Phosphorus is an important element in this process and can limit biological assimilation of nitrate. Assimilated nutrients can leak back into the environment due to breakage and decay of organism cells. | Biological assimilation of nitrate in the Yandi pit lake is likely to be limited due to the limited phosphorus concentrations expected in iron ore pit lakes. In low to medium productivity lakes such as Yandi, sediments are likely to be N-sinks rather than N-sources. |
| Anammox | Anaerobic ammonium oxidation (anammox) is a major microbial pathway for N removal in aquatic environments, especially at warmer temperatures typical of the Yandi region. The anammox reaction consists of the oxidation of ammonium using nitrate and $NO_2^-$ to produce $N_2$ without $N_2O$ emission. | Few estimates of anammox exist for lakes, but when measured in a deep tropical lake analogous to depths expected of Yandi pit lakes, around 13% of produced nitrogen could be attributed to the anammox process whereas the remainder was related to denitrification. Annamox may, therefore, be moderately important to pit lakes, dependent upon temperature, organic matter loads and extent of hypoxia (due to mixing regimes). |
| Denitrifying anaerobic methane oxidation (DAMO) | DAMO is a recently discovered process in which NOx is reduced obligatorily anaerobically by bacterial *Methylomirabilis* or archaeal *Methanoperedens* microbes, using methane ($CH_4$). | DAMO is not likely a relevant nitrate loss process in Yandi lakes which will not have high methane concentrations. |
| Dissimilatory nitrate reduction to ammonium (DNRA) | DNRA is another pathway of nitrate reduction, and also consumes $NO_x^-$ under anaerobic conditions, with ammonium as the end product. The DNRA reaction is promoted strictly by anaerobes and recent studies suggest their role in $N_2O$ consumption. During DNRA, nitrate is reduced to $NO_2^-$, which subsequently is directly reduced to ammonium without producing any intermediate N compound. Ammonium is more biologically reactive than nitrate and is subsequently oxidised to nitrate by nitrifier bacteria. | The importance of DNRA in lakes appears to be minor relative to denitrification in both saline and freshwater aquatic ecosystems. |
| **Interactions with other lake / pit lake biogeochemistry** | | |
| Phosphorous | A lake's nitrogen-phosphorus ratio influences dominance of phytoplankton by nitrogen-fixing cyanobacteria or by nitrogen consuming green algae. Phosphorus levels are typically a limiting factor in microorganism growth in aquatic ecosystems globally, and especially so in natural Western Australian lakes.<br>Sorption of P to abundant Fe(III) minerals in upper, oxic pit lake layers may reduce dissolved and, therefore, bioavailable P concentrations. If bioavailable P concentrations are limiting, then, organic C fixation by phototrophs and hence nitrate assimilation may be limited. Phosphorus additions alone in pit lakes can increase assimilation and dissimilation rates of $NO_x$ into organic matter. | Yandi is expected to have a continuous supply of nitrate through groundwater, meaning P limitation is highly likely. |
| Carbon | Algae are photosynthetic and do not need organic carbon but can become a source of organic carbon and may become the base of a trophic system. Heterotrophic bacteria grow relatively fast and consume primarily dissolved pools of inorganic and organic matter and thus are an important factor determining relative nutrient concentrations. | External sources of organic substances, such as humic acids, resulting from surface runoff, can be an important source of organic carbon to pit lakes. Sedimentation and consequent bacterial decomposition of organic matter (detritus, plankton) in the lake may lead to physico-chemical conditions conducive to microbially-mediated reductive processes in the lake sediment such as reduction of nitrate, manganese, iron and sulphate led by denitrification. These reactions are commonly executed by anaerobic bacteria within the water / sediment interface. |

| Aspect | Literature findings | Relevance to Yandi |
|---|---|---|
| Salinity | Although denitrification is not affected by salinity specifically, increased solute concentrations reduce oxygen solubility and oxygen concentrations are consequently very low in saline lakes. Most hypersaline lake microorganisms are therefore aerobic consumers that are also fermenters of organic matter when conditions require.<br>Increases in nitrate concentrations in saline lakes can promote harmful algal bloom development, which can lead to excess lake nutrients, even under saline or hypersaline conditions. However, seston[44] ratios become more similar to average conditions over increasing conductivity, with decreased C:N and C:P ratios. | Pit lakes at Yandi are likely to become saline over time, with W2 becoming saline, E7 highly saline and W3 and C/45 hypersaline (brine) (Section 5.14.3.1). |
| Sulphur | Microbial S transformations can play an important role in nitrate removal in freshwater wetland sediments. For instance, sulphide can drive nitrate respiration through long term sulphur oxidation which sustains primary producer cell growth. S cycling typically occurs at the boundary layer of the sediment-water interface. Lakes with sulphide-rich ecosystems and easily oxidisable metal-bound sulphides (such as $FeS_2$) near the sediment surface may act as denitrification hot spots, although the reaction mechanisms coupling de nitrification processes to pyrite oxidation are still questionable. Nitrogenase enzyme activity in sediments of cyanobacterial blooms areas is higher than those in vegetation-dominated habitats, indicating that high levels of sulphide may inhibit nitrogen fixation in vegetation-dominated sediments.<br>S particularly plays a key role in saline lakes, where high concentrations of sulphate are often found. High sulphate concentrations may inhibit autotrophic denitrification, beginning at concentrations above 5 g/L. $H_2S$ is also known to inhibit N transformations, including denitrification. N may, therefore, have a high availability due to high sulphate concentrations in saline lakes. | Sulphate concentrations are predicted to increase in the Yandi pit lakes with evapo-concentration (Section 5.14.3.1). |
| Iron | Both abiotic and biotic roles of iron occur in nitrogen cycling where $NO_2$ can be rapidly reduced in the presence of dissolved $Fe_2^+$ to form $N_2O$. The generated $N_2O$ can be further reduced by microorganisms. Biomass and / or adsorbed organic substances can also be absorbed onto ferric mineral particles. Together, these abiotic and biotic processes constitute a complex vertical and linked cycling model for iron and nitrate in pit lakes that are stratified, with iron precipitation in the upper layers and re-dissolution in the lower layer. | Alkaline and aerobic conditions in the Yandi pit lakes will not favour the presence of Fe in solution. However, where / if the pit lake is under anoxic / reducing conditions, elevated $Fe_2^+$ concentrations may be sustained. |
| **Pit lake dynamics** | | |
| Temporary lakes | The different stages of a temporary lake's hydrological cycle have the potential to influence nitrate dynamics and, therefore, concentrations through:<br>• Availability of water to transport dissolved fractions of nitrogen as nitrate or provide conditions conducive to organic decomposition.<br>• Increases in depth and / or changes to lake stratification.<br>• Changes in availability of nutrients such as P that might drive microbial processes consuming / respiring / fixing nitrogen and organic carbon.<br>All nutrients (including nitrogen) are usually a limiting factor for the growth of microorganisms in temporary waters and terrestrial nutrient ratios (such as those derived from the riparian vegetation at Yandi) tend to be higher than microbial ratios due to increased concentrations of structural carbohydrates and lignin. Further, drought events negatively affect microbial processes in temporary waters. A low biomass of microbes is negatively correlated with redox and nitrate reducing conditions.<br>Organic carbon and nitrogen concentrations are generally low in early stages of lake depth in temporal lakes, although they increase slightly during flooded stages in Western Australian lakes. Nitrification and ammonia oxidation are significantly higher within the salt mat during the early flooding stage. Nutrient ratios are especially influenced by algal blooms (which are rich in nitrogen) during periods of flooding as the appearance / dominance of cyanobacteria in the phytoplankton community can tend to lower plankton C:N ratios. Meanwhile, vascular plants (which have lower nitrogen) dominate during episodes of drought. Nitrogen concentrations are highest during mid temporary lake drying, likely due to photosynthetic inputs via blooming of salinity-tolerant algae. | Several seasonal expressions of water are predicted for Yandi (Section 5.14.1). |
| Depth and stratification | Lake edges and surface waters tend to support most primary production, favouring nitrogen assimilation and temporal retention in the primary producer biomass.<br>Very deep lakes, or lakes with either saline or otherwise deep inflows of denser e.g., more saline, waters may permanently stratify and exhibit vertical gradients in organisms, nutrients, and oxygen. Each layer represents a habitat with different light, nutrient, and chemical energy availability.<br>• The upper oxygenated layer is frequently colonised by green algae relying on light for energy and geochemical oxidisers. Algae assimilate nitrogen in the upper layers of stratified lakes using nitrate, ammonium, or urea as a nitrogen source.<br>• Denitrification rates decrease from lake edges to lake depths. Denitrification rates and net nitrogen assimilation are also diminished from low to high nutrient conditions.<br>• Benthic nitrogen fluxes and denitrification vary between and within lakes with depth. Organomineral interactions transport N, and P to deep water via physical settling, and subsequent decomposition and release via reductive dissolution of dissolved organic matter. Nitrogen concentrations as ammonia (as well as nutrients of organic and inorganic carbon, phosphorus,) can all increase with depth in pit lakes. However, nitrate is usually present at low concentrations in deep layers. The activity of nitrogen- fixers and nitrate-reducers in deep layers may explain increasing concentrations of reduced species such as ammonium with depth.<br>The addition of organic carbon introduces energy to the aquatic system, which fuels biogeochemical turnover, including nitrogen dynamics and drives a vertical succession of redox reactions by microbial respiration beyond oxic-anoxic interfaces (e.g., chemoclines and the water-sediment interface). | Pit lakes can especially develop stratified layers due to their steep walls and narrow geometry, typically with increasing pH and higher concentrations of sulphate and dissolved iron and metals with depth. An initial review of the Yandi pit lakes indicates that they are unlikely to permanently stratify (Section 5.14.5), but further work is required to confirm this. |
| Redox conditions | Redox potential (Eh) is the measurement of the tendency of an environment to oxidise or reduce substrates. Strong redox gradients have been observed in pit lakes, with low Eh values (100-200 mV) near lake sediments suggesting anaerobic reducing reactions occurring. Anoxia or even anaerobia (whereby bound oxygen such as nitrate is depleted) can also occur in the water column below pit lake stratified layers.<br>Many bacteria and algae can grow in the absence of oxygen, depending on whether they tolerate certain oxic conditions. When oxygen is limited or unavailable, microorganisms can reduce nitrate to either a gaseous product ($N_2$ or $N_2O$) or ammonium to obtain energy. Under anoxic conditions significant amounts of dissolved organic carbon can also be released from organic carbon stored in sediments and enter the active aquatic carbon cycle again. | As discussed in Section 5.14.3.2, pit lakes generally have higher relative depths compared to naturally formed Australian lakes. Pit lakes and water at depth is expected to represent a strongly reducing environment.<br>The redox state of a pit lake is influenced to a large degree by whether or not the lake overturns seasonally. An initial review of the Yandi pit lakes indicates that they are unlikely to permanently stratify (Section 5.14.5), but further work is required to confirm this. |

Source: adapted from Mine Lakes Consulting (2023)

[44] Biological material in water.

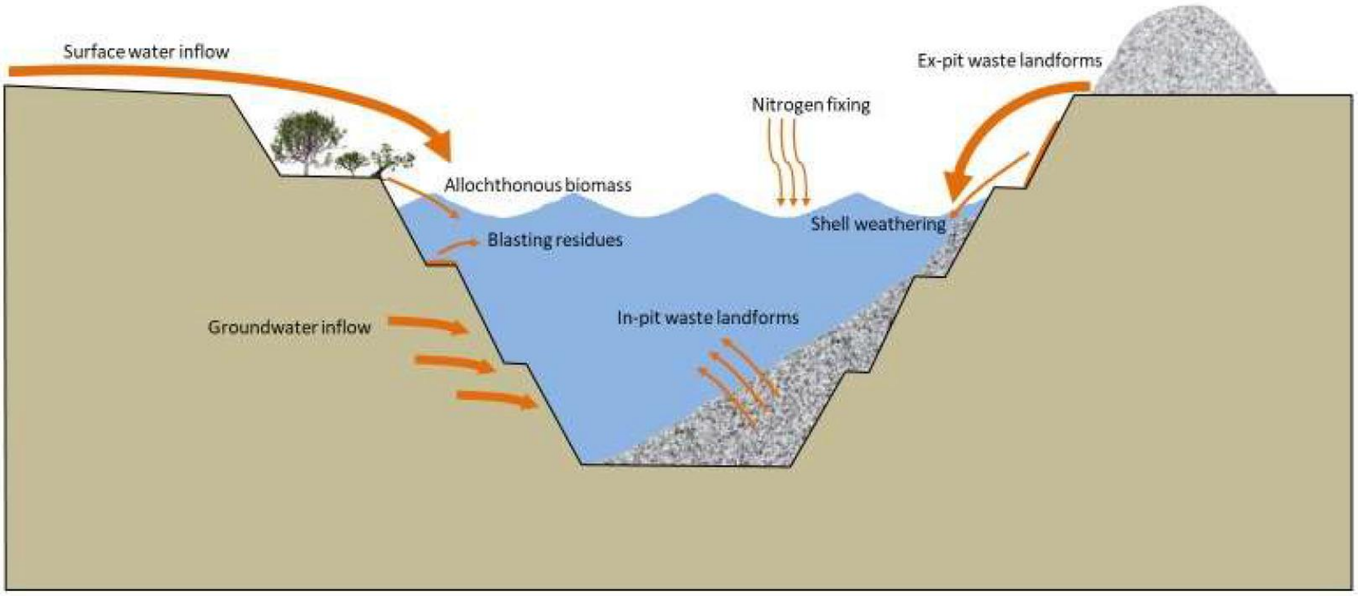
## Conceptualisation

The conceptualisation described below has found that, although Yandi pit lakes are likely to contain elevated concentrations of nitrate initially, nitrate concentrations are expected to diminish, and not increase over time as the hydrogeochemical modelling in Section 5.14.3.1 has suggested (Mine Lakes Consulting, 2023).

### *Nitrogen inputs and outputs*

#### Inputs

Based on the literature review, the potential nitrate inputs to Yandi pit lakes are summarised in Figure 5-59 and include the potential for blasting residues captured on pit walls and in overburden, groundwater inflows, geological weathering of the pit shell and ex-pit rocks, and two microbially-mediated sources; fixing of atmospheric nitrogen and decomposition of organic matter followed by nitrification of ammonia (Mine Lakes Consulting, 2023).




Source: Mine Lakes Consulting (2023)

**Figure 5-59 Potential nitrate inputs to the Yandi pit lakes**

The significance of each input to the Yandi pit lakes in the short and long term is summarised in Table 5-55. Contaminated in-pit and ex-pit waters with elevated nitrate from dissolution of blasting agents are likely to be the main nitrate sources along with groundwater inflows from aquifers with elevated nitrate concentrations (Mine Lakes Consulting, 2023).

**Table 5-55 Conceptualisation of relative short and long-term importance of nitrate gains to Yandi pit lakes**

| Gains | Notes | Short-term | Long-term |
|---|---|---|---|
| Blasting residues | Blasting residues may be an important component in first run-off events as residues are washed from pit walls into a filling lake. | High | Low |
| Groundwater inflows | Groundwater inflow nitrate concentrations are high in the aquifer that transects the Yandi pit lakes. | Moderate | Moderate |
| Overburden (OSAs) | Blasting residues may be important through first-flushes of mine overburden stored either in-pit or ex-pit. | Moderate | Moderate |
| Ex-pit geological weathering | Rainfall rates are very low. | Low | Low |
| Mine void weathering | Even under enhanced weathering, limited rainfall results in relatively little geological weathering in the nitrogen-poor country and host rocks of Yandi. | Low | Low |
| Nitrogen fixation | Low primary production rates are predicted due to very low P concentrations in small and nutrient-poor pit lake catchments and in the presence of elevated FeOOH concentrations expected in the Yandi pit lakes. | Low | Low |
| Organic nitrogen degradation | There is little organic matter in small catchments with little revegetation. | Low | Low |
| Nitrification | Low. Ammonia concentrations from ANFO are already largely present as nitrate. Groundwater chemistry is dominated by nitrate rather than ammonia. | Low | Low |

Source: Mine Lakes Consulting (2023)

#### Outputs

Case studies of pit lakes have found that nitrate appears to undergo net removal over time, relative to concentration. Pit lake nitrate loss processes tend to be dominated by microbial denitrification and ammonification of nitrate and other nitrogen compounds similar to a natural lake's nitrogen cycle (Table 5-56) (Mine Lakes Consulting, 2023).

**Table 5-56 Conceptualisation of relative short and long-term importance of nitrate losses to Yandi pit lakes**

| Losses | Notes | Short-term | Long-term |
|---|---|---|---|
| Denitrification | Although limited by carbon, denitrification is a dominant microbial pathway for nitrate in lakes, especially in benthic waters and sediments under stratified and consequently anoxic conditions typical of steep-sided pit lakes. | High | Moderate |
| Annamox | Some reduction of nitrate to nitrite and ammonia will occur under anoxic conditions. These reduced forms of nitrate will be converted directly to gaseous nitrogen and lost from the system through annamox. | Moderate | Low |
| Biological assimilation | Limited biological assimilation of nitrate by green and other non-nitrogen fixing algae (especially phytoplankters) is likely under oligotrophic conditions resulting from low free reactive phosphorous concentrations. | Moderate | Moderate |
| DNRA | The importance of DNRA is expected to be minor relative to denitrification in both saline and freshwater lake states and types. | Low | Low |
| DAMO | Low primary production rates due to very low P concentrations in undeveloped catchments and in the presence of elevated FeOOH concentrations. | Low | Low |

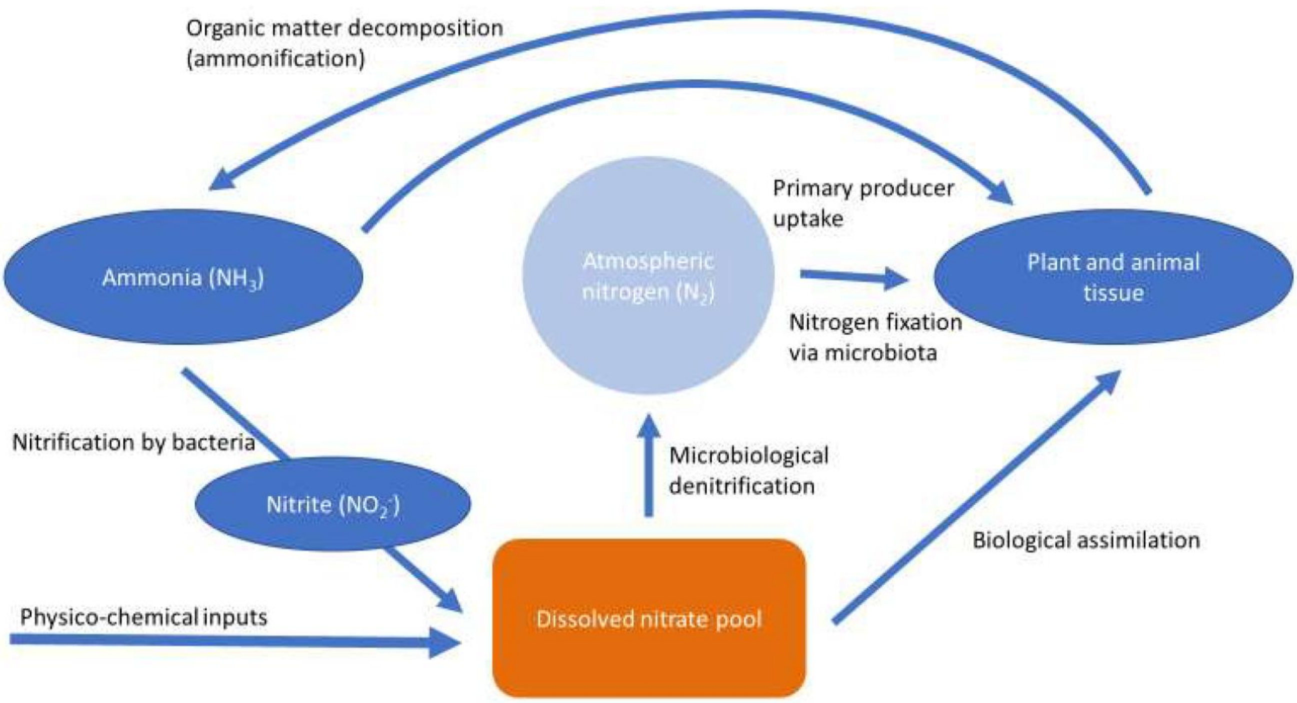
Source: Mine Lakes Consulting (2023)

### *Pit lake nitrate dynamics*

The conceptualisation of nitrogen dynamics within the Yandi pit lakes is shown in Figure 5-60. This shows external inputs of nitrate from physico-chemical inputs and microbial processes (Table 5-55), and nitrate conversions that retain nitrogen in the system and are mainly due to biological assimilation (especially as algal biomass). Key processes are (Mine Lakes Consulting, 2023):

- Fully mixed upper layers of lake water correspond to oxygen-saturated conditions with all solutes predominantly in their oxidised forms. Primary production takes place in these layers and provides a continuous source of organic substances (dissolved organic acids, dead algal and bacterial biomass) for the secondary decomposers. Maximum oxygen concentrations occur near the thermocline and approach the location of chlorophyll-a concentration peaks.
- The strongly reducing environment of the lake water at depth is characterised by anoxia and a very high Fe concentration as Fe(II). This anoxic and reducing lake bottom environment commonly supports secondary decomposers of organic matter (e.g., Fe and S-reducing bacteria).
- The lake's nitrogen-phosphorus ratio influences the dominance of phytoplankton by either nitrogen fixing cyanobacteria or solely nitrogen consuming green algae. For most lakes without significant N inputs, the effect of N fixation is to balance the N content with the P content, which means that the algal biomass is limited by the P content. However, Yandi is expected to have a continuous supply of nitrate through groundwater, meaning P limitation is highly likely.
- Aquatic plant root oxygenation leads to a potential redox gradient between the plant roots and surrounding sediment, promoting nitrate reduction. Wetland plants, especially lake edge species, can transport atmospheric $O_2$ to the rhizosphere. In turn, the root zone offers an oxidative micro-environment which provides redox conditions for both organic matter degradation and also nitrifying bacteria growth. These complementary processes result in nitrate accumulation in the lake edge littoral zones which then diffuses to anoxic environments where it is removed by nitrate reduction. However, pit lakes typically have very small lake edge areas, limiting the contribution of nitrate reduction in these zones.

System losses of nitrate are mainly due to denitrification and resulting exports of nitrogen gas (Mine Lakes Consulting, 2023).




Source: Mine Lakes Consulting (2023)

Notes: refer to Table 5-55 for significance of different physico-chemical inputs and Table 5-56 for significance of nitrate removal processes

**Figure 5-60 Conceptualisation of key nitrate dynamics in pit lakes**

#### 5.14.3.4 Knowledge gaps & forward work program

Depending on the final backfill strategy, further work may be required to:

- Update hydrogeochemical modelling as closure designs are refined.
- Investigate the significance of backfill permeability and surface topography to salt accumulation as backfill designs are refined.

Following closure and recovery of groundwater, the behaviours of pit lakes will be monitored as outlined in Section 10.1.9 and models reviewed / refined as appropriate.

### 5.14.4 Release of water captured by W4 Pit to Marillana Creek

Mine Waste Management (2023c) conducted an assessment of the potential impact of pit lake water on Marillana Creek during an overtopping event which may occur in the event of extreme (and highly unlikely) flood conditions post-closure. The surface water management system design for closure is designed to prevent the overtopping of any Yandi pit, except W4, into Marillana Creek, and overtopping from W4 is designed to be limited to events greater than 1:10,000 AEP. W1 Pit is designed to flow into W4 Pit (Section 5.14.7). Modelling was conducted to assess the impact of an overtopping event from the W4 Pit on the mixing zone within Marillana Creek. The conceptual model and modelling approach are described in Sections 5.14.4.1 and 5.14.4.2 respectively and model outputs in Section 5.14.4.3.

**Summary**

- The W4 Pit discharge mixing zone was defined as the zone between the W4-SP3 flood channel[45] to where the Yandi lease boundary crosses the creek (approximately 12,500 m).
- W4 is only predicted to overtop in a 1 in 10,000 AEP event at which time, the Marillana Creek upstream of the W1 Pit will be flowing at full capacity. As Marillana Creek passes the W1 Pit, a portion of flow will be diverted via the W1-SP0 flood channel to W1 Pit. This results in a reduced flow downstream of the W1 Pit to the exit point of the W4-SP3 flood channel. The W1-SP3 flood channel conveys flows between W1 and W4 pits. Once W1 and W4 pits are full, W4 will overtop into Marillana Creek via the W4-SP3 flood channel, increasing flows downstream of the W4-SP3 flood channel.

[45] Since the completion of the Mine Waste Management (2023c) study, the flood channel alignment has changed to the W4-SP4 alignment.

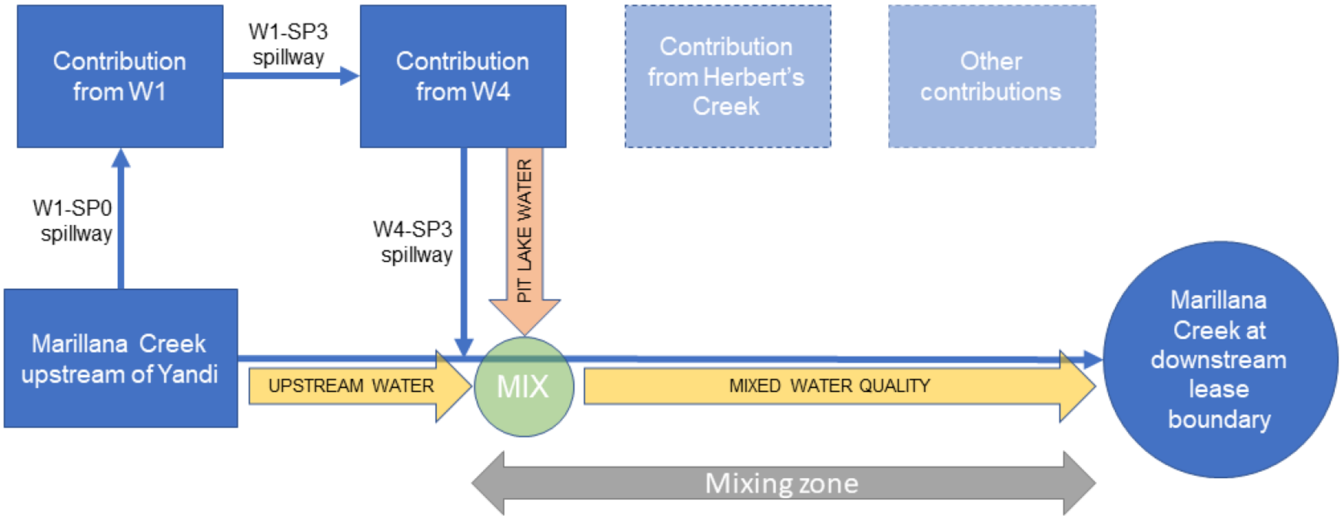
- Geochemical mixing was modelled using PHREEQC and a modified Pitzer database was used to minimise errors in speciation predictions for high ionic strength solutions (i.e., saline pit lakes).
- Several scenarios were modelled to simulate the dilution of evapo-concentrated water in W1 and W4 pits by the volume of upstream Marillana Creek water produced by the 1:500 AEP and 1:10,000 AEP events. The different scenarios variously assumed:
  - Different pit lake water qualities based on median and conservatively high / maximum modelled water qualities (due to evapo-concentration). Modelled water qualities were based on early pit lake hydrogeochemical modelling conducted by Mine Waste Management (2022b) for the C4/5 Pit. This modelling has since been superseded by the modelling described in Section 5.14.3.1.
  - Different antecedent volumes (i.e., pit lake levels existing prior to the modelled rainfall event) in W1 and W4 pits.

  All modelled scenarios are conservative as they are extremely unlikely to occur given the very low probability of rainfall events of sufficient magnitude to partially fill W1 and W4 and the likelihood of two or more such events occurring in relatively quick succession (i.e., in the 25-year period before the water in the W1 and W4 pits has evaporated) is even less probable. The most likely modelled event was the base case where both pits were empty prior to a 1 in 10,000 AEP event. The least likely was both pits being full with maximum concentrations of TDS (3,003 mg/L for W1, 26,000 mg/L for W4) prior to a 1 in 10,000 AEP event.
- The model results indicated that overtopping presents a low risk to downstream water quality. Should one of the unlikely overtopping scenarios occur, and if the conservative water qualities used in the modelling apply, modest exceedances of ANZECC & ARMCANZ (2000) water quality guideline values could occur in the mixing zone in the short term (<30 hours):
  - All scenarios exceeded the freshwater 95% Species Protection Level (SPL) guideline value for nitrate, although:
    - Geochemical modelling did not consider biochemical nitrate cycling processes and the conceptual model for nitrogen dynamics (Section 5.14.3.3) indicates that concentrations in pit lakes are likely to be much lower.
    - Median upstream water quality concentrations also exceeded guidelines.
  - Three scenarios 1A (both pits full and have maximum TDS prior to a 1 in 10,000 AEP event), 3A (both pits full and have maximum TDS prior to a 1 in 500 AEP event) and 4A (W1 full and W4 part full and have maximum TDS prior to a 1 in 500 AEP event) marginally exceeded the freshwater 95% SPL guideline value for zinc (up to 0.021 vs. 0.008 mg/L).
  - Scenario 3A had minor exceedances of:
    - The livestock drinking water guideline for salinity (5,785 mg/L vs 5,000 mg/L) and sulphate (1,079 mg/L vs 1,000 mg/L).
    - The freshwater 95% SPL guideline value for nickel (0.013 vs 0.011 mg/L).

##### 5.14.4.1 Conceptual model

Key features of the conceptual model (Figure 5-61) based on the construction of the W1-SP0 and W4-SP3 flood channels (refer to footnote 45) are as follows (Mine Waste Management, 2023c):

- W4 is only predicted to overtop in a 1 in 10,000 AEP event at which time, the Marillana Creek upstream of the W1 Pit will be flowing at full capacity. As Marillana Creek passes the W1 Pit, a portion of flow will be diverted via the W1-SP0 flood channel to W1 Pit. This results in a reduced flow downstream of the W1 Pit to the exit point of the W4-SP3 flood channel.
- The W1-SP3 flood channel will convey flows between W1 and W4 pits. Once W1 and W4 pits are full, W4 will overtop into Marillana Creek via the W4-SP3 flood channel increasing flows downstream of the W4-SP3 flood channel.
- Inflows into Marillana Creek from its tributaries (including those between the W1-SP0 and W4-SP3 flood channels) are considered negligible. All tributaries have smaller catchments with concentration times and peak flows that are significantly less than the Marillana Creek catchment.
- For the purposes of the assessment, a mixing zone (~12,500 m) was defined in Marillana Creek from the W4-SP3 discharge to where the Yandi lease boundary crosses the creek. Water quality in the mixing zone depends on:
  - Marillana Creek upstream water quality (i.e., prior to interaction with Yandi operations).
  - Water quality discharging from the W4-SP3 flood channel, as a combination of pit lake water from W1 and W4 and the Marillana Creek upstream water quality diverted into W1.
  - The relative proportion of flows from W4-SP3 and Marillana Creek upstream of the W4-SP3 discharge point.
- If there is no significant quantity of water in W1 and W4 pits prior to the flood event, the water quality in the mixing zone is the same as the upstream water quality. This assumes:
  - Geochemical interaction of diverted water with pit walls and backfill is negligible due to the short timeframes over which flood events will occur, resulting in no addition to the dissolved load.
  - Accumulated salt in the pits (if any) has a negligible effect on dissolved load.
- W4-SP3 discharge water quality depends on the volume of water in the W1 and W4 pit lakes and the mass of salts in solution.




Source: Mine Waste Management (2023c)

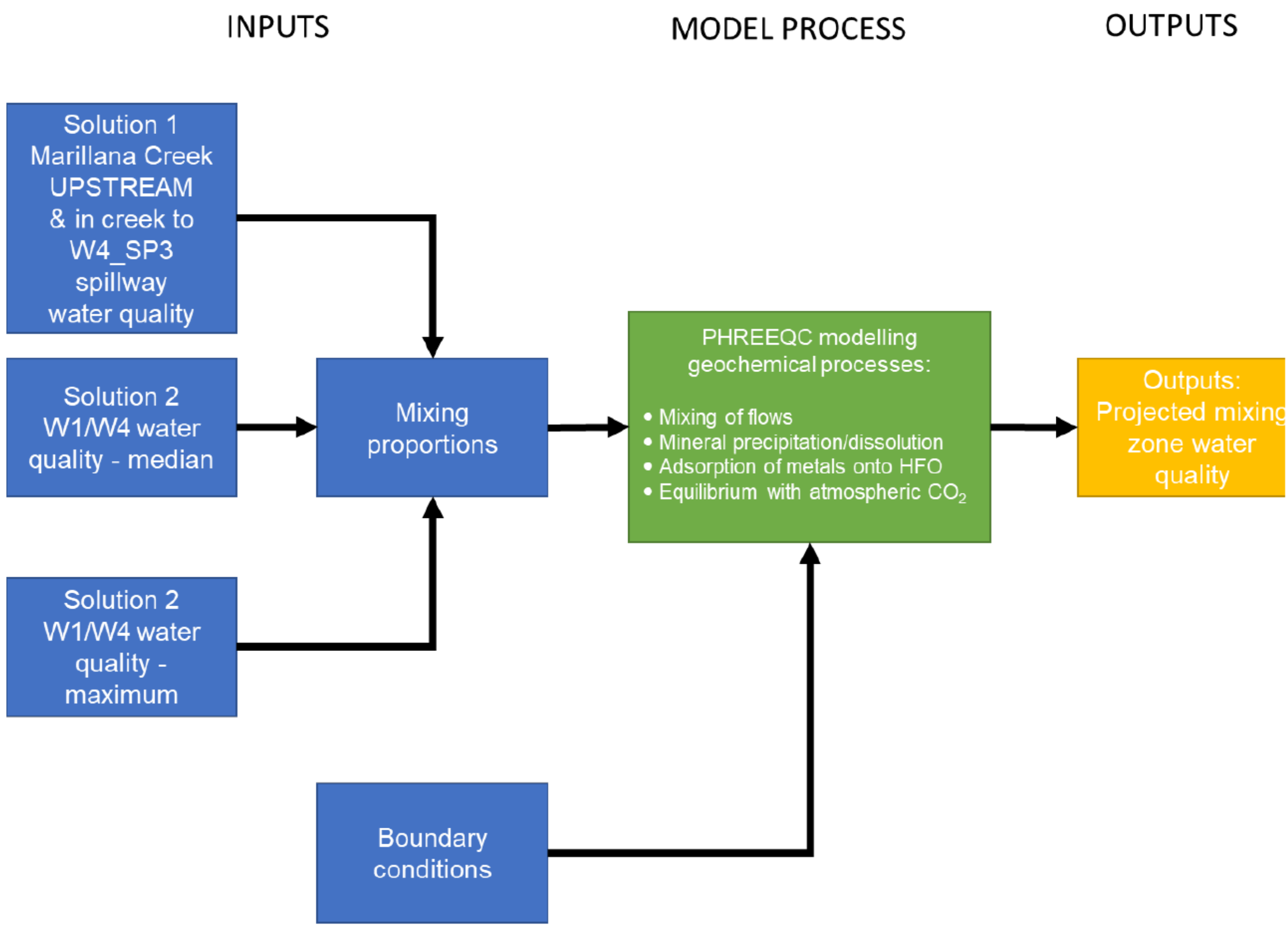
**Figure 5-61 Conceptual model of Yandi overtopping water quality**

#### 5.14.4.2 Modelling approach

Geochemical mixing was modelled using PHREEQC (Parkhurst & Appelo, 2013) and a modified Pitzer database was used to minimise errors in speciation predictions for high ionic strength solutions (i.e., saline pit lakes) (Mine Waste Management, 2023c).

The model structure is shown in Figure 5-62 and key assumptions / limitations of the approach are (Mine Waste Management, 2023c):

- Rainfall occurring over the W1 and W4 pit lake catchment areas was not considered. All rainfall driving the relevant flood event occurs in the catchment upstream of Yandi.
- Due to the short timeframes over which overtopping may occur, geochemical interaction of flood water with pit / creek walls and evapotranspiration were excluded from the model.
- Complete flushing of any ponded water in W1 and W4 pits as the flood event passes through, i.e., complete and thorough mixing of source waters. This has the effect of:
  - Marillana Creek water replacing any ponded water in W1.
  - Overflow of W1 into W4 completely replacing any ponded water in W4 with Marillana Creek water.




Source: Mine Waste Management (2023c)

**Figure 5-62 Hydrogeochemical model structure for overtopping of Yandi pit lakes**

The following sub-sections outline the inputs to the model (including assumptions and limitations), and modelled scenarios.

## Model inputs

### *Water quality*

Key assumptions and limitations associated with the water quality source terms are as follows (Mine Waste Management, 2023c):

- The W4 pit lake water quality was based on early pit lake hydrogeochemical modelling conducted by Mine Waste Management (2022b) for the C4/5 Pit. This has since been superseded by the modelling summarised in Section 5.14.3.1. The 2022 model:
  - Considered pit wall runoff, rainfall, and secondary mineral precipitation, but not backfill solute load.
  - Did not include arsenic and selenium as these elements were only relevant when backfill solute release was considered.
  - Did not account for biochemical processes such as nitrogen cycling which would affect nitrogen concentrations.

#### Marillana Creek upstream quality

Water quality for the Marillana Creek upstream flow was derived from surface water quality monitoring data from YNSWPC002, a sampling point upstream of W1 Pit within Marillana Creek. Data were selected from monitoring conducted in January 2018 as the data for this sample were generally closest to the median of all samples (refer to Appendix F.2.6) (Mine Waste Management, 2023c).

#### W1 and W4 pit lake water quality

As outlined above, the W1 and W4 pit lake qualities were based on early geochemical modelling conducted by Mine Waste Management (2022b) which has since been superseded by the modelling outlined in Section 5.14.3.1. The TDS concentrations predicted by the AQ2 (2022) Yandi closure water balance (Section 5.14.1 and Appendix F.1.3) guided the extrapolation of modelled pit lake water quality outputs from the hydrogeochemical model (Mine Waste Management, 2023c):

- The median water balance model salinity in W1 Pit varies around ~2,000 mg/L TDS with a maximum of ~3,000 mg/L TDS.
- The median water balance model salinity in W4 Pit is ~2,000 mg/L TDS. The maximum TDS extends to ~65,000 mg/L, however, this only occurs once all the water captured by the pit in a 1 in 10,000 AEP event has been completely evapo-concentrated (i.e., nearly all water evaporated). Modelled pond water elevations were therefore reviewed, and an upper

estimate of TDS of 26,000 mg/L was selected. This corresponds to a pond elevation of 545 m which the closure water balance predicts will only be exceeded on two other occasions and, therefore, represents a pond volume that is meaningful with respect to the adopted overtopping scenarios being assessed and provides a sufficiently conservative value for TDS.

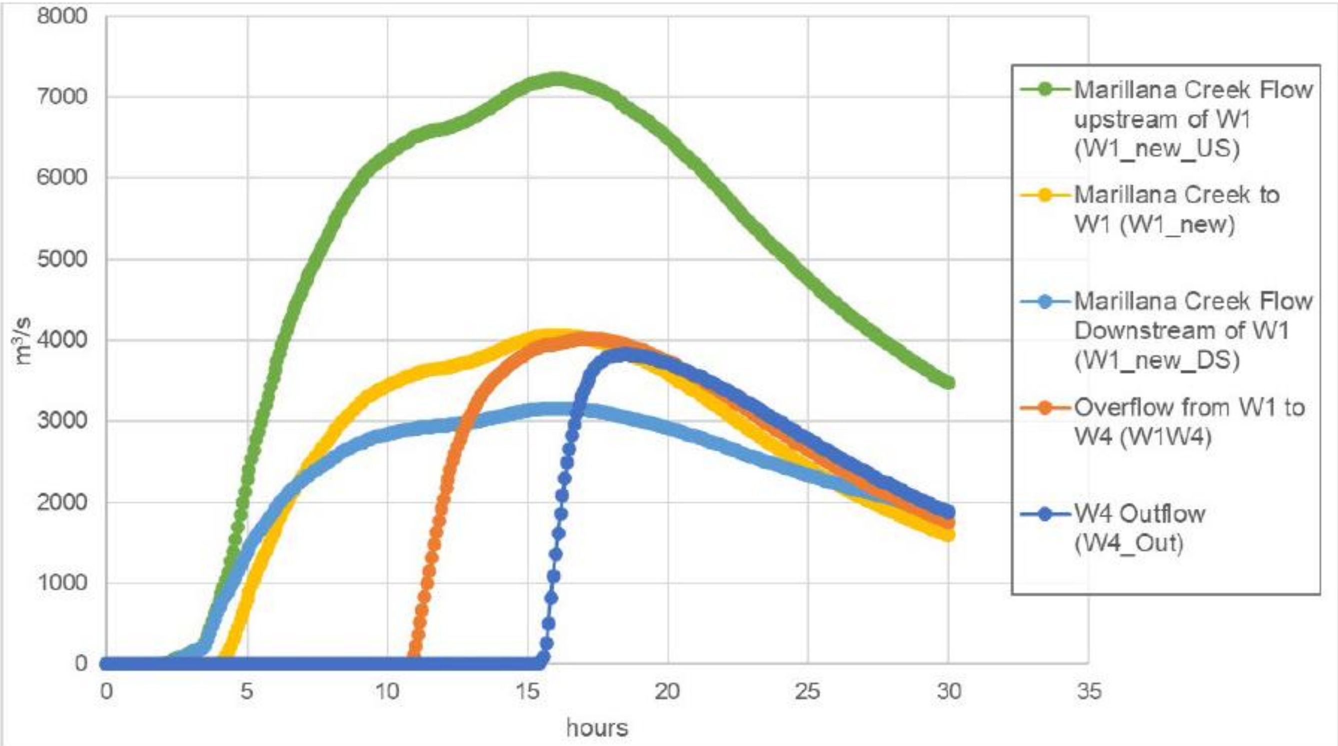
The extrapolated water qualities are provided in Appendix F.2.6 and assumed that evapo-concentration of ponded water in W1 and W4 would result in similar chemistry to those modelled by Mine Waste Management (2022b) for C4/5 pit lake[46] (Mine Waste Management, 2023c).

*Relative proportion of flows*

The proportions of flows within the mixing zone were calculated from flood modelling outputs provided by Advisian as part of the Yandi closure study. It was assumed that creek leakage is minimal, and therefore, the loss of water from the mixing zone was not considered. Flood modelling hydrographs were provided for a 1 in 10,000 AEP event (Figure 5-63) and a 1 in 500 AEP event (Appendix F.2.7). The 1 in 500 AEP event would not cause flow into W4 from W1, nor overtopping of W4, but the outputs allow scenarios to be modelled where two or more rainfall events with sufficient magnitude to partially fill W1 and W4 occur in quick succession. The proportion of flows into the mixing zone from Marillana Creek, W1 Pit and W4 Pit were calculated (see Appendix F.2.7) for situations where (Mine Waste Management, 2023c):

- Both W1 and W4 pits were full.
- W1 Pit was full and W4 Pit was part full (corresponding to the volume of a pond with TDS 26,000 mg/L).

The hydrograph for the 1 in 10,000 AEP event (Figure 5-63) shows that overtopping from W4 Pit to Marillana Creek would commence after ~15.5 hours overflow (“W4 Outflow”) (Mine Waste Management, 2023c).




Source: Advisian (2022) as cited by Mine Waste Management (2023c)

**Figure 5-63 Modelled hydrographs for W1 / W4 / Marillana Creek system for 1:10,000 AEP event**

*Boundary conditions*

The Mine Waste Management (2022b) pit lake modelling assumed oxic pit lake water. Considering the W1 / W4 / Marillana Creek system comprises shallow and rapidly flowing water, conditions in the mixing zone were also assumed to be oxic. A pe value of 10 was applied for the mixing model, and equilibrium was assumed between the water in the mixing zone and atmospheric gases ($O_2$ and $CO_2$) at typical ambient concentrations (Mine Waste Management, 2023c).

[46] TDS concentrations may differ from the hydrogeochemical modelling discussed in Section 5.14.3.1 as the modelling in Section 5.14.3.1 includes solute loads from backfill

Precipitation of supersaturated mineral phases from the mixed solutions was not allowed as it was assumed that precipitation within the mixing zone would be negligible given the rapid rate of downstream flow. For similar reasons, interaction with pit walls and creek bed / banks was not considered (Mine Waste Management, 2023c).

#### Modelling scenarios

Hydrological modelling indicates that overtopping of W4 into Marillana Creek would be inherently unlikely as it would be associated with a 1:10,000 AEP rainfall event, i.e., probability of 0.0001 or 0.01%. More frequent rainfall events might result in overtopping if W1 and W4 contained water prior to the event. However, due to the high-evaporation climate of the Pilbara region, the duration of significant temporary ponding is limited. Water balance modelling suggests the duration of ponds in W1 and W4 would be generally less than 25 years (Scenario B.1 (AQ2 2022)). This implies that the following sequence would be required for W4 overtopping to have a significant impact on water quality in the mixing zone (Mine Waste Management, 2023c):

- A rainfall event large enough to cause W4 overtopping or partially fill W1 and W4 pits.
- An interval during which evapo-concentration of the W1 and W4 ponds had occurred but a significant pond volume remained (estimated <25 years).
- A subsequent rainfall event large enough to fill both W1 and W4 and displace the evapo-concentrated water into the mixing zone.

Based on the current understanding of the Marillana Creek-W1-W4 system with proposed flood channels, the likelihood of the above sequence occurring is exceptionally low. This is because, in the semi-arid Pilbara climate, the probability of rainfall events of sufficient magnitude to partially fill W1 and W4 is inherently low. The occurrence of two or more such events in relatively quick succession (i.e., less than 25 years apart) is less probable (Mine Waste Management, 2023c).

Considering the above, eight conservative modelling scenarios were developed to assess potential water quality impacts in the mixing zone downstream of the W4-SP3 flood channel (Table 5-57). The modelled scenarios simulated dilution of evapo-concentrated water in W1 and W4 pits by the volume of upstream Marillana Creek water produced by the 1:500 AEP and 1:10,000 AEP events. The scenarios are termed "conservative" since they are all inherently unlikely, however, some events are less likely than others and have been ranked in Table 5-57 accordingly (see Column 7). A ranking of 9 implies the highest relative likelihood with 1 being least likely and, therefore, the most conservative scenario (Mine Waste Management, 2023c).

The most likely scenario is Scenario 0 (base case) which assumes no water has accumulated in either W1 or W4 prior to the 1 in 10,000 AEP event. Therefore, overflow from Marillana Creek via the W1-SP0 flood channel would pass rapidly through these pits and overflow back into the creek via the W4-SP3 flood channel with no significant change in water quality. The least likely scenario is Scenario 1A which assumes that both pit lakes W1 and W4 are full prior to the rainfall event <u>and</u> have high TDS concentrations (3,003 mg/L for W1, 26,000 mg/L for W4). This is extremely unlikely considering the rarity of rainfall events sufficient to fill both pits and cause W4 to overflow (Mine Waste Management, 2023c).

**Table 5-57 Scenarios to estimate mixing zone water quality**

| Scenario | Water quality W1 | Water quality W4 | Antecedent volume - W1 | Antecedent volume - W4 | Rainfall event | Relative likelihood* |
|---|---|---|---|---|---|---|
| 0 (base case) | M. Creek Water | M. Creek Water | Empty | Empty | 1:10,000 AEP | 9 (most likely) |
| 1 | 2,023 mg/L TDS | 2,023 mg/L TDS | Full | Full | 1:10,000 AEP | 2 |
| 1A | 3,003 mg/L TDS | 26k mg/L TDS | Full | Full | 1:10,000 AEP | 1 (least likely) |
| 2 | 2,023 mg/L TDS | 2,023 mg/L TDS | Full | Part full | 1:10,000 AEP | 4 |
| 2A | 3,003 mg/L TDS | 26k mg/L TDS | Full | Part full | 1:10,000 AEP | 3 |
| 3 | 2,023 mg/L TDS | 2,023 mg/L TDS | Full | Full | 1:500 AEP | 6 |
| 3A | 3,003 mg/L TDS | 26k mg/L TDS | Full | Full | 1:500 AEP | 5 |
| 4 | 2,023 mg/L TDS | 2,023 mg/L TDS | Full | Part full | 1:500 AEP | 8 |
| 4A | 3,003 mg/L TDS | 26k mg/L TDS | Full | Part full | 1:500 AEP | 7 |

Source: Mine Waste Management (2023c)

Notes: *Relative likelihood = Qualitative relative ranking of scenario probability; 9 being more likely and 1 being least likely.

### 5.14.4.3 Model outputs

The mixing model results are presented in Table 5-58, together with upstream baseline concentrations in Marillana Creek (Section 5.9.3). In lieu of site-specific water quality criteria, the projected mixing zone values were also compared with generic water quality criteria; Freshwater Aquatic Ecosystem 95% Species Protection Level (SPL) and Livestock Drinking Water guidelines (ANZECC & ARMCANZ, 2000) (Mine Waste Management, 2023c).

**Table 5-58 Mixing zone model outputs**

| Parameter | Units | Marillana Creek Baseline Concentrations (Upstream) | | | Scenario 1 | Scenario 1A | Scenario 2 | Scenario 2A | Scenario3 | Scenario 3A | Scenario 4 | Scenario 4A | Environmental Quality Screening Criteria | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Median | Max. | W1: 2,023 mg/L TDS W4: 2,023 mg/L TDS pit water. | W1: 3,003 mg/L TDS W4: 26k mg/L TDS pit water. | W1: 2,023 mg/L TDS W4: 2,023 mg/L TDS pit water. | W1: 3,003 mg/L TDS W4: 26k mg/L TDS pit water. | W1: 2,023 mg/L TDS W4: 2,023 mg/L TDS pit water. | W1: 3,003 mg/L TDS W4: 26k mg/L TDS pit water. | W1: 2,023 mg/L TDS W4: 2,023 mg/L TDS pit water. | W1: 3,003 mg/L TDS W4: 26k mg/L TDS pit water. | Freshwater Aquatic Ecosystem 95% SPL | Livestock guidelines |
| | | | | | W1 and W4 full prior to 1:10,000 AEP event. | | W4 part full. W1 full prior to 1:10,000 AEP event. | | W1 and W4 full prior to 1:500 AEP event. | | W4 part full. W1 full prior to 1:500 AEP event. | | | |
| pH | pH units | 7 | 7.4 | 8.1 | 7.6 | 7.4 | 7.5 | 7.5 | 7.7 | 7.5 | 7.6 | 7.5 | 6-8.5 | N/A |
| TDS | mg/L | 57 | 150 | 350 | 725 | 4,031 | 560 | 1,378 | 982 | 5,785 | 776 | 2,022 | N/A | 5,000 |
| Total Alkalinity as $CaCO_3$ | mg/L | 32 | 65 | 143 | 78 | 71 | 75 | 73 | 81 | 72 | 78 | 74 | N/A | N/A |
| Al | mg/L | 0.0025 | 0.02 | 0.31 | 0.007 | 0.006 | 0.007 | 0.006 | 0.008 | 0.006 | 0.007 | 0.006 | 0.055 | 5 |
| B | mg/L | 0.0025 | 0.062 | 0.17 | 0.012 | 0.013 | 0.008 | 0.009 | 0.017 | 0.019 | 0.013 | 0.014 | 0.37 | 5 |
| Ba | mg/L | - | - | - | 0.008 | 0.006 | 0.006 | 0.005 | 0.012 | 0.009 | 0.009 | 0.008 | N/A | N/A |
| Br | mg/L | - | - | - | 0.007 | 0.009 | 0.005 | 0.007 | 0.010 | 0.014 | 0.008 | 0.010 | N/A | N/A |
| Ca | mg/L | 8.2 | 11 | 25 | 31 | 162 | 25 | 57 | 40 | 230 | 33 | 82 | N/A | 1000 |
| Cl | mg/L | 9 | 11 | 65 | 243 | 1,564 | 180 | 507 | 343 | 2,261 | 263 | 762 | N/A | N/A |
| F | mg/L | - | - | - | 1.3 | 1.3 | 0.92 | 0.92 | 1.9 | 1.9 | 1.4 | 1.4 | N/A | 2 |
| Fe | mg/L | 0.005 | 0.028 | 0.77 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0007 | 0.0007 | 0.0005 | 0.0005 | N/A | N/A |
| K | mg/L | 2.4 | 4 | 6.1 | 16 | 87 | 12 | 30 | 21 | 125 | 17 | 44 | N/A | N/A |
| Li | mg/L | - | - | - | 0.003 | 0.008 | 0.002 | 0.004 | 0.004 | 0.011 | 0.003 | 0.006 | N/A | N/A |
| Mg | mg/L | 3.3 | 5.5 | 22 | 44 | 255 | 33 | 86 | 62 | 368 | 48 | 127 | N/A | 2,000 |
| Mn | mg/L | 0.0005 | 0.001 | 0.028 | 0.064 | 0.16 | 0.047 | 0.076 | 0.091 | 0.22 | 0.07 | 0.11 | 1.9 | N/A |
| Na | mg/L | 2.5 | 8.8 | 38 | 149 | 973 | 108 | 313 | 212 | 1,409 | 162 | 473 | N/A | N/A |
| Nitrate as $NO_3$ | mg/L | 0.21 | 1.7 | 6.3 | 23 | 151 | 17 | 49 | 33 | 219 | 25 | 73 | 0.7 | 400 |
| Ni | mg/L | 0.0005 | 0.005 | 0.005 | 0.006 | 0.011 | 0.006 | 0.008 | 0.006 | 0.013 | 0.006 | 0.009 | 0.011 | 1 |
| Sulphate as $SO_4^{2-}$ | mg/L | 5 | 10 | 31 | 117 | 746 | 86 | 242 | 165 | 1,079 | 126 | 364 | N/A | 1,000 |
| Si | mg/L | - | - | - | 0.88 | 0.83 | 0.63 | 0.61 | 1.3 | 1.2 | 0.96 | 0.94 | N/A | N/A |
| Sr | mg/L | - | - | - | 0.008 | 0.02 | 0.006 | 0.009 | 0.011 | 0.029 | 0.009 | 0.014 | N/A | N/A |
| Zn | mg/L | 0.0025 | 0.0025 | 0.025 | 0.006 | 0.015 | 0.004 | 0.007 | 0.008 | 0.021 | 0.006 | 0.011 | 0.008 | 20 |

Source: Mine Waste Management (2023c)

Notes: Mixing zone is downstream of the W4 outflow and includes creek flow downstream of the W1 flood channel and a mixed impacted flow comprising W1, W4 and creek inflows to W1

NA = not available or not applicable. Dashes indicate data were not available.

Orange = exceeds Freshwater Aquatic Ecosystem 95% SPL (ANZECC & ARMCANZ, 2000)

Yellow = exceeds Livestock Guidelines (ANZECC & ARMCANZ, 2000) but below Freshwater Aquatic Ecosystem 95% SPL

The model results indicate that overtopping presents a low risk to downstream water quality. Should one of the highly unlikely overtopping scenarios occur, and if the conservative water qualities used in the modelling apply, the model results suggest modest exceedances of water quality guideline values in the short term (<30 hours) (Table 5-58). Modelled (Mine Waste Management, 2023c):

- pH for all scenarios was circumneutral (pH 7.4 - 7.5) and consistent with upstream water quality.
- Salinity varied from 560 - 5,785 mg/L TDS and was consistently elevated compared with the median Marillana Creek water quality (150 mg/L), however, the projected mixing zone TDS concentration only marginally exceeded the livestock drinking water guideline (5,000 mg/L TDS) in Scenario 3A.
- Concentrations of major ions (calcium, chloride, potassium, magnesium, sodium, nitrate, and sulphate) exceeded Marillana Creek upstream water quality by factors of up to 200. However:
  - No scenarios exceeded livestock drinking water quality guidelines for calcium, magnesium and nitrate.
  - Although nitrate freshwater 95% SPL guidelines were exceeded in all scenarios, median upstream water quality concentrations also exceeded guidelines. In addition, modelled nitrate values are conservative as biochemical processes have not been considered in pit lake modelling (Section 5.14.3.3).
  - The livestock drinking water guideline for sulphate was only marginally exceeded in Scenario 3A.
- Concentrations of dissolved Al and Fe were low relative to upstream Marillana Creek water. This reflects low concentrations in the input solutions due to control by Al and Fe oxyhydroxide mineral precipitation assumed in the modelling from which the source terms were derived.
- Manganese concentrations in the mixing zone were between 0.05 and 0.22 mg/L. These are one or two orders of magnitude higher than the Marillana Creek upstream concentrations, although mixing zone concentrations remained well below the freshwater 95% SPL guideline value (1.9 mg/L).
- Mixing zone nickel concentrations were elevated compared to median upstream values (by a factor of up to 3), but only Scenario 3A had a minor exceedance of the freshwater 95% SPL guideline value (0.013 vs. 0.011 mg/L).
- Zinc concentrations were elevated (by a factor of up to 9 compared with median upstream concentrations) but there were only minor exceedances of the freshwater 95% SPL guideline value (up to 0.021 vs. 0.008 mg/L) under Scenarios 1A, 3A and 4A.

#### 5.14.4.4 Knowledge gaps & forward work program

Should changes to closure designs or associated knowledge base warrant, the implications for pit lake water release to Marillana Creek will be reviewed, and modelling updated, if required.

### 5.14.5 Potential for stratification & density driven flow in pit lakes

Evapo-concentration is expected to result in development of highly saline pit lakes. Highly saline, dense water within the pit may induce density driven hydraulic gradients between the pit and the surrounding groundwater. For significant density driven flows to occur from a pit lake into the surrounding groundwater, the density induced gradients away from the pit must exceed the hydraulic heads driving water toward the pit. The potential for pit lake stratification influences the potential for density driven flows. Many lakes are not permanently stratified and will overturn and homogenise at least once a year (SRK, 2023). In a fully mixed lake, hydrogeochemical modelling indicates that the TDS concentration does not exceed the halite saturation of 360,000 mg/L for long periods, before rainfall and groundwater inflow decrease the concentration (Section 5.14.3.1).

The ratio of the maximum depth of the lake to the mean lake diameter (the relative depth, Zr) can be used to infer the potential for permanent stratification, using the following calculation (SRK, 2023):

$$Z_r = \frac{50\ x\ Z_m\ x\ \sqrt{\pi}}{\sqrt{A_0}}$$

where $Z_r$ = relative depth (%)

$Z_m$ = maximum depth (m)

$A_0$ = lake surface area ($m^2$)

Pit lakes with $Z_r$ values greater than 4% have a higher potential to stratify. All calculated $Z_r$ values for Yandi permanent pit lakes are less than 4% (Table 5-59), suggesting that permanent stratification is unlikely (SRK, 2023).

**Table 5-59 Relative depth ($Z_r$) for permanent pit lakes**

| Pit identifier | Maximum depth (m) | Surface area ($m^2$) | Relative depth, $Z_r$ (%) |
|---|---|---|---|
| W2 | 24 | $4 \times 10^5$ | 3.4 |
| W3 | 20 | $5 \times 10^5$ | 2.5 |
| C4/5 | 11 | $1 \times 10^6$ | 0.97 |
| E7 | 34 | $8 \times 10^5$ | 3.4 |

Source: SRK (2023)

In the event that outflow did occur, a plume of the dense, saline water could be expected to flow downwards initially. As the denser plume water mixes with (less saline) groundwater, the density would change and gradually become equivalent to that of the groundwater. At this point, the plume could spread laterally within the groundwater system. Should density driven flow occur at Yandi, it would most likely be observed in the deeper Weeli Wolli bedrock aquifer system and impacts to the shallower alluvial aquifer groundwater may be less likely (SRK, 2023).

#### 5.14.5.1 Knowledge gaps & forward work program

More detailed assessment is required to further examine the potential for density driven flow from any Yandi pit lakes, noting that the backfill strategy may change based on the outcomes of consultation.

### 5.14.6 Pit lake risk assessment

A source-pathway-receptor assessment and human health and ecological risk assessment was conducted by Mine Lakes Consulting to understand whether pit lakes at Yandi would present an environmental risk at closure and if any pit lakes posed greater risks or opportunities than others. The assessment was peer reviewed by AQ2 (2022b) and SRK (2022b) and was subsequently revised and reported in Mine Lakes Consulting (2022). This section summarises the Mine Lakes Consulting (2022) work and makes reference to comments provided by independent peer reviewers, where relevant. The assessment followed established methods for human health and ecological risk assessment and comprised:

- Development of a conceptual site model (Section 5.14.6.1).
- Establishment of source-pathway-receptor linkages (Section 5.14.6.2).
- Qualitative human health and ecological risk assessment for significant identified source-pathway-receptor linkages (Section 5.14.6.3).
- Alternative pit lake configuration assessment (Section 5.14.6.4).

The outcomes of the assessment were used to determine whether any of the pits should be preferentially backfilled and informed the backfill options selection process.

**Summary**

A conceptual model was developed for a conceivable "worst case" pit lake forming at Yandi from completion of mining and cessation of dewatering to around 500 years post-closure (i.e., the assessment was not based on any one of the Yandi pit lakes in particular, rather a theoretical worst case that encompassed all potential environmental risks that could theoretically be posed by any single or multiple pit lakes). The model considered the water balance, sources of constituents of environmental concern, pathways, receptors, and residual void shape. SRK (2022b) concluded that the conceptual site model is comprehensive, and no significant gaps were identified. The model assumed the following pit lake characteristics:

- A large deep pit with steep unstable sides and relatively little perimeter for littoral or riparian habitat development.
- A terminal sink with:
  - Evapo-concentration leading to hypersaline water with some elevated constituents of potential concern.
  - Occasional throughflow to shallow aquifers and rare decant to Marillana Creek during extreme (e.g., 1 in 10,000 AEP) rainfall events.
  - Potential for some density driven saline seepage.
  - Seasonal stratification.

Consistent with the hydrogeochemical modelling, sources of potential constituents of concern were identified as OSAs / ISAs, pit walls, and groundwater.

Key pathways were identified as:

- Direct contact, drinking and biomagnification. Bioaccumulation of constituents of potential concern may potentially occur through drinking, but biomagnification is unlikely as wildlife and livestock are not expected to receive a dominant proportion of food items from the pit lake.
- Over topping and discharge to the environment (unlikely).
- Density driven seepage and throughflow (unlikely).

Key receptors were identified as:

- Terrestrial wildlife, livestock and birds. However, given lake salinity, waterfowl were expected to be most likely impacted.
- Humans mainly through direct contact such as swimming, as the pit lake is expected to have poor hunting and fishing values due to low abundances / unlikely incidence of target bushtucker species.
- Riparian vegetation of adjacent and downstream creeks.
- Stygofauna (very unlikely due to low likelihood of density driven seepage or temporary throughflow).

The review concluded that any potential impacts of the pit lakes would be expected to be restricted to the catchment for most receptors but to the broader region for birds and humans. Inherent risks were assessed as low due to the only moderately poor water quality for livestock drinking (also serving as a proxy for wildlife drinking) and relatively short-term exposures expected from all receptors spending little time drinking and contacting Yandi Pit Lake waters. SRK (2022b) concluded that there were no fatal flaws in the approach and broadly concurred with the conclusions drawn in the report. AQ2 (2022b) similarly concurred with the conclusion that the presence of saline pit lakes within the Yandi mine footprint is unlikely to result in significant risk to biotic receptors regionally.

The greatest risks identified were for birds, bats and humans eating aquatic biota from pit lakes. This was predominantly due to a very high likelihood of these events occurring even with a low expectation of environmental impact. There was also an elevated risk for humans drinking pit lake water, especially before it becomes salinized and unpalatable, as water quality is not expected to meet potable standards. Some water may be ingested during active recreational activities.

To determine whether any of the Yandi pit lakes would be likely to have greater risks or benefits than others, data for 47 pit lake attributes were collected for each pit and scored, where possible using quantitative numeric data, otherwise, by assigning a rank scale or binary flag (0 or 1). Analysis of these attributes resulted in four groups of pit lake types. Attributes driving the greatest differences between the pit lake types were remaining mineralised material, decant frequency and salinity, water permanence, distance to neighbours and lithological exposures of ochreous, Weeli Wolli dolerite, eastern clay and weathered eastern clay stratigraphies present on final pit surfaces. These attributes were then used as the basis for a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis.

The SWOT analysis assumed no backfill in any pits[47] and resulted in slightly negative scores for all pit types. The analysis was unable to identify strong differences between the pit groupings, although W4 was found to have a slightly more negative rating than the other pits and was, therefore, identified as potentially preferred for backfilling.

The opportunity assessment was based on a preliminary assessment of the potential benefits that pit lakes could pose post-mining. There were limited site-specific data to inform the opportunity assessment, and further work is required to investigate potential options (refer to Section 6), however, the assessment provided some indications of where further studies could be focused (conservation, carbon sequestration, traditional use, water remediation and tourism).

#### 5.14.6.1 Conceptual site model

For the purposes of the risk assessment, a conceptual model was developed for a conceivable "worst case" pit lake forming at Yandi Mine following completion of mining and cessation of dewatering to around 500 years post-closure (i.e., the assessment was not based on any one of the Yandi pit lakes in particular, rather a theoretical worst case that encompassed all potential environmental risks that could theoretically be posed by any single or multiple pit lakes). The model considered the water balance, sources of constituents of environmental concern, pathways, receptors, and residual void shape. SRK (2022b) concluded that the conceptual site model is comprehensive, and no significant gaps were identified.

The conceptual model was based on Yandi closure study findings current at the time of the risk assessment[48] and a literature review. Key features of the conceptual model developed for the risk assessment are as follows (Mine Lakes Consulting, 2022):

- The pit was envisaged to be:
  - Large with potentially steep unstable sides.
  - Deep with a very large permanent volume and surface area and with relatively little perimeter likely to be suitable for littoral or riparian habitat development.
- Due to the arid climate, and relatively high evaporation rates, the overall water balance was assumed to be negative, i.e., the lake represents a water sink and continuous groundwater outflow is unlikely to occur. However, occasional through-flow to shallow aquifers and rare decant down Marillana Creek was envisaged during heavy (and very unlikely) rainfall events (e.g., 1 in 10,000 AEP). Some potential for density-driven saline seepage was assumed, although this was expected to be low.
- Ex-pit and in-pit OSAs as well as pit wall lithological exposures (especially above waterline) were assumed to release salinity and some constituents of potential concern to the pit lake. Groundwater inflows were also assumed to provide a source of salinity and other solutes. Direct rainfall and occasional creek inflows could act as a diluent of pit lake water solutes.
- Water quality would initially be fresh but with some elevated constituents of potential concern exceeding guidelines and becoming increasingly concentrated over time through evapo-concentration to yield a hypersaline lake. SRK (2022b) notes that the temporal changes in water quality may take decades to develop which may impact the risk profile temporarily until steady state conditions are reached.
- The lake would seasonally stratify with warmer, more saline waters over the dry season and overturn over the wet season; especially following heavy rainfall events.
- The pit lake would not be expected to develop a diverse ecosystem due to factors such as:
  - Steep pit sides limiting establishment of vegetation and wildlife food sources and foraging opportunities at lake edges.

47 This assumption was for the purposes of informing the backfill strategy (i.e. whether any pits should be preferentially backfilled) and is not consistent with current closure plans.

48 Some of the studies have since been superseded, however, the findings of the risk assessment remain valid. Studies referenced during the assessment include AQ2 water balance and ecohydrology review work conducted to 2020 (and reported in the 2020 version of the MCP) and Mine Waste Management work conducted to 2021 (which included a draft version of the information presented in Section 5.2.3 of this MCP).

  - Slightly poor pit lake water quality which would slightly limit what lake ecosystem is able to develop.
  - Limited connectivity with other water bodies limiting colonisation by fully-aquatic or poorly dispersing species.
  - Absence of significant water courses flowing into the lake, reducing both accumulation of coarse woody debris that forms important habitat and also finer organic matter that provides a key source of nutrients to the aquatic ecosystem.
- Pit lake biota were expected to be limited and unlikely to support a strong local food chain.
- Although regional native ecology is well adapted to make use of the riverine pools that form across the nearby creeks following wet season rainfall, this same ecology is poorly adapted to utilise deep, permanent waterbodies such as a pit lake. However, it was considered that some wildlife species may utilise the lake as both a food and drinking water source:
  - Some waterfowl adapted to more permanent water bodies may potentially feed on the low abundances of pit lake aquatic biota e.g., macroinvertebrates. Waterfowl may also use the lake as resting and foraging habitat.
  - Terrestrial wildlife e.g., black-footed wallaby may graze on vegetation near the lake.
- Bioaccumulation of constituents of potential concern may potentially occur through drinking. However, biomagnification through aquatic and amphibious biota contaminated by pit lake waters was not considered likely as wildlife and livestock would not be expected to receive a dominant proportion of food items from the pit lake.
- The only groundwater receptors identified were the riparian vegetation of adjacent and downstream creeks.

#### 5.14.6.2 Source-pathway-receptor model

A source pathway receptor model was developed (Figure 5-64) which identified the key sources of constituents of potential concern, the potential receptors to contamination and the pathways that link the two. The model was cognisant of both limnology and aquatic ecology of the Pilbara region but also known physical, chemical and ecological limitations to development of pit lake aquatic ecosystems (Mine Lakes Consulting, 2022). SRK (2022b) concluded that the source-pathway-receptor analysis was comprehensive, and no significant gaps were identified.

A brief discussion of the sources, pathways and receptors follows in the sub-sections below.

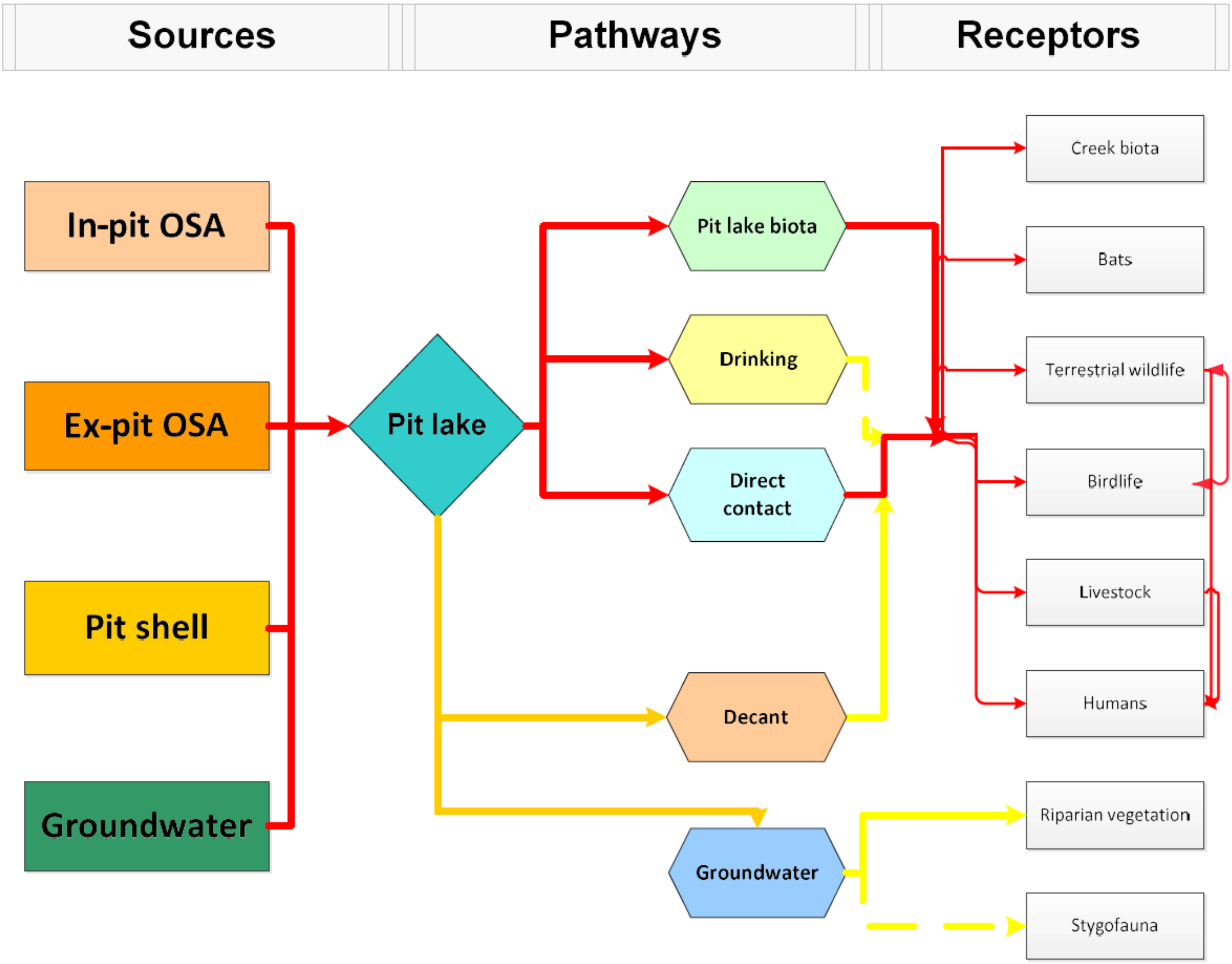
**Sources**

Based on the conceptual site model in Section 5.14.6.1, geochemical testing reported in Section 5.2.3, and AQ2 water balance modelling conducted to 2020, key sources of potential constituents of concern were identified as outlined in Table 5-60 (Mine Lakes Consulting, 2022).

**Table 5-60 Potentially significant contaminant sources from the Yandi Pit Lake**

| Source Name | Source Location | Potential contaminant type(s) |
|---|---|---|
| ISAs | Overburden placed within pit lake void. | Classified as NAF (AMD0); likelihood of generating acidic drainage is low. The low total sulphur content of the Yandi deposit suggests the generation of neutral metalliferous and / or saline drainage resulting from sulphide oxidation is unlikely. |
| OSAs | Overburden placed within pit lake catchment, but not in the mine void proper. | |
| Pit walls | Present as a completely filled and permanent lake water body within the mine void with some geochemically enriched pit wall exposures always above equilibrium water level. | |
| Groundwater | Regional aquifers intercepted by the mine void (especially Weeli Wolli Formation). | Salinity ranges from 100 - 1,300 mg/L in CID and 400 - 600 mg/L in the alluvial aquifer. pH varies from 7.5 - 8.4. |

Source: Mine Lakes Consulting (2022)




Source: Mine Lakes Consulting (2022)

Notes: Likely potential contaminant transport pathways are shown in red, unlikely pathways are shown in orange, extremely unlikely pathways shown in yellow.

**Figure 5-64 Pit lake source-pathway-receptor model**

### Pathways

Several direct contaminant pathways were identified from the sources of constituents of potential concern through the pit lake to receptors, including:

- Direct contact, drinking and biomagnification.
  - Direct contact can occur with animals wading or swimming for foraging or drinking. Ingestion is a higher risk than direct contact itself so direct contact was considered conservatively by using the potential for drinking and bioaccumulation pathways as proxies.
  - Aquatic biota may become a pathway for transport and biomagnification of constituents of potential concern through the food chain. Although some ingestion of pit lake biota will occur by receptors, the lake is not expected to demonstrate water quality or habitat likely to result in significant primary production rates, biomass or food chain length and, therefore, is unlikely to result in as bioaccumulation within receptors that have spent only a small proportion of their lifetime on and around the lake.
- Overtopping of the pit lake and discharge to the environment. The likelihood of this event is very low and dilution of constituents of potential concern is likely to occur due to high surface flows at the time of discharge such that constituents of potential concern are unlikely to reach receptors in significant concentrations (see Section 5.14.4).
- The likelihood of groundwater seepage from either throughflow or density driven seepage is expected to be low (Sections 5.14.1.4 and 5.14.5).

These pathways are summarised in Table 5-61 in order of priority.

**Table 5-61 Potentially significant contaminant pathways**

| Source Name | Pathway Type(s) | Pathway |
|---|---|---|
| OSAs, pit shell, groundwater | Pit lake | Direct contact |
| | Pit lake | Drinking |
| | Pit lake | Biomagnification |
| | Decant to Creeks | Direct contact |
| | Decant to Creeks | Drinking |
| | Decant to Creeks | Biomagnification |
| | Groundwater seepage | Direct contact |
| | Groundwater seepage | Drinking |
| | Groundwater seepage | Biomagnification |

Source: Mine Lakes Consulting (2022)

### Receptors

The key potential receptors to constituents of potential concern from Yandi pit lakes are summarised in Table 5-62.

The main ecological receptors are expected to be terrestrial wildlife, livestock and birds. However, given lake salinity, only isolated wildlife species are expected to make use of the lake, with predominantly waterfowl adapted to ephemeral saline lakes and potentially feeding when aquatic biota e.g., fairy shrimp, are present. Waterfowl may also use the lake as resting and foraging habitat. Terrestrial wildlife may graze terrestrial vegetation near the lake.

It is possible that the Yandi pit lake might impact upon stygofauna and other groundwater dependent communities downgradient (e.g., riparian vegetation) by surcharge then seepage and / or through-flow of groundwaters through backfilled overburden, however, this pathway is very unlikely.

Humans are also likely to interact with the lake, but mainly through direct contact from swimming, as the pit lake is expected to have poor hunting and fishing values due to low abundances / unlikely incidence of target bushtucker species.

**Table 5-62 Summary of potential receptors**

| Receptor | Receptor Location | Description | Conclusions |
|---|---|---|---|
| Vegetation | Riparian margins of Weeli Wolli, Marillana Creeks and Fortescue Marsh. | Dominated by canopy of endemic phreatophyte tree species of the riparian zone; *Eucalyptus camaldulensis, E. victrix* and *Melaleuca argentea* which all access shallow groundwater.<br>The Priority 1 Fortescue Marsh PEC is located approximately 30 km to the north-east of the mine downstream. | Down-gradient riparian vegetation has significant conservation values and may already be stressed by ecohydrological impacts. Upstream sites are not expected to be significantly affected by pit lake quality. |
| Regional bird life | Highly mobile, up to hundreds of kms around Yandi. | The lake will become an increasingly saline aquatic habitat with low ecosystem diversity and abundance. Waterfowl and other protected birdlife may make short-term use for habitat and may briefly feed and rest but are unlikely to drink. Although, drinking is expected to be a minor component of contaminant load intake relative to food intake, drinking was conservatively considered the priority pathway for further analysis. | Despite a paucity of aquatic and catchment habitat, some birdlife, especially waterfowl might occasionally use the lake for foraging and resting. |
| Terrestrial life | Primarily local, surrounds of lake but not utilising riparian or saline wetted areas. | Increasingly saline water provides poor drinking water resource. No foraging values from low biomass of prey items (aquatic macroinvertebrates and fishes), and little to no littoral habitat. | No watering value as water is saline with little food value with no littoral and riparian vegetation and habitat.<br>While water rats occur in brackish and productive marine habitats, they are unlikely to use hypersaline habitats for shelter or food foraging.<br>The Pilbara Olive Python hunts in water holes with a broad diet of larger animals such as birds, mammals and other reptiles but the low prey density expected due to hypersaline waters will likely provide little food source. |
| Regional ghost bats | May drink and feed around the pit lake but not utilise riparian or saline wetted areas. | Bats may nest locally, although this is unlikely due to specific habitat requirements. The pit lake provides depauperate aquatic food diversity and abundance. | Some regional native bats might use the pit lake for drinking or foraging. |
| Livestock | Around the mine void and immediately downstream reaches from pit lake. | Increasingly saline presenting poor drinking water resource. Poor in-pit grazing discourages stock access. | Despite access restrictions and no revegetation, some stock might enter the pit lake catchment but are not expected to graze significantly (due to poor resources), or drink. |
| Humans | Regional with high mobility. Communities reside in nearby towns and can easily drive to Yandi mine along highways and access roads / tracks. | Poor hunting and fishing values due to low abundances / unlikely incidence of target bushtucker species. Saline water is less attractive for swimming but will be available all year round; including during the late dry season when most other water bodies are absent from the landscape. | People are expected to use the broader project area, and some people might enter the pit lake catchment despite access restrictions as people are attracted to old mining areas and large water bodies. Where humans have regularly accessed even AMD degraded pit lakes for contact pathways such as swimming, no significant health effects from direct contact have been noted. Hunting / fishing and drinking unlikely with saline waters. |
| Stygofauna | Present within the groundwater at Yandi | The Yandi mining area supports a diverse and abundant stygofauna assemblage. | Seepage of saline (8,000 mg/L) water from pit lake might reach stygofauna downgradient, but this release is considered unlikely and all recorded stygal SREs have distributions which extend outside the Yandi development envelope with epigean species commonly recorded throughout the Marillana, Weeli Wolli and Fortescue catchments. |

Source: Mine Lakes Consulting (2022)

#### 5.14.6.3 Human health and ecological risk assessment

A risk workshop was conducted on 21 July 2021 and was attended by BHP staff and consultants familiar with the Yandi pit lakes context and contaminant hazard sources, pathways and receptors. The risks associated with the key source-pathway-receptor linkages (Section 5.14.6.2) were assessed qualitatively using the risk matrices provided in Appendix F.3.2. All variables were assigned a rating from a scale of 1 to 5 (lowest to highest). The variables assessed were:

- **Consequence** which considered the type and concentrations of constituents of potential concern. Where concentrations and the nature of contaminants both elicited higher toxicity, a higher consequence was allocated. A conservative view of water quality was taken from modelled pit lake water quality evolution over time.
- **Likelihood** of the receptors contacting mining contaminated waters which was defined as the expected frequency of the expected occurrence of the associated hazard's consequence within the time frame of a few centuries following closure.
- **Extent** which was defined as distance from the Yandi Pit Lake's wetted perimeter.
- **Duration** which was defined as how long the hazard was expected to be present over the course of hundreds of years.
- **Confidence** which identifies the workshop panel's confidence in their collective knowledgebase informing that hazard's risk rating.

A risk rating was derived by multiplication of Consequence, Likelihood, Extent, Duration and Confidence values and risks classified as shown in Table 5-63.

**Table 5-63 Risk classification**

| Risk Rating | Classification |
|---|---|
| 5-120 | Very Low |
| 121-600 | Low |
| 601-1,500 | Moderate |
| 1,501-2,500 | High |
| 2,501-3125 | Extreme |

Source: Mine Lakes Consulting (2022)

Key assumptions made in the assessment of risk are documented in Appendix F.3.1 along with SRK's (2022b) commentary and opinion on the materiality of the assumptions. Only one of the assumptions was identified as material; the assumption that the lakes will be permanent sinks. Predicated on this assumption is the conclusion that while water quality will deteriorate over time, impacts would be limited to the local lake environment, with little or no risk to downstream receptors. As the lakes are unlikely to sustain diverse ecosystems, local impacts relate solely to occasional exposures due to direct contact and / or ingestion. Should this assumption be flawed for any reason (albeit considered unlikely), the risk profile may be higher.

The results of the risk assessment are provided in Table 5-64. Inherent risks were assessed as low and both SRK (2022b) and AQ2 (2022b) concurred with this assessment. Mine Lakes Consulting (2022) concluded that:

- Any potential impacts would be expected to be restricted to the catchment for most receptors but to the broader region for birds and humans.
- Risks were all low due to the only moderately poor water quality for livestock drinking (also serving as a proxy for wildlife drinking) and relatively short-term exposures expected from all receptors spending little time drinking and contacting Yandi Pit Lake waters.
- The greatest risks are for birds, bats and humans eating aquatic biota from the pit lake. This is predominantly due to a very high likelihood of these events occurring even with a low expectation of environmental impact. Confidence in these events was not high due to there being few studies on pit lake ecological development (especially for saline lakes) and how these lakes might be used for drinking and feeding habitat by native wildlife.
- There is an elevated risk for humans drinking pit lake water, especially before it becomes salinized and unpalatable, as water quality is not expected to meet potable standards. Some water may be ingested during active recreational activities.

SRK noted that should a significant through-flow system develop, or temporary intermittent events dictate the dynamics of the pit lakes, the risk profile may be higher, but acknowledged that the likelihood of the pit becoming a throughflow system is low and sensitive receptors are located some considerable distance from the Yandi area and attenuation / dilution processes along long flow paths may mitigate water quality impacts at distant downstream receptors.

**Table 5-64 Risk assessment for key source-pathway-receptor linkages associated with a conceptual worst case pit lake**

| # | Source | Pathway | Receptor | Justification | Consequence | Likelihood | Extent | Duration | Confidence | Risk* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Evapo-concentrated overburden and pit shell geochemistries and regional groundwater | Pit lake biota ingestion | Bats | Some constituents of potential concern in pit lake water present a biomagnification risk. Direct consumption of pit lake aquatic biota, especially flying invertebrates with aquatic life stages, brine shrimp and tadpoles. Low primary productivity limits food-chain length and thus trophic biomagnification. Pit lake aquatic biota unlikely to form significant part of overall diet. Lake will not be rehabilitated as wildlife habitat. Eventual high salinity will reduce aquatic invertebrate food item biomass. | 2 | 5 | 4 | 5 | 3 | 600 |
| 2 | | Pit lake water direct contact | Bats | Saline water decanting from the Yandi pit lake might enter Weeli Wolli Creek and travel downstream as far as Fortescue Marsh. Decant concentrations during large rainfall events would be massively diluted by background river flow. Some pit lake water might through-flow eastwards via groundwater through remnant Marillana Formation, Munjina Formation and the shallow alluvial aquifer associated with the Marillana Creek bed. Inadvertent contact by a few bats that ingress pit lake void. Little bat roosting or foraging habitat from no pit lake catchment rehabilitation and saline pit lake water. | 1 | 3 | 4 | 5 | 3 | 180 |
| 3 | | Pit lake water drinking | Bats | Bats might live in catchment and might drink from lake but not frequently due to salinity. Pit lake will not be rehabilitated as wildlife habitat. Potential cave habitat in scree slopes but not in absent riparian tree hollows. | 2 | 4 | 4 | 5 | 3 | 480 |
| 4 | | Pit lake biota ingestion | Birdlife | Some constituents of potential concern in pit lake water present a biomagnification risk. Direct consumption of pit lake aquatic biota, especially flying invertebrates with aquatic life stages and amphibians. Wading birds such as conservation-significant species identified as likely to occur in region but unlikely to feed on depauperate littoral habitat. Few food items so expected time spent is low. Highly mobile so not resident and pit lake aquatic biota is unlikely to form a significant part of diet. Low primary productivity limits food-chain length and thus trophic biomagnification. Eventual high salinity will reduce aquatic invertebrate food item biomass. Pit lake will not be rehabilitated as wildlife habitat. | 2 | 4 | 4 | 5 | 3 | 480 |
| 5 | | Pit lake water direct contact | Birdlife | Lake water does not meet ecosystem protection guidelines. Some conservation-significant birds might use the pit lake as habitat for predator avoidance and might also attempt to forage in it in spite of little habitat being available due to saline waters and pit lake not being rehabilitated as a wildlife habitat. | 2 | 3 | 5 | 5 | 4 | 600 |
| 6 | | Pit lake water drinking | Birdlife | Some conservation-significant regional birds might drink from pit lake. Pit lake will not be rehabilitated as wildlife habitat. High salinity means that birds unlikely to drink in significant quantities. | 2 | 2 | 4 | 5 | 3 | 240 |
| 7 | | Pit lake biota ingestion | Humans | Some constituents of potential concern in pit lake water present a biomagnification risk. Lake will not be rehabilitated as wildlife habitat and represents poor habitat. Typical food items of large invertebrate (e.g., prawn) and finfish not likely to be present at all or in high abundances. Direct consumption of pit lake aquatic biota and wildlife that frequently feed on pit lake biota (especially larger typical bush tucker vertebrates such as fin fish and crustacea and waterfowl) are only likely to be a very small component of overall diet. Food items would be mainly waterfowl which would have a very low body burden. Unlikely to catch fish as populations very low. Eventual high salinity will reduce aquatic food item biomass. | 2 | 4 | 5 | 5 | 3 | 600 |
| 8 | | Pit lake water drinking | Humans | Communities reside in nearby towns and can easily drive to Yandi mine along highways and access roads / tracks. People are attracted to old mining areas and large water bodies. Saline water is not attractive for swimming but will be available all year round; including during the late dry season when most other water bodies are absent from the landscape. | 2 | 2 | 4 | 5 | 3 | 240 |
| 9 | | Pit lake water drinking | Humans | High salinity means that water will be unpalatable. Small amounts (10% salinity toxicity) might be ingested during active recreation. | 1 | 3 | 4 | 5 | 3 | 180 |
| 10 | | Pit lake biota ingestion | Livestock | Cattle will access mine voids to graze upon vegetation growing in void and around pit lake margin. Most vegetation will grow away from the water's edge due to saline water. Some constituents of potential concern in pit lake water present a biomagnification risk. Little habitat for riparian and littoral vegetation to establish. However, cattle will also graze saltmarsh as both a food source and for mineral salts. Eventual high salinity will reduce littoral vegetation biomass. Pit lake aquatic biota unlikely to form significant part of overall diet. | 2 | 3 | 4 | 5 | 2 | 240 |
| 11 | | Pit lake water direct contact | Livestock | Beef cattle ingress pit lakes for short periods to either wade, feed or drink and make direct contact with pit lake water. | 1 | 4 | 4 | 5 | 2 | 160 |
| 12 | | Pit lake water drinking | Livestock | Beef cattle ingress pit lakes for short periods. Saline water provides poor drinking source and does not function as attractant. No other local watering available. Potential watering source, especially during hot dry weather. | 2 | 4 | 4 | 5 | 2 | 320 |
| 13 | | Pit lake biota ingestion | Reptiles and amphibians | Some constituents of potential concern in pit lake water present a biomagnification risk. Pit lake will not be rehabilitated as wildlife habitat and represents poor habitat. Typical food items of large invertebrate (e.g., prawn) and finfish not likely to be present / present in high abundances. Absence of sandy beaches will reduce habitat value to turtles reducing likelihood and duration of habitat use. | 2 | 3 | 4 | 5 | 2 | 240 |
| 14 | | Pit lake water direct contact | Reptiles and amphibians | Lake will not be rehabilitated as wildlife habitat. Pit lake unlikely to have resident populations of reptiles and less so amphibians given poor wetted and catchment habitat and pit lake salinity. However, reptiles and amphibians may enter the lake during wet season events and flow, becoming resident for short periods. Lake water does not meet ecosystem protection guidelines. No endangered amphibians expected to be present, but potentially regional snakes which are tolerant of poor water quality. | 1 | 3 | 4 | 5 | 2 | 120 |
| 15 | | Pit lake water drinking | Reptiles and amphibians | Some conservation-significant regional reptiles might drink from pit lake, but Australian reptiles (especially arid zone) have very low water requirements. Pit lake will not be rehabilitated as wildlife habitat. High salinity means that reptiles unlikely to drink in significant quantities. No conservation significant amphibians in region. | 2 | 3 | 4 | 5 | 3 | 360 |
| 16 | | Pit lake biota ingestion | Terrestrial native | Some constituents of potential concern in pit lake water present a biomagnification risk. Potentially locally resident populations. Some native terrestrial wildlife might feed upon the small abundances of invertebrates such as insects with aquatic juvenile stages. However, conservation-significant species are not expected to use the lake for a significant component of their foraging. Low primary productivity limits food-chain length and thus trophic biomagnification. The lack of woody vegetation in rehabilitation within the pit restricts habitat available. Eventual high salinity will reduce aquatic invertebrate food item biomass. | 2 | 4 | 4 | s | 2 | 320 |
| 17 | | Pit lake water direct contact | Terrestrial native | Inadvertent contact by few terrestrial wildlife that access pit lake. Little habitat as the pit lake is saline and not rehabilitated as wildlife habitat. Conservation-significant species are not expected to frequent the lake as habitat and therefore unlikely to contact regularly. Native terrestrial animal water consumption is low, but they might still be attracted. Conservation-significant species not expected to use lake as habitat - saline water unpalatable. | 1 | 4 | 4 | 5 | 2 | 160 |
| 18 | | Pit lake water drinking | Terrestrial native | High salinity means that birds unlikely to drink in significant quantities | 2 | 4 | 4 | s | 2 | 320 |

Source: Mine Lakes Consulting (2022)

*Notes: refer to Table 5-63 for risk classification scheme

#### 5.14.6.4 Alternative pit lake configuration

To determine whether any of the Yandi pit lakes were likely to have greater risks or benefits, data for 47 pit lake attributes were collected for each pit and scored, where possible using quantitative numeric data, otherwise, by assigning a rank scale or binary flag (0 or 1). The full list of attributes data is provided in Appendix F.3.3 and included:

- Water balance variables.
- Remaining resource and backfill type and relative volume.
- Distance to receptors.
- Surface and groundwater transport potential.
- Salinity.
- Orientation and project area location.
- Depth and water permanence.
- Type of lithological exposures.

Analysis of the attribute data was used to define four lake types and then determine which were statistically different from each other. This resulted in the identification of the following statistically different pit types (assuming for the purposes of the study that none are backfilled):

- W1.
- E2/3/5/6.
- W4.
- Remaining pit lakes.

Attributes driving the greatest differences between the groups were remaining mineralised material, decant frequency and salinity, water permanence, distance to neighbour and lithological exposures of ochreous, Weeli Wolli dolerite, eastern clay and weathered eastern clay stratigraphies present on final pit surfaces. These attributes were then used as the basis for a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for the four different pit lake types (Appendix F.3.4).

The SWOT analysis assumed no backfill in any pits. It resulted in slightly negative scores for all pit types and was unable to identify strong differences between the pit groupings, although W4 was found to have a slightly more negative rating than the other pits and was, therefore, identified as potentially preferred for backfilling.

The opportunity assessment was based on a preliminary assessment of the potential benefits that pit lakes could pose post-mining. There were limited site-specific data to inform the opportunity assessment, and further work is required to investigate potential options (refer to Section 6), however, the assessment provided some indications of where further studies could be focused (conservation, carbon sequestration, traditional use, water remediation and tourism). As identified by AQ2 (2022b) opportunities could also be explored for interventions to improve the void / lake so it is not a “worst-case” lake (e.g., shaping of backfill).

#### 5.14.6.5 Knowledge gaps and forward work program

Depending on the final backfill strategy, the pit lake risk assessment will be refined as the Yandi closure designs progress.

### 5.14.7 Flood channel design studies

Several studies have been conducted to progress the designs of flood channels (formerly referred to as spillways) at Yandi including:

- A benchmarking exercise conducted by Advisian (2019) to identify applicable lessons where rock flood channels have been used in other locations (Section 5.14.7.2).
- Optimisation of the number and locations of flood channels (Section 5.14.7.3).
- Flood channel geotechnical investigation (Section 5.14.7.4).
- Various studies to optimise the location and geometry of flood channel W1-SP0, including alternative alignment selection, flood channel width and energy dissipator (Section 5.14.7.5).
- A review of the W1-SP3 flood channel (Section 5.14.7.6).
- A review of the W4-SP4 flood channel (Section 5.14.7.7).

A further assessment was conducted to understand how a ‘no flood channels’ scenario would compare to the flood channel scenarios outlined in Section 5.14.7.3. This is reported in Section 5.14.7.8. Knowledge gaps and forward works are summarised in Section 5.14.7.9.

**Summary**

In 2019, a study was conducted to optimise the number and location of flood channels. This was reported in the 2020 MCP and reduced the number of flood channels from nine to four. This was achieved by designing the placement of the larger W1-SP0 flood channel at the upstream / western end of the lease with the following advantages:

- The geology at the W1-SP0 location was expected to be highly favourable (compared to unfavourable at many of the other locations).
- The increased length of the W1-SP0 flood channel from the creek to the W1 Pit (as well as the fresh dolerite expected at this location) would significantly reduce the risk of scour and creek capture.
- The risk of creek capture was relatively high in one of the eliminated flood channels.

Following an analysis of options to eliminate the need for flood bunds at constrained locations (see Section 5.14.8), a floodplain landform was chosen for W6 Pit and a further flood channel (HP-SP2) was removed from the design as it is anticipated that excess flood water from Herbert's Creek will spill west onto the floodplain and into Marillana Creek.

To confirm (or otherwise) that the flood channel option is the most appropriate option for closure, a no-flood channel scenario analysis was conducted. This used TUFLOW modelling to compare the optimised flood channel scenario with a no-flood channel scenario. The review concluded that while there are several risks associated with flood channels (discussed further below), removing the flood channels would introduce several new risks:

- Extensive bunding would be required in place of the flood channels. These bunds would encroach into the floodplain increasing flood levels and velocities with overall risk to the bunds and the potential for creek capture. Very large rock armour (median diameter 1.45 m and a mass of 4 tonnes) would, therefore, be required resulting in a construction risk.
- High velocity water would occur across the two natural land bridges (W1-W2 and W3-W4) which could be a fatal flaw.
- Flows would impinge directly on the bund at W3 at high velocity with a high risk of creek capture.

The risks associated with the flood channels are as follows and informed the additional studies conducted for the flood channels which are summarised in further detail below:

- Erosion of the flood channels leading to creek capture.
- Potential for exposure of asbestiform minerals in the flood channel excavations.
- Potential for people to become trapped or fall from heights.
- Potential for saline water to spill to Marillana Creek (see Section 5.14.4).
- Potential for impacts to cultural values. This is the subject of ongoing consultation with the Banjima people (refer to Section 4).

Since the 2020 MCP, the location of the W1-SP0 has been changed due to heritage constraints. Several alternative alignments were considered, and Alternative 1D with a bund across the breakout channel was selected because the geology was suitable, and the alignment performed to the same level as the original flood channel. During the drilling program, fibrous materials (actinolite) were intersected in the dolerite within the W1-SP0 Alternative 1D alignment. These exposures form only a small proportion of the drill core (0.068%) and are likely to be lenticular with random and unpredictable occurrence (refer to Section 5.2.4.5). It is not possible to eliminate the exposures of fibrous materials by relocating / redesigning the W1-SP0 flood channel due to the random and unpredictable nature of these materials, however, a reduced flood channel width could reduce the potential extent of the exposure of these materials.

An analysis of the W1-SP0 flood channel design was conducted to determine the optimal flood channel width and energy dissipator combination (as the dissipator design affects the required width of the flood channel). This analysis considered flood channels 300 m, 200 m and 100 m wide with both stepped and sloped dissipators. The stepped dissipator would require a 200 m wide flood channel and, while the sloped dissipator would only require a 100 m flood channel, exit velocities would be higher and have the potential to impact the opposite wall in W1 Pit (although it was noted that floodwaters in the pit would have a dampening effect). The review concluded that the optimal design may be a natural analogue dissipator with a nominal width of 150 m. This dissipator comprises a nominal halfway point between the stepped and sloped dissipators (perhaps closer to the sloped) which would result in more energy dissipation within the flood channel compared with the sloped dissipator. It also has the advantage of a more natural appearance. This design will be investigated in further detail and reported in future MCPs.

Given that elimination of exposures of fibrous materials is not possible, the potential risks associated with these exposures was reviewed along with options for mitigation. The review concluded that the key receptors would be people who walk up Marillana Creek and access the flood channel or backfill in W1 Pit. While covering the exposures (e.g., with shotcrete or bituminous sealant) may represent medium term controls (in the order of around 50 years), they are not permanent solutions. The main control would be reducing the potential for people to access the area. Of the access controls considered, the most feasible was an ~1.5 m deep cut in rock at the W1-SP0 flood channel entrance. There are natural analogues with a similar appearance. This approach would also reduce the risk of people accessing the pit or falling from drops of ~3 m (associated with a stepped dissipator). The risks associated with fibrous material exposures will be further reviewed and compared with natural exposures of asbestiform minerals in the dolerite at Flat Rocks and in the Marillana and Iowa creek beds (fibres and lumps of fibrous materials have been noted to have been washed downstream and deposited in the alluvial beds in these locations). The results of these assessments will be reported in future MCPs.

A geotechnical stability analysis of the W1-SP0 flood channel was conducted based on the results of investigation programs undertaken since the 2020 MCP and concluded that:

- Negligible erosion would generally occur in the fresh dolerite base of the channel from Marillana Creek to approximately 200 m south of the inlet at the maximum stream power estimated for the 1:10,000-year event (15 $kWm^2$). Locally, minor to moderate erosion may be experienced if the flood channel is located within distinctly weathered material.
- Near the W1 Pit, there is a relatively rapid transition from non-erodible to highly erodible materials which would exhibit mostly serious erosion at a stream power of 15 $kWm^2$. To lower water velocities and subsequent potential erodibility, this section of the flood channel has been designed to be almost flat. The depths of fresh dolerite in this area also mean that any erosion would be unlikely to propagate further upstream which is expected to mitigate head-cut erosion risk.
- All assessed sections had a:
  - Static FoS >1.5 for inter ramp angles of 25° to 37°, except for Section 1 in a scenario where there is a 10 m increase in pre-mining groundwater levels.
  - Seismic FoS >1.2 for inter ramp angles of 25° to 37°.
- At the flood channel / pit interface, both dolerite and BIF materials had a static FoS >1.5 and Seismic FoS >1.3 at an inter ramp angle of 25°.

Following a review of the geological conditions at the W1-SP3 flood channel location, the flood channel design was modified by rotating the alignment to help reduce the potential long term stability risks along the W4 southern pit wall. A geotechnical assessment of this alignment concluded that:

- There would be:
  - Negligible erosion in the fresh dolerite and BIF located within the western and central portion of the flood channel.
  - Erosion up to Class IV (large) near the third step.
  - Erosion of up to Class V (extensive) at the inlet and outlet. Near the inlet, materials may erode to the same level as the fresh dolerite.
- For the design cases assessed:
  - Dolerite had static and seismic FoS >2 at inter-ramp angles of 45° to 60°.
  - BIF had static FoS >1.5 for inter ramp angles of 45° and 50°, and seismic FoS >1.3 for inter-ramp angles of 45° to 60°.

The design was adjusted to have an approximate 40 m elevation drop between the inlet and outlet to take advantage of fresh materials with negligible erodibility. Closer to the pits, the channel is almost flat and flares (due to a high cut depth through low strength materials) to limit erosion.

A review of the design reported in the 2020 MCP for the W4-SP3 flood channel identified that it would be cut into material that is susceptible to erosion during 1:10,000-year flow events leading to a risk of head-cut erosion and creek capture. To address this risk, the W4-SP4 flood channel alignment was modified to pass through more favourable geology. The spill crest was also set at a location and elevation where competent rock resistive to erosion is more likely to be encountered; namely 700 m away from the pit edge. A review of the maximum stream power in a 1:10,000-year event indicated that minor to moderate erosion may be experienced in isolated sections where the stream power is >6 $kWm^2$, but that the stream power at the inlet and outlet is low (commonly ≤2 $kWm^2$) and limited erosion is anticipated.

Given the uncertainties associated with the geology at the W1-SP3 and W4-SP3 flood channels, an alternate flood channel configuration was reviewed as a contingency. This would use only W1 Pit for flood attenuation (as opposed to W4 via the W1-SP3 flood channel) and would pass the overflow of the W1 Pit back to Marillana Creek from an outlet location in W1 via a new flood channel (W1-SP4). This review concluded that W1-SP4 was not the preferred design, predominantly because of the risks posed by increased flood levels and velocities through the constrained section of Marillana Creek between W4 and W5 pits, and the need to construct additional flood bunding along the W3 Pit crest. However, the option could potentially be reconsidered if drilling at either the W1-SP3 or W4-SP3 sites reveals unfavourable geological conditions.

Designs will be further reviewed and optimised following collection of additional geotechnical data and additional hydraulic modelling.

#### 5.14.7.1 Basis of Design

The basis of design for flood channels is outlined in Table 5-65.

**Table 5-65 Flood channel basis of design**

| Flood Event | Design Objectives |
|---|---|
| Less than 20-year event (5% AEP) | • No flow from Marillana Creek to pass over flood channels - all to be retained in creek.<br>• No flow from other tributaries to pass over flood channels if possible. |
| 20 to 100-year event (5% - 1% AEP) | • Maintain similar hydraulics in the E1 and E4 diversions (i.e. the diversions still behave as a similar fluvial system to Marillana Creek).<br>• Minimise the number of flood channels activated during rare (20-year to 100-year AEP) flood events.<br>• Majority of flood channel flow to pass through the most robust flood channel(s) (e.g. a flood channel cut in fresh dolerite). |

| Flood Event | Design Objectives |
|---|---|
| 100 to 500-year event (1% - 0.2% AEP) | • Minimise the risk of creek capture by mine voids.<br>• Minimise the number of flood channels activated during very rare (100-year to 500-year AEP) flood events.<br>• Majority of flood channel flow to pass through the most robust flood channel(s) (e.g. a flood channel cut in fresh dolerite). |
| 500 to 10,000-year event (0.2% - 0.01% AEP) | • Minimise the risk of creek capture by mine voids.<br>• Flood channel geometry to be designed to minimise the stream power of a 1:10,000 AEP flood event and thereby reduce likelihood of significant erosion in in-situ rock. Flood channels to be located within area of most competent rock (informed by results from geotechnical drilling) where feasible. |
| General design | • Significant scour to be prevented.<br>• Excavated slopes to be stable with a minimum FoS of:<br>- ≥1.1 under saturated conditions for individual batters, applied to limit equilibrium under saturated conditions.<br>- ≥1.5 under static conditions.<br>- ≥1.2 under seismic conditions<br>• Public access to be prevented where excessively steep or vertical drops are included in the design (i.e. stepped flood channels). |

Source: Advisian (2020a)

#### 5.14.7.2 Benchmarking

The objectives of Advisian's (2019) benchmarking study were to:

- Review examples of flood channels cut into rock where scour was an important issue and identify how these issues have been managed.
- Conduct a literature review to identify examples of analyses carried out to determine erosion mechanisms.
- Identify examples of existing rock-lined flood channels that could inform the design of the Yandi flood channels to mitigate the potential risks associated with scour.

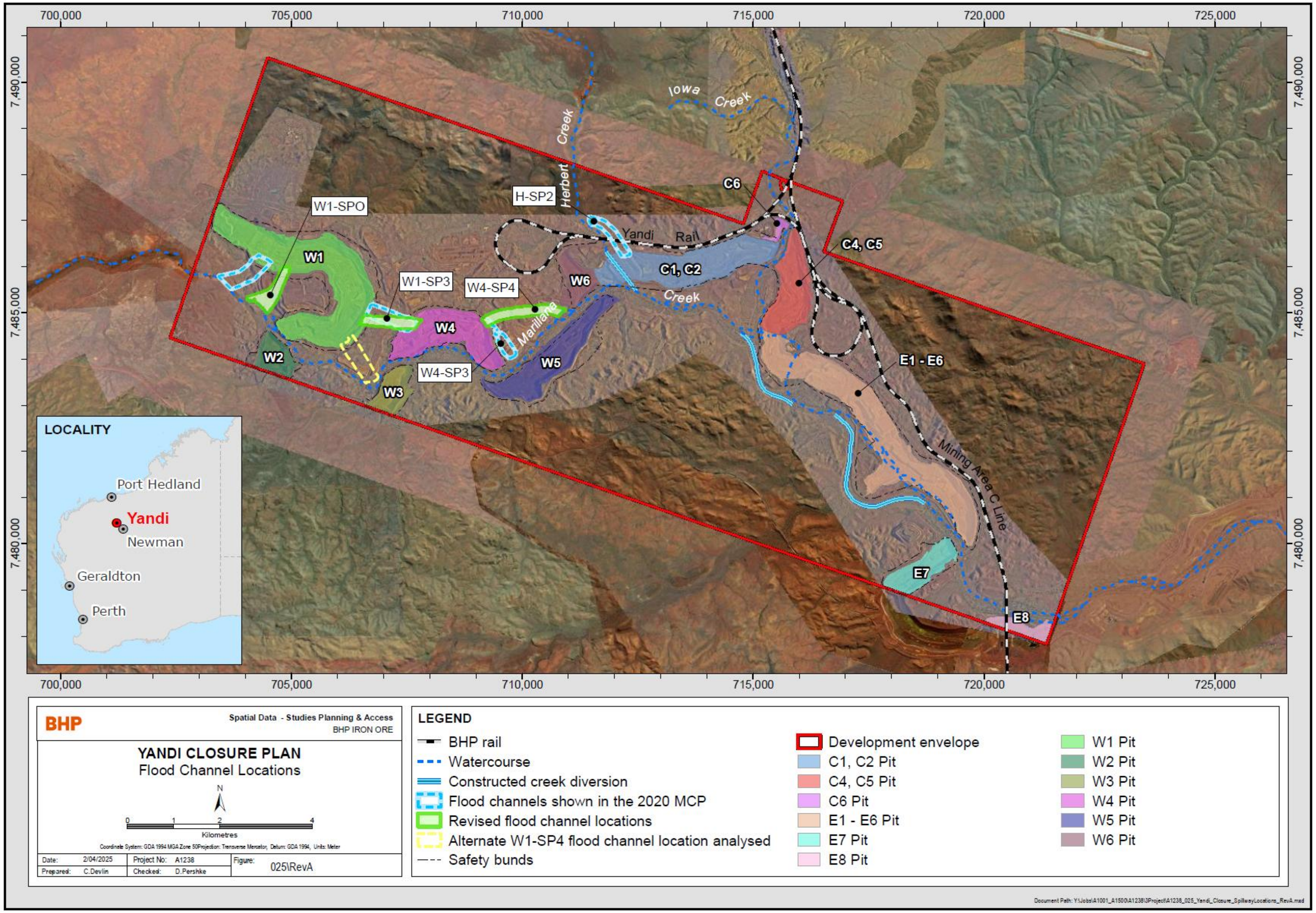
Advisian's (2019) review included an analysis of a range of flow situations over flood channels which inflicted appreciable scour in the rock downstream of a flood channel; sometimes in a plunging flow as the jets impacted the rock at a large angle and sometimes flowing across the rock surfaces in a shearing action that 'plucked out' rock by drag. The review concluded that:

- The geology of the plunge areas is vital to erodibility. The character of the rock mass with its variability and low strength character is key to the way the rock will respond to the flows impacting it.
- It is not just the velocity or stream power that affects the occurrence of scour, but also the transient pressures inside the rock mass and the effect of this on fracturing and block uplift. The transient pressures are affected by the characteristics of turbulence and the intensity of turbulence in the energy dissipation process. The presence of entrained air is important because of the physics of flows impacting rock bodies which contain an array of fissures.
- There are comprehensive methods available to predict rock scour that have been shown to closely match observed scour.
- There are several examples of successfully functioning flood channels cut into rock in Australia and around the world; some for design flow rates much larger than those of the Yandi flood channels. These examples include flood channels at Penrith Lakes, sand and gravel mining in the Goulbourn River floodplains, Darwin River, Cairn Curran Reservoir, Boondooma Dam and Robert Bourassa Dam. The proposed Yandi flood channels are not significantly different from other flood channels that have been successfully implemented.
- The performance of a flood channel cut into in-situ rock is site-specific. The design of the Yandi flood channels must, therefore, focus on the hydrology, geology and risks specific to the site. There are precedents for the Yandi flood channel proposals which should be referenced, and the designs should be based not only on the hydraulics of the flood channels, but also on the geology, structure and the character of the break-out surfaces which affect hydraulic roughness and the impact of turbulence and transient pressures.

#### 5.14.7.3 Flood channel optimisation

The Advisian (2019) study to optimise the number and location of flood channels was summarised in the 2020 MCP and reduced the number of flood channels from nine to four (W1-SP0, W1-SP3, W4-SP3 and H-SP2 - Map 5-30). This was achieved by placing the larger W1-SP0 flood channel at the upstream / western end of the lease with the following advantages:

- The geology at the W1-SP0 location was expected to be highly favourable (compared to unfavourable at many of the other locations).
- The increased length of the W1-SP0 flood channel from the creek to the W1 Pit (as well as the fresh dolerite expected at this location) would significantly reduce the risk of scour and creek capture.
- The risk of creek capture was relatively high in one of the eliminated flood channels.




See Appendix Q for a pdf version of this map

**Map 5-30 Flood channel locations**

Alternative alignments for W1-SP0 were considered in 2020 (Advisian, 2020b) to address heritage constraints (Appendix G.1). A further review of the selected alignment was conducted in 2022 and is reported in Section 5.14.7.5. An alternative alignment has also been defined for W1-SP3 to optimise flows and to remove existing wall failures and potential weak spots within both the inlet and outlet locations (Section 5.14.7.6).

Given the potential for unfavourable geology in the W1-SP3 and W4-SP3 locations, a review was conducted of using an alternative flood channel (W1-SP4) to direct flows out of the W1 Pit without passing through W4 Pit (Section 5.14.7.6). This review concluded that the W1-SP3 and W4-SP3 flood channel option was preferred, but the W1-SP4 option could potentially be reconsidered if drilling at either the W1-SP3 or W4-SP3 sites revealed unfavourable geological conditions.

Considering the unfavourable geology at W4-SP3, a new flood channel alignment (W4-SP4) was investigated and incorporated into the current design (Section 5.14.7.7).

The H-SP2 flood channel was included to protect the Herbert's Creek land bridge during extreme flood events. However, following an analysis of options to eliminate the need for flood bunds at constrained locations, a floodplain landform was chosen for W6 Pit (Section 5.14.8.2) and the HP-SP2 flood channel was removed from the design as it is anticipated that excess flood water from Herbert's Creek will spill west onto the floodplain and into Marillana Creek. The closure designs for the Herbert's Creek land bridge and associated water management measures require further review (Section 5.14.10).

The current (SPS design) flood channel layout is shown in Map 5-30.

#### 5.14.7.4 Geotechnical investigation

A high-level assessment of the geological and potential geotechnical conditions at each of the originally proposed flood channel locations was conducted by Advisian (2019). This was followed by a geotechnical investigation in 2020 which targeted the alternative alignments for W1-SP0 outlined in Appendix G.1, and a subsequent investigation in 2023 which targeted the W1-SP3 and new W1-SP0 flood channel alignments (refer to Figure 5-65 and Figure 5-67 for bore locations). A review of the geological records from bores within the W4-SP4 alignment was also conducted (Advisian, 2023f).

Figure 5-66 to Figure 5-70 present several geological cross sections developed from the available geological and geotechnical investigation data. These sections have classified the Weeli Wolli dolerite and BIF according to degree of weathering (Advisian, 2023f):

- XW - extremely weathered.
- HW - highly weathered.
- DW - distinctly weathered.
- FR - fresh.

Drill core samples from geotechnical testing showed that values for fresh dolerite range from Very High Strength to Extremely High Strength (Advisian, 2020a).

A geotechnical stability assessment was conducted for each food channel based on the outcomes of investigations and design studies (refer to Sections 5.14.7.5 to 5.14.7.7). The material parameters adopted for the analyses are provided in Table 5-66.

**Table 5-66 Adopted material parameters**

| Domain | Material ID | Material | Density (kN/m$^3$) | C kPa | ϕ° |
|---|---|---|---|---|---|
| 1 | **1** | Fill | 20 | 2 | 38 |
| | **2** | Alluvium | 20 | 5 | 27 |
| | **3** | Colluvium | 20 | 5 | 38 |
| 2 | **4** | Highly to Extremely Weathered BIF | 20 | 50 | 35 |
| | **5** | Highly to Extremely Weathered Dolerite | 20 | 50 | 37 |
| | **6** | Distinctly Weathered BIF | 26 | 72 | 55 |
| 3 | **7** | UCID | 24 | 138 | 39 |
| | 8 | Distinctly Weathered Dolerite | 26 | 211 | 46 |
| 4 | 9 | Slightly Weathered to Fresh BIF | 26 | 200 | 45 |
| | 10 | Slightly Weathered to Fresh Dolerite | 26 | 300 | 55 |

Source: Advisian (2023f)

### Overview of geological units

During the formation of the paleochannel, the Weeli Wolli Formation was decompressed, and tension joints developed parallel to the channel. These joints became preferential flow paths for groundwater, accelerating the weathering process, eventually leading to reduced geotechnical characteristics of the rock mass. Nevertheless, good quality rock mass may still be present locally where the weathering process did not occur, or the weathered material was eventually washed away as the geomorphological evolution surrounding the CID continued (Advisian, 2019).

The thickness of the weathered rim of the palaeochannel will have significant variation, and the thickness of the remaining CID layer is variable depending on the final geometry of the pit shell. The Basal Clay layer is considered highly susceptible to erosion and, ultimately, drives the stability of the CID left in the pits. Although variable in strength and weathering conditions, the UCID presents, in general, better geomechanical characteristics when compared to the LCID (Advisian, 2019).

Given the presence of the Basal Clay behind the CID and the potential poor geomechanical characteristics of the rock mass close to the pit as a result of geomorphological evolution, flood channels should be developed within the hosting rock (Weeli Wolli Formation, including Dolerite and BIF), as opposed to the UCID to minimise the risk of scour and creek capture (Advisian, 2019).

#### Flood channel W1-SP0

The geology within the proposed W1-SP0 channel simplistically comprises two dolerite units separated by distinctly weathered BIF, with paleochannel deposits near the W1 Pit. Distinctly weathered BIF is present near surface through the southern portion of the flood channel, overlain by a thin layer of residual dolerite or surficial soil. This layer is approximately 10 m thick and appears to be present along the extent of the flood channel, shallowly dipping towards the W1 Pit (Figure 5-66) (Advisian, 2023f).

A lower dolerite sill underlies the distinctly weathered BIF. The top of the sill is highly weathered, associated with the contact with the overlying BIF and transition into distinctly weathered dolerite and fresh dolerite with depth. The thickness of weathered materials underlying BIF varies from approximately 5 m to 10 m (Figure 5-66) (Advisian, 2023f).

An increased weathering zone within the Weeli Wolli Formation is present near the interface of the paleochannel deposits. Locally, weathered zones within the Weeli Wolli may be present once fresh materials are encountered, although this appears to be relatively uncommon (Figure 5-66) (Advisian, 2023f).

The base of the channel from Marillana Creek to the first step has generally been designed at the top of the fresh dolerite, with the series of steps within fresh dolerite. The final 200 m or so of the channel will be located within weathered dolerite and paleochannel deposits. Cut depths generally increase with proximity to the pit, varying from approximately 10 m to 50 m below natural ground surface (it is assumed that all fill will be removed prior to excavation) (Figure 5-66) (Advisian, 2023f).

#### Flood channel W1-SP3

The W1-SP3 flood channel will connect the W1 and W4 pits (Map 5-30). The geology within the proposed channel simplistically comprises two dolerite units separated by distinctly weathered BIF, with paleochannel deposits near the W1 and W4 pits. BIF is present near surface through the eastern portion of the flood channel, overlain by a thin layer of Detritals, and is inferred to shallowly dip to the west. The layer is inferred to be approximately 20 m thick and of a similar thickness between W1 and W4, however, this is based on a limited amount of intrusive data. Highly weathered materials are present near the paleochannel margins, with a relatively thin layer of distinctly weathered materials at the top of the unit. Fresh materials are inferred to be present through most of the unit away from the paleochannel (Figure 5-68) (Advisian, 2023f).

An upper dolerite unit overlies the BIF. This unit is distinctly weathered near surface and becomes fresh with depth, with the depth of weathering varying from around 10 m to 15 m. Highly weathered materials are limited to near the W1 Pit (Figure 5-68) (Advisian, 2023f).

A lower dolerite unit underlies the BIF. The distribution of this layer has been inferred based on a very limited amount of intrusive data and ground conditions within this layer should be confirmed by future drilling (Figure 5-68) (Advisian, 2023f).

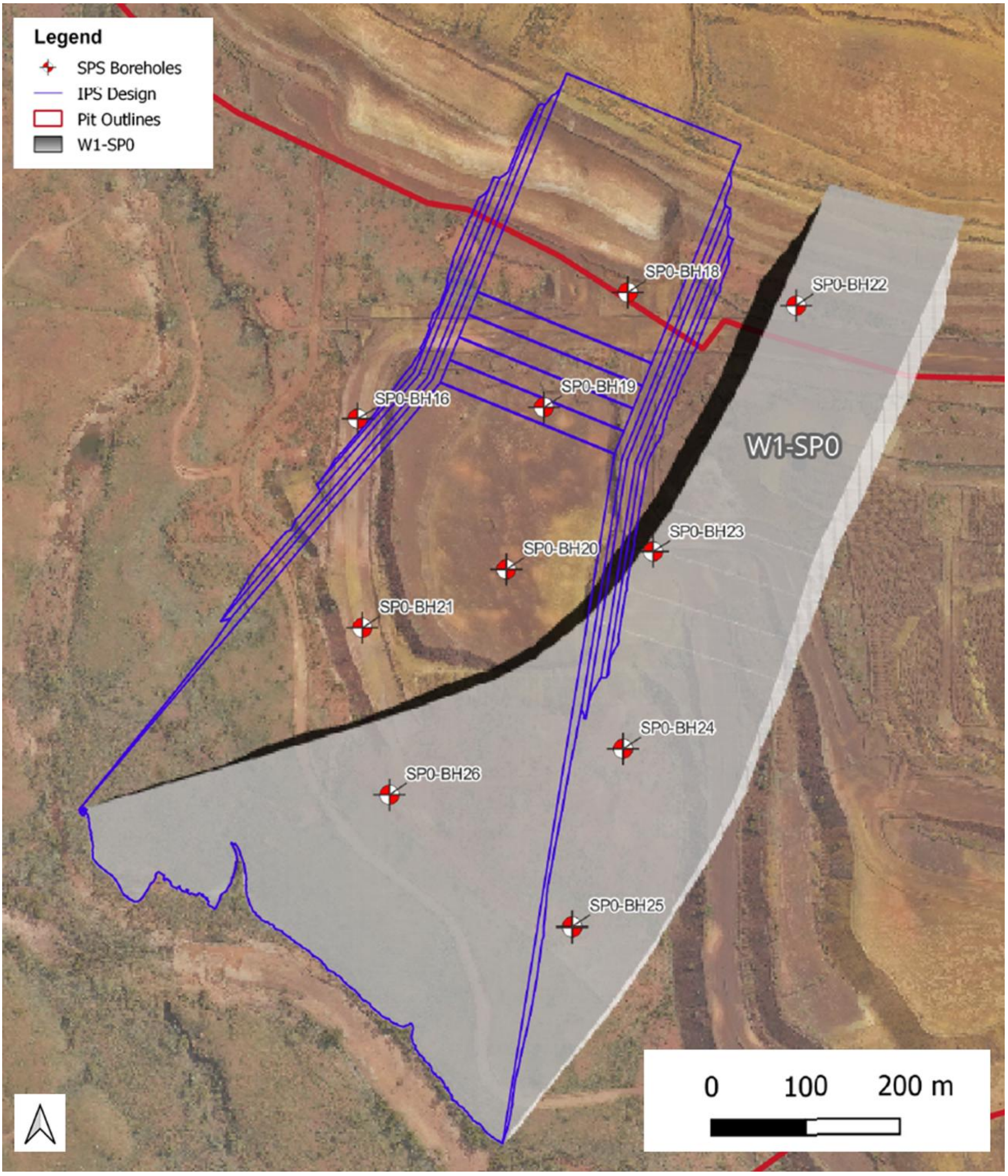
#### Flood channel W4-SP4

The proposed W4-SP4 flood channel (Map 5-30) will allow water to flow back to Marillana Creek at a controlled location once W4 Pit fills up. Surface geological mapping shows an extensive colluvium covering the BIF. The geology along the W4-SP4 flood channel at depth is largely unknown, with data only available in the immediate vicinity of the inlet and outlet (Figure 5-69 and Figure 5-70) (Advisian, 2023f).

Near the inlet, boreholes have intersected paleochannel deposits. A limited number of boreholes appear to have been drilled below the paleochannel deposits. Although boreholes in the immediate vicinity of the channel footprint have not been interpreted below the paleochannel deposits, boreholes drilled at a greater distance from the channel indicate that highly weathered BIF underlies paleochannel deposits at the W4-SP4 inlet (Figure 5-69 and Figure 5-70) (Advisian, 2023f).

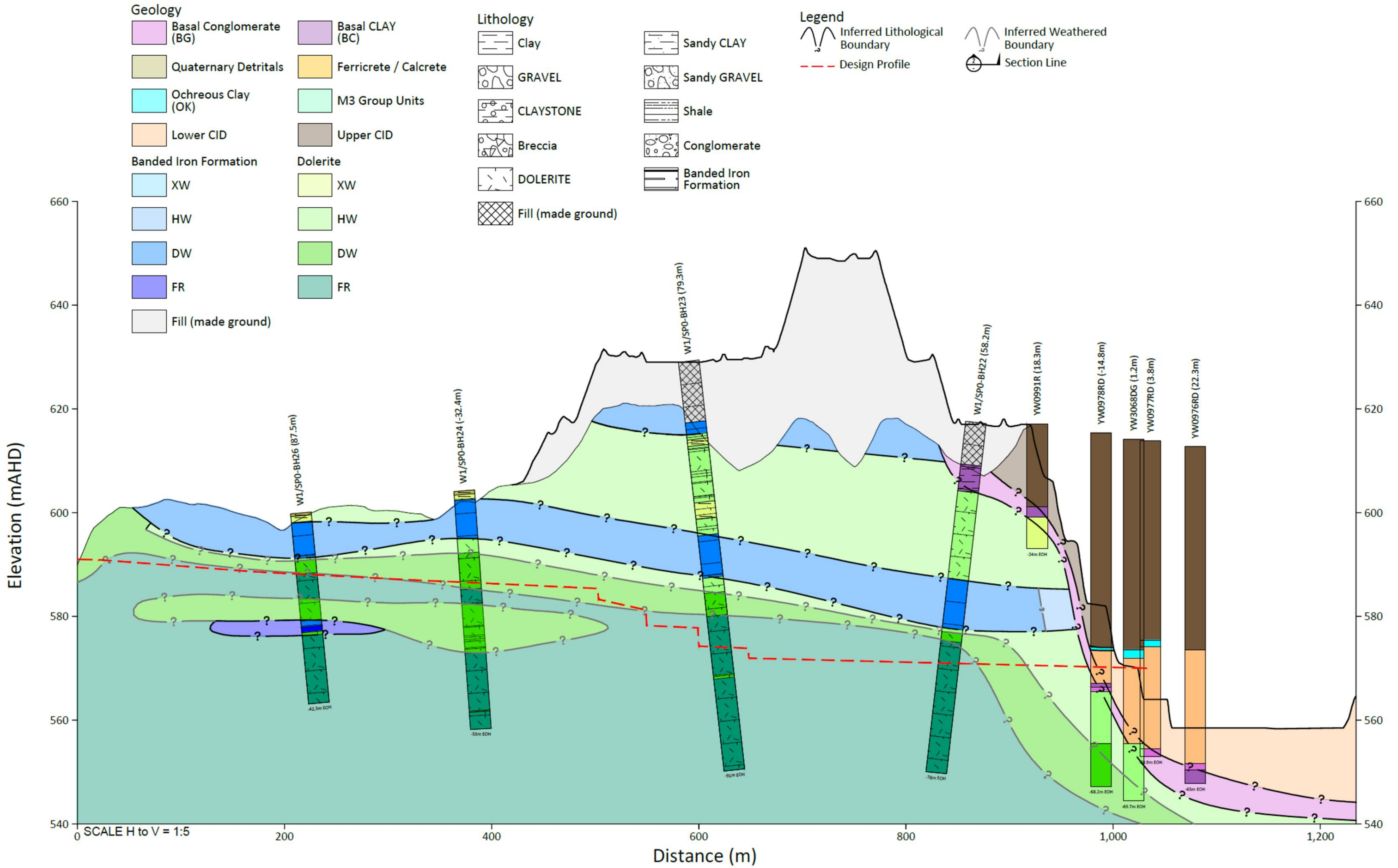
Boreholes drilled in the vicinity of the outlet are located within the current Marillana Creek channel. The geological profile comprises alluvium overlying paleochannel deposits, with the base of boreholes terminated above the Weeli Wolli Formation (Figure 5-69) (Advisian, 2023f).

Available information indicates that the Weeli Wolli Formation is present along the majority of the channel alignment, away from the immediate vicinity of the inlet and Marillana Creek. However, there is no indication of whether surficial materials comprise dolerite or BIF, nor of the extent of material weathering at surface or with depth (Advisian, 2023f).




Source: adapted from Advisian (2024a)

**Figure 5-65 W1-SP0 geotechnical drill hole locations**



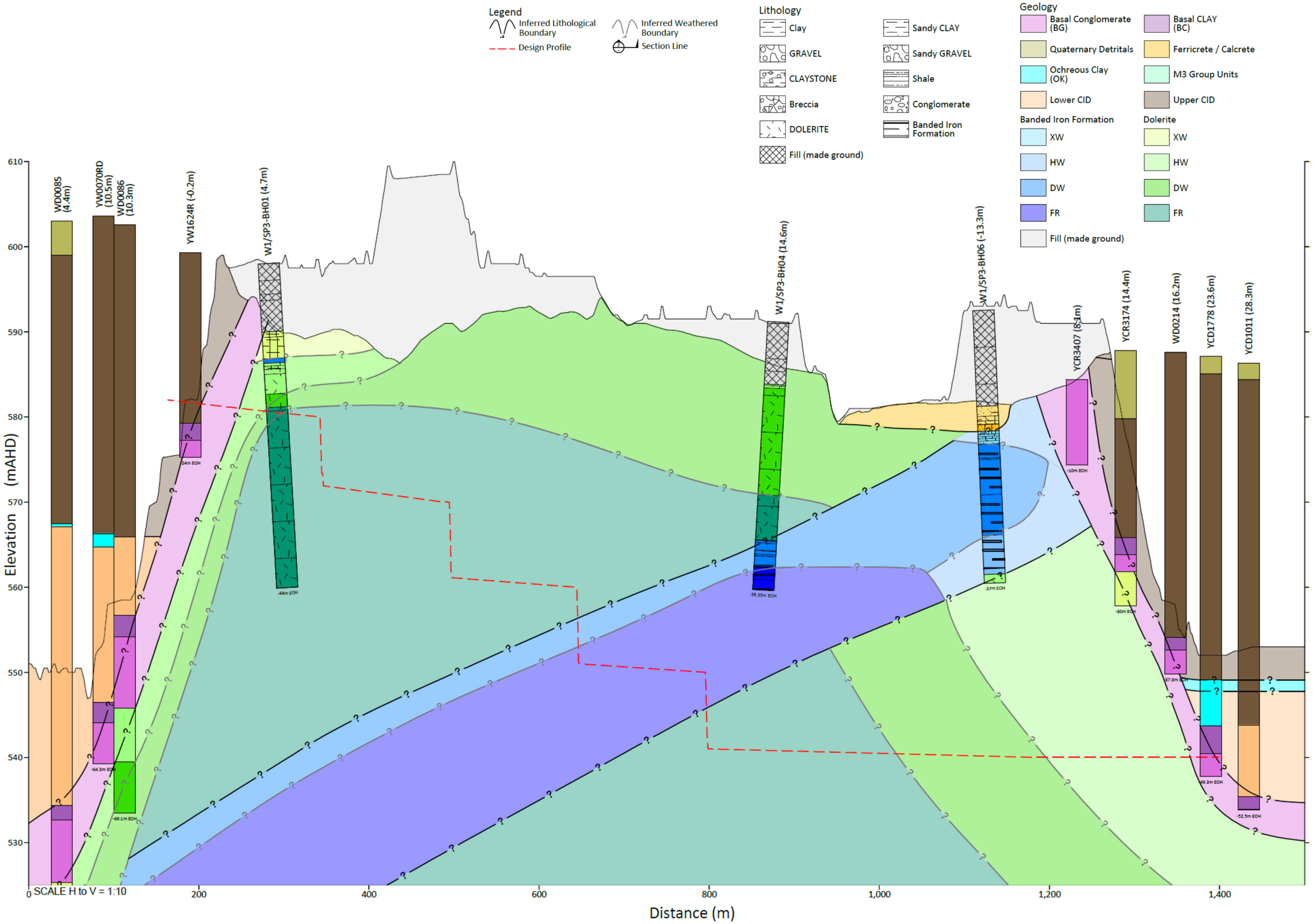

Source: adapted from Advisian (2023f)

Notes: XW - extremely weathered; HW - highly weathered; DW - distinctly weathered; FR - fresh. Refer to Figure 5-65 for bore locations.

**Figure 5-66 Interpreted geological at W1-SP0 Alternative 1 centreline**


Source: adapted from Advisian (2024a)

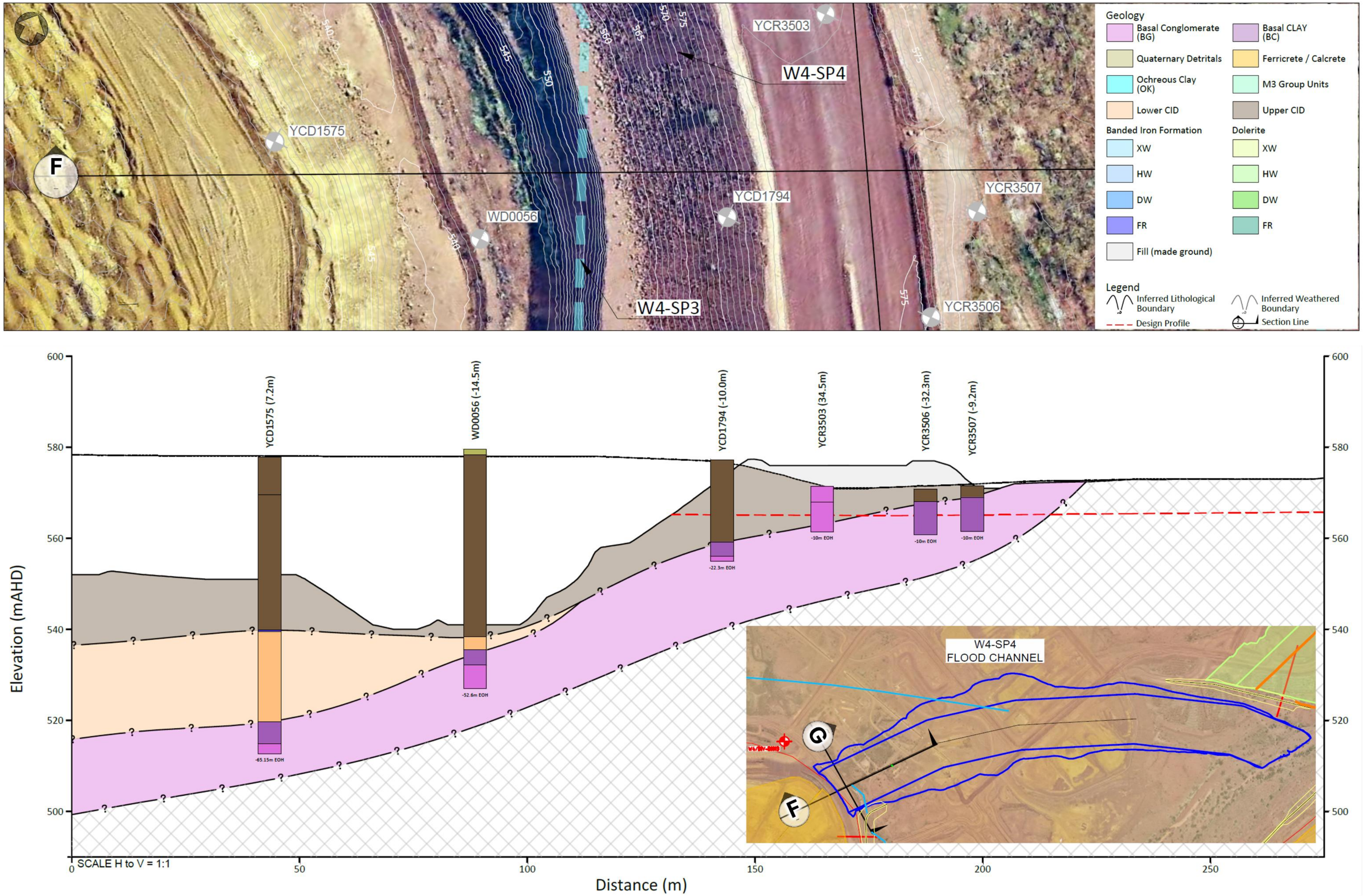
**Figure 5-67 W1-SP3 geotechnical drill hole locations**




Source: adapted from Advisian (2023f)

Notes: XW - extremely weathered; HW - highly weathered; DW - distinctly weathered; FR - fresh. Refer to Figure 5-67 for location of bores.

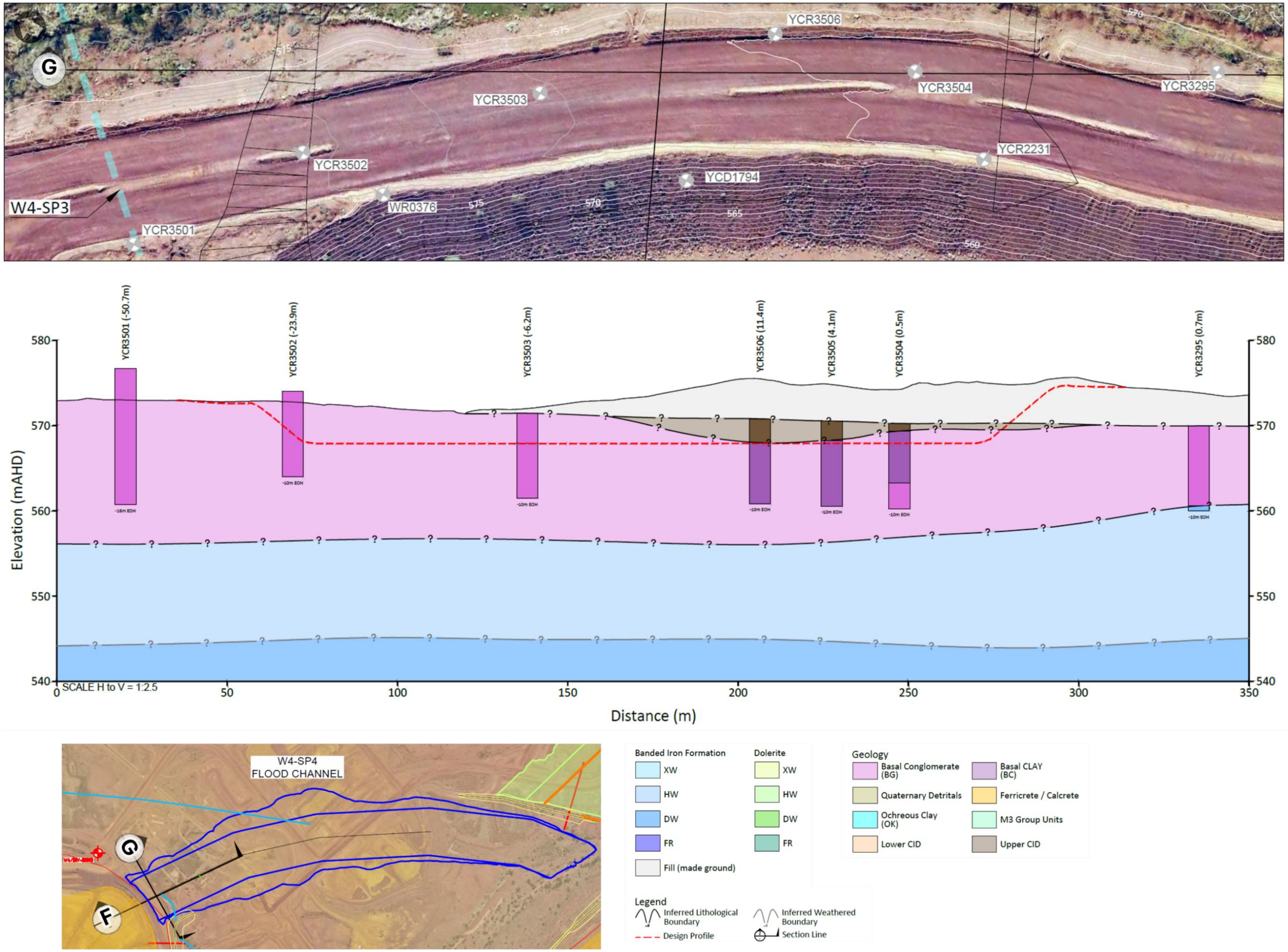
**Figure 5-68** **Interpreted geological at W1-SP3 long section**




Source: adapted from Advisian (2023f)

Note: figure shows the intersection of the original alignment of the W4-SP3 flood channel with that of the new W4-SP4 flood channel

**Figure 5-69 Interpreted geological at W4-SP4 long section**




Source: adapted from Advisian (2023f)

Notes: XW - extremely weathered; HW - highly weathered; DW - distinctly weathered; FR - fresh.

Figure shows the intersection of the original alignment of the W4-SP3 flood channel with that of the new W4-SP4 flood channel

**Figure 5-70 Interpreted geological at W4-SP4 inlet cross section**

### 5.14.7.5 Flood channel W1-SP0 design option selection

The proposed W1-SP0 flood channel will connect the Marillana Creek to the W1 Pit. Various studies have been conducted to optimise the W1-SP0 flood channel design. These include studies to select the optimal alignment, flood channel width and associated energy dissipator. A review has also been conducted of the options for managing the fibrous (asbestiform) minerals detected in the dolerite in which the flood channel would be constructed (Section 5.2.4.5). The outcomes of these studies are summarised in the relevant subsections below.

#### Alternative alignment selection

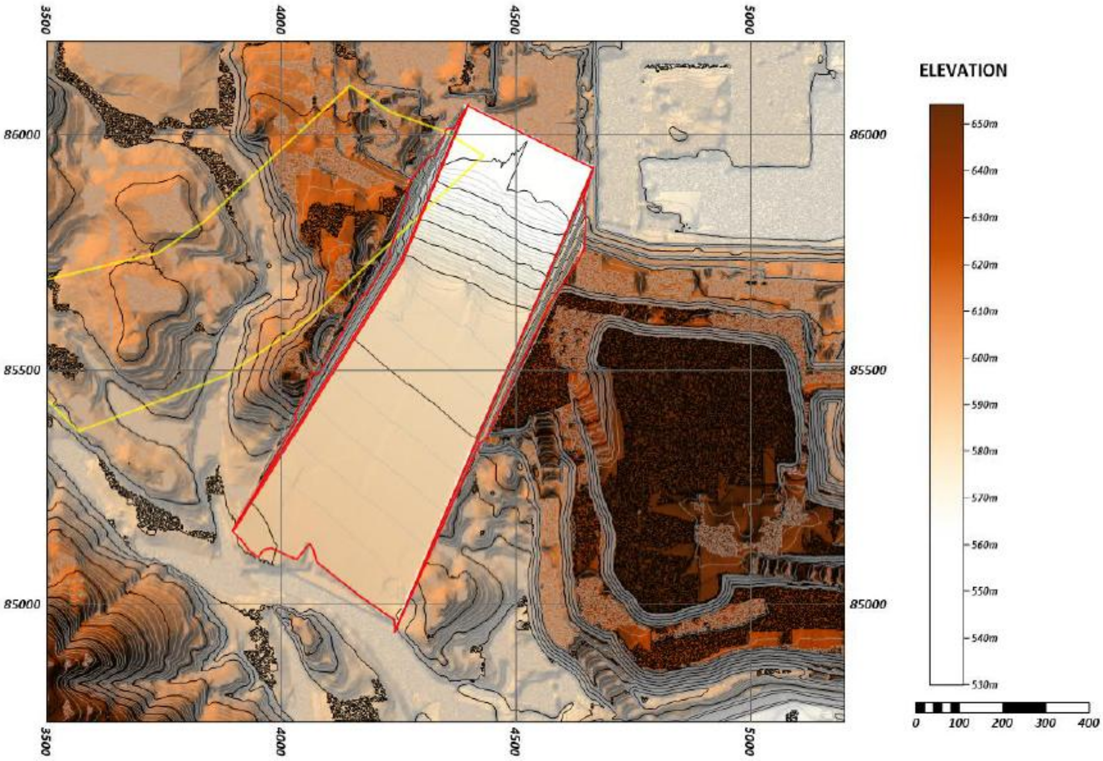
Further to the 2020 MCP, alternative alignments were investigated for the W1-SP0 flood channel to address heritage constraints (refer to Appendix G.1) and two alternatives were selected as more favourable (Alternatives 1A and 1B) because they:

- Were considered likely to cross similar geological conditions to the original alignment.
- Do not cross the northern tributary, eliminating additional structures to divert its flow.

In further optimisation studies, a combined geometry between Alternatives 1A and 1B (named Alternative 1C) was developed assuming the same hydraulic conditions of the original flood channel. The design for this flood channel is as follows (Advisian, 2020b):

- A 400m wide entrance with variable invert level as per the flood modelling (from RL 590m [upstream] to 589m [downstream]).
- 1% grade transition to a 300 m wide channel at the beginning of the drop structure.
- Drop structure with 6 m high steps.
- Discharge level into W1 Pit at RL 555 m.

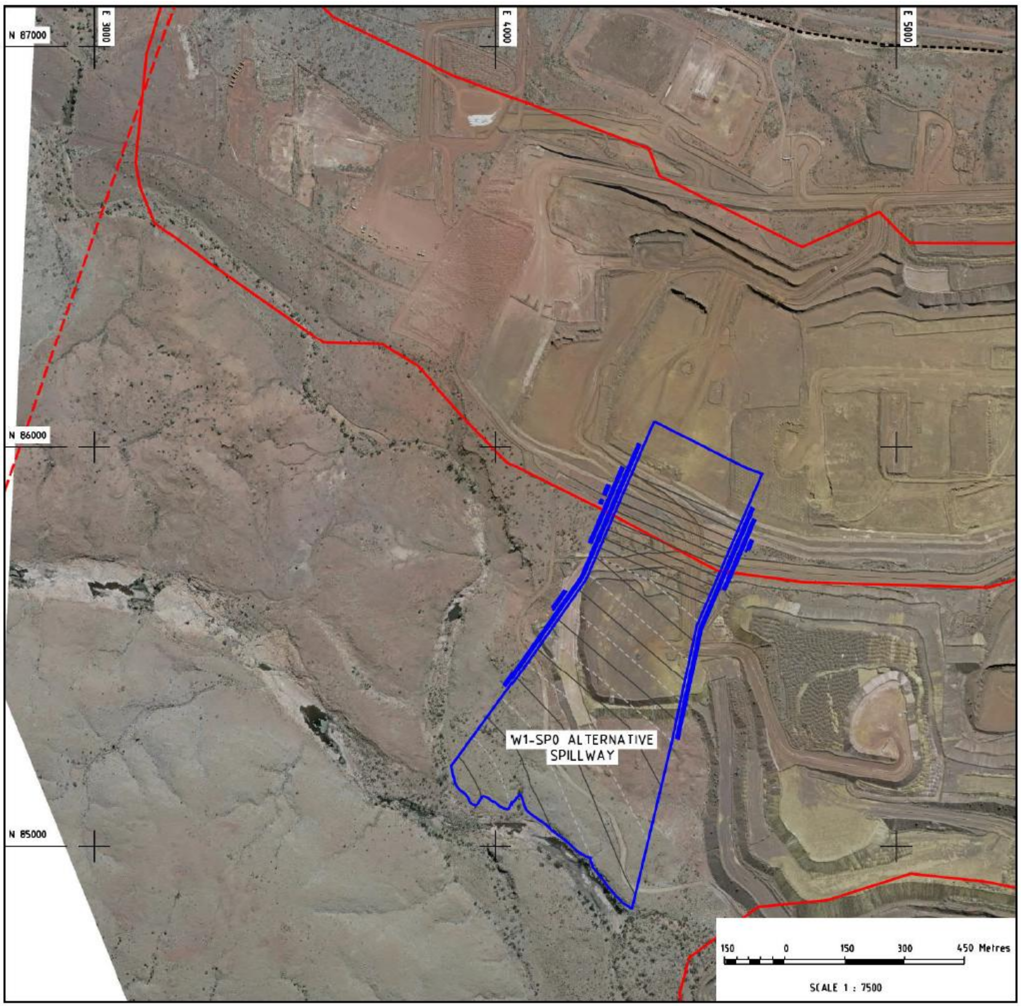
However due to differences in the topography and flood hydraulics in the vicinity of the two alignments, there was uncertainty as to whether Alternative 1C would perform comparably with the original alignment and consequently, hydraulic modelling was conducted to test and refine the design of Alternative 1C so that it would convey a similar flow of water in the 1:10,000 (0.01%) AEP (Advisian, 2022).




Source: Advisian (2020b)

**Figure 5-71 W1-SP0 flood channel Alternative 1C**

TUFLOW flood modelling demonstrated that Alternative 1C passed approximately 25% less flow than the original alignment. The Alternative 1C flood channel was, therefore, widened by approximately 150 m at the confluence with Marilina Creek to increase the flow captured by the flood channel. Due to heritage constraints to the west, the flood channel widening needed to be to the south-east. This design is referred to as the 'Alternative 1D' flood channel (Figure 5-72) (Advisian, 2022).



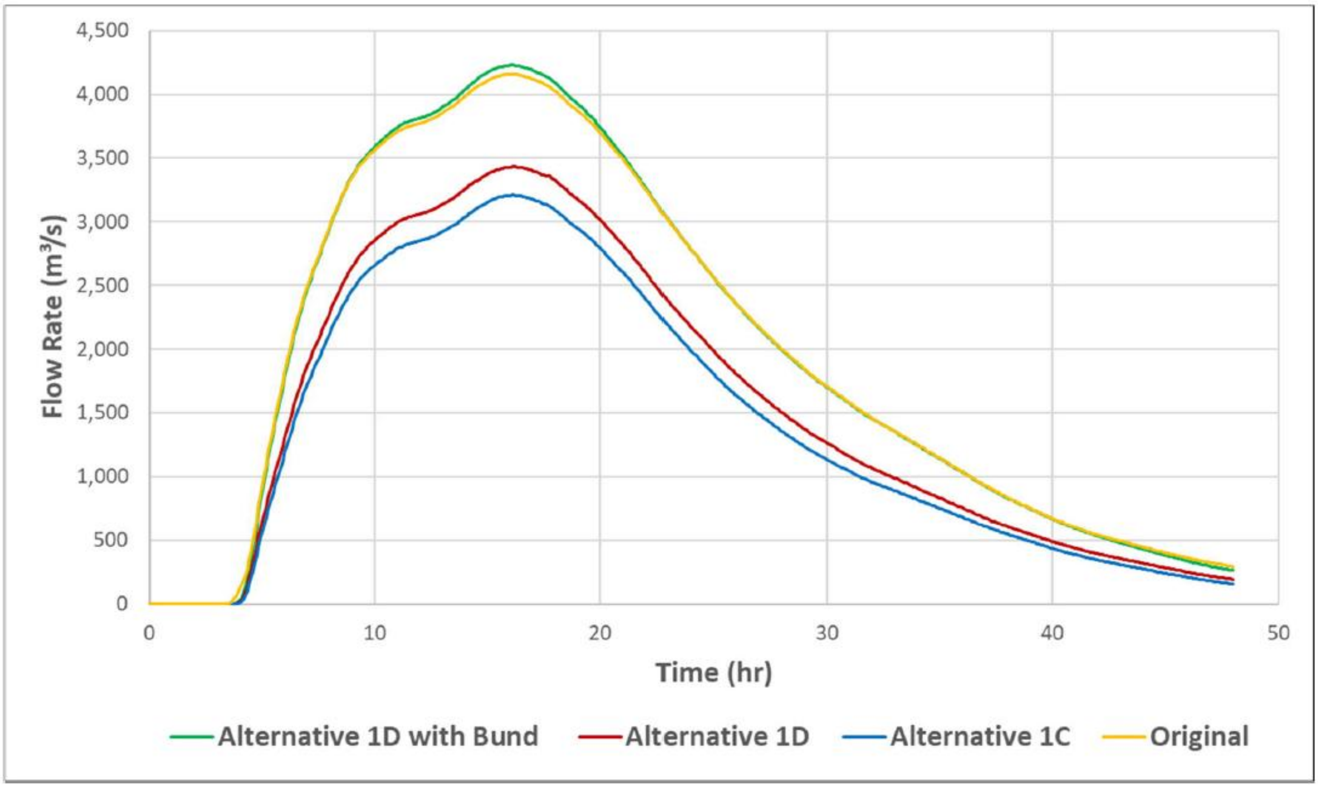

Source: Advisian (2022)

**Figure 5-72 Alternative 1D flood channel alignment**

While Alternative 1D showed a slight increase in flow capacity compared to Alternative 1C, modelling showed that the flood channel still conveyed significantly less flow than the original alignment (Figure 5-73). Two options were subsequently considered to increase flow entering the Alternative 1D flood channel (Advisian, 2022):

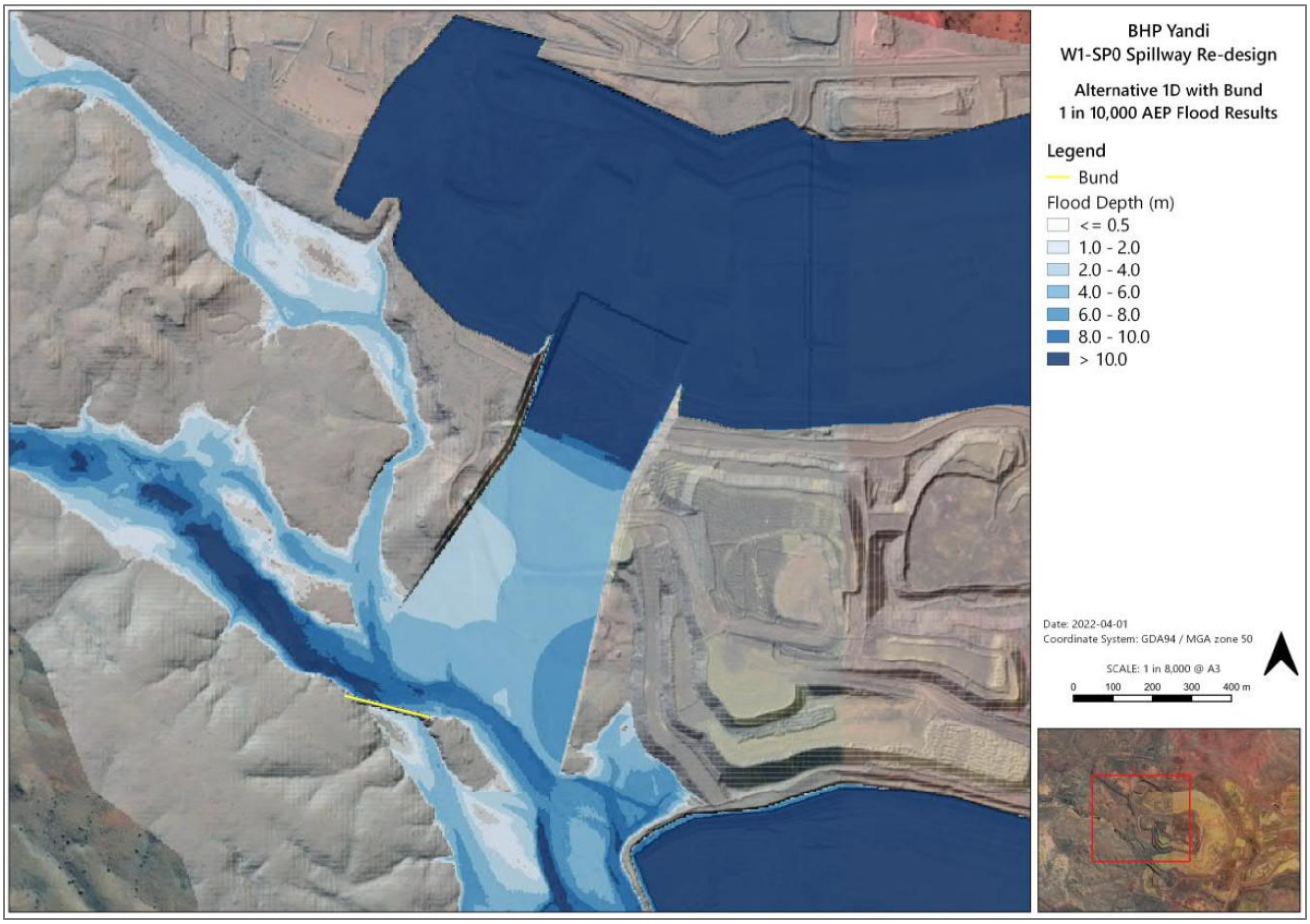
- Locally deepening the creek at the upstream end of the flood channel to aid the hydraulics of flow into the flood channel; and
- Constructing a bund across the breakout channel which is located on the southern side of the creek as it passes the flood channel (Figure 5-74).

Modelling predicted that locally deepening the creek would have an insignificant effect on the flow into the flood channel for the 0.01% AEP event. However, constructing a bund across the breakout channel was predicted to increase flow through the Alternative 1D flood channel to marginally higher than that through the original alignment for the 0.01% AEP event (Figure 5-73) and slightly lower than the original alignment for the 1% AEP event (Figure 5-75). Initial work, therefore, indicates that constructing this bund would result in the Alternative 1D flood channel performing on a like-for-like basis compared with the original. Further assessment of the optimal W1-SP0 flood channel geometry is discussed below (Advisian, 2022).



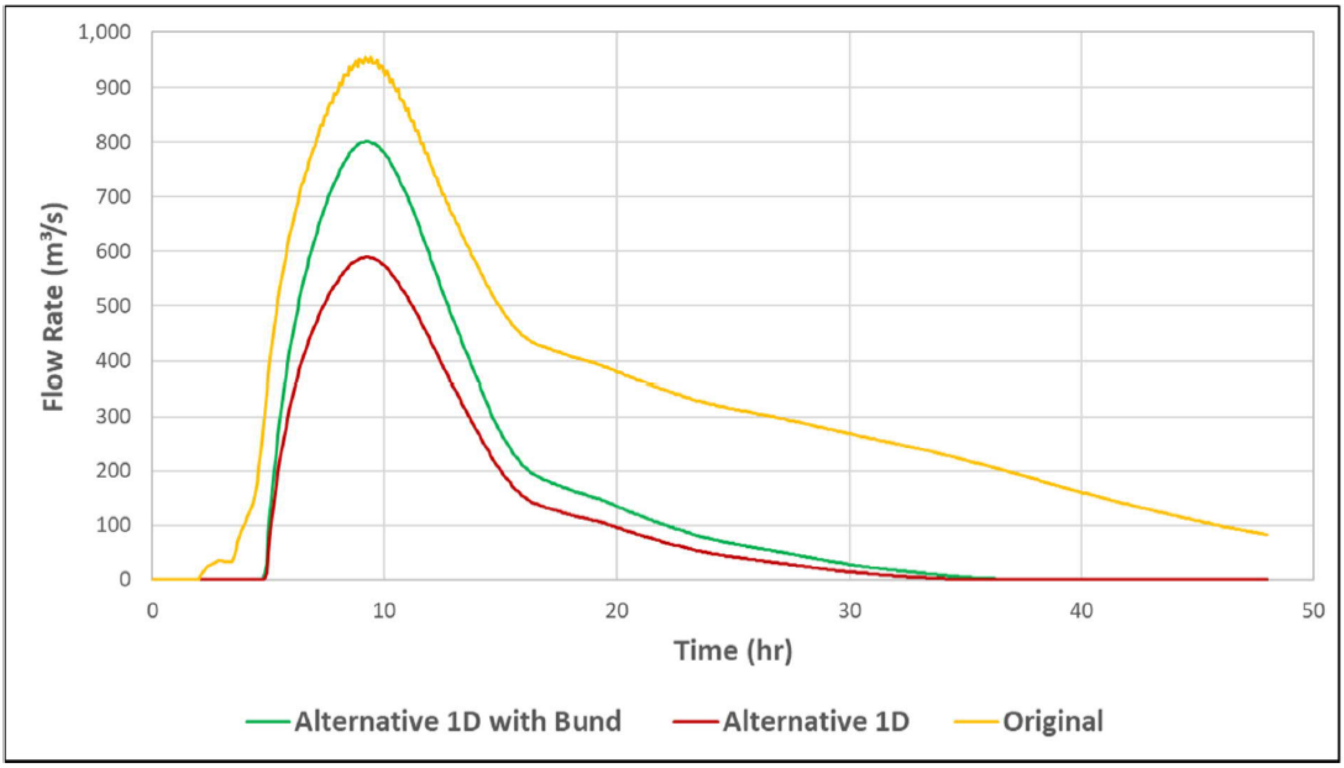

Source: Advisian (2022)

**Figure 5-73 Comparison of flow through the W1-SP0 flood channel alternatives for the 0.01% AEP event**




Source: Advisian (2022)

**Figure 5-74 0.01% AEP flood modelling with a bund to block the breakout channel**

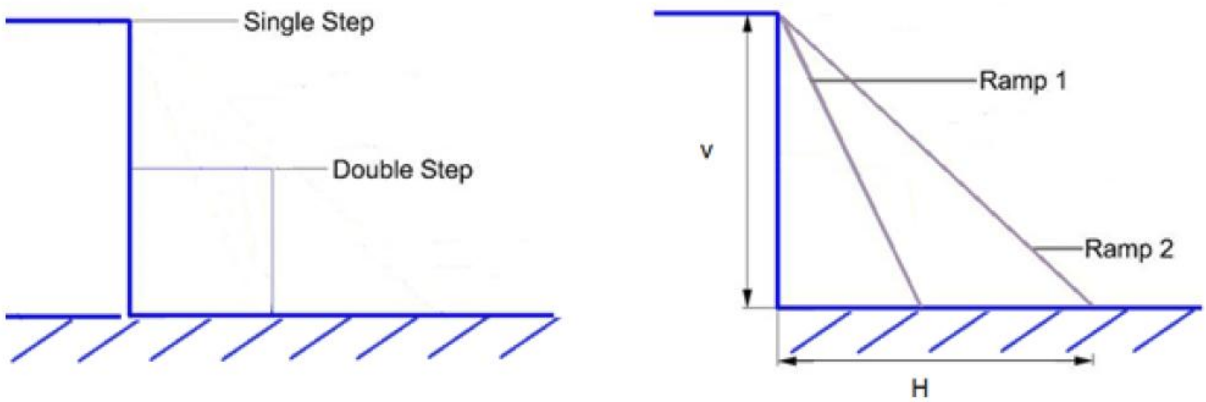



Source: Advisian (2022)

**Figure 5-75 Comparison of flow through the W1-SP0 flood channel alternatives for the 1% AEP event**

#### W1-SP0 flood channel width

A study was conducted to determine the optimal width of the Alternative 1D alignment of the W1-SP0 flood channel, since this affects the area of disturbance and quantity of material to be excavated. This assessment assumed a backfill level of 570 mRL consistent with recent modelling conducted by AQ2 (Section 5.14.1.4). 2D hydraulic (TUFLOW) modelling was conducted for both stepped and sloped energy dissipators (Figure 5-76) for three flood channel widths (Figure 5-77). 3D Computational Fluid Dynamics (CFD) modelling (using Ansys-CFX) was also conducted for the sloped flood channel with a width of 100 m and for both stepped and sloped flood channels with widths of 300 m (Advisian, 2023b).




Source: Advisian (2019)

**Figure 5-76 Possible energy dissipator designs**

300 m　　200 m　　100 m

Source: Advisian (2023b)

**Figure 5-77 W1-SP0 flood channel widths modelled**

Steam powers were modelled / calculated for each scenario using three different methods (TUFLOW, CFD modelling and Pells et. al., (2021) analytical solution) which produced relatively consistent results. The adopted stream power ranges for the stepped and sloped flood channels 100 m and 300 m wide are shown in Table 5-67 and indicate that (Advisian, 2023b):

- A reduction in flood channel width results in an increased stream power.
- The stepped energy dissipator results in a higher estimated stream power.

Overall, the stream power values estimated for this study are a reduction in the 90 kW/m² adopted for the IPS due to the different methods applied for analysis (Advisian, 2023b).

**Table 5-67 Calculated / modelled stream powers for W1-SP0 flood channel width / dissipator scenarios**

| Geometry | Width (m) | Unit Stream Power Dissipation (kW/m2) | |
|---|---|---|---|
| | | LOW | HIGH |
| Stepped | 100 | 30 | 45 |
| | 200 | 20 | 35 |
| | 300 | 10 | 30 |
| Sloped | 100 | 10 | 25 |
| | 300 | 5 | 15 |

Source: Advisian (2023b; 2023d)

The erodibility of the stream powers outlined in Table 5-67 was assessed using the Pells (2016) method and erosion for the (Advisian, 2023b):

- Sloped 300 m wide geometry was classified as:
  - Predominantly Class II (Minor) with;
  - Class I (Negligible) possibly expected within better quality rock mass during flows characterised by the lower end of anticipated stream power range.
- Stepped 300 m and sloped 100 m geometries were classified as:
  - Class II (Minor) with;
  - Class III (Moderate) erosion possibly expected within poorer quality rock mass during flows characterised by the higher end of anticipated stream power range.
- Stepped 100 m geometry was classified as predominantly Class III (Moderate).

Considering the large distance from the energy dissipator to Marillana Creek, the thickness of competent dolerite underlying the flood channel base and the likelihood of the design flood event occurring (1 in 10,000 AEP), the study recommended a 200 m width for the stepped energy dissipator and a 100 m width for the sloped energy dissipator. These widths target the Class II (Minor) erosion category, corresponding to 10 - 30 m³ of erosion per 100 m² face (average of 0.1 - 0.3 m depth of scour) (Advisian, 2023b).

A further review of the optimal combination of flood channel width and dissipator design was recommended and is summarised below.

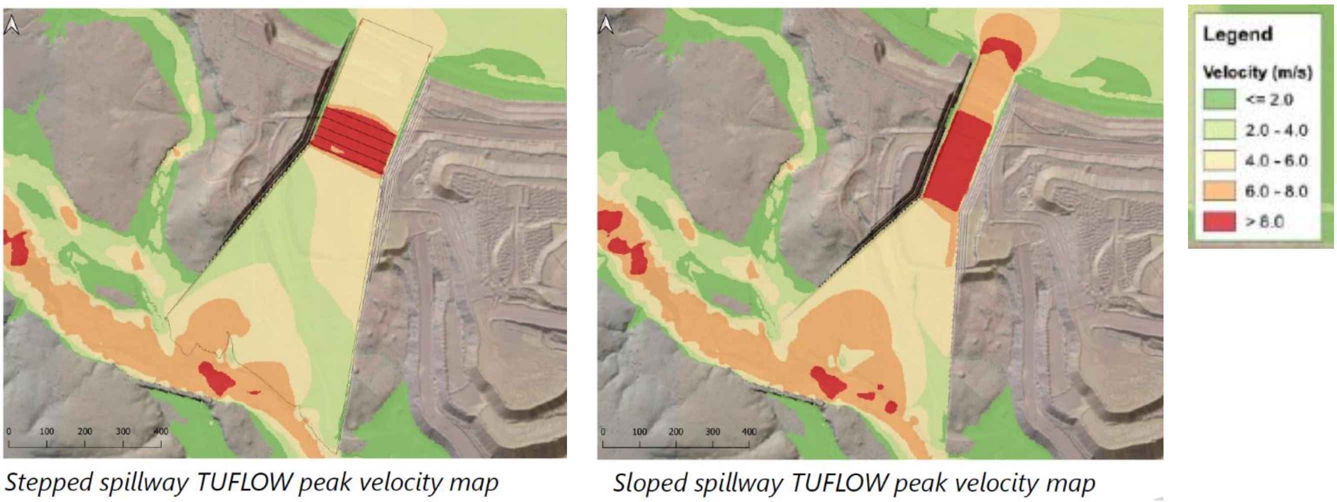
### W1-SP0 optimisation of flood channel width / energy dissipator

An analysis was conducted by Advisian (2023d), of the relative advantages and disadvantages of the 200 m stepped and 100 m sloping flood channel options to select the preferred dissipator type. The outcomes of this study are reported below.

While the stream power for the stepped energy dissipator is higher than the sloped (Table 5-67), TUFLOW modelling shows that the stepped flood channel dissipates more energy than the sloped flood channel (Figure 5-78). The velocity of water exiting the sloped flood channel is, therefore, higher as it enters W1 Pit (Figure 5-78). Modelled velocities for the (Advisian, 2023d):

- Stepped flood channel 200 m wide were estimated to be 4 to 6 m/s.
- Flows exiting the sloped flood channel 100 m wide were estimated to be 11 to 16 m/s and up to 12 m/s as the water reaches the opposite pit wall in W1 Pit.

However, the modelling also showed that the steps or slope of the energy dissipator would be submerged as the peak flow comes through the flood channel which would have a dampening effect of the floodwater impact on the steps / slope and W1 Pit. As the peak discharge occurs, the pit backfill is likely to be submerged by more than 10 m (up to 18 m) of water.




Source: Advisian (2023d)

**Figure 5-78 Comparison of velocity of water through sloped and stepped energy dissipators**

Further to the hydraulic modelling of the two options, an assessment of the relative advantages and disadvantages of each option was conducted (Table 5-68). Both had several (different) advantages and disadvantages. A 'natural analogue' dissipator has, therefore, been proposed which (Advisian, 2023d):

- Mimics or resembles natural features reflective of the local area and would be a nominal halfway point between the stepped and sloped dissipators (perhaps closer to the sloped).
- Would contain features similar to those seen at Flat Rocks (Figure 5-79) including uneven ground, bumps, small drops and irregularities.
- Has a nominal width of 150 m as the irregular features would result in more energy dissipation within the flood channel compared with the sloped dissipator.


Advisian (2024a)

**Figure 5-79 Natural energy dissipation features at Flat Rocks**

The advantages and disadvantages of the 'natural analogue' option would be very similar to the sloped flood channel, with one key difference; the potential to develop a more natural landform feature in keeping with the surrounding landscape. This option will be further reviewed and refined as the closure studies progress towards detailed design (Advisian, 2023d).

**Table 5-68 Relative advantages and disadvantages of stepped and sloped energy dissipators**

| Geometry | Disadvantages | Advantages |
|---|---|---|
| Stepped | • Each step is 3 m in height. This drop height represents a safety risk to pedestrians and vehicles.<br>• Construction is more challenging, and careful blasting will be required. Dominant defect sets in the bedrock will play a significant role in the final geometry; squared edges of steps might not be achievable.<br>• Plucking during flow events will affect geometry and "smooth" out profile with time.<br>• Jet impact causes localised areas of high stream power. | • Reduced energy and velocity water leaving the flood channel and entering W1 Pit. |
| Sloped | • Very high energy water at flood channel outlet leading to erosion of backfill material.<br>• High velocity impact of flood water on pit walls leading to possible failure of the walls.<br>• High energy at flood channel outlet leading to undercutting and eventual failure of structure, although this is expected to be almost inconceivable given the location of the outlet in competent dolerite and the 10 m of backfill covering weaker units. There is also a large distance between the flood channel exit at W1 and the entrance (~1,000 m). | • Easier construction.<br>• Eliminates safety issues associated with the 3 m drop. |

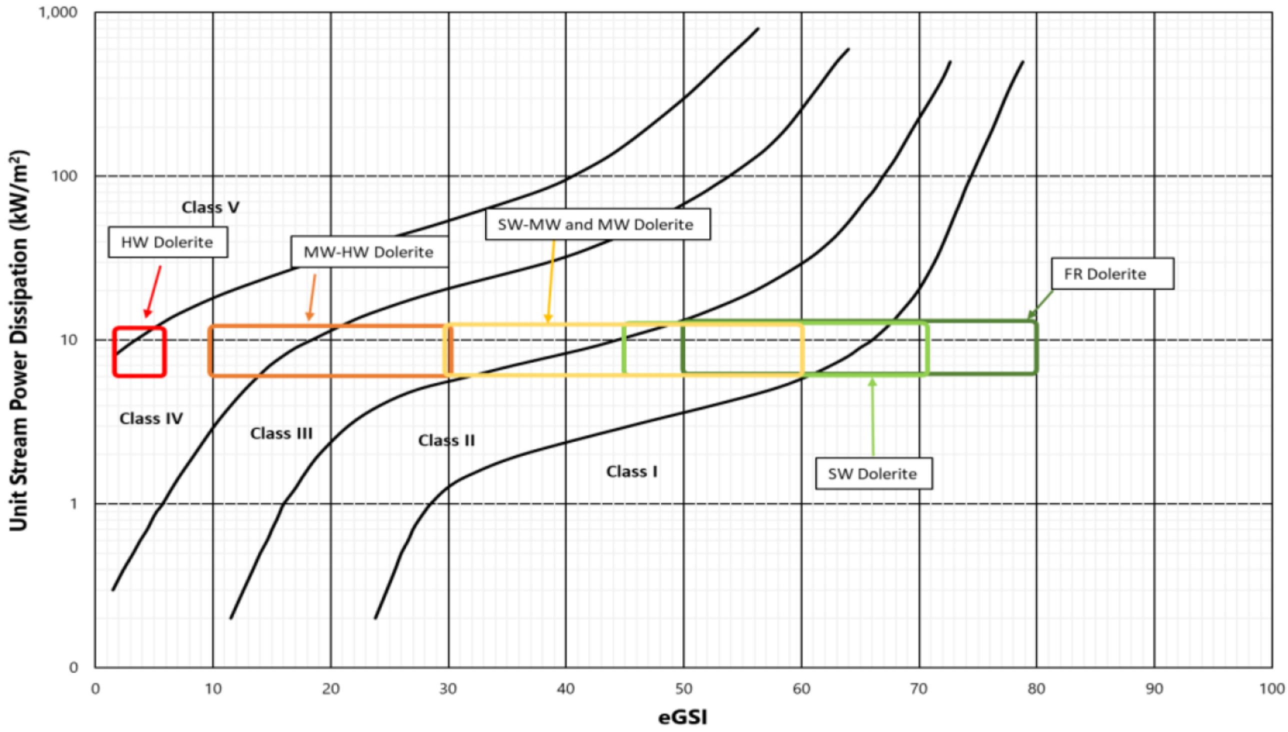
Source: Advisian (2023d)

### Geotechnical stability analysis

An erosion assessment of the W1-SP0 flood channel was conducted based on the data gathered from the geotechnical investigation reported in Section 5.14.7.4 and the maximum stream power (15 kWm$^2$) estimated from hydraulic modelling conducted for a 1:10,000-year event (Figure 5-80) (Advisian, 2024a).

The base of the channel from Marillana Creek to approximately 200 m south of the inlet is generally located within fresh dolerite, with a limited amount of the channel within distinctly weathered dolerite (Figure 5-66, Section 5.14.7.4). Fresh dolerite is anticipated to experience negligible erosion at a stream power of 15 kWm$^2$. Locally, minor to moderate erosion may be experienced if the flood channel is located within distinctly weathered material (Figure 5-80) (Advisian, 2024a).

A relatively rapid transition from non-erodible to highly erodible materials occurs near the W1 Pit, where fresh dolerite transitions to highly weathered dolerite and paleochannel materials. Highly weathered dolerite and paleochannel deposits are anticipated to exhibit mostly serious erosion at a stream power of 15 kWm$^2$. To lower water velocities and subsequent potential erodibility, this section of the flood channel has been designed to be almost flat. It should also be noted that due to the depths of fresh dolerite found in boreholes W1/SP0-BH22, BH23, BH24 and BH26 (Figure 5-66, Section 5.14.7.4), any erosion would be unlikely to propagate further upstream which is expected to mitigate head-cut erosion risk (Advisian, 2023f; 2024a).




**Erosion classes** (Pells, 2016)

| Maximum Erosion Depth *m* | General Erosion Extent $m^3$ per 100 $m^2$ | Erosion Class | Erosion Descriptor |
|---|---|---|---|
| <0.3 | <10 | I | Negligible |
| 0.3 to 1 | 10 to 30 | II | Minor |
| 1 to 2 | 30 to 100 | III | Moderate |
| 2 to 7 | 100 to 350 | IV | Large |
| >7 | >250 | V | Extensive |

Source: Advisian (2024a)

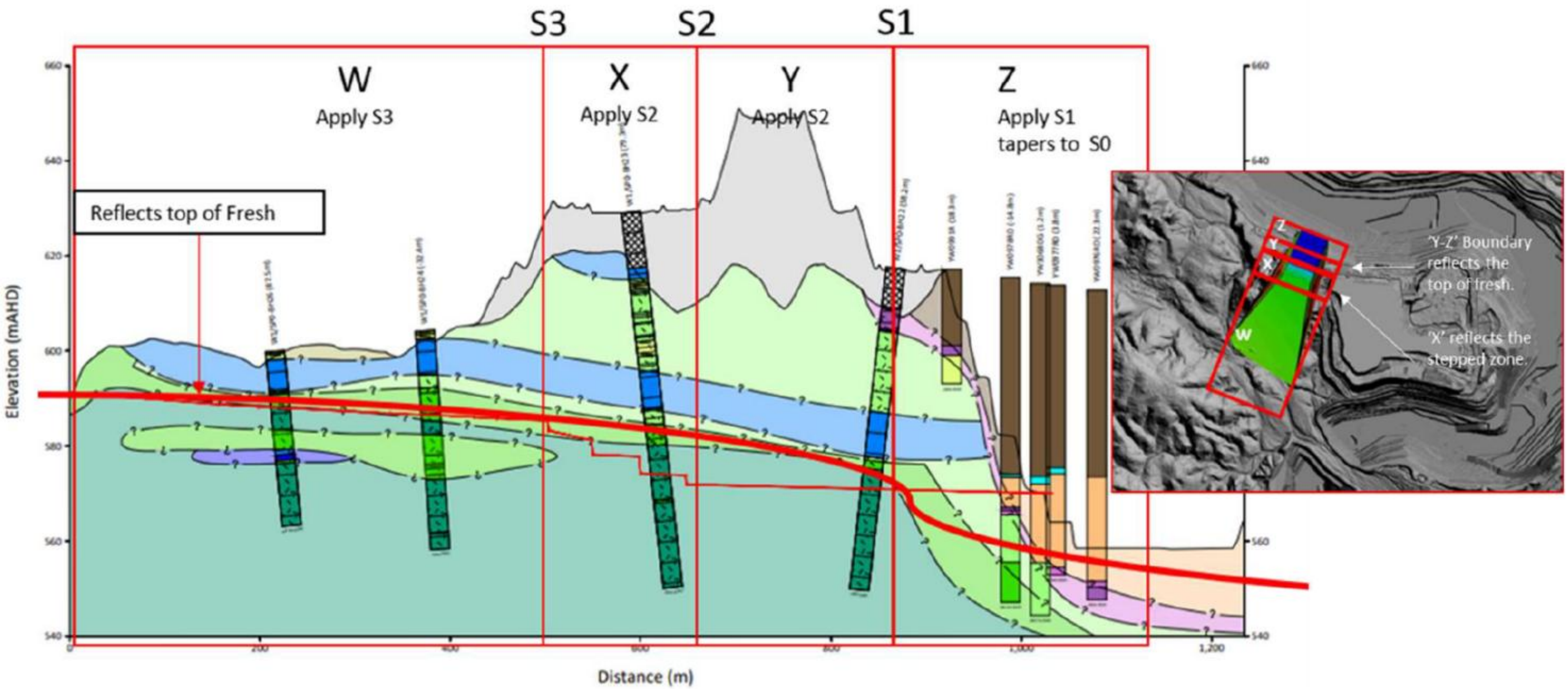
Notes: the distinctly weathered (DW) classification includes slightly weathered (SW) and moderately weathered (MW)

**Figure 5-80 Erosion assessment of W1-SP0**

Advisian (2023f) used RocScience software DIPS (version 8) to analyse the potential for kinematic failures (sliding, toppling and wedge failures) of oriented defects encountered at the flood channel. The analysis concluded that neither planar sliding nor wedge sliding were kinematic issues for any rock type at any condition. Flexural toppling was identified as being an issue for dolerite only, within one joint set, at batter angles of >45˚. However, this is a minor joint set, and the overall number of poles affected is less than 5% of the total poles in the stereonet. Flexural toppling was, therefore, considered to be low risk for W1-SP0. As there is a dominant sub-horizontal set within all rock types identified, direct toppling was flagged as a potential issue for all analyses. However, based on a sensitivity analysis, direct toppling was considered to present a relatively low risk, with <10% of poles within the stereonet affected by direct toppling (intersection) and oblique toppling (intersection) (Advisian, 2023f).

Slope stability analyses were completed for static and seismic conditions on (Advisian, 2023f):

- Flood channel walls: The flood channel walls were analysed over three sections covering varying geology and channel height (Figure 5-81). The analysis also considered two sensitivity cases; Case 1 assumed all weathered material strength, and Case 2 assumed a +10 m increase in the pre-mining groundwater level.
- Flood channel pit interface: The flood channel interface mainly comprises weathered dolerite. An inter-ramp angle of 25° was adopted, with a sensitivity analysis adopting the weathered BIF characteristics.




Source: Advisian (2023f)

**Figure 5-81 W1-SP0 sections analysed for slope stability**

The results of the stability analyses are provided in Table 5-69 and Table 5-70 for the flood channel domains W to Z and the flood channel pit interface, respectively. Based on the outcomes of the analysis, the slope configurations in Table 5-71 were recommended.

**Table 5-69 Slope stability analysis - W1-SP0 flood channel walls**

| IRA | S1 (Figure 5-81) Domain Y and Z | | | S2 (Figure 5-81) Domain X and Y | | | S3 (Figure 5-81) Domain W | | |
|---|---|---|---|---|---|---|---|---|---|
| | Base | Case 1 | Case 2 | Base | Case 1 | Case 2 | Base | Case 1 | Case 2 |
| **Static** | | | | | | | | | |
| 25 | 1.95 | 1.83 | 1.86 | 2.05 | 2.04 | 2.04 | 2.16 | 1.91 | 1.68 |
| 30 | 1.96 | 1.73 | 1.65 | 2.04 | 2.04 | 1.84 | 2.36 | 1.91 | 1.67 |
| 35 | 1.95 | 1.58 | 1.47 | 2.04 | 1.90 | 1.68 | 2.16 | 1.82 | 1.61 |
| 37 | 1.95 | 1.53 | 1.40 | 2.04 | 1.83 | 1.63 | 2.06 | 1.76 | 1.56 |
| **Seismic** | | | | | | | | | |
| 25 | 1.80 | 1.69 | 1.64 | 1.88 | 1.88 | 1.79 | 1.98 | 1.79 | 1.53 |
| 30 | 1.79 | 1.54 | 1.46 | 1.88 | 1.88 | 1.63 | 1.98 | 1.76 | 1.53 |
| 35 | 1.79 | 1.42 | 1.32 | 1.88 | 1.71 | 1.51 | 1.93 | 1.64 | 1.45 |
| 37 | 1.77 | 1.38 | 1.27 | 1.88 | 1.65 | 1.48 | 1.86 | 1.59 | 1.41 |

Source: Advisian (2023f)

Notes: Case 1 - all weathered material strength; Case 2 +10 m increase in groundwater level; IRA - Inter Ramp Angle

**Table 5-70 Slope stability analysis flood channel pit interface**

| Flood Channel | Dolerite (Groups 3 and 4) | BIF (Groups 3 and 4) |
|---|---|---|
| Static | 1.61 | 1.53 |
| Seismic | 1.42 | 1.35 |

Source: Advisian (2023f)

**Table 5-71 Slope configuration recommendations for W1-SP0 flood channel**

| Design Domain | Group | Batter Type | BFA | Max Height | Berm Width | IRA |
|---|---|---|---|---|---|---|
| Z (Figure 5-81) | 2 | Single | 45 | 21 | 24 | 25 |
| X and Y (Figure 5-81) | 3 | Split | 76 | 21 | 7 | 30 |
| | 2 | Single | 45 | 21 | 15 | 30 |
| W (Figure 5-81) | 2 | Single | 45 | 21 | 7 | 37 |

Source: Advisian (2023f)

Notes: IRA - Inter Ramp Angle; BFA - Batter Face Angle

### Design options for managing fibrous materials exposures

Advisian (2023e) conducted a study to review the design options for potential exposures of fibrous materials in the W1-SP0 flood channel. A preliminary analysis of the source-pathway-receptor relationships for these materials was used to frame potential exposure controls and is as follows:

- **Source:** small, localised exposures of actinolite in the W1-SP0 cut. Initially loose material will be present at surface, which will then erode through wind / rain / water action.
- **Pathway:** a preliminary review suggests that mobilisation of exposed actinolite out of W1-SP0 would be via wind or water (rainfall or W1-SP0 flow events).
- **Receptor:** people who walk up Marillana Creek and access the flood channel or backfill in W1 Pit.

Table 5-72 summarises the possible risk controls identified by Advisian (2023e) and associated advantages, disadvantages and feasibility for implementation at the W1-SP0 flood channel. Based on this review, it was concluded that:

- It is not possible to eliminate the exposures of fibrous materials by relocating / redesigning the W1-SP0 flood channel due to the random and unpredictable occurrence of these materials within the dolerite layer. Optimisation of the flood channel width will likely reduce the extent of fibrous material exposures.
- Mitigating risks in the medium term (e.g., by using shotcrete) may be possible, but these are not permanent solutions.

- Controlling access would reduce the potential for people to be exposed to fibrous materials. Of the access controls considered, the most feasible was an ~1.5 m deep cut in rock at the W1-SP0 flood channel entrance.
- Natural exposures of asbestiform minerals have been observed:
  - In the dolerite at Flat Rocks.
  - Commonly in Marillana and Iowa creek beds. Fibres and lumps of fibrous materials have been noted to have been washed downstream and deposited in the alluvial beds in these locations.

  The risks of the W1-SP0 exposures need to be considered in the light of the risks posed by these natural analogues. BHP has added a further assessment of risk to the forward work program in Sections 5.14.7.9 and 13.3.

**Table 5-72 Review of potential risk controls for fibrous materials exposures**

| Potential Control | Type | Comment |
|---|---|---|
| Avoid | Elimination | • There is no practical solution to avoid a potential fibrous materials seam from being exposed (occurrence is random and not possible to predict).<br>• Designs that minimise disturbance will likely reduce the extent of fibrous material exposures. |
| Shotcrete barrier over exposed fibrous materials seams to reduce exposure (during monitoring and post-closure) | Engineering | • A shotcrete barrier has a design life in the order of ~50? years and is not a permanent solution.<br>• Over time the exposed face will erode naturally and disperse to the floodplain.<br>• May be an excessive solution for seams < 100 mm thick and of unknown length - shotcrete is typically applied to larger areas (10s - 100s $m^2$). |
| Bituminous paint / sealant over seams to reduce exposure (during monitoring and post-closure) | Engineering | • Requires identification of an appropriate product that would withstand environmental conditions (heat, UV) and can be applied to bare rock.<br>• Likely to be effective for ~50? years and is not a permanent solution.<br>• Could be completed during / immediately following mapping (painted on by hand with brush). |
| Access control: construct concrete crest block at W1-SP0 entrance to control access post-construction (monitoring and post-closure) | Engineering | • Not aesthetically pleasing and requires a lot of concrete - not a practical or sustainable closure design.<br>• Hydraulically efficient if designed appropriately (e.g. ogee crest). |
| Access control: include a ~1.5 m cut at the W1-SP0 entrance to control access | Engineering | • Feasible, can be considered in the design, in addition to safety bunds. Natural analogues exist in immediate area (Figure 5-82). |
| Access control: fencing / signage to control inadvertent access to W1-SP0 post-construction (monitoring and post-closure) | Administrative | • Fencing, signage not practical / effective post-closure (will not withstand flood events, vandalism, wear and tear). |

Source: Advisian (2023e)

Source: Advisian (2023e)

**Figure 5-82 Examples of natural analogues of ~1.5 m cut in dolerite to deter access**

#### 5.14.7.6 Flood channel W1-SP3 design option selection

The proposed W1-SP3 flood channel will direct water from the W1 Pit to W4 Pit in the event that W1 Pit reaches capacity. Once the W4 Pit reaches capacity, the W4-SP3 flood channel would discharge water back to Marillana Creek from the W4 Pit. Prior to the geotechnical investigation (Section 5.14.7.4), there was limited information on the geology of the W1-SP3 and W4-SP3 flood channel locations, and unfavourable geology would increase the risk of erosion. Given these unknowns, an alternate flood channel configuration was reviewed which used only W1 Pit for flood attenuation and passed overflow from the W1 Pit back to Marillana Creek from an outlet location in W1 via a new flood channel (W1-SP4) (Map 5-30) (Appendix G.2). The outcome of this study was that the preferred option is the W1-SP3 and W4-SP3 flood channels utilising both W1 and W4 pits for attenuation of flow. This is predominantly because of the risks posed by the alternative W1-SP4 flood channel due to increased flood levels and velocities through the constrained section of Marillana Creek between W4 and W5 pits, and the need to construct additional flood bunding along the W3 Pit crest. However, it was noted that the W1-SP4 option could potentially be reconsidered if drilling at either the W1-SP3 or W4-SP3 sites reveals unfavourable geological conditions (Advisian, 2024a).

Further to the geotechnical investigation outlined in Section 5.14.7.4, the W1-SP3 flood channel design was modified by rotating the alignment to help reduce the potential long term stability risks along the W4 southern pit wall (Figure 5-67 , Section 5.14.7.4). Steps were included in the flood channel design for energy dissipation and the invert level at the outlet adjusted to tie in with the SPS pit backfill level in W4 (Section 5.14.1.4). Step heights of 10 m were nominally adopted for the SPS design (Advisian, 2024a).

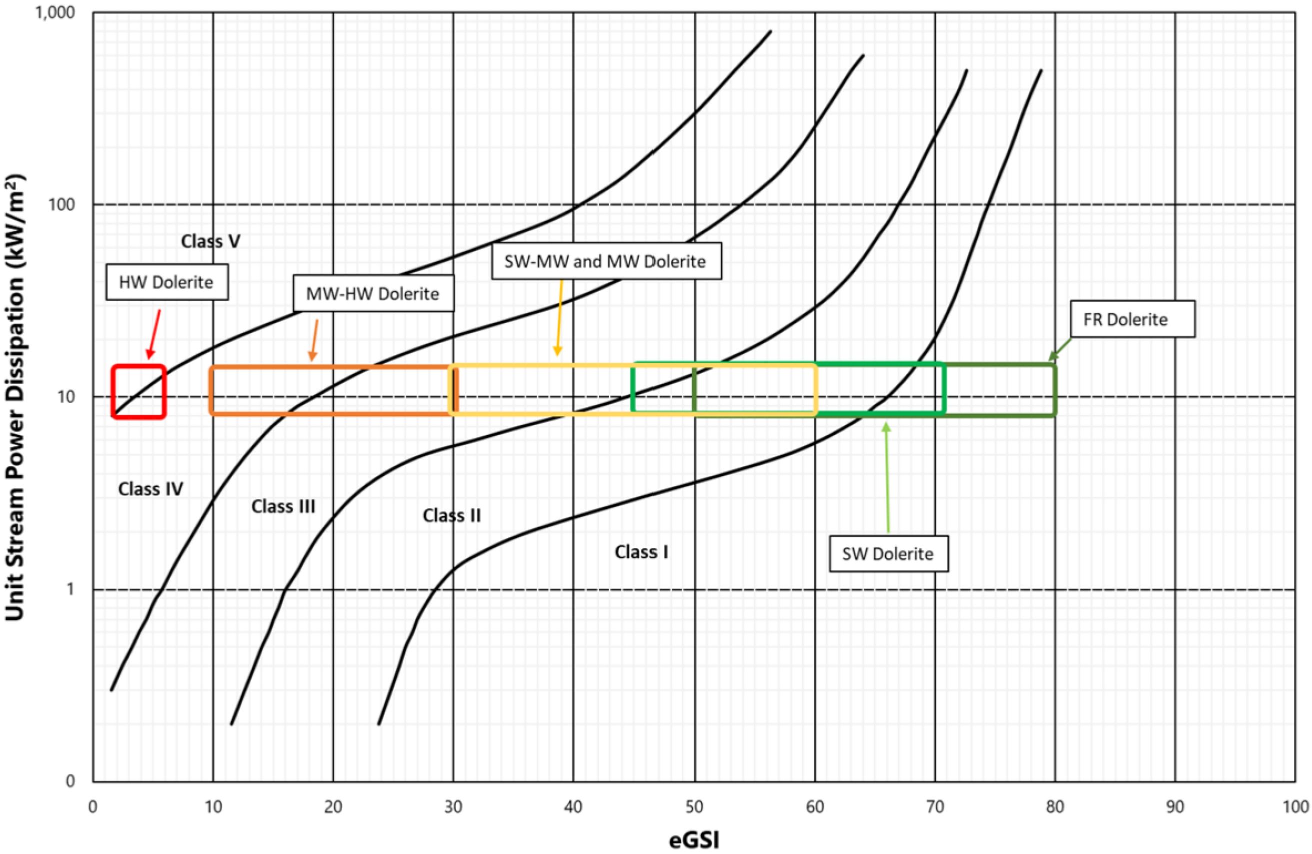
**Geotechnical stability analysis**

The interpreted geology (Figure 5-68, Section 5.14.7.4) suggests that the top two steps of W1-SP3 would be located in fresh (FR) dolerite, however, the third step intersects a region of distinctly weathered (DW) BIF at chainage 700 m. In addition, the inlet and outlet of the flood channel intersect regions of highly erodible palaeochannel deposits and weathered (HW) dolerite (Advisian, 2024a).

Hydraulic modelling of a 1:10,000-year event estimated the stream power for this design to be between 8 to 14 kW/m$^2$. This corresponds to (Figure 5-83) (Advisian, 2024a):

- Negligible erosion in the fresh dolerite and BIF located within the western and central portion of the flood channel.
- Erosion up to Class IV near the third step.
- Erosion of up to Class V at the inlet and outlet. Near the inlet, materials may erode to the same level as the fresh dolerite (refer to W1/SP3-BH01; Figure 5-68 in Section 5.14.7.4) over time.

It is recognised that there are some gaps in the geotechnical / geological data along this flood channel alignment, so additional drilling and investigation is required to confirm the geology and geotechnical conditions and further optimise the design (Advisian, 2024a).




**Erosion classes** (Pells, 2016)

| **Maximum Erosion Depth** ***m*** | **General Erosion Extent $m^3$ per 100 $m^2$** | **Erosion Class** | **Erosion Descriptor** |
|---|---|---|---|
| <0.3 | <10 | I | Negligible |
| 0.3 to 1 | 10 to 30 | II | Minor |
| 1 to 2 | 30 to 100 | III | Moderate |
| 2 to 7 | 100 to 350 | IV | Large |
| >7 | >250 | V | Extensive |

Source: Advisian (2024a)

Notes: the distinctly weathered (DW) classification includes slightly weathered (SW) and moderately weathered (MW)

**Figure 5-83 Erosion assessment of W1-SP3**

A kinematic analysis conducted by Advisian (2023f) using RocScience software DIPS (version 8) concluded that:

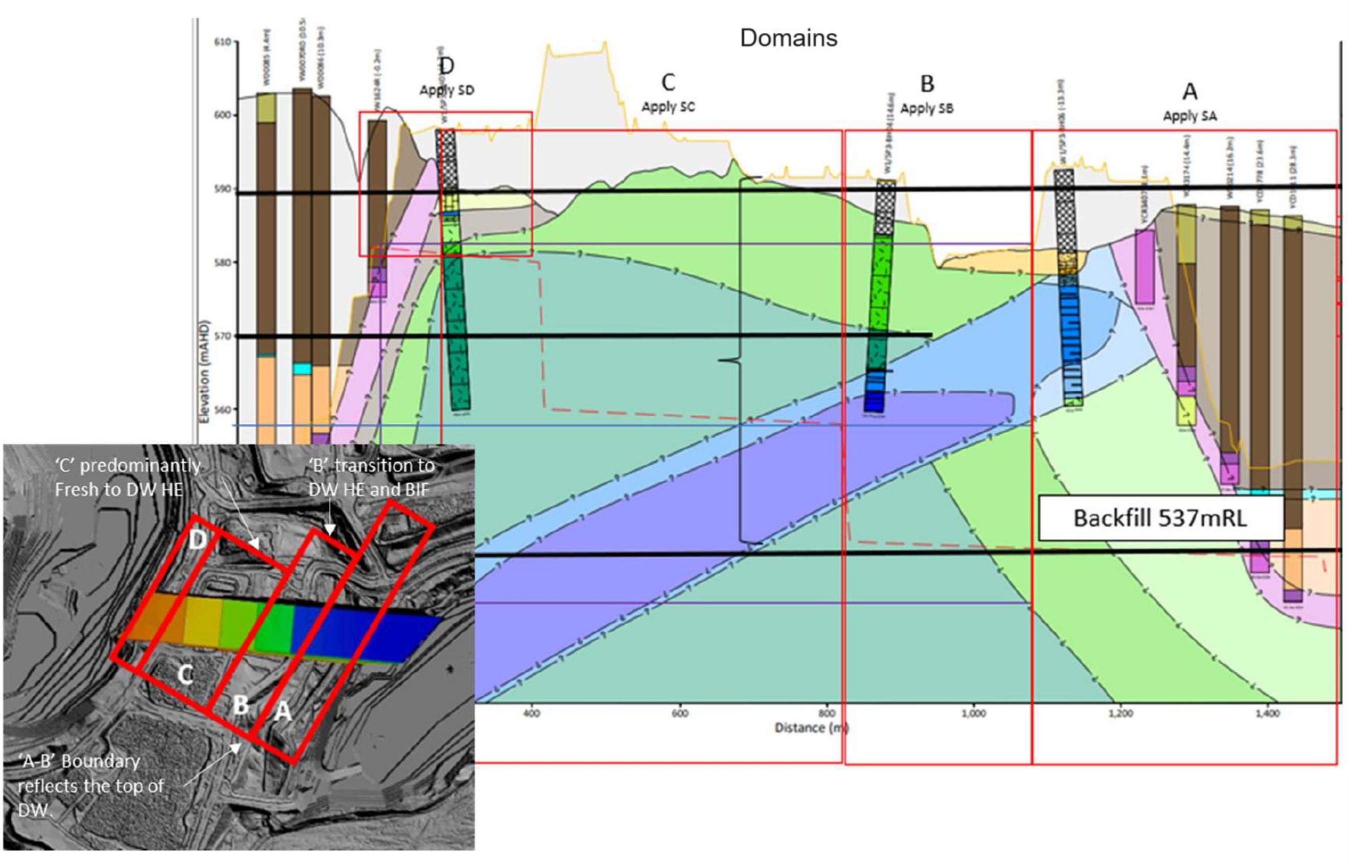
- Planar sliding and flexural toppling were issues for dolerite and BIF at the 4V:1H slope angle only and were considered a low risk as the overall number of poles affected is less than 25%, and commonly less than 10% of the total poles in the stereonet.
- As there is a dominant sub-horizontal defect set within all rock types identified, direct toppling was flagged as a potential issue for all analyses. However, based on a sensitivity analysis, direct toppling was considered to present a relatively low risk, with <10% of poles within the stereonet affected by direct toppling (intersection) and oblique toppling (intersection).

Wedge Sliding was only identified as an issue for BIF on the northern wall at a 4V:1H slope angle, however, in the areas where a 4V:1H slope angle would occur, the number of poles affected is <10%. In addition, a limited thickness of slightly weathered to fresh BIF is present along the flood channel alignment and, within slightly weathered to fresh BIF, defects are relatively widely spaced. Therefore, wedge sliding was considered a low risk for W1-SP3.

Slope stability analyses were completed for static and seismic conditions on a conceptual section of Domain C (Figure 5-84) for different inter-ramp angles and two design cases (Advisian, 2023f):

- Design Case 1 assumed a maximum slope angle of 76° over 21 m height.
- Design Case 2 assumed a slope configuration with an offset of 3 m introduced after the first 7 m.

The analyses also considered the sensitivity of stability to material strength (dolerites vs. BIF of varying weathering state). A mean PGA of 0.12 g was adopted and a seismic loading of 0.06 was applied using RocScience Slide2 (Advisian, 2023f).




Source: Advisian (2023f)

**Figure 5-84 Slope stability domains**

The results of the stability analyses are provided in Table 5-73, and based on the outcomes of the analysis, the slope configurations in Table 5-74 were recommended. The resulting design has an approximate 40 m elevation drop between the inlet and outlet to take advantage of fresh materials with negligible erodibility. Closer to the pits, the channel is almost flat to limit erodibility within weathered BIF and dolerite materials associated with the paleochannel interface, as well as within paleochannel materials. Using the recommendations for each domain in Table 5-73, much of the channel alignment has steep cut slopes associated with fresh BIF and dolerite. However, the channel flares near the interface with both the W1 and W4 pits, and particularly at the outlet, due to a high cut depth through low strength materials.

**Table 5-73 Slope stability analysis - W1-SP3 flood channel walls**

| IRA | IRA Test | | Case 1 | | Case 2 | |
|---|---|---|---|---|---|---|
| | Dolerite | BIF | Dolerite | BIF | Dolerite | BIF |
| **Static** | | | | | | |
| 45 | 2.86 | 1.94 | 2.75 | 1.85 | 2.84 | 1.92 |
| 50 | 2.62 | 1.77 | 2.56 | 1.71 | 2.64 | 1.78 |
| 60 | 2.21 | 1.46 | 2.26 | 1.50 | 2.52 | 1.69 |
| **Seismic** | | | | | | |
| 45 | 2.62 | 1.77 | 2.51 | 1.68 | 2.59 | 1.75 |
| 50 | 2.42 | 1.63 | 2.35 | 1.57 | 2.42 | 1.62 |
| 60 | 2.06 | 1.36 | 2.09 | 1.38 | 2.32 | 1.55 |

Source: Advisian (2023f)

Notes: Design Case 1 - maximum slope angle of 76° over 21 m height; Design Case 2 - offset of 3 m introduced after the first 7 m.
IRA - inter ramp angle

**Table 5-74 Slope configuration recommendations for W1-SP3 flood channel**

| Design Domain | Group | Batter Type | BFA | Max Height | Berm Width | IRA | Other |
|---|---|---|---|---|---|---|---|
| A (Figure 5-84) | 2 | Single | 45 | 21 | 24 | 25 | - |
| B (Figure 5-84) | 3 | Split | 73 | 21 | 7 | < 60 | - |
| | 2 | Single | 45 | 21 | 7 | < 60 | - |
| | 3 | Split | 76 | 21 | 7 | < 60 | - |
| C (Figure 5-84) | 3 | Split | 63 | 21 | 7 | < 60 | - |
| | 4 | Split | 76 | 21 | 7 | < 60 | - |
| D (Figure 5-84) | - | - | 45 | 21 | - | - | Single Batter |

Source: Advisian (2023f)

Notes: IRA - Inter Ramp Angle; BFA - Batter Face Angle

#### 5.14.7.7 Flood channel W4-SP4 design option selection

The proposed W4-SP4 flood channel will allow excess floodwater in W4 Pit to discharge back into Marillana Creek in a controlled manner.

The geology at the W4-SP4 flood channel location was assessed using the IPS information reported in the 2020 MCP for the W4-SP3 location (Map 5-30, Section 5.14.7.3) and 2D hydraulic modelling, to assess the risk posed by scour and erosion. While there is limited available geological and geotechnical data at this flood channel location, the available data suggests the design reported in the 2020 MCP would be cut into material that is susceptible to erosion during flow events. This presents a risk of head-cut erosion which has the potential to result in capture of Marillana Creek. To address this risk, the W4-SP4 flood channel alignment was developed to pass through more favourable geology. The spill crest was also set at a location and elevation where competent rock resistive to erosion is more likely to be encountered; namely 700 m away from the pit edge to reduce the risk of head cut erosion and creek capture. The optimised flood channel design shown in Map 5-30 (Section 5.14.7.3), is a sloping structure of approximately 1.7 km length, at a grade of 0.6% and 200 m width. The flood channel requires minor flood bunds at the inlet and outlet to contain the design flow (Advisian, 2024a).

##### Geotechnical assessment

A detailed erodibility assessment could not be performed for W4-SP4 due to a lack of geotechnical data. However, the following assumptions on potential ground conditions were made on the basis of ground conditions encountered elsewhere on site and distance from the pit and Marillana Creek (Advisian, 2023f):

- Highly weathered materials are present for a depth of 10 m within 200 m of the W4 Pit and Marillana Creek.
- Highly weathered materials are present for a depth of 5 m outside of a 200 m buffer from the W4 Pit and Marillana Creek, with moderately weathered materials present to a cut depth of 15 m and slightly weathered materials present below.

Hydraulic modelling estimated the maximum stream power within the proposed W4-SP4 flood channel to be approximately 12 $kWm^2$. However, estimates indicated it is commonly less than around 6 $kWm^2$ and locally ramps at the crest (~700 m from the inlet), before decreasing relatively rapidly (Advisian, 2023f).

Based on the geological assumptions and variations in stream power along the flood channel, minor to moderate erosion may be experienced where stream power is >6 $kWm^2$, however in the event that materials are slightly weathered or better, negligible erosion is anticipated. Elsewhere along the channel, minimal erosion is anticipated. Near the inlet and outlet, modelled stream powers were commonly 2 $kWm^2$ or less, and limited erodibility is anticipated as, even though materials are highly erodible, stream powers are low (Advisian, 2023f).

The maximum height of the flood channel wall would be approximately 25 m. The adopted geological assumptions of 14 m of residual strength materials followed by weathered rocks, does not support the steeper configurations used for the W1-SP0 and W1-SP3 flood channels. Due to the lack of geological data across the W4-SP1 flood channel alignment, the configuration suggested for the flood channel is based on that recommended for the pit interfaces of W1-SP0 and W1-SP3 as follows (Advisian, 2023f):

- Max height: 21 m.
- Max batter face angle: 45°.
- Bench widths by height:
  - 0 to 7 m - 3m bench width (IRA ~35°).
  - 7 to 14 m - 5.5 m bench width (IRA ~35.7°).
  - 14 to 21 m - 7 m bench width (IRA ~36.9°).

The W4-SP4 design will be reviewed and refined during future design phases.

#### 5.14.7.8 No flood channels scenario analysis

A 'no flood channels' scenario was modelled by Advisian (2023a) using TUFLOW modelling software. The following modifications to the closure designs were included in the TUFLOW model to accommodate the removal of flood channels:

- Widening of the E1 and E4 creek diversions by 60 - 80 m and 60 - 110 m respectively, to accommodate flows above the 5% to 1% AEP design events.
- Provision of extensive and generally higher bunding around pits (as shown in Appendix G.3) to prevent ingress of flood waters. Due to increased velocities, larger rock armour would be required for many of the bunds.

The review concluded that while off-setting some of the risks associated with flood channels (discussed in Sections 5.14.4 and 5.14.7.3 to 5.14.7.7, and summarised in Table 5-75), removing the flood channels would introduce several new significant risks (Advisian, 2023a):

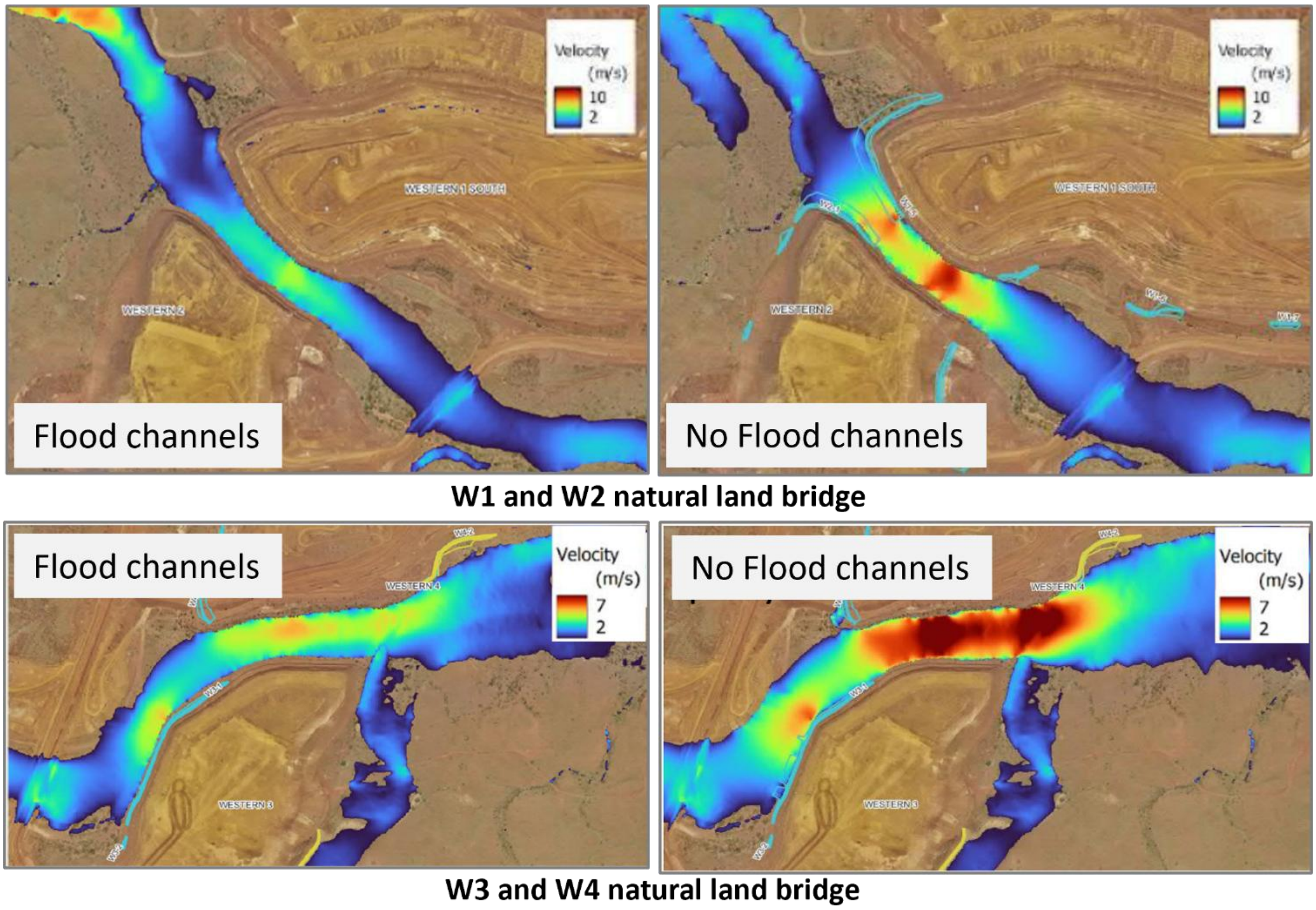
- Flood channels would need to be replaced by extensive bunding. The bunds in several areas would encroach substantially into the floodplain, which increases flood levels and velocities and the overall risk to the bunds and potential for creek capture.
- Up to 4 Tonne Class (and greater) armour rock would be required on some bunds, which is beyond business-as-usual for Pilbara mines. This class of rock armour has a median particle diameter of 1.45 m and a mass of 4 tonnes.
  - Specialist equipment and expertise (such as from marine contractors familiar with breakwater construction) may be required and there may be difficulties in procuring and transporting large volumes of rock of this size.
  - Very large rock is required for both scenarios, but more rock of this class or greater is required for the 'no flood channels' scenario.
- High velocity water across two of the natural land bridges (W1-W2 and W3-W4) represent significant risks that could be considered potential fatal flaws (Map 5-31). Flows would impinge directly on the bund at high velocity at W3 Pit, which is potentially a high-risk location for creek capture (Map 5-31).
- There are very large flows, depths and velocities at the E6 - E7 natural land bridge for both scenarios, though the risk is higher for the 'no flood channels' scenario.
- The widening of E1 and E4 diversions would result in disturbance to the revegetation within the creek diversion and additional footprint over undisturbed areas.

Based on the available data, the review concluded that the closure design should include flood channels (Advisian, 2023a).

**Table 5-75 Summary of key risks associated with flood channels**

| Aspect | Risk description |
|---|---|
| Erosion | Advisian (2019) noted that the long-term deterioration of flood channels by erosion and scour is inevitable, however the actual rate of erosion and scour is governed by the site-specific geology and hydraulics. Geotechnical investigations and hydraulic modelling have been used to optimise the location and design of the flood channels (refer to Sections 5.14.7.3 to 5.14.7.7 for discussion). While materials more prone to erosion may be exposed at inverts near pits, limited head cutting is anticipated due to lesser weathered materials distal from the pit edge. Given these controls, the timeframes for erosion to compromise to the function of the flood channel would be in the thousands to tens of thousands of years |
| Potential for creek capture | The risk of capture of Marillana Creek to W1 Pit is likely to be low due to the distance between the pit and Marillana Creek, and the substantial amount of dolerite that appears to be present. W1-SP3 links the W1 and W4 pits and does not interact with Marillana Creek. The risk of creek capture associated with W4-SP4 is lower than for the W1-SP0 flood channel as the W4-SP4 flood channel would only discharge from W4 Pit once the pit is full (i.e., there would be no large hydraulic head between the outlet of W4-SP4 and Marillana Creek). |
| Safety | Potential for injuries or fatalities post-closure from people falling or being trapped by floods (which can be mitigated by measures to deter access). |
| | Exposure to people of fibrous materials in flood channel excavations. This risk can be reduced by measures to deter access (refer to Section 5.14.7.5 for discussion). |
| Impacts to surface water quality | Potential for saline or brackish water from the pits to spill back into Marillana Creek which would only occur infrequently and has been assessed to have a low impact (refer to Section 5.14.4 for discussion). |
| Impact to cultural values | Potential that Traditional Owners will not view the concept of moving water from the creek into the pits favourably. This is the subject of ongoing consultation with the Banjima people (refer to Section 4). |

Source: Advisian (2019; 2023a; 2023f)




Source: Advisian (2023a)

**Map 5-31 No flood channel scenario - 1 in 10,000 AEP flood velocities across natural land bridges**

#### 5.14.7.9 Knowledge gaps & forward work program

The following knowledge gaps and additional studies have been identified for flood channels:

- Further geotechnical investigations and analyses at the W1-SP3, W4-SP4 and eastern part of the W1-SP0 flood channel locations.
- Optimisation of flood channel designs based on geotechnical data and additional hydraulic modelling.
- Further assessment of the risks associated with fibrous materials in comparison to natural analogues and review of mitigation options, if required.

### 5.14.8 Flood bund & floodplain design studies

Since the 2020 MCP, various studies have been conducted to optimise the flood bund configuration which have resulted in some flood bunds being removed and replaced with floodplains (Section 5.14.8.2). A preliminary geotechnical analysis of these floodplain landforms has been conducted to inform future design phases (Section 5.14.8.3). For the flood bunds remaining, various studies have been conducted to optimise designs for erosion protection and geotechnical stability (Section 5.14.8.4). Investigations have focused on the most significant bunds that pose the highest post-closure risk (i.e., those adjacent to pit crests along Marillana Creek). Detailed assessments of minor bunds (refer to Appendix G.5) will be conducted in future design phases. Remaining knowledge gaps and forward works are summarised in Section 5.14.8.5.

**Summary**

Several bunds were identified as required in the 2020 MCP. Since that time, a number of studies have been conducted to optimise the flood bund configuration and progress designs.

A review was conducted of upgrade options for the E1 and E4 creek diversion flood bunds considering the interaction of the bunds with the adjacent pits and Marillana Creek floodplain. The study concluded that:

- Flood bunds E1-2, E1-3, E1-4, E4-1 and E4-2 do not encroach on the pit set back and, therefore, the preferred option is that they are raised on the pit side of the bund, thereby avoiding impact to the hydraulics in Marillana Creek.
- Flood bund E7-2 has not yet been constructed and can be constructed to the closure design which does not interact with the pit setback.
- Flood bunds E1-1, E4-3 and E7-1 have the potential to interact with the pit setback and it was recommended that:
  - The northern section of E1-1 be raised on the creek side of the bund as this will not impact any large riparian trees and avoids the need for additional buttressing.
  - The southern section of E1-1 flood bund be raised on the pit side as this section of the bund does not require buttressing.
  - The E4-3 and E7-1 flood bunds be raised on the pit side (entailing buttressing of the pit wall) as raising on the creek side will encroach on the creek and require the removal of large trees. It will also impact the hydraulics in the creek and potentially increase the erosive forces and rock size required for armouring the bund. There are some construction complexities to navigate for raising the E7-1 flood bund on the pit side (potential settlement of flood bund constructed across CID and buttress / backfill), but these are outweighed by the risk of a creek side raise.

Options were assessed for replacing flood bunds with floodplain designs in reaches of Marillana Creek where the floodplain is constrained between pits or other mine infrastructure (at W1-W2, W3-W4, W4-W5, W5-W6 and E6-E7). These constrained areas experience deep flows and high velocities during extreme flood events. A site visit and constructability review found that at W4-W5, W5-W6 and E6-E7, it would not be feasible to construct the flood bund on top of remnant CID and consequently, the bunds would need to be constructed in Marillana Creek adjacent to the remnant CID, further constraining the already constrained section of creek and causing damage to riparian vegetation. Based on these considerations and constraints, floodplain designs with the aim of reducing flood depths, flow velocities and where possible, eliminating the requirement for bunds, were explored and the following floodplain designs adopted:

- Backfilling of a portion of W6 which eliminates the requirement for additional bunds along the western side of W5, assuming the in-situ CID is sufficient for flood protection.
- Backfilling the western corner of W5 Pit which removes the need for a flood bund at this location.
- Partially backfilling a portion of E6 Pit, as well as some additional floodplain widening along the northern bank of Marillana Creek downstream of E6 and E7. One small flood bund is still required to prevent floodwater ingress at the north-eastern corner of the E7 Pit.

Assessment of the potential to remove the closure flood bund at the W5 mid-section, by widening the floodplain blocked by mine overburden adjacent to W5 Pit, showed that there would be a considerable reduction in flow velocity. This design was, therefore, adopted.

A slope stability analysis of the floodplain landforms was conducted and indicated that to achieve the basis of design requirements (static FoS ≥1.5, seismic FoS ≥1.2), minimum global batter angles should be:

- 1V:2H for E6.
- 1V:3H for W5.
- 1V:3.5H for W6.

Additional geotechnical studies and hydraulic modelling will be required to inform detailed closure designs.

For the remaining flood bunds, hydraulic modelling was conducted to inform the design height of bunds and the rock armour requirements for erosion and scour protection. The outcomes from this study have been incorporated into the designs provided in Section 9.2.4.3.

A review of the relative advantages of disadvantages of a submerged bund toe or launchable toe design was also conducted. A bund design with a submerged toe was recommended due to a greater certainty of protection from scour, erosion and undercutting. A launchable toe option could be considered to protect trees, but at a greater long-term risk.

The grading of alluvium and overburden materials suggests that neither the alluvium nor overburden materials are pre-disposed to piping and the risk of uplift pressure on the downstream side of flood protection bunds is low. Preliminary screening of the Alluvium based on the particle size distribution in Section 5.2.4.2 indicates that the material is unlikely to be susceptible to liquefaction.

An assessment of the potential for seepage and associated stability risk indicated that:

- For the flood protection bunds that straddle CID or BIF, the current design configuration satisfactorily manages seepage.
- Outflows into the pit wall at E1-1, E4-2A and E4-2B (where alluvium intersects the pit wall) are very significant and will require mitigation where permeabilities of $1x10^{-3}$ m/s are assumed. Mitigation options will be considered in future design phases.

A slope stability analysis indicated that:

- The proposed batter angles for the flood protection bunds (upstream and downstream batters) meet the basis of design requirements for static (FoS ≥1.5) and seismic (FoS ≥1.2) loading conditions.
- For sections where alluvium intersects the pit wall at W5, E1 and a local section of E4 (E4-2B), the stabilities of the pit slope batters intersecting the alluvium, do not meet the conditions for the basis of design (based on the assumed seepage parameters adopted for the sensitivity analysis of the alluvium). Further evaluation of mitigation measures is required in future design phases.

Additional geotechnical studies and hydraulic modelling will be required to inform detailed closure designs. A detailed investigation of existing minor flood bunds is also required

##### 5.14.8.1 Basis of design

Table 5-76 provides the basis of design for flood bunds.

**Table 5-76 Flood bund basis of design**

| Significance of structure* | Design criteria |
|---|---|
| Major diversion bunds (Marillana Creek) | Accommodate predicted flood levels and velocities for a 1:10,000-year flood event (0.01% AEP) |
| Intermediate diversion bunds | Accommodate predicted flood levels and velocities for a 1:1,000-year flood event (0.1% AEP) |
| Minor diversion bunds | Accommodate predicted flood levels and velocities for a 1:100-year flood event (1% AEP) |
| All | Armour rock protection to be included (where required) on upstream face of bund for respective design flood event. Rock sizes will be based on rock classes in Austroads (1994) |
| | Bund crest levels to have 1 m freeboard to the flood level of the respective design flood event. |
| | Toe depth of the rock protection to be based on estimated scour depths in the adjacent creek channel (primary low flow channel) for respective design flood events. |
| | Minimise disturbance to mature trees where practicable |
| Flood bunds & floodplains | Design slope factor of safety minimum of 1.5 for overall slope stability under static conditions and minimum of 1.2 under seismic conditions |

Source: Advisian (2023f; 2024a)

*Notes: significance of structure has been defined based on BHP's risk-based approach outlined in Section 9.1.2

##### 5.14.8.2 Flood bund configuration

The 2020 MCP identified several bunds that require upgrades for closure, as well as some new bunds required to prevent a 1 in 10,000 AEP flood event from overtopping pit crests at selected locations. Since the 2020 MCP, further studies have been conducted to assess:

- The upgrade options for the E1 and E4 creek diversion flood bunds considering the interaction of the bunds with the adjacent pits and Marillana Creek floodplain (Advisian, 2023i).
- Options for replacing flood bunds with floodplain designs in reaches of Marillana Creek where the floodplain is constrained between pits or other mine infrastructure (Advisian, 2024a).

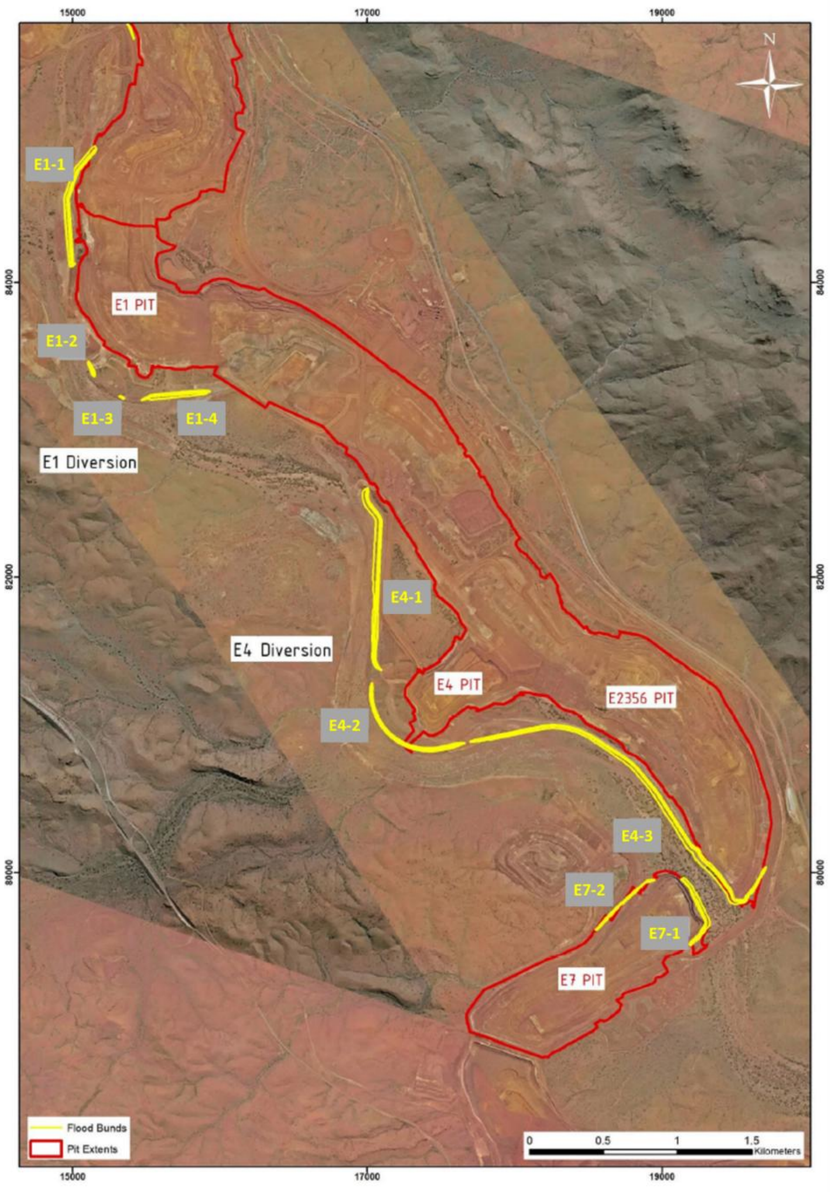
The outcomes of these studies are summarised in the relevant sub-sections below and have informed the configuration of surface water management infrastructure provided in Section 9.2.4, and the design studies outlined in Sections 5.14.8.3 and 5.14.8.4.

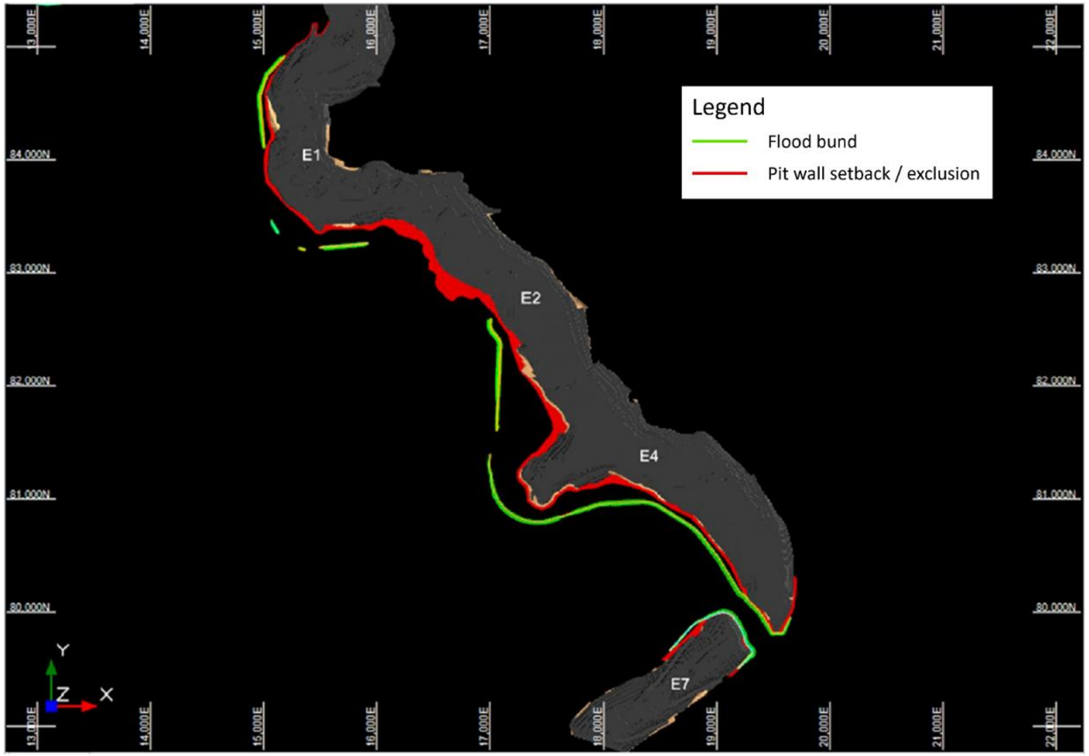
**Upgrade options for E1 and E4 creek diversion flood bunds**

Advisian (2023i) reviewed the option of extending bunds towards the pit side when raising the height of the bunds for closure compared to extending into the Marillana Creek floodplain. Pit side raises will generally require buttressing of the pit walls for stability. The flood bunds assessed are shown on Map 5-32.

To determine buttressing requirements (Advisian, 2023i):

- Pit setbacks were defined at each flood bund location based on 2D sectional analysis of the intersection of HJ (Weeli Wolli Formation) with the pre-mining surfaces, and the remaining CID. A 10 m buffer was applied to crest offsets where applicable. The risk of pit wall instabilities is higher under greater pore pressure conditions associated with high rainfall and flood events. Therefore, pit setback calculations assumed high pore-pressure conditions.
- The difference between the upstream (creek side) design and the existing flood bund was measured and estimated to be 5 m. The downstream (pit side) toe location was estimated by expanding the toe of the current flood bund outward by 5 m.
- Probable buttress locations (due to downstream raising encroaching on pit setbacks) were identified using the interaction between the toe line and the exclusion zone (Map 5-32).




Source: Advisian (2023i)

**Map 5-32 E1 & E4 diversion flood bund interaction with pit setbacks**

Table 5-77 summarises the recommended approach for each flood bund and the rationale for the recommendations follows.

- The analysis of the interaction between closure flood bund designs and pit setback / exclusion zone distances indicates that flood bunds E1-2, E1-3, E1-4, E4-1, E4-2 do not encroach on the pit set back. Therefore, the preferred option is that they are raised on the pit side of the bund, thereby avoiding impact to the hydraulics in Marillana Creek. Flood bund E7-2 has not yet been constructed and can be constructed to the closure design which does not interact with the pit setback. Flood bunds E1-1, E4-3 and E7-1 have the potential to interact with the pit setback.
- Based on a review of the relative advantages and disadvantages of each option, Advisian (2023i) recommended that:
  - The northern section of E1-1 be raised on the creek side of the bund as this will not impact any large riparian trees and avoids the need for additional buttressing.
  - The southern section of E1-1 flood bund be raised on the pit side as this section of the bund does not require buttressing.
  - The E4-3 and E7-1 flood bunds be raised on the pit side (entailing buttressing of the pit wall) as raising on the creek side will:
    - Encroach on the creek and require the removal of large trees.
    - Impact the hydraulics in the creek and potentially increase the erosive forces and rock size required for armouring the bund.

  There are some construction complexities to navigate for raising the E7-1 flood bund on the pit side (potential settlement of a flood bund constructed across CID and buttress / backfill), but these are outweighed by the risk of a creek side raise.

**Table 5-77 Summary of recommended upgrades for E1 and E4 creek diversion flood bunds**

| Flood Bund | Status | Interaction with Pit Setback | Recommendation |
|---|---|---|---|
| E1-1 | Constructed | Potential interaction with pit set back distance | Raise northern section on creek side.<br>Raise southern section on pit side (no buttress). |
| E1-2 | Constructed | Outside pit set back distance | Raise on pit side |
| E1-3 | Constructed | Outside pit set back distance | Raise on pit side |
| E1-4 | Constructed | Outside pit set back distance | Raise on pit side |
| E4-1 | Constructed | Outside pit set back distance | Raise on pit side |
| E4-2 | Constructed | Outside pit set back distance | Raise on pit side |
| E4-3 | Constructed | Potential interaction with pit set back distance | Raise on pit side with buttress |
| E7-1 | Constructed | Potential interaction with pit set back distance | Raise on pit side with buttress |
| E7-2 | Not yet constructed | Closure design outside pit set back distance | Construct to closure design |

### Options for replacing flood bunds with floodplains

There are several constrained reaches of Marillana Creek between pits (at W1-W2, W3-W4, W4-W5, W5-W6 and E6-E7) which experience deep flows and high flow velocities during extreme flood events. At closure, flood protection bunds are required at several locations within the constrained sections of creek, to prevent uncontrolled overtopping of pit crests and inflows to mine voids during the 1:10,000 AEP event (Advisian, 2024a).

The deep flows and high flow velocities experienced in the constrained sections require bund designs with significant rock armour. A site visit and constructability review found that at W4-W5, W5-W6 and E6-E7, it would not be feasible to construct the flood bund on top of remnant CID and consequently, the bunds would need to be constructed in Marillana Creek adjacent to the remnant CID, further constraining the already constrained section of creek and causing damage to riparian vegetation (Advisian, 2024a).

Based on these considerations and constraints, opportunities to widen the Marillana Creek floodplain were explored at W4-W5, W5-W6 and E6-E7 with the aim of reducing flood depths, flow velocities and where possible, eliminating the requirement for bunds. A further assessment was also conducted of the potential to remove the closure flood bund at the W5 mid-section by widening the floodplain blocked by mine overburden adjacent to W5 Pit (Advisian, 2024a). 2D modelling was conducted to assess various options and the outcomes of the assessments are summarised by feature below.

#### *W5-W6 floodplain option assessment*

At W5-W6 the following options for in-pit floodplain widening were explored (Advisian, 2024a):

- Partial backfilling of W5 at the constriction.
- Partial backfilling of W6.
- A combination of backfilling W5 and W6.

The natural landform in this area is approximately 2 m above the adjacent creek. All scenarios, therefore, involved trimming down the in-situ CID around the pit crest to the required floodplain level, such that frequent flood events would be contained in the main Marillana Creek channel, and the floodplain only activated in the larger flood events. Retaining the in-situ CID on the margins of the creek also protects the constructed floodplain from scour, erosion, and lateral channel migration (Advisian, 2024a).

Key outcomes of the assessment were (Advisian, 2024a):

- Backfilling of W5 did not eliminate the requirements for a bund at W6 (flood levels only reduced by <1 m) (Figure 5-85).
- There were minimal differences (<0.5 m) in flood level between the scenarios where W5 and W6 were backfilled together, and where W6 was backfilled alone (Figure 5-85).
- Backfilling of W6 eliminates the requirement for additional bunds along the western side of W5 assuming the in-situ CID is sufficient for flood protection (Figure 5-85).

Modelling showed only a minor reduction in the velocities through the reach for all scenarios, however, the W6 backfilling configuration enables the W5 bund to be removed, and, therefore, reduces the risks associated with erosion and scour at closure. The W6 backfilling option is, therefore, the preferred option.

*W4-W5 floodplain option assessment*

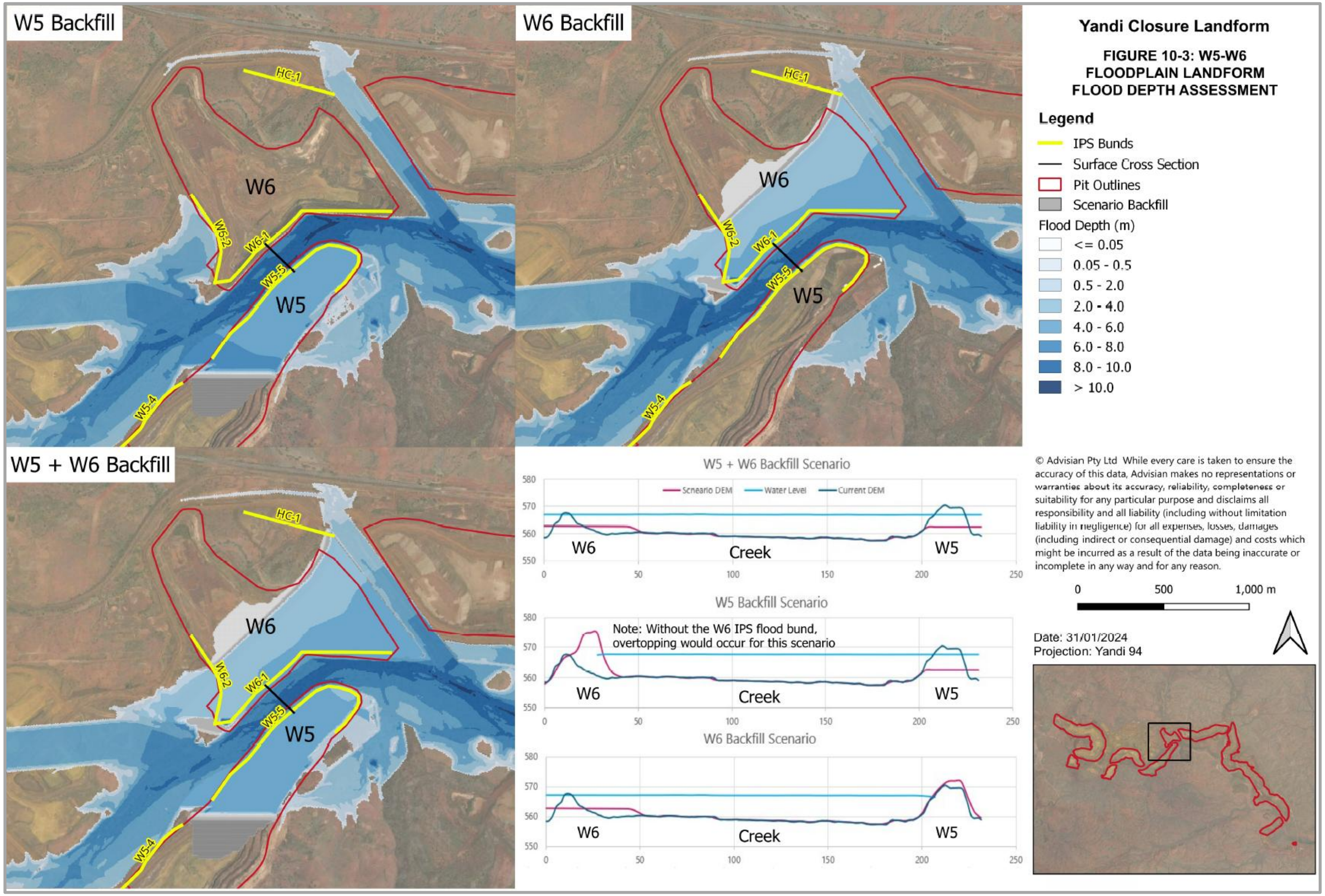
Modelling suggests that without surface water management measures, overtopping of floodwater into the western corner of W5 Pit would occur in the 1:10,000 AEP event (Advisian, 2024a).

The W4-W5 floodplain widening option involves partially backfilling the western corner of W5 Pit. The proposed in-pit floodplain landform design is sloped (away from the pit) and does not require a flood bund to prevent inflow into the pit. The in-situ CID is assumed to remain in place around the pit crest protecting the floodplain from scour, erosion, and lateral channel migration. Modelling shows that this design contains the 1:10,000 AEP flood event without ingress into W5 Pit (Figure 5-86). This design has, therefore, been adopted for the SPS (Advisian, 2024a).

*E6-E7 floodplain option assessment*

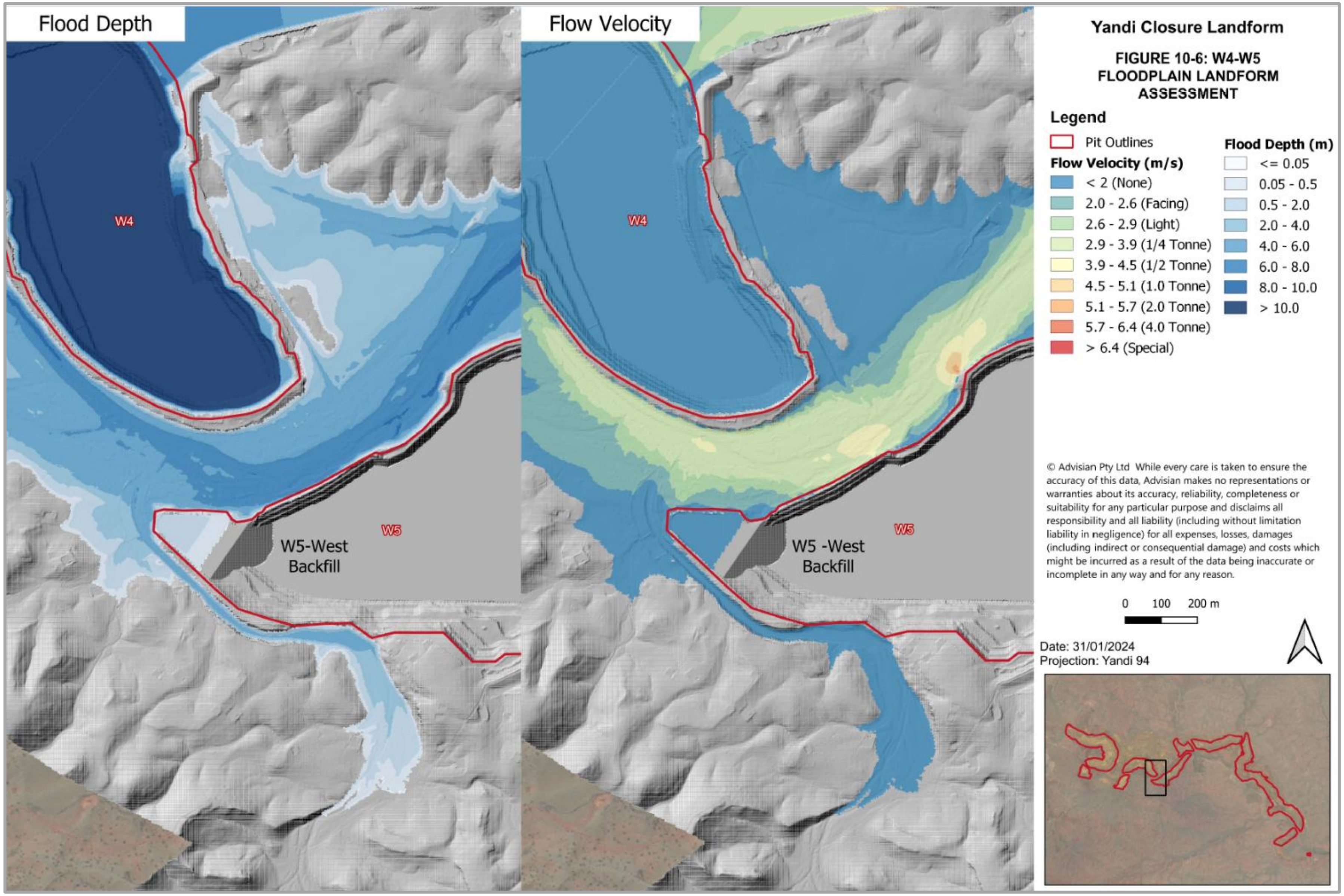
The E6-E7 floodplain widening option involves partially backfilling a portion of E6 Pit, as well as some additional floodplain widening along the northern bank of Marillana Creek downstream of E6 and E7. The proposed in-pit floodplain landform design is sloped (away from the pit) and does not require a flood bund to prevent inflow into the pit. The in-situ CID is assumed to remain in place around the pit crest protecting the floodplain from scour, erosion, and lateral channel migration (Advisian, 2024a).

Based on this design, the modelling results show a substantial reduction in the depth of flow and peak velocities through the constriction between E6-E7. However, one small flood bund is still required to prevent floodwater ingress at the north-eastern corner of the E7 Pit (Figure 5-87). This design has been adopted for the SPS (Advisian, 2024a).



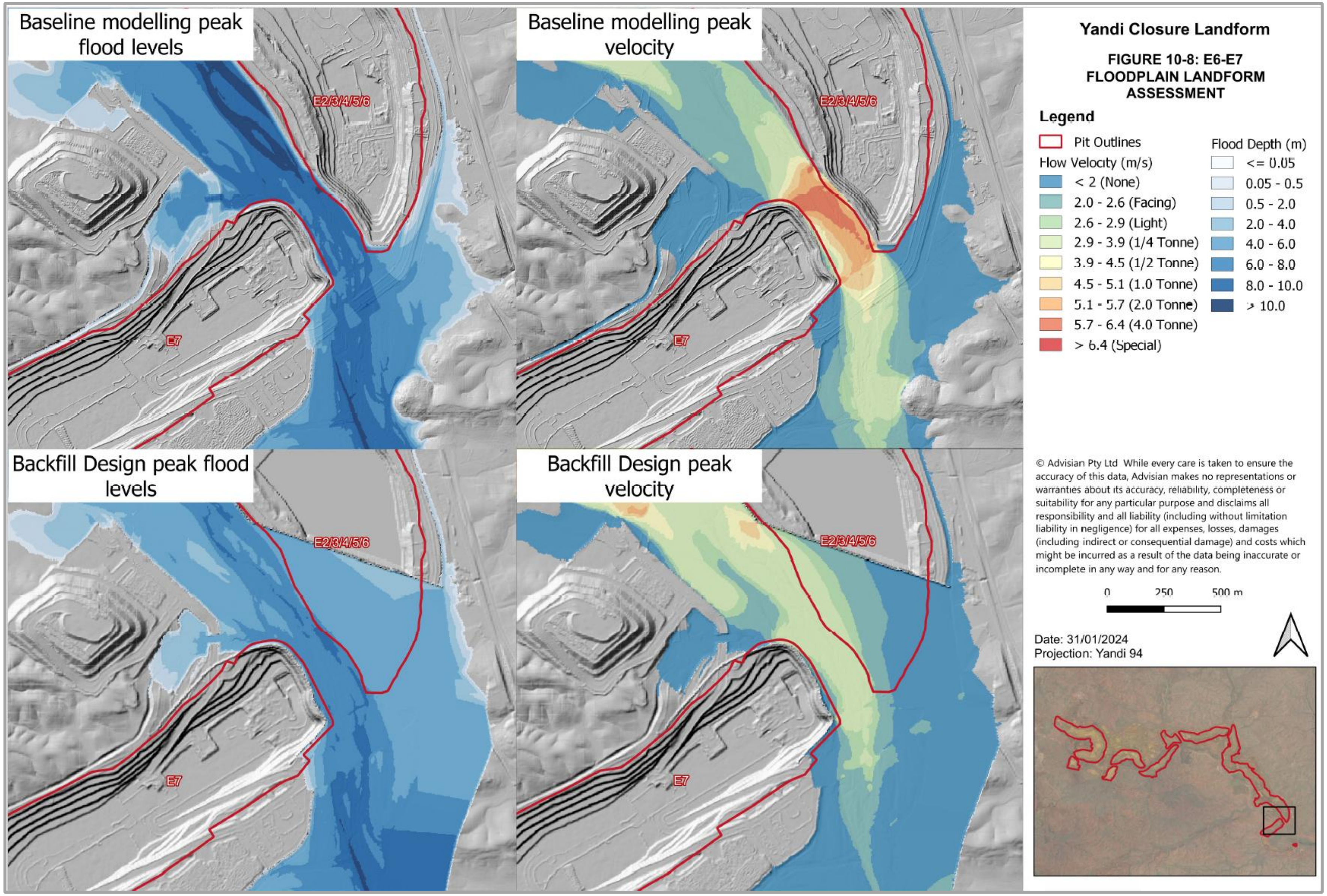

Source: Advisian (2024a)

**Figure 5-85 W5-W6 floodplain options 1:10,000 AEP flood depths**




Source: Advisian (2024a)

**Figure 5-86 W4-W5 floodplain 1:10,000 AEP flood depths & velocities**




Source: Advisian (2024a)

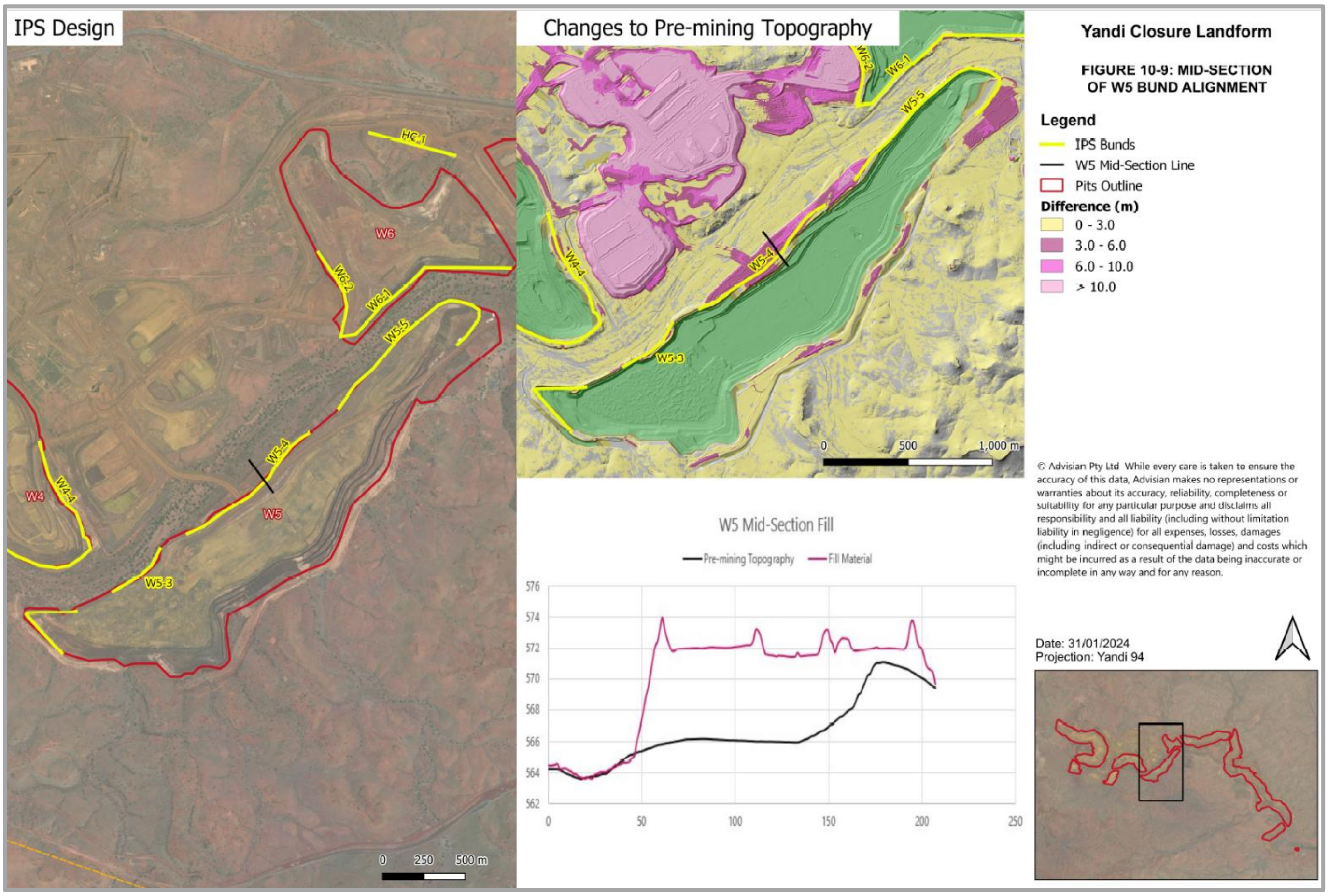
**Figure 5-87 E6-E7 floodplain 1:10,000 AEP flood depths & velocities**

*W5 mid-section floodplain widening assessment*

The middle section of W5, was identified as an opportunity for floodplain widening as (Figure 5-88):

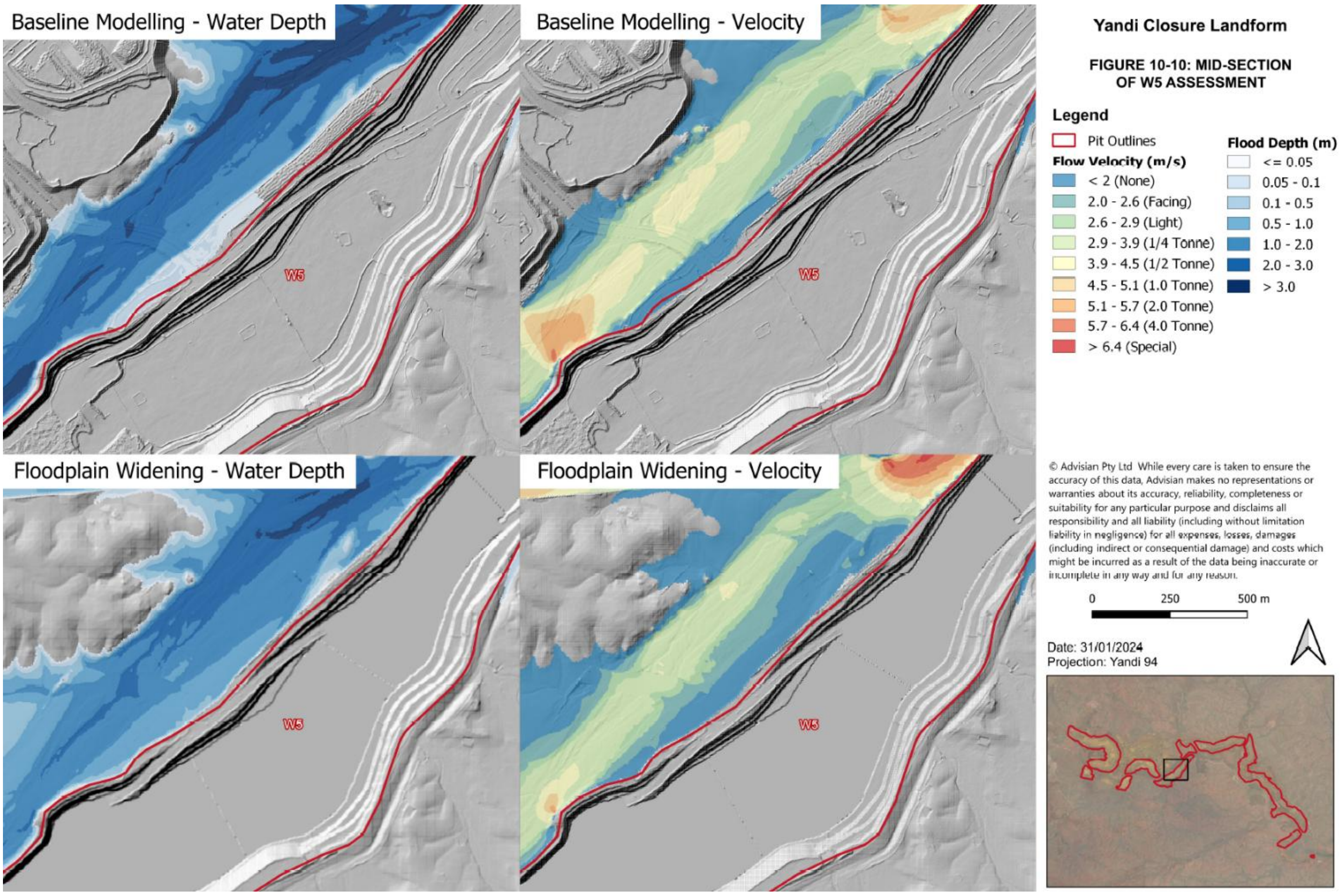
- Overburden on the northern side of W5 Pit, encroaches on the pre-development floodplain.
- The material on the southern side of the pit is not a suitable foundation for the flood bund and must be removed at closure, prior to construction of a flood bund.
- This reach of Marillana Creek features alluvial material that extends to the pit edge, presenting a seepage risk. Flood bunds, therefore, cannot be placed at the pit edge and must be offset.

Modelling shows a considerable reduction in flow velocity in the widened floodplain scenario (Figure 5-89). Therefore, the widened floodplain scenario and associated flood bund design was adopted for SPS design (Advisian, 2024a).




Source: Advisian (2024a)

**Figure 5-88 W5 mid-section bund current topography versus pre-mining**




Source: Advisian (2024a)

**Figure 5-89 W5 mid-section 1:10,000 AEP flood depths & velocities**

### 5.14.8.3 Floodplain design assessments

Further to the design option selection work outlined in Section 5.14.8.2, floodplains have been selected as the preferred surface water management alternative for W5-W6, W4-W5, E6-E7 pits. Given the early stage of these design options, a preliminary geotechnical assessment has been conducted and is outlined below. However, further work is required to develop designs, including an assessment of settlement.

#### Preliminary geotechnical assessment

The floodplain landforms are anticipated to be constructed from overburden or material won from the flood channel excavations, using mine fleet. As such, the geotechnical performance is expected to be similar to that of pit buttresses, although the material will be exposed to partial saturation through the transient flood events across the landform. A preliminary geotechnical analysis has been conducted to inform the designs outlined in this MCP. Further analysis will be required as the designs evolve (Advisian, 2023f).

*Seepage assessment*

2-D seepage analyses were undertaken (using SEEP/W software, developed by GeoSlope International Ltd., Canada) and considered (Advisian, 2023f):

- The transient nature of a 1:10,000 AEP flood event using flood hydrographs derived from flood modelling conducted by Advisian (2024a).
- A local groundwater level derived from AQ2 (2023b).

One cross section from each floodplain landform was assessed, and the results (Table 5-78) used in the stability assessment discussed below (Advisian, 2023f).

**Table 5-78 Transient seepage results for landform floodplain cross sections**

| Section | Floodplain Landform Permeability (m/s) | Maximum Water Discharge at the Pit Wall ($m^3$/hr/m) |
|---|---|---|
| W5 | $10^{-4}$ | 1.12 |
| W6 | $10^{-4}$ | 0.13 |
| E6 | $10^{-4}$ | 0.34 |

Source: Advisian (2023f)

*Stability assessment*

Slope stability analyses were performed for static and seismic scenarios using (Advisian, 2023f):

- Earthquake horizontal acceleration of 0.12 g.
- The predicted position of the phreatic surface during flooding, as determined from the seepage modelling (Table 5-78).

The results (Table 5-79) indicate that to achieve the basis of design requirements, minimum global batter angles for the floodplain landforms are:

- 1V:2H for E6.
- 1V:3H for W5.
- 1V:3.5H for W6.

**Table 5-79 Slope stability analyses - floodplain landform cross sections**

| Section | Floodplain Landform Batter | Seismic Condition $FoS_{min}$ = 1.2 | Static Condition $FoS_{max}$ = 1.5 |
|---|---|---|---|
| W5 | 1V:2H | 0.88 | 1.06 |
| | 1V:2.5H | 1.06 | 1.27 |
| | 1V:3H | 1.21 | 1.50 |
| | 1V:3.5H | 1.47 | 1.85 |
| W6 | 1V:2H | 0.81 | 0.95 |
| | 1V:2.5H | 1.01 | 1.15 |
| | 1V:3H | 1.11 | 1.37 |
| | 1V:3.5H | 1.34 | 1.69 |
| E6 | 1V:2H | 1.32 | 1.54 |
| | 1V:2.5H | 1.53 | 1.78 |
| | 1V:3H | 1.66 | 2.09 |
| | 1V:3.5H | 1.87 | 2.43 |

Source: Advisian (2023f)

#### 5.14.8.4 Flood bund design assessments

A series of studies have been conducted since the 2020 MCP to further develop the designs for flood bunds. These include:

- An assessment of whether flatter bund slopes could reduce the rock armour classes adopted (Advisian, 2023g).
- An assessment of the relative advantages of disadvantages of a submerged bund toe or launchable toe design (Advisian, 2023h).
- Modelling to determine bund height and rock protection requirements (Advisian, 2024a).
- Geotechnical stability analyses (Advisian, 2023f).

The results of these studies have been used to inform the design presented in Section 9.2.4 and are summarised in the relevant sub-sections below. To date, studies have focused on the significant flood bunds adjacent to pit crests along Marillana Creek as these present the highest risk of creek capture. Other lower risk flood bunds along Marillana Creek and its tributaries have been assessed to a reduced level of detail which is considered appropriate for SPS level accuracy. These bunds will be assessed in greater levels of detail as the closure designs evolve.

**Influence of flatter slopes on rock armour requirements**

The bund design reported in the 2020 MCP assumed batter slopes of 1V:2H and adopted rock classes of up to 4 Tonne (d50 = 1.45 m). A study was conducted by Advisian (2023g) to assess whether flatter bund batter slopes would reduce the size and class of rock protection required. Several methods were reviewed for sizing rock armour, some of which consider batter slope when sizing rock protection, and others which do not. The study concluded that the Austroads (2019) method is tried and tested in the Pilbara Region of WA and, apart from recommending that the rock sizing tables are used for slopes no steeper than 1V:1.5H, does not consider batter slope. In the absence of any other proven methods for rock sizing in Western Australia, which account for flatter batter slopes, Advisian (2023g) recommended the use of Austroads (2019).

### Submerged toe vs launchable toe option assessment

Advisian (2023h) conducted a study to compare design options for significant flood bunds. The two options considered were:

- A bund with a submerged toe which has the following characteristics:
  - Rock armour is extended to below the base of the primary low flow channel (assumed to be 3 m[49] or until rock is encountered) to protect the toe of the bund from scour / erosion and undercutting.
  - A geofabric layer is provided under the rock to prevent washing of fines from the bund formation (which can destabilise the flood bund).
  - Rocks are mechanically interlocked into place.
- A bund with a launchable toe which has the following characteristics:
  - Rock armour does not extend below the surface, rather the rocks slide / drop into place as erosion occurs. Therefore, the rocks are not mechanically interlocked.
  - There is no geofabric layer under the rock to prevent washing of fines from the bund formation.

The relative advantages and disadvantages of each option are summarised in Table 5-80. Based on this review, Advisian (2023h) recommended that the bund design with a submerged toe be adopted, due to a greater certainty of protection from scour, erosion and undercutting. A launchable toe option could be considered to protect trees, but at a greater long-term risk.

**Table 5-80 Relative advantages & disadvantages of submerged toe versus launchable toe flood bund designs**

| Option | Advantages | Disadvantages |
|---|---|---|
| Submerged toe | Rock is mechanically locked into place and present below the estimated depth of scour in the low flow channel.<br>Geofabric is installed to prevent fines from washing out which reduces the potential for loss of fines to destabilise the flood bund.<br>Provides greater certainty in terms of protection from scour, erosion and undercutting of flood bund. | Requires excavation to construct which may require dewatering of the alluvium and result in disturbance to / clearing of riparian vegetation. |
| Launchable toe | The bund is easier to construct and requires no excavation or dewatering to install.<br>It could be used in areas to avoid impacts to riparian trees. | Has been widely used on watercourses with sand beds, however for gravel beds use is not as widely accepted, as there have been instances where scour depths in gravel beds, rock size and rock volumes have been underestimated due to the rapid scour occurring in these environments.<br>Design guidance suggests that ongoing operational maintenance is required to supplement rock following high scour events. |

Source: Advisian (2023h)

### Flood modelling

2D hydraulic modelling outputs were used to inform the designs for high-risk flood bunds, including (Advisian, 2024a):

- Locating flood bunds to reduce risk of scour / erosion and overtopping.
- Setting the bund crest heights based on flood depths, providing 1 m freeboard to the 1:10,000 AEP event.
- Rock protection requirements based on peak velocities in the 1:10,000 AEP event including:
  - Rock class / size.
  - Rock thickness.
  - Depth of rock below ground level to protect from scour and erosion of the toe.

Table 5-81 details the flood bunds included in the SPS design following the studies outlined in Section 5.14.8.2 compared to the bunds proposed in the 2020 MCP.

49 The estimated depth of scour in the low flow channel of Marillana Creek.

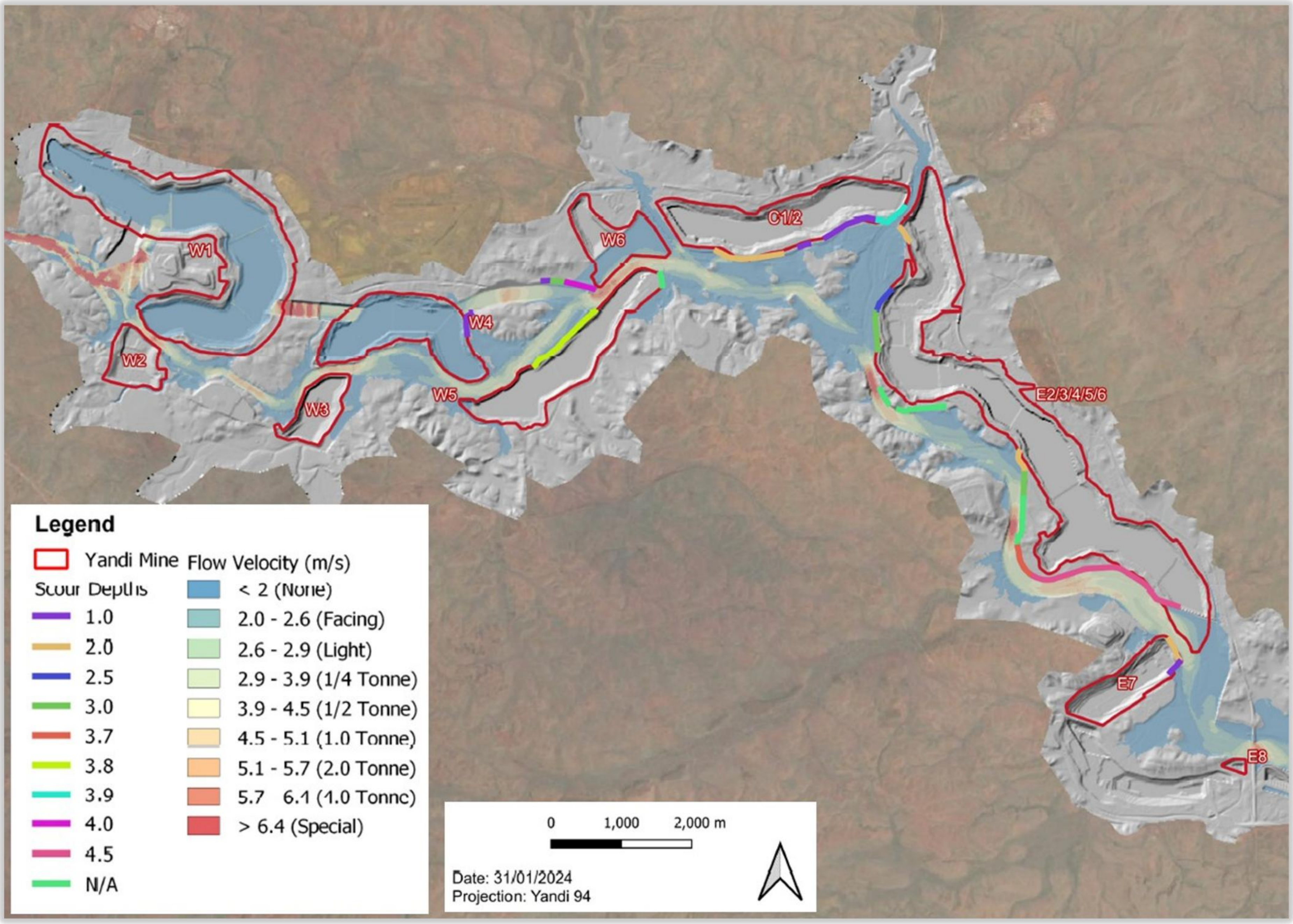
**Table 5-81 SPS flood bunds compared to the bunds proposed in the 2020 MCP**

| Name in 2020 MCP | SPS Name | SPS Status | New bund, Upstream or Downstream Raise |
|---|---|---|---|
| W1-1 | - | Not assessed due to the realignment of the W1-SP0 flood channel and the requirement for further assessment of geotechnical conditions. The diversion is relatively minor and does not pose a risk to pit stability so will be progressed during future design phases | - |
| W1-2 | - | | - |
| W1-3 | - | Removed as the W1-SP0 design has been modified | - |
| W1-4 | - | | - |
| W4-1 | W4-1 | Bund modified as the W1 & W4 storage reduces the flood depths through this reach | New |
| W4-2 | - | Removed as the W1 & W4 storage reduces the flood depths through this reach | - |
| W4-3 | - | | - |
| W4-4 | - | Removed. W4-SP4 configuration eliminates this bund | - |
| W4-5 | - | Removed due to realignment of W1-SP3 | - |
| W5-1 | - | Replaced with floodplain landform | - |
| W5-3 | - | Removed. W4-SP4 configuration eliminates this bund | - |
| W5-4 | W5-1 | Revised alignment accounting for fill material removal | New |
| W5-5 | W5-2 | Mostly removed owing to W6 floodplain landform | New |
| W6-1 | - | Removed. Floodplain landform eliminates this bund | - |
| W6-2 | - | Removed. Floodplain landform eliminates this bund | - |
| - | W6-1 | New bund at outlet of W4-SP4 to prevent flows onto the W6 floodplain landform | New |
| HC-1 | HC-1 | Requires confirmation following development of closure designs for Herbert's Creek land bridge | |
| C1-1 | C1-1 | The configuration of these bunds has been consolidated with the revised hydrology, flood channels and floodplain landforms. | New |
| C1-2 | | | |
| C1-3 | C1-2 | | |
| C1-4 | | | |
| C5-1 | C5-1 | New bund extended from the design presented in the 2020 MCP | New |
| E1-1 | E1-1 | Extension of existing bund | Upstream |
| E1-2 | E1-2 | New bund modified from the design presented in the 2020 MCP | New |
| E1-3 | E1-3 | New bund modified from the design presented in the 2020 MCP | New |
| E1-4 | E1-4 | New bund modified from the design presented in the 2020 MCP | New |
| E4-1 | E4-1 | Modified from the design presented in the 2020 MCP | Downstream |
| E4-2 | E4-2 | New bund modified from the design presented in the 2020 MCP | New |
| E4-3 | E4-2 | Modified from the design presented in the 2020 MCP and shortened by the E6 floodplain landform | New |
| E7-1 | E7-1 | Modified from the design presented in the 2020 MCP | New |
| E7-2 | - | Removed owing to the E6 backfill | - |

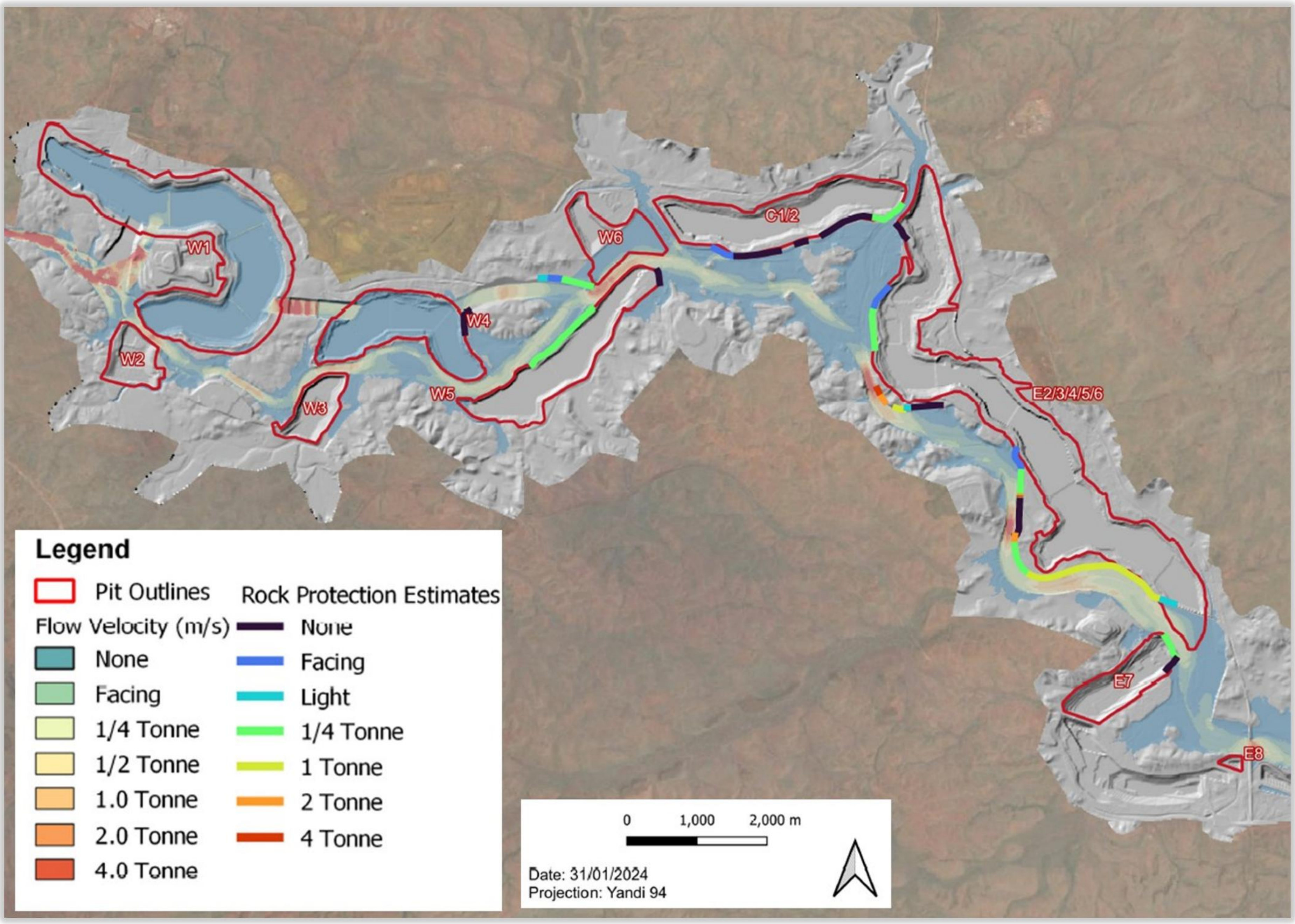
Source: Advisian (2024a)

*Scour protection*

Scour depths were estimated based on the hydraulic modelling outputs (peak velocities and depths) and particle size distribution data for the Marillana Creek alluvium (Section 5.2.4.2). The scour depth estimates in the primary low flow channels adjacent to the bunds were used to estimate the scour elevation (mAHD) which was then projected to the bund location (Figure 5-90). The flood bund rock protection will be extended to the scour elevation or until competent rock is encountered. The resulting rock protection requirements extend between 1.0 m and 4.5 m below ground level at each of the bund locations (Advisian, 2024a).




**Assessment of scour depths**




**Assessment of rock armour requirements**

Source: adapted from Advisian (2024a)

**Figure 5-90 Hydraulic modelling outputs used to inform flood bund design**

### *Rock protection*

Peak velocities from hydraulic modelling were used in combination with Austroads (1994) to determine rock armour requirements (Figure 5-90). This requires interpretation of flow velocities to consider the following factors:

- Distance from the low flow channel (and peak velocities within the channel) and the potential for the low flow channel to migrate towards the bund.
- Whether flows are parallel to the bund or impinging on the bund. Given a paucity of data supporting a different approach for impinging and parallel flows, this factor was generally not considered unless flow velocities were close to the boundary between two rock classes. In these cases, the lower rock class was selected for parallel flows and higher for impinging flows.
- Constructability of the bunds. Flow velocities can vary significantly along a bund, resulting in a different rock class every 20 to 50 m which adds to the complexity of construction. Therefore, rock classes were determined to minimise the number of different classes on each bund, whilst ensuring there is adequate protection.

### Geotechnical assessment

Seepage and geotechnical stability assessments were conducted for the following design (Advisian, 2023f):

- Single zone of compacted rockfill from selected / screened overburden and material from excavated from flood channels and diversions which:
  - Is classified as GM, GC, SM, SC as per AS 1289.
  - Is free of all organic and deleterious material.
  - Has a liquid limit less than 35% and a plasticity index less than 12%.
  - Contains at least 10% by weight of fractions finer than 0.075 mm.
  - Contains no material greater than 250 mm.
  - Has a compacted in-situ density >95% Standard Maximum Dry Density (SMDD).
- Crest width 5.0 m.
- Upstream and downstream batter of 1V:2.5H.
- Use of geotextile (A64 Bidim) on upstream face.
- Rock armour on upstream face as specified (including buried rock armour toe to protect against scour).
- Ballasting of crest and downstream face to manage erosion with thickening of the ballast cover to afford protection to the crest and downstream batter.
- Compaction of coarse alluvium where it is present within the foundation footprint, to minimise the risk of piping occurring between the bund fill and the underlying alluvium foundation.

### *Seepage assessments*

2-D seepage analyses were undertaken (using SEEP/W software, developed by GeoSlope International Ltd., Canada) and considered (Advisian, 2023f):

- The transient nature of a 1:10,000 AEP flood event using flood hydrographs derived from modelling conducted by Advisian (2024a).
- A groundwater level in the alluvium of 2 mbgl, based on site investigations. This groundwater level may represent a perched water table but has been conservatively assumed for all bunds for the purposes of the analysis.
- Permeability of alluvium ranging from $1x10^{-3}$ m/s to $1x10^{-5}$ m/s.

Eight type sections were selected across a variety of selected flood protection bunds with differing foundation conditions (Appendix G.4). The sections were selected based upon the anticipated foundation conditions, targeting in particular, circumstances where bunds are adjacent to pits where Marillana Creek alluvium intersects the pit walls. This was considered important in terms of assessing the need for any cut-off requirements along such flood protection bund sections (Advisian, 2023f).

The seepage results indicated that (Advisian, 2023f) (Table 5-82):

- For the flood protection bunds that straddle CID or BIF, the current design configuration satisfactorily manages seepage.
- The seepage modelling is very sensitive to the assumed alluvium permeability.
- Outflows into the pit wall at E1-1, E4-2A and E4-2B (where alluvium intersects the pit wall) are very significant and will require mitigation where permeabilities of $1x10^{-3}$ m/s are assumed. In these areas, mitigation may take the form of a cut-off trench below the flood protection bund or flattening the alluvium batter exposed in the pit wall and protecting it with a layer of rockfill.

**Table 5-82 Transient seepage results for selected flood bund sections**

| Section | Permeability (m/s) | Maximum Water Discharge at the Pit Wall (Downstream of Bund) ($m^3$/hr/m) |
|---|---|---|
| W5-1C | $10^{-3}$ | 0.73 |
| | $10^{-4}$ | 0.01 |
| | $10^{-5}$ | 0.00 |

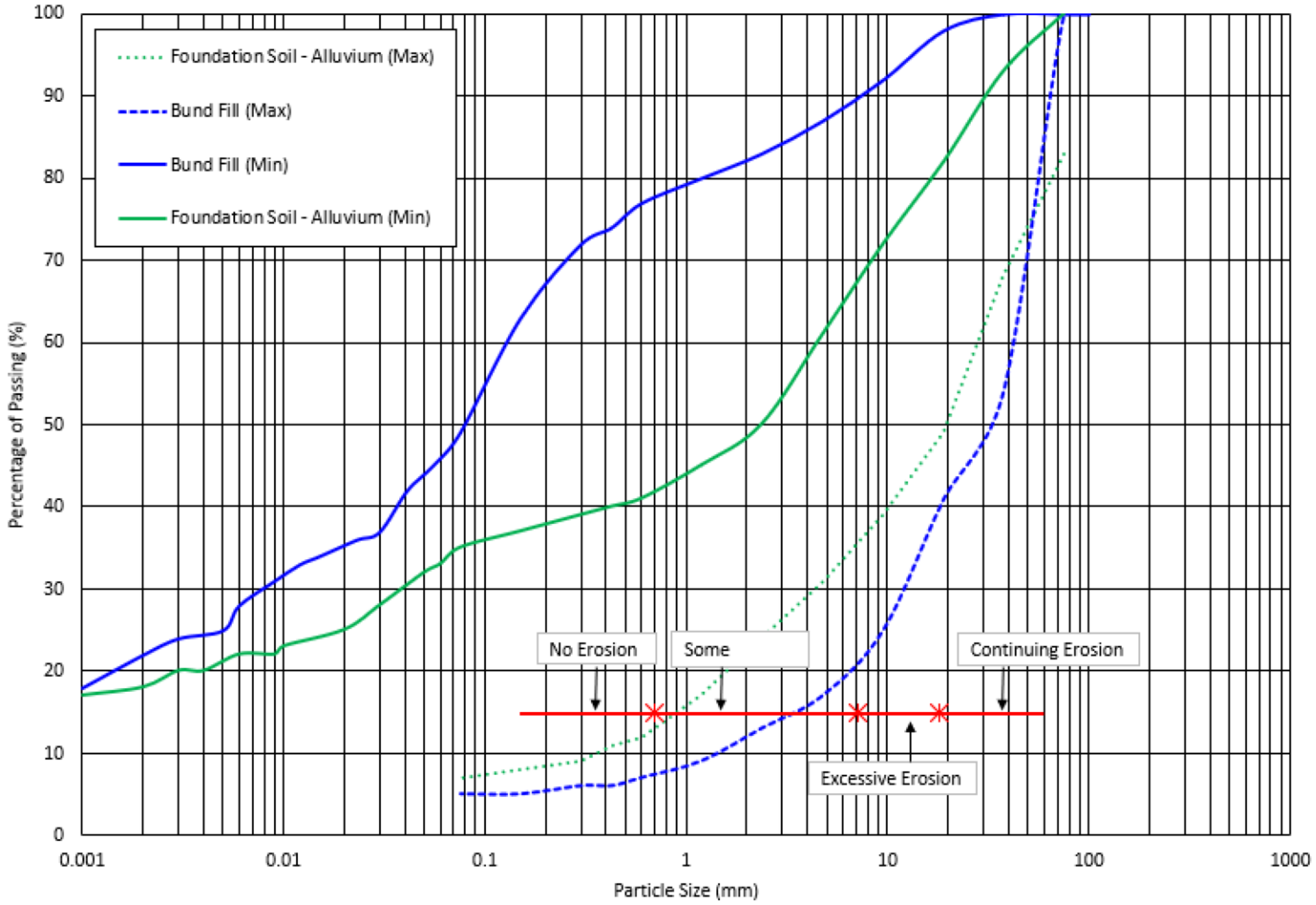
| Section | Permeability (m/s) | Maximum Water Discharge at the Pit Wall (Downstream of Bund) ($m^3$/hr/m) |
|---|---|---|
| C1/2-1 | $10^{-3}$ | - |
| | $10^{-4}$ | - |
| | $10^{-5}$ | - |
| E1-1 | $10^{-3}$ | 4.23 |
| | $10^{-4}$ | 0.10 |
| | $10^{-5}$ | 0.00 |
| E1-4 | $10^{-3}$ | - |
| | $10^{-4}$ | - |
| | $10^{-5}$ | - |
| E4-1 | $10^{-3}$ | - |
| | $10^{-4}$ | - |
| | $10^{-5}$ | - |
| E4-2A | $10^{-3}$ | 2.33 |
| | $10^{-4}$ | 0.59 |
| | $10^{-5}$ | 0.02 |
| E4-2B | $10^{-3}$ | 3.67 |
| | $10^{-4}$ | 0.17 |
| | $10^{-5}$ | 0.01 |
| E7 | $10^{-3}$ | - |
| | $10^{-4}$ | - |
| | $10^{-5}$ | - |

Source: Advisian (2023f)

*Potential for piping*

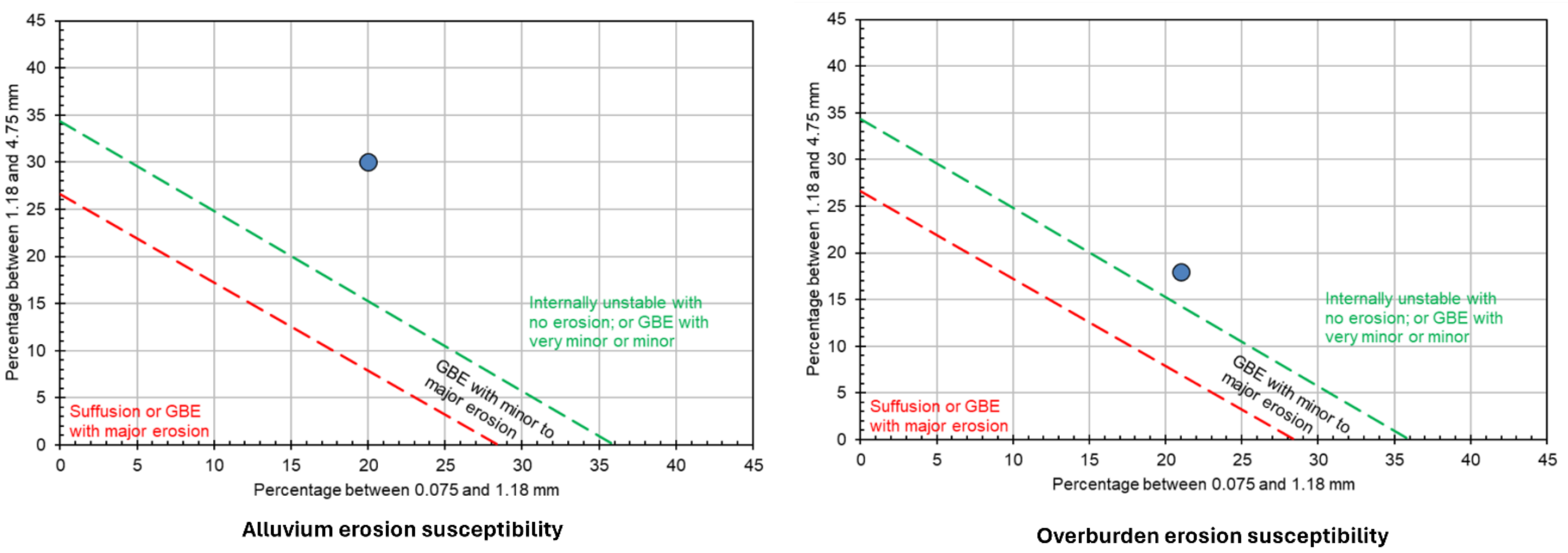
Although the flood protection bunds have been designed to mitigate transient flood water levels for the 1:10,000 AEP event, and hence do not have a requirement for a filter or clay core, a filter compatibility assessment was conducted to ensure that the proposed flood protection bund material does not pipe or erode into the underlying, coarse-grained alluvium. The assessment used the characteristic grading envelopes for the alluvium and overburden materials (Figure 5-91) and indicated that the flood protection bund fill may undergo limited erosion ("Some Erosion") where the coarser alluvium will be encountered in the foundation footprint. In these instances, compaction of the coarser alluvium, where it occurs within the flood protection bund foundation footprint, will be required (Advisian, 2023f).

The grading of alluvium and overburden materials (Figure 5-92), suggests that neither the alluvium nor overburden materials are pre-disposed to piping.




Source: Advisian (2023f)

**Figure 5-91 Filter compatibility assessment for internal erosion**




Source: Advisian (2023f)

**Figure 5-92 Erosion susceptibility**

### *Uplift pressures*

The critical hydraulic gradient for a variety of bund sections was assessed to evaluate the risk of uplift pressure on the downstream side of the flood protection bunds, particularly where thick alluvium underlies the bunds. The assessment used the results of the seepage modelling (Table 5-82) and assumed an alluvium permeability of between 1 x $10^{-3}$ m/s and 1 x $10^{-5}$ m/s. The preliminary results show that this risk is low (Advisian, 2023f).

### *Liquefaction screening assessment*

A review of the available information indicates that the alluvium encountered below the proposed flood protection bunds comprises predominantly cohesionless soils (sands / gravels) of loose to medium dense consistency. In the presence of a shallow water table, these materials could be susceptible to liquefaction under seismic loading. Preliminary screening of the alluvium, based on the particle size distribution in Section 5.2.4.2, indicates that the material is unlikely to be susceptible to liquefaction (2023f).

### *Stability analysis*

Slope stability analyses were performed for static and seismic scenarios using (Advisian, 2023f):

- Peak ground acceleration of 0.12 g.
- Transient flood conditions modelled from the predicted position of the phreatic surface during flooding, as determined from the seepage modelling (Table 5-82).
- A range of permeabilities for the alluvium from 1 x $10^{-3}$ m/s to 1 x $10^{-5}$ m/s.
- No rock armour.

The analysis included an assessment of the stability of the flood protection bunds (upstream and downstream batters) as well as an assessment of the alluvium exposed within the pit walls to understand the impact of seepage on the stability of slopes at these locations. The study concluded that (Table 5-83) (Advisian, 2023f):

- The proposed batter angles for the flood protection bunds (upstream and downstream batters) meet the basis of design requirements for static (FoS ≥1.5) and seismic (FoS ≥1.2) loading conditions.
- For sections where alluvium intersects the pit wall at W5, E1 and a local section of E4 (E4-2B), the stabilities of the pit slope batters intersecting the alluvium, do not meet the conditions for the basis of design (based upon the assumed seepage parameters adopted for the sensitivity analysis of the alluvium). Further evaluation of mitigation measures is required and could include a cut-off trench as part of the bund design or rockfill over the pit crest to improve stability of the batter slope where the alluvium is exposed.

**Table 5-83 Slope stability analysis - flood bunds**

| Section | Alluvium Permeability m/s | Seismic Condition $FoS_{min}$ = 1.2 | | | Static Condition $FoS_{max}$ = 1.5 | | |
|---|---|---|---|---|---|---|---|
| | | Bund Upstream | Bund Downstream | Pit wall Intersected by Alluvium | Bund Upstream | Bund Downstream | Pit wall Intersected by Alluvium |
| W5-1C | $10^{-3}$ | 1.99 | 2.04 | 0.92 | 2.37 | 2.4 | 1.02 |
| | $10^{-4}$ | 2.05 | 2.05 | 0.94 | 2.39 | 2.4 | 1.04 |
| | $10^{-5}$ | 2.04 | 2.05 | 0.95 | 2.40 | 2.40 | 1.07 |
| C1/2-1 | $10^{-3}$ | 1.87 | 1.69 | - | 2.19 | 1.99 | - |
| | $10^{-4}$ | 1.89 | 1.97 | - | 2.22 | 2.31 | - |
| | $10^{-5}$ | 1.97 | 1.97 | - | 2.31 | 2.31 | - |
| E1-1 | $10^{-3}$ | 1.94 | 1.88 | 1.12 | 2.28 | 2.21 | 1.28 |
| | $10^{-4}$ | 1.94 | 1.90 | 1.21 | 2.28 | 2.23 | 1.37 |
| | $10^{-5}$ | 1.94 | 1.89 | 1.32 | 2.28 | 2.23 | 1.56 |
| E1-4 | $10^{-3}$ | 1.84 | 1.87 | - | 2.21 | 2.18 | - |
| | $10^{-4}$ | 1.86 | 1.94 | - | 2.23 | 2.27 | - |
| | $10^{-5}$ | 1.79 | 1.94 | - | 2.08 | 2.27 | - |
| E4-1 | $10^{-3}$ | 2.06 | 1.50 | - | 2.46 | 1.78 | - |
| | $10^{-4}$ | 1.99 | 1.83 | - | 2.44 | 2.16 | - |
| | $10^{-5}$ | 1.89 | 1.88 | - | 2.35 | 2.21 | - |

| Section | Alluvium Permeability m/s | Seismic Condition $FoS_{min}$ = 1.2 | | | Static Condition $FoS_{max}$ = 1.5 | | |
|---|---|---|---|---|---|---|---|
| | | Bund Upstream | Bund Downstream | Pit wall Intersected by Alluvium | Bund Upstream | Bund Downstream | Pit wall Intersected by Alluvium |
| E4-2A | $10^{-3}$ | 2.08 | 1.76 | 2.11 | 2.44 | 2.08 | 2.56 |
| | $10^{-4}$ | 2.08 | 2.05 | 2.08 | 2.47 | 2.41 | 2.56 |
| | $10^{-5}$ | 2.07 | 2.06 | 2.09 | 2.44 | 2.41 | 2.55 |
| E4-2B | $10^{-3}$ | 2.18 | 1.73 | 1.26 | 2.52 | 1.99 | 1.38 |
| | $10^{-4}$ | 2.14 | 1.73 | 1.33 | 2.52 | 1.99 | 1.47 |
| | $10^{-5}$ | 2.1 | 1.74 | 1.33 | 2.52 | 2.06 | 1.49 |
| E7 | $10^{-3}$ | 1.91 | 1.59 | - | 2.25 | 2.2 | - |
| | $10^{-4}$ | 1.93 | 1.81 | - | 2.27 | 2.11 | - |
| | $10^{-5}$ | 1.93 | 2.16 | - | 2.27 | 2.15 | - |

Source: Advisian (2023f)

#### 5.14.8.5 Knowledge gaps & forward work program

The following studies are required to further develop the:

- Floodplain landform designs:
  - Inspection of remnant CID in the floodplain locations, and further geotechnical stability assessments.
  - Settlement modelling to estimate the depth of settlement following closure.
  - Further hydraulic modelling and design optimisation to manage the risk of scour and erosion.
  - Consideration of the interaction of the W6 floodplain landform with Herbert's Creek land bridge design for closure (refer to Section 5.14.10).
- Flood bund designs:
  - Further geotechnical inspections / investigations and analysis of new or existing flood bund locations where further data is required, including assessment of:
    - The impact of seepage through the alluvium where it intersects the pit wall.
    - The potential for dissolution of the calcareous materials of the Oakover Formation.
    - The condition of the CID where flood bunds are proposed to be constructed on this material.
  - Detailed investigation and assessment of existing minor flood bunds.
  - Further hydraulic analysis and scour modelling, including a sensitivity analysis for design flows and consideration of scour from more frequent events in tributaries without backwater impacts from Marillana Creek.
  - Confirmation, or otherwise, of the suitability of in-situ material along pit crests to retain a 1:10,000 AEP event without the need for additional flood bunds.
  - Optimisation of the tie in of flood bunds with existing creek and floodplain surfaces to minimise local scour and erosion and ensure avoid impacts to heritage features during construction.
  - Assessment of the need for erosion protection for the backslope (downstream slope) of bunds.

### 5.14.9 Minor and intermediate diversions

Since the 2020 MCP, several modifications have been made to the surface water design for closure (modification to flood channels and introduction of floodplain landforms) which impacts the requirement for new / modified minor and intermediate diversions. As part of the Yandi closure SPS, Advisian (2024a) conducted a review of these minor and intermediate diversions based on the outcomes of a site visit and updated hydraulic modelling. This section summarises the outcomes of this review by feature (refer to Map 5-33), except for:

- Herbert's Creek land bridge which is discussed in Section 5.14.10.
- W1 diversion. The W1-SP0 flood channel has been realigned, and additional geotechnical investigations are required in the eastern portion of the alignment near the inlet where it intersects the creek redirected by the W1 diversion. This diversion is relatively minor as it does not pose a risk to pit stability and will be reviewed in further detail as designs progress.

It should be noted that the information in this section represents an advance in the designs reported in the 2020 MCP, but further work is required to refine designs as data is collected on geotechnical conditions, and the overall surface water infrastructure design for closure progresses.

**Summary**

Hydraulic modelling has been conducted to inform the upgrades of existing diversions and designs of new diversions for closure. In accordance with BHP's risk-based process (Section 9.1.2), intermediate diversions are designed to accommodate a 1:1,000-year (0.1% AEP) event and minor diversions a 1:100-year (1% AEP) event.

***Intermediate diversion***

The **W3 (Lamb Creek)** diversion is an intermediate diversion and redirects Lamb Creek around the western edge of the W3 Pit. The existing diversion includes near right angled turns around the pit. Design modifications are constrained by the pit edge and tenement boundary. A design that widens the channel to 140 m on the south to north alignment was assessed and accommodated a modelled 1:1,000-year event within the diversion. However, there was no freeboard, and the velocities remained very high (>6 m/s) where the diversion turns north around the pit, despite the assessment of several design configurations in the hydraulic model. Further assessment is required in future design phases.

***Minor diversions***

The **W4 diversion** has not yet been constructed and will be required to redirect flows past the northern boundary of W4 Pit into the W4-SP4 flood channel. Hydraulic modelling of the design indicates that the flow velocities would be generally low, and depending on the material in the system, may represent a low erosion risk. This diversion has been impacted by the realignment of the W4-SP4 flood channel, and further work is required to optimise the design at the confluence with the flood channel where a drop of several meters presents an erosion and head-cutting risk.

The existing **W2 diversion** conveys flow from the catchment upstream of W2, south and east to Marillana Creek. Options for modifying the diversion channel are limited by the tenement boundary and distance to Marillana Creek. However, a design adjusting the channel width to 60 m would result in velocities typically less than 2 m/s, except at the upstream end of the diversion where the confined natural channel enters, and high velocity flows would be directed at the bund protecting the pit. Modifications to manage this issue will be considered in future design phases.

The **W5 West diversion** redirects a minor creek around the western side of W5. A site inspection noted several areas of erosion within the diversion channel, which would be anticipated as the material adjacent to the pit is highly weathered dolerite and BIF. More competent CID is located closer to the pit edge, though the extent is limited. The maximum modelled velocity within the diversion would be reduced to around 2.2 m/s if the channel is widened to a typical width of 40 m, which would help reduce risk of lateral channel migration and need for rock protection. The need for channel widening is dependent on the cut material properties which will need to be confirmed in future design phases.

The **W5 East diversion** replicates a pre-mining creek that partially flowed over the W5 Pit footprint before discharging into Marillana Creek downstream of the pit. During a site visit, significant erosion was identified through the channel and, as the diversion is within 30 m of the pit crest, there is an inherent risk of the channel migrating towards the pit. Hydraulic modelling showed that if the diversion channel width is increased to 65 m, flow velocities would be generally below 2.5 m/s with two small reaches around 3.0 m/s. The higher velocity hot spots will be addressed in future design phases.

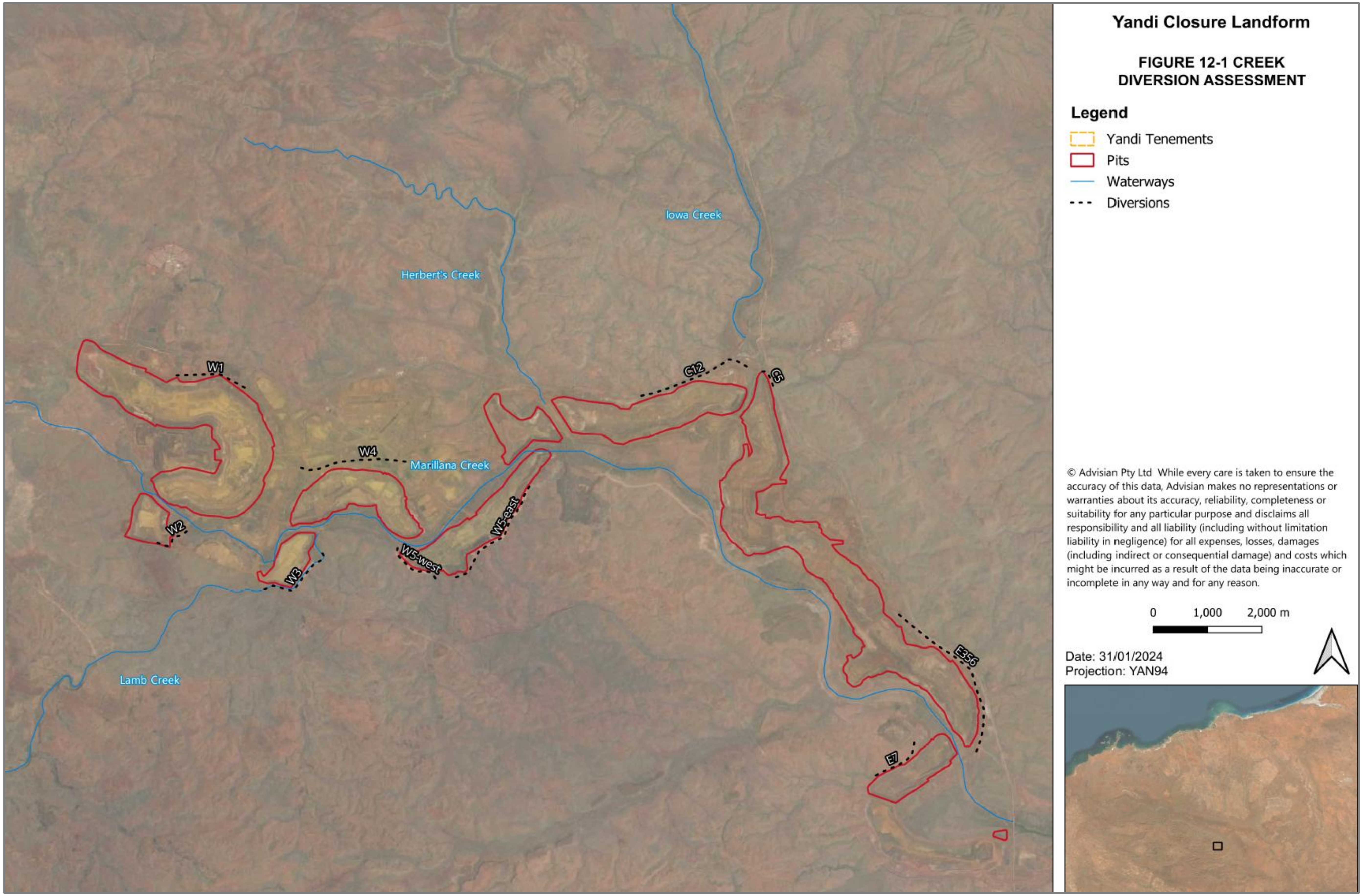
The **C1/2 diversion** is an operational diversion north of the C1/2 Pit that conveys catchment flows east to Iowa Creek, upstream of the natural land bridge. Modelled velocities along the diversion are generally low. The key risk area is at the downstream end of the channel, near the confluence with Iowa Creek where flows will intersect the backfill of C6 Pit. This backfilled area will need to be designed to prevent uncontrolled flows into the C1/2 Pit.

The **C5 diversion** diverts flows around the northern end of Pit C5. Site visits have identified locations where weathered dolerite exposed in the bed and banks has eroded during flood events, resulting in undercutting and significant slope failures. A section of the diversion channel has migrated north. Hydraulic modelling has identified two sections of high velocity, upstream and downstream of the actively eroding section. Modelled velocities would be generally below 2.5 m/s if the diversion is widened to 35 m which reduces the potential for erosion. However, the presence of erodible material may require additional treatments which will be investigated during future design phases.

The existing **E3/5/6 diversion** flows north to south between the E3/5/6 Pit and BHP rail, conveying runoff from several minor catchments. The diversion is located at the foot of surrounding hills, limiting opportunities to modify the planform design. Hydraulic modelling shows that widening the downstream reach of the diversion to 50 m would reduce maximum flow velocities to below 2 m/s which reduces erosion risks. Opportunities for tying the diversion channel in with the E6 floodplain landform and developing a more natural form will be considered during future design phases.

The **E7 diversion** intercepts a creek which prior to mining, would flow through the pit footprint and discharge to Marillana Creek. The existing diversion is largely constrained by the pit edge and adjacent steep topography. Hydraulic modelling shows minimal variation in the flow velocities through the diversion channel. At the downstream end, as the diversion moves away from the pit, the flow velocities increase prior to dispersing at Marillana Creek. Widening the diversion in this location from 25 m to 40 m would reduce modelled velocities to approximately 2.0 m/s. The potential for erosion through this reach is dependent on the local material and design phases will confirm the materials present.

Further studies (hydrological, hydraulic, geomorphological and geotechnical) are required to optimise diversion designs including consideration of the potential to achieve more natural looking systems.




Source: Advisian (2024a)

**Map 5-33 Minor and intermediate creek diversions**

#### 5.14.9.1 Basis of design

Table 5-84 provides the basis of design for minor and intermediate creek diversions, which is based on BHP's risk-based approach outlined in Section 9.1.2.

**Table 5-84 Minor & intermediate diversion basis for design**

| Significance of structure* | Design criteria |
|---|---|
| Intermediate diversion | Accommodate predicted flow rates for the 1:1,000-year flood event (0.1% AEP) |
| Minor diversion | Accommodate predicted flow rates for the 1:100-year flood event (1% AEP) |
| All | Include rock protection (where required) to prevent against scour and erosion from respective design flood events. Rock sizes will be based on rock classes in Austroads (1994) |
| | Diversion design bank slope FoS ≥1.5 for overall slope stability under static conditions and ≥1.2 under seismic conditions |

Source: Advisian (2024a)

*Notes: significance of structure has been defined based on BHP's risk-based approach outlined in Section 9.1.2

#### 5.14.9.2 Intermediate diversion

**W3 (Lamb Creek) diversion**

The W3 diversion redirects Lamb Creek around the western edge of the W3 Pit and includes near right angled turns around the pit. The operational diversion has been designed for the 1% AEP event, but as Lamb Creek is one of the intermediate tributaries of Marillana Creek, the W3 diversion requires an upgrade to convey the 0.1% AEP event at closure. The diversion is located close to the pre-mining Lamb Creek alignment, and the basic geomorphic features are similar (Table 5-85).

**Table 5-85 Comparison of the W3 diversion characteristics with those of the pre-mining creek**

| Parameter | Pre-Mining Creek | W3 Diversion |
|---|---|---|
| Creek Length (m) | 2,095 | 2,390 |
| Slope | 0.004 | 0.004 |
| Sinuosity | 1.06 | 1.04 |
| Typical Channel Width (m) | 90 | 84 |
| Maximum 0.1% AEP Velocity (m/s) | | 6.7 |

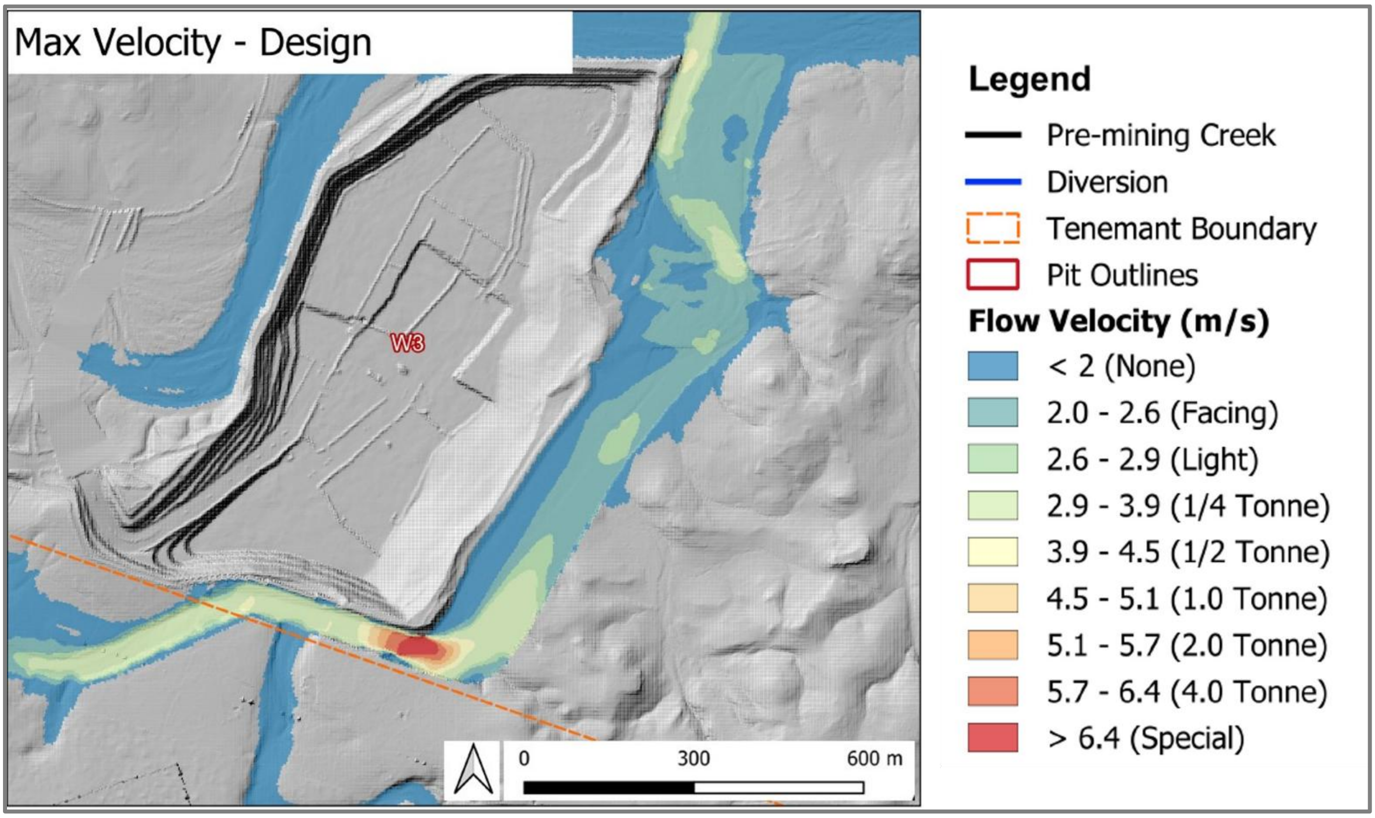
Source: Advisian (2024a)

The existing design results in high velocities and overtopping of the existing flood bund in a 0.1% AEP event. Design modifications are constrained by the pit edge and tenement boundary and hence, the design can only be modified by widening the channel to 140 m on the south to north alignment (Advisian, 2024a).

Hydraulic modelling of the modified design indicated that (Advisian, 2024a):

- The velocity at the location of the existing bund would remain at ~4 m/s and the impinging direction of the flow will need to be considered during more detailed design phases.
- Velocities would remain very high (>6 m/s) where the diversion turns north around the pit, despite several design configurations being assessed in the hydraulic model. Previous geotechnical investigations have noted that this area is colluvium over CID, and further investigations are required to assess:
  - The condition of the CID for exposure to high flow velocities.
  - The need for rock protection.
- Following widening, the upstream bund would not overtop, however there is no freeboard for the design event (0.1% AEP) and, therefore, modifications will be considered during more detailed design phases.

The competency of the geology will need to be assessed in the constricted sections of diversion cut that cannot be widened, along with the peak velocities to evaluate scour, erosion, risk of lateral channel migration, and whether rock protection is required (Advisian, 2024a).




Source: adapted from Advisian (2024a)

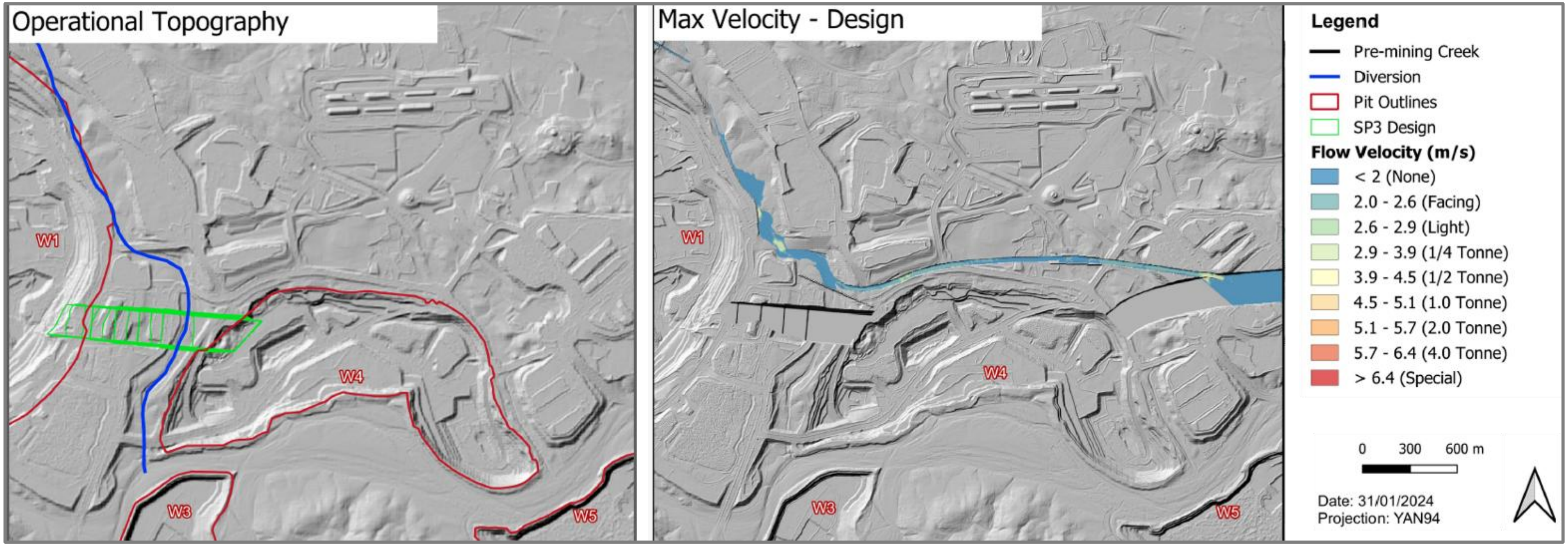
**Figure 5-93 Modelled velocities in widened W3 creek diversion (1:1,000-year event)**

#### 5.14.9.3 Minor diversions

**W4 diversion**

The W4 diversion has not yet been constructed and will be required to redirect flows past the northern boundary of W4 into the W4-SP4 flood channel (Figure 5-94). Hydraulic modelling indicates that the flow velocities are generally low (Figure 5-94), and depending on the material in the system, may represent a low erosion risk.

The design of this diversion has been impacted by the realignment of the W4-SP4 flood channel (Section 5.14.7.3) and further work is required to optimise the design at the confluence with the flood channel. In this location, there is a drop of several meters from the diversion into the flood channel which presents an erosion and head-cutting risk. Opportunities for varying the morphology to achieve a more natural looking system will also be considered.




Source: adapted from Advisian (2024a)

**Figure 5-94 W4 diversion velocities in a 1:100-year event**

## W2 diversion

The existing W2 diversion conveys flow from the catchment upstream of W2, south and east to Marillana Creek. The characteristics of the diversion compared to the pre-mining alignment are outlined in Table 5-86.

**Table 5-86 Comparison of W2 diversion characteristics with those of the pre-mining creek**

| Parameter | Pre-Mining Creek | W2 Diversion |
|---|---|---|
| Creek Length (m) | 560 | 520 |
| Slope | 0.007 | 0.004 |
| Sinuosity | 1.090 | 1.049 |
| Typical Channel Width (m) | 33 | 25 |
| Maximum 1% AEP Velocity (m/s) | - | 4.7 |

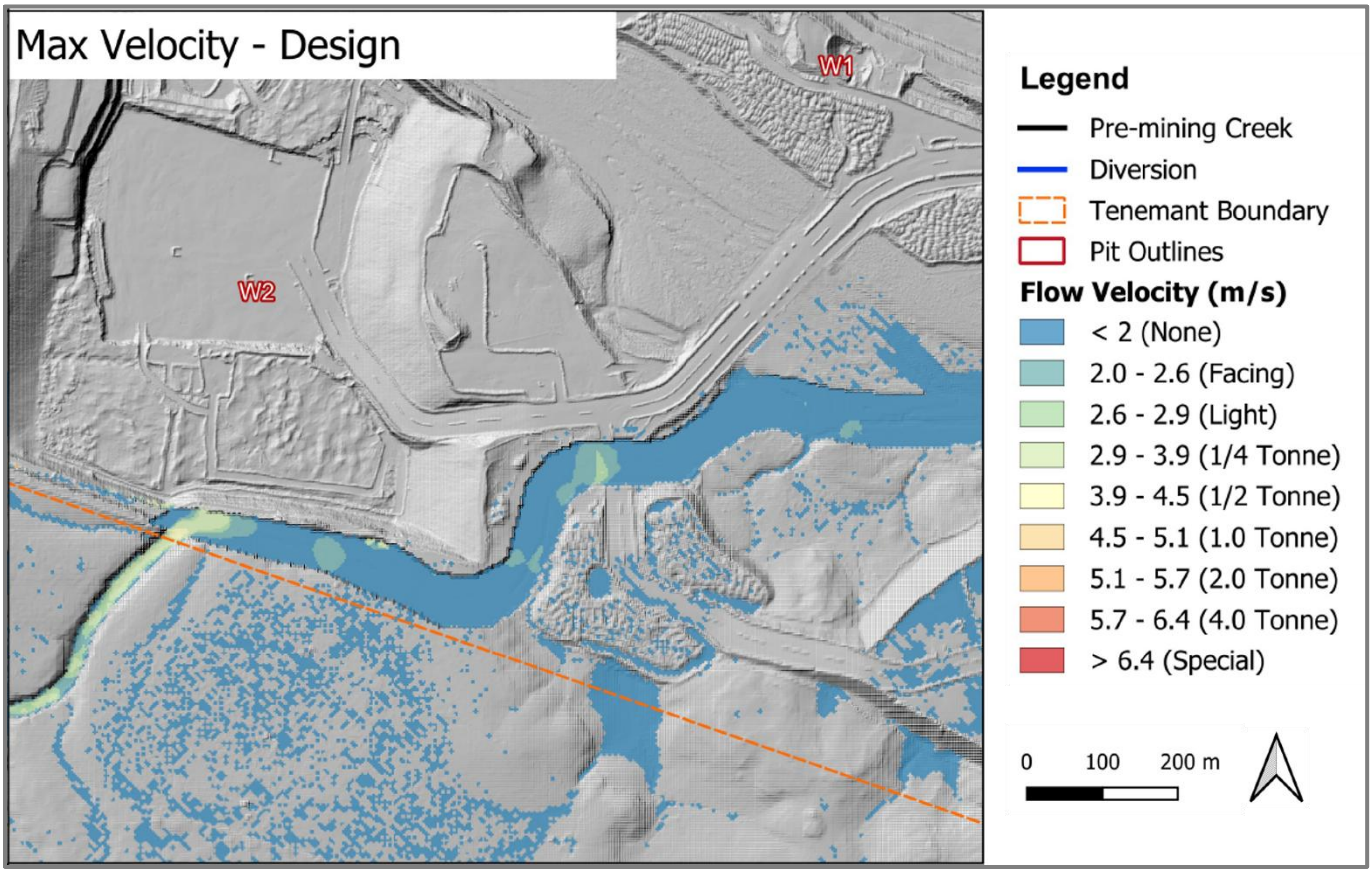
Source: Advisian (2024a)

Immediately upstream of the diversion, the creek is largely constrained by geology, and has a deep, narrow, channel with no vegetation. The diversion channel retains this narrow width to the Marillana Creek confluence, and the bank material consists of weathered dolerite in places, and CID in the section of deepest cut. The deepest section of cut which is adjacent to the flood bund, has CID exposed at the surface of the bed.

Hydraulic modelling of the existing design identified velocities greater than 4 m/s at several locations. Options for modifying the diversion channel are limited by the tenement boundary and distance to Marillana Creek, but the channel width design was adjusted to 60 m and modelled velocities were:

- Typically, less than 2 m/s (Figure 5-95) which significantly reduces the potential for erosion.
- High at the upstream end of the diversion where the confined natural channel enters, and flows are directed at the bund protecting the pit.

Modifications to manage the high velocities at the upstream end of the diversion will be considered in future design phases along with options for encouraging vegetation growth similar to the natural analogue upstream.




Source: Advisian (2024a)

**Figure 5-95 Modelled velocities in widened W2 creek diversion (1:100-year event)**

### W5 West diversion

The W5 West diversion redirects a minor creek around the western side of W5. The characteristics of the diversion compared to the pre-mining alignment are outlined in Table 5-87. A site inspection indicated that limited alluvium and trees are present within the central section of the diversion where there is a deeper cut and bedrock exposed at the base of the channel (Advisian, 2024a).

**Table 5-87 Comparison of W5 West diversion characteristics with those of the pre-mining creek**

| Parameter | Pre-Mining Creek | W5 Diversion |
|---|---|---|
| Creek Length (m) | 670 | 1,062 |
| Slope | 0.010 | 0.003 |
| Sinuosity | 1.014 | 1.025 |
| Typical Channel Width (m) | 32 | 24 |
| Maximum 1% AEP Velocity (m/s) | - | 3.25 |

Source: Advisian (2024a)

The pre-mining creek has a steeper grade and shorter length when compared with the operational diversion channel, however, the W5 diversion channel is narrower. A site inspection in August 2023, noted several areas of erosion within the diversion channel, which would be anticipated as the material adjacent to the pit is highly weathered dolerite and BIF. More competent CID is located closer to the pit edge, though the extent is limited. Hydraulic modelling identified (Advisian, 2024a):

- Areas with elevated hydraulics in locations where site observations indicate a potential risk of lateral channel migration and pit capture.
- That the maximum velocity within the diversion would be reduced to around 2.2 m/s if the channel is widened to a typical width of 40 m. This would help reduce risk of lateral channel migration and need for rock protection.

The need for channel widening is dependent on the cut material properties which will need to be confirmed in future design phases. Available information indicates that highly weathered BIF and dolerite are likely to be present throughout the diversion widening and locally, distinctly weathered Weeli Wolli materials may be encountered in areas of deeper cut (Advisian, 2023f; 2024a).

### W5 East diversion

The W5 East diversion replicates a pre-mining creek that partially flowed over the W5 Pit footprint before discharging into Marillana Creek downstream of the pit. The diversion channel ties back into the natural creek approximately 1 km upstream of the Marillana Creek confluence. A comparison of the geomorphic features of the pre-mining creek and diversion is provided in Table 5-88 and indicates that the geomorphic parameters for the pre-mining creek and diversion are similar. For both systems, deep alluvium is unlikely to form, and vegetation would not be expected to develop throughout the steeper sections.

**Table 5-88 Comparison of the W5 East diversion characteristics with those of the pre-mining creek**

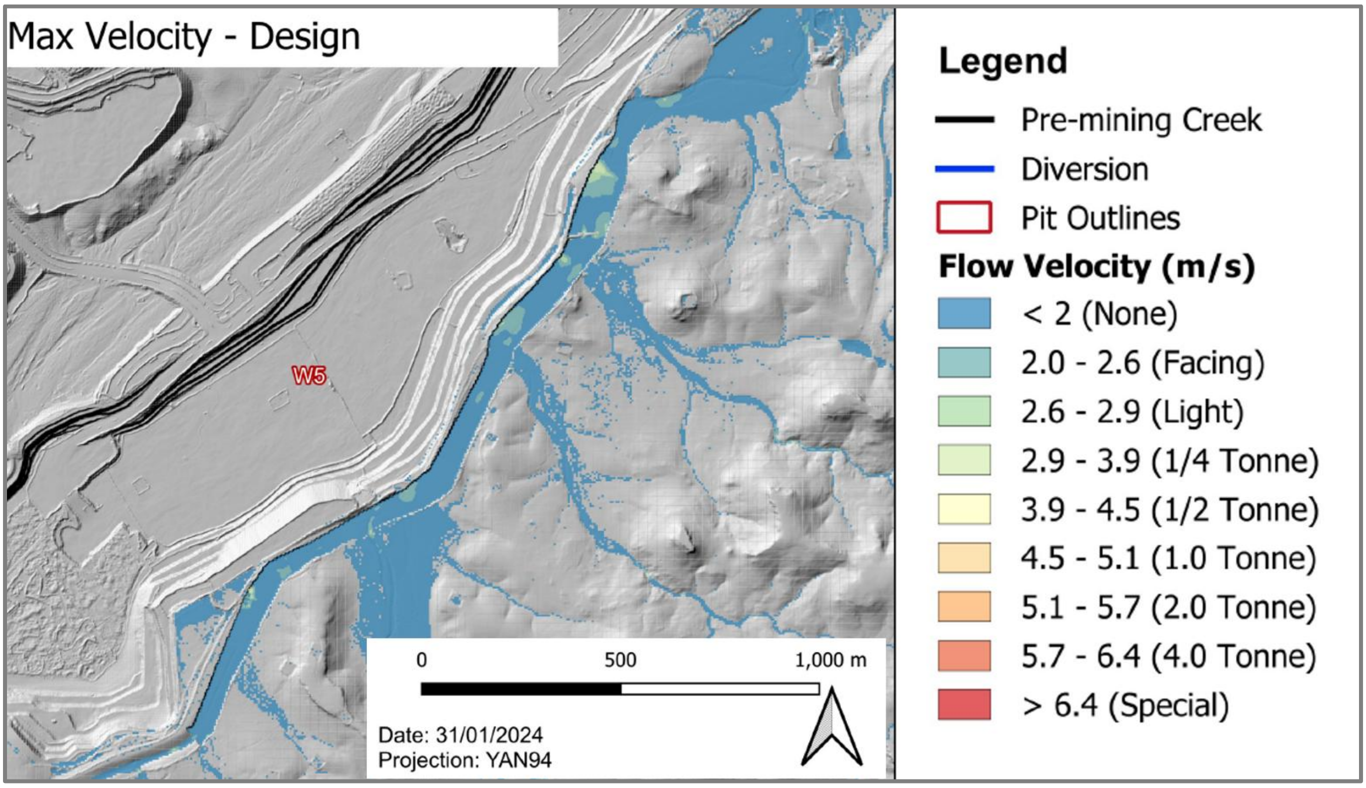
| Parameter | Pre-Mining Creek | Operational Diversion |
|---|---|---|
| Creek Length (m) | 1,360 | 1,280 |
| Slope | 0.008 | 0.007 |
| Sinuosity | 1.07 | 1.01 |
| Typical Channel Width (m) | 33 | 24 |
| Maximum 1% AEP Velocity (m/s) | - | 5.8 |

Source: Advisian (2024a)

During a site visit in August 2023, significant erosion was identified through the channel and, as the diversion is within 30 m of the pit crest, there is an inherent risk of the channel migrating towards the pit. As the diversion has a similar sinuosity and slope to the pre-mining creek, widening the channel was determined to be the most effective modification to reduce velocities and associated erosion risks.

Hydraulic modelling shows that if the diversion channel width is increased to 65 m, flow velocities would be generally below 2.5 m/s with two small reaches around 3.0 m/s (Figure 5-96).

The higher velocity hot spots will be addressed in future design phases and options will be considered to modify the channel morphology to encourage deposition of alluvial material and increase habitats.




Source: Advisian (2024a)

**Figure 5-96 Modelled velocities in widened W5 East creek diversion (1:100-year event)**

### C1/2 diversion

The C1/2 diversion is an operational diversion north of the C1/2 Pit, that conveys catchment flows east to Iowa Creek, upstream of the natural land bridge. Prior to mining, these catchments flowed north to south, either to Herbert's Creek or through the C1/2 Pit footprint to Iowa Creek downstream of the land bridge. The C1/2 diversion acts as a cut-off drain that is orientated perpendicular to the pre-mining flows (Advisian, 2024a).

The key risk area is at the downstream end of the channel, near the confluence with Iowa Creek. The diversion flows (with low velocities) over the proposed C6 Pit which is assumed to be backfilled at closure. The backfill design, will be developed during future design phases to prevent uncontrolled flows into the C1/2 Pit (Advisian, 2024a).

As the velocities along the C1/2 diversion are low, modifications would be limited to aesthetic improvements that may be considered during future design phases to make the channel appear more natural (Advisian, 2024a).

### C5 diversion

The C5 diversion diverts flows around the northern end of Pit C5, where the pre-mining creek flowed east to west across the pit footprint. A comparison of the geomorphic features of the pre-mining creek and diversion is provided in Table 5-89

**Table 5-89 Comparison of the C5 diversion characteristics with those of the pre-mining creek**

| Parameter | Pre-Mining Creek | C5 Diversion |
|---|---|---|
| Creek Length (m) | 529 | 498 |
| Slope | 0.006 | 0.003 |
| Sinuosity | 1.07 | 1.10 |
| Typical Channel Width (m) | 40 | 15 |
| Maximum 1% AEP Velocity (m/s) | - | 4.1 |

Source: Advisian (2024a)

Site visits have previously identified locations where weathered dolerite exposed in the bed and banks has eroded during flood events, resulting in undercutting and significant slope failures. Steep banks and collapsed blocks, typical of undercutting by frequent flows, indicate erodible material and an unstable system. A section of the diversion channel has migrated north. Hydraulic modelling has identified two sections of high velocity, upstream and downstream of the actively eroding section. If the diversion is widened to 35 m, hydraulic modelling indicates that velocities would be generally below 2.5 m/s which reduces the potential for erosion. However, the presence of erodible material within the diversion may require additional treatments, which will be investigated during future design phases.

#### E3/5/6 diversion

The existing E3/5/6 diversion flows north to south between the pit and BHP rail, conveying runoff from several minor catchments. The diversion, therefore, acts as a cut-off drain which is significantly longer than the pre-mining creeks and does not have a natural analogue.

The diversion is located at the foot of surrounding hills, limiting opportunities to modify the planform design. Hydraulic modelling indicates that flow velocities increase significantly (>3 m/s) in the final 1 km of the diversion before the confluence with Marillana Creek. This reach receives flows from additional tributaries but has the same width as upstream reaches of the diversion.

Hydraulic modelling shows that widening the downstream reach of the diversion to 50 m would reduce maximum flow velocities to below 2 m/s which reduces erosion risks. During future design phases:

- The presence of erodible material will be confirmed so any necessary design modifications can be made.
- Opportunities for tying the diversion channel in with the E6 floodplain landform and developing a more natural form will be considered.

#### E7 diversion

The E7 diversion is an operational diversion that intercepts a creek which, prior to mining, would flow through the pit footprint and discharge to Marillana Creek. The diversion intercepts the creek and diverts flows north of the E7 Pit to Marillana Creek. A comparison of the geomorphic features of the pre-mining creek and diversion is provided in Table 5-90.

**Table 5-90 Comparison of the E7 diversion characteristics with those of the pre-mining creek**

| Parameter | Pre-Mining Creek | E7 Diversion |
|---|---|---|
| Creek Length (m) | 2,730 | 2,640 |
| Slope | 0.008 | 0.007 |
| Sinuosity | 1.21 | 1.08 |
| Typical Channel Width (m) | 35 | 25 |
| Maximum 1% AEP Velocity (m/s) | - | 3.5 |

Source: Advisian (2024a)

The existing diversion is largely constrained by the pit edge and adjacent steep topography. Hydraulic modelling shows minimal variation in the flow velocities through the straight diversion channel. At the downstream end, as the diversion moves away from the pit, the flow velocities increase prior to dispersing at Marillana Creek. Hydraulic modelling shows that widening the diversion in this location from 25 m to 40 m would reduce the velocities to approximately 2.0 m/s. The potential for erosion through this reach is dependent on the local material, and future design phases will confirm the materials present. Opportunities for improving the natural aesthetic of the diversion are limited by the space available between the pit and steeper topography. Creating meanders and variable cross-section morphology in the straight section of the diversion would require significant cut material for minimal gain.

### 5.14.9.4 Knowledge gaps & forward work program

The following studies are required to further develop the diversion designs:

- Complete hydrological, hydraulic, geomorphological and geotechnical assessments to inform diversion designs, including collection of additional geotechnical information, as required.
- Optimise diversion designs including consideration of:
  - The risk of lateral channel migration.
  - Geomorphology and:
    - The potential to achieve more natural looking systems.
    - Erosion and deposition processes.
  - Establishment of riparian vegetation.
  - Diversions that require additional measures to manage erosion and increase capacity (e.g., W3, W2, W5 East, C5).
- Design the tie in of the W4 diversion with the W4-SP4 flood channel as this design is optimised.
- Determine the W1 diversion (south of W1) tie-in with the W1-SP0 following optimisation of flood channel design.
- Optimise the configuration of C1/2 diversion as the backfill designs for C6 are progressed.

## 5.14.10 Herbert's Creek land bridge

Herbert's Creek land bridge diversion was constructed in 2018 and conveys water from Herbert's Creek over C1/2 Pit. Inspections and monitoring have identified that design modifications are required for closure. There have also been several design changes to the overall surface water management system for closure that will impact the final design for this land bridge. This section summarises:

- The current land bridge design (Section 5.14.10.1).

- Information arising from inspections and performance assessments (Section 5.14.10.2).
- Landform evolution modelling conducted to inform the closure design (Section 5.14.10.3).
- Changes to the overall surface water management designs that influence the closure design of the land bridge (Section 5.14.10.4).

Given the changes to the overall surface water management designs, the closure design has yet to be developed for the land bridge. Section 5.14.10.5 summarises the forward works required to develop the design.

**Summary**

Herbert's Creek land bridge is routinely monitored for settlement using several prisms established across the length of the flood channel. Monitoring data have indicated that vertical displacement ranges from 7 mm to 559 mm, with the greatest settlements associated with the middle sections of the land bridge, as expected. From 2019 - 2021 the rate of settlement increased over the wetter months (November to April), but this trend is not apparent in 2022 and 2023. A stability assessment of the land bridge in 2021, concluded that lateral displacement is generally towards the centre of the land bridge which is indicative of settlement rather than slope instability. A small section on the western slope showed movement to the west which was potentially related to pooling water during the wet season. Differential settlement and pooling of water could increase tension stress on the geosynthetic clay liner.

An inspection in 2023, identified:

- Two transverse cracks in the land bridge.
- Head cutting at the outlet with the potential to cut back to the location of flood bunds.
- Sediment transport into the land bridge and deposition (slug up to 0.6 m) near the inlet.
- Vegetation in both the low flow and main diversion channel with trees up to 5 - 6 m tall which have the potential to impact the geosynthetic clay liner.

SIBERIA landform evolution modelling assessed the potential hillslope erosion and crest recession that could result from the development of gullies over 1,000 years. The modelling was based on the current geometry of the Herbert's Creek land bridge and bunds and used the physical characteristics of UCID and LCID materials derived from historic characterisation and WEPP modelling (Section 5.2.4.1). Rainfall conditions predicted for a climate change scenario (assuming an increase of 5% in annual rainfall) were applied to the entire 1,000-year modelling period. Given the mixed materials used to construct the land bridge and their unknown proportions and distribution, both LCID and UCID materials were selected for modelling. These scenarios provide an understanding of the potential range of outcomes and inform the requirement for rock armour on the outer embankment. The outputs of the model showed that, from a hillslope erosion perspective:

- The main channel remains functional over the term of the model, regardless of the construction materials used.
- Crest recession is likely to occur, but may be negligible, depending on the specific mix of materials and whether armour is used on the outer face.
- If constructed from UCID materials, the landform is erosionally stable with minimal erosion on regularly shaped faces where flows do not concentrate, and only small gullies (up to ~2 m deep) at the base of access ramps where flows may concentrate.
- If the more erodible LCID materials are used, a recession of up to approximately 15 m is predicted over the 1000-year duration of the model. However, this does not extend to the main land bridge channel. Gullying occurs where surface water flows concentrate.
- Bunds will evolve over time to lower relief features. The eroded thickness of a bund may vary from 0.07 m (UCID) and 0.8 m (LCID) for a 2 m high bund to 0.18 m (UCID) and 1.9 m (LCID) for a 10 m bund. While LCID materials are not recommended for bunds, the erosion rates of LCID can be used to determine a conservative intermediate value based on the UCID: LCID material ratio where mixed materials are used in construction. Erosion of bunds can be managed through design, by including additional sacrificial thickness to extend their functional life.

The inclusion of the W6 floodplain and subsequent removal of the H-SP2 flood channel from the overall surface water management design for closure, influence the closure design for the Herbert's Creek land bridge. The floodplain landform has the potential to buttress the western side of the land bridge, but the interface between the landform and flows from Herbert's Creek towards the land bridge requires further review.

Closure designs will be developed in future design phases, and will be informed by geotechnical investigations and analysis, hydraulic modelling and geomorphic assessments.

#### 5.14.10.1 Current design

The current design of the Herbert's Creek land bridge was described in the 2020 MCP. This description has now been moved to Appendix G.6 and is summarised below:

- The current land bridge design has been designed to accommodate a 1:100-year flood event.
- An overfill section in the central areas of the land bridge was incorporated into the design to accommodate differential settlement of the newer (middle) sections of the land bridge compared to the older northern and southern sections, where settlement would have largely taken place by the time of construction.

- A bed slope of 0.15% was selected to result in velocities ranging between 1.8 and 2.3 m/s.
- A drop structure (dropping 2 m at a 1:20 slope from the invert of Herbert's Creek) was designed to accommodate the excess elevation along the diversion route due to the erosion resistant CID upstream of the diversion.
- Bunds 2.5 m high with a 5 m crest width were included on both sides of the land bridge.
- A geosynthetic clay liner was incorporated into the design to ensure that the majority of water which enters the land bridge also exits it.
- A 1.0 m cover was provided over the geosynthetic clay liner to maintain the mobile bed zone away from the liner.
- A low flow channel with a shallow meander sequence, was designed so that the meander will push towards the widest part of the land bridge (east) which contains the light vehicle track.
- Both sides of the land bridge have a 25 m wide buttress to achieve a FoS of 1.5.

#### 5.14.10.2 Monitoring and inspection results

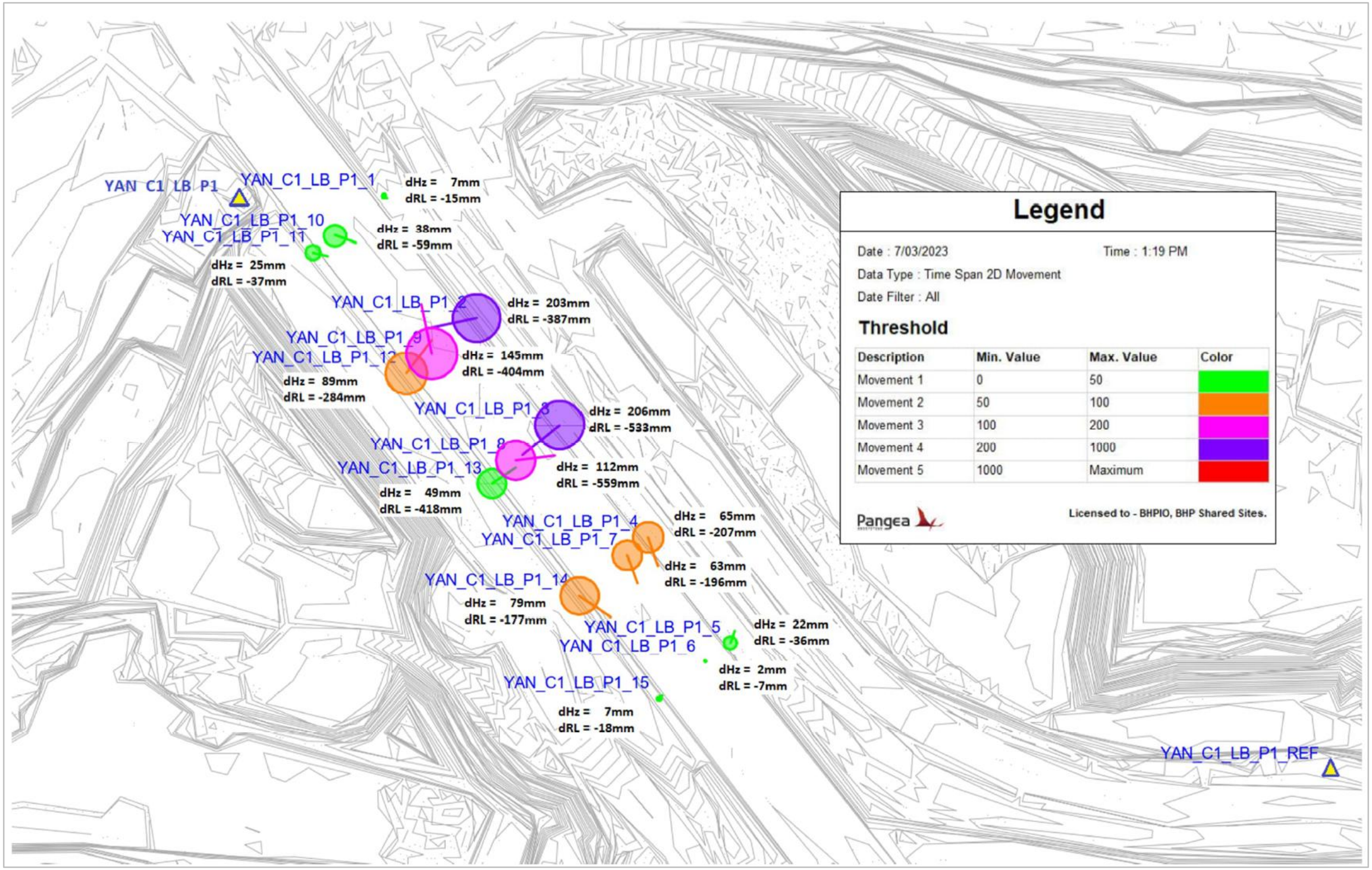
Since construction, the performance of the Herbert's Creek land bridge has been routinely monitored. The sub-sections below provide details of settlement monitoring and stability assessments, and the findings of recent inspections.

**Settlement and stability assessments**

Herbert's Creek land bridge is routinely monitored for settlement using several prisms established across the length of the flood channel (Figure 5-97). Flow gauges have also been established upstream and downstream of the diversion to detect any significant leaks occurring across the length of the land bridge.

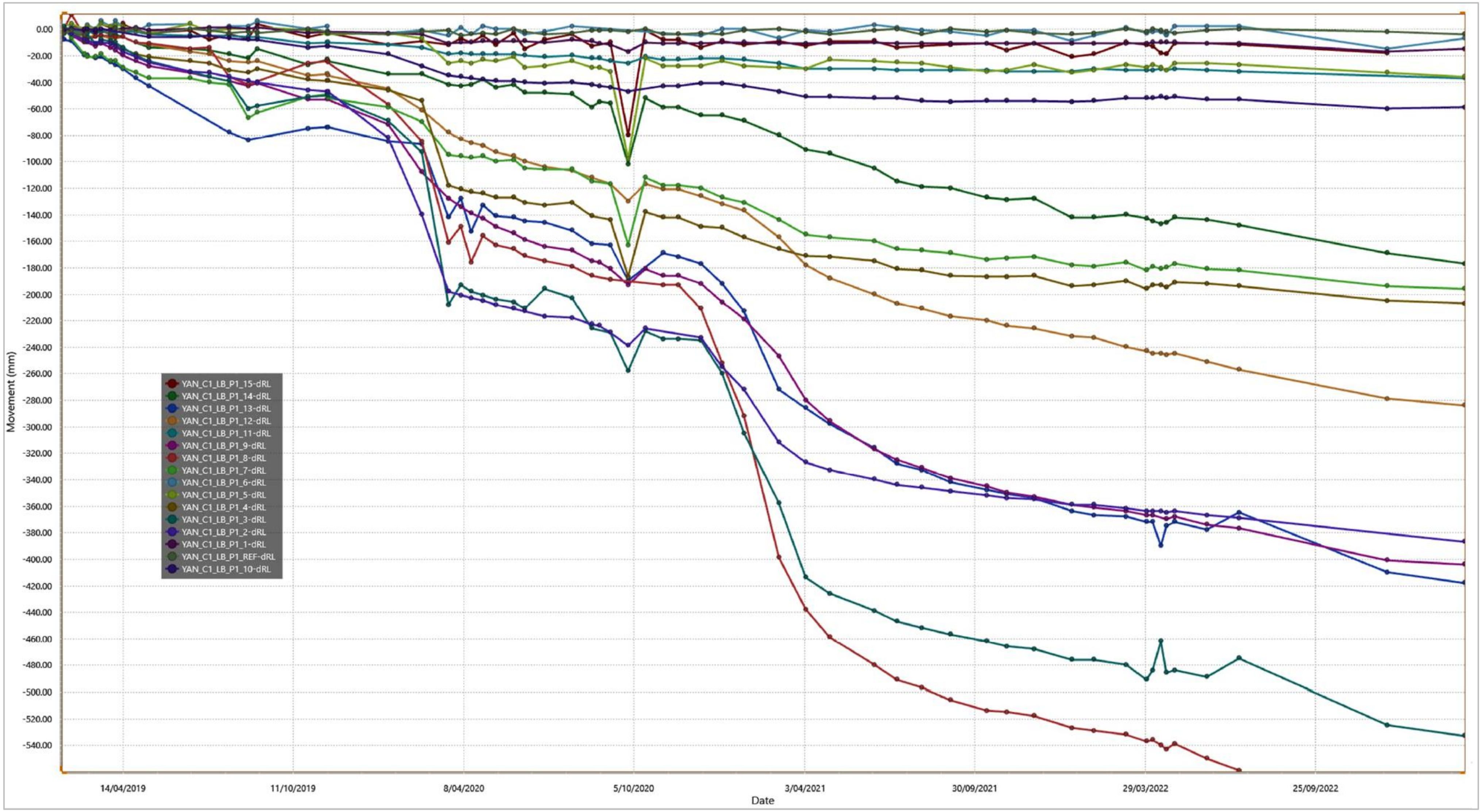
Settlement monitoring data has indicated that vertical displacement ranges from 7 mm to 559 mm (Figure 5-97). The greatest settlements are associated with the middle sections of the land bridge, as expected. The rate of settlement increased over the wetter months (November to April) for the years 2019 to 2021 within the central portion of the land bridge. However, this trend is not apparent for the wetter months over the years 2022 and 2023 (Figure 5-98).

Hydrographs for a recent flow event in 2024 (Figure 5-99) show that, although there is a slight difference in flow depth (~0.1 m after adjusting for the zero reading), the flow entering the land bridge is similar to that exiting. The slight difference is due to variances in local cross sections.




Source: BHP (2023k)

**Figure 5-97 Herbert's Creek prism displacement vectors and magnitude**




Source: BHP (2023k)

**Figure 5-98 Herbert's Creek settlement trends**

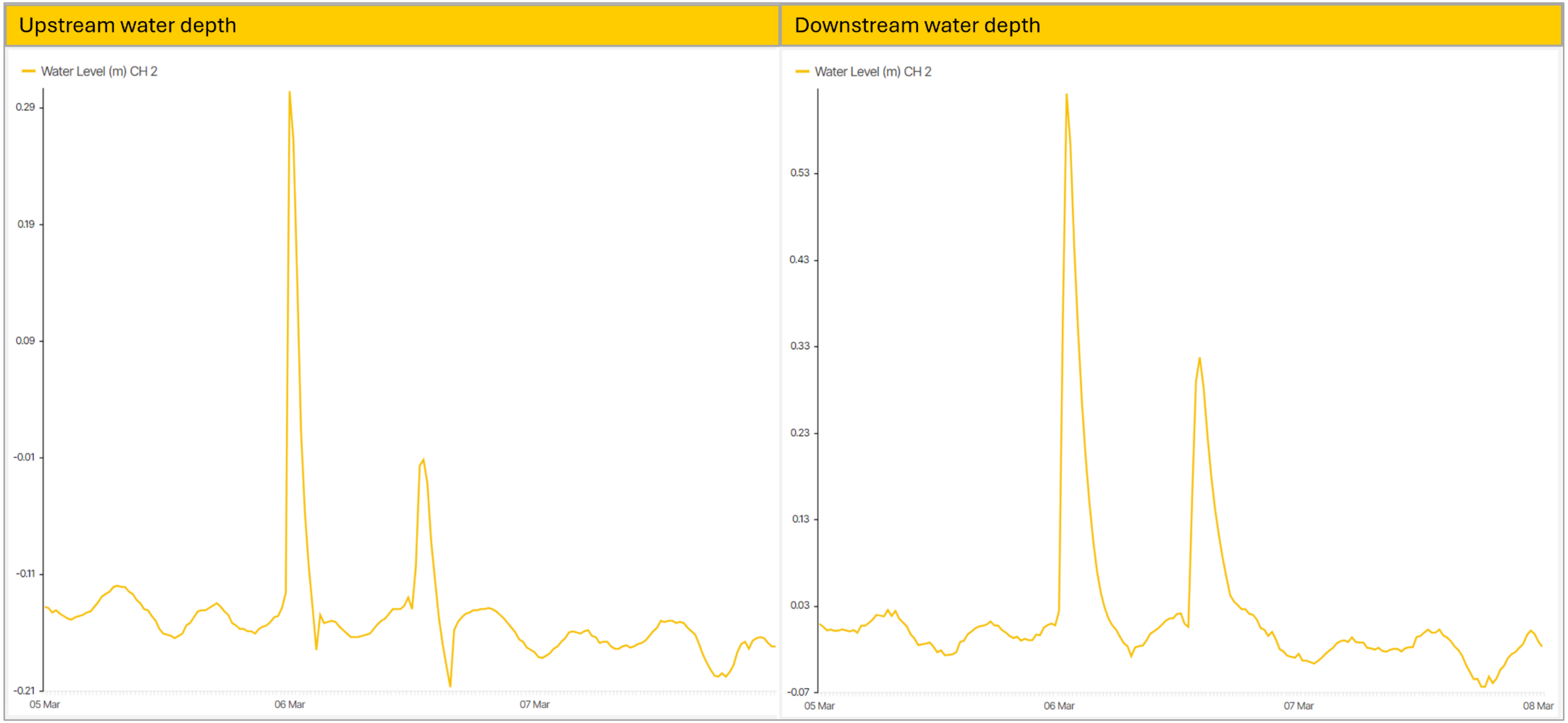
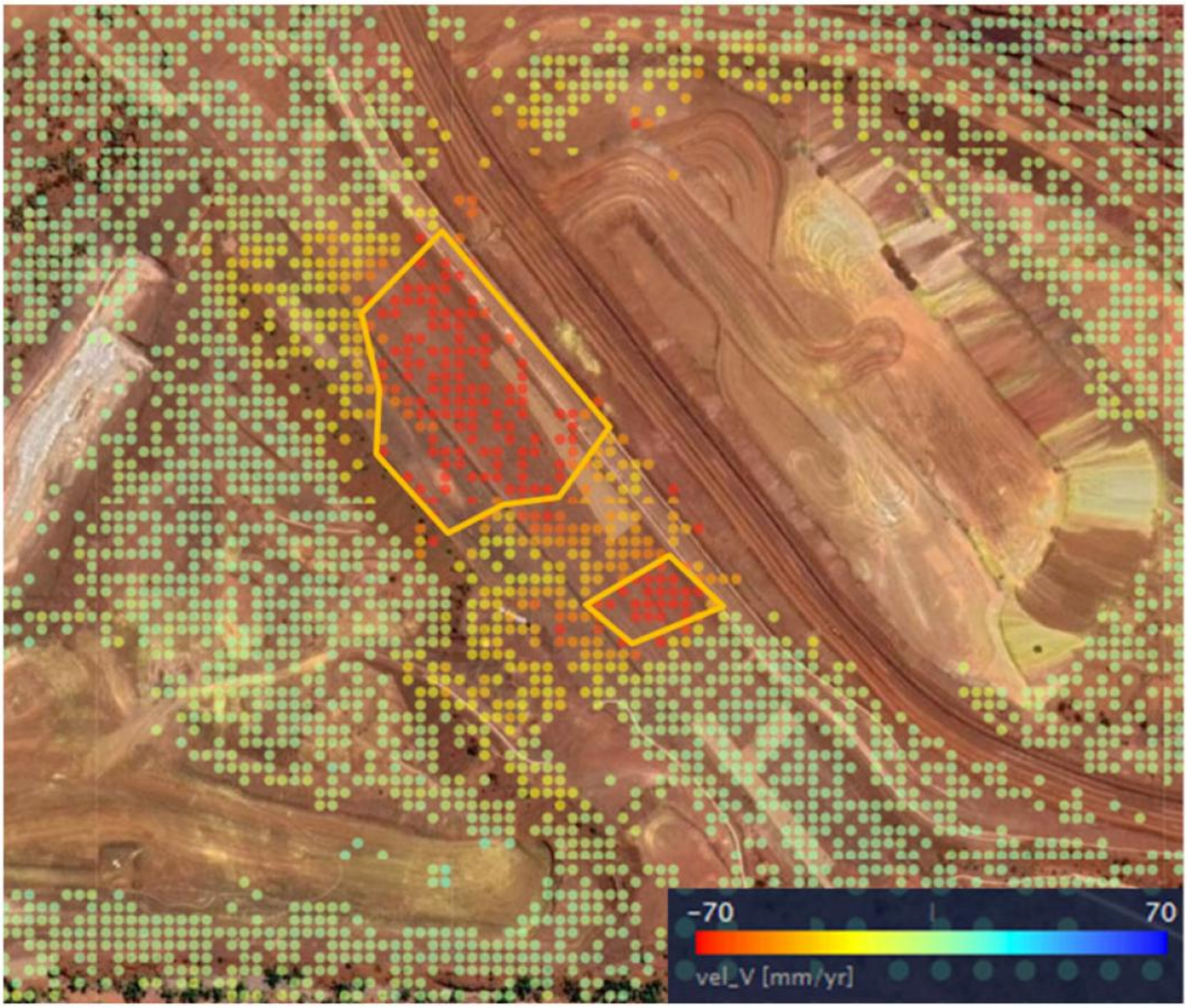



**Figure 5-99 Hydrographs of March 2024 flow event across Herbert's Creek land bridge**

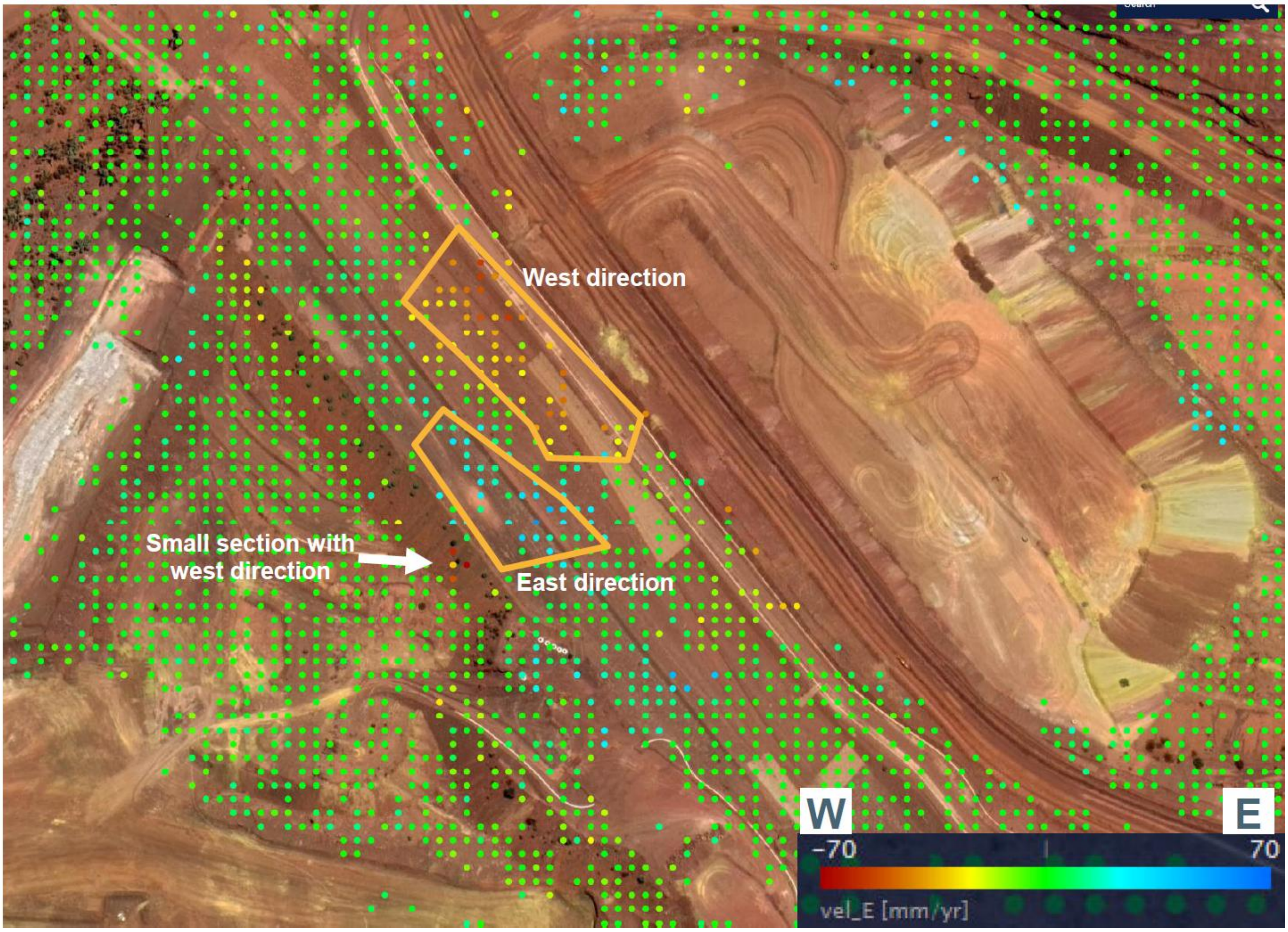
A stability assessment of the land bridge was conducted in 2021 and used both prism and InSAR data which produced consistent findings. The assessment concluded that (BHP, 2021c):

- The middle sections of the land bridge shown in Figure 5-100 had the greatest settlement.
- Lateral displacement is generally towards the centre of the land bridge (Figure 5-101) which is indicative of settlement rather than slope instability.
- A small section on the western slope showed movement to the west which was potentially related to pooling water during the wet season (Figure 5-101).
- Differential settlement and pooling of water could increase tension stress on the geosynthetic clay liner and that this should be assessed to determine whether it is within design tolerances.




Source: BHP (2021c)

**Figure 5-100 Herbert's Creek vertical displacement (InSAR data 2021)**




Source: BHP (2021c)

**Figure 5-101 Herbert's Creek horizontal displacement (InSAR data 2021)**

#### Inspection results

Inspections in August and October 2023 identified:

- Two transverse cracks. Cracks were also identified during the stability assessment in 2021.
- Head cutting at the outlet with the potential to cut back to the location of flood bunds. Alluvial soils and channel margin type materials (basal conglomerate / clay) were the materials predominantly observed at exposed retreating faces and base, and there was no visible evidence of competent UCID in the immediate vicinity to arrest head cutting.
- Sediment transport into the land bridge and deposition (slug up to 0.6 m) near the inlet.
- Vegetation in both low flow and main diversion channel with trees up to 5 - 6 m tall (predominantly closer to the inlet than at the outlet) which may have impacted the geosynthetic clay liner. The design was originally developed to discourage vegetation to minimise impacts on the integrity of the liner.

### 5.14.10.3 Landform evolution modelling

Okane (2023b) conducted landform evolution modelling of Herbert's Creek land bridge, flood bunds, and buttresses over a 1,000-year period to estimate the potential hillslope erosion and crest recession that could result from the development of gullies over time. Crest recession, in this context, refers to the movement of the crest back from the constructed location due to erosion which is a potential factor that could affect the longevity of the land bridge. The approach taken to the modelling and the results of the modelling are summarised in the sub-sections below.

#### Approach to modelling

SIBERIA modelling was used to assess the potential hillslope erosion and crest recession that could result from the development of gullies over time at Herbert's Creek land bridge. A 1000-year assessment period was used for this purpose as the overall elevation change is of primary importance (rather than an annualised erosion rate which is more relevant to the assessment of OSA performance). The inputs to the model were (Okane, 2023b):

- Existing geometry of Herbert's Creek land bridge and bunds based on survey data. The model did not consider future floodplain landforms or pit backfill.

- The physical characteristics and WEPP erosion modelling outputs generated by Landloch (2016) for the LCID and UCID materials (Section 5.2.4.1) which are reflective of both the mined materials and the regional hydrology. LCID overburden exhibits greater susceptibility to erosion, while the competent, rocky UCID overburden is relatively stable.
- Rainfall derived from 2090 predictions using the Climate Change Australia Projections Tool (CSIRO and Bureau of Meteorology, 2023) for the nearest rainfall station (Wittenoom Gorge) to account for climate change (assuming the maximum increase in annual rainfall of 5%).

The model made no allowance for the mitigating effects of vegetation which is an appropriately conservative assessment given the nature and design of the land bridge structure (refer to Appendix G.6 for further information on the landform design) (Okane, 2023b).

Given the mixed materials used to construct the land bridge, and their unknown proportions and distribution, both LCID and UCID materials were selected for modelling. These scenarios provide an understanding of the potential range of outcomes and inform the requirement for rock armour on the outer embankment (Okane, 2023b).

It should be noted that this assessment does not consider the potential for scour erosion, caused by surface water flows along the land bridge, which requires a different modelling approach (Okane, 2023b) and will be conducted as part of the forward work program (Section 5.14.10.5).

**SIBERIA modelling outputs**

The SIBERIA model outputs for the Herbert's Creek LCID and UCID scenarios, and flood bunds are outlined separately in the sub-sections below. In summary (Okane, 2023b):

- The Herbert's Creek land bridge model indicates that from a hillslope erosion perspective, the main channel remains functional over the term of the model. Crest recession is likely to occur, but may be negligible, depending on the specific mix of materials and whether armour is used on the outer face. If more erodible LCID materials are used, a recession of up to approximately 15 m is predicted over the 1000-year duration of the model. However, this does not extend to the main land bridge channel.
- Bunds form key features in the closure landscape to manage erosion and will evolve over time to lower relief features. Erosion of bunds can be managed through design, by including additional sacrificial thickness to extend their functional life.

*Herbert's Creek land bridge LCID scenario*

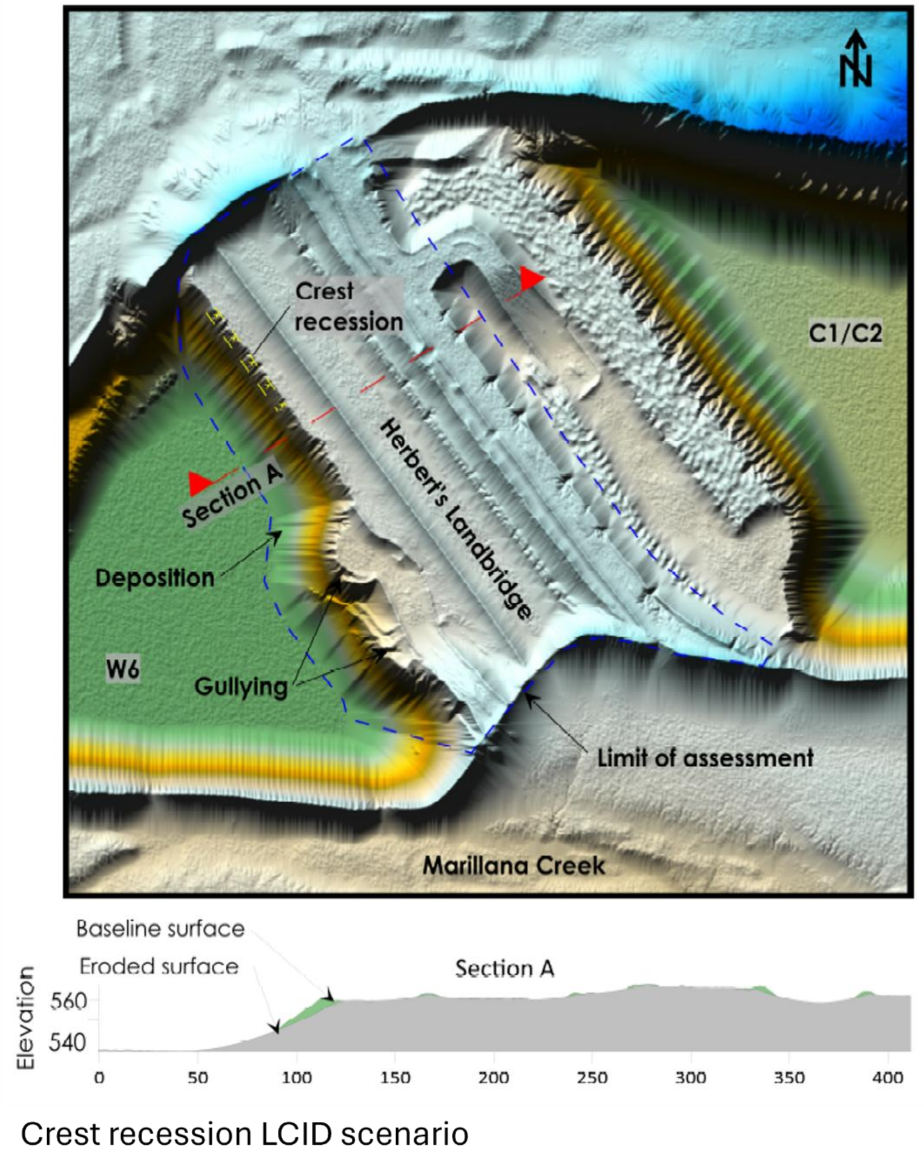
The LCID scenario modelling results indicate (Okane, 2023b):

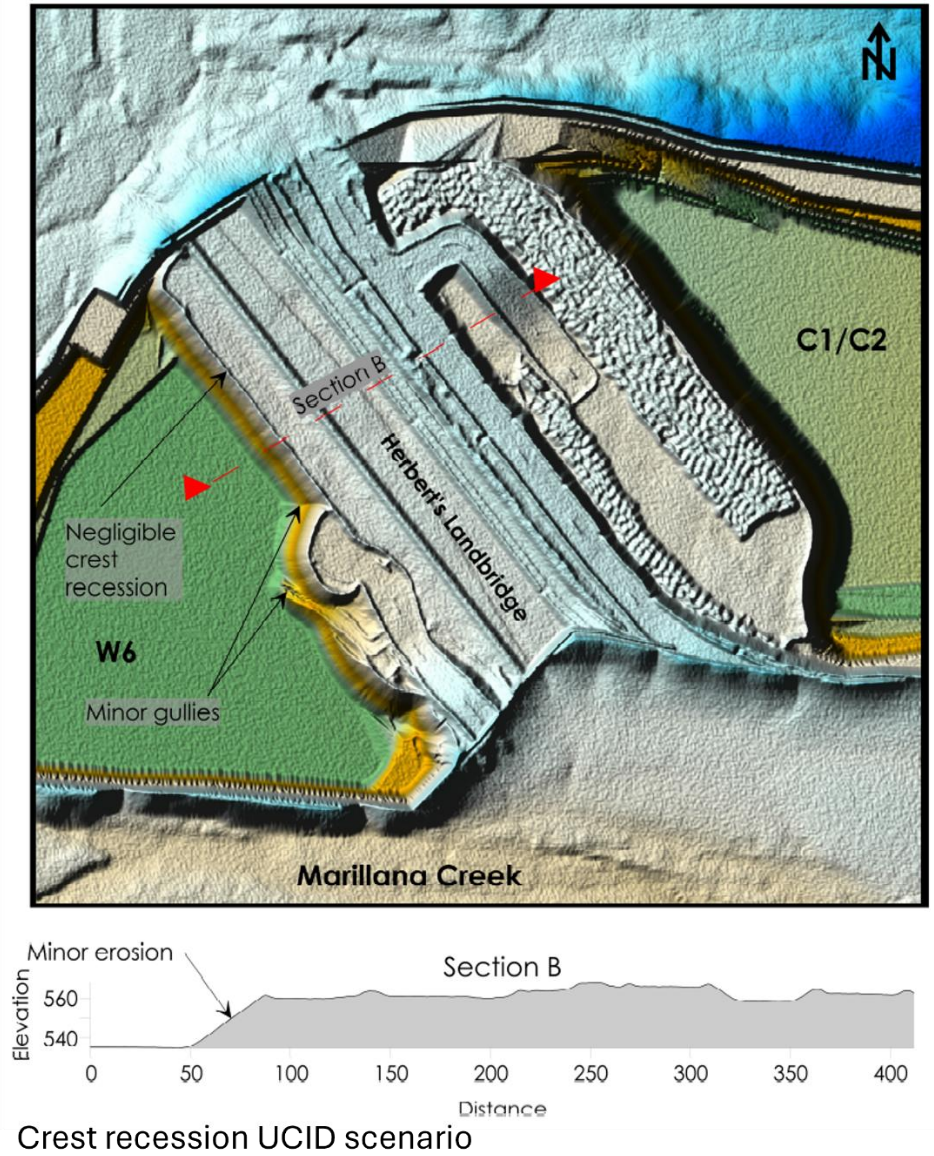
- The predicted range of crest recession varies from approximately 5 to 15 m horizontal, but the crest does not recede sufficiently to compromise the main surface channel on the land bridge.
- Erosion of the main channel embankment / bund occurs with a loss of effective height and top width of the bund.
- The western embankments tend to erode to a concave profile over the period of the model (Figure 5-102).
- The western side of the land bridge concentrates surface water runoff which drains at the existing road and causes gullies to develop (Figure 5-102).

*Herbert's Creek land bridge UCID scenario*

The UCID modelled scenario indicates (Okane, 2023b):

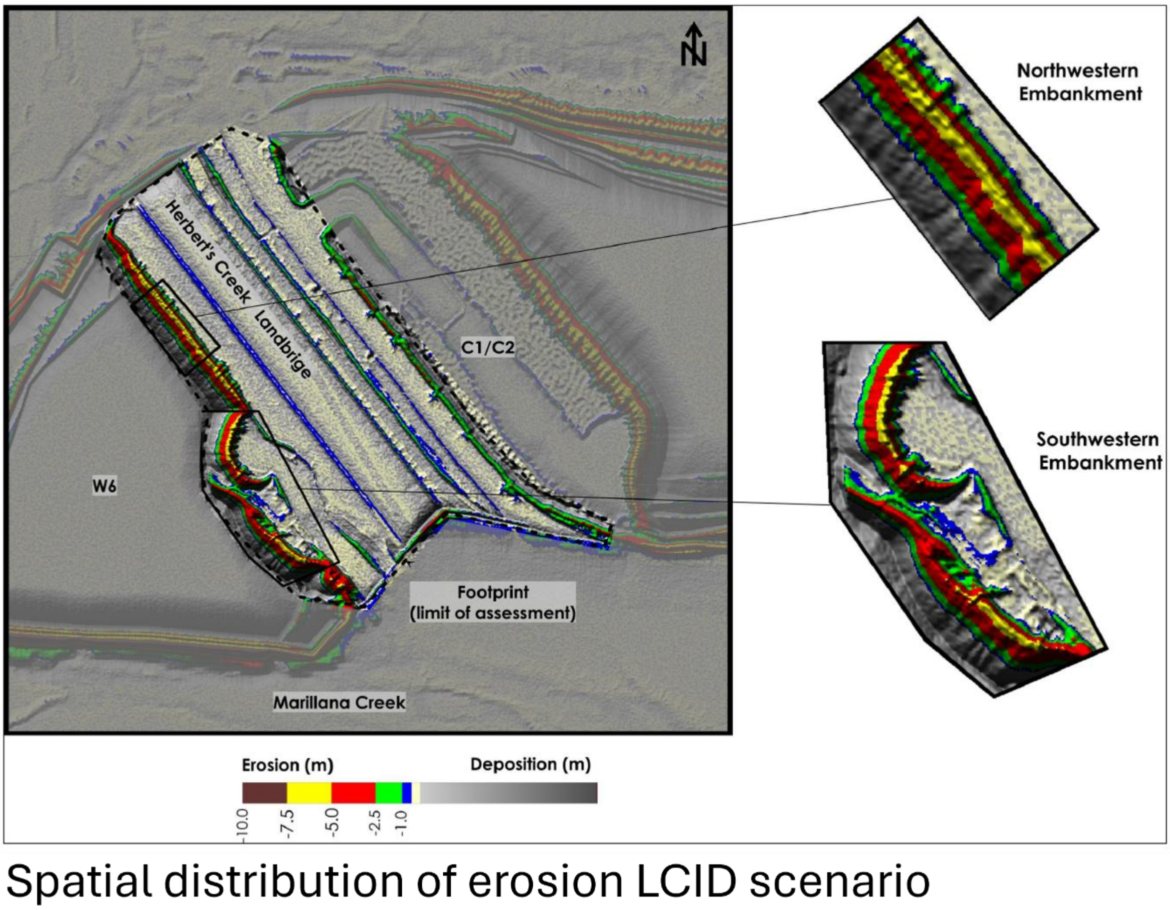
- Overall, an erosionally stable landform, in terms of hillslope erosion (Figure 5-103).
- Development of small gullies (up to approximately 2 m deep) at the base of access ramps and in areas where flows may concentrate (Figure 5-102).
- Minimal erosion on regularly shaped face slopes, where flows do not concentrate (Figure 5-103).
- The western embankments tend to retain their linear profile (Figure 5-102).
- Negligible crest recession (Figure 5-102).

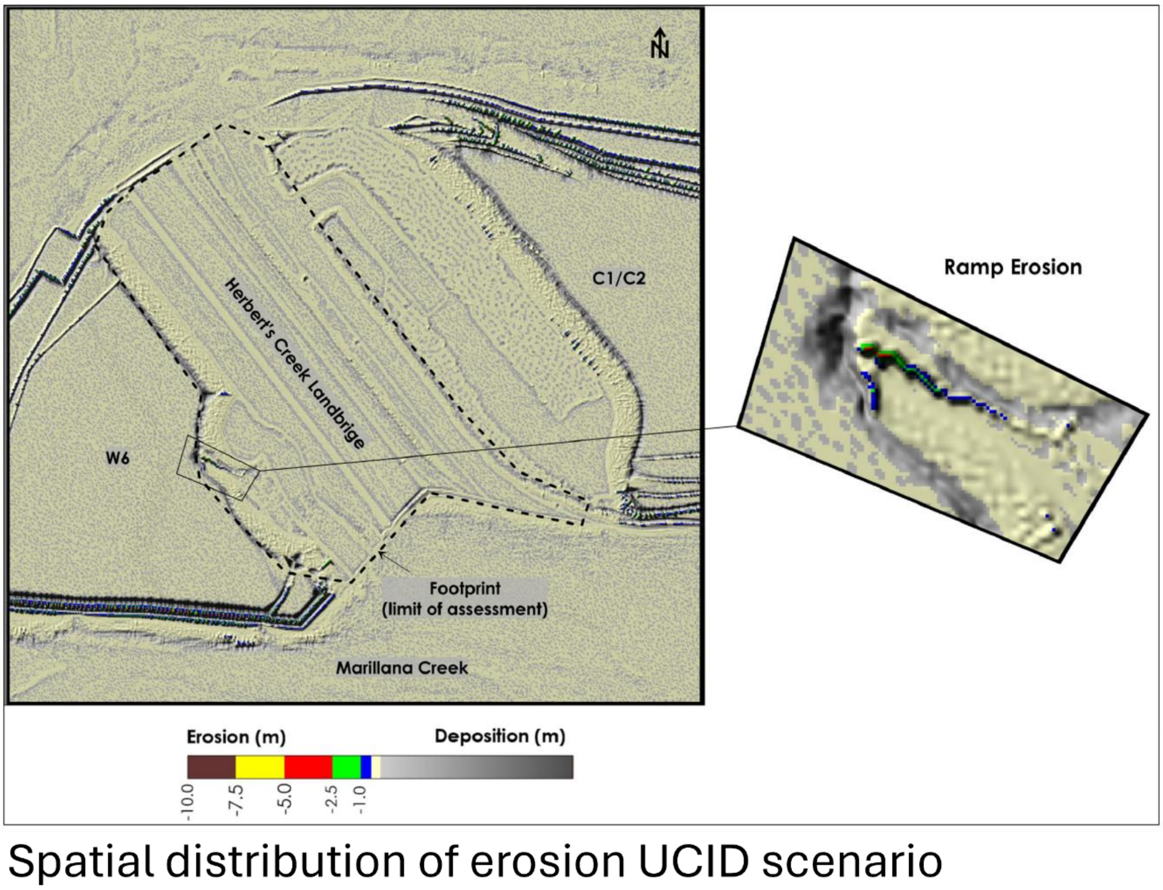



Source: Okane (2023b)

**Figure 5-102 Predicted eroded surface for Herbert's Creek land bridge at 1,000 years**




Source: Okane (2023b)

**Figure 5-103 Predicted spatial distribution of erosion of Herbert's Creek land bridge at 1,000 years**

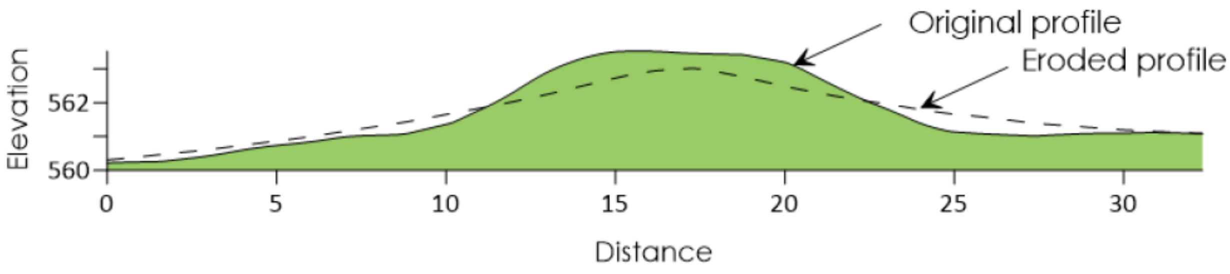
*Bunds*

The bunds were predicted to evolve to a shallower profile with reduced effective thickness in the upper part of the bunds and reduced overall height (Figure 5-104). Table 5-91 shows the predicted thickness of erosion of bunds of different heights depending on the construction material, noting that this does not account for scour from surface water flows (which will be assessed as part of the forward work program; Section 5.14.10.5). This can be used to determine the sacrificial thickness that may be incorporated into designs. While LCID materials are not recommended for bunds, the erosion rates of LCID can be used to determine a conservative intermediate value based on the UCID: LCID material ratio where mixed materials are used in construction (Okane, 2023b).

**Table 5-91 Predicted erosion of bunds**

| Bund Height (m) | Eroded thickness (UCID), (m) | Eroded thickness (LCID), (m) |
|---|---|---|
| 2 | 0.07 | 0.8 |
| 5 | 0.10 | 1.5 |
| 10 | 0.18 | 1.9 |

Source: Okane (2023b)




Source: Okane (2023b)

**Figure 5-104 Typical predicted erosion of bunds on Herbert's Creek land bridge (LCID)**

#### 5.14.10.4 Implications of surface water management closure design studies for Herbert's Creek land bridge

The inclusion of the W6 floodplain and subsequent removal of the H-SP2 flood channel from the overall surface water management design for closure influence the closure design for the Herbert's Creek land bridge. The floodplain landform has the potential to buttress the western side of the land bridge, but the interface between the landform and flows from Herbert's Creek towards the land bridge requires further review.

#### 5.14.10.5 Knowledge gaps & forward work program

The closure design for Herbert's Creek land bridge requires further analysis including:

- Geotechnical investigation and analysis taking into account the proposed floodplain landform and backfill design.
- Hydraulic modelling.
- Geomorphological assessments.
- An assessment of the need for a geosynthetic liner and the risks associated with tree growth and long-term stability.

### 5.14.11 Mine void stabilisation options

Final pit wall stability designs will be dependent on several factors including, the mine plan, backfill scenario, and surface water management designs. To help inform mine void stabilisation options, Golder (2020c) assessed a number of scenarios as an example of the impacts of different designs on stability:

- Backfill versus pit lakes; and
- Slope angles and buttressing.

The outcomes of these assessments are described in further detail in Sections 5.14.11.1 and 5.14.11.2. Golder (2020c) also conducted an initial assessment of safety bund locations and this is reported in Section 5.14.11.3.

Further work was being progressed at the time of writing, but was not available for inclusion in this MCP, and is subject to change following ongoing consultation with BNTAC and the Banjima people. Updated information will be included in the next statutory update of the MCP (Section 5.14.11.4).

**Summary**

Golder (2020c) analysed pit wall stability for several scenarios with and without backfill, and with and without a pit lake. Backfill was shown to improve the FoS, but a pit lake reduced the stability for one section analysed.

A further assessment of the impact of backfill on end walls and land bridges (which typically have lower FoS) concluded that for the backfill scenario modelled, FoS increased to >2, except at east pit end walls and land bridges where there was limited backfill in the modelled scenario. However, these sections had FoS >1.50 as the walls are constructed primarily in the more competent UCID material.

A scenario analysis to understand slope design requirements to achieve a FoS ≥1.50 within an end wall CID sequence for both a constructed and a buttressed slope concluded that:

- An overall slope angle of 25° is an option for a CID slope design.
- A slope angle of 30° is an option for a buttressed slope.

The findings of the pit wall landform evolution modelling (Section 5.4.3) and Herbert's Creek land bridge modelling (Section 5.14.10) were interpreted by Okane (2023b) to provide the following recommendations for buttress design for closure:

- Compartmentalisation of the upper flat catchments of buttresses using inter bunds, but no crest bunds as surface water should be allowed to discharge off the benches.
- Reducing the extent of ex-pit catchments to increase the longevity of the buttresses.

An initial assessment of the stand-off distances required for safety bunds concluded that, safety bunds may be placed a minimum distance of 10 m from:

- The intersection of the BIF-CID contact with the topography;
- The crest of a slope where the overall slope angle is 25° or less; and
- An identified potentially unstable pit edge zone.

Pit wall stability designs will be updated based on updates to the backfill strategy following ongoing consultation with BNTAC and the Banjima people. This, in turn, will impact the location / design of safety bunds which will be updated as closure designs progress, and will include consideration of the interaction of bunds with surface water flows and management systems, and the stability of bunds constructed over unconsolidated material.

#### 5.14.11.1 Impact of backfill & pit lakes on stability

To gain an understanding of the impact of backfill and pit lakes on stability, Golder (2020c) ran the following scenarios on Section Central CM (see Section 5.4.2.2):

- Base case (no backfill or pit lake);
- Pit lake - adopts the pit design and fills to water table;
- Pits backfilled with overburden to the water table; and
- Pits backfilled with overburden to 5 m above the water table.

The results show that the FoS generally improves with respect to the base case in all scenarios (except for the Wall CM' section in the pit lake scenario) (Table 5-92) (Golder, 2020c).

**Table 5-92 Design option scenario analysis**

| Scenario | Section | Wall CM (FoS) | Wall CM' (FoS) |
|---|---|---|---|
| Base case | Central CM | 3.12 | 2.50 |
| Pit Lake to local water table | Central CM | 3.40 | 2.40 |
| Backfill to local water table | Central CM | 4.23 | 2.64 |
| Backfill to local water table + 5m | Central CM | 5.04 | 2.57 |

Source: Golder (2020c)

Given that end walls and land bridges constructed in CID material typically gave lower FoS values and deeper instability mechanisms (Section 5.4.2.2), a more in-depth assessment of the impact of backfill was conducted for these areas. Modelled backfill assumptions for each pit are recorded in Appendix C. In the backfill scenario, the end walls and land bridges all had slope stabilities with a FoS >2 (Table 5-93) which exceeds the closure criterion of FoS ≥1 .50. The east pit end walls and land bridges had limited backfill in the modelled scenario, but they had FoS >1.50 as the walls are constructed primarily in the more competent UCID material (Golder, 2020c).

**Table 5-93 End wall & land bridge backfill design scenario analysis**

| Section / Wall | Base case FoS | Backfill FoS |
|---|---|---|
| West K | 1.31 | 4.39 |
| West K' | 1.33 | 3.49 |
| West M | 1.42 | 4.21 |
| West N | 1.30 | 8.11 |
| West R | 1.64 | 4.30 |
| West R' | 1.74 | 4.28 |
| West X | 1.35 | 7.21 |
| West AH | 2.73 | 3.64 |
| West AH' | 3.24 | 3.41 |
| Central CF | 2.09 | 2.16 |
| Central CF' | 1.83 | 2.86 |
| East EI' | 2.51 | 3.84 |

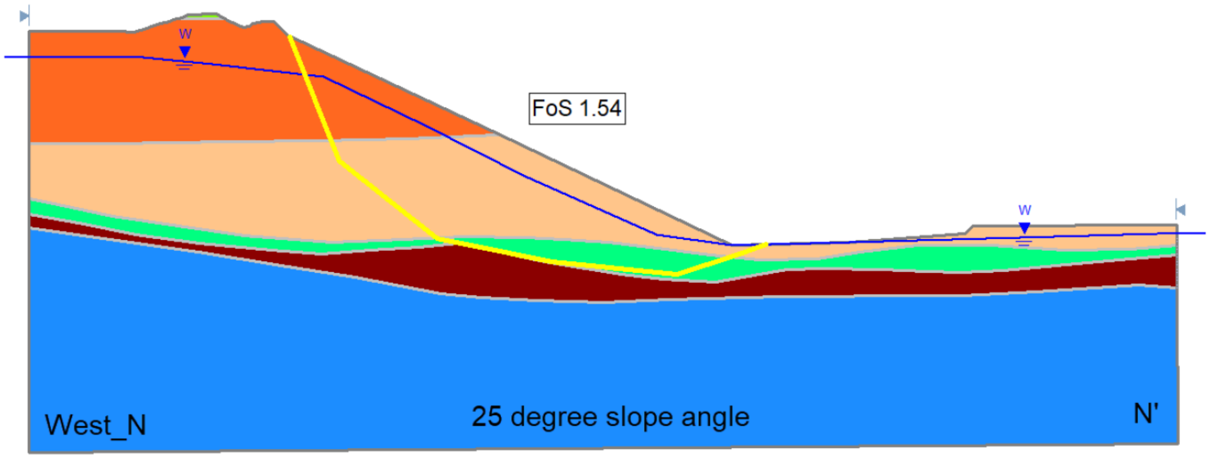
Source: Golder (2020c)

#### 5.14.11.2 Impact of slope angles and buttressing on stability

Sensitivity analyses were run on the Section West N (Section 5.4.2.2) to understand slope design requirements to achieve a FoS ≥1.50 within an end wall CID sequence for both a constructed and a buttressed slope. In both scenarios, successively flatter slope angles were run through the base case models starting from the design angle of 41° through to 20° for the design model and 35° to 20° for the buttress model. Water tables were adjusted for the decreasing slope angles (Golder, 2020c).

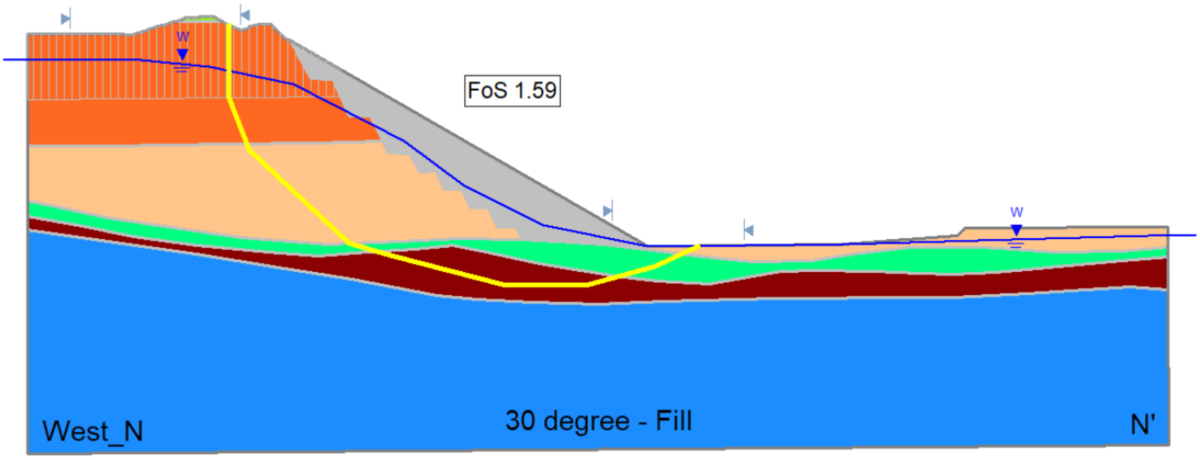
The scenario analysis indicated that to achieve a FoS ≥1.50 (Golder, 2020c):

- An overall slope angle of 25° is an option for a CID slope design (Figure 5-105).
- A slope angle of 30° is an option for a buttressed slope (Figure 5-106).




Source: Golder (2020c)

**Figure 5-105 FoS for 25° design slope angle**




Source: Golder (2020c)

**Figure 5-106 FoS for 30° fill buttress**

#### Erosional stability of buttresses

While Okane (2023b) did not specifically assess the erosional stability of buttress designs, the findings of the pit wall landform evolution modelling (Section 5.4.3) and Herbert's Creek land bridge modelling (Section 5.14.10) can be interpreted to provide the following recommendations for buttress design:

- Compartmentalisation of the upper flat catchments of buttresses using inter bunds for closure. This limits surface water concentration on top of the buttress, which could accelerate erosion of the buttresses. Surface water should be allowed to discharge off the benches, and as such no crest bunds need be constructed.
- Reducing the extent of ex-pit catchments. Erosion risk for buttresses will be higher where ex-pit catchments are permitted to drain down over pit faces and onto the buttress. Reducing the extent of ex-pit catchments will increase the longevity of the buttresses.

### 5.14.11.3 Safety bund locations

The guidelines for safety bunds (DoIR, 1997) suggest using angles of 25° for weathered rock and 45° for unweathered rock to identify the potentially unstable rock mass, and ultimately the standoff required from the crest of the pit edge zone for the safety bund.

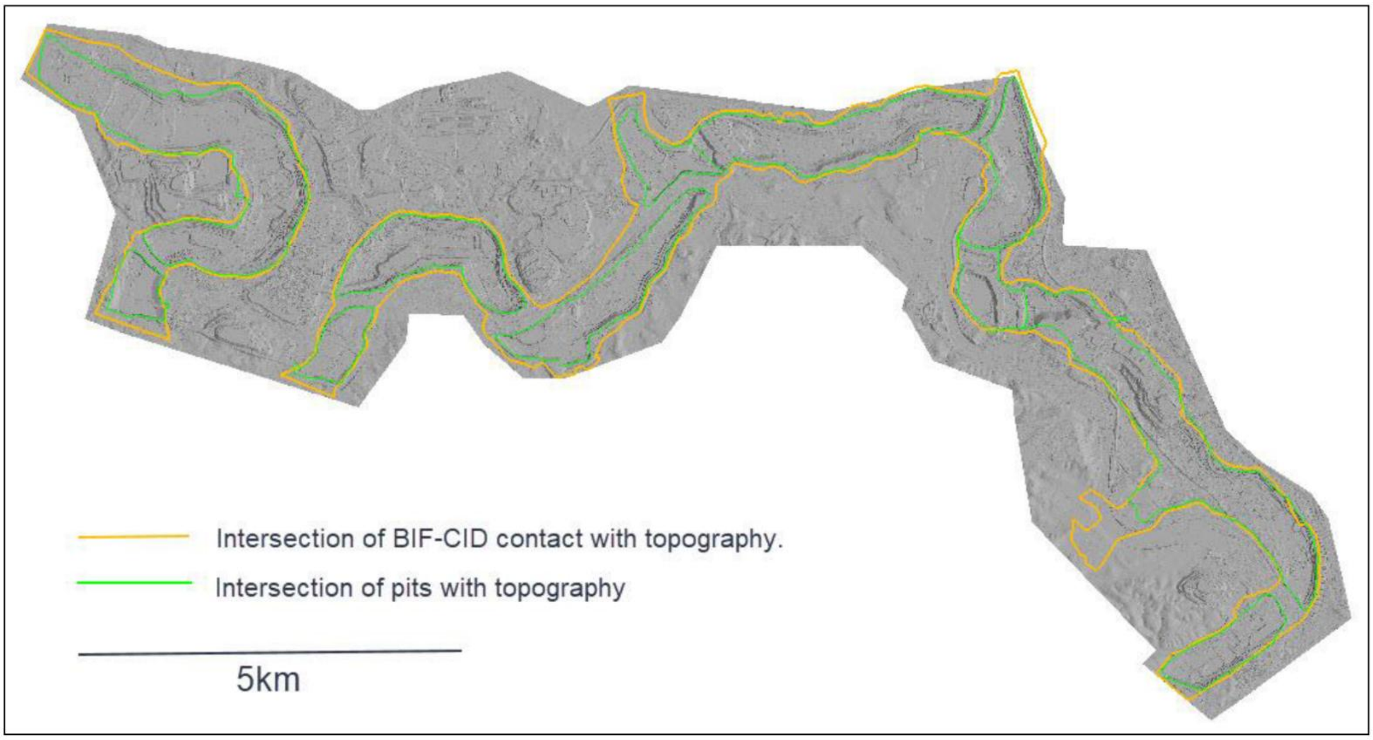
At Yandi, the Weeli Wolli BIF is considered to be an unweathered material and the CID stratigraphies are considered weathered. Because of the nature of the orebody, (i.e. the CID is bound by the BIF - refer to Figure 5-3 in Section 5.2.1), the pit edge zone can be defined by the intersection of the BIF with the ground surface. Any projection of the unstable rock mass up from the slope toe of any in pit CID will ultimately intersect the BIF. Given that the BIF-CID contact is typically shallower than the 45° angle for unweathered rock, the unstable rock mass has been defined by the contact (Golder, 2020c).

The proposition of identifying the CID as the potentially unstable rock mass is further supported by slope stability modelling (Section 5.4.2.2), which typically has the critical instability running along the base of the CID for the base case scenarios. Failures through the BIF generate FoS >1.50 with base case parameters (Golder, 2020c).

Where there is a significant thickness of CID, such as end walls, then a 25° design angle may be adopted to achieve acceptable FoS (Golder, 2020c) (see Section 5.14.11.2).

Safety bunds may, therefore, be placed at a minimum distance of 10 m from (Golder, 2020c):

- The intersection of the BIF-CID contact with the topography (Map 5-34);
- The crest of a slope where the overall slope angle is 25° or less; and
- An identified potentially unstable pit edge zone.




Source: Golder (2020c)

**Map 5-34 Intersection of the BIF-CID contact with topography to inform safety bund placement**

#### 5.14.11.4 Knowledge gaps & forward work program

Pit wall stability designs will be updated based on updates to the backfill strategy following ongoing consultation with BNTAC and the Banjima people. This, in turn, will impact the location / design of safety bunds which will be updated as closure designs progress, and will include consideration of the interaction of bunds with surface water flows and management systems, and the stability of bunds constructed over unconsolidated material. Updated information will be included in the next statutory update of the MCP.

### 5.14.12 Preliminary materials balance

A preliminary materials balance is provided in (Table 5-94). The backfill requirement and reclaimable material within OSAs / ISAs for use in backfill have been updated through the recent pit backfill design (Okane, 2024a). This study excluded consideration of the additional material that may be sourced from:

- Areas outside of the provided ex-pit (OSA, ROM, topsoil stockpile bases) polygons and ISAs (W4 Pit and E2 Pit) such as material from haul roads and mining infrastructure areas.
- Backfill material sourced from potential pit wall cutbacks.
- Backfill material sourced from the establishment of flood channels and creek diversions.

A preliminary assessment of the material that may be available from the haul roads and flood channels has been included in Table 5-94 along with estimates of additional overburden to be mined based on the FY24 5YP.

Estimates of the volumes of material required for closure designs such as buttressing and safety bunds have been derived from the most recent information available, noting that designs have not been finalised and are subject to change following consultation with BNTAC and the Banjima people.

The overburden balance shows currently shows an approximate balance of material available versus material required. Material balances will be optimised as the design process progresses towards detailed design.

**Table 5-94 Yandi preliminary materials balance**

| Description | | Overburden Quantity (million cubic metres) |
|---|---|---|
| Indicative overburden available | Reclaimable ex-pit overburden volume[1, 2] | 84.1 |
| | In-pit overburden volume[2, 3] | 75.8 |
| | Overburden to be mined[4] | 5.7 |
| | Haul road material | 11.7 |
| | Material from flood channel & diversion construction | 17.7 |
| **Total available material** | | **195** |
| Indicative overburden required | Pit backfill[2] | -162 |
| | Flood bunds | -1.9 |
| | Floodplain landforms | -19 |
| | Safety bunds | -1.8 |
| | Slope stability | -8.2 |
| | Rock armour | -0.2 |
| **Total material required** | | **-193.1** |
| **Preliminary material balance** | | **1.9** |

Notes: [1]Excludes C1 and E2 OSAs which have been rehabilitated and will remain post-closure
[2]Derived from Okane (2024a)
[3]Includes overburden within the pit backfill design surface and potentially reclaimable overburden outside the surface
[4]Mine planning FY24 5YP

## 5.14.13 Sustainable yield assessment

A yield assessment of the eastern pits was conducted (AQ2, 2020b) to determine the quantum of water that may be available to support a post-mining land use, and whether the eastern pits should be left open to provide this supply, or whether they should be backfilled. A summary of this study follows:

- The sustainable yield of the eastern pits was estimated to be around 6,500 kL/d (from groundwater flow and surface inflows). This is consistent with, though greater than, the 4,000 to 5,000 kL/d of "natural throughflow" that has been estimated for the CID aquifer prior to mining (Section 5.9.2.4). This increase is likely to have resulted from post-mining changes to the natural water system such as the capture of local runoff and creek flow in the eastern pits.
- The estimated yield assumed no inflow to E7 from RTIO's adjacent pit. If such inflow were to occur, the quality of the inflow would depend on RTIO's closure strategy.
- The largest single water influx to the downstream pits within the model was the seepage from the basement, followed by the throughflow from the upstream (backfilled) pits. The basement seepage was an assumed constant rate within the model and was based on a value provided by BHP from groundwater modelling.
- Cumulatively, the water influx from the rainfall generated processes (local runoff, creek seepage and creek overflow) were a similar order of magnitude as the influx from the basement. These are not constant inflows, but dependent on rainfall processes such that the yield from the pits in some years would be higher than the average, and in other years there may be no yield from rainfall / runoff processes.
- The salinity of the open voids will not increase with time provided that stored water is turned over by abstraction. As such, operating an abstraction scheme from the two dedicated "saline sinks" at C4/5 and E7 could result in no hyper-saline water across the site whilst abstraction is occurring (depending on the conditions in RTIO's adjacent Mungadoo Pit).
- The yield from the eastern pits is relatively small compared with a supply likely to be required to support a regional agricultural development (assumed to be 12 to >20 GL/yr[50]), and water from other supply points would also need to be provided to supplement the supply.
- The storage volume within the C4/5 Pit alone is estimated to be in the order of 35 $Mm^3$ (35 GL) to the pit crest. This represents a storage capacity equivalent to about three years of agricultural demand at 12 GL/yr (assuming no losses or inputs). The E7 void would add a further 26 GL storage capacity (a further two years storage).

50 Note a separate study (refer to Appendix J.1) concluded that for storage of water for large-scale irrigated agriculture to be viable, water quality in the pit would need to be <1,000 mg/L TDS and the pit(s) would need to provide a sustainable water yield of >20 GL/yr.

Based on these results AQ2 (2020b) concluded that there is no requirement for all the eastern pits to be left open to allow for additional water storage capacity. This is because a supply of ≥12 GL/yr will require water from other sources and consequently the supply is largely independent of the yield from the open voids and the primary function of the open void is water storage.

## 5.15 Research, trials and progressive rehabilitation performance

This section provides a summary of the performance of areas that have been rehabilitated at Yandi to provide an indication of the success of techniques implemented at Yandi to date and includes summaries of the:

- Overall rehabilitation performance assessed via remote sensing (Section 5.15.2).
- Marillana Creek E1 and E4 diversion designs and performance (Section 5.15.3).
- Performance and designs of OSAs that have already been rehabilitated and will remain in the landscape post-closure (C1 and E2) (Section 5.15.4).
- Research that Syrinx (2019) and others have conducted into rehabilitation success and appropriate revegetation completion criteria for BHP's Pilbara sites.

It also outlines the partnership with the Banjima people to research the production of seeds / plants for use in rehabilitation at Yandi (Section 5.15.6), and the rehabilitation trial planned for FY25 (Section 5.15.7) which will provide further information on the relative performance of different growth media, rehabilitation techniques and seed mixes. This trial will be used to refine the Yandi revegetation strategy outlined in Section 9.3.

### 5.15.1 BHP-wide approach to rehabilitation trials and research

BHP has undertaken progressive rehabilitation throughout its Pilbara Operations, which enable learnings from one project area to be applied to new areas through an adaptive management approach (Section 7.1). In addition, ongoing external research programs, through the University of Western Australia[51], continue to provide input to improving rehabilitation success across BHP's Pilbara Operations. The outcomes of monitoring, research and trials are reported in further detail in the Annual Environmental Reports (AERs) for BHP's operations. Appendix K provides a summary of historical research findings and current research projects. The results and recommendations from these projects are used to refine BHP's rehabilitation procedures and techniques across the Pilbara.

### 5.15.2 Overall rehabilitation performance

Since 2020, BHP has been using remote sensing in its rehabilitation monitoring program to assess rehabilitation performance against interim internal targets and completion criteria developed by Syrinx (2019; 2023) (see Section 5.15.5.1). The interim internal targets are designed to help gauge whether rehabilitation less than 15 - 20 years old is likely to be successful in the future, and to indicate where intervention may be necessary, to improve the likelihood of future rehabilitation success. These targets are applied to young rehabilitation (< 5 years old) and progressive rehabilitation (5 - 15 years old) and are derived from an analysis of relationships between early-stage metrics with later rehabilitation success evident in historical rehabilitation datasets. Overall, the analysis indicates that *Triodia* cover, *Triodia* density, shrub cover, and weed cover are key targets. Relative abundance is important and differs at different points in time. Relative abundance can be represented as ratios since this better represents the dynamics of developing sites and is instantly informative in terms of flagging remedial actions. The metrics of these internal targets continue to be refined based on analysis and review of rehabilitation monitoring.

A total of 253.0 ha of rehabilitated land was classified across 203 sites at Yandi, which comprised of 26 crest (69.1 ha), 103 flat (86.5 ha), and 74 slope (97.4 ha) landforms. The average native cover across rehabilitation sites greater than 0.25 ha at Yandi was 67.2% and ranged between 11.3% and 98.8%. Rehabilitated crests, flats, and slopes had an average native cover of 70.9%, 64.3%, and 69.5%, respectively. On average, native vegetation cover at Yandi consisted of 1.4% herb, 21.3% other grass (Tussocks), 19.6% hummock grass (*Triodia* spp.), 20.8% shrub, 1.4% Mulga (*Acacia aneura* complex), and 2.6% tree cover. Mean hummock grass cover was consistent across crest (16.0%), flat (20.8%), and slope (19.5%) landforms. Introduced plant species weeds covered 11.0% of Yandi rehabilitation on average and weed cover was similar between crest (8.9%) and flat (10.8%) landforms but was highest across slopes at 12.3%. Bare areas (defined as patches devoid of vegetation with a diameter >20 m), covered 0.0% of Yandi rehabilitated sites on average and ranged between 0.0% and 85.4% (Spectrum Ecology, 2023).

Rehabilitation sites greater than 15 years old accounted for 93.4 ha of rehabilitated land at Yandi, of which 0.0% met all completion criteria targets for "Low Tree Steppe". However, all sites met the criteria for bare areas and other grass cover and >70% of sites met the criteria for **Cenchrus*, total weed, shrub and herb cover. The key criteria that were not were not met were tree cover (~87% of crest sites and ~48% of slope sites) and hummock grass cover (~44% of crest sites and ~77% of slope sites) (Table 5-95) (Spectrum Ecology, 2023).

[51] Restoration Engineering Seed Technology Deployment Program Research Collaborative Agreement

**Table 5-95 Summary of achievement of completion criteria assessed with remote sensing**

| Site Details | | | Percent of Total Rehabilitated Area | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | All Criteria | Bare Ground Cover | *Cenchrus* Cover | Total Weed Cover | Tree Cover | Shrub Cover | Hummock Grass Cover | Other Gras Cover | Herb Cover |
| **Landform** | **Area (ha)** | **Outcome** | | **< 50%** | **< 10%** | **< 10%** | **>1%** | **>2%** | **>20%** | **>0.04%** | **>0.05** |
| Crest | 59.7 | Pass | 0.0 | 100.0 | 92.1 | 92.1 | 13.1 | 81.8 | 55.7 | 100.0 | 99.2 |
| | | Change* | 0.0 | 16.3 | -6.6 | -6.6 | 11.8 | 6.3 | 0.0 | 0.0 | 74.8 |
| Slope | 33.7 | Pass | 0.0 | 100.0 | 72.8 | 72.8 | 52.0 | 100.0 | 23.3 | 100.0 | 82.6 |
| | | Change* | 0.0 | 0.0 | -18.2 | -18.2 | 51.5 | 6.1 | -0.2 | 0.0 | 51.4 |

Source: Spectrum (2023)

Notes: Only rehabilitation areas >15 years old are assessed against completion criteria. This includes C1 OSA and E2 OSA.

*Change indicates change since 2022 monitoring event

A total of 26.7% (38.9 ha) of the 145.5 ha of rehabilitated land between 5 and 15 years old (or with no accurate date information) is currently met internal performance targets. Rehabilitation sites less than 5 years old accounted for 14.1 ha of the rehabilitated land at Yandi, of which 22.4% met internal performance targets for young sites (Spectrum Ecology, 2023).

Appendix N.4 summarises the most recent on-ground rehabilitation monitoring results and provides a summary of the rehabilitation techniques applied at these sites.

## 5.15.3 Marillana Creek diversions

The E1 and E4 Marillana Creek diversions have been constructed (Figure 5-107 and Figure 5-108) with the aim of reinstating ecological habitat and achieving similar flow and sediment transport characteristics to the natural creek line. Construction of the diversions was completed in 2018 and 2019 respectively.

**Summary**

The Marillana Creek diversion design studies were described in the 2020 MCP. The key design features are:

- Planform type, width, depth, slope, sediment depth and roughness within the ranges seen in the natural system.
- An engineered shallow aquifer to support riparian vegetation. Natural alluvium was used as a surface layer for this aquifer and provides a seed source and habitat structure important to microbes and invertebrates.
- Induced roughness elements to slow water flows and reduce erosion (e.g. woody debris and boulders). These roughness elements also promote natural colonisation of plants as they encourage deposition, not only of finer alluvium, but also seed being dispersed by water.
- Revegetation to be achieved through natural recruitment from seasonal flows.

Monitoring of the E1 and E4 creek diversions is conducted in accordance with the Marillana Creek Diversion Management Plan (as summarised in Section 10.1.8). To date, monitoring and inspections have shown that the diversions are functioning as intended and will require little or no intervention for closure.

The Index of Diversion Condition (IDC) scores were last assessed in 2021 and:

- Total IDC scores were 57% and 52% of the upstream control reach scores for E1 and E4 diversions, respectively (compared to a target of >70%). However, the overall scores were affected by the low riparian indices due to the young age of the diversions and associated early establishment phase of vegetation.
- A comparison of the geomorphological indices showed that the E1 diversion achieved a geomorphic index score of 88% of the score for the control reach and the E4 diversion 64%.

In 2021, neither diversion met the target of 8 out of 10 ecological indicators due to the young age of the diversions. However, since that time, monitoring has shown that vegetation is becoming established along the banks and creek beds, with trees up to 5 - 6 m high. Non-native species were noted to be competing with native vegetation in the E4 diversion. Operational weed spraying is used to manage non-native plant establishment.

LiDAR data show that the diversions are performing as expected with an area of deposition in the northern portion of the E1 diversion indicative of natural processes establishing within the diversion. Some areas of erosion and slumping have been observed, but this is consistent with the design expectation that the system will evolve to a natural state over many years and is not considered to require any intervention.

During an inspection in 2023, scour / head cutting was observed for a tributary entering the E1 diversion, but the extent of the upstream cutback was limited, and appeared to have stabilised on protruding BIF. Sediment deposited in the creek from the cut back appeared to be integrating into the landform.

#### 5.15.3.1 Design

The Marillana Creek diversion design objectives were documented in the Marillana Creek Diversion Management Plan (BHP Billiton, 2016) and are outlined in Table 5-96 and Table 5-97 details specific design criteria. These objectives and design criteria have been incorporated into the objectives and completion criteria outlined in Section 8.3.

**Table 5-96 Marillana Creek diversion design objectives**

| Category | Objective |
|---|---|
| Hydrology | Surface water flow volumes are sustained within acceptable ranges to minimise downstream ecological impacts |
| Water quality | Diversions do not have an adverse impact on water quality |
| Hydraulics | Velocity, shear stress and stream power throughout diversions are similar to those seen through existing channel reaches |
| Sediment regime | The volume of sediment exiting diversions is similar to that entering |
| Geomorphology | The channel incorporates, and has the capacity to develop, geomorphic features that are similar to those seen through existing channel reaches |
| Ecology | A diversity of habitats is established that supports representative flora and fauna species and provides ecological function and connectivity through the system |
| Cost | The design should be practicable such that the capital investment required should achieve an acceptable return on investment |

Source: BHP Billiton (2016)

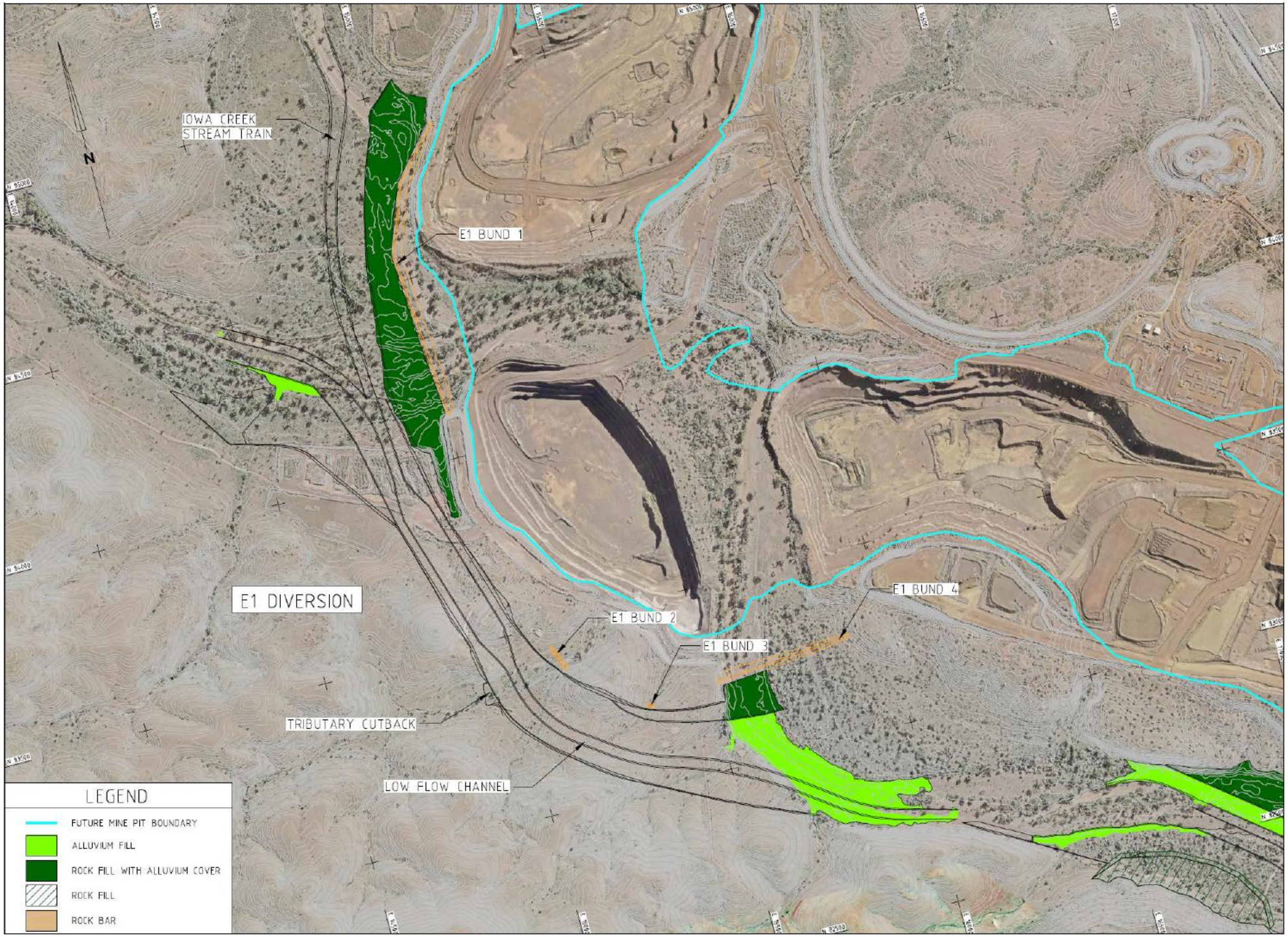
**Table 5-97 Design criteria**

| Category | Objective |
|---|---|
| Design flood event | 1:10,000-year flood event (0.01% AEP) |
| Stability | Diversion design bank slope FoS ≥1.5 for overall slope stability under static conditions and FoS ≥1.2 under seismic conditions. |

Source: Advisian (2024a)

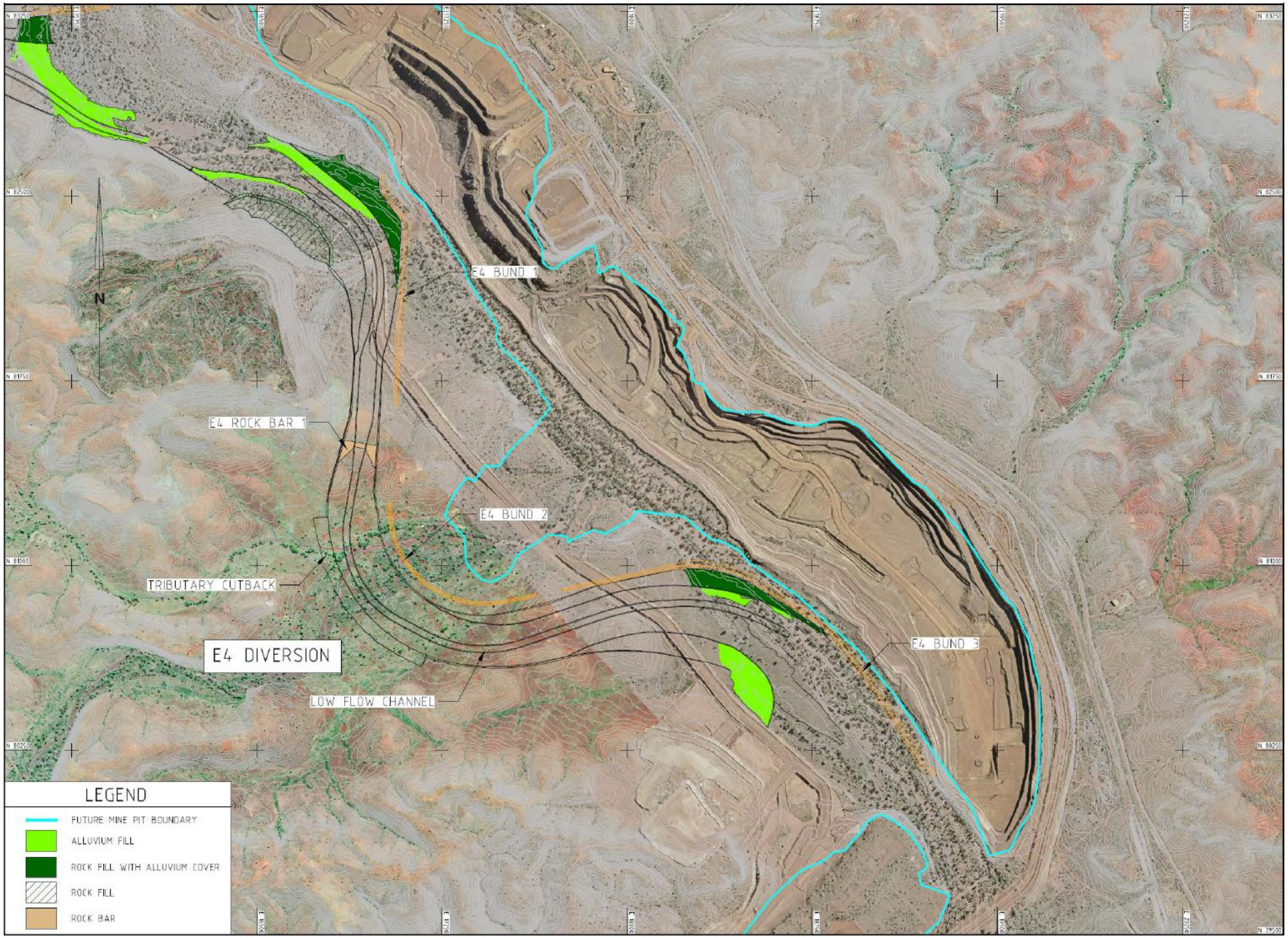
The Marillana Creek Diversion Management Plan (BHP Billiton, 2016) outlined the concept designs for the creek diversions. A series of studies (Advisian, 2017a; 2017b; 2017c; 2017d; Advisian, 2019) (AQ2, 2017) then followed to guide the development of detailed designs for the diversion. The studies considered both operational and closure conditions and were summarised in the 2020 MCP. This summary has been moved to Appendix N.1, but a precis of the key aspects considered in the design has been provided in the sub-sections below. The main design features are shown in Figure 5-107 and Figure 5-108 and include (refer to Appendix N.1 for further details):

- Planform type, width, depth, slope, sediment depth and roughness within the ranges seen in the natural system.
- An engineered shallow aquifer to support riparian vegetation. Natural alluvium was used as a surface layer for this aquifer and provides a seed source and habitat structure important to microbes and invertebrates (e.g. sediment matrix structure and interstitial velocities).
- Induced roughness elements to slow water flows and reduce erosion (e.g. woody debris and boulders). These roughness elements also promote natural colonisation of plants as they encourage deposition, not only of finer alluvium, but also seed being dispersed by water.
- Revegetation of the diversions to be achieved through natural recruitment from seasonal flows.




Source: Advisian (2017e)

**Figure 5-107 E1 creek diversion layout (key features to support function and closure outcomes)**




Source: Advisian (2017e)

**Figure 5-108 E4 creek diversion layout (key features to support function and closure outcomes)**

### Hydraulic modelling

2D hydraulic modelling conducted by Advisian (2017a; 2019) concluded that the hydraulic conditions within the diversions would be similar to those of the existing Marillana Creek system up to a 100-year ARI event. There were some minor exceedances of the S-curve bands (Appendix N.1.9), however there were no reaches where this was considered to pose a significant risk. A sensitivity analysis of the impact of the E1 or E4 creek diversion channel roughness being higher or lower than expected indicated that the hydraulics within the majority of diversion reaches would be similar to, or only slightly in excess of, the range of values associated with the existing Marillana Creek. Increases were localised and minor, and the diversions would therefore still function in a similar manner to the existing creek (Advisian, 2017a).

Multiple low flow channels are expected to form within the diversions over time and have the potential to change the diversion's hydraulic performance. Modelling of additional low flow channels in the E1 diversion was, therefore, conducted and the results compared to those from a single low flow channel. The number, depth and width of additional low flow channels were selected to match natural analogues within Marillana Creek. Comparison of S-Curves developed from the modelling suggested that the hydraulic behaviour of the diversions is not sensitive to the number of low flow channels that form over time. It is, therefore, appropriate to assess the long-term performance of the diversion designs on the hydraulic performance of the design that will be constructed, even though it is intended and expected that the morphology of the diversions will evolve over time (Advisian, 2017a).

### Sediment transport modelling

Sediment transport is a natural process in creeks with some areas accumulating sediment (aggradation) and other losing sediment (degradation). Sediment transport modelling of the E1 and E4 creek diversions was, therefore, conducted by Advisian (2017c) to compare the performance of the natural creek sections with those of the designs. The key results of this modelling are summarised below.

#### *Bed elevation changes*

The range of bed elevation changes predicted by the models for the 10 and 100-year ARI events for existing conditions and closure were similar[52]. Comparison of the 2D bed elevation maps and bell curves indicated that the range of bed elevation changes for the E1 and E4 diversions under closure conditions would be similar to existing conditions. The maximum bed elevation changes within the diversions ranged between +/-1.8 m, with 99 % of the cells having bed elevation changes of less than 1.8 m. The bell curves were symmetrical and centred on a zero change in bed elevation (Advisian, 2017c).

Modelling was conducted over 2,000 years to gain an understanding of long-term sediment transport conditions, and concluded that the sediment transport trends for existing and closure conditions were generally similar, with aggradation in the upstream reaches and degradation in the downstream reaches of Marillana Creek, and only minor changes in long term average bed elevations (<0.65 m) occurring over 2,000 years (Advisian, 2017c).

#### *Risk of scour to shallow aquifer*

Sediment transport modelling was used to inform the design of the shallow aquifer in the creek diversions such that the upper layer of the shallow aquifer was predicted to be at least 0.5 m deeper than the estimated maximum depths of scour.

#### *Risk to flood channels*

Advisian (2017b; 2017c) investigated the risk of water loss over flood channels during flows in excess of the 20-year ARI flow leading to a reduction in sediment transport capacity and subsequent sediment deposition at flood channels to determine if this could lead to diversion of more water over the flood channel and progressive loss of diversion capacity. Modelling indicated that sediment aggradation due to flood channels was not expected to result in a significant long-term increase in the magnitude and frequency of flood channel flows or increase in the risk of overtopping flood bunds, particularly over the first 100 years. Although accretion may occur in the creek adjacent to flood channels during large floods, the more frequent low-flow events scour the active channels sufficiently so that significant long-term increases in floodwater levels and flood channel flows do not occur (Advisian, 2017b; 2017c).

#### *Risk of scour to flood bunds*

Rock bars present a physical partial barrier to sediment transport during flow events and therefore lessen the risk of depletion of alluvium to some degree. However, scour areas are likely to form downstream of the rock bars during flow events. These are likely to be relatively limited in extent and provide some remnant pool benefits for aquatic habitats (Advisian, 2017b). The results of 2D sediment transport modelling (Advisian, 2017c) suggested that scour holes could be approximately 3 m deep at the toe of the rock bar and extend at shallower depth up to approximately 200 m downstream for the 100-year ARI event. Modelling showed that the rock bar scour holes were located at a sufficient distance upstream of flood bunds to minimise the risk of the scour holes impacting on the structural integrity of the bunds (Advisian, 2017c).

52 The sediment transport assessment makes relative comparisons of bed elevation changes rather than predicting absolute values due to the limitations of sediment transport modelling.

### Lateral migration of the main channel

Advisian (2017b) assessed the mobility of anabranches and low flow channels and concluded that some readjustment of the channel form is inevitable (which is intended and desirable), but large-scale change was considered unlikely given the behaviour of the low flow channel in the natural creek. Lateral erosion leading to connection of the diversion and pit was considered to be a low risk due to the distances between the walls of the diversions and the pits.

### Stability of transition zones

The transition zones (tie-in points where the diversions intersect Marillana Creek) are locations where the morphology of the channel and associated hydraulics change rapidly. Therefore, there is a potential risk of accelerated erosion (specifically head cutting) and / or deposition (Advisian, 2017b).

While upstream progressing head cutting was considered to be a low risk, hydraulic modelling indicated that modest morphological adjustment is likely to occur. Design modifications were made to reduce these risks in the transition zones including (Advisian, 2017b):

- Removal of all rock bars from E1 and the first (upstream) rock bar from E4.
- Modifications to channel widths and bed gradients.

### Vegetation

AQ2 (2017) conducted ecohydrological water balance modelling to determine the appropriate depth of alluvium for creek diversions to enable them to support riparian vegetation at currently observed tree densities over periods between recharge events of up to 6 years. The modelling concluded that an aquifer thickness of 6 m (beneath the zone supporting vegetation) would provide a soil moisture content between 3% and 18%, and the soil matric potential would remain above -4,500 kPa, to allow the survival of some tree species in drought conditions; specifically, *Eucalyptus victrix*.

The design of the shallow aquifer was adjusted for each diversion reach type / category to reflect the vegetation distributions and densities of natural analogues as follows (AQ2, 2017):

- **Anabranching:** the aquifer must support trees at a similar density to the existing creek over the full width of the active channel zone, and support scattered trees, shrubs, spinifex and other grass species on the floodplain areas.
- **Incised - Category 1:** the aquifer must support trees at similar density to the existing creek on the marginal benches of the channel, with no vegetation expected to be permanently established in the centre of the channel.
- **Incised - Category 2:** the aquifer must support trees at a similar density to the existing creek over the full width of the active channel zone.

AQ2 (2017) predicted that where the creek diversion and associated engineered shallow aquifer crosses permeable geology (e.g. alluvium or colluvium of tributary creeks or residual CID), then groundwater would seep from the bottom of the engineered aquifer into the underlying material, particularly where this material is in connection with the mine-voids. While recharge will replenish the aquifer, water levels will recede between recharge events and no permanent shallow water table can be expected. Trees likely to establish in these environments are *Eucalyptus victrix* and *E. camaldulensis* subsp. *Refulgens* (BHP Billiton, 2016). In some small areas of the diversions, locally reduced water availability may result in reduced tree-density of potentially 30% or more (AQ2, 2017).

#### 5.15.3.2 Monitoring results

Monitoring of the E1 and E4 creek diversions is conducted in accordance with the Marillana Creek Diversion Management Plan (BHP Billiton, 2016). This program is summarised in Section 10.1.8.

The plan requires different levels of monitoring to be conducted based on the results of the previous monitoring program and level of risk associated with each diversion. The last Level III monitoring was conducted in FY21. Since that time, flow events have been lower than the 2-year AEP event and so only Level I monitoring has been conducted. To date, monitoring has shown that the diversions are performing as expected with visible banks forming in the channel and vegetation re-establishing. Further details of the results of the 2021 Level III and 2023 Level I monitoring events are summarised below.

In addition to the Level I and Ill monitoring:

- BHP also routinely monitors sediment upstream and downstream of the E1 and E4 creek diversions.
- Advisian conducted an inspection of the creek diversions in 2023 as part of the Yandi closure study.

The results of these studies are also summarised below.

### 2021 Level III monitoring results

Level III monitoring includes an assessment of the Index of Diversion Condition (IDC) and evaluation of ecological indicators. The target performance is that the diversions achieve a total IDC score that is comparable (>70%) to the upstream control reach (refer to Table 8-2, Section 8.3.2). A comparison of the IDC scores for each diversion against the control reach are shown in Figure 5-109. The total IDC scores are 57% and 52% of the upstream control reach scores for E1 and E4 diversions, respectively. However, the overall scores are affected by the low riparian indices which are due to the young age of the diversions. Photo monitoring showed that vegetation has established along creek banks and within the creek bed, however, neither diversion met the target of 8 out of 10 ecological indicators due to the early establishment phase of vegetation. Non-native species were noted to be competing with native vegetation in the E4 diversion.

A comparison of the geomorphological indices (which includes consideration of development of natural creek features) show that the E1 diversion achieved a geomorphic index score of 88% of the control reach, and the E4 diversion an index of 64% of the control reach.

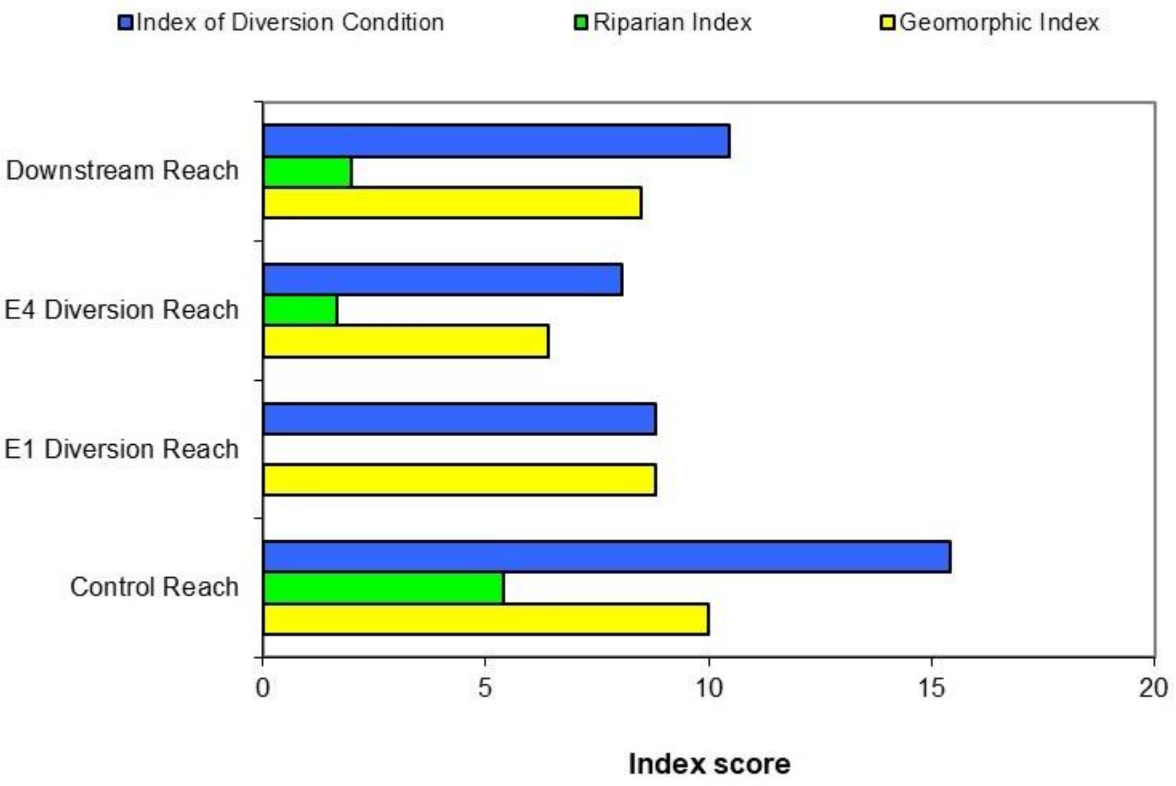



**Figure 5-109 E1 and E4 diversion IDC scores compared to the control reach**

### 2023 Level I monitoring results

Figure 5-111 and Figure 5-112 show photographs taken of the diversions during the Level I monitoring event in 2023. Figure 5-113 shows photographs of the upstream control site taken in 2022.

Vegetation in the E1 creek diversion is becoming established along the banks (Transect 1 Figure 5-111) and within the creek beds (all transects Figure 5-111). Heavy vehicle tracks left post-construction were only minimally visible, as sediments are establishing a more natural form within the creek bed.

Ground cover density at transect 1 of E4 creek diversion (Figure 5-112) was observed to have increased, but this was accompanied by an increase in non-native vegetation. At transect 2 (Figure 5-112), vegetation was observed establishing at the base of the embankment and the transition between the embankment and creek bed was less marked signalling a return to a more natural geomorphological state. While vegetation was sparse within transect 3 (Figure 5-112), a small bench had formed within the middle of the creek bed indicative of a healthy geomorphic feature.

LiDAR data (Figure 5-114 and Figure 5-115) show that the diversions are performing as expected, with the area of deposition shown in the northern portion of the E1 diversion indicative of natural processes establishing within the diversion.

Some areas of erosion and slumping have been observed (for example see Figure 5-110 which was taken in 2020), however, this is consistent with the design expectation that the system will evolve to a natural state over many years, and is not considered to require any intervention (WAIO, 2020b).

Source: WAIO (2020b)

**Figure 5-110 E1 diversion oblique view example of erosion / slumping**


**Figure 5-111 E1 creek diversion aerial imagery and photographs taken in 2023**

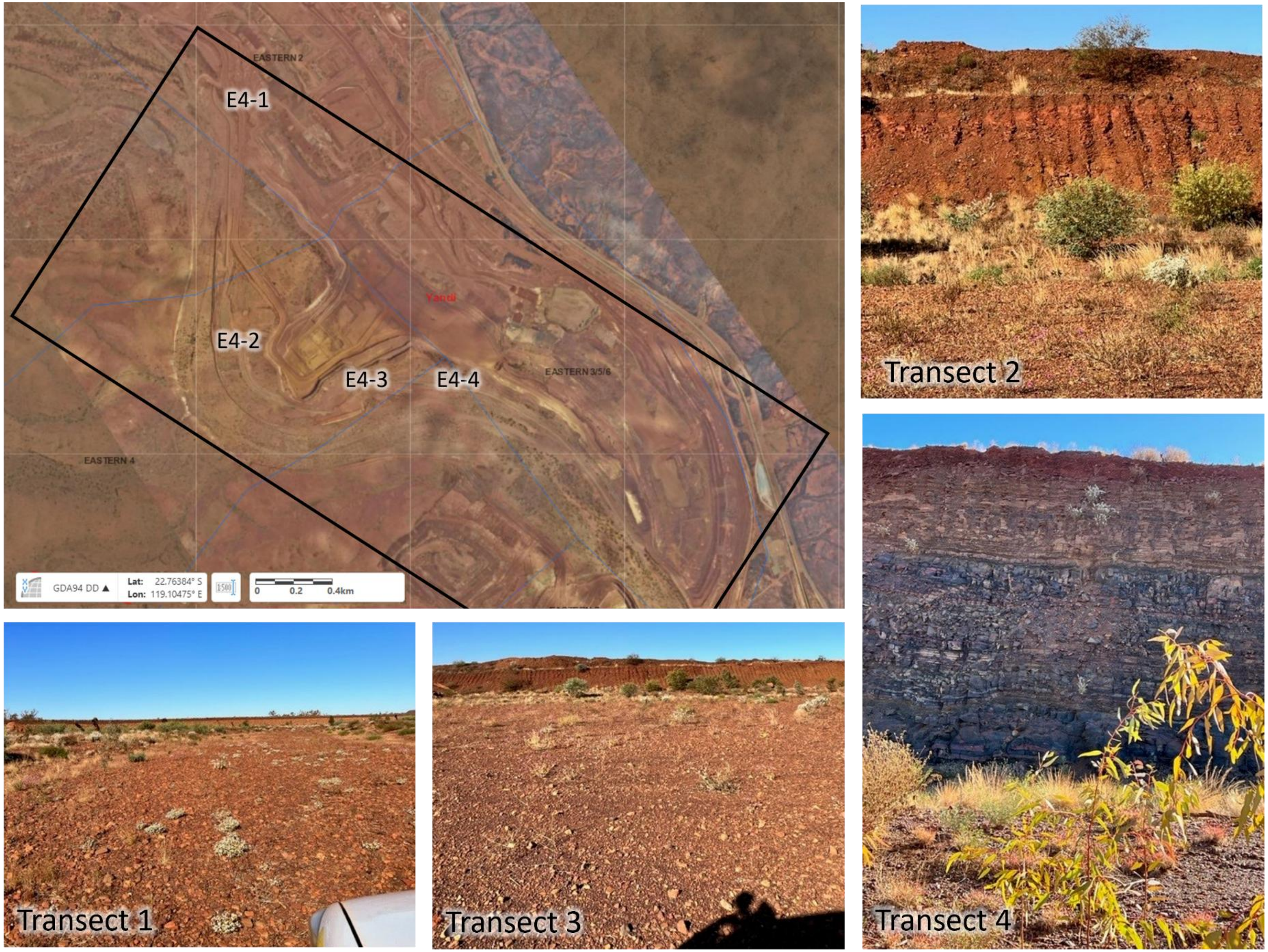



**Figure 5-112 E4 creek diversion aerial imagery and photographs taken in 2023**

**Figure 5-113 Photographs of upstream control site in 2022**

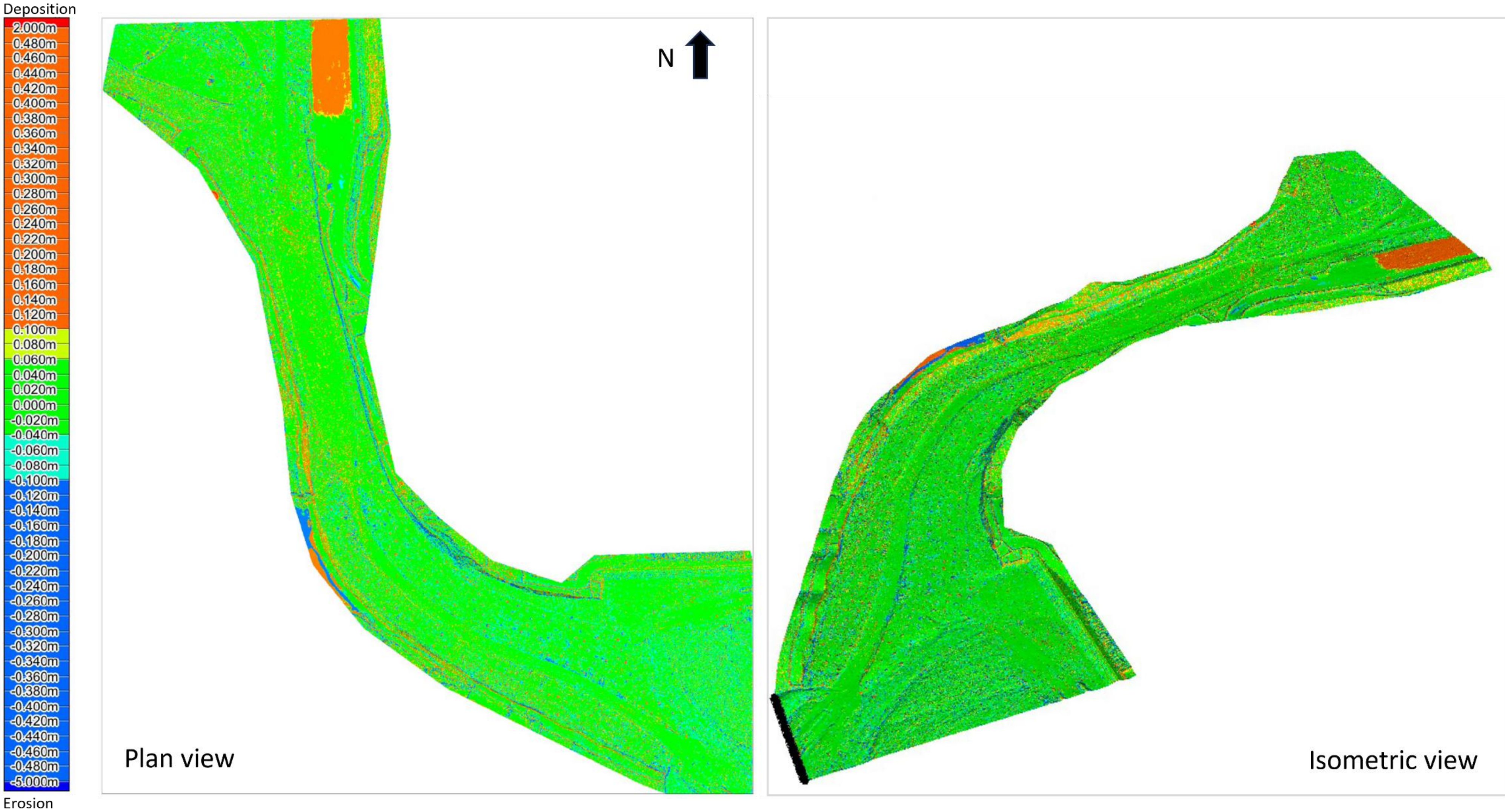



**Figure 5-114 2023 LiDAR survey of E1 creek diversion**

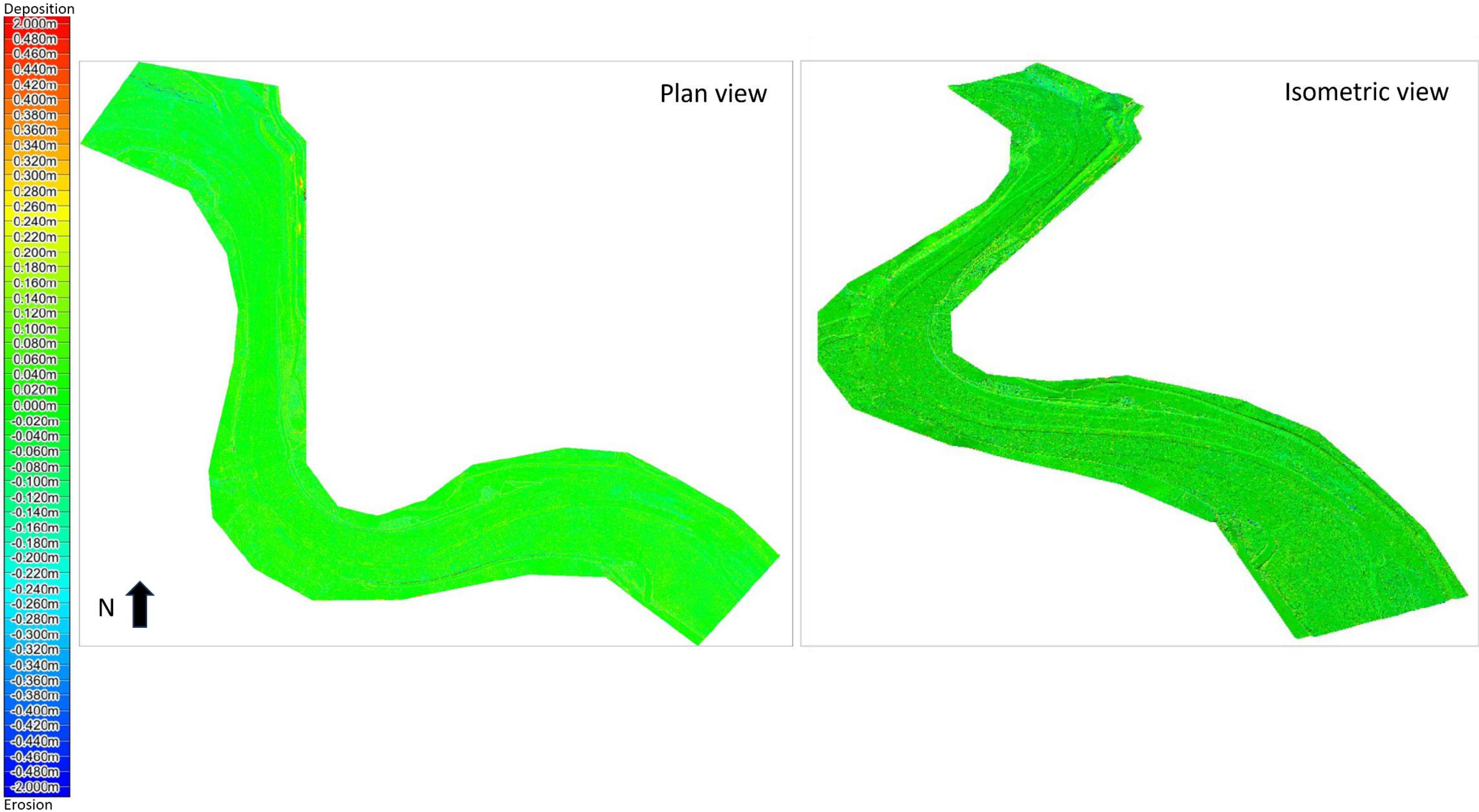



**Figure 5-115 2023 LiDAR survey of E4 creek diversion**

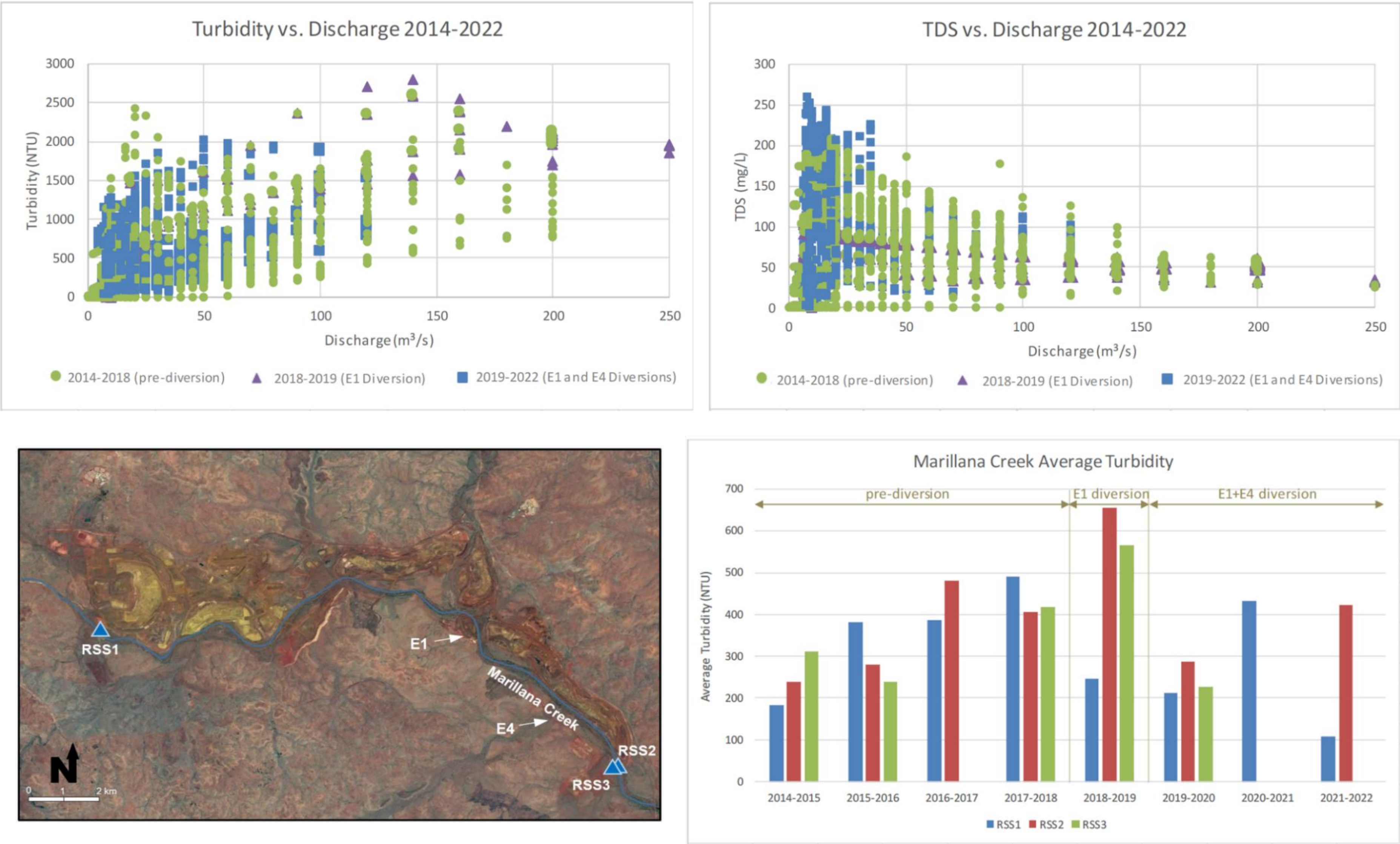
### Sediment monitoring

BHP installed rising stage samplers upstream and downstream of the E1 and E4 creek diversions prior to their construction and has continued to use these locations to monitor the performance of the diversions (refer to Section 10.1.8.2 for map of locations).

Figure 5-116 shows

- TDS and turbidity vs. discharge for the two downstream gauges for the entire monitoring period. Results from:
  - Before the construction of the Marillana Creek diversions (2015-2018) are shown in green.
  - The first year of the E1 diversion being in place (2018-2019) are shown in violet.
  - 2019-2022, with both the E1 and E4 diversions in place, are shown in blue.
- The average turbidity at each sampling location for the entire period.

The results show a notable increase in turbidity at downstream locations in 2018-2019 (which is the first year that the E1 diversion was in place) with a subsequent reduction in 2019-2020. The 2021-2022 average data reflect a trend of increasing turbidity in the downstream direction, however, the limited data mean that these results are inconclusive (Surface Water Consulting, 2023). The graph of turbidity versus discharge indicates that between 2019 and 2022, turbidity has generally been within the range of pre-diversion levels (Figure 5-116).




Source: Surface Water Consulting (2023)

Note: 2020-2022 turbidity units have been reported in FNU, whereas turbidity data prior to 2020 have been reported in NTU. No adjustments have been made to the readings.
The turbidity and TDS versus discharge graphs show data for the two downstream monitoring gauges only.

**Figure 5-116 Marillana Creek diversion sediment monitoring**

#### Advisian 2023 site inspection

Advisian conducted an inspection of the E1 and E4 creek diversions in August 2023 and concluded that the diversions are functioning as intended and will require little or no intervention for closure. Observations from the site inspection are (Advisian, 2024a) (Figure 5-117):

- Vegetation growth is performing well; many trees 5 m to 6 m high were noted in the main channel with smaller shrubs and trees on floodplain areas.
- Roughness elements (tree stumps, rock piles, boulder piles) have performed well, and there is evidence of deposition and vegetation growth behind these elements, as intended.
- Scour / head cutting was observed for a tributary entering the E1 diversion, however, the extent of the upstream cutback was limited and appeared to have stabilised on protruding BIF. Sediment deposited in the creek from the cut back appeared to be integrating into the landform.
- A rock bar is outcropping in E4 diversion could be utilised to create an ephemeral pool.

#### 5.15.3.3 Remedial action

Infill planting will be considered, if required to achieve completion criteria for vegetation diversity, and operational weed spraying is being used to manage non-native plant establishment.


Source: Advisian (2024a)

**Figure 5-117 Photographs from Advisian 2023 site visit**

### 5.15.4 OSA performance

Most of the ex-pit OSAs at Yandi will be relocated into the pits to achieve the proposed final backfill design (Section 9.2.3.1), noting that this design is under review. Two OSAs (C1 and E2) have been fully rehabilitated (except for a small active landfill area) and will remain in the landscape post-closure for the reasons outlined in Section 9.2.1. Other OSAs are being relocated as backfill to the pits. Some have previously been partially rehabilitated (small areas), but the ex-pit material is required as part of the updated closure backfill strategy. This section, therefore, focuses on the performance of those OSAs that are proposed to remain in the landscape, to provide an indication of the long-term success of rehabilitation.

A brief description of each OSA and current rehabilitation performance is provided in Sections 5.15.4.1 and 5.15.4.2, with further details provided in Appendices N.2 and N.3. Rehabilitation at both OSAs commenced approximately 20 plus years ago and consequently design information is limited. To provide confidence in the long-term stability of the landforms, landform evolution modelling was conducted for the current landform geometries using conservative assumptions for material properties (Section 5.15.4.3). Together, the rehabilitation monitoring and landform evolution modelling results show that the OSAs are on track to achieve completion criteria.

**Summary**

The C1 OSA was rehabilitated between 2005 and 2011. However, an area on the eastern side of the OSA was identified as requiring additional work and this rework was completed in 2020. The last on-ground monitoring (2021) noted that that all 'on-ground' completion criteria were met, and that the eastern part of the OSA rehabilitated in 2005 (area to the east of the recently remediated area) was reflective of an analogue state. Remote sensing metrics of the older rehabilitation areas have shown that six of eight completion criteria have been met, and that tree cover is within 25% of the completion criteria target. The hummock grass cover target was not met, but may have been affected by increased shrub cover after above average rainfall conditions

E2 OSA was rehabilitated between 1998 and 2004. On-ground monitoring (2021) indicated that the sites monitored had met all on-ground completion criteria and that the top surface of the OSA was reflective of an analogue state. Remote sensing has indicated that completion criteria are largely met, except for the tree cover and herb cover criteria, although it was noted in 2021 that most areas were close to meeting the tree cover criterion. The hummock grass cover target has not been met in the northern portion of the OSA.

The SIBERIA modelling conducted for the C1 and E2 OSAs is underpinned by historic materials testing and two-dimensional erosion modelling, as well as rehabilitation monitoring results quantifying the level of vegetation cover. The outputs are, therefore, considered quantitative. While landforms are expected to predominantly comprise erosion resistant UCID, modelling conservatively assumed a 75% UCID 25% LCID (more erodible) mix. Rainfall conditions predicted for a climate change scenario (assuming a maximum increase of 5% in annual rainfall) were also conservatively used for the full 100-year modelling period.

The outputs of the modelling showed that:

- Both C1 and E2 OSAs predicted erosion rates met completion criteria for annual and peak erosion rates due to the substantial current vegetation cover and robust OSA designs which include appropriate slopes and measures for controlling run-off down slopes.
- Incisive erosion was not widespread, and erosion was generally minor and non-continuous / diffuse.

Given the significant impact that vegetation cover can have on erosion rates, a sensitivity analysis was conducted to determine the effects of increasing or reducing cover by 20%. The modelling concluded that annual erosion rates for E2 OSA would meet the completion criterion of 6 t/ha/y in both increased (1 t/ha/y) and decreased (4 t/ha/y) vegetation scenarios. The modelling for the C1 OSA predicted an annual erosion rate of 8 t/ha/y in the decreased vegetation scenario which exceeds the completion criterion of 6 t/ha/y, however, for this rate to persist in the long term, vegetation cover would need to be consistently lower than current conditions.

#### 5.15.4.1 C1 OSA

**Description**

The C1 OSA was rehabilitated between 2005 and 2011. However, an area on the eastern side of the OSA was identified as requiring additional work and this rework was completed in 2020. An active landfill is located in the north-eastern corner of the landform, and this will be backfilled and integrated into the rest of the landform, then rehabilitated at closure (Figure 5-118).

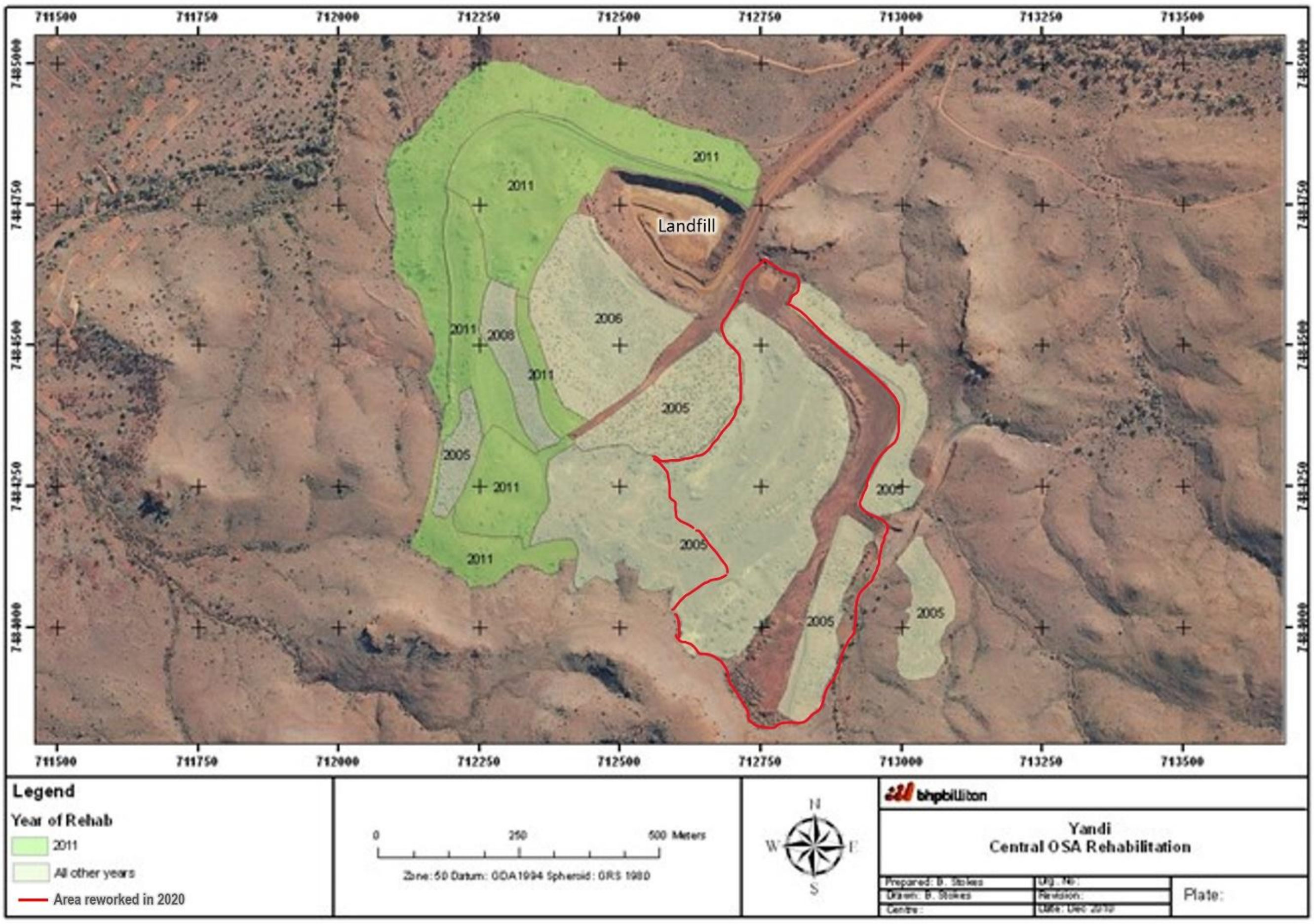



**Figure 5-118 C1 OSA rehabilitation areas**

## Design

The design for the rework was reported in the 2020 MCP and this description has been moved to Appendix N.2 along with an overview of the rehabilitation designs / techniques used prior to 2020. The C1 OSA landform has been predominantly reprofiled to slopes between 17 and 20°. Figure 5-120 shows the full extent of the landform in 2024 and Figure 5-119 focuses on the section remediated in 2020.

Topsoil has been applied across the landform and the areas rehabilitated in 2011 were seeded. Crest bunds, inter bunds and rock armour have been installed in key locations to manage surface drainage and erosion, and Figure 5-119 clearly shows how the design directs excess surface water flow from the OSA to the surrounding area, with the discharge point being located close to natural topography rather than discharging down OSA slopes. Fauna habitats have also been installed in several locations (Figure 5-119). A moonscaping (scalloping) technique was used in one of the older areas to enhance water infiltration and vegetation growth (Figure 5-119).

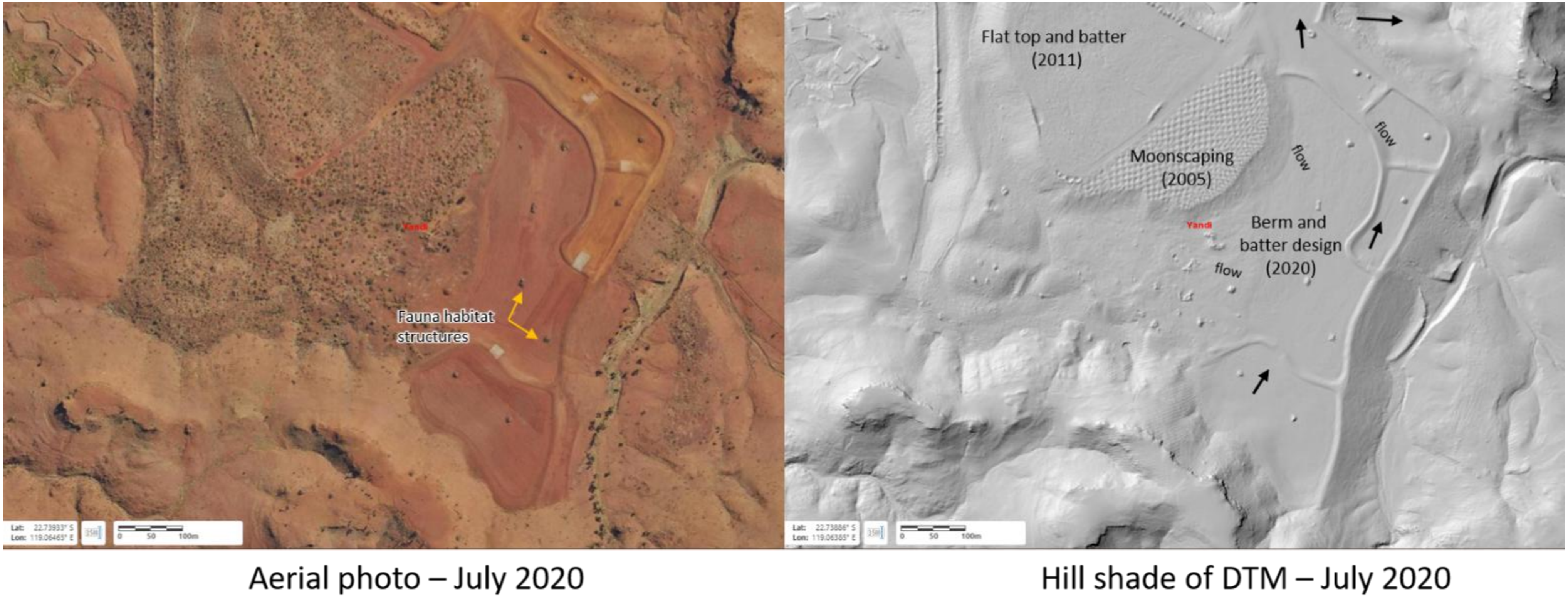



**Figure 5-119 C1 OSA status as at July 2020**

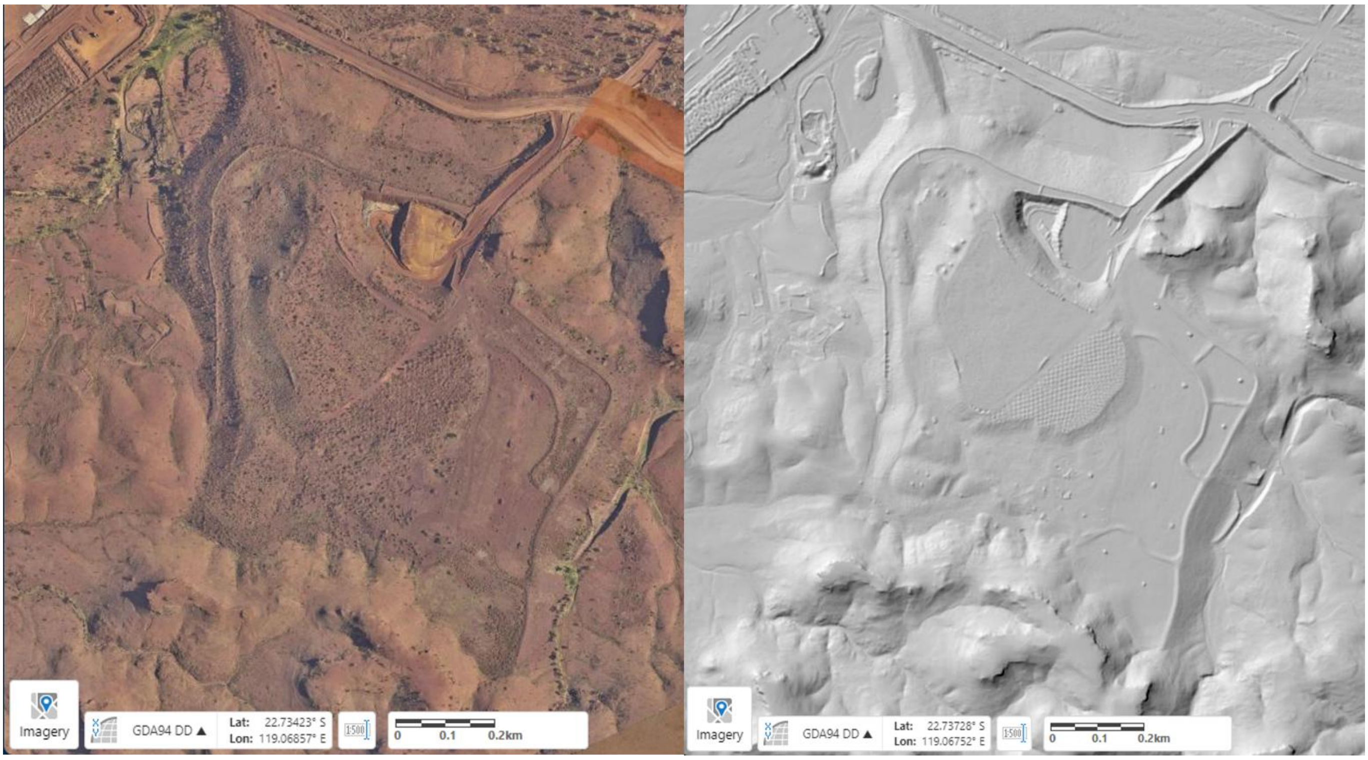



**Figure 5-120 C1 OSA (February 2024)**

### Monitoring results

The last on-ground monitoring was conducted in 2021 and noted that that all ‘on-ground’ completion criteria (annual and perennial species richness, and priority alert weed species) were met, and that the eastern part of the OSA rehabilitated in 2005 (located to the east of the area remediated in 2020) was reflective of an analogue state. Figure 5-121 shows photographs taken during the last on-ground monitoring exercise. Remote sensing metrics in 2021 showed that the OSA was meeting six of the eight completion criteria. One monitoring area (YNM_S_54) on the eastern portion of the OSA (outside of the area reworked in 2020) was meeting all completion criteria except tree cover. The remaining sites were within 25% of the completion criteria target for trees but did not meet the target for hummock grass cover. However, it was noted that hummock grass cover may have been affected by increased shrub cover after above average rainfall conditions (Spectrum Ecology, 2021).

Buffel grass (*Cenchrus ciliaris*) was observed to be establishing in recently topsoiled areas of the area reworked in 2020.

Source: Spectrum (2021)

**Figure 5-121 C1 OSA rehabilitation during on-ground monitoring (2021)**

### Remedial action

Rehabilitation on C1 OSA is progressing and meets most completion criteria. The 2021 monitoring report recommended that monitoring be continued.

The areas of observed buffel grass growth on the area of the OSA reworked in 2020 are being treated. Once this species has been successfully controlled, this area will be seeded, if required.

#### 5.15.4.2 E2 OSA

### Description

E2 OSA was rehabilitated between 1998 and 2004. The E2 OSA was primarily constructed of overburden from the E2 Pit.

### Design

Available information on the design of the E2 landform was reported in the 2020 MCP and has been moved to Appendix N.3. Slopes were re-profiled to between 15° and 20°. The top surface of the OSA was designed to be internally draining; bunds were constructed around the perimeter of the top surface to prevent water from flowing down the slopes and minimise the potential for erosion. Topsoil was variously applied to different sections of the landform, and the available data indicates that the older sections of the landform were not seeded, but more recent sections were. Fauna habitats have been constructed in both older and newer sections of rehabilitation. Figure 5-122 shows a recent aerial photograph of the OSA and a hill shade view that shows the landform in more detail.

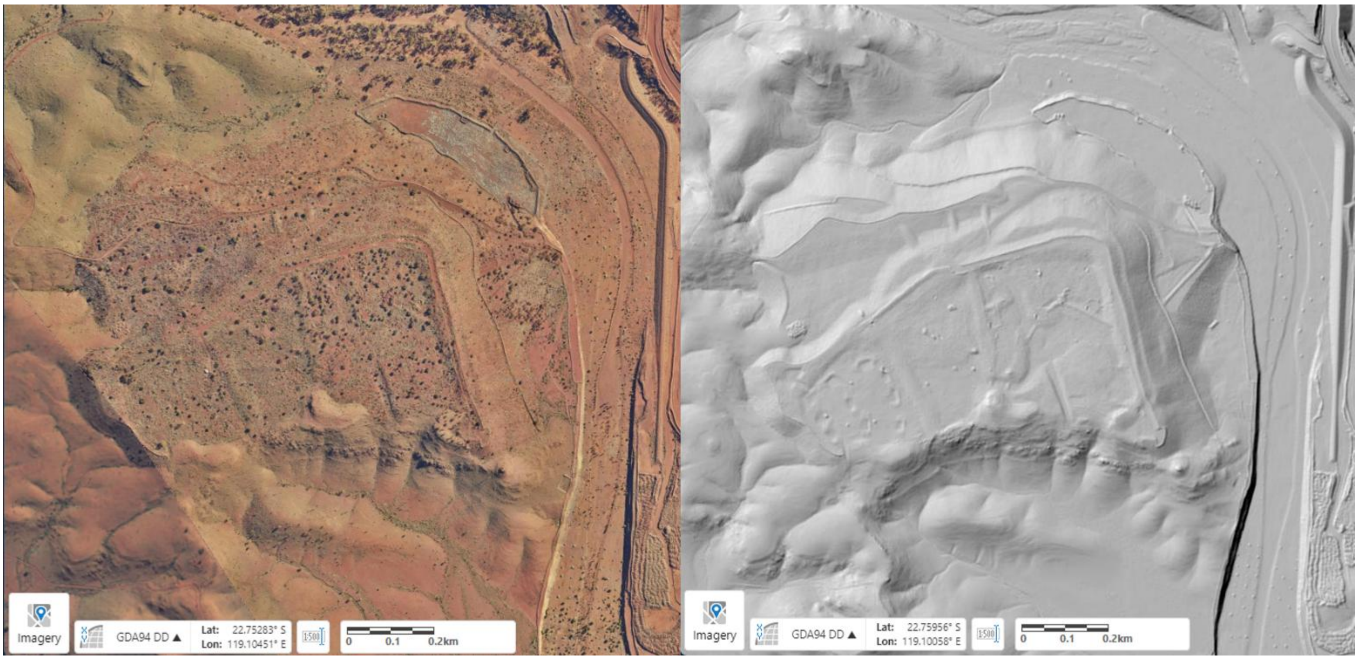



**Figure 5-122 E2 OSA (August 2023)**

### Monitoring results

On-ground monitoring in 2021 indicated that the sites monitored had met all on-ground completion criteria and that the top surface of the OSA was reflective of an analogue state. Remote sensing at this time indicated that the top surface had achieved seven out of eight completion criteria, with only the tree cover criterion not met (cover of 0.8% as opposed to a target of 1%) (Spectrum Ecology, 2021). In 2022 remote sensing indicated that neither the tree cover criterion nor the herb cover criterion had been met (Spectrum Ecology, 2022).

In 2021, the eastern slope of the OSA had achieved most of the completion criteria measured by remote sensing, but did not meet the tree cover, **Cenchrus*, and total weed cover completion criteria targets. However, in 2022, remote sensing indicated that this area had met all criteria except for tree cover and herb cover (Spectrum Ecology, 2021; 2022).

An inspection was conducted of the northern portion of the OSA in 2021 and confirmed that hummock grass cover was low. In 2022, remote sensing indicated that all completion criteria had been met except for tree, hummock grass and herb cover, although it is noted that in 2021, the herb cover target was met and tree cover was 1% (compared to a target of >1%) (Spectrum Ecology, 2021; 2022).

Photographs taken during on-ground monitoring are provided as Figure 5-123.

Source: Spectrum (2021)

**Figure 5-123 E2 OSA rehabilitation during on-ground monitoring (2021)**

#### Remedial action

Given the progress of the rehabilitation to date, no remedial works are planned.

### 5.15.4.3 OSA landform evolution modelling

Okane (2023b) conducted landform evolution modelling to assess the long-term erosional stability of the C1 and E2 OSAs. The following sections summarise the approach taken to the assessment, and the results of the modelling by landform.

#### Approach to modelling

SIBERIA modelling was used to assess long-term erosional stability and is considered quantitative as it is underpinned by historic materials testing and two-dimensional erosion modelling. The inputs to the model were (Okane, 2023b):

- The current landform geometry of the C1 and E2 OSAs based on survey data. The landfill in the north-eastern corner of the C1 OSA was, therefore, modelled in its current state (open with relatively steep embankments that will be backfilled and re-profiled during closure).
- The physical characteristics and WEPP erosion modelling outputs generated by Landloch (2016) for the LCID and UCID materials (Section 5.2.4.1). These inputs are reflective of both the mined materials and the regional hydrology. LCID overburden exhibits greater susceptibility to erosion, while the competent, rocky UCID overburden is relatively stable. The OSAs are expected to contain predominantly UCID material, but they were conservatively modelled as a 75% UCID / 25% LCID mix which allows for the potential heterogeneity and weathering of the materials present in landforms.
- The vegetation cover on the landforms measured during rehabilitation monitoring by Spectrum (2019) which was 40% for C1 OSA and 27% for E2 OSA. The impact of ground cover on resisting erosion rates was estimated using the Revised Universal Soil Loss Equation (RUSLE) which is based on an exponential decay relationship between the percentage soil loss compared to an unvegetated condition and has been well-corroborated with multiple field and modelling studies.
- Rainfall derived from 2090 predictions using the Climate Change Australia Projections Tool (CSIRO and Bureau of Meteorology, 2023) for the nearest rainfall station (Wittenoom Gorge) to account for climate change. This results in the assumption of a maximum increase in annual rainfall of 5%. These conditions were conservatively applied to all years of modelling.

The effectiveness of vegetation in reducing erosion rates is widely acknowledged. It contributes to erosion control by (Okane, 2023b):

- Binding particles together through root systems and cryptogams.
- Dissipating the energy of rainfall and runoff.
- Increasing gravitational / frictional resistance to particle detachment and transport.
- Elongating the hydrological response of surface water runoff, thereby reducing surface water runoff rates and velocities.

Given the significant influence of vegetation on erosion, a sensitivity analysis was conducted for both a 20% increase and 20% decrease in vegetation cover compared to the cover measured by Spectrum (2019) (Okane, 2023b).

Erosion rates have been evaluated against BHP's completion criterion of an average erosion rate of ≤6 t/ha/y[53] (Section 8.3.2). To enable the outputs of SIBERIA modelling to be compared to this criterion, the criterion was defined as average erosion rates of 6 t/ha/y or less on OSA slopes, calculated over a 100-year period at the 2 m x 2 m grid scale (Okane, 2023b).

The criterion of <12 t/ha/y maximum erosion rate at any point on a slope was replaced by no widespread incisive erosion on OSAs over a 100-year timeframe. This adjustment (Okane, 2023b):

- Addresses the potential for inconsistent performance across the OSA.
- Retains the intent of the criterion for achieving erosionally stable OSAs.
- Addresses the differences in scale and timeframes that arise when comparing WEPP and SIBERIA outputs. As SIBERIA is a three-dimensional model, the 99th percentile erosion depth is used as a metric for assessing performance across 99% of the landform and whether gullying is 'widespread'.

### C1 OSA SIBERIA model outputs

Based on the outputs of the SIBERIA model for C1 OSA (Figure 5-124), Okane (2023b) concluded that predicted erosion rates meet completion criteria due to the substantial current vegetation cover and robust OSA designs. Specifically:

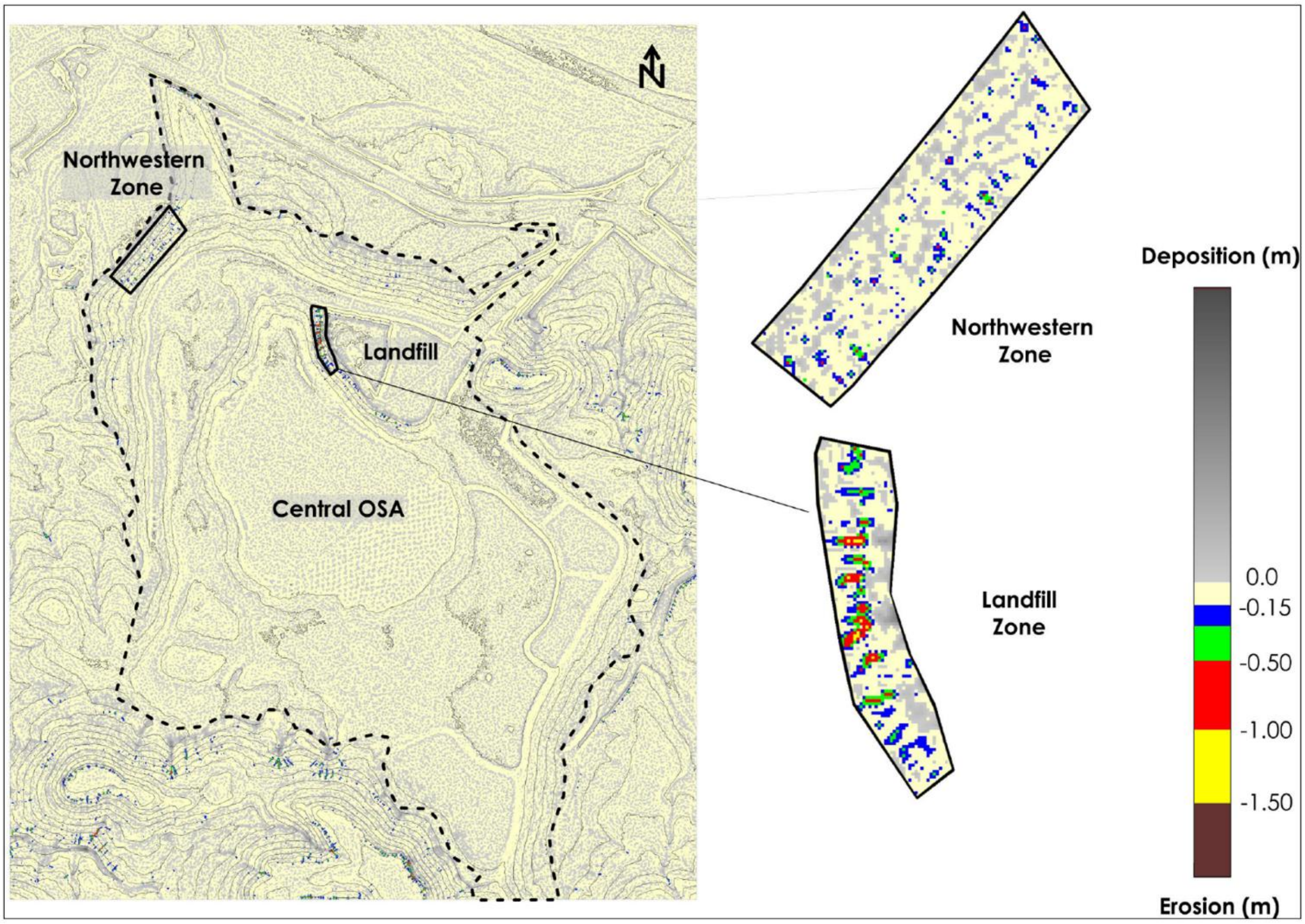
- Average erosion rates on sloping embankment areas were predicted to be 2 t/ha/y with the current vegetation cover and met the completion criterion of ≤6 t/ha/y.
- A maximum erosion depth of 0.8 m was predicted, although this was not representative of conditions across the OSA. The 99th percentile erosion depth was ~0.09 m, indicating that incisive erosion would not be widespread. Erosion was generally minor and non-continuous, satisfying targets for peak erosion conditions.
- A visualisation of the north-western OSA slopes (where erosion is the highest across the OSA) shows the general absence of incisive erosion (Figure 5-124).
- The +/- 20% vegetation scenarios resulted in modelled average erosion rates of 2 t/ha/y and 8 t/ha/y respectively. This indicates that a substantial vegetation decline of 20% would result in an exceedance of the average erosion rate criterion of <6 t/ha/y, however, for this rate to persist in the long term, vegetation cover would need to be consistently lower than current conditions.

It should be noted that the model includes the landfill which is still being used and consequently has not yet been rehabilitated. The landfill will ultimately be backfilled and reprofiled for closure and so the model results cannot be treated as valid for this area (Okane, 2023b).

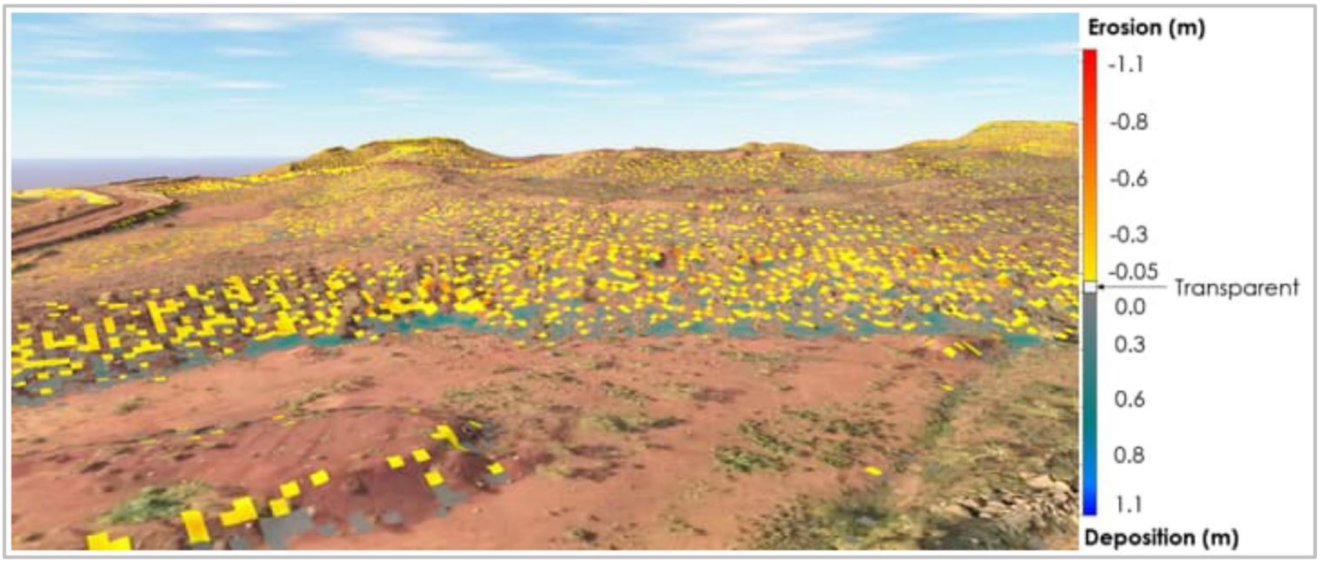
The stable predictions were attributed to (Okane, 2023b):

- The high proportion (75%) of stable, rocky UCID materials considered in the model.
- High levels of existing vegetation cover which have a significant effect on mitigating erosion.
- The OSA rehabilitation design includes engineered structures to direct surface water runoff along preferred drainage routes. These features include crest bunds and inter-bunds which are specifically designed to manage surface water and erosion. These structures compartmentalise OSA sub-catchments and direct surface water run-off away from higher risk slope areas.
- The absence of excessively steep embankments. The steepest areas surround the open landfill areas on the northeastern part of the OSA, which have not yet been rehabilitated.

[53] Note: the Okane (2023b) study used targets previously adopted by Landloch (2016) of ≤5 t/ha/y and ≤10 t/ha/y which have since been superseded by BHP's completion criteria targets of ≤6 t/ha/y and ≤ 12 t/ha/y which have been based on work conducted by Landloch (2018). The analysis in the following sub-sections uses the current completion criteria targets.




**Landform overview**




**Area of modelled peak erosion**

Source: Okane (2023b)

Note: the slopes outside the dotted boundary of the OSA are natural slopes are do not form part of the assessment.

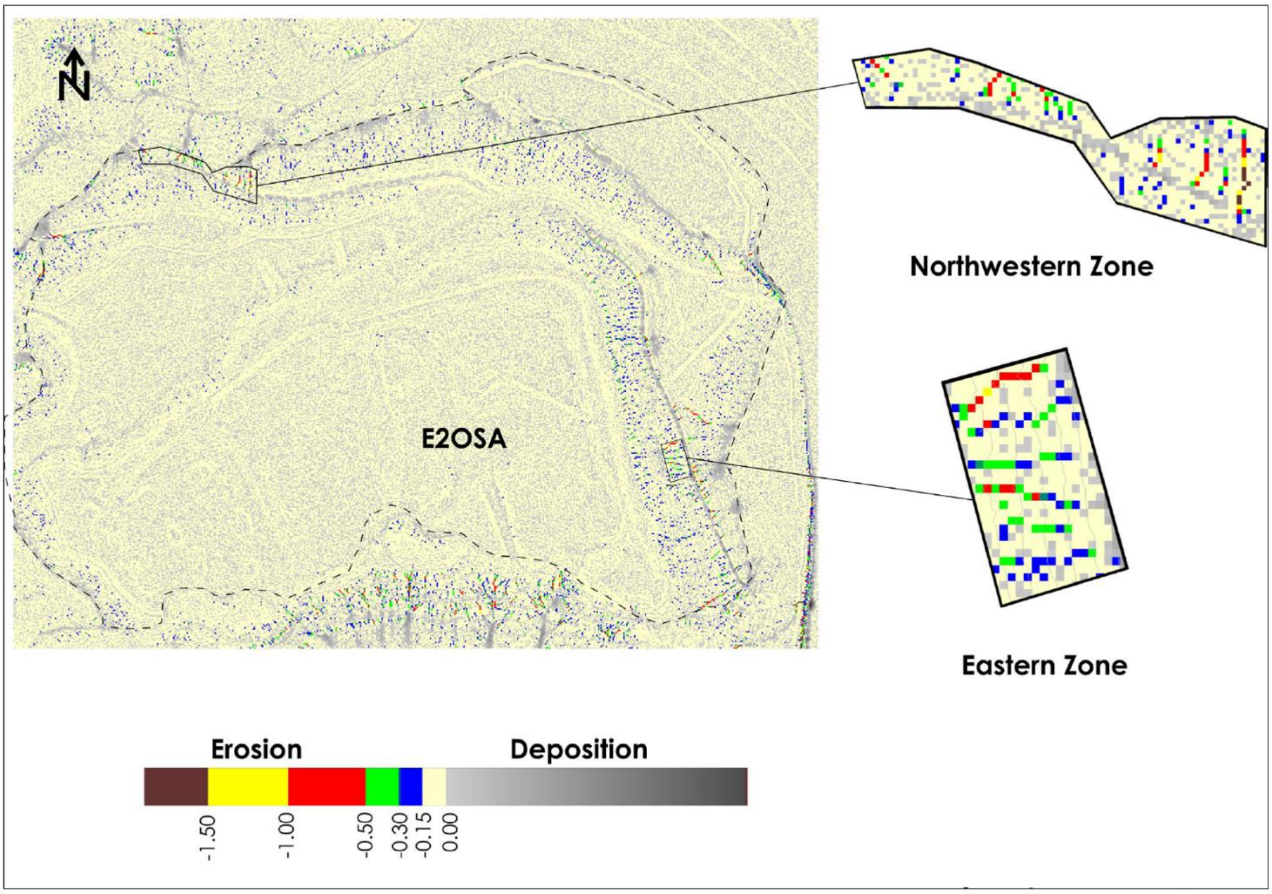
**Figure 5-124 C1 OSA SIBERIA modelling outputs**

### E2 OSA SIBERIA model outputs

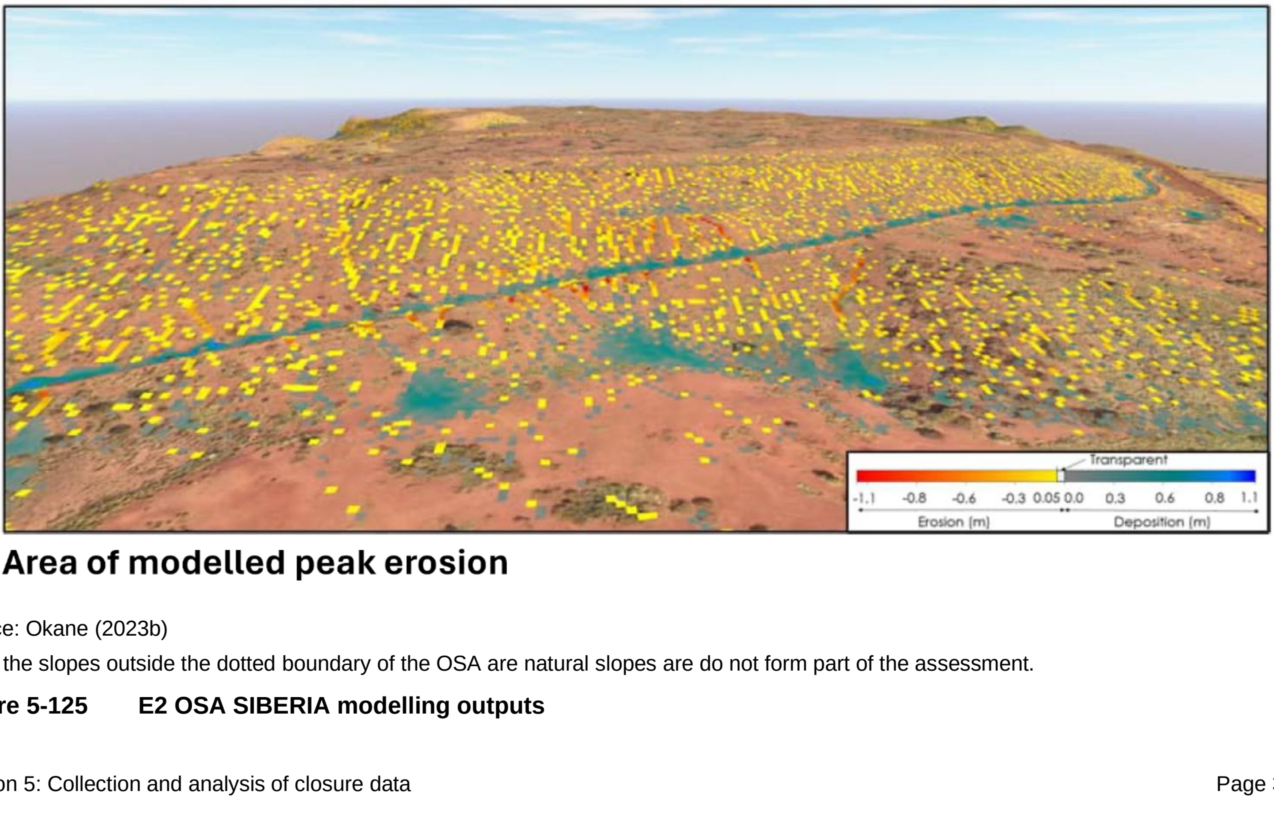
Based on the outputs of the SIBERIA model for E2 OSA (Figure 5-125), Okane (2023b) concluded that predicted erosion rates meet completion criteria due to the substantial current vegetation cover and robust OSA designs. Specifically:

- The average erosion rates on sloping embankment areas were predicted to be 4 t/ha/y with the current vegetation cover and met the completion criterion of ≤6 t/ha/y.

- A maximum erosion depth of 1.8 m was predicted, but this was not indicative of widespread conditions. The 99th percentile erosion depths across the OSA were ~0.2 m, indicating that incisive erosion would not be widespread, satisfying targets for peak erosion. Predicted erosion was generally minor and diffuse, with few incisive erosion features developing across the rehabilitated slopes.
- A visualisation of the north-western OSA slopes (where erosion is the highest across the OSA) shows the general absence of incisive erosion (Figure 5-125).
- The +/- 20% vegetation scenarios resulted in modelled erosion rates of 1 t/ha/y and 4 t/ha/y respectively, meeting completion criteria.




**Landform overview**




**Area of modelled peak erosion**

Source: Okane (2023b)

Note: the slopes outside the dotted boundary of the OSA are natural slopes are do not form part of the assessment.

**Figure 5-125 E2 OSA SIBERIA modelling outputs**

The stable erosion predictions for E2 OSA were attributed to (Okane, 2023b):

- The high proportion (75%) of stable, rocky UCID materials considered in the model.
- The high vegetation coverage and the erosion resistance that vegetation provides.
- The presence of engineered structures to limit slope lengths and direct surface water runoff along preferred drainage routes including engineered structures such as surface water drains and crest bunds which avoid discharges over slopes and direct surface water runoff.
- The absence of excessively steep embankments.
- The absence of large, expansive plateau catchments draining over slopes.

### 5.15.5 Vegetation completion criteria research

Syrinx (2019) conducted a study to develop vegetation completion criteria for BHP's Pilbara sites (Section 5.15.5.1 and Appendix M.1). The outcomes of this study form the basis for the vegetation criteria outlined in Section 8.3.2, although targets and species lists have been refined since 2019, based on monitoring data (Syrinx Environmental, 2023). Additional research has been conducted by AQ2 (2020a) and Okane (2024b) to consider domain-specific criteria to be applied at Yandi, including the vegetation communities that may be established in backfilled pits. The outcomes of these studies are summarised in Sections 5.15.5.2 and 5.15.5.3 and are being used to define the revegetation strategy for Yandi. Section 5.15.5.4 provides an overview of the forward work plan to further develop the revegetation strategy and associated criteria. This includes the establishment of trials. Section 5.15.7 describes a trial that will be established in FY25.

**Summary**

Syrinx's (2019) study to develop the vegetation completion criteria outlined in Section 8.3.2 included an assessment of:

- The appropriate scale to which completion criteria should be applied.
- The type of metrics that are most appropriate for use in the Pilbara based on a literature review and review of baseline and reference site data.
- The timescale appropriate for measuring success.

The review concluded that vegetation at the broad scale (e.g., shrub-steppe, low woodland etc.) was the logical reference unit for criteria and the following major vegetation types should be used as the target ecosystems for rehabilitation:

- Low tree-steppe.
- Shrub-steppe.
- Grass-steppe.
- Low woodlands.
- Bunch grasslands (riparian vegetation).

The most appropriate attributes for measuring completion success were defined on the basis of a literature review, and naturalness, resilience and habitat value were identified as the key characteristics of importance. The key attributes capturing these characteristics were defined as bare ground, vegetation types, indicator species, plant cover, species richness, reproductive capacity (resilience) and weed invasiveness.

Based on a review of baseline / reference site data, targets were identified for each attribute by ecosystem. To best capture natural variability of vegetation in the Pilbara, the interquartile range (IQR) statistical approach was used, and the interquartile Q1 - Q3 range used to define native plant cover and species richness targets. The Q1 - Q3 range was used as it effectively targets the 'middle-range' range of data.

Buffel grass was used as the basis for selecting the weed target as it is the most significant weed in the Pilbara in terms of cover and extent. This species is not confined to mining operations and is seen by many pastoralists as an important component of pastoral lands. The occurrence of buffel grass correlates with landform more than vegetation type and is particularly dominant in drainage lines and floodplains at most sites. Separate targets have, therefore, been applied to hills, plains and drainage lines / floodplains to reflect this.

A review of rehabilitation monitoring data indicated that measurement of a site against completion criteria after 15 and 20 years would not be an unreasonable time point for final assessment. Even with a sequence of good rainfall years and improvements in rehabilitation methods, it is unlikely that any site will be ready for assessment against completion criteria before 10 years.

AQ2 (2020a) reviewed environments that may provide insights for the types of vegetation communities that may establish in backfilled pits post-closure and identified examples of passive establishment of *Eucalyptus camaldulensis* trees on pit walls where groundwater seepage is occurring and native vegetation in constructed diversions. Along the fringes of finger channels entering Ophthalmia Dam where flooding may be in the order of months, *E. camaldulensis* was observed to have developed adventitious roots (emanating from the stem) that enable it to tolerate waterlogged soils by enabling oxygen uptake.

Okane (2024b) conducted a review of the various ecosystems that would be applicable to the Yandi post-mining landscape and concluded that in addition to low tree steppe the key vegetation communities applicable to different environments at Yandi include:

- Crests - grass steppes.

- Slopes - grass steppes.
- Plains - grass and shrub steppes.
- Riparian - riparian woodlands

Domain-specific completion criteria for Yandi will be refined on the basis of:

- Post-mining land use discussions with BNTAC and the Banjima people.
- Refinements to closure designs and confirmation of the vegetation communities and species mix to be assigned to each domain.
- Data from trials and progressive rehabilitation monitoring.

#### 5.15.5.1 Syrinx completion criteria study

The Syrinx (2019) study included an assessment of:

- The appropriate scale to which completion criteria should be applied.
- The type of metrics that are most appropriate for use in the Pilbara based on a literature review and review of baseline and reference site data.
- The timescale appropriate for measuring success.

A brief summary of the study outcomes is provided below.

**Scale**

Baseline and reference data were analysed across several scales (regional, hub, site and ecosystem). The data showed that:

- The site, hub and regional scales do not provide a meaningful basis of assessment for most attributes, because they are geographic and not climatic or ecological boundaries.
- Both land systems and vegetation types are key influencing variables in the Pilbara region. Comparisons using land systems is complex and does not tease out the key ecological differences useful to determining the appropriate reference scale for measuring rehabilitation success.

Vegetation at the broad scale (e.g., shrub-steppe, low woodland etc.) was, therefore, considered to be the logical reference unit for criteria. Across BHP's Pilbara operations, there are a variety of terrestrial and wetland ecosystems. The term ecosystem is applied at various scales, and in WA has been used at the scale of a specific community (e.g. wetland communities associated with Weeli Wolli Spring) as well as at the broader vegetation scale (e.g. spinifex grasslands) or geomorphic scale (e.g. claypan). In terms of rehabilitation, the specific pre-mining environment is generally significantly altered and does not necessarily form the appropriate target ecosystem for future rehabilitation. As such, the following major vegetation types defined in Beard et. al. (2013) were used as the target ecosystems for rehabilitation:

- Spinifex grasslands:
  - Low tree-steppe comprising a hummock grassland with an overstorey of scattered low trees and a spinifex layer dominated by *Triodia wiseana*.
  - Shrub-steppe comprising *Triodia* spp. with an open overstorey of shrubs such acacia, grevillea and mallee eucalypts. It is the characteristic vegetation of the interdunal swales and desert sandplains that receive less than 250 mm rainfall per annum, and on stony ground under higher rainfall conditions.
  - Shrub-steppe comprising *Acacia pyrifolia* over soft spinifex (*Triodia pungens*) occurs on the deeper soils on granite in the Abydos Plain, Oakover Valley and extends south into the Chichester Plateau.
  - Grass-steppe comprising a hummock grassland without emergent trees or shrubs which is classified according to the dominant spinifex species (*Triodia* spp.). A variety of herbs may be present between the hummocks, and the species composition of this component is dependent upon the amount and season of rainfall. Grass-steppe is not common and in general occurs as patches on rocky outcrops rather than in wide expanses.
- Low woodlands including open low woodland and sparse woodland. The *Acacia aneura* s.l. (mulga) low woodland, open low woodland and sparse woodland type is typical of the valley plains in the Pilbara Bioregion. It has an understorey of shrubs of *Eremophila* spp. and *Senna* spp. and annuals such as *Ptilotus nobilis*[54].
- Bunch grasslands which comprise riverine sedgeland / grassland with trees and are associated with drainage lines. In the Pilbara the trees are mainly *Eucalyptus victrix* (coolibah) and *E. camaldulensis* (river gum) over mixed sedges from the families *Cyperaceae* and *Restionaceae*, and grasses (*Aristida* spp. and *Eragrostis* spp.).

**Metrics**

The most appropriate attributes for measuring completion success were defined on the basis of a literature review and naturalness, resilience and habitat value were identified as the key characteristics of importance. The most significant variables relevant to

[54] Since the 2019 study this classification has been revised and is most likely *Ptilotus exaltatus*.

resilience (soil stability, pattern, richness) were found to be vegetation cover, species composition and buffel grass (*Cenchrus ciliaris*) cover, and those relevant to naturalness and habitat were structure and pattern. The key attributes capturing the objectives of naturalness, resilience and habitat connectivity were defined as:

- Bare ground;
- Vegetation types;
- Indicator species;
- Plant cover;
- Species richness;
- Reproductive capacity (resilience); and
- Weed invasiveness.

The approach to setting specific targets for the attributes was based on:

- The closure objectives, which are not seeking replication of nature, but conformity with naturalness, resilience of rehabilitated landscapes, and habitat connectivity.
- The variability within the Pilbara, which does not favour the use of averages for ecological targets, but ranges that capture the typical variability based on vegetation types and landform (weeds attributes).
- Disturbance impacts, such as from existing pastoral activities, road and rail corridors, townships etc, as well as wider climate influences, that have resulted in modifications to the pre-European condition.

In general, the targets applied to the attributes include:

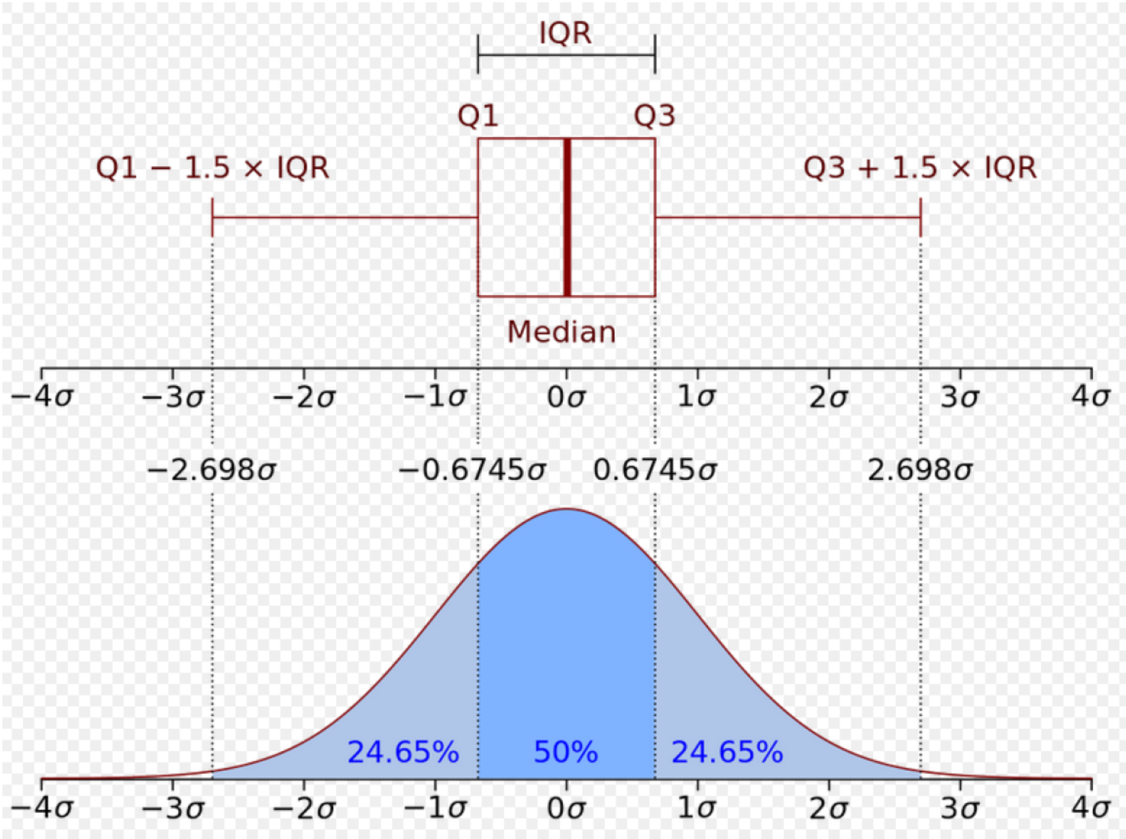
- Minimum or maximum values, derived from reference sites (weeds, bare ground);
- Presence / absence data (indicator species); and
- Ranges (species richness, vegetation cover).

To best capture natural variability of vegetation covers within individual vegetation types, the 'typical' cover ranges for each stratum were determined for each of the major vegetation types based on data from reference sites. For each vegetation type and each stratum (tree, shrub, *Triodia*, other grasses, herb) ranges were determined using the interquartile range (IQR) statistical approach which accounts for variability. This approach divides a data set into four equal groups (by count of numbers), each representing a fourth of the distributed sampled population (Figure 5-126). The:

- Q1 (lower quartile) is the "middle" value in the first half of the rank-ordered data set and is equal to the 25th percentile of the data.
- Q2 (middle quartile) is the median value in the set and is equal to the 50th percentile of the data.
- Q3 (upper quartile) is the "middle" value in the second half of the rank-ordered data set and is equal to the 75th percentile of the data.

The interquartile Q1-Q3 range is defined as the difference between the largest and smallest values in the middle 50% of a set of data (Figure 5-126). Because of the natural variability of the Pilbara, and because the objectives are based around naturalness and resilience, and are not attempting to replicate natural vegetation communities, this approach effectively targets the 'middle-range' and is considered appropriate for application to all quantitative targets.

Buffel grass was used as the basis for selecting the weed target as it is the most significant weed in the Pilbara in terms of cover and extent. This species is not confined to mining operations and is seen by many pastoralists as an important component of pastoral lands. An analysis of data across BHP's sites indicated that the average weed cover across all hubs is ~5.3%. In 2016, the CSIRO (Webber, Batchelor, & Scott, 2016) aggregated data from 630 flora and vegetation reports which showed that the weed was widespread and known from nearly 12,000 locations. This included occurrences within lands managed for conservation. The occurrence of buffel grass correlates with landform more than vegetation type and is particularly dominant in drainage lines and floodplains at most sites. Separate targets have, therefore, been applied to hills, plains and drainage lines / floodplains to reflect this.




Source: Syrinx (2019)

**Figure 5-126 The interquartile range (IQR) statistical approach adopted for setting cover targets**

#### Timescale

To assess the appropriate timescales to use, data from all rehabilitation plots were aggregated into classes based on the age of rehabilitation, and assessed for *Triodia* cover, given this species is the major component of most of the target vegetation groups and has typically been considered as the most important plant genera in terms of naturalness. The data suggested that measurement of a site against completion criteria after 15 years, and 20 years would not be an unreasonable time point for final assessment. Even with a sequence of good rainfall years and improvements in rehabilitation methods, it is unlikely that any site will be ready for assessment against completion criteria before 10 years, since even if some areas do attain the required metrics at this time, the site would need to sustain this during a poor climatic period and fire event to demonstrate resilience of the rehabilitation.

#### 5.15.5.2 AQ2 survey

Vegetation to be established on backfill surfaces will reflect the groundwater / inundation regime:

- Where water levels are greater than 10 m below the surface, xerophytic vegetation (e.g. Acacia grassland) will develop and is unlikely to be affected by salinity.
- Where water is between 1 m above, and 10 m below, the surface, and inundation is less frequent than 1 in 100 years, a riparian ecosystem could develop. However, where inundation is more frequent than 1 in 100 years, areas may not be suitable for a riparian vegetation community but may be more similar to an alluvial flat or salt marsh, depending on water quality.

AQ2 (2020a) conducted a literature review of factors affecting vegetation establishment in the Pilbara (Appendix M.2) and conducted a site visit to various small creek diversions and Ophthalmia Dam to characterise niche environments that may be applicable to backfilled pits, and regeneration processes supporting plant recruitment in these areas. Key observations from the site visit are as follows:

- *Eucalyptus camaldulensis* trees have established on a portion of the pit wall where groundwater seepage is occurring (Figure 5-127) which provides an example of the ability of this species to establish on relatively unfavourable substrates if persistent water is available and also demonstrates that seed from this species is readily dispersed in the Yandi environment. It is likely that passive recruitment would occur in the Yandi mine voids if a favourable moisture regime were in place.
- Passive recruitment of multiple species has occurred in constructed diversion channels. Plant establishment correlates with micro-niches on the channel fringes and bed, in depressions where fine sediments and organic matter accumulate. The pattern of Eucalypt establishment correlates with flood line seed deposition zones on the channel fringes.
- Typha reeds have a strong propensity to establish at permanent waterbodies in the Pilbara, and seeds are probably dispersed by avifauna. If the mine voids include permanent pools, it is likely that this species will passively establish;

however, it dies out without permanent water. Where flooding is less prolonged (circa months), *E. camaldulensis* can develop adventitious roots (emanating from the stem) that enable it to tolerate waterlogged soils by enabling oxygen uptake. This was observed along the fringes of finger channels entering Ophthalmia Dam.

Source: Okane (2023c)

Note: This picture was not taken during the AQ2 (2020a) survey, rather it provides an example of the establishment of trees on pit walls at Yandi.

**Figure 5-127 Trees growing on Yandi pit walls**

#### 5.15.5.3 Okane survey

Further to Syrinx's (2019) work that defined the target ecosystems for rehabilitation across BHP's Pilbara operations, Okane (2024b) conducted a review of the various ecosystems that would be applicable to the Yandi post-mining landscape which include:

- Marillana Creek;
- Backfilled pits with seasonal expressions of water;
- Backfilled pits with no seasonal expressions of water;
- Ex-pit areas including OSA / stockpile footprints, access tracks, camps; and
- C1 and E2 OSAs.

Based on these domains, Okane (2024b) defined several different environments that could be used as approximate analogues of post-closure conditions at Yandi:

- Plains - defined as low-lying flats.
- Crests - defined as flats on the top of hills or slopes which are more vulnerable to winds than low lying plains.
- Slopes.
- Riparian areas.

To gain an understanding of the natural variation within topographical areas and vegetation communities, a site visit was conducted in August 2023, and four transects were assessed across each of the four environments outlined above (Table 5-98). These concluded that in addition to low tree steppe the key vegetation communities applicable to different environments at Yandi include:

- Crests - grass steppes.
- Slopes - grass steppes.
- Plains - grass and shrub steppes.
- Riparian - riparian woodlands

The data collected from the site visit has been used to develop a preliminary vegetation strategy for the Yandi closure domains (Section 9.3). This will be reviewed and revised as:

- The backfill strategy (and associated returning groundwater levels) is refined, and further modelling provides a better understanding of the timeframes for groundwater recovery.
- Data become available from trials (Section 5.15.7) and progressive rehabilitation.

**Table 5-98 Summary of Okane site observations at crest, slope, plains and riparian zones**

| Representative photographs* | Transect No. | Species composition | Ground cover (%) | Litter cover (%) | Vegetation community structure | Comments | Summary of observations for zone |
|---|---|---|---|---|---|---|---|
| **Crest Zone** | | | | | | | |
|  | 3 | 4 - 8 | 75 - 100 | 0 - 25 | Open spinifex grasslands | The grassland area hosted predominantly Spinifex species, spaced densely with high ground coverage. Shrubs species were found scattered throughout. No weed species were observed within the transect. | • Largest variety in the number of species recorded across the transects surveyed.<br>• No invasive species identified, indicating its relative resilience to external threats.<br>• Characterised by rocky outcrops, emphasising the unique habitat characteristics that support a diverse range of species. |
| | 8 | 8 - 12 | 25 - 50 | 0 - 25 | Sparse shrubs, with spinifex | The ground surface was predominantly composed of gravel like material, scattered with moderately sized termite mounds. Spinifex grass was the predominant keystone species, with sparsely scattered shrubs throughout the surveyed transect. No weed species were observed within the transect. | |
| | 12 | 0 - 4 | 0 - 25 | 0 - 25 | Sparse spinifex and low-lying trees with occasional shrub | Spinifex grass was the dominantly native species spaced approximately 50 cm to 1 m apart. The surface was composed of loose gravel material, with termite mound present. A Hakea shrub was present just outside of the transect boundary. No weed species were observed within the transect. | |
| | 13 | 4 - 8 | 25 - 50 | 0 - 25 | Sparse spinifex | The transect was dominated by open spinifex grasslands with the occasional tree. The ground surface was composed of loose gravel, with termite mounds present. Twelve dead herbaceous individuals were observed, and no weed species were identified within the transect. | |
| **Slope zone** | | | | | | | |
|  | 4 | 4 - 8 | 75 - 100 | 0 - 25 | Open spinifex grasslands with shrubs | Slope (facing the southward direction). Open spinifex grassland covered 75-100% of the surface. No weed species were observed within the transect. | • Coexistence of various species (including trees, shrubs, and grasses).<br>• Grass species play a vital role in maintaining ground cover, resulting in relatively low levels of bare ground. |
| | 5 | 4 - 8 | 25 - 50 | 0 - 25 | Open spinifex grasslands with shrub and occasional tree | Slope (facing the south-west direction). The surface material was composed of gravel sized particles, with little, sparse topsoil present. Keystone species included a mix of Spinifex, Hakea, and Banksia species. No weed species were observed within the transect. | |
| | 9 | 8 - 12 | 50 - 75 | 0 - 25 | Spinifex with sparse trees and shrubs | Slope, located on rock outcrops facing the south-westerly direction. Spinifex grass species dominated the area, with sparse shrubs and trees recorded within the transect. Six dead shrubs were recorded. No weed species were observed within the transect. | |
| | 16 | 4 - 8 | 25 - 50 | 0 - 25 | Spinifex interspersed with shrubs and trees | The habitat within the transect (and surrounds) contains rocky outcrops. No weed species were identified within the transect. | |
| **Plains zone** | | | | | | | |
|  | 7 | 4 - 8 | 50 - 75 | 0 - 25 | Scattered trees with shrubs and spinifex | The location of this transect was just over 100 m from an access road; just over the borderline of suitability for analogue conditions as a minimum buffer of 100 m is required to reduce the likelihood of edge effects and local disturbance. Keystone species includes Eucalypt spp. tree, Wattle shrubs, and Spinifex spp. grasses. No weed species were observed within the transect. | • Consistent species diversity across all four transects.<br>• High percentage of bare ground, suggesting potential challenges for plant establishment and ecosystem stability in this zone |
| | 10 | 4 - 8 | 25 - 50 | 0 - 25 | Open spinifex grassland with occasional shrub | Rock outcrops extended up to 30 cm high from the surface, a mixture of gravel and thin, sparse topsoil was present. The transect was dominated by Spinifex species. Three dead shrubs were recorded. No weed species were observed within the transect. | |
| | 14 | 4 - 8 | 25 - 50 | 0 - 25 | Spinifex interspersed with shrubs with bare ground | The transect was dominant by Spinifex (*Triodia*) with scattered shrubs and trees. The surface was a combination of gravel, soil, and bare ground. Five dead shrub individuals were identified, and no weed species were observed within the transect. | |
| | 15 | 4 - 8 | 25 - 50 | 0 - 25 | Spinifex interspersed with shrubs | The surface was a combination of soil and loose gravel material with Spinifex grasses and Eucalypt trees. No weed species were identified within the transect. | |

| Representative photographs* | Transect No. | Species composition | Ground cover (%) | Litter cover (%) | Vegetation community structure | Comments | Summary of observations for zone |
|---|---|---|---|---|---|---|---|
| **Riparian zone** | | | | | | | |
|  | 1 | 8-12 | 0-25 | 0-25 | No trees, low lying herbs present with spinifex and reeds. | The habitat within the transect (and surrounds) contained fallen coarse woody debris (logs) and rocky outcrops, with standing water located approximately 40 m away. The presence of topsoil supported vegetation growth, including shrubs that reached up to 4 m in height. Spinifex grasses (*Triodia* spp.) were identified as the keystone species, and no weed species were observed to be present within the transect. | • Highest diversity of species, showcasing the remarkable richness of biodiversity in this area.<br>• Highest presence of invasive species, which poses a potential threat to the native flora and fauna.<br>• All transects surveyed displayed the most exposed or bare ground cover that exceeded 50% relative to other areas of interest. |
| | 2 | 8 - 12 | 25 - 50 | 25 - 50 | Riparian woodland with Eucalypts and various shrubs, grasses, herbs, and weeds | Well-established Melaleuca trees reached up to 20 m, spaced at distances of 1 to 3 m. The understorey was populated by grasses and weeds. The area had been used by grazing cattle; scat was present throughout. A permanent water body was present, featuring observable fish of two distinct species, rendering it a potential model for rehabilitation initiatives involving permanent riparian habitats. Five species of weeds were observed in this transect. | |
| | 6 | 8 - 12 | 0 - 25 | 0 - 25 | Sparse shrubs and trees | Comprised a dry ephemeral riparian riverbed. Car tracks from infrequent light vehicle access were noted running perpendicular through the middle of the transect. Keystone species for this transect were Eucalyptus species. One weed species was identified, Buffel grass (*Cenchrus ciliaris*). | |
| | 11 | 8 - 12 | 0 - 25 | 25 - 50 | Ephemeral riverbed with Eucalypts | Evidence of scattered debris composed of fallen logs and coarse wood material could be seen, likely resulting from surface runoff during months of heavy rainfall. Channels and rills were situated at the riverbed's foundation due to the erosive action of water. Adjacent to the riverbed, areas with lifeless patches of grass were observed. The primary keystone species present was Eucalyptus. One weed species was observed. | |

Source: Adapted from Okane (2024b)

*Notes: additional photographs showing the variation within and across transects are provided in Appendix M.3.

#### 5.15.5.4 Knowledge gaps & forward work program

Domain-specific completion criteria for Yandi will be refined on the basis of:

- Post-mining land use discussions with BNTAC and the Banjima people.
- Refinements to closure designs and confirmation of the vegetation communities and species mix to be assigned to each domain.
- Data from trials and progressive rehabilitation monitoring.

### 5.15.6 Yandi seed production area and tree nursery

BHP and the Banjima people have a land rehabilitation partnership which is being used to research the production of materials for use in revegetation programs at Yandi. A spinifex seed production area was established in 2023 to test the potential for bulk / controlled production and harvesting of *Triodia* species and a tree nursery has also been established. The materials generated from these facilities will be used, in conjunction with trials, to refine BHP's revegetation program for Yandi. The facilities are operated by Banjima trainees who are also involved in establishing and monitoring rehabilitation trials.

### 5.15.7 Rehabilitation trials

Growth media trial plots are proposed to be established in FY25. The design and scope of the trial was being finalised at the time of writing, with the initial objectives of the trial being to evaluate different growth media mixes (various proportions of topsoil and CID), seed mixes, seeding techniques, and fertiliser treatments.

# 6 Post-mining land use

As discussed in Section 8.2, BHP's overarching closure and rehabilitation objective is to develop a safe, stable, non-polluting and sustainable landscape that is consistent with social and environmental values informed by stakeholder consultation and aligned with creating optimal business value. This objective and associated guiding principles for mine closure (see Section 8.2) set the framework for post-mining land use planning and have been taken into account in the consideration of the possible land use options for Yandi described below. Of particular relevance, is the guiding principle which states that the post-closure land use should be sustainable and consider, *inter alia*, local land management practices and ongoing management requirements as well as the capability and constraints associated with the land post-mining.

## 6.1 Status of post-mining land use planning

BHP commenced the investigation of post-mining land uses in 2019 with a strategic opportunity assessment of its central and eastern Pilbara operations (Pershke Consulting, 2019). Since that time, several other studies have been conducted and consultation with BNTAC and the Banjima people about land use planning for Yandi has commenced. Appendix J.1 provides a summary of the post-mining land use studies conducted to date. This was provided to BNTAC in January 2024 and proposes the next steps for collaborating with BNTAC and the Banjima people to define the post-mining land uses for Yandi that can become self-sustaining by the time mining ceases in the area. Subsequent email correspondence from BNTAC suggests that it is the organisation's intention to engage Yandi-specific Traditional Owners and BHP on post-mining land uses, to gain alignment on a post-mining future at Yandi as per BHP's proposed next steps.

In the context of post-mining land use transition planning, it should be noted that some areas of Yandi will become available for the establishment of post-mining land uses before others as it is proposed that Yandi be used as a hub for processing ore from satellite operations beyond cessation of mining at Yandi, and active backfilling operations will not be complete until around 2036. It should also be noted that post-mining land use transition planning in a remote location is a multi-year process that requires consideration of the development of an ecosystem of businesses that will enable a critical mass of self-sustaining economic activity to be achieved over time along with the local workforce skills and capacity to service these businesses.

Since post-mining land use planning is an ongoing discussion, the Yandi closure study has taken the approach of working towards an interim land use that is consistent with the underlying tenure (pastoral) (Section 2.5) but has used the outcomes of studies conducted to date to develop closure designs that do not preclude potentially viable land uses. Alternate land use opportunities that have been identified are outlined in Section 6.2. To date, there has been no assessment of the feasibility of these land uses other than high level investigations, such as the sustainable yield study (Section 5.14.13), to enable the closure study to determine whether closure design decisions will preclude a particular land use. As part of ongoing post-mining land use investigations, BHP seeks to collaborate with BNTAC, as well as other stakeholders, to gain alignment on a post-mining future at Yandi. It is expected that the process will be iterative as there will be a need to collaboratively explore options to determine whether they are suitable / viable and to understand the mechanism by which they would occur.

## 6.2 Potential post-mining land use options identified to date

The strategic post-closure land use opportunity assessment in 2019 identified, from publicly available strategic planning documents, various initiatives and policies that might promote / provide opportunities for certain types of land use within the Pilbara. Based on these strategies and initiatives, the following land uses were identified for possible consideration:

- Agri-business including irrigated broad-scale agriculture, closed loop horticulture, algal culture, aquaculture, cultivation of ethnobotanic species (native ingredients for food or cosmetics).
- Renewable energy including consideration of solar, wind, pumped hydro, battery storage and renewable hydrogen.
- Hazardous waste disposal (in pits).
- Equipment testing / training facilities (e.g., for remotely operated vehicles).
- Space applications (e.g., space object tracking, applying / testing new technologies available for robotic and human space exploration).
- Water supply.
- Tourism.
- Conservation (undisturbed or lightly disturbed areas).
- Carbon sequestration (e.g., carbon farming).

High level investigations have ruled some land uses out:

- Wind generation - the wind resource at Yandi is poor.
- Pumped hydro - there are insufficient differences in elevation between the pits at Yandi.
- Broad scale agricultural irrigation as there is insufficient sustainable yield from groundwater to supply a broad scale irrigated agriculture project (refer to Section 5.14.13), and water would need to be harvested from surface water during flood events which may have potential impacts on downstream ecosystems reliant on recharge from these events.
- Hazardous waste disposal in pits due to the strong connection with groundwater.

Other labour-intensive land uses such as closed loop horticulture, algal culture, aquaculture and equipment testing may also be less viable given the remote location of Yandi. However, this would depend on the scale of the land use and the presence of other land uses in the area.

BHP is currently a participant in research conducted by the Cooperative Research Centre for Transitions in Mining Economics (CRC TiME) and the Australian Coal Industry's Research Program (ACARP) on emerging land uses such as those that can be established in pit lakes.

## 6.3 Interim post-mining land use

As outlined in Section 6.1, consultation with BNTAC and the Banjima people on the post-mining land uses for Yandi is ongoing and there are several aspects that will need to be considered in the determination of the post-mining land uses for the site including technical and economic viability and appropriate tenure. However, closure planning needs to have an end in mind and, consequently, interim post-mining land uses have been identified for the various Yandi closure domains according to the underlying tenure and the Australian Land Use Management Classifications (ABARES, 2016) (Table 6-1 and Map 6-1). However, the current proposed closure approach for Yandi does not preclude the land uses listed in Section 6.2 that have not been ruled out for other reasons.

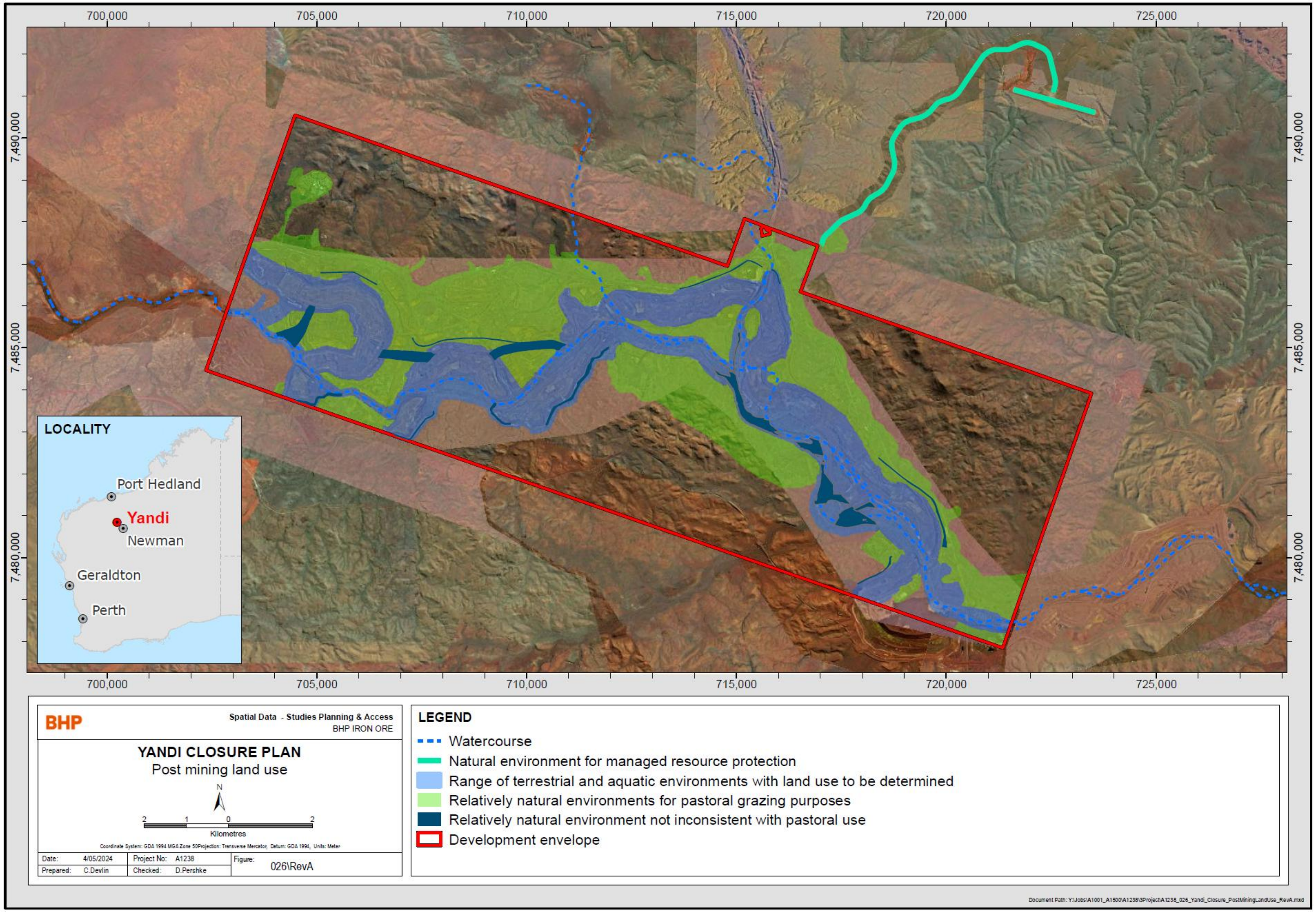
**Table 6-1 Interim post-closure land use by site domain**

| Domain | Sub-domain | Post-closure land use |
|---|---|---|
| Mine voids | Backfilled pits with seasonal expressions of water | Range of terrestrial and aquatic (safe and stable) systems not inconsistent with the surrounding pastoral grazing land use. It is expected that stock would be discouraged from entering mine voids. |
| | Permanent pit lakes | |
| | Backfilled pit with no seasonal expression of water | |
| Ex-pit | Remaining OSAs | Relatively natural environments for pastoral grazing purposes. |
| | OSAs relocated to backfill | |
| | Infrastructure areas | |
| Marillana Creek | | Relatively natural environments for pastoral grazing purposes. |
| Surface water infrastructure | | Relatively natural environments not inconsistent with pastoral use. |
| Infrastructure jointly owned with RTIO | | Natural environments for managed resource protection. |

While a pastoral land use is consistent with the underlying tenure of the Yandi mine, it should be noted that the natural landscape within the development envelope is dominated by stony plains and hills supporting spinifex grasslands associated with the Mackay land system (Section 5.5.2). Across the Pilbara, this land system is considered to have very low pastoral potential (van Vreeswyk, Leighton, Payne, & Henning, 2004). These land systems are characterised by hard spinifex grasslands that are not preferred by livestock, although soft spinifex may be grazed for a few years following fire.

Post-closure land uses for specific locations within domains will consider technical, environmental and other constraints, as discussed in Section 5.

Depending on the final land use, and in line with the level of landscape disturbance at Yandi, revegetated areas will align with the 'rehabilitation' outcome as described in the National Standards for Ecological Restoration (SERA, 2021) and, in line with this outcome, BHP will target two or three stars across each of the six attributes in the SERA (2021) framework.




See Appendix Q for a pdf version of this map

**Map 6-1** **Provisional post-mining land use**

# 7 Identification and management of closure issues

Planning for closure is conducted over the life of an asset (Figure 7-1), and is updated via an adaptive management approach (Section 7.1) as mine plans change and data is gathered from operational monitoring activities and progressive closure studies. As a site approaches closure, studies become more detailed and closure plans and designs are optimised to integrate the various aspects of the closure design.

Mining at Yandi (including E8) is expected to be complete around 2032 although options are currently under internal consideration for mining remnant ore, and utilising Yandi infrastructure as a regional processing hub for satellite ore bodies beyond cessation of current mining activities. Yandi is therefore in the closure investment study phase which will ultimately work towards the development of an executable closure and rehabilitation plan. As discussed in Section 1.4, the SPS for Yandi has been partially completed, and is currently on hold at the request of BNTAC and the Banjima people until, *inter alia*, post-mining land uses have been workshopped. The risk assessment in Section 7.4, therefore, reflects this level of maturity and remaining issues that require further investigation.

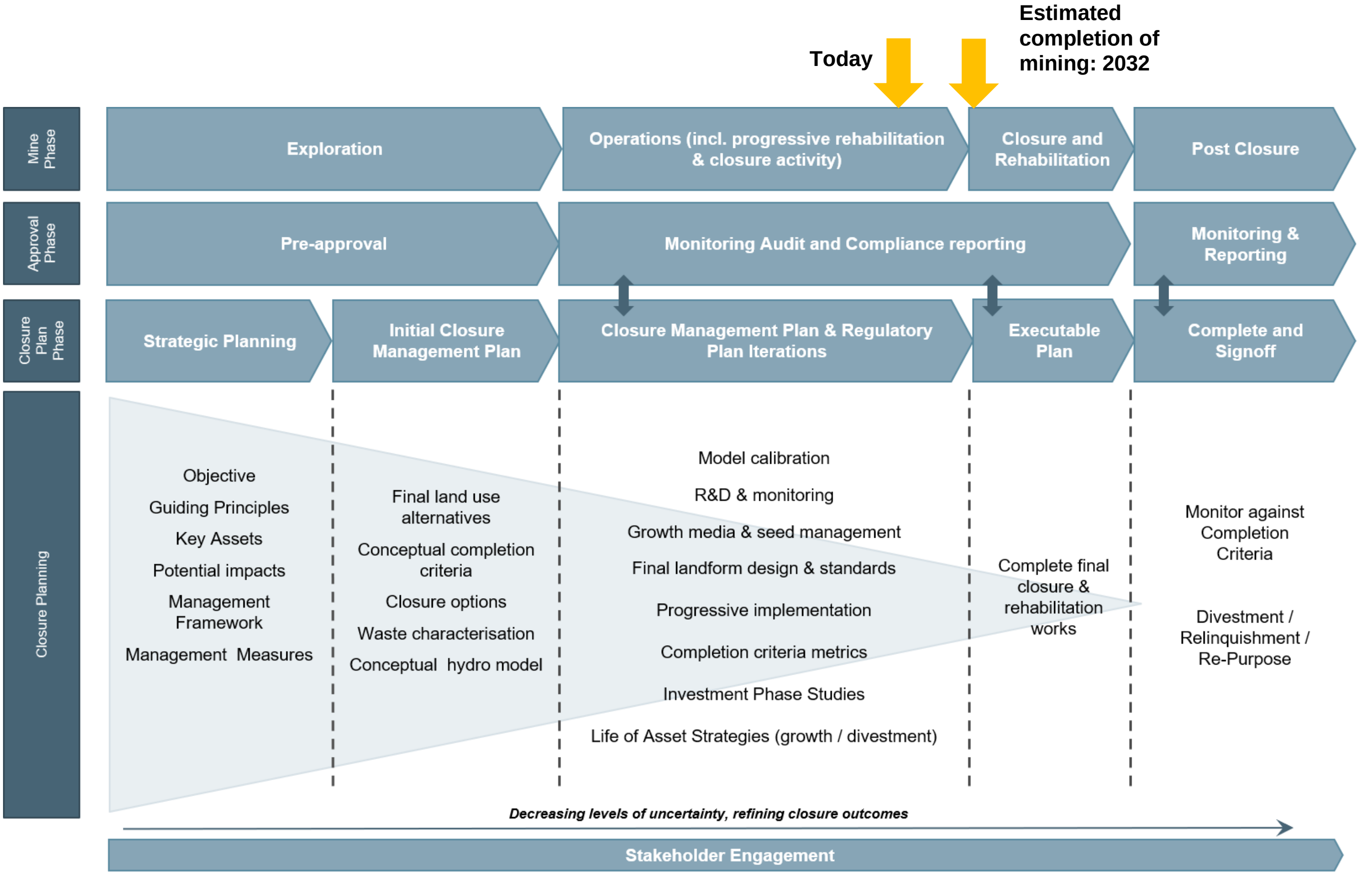



**Figure 7-1 Closure planning over the Yandi life cycle**

## 7.1 Adaptive management

The concept of adaptive management is a structured, procedural, iterative approach to decision making (Figure 7-2). It allows incremental improvement in the success of mine closure techniques by review of rehabilitation monitoring data and integration of findings into forward work programs and future closure and rehabilitation designs. The adaptive management approach allows for the investigation and continual evaluation of preferred mitigation controls so that they are progressively improved and refined, or entirely alternate solutions adopted.

This adaptive management approach is applied to the Yandi operations and associated closure issues taking into consideration the results of closure studies, rehabilitation and trials from BHP's other Pilbara Operations and best practice rehabilitation techniques used elsewhere in the mining industry.

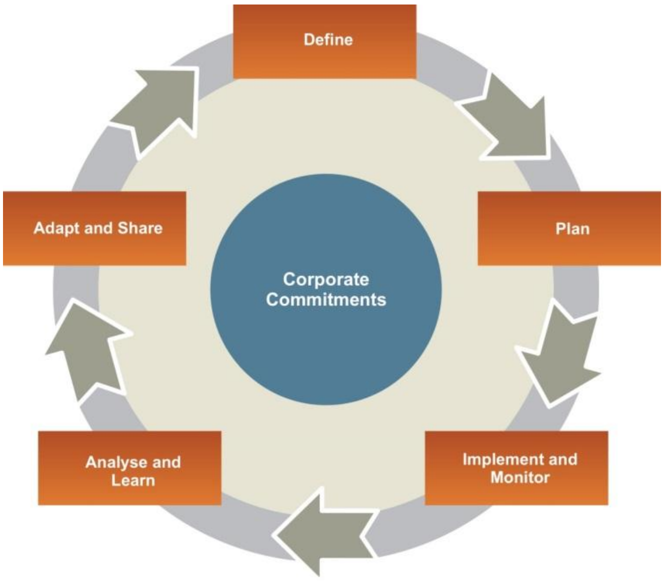



**Figure 7-2 Adaptive management cycle**

## 7.2 Risk management

Risk management is an integral component of the BHP Closure planning process. Risk management is undertaken to qualitatively and quantitatively guide the selection of closure options, assess specific risks, and identify controls for the design and execution of closure projects.

In general accordance with BHP's Corporate Alignment Planning process (BHP, 2023b), risk assessments are conducted for all of BHP's operations in order to prioritise and manage risks consistent with Australian Risk Management Standard AS/NZS ISO 31000:2018 Risk Management - Principles and Guideline (Standards Australia, 2018).

The primary objective of BHP's risk assessment and management system is to minimise risk in all aspects of its operations, including closure planning. The risk assessment process for closure, and the development of a risk profile are undertaken following BHP's Global Standard for Risk Management (BHP, 2023f) and DEMIRS guidance on environmental risk assessments for closure plans (DMIRS, 2020a; 2020b).

In the closure context, risk management processes include three main types of risk assessment:

- Closure planning risk assessment (health, safety, environment, legal, community, financial): a predominantly qualitative assessment (including stakeholder consultation) to identify mine closure risks and opportunities associated with closure and management strategies to preserve, maintain or enhance values or beneficial uses. These assessments also include consideration of post-closure event risks (e.g., failure).
- Scientific risk assessments: scientific source, pathway and receptor risk assessments for environmental, ecological, or human health risk involving technical specialists and quantitative assessment based on scientific data and information. For example, AMD risk assessments and ecological risk assessments.
- Construction / workplace risk assessments: as a closure project reaches execution, risk management is used to guide the effective management of risk in the execution phase.

Closure planning risk assessments are undertaken to optimise the closure outcome. Mitigating unacceptable risks to a tolerable level may involve the development of control options for each of risk factor, including the commissioning of additional technical studies and / or research. Such a process is iterative and is aimed at providing, on balance, the most appropriate closure outcome given the key risk drivers. Closure risks are reviewed annually at a minimum (BHP, 2023f), and are recorded and maintained in a closure risk register. As the mine closure strategy is developed, the risk assessments progressively mature with the increase in knowledge and information over the life of the mine.

Closure planning and construction risk assessments at BHP, involve people with a cross section of relevant knowledge and experience, including employees, contractors and other stakeholders. Stakeholders and specialists may be called upon to advise on aspect areas of significance or where in-house expertise is unavailable or unsuitable. Evaluation of identified risks is undertaken by the level of management that is consistent with the significance of the closure risk.

Scientific risk assessments are undertaken by specialists in the relevant field and are typically conducted to investigate the risks associated with a specific issue (e.g., significance of results from contaminated sites investigations) in more detail. The need for such investigations is identified through the closure planning process (i.e., review of knowledge base and closure planning risk assessments).

## 7.3 Cumulative change assessment

Based on the information in Section 5, this section summarises the cumulative changes to the environment resulting from the closure of Yandi (Section 9) and informs the risk assessment in Section 7.4. However, it should be noted that Yandi cannot be considered in isolation and should be viewed in relation to the regional context of the Yandi mine which is briefly summarised in Section 7.3.1.

### 7.3.1 Regional context

As discussed in Section 2.1, RTIO holds leases upstream and downstream of the Yandi mine (Map 2-1, Section 2.1), with the active Yandicoogina mine lying to the east of Yandi. The closure strategies at RTIO's Yandicoogina mine impact the closure outcomes at BHP's Yandi mine and vice versa (Section 5.14.1). Any future development upstream of Yandi mine also has the potential to impact closure outcomes at Yandi. BHP and RTIO have recognised the interdependencies between their operations and have a closure / water data sharing agreement to facilitate closure planning to optimise regional outcomes. There have been several meetings between RTIO and BHP and a joint BHP/ RTIO meeting with BNTAC to discuss water and closure-related matters (Section 4.3). BHP and RTIO have committed to continuing to work together to progress their respective closure strategies in consultation with BNTAC and the Banjima people.

### 7.3.2 Yandi post-mining outcomes

Table 7-1 outlines the features that will be left in the landscape following the closure of the Yandi mine in accordance with the designs in Section 9 which were recommended following the design studies in Section 5.14. The table also provides an indication of those features that may contribute to a cumulative change to the post-mining environment compared to the pre-mining environment. These changes are briefly discussed in Sections 7.3.2.1 to 7.3.2.7. The post-mining land use(s) for Yandi remain interim subject to further consultation with BNTAC and the Banjima people in relation to post-mining land use planning and closure planning for Yandi in general (Section 13.3).

#### 7.3.2.1 Surface water

**Surface water flows**

The current and future mines along Marillana and Weeli Wolli creeks have the potential to impact on local and regional scale drainage processes. The Fortescue Marsh is the ultimate receptor for surface flows; however, the delivery of flows from Weeli Wolli Creek is limited to infrequent large-scale events associated with cyclonic rains (i.e. roughly every 5 to 7 years) (Section 5.9.1). MWH (2016a) conducted hydrological modelling to assess changes in the surface water contribution to Fortescue Marsh via Weeli Wolli Creek under a variety of regional development scenarios. This indicated that, with Marillana Creek diversions in place, flood channels that are only activated above 20-year AEP events, and retention of the connection of northern tributaries with Marillana Creek, a modelled reduction in annual surface water contribution to Fortescue Marsh of 0.5% would be expected. This is consistent with historical environmental impact assessments (BHP Iron Ore, 1995). Retention of surface water inputs from northern tributaries, in particular Iowa Creek (Map 5-16), minimises downstream changes in flow volumes (BHP Billiton, 2016).

Recent modelling conducted by Advisian (2024a) assessed flood levels and velocities post-mining (i.e. following construction of the proposed surface water management infrastructure designs outlined in Section 9.2.4 and backfilling of the proposed E8 Pit to the Marillana Creek invert level[55]) (Figure 7-3 and Figure 7-4). A comparison of these characteristics with current (2022 operational conditions) shows how the designs prevent flood waters from intersecting pits in 1:10,000 AEP flood conditions, except where controlled inflows via flood channels have been designed, or where floodplain landforms are proposed. The W1-SP0 flood channel has been designed such that it only captures a proportion of flows in rare events to prevent impacts to the integrity of diversions and flood bunds and is only activated in events which exceed the 1:20 year flood event. In this way, downstream flows in Marillana Creek are maintained.

To gain an understanding of the impact of climate change on the closure design, Advisian (2024a) conducted a sensitivity analysis which simulated future climate conditions for 2075 for the 1:10,000 AEP event. The differences in peak flood level and velocity were calculated (Figure 7-3 and Figure 7-4) and indicate that:

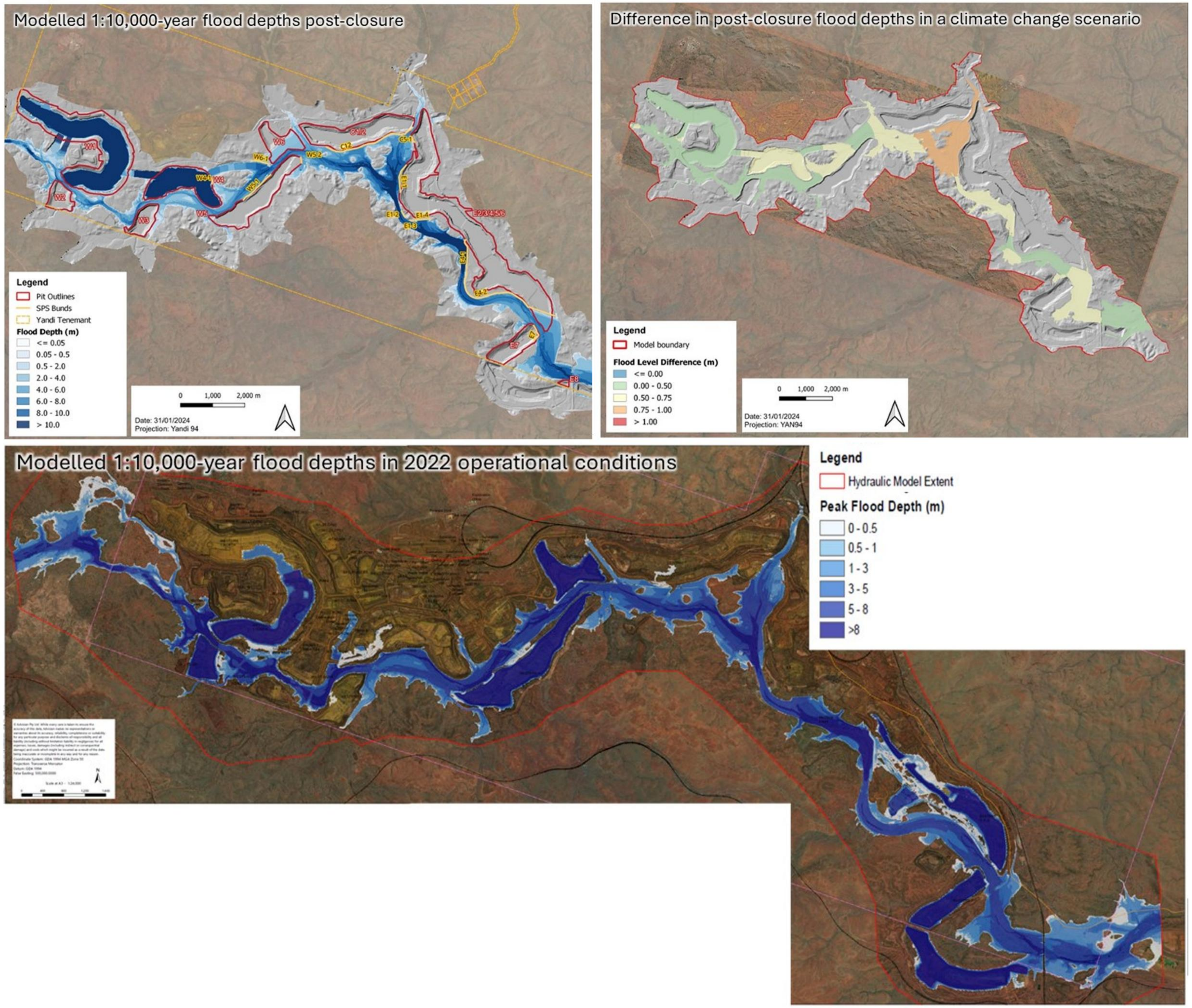
- Peak flood level increases of up to 1.0 m may occur across the site, but pit capture does not occur due to the flood protection bund freeboard of 1.0 m.
- Velocity increases of up to 1 m/s occur within the flood channels and in Marillana Creek adjacent to W5 Pit and in the E1 and E4 diversion channels. This results in an increased risk of erosion of the flood channels as stream power increases, along with the risk of scour of the flood protection bunds along Marillana Creek which will be considered during future design phases.

The current design maintains surface flows to Fortescue Marsh and to riparian vegetation along Marillana Creek.

[55] Defined as the level of the low flow channel.

**Table 7-1 Features that will remain post-mining based on the current closure design & contribution to cumulative change**

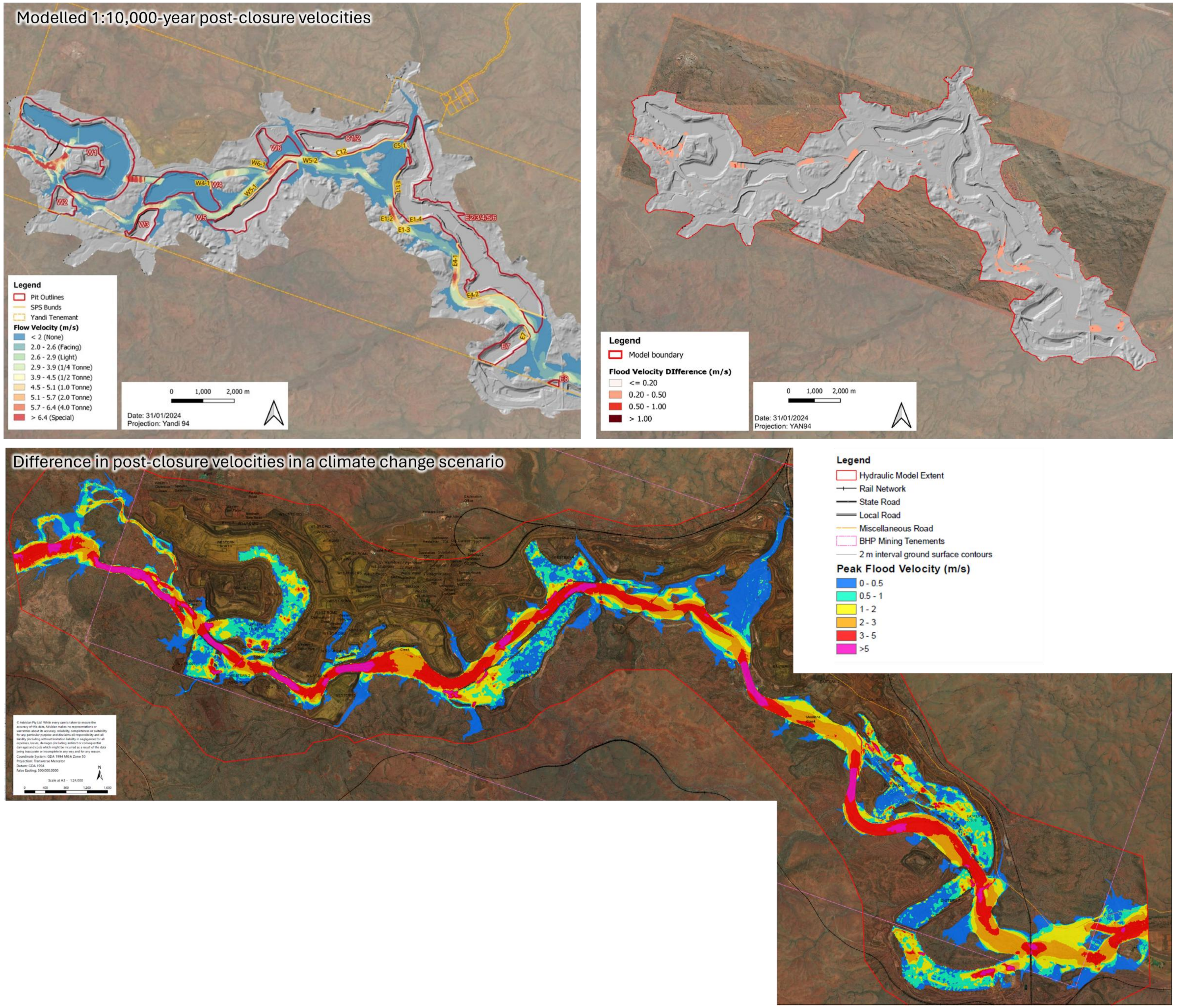
| Features remaining post-mining | | Cumulative changes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Category | Features | Surface water flows | Surface water quality | Groundwater (inc. alluvium) levels / flows | Groundwater quality | Seasonal water | Permanent pit lake | Visual | Vegetation communities | Safety hazard profile |
| OSA, ROM, stockpile, infrastructure footprints | | | | | | | | | | |
| OSAs | C1 & E2 | | | | | | | ✓ | | |
| Backfilled pit to above the water table - no seasonal expression of water | C6 | | | | | | | ✓ | ✓ | ✓ |
| Backfill design has yet to be finalised, but BHP intends to backfill the pit to the level of the Marillana Creek invert to prevent creek capture. This is above the pre-mining groundwater level and therefore, there will be no seasonal expression of water | Proposed E8 Pit | | | | | | | ✓ | ✓ | ✓ |
| Backfilled pits with seasonal expressions of water - occasional interaction with Marillana Creek | W1, W4 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Backfilled pits with seasonal expressions of water - no interaction with Marillana Creek | W5, W6, E1 - E6 | | | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| Permanent pit lakes | W2, W3, C1/2, E7 | | | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Flood channels | W1-SP0, W1-SP3, W4-SP4 | ✓ | | | | | | ✓ | ✓ | ✓ |
| Major creek diversions | E1 & E4 | ✓ | | | | | | ✓ | | |
| Intermediate creek diversions | Herbert's Creek, W3 | ✓ | | | | | | ✓ | ✓ | |
| Minor creek diversions | W4, W2, W5, C1/2, C5, E3/5/6, E7 | ✓ | | | | | | ✓ | ✓ | |
| Floodplain landforms | W5, W6, E6 | ✓ | | | | | | ✓ | | |
| Flood bunds | W4, W5, W6, C1/2, C5, E1, E4, E7 plus several minor bunds | ✓ | | | | | | ✓ | ✓ | |
| Safety bunds | Several | ✓ | | | | | | ✓ | ✓ | |




Source: Advisian (2023c; 2024b)

Refer to Appendix Q for original pdfs

**Figure 7-3 Post-closure flood depth comparison for operations and a climate change scenario**




Source: Advisian (2023c; 2024b)

Refer to Appendix Q for original pdfs

**Figure 7-4 Post-closure flood velocity comparison for operations and a climate change scenario**

**Surface water quality**

Minimal impacts are expected to post-closure surface water quality as:

- The overburden at Yandi is NAF with a low risk of neutral metalliferous and saline drainage (Section 5.2.3).
- There is one small (350 $m^2$) PAF exposure in the E1 creek diversion with the potential to generate low levels of acidity which can be managed through the soluble alkalinity in Marillana Creek water and available ANC in the alluvium (Section 5.2.3.4).
- All OSAs, ROM, stockpiles and stockpile bases except C1 and E2 OSAs will be rehandled as backfill to the pits and the footprints returned to a profile similar to pre-mining conditions. Landform evolution modelling of C1 and E2 OSAs shows they are erosionally stable (Section 5.15.4.3). Sediment impacts to surface water quality are, therefore, not expected.
- The only pit that could release water to Marillana Creek is W4 (via the W4-SP4 flood channel). This would only be expected to be activated in a very rare (1:10,000 AEP event) and modelling has shown that only short term (<30 hours), modest exceedances of some water quality guideline values (nitrate, salinity, sulphate, nickel and zinc depending on the modelled scenario) could occur in the mixing zone[56] (Section 5.14.4). While this modelling was conducted for the W4-SP3 flood channel design, the results serve as a proxy for the proposed W4-SP4 flood channel that will serve the same purpose as the W4-SP3 design.
- While nitrate is elevated in surface water at Yandi, there is no clear evidence of persistent point sources, and concentrations are not elevated in Marillana Creek downstream of Yandi (Section 5.9.3.2).

#### 7.3.2.2 Groundwater

**Groundwater levels**

Mining at Yandi has resulted in impacts to groundwater levels upstream in the CID at Flat Rocks and along the CID aquifer within BHP and RTIO's tenements. Drawdown also extends into the Weeli Wolli Formation and potentially the Ministers North aquifer (with associated impacts to groundwater levels at Yandicoogina Gorge), although it is not clear whether observed changes to groundwater levels in this location are due to lower rainfall or a combination of climatic variation and dewatering (Section 5.9.2.3). Water levels in the alluvium, also have the potential to be impacted by mining where the CID and / or mine voids intersect the alluvial aquifer. The persistence of water in the alluvium supports riparian vegetation, and where this has been impacted by mining, tree deaths been observed (Section 5.9.2.3). This includes vegetation at Flat Rocks which has declined in response to groundwater drawdown. The feasibility of low permeability barriers is being investigated, as part of the Marillana Creek Water Resource Management Plan, to protect the vegetation at Flat Rocks upstream of W1 Pit. Any implications for mine closure planning will be included in future iterations of this MCP (Section 9.2.3.2).

Groundwater levels are expected to increase at the cessation of dewatering and following the implementation of the backfill strategy. Some recovery of groundwater levels in the CID has already been observed at W0 (western end of W1 Pit) in response to a reduction in abstraction (Section 5.9.2.3). However, because there is insufficient overburden to backfill all the pits to above the pre-mining water table, some permanent groundwater sinks (pit lakes) will remain in the landscape which means that recovered groundwater levels will be lower level than pre-mining conditions. The extent to which water levels will recover regionally has yet to be investigated via the integration of regional groundwater modelling with pit lake water balance modelling. This forms part of the forward work program in Section 13.3.

While groundwater levels in the CID are expected to recover to a new equilibrium post-closure, it is anticipated that, where the alluvium directly overlies the CID and / or intersects mine voids, water may not persist in the alluvial aquifer following recharge events and may not support riparian species such as *Melaleuca argentea* post-closure, although other riparian Eucalypt species (e.g., *Eucalyptus victrix*) may be more resilient (refer to Section 7.3.2.6 for further discussion).

**Groundwater quality**

There are not expected to be any significant impacts to surrounding groundwater quality post-closure as:

- The overburden at Yandi is NAF with a low risk of neutral metalliferous and saline drainage (Section 5.2.3).
- While the salinity of the water in the CID between pits may become higher as salt is flushed from temporary pit lakes post-closure, the salinity will ultimately be captured by the permanent pit lakes which are expected to act as groundwater sinks (Section 5.14.1). Density driven flow from the pit lakes is considered unlikely (Section 5.14.5), although further work is required to confirm this.
- The current closure design is for the downstream pit at Yandi (E7) to remain as a permanent pit lake and groundwater sink which would prevent any migration of salinity or constituents of potential concern beyond this point (Section 5.14.1).

#### 7.3.2.3 Seasonal expressions of water

There may be seasonal expressions of water within several backfilled pits. Assuming that there is sufficient backfill to achieve the Scenario B.1 outcomes outlined in Section 5.14.1 post-settlement, modelling has indicated that salt build up in these water

[56] Defined as the ~12,500 m between the discharge of water from W4 Pit to Marillana Creek to where Marillana Creek crosses the Yandi lease boundary.

bodies is unlikely. This is because most, if not all, precipitated salt will be flushed into the groundwater to be captured in the permanent pit lakes which act as groundwater sinks (Section 5.14.3). There are natural analogues for seasonal expressions of water, and the backfill surface design and revegetation strategy aims to emulate aspects of these natural conditions, where practical (Section 9.2.3.1).

#### 7.3.2.4 Pit lakes

Permanent pit lakes are a feature of the post-mining landscape that were not present pre-mining. The water quality in the permanent pit lakes will deteriorate over time due to evapo-concentration of solutes in water sources entering the pit lakes (groundwater, throughflow from backfill, surface water and rainfall). Salinity will increase, and there may be exceedances of sulphate, boron, fluoride, selenium and nitrate while salinity is in the "tolerable" range for livestock[57] (Section 5.14.3). Biochemical processes are likely to reduce nitrate levels in the pit lakes over time (Section 5.14.3.3). A preliminary assessment indicated that the risk to human health and wildlife from saline pit lakes is low (Section 5.14.6). However, a potential impact to cultural values remains, as the Banjima people have expressed their aversion to permanent saline pit lakes (Section 4).

#### 7.3.2.5 Visual

The visual aspects of the post-mining environment will be different to the pre-mining environment. However, the following measures are being incorporated into the closure designs to minimise visual impact:

- Most OSAs / ROM pads / stockpiles / stockpile bases will be rehandled back to the pits as backfill and the footprints will be revegetated and have a similar profile to pre-mining conditions, where practical (Section 9.2.2).
- C1 and E2 OSAs have been designed to blend with the natural landforms in the area (Sections 5.15.4.1 and 5.15.4.2).
- The backfill surface will be contoured to create a more natural looking surface, revegetated and provide for seasonal ponds (Sections 9.2.3.1 and 9.3).
- The W1-SP0 flood channel energy dissipation system will be designed to resemble natural analogues (Sections 5.14.7.5 and 9.2.4.1).
- Revegetation will be encouraged in creek diversions consistent with the morphology of the diversion (Sections 5.14.9 and 9.3).
- Pit wall buttresses and laybacks will be revegetated (Section 9.3). There will not be active revegetation of the pit walls themselves, but some trees have already naturally established on some of the pit walls (Section 5.15.5.2).

Further consultation with BNTAC and the Banjima people is required to discuss the visual characteristics of the post-mining landform.

#### 7.3.2.6 Vegetation communities

The revegetation strategy for Yandi is under development. Our current understanding of the strategy is outlined below. The intent of the strategy is to establish native vegetation that blends with surrounding areas and is consistent with the post-mining land use, including provision of habitat and foraging areas for native fauna, where appropriate. In some areas, the post-mining environment will differ from the pre-mining environment (e.g. backfilled pits with seasonal expressions of water), and work is ongoing to determine the native vegetation communities that may be established in these areas.

**Ex-pit OSAs and footprints of demolished infrastructure and OSAs / ROM / stockpiles rehandled to the pits**

The C1 and E2 OSAs have already been revegetated and are progressing towards completion criteria. The revegetation plan for the remaining ex-pit areas of the Yandi mine aims to return vegetation communities that resemble those found in similar topographies to the post-mining landform (Sections 5.15.4 and 9.3).

**Pit walls, laybacks and buttresses**

There will not be active vegetation of pit walls, but it is proposed that pit laybacks and buttresses will be revegetated. The vegetation communities to be established in these areas will be further researched (Section 9.3).

**Pit backfill surfaces**

Pit backfill surfaces will be revegetated. The re-established vegetation may represent novel communities, and work is ongoing to further research the communities that might be returned to these areas (Section 9.3).

**Riparian vegetation**

Riparian vegetation at Flat Rocks has been impacted by a reduced groundwater level in the CID (Sections 5.6.3.1 and 5.9.2.3). This impact is being managed in accordance with the Marillana Creek Water Resource Management Plan including exploration

[57] Salinity is a primary control on water quality risk from a toxicological perspective as it determines the palatability of the water for drinking and potential for aquatic species to establish / live in lakes and accumulate contaminants. The tolerable range for livestock drinking water has been used as a proxy for impacts to other species.

of the feasibility of using low permeability barriers to maintain groundwater levels in the long term. Depending on the outcomes of these studies, long-term measures for protecting the vegetation at Flat Rocks will be incorporated into future iterations of this MCP, if required (Section 9.2.3.2).

It is possible that cumulative dewatering, along with climate change, could contribute to impacts to groundwater levels at Yandicoogina Gorge, with implications for riparian vegetation in this area, however, this is uncertain and requires investigation. Groundwater levels will recover post-backfill (albeit to a lower level than pre-mining groundwater levels) (Section 5.14.1.4), but the extent to which this may influence regional groundwater levels has not yet been modelled. Both the investigation of the contribution of cumulative dewatering to groundwater level decline at Yandicoogina Gorge and the modelling of post-backfill groundwater levels form part of the forward work program in Section 13.3.

While a proportion of larger flood events will be captured by flood channels, the closure design allows the shallow aquifer supporting riparian vegetation to be replenished by lower frequency events and thus continue to support riparian vegetation (Section 5.14.7). However, where groundwater levels in the CID have declined and the alluvium directly overlies the CID and / or intersects mine voids, water may not persist in the alluvial aquifer following recharge events (Section 5.9.2.3). Mature tree health decline has been observed in proximity to these areas. The principal riparian tree species most likely to be impacted is *Melaleuca argentea*. The major riparian Eucalypt species are likely to be more resilient to lowered water tables if the surface water regime (i.e. supporting regular vadose-zone replenishment) is maintained (Section 5.6.3.1). However, some areas that historically supported stands of *Melaleuca argentea* may not remain viable for this species (AQ2, 2017). These impacts have been highlighted and accepted via approval submissions (BHP Iron Ore, 1995; EPA, 2005).

Currently high-density riparian vegetation is being supported to the north of the proposed E8 Pit by discharge of dewatering water which has created an artificial pool. The CID in this area is in hydraulic contact with the alluvium and residual cumulative drawdown in the CID will impact the retention time of water in the alluvium which, in turn, will impact the ability of the alluvium to support riparian vegetation. Following cessation of the discharge of dewatering water, riparian vegetation communities will change to a new equilibrium commensurate with the post-mining availability of water. The enhanced riparian vegetation growth and seedling establishment at the discharge point was acknowledged by the EPA (2005) and the impact to vegetation following cessation of discharge was documented and approved via BHP's Life of Mine Environmental Protection Statement for Yandi (BHP Billiton Iron Ore, 2005). However, the closure design for E8 represents a potential opportunity to support riparian vegetation in this area. The feasibility of this opportunity is currently being explored in consultation with Traditional Owners, and if feasible, will be incorporated into future updates to this MCP.

Riparian vegetation is re-establishing in the E1 and E4 Marillana Creek diversions (Section 5.15.3). Vegetation has also been observed to have established naturally in some of the minor and intermediate creek diversions (Section 5.14.9 and 5.14.10), and detailed designs will explore opportunities for revegetation of the upgraded diversions consistent with the morphology of the diversion (Section 9.3).

#### 7.3.2.7 Safety hazard profile

As outlined in Section 5.2.4.5, some fibrous material lenses have been intersected during geotechnical drilling for the W1-SP0 flood channel. The intersections are random and unpredictable and consequently are not practical to avoid. Natural exposures of asbestiform minerals have been observed in the dolerite at Flat Rocks and flood channel exposures are expected to pose the same hazard as these natural areas, although more a detailed risk assessment has been incorporated into the forward work program in Section 13.3. To reduce the risk of exposures to people, a ~1.5 m deep cut has been incorporated into the flood channel entrance to deter access (Section 9.2.3.4).

Other ex-pit areas are expected to pose similar natural hazards to other non-mined areas with similar topography following demolition and rehabilitation.

Steep drops associated with pit walls represent a new hazard in the landscape and inadvertent access will be controlled via safety bunds as per DEMIRS guidance (DoIR, 1997). Post-mining access to pits will be considered in future design phases, however, pit backfill surfaces have been designed with perimeter benches to provide a refuge and access to ramps when the remainder of the pit may be inundated. Where here are temporary ponds or permanent pit lakes, backfill surfaces have been designed to slope gently towards the floor of the pond or lake, to reduce the risk of drowning.

## 7.4 Risk assessment

A closure planning risk assessment has been undertaken for Yandi and the outcomes are provided in Table 7-2. Participants in the risk assessment included stakeholders within BHP with expertise in technical closure disciplines. In accordance with DEMIRS guidance (DMIRS, 2020b), the risks outlined in Table 7-2 only consider environmental risks. Within the definition of environment, BHP has also incorporated consideration of potential impacts to the community (e.g. in relation to post-mining land uses, safety of the site post-closure and impacts to sites of cultural significance). The approach taken to framing the risks in Table 7-2 is outlined in Section 7.4.1 and the risk matrix used to assess and prioritise risks is provided in Appendix L.1. Following ISO 31000 (Standards Australia, 2018), assessments of each risk consider the likelihood of a given level of consequences occurring rather than simply an assessment of the likelihood of an initiating event occurring (i.e., the initiating event **and** the assessed level of consequences occur). Worst case consequences would typically have extremely low likelihoods, whereas reasonably foreseeable consequences may have much higher likelihoods. In accordance with the BHP risk management standard (BHP, 2023f), the inherent risk assessment in Table 7-2 has typically assumed the maximum foreseeable loss and the residual risk assessment has typically assumed the reasonably foreseeable loss following application of controls.

Closure risks are reviewed annually at a minimum (BHP, 2023f).

Responsibilities for closure risk mitigation and management are addressed in WAIO's internal processes and procedures. The Planning function (including Resource Planning and Exploration teams) in conjunction with the Environment Rehabilitation and Biodiversity team lead integration of closure management requirements into the Yandi mining operations plans as part of the business planning process (as outlined in Section 1.5). Implementation of the risk mitigation measures incorporated into the closure plan is the responsibility of the Yandi operations team.

Risk management measures will be refined progressively (in line with the adaptive management approach).

### 7.4.1 Approach to risk framing

The purpose of the closure risk assessment for Yandi is to systematically identify those issues that require a closure design or management response, and prioritise studies and design work to address those issues that will make a material difference to closure and stakeholder outcomes. Therefore, the way that the risks are framed, must meet these objectives and may require different approaches to be taken for different domains / features / aspects. This is so that an appropriate priority is assigned to key risks and that the outputs of the risk assessment can be used to frame an appropriate forward work program. Appendix L.2 provides detail on the approach taken to framing each of the risks outlined in Table 7-2. Where an inherent risk has been assessed as very low, it is outlined in Appendix L.2, but has not been carried through to Table 7-2, to maintain a focus on the key risk issues of importance to Yandi. The key aspects considered in framing the risks are:

- The appropriate level of aggregation to use in the risk assessment:
  - In many instances, it is appropriate to aggregate several mine features into one risk to gain an understanding of the cumulative risk posed by these features (e.g. risk to surface water flows). When considered in isolation, each risk may have a relatively low risk rating but cumulatively may represent a much higher risk. Failure to aggregate risks appropriately may lead to a false impression of the overall risk to the environment.
  - Similarly, it is not always appropriate to analyse a risk by individual causes. Several causes may contribute to an unwanted closure outcome and need to be considered together to understand the overall risk to the environment (e.g., change to surface water flows can be impacted by erosion of a flood bund, and pit wall instability resulting in creek capture).
- The appropriate condition on which to base an assessment of risk:
  - Some closure designs may introduce new or different risks that require assessment to inform the next stage of design studies. In other instances, it may be more appropriate to assess the risk associated with the current condition of the mine (i.e., the risk if no closure controls were implemented). Both approaches have been used for key features to enable a systematic assessment of risks that need to be managed, and identification of areas where significant study / design effort is required.
  - Where a closure design has already been executed (e.g., for the E1 and E4 Marillana Creek diversions), the inherent risk represents the current condition as there is little value in assessing a risk prior to the execution of a design.

Table 7-2 is structured as follows:

- Column 1 outlines the Risk ID. This is used to link the risks with the completion criteria outlined in Table 8-2.
- Column 2 describes the risk event being considered and whether it is relevant to the inherent condition (i.e., current condition of the Yandi mine or condition post-closure if no closure measures are implemented), or the closure condition (i.e., once closure controls have been applied).
- Column 3 identifies the domain(s) to which the risk applies.
- Following the Western Australian Biodiversity Science Institute (WABSI) guidance for completion criteria (Young, et al., 2019), Column 4 of Table 7-2 identifies those performance indicators / completion criteria (detailed in Section 8.3.2) that are relevant to each risk, to assist in identifying the importance of each set of criteria.
- Column 5 outlines the contributing causes to each risk event.
- Column 6 outlines the potential impact to receptors and provides links to sections of the MCP that describe potential impacts in more detail.
- Columns 7 to 9 provide the inherent risk ratings (relevant to the condition being assessed).
- Column 10 outlines the risk controls. These include controls implemented during planning as well as the measures incorporated into the designs outlined in Section 9. Links are provided to those sections within the MCP that describe the studies conducted during the planning phase to reduce residual risks.
- Columns 11 to 13 provide the residual risk ratings.
- Column 14 summarises the improvement activities incorporated into the forward work program in Section 13.3. It should be noted that, given the space constraints in the table, a summary form of words has often been used in this column. See Section 13.3 for the full text.

**Table 7-2 Yandi closure risk assessment**

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk: Consequence | Inherent Risk: Likelihood | Inherent Risk: Risk | Controls (Treatment) | Residual Risk: Consequence | Residual Risk: Likelihood | Residual Risk: Risk | Improvement Activity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 1 | Failure of existing Herbert's Creek diversion leads to capture of Herbert's Creek and reduction of surface water flows to Marillana Creek resulting in impacts to downstream receptors (riparian vegetation)<br>*Inherent condition* | Surface water infrastructure - Herberts Creek | C3.2<br>C3.4<br>C5.2 | **Primary causes:**<br>Loss of downstream flow and / or potential geotechnical instability arises from:<br>• Design not adequately allowing for post-construction settlement / differential settlement.<br>• Vegetation growth in the diversion channel which impacts the integrity of the geosynthetic clay liner.<br>• Excessive sediment transport and deposition within the land bridge channel.<br>• Head cutting at the channel outlet with the potential to impact the integrity of the flood bunds associated with the channel.<br>• Long term hillslope erosion that impacts the integrity of the land bridge embankments or bunds.<br>**Contributing factors to poor design outcomes:**<br>• Poor overburden characterisation.<br>• Inadequate geotechnical information.<br>• Land bridge and diversion channel not being constructed to design.<br>• Inadequate modelling of post-closure flood conditions (e.g., regional cumulative influences poorly accounted for).<br>• Inadequate sensitivity testing (e.g., to accommodate climate change). | Herbert's Creek is an intermediate creek and represents a relatively small proportion of the overall flows in Marillana Creek at its confluence with Herbert's Creek, as the Herbert's Creek catchment is ~2% of the Marillana Creek catchment (Section 5.9.1.1).<br>The Herbert's Creek land bridge is located just upstream of the confluence with the Marillana Creek (Map 5-33, Section 5.14.9), and consequently riparian vegetation along Herbert's Creek itself would be unlikely to be impacted by a loss of flow at the land bridge. As the land bridge itself represents only a small proportion of the flow in Marillana Creek, the impact to riparian vegetation within the creek would be expected to be low.<br>The land bridge is only currently designed for a 1:100-year event. Since it is an intermediate diversion, it requires an upgrade to a 1 in 1,000-year event, in line with BHP's risk-based approach (Section 9.1.2). Landform evolution modelling has indicated that hillslope erosion processes are not likely to impact the long-term function of the diversion channel.<br>Monitoring and inspections have identified issues that require rectification and upgrades for closure (Section 5.14.9). | 2 | Likely | Moderate | • Hydraulic modelling, geomorphological and geotechnical assessments inform the closure design (Section 5.14.10 and Appendix G.6).<br>• The W6 floodplain landform has the potential to dissipate flows from Herbert's Creek on to the land bridge, however, further assessment of this interaction is required (Sections 5.14.8, 5.14.10 and 9.2.4).<br>• Upgrades of the diversion will be designed to address identified issues and accommodate a 1:1,000 year event (Sections 5.14.10 and 9.2.4).<br>• Assessment of compliance to plan (Section 9.1.4).<br>• Climate change is considered in surface water modelling (Section 7.3.2.1). | 2 | Possible | Low | • Geotechnical investigation and analysis taking into account the proposed floodplain landform and backfill design.<br>• Assessment of the need for a geosynthetic liner and the risks associated with tree growth and long-term stability.<br>• Conduct hydraulic modelling and geomorphic assessments to:<br>- Inform the upgrade of the Herbert's Creek land bridge for closure.<br>- Manage the interaction of the W6 floodplain landform with the Herbert's Creek land bridge design for closure. |
| R 2 | Failure of existing W3 diversion leads to capture of Lamb Creek and reduction of surface water flows to Marillana Creek resulting in impacts to downstream receptors (riparian vegetation)<br>*Inherent condition* | Surface water infrastructure - W3 diversion | C3.2<br>C3.4<br>C5.2 | **Primary causes:**<br>• Pit wall instability and failure compromises the W3 diversion.<br>• Failure of the diversion itself results from:<br>- Overtopping of the W3 flood bund in the design event.<br>- Scour of the in-situ CID adjacent to the pit.<br>- Long-term sedimentation in the diversion reduces its capacity.<br>**Contributing factors to poor design outcomes:**<br>• Inadequate geotechnical information.<br>• Inadequate modelling of post-closure flood conditions (e.g., regional cumulative influences poorly accounted for).<br>• Inadequate sensitivity testing (e.g., to accommodate climate change).<br>• Diversion channel is not constructed to design. | Lamb Creek is an intermediate creek with a catchment around 6% of the Marillana Creek catchment (Section 5.9.1.1). It, therefore, represents only a small proportion of the overall flows in Marillana Creek. Capture of the creek has the potential to impact a small area of riparian vegetation between the W3 Pit and Marillana Creek (Section 5.6.2).<br>The current W3 diversion is designed to accommodate a 1:100-year flood event. As Lamb Creek is an intermediate creek, it requires an upgrade to a 1 in 1,000-year event, in line with BHP's risk-based approach.<br>Velocities would be high for a 1 in 1,000-year event in the existing diversion (Section 5.14.9.2). | 3 | Possible | Moderate | • Hydraulic modelling, geomorphological and geotechnical assessments inform the closure design (Section 5.14.9.2).<br>• Upgrades will be made to the diversion to accommodate a 1 in 1,000-year event (Section 9.2.4). Current design studies (Section 5.14.9.2) indicate that even if the creek is widened to 140 m where tenement and pit edge constraints allow, velocities remain high at the existing flood bund and where the diversion turns north around the pit. In a climate change scenario, these velocities could increase by up to 1 m/s (Section 7.3.2.1). Further study is required to identify appropriate controls.<br>• Assessment of compliance to plan (Section 9.1.4). | 3 | Unlikely | Low | • Hydrological, hydraulic, geomorphological and geotechnical assessments, including collection of additional geotechnical information.<br>• Following cessation of mining conduct a final check of pit wall stabilities, where required.<br>• Optimise diversion design including consideration of:<br>- The need for additional measures to manage erosion and increase capacity.<br>- The potential to achieve a more natural looking system, erosion and deposition processes and establishment of riparian vegetation. |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk: Consequence | Inherent Risk: Likelihood | Inherent Risk: Risk | Controls (Treatment) | Residual Risk: Consequence | Residual Risk: Likelihood | Residual Risk: Risk | Improvement Activity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 3 | Failure of existing minor operational creek diversions and flood bunds results in capture of minor creeks and reduction of surface water flows to Marillana Creek resulting in impacts to downstream receptors (riparian vegetation)<br>*Inherent condition* | Surface water infrastructure - minor diversions & flood bunds | C3.2<br>C3.4<br>C5.2 | **Primary causes:**<br>• Pit wall instability and failure compromising the diversions.<br>• Overtopping of the diversions / flood bunds in the design event.<br>• Scour of diversion embankments / flood bunds adjacent to pits.<br>• Long-term sedimentation reduces the capacity of the diversion, or effective height of a flood bund.<br>**Contributing factors to poor design outcomes:**<br>• Inadequate geotechnical information.<br>• Inadequate modelling of post-closure flood conditions (e.g., regional cumulative influences poorly accounted for).<br>• Inadequate sensitivity testing (e.g., to accommodate climate change).<br>• Diversion channel / flood bund is not constructed to design. | There are seven current operational diversions and one diversion that will require construction to redirect flows past the northern boundary of W4 Pit into the W4-SP4 flood channel when it is constructed (Sections 5.14.9.3 and 9.2.4.2).<br>There are also several minor flood bunds which require assessment in future design phases.<br>Together the minor creeks represent only a small portion of the flow entering Marillana Creek and consequently would be expected to have only minor impacts on the health of riparian vegetation (Section 5.6.2).<br>Most diversions require design upgrades to reduce the potential for erosion and scour in the 1% AEP design event to compromise the integrity of designs following closure. | 2 | Possible | Low | • Hydraulic modelling, geomorphological and geotechnical assessments inform closure designs (Section 5.14.9.3).<br>• Upgrades will be made to diversions and flood bunds to reduce the potential for scour / erosion and deposition to compromise the function of these structures in the design event (Section 9.2.4).<br>• Upgrades to diversions typically include widening of the diversion, but further investigation of design solutions is required for diversions that intersect potentially erodible materials.<br>• Modelling for a climate change scenario indicates that flooding does not enter pits in a 1 in 10,000-year flood event (Section 7.3.2.1).<br>• Assessment of compliance to plan (Section 9.1.4). | 2 | Unlikely | Very low | • Complete hydrological, hydraulic, geomorphological and geotechnical assessments to inform diversion designs, including collection of additional geotechnical information, as required.<br>• Following cessation of mining conduct a final check of pit wall stabilities, where required.<br>• Optimise diversion designs including consideration of:<br>- Additional measures to manage erosion and increase capacity (e.g., W2, W5 East, C5).<br>- Manage the risk of lateral channel migration.<br>• Design the tie in of the W4 diversion with the W4-SP4 flood channel as this design is optimised.<br>• Determine the W1 diversion (south of W1) tie-in with the W1-SP0 following optimisation of flood channel design.<br>• Optimise the configuration of C1/2 diversion as the backfill designs for C6 are progressed. |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk – Consequence | Inherent Risk – Likelihood | Inherent Risk – Risk | Controls (Treatment) | Residual Risk – Consequence | Residual Risk – Likelihood | Residual Risk – Risk | Improvement Activity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 4 | Overtopping of pit crests in extreme rainfall event, or failure of existing flood bunds, major diversions or remnant CID results in capture of Marillana Creek causing impacts to downstream riparian vegetation<br>*Inherent condition* | Mine voids, surface water infrastructure - major flood bunds | C3.2<br>C3.4<br>C5.2 | **Primary causes:**<br>• Pit crests / remnant CID overtopping in extreme rainfall events post-closure.<br>• Scour / erosion and failure of remnant CID.<br>• Pit wall instability leading to failure.<br>• Poor foundation conditions or inappropriate materials used in construction.<br>• Existing flood bunds or major diversions are not constructed for the closure design event.<br>**Contributing factors to poor design outcomes:**<br>• Inadequate geotechnical information and assessment.<br>• Inadequate characterisation of construction materials.<br>• Inadequate modelling of post-closure flood conditions (e.g., regional cumulative influences poorly accounted for).<br>• Inadequate sensitivity testing (e.g., to accommodate climate change).<br>• Flood bunds / floodplains / major diversions are not constructed to design. | Overtopping of the pit crests, or failure of the existing E1 or E4 diversions and flood bunds or remnant CID could result in the capture of a portion of the Marillana Creek flows resulting in loss of downstream flows and impacts to riparian vegetation. Given the significance of regular flood events to recharging the alluvium that supports the riparian vegetation in the creek (Sections 5.9.2.5 and 5.9.4.1), the potential impact would be expected to be high between the portion of the creek captured by a pit and the confluence with the next significant creek downstream.<br>Studies have identified that (Section 5.14.8):<br>• Neither the alluvium nor overburden materials are pre-disposed to piping.<br>• The risk of uplift pressure on the downstream side of flood protection bunds is low.<br>• Alluvium is unlikely to be susceptible to liquefaction.<br>Monitoring of the E1 and E4 Marillana Creek diversions indicates that they are performing to design (Section 5.15.3). | 4 | Possible | High | • Hydraulic modelling, geotechnical assessments and various optimisation studies (Section 5.14.8) have informed bund designs including (Section 9.2.4):<br>- The flood bund heights required to accommodate a 1 in 10,000-year event.<br>- Rock armour specifications<br>- Depth of scour protection required.<br>• Flood channels have been designed to direct portions of extreme flood events up to a 1 in 10,000-year flood event to W1 and W4 pits to attenuate downstream flows and prevent damage to flood bunds (Sections 5.14.7 and 9.2.4).<br>• Floodplains have been designed for constrained sections of Marillana Creek between W5-W6, W4-W5 and E6-E7 to reduce the risks of erosion, lateral channel migration and / or overtopping of the CID / flood bunds (Sections 5.14.8.2 and 9.2.4.4).<br>• Studies have identified that closure designs for flood bunds (Section 5.14.8.3):<br>- Achieve FoS ≥1.5 (static) and ≥1.2 (seismic).<br>- In most cases, manage seepage risks, but mitigation may be required for W5, E1 and E4 flood bunds where the alluvium intersects the pit wall.<br>• The floodplain adjacent to the mid-section of W5 Pit will be widened to reduce flow velocities in this region which enables the flood bund to be offset from the pit edge to assist in managing risks associated with seepage through the alluvium (Sections 5.14.8.2 and 9.2.4.4).<br>• The proposed E8 Pit will be backfilled to the level of the Marillana Creek invert to prevent creek capture (Section 9.2.3).<br>• Modelling for a climate change scenario has indicated that the flood protection freeboard allowances prevent flooding from entering pits in a 1 in 10,000-year flood scenario, but velocity increases of up to 1 m/s may be experienced at E1 and E4 diversions. Further study is required to determine whether additional controls may be required (Section 7.3.2.1). | 4 | Very unlikely | Moderate | • Further geotechnical inspections / investigations and analysis of flood bund foundations (CID, alluvium, Oakover Formation), and floodplain locations, where required.<br>• Assessment of the suitability of in-situ CID material along pit crests to retain a 1 in 10,000-year flood event.<br>• Following cessation of mining conduct a final check of pit wall stabilities, where required.<br>• Detailed investigation and assessment of existing minor flood bunds.<br>• Further hydraulic analysis and scour modelling to optimise flood bund designs including the tie in of flood bunds with existing creek and floodplain surfaces.<br>• Assessment of the need for erosion protection for the backslope (downstream slope) of bunds.<br>• Further hydraulic modelling and design optimisation of floodplains to:<br>- Manage the risk of scour and erosion.<br>- Manage the interaction of the W6 floodplain landform with Herbert's Creek land bridge design for closure.<br>• Conduct further assessment of overburden settlement rates to inform floodplain designs.<br>• Investigate the need for upgrades to E1 and E4 diversions to accommodate a climate change scenario. |
| R 5 | Failure of W1-SP0 flood channel constructed for closure results in capture of Marillana Creek causing impacts to downstream riparian vegetation<br>*Closure condition* | Surface water infrastructure - W1-SP0 flood channel | C3.2<br>C3.4<br>C5.2 | **Primary causes:**<br>• Scouring, plucking or knickpoint erosion.<br>• Deposition leading to elevated water levels and diversion of more water to the W1 Pit.<br>• Pit wall instability.<br>**Contributing factors to poor design outcomes:**<br>• Inadequate geotechnical information.<br>• Inadequate modelling of post-closure flood conditions (e.g., regional cumulative influences poorly accounted for).<br>• Inadequate sensitivity testing (e.g., to accommodate climate change).<br>• Flood channel is not constructed to design. | Failure of the W1-SP0 flood channel could result in the capture of a portion of the Marillana Creek flows with impacts to downstream riparian vegetation.<br>Given the significance of regular flood events to recharging the alluvium that supports the riparian vegetation in the creek (Sections 5.9.2.5 and 5.9.4.1), the potential impact is considered to be high between portion of the creek captured by W1 Pit and the confluence with the next significant creek downstream.<br>However, an assessment of the potential for creek capture indicated that the likelihood would be low due to the distance between the pit and Marillana Creek and the substantial amount of dolerite along the alignment (Section 5.14.7.8). | 4 | Highly unlikely | Low | • The design of the flood channels (Section 9.2.4) has been informed by geotechnical investigations and hydraulic modelling (Section 5.14.7).<br>• Given the distance of the creek to the flood channel outlet, and the dolerite along the alignment, the risk of creek capture is considered to be low. However, further geotechnical investigations will be conducted to optimise the design, but at this stage are not expected to make a material difference to the current risk rating. | 4 | Highly unlikely | Low | • Further geotechnical investigations and analyses at the eastern part of the W1-SP0 flood channel.<br>• Optimisation of W1-SP0 flood channel design based on geotechnical data and additional hydraulic modelling. |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk | | | Controls (Treatment) | Residual Risk | | | Improvement Activity |
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| | | | | | | Consequence | Likelihood | Risk | | Consequence | Likelihood | Risk | |
| R 6 | Change to groundwater levels in the CID which impacts groundwater levels in the alluvium where it intersects the CID and impacts riparian vegetation beyond that accepted via project approvals<br>*Inherent condition following groundwater recovery - assuming no closure measures implemented* | Mine voids | C3.4<br>C5.5 | **Primary causes:**<br>• Following closure and groundwater recovery, evaporation from open mine voids permanently depresses groundwater levels in the CID and Weeli Wolli in some locations.<br>• Where the CID or pits intersect the alluvium, recession of water levels following rainfall and streamflow is more rapid than pre-mining conditions.<br>• There is insufficient overburden to backfill pits to enable pre-mining groundwater levels to be re-established.<br>• Third party mining operations impact on groundwater flows resulting in different / unpredicted closure outcomes.<br>• Surface erosion of the backfilled pits reduces the thickness of backfill above the returning groundwater level leading to a reduction in post-mining groundwater levels.<br>**Contributing factors to poor design outcomes:**<br>• The hydraulic conductivity of backfill differs from model assumptions which results in unanticipated groundwater levels post-closure. | Impacts to riparian vegetation at Flat Rocks have already been detected and are being managed via the Marillana Creek Water Resource Management Plan (Section 7.3.2.6).<br>Within the Yandi mining lease, mature tree health decline has been observed in proximity to areas where groundwater levels in the CID have declined and the alluvium directly overlies the CID and / or intersects mine voids. The principal riparian tree species most likely to be impacted is *Melaleuca argentea*. The major riparian Eucalypt species are likely to be more resilient to lowered water tables if the surface water regime supporting regular vadose-zone replenishment is maintained (Section 5.6.3.1). However, some areas that historically supported stands of *Melaleuca argentea* may not remain viable for this species (Section 7.3.2.6).<br>The impacts to riparian vegetation within the Yandi lease area have been highlighted in and accepted via approval submissions (BHP Iron Ore, 1995; EPA, 2005).<br>Currently high-density riparian vegetation is being supported to the north of the E8 Pit by discharge of dewatering water which has created an artificial pool. Following cessation of discharge, riparian vegetation communities will change to a new equilibrium commensurate with the post-mining availability of water (Section 7.3.2.6). | 3 | Likely | High | • The current backfill design is for W1 Pit to be partially backfilled with seasonal expressions of water which will reduce the hydraulic gradient and drawdown at the areas of riparian vegetation at Flat Rocks (Section 9.2.3.1).<br>• Monitoring has shown that groundwater levels are recovering following a reduction in dewatering at W0 (western end of W1 Pit) (Section 5.9.2.3). The residual regional drawdown post-groundwater recovery has yet to be modelled.<br>• The impacts at Flat Rocks are currently being managed via the Marillana Creek Water Resource Management Plan. If any of the options require action at closure, these will be incorporated into future iterations of the MCP, as required (Section 9.2.3.1).<br>• The closure design for the proposed E8 Pit represents a potential opportunity to support riparian vegetation in this area. The feasibility of this opportunity is currently being explored in consultation with Traditional Owners, and if feasible, will be incorporated into future updates to this MCP (Section 7.3.2.6).<br>*The residual risk assessment assumes the implementation of the Marillana Creek Water Resource Management Plan to mitigate impacts at Flat Rocks.* | 3 | Possible | Moderate | • Complete further permeability testing of backfill materials that increases the spatial distribution of test locations.<br>• Update water balance modelling based on:<br>- The outcomes of consultation with BNTAC and the Banjima people.<br>- Revisions to permeability assumptions (if required).<br>- Data sharing with RTIO.<br>- Further assessment of overburden settlement rates.<br>- Pit wall stability and floodplain designs.<br>• Incorporate modelling of closure conditions into the regional groundwater model and align GoldSim and regional groundwater model inputs and outputs.<br>• Following the study into long-term mitigation measures for groundwater decline at Flat Rocks, incorporate relevant measures into the MCP, if required.<br>• Update the assessment of the influence of post-mining groundwater levels in the CID on riparian vegetation within the Yandi lease. |
| R 7 | Cumulative drawdown that impacts Yandicoogina Gorge<br>*Inherent condition following groundwater recovery - assuming no closure measures implemented* | Mine voids | C3.4<br>C5.5 | As for R 6 above | Limited data from the Ministers North aquifer shows a decline in groundwater levels since 2018. It is not clear whether this is due to lower than average rainfall, or a combination of dewatering and climate variability (Section 5.9.2.3). This observed impact requires further investigation.<br>Following the precautionary principle, the consequence rating assumes that there could be some impact to Yandicoogina Gorge from a change to groundwater levels resulting from cumulative mining related drawdown (Section 5.9.2.7). | 3 | Possible | Moderate | • BHP's backfill strategy for Yandi that minimises the area of pit lakes post-closure and reduces impacts to groundwater levels post-closure (Section 9.2.3.1).<br>• Groundwater levels will recover post-backfill (albeit to a lower level than pre-mining groundwater levels) (Section 5.14.1.4), but the extent to which this may influence regional groundwater levels has not yet been modelled. The likelihood assigned to the residual risk reflects this uncertainty. | 2 | Possible | Low | As for R 6 above plus:<br>• Complete investigations to assess the potential for a connection between dewatering in the CID and Ministers North aquifer to the south. |

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| R 8 | Traditional Owners do not accept permanent saline pit lakes in the environment<br>*Inherent condition following groundwater recovery - assuming no closure measures implemented* | Mine voids | C3.4<br>C5.4<br>C5.8 | **Primary causes:**<br>• There is insufficient overburden to backfill pits to prevent the formation of permanent saline pit lakes.<br>• Evapo-concentration of water in pit lakes increases pit lake salinity.<br>• Inputs of additional water (from creek discharges / rainfall) can further increase salinity due to the additional associated salts that are left following evaporation.<br>• Erosion of backfill surface may change salinity classification of backfilled pits.<br>• Settlement of backfill beyond predictions changes salinity classification of backfilled pits.<br>• Third party activities influence design outcomes.<br>**Contributing factors to poor design outcomes:**<br>• Insufficient sensitivity testing of models / assumptions.<br>• Permeability of overburden is different to model assumptions.<br>• Predictive assessments do not consider climate change. | If there was no backfill-post-closure the following pits would become permanent saline pit lakes W2, W3, W6, C1/2, C4/5, E1/2/3/5/6. W1 would become a frequently inundated saline wetland and W4 a permanent brackish pond (Appendix F.1.3).<br>The Banjima people have stated an aversion to saline pit lakes. | 4 | Highly likely | High | • Backfill strategy that minimises the footprint of hyper-salinity in the landscape with only W2, W3, C4/5 and E7 becoming permanent saline pit lakes (Sections 5.14.1.4 and Section 9.2.3.1).<br>• The backfill strategy has been informed by:<br>- Modelling and sensitivity testing including climate change scenarios (Section 5.14.1).<br>- Permeability testing (Section 5.2.4.3).<br>- Data sharing agreement with RTIO (Sections 5.14.1 and 7.3.1).<br>• Excluding C1 and E2 OSAs from the backfill design provides a source of materials for supplementing backfill in areas where settlement may be more than predicted (Section 9.2.1).<br>• Measures have been incorporated into the backfill strategy to minimise the potential for erosion including (Section 9.2.3.1):<br>- Gentle slopes<br>- Ramp landings to dissipate energy from surface water run-off from ramps.<br>- Energy dissipation apron at the toe of the W1-SP0 flood channel.<br>• Surface water management infrastructure manages ingress of water to pits (Section 9.2.4).<br>• Consultation and exploration of alternative closure strategies with Traditional Owners. | 3 | Highly likely | High | • Review and, if necessary, revise or refine the backfill strategy based on:<br>- Further consultation and post-mining land use planning with BNTAC and the Banjima people.<br>- Data sharing with RTIO.<br>- Further assessment of overburden settlement rates.<br>- Pit wall stability and floodplain designs.<br>- Updated modelling including any revisions to permeability assumptions.<br>- Updated material balance.<br>• Complete further permeability testing of backfill materials that increases the spatial distribution of test locations.<br>• Align GoldSim and regional groundwater model inputs and outputs. |
| R 9 | Impact to Traditional Owner cultural values from aspects of the closed mine other than saline pit lakes<br>*Inherent condition* | OSAs, backfilled mine voids, surface water infrastructure, ex-pit infrastructure | C3.1<br>C5.8 | • Traditional Owners are not identified or consulted.<br>• Visual aspects of landforms or other aspects of closure designs impact on cultural values.<br>• Access to key areas of country post-mining, including to significant sites, is not possible or has not been adequately considered in closure designs.<br>• Landform failure (see Risks R 1 to R 5).<br>• Vegetation fails and / or excessive weed infestation displaces native species (see Risks R 13 to R 15).<br>• Vegetation does not include species of cultural significance.<br>• Return of fauna habitat is not considered in rehabilitation plans (see Risks R 13 to R 15).<br>• Rehabilitation earthworks are not executed to standard or as defined in the project work pack.<br>• Cultural Heritage Management Plan commitments (e.g., repatriation of cultural artefacts) are not adequately met at closure. | Impact to Traditional Owner cultural values | 3 | Possible | Moderate | • Consultation with Traditional Owners (Sections 4 and 13.3).<br>• All OSAs except C1 and E2 will be rehandled to the pits as backfill and the ex-pit area returned to an approximation of the pre-mining topography (Section 9.2.2).<br>• Marillana Creek E1 and E4 diversions have been constructed to resemble analogue reaches of Marillana Creek (Section 5.15.3).<br>• Minor and intermediate diversion designs will be optimised to include consideration of the potential to develop more natural looking systems which support riparian vegetation (Sections 5.14.9 and 13.3).<br>• Backfill design incorporates features to make the surface more natural looking (Section 9.2.3.1).<br>• The W1-SP0 energy dissipator will be designed to resemble natural analogues (Section 5.14.7.5).<br>• Standard rehabilitation strategies (Section 9.1.5), rehabilitation research and trials (Section 5.15) and revegetation strategy for Yandi (Section 9.3).<br>• Seed mixes contain culturally significant species (Appendix I).<br>• Post-mining land use planning (Section 6.1 and 13.3).<br>• Archaeological and ethnographic surveys (Sections 5.12 and 9.1.8).<br>• Also refer to controls for R 1 to R 5 and R 13 to R 15. | 2 | Possible | Low | • Further consultation and post-mining land use planning with BNTAC and the Banjima people.<br>• Optimisation of backfill, creek diversion, floodplain and flood channel designs to:<br>- Manage impacts on heritage sites and cultural values.<br>- Achieve more natural looking systems, erosion and deposition processes and establishment of riparian vegetation in creek diversions.<br>• Consider options for incorporating measures for safe access and egress into designs.<br>• Conduct further research and trials to inform the revegetation strategy for backfilled pits.<br>• Refinements to closure designs and confirmation of the vegetation communities and species mix to be assigned to each domain.<br>• Research program to investigate fauna habitat and the return of fauna to rehabilitated areas, including consideration of key species of significance to Traditional Owners. |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk Consequence | Inherent Risk Likelihood | Inherent Risk Risk | Controls (Treatment) | Residual Risk Consequence | Residual Risk Likelihood | Residual Risk Risk | Improvement Activity |
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| R 10 | Impact to heritage sites as a result of additional disturbance required to execute closure<br>*Inherent condition* | OSAs, safety bunds, infrastructure, surface water | C5.8 | • Traditional Owners are not identified or consulted.<br>• Closure landforms / earthworks execution require additional disturbance footprint.<br>• Rehabilitation earthworks not executed to standard or as defined in the project work pack. | Impact to Traditional Owners.<br>Several designs have already been modified to avoid heritage sites due to the implementation of BHP's controls (e.g., W1-SP0 alignment) (Section 5.14.7). | 3 | Possible | Moderate | • Consultation with Traditional Owners (Sections 4 and 13.3).<br>• Disturbance for closure execution activities to be approved through Project Environmental and Aboriginal Heritage Review (PEAHR) process (Section 9.1.8). | 2 | Highly unlikely | Very low | - |
| R 11 | Pits become temporary throughflow systems which impact downstream groundwater quality and associated receptors<br>*Inherent condition* | Mine voids, surface water infrastructure | C3.2<br>C5.6 | • Failure of existing surface water infrastructure due to:<br>- Flood events exceeding the operational design event.<br>- Geotechnical instability and failure of diversion embankments or pit walls adjacent to surface water infrastructure.<br>- Erosion and scour.<br>- Long-term sedimentation in diversions reduces capacity.<br>• Density driven flow. | If there was no backfill post-closure, all pits would become pit lakes and act as groundwater sinks. Uncontrolled surface water flows into a pit(s) may result in pits becoming temporary throughflow systems.<br>Water levels in this scenario have not been modelled, however, taking a precautionary approach, impacts have been rated on a theoretical scenario where flows through the CID could impact the water quality in the alluvial aquifer and impact riparian vegetation.<br>An initial assessment has indicated that the risk of density driven flow is low (Section 5.14.5), however, further work is required to confirm this. | 3 | Possible | Moderate | • Surface water management designs for closure prevent uncontrolled discharge of surface water to pits (Section 9.2.4) and have been based on hydraulic modelling, geomorphic and geotechnical assessments and various optimisation studies (Sections 5.14.7 to 5.14.9).<br>• Flood channels have been designed to direct portions of extreme flood events up to a 1 in 10,000-year flood event to W1 and W4 pits to attenuate downstream flows and prevent damage to surface water infrastructure (Sections 5.14.7 and 9.2.4).<br>• The current closure design maintains groundwater sinks in strategic locations to prevent impacts to surrounding groundwater quality and water balance modelling indicates that these pits are maintained as sinks during controlled discharges of flood waters to W1 and W4 Pits. Water balance modelling also shows that maximum water levels do not intersect the alluvial aquifer based on the backfill strategy (Section 5.14.1).<br>• Modelling for a climate change scenario has indicated that the flood protection freeboard allowances prevent flooding from entering pits in a 1 in 10,000-year flood scenario (Section 7.3.2.1). | 3 | Unlikely | Low | • Further investigation and optimisation of surface water management infrastructure designs, as outlined for Risks R 1 to R 5.<br>• Further investigate the potential for the Yandi pit lakes to stratify and result in density driven flow. |
| R 12 | Uncontrolled surface water flows into pits causes uncontrolled overtopping of pit lakes into Marillana Creek and impacts to surface water quality and downstream receptors<br>*Inherent condition* | Mine voids, surface water infrastructure | C3.2<br>C5.3 | As for R 11 above. | If there was no backfill post-closure, all pits would become pit lakes. Uncontrolled surface flows into a pit(s) may result in overtopping.<br>This scenario has not been modelled, however, the potential for controlled discharges from W4 Pit has been modelled (Section 5.14.4) and shows that this event poses only a low short term (<30 hours) impact to water quality.<br>Given that the inherent risk for this risk event represents an uncontrolled scenario, the impact has been assumed to be a level of severity higher than controlled discharges. | 2 | Possible | Low | As for R 11 above plus:<br>• W4-SP4 flood channel is designed as a controlled discharge to Marillana Creek once W4 Pit is full.<br>• Modelling of the W4 controlled discharge concluded that the W4 flood would only be expected to be activated in a very rare (1 in 10,000-year event) and only short term (<30 hours), modest exceedances of some water quality guideline values (nitrate, salinity, sulphate, nickel and zinc depending on the modelled scenario) could occur in the mixing zone (Section 5.14.4). | 1 | Highly unlikely | Very low | • Further investigation and optimisation of surface water management infrastructure designs, as outlined for Risks R 1 to R 5.<br>• Should changes to closure designs or associated knowledge base warrant, review the implications for pit lake water release to Marillana Creek and update modelling, if required. |

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| R 13 | Revegetation of ex-pit domains (excluding creek diversions) does not meet ecological completion criteria<br>*Inherent condition* | OSAs, infrastructure | C4.1<br>C4.2<br>C4.3<br>C4.4<br>C4.5 | • Lack of topsoil or suitable alternate growth medium for establishing and sustaining native vegetation.<br>• Incorrect species selection or viable provenance seed unavailable for seeding at completion of earthworks.<br>• Limited seed available in growth media applied to project area.<br>• Poor or no germination / establishment following seeding.<br>• Climate change and prolonged periods of drought during crucial growth phases or above average fire frequency post establishment.<br>• Excessive weed infestation displaces native species.<br>• Feral animals.<br>• Return of fauna habitat is not considered in rehabilitation plans.<br>• Rehabilitation earthworks are not executed to standard or as defined in the project work pack.<br>• Third party activities on the land are outside the closure design parameters. | • Impact to surrounding native vegetation communities through uncontrolled weed spread (invasive species).<br>• Potential impact to post-mining land use capacity or capability.<br>• Minor visual amenity impacts e.g., dust or bare areas.<br>• Return of fauna delayed due to lack of habitat.<br>• The rehabilitated OSAs C1 and E2 are progressing towards completion criteria (Section 5.15.4) indicating that rehabilitation techniques for ex-pit areas can establish target vegetation communities.<br>*Note: C1 and E2 OSAs have been assessed as having a very low inherent risk (Appendix L.2) based on performance monitoring conducted to date (Section 5.15.4).* | 3 | Possible | Moderate | • Topsoil reconciliation and overburden characterisation for use as growth media (Section 5.3).<br>• Progressive rehabilitation and associated monitoring and feedback loops (Section 5.15).<br>• Growth media / rehabilitation trials and rehabilitation research (Section 5.15 and Appendix K).<br>• Standard rehabilitation procedures (Section 9.1.5).<br>• Weed monitoring and management procedures (Section 10.1.3).<br>• Use of local provenance seed (Section 9.1.5.4).<br>• Opportunities to provide habitat for fauna are considered during rehabilitation (Section 9.1.5.5).<br>• Revegetation strategy for Yandi (Section 9.3). | 2 | Unlikely | Very low | • Test topsoil stockpiles for a range of physical and chemical parameters that influence plant growth.<br>• Implement the proposed growth media trial and refine revegetation strategies accordingly.<br>• Maintain a watching brief on emerging research associated with the use of out of provenance seed sources to increase genetic diversity to provide resilience to climate change.<br>• Research program to investigate fauna habitat and the return of fauna to rehabilitated areas. |
| R 14 | Revegetation of backfilled pits does not meet ecological completion criteria<br>*Closure condition* | Mine voids - backfilled | C4.1<br>C4.2<br>C4.3<br>C4.4<br>C4.5 | As for R 13 above plus:<br>• Conditions in backfilled pits may be different from those expected / predicted.<br>• Insufficient research and trials to determine the correct species mix for use in backfilled pits.<br>• Erosion of backfill surface may change salinity classification of backfilled pits.<br>• Settlement of backfill beyond predictions changes salinity classification of backfilled pits. | • Impact to surrounding native vegetation communities through uncontrolled weed spread (invasive species).<br>• Potential impact to post-mining land use capacity or capability.<br>• Minor visual amenity impacts e.g., dust or bare areas.<br>• Return of fauna delayed due to lack of habitat. | 3 | Possible | Moderate | As for R 13 above plus:<br>• Modelling and sensitivity testing has been used to inform the backfill strategy (Section 5.14.1).<br>• Measures have been incorporated into the backfill strategy to minimise the potential for erosion including (Section 9.2.3.1):<br>- Gentle slopes.<br>- Ramp landings to dissipate energy from surface water run-off from ramps.<br>- Energy dissipation apron at the toe of the W1-SP0 flood channel<br>• Contouring of the backfill is proposed to collect seasonal water in low points. Modelling indicates that salt build up in the low points will likely be flushed to deeper levels in the backfill profile and the development of sodicity is likely to be limited. However, the potential for localised areas of sodicity cannot be excluded (Section 5.14.3.2). | 2 | Possible | Low | As for R 13 above plus:<br>• Complete further permeability testing of backfill materials that increases the spatial distribution of test locations.<br>• Align regional groundwater model and GoldSim inputs and outputs.<br>• Review and, if necessary, revise or refine the backfill strategy and domain-specific vegetation completion criteria based on the outcomes of:<br>- Further consultation with BNTAC and the Banjima people.<br>- Data sharing with RTIO.<br>- Settlement studies.<br>- Pit wall stability and floodplain designs.<br>- Updated modelling including any revisions to permeability assumptions.<br>- Updated material balance.<br>• Investigate the significance of backfill permeability and surface topography to salt accumulation as backfill designs are refined.<br>• Research and trials to inform the species mix to be used in backfilled pits including floodplains, buttresses and pit laybacks. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 15 | Revegetation of creek diversions with a morphology suitable to revegetation establishment does not meet ecological completion criteria<br>*Inherent condition* | Surface water infrastructure | C4.1<br>C4.2<br>C4.3<br>C4.4<br>C4.5 | • No or insufficient aquifer within diversion channels to sustain vegetation.<br>• Alluvial aquifer within the diversion intersects CID impacted by dewatering.<br>• Alluvial aquifer is impacted by scour.<br>• Geomorphology of diversion is not suited to vegetation establishment.<br>• Excessive weed infestation displaces native species.<br>• Feral animals. | • Impact to surrounding native vegetation communities through uncontrolled weed spread (invasive species).<br>• Potential impact to post-mining land use capacity or capability.<br>• Minor visual amenity impacts.<br>• Return of fauna delayed due to lack of habitat.<br>• Vegetation is returning to E1 and E4 diversions through a combination of natural recruitment and seeding / selected tube stock placement on flood benches (Section 5.15.3). | 3 | Unlikely | Low | • An engineered aquifer has been provided for E1 and E4 creek diversions.<br>• Options will be considered for encouraging vegetation growth through design upgrades to intermediate and minor creek diversions where appropriate to the design / geomorphology. | 2 | Unlikely | Very low | Optimise diversion designs including consideration of geomorphology and:<br>• The potential to achieve more natural looking systems.<br>• Erosion and deposition processes.<br>• Establishment of riparian vegetation. |
| R 16 | Inadvertent access to unsafe areas causes injury or fatality<br>*Inherent condition* | Mine voids, infrastructure | C2.1<br>C3.2 | **Primary causes:**<br>• Security measures are not in place (e.g., fence, gate, signage, safety bunds) or are not inspected and maintained prior to relinquishment.<br>• Leaving behind attractive features (e.g., disused infrastructure, scrap metal yards) not planned for public access.<br>• Uncontrolled access to potential hazards such as unstable slopes, steep drops, fibrous materials.<br>**Contributing factors to poor design outcomes:**<br>Security measures are inadequate or ineffective:<br>• The safety bund is incorrectly positioned for pit wall slope / stability and is inconsistent with DEMIRS guidelines (DoIR, 1997) due to:<br>- Unknown slope stability risks not realised at the time of design.<br>- Elevated water levels impacting pit wall stability.<br>- Physical or legal constraints (e.g. tenure) preventing the safety bund from being located appropriately.<br>- Inadequate community engagement.<br>- A flood channel / diversion or bund fails and erodes a pit wall.<br>- The impacts of climate change are not considered in designs and stability assessments.<br>- The final pit wall and / or safety bund are not built to design or plan<br>• Inadequate infrastructure removal planning and / or execution to plan.<br>*Note the following risks have been considered separately:*<br>• *Controlled access to backfilled pits (R 17)*<br>• *Access to pit lakes (R 18 and R 19)*<br>• *Access to flood channels (R 20 and R 21)* | Community injury or fatality. | 4 | Possible | High | • Pit wall stability assessments have been conducted (Section 5.4.2) and slopes that achieve a FoS< 1.5 (static) and <1.0 (seismic) may be buttressed or reprofiled to achieve a lower slope angle to improve stability (Section 9.2.3.3).<br>• Geotechnical assessments and hydraulic modelling have informed surface water infrastructure designs and their potential to impact on pit wall stabilities (Sections 5.14.7 to 5.14.9).<br>• Backfill designs improve pit wall stability (Section 5.14.11).<br>• Safety bunds will be constructed to meet DEMIRS guidance (DoIR, 1997) (Section 9.2.3.4).<br>• The Master Area Design Review process verifies that geotechnical design guidance has been incorporated into pit and safety bund designs (Section 9.1.4).<br>• Assessment of compliance to plan (Section 9.1.4).<br>• Any potentially fibrous materials encountered during regrading or recovery for mine void backfill are placed at least 1 m below inert non-fibrous overburden (Section 9.1.7).<br>• Geological (highlights fault zones) and geotechnical models inform pit designs (Section 9.1.4).<br>• Unused infrastructure will be demolished and the footprint re-profiled and rehabilitated (Section 9.2.5). | 4 | Highly Unlikely | Low | • Complete pit wall stability analyses and design of safety bunds and pit wall stabilisation measures as pit wall and closure designs evolve. Incorporate updated information into the next revision of the MCP.<br>• Following cessation of mining conduct a final check of pit wall stabilities to confirm stability assessments based on as constructed pit geometries, where required.<br>• Further geotechnical assessments to inform flood channel, flood bund and diversion designs (risks R 1 to R 5).<br>• Optimise flood channel designs (including considerations of safety measures) based on additional geotechnical data.<br>• Develop decommissioning and demolition plans for Stage 2 demolition.<br>• Identify post-closure land management requirements through the post-closure monitoring and maintenance program. |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk – Consequence | Inherent Risk – Likelihood | Inherent Risk – Risk | Controls (Treatment) | Residual Risk – Consequence | Residual Risk – Likelihood | Residual Risk – Risk | Improvement Activity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 17 | Controlled access to backfilled pits post-closure results in injury or fatality<br>*Closure condition* | Mine voids - backfilled | C2.1<br>C3.2 | • Unstable pit walls fail.<br>• No egress from the pit in the case of bush fire or flooding. | Community injury or fatality.<br>*Note, this risk is assessing a closure condition and, therefore, the likelihood assigned to this risk assumes the control measures outlined in risk R 16 have been implemented.* | 4 | Unlikely | Moderate | As for R 16 above except:<br>• Where pits are designed for controlled access, pit walls will be designed to achieve a FoS consistent with natural hazards in the surrounding area.<br>• Boulders may be placed at the top of access ramps to restrict vehicle access (Section 9.2.3.4).<br>• Backfill design includes slopes to direct water away from pit walls to avoid ponding which causes geotechnical instability (Section 9.2.3.1).<br>• Perimeter benches have been designed to provide an elevated surface for pit access when conditions are unsuitable on the remainder of the pit backfill surface (Section 9.2.3.1). | 4 | Highly unlikely | Low | As for R 16 plus:<br>• Following confirmation of the backfill strategy, consider options for incorporating measures for safe access and egress into designs. |
| R 18 | Public access to pit lakes impacts human health and safety<br>*Inherent condition following groundwater recovery - assuming no closure measures implemented* | Mine voids - permanent pit lakes (C4/5) | C2.1<br>C3.3<br>C3.4<br>C5.4 | • Ingestion or contact with poor quality water.<br>• Steep drop-offs. | Hydrogeochemical modelling (Section 5.14.3.1) indicates that there may be elevated levels of sulphate, boron, fluoride and selenium while salinity is in the tolerable range for livestock (which has been used as a proxy for identifying the palatability of water for drinking).<br>The pit lake risk assessment (Section 5.14.6.3) concluded that:<br>• Risks to human health from contact with, or ingestion of pit lake waters are low as:<br>- High salinity will result in unpalatable water for drinking and hence will reduce the potential for ingestion of constituents of concern that may become elevated in evapo-concentrated waters.<br>- Small amounts of water may be ingested during recreational activities, but the exposure risk is likely to be low. Where humans have regularly accessed even AMD degraded pit lakes for contact pathways such as swimming, no significant health effects from direct contact have been noted.<br>• Minor reversible health effects may occur that require medical intervention.<br>• Steep drop-offs into water may result in drowning. | 4 | Unlikely | Moderate | As for R 16 above except:<br>• Where backfill surfaces intersect the C4/5 pit lake, they have been graded to form shallow beaches to reduce the potential for steep drop offs to lead to drowning. | 4 | Highly unlikely | Low | • Once pit shell designs have been finalised, including consideration of any pit wall stabilisation measures (e.g., buttressing, pit wall re-profiling), the geochemical characteristics of pit wall exposures will be reassessed.<br>• Conduct drilling and characterisation of materials prior to flood channel construction to assess the potential for exposing PAF materials.<br>• Update the pit lake hydrogeochemical modelling, if required following update of backfill designs.<br>• Refine the pit lake risk assessment based on the outcomes of modelling. |
| R 19 | Access to pit lakes impacts wildlife health<br>*Inherent condition following groundwater recovery - assuming no closure measures implemented* | Mine voids - permanent pit lakes | C3.3<br>C3.4<br>C5.4 | • Ingestion or contact with poor quality water.<br>• Steep slopes / pit walls. | Hydrogeochemical modelling (Section 5.14.3.1) indicates that there may be elevated levels of sulphate, boron, fluoride and selenium while salinity is in the tolerable range for livestock (which has been used as a proxy for identifying the palatability of water for wildlife drinking).<br>The pit lake risk assessment (Section 5.14.6.3) concluded that risks to wildlife from contact with, or ingestion of pit lake waters or pit lake biota are low as:<br>• High salinity will result in unpalatable water for drinking and hence will reduce the potential for ingestion of constituents of concern that may become elevated in evapo-concentrated waters.<br>• The pit lakes will represent poor wildlife habitat with low ecosystem diversity and abundance.<br>• Steep sides may result in drowning. | 2 | Possible | Low | Where backfill surfaces intersect pit lakes, they have been graded to form shallow beaches to reduce the potential for steep drop offs to lead to drowning. | 2 | Possible | Low | As for R 18 above |

| Risk ID | Risk Event (Source & Pathway) | Domain & features | Completion criteria | Causes | Impact to Receptors | Inherent Risk: Consequence | Inherent Risk: Likelihood | Inherent Risk: Risk | Controls (Treatment) | Residual Risk: Consequence | Residual Risk: Likelihood | Residual Risk: Risk | Improvement Activity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 20 | Access to W1 flood channel results in injury or fatality<br>*Closure condition* | Surface water infrastructure - W1-SP0 | C2.1 | • Steep drops.<br>• Fibrous material exposures in flood channel.<br>• Major (rare) flood event. | Community injury or fatality. | 4 | Unlikely | Moderate | • The energy dissipator for the W1-SP0 is designed to represent an analogue system and incorporates shallow steps and irregularities (Section 5.14.7.5).<br>• Fibrous material exposures in W1-SP0 are expected to pose similar hazards to natural occurrences at Flat Rocks and other places locally.<br>• A 1.5 m cut has been designed at the entrance to the W1-SP0 flood channel to deter access (Section 9.2.3.4). | 4 | Highly unlikely | Low | • Further risk assessment of the potential fibrous material exposures in the W1-SP0 flood channel in comparison to natural analogues and review of mitigation options, if required.<br>• Where there is safe access following construction, map fibrous materials exposures to enable confirmation (or otherwise) that the assumptions used in risk assessments are valid. |
| R 21 | Access to W3-SP3 and W4-SP4 flood channels results in injury or fatality<br>*Closure condition* | Surface water infrastructure - W1-SP3 & W4-SP4 | C2.1 | • Steep drops.<br>• Major (rare) flood event. | Community injury or fatality. | 4 | Unlikely | Moderate | • W1-SP3 has been designed with stepped energy dissipators (10 m high), but the accessibility of the flood channel from ex-pit areas is limited as it connects the W1 and W4 pits (Sections 5.14.7.6 and 9.2.4.1).<br>• The W4-SP4 flood channel has been designed as a sloped system (no steps) (Sections 5.14.7.7 and 9.2.4.1). Further work is required to consider prevention of inadvertent access to the W4 Pit from the channel. | 4 | Highly unlikely | Low | • Optimise flood channel designs (including considerations of safety measures) based on additional geotechnical data and hydraulic modelling.<br>• Where there is safe access following construction, confirm, or otherwise, the absence of fibrous materials exposures. |
| R 22 | Identified areas of contamination have not been managed during operations or the contaminated sites classification under the CS Act is not suitable for the agreed post-mining land use.<br>*Closure condition* | Infrastructure | C5.7 | • Contaminated sites are not identified, assessed and remediated during operations.<br>• Incomplete recovery of known contamination or ineffective remedial measures.<br>• Poor hydrocarbon / chemical management during closure execution.<br>• CS Act classification obtained during operations is not suitable for the post-mining land use. | • Potential for localised groundwater contamination.<br>• Regionally, groundwater would not be expected to show an increase in contaminants due to attenuation and dilution.<br>• Potential minor impacts on local stygofauna (minor decline in populations numbers) in the vicinity of the mine with recovery expected after several years.<br>• Impact to post-closure land use. | 2 | Possible | Low | BHP has a suite of procedures for managing contaminated sites during operations including:<br>• WAIO Contaminated Sites Register and risk-based schedule for investigation including PSIs and DSIs (Sections 5.10 and 9.1.10).<br>• Pre-closure monitoring which enables groundwater and surface water contamination to be identified and remediated if required (Sections 10.1.8 and 10.1.10).<br>• Programs for remediation of known contamination (including PFAS) as required (Sections 5.10 and 9.1.10).<br>• Demolition and decommissioning plan addresses management of hydrocarbons / chemicals (Section 9.2.5). | 2 | Unlikely | Very low | Conduct PSIs and DSIs to assess contamination, and develop remediation action plans, if required. |
| R 23 | Land / infrastructure condition is not suited to the post-mining land use<br>*Inherent condition* | OSAs, mine voids, surface water infrastructure, infrastructure | C1.1<br>C1.2<br>C1.3 | • Post-mining land use performance objectives and completion criteria are not supported by key stakeholders.<br>• Infrastructure transferred to third parties does not meet agreed condition.<br>• The long-term active management requirements for the site are beyond those required to manage adjacent land with a similar land use. | Potential to impact viability of defined post-closure land use.<br>The post-mining land use for Yandi has not yet been defined in consultation with stakeholders. However, the closure designs for Yandi have been developed so that they don't preclude potentially feasible land uses (Section 6).<br>*Note: risks above identify risks to specific closure objectives (e.g., revegetation, stability, water quality).*<br>*This risk is specifically focused on impacts likely to arise as a result of failing to consult, remaining infrastructure condition and post-relinquishment land management requirements. It does not include the risk associated with the Banjima people's perception of saline pit lakes as this is already covered by risk R 8.* | 3 | Possible | Moderate | • Consultation / collaboration with BNTAC and the Banjima people to define post-mining land uses for Yandi (Section 6).<br>• Consultation with key stakeholders to inform post-mining land use performance objectives and completion criteria (Sections 4.2 and 6).<br>• Consultation with stakeholders on requirements for infrastructure prior to demolition. Assessment of infrastructure condition and documentation of the condition of the infrastructure to be transferred in transfer agreements (Section 9.2.5.1).<br>• Identification of land management requirements through post-closure monitoring and maintenance program (Section 10). | 2 | Possible | Low | • Consult with key stakeholders regarding post-mining land uses at Yandi and domain specific completion criteria.<br>• Identify post-closure land management requirements through the post-closure monitoring and maintenance program.<br>• Undertake government and stakeholder consultation to identify requirements for infrastructure prior to Stage 2 demolition.<br>• Develop decommissioning and demolition plans for Stage 2 demolition. |

# 8 Closure outcomes and completion criteria

In line with BHP's Charter, we demonstrate environmental responsibility by minimising environmental impacts and contributing to enduring benefits to biodiversity, ecosystems and other environmental resources.

## 8.1 Closure and rehabilitation standards

BHP employs its Closure and Rehabilitation Standards (WAIO, 2023c; BHP, 2021b) across its Pilbara sites. The Closure Standard provides the overarching framework for the development of the mine closure strategy and supporting closure provision. The Rehabilitation Standard provides the overarching framework for successful rehabilitation of areas impacted by BHP operations in the Pilbara.

The Standards provide a consistent approach for closure and rehabilitation across BHP's Pilbara operations.

## 8.2 Objective and guiding principles

The BHP closure and rehabilitation objective is to:

> *Develop a safe, stable, non-polluting and sustainable landscape that is consistent with key stakeholder agreed social and environmental values and aligned with creating optimal business value.*

To guide the development and implementation of mine closure and rehabilitation for the Pilbara operations, BHP has established a set of guiding closure principles:

- **Informed planning and design**: rehabilitation and decommissioning requirements are considered at a mine deposit and regional scale upfront and integrated into mine plans to achieve optimal business value and a sustainable post-closure land use.
- **Sustainable post-closure land use**: post-closure land use and rehabilitated areas are acceptable to key stakeholders and consider the following:
  - Local land management practices;
  - Ongoing management requirements (e.g. roads and tracks);
  - Closure landform integration, including visual impacts, landform stability (physical and geochemical) and hydrological regimes;
  - Local baseline conditions (e.g. flora, vegetation, fauna and fauna habitat);
  - Ecosystem resilience in terms of flora, vegetation, fauna, and surface and groundwater regimes;
  - Infrastructure transfer or decommissioning;
  - Management or remediation of contaminated sites; and
  - Amenity.
- **Safety**: All mine rehabilitation and decommissioning is planned so that the risks to health and safety of people within BHP's area of influence are minimised. Unauthorised public access risk will be managed through the implementation of controls in accordance with regulatory requirements and consideration of industry guidance.
- **Effective stakeholder engagement**: transparent and proactive stakeholder engagement occurs for all planned activities that may impact surrounding communities, including consideration of communities impacted by closure.

The Yandi-specific closure objective is for the project to be decommissioned and rehabilitated in an ecologically sustainable manner (as required by MS 1039). In addition, given the interrelationships between surface water and groundwater, a set of Yandi-specific Closure Guiding Principles (Table 8-1) have been defined as the foundation for developing a sustainable closure solution[58]. The closure approach for Yandi commits to maintaining the three key regional environmental receptors of Fortescue Marsh, Weeli Wolli Creek and Marillana Creek by committing to sustain the surface water flow regime (water resource, hydraulic conditions and fluvial system). Local groundwater outcomes will be informed by consultation with key stakeholders. The Yandi mine void closure strategy aims to optimise:

- Pit lake quality and levels and the potential for vegetation to establish in backfilled pits.
- Post-mining groundwater levels including levels upstream of mining areas.

The closure objectives and guiding closure principles (BHP and Yandi-specific) provide the foundation for developing site specific completion criteria, as outlined in Section 8.3.

58 BHP acknowledges the recent receipt (late March 2025) of the Banjima Mine Closure Objective, Principles and Outcomes which will be used to inform future discussions with the Banjima people and updates to the MCP.

Rehabilitation and revegetation activities undertaken at Yandi will be targeted at the post-closure land uses described in Section 6 and developed to function in line with the two or three star outcomes as described in SERA (2021), meaning the rehabilitation outcome will: reinstate a level of ecosystem functionality on degraded sites where ecological restoration is not the aspiration, as a means of enabling ongoing provision of ecosystem goods and services. This is consistent with the SERA (2021) definition of a rehabilitated outcome and the level of landscape disturbance at Yandi.

**Table 8-1 Yandi closure guiding principles**

| Regional environmental outcomes maintained (Fortescue Marsh, Weeli Wolli Creek, Marillana Creek)<br>Local mine void outcomes informed by options assessment and stakeholder consultation | | |
|---|---|---|
| **Land** | **Water** | **Heritage** |
| • Post-mining land use will be informed by consultation with key stakeholders;<br>• Residual mine voids will be left in a geotechnically stable state;<br>• Overburden will be used to partially fill and profile mine voids to achieve beneficial local ecosystem outcomes; and<br>• Mine landforms will be revegetated to establish local native vegetation appropriate for the area. | • Fortescue Marsh and Weeli Wolli Creek regional outcomes will be maintained by committing to a sustainable Marillana Creek surface water flow regime; and<br>• Local groundwater outcomes will be informed by collaboration with key stakeholders including adjacent mines and Banjima People. | • The Banjima People will be engaged to inform the rehabilitation program consistent with the obligations and aspirations of the Banjima Comprehensive Agreement; and<br>• The integrity of, and access to, places of cultural significance will be maintained in the closure design to the greatest extent practicable. |

## 8.3 Completion criteria

Completion criteria are defined in the DEMIRS (2021) Mine Closure Completion Guideline as *providing the basis on which successful rehabilitation and mine closure are determined and so enable formal acceptance that rehabilitation and closure obligations agreed to in an approved MCP have been met.* The DEMIRS guideline has been developed for rehabilitation and closure obligations under the *Mining Act 1978 (WA)*. However, in the absence of specific guidance for rehabilitation and closure obligations arising from a Part IV EP Act approval, it can provide a general template for achieving completion of these sites and be submitted in support of a request for withdrawal of a Ministerial Statement under Section 47A of the EP Act.

The process of 'completion' is a pre-cursor to, but separate from, the process to relinquish or surrender tenure (discussed further in Section 10.4). Once completion has been achieved, monitoring, inspection and any maintenance activities can be reduced from those necessary to achieve and demonstrate completion and would be commensurate with those required post relinquishment. Following completion or withdrawal of a Ministerial Statement under the EP Act, DEMIRS / DWER can also determine that submission of AERs and MCPs is no longer required. The DEMIRS (2021) guideline provides for progressive completion reporting and sign-off as portions of mine disturbance are rehabilitated and completion criteria achieved. Given the proposed ongoing use of Yandi for processing ore from satellite mines, the timeframe between completion of certain areas and relinquishment of tenure may be significant. Section 10.4 deals with completion reporting and relinquishment, and the intervening period (referred to as post-completion).

Several terms have been used in this section to define the time between operations and completion as follows:

- Operations refers to the time when active mining or processing operations are occurring. Most of the planning for closure occurs during this time.
- Execution refers to the phase where closure and rehabilitation activities are conducted. Progressive closure execution may occur during the operational phase following cessation of mining / processing in a particular area.
- Post-closure refers to the time following execution of closure and rehabilitation where the success of closure and rehabilitation is being monitored and maintenance / rectification of areas not on track to meet completion criteria might occur.
- Completion refers to the time where achievement of completion criteria can be demonstrated and sign-off achieved.
- Post-completion refers to the period following completion but prior to relinquishment of tenure.

Completion criteria are the measures against which achievement of closure objectives and guiding principles can be assessed. BHP continues to actively review and improve its completion criteria based on new information and techniques. There have been several studies into the development of completion criteria for Yandi, including:

- Several studies of vegetation communities that may be applicable to those to be re-established through rehabilitation of the Yandi mine (Section 5.15.5). The current vegetation completion criteria in Table 8-2 have been based on:
  - The research conducted by Syrinx Environmental (2019) (Section 5.15.5.1 and Appendix M.1) and updated in 2023 based on rehabilitation monitoring data.
  - Studies conducted to support the criteria outlined in the Marillana Creek Diversion Management Plan (BHP Billiton, 2016) which has been approved by DWER.
- A review of the Yandi surface water and groundwater monitoring programs with a view to the development of numerical completion criteria (Section 5.9.3).
- Guidance developed by Landloch (2018) on acceptable erosion rates for landforms in the Pilbara (refer to Appendix R).

- Design studies outlined in Section 5.14.

Ongoing discussions on post-mining land uses and Banjima closure principles and values will shape the closure outcomes for Yandi going forward which in turn, will require the development / amendment of supporting completion criteria. In the development of appropriate completion criteria, reviews will be conducted of the technical information available / required to support the criteria and peer reviews of selected criteria will be requested from technical specialists in relevant fields, as appropriate.

Monitoring, research, including proposed rehabilitation trials (Section 5.15.7), closure design studies and consultation with key stakeholders (Section 4) will support the refinement of criteria. These refinements will be presented in future iterations of this MCP.

### 8.3.1 Approach

BHP recognises that closure outcomes are controlled by planning, design and execution activities. BHP's criteria, therefore, include both leading indicators describing the activities and designs necessary to achieve desired outcomes (e.g. landforms have been designed and constructed to take account of overburden characteristics affecting stability), as well as lagging indicators (completion criteria) which describe closure outcomes to be achieved (e.g. total hummock grass cover to be 14-25%).

Closure and rehabilitation objectives and criteria are based on the land uses applicable to a particular area, in recognition of the fact that the land is altered fundamentally from its pre-existing condition. The completion criteria for the Yandi mining operations are currently based on an assumed outcome of *relatively natural environment for pastoral grazing purposes* (as discussed in Section 6.3). In the event that alternate post-closure land uses are agreed for the site, additional / different completion criteria or criteria with different thresholds may apply.

The purpose of the completion criteria is to demonstrate that areas will display self-sustaining characteristics suitable to the post-mining land use and give government regulators confidence that, to the maximum possible extent, they can be managed in the long term according to the intended land use (or uses), using normal management practices without the input of additional resources.

The criteria outlined in Section 8.3.2 have been divided into three stages. The first two stages are performance indicators that are aimed at providing assurance that completion criteria will be met and guide appropriate planning and execution of closure:

- **Stage 1 Planning**: Describes criteria designed to confirm that the necessary planning and operating procedures have been developed and are supported by regulators and other relevant stakeholders.
- **Stage 2 Execution**: Describes criteria designed to confirm that rehabilitation operations have been implemented according to the above planning and operating procedures. The assessment method for these criteria will be by reviewing and auditing closure execution records, and site inspections and surveys, as required.

The **Stage 3 Completion Criteria** are the criteria which, when met, indicate that closure and rehabilitation has achieved an acceptable standard and is suitable for the defined post-closure land use. These are the criteria that will be measured to support an application for completion.

It should be noted that for older rehabilitation, it may not be possible to assess some of the planning and execution criteria.

In line with the WABSI completion criteria framework (Young, et al., 2019), BHP has correlated the inherent risk ratings relevant to each set of criteria to assist in prioritising focus on those criteria of most importance.

### 8.3.2 Completion criteria and performance indicators

The completion criteria for the Yandi mining operations are presented in Table 8-2. For clarity, column headings are designed to broadly align with WABSI guidelines (Young, et al., 2019) for completion criteria and are defined as follows:

- **Aspect:** A key theme or element of rehabilitation that needs to be addressed in order to meet closure objectives.
- **Criterion Objective:** The purpose or objective of the particular criterion. As defined in Young et. al, (2019) the closure objective provides a clear indication on what the proponent commits to achieve at closure.
- **Risk ID:** Refers to the Risk ID in Table 7-2, Section 7. Where more than one risk relates to a particular set of criteria, this has been shown in the Risk ID column, and the specific domains to which each risk relates are outlined in the adjacent domain column. The colour coding relates to the colour coding used in Table 7-2 for the inherent risk rating, i.e.,

| | | | |
|---|---|---|---|
| High | Moderate | Low | Very Low |

- **Domain:** Areas of similar operational land uses that have similar closure requirements and to which a particular completion criterion relates. Additional information relating to closure implementation for each closure domain is provided in Section 9.2.
- **Performance Indicator**: A level of performance through planning and execution that provides assurance that completion criteria will be met.
- **Completion Criterion:** A defined standard or level of performance that can be objectively verified and demonstrates successful closure of a site for a particular objective.
- **Verification Procedure:** The method used to confirm that the identified standard for the criterion has been achieved. As outlined by DEMIRS (2021), verification may rely on quantitative measurements or could be a process of certification, for example, compliance with an approved design. Verification processes have been identified for the planning, execution and

completion phases of closure. The completion phase is the phase during which a completion report would be developed to support sign-off against completion criteria in accordance with DEMIRS (2021).

- **Monitoring Method:** The monitoring method column cross references the relevant section of the MCP that describes the monitoring methods that will be applied to assess achievement of each completion criterion.

Consistent with the WABSI completion criteria guidance (Young, et al., 2019), completion criteria can incorporate qualitative measures as well as quantitative numerical targets. Young et. al (2019) identifies three types of criteria which have been used in the development of the criteria outlined in Table 8-2:

- P - installed / built as planned. For example, habitat features have been installed / constructed as planned / designed.
- C - categorical - a feature is present or absent, or an activity has been achieved or not. For example, overburden materials with adverse geochemical properties are not exposed on OSAs.
- Q - quantitative - the attribute can be measured and compared against a numerical target. For example, total hummock grass cover to be 14-25%.

The qualitative categorical and installed / built as planned criteria can be measured by audit, inspection or survey whereas quantitative criteria would typically be measured through a specific environmental monitoring program. These monitoring and measurement / verification programs are described in Section 10.

### 8.3.3 Progressive sign-off

The principle of progressive signoff will be adopted where appropriate, to recognise areas where the development of rehabilitation has reached acceptable standards and facilitate the transition to a post-mining land use. In these instances, criteria that change over time will not be applied retrospectively.

**Table 8-2 Yandi completion criteria**

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| **Post-closure land use** | | | | | | | | |
| C1.1 Post-closure Land Use | Post-closure land use has been informed by consultation with relevant stakeholders. | R 23 | All | Post-closure land use has been informed by consultation with key stakeholders (C).<br>Specific rehabilitation objectives, including requirements for safe access, have been developed so that, when met, areas will fulfil the post-completion land use requirements (C).<br>The rehabilitation objectives that will enable the post-completion land use to be implemented have been informed by consultation with end land users / owners (C).<br>Mine closure designs have been developed to meet rehabilitation objectives (C). | Mine closure execution is conducted substantially in accordance with designs (P). | Monitoring, inspection and / or survey reports that the rehabilitation objectives have been substantially met. These are the measures that the post-mining land use has been met (C).<br>The current assumed land use is related to underlying tenure (pastoral) and achievement of the criteria for land management (C1.3), stability (C3.2 - C3.4), revegetation (C4) and water (C5) will indicate that this criterion has been met (C). | **Planning**<br>Documented approval of land use performance objectives with end land users / owners and administering authority.<br>Mine closure design review.<br>**Execution**<br>As-constructed report, or post-construction survey or inspection report.<br>**Completion**<br>Post-closure monitoring and survey reports.<br>Post-closure land user / owner provides written acknowledgement that rehabilitation objectives and completion criteria have been met. | 10.1.1. Closure completion audit and inspection |
| C1.2 Infrastructure | Infrastructure has been decommissioned and removed where transfer to a third party is not agreed. | R 23 | All where infrastructure exists | Agreement has been reached with government and stakeholders (including post-mining land holder) as to whether any infrastructure is required to remain post-mining (C).<br>The agreement includes condition of infrastructure at transfer (C).<br>The depth of removal of in-ground infrastructure has been informed by the risks to post-closure land uses and consultation with the post-closure landowner / land manager and is specified in demolition plans (C).<br>Waste disposal requirements and locations have been informed by consultation with key stakeholders and incorporated into mine closure programs (C). | Unless otherwise agreed with stakeholders, or a risk assessment indicates a greater depth is required, infrastructure has been removed to at least 0.6 mbgl (C).<br>Infrastructure removal is generally in accordance with demolition specifications (P).<br>Remaining infrastructure condition has been assessed and referenced in stakeholder agreements (P).<br>Waste disposal plans have been implemented (P). | Stakeholders agree to the transfer of infrastructure ownership and accept ongoing responsibility for maintenance of the infrastructure (C).<br>In-ground infrastructure has been removed to 0.6 mbgl unless (C):<br>• An alternate standard has been agreed with the post-mining landowner / manager.<br>• Risk assessment indicates that a different specification is required. | **Planning**<br>Documented agreement of infrastructure to be removed and standard of demolition (including extent to which concrete foundations and buried services will be removed).<br>Documented agreement on infrastructure to remain and condition of infrastructure at transfer.<br>Demolition plan outlining infrastructure to be removed and standard of demolition (including extent to which concrete foundations and buried services will be removed).<br>**Execution**<br>Demolition contractor's report against agreed standard.<br>Condition assessment report of remaining infrastructure.<br>Waste disposal records.<br>**Completion**<br>Documented transfer of infrastructure to stakeholders.<br>Site inspection report following demolition.<br>Demolition contractor's report against agreed standard. | 10.1.1. Closure completion audit and inspection |
| C1.3 Land Management | Long-term management requirements have been addressed. | R 23 | All | The long-term management requirements of the closure strategy and alignment with the post-closure land use have been considered (C).<br>Post-completion land management requirements have been defined through the post-closure monitoring and maintenance program and contaminated sites assessment (C).<br>Where active management is likely to be required post-closure, land use representatives agree on level of effort / resources required to actively manage the site post-completion (C). | Post-completion land management plan has been developed (C). | At the time mine closure is considered complete, site land management requirements are aligned to the post completion land use and / or approved closure strategy (C).<br>If additional management actions are required post-completion, these will have been agreed with the landowner / manager (C). | **Planning**<br>Report of the post-closure monitoring and maintenance activities required during the post-closure phase.<br>Documented approval of closure strategy with post-mining land users / owners.<br>**Execution**<br>Post-completion land use management plan.<br>**Completion**<br>Post-relinquishment land management plan.<br>Closure strategy achieved as demonstrated by achievement of post-mining land use criterion C1.1<br>Documented agreement of additional active management measures required post-completion. | 10.1.1. Closure completion audit and inspection |

[59] Verification procedures may be updated as part of the continuous improvement process.

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| **C2 Safety** | | | | | | | | |
| C2.1 Safety | There are no unsafe areas where members of the general public could gain inadvertent access and residual risks are consistent with natural hazards in the surrounding area | R 16 | Mine voids, infrastructure - *inherent condition* | **All**<br>A hazard assessment of aspects of the closed site that could endanger the safety of any person or animal has been conducted (C).<br>Designs have been developed to eliminate or mitigate identified hazards (C).<br>Decommissioning and demolition plans have been developed for all infrastructure not required by third parties post-closure (C).<br>**Mine void**<br>Pit wall stability assessments inform the location of safety bunds (C).<br>**OSAs / ISAs / mine voids**<br>Materials characterisation has been conducted and any PAF or fibrous materials have been identified and managed (C). | **All**<br>Mine closure execution is conducted generally in accordance with designs (P).<br>**Mine voids**<br>Safety bunding which meets the DEMIRS guidelines (DoIR, 1997) is in place to prevent inadvertent access to voids (P).<br>Landforms designed for controlled access provide adequate long-lasting access / egress (C).<br>Fibrous materials encountered in OSAs reclaimed for backfill have been covered with a minimum of 1 m of non-fibrous inert material (C).<br>**Flood channel**<br>Flood channel construction restricts inadvertent access where there are excessively steep or vertical drops in the design and access to fibrous material exposures (C).<br>**Mine voids & surface water infrastructure**<br>The geotechnical and geochemical stability execution performance indicators (C3.2 and C3.3) have been met.<br>**Infrastructure**<br>All infrastructure is de-energised and inadvertent access controlled following closure, and prior to demolition (C). | Residual safety and health hazards have been identified and controlled in accordance with regulatory requirements and consideration of industry guidance, and are acceptable to the District Mines Inspector (C).<br>The geotechnical and geochemical stability criteria (C3.2 and C3.3) have been met (C). | **Planning**<br>Mine closure design hazard assessment.<br>DEMIRS endorsement via MCP updates.<br>Decommissioning and demolition plans.<br>Materials characterisation reports.<br>Geotechnical stability reports<br>**Execution**<br>As-constructed report, or post-construction / demolition survey or inspection report<br>**Completion**<br>All sites are assessed as acceptable with regards to safety by the District Mines Inspector<br>Audit showing the geotechnical and geochemical stability criteria (C3.2 and C3.3) have been met. | 10.1.1. Closure completion audit and inspection<br>10.1.12. Public safety monitoring |
| | | R 17 | Backfilled mine voids with controlled access - *closure condition* | | | | | |
| | | R 18 | Permanent pit lakes - *inherent condition* | | | | | |
| | | R 20 | W1 flood channel - *closure condition* | | | | | |
| | | R 21 | W4-SP4 flood channels - *closure condition* | | | | | |
| **C3 Landforms** | | | | | | | | |
| C3.1 Visual Amenity | Visual amenity of constructed landforms is compatible with that of local Pilbara landforms. | R 9 | Impact to Traditional Owners | Within the constraints imposed by aspects such as the physical nature of the materials available, tenement boundaries, and proximity to water courses, landforms have been designed to blend into the surrounding landscape (C).<br>Visual impacts, design constraints and solutions have been discussed with stakeholders, where visual impact is a key concern (C). | Mine closure execution is substantially in accordance with designs (P). | Landforms meet visual design criteria (P). | **Planning**<br>Mine closure design review.<br>Stakeholder consultation records where visual impact is a key concern.<br>**Execution**<br>Report on rehabilitation works confirms landform has been substantially constructed according to design.<br>**Completion**<br>Rehabilitation inspections confirm final landform has substantially met landform visual design criteria. | 10.1.1. Closure completion audit and inspection |
| | | Refer to Appendix L.2 | Impact to other stakeholders | | | | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| C3.2 Geotechnical Stability | Constructed landforms are safe and geotechnically stable. | Refer to Appendix L.2 | OSAs | C1 and E2 OSAs have been designed to:<br>• Account for overburden characteristics affecting stability (physical and chemical) and the zone of instability of the void (C).<br>• Achieve a Static FoS of ≥1.5 (C) | Mine closure execution is conducted generally in accordance with designs (P) | OSAs conform to DEMIRS guidelines for structural stability (DMIRS, 2019) and achieve design FoS criteria (C).<br>There is no significant slumping of failure of slopes or berms (C). | **Planning**<br>Mine closure design review against DEMIRS guidelines (DMIRS, 2019).<br>Overburden characterisation and OSA landform design shows target FoS will be achieved.<br>Pit wall stability modelling shows target FoS will be met.<br>Surface water infrastructure geotechnical assessments show that target FoS will be met.<br>DEMIRS endorsement via MCP updates.<br>**Execution**<br>Report on landform construction methods following execution confirms construction has substantially met relevant design criteria.<br>**Completion**<br>Report on performance in relation to design criteria and DEMIRS guidelines (DMIRS, 2019).<br>Results of inspections of the rehabilitated landforms conducted to completion. | 10.1.1Closure completion audit and inspection<br>10.1.11. Landform and erosion monitoring |
| | | R 17 | Backfilled void with controlled access | Pit walls have been designed achieve a FoS:<br>• ≥1.5 (static) and ≥1.0 (seismic) where failure could otherwise encroach on infrastructure designed to remain post-mining (e.g., surface water controls, safety bunds) (C).<br>• Consistent with natural hazards in the surrounding area where long-term pit access is allowed (C). | | Mine voids conform to DEMIRS guidelines for structural stability (DMIRS, 2019) and achieve design FoS criteria (C). | | |
| | | R 4<br>R 16 | Mine void | | | | | |
| | | R 4 | Flood bunds | **Flood bunds, floodplains & diversions**<br>Overall slope stability to have FoS:<br>• ≥1.5 under static conditions<br>• ≥1.2 under seismic conditions | | Surface water infrastructure achieves design FoS criteria (C) | | |
| | | R 1<br>R 2 | Intermediate diversions | | | | | |
| | | R 3 | Minor diversions | | | | | |
| | | R 5 | W1 flood channel | **Flood channels**<br>Excavated slopes to be stable with a FoS of:<br>• ≥1.1 under saturated conditions for individual batters, applied to limit equilibrium under saturated conditions.<br>• ≥1.5 under static conditions.<br>• ≥1.2 under seismic conditions | | | | |
| | | Refer to Appendix L.2 | W4-SP4 flood channel | | | | | |
| C3.3 Geochemical Stability | Materials with poor chemical properties do not compromise rehabilitation (landform stability and revegetation) or water quality. | Refer to Appendix L.2 | OSAs | **OSAs, mine voids, creek diversions & flood channels**<br>Geochemical characterisation and an AMD risk assessment have been conducted (C). | **OSAs, mine voids, creek diversions & flood channels**<br>PAF exposures have been identified and managed, if required (C).<br>Excavated PAF materials have been managed according to the Mines Closure Design Technical Process Instruction (WAIO, 2022f) (C). | **OSAs, mine voids, creek diversions & flood channels**<br>Surface water and groundwater quality completion criteria (C5.3 and C5.6) are met (C). | **Planning**<br>Material characterisation reports available for review.<br>**Execution**<br>Construction reports confirm that where designs incorporate mitigation measures for geochemical hazards, these measures have been implemented.<br>**Completion**<br>Surface water and groundwater quality monitoring to completion. | 10.1.8. Surface water monitoring<br>10.1.10 Groundwater monitoring |
| | | Refer to Appendix L.2 | Surface water infrastructure | | | | | |
| | | Refer to Appendix L.2 | Mine voids | | | | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators: Planning (Stage1) | Performance indicators: Execution (Stage 2) | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| C3.4 Surface Stability | The constructed surface is stable and showing no signs of significant erosion or release of sediment beyond design criteria which causes adverse impacts to drainage lines. | Refer to Appendix L.2 | OSAs | Post-mining landform designs have been informed by, and take account of, the following, as appropriate to the landform:<br>• Overburden characteristics (physical and chemical) (C).<br>• Erosion modelling. Modelled average annual erosion rates for OSAs are ≤6 t/ha/yr and maximum erosion rates ≤12 t/ha/yr (Q).<br>• Design rainfall events. OSA landforms are designed to retain the 1 in 200-year rainfall event on the landform and allow the controlled discharge of higher rainfall events to erosion resistant areas (C).<br>• Flood modelling. OSAs are located outside the 1 in 10,000-year floodplain, or designs include appropriate erosion protection (C).<br>Appropriate surface treatments have been identified given landform design, post-closure hydrology and available construction materials (C). | Mine closure execution is substantially in accordance with designs (P).<br>Landform evolution modelling shows that constructed designs will be erosionally stable in the long term (Q). | Slope surfaces do not show significant erosion which may be defined as having (C):<br>• Channelised flow resulting in extensive active gullies;<br>• Failure of banks, berms or bunds; and<br>• Evidence of ongoing significant sheet erosion (including large accumulation of silt at base of slope, exposed subsoil, poor seedling establishment).<br>The average rate of erosion of slopes, flats and crests of OSAs measured at completion is <6t/ha/yr (Q).<br>The erosion rate at any point on a slope does not exceed the target threshold average rate by more than 100% (Q).<br>Geotechnical stability completion criterion (C3.2) is met (C). | **Planning**<br>Mine closure design review.<br>DEMIRS endorsement via MCP updates.<br>Overburden characterisation report.<br>Pit backfill design investigations and reports.<br>**Execution**<br>Report on landform construction, and any additional maintenance works undertaken, confirm earthworks have substantially met final landform designs.<br>Landform evolution modelling report.<br>**Completion**<br>Visual assessment and erosion monitoring to completion indicate:<br>• Gullies and rills on OSAs have stabilised and there is no significant sheet erosion.<br>• Average and maximum erosion rates across OSAs have been achieved.<br>• Surface water infrastructure is performing as designed.<br>• Backfill / floodplain settlement is within design tolerances.<br>• Erosion does not compromise backfill / floodplain design objectives. | 10.1.11. Landform and erosion monitoring |
| | | R 1<br>R 2 | Intermediate creek diversions | Surface water infrastructure has been designed on the basis of hydraulic modelling (C) and:<br>• Rock protection has been designed for the design flood event applicable to the bund / diversion with rock sizes based on Austroads (1994).<br>• Toe depth of the rock protection on bunds has been based on estimated scour depths in the adjacent creek channel (primary low flow channel) during the design flood event applicable to the bund.<br>• Shows that significant scour will not occur in flood channels in the design flood event. | Mine closure execution is substantially in accordance with designs (P). | Surface water infrastructure is performing as designed (C).<br>Geotechnical stability completion criterion (C3.2) is met (C). | | |
| | | R 3 | Minor creek diversions | | | | | |
| | | R 4 | Flood bunds, pit crests | | | | | |
| | | R 5 | Flood channels | | | | | |
| | | R 6 | Backfilled pit - impacts to GW levels in CID | Pit backfill and floodplain designs have been developed to (C):<br>• Meet design levels following settlement.<br>• Manage erosion such that the developing in-pit / floodplain morphology does not impact design criteria. | Mine closure execution is substantially in accordance with designs (P). | Backfill / floodplain settlement is within design tolerances (Q).<br>Erosion does not compromise the design objectives for the backfill / floodplain surface (C). | | |
| | | R 7 | Backfilled pit - impacts to Yandicoogina Gorge | | | | | |
| | | R 9 | Backfilled pit - impacts to Traditional Owner values | | | | | |
| | | R 18 | Backfilled pit - impacts to pit lake quality & human health risk | | | | | |
| | | R 19 | Backfilled pit - impacts to pit lake quality & wildlife risk | | | | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| **C4 Revegetation** | | | | | | | | |
| C4.1 Growth Media | A suitable growth medium has been identified to facilitate plant establishment and growth. | Refer to Appendix L.2 | C1 & E2 OSAs | Topsoil stockpiles have been mapped, volumes calculated, and the relevant plans and databases have been prepared, updated and maintained (C).<br>Available topsoil has been assessed against topsoil required for rehabilitation and alternate sources of growth media have been identified where there is a deficit of topsoil (C).<br>Material identified for placement on the outer surface of landforms has been assessed for its suitability as a growth medium and takes into consideration depth and characteristics required to support sustainable vegetation development including structure, water holding capacity, and elements that might affect plant growth or survival (C). | Soil stripping and management has been undertaken generally in accordance with the WAIO Rehabilitation Standards and Procedures (P).<br>Where available and appropriate to meet the landform design requirements, topsoil has been used to provide a suitable medium for plant establishment and a source of propagules (P).<br>Topsoil / growth medium has been substantially placed in accordance with rehabilitation plans (P). | Achievement of vegetation development criterion (C4.2) (C). | **Planning**<br>Topsoil reconciliation information.<br>Growth media characterisation reports.<br>Rehabilitation monitoring results and / or trials provide feedback to determine the suitability of growth medium.<br>**Execution**<br>Report on landform construction.<br>Rehabilitation inspections confirm earthworks have substantially met final landform designs.<br>**Completion**<br>Rehabilitation monitoring results to completion. | 10.1.2. Rehabilitation monitoring |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 14 | Backfilled pits | | | | | |
| | | R 15 | Floodplains, minor & intermediate creek diversions | | | | | |
| C4.2 Vegetation Development | Vegetation is suited to the final landform and post-closure land use. | Refer to Appendix L.2 | C1 & E2 OSAs | Rehabilitation plans and target seed mixes are designed to return target vegetation communities (C).<br>The potential to return bush tucker species as part of the rehabilitation program has been investigated, and amendments made to rehabilitation plans and seed mixes, as appropriate (C). | Rehabilitation is substantially executed in accordance with plans (P). | **Land use: Relatively natural environments for pastoral grazing purposes**<br>• % bare ground (Q):<br>- Hills, slopes, dry plains <u><</u>50%.<br>- Drainage lines and floodplains (excluding channel bed) <u><</u>20%.<br>• Perennial native species richness recorded in aggregated 50 x 50 m plot achieves target % for each target vegetation type (Appendix M.4.2) (Q).<br>• At least one dominant species from each stratum present (see Appendix M.4.2) (Q).<br>• >50% common species for the target vegetation type present (Appendix M.4.2) (Q).<br>• Plant cover achieves target % for each stratum and vegetation type (Appendix M.4.2) (Q) | **Planning**<br>Review of rehabilitation monitoring results, and related rehabilitation monitoring procedures.<br>Research reports and findings from trials.<br>**Execution**<br>Rehabilitation execution completion report.<br>Site inspection to confirm rehabilitation has been substantially conducted in accordance with the plan.<br>**Completion**<br>Monitoring of vegetation re-establishment using WAIO rehabilitation monitoring procedures until monitoring shows that the vegetation is on trajectory towards meeting completion criteria. | 10.1.2. Rehabilitation monitoring |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 14 | Backfilled pits | Research and trials have been conducted to identify appropriate target vegetation communities and seed mixes (C). | Rehabilitation is substantially executed in accordance with plans (P). | Rehabilitation of in-pit areas falls within the acceptable ranges defined for the novel ecosystems targeted for each area. Further work is required to investigate and define these criteria. | | |
| | Vegetation is suitable to the geomorphology and function of the surface water structure. | R 15 | Floodplains, minor & intermediate creek diversions | Target vegetation communities have been identified for floodplains and intermediate and minor creek diversions based on the geomorphology and function of the structure (C). | Floodplains and minor and intermediate creek diversions have been substantially constructed in accordance with designs (P). | Rehabilitation of flood bunds, floodplains and minor and intermediate creek diversions falls within the acceptable ranges defined for the ecosystems targeted for each area. Further work is required to investigate and define these criteria. | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| *C4.2 Vegetation Development (cont'd)* | A diversity of habitats is established that supports representative flora and fauna species and provides ecological function and connectivity through the system. | R 15 | E1 and E4 creek diversions | Creek diversion designs incorporate measures to support different habitat zones and vegetation (e.g. channel geometries and engineered alluvial aquifer) (C). | Diversions have been substantially constructed in accordance with designs (P). | The Marillana Creek Diversion Management Plan (BHP Billiton, 2016) specifies the performance criteria for the E1 and E4 creek diversions. These are summarised below[60].<br>Marillana Creek diversions to achieve 8 out of 10 key ecological indicators during, or prior to, the equilibrium phase of diversion morphological development. Key ecological indicators are:<br>• Structural intactness for vegetation is comparable to natural channel reaches.<br>• There is evidence of recruitment in diversions.<br>• The longitudinal connectivity of vegetation cover in diversions is comparable to natural channel reaches.<br>• There is a variety of ages evident in vegetation.<br>• Key species are present (refer to Appendix M.4.1):<br>- Trees - 1 out of 4 species present.<br>- Lower trees 2 out of 5 species present.<br>- Shrubs 3 out of 9 species present.<br>- Low shrubs 1 out of 1 species present.<br>- Grasses 2 out of 5 species present.<br>• There is evidence of pool formation.<br>• Persistence of pools is comparable to that in natural channel reaches.<br>• There is evidence of organic matter in, or adjacent to pools.<br>• There is evidence of macrophytes or algal covers in pools. | **Planning**<br>Creek diversion design studies and reports.<br>**Execution**<br>Report on creek diversion construction and rehabilitation including seed mix summary.<br>Site inspections confirm creek diversion has been substantially constructed in accordance with designs.<br>**Completion**<br>Monitoring of geomorphological and vegetation indicators until results show that diversions are on trajectory to completion. | 10.1.5 Marillana Creek E1 & E4 diversion monitoring |
| C4.3 Resilience | Demonstrated capacity of the site to recover from fire, drought and other disturbances. | Refer to Appendix L.2 | C1 & E2 OSAs | Seeds to be used in rehabilitation reflect a range of species found in the bioregion (C).<br>Seed requirements for rehabilitation have been identified and appropriate quantities of seed collected from local provenance areas, within the Pilbara IBRA region, to support the five-year rehabilitation plan (C).<br>Rehabilitation techniques are informed by trials, research and monitoring of rehabilitated areas (C). | Rehabilitation is substantially executed in accordance with plans (P).<br>Revegetation has used local provenance native seed from the Pilbara IBRA region (C). | Flowering and seed production observed in more than one native lifeform (Q).<br>Different aged plants observed for more than one native species and for all lifeforms (Q). | **Planning**<br>Seed database.<br>Review of progress and performance from rehabilitation monitoring results, and related rehabilitation monitoring procedures.<br>Research findings from trials on representative rehabilitated areas investigating post-disturbance recovery of revegetation.<br>**Execution**<br>Rehabilitation execution completion report including seed mix summary.<br>Site inspection to confirm rehabilitation has been substantially conducted in accordance with the plan.<br>**Completion**<br>Monitoring of vegetation re-establishment using WAIO rehabilitation monitoring procedures until monitoring shows that the vegetation is on trajectory towards meeting completion criteria. | 10.1.2. Rehabilitation monitoring |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 14 | Backfilled pits | | | | | |
| | | R 15 | Floodplains, minor & intermediate creek diversions | | | | | |

[60] It there are discrepancies between the criteria for Marillana Creek diversions outlined in this MCP and those in the Marillana Creek Diversion Management Plan, the criteria in the Marillana Creek Diversion Management Plan (including any updates) take precedence.

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| C4.4 Weeds | DBCA priority list weed species to be managed so as not to cause unacceptable risk to surrounding environments. | Refer to Appendix L.2 | C1 & E2 OSAs | Weeds have been monitored and risk-based control plans developed which are compatible with the defined post-mining land use (C). | The requirements of the WAIO Weed Management Procedure have been substantially implemented as demonstrated by reports that populations of weeds have been monitored and controlled based on risk (P). | Priority alert weed species are not present (C), or if present, cover is less than or equal to the surrounding areas (regional baseline) (Q).<br>No new priority alert weed species introduced (C). | **Planning**<br>Review of weed monitoring and control.<br>**Execution**<br>Report on weed monitoring and control records.<br>**Completion**<br>Surveys and comparison with regional baseline data.<br>Measurement of weed abundance to completion. | 10.1.3. Weed monitoring |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 14 | Backfilled pits | | | | | |
| | | R 15 | Floodplains, minor & intermediate creek diversions | | | | | |
| | Total weed cover to be typical for each site and landform and reflect final land use. | Refer to Appendix L.2 | C1 & E2 OSAs | | | **Land use: Relatively natural environments for pastoral grazing purposes**<br>Total weed cover (Q):<br>• Drainage lines, floodplains <20%.<br>• Upland hills, slopes and flats <10%.<br>Buffel grass cover (Q):<br>• Drainage lines, floodplains <10%.<br>• Upland hills, slopes and flats <10%. | | |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 15 | Floodplains, minor & intermediate creek diversions | | | | | |
| | | R 14 | Backfilled pits | | | Weed cover is within the acceptable ranges defined for in-pit environments (Q).<br>*Note criteria have yet to be developed.* | | |
| | | R 15 | E1 & E4 creek diversions | | | New weed species are absent (refer to footnote 61) (C). | | |
| C4.5 Fauna | Vegetated areas provide fauna habitat | Refer to Appendix L.2 | C1 & E2 OSAs | Rehabilitation plans consider return of fauna habitat through selection of target vegetation communities and / or constructed habitat features (C).<br>Constructed fauna habitat designs are based on the results of research and trials (C). | Rehabilitation is substantially executed in accordance with plans (P). | Achievement of vegetation development criterion (C4.2). | **Planning**<br>Rehabilitation plans incorporate creation of fauna habitats.<br>Review of research and trials.<br>**Execution**<br>Report on habitat construction<br>**Completion**<br>Monitoring of vegetation re-establishment using WAIO rehabilitation monitoring procedures until monitoring shows that the vegetation is on trajectory towards meeting completion criteria. | 10.1.2. Rehabilitation monitoring<br>10.1.4 Fauna inspection of rehabilitation areas |
| | | R 13 | Ex-pit areas (OSA, ROM, stockpile, infrastructure footprints) | | | | | |
| | | R 14 | Backfilled pits | | | | | |
| | | R 15 | Floodplains, minor & intermediate creek diversions | | | | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| **C5 Water** | | | | | | | | |
| C5.1 Marillana Creek Flow Regime | Major creek diversions function similarly to pre-development conditions (hydraulics, sediment transport, geomorphology) and do not exhibit substantial long-term geomorphological change that could destabilise the landform. | Refer to Appendix L.2 | E1 and E4 creek diversions | Creek diversion designs have been informed by geomorphological assessments, hydraulic and sediment transport modelling (C). | The creek diversions have been substantially constructed in accordance with designs (P). | The Marillana Creek Diversion Management Plan (BHP Billiton, 2016) specifies the performance criteria for the E1 and E4 creek diversions. These are summarised below (refer to footnote 61).<br>• The channel incorporates, and has the capacity to develop, geomorphic features that are similar to those seen through existing channel reaches.<br>• Marillana Creek diversions to achieve a total Index of Diversion Condition (IDC) score in diversion reaches that is comparable (>70%) with the total IDC score for the upstream control reach during the establishment phase of diversion morphological development. IDC indicators are:<br>- Width of high flow channel, active channel and low flow channel.<br>- Bank condition and piping of banks.<br>- Bed condition.<br>- Spoil piles.<br>- Recovery.<br>- In-stream structures.<br>• The volume of sediment exiting diversions is similar to that entering.<br>• Channel stability and erosion is within acceptable ranges consistent with the Marillana Creek Diversion Management Plan (BHP Billiton, 2016). | **Planning**<br>Design study reports (hydraulic and sediment transport modelling, geomorphological assessments) are available for review<br>**Execution**<br>Report on creek diversion construction.<br>Site inspections confirm creek diversion has been substantially constructed in accordance with designs.<br>**Completion**<br>Monitoring of geomorphological indicators until results show that diversions are on trajectory to completion.<br>Downstream vegetation monitoring. | 10.1.5 Marillana Creek E1 & E4 diversion monitoring |
| C5.2 Surface water flows | Rehabilitation drainage patterns have been established and impacts on natural surface water flows are acceptable at key receptors. | R 1<br>R 2 | Intermediate creek diversions | Except where W1-SP0 directs controlled flows from Marillana Creek to W1 Pit, surface water management infrastructure has been provided around closure landforms to prevent capture of flow in the selected closure design event (C).<br>Hydraulic modelling shows that surface water management infrastructure designs can withstand selected closure design flood events (Q). | Mine closure execution is substantially in accordance with designs (P). | Flows will be acceptable at downstream environmental receptors as evidenced by:<br>• The physical condition of surface water infrastructure which should perform as designed (e.g. no significant head cutting or erosion beyond design parameters) (P).<br>• Riparian vegetation monitoring which should be within the ranges accepted via project approvals (Q). | **Planning**<br>Surface water assessment and modelling reports.<br>Design review.<br>**Execution**<br>Report on landform (flood channel, flood bund and creek diversion) construction.<br>**Completion**<br>Monitoring of riparian vegetation to completion.<br>Inspections / monitoring of surface water infrastructure.<br>Site inspection to verify no unplanned impacts on surrounding natural drainage patterns or landform failures. | 10.1.6 Riparian vegetation and tree health monitoring<br>10.1.8. Surface water monitoring |
| | | R 3 | Floodplains and minor creek diversions and flood bunds | | | | | |
| | | R 4 | Flood bunds along Marillana Creek | | | | | |
| | | R 5 | Flood channels | Modelling shows no flow will pass from Marillana Creek into flood channels in floods smaller than a 5% AEP event (Q). | | | | |

[61] It there are discrepancies between the criteria for Marillana Creek diversions outlined in this MCP and those in the Marillana Creek Diversion Management Plan, the criteria in the Marillana Creek Diversion Management Plan (including any updates) take precedence.

| Category | Criterion objective | Risk ID | Domain | Performance indicators: Planning (Stage1) | Performance indicators: Execution (Stage 2) | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| C5.3 Surface water quality | Surface water quality is acceptable at key receptors. | Refer to Appendix L.2 | OSAs | The geochemical planning and surface stability planning criteria (C3.3 and C3.4) for OSAs have been met (C). | Mine closure execution is substantially in accordance with designs (P). | Surface water quality is within limits (Q):<br>• Defined, through the detailed analysis of pre-closure monitoring data from appropriate reference sites, to represent no significant impact to downstream ecohydrological receptors; and / or<br>• Accepted via project approvals or other regulatory processes.<br>Monitoring shows that pit lake quality aligns with hydrogeochemical modelling trajectory and risk assessment assumptions (Q). | **Planning**<br>Refer to surface stability planning (C3.4).<br>Refer to geochemical planning (C3.3).<br>Surface water and hydrogeochemical modelling reports.<br>**Execution**<br>Report on landform (OSA, flood channel, flood bund and creek diversion) construction.<br>**Completion**<br>Surface water quality monitoring to completion.<br>Site inspection to verify that there have been no unplanned impacts associated with sediment transport.<br>Audit of the achievement of contaminated sites criterion C6.1.<br>Pit lake monitoring to validation of modelled quality. | 10.1.8 Surface water monitoring<br>10.1.9 Pit lake monitoring |
| | | Refer to Appendix L.2 | Flood channels & diversions | The geochemical planning criteria (C3.3) for diversions and flood channels have been met (C). | | | | |
| | | R 12 | Mine voids | Hydraulic and hydrogeochemical modelling shows no significant impact to Marillana Creek resulting from the overflow of W4 Pit to the creek (Q). | | | | |
| C5.4 Pit Lakes | Permanent pit lakes should have no unacceptable impacts to people and fauna. | R 8 | Mine voids - Traditional Owners do not accept permanent saline pit lakes | Pit backfill designs have been informed by pit lake water balance modelling (C).<br>Predictive pit lake hydrogeochemical modelling has been conducted (C).<br>A pit lake risk assessment has been performed and potential impacts and requirements for mitigation measures identified (C). | Backfill has been conducted substantially in accordance with designs (P).<br>Management measures have been implemented if hydrogeochemical modelling and risk assessment indicate that specific management measures are necessary (P). | The pit lake risk assessment shows no significant impact to human health or native fauna (C).<br>Monitoring shows that pit lake quality aligns with hydrogeochemical modelling trajectory and risk assessment assumptions (Q).<br>Groundwater level data show that permanent pit lakes will act as sinks (Q). | **Planning**<br>Pit lake water balance modelling reports.<br>Pit lake hydrogeochemical modelling report.<br>Pit lake risk assessment report.<br>**Execution**<br>Post-construction survey of backfill.<br>Construction reports confirm that where designs incorporate mitigation measures for geochemical hazards, these measures have been implemented.<br>**Completion**<br>Report on pit lake monitoring and validation of hydrogeochemical modelling and risk assessment assumptions.<br>Report on validation of groundwater level modelling. | 10.1.9. Pit lake monitoring |
| | | R 18 | Impacts to human health | | | | | |
| | | R 19 | Impacts to wildlife | | | | | |
| C5.5 Groundwater levels | Impacts to groundwater dependent receptors from water levels in the CID / alluvium are acceptable. | R 6 | Mine voids | Groundwater modelling has been conducted to identify impacts to groundwater levels post-closure (C).<br>Where unacceptable impacts have been identified at key receptors, closure designs, including backfilling if required, have been developed to mitigate these impacts (C). | Mine closure execution is substantially in accordance with designs (P). | Groundwater levels at key environmental receptors are within model predictions and the parameters accepted via project approvals and informed by stakeholder consultation (Q). | **Planning**<br>Groundwater assessment and modelling reports.<br>Design review.<br>**Execution**<br>Report on landform construction.<br>**Completion**<br>Post completion groundwater monitoring and groundwater model validation reports.<br>Riparian area and tree health monitoring. | 10.1.6 Riparian vegetation and tree health monitoring<br>10.1.10. Groundwater monitoring |
| | Regional groundwater levels are acceptable at key receptors. | R 7 | | | | | | |
| C5.6 Groundwater quality | Groundwater quality is acceptable at key receptors | R 11 | Mine voids - *risk rating assumes theoretical scenario of no backfill or surface water controls for closure, and temporary impact to alluvium* | The planning criteria have been met for geochemical stability (C3.3) (C).<br>Modelling shows permanent pit lakes will remain sinks and that the potential for density driven flow impacts is low (C). | Mine closure execution is substantially in accordance with designs (P). | Pit lake water quality aligns with hydrogeochemical modelling trajectory and demonstrates that the potential for density driven impacts is low (Q).<br>Groundwater quality (and long term trajectory) is within limits (Q):<br>• Defined, through the detailed analysis of pre-closure monitoring data from appropriate reference sites, to represent no significant impact to downgradient ecohydrological receptors; and / or<br>• Accepted via project approvals or other regulatory processes. | **Planning**<br>Refer to geochemical planning (C3.3).<br>Modelling report on pit lake dynamics.<br>**Execution**<br>Refer to geochemical execution (C3.3).<br>**Completion**<br>Report on pit lake monitoring and validation of hydrogeochemical modelling<br>Groundwater quality monitoring to completion.<br>Audit of the achievement of contaminated sites criterion C6.1. | 10.1.9. Pit lake monitoring<br>10.1.10. Groundwater monitoring |
| | | Refer to Appendix L.2 | OSAs, ex-pit areas including OSA, ROM, stockpile footprints | | | | | |

| Category | Criterion objective | Risk ID | Domain | Performance indicators | | Completion (Stage 3) | Verification procedure[59] | Monitoring method |
|---|---|---|---|---|---|---|---|---|
| | | | | Planning (Stage1) | Execution (Stage 2) | | | |
| **Contaminated sites** | | | | | | | | |
| C5.7 Contaminated sites | Contaminated sites have been documented and managed to achieve a classification commensurate with the post-mining land use. | R 22 | All where relevant | Contaminated sites have been identified, investigations undertaken and, where required, remediation action plans developed (C).<br>Remediation action plans have been approved by a contaminated sites auditor, where required (C). | Implementation of the approved remediation action plan (P).<br>Validation sampling shows remediation has achieved remediation criteria (Q). | Contaminated sites classification issued by DWER is consistent with the post-mining land use (C). | **Planning**<br>Preliminary Site Investigation (PSI), Sampling and Analysis Plan (SAP), DSI and Remediation Action Plan (RAP) - produced by a contaminated site consultant and reviewed by an independent auditor.<br>**Execution**<br>Reports produced by remediation contractor including validation sampling and waste disposal records.<br>Contaminated sites auditor produces Voluntary Audit Report (VAR) or Mandatory Audit Report (MAR)<br>**Completion**<br>Audit of DWER contaminated sites classification relative to agreed post-mining land use. | 10.1.1. Closure completion audit and inspection |
| **Cultural value** | | | | | | | | |
| C5.8 Cultural Value | Protection of cultural values, and access to sites of cultural importance has been incorporated into mine closure planning following consultation with the Traditional Owners. | R 8 | Permanent pit lakes | Following consultation with the Traditional Owners:<br>• Cultural values associated with final landforms have been identified and addressed in designs (C).<br>• Provisions for safe access to sites of importance have been incorporated into closure designs (C).<br>• Requirements for repatriation of cultural artefacts have been identified (C). | Mine closure execution is substantially in accordance with designs for the protection of cultural values (P).<br>Cultural artefacts have been repatriated in accordance with stakeholder requirements (P). | Stage 2 performance indicators have been met (C). | **Planning**<br>Mine closure designs have incorporated safe access to sites of cultural importance and responses to cultural values identified during consultation.<br>Documented agreement regarding the repatriation of cultural artifacts.<br>**Execution & completion**<br>As constructed report.<br>Confirmation by Banjima People representative that artifacts have been repatriated. | 10.1.1. Closure completion audit and inspection |
| | | R 9<br>R 10 | Pits with no / seasonal expressions of water, OSAs, surface water infrastructure, other infrastructure) | | | | | |

# 9 Closure implementation

This section outlines:

- The procedures and processes that BHP progressively implements during operations and when planning for closure to manage key closure risks (Section 9.1).
- The proposed closure and rehabilitation strategies for each domain based on the studies conducted to date but acknowledging that further studies, investigations and design work are required before a final design can be developed (Section 9.2 to 9.3). This includes consultation with BNTAC and the Banjima people on closure outcomes (Section 4).
- Closure implementation schedule (Section 9.4).
- Actions to be taken in the event of unplanned or unexpected closure (Section 9.5).

Completion of mining at Yandi (including E8) is expected around 2032 with options currently under internal consideration for mining remnant ore and utilising Yandi infrastructure as a regional processing hub for satellite ore bodies beyond cessation of current mining activities.

## 9.1 Closure management procedures and processes

This section describes the procedures and processes that BHP implements in planning for closure.

### 9.1.1 Acid, metalliferous and / or saline drainage management

This section provides an overview of BHP's standard procedures for identifying and managing acid, metalliferous and /or saline drainage risk across its Pilbara operations (Section 9.1.1.1) and the strategies implemented at Yandi based on the geochemical characterisation conducted for the site (Section 9.1.1.2).

#### 9.1.1.1 Overview of BHP's standard procedures for managing geochemical risk

BHP is committed to managing and mitigating geochemical risk using a structured approach, consistent with global leading practice guidelines including INAP (2014) and DISER (2016c). Procedures for managing geochemical risk are outlined in several procedures including:

- BHP's Global Mined Management Standard (BHP, 2021a) which sets company-wide standards for geochemical risk management.
- WAIO's suite of procedures that outline how geochemical risk is identified, assessed and managed across BHP's Pilbara operations. These procedures include:
  - Acid and Metalliferous Drainage Management Technical Process Instruction (WAIO, 2022a).
  - Reactive Ground and AMD Potential: Mining Design and Dumping Procedure (WAIO, 2021a).
  - Reactive Ground and Associated Gases Procedure 0129611 (WAIO, 2020d).
  - Mines Closure Design Guidance Procedure (WAIO, 2022f).
  - Preliminary AMD Risk Assessment Procedure 0132980 (WAIO, 2017b).

The Acid and Metalliferous Drainage Management Technical Process Instruction (WAIO, 2022a) outlines the overall strategy for management of geochemical risk (Figure 9-1) and considers the full mine life cycle. This standard is provided in Appendix H.1.

The approach shown in Figure 9-1 is a risk-based approach which is refined with increasing knowledge of the geochemical characteristics of overburden material. Specifically, the characterisation stage (Stage 1) informs Stages 2 through 5 which result in OSA designs and mine void management practices aimed at minimising the potential risks associated with acid, metalliferous and / or saline drainage.

Characterisation of mined material commences at the exploration stage and is progressively refined through subsequent resource definition, short term geological drilling and grade control drilling, as applicable (Figure 9-1 and Figure 9-2). Based on geochemical characterisation test work across BHP's mining operation, BHP has developed an algorithm that is used to classify materials within the resource model as either NAF (AMD0) or PAF (AMD1, AMD2 and AMD3) (refer to Section 5.2.2.1). This enables mine planners to identify materials that require management, and to determine their placement according to their geochemical risk. The geochemical risk of materials generated at each site is confirmed through site-specific targeted geochemical testing and risk assessment (Section 5.2.3). This work informs the management requirements for geochemically problematic materials and, depending on risk, can include predictive hydrogeochemical modelling.

Further to the geochemical characterisation work, geochemical classifications in the resource model are confirmed though analysis and inspection of blast cone chips prior to mining and the results of this analysis are integrated into the short term mine plan and communicated to the production team (Figure 9-2).

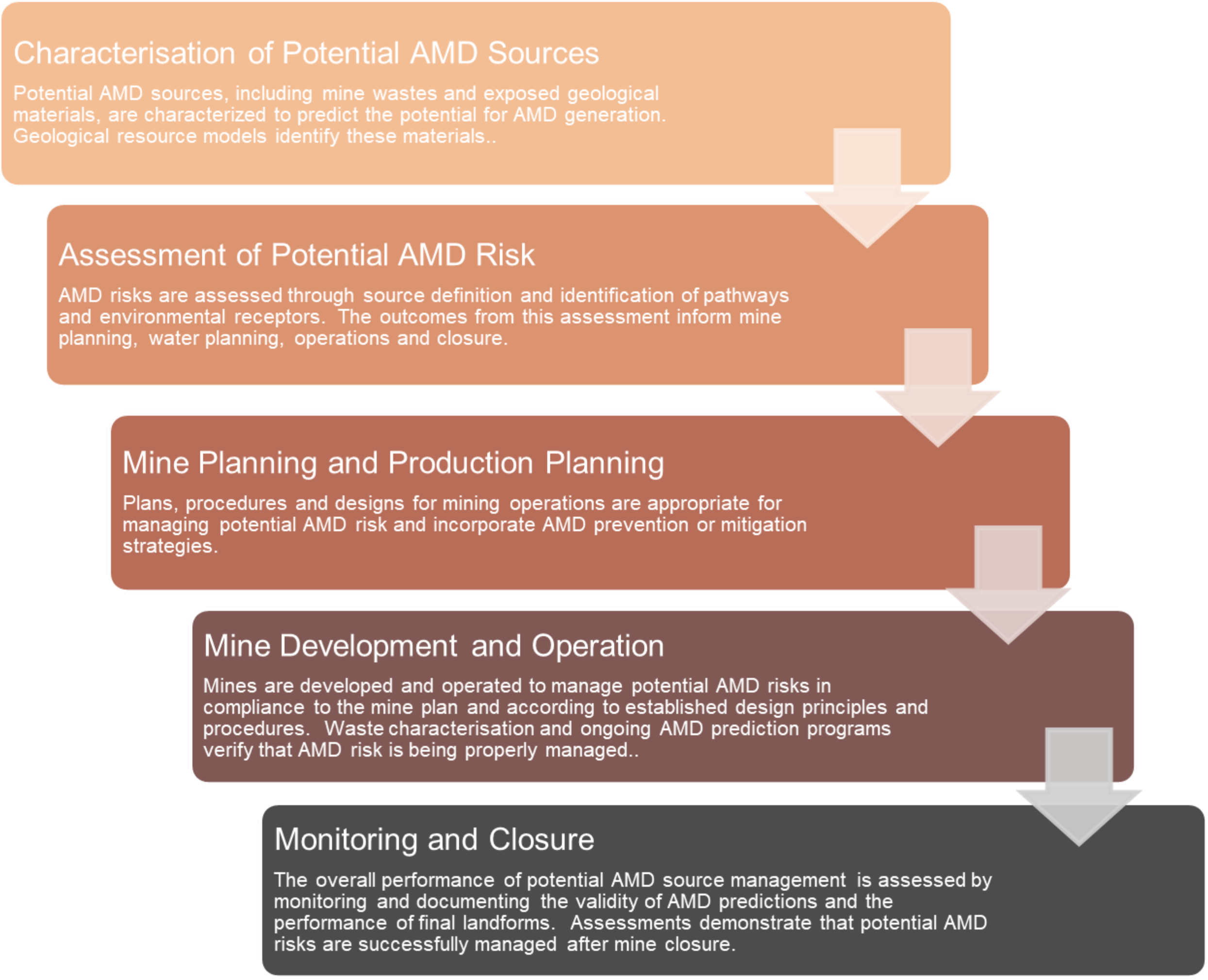



**Figure 9-1 BHP's AMD management process**

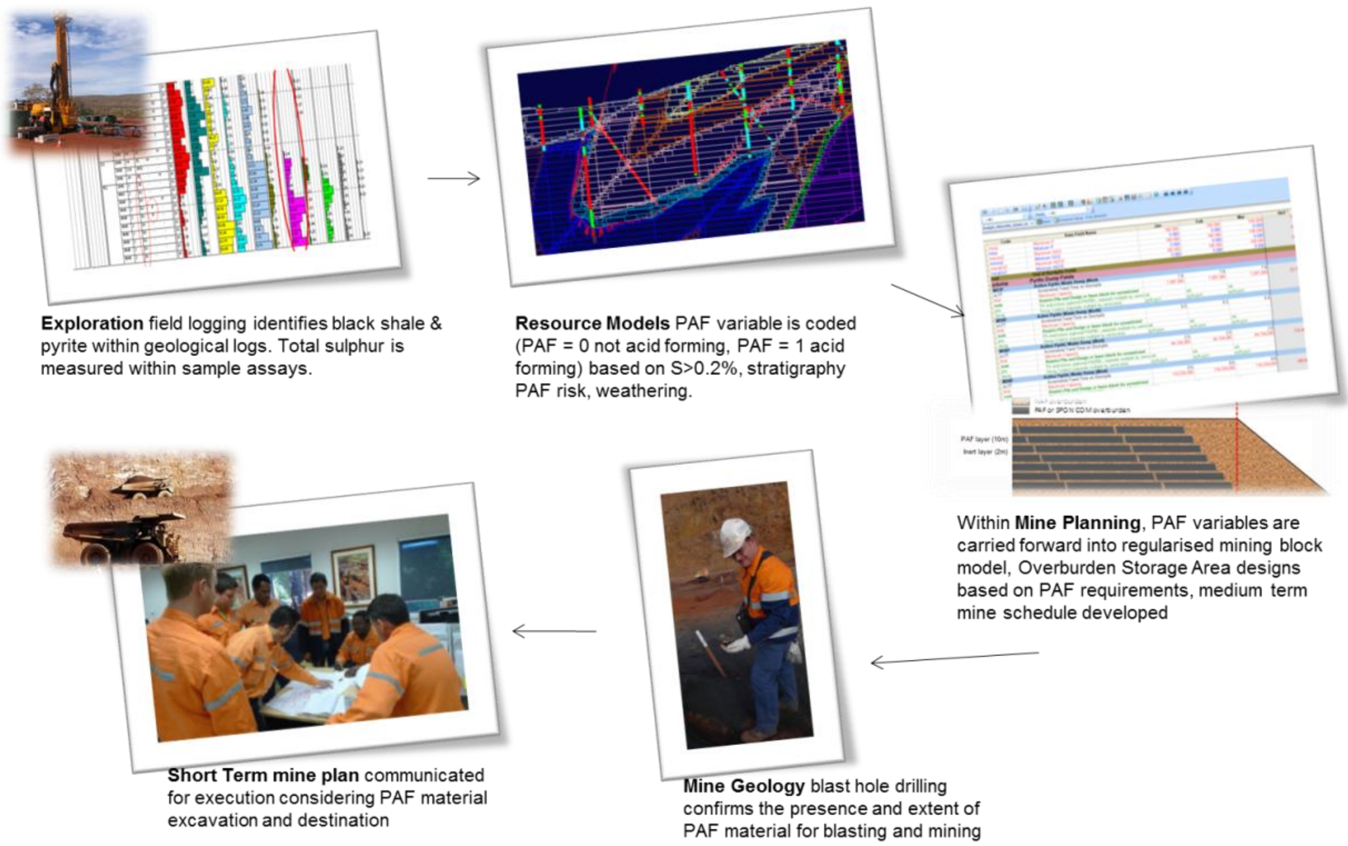



**Figure 9-2 PAF management process flow (BHP's ELearning tool)**

There are a variety of overburden management and mitigation options available for higher risk stratigraphies that have AMD generation potential (Figure 9-3). Material can be encapsulated, co-disposed with inert or acid neutralising material, disposed sub-aqueously or a combination of options can be applied. These options are evaluated on a site-specific basis following the completion of appropriate material characterisation, risk assessment and modelling.

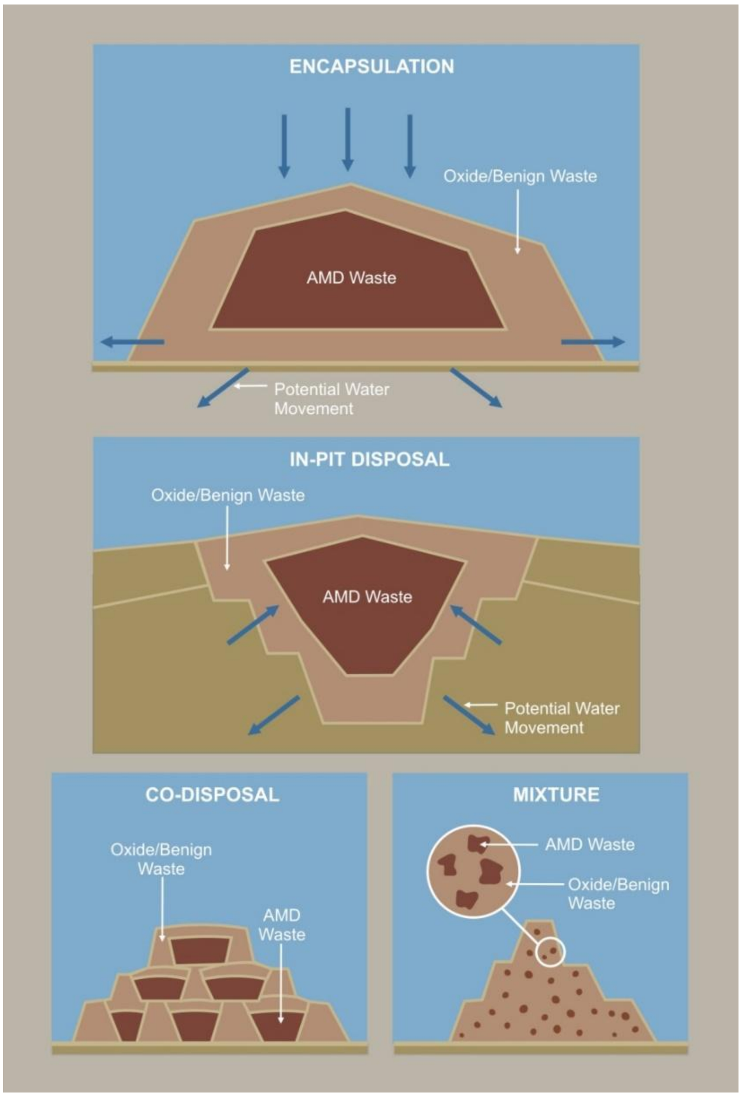



**Figure 9-3 BHP's PAF overburden management strategies (following DISER (2016c))**

#### 9.1.1.2 Management of acid, metalliferous and / or saline drainage risk at Yandi

As discussed in Section 5.2.3, the risk of acid, neutral metalliferous and saline drainage from overburden and pit wall exposures at Yandi is low and no specific management measures for overburden or pit wall exposures are required.

The geochemical characterisation work has been used to derive source terms for pit lake water quality modelling. This has shown that, due to evapo-concentration, there are some exceedances of livestock drinking water guideline values for sulphate, boron, fluoride and selenium while salinity is in the tolerable (4,000 - 8,000 mg/L) range[62], and nickel when salinity approaches 180,000 mg/L. However, an initial pit lake risk assessment has shown that the risk to wildlife and humans from pit lakes at Yandi is low (Section 5.14.6). As discussed in Section 5.14.6.5, this assessment will be updated as Yandi closure designs are refined.

Excavation of the E1 Marillana Creek diversion has resulted in a very small exposure (350 m$^2$) of PAF material which can be managed through the natural ANC in the alluvium that was relocated to the diversion (Earth Systems, 2019a). If monitoring indicates that additional management measures are necessary in the future, limestone will be added to the alluvium to increase its ANC. To date, an analysis of water monitoring data has indicated that acid, neutral metalliferous and / or saline drainage is unlikely to be a process affecting water chemistry at Yandi (Section 5.9.3).

The few thousand tonnes of PAF material generated during the excavation of the E1 creek diversion were managed in accordance with WAIO's Acid and Metalliferous Drainage Management Technical Process Instruction (2022a) and placed in the E2 ISA. In the unlikely event that overburden or wall rock exposure presents an AMD risk in the future, it would be managed in accordance

62 Salinity is a primary control on water quality risk from a toxicological perspective as it determines the palatability of the water for drinking and potential for aquatic species to establish / live in lakes and accumulate contaminants. The tolerable range for livestock drinking water has been used as a proxy for impacts to other species

with the Acid and Metalliferous Drainage Management Technical Process Instruction (Appendix H.1) and mines closure design procedure (WAIO, 2022f).

As outlined in Section 5.2.3.5, drilling will be conducted prior to the construction of the flood channels to confirm that there is a low risk of exposing PAF material during construction.

### 9.1.2 Surface water

This section outlines the procedures that BHP uses to progressively refine surface water management measures for closure throughout the life of a mine. The surface water management designs proposed for Yandi based on currently available information are discussed in Section 9.2.4.

BHP uses flood modelling to identify the need for surface water management measures at closure. This modelling is periodically updated over the life of a mine as the mine develops and modifies drainage characteristics. The modelling is used to inform the designs of surface water management measures such as flood bunds or diversions. Depending on the significance of a structure, closure is generally considered at a conceptual level during the operational design phase to enable interactions with other infrastructure to be planned for (e.g., pit set back distances, locations of OSAs). However, unless design studies indicate otherwise, a detailed design is generally not progressed until closer to the time of closure when the full mine footprint has been developed. This is because mine plans change throughout the life of a mine, according to many factors including economics, and as the mine footprint changes, so do the surface water drainage characteristics that must be managed at closure.

Executed operational designs are revisited at least 5 years prior to the closure of a site (or individual pit if this will not be impacted by changes to other areas of the mine) and a detailed closure design is developed. The development of the closure design near to the end of a mine's (or pit's) life will permit the closure design to benefit from the data captured through the operational period as well as the increased certainty around final landforms.

Surface water designs for closure focus on achieving long term stability of OSAs, creek diversions, flood bunds and pit walls adjacent to natural creek sections. Closure designs consider:

- The interaction of flood waters with ex-pit landforms such as OSAs and the need for diversions, flood bunds or armouring to protect the OSAs from erosion post-closure. Section 9.1.4 discusses how landform designs address flood risks.
- The potential impacts of surface water drainage designs on ecosystems sensitive to changes in surface water flows such as riparian vegetation and sheet-flow dependent Mulga. The surface water system at closure will be designed to meet the closure principle of no significant impact on surface water quality and flow regimes in nearby waterways beyond the levels accepted by project approvals.
- The stability of pit walls adjacent to diversions, flood bunds or natural creek sections to prevent 'creek capture' post-closure. Consistent with DEMIRS Ground Control Guidelines (2019), target FoS for pit walls are defined based on risk. A static FoS ≥1.5 is typically used, and where this is not achieved, pit walls may be designed to achieve a lower slope angle or may be buttressed to improve stability. Creek diversions and flood bunds are located outside pit setback distances which define the safe distance between the infrastructure and mine voids.
- The potential impact of climate change on flood events, and the potential for major events to damage surface water controls (including those on constructed landforms) that may in turn impact future groundwater / surface water interactions, and hence, long term water balances.

The flood protection works required for closure are designed and constructed to achieve stable, maintenance-free, freely draining landforms. Hydraulic modelling of the flow characteristics of the modified drainage layout informs the designs and provides information on requirements for additional rock armouring or changes to the elevation and slope of flood protection bunds, and stream management, to locally reduce velocities at critical locations.

Significant creek diversions are designed to mimic natural conditions and may be informed by a combination of geomorphic assessment and hydraulic and sediment transport modelling.

Closure designs for surface water management are based on an assessment of risk which considers (Table 9-1):

- Catchment size.
- The sensitivity of the receiving environment and likely impact from a change in flows.
- The risks of permanent creek capture or compromising the stability of post-closure landforms such as OSAs.

The design event for each surface water management feature constructed for closure is considered on a case-by-case basis using the guidance provided in Table 9-1. The element in Table 9-1 that has the highest risk drives the flood event to be used as the basis for the design of surface water management infrastructure. For high-risk surface water management structures, modelled 1 in 10,000-year ARI events are typically used to inform designs. Probable Maximum Floods (PMF) have been calculated for comparison, however, are not used by BHP as a basis of design. This is due to the very large extrapolation and uncertainties involved in their estimates. Furthermore, the PMF method produces flood estimates significantly larger when adjusted for catchment area than any contained in the palaeo record of any Australian River (Appendix D.4). The 10,000-year event estimates generally result in a flow rate several times larger than the 1% (100-year) AEP event and are considered an appropriately conservative basis for a closure design for a high-risk structure.

**Table 9-1 Guidance for selection of design events for surface water management infrastructure**

| Catchment Size | Design ARI Applicable (Years) | | | | | |
|---|---|---|---|---|---|---|
| | Risk of Creek Capture or to Stability of Post-closure Landform | | | Sensitivity of Receiving Environment & Potential Impact | | |
| | Low | Moderate | High | Low | Moderate | High |
| Small (<10 $km^2$) | 100 | 1,000 | 1,000 | 100 | 1,000 | 10,000 |
| Medium (10 - 100 $km^2$) | 1,000 | 1,000 | 10,000 | 1,000 | 1,000 | 10,000 |
| Large (100 - 1,000 $km^2$) | 1,000 | 10,000 | 10,000 | 1,000 | 10,000 | 10,000 |
| Very Large (>1,000 $km^2$) | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |

Discharges to surface water during operations are typically managed via Part V licence conditions, or management plans approved under relevant ministerial statements. Discharges to Marillana Creek of water abstracted from pits during dewatering are managed under the Marillana Creek Water Resource Management Plan and hence do not form part of this MCP.

## 9.1.3 Groundwater

This section outlines the procedures that BHP uses to define groundwater impacts and management measures for closure. The backfill designs currently proposed for Yandi are provided in Section 9.2.3.1, however, as noted in Section 4, these may be subject to change following consultation with the Banjima people and further design studies.

BHP seeks approval for dewatering of below water table pits from the EPA via a Part IV approval (Section 3.1) and DWER via a groundwater licence (Section 3.3.4). Detailed hydrogeological assessments are developed to support these approval applications. The assessments include numerical modelling to define the predicted drawdown associated with dewatering operations. The numerical models are developed on the basis of a conceptual understanding of aquifers and groundwater movements obtained from groundwater monitoring data. This conceptual understanding is updated as aquifer responses to dewatering are defined through ongoing monitoring. Groundwater Operating Strategies, required by the groundwater licences, outline the monitoring program that enables aquifer responses to abstraction to be confirmed / better understood. These strategies are approved by DWER and are periodically updated, where required, to improve our understanding of groundwater behaviour. Aquifer monitoring data are reported to DWER in Annual and Triennial Aquifer Reviews.

Conceptual and numerical modelling is used to define potential impacts to ecohydrological receptors from drawdown and discharges to groundwater (where relevant). Impacts during operations are managed via environmental licences and management plans approved by DWER (Sections 3.1.2, 3.2 and 3.3.3). These impacts may be related to aquifer drawdown, increase in groundwater levels due to managed aquifer recharge schemes or changes to groundwater quality due to discharges approved via environmental licences (which, depending on the site may include seepage from tailings storage facilities). Contaminated sites are managed as discussed in Section 9.1.10.

Impacts requiring management at closure are integrated into MCPs and, depending on site circumstances, may be informed by one, or a combination of:

- Conceptual models.
- Modelling of groundwater and pit lake recovery levels.
- Water balance modelling.
- Hydrogeochemical modelling.
- Contaminant transport modelling.

An operational management matter will only be incorporated into the MCP if it requires a closure management response (e.g., residual drawdown from open voids post-closure, impacts sensitive receptors and requires pits to be backfilled).

## 9.1.4 Landforms

Landforms such as OSAs, ISAs and mine voids are managed in accordance with WAIO's Mines Closure Guidance Design procedure (WAIO, 2022f). Surface water management infrastructure designs are managed as discussed in Section 9.1.2.

The development of the post-mining landform design is an iterative process, integrating all the closure domains. Important to the transformation of the operational domains, to a successful and sustainable post-closure landform design is a fundamental understanding of the chemical and physical properties of overburden material used to construct final landforms (Section 5.2) and the site's hydrological setting (Section 5.9). In particular, the surface materials must be appropriate to withstand erosive forces and sustain vegetation growth in the long term.

BHP follows the adaptive management framework, with the mine plan and closure landform designs evolving over the life of mine as knowledge of constraints and opportunities become available over time. As operations / landforms in certain areas approach completion, closure designs are progressively developed and implemented. Final landform designs, therefore, continue to evolve over the life of a mine. Designs are based on multi-disciplinary inputs including for example:

- Exploration data;
- Overburden characterisation;
- Hydrology, hydrogeology, and hydro-geochemistry information;

- Post-mining land use and tenure considerations;
- Physical footprint;
- Cumulative impacts;
- Visual impact considerations;
- Mine planning, scheduling, and overburden volumes;
- Flora, fauna and heritage issues;
- Stakeholder inputs; and
- Safety and access considerations (discussed further in Section 9.1.7).

Final landform designs require integration of all the domains listed in Table 2-2 (Section 2.4) including:

- OSAs, ISAs, ROM pads and stockpiles (discussed in Section 9.1.4.1);
- Mine voids (discussed in Section 9.1.4.2);
- Infrastructure including:
  - Surface water management and flood protection works (discussed in Section 9.1.2); and
  - Roads and post-closure access (discussed in Sections 9.1.7 to 9.1.9).

BHP undertakes a suite of work to inform and guide the landform design process including:

- **Resource Sterilisation Assessment**: which is an assessment of resource or potential mineralisation beneath an area typically selected for proposed OSA construction. This assessment also applies to mine voids where backfill is proposed as part of the operations and / or closure strategy. It adds to the spatial dataset to assist with OSA positioning at the conceptual stage.
- **The Resource Block Model**: which contains geological resource information for planned and operational mines. The model contains, amongst other things, the relevant stratigraphies, physical and geochemical properties of the rock mass allowing for the identification of ore and appropriate classification of overburden material.
- **Overburden Characterisation**: identifies material suitable for use on final slopes and problematic material (e.g. PAF, sodic) which should be buried within an OSA or mine void as appropriate.
- **Mine Plan Optimiser**: Mine planning software is used to assist in generating an optimal pit design based on financial and geotechnical parameters, assuming an appropriate risk level. The mine planning software is also used to schedule multiple deposits based on optimal maximised net present value (in consideration of operational and environmental constraints). Schedules provide the necessary information to develop optimal overburden strategies and are an iterative process. This influences OSA designs and backfill strategies.
- **Physical Erosion Potential Modelling**: An examination of overburden that forms the outer surfaces of OSA landforms is undertaken to determine the key erosion characteristics of the overburden material. This is conducted under laboratory conditions using predicted rainfall events based on local rainfall data. It provides validated data for the numerical modelling on how well a specific overburden type behaves in surface flow conditions and informs detailed OSA design such as stable slope angles and material use. In addition, field trials are utilised where appropriate, to validate laboratory findings.
- **Numerical Erosion Potential Modelling**: Surface erosion modelling (e.g., WEPP, SIBERIA) can be undertaken as part of the detailed OSA design stage to evaluate the predicted rates and locations of erosion on a final landform. This process is supported by numerical inputs obtained from the material characterisation programs. This activity supports planning considerations around final landform design and overburden scheduling objectives.

#### 9.1.4.1 Design of OSAs and ISAs

Potential requirements for OSA designs are integrated into the Master Area Design for a mine and are refined throughout the mine planning process (Figure 9-4). During the early stages of mine planning (see 'Range Analysis' and 'Development Strategy' on Figure 9-4), conceptual OSA landform designs are used to delineate OSA locations and disturbance extents for approval purposes. In these strategic planning stages, the overall landform extent and conservative assessment of slope angle is used to estimate a final disturbance area. As more localised information becomes available and knowledge improves, a final landform design will be developed (see 'Engineering' stage on Figure 9-4) which will transition into an executable design. During construction, assessments are undertaken of compliance to plans based on survey data.

Erodible overburden may be backfilled into pits (sometimes as constructed ISA landforms) or placed in ex-pit OSAs which have appropriate geometries and are sheeted with competent material defined through materials characterisation studies. OSAs are generally located outside the Zone of Instability (ZOI) of pits, but where this is not possible, pit walls will be buttressed or pits backfilled to increase stability, or the ex-pit overburden material will be transferred to an alternative location. OSAs will also typically be located outside the 1 in 10,000-year floodplain. However, where the 1:10,000 floodplain intersects OSAs, consideration will be given to additional rock armouring or toe protection bunds or diversions to minimise the potential for erosion in a post-closure flood event.

The final shape of OSAs and ISAs will be designed to maintain surface stability. Erosion of OSAs is minimised by managing surface water run-off and designing slopes that will result in minimal rilling as this minimises the opportunity for accelerated erosional forces to develop within channel flows. Such slopes will have minor potential to become heavily gullied, and any interrill erosion that occurs will be insignificant relative to potential rates of erosion by rilling that could develop on long, steep, slopes. If rilling and gullying is avoided, the slope should be stable.

# Waste Resource Planning Knowledge Map

**Purpose:** To layout the waste planning activities and study levels during the various stages of project development, from early Range Analysis to execution by Operations. By detailing the study/management level, risks can be identified and separate management plans to manage the risks can be developed.

**Scope:** This document covers the management of waste material at WAIO sites. Waste generated at WAIO sites includes:
1. Non-mineralised waste rock (mining overburden).
2. Mineralised waste rock (Low/Blend Grade).
3. Quarried rock used for construction.

LoA Waste Knowledge Understanding

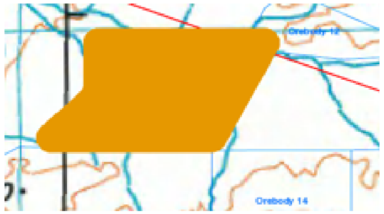
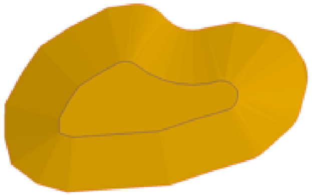
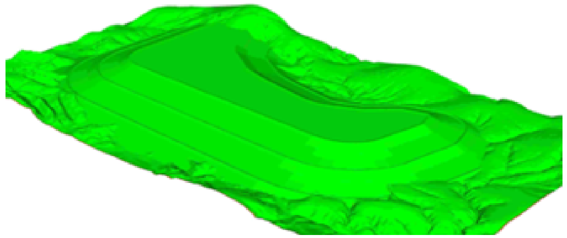
| | Range Analysis | Development Strategy | Engineering | Implementation |
|---|---|---|---|---|
| OVERVIEW | The waste and landform considerations will generally be at a high level due to a limited waste understanding caused by the model maturity. | A conceptual 9 degree OSA final design with no ramps developed for extents that considers preliminary geochemistry and landform requirements. Assumes all waste/LG/BG dumped ex-pit. | Executable rehabilitated designs are developed to inform the as-tipped designs. The design is to consider the material properties of the waste and physical environmental conditions of the area. | Mine Operations execute the OSA and landform structure in accordance with the approved as-tipped design. Waste schedule optimises waste placement objectives to minimise haulage and rehabilitation costs. |
| OSA LANDFORM REQUIREMENT |  |  |  | |
| KNOWLEDGE LIMITATIONS | *Initial drilling program that has broadly defined a known mineral deposit. Footprint of conceptual OSA should consider drainage alignments and future pit and infrastructure footprints.* | *Infill drilling has allowed for the development of resource models that consider the waste risks of the deposit.* | *Infill drilling completed, resource and mining models available with a good understanding of lithologies and PAF potential. Site specific material characterisation work may not yet have been completed but reviews of adjacent studies has been undertaken.* | *Monthly review of compliance to plan undertaken to ensure compliance with design during execution of landforms. As material competency investigations are completed, mine plans are amended to optimise waste placement objectives if possible.* |

**Figure 9-4 OSA landform development stages during mine planning**

Where berms are deemed necessary in design due to overall landform geometry, berm cross-sectional water holding storage is based on 200-year 72 hr event with 300 mm freeboard from top of crest embankment. Berm design includes engineered features to contain or direct slope run-off above 200-year events up to a 10,000-year event.

Opportunities to minimise the size of the OSAs by increasing the amount of overburden material used to infill final voids are explored as part of ongoing operational planning.

Final OSA landform designs are informed by:

- Final contours of an 'as tipped' OSA;
- Surface water assessments including an assessment of the catchments that impact on the OSA and potential for run-off from the OSA;
- Materials characterisation (Section 5.2.4); and
- Modelling of erosion (Section 5.2.4).

There are several standard design elements that are typically integrated into most landform designs. These comprise:

- Frontal crest bunds to control surface water run-off down slopes (Figure 9-5). A typical cross section is shown in Figure 9-6.
- Inter-bunds to control surface water movement across landform surfaces (Figure 9-7). Cells generally run perpendicular to the frontal crest bunds. A typical cross section is shown in Figure 9-8. Finished cell surfaces are deep ripped. The top RL of inter-bunds is required to be a minimum of 300 mm below the frontal crest bunds.

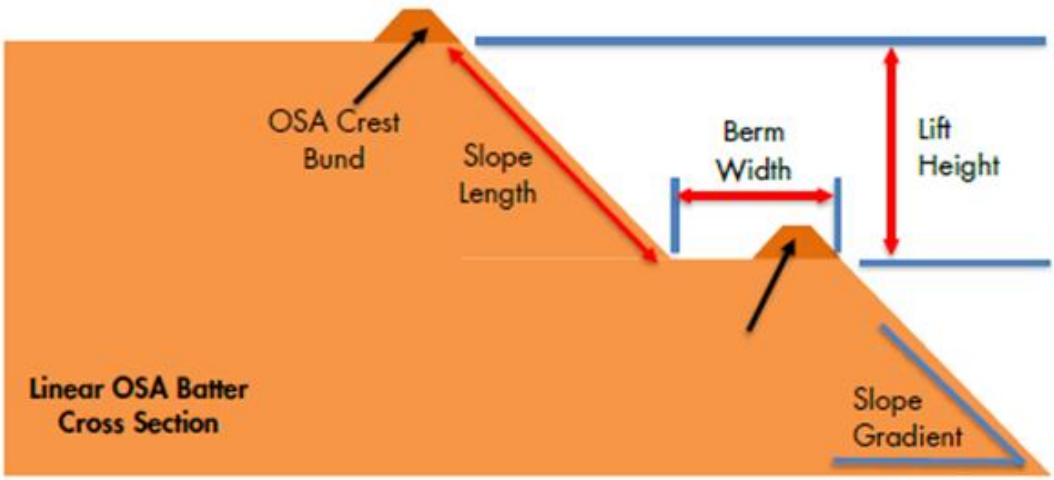



**Figure 9-5 Linear OSA batter cross section showing location of crest bunds**

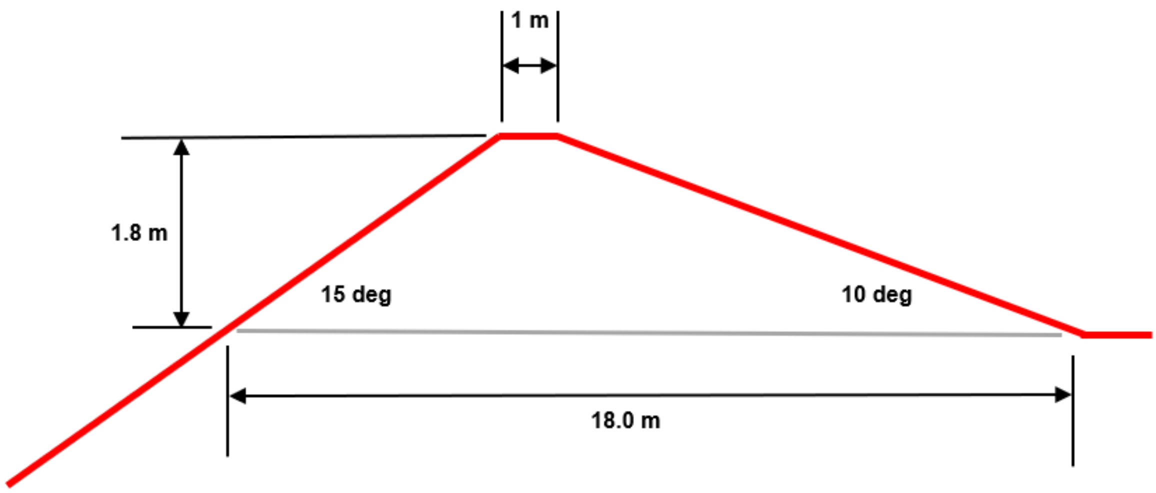



**Figure 9-6 Typical frontal crest bund cross section**

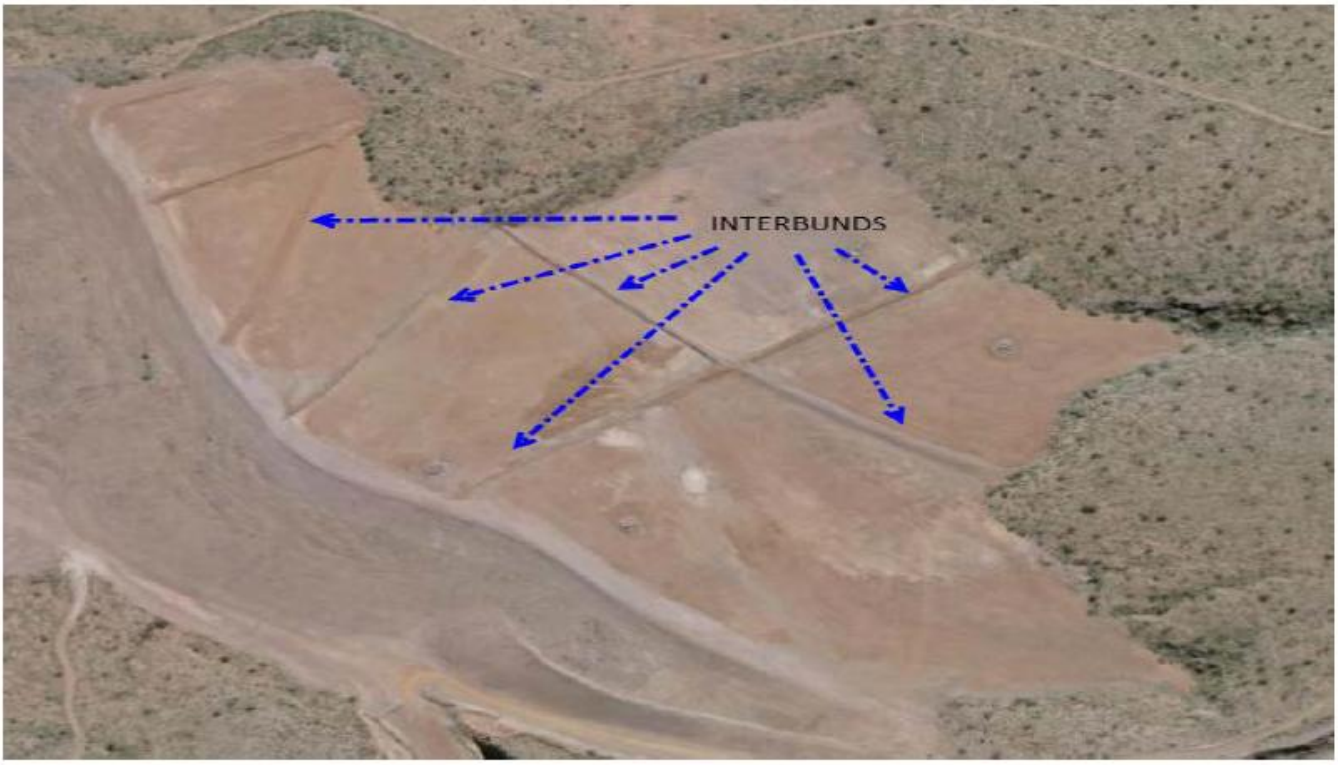



**Figure 9-7 Example inter-bund configuration**

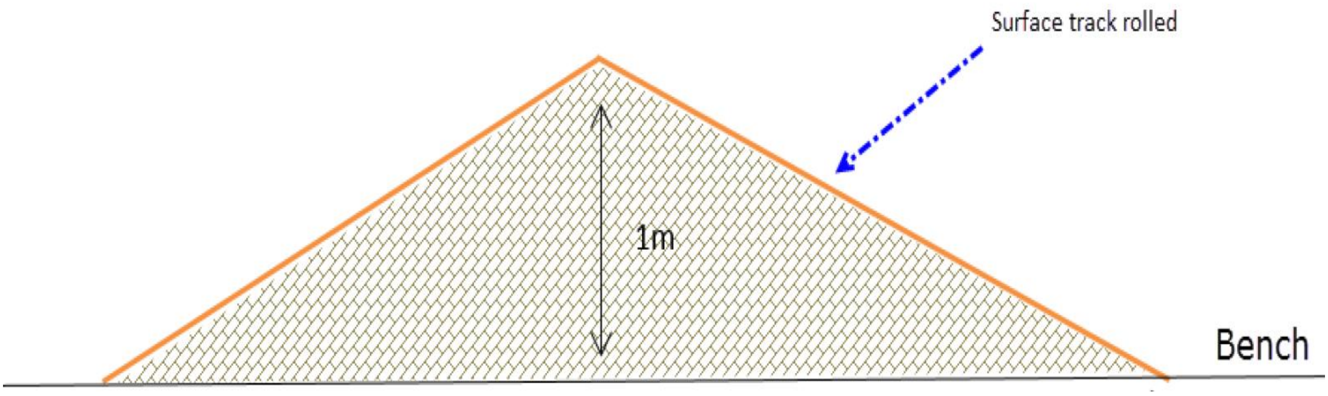



**Figure 9-8 Typical cell bund cross section**

#### 9.1.4.2 Mine voids

Mine void closure strategies consider the post-closure influence of mining areas on groundwater and associated receptors, as well as opportunities for reducing the ex-pit footprint of OSAs and management of physically or geochemically problematic materials. Following the confirmation of the preferred mine void closure strategy (e.g., whether they will be backfilled) and final pit shells, pit wall stability is assessed and the potential for the ZOI of the pits to impact on infrastructure (such as safety bunds and surface water management infrastructure) determined. Where post-closure infrastructure falls within the ZOI of pits (determined in accordance with DEMIRS guidelines (DMIRS, 2019) on the basis of risk, but typically using a FoS of ≥1.5), pit walls may be designed to achieve a lower slope angle or buttressed or backfilled to improve stability.

Geological and geotechnical models are produced for each pit which are used as the basis for geotechnical assessments. Geotechnical, hydrological and hydrogeological assessments are used to inform pit designs and pit wall stabilities and BHP's Master Area Design Review process checks that geotechnical guidance has been incorporated into designs. Following construction, surveys are undertaken as part of BHP's compliance to plan processes to check final pit walls against designs.

At closure, safety bunds will be located outside the ZOI of the pits in line with DEMIRS guidelines (DoIR, 1997), and designs (Section 9.2.3.4) will consider the outcomes of recent consultation with DEMIRS (Section 4.3). Consideration will also need to be given to how the safety bunds interact with surface water management infrastructure remaining post-closure (e.g., flood bunds and diversions).

### 9.1.5 Rehabilitation

BHP implements its Rehabilitation Standard (0001074) (WAIO, 2023c) and associated procedures relevant to rehabilitation works including rehabilitation planning, growth media management, earthworks for rehabilitation, audit and inspection, seed management, rehabilitation data management and rehabilitation monitoring. These procedures have been based on previous rehabilitation success and to manage identified issues. The results of rehabilitation monitoring are used to adjust and refine the methodology in accordance with BHP's adaptive management approach (Section 7.1). The rehabilitation standard and associated procedures are used across BHP's Pilbara mine sites and other areas, where appropriate. Further details of various aspects of the standard and procedures are provided in the subsections below.

#### 9.1.5.1 Rehabilitation planning

Rehabilitation planning is conducted generally in accordance with BHP's Rehabilitation Planning and Execution Technical Process Instruction (WAIO, 2023b). This requires that a 5-year rehabilitation plan be developed in consultation with the mine planning and production scheduling teams. The plan is updated as part of the financial closure provision process and is used as the basis of a five-year seed supply plan which guides seed purchases (species and volumes).

For each area of rehabilitation, a work pack (and / or scope of work if rehabilitation is to be executed by an external contractor) is developed. Work packs typically outline the key tasks for the project with appropriate stages, which require sign-off by all relevant parties, validating that the work conforms to BHP's rehabilitation and closure standards and objectives.

#### 9.1.5.2 Earthworks

The Earthworks for Rehabilitation Procedure (WAIO, 2023a) has been prepared to provide a consistent methodology for rehabilitation earthworks across BHP's operations including:

- Relocating materials (e.g. backfilling pits).
- Re-profiling the land surface to create landforms that are consistent with the surrounding landscape, within the constraints imposed by the physical nature of the materials.
- Reshaping slopes to a profile suited to the nature of the material used (determined by overburden characterisation studies and modelling of erosion potential).
- Constructing surface water controls.
- Application of rock armour.
- Implementing the surface treatments outlined in Section 9.1.5.3.
- Constructing fauna habitats as outlined in Section 9.1.5.5.

At the end of each earthworks phase, a rehabilitation inspection is conducted generally in accordance with WAIO's Rehabilitation Inspection and Sign-off procedure (WAIO, 2022e) to confirm conformance to the work pack / scope of work for that area.

#### 9.1.5.3 Surface treatment

Several surface treatments may be used, depending on the size and nature of the rehabilitated area. Surface treatments for rehabilitation areas are developed to satisfy closure objectives and may consist of one or more of the following:

- Deep ripping of compacted surfaces, and cross ripping if clod size is greater than 150 mm.
- Selective application of topsoil material (or alternative growth media) to provide a medium to support plant growth.
- Application of inorganic or organic amendments informed by assessment of the growth media and research findings (refer to Appendix K).
- Surveyed contour ripping or scarifying of surfaces following the application of soils to maximise water infiltration and enhance revegetation success (Figure 9-9). When scarifying on the contour is not appropriate due to physical constraints (such as narrow areas or areas constrained by infrastructure or natural features), a herringbone technique may be used (Figure 9-10). Where there is high rock content and natural surface roughness of the final designed surface, contour ripping may not be required. Based on the outcomes of research and trials across BHP's operations, a no-rip approach is the preferred approach, where possible. This can be achieved through deep ripping to treat compacted areas prior to the spread of armouring material / growth media.
- Selective placement of logs or smaller woody debris and / or boulders (if available) across the re-profiled surface (Figure 9-11) and / or constructing rocky cliff features (where potential exists) to provide additional habitat areas for fauna species recorded prior to mining.

The Management of Growth Media for Rehabilitation Procedure (WAIO, 2022c) provides general information on soils of the Pilbara region and methods for soil stripping, stockpiling and use in rehabilitation. The procedure has been informed by the results of the 5-year Restoration Seedbank Initiative research program completed in 2020 (Appendix K).

Topsoil stockpiles are regularly surveyed and, where topsoil deficits exist, alternate growth media are tested and trialled. Topsoil resources are typically prioritised for areas that will provide the best benefit to rehabilitation outcomes.

Direct placement of topsoil onto rehabilitation areas is preferable. If direct placement is not possible, contemporary guidance for topsoil stockpiles is that soil should be stockpiled in mounds no more than 3 m high with an overall convex shape that has a slight watershed slope across the entirety of the stockpile to prevent the degradation of topsoil and seedbank by pooling water. Stockpiles should be placed away from large populations of weeds and should not be located in areas where water is likely to collect against the stockpile. Compaction of the topsoil stockpiles is minimised through the use of track based machinery and deep ripping.

**Figure 9-9 Contour ripping**

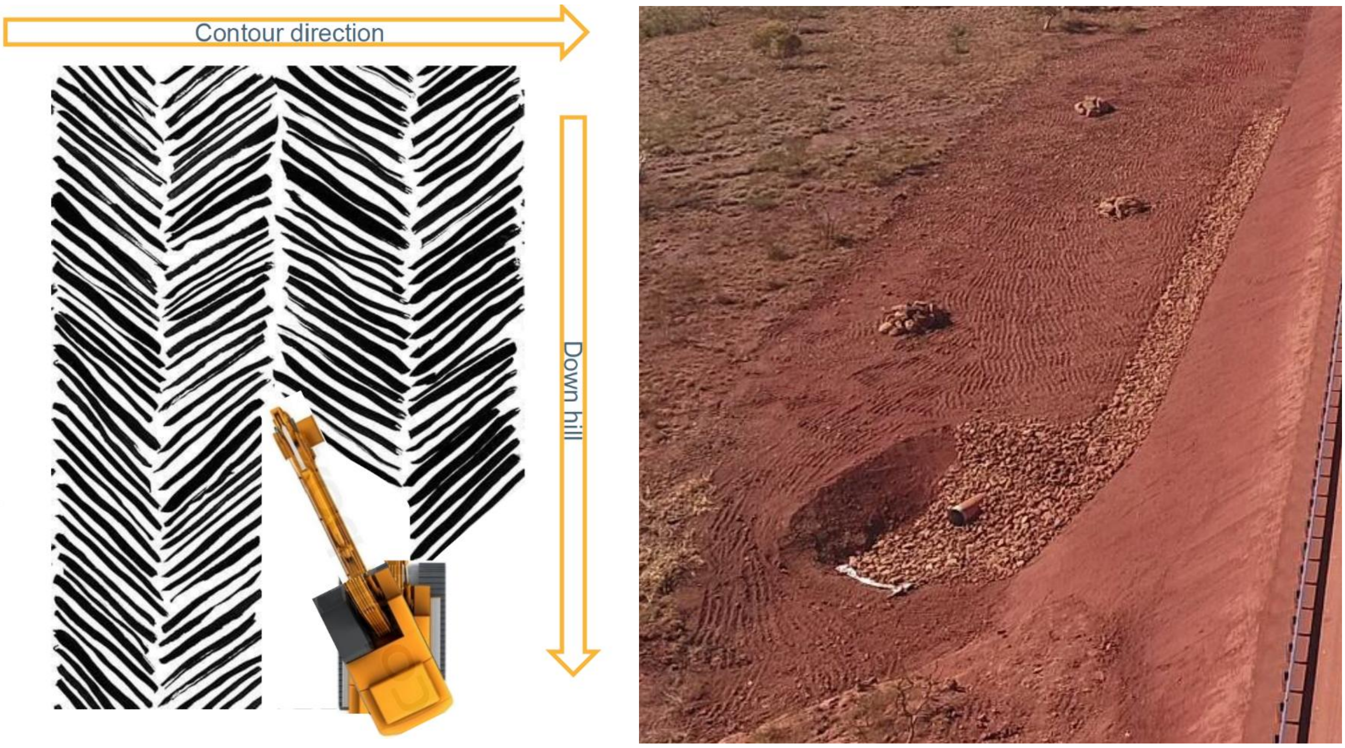



**Figure 9-10 Herringbone scarification**


**Figure 9-11 Example of placement of logs & branches as fauna habitat**

At the completion of works, a rehabilitation inspection is conducted generally in accordance with WAIO's Rehabilitation Inspection and Sign-off procedure (WAIO, 2022e) to confirm conformance to the work pack / scope of work for that area.

#### 9.1.5.4 Revegetation

Revegetation programs are typically designed to establish native vegetation that blends with surrounding areas and provides habitat and foraging areas for native fauna, while taking into consideration the constructed landform design and overburden material characteristics within the potential root zone.

The Rehabilitation Standard (WAIO, 2023c) requires that revegetation be conducted to establish plant species that will support the approved post-mining land use(s). The plant species used in revegetation are selected from revegetation species lists generated for each site as part of planning works (see Appendix I). Plant species lists for different domains are generated, using baseline vegetation data, to include a range of typical vegetation assemblages suited to the post-mining landform. While selected plant species will typically be consistent with vegetation associations and native species recorded in the mine area prior to mining, some domains (e.g. backfilled pits) or post-mining land uses, may require the return of novel ecosystems. Where a novel ecosystem is proposed, research / studies are conducted to define appropriate species for use in revegetation of these areas. Seed used in rehabilitation is of local provenance and sourced from the local area (but as a minimum from within the Pilbara Biogeographic Region and 100 km of the site), unless novel ecosystems require seed sourced from elsewhere.

Based on the available climate change predictions, BHP considers that the most appropriate revegetation approach is to select native species based on the current climatic conditions. If there were to be an effect on revegetation from climate change, those changes would reasonably be expected to be gradual and would be experienced across the entire region, including adjoining unmined areas. Major differences between regional and post-mined vegetation will be managed by planning for diversity of species within rehabilitated sites, so that the natural adjustments to a changing climate will be accommodated within the local species pool. However, BHP will maintain a watching brief on emerging research associated with the use of out of provenance seed sources to increase genetic diversity to provide resilience to climate change.

The Seed Management Procedure (WAIO, 2020e) describes the types of seed species mixes and seeding rates that BHP uses at its Pilbara mining operations. Through BHP's adaptive management approach (refer Section 7.1), seed mixes and methods of seed handling, assessment of seed viability and seeding rates will continue to be improved and informed by ongoing monitoring results, and research. All seed collections are recorded in BHP's seed collection database (developed as part of the Restoration Seedbank Initiative). This database records information for each seed batch such as provenance zone, seed test data, and landform position, and aspect, preferred by each species.

Where monitoring results indicate vegetation establishment may not meet required standards, (vegetation density, species diversity and plant age heterogeneity), additional seeding (in subsequent years) may be undertaken.

Two rainfall periods characterise the Yandi region - one from January to March and the other from May to August. The most reliable rainfall period occurs from January to March. Accordingly, revegetation activities are completed during November and December where practicable. Work completed as part of the Restoration Seed Bank Initiative has highlighted the significance of sowing time (in relation to expected rainfall events) to the success of seed germination.

Weeds are monitored and controlled in accordance with the Weed Management Procedure (WAIO, 2020c).

#### 9.1.5.5 Fauna habitats

Rehabilitation plans address the return of fauna habitat through selection of target vegetation communities and / or specialised constructed habitat features. Establishment of specialised fauna habitats is considered during the development of landform designs and associated work packs for execution.

Where available, large rocks (with a minimum of 500 mm diameter) may be used to create fauna habitats. The rock habitats are formed with a wide base, often sunk into the ground, with multiple layers of rocks to 2.5 m high (Figure 9-12). Topsoil is pushed back in / around the lower section of the rock stack. These rock habitat structures provide gaps and voids to allow species such as quolls and pebble mound mice to gain entry.

Landform designs typically require a higher percentage of rock on slopes for stability, but the surfaces of OSAs may contain less rock and, therefore, are of greater suitability for species that require less rocky habitat.

BHP is in the process of planning a research program on fauna habitat, including consideration of key species of importance to Traditional Owners, and the return of fauna to rehabilitated areas. This will inform future rehabilitation practices.

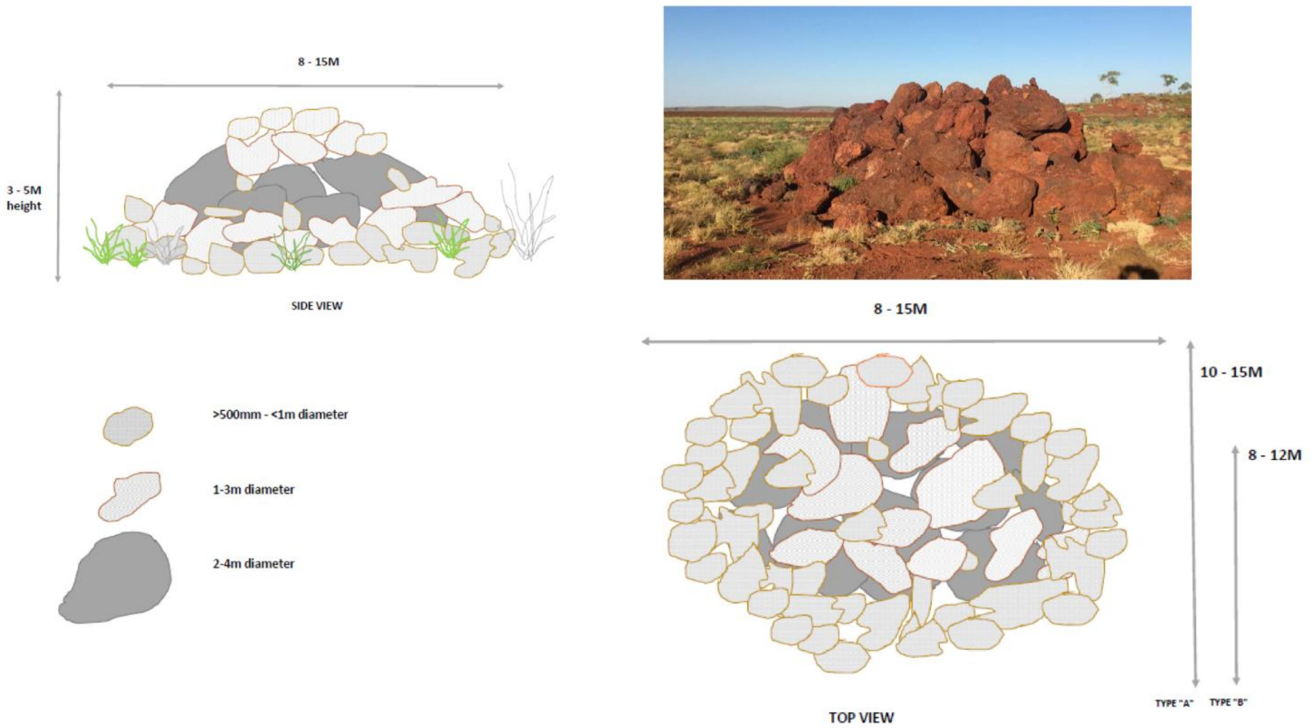



**Figure 9-12 Fauna habitat**

#### 9.1.5.6 Knowledge gaps & forward work program

The following programs will inform future rehabilitation strategies:

- BHP is maintaining a watching brief on emerging research associated with the use of out of provenance seed sources to increase genetic diversity to provide resilience to climate change.
- BHP is in the process of planning a research program on fauna habitat, including consideration of key species of importance to Traditional Owners, and the return of fauna to rehabilitated areas. This will inform future rehabilitation practices.

### 9.1.6 Borrow pits

Borrow pits will be closed in accordance with the Borrow Pit Management and Rehabilitation Procedure (WAIO Borrow Pit Management and Rehabilitation Procedure: SPR-IEN-LAND-008) provided as Appendix H.3 which broadly requires:

- Borrow pit walls to be battered to blend with the surrounding environment.
- Straight edges to be avoided and edges to be blended with the surrounding environment.
- Borrow pits to be free draining.
- Compacted areas to be deep ripped prior to topsoil return.
- Light scarification of topsoil and seeding.

### 9.1.7 Site safety & security

Safety considerations for closure include:

- The post-mining land use and associated requirements for safe access.
- Safe access to sites of significance for Traditional Owners.
- Measures to prevent inadvertent access to hazardous areas.
- Management of hazardous materials.
- Decommissioning and removal of above ground infrastructure that will not be transferred to a third party post-mining.

Safety hazards are identified during risk assessments conducted during appropriate design phases, and where practicable, are eliminated through a range of measures including, but not necessarily limited to:

- Placement of fibrous overburden encountered during mining, 1 m below the surface of an OSA / ISA / backfill. Where, due to historic practices, there may be an absence of detailed destination information for materials placed in OSAs, any potentially fibrous materials encountered during regrading or recovery for mine void backfill will be placed at least 1 m below inert non-fibrous overburden.
- Removal of infrastructure, filling of voids left after infrastructure removal and capping of bores.

Where hazards cannot be eliminated, designs are developed to prevent inadvertent access. In defining appropriate site safety and security measures to prevent inadvertent access, consideration is given to the accessibility of a site (such as proximity to public access routes). Consultation is also conducted with post-mining land managers and Traditional Owners to identify safe access requirements to accommodate the post-mining land use and access to sites of importance to Traditional Owners. Inadvertent access is typically controlled using safety bunds which are designed to be located outside the zone of instability of the pits in accordance with DEMIRS guidelines (DoIR, 1997) and include consideration of matters raised during consultation with DEMIRS in 2019 (Section 4.3). However, for some sites near population centres, fencing, signage and locked gates may also be required. In these instances, provision would need to be made for ongoing inspection and maintenance post-closure.

At sites where flood bunds and creek diversions remain post-closure, the interaction of safety bunds with these features will be factored into designs.

### 9.1.8 Cultural values and heritage

#### Protection of cultural heritage

Comprehensive archaeological and ethnographic surveys are undertaken to identify sites of cultural significance prior to ground disturbing activities. In general, closure activities are unlikely to impact these sites as these activities usually occur in areas that have already been disturbed. However, where new disturbance is required to execute closure designs, BHP reviews and authorises the disturbance (currently via its Project Environmental Aboriginal Heritage Review (PEAHR) procedure (WAIO, 2021b)) prior to work commencing. For each planned disturbance area, the following details are addressed in the PEAHR form:

- A summary of the proposed disturbance activities;
- A plan showing the location of the proposed works;
- The anticipated environmental, land access and Aboriginal heritage impacts; and
- Specific management measures where necessary.

The primary mechanism for protection of cultural heritage sites identified as being significant, is the development of closure plans and designs to avoid identified sites. Any post-closure issues (including ongoing management) relevant to these sites will be discussed with the relevant Traditional Owners through the stakeholder engagement process (Section 4.3). Discussions will also include:

- The opportunity to repatriate artefacts that have been collected and stored during the mining process, if required.
- Options for closure designs to provide safe access to sites of importance post-closure.
- Cultural values and potential closure designs to incorporate / retain these values.

All work will be conducted in compliance with relevant legislation, and in accordance with BHP's comprehensive agreement with the Banjima People.

#### Protection of cultural values at Yandi

Closure designs and approaches to address cultural values at Yandi are the subject of ongoing consultation (refer to Section 4). However, considerations to date include:

- E1 and E4 diversions have been designed to function as a fluvial system similar to the natural sections of the Marillana Creek system.
- Pit backfill strategy to reduce permanent, saline pit lakes, and design to incorporate natural looking features.
- Surface water management strategy to maintain flows to Marillana Creek, protect riparian vegetation and improve the aesthetics of diversions to achieve a more natural looking landform.
- Seed production area / tree nursery developed in partnership with the Banjima people to research the production of materials for use in revegetation programs at Yandi.
- Fauna research program currently in planning.

### 9.1.9 Post-closure land use

Stakeholder views (including those of Traditional Owners) and the appropriateness / feasibility of different land uses changes over time. BHP's ongoing stakeholder consultation program will enable future land use options to be identified and studied in further detail throughout a mine's life, and detailed land use-specific performance objectives and completion criteria to be developed.

As a site approaches closure, discussions will be held with key stakeholders to determine whether they have a requirement for site infrastructure post-closure. If infrastructure is to be transferred to third parties, a condition assessment of the infrastructure will be conducted, and the infrastructure (including responsibilities for ongoing management and maintenance) will be formally transferred to its new owner.

Post-closure monitoring will be used to gain an understanding of any long-term land maintenance requirements. Where specific long-term management actions are required, which are above those expected for the post-closure land use, an agreement will be made to provide for these actions prior to relinquishment.

### 9.1.10 Site contamination

In areas where the potential for soil contamination has been identified, assessment and remediation is managed in accordance with the CS Act and DWER requirements (including sampling / analysis and remediation / management) during a site's operational life and not left unresolved at the time of closure. As a site approaches closure, investigation and remediation of any remaining contamination is considered during BHP's closure study phases (refer to the introduction to Section 5). This includes consideration of whether the contamination land use classification of sites previously investigated / remediated is commensurate with the agreed post-mining land use.

Remaining surfaces are reshaped to conform to surrounding landforms, with surface treatment and revegetation implemented as outlined in Section 9.1.5.3 and 9.1.5.4.

### 9.1.11 Dust emissions

Dust has the potential to be emitted during decommissioning and bulk earthworks activities during closure. Dust control measures will be implemented during closure, e.g. regular watering of unsealed roads, exposed surfaces and active earthwork areas. Upon closure, dust generation from the rehabilitated surfaces is expected to be similar to other nearby natural landforms.

## 9.2 Closure strategies by domain

This section outlines closure designs based on studies conducted to date (Section 5.14), acknowledging that further consultation with BNTAC and the Banjima people is required before designs are finalised. The designs presented in this section will be updated as consultation with BNTAC and the Banjima people, and associated design studies progress.

### 9.2.1 Overview and rationale for current design concept

This section outlines the current design concept for the closure of Yandi mine, however, we acknowledge that the Banjima people are averse to saline pit lakes and will continue to consult with them in refining the closure design for Yandi.

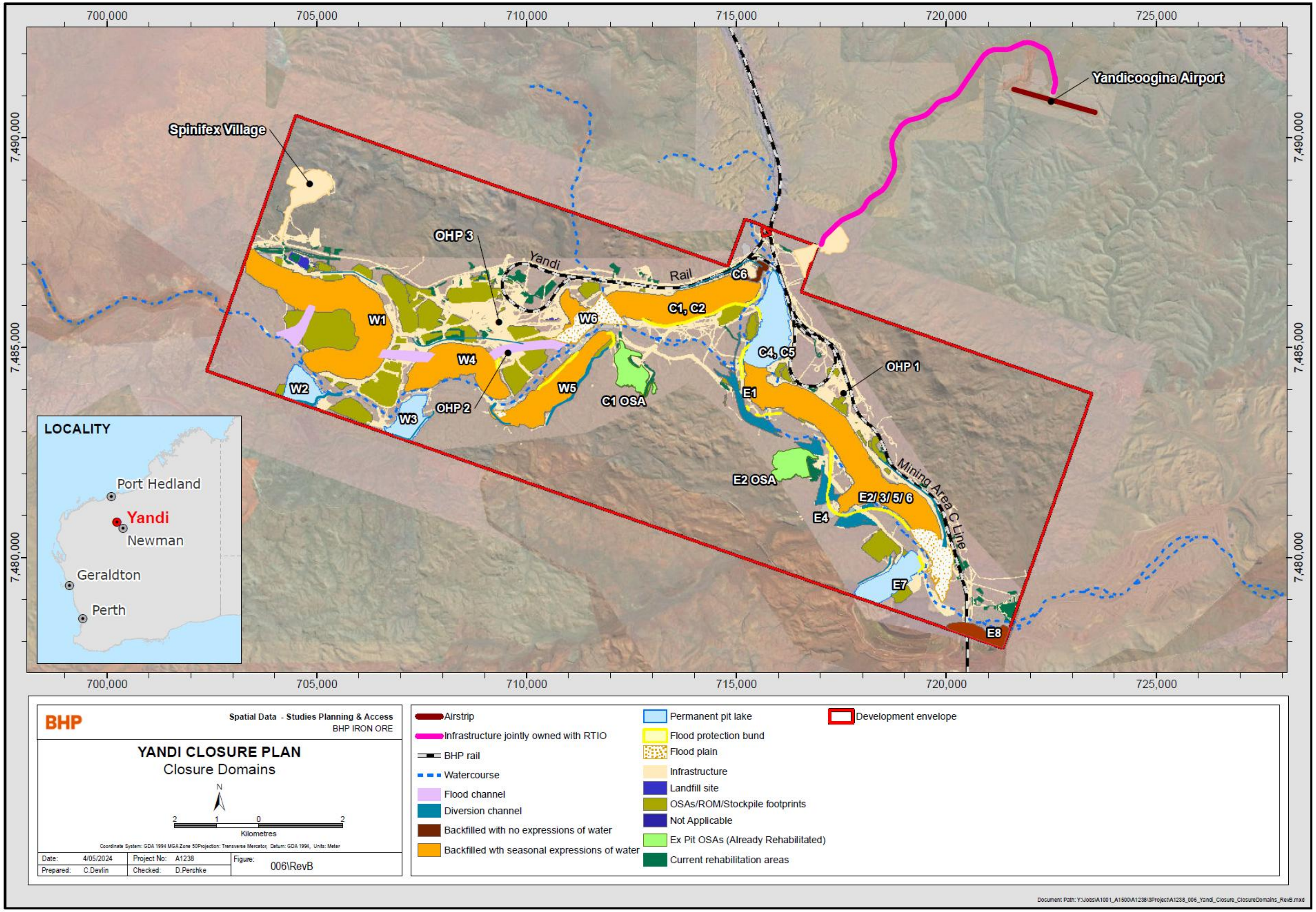
As discussed in Section 2.1, Yandi mine cannot be considered in isolation, as the closure designs implemented by third party mining operations adjacent to Yandi tenure have the potential to influence the closure outcomes at Yandi. There is insufficient material to backfill all the Yandi pits to above the water table, so the current closure concept is to backfill the pits to minimise the footprint of hyper-salinity in the landscape (as outlined in Section 5.14.1). This results in permanent pit lakes at W2, W3, C4/5 and E7 which will become hypersaline over time due to evapo-concentration. The E7 Pit is adjacent to RTIO's Mungadoo Pit and there are plans to mine the pillar of CID between the two pits. RTIO also has insufficient material to backfill all the Yandicoogina pits to above the water table, and the current closure plan for Mungadoo Pit is that it will also become a permanent pit lake.

With the exception of C6 and the proposed E8 Pit, the partially backfilled pits are predicted to have seasonal expressions of non-saline water. C6 and E8 will be backfilled to above the recovered water level and are not expected to have expressions of water.

To achieve the current closure concept, all ROM pads, stockpile bases and OSAs (except C1 and E2) will be rehandled back to the Yandi pits as part of the backfill design. C1 and E2 OSAs will remain in the landscape as they have already been rehabilitated, and landform evolution and rehabilitation monitoring have shown that they will be stable in the long-term and vegetation is progressing towards completion criteria (Section 5.15.4). The additional volume of overburden in these OSAs will not enable substantially different outcomes to be achieved if rehandled to the pits, and maintaining them as ex-pit OSAs provides a buffer of material that can be used to supplement backfill areas if monitoring indicates this is required.

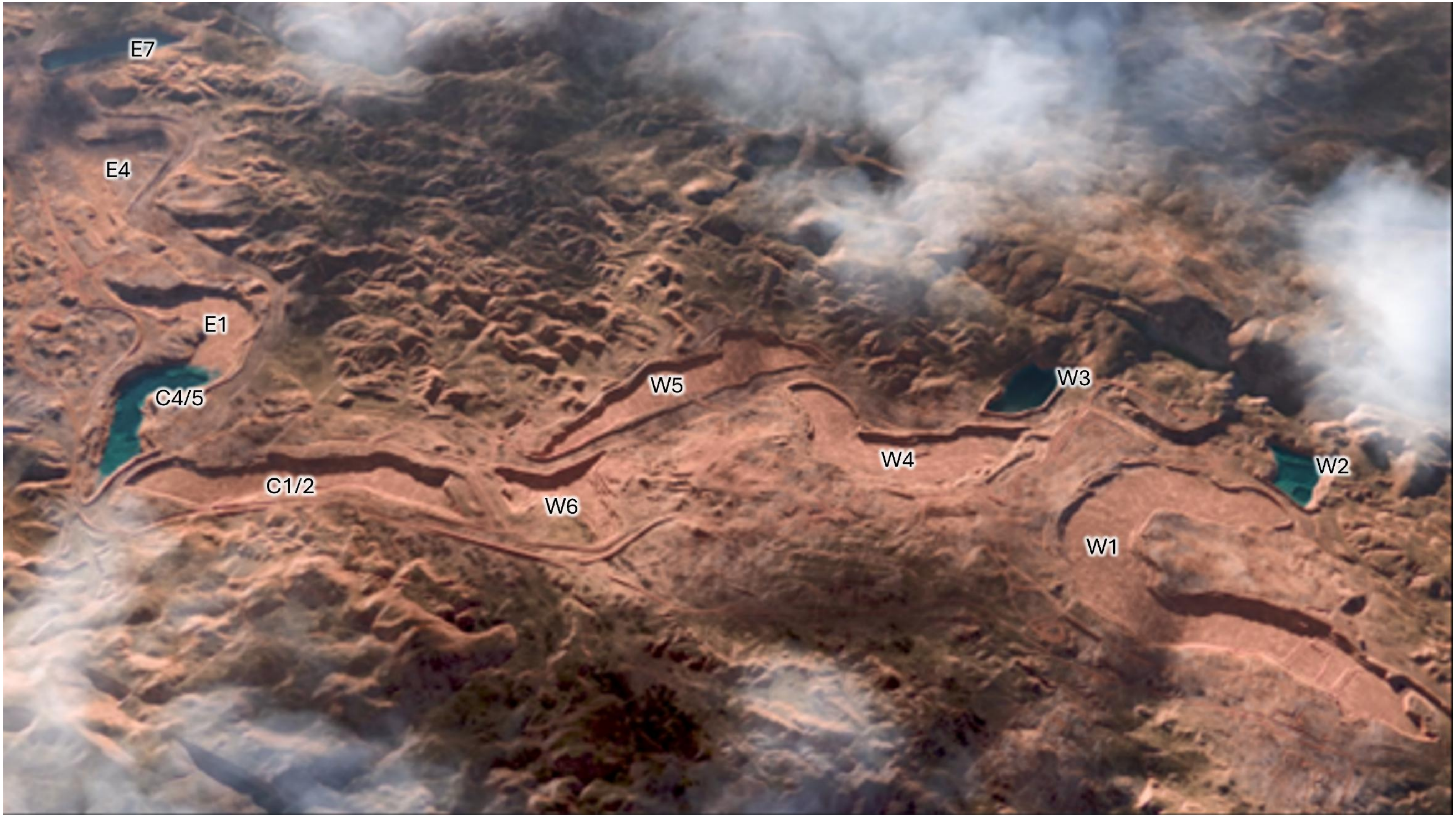
To prevent the capture of Marillana Creek by the pits, a series of surface water management measures have been designed including creek diversions, flood bunds, floodplains and flood channels. The flood channels will allow Marillana Creek to overflow into pits in a controlled manner during extreme rainfall post-closure events and prevent erosion or damage to diversions / flood bunds / floodplains or uncontrolled overtopping of downstream pit crests. In addition, while the backfill design for E8 has yet to be finalised, BHP intends to backfill the pit to the level of the Marillana Creek invert (defined as the low flow channel) to prevent creek capture.

A plan showing the post-mining outcomes from the current design is provided in Map 9-1 and a visualisation is provided in Figure 9-13. Further details of designs and the revegetation strategy are provided in Sections 9.2.2 to 9.2.5.8 and 9.3.




See Appendix Q for a pdf version of this map

**Map 9-1 Closure domains**




Notes: This visualisation was created before floodplain landforms were introduced into the closure design
Visualisation looks north / south with significant vertical exaggeration

**Figure 9-13 Visualisation of the Yandi closure design concept incorporating permanent pit lakes at W2, W3, C4/5 and E7**

### 9.2.2 OSAs, ROM and stockpile bases

Based on our current understanding of the pit backfill strategy, all OSAs, ROM pads and stockpile bases (refer to Map 9-1) except C1 and E2 OSAs (which have already been rehabilitated) will be rehandled back to the pits to achieve the outcomes outlined in Sections 5.14.1 and 9.2.3. The OSAs will be reclaimed back to pre-mining contours to the extent practical (see Figure 9-14 for example).

Should the backfill strategy change and result in ex-pit overburden landforms additional to C1 and E2 remaining post-backfilling, the procedures outlined in Section 9.1.4 will be used to define appropriate landform designs.

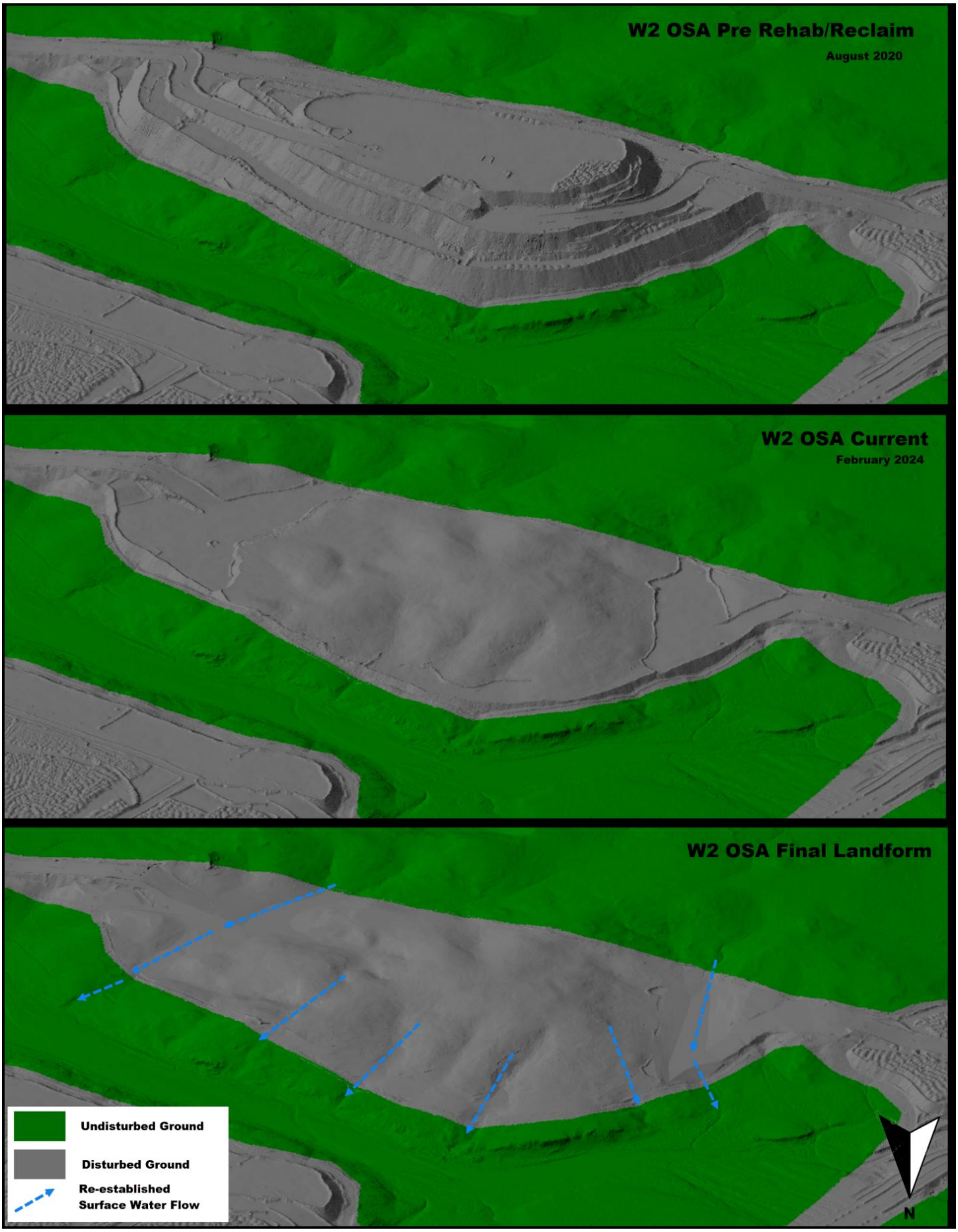



**Figure 9-14 Example of progression of a reclaimed OSA to final landform**

### 9.2.3 Mine voids

Closure and rehabilitation design considerations for mine voids include:

- Backfill strategy (Section 9.2.3.1).
- Options for maintaining post-closure groundwater levels at upstream areas of riparian vegetation (Section 9.2.3.2).
- Requirements for improving the stability of pit walls through buttressing or re-profiling to a lower slope angle (Section 9.2.3.3).
- Measures for controlling safety (Section 9.2.3.4).

The current mine void closure strategy assumes that most pits are partially backfilled, with permanent pit lakes remaining at four pits (Table 9-2 and Map 9-1), however, as outlined in Section 4, this may change following further consultation with BNTAC and the Banjima people.

**Table 9-2 Mine void closure strategy**

| Pit | Closure strategy |
|---|---|
| W1 | Partially backfilled with seasonal expressions of water. Used to attenuate extreme flood events along Marillana Creek. |
| W2 | Permanent pit lake. |
| W3 | Permanent pit lake. |
| W4 | Partially backfilled with seasonal expressions of water. Used to capture overflow from W1 Pit and attenuate extreme flood events along Marillana Creek. |
| W5 | Partially backfilled with seasonal expressions of water. |
| W6 | Partially backfilled with seasonal expressions of water. |
| C1/2 | Partially backfilled with seasonal expressions of water. |
| C6 | Partially backfilled to above the predicted water level in C1/2 with no seasonal expressions of water. |
| C4/5 | Permanent pit lake. |
| E1 | Partially backfilled with seasonal expressions of water. |
| E2/3/4/5/6 | Partially backfilled with seasonal expressions of water. |
| E7 | Permanent pit lake. |
| E8 (proposed) | Backfill designs have yet to be finalised, but BHP intends to backfill the pit to the level of the Marillana Creek invert. This is above the recovered groundwater level and seasonal expressions of water are not expected. |

#### 9.2.3.1 Backfill strategy

The backfill design, based on work conducted to date, is outlined below and shown in Figure 9-15 to Figure 9-20 (noting it may be subject to change following consultation with the Banjima people). An expanded set of drawings is provided in Appendix P.

The pit backfilled surfaces will be contoured with gentle slopes (typically less than 1%) across the longitudinal axis of each pit sequence. For pit sequences containing land bridges (e.g., W5 and between W6 and C1/2) design slopes are typically 2% to 3% to direct surface water run-off perpendicularly away from the structure and eliminate water ponding at the toe. Where backfill surfaces and pit lakes intersect, the backfill surface will be tapered down to the pit lake floor at a gradient of up to 2%, to transform the vertical drop-off into a “beach” to improve safety.

Several design features have been incorporated into backfill strategy following the site observations outlined in Section 5.14.2 and comprise (Figure 9-15 to Figure 9-20):

- Perimeter benches.
- Ramp landings.
- Seasonal expressions of water.
- Alluvial bars.
- Energy dissipation aprons.

Further details are provided on each feature in the following sub-sections.

Note pit wall stabilisation measures have not been incorporated into Figure 9-15 to Figure 9-20 as this MCP is being submitted mid-way through a study (which is currently on hold at the request of BNTAC and the Banjima people) and the current buttressing designs were not available at the time of writing.

As outlined in the forward work program (Section 13.3), backfill sterilisation reports will be progressively provided to DEMIRS as the backfill strategy evolves in line with stakeholder consultation, and backfill operations are progressively implemented.

**Perimeter benches**

Perimeter benches are continuous, earthen structures that run the entire internal perimeter of the pits and are a key safety element. The primary purpose of the benches is to provide an elevated surface for access to and from the pit when conditions are unsuitable on the remainder of the pit backfill surface. Perimeter benches are in essence, emergency access paths for stakeholders and fauna, and are not designed to be highly trafficked areas due to their proximity to pit walls (Okane, 2024a).

Perimeter benches were designed to blend with the surrounding geomorphology and to gently slope away (typically between 2% and 3%) from the pit walls to encourage water movement from these areas towards the pit backfill centre. This design feature was particularly important at the lowest elevation in each pit sequence, as it avoids ponding of water at the pit wall which may lead to geotechnical instability. The slopes have been designed to be gentle enough to discourage the movement of scree from erosion of pit walls (refer to Section 5.4.3) across the pit backfill surface (Okane, 2024a).

#### Ramp landings

Pit ramp landings are another key safety element and are earthen structures that extend from the perimeter bench to provide a gently sloped pad at the base of each ramp. The primary purpose of the landing is to provide a large area to dissipate the energy from ramp surface water run-off, thereby reducing erosion. The design feature also provides a pad from which activities in the pit can be co-ordinated (e.g., monitoring). Like perimeter benches, landings were designed to complement the surrounding geomorphology (Okane, 2024a).

The ramp landings are located at nominal locations for restricted pit access post-closure. Further work is required to consider the potential for post-closure pit access based on consultation with the Banjima people and the defined post-mining land uses (Okane, 2024a).

#### Seasonal expressions of water (ponds)

Seasonal expressions of water (referred to as ponds on Figure 9-15 to Figure 9-19) are oval shaped depressions in the pit backfill surface designed to accumulate surface water run-off from surrounding pit walls and elevated pit backfill surfaces. This approach allows water to be stored water away from pit walls and standing structures that may otherwise contribute to instability. The features are designed to be accessible from the pit backfill surface and to sit above the expected returning groundwater level to limit the inflow of groundwater that may lead to an increase in salinity over time (Okane, 2024a).

The primary purpose of the ponds is to provide centralised areas for the collection of water, where native vegetation communities can establish and provide a habitat for fauna. They have been contoured with variable depth as either concentric (deepest in the centre) or graded (deepest downslope) depressions and have been designed to be aesthetically pleasing and provide relief on the pit backfill surface. They are depicted as large, single ponds in layout, but may be re-designed as a collection of smaller ponds, where appropriate (Okane, 2024a).

#### Alluvial bars

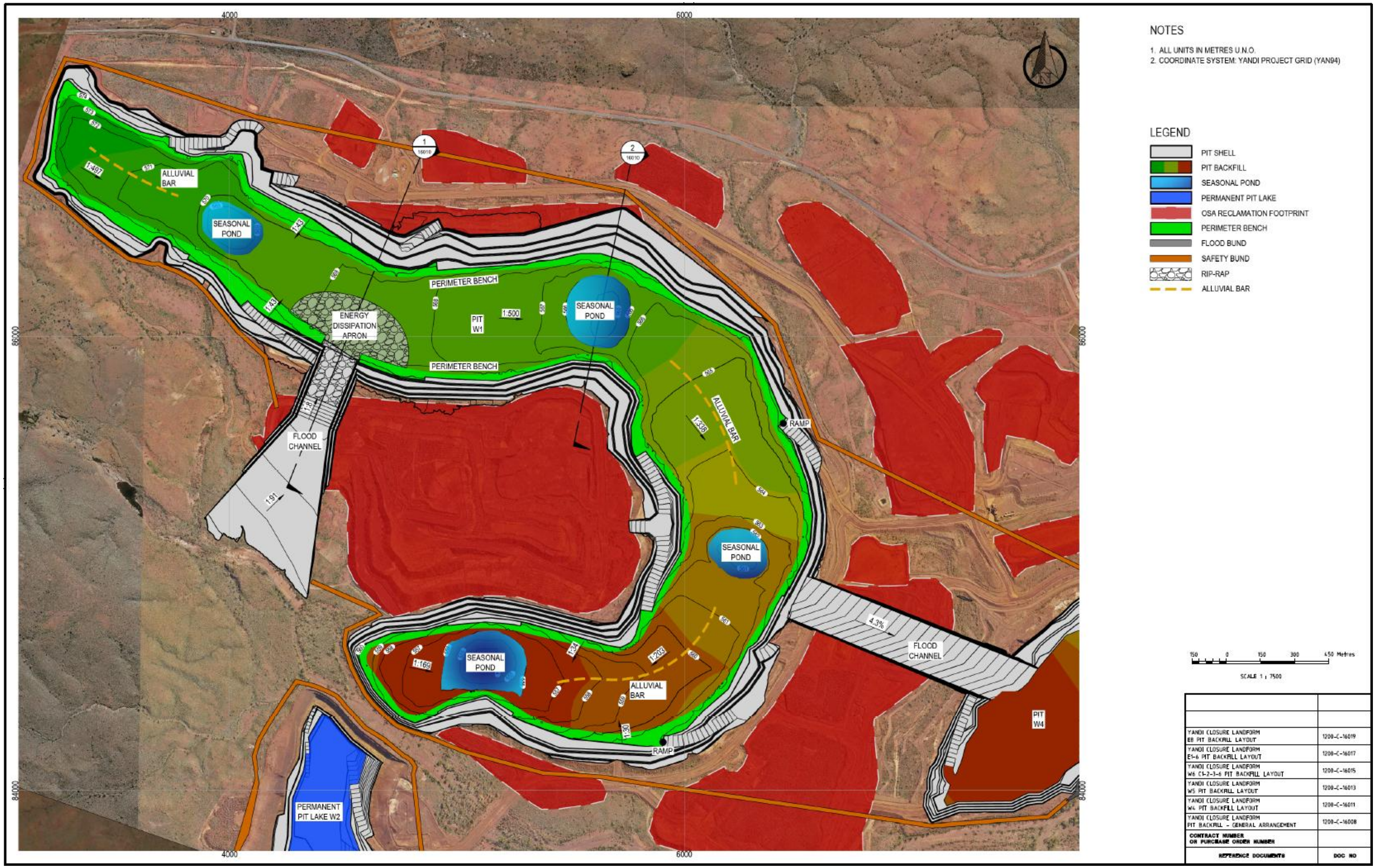
Alluvial bars are features added to promote ecology and provide relief on pit backfill surfaces. They are elongated, earthen structures that run parallel to the surrounding pit walls at a height of between 2 to 3 m and width of between 5 to 10 m. The purpose of these features is to provide habitat for fauna, and relief on the pit backfill surface (Okane, 2024a).

The upstream point of alluvial bars will need to be constructed of more competent material to resist erosion. This design will be of greatest importance in W1 and W4 Pits where flood channels will discharge water (Okane, 2024a).

#### Energy dissipation apron

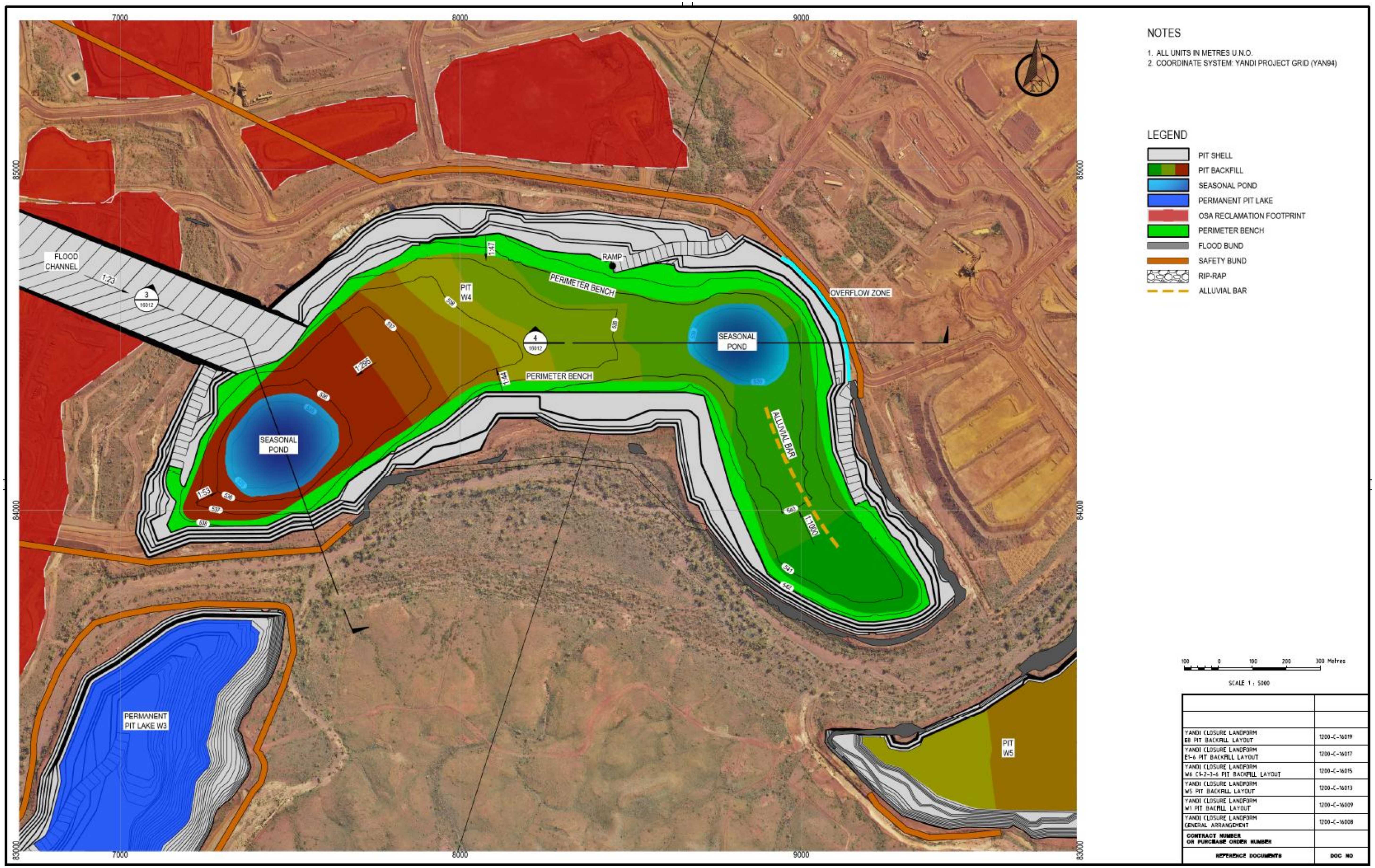
An energy dissipation apron was added on the pit backfill surface at the toe of the W1-SP0 flood channel, to minimise the impact of flood waters on the pit backfill design surface, features and ecology, by absorbing and dissipating the energy associated with the flow (Okane, 2024a).

The design includes partially embedding boulders of competent rock (e.g., dolerite from the blasted material exposed during construction of the flood channel) into the pit backfill surface at the exit of the flood channel and placing interlocking boulders on top in concentric semi-circles. The design extends back into the floor of the flood channel to maximise the effect (Okane, 2024a).




Note: An expanded set of figures is provided in Appendix P

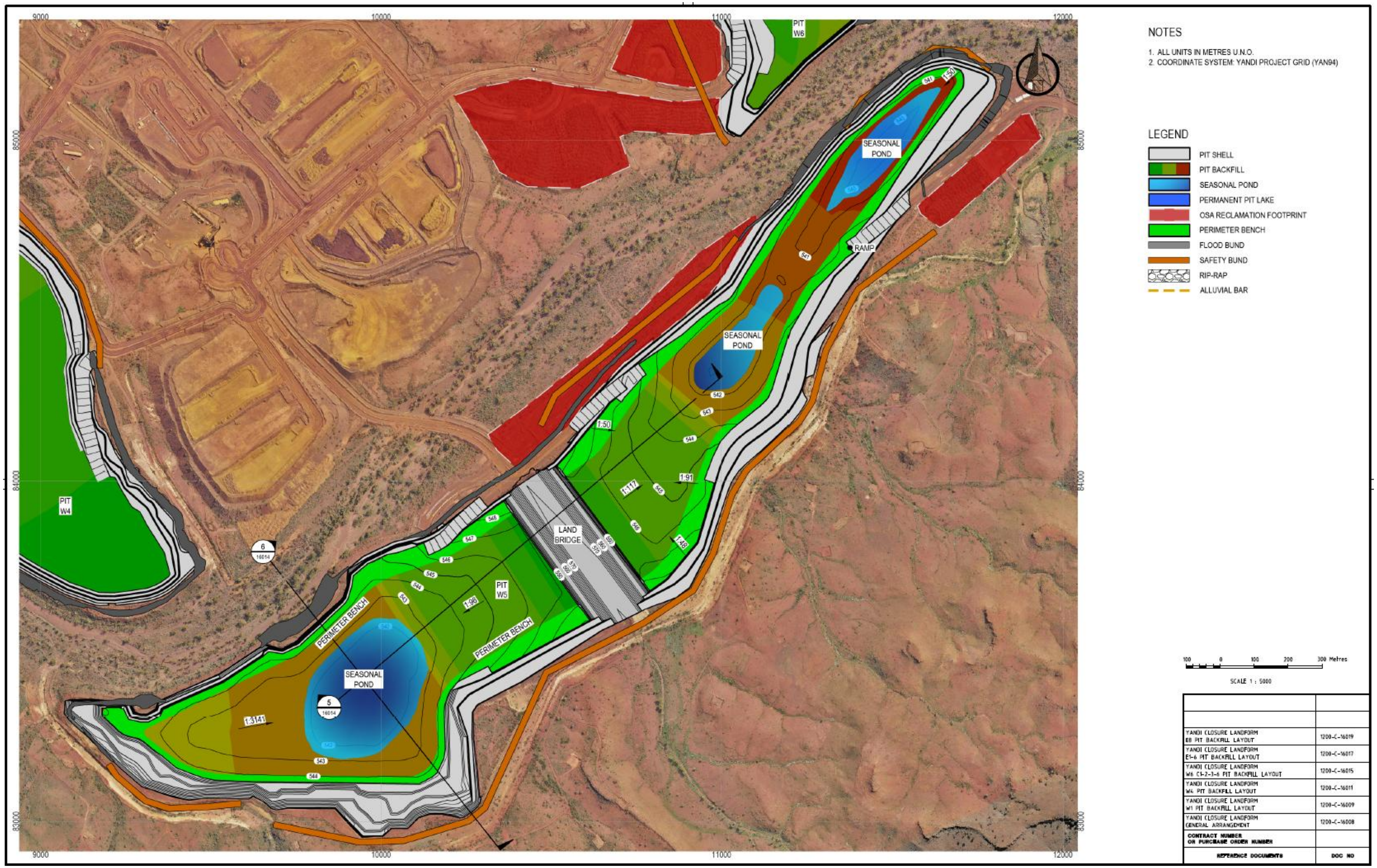
**Figure 9-15 W1 Pit backfill current design**




Note: As different elements of the closure study run concurrently, and this plan is being submitted mid-way through a study (which is currently on hold at the request of BNTAC and the Banjima people), the current design for W4-SP4 flood channel not shown.

An expanded set of figures is provided in Appendix P

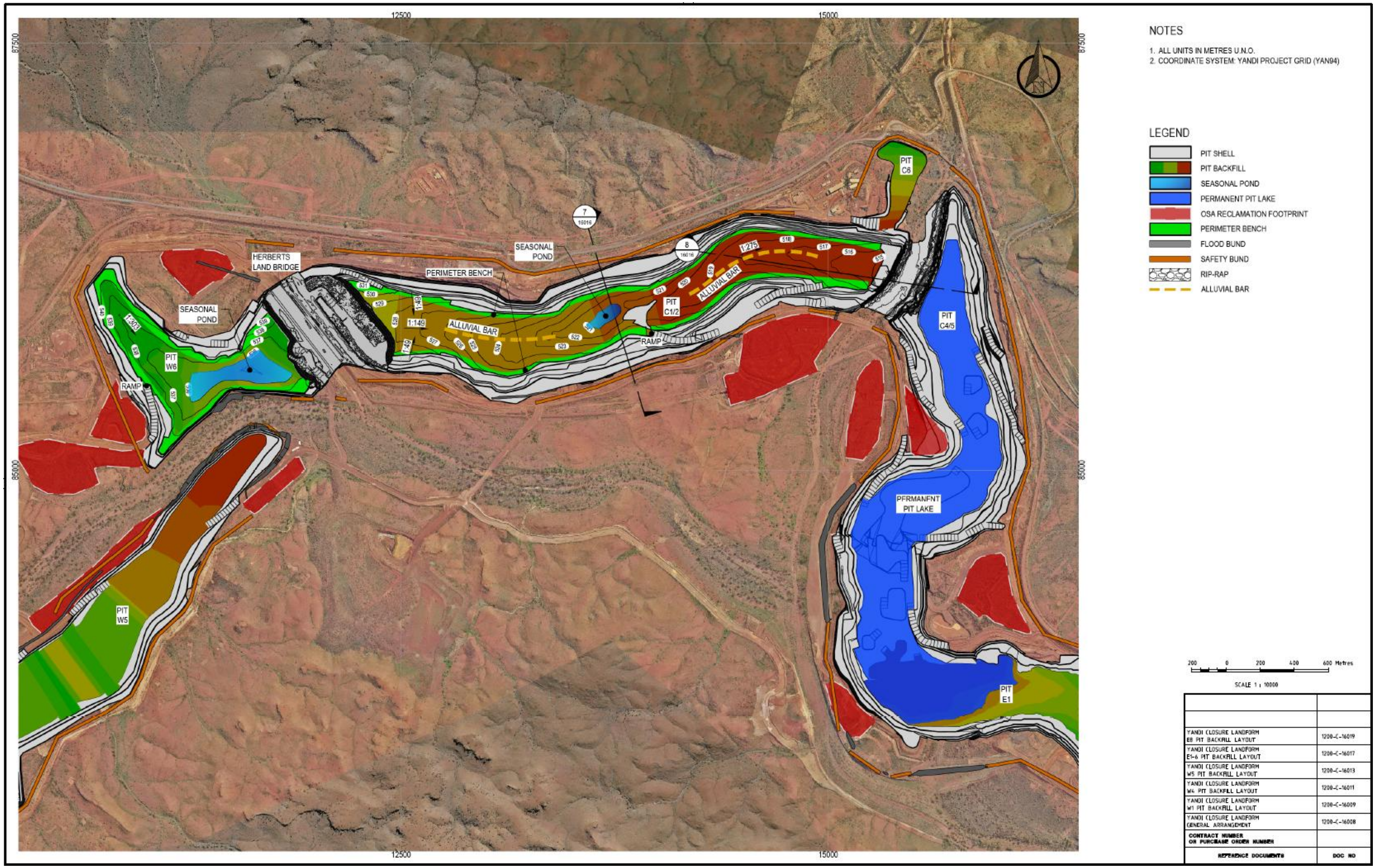
**Figure 9-16 W4 Pit current backfill design**




Note: As different elements of the closure study run concurrently, and this plan is being submitted mid-way through a study (which is currently on hold at the request of BNTAC and the Banjima people), the current design for the W5 floodplain is not shown.

An expanded set of figures is provided in Appendix P

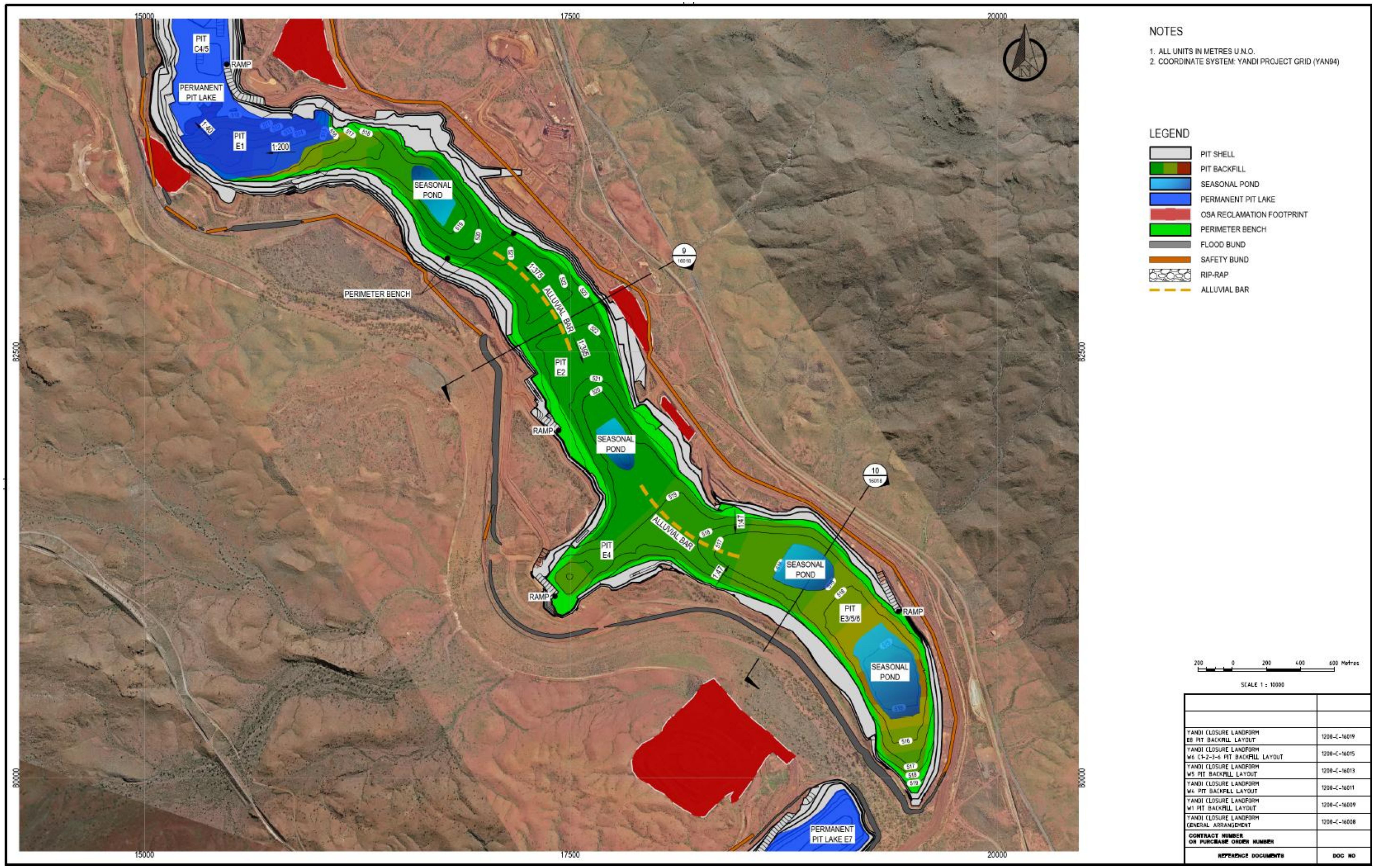
**Figure 9-17 W5 Pit current backfill design**




Note: As different elements of the closure study run concurrently, and this plan is being submitted mid-way through a study (which is currently on hold at the request of BNTAC and the Banjima people), the current design for the W6 floodplain is not shown.

An expanded set of figures is provided in Appendix P

**Figure 9-18 W6, C1/2, C6 Pits current backfill designs**




Note: An expanded set of figures is provided in Appendix P

**Figure 9-19 E1 - E6 Pits backfill current design**


Note: The backfill designs for E8 have yet to be finalised, but if approved, BHP intends to backfill the proposed E8 Pit to the level of the Marillana Creek invert to prevent creek capture. This is above the recovered groundwater level and consequently, the pit is not expected to have seasonal expressions of water post-closure. Opportunities to use the closure of E8 to support riparian vegetation to the north of the pit are currently being explored in consultation with Traditional Owners.

**Figure 9-20 Proposed E8 Pit current backfill design**

#### 9.2.3.2 Options for maintaining post-closure groundwater levels at upstream areas of riparian vegetation

As discussed in Section 5.9.4.2, changes to groundwater levels have impacted riparian tree health upstream of Yandi mine. Tree health decline is being managed via the Marillana Creek Water Resource Management Plan and includes consideration of both short- and long-term mitigation measures. Long-term measures require further investigation and review but could include the installation of low permeability barriers to slow groundwater flow into W1 Pit and force water to mound within the CID channel upstream. Section 13.3 includes a forward work program to integrate mitigation measures investigated in accordance with the Marillana Creek Water Resource Management Plan into the MCP, if required.

#### 9.2.3.3 Pit wall stabilisation

Where pit walls achieve a FoS <1.5, buttressing or re-profiling may be required. Areas requiring further stabilisation will depend on the backfill strategy adopted. Figure 9-21 shows a concept sketch for a buttress. The buttress would be constructed from competent material; most likely a mixed overburden comprising 70-100% UCID material as UCID material has the lowest erosion risk (Section 5.2.4). Further analysis of pit wall stability will be conducted following confirmation of the preferred backfill strategy, and the locations where buttressing or slope reprofiling is required, will be identified.

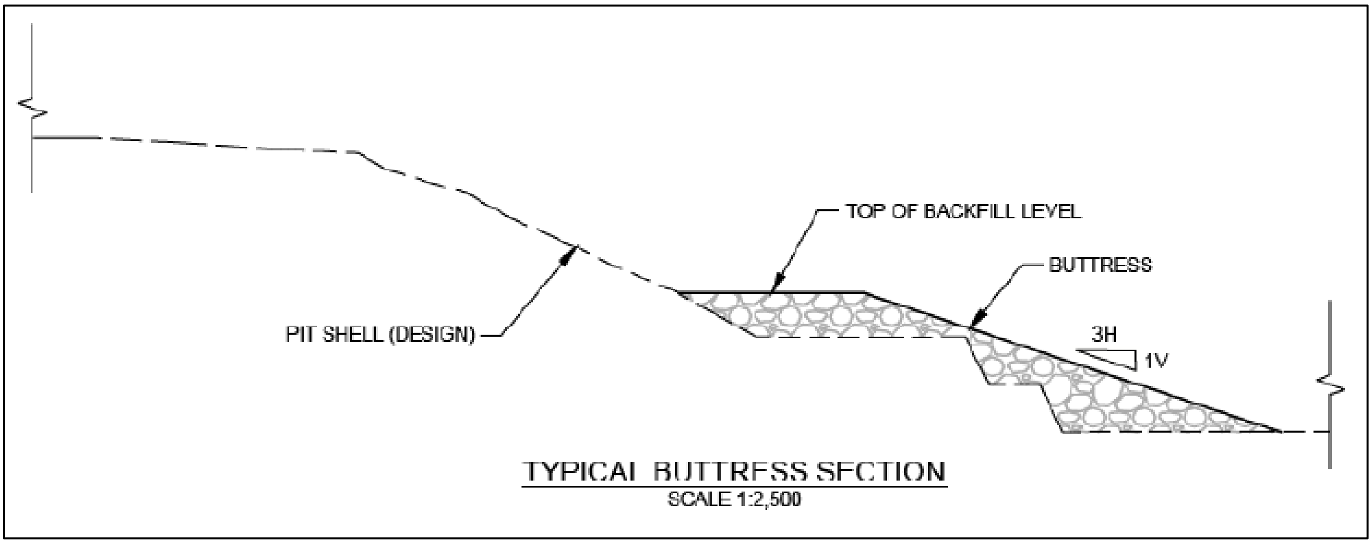



**Figure 9-21 Buttress concept sketch**

The recommendations made by Okane (2023b) to reduce erosion of pit walls and buttresses (Section 5.14.11.2) will be considered in the development of the final pit wall stability designs including:

- Compartmentalisation of the upper flat catchments of buttresses using inter bunds for closure.
- Reducing the extent of ex-pit catchments.

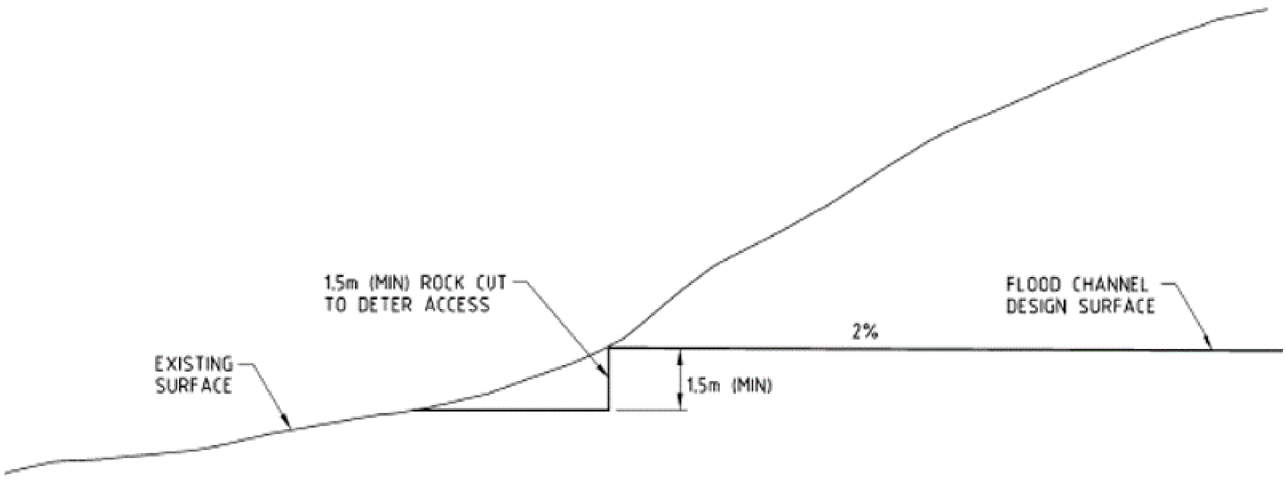
#### 9.2.3.4 Safety bunds & access controls

Safety bunds will be constructed around mine voids in accordance with DEMIRS recommended practice (DoIR, 1997) and the outcomes of recent consultation (Section 4.3). The bunds will be a minimum 2 m high with a base width of minimum 5 m and constructed at least 10 m away from the edge of the area known to contain potentially unstable rock mass as per recommended practice (Section 5.14.11.3).

The final locations for safety bund placement will be determined once closure designs have been finalised, to allow consideration of the effects of backfill on pit wall stability and any pit wall slopes that are reprofiled. Consideration will also be given to how the bunds interact with surface water flows and surface water management infrastructure, and the stability of bunds located over unconsolidated material. Map 9-2 shows indicative locations for bunds. These will be reviewed and revised during detailed designs.

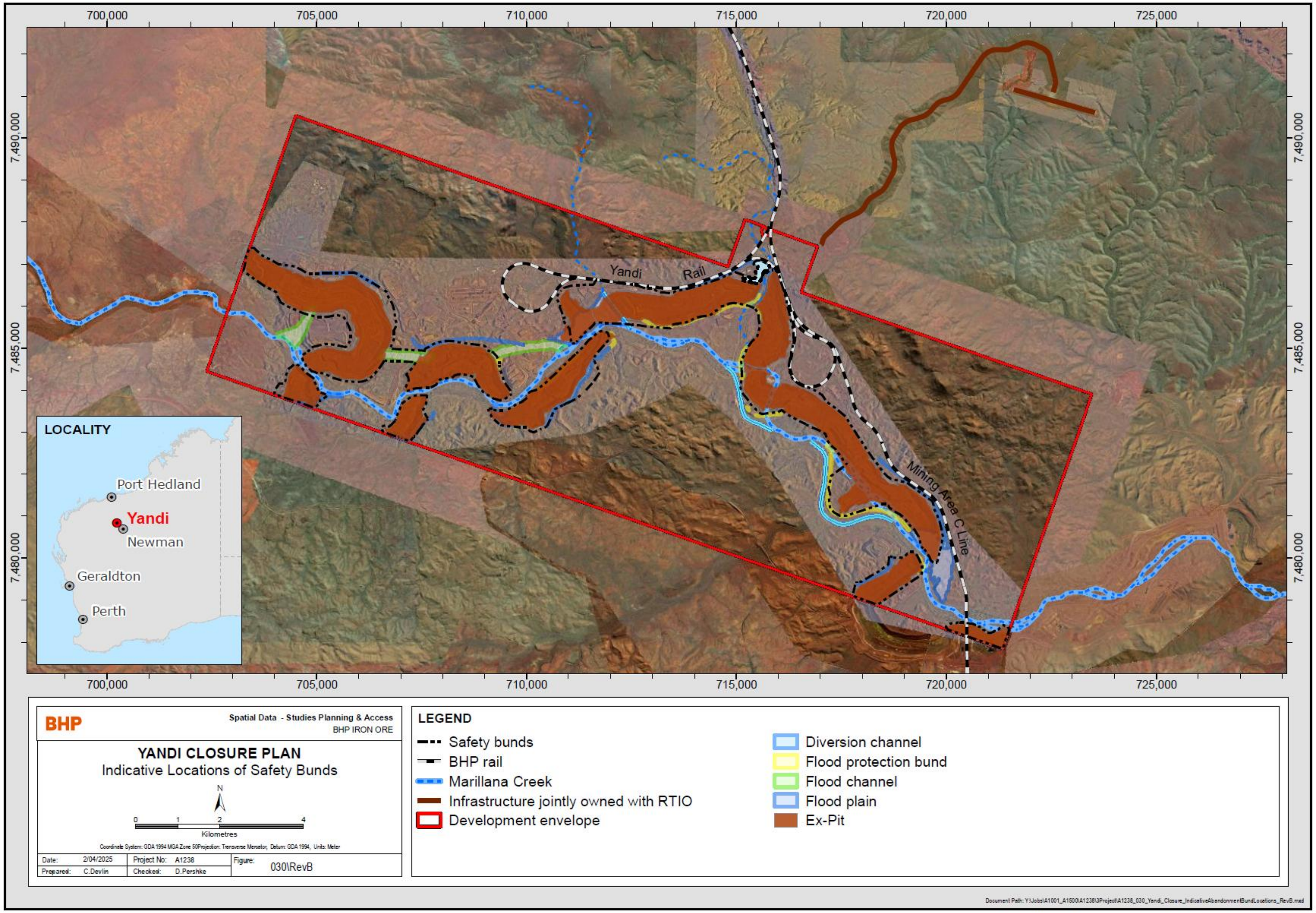
The current pit backfill designs include nominal locations for pit access (Figure 9-15 to Figure 9-20). Boulders may be placed at the top of ramps to restrict access to the ramp landings (Okane, 2024a).

To deter access to the W1-SP0 flood channel, a 1.5 m cut will be constructed at the entrance of the flood channel (Figure 9-22).




Source: Advisian (2024b)

**Figure 9-22 Cut at the entrance to the W1-SP0 flood channel to deter access**




See Appendix Q for a pdf version of this map

**Map 9-2 Indicative locations of safety bunds**

### 9.2.4 Surface water management infrastructure

The closure designs for surface water management infrastructure have been informed by the design studies in Sections 5.14.1, and 5.14.7 to 5.14.9.

The surface water management structures that will remain post-closure and require upgrade or construction for closure are (Map 9-3):

- Flood channels from Marillana Creek to mine voids;
- Intermediate and minor creek diversions;
- Floodplain landforms; and
- Flood bunds.

The E1 and E4 creek diversions have already been constructed, and a summary of the design and performance of these structures is provided in Section 5.15.3. Since no further work is required to implement the diversion designs, they are not described further in this section. The designs for the remaining elements of surface water infrastructure are discussed in Sections 9.2.4.1 to 9.2.4.3. It should be noted that while these designs have advanced since the 2020 MCP, further work is required to close knowledge gaps and optimise the designs (as outlined in Sections 5.14.7 to 5.14.10 and summarised in Section 13.3). It should also be noted that any changes to the backfill strategy arising from consultation with BNTAC and the Banjima people may also influence the final designs.

#### 9.2.4.1 Flood channels

Once earthworks are largely complete, flood channels will be cut between Marillana Creek and the mine voids. Flood channels have been designed to safely convey peak flows in Marillana Creek into W1 and W4 pits in a controlled manner and, if the capacity of W4 Pit is exceeded, from W4 Pit back to Marillana Creek. The intent of the channels is to attenuate peak flows to protect downstream infrastructure (flood bunds, creek diversions) from scour and erosion, and in turn, to prevent creek capture. The channels have also been designed to maintain sufficient flows in the downstream creeks to protect the health of riparian vegetation.

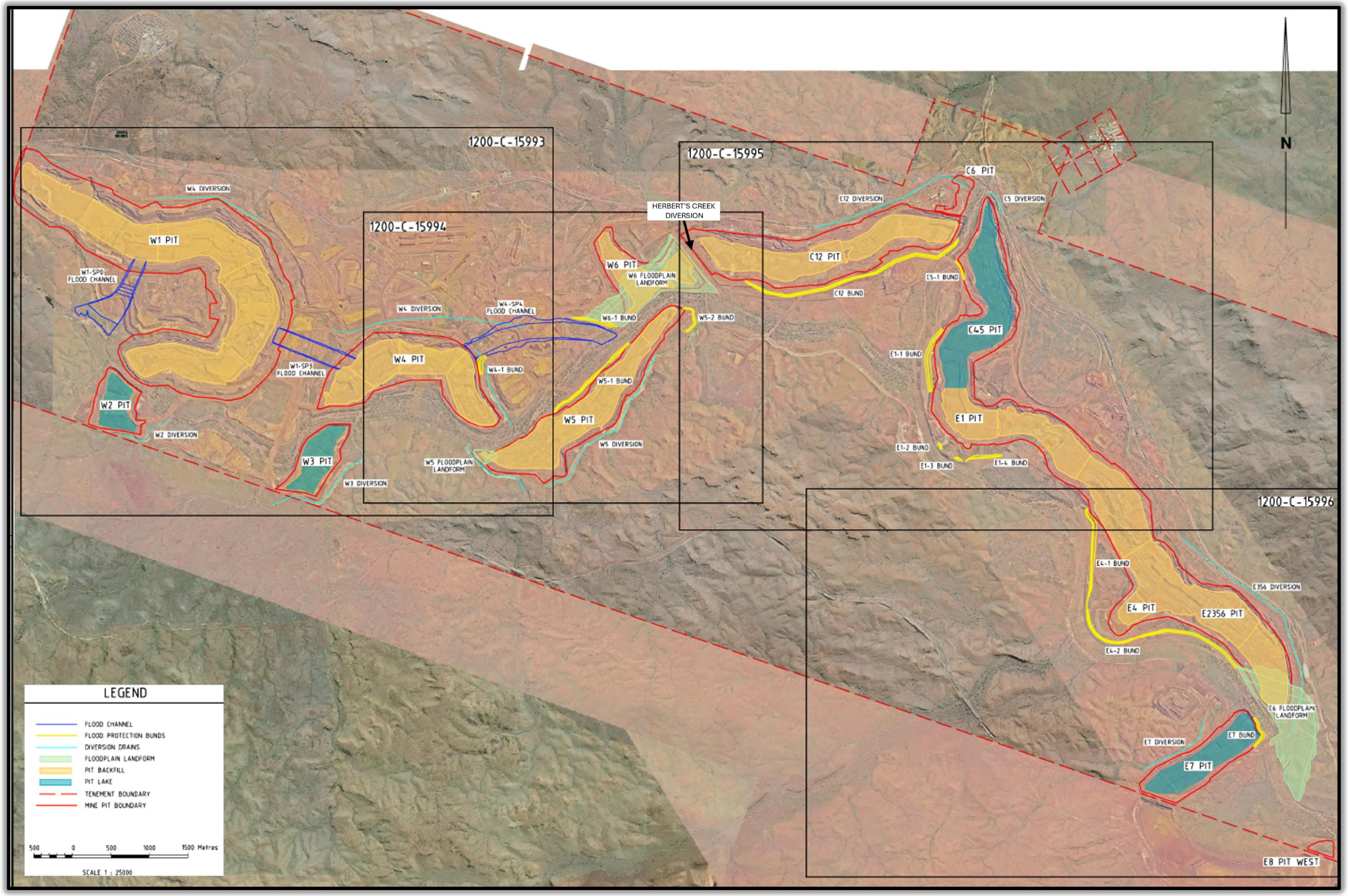
As described in Section 5.14.7, the flood channel configuration and designs have been updated since the 2020 MCP based on studies conducted since that time. Map 9-3 shows the layout of the proposed flood channels and, selected cross sections are provided in the following sub-sections. Further design drawings are provided in Appendix P.

**W1-SP0**

The W1-SP0 flood channel will connect Marillana Creek to the W1 Pit. The channel design is slightly curved and is oriented east north-east near the inlet at Marillana Creek, becoming north north-east near the outlet at the W1 Pit. The channel will be wider near the inlet (~550 m) and progressively narrow from around the midpoint of the channel to the outlet which is ~150 m. This channel orientation, footprint and curvature has been designed to reduce flow velocities as the flow exits the Marillana Creek. The channel inlet elevation at Marillana Creek will be approximately 590 mAHD, with the outlet at W1 at approximately 570 mAHD (Figure 9-23) (Advisian, 2023f). The energy dissipator will be a 'natural analogue' design as discussed in Section 5.14.7.5.

**W1-SP3**

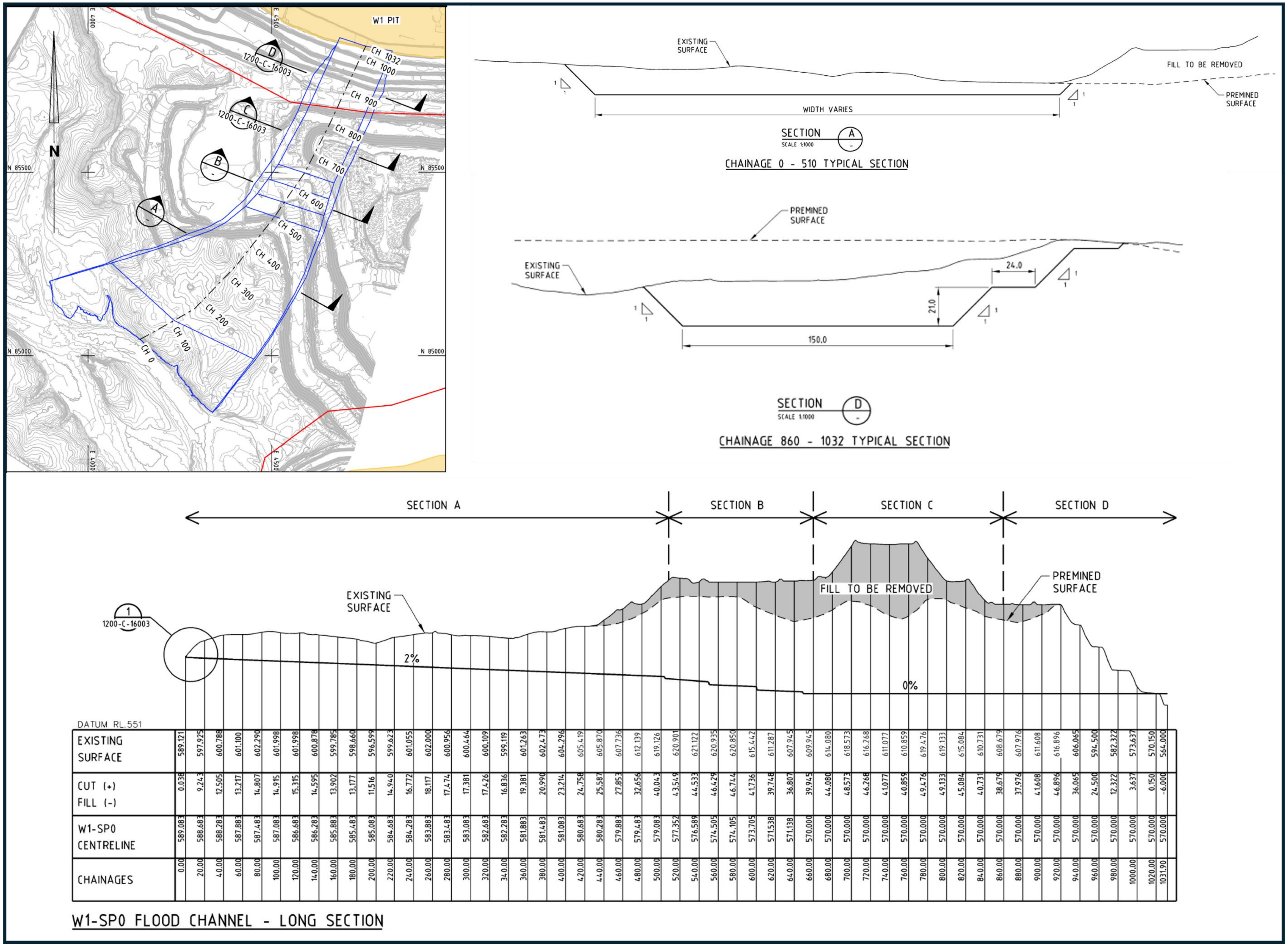
The W1-SP3 flood channel will link the W1 and W4 pits. The channel design is ~1,300 m long and ~200 m wide. It trends in an east-west orientation with the inlet at W1 at ~582 mAHD and the outlet at W4 at ~540 mAHD. The channel will be flat near the inlet and outlet, with a series of steps through the western portion. Four steps are currently proposed, with the first step located approximately 150 m from the inlet. Each step will be ~10 m high and the steps will be ~150 m apart, resulting in an elevation drop of approximately 40 m over a horizontal distance of 450 m. Between steps, the channel will be essentially flat. The channel will also be essentially flat east of the final step to the outlet at W4, with approximately a 2 m drop in elevation over 600 m (Figure 9-24) (Advisian, 2023f).




Source: Advisian (2024b)

Note: an expanded set of drawings is provided in Appendix P

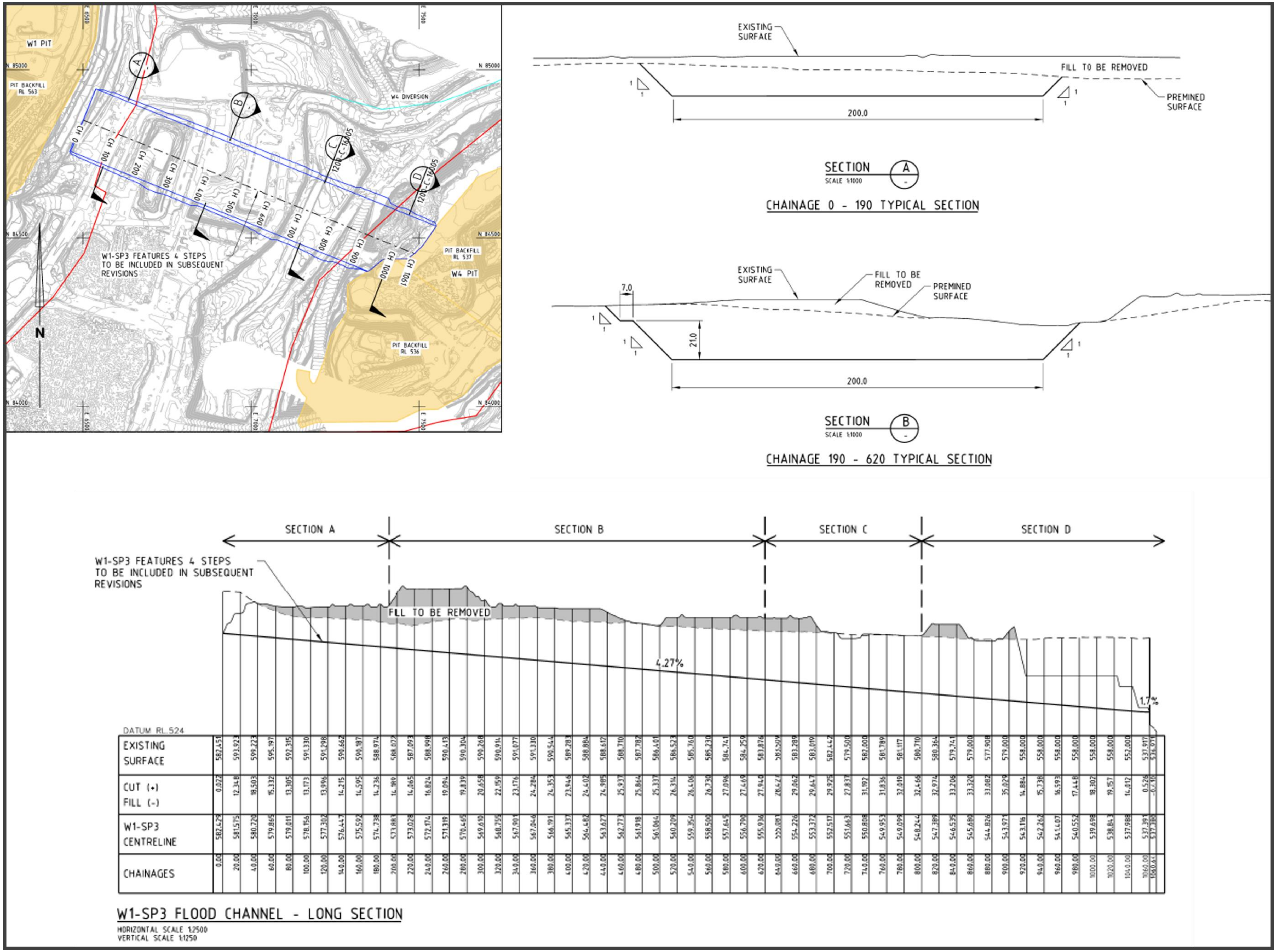
**Map 9-3 Surface water management features requiring upgrade or construction for closure**




Source: Advisian (2024b)

Note: an expanded set of drawings is provided in Appendix P

**Figure 9-23 W1-SP0 flood channel selected cross sections**




Source: Advisian (2024b)

Note: an expanded set of drawings is provided in Appendix P

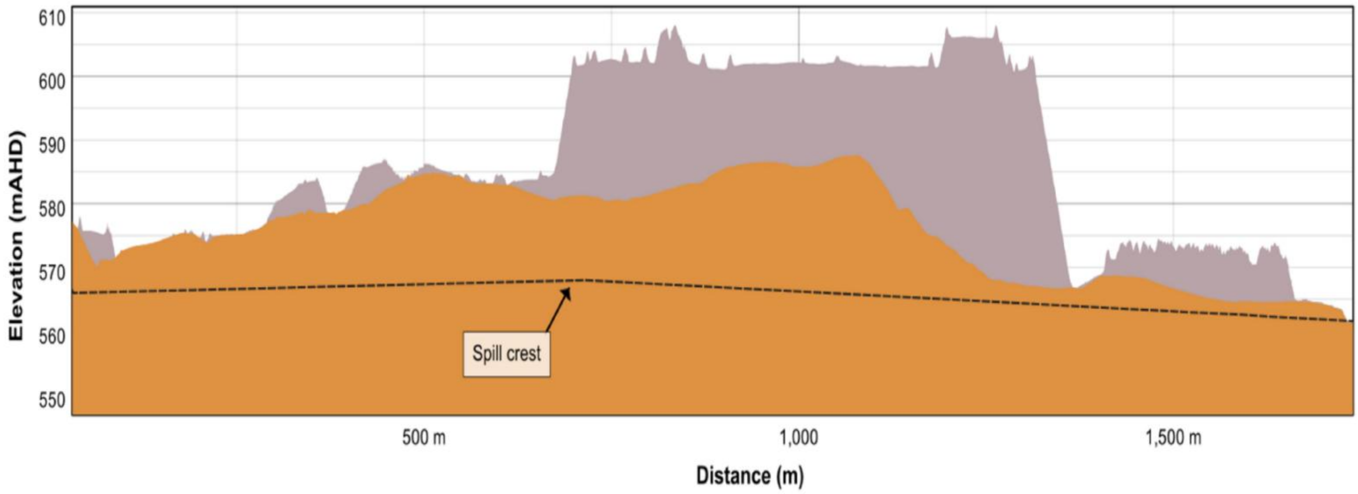
**Figure 9-24 W1-SP3 flood channel - selected cross sections**

### W4-SP4

The W4-SP4 flood channel will connect the W4 Pit back to Marillana Creek. The channel design is slightly curved and trends east to east north-east near the inlet at W4, becoming south-east near the outlet at Marillana Creek. The channel will be ~1,750 m long and ~200 m wide. The inlet elevation at W4 will be ~568 mAHD, and the outlet at Marillana ~562 mAHD. To limit stream powers and potential erodibility, a crest will be placed within the channel at ~750 m from the pit edge (Figure 9-25) (Advisian, 2023f).

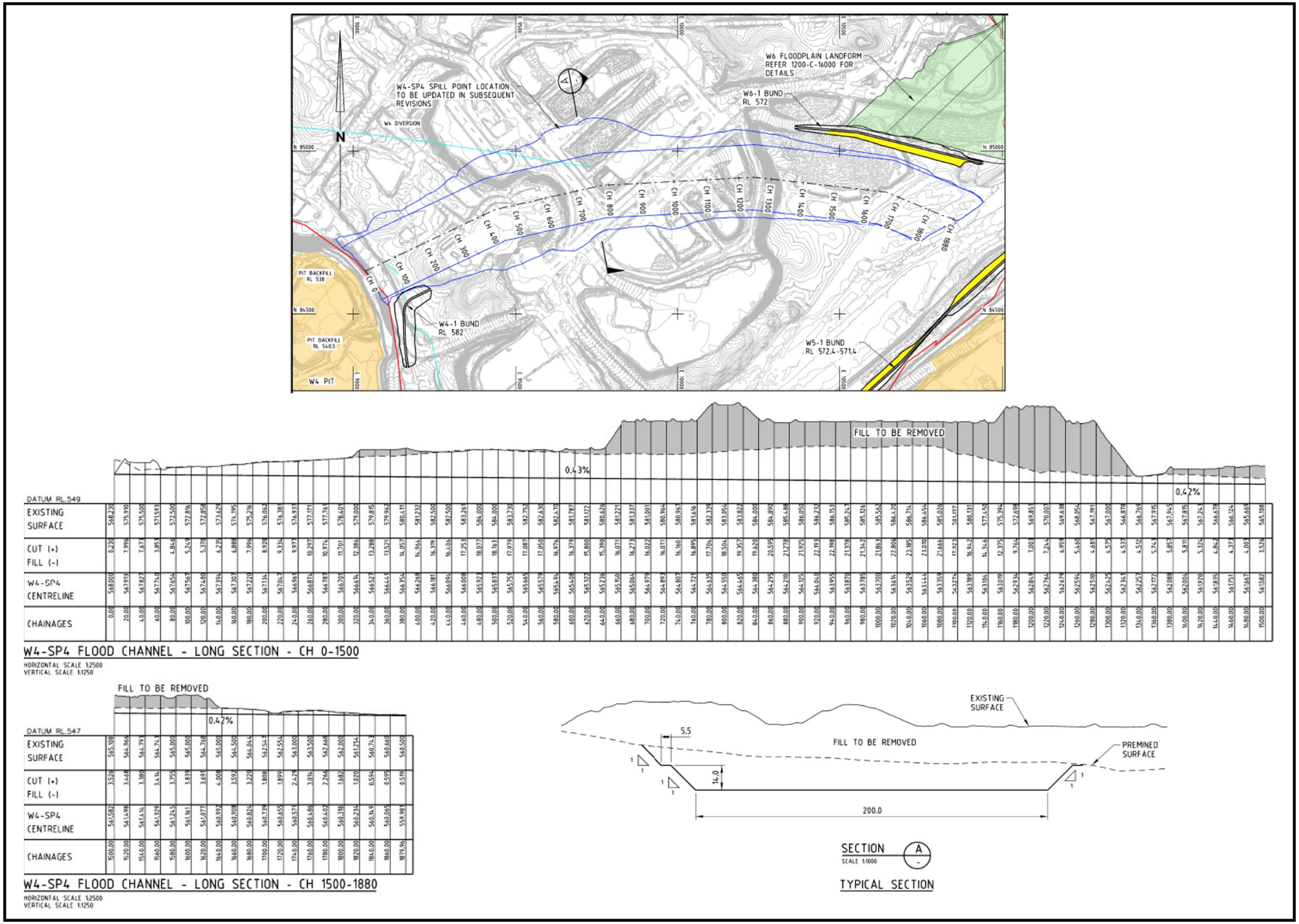
The maximum depth of cut will be ~25 m along the channel alignment. Cut depths vary from approximately (Figure 9-26) (Advisian, 2023f):

- 6 to 8 m below natural ground surface near the inlet.
- 10 to 15 m below natural ground surface from ~200 m from the inlet.
- ~20 to 25 m in a section of the channel ~800 to 950 m from the inlet before rapidly decreasing to less than 5 m for approximately the last 400 m before Marillana Creek.




Source: Advisian (2024a)

**Figure 9-25 Crest within W4-SP4 flood channel**




Source: Advisian (2024b)

Note: an expanded set of drawings is provided in Appendix P

**Figure 9-26 W4-SP4 flood channel - selected cross sections**

#### 9.2.4.2 Intermediate and minor creek diversions

The goals of the intermediate and minor diversion designs are to safely convey water around / across pits post-closure without loss to the pits. As discussed in Sections 5.14.9 and 5.14.10, several upgrades are required to existing diversions, and a new diversion (W4) requires construction (Map 9-3). Herbert's Creek land bridge and Lamb Creek (W3) diversion are both intermediate diversions and consequently must be designed to accommodate a 1:1,000-year event. The remaining diversions are minor diversions that must accommodate a 1:100-year event. Table 9-3 provides a summary of the current designs for the diversions and the modifications required for closure. As discussed in Section 5.14.9 and captured in the forward work program in Section 13.3, there is still work required to optimise these designs, including opportunities to achieve more natural looking systems, erosion and deposition processes and establishment of riparian vegetation. It should also be noted that changes to the backfill designs have the potential to impact these diversion designs.

**Table 9-3 Upgrades required to minor and intermediate diversions**

| Type | Diversion ID | Modification | Length (m) | Current Width (m) | Widening width | Maximum RL (mAHD) | Minimum RL (mAHD) |
|---|---|---|---|---|---|---|---|
| **Intermediate diversions** | | | | | | | |
| Existing | W3 | Widening | 2,390 | 50 - 100 | 140 | 580.0 | 570.9 |
| | Herbert's Creek | Given the changes to the overall surface water management designs, the closure design has yet to be developed, and further work will be conducted to develop designs through future design phases | | | | | |
| **Minor diversions** | | | | | | | |
| Existing | C1/2 | Widening and realignment | 800 | 20-30 | 30 | 564.8 | 562.0 |
| | C5* | Widening | 500 | 15-30 | 30 | 561.5 | 558.0 |
| | E3/5/6* | Widening | 1,200 | 12 | 48 | 542.9 | 536.8 |
| | E7 | Widening | 1,100 | 20 | 40 | 546.0 | 539.7 |
| | W1 | Modifications require further investigation following amendment to W1-SP0 alignment & design | | | | | |
| | W2* | Widening | 1,250 | 40 | 60 | 584.0 | 577.9 |
| | W5 East* | Widening | 3,350 | 35 | 65-70 | 584.8 | 555.9 |
| | W5 West | Widening | 1,150 | 20-30 | 40 | 570.8 | 566.1 |
| New | W4 | New Diversion | 2,700 | - | 35 | 585 | 575 |

Source: Advisian (2023f; 2024a)

*Notes: refer to Appendix P for drawings

#### 9.2.4.3 Flood bunds

The goal of flood bunds is to prevent surface water from entering pits in an uncontrolled manner during extreme rainfall events post-closure and resulting in creek capture and permanent diversion of water to the pits. Closure designs for the flood bunds have been informed by hydraulic modelling and geotechnical assessments (Section 5.14.8), and areas have been identified where the height of bunds needs to be increased, or additional rock protection provided to reduce the potential for erosion and creek capture (Table 9-4). Investigations have focused on the most significant bunds that pose the highest post-closure risk (i.e., those adjacent to pit crests along Marillana Creek) (Map 9-3). Detailed assessments of minor bunds (Appendix G.5) will be conducted in future design phases.

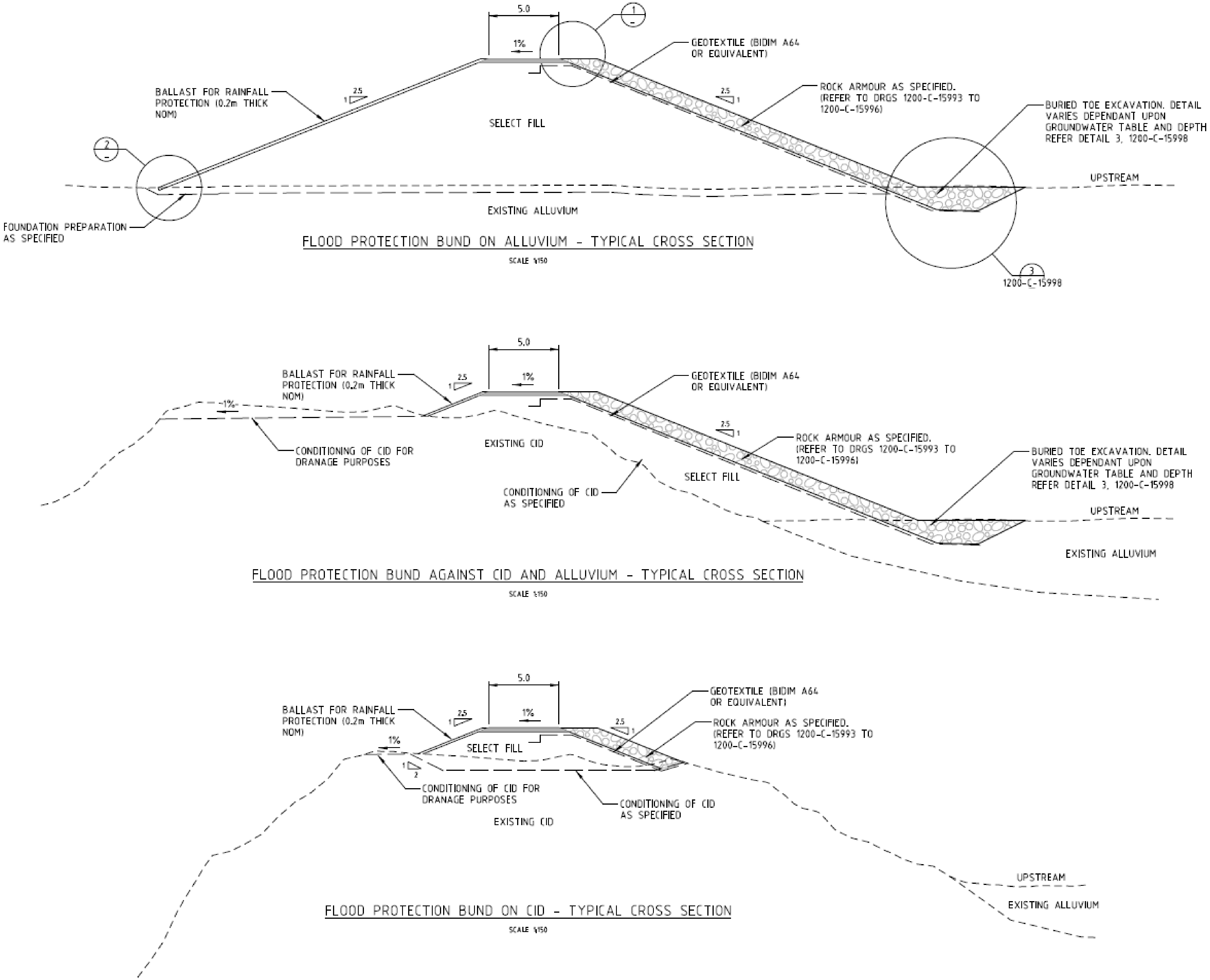
Typical cross sections of flood bunds constructed on different foundations are shown in Figure 9-27. Further cross sections showing upstream and downstream raises are provided in Appendix P.

**Table 9-4 New flood bunds and upgrades to existing flood bunds for closure**

| Name | New or upgrade | Design event (AEP) | Length (m) | Typical Height (m) | Rock Protection Size | Typical Scour Depth (m) |
|---|---|---|---|---|---|---|
| W4-1 | New | 1:10,000 | 345 | 12.0 | None | 1.0 |
| W5-1 | New | 1:10,000 | 1,365 | 6.0 | ¼ Tonne | 3.8 |
| W5-2 | New | 1:10,000 | 530 | 6.0 | None | 1.0 |
| W6-1 | New | 1:10,000 | 610 | 7.0 | Facing / Light / ¼ Tonne | 3.0 |
| C1/2 | New | 1:1,000 / 1:10,000 | 3,090 | 4.0 | None / ¼ Tonne | 1.5 |
| C5-1 | New | 1:10,000 | 305 | 7.0 | None | 2.0 |

| Name | New or upgrade | Design event (AEP) | Length (m) | Typical Height (m) | Rock Protection Size | Typical Scour Depth (m) |
|---|---|---|---|---|---|---|
| E1-1 | Upstream raise | 1:10,000 | 965 | 5.0 | Facing / ¼ Tonne | 2.5 |
| E1-2 | New | 1:10,000 | 120 | 7.0 | 2 Tonne / 4 Tonne | None |
| E1-3 | New | 1:10,000 | 140 | 5.0 | 1 Tonne | None |
| E1-4 | New | 1:10,000 | 495 | 7.0 | Light / None | None |
| E4-1 | Downstream raise | 1:10,000 | 1,275 | 9.0 | Light / None / Facing / ¼ Tonne / 2 Tonne | 3.0 |
| E4-2 | New | 1:10,000 | 2,510 | 12.0 | 1 Tonne / Light | 4.5 |
| E7 | New | 1:10,000 | 510 | 4.0 | ¼ Tonne / None | 2.0 |

Source: Advisian (2024a)




Source: Advisian (2024b)

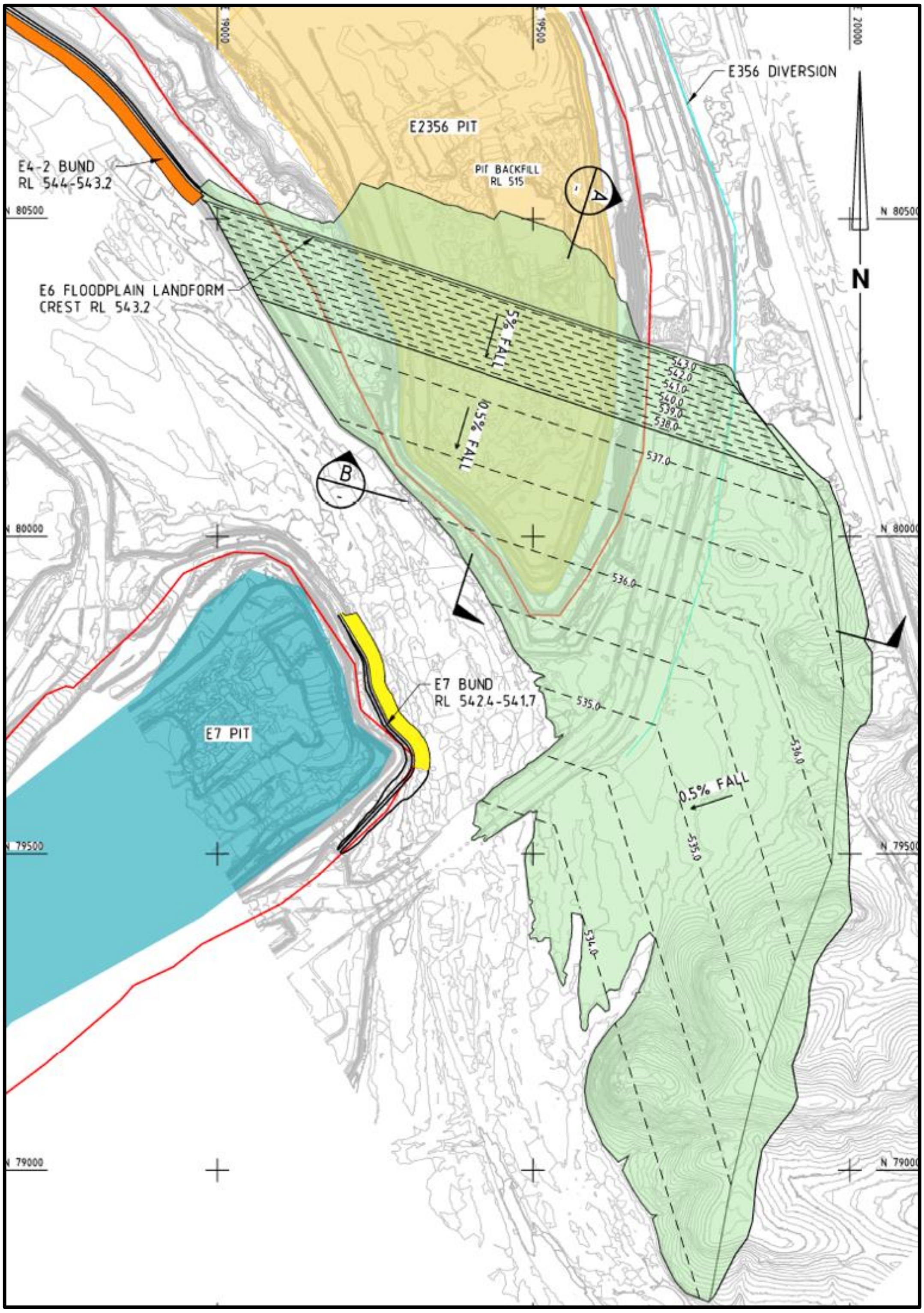
Note: An expanded set of drawings is provided in Appendix P

**Figure 9-27 Typical bund cross sections for different foundation conditions**

#### 9.2.4.4 Floodplain landforms

As discussed in Section 5.14.8, floodplain landforms have been introduced at W5, W6 and E6 pits to address deep flows and high velocities in constrained reaches of Marillana Creek between pits (Map 9-3). Further work is required to develop geotechnically and erosionally stable designs for these landforms and consider implications to Traditional Owner heritage sites and values (as captured in the forward work program in Section 13.3), however, conceptual drawings for the landforms are provided in Figure 9-28 to Figure 9-30.

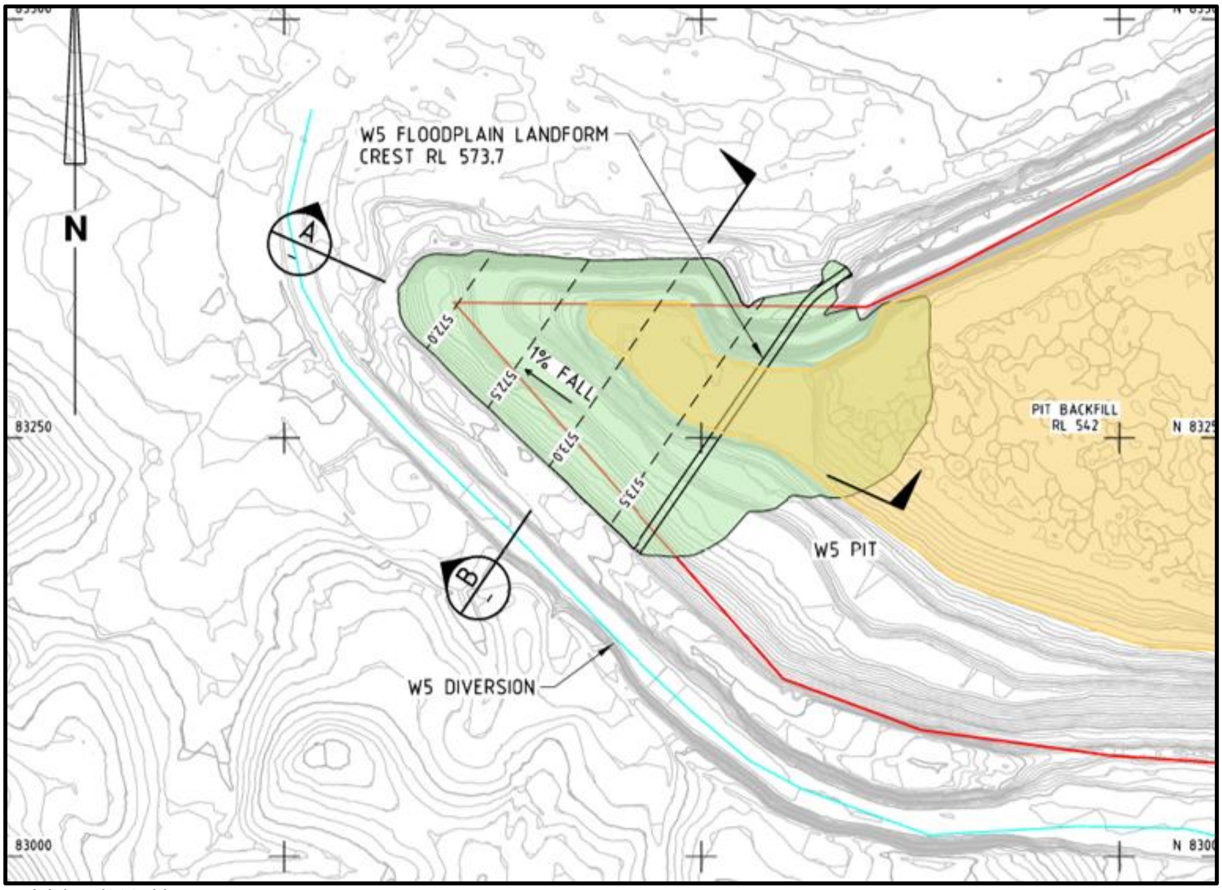
The material in floodplain adjacent to the mid-section of W5 Pit will also be removed as shown in Figure 9-31 to reduce flow velocities along this section of creek. The mined material will be removed to approximate pre-mining levels.




Source: Advisian (2024b)

Note: refer to Appendix P for original pdf drawing

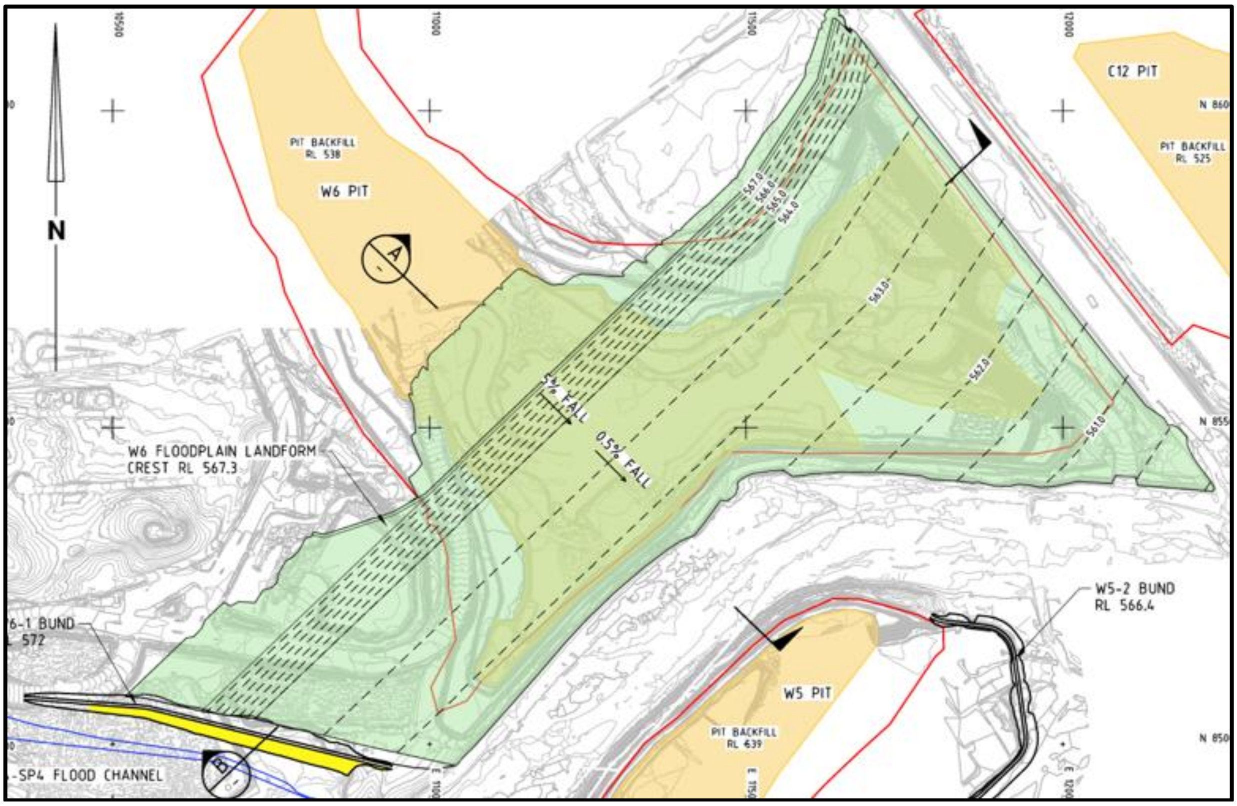
**Figure 9-28 Concept design of E6 floodplain landform**




Source: Advisian (2024b)

Note: refer to Appendix P for original pdf drawing

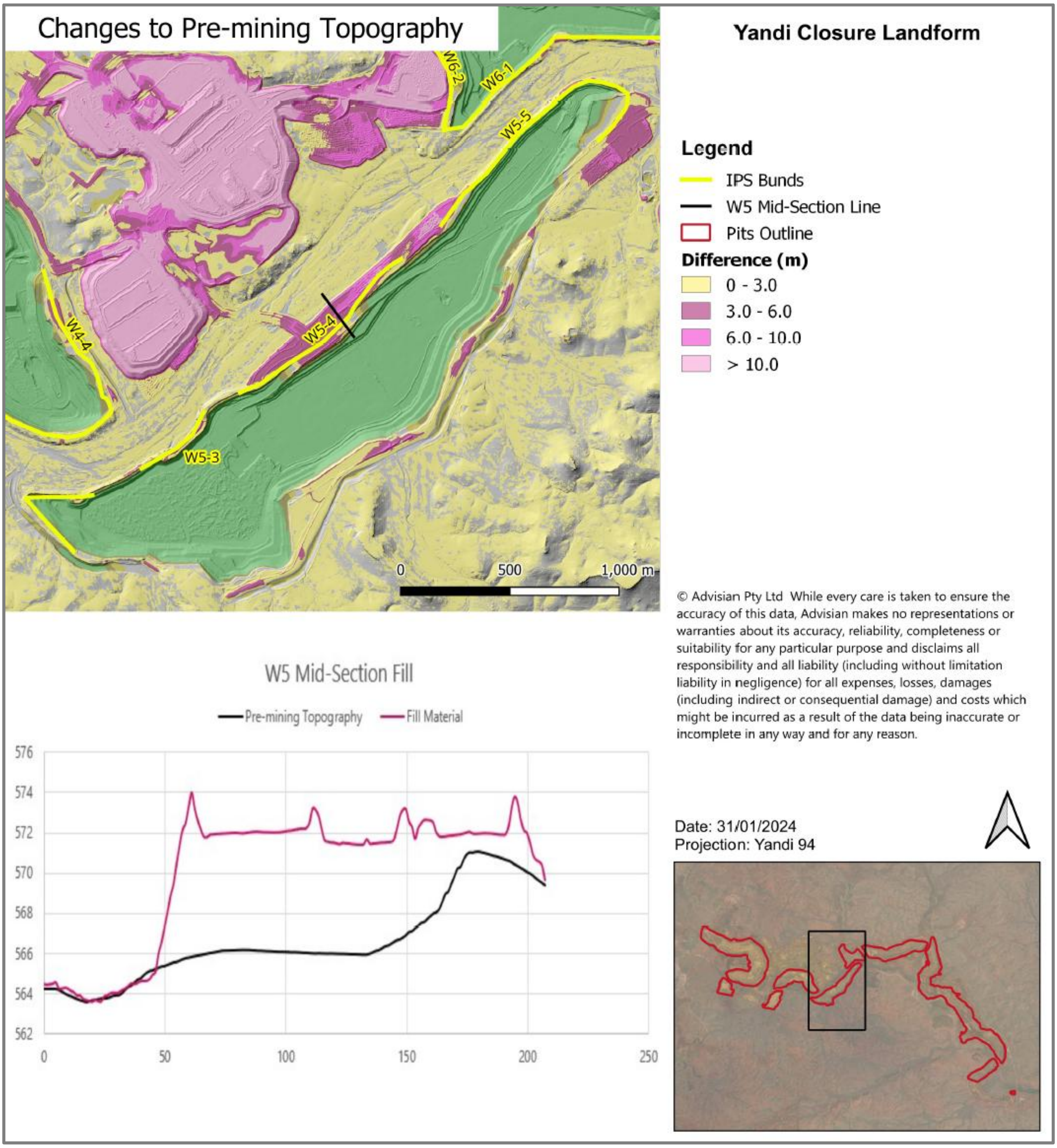
**Figure 9-29	Concept design of W5 floodplain landform**




Source: Advisian (2024b)

Note: refer to Appendix P for original pdf drawing

**Figure 9-30	Concept design of W6 floodplain landform**




Source: Advisian (2024b)

**Figure 9-31 Material to be removed to approximate pre-mining levels to widen floodplain**

## 9.2.5 Infrastructure, roads, rail and landfills

Since the 2020 MCP, BHP has conducted a review of infrastructure that would be required to support the processing of ore from satellite mines and would, therefore, need to be retained beyond cessation of current mining operations. The remaining infrastructure has either been scheduled for demolition in the period to 2026 or will be retained in accordance with an asset retention and maintenance plan for the next 5 to 10 years. This section summarises:

- General procedures for asset transfer (Section 9.2.5.1).
- The key assets to be retained to support processing of ore from satellite mines (Section 9.2.5.2).
- The Stage 1 demolition plan for the assets being removed to 2026 (Section 9.2.5.3).
- The asset retention and maintenance plan for the assets that will be retained for the next 5 to 10 years (Section 9.2.5.4).
- Decommissioning, demolition and rehabilitation of the airport and access road (Section 9.2.5.5).

- Rehabilitation of haul roads and tracks (Section 9.2.5.6).
- General decommissioning and demolition procedures for rail infrastructure (Section 9.2.5.7).
- Rehabilitation of waste management facilities (Section 9.2.5.8).

#### 9.2.5.1 Procedures for asset transfer

When infrastructure is confirmed as no longer required for future use, stakeholders including the State and adjacent landholders are consulted regarding their interest in the infrastructure. Where infrastructure is to be transferred to a third-party, a condition assessment of the infrastructure is conducted, and this is documented in the transfer agreement along with responsibilities for ongoing management and maintenance. Once the agreement is signed by both parties, the infrastructure is formally transferred to the new owner.

In preparation for the Stage 1 demolition, DJTSI, DMIRS (now DEMIRS) and the EPA were notified of the progressive decommissioning program (Section 4.3). A call for expressions of interest for surplus infrastructure was released to not-for-profit organisations, Aboriginal Community Controlled Organisations and Prescribed Bodies Corporate within the Shire of East Pilbara. Prior to releasing the call for expressions of interest, BHP consulted with the Shire of East Pilbara about the expression of interest process and the local government building and planning permit requirements. Applications were prioritised based on those that met the eligibility criteria, the purpose of the buildings being requested and the feasibility of delivering items to nominated locations. Infrastructure was donated to those organisations that met all of the pre-requisite criteria and were able to obtain the necessary shire approvals.

#### 9.2.5.2 Key assets required to support future operations

At a high level, the key assets required to support future operations are:

- OHP 3 and surrounding non-process infrastructure.
- Spinifex village and associated potable water bores.
- Eastern workshop.
- Train Load Out 2.
- Rail lines.

At completion of operations, these assets will be decommissioned and demolished in accordance with the general procedures outlined in Section 9.2.5.3.

#### 9.2.5.3 Stage 1 decommissioning and demolition plan

The Stage 1 decommissioning and demolition program is currently in progress. A snapshot of the status of the program is provided in Appendix O. At a high level, the program includes:

- Complete removal of Yandi village.
- Complete removal of the eastern fire response training centre.
- Selected unused assets at the Central Administration area with a high risk of degrading.
- Selected non-process assets at OHP 1 with a high risk of degrading and damaged assets at OHP 2.
- Removal of Iowa crusher.
- Removal of chutes at the Train Load Out 1 tunnel and the OHP 1 coarse ore stockpile tunnel.

Demolition plans assume that:

- All above ground infrastructure will be demolished, and:
  - Berms around building and parking locations will be bulldozed to a self-draining condition.
  - All overhead electrical and communications network poles will be dismantled. Poles and anchors will be pulled out of the ground and all cables removed.
  - All exterior lighting poles and bases will be removed from the ground. The extent of the removal will be determined based on future needs, and near-term and final landform requirements.
  - All guide rails and truck and heavy equipment tyres along roadways and in lay-down areas will be removed and either recycled or disposed of.
- Buried infrastructure will generally be removed to a minimum depth of 600 mm below ground surface, to allow for backfilling and grading of the site to a self-draining condition. The extent of slab and foundation removal will be determined based on future needs, and near-term and final landform requirements. Final depths of infrastructure removal may be greater if required due to site specific conditions or risks, or agreements with stakeholders. Below ground service infrastructure encompasses:
  - Electrical lines (high voltage and on-site distribution network at various voltage levels);
  - Communications lines;
  - Fibre optic cables and infrastructure;
  - Fuel delivery infrastructure, fuel islands and fuel tanks;
  - Other process services between buildings and infrastructure (air, instrument air, steam, process water);

  - Process water infrastructure;
  - Mine dewatering infrastructure;
  - Potable water filtration plants;
  - Potable water infrastructure and distribution networks;
  - Sanitation infrastructure; and
  - Storm water management infrastructure (if applicable).
- Infrastructure associated with dewatering will be removed and the water bores will be capped in accordance with the requirements of the relevant government administering authority and NUDLC (2020).

The approach to decommissioning and demolition follows a similar sequence of events for all buildings and infrastructure, as summarised in Table 9-5.

**Table 9-5 Decommissioning and demolition sequence**

| Item | Task | Description |
|---|---|---|
| 1 | Work area delineation[63] | Installation of barriers around the work site to provide a working environment delineated from the other site activities. |
| 2 | Decommissioning[63] | • Removal of dangerous goods and flammable liquids (fuels, greases and oils). These items may be used for other purposes, resold back to the provider, or disposed at licensed waste facilities.<br>• Removal of salvageable materials.<br>• Removal of contents that could be used at other locations, adaptively reused, or sold. |
| 3 | Zero energy state / cold and dark | Each demolition area will be brought to a zero-energy condition, which will include, as necessary:<br>• Positioning equipment in a zero potential energy state.<br>• Electrical service isolation and air-gapping of in-feed conductors at transformers, switch gear and / or pull boxes.<br>• Cutting and capping of water services and sewer services.<br>• Isolation of storm water management infrastructure around the demolition area.<br>• Removal / isolation of communications and fibre optic networks.<br>• Removal / isolation of other site services such as air, process water.<br>Consideration is given to potential interdependencies which need to be addressed. |
| 4 | Documentation of zero-energy state | The documentation outlines the existing interdependencies including any infrastructure / service protections that may be required, and where they are to be constructed. |
| 5 | Confirmation of zero-energy | Decommissioning and zero energy state compliance checked by BHP or nominated client representative. |
| 6 | Removal of interior contents | Removal of all contents from inside the structure without damaging or disturbing potential asbestos-containing materials (if applicable) or other designated substances identified. |
| 7 | Abatement of hazardous building materials or process substances | Removal of all hazardous building materials or process substances from the building including:<br>• Removal of any cooling oils from transformers (as necessary)<br>• All fuel removed from tanks and delivery piping, sludges removed from tanks, fuel filtration systems removed and disposed. All tanks and lines washed. |
| 8 | Structural demolition to grade | Structural demolition of buildings and structures using excavators. |
| 9 | Removal of slabs and foundations | • Break up and removal of concrete slabs and foundations, footings and floor slabs of buildings with basements.<br>• Foundations will generally be demolished / removed to a minimum depth of 600 mm below ground surface (or greater depth if required by a risk assessment or agreement with stakeholders), to allow for backfilling and grading of the site to a self-draining condition. |
| 10 | Backfilling / site grading | Backfilling of residual voids with inert overburden from the site in 300 mm lifts; nominally compacted to approximately 95% Standard Proctor Maximum Dry Density. All areas are to be left in a self-draining condition to minimise the risk of long-term ponding post-closure. |
| 11 | Final clean-up | Removal of any final debris (75 mm or larger). |

[63] Decommissioning and zero energy state / cold and dark steps may need to be done in reverse order

An assessment of hazardous materials was conducted by GHD (2022) during detailed demolition planning and recommendations made for management during demolition. The waste categories associated with demolition and associated waste management plan are outlined in Table 9-6.

**Table 9-6 Demolition waste categories and waste management plan**

| Potential waste stream | Description | Disposal plan |
|---|---|---|
| Structural steel | • Structural steel (heavy, light, shred)<br>• Non-ferrous (copper, aluminium) | • Structural steel - salvage and off-site recycling |
| Concrete | • Steel reinforced cast in place and precast concrete structures, foundations, footings, interior and exterior slabs, core slabs, cast in place structure elements<br>• Concrete masonry units - block walls, footpath etc. | • ~70% crushed to less than 250 mm, protruding reinforcement removed, concrete cleaned and reused<br>• ~30% disposed to inert on-site inert landfill in accordance with the Part V environmental licence (Section 3.2) |
| Miscellaneous demolition waste | • Wood / plywood / mixed wood such as interior wall partitions, wood structures and sheds, exterior wood cladding, shelving, core boxes, interior finishes, etc.<br>• Windows<br>• Painted / laminated wood in counters, wooden and laminate office furniture and lab installations, cabinets, etc.<br>• Plastics<br>• Particle board / tile used for interior finishes and in bathrooms<br>• Brick (clay based) products such as terracotta block, speed block, clay based exterior brick veneers<br>• Mixed debris / demolition waste<br>• Interior contents of buildings which are removed prior to structural demolition and segregated from demolition waste and building debris | • Disposal to on-site putrescible landfill in accordance with the Part V environmental licence (Section 3.2) |
| Contaminated soils | • Predominantly assumed to be hydrocarbons and PFAS as identified locally during demolition to require removal and remediation | • Hydrocarbons to be remediated in on-site land farm in accordance with the Part V environmental licence (Section 3.2).<br>• Other contamination will be assessed and disposed to an appropriately licensed landfill on-site or off-site. |
| Hazardous materials | Minor quantities of<br>• Asbestos containing materials<br>• Lead based paint systems<br>• Synthetic mineral fibre<br>• Polychlorinated biphenyls | • Disposed to an on-site or off-site landfill licensed to accept the material to be disposed. |

Following the removal of infrastructure, the land will be re-profiled to a self-draining condition and local drainage re-instated. Additional surface treatments and rehabilitation works will be implemented in accordance with the standard rehabilitation procedures / techniques described in Section 9.1 and the area will be revegetated as an ex-pit area, as described in Section 9.3.

#### 9.2.5.4 Asset retention and maintenance plan

At a high level, the key assets that may be retained for 5 to 10 years in accordance with an asset retention plan are:

- OHP 1 and remaining non-process infrastructure[64].
- OHP 2 and associated non-process infrastructure[64].
- Train Load Out 1.

BHP manages assets in accordance with its Asset Integrity Management Standard (BHP, 2023a) and Asset Integrity Management System Procedure (BHP, 2022a). These outline requirements for identifying critical equipment (defined *inter alia,* as structures with a high safety risk) and conducting regular inspections and management of identified defects. Under these procedures, a detailed asset integrity inspection will be conducted every five years following decommissioning of the Yandi structures to a zero-energy state. Should the results of the first inspection indicate that demolition of some structures should proceed sooner than ten

[64] At the time of writing, plans were being progressed to demolish these assets sooner (potentially FY26).

years, then a detailed demolition plan will be developed and executed for those structures following the inspection. Demolition plans for the remaining infrastructure will be developed after ten years. Demolition will be conducted in accordance with the general procedures outlined in Section 9.2.5.3.

In addition to the five yearly detailed asset integrity inspections, general inspections will be conducted on a 2-yearly basis and, based on the outcomes of these inspections, the ongoing interval for various care and maintenance activities (Table 9-7) will be determined according to observed deterioration rates and a risk assessment. The maintenance interval may also need to be varied in case of unforeseen events (for example high wind, cyclone or heavy rain). More detailed inspections may be warranted at a longer interval should the condition of the plant warrant this.

Ongoing inspections will check that structural areas are not compromised by the accumulation of rainwater that could accelerate corrosion rates, and accumulations of dust and dirt around footings will be cleaned. All defects will remediated or barricaded off if not remediated. All platforms, walkways and access areas will be checked and made safe where they need to be accessed for ongoing inspections or demolition activities.

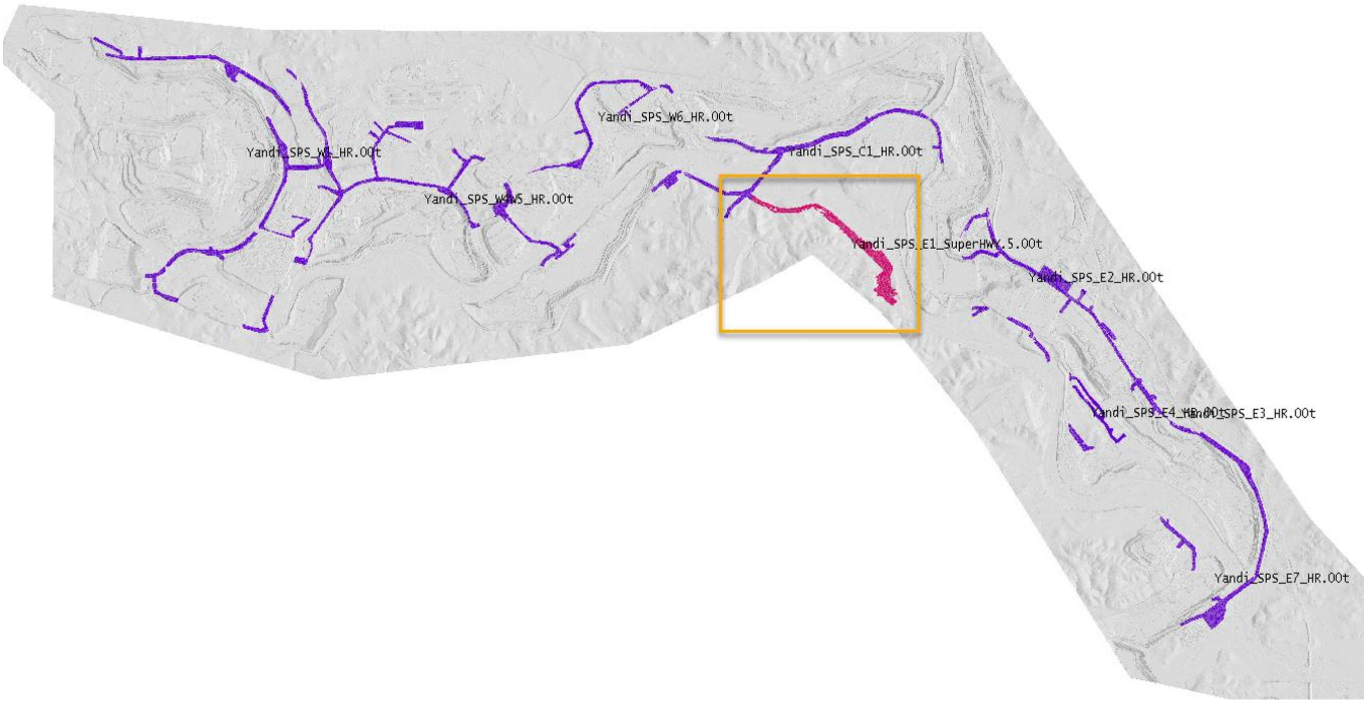
It is anticipated that the majority of inspections can be carried out as visual inspections from the existing accesses and walkways. This differs from the close visual inspection methodology used for the detailed five-yearly asset integrity inspection program. It is possible that over time, due to deterioration rates, some areas of the structures that are not accessible will need closer inspection which may require the use of an elevated work platform and / or a drone inspection.

#### 9.2.5.5 Decommissioning, demolition and rehabilitation of airport and access road

As discussed in Section 2.3, the airport and associated access road are jointly owned with RTIO. Plans for decommissioning, demolition and rehabilitation of this infrastructure will, therefore, need to be developed with consideration to RTIO requirements. At this stage, both organisations need the infrastructure to support ongoing operations beyond the life of the Yandi mine. It is expected that prior to closure, stakeholders will be consulted about their interest in the infrastructure, and the asset will either be transferred in accordance with the general processes outlined in Section 9.2.5.1, or decommissioned and demolished according to the general procedures outlined in Section 9.2.5.3. Following demolition, the area will be re-profiled and rehabilitated generally according to the procedures outlined in Section 9.1.

#### 9.2.5.6 Rehabilitation of haul roads and tracks

Material used to construct haul roads above grade (Map 9-4) will be recovered and the area re-profiled to resemble the surrounding area. Recovered material will be rehandled to pits as backfill. At the time of writing the E1 Superhighway (refer to pink highlighting on Map 9-4) was being recovered. Once reprofiled, the areas will be rehabilitated generally according to the procedures outlined in Section 9.1.




**Map 9-4 Haul roads material to be recovered and rehandled to pits**

**Table 9-7 Care & maintenance activities**

| Equipment / Structure / Service | Maintenance Plan | Activities | Resource | Record |
|---|---|---|---|---|
| Tanks | Periodic Plan | Inspect all tanks and supporting structures. Inspect structural integrity of steelwork, cladding and hold down bolts.<br>Inspect integrity of covers of underground tanks. | Structural engineer | Condition / integrity records |
| | Corrective Plan | Repair as required. | Contractor | - |
| Concrete | Periodic Plan | Inspect condition of concrete supports and pedestals and compare to condition as per previous inspections. | Structural engineer | Register & photos |
| | Corrective Plan | As required - remove the cracked and damaged concrete, clean up, clean and coat exposed reo bar, inspect the anchor bolts for corrosion - repair as per BHP standards. | Contractor | - |
| Stacker | Periodic Plan | Carry out inspections of stacker stay cables as per Australian Standard AS 4324.1. | Competent structural engineer | Register & photos |
| | Corrective Plan | Repair as required. | Contractor | - |
| Retaining walls | Periodic Plan | Inspect integrity of mechanically stabilised earth walls and shotcrete retaining walls. | Structural engineer | Register & photos |
| | Corrective Plan | Remediate where necessary. | Contractor | - |
| Buildings, shipping containers and shade structures | Periodic Plan | Inspect integrity of buildings and security and ensure that all cladding is secure. Inspect roof covering of dome structures. | Structural engineer | Register & photos |
| | Corrective Plan | Repair as required. | Contractor | - |
| Electrical infrastructure | Periodic Plan | Inspect electrical cabinets to check that they are closed and the integrity of structure / cladding. | Structural engineer | Register & photos |
| | Corrective Plan | Repair as required. | Contractor | - |
| Steel Structures i.e., conveyors, transfer stations, ROM Bins, crane and monorail etc. | Periodic Plan | Inspect structures and compare to previous inspection. Document any deterioration that has advanced, inspect for objects that have become a risk of falling (dropped objects). Assessment and follow-on actions will follow relevant BHP standards.<br>Ensure that sumps are not flooded to a level that would affect the structure.<br>Ensure that there is no build-up of dust around footings. | Structural engineer | Register & photos |
| | Corrective Plan | Repair / re-coat as required.<br>Remove (pump out) accumulated water. Remove accumulated dust. | Contractor | - |
| Fencing / barricading | Periodic Plan | Inspect condition of fencing to ensure that a secure perimeter is maintained around the secured location.<br>Inspect barricading to ensure integrity. | Mechanical technician | Register & photos |
| | Corrective Plan | Repair / replace fencing as required. | Contractor | - |
| Signage | Periodic Plan | Inspect signage as per the register. Ensure, condition, security and legibility. | Mechanical technician | Register of signage |
| | Corrective Plan | Repair / replace as required. | Contractor | - |

| Equipment / Structure / Service | Maintenance Plan | Activities | Resource | Record |
|---|---|---|---|---|
| Accesses and walkways | Periodic Plan | Inspect accesses and walkways and compare to previous inspection. Document any deterioration that has advanced. | Structural engineer | Register & photos |
| | Corrective Plan | Repair / replace as required. | Contractor | - |
| Tunnels | Periodic Plan | Train Load Out Tunnel - periodic structural inspections of concrete tunnel.<br>Conveyor tunnel - ensure that tunnel is not flooded. Check integrity of tunnel walls. Ensure that tunnel drainage is not blocked. | Structural engineer | Register & photos |
| | Corrective Plan | Remove build-up of water (pump out). Repair as required. | Contractor | - |
| Power, lighting and communication poles | Periodic Plan | Inspect structural integrity. | Structural engineer | Register & photos |
| | Corrective Plan | Repair as required. | Contractor | - |
| Cladding | Periodic Plan | Inspect cladding for looseness or areas that have the potential to become loose. | Structural engineer | Register & photos |
| | Corrective Plan | Remove or secure cladding. | Contractor | - |

#### 9.2.5.7 Rail infrastructure

Should the State or other stakeholders not wish to take ownership of the rail lines:

- Decommissioning plans will be prepared to guide the safe decommissioning, demolition and removal of all fixed site assets in accordance with the *Rail Safety National Law WA (2015) Act* and associated regulations. In-ground infrastructure >0.6 mbgl will remain unless a risk assessment indicates that removal to a greater depth is required, or a different standard is agreed with stakeholders.
- Rail ballast and sleepers will be managed during closure in a similar manner to how used ballast and sleepers removed during operational maintenance activities are managed. As outlined in BHP's Code of Practice for Track Maintenance Standard (BHP, 2018), this includes testing for contamination prior to identifying a disposal pathway. Material identified as Class 3 or 4 waste is disposed off-site. Class 1 or 2 materials are disposed in BHP rail quarries with the appropriate licence receive ballast. The management strategy at closure will be informed by the waste classification guidelines in force at the time of decommissioning (currently DWER (2019)). Other materials will be broken up / placed within areas of general backfill or buried in-situ to a minimum depth of 1.5 m below the rehabilitated surface.
- Rail corridors will be reprofiled to blend in with surrounding topography. Batter angles will reflect the angle of the surrounding slopes to a maximum of 3:1. Portions of rail embankments and culverts will be removed, where necessary. The decommissioning of rail corridors will involve consideration of the design discharge, durability and long-term stability of culverts and other surface water management measures. Rail embankments will be removed, or surface water management measures enhanced if the existing embankment would result in significant adverse impacts on surface water drainage or quality in the long term.

#### 9.2.5.8 Waste management facilities

Landfills will be covered with a suitable depth of overburden material (at least 1 m) which includes filling excavations to the level of the surrounding ground. The cover will be profiled to a free draining landform and will be rehabilitated in accordance with the procedures outlined in Section 9.1.

## 9.3 Yandi revegetation strategy

Golder (2020b) developed a preliminary revegetation strategy for Yandi which was reported in the 2020 MCP. This was reviewed and, where relevant, was refined by Okane (2024b) to reflect updated information arising from the Yandi closure studies reported in this MCP. The strategy will be progressively refined based on consultation with BNTAC and the Banjima people, and the outcomes of further design studies and trials.

#### 9.3.1.1 Topsoil and growth media strategy

Given there is an estimated topsoil deficit of approximately 2.2 $Mm^3$ (Table 5-21, Section 5.3). Golder (2020b) proposed that topsoil application be prioritised for use in ex-pit areas since ex-pit areas are typically less disturbed than the backfilled open pits, with intact lower subsoil profiles. However, a series of trials are planned to test different growth media mixes to enable this strategy to be tested and refined (Section 5.15.7). The trial will be implemented in FY25, and based on the outcomes of the trial, appropriate growth media mixes will be defined for each domain and incorporated into material movement scheduling.

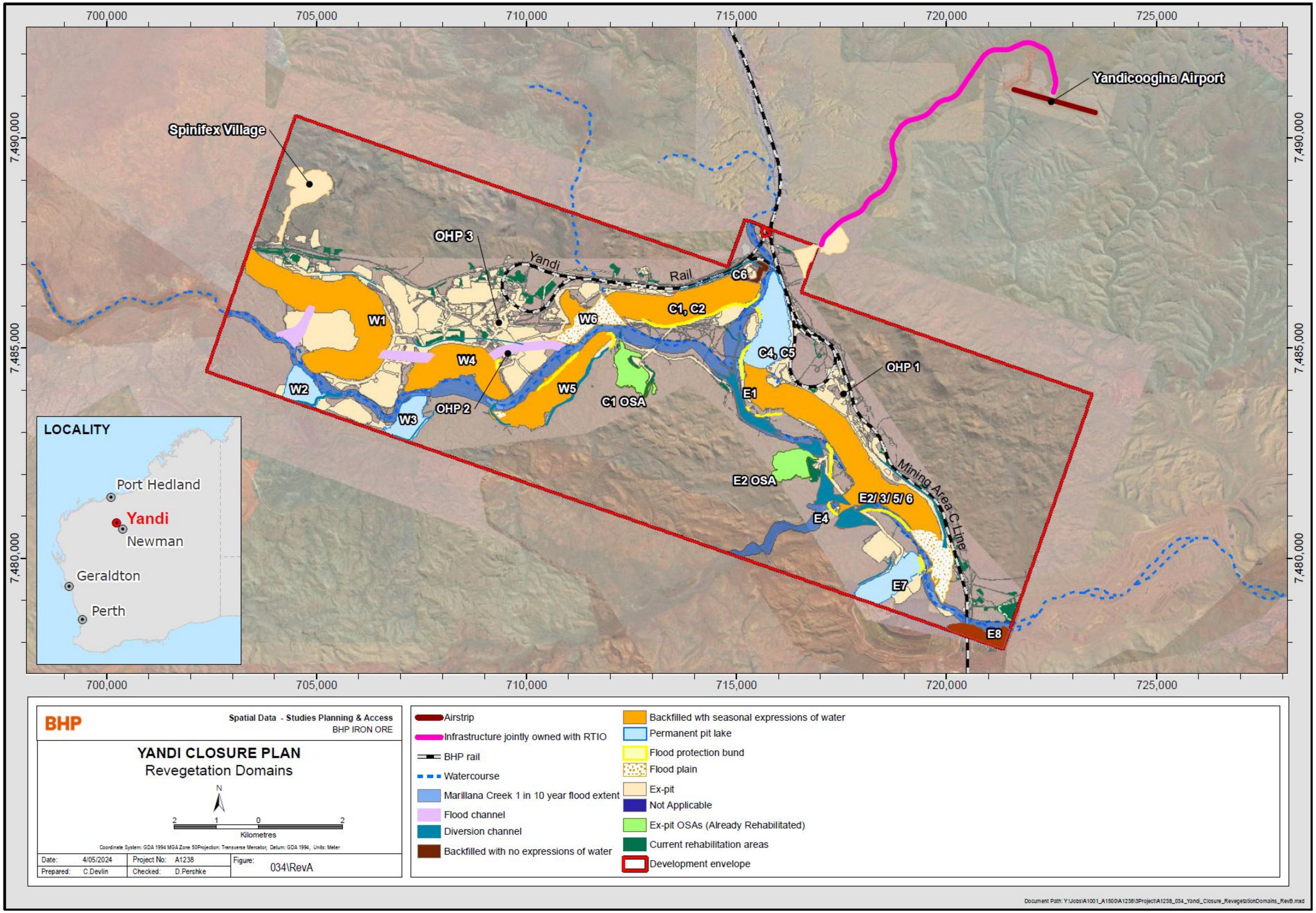
#### 9.3.1.2 Revegetation

Since the 2020 MCP, further work has been done to define a backfill strategy for Yandi which minimises the salinity footprint in the landscape (Section 5.14.1). The revegetation strategy outlined below has been based on the backfill designs outlined in Section 9.2.3.1, but it is noted that the strategy may change following further consultation with BNTAC and the Banjima people.

The key revegetation domains are (Map 9-5):

- Marillana Creek diversions and other surface water diversions.
- Backfilled pits.
- Ex-pit areas including OSA, ROM, stockpile and infrastructure footprints.

Each domain is discussed in further detail in the subsections below. At this stage of the design, the revegetation plan is high-level and will be refined as closure designs and returning groundwater levels are more fully defined.




See Appendix Q for a pdf version of this map

**Map 9-5 Revegetation domains**

#### Marillana Creek diversions and other surface water diversions

Creek diversions will be revegetated where the geomorphology of the diversion is appropriate to the establishment of vegetation.

Revegetation of the E1 and E4 Marillana Creek diversions has been achieved through natural recruitment of vegetation via seasonal flows and seeding / selected tube stock placement on flood benches away from the main channel. Monitoring has indicated that vegetation is successfully returning to the diversion (Section 5.15.3) and inspections of Herbert's Creek land bridge, and W4 and C5 diversions have identified passive recruitment of vegetation in other constructed operational diversion channels (Section 5.14.10 and Appendix M.2). Ongoing monitoring of these structures will inform the future revegetation strategies for these areas. The indicator species targeted for the E1 and E4 Marillana Creek diversions are outlined in Appendix M.4.1.

#### Backfilled pits

Backfilled pits are categorised into two categories; those expected to experience seasonal expressions of water and those which are not (Map 9-5). '*Backfilled pits with no seasonal expressions of water*' are not expected to be able to use groundwater as a water source for vegetation due to the vertical distance between the anticipated returning groundwater level and the final backfill surface level. *'Backfilled pits with seasonal expressions of water'* are expected to have access to groundwater with possible seasonal ponding (from rainfall and flood channels) in the long-term, however, the timing for groundwater rebound in in-pit areas is estimated to be in the order of decades to a hundred years. Should timing be towards the longer term, then revegetation strategies for these areas will need to plan for terrestrial vegetation communities, based on the groundwater level at the time of planting, with an expectation that the communities will adapt to shallower groundwater and evolve to riparian ecosystems in the future (Okane, 2024b).

The revegetation strategy for (Okane, 2024b):

- **Backfilled pits with seasonal expressions of water** (W1, W4, W5, W6, C1/2, E1-6) is grass, shrub, and low tree steppes in staged zones with varying access to surface and groundwater, and riparian woodland in around seasonal water.
- **Backfilled pits with no seasonal expressions of water** (C6, E8W, E8E) is grass, shrub, and low tree steppes in staged zones with varying access to surface and groundwater.

Key indicators for these vegetation communities are outlined in Appendix M.4.2 and the seed mixes in Appendix I.1.

Conceptually, the various features included in the pit backfill designs outlined in Section 9.2.3 may be revegetated as follows (Okane, 2024a; 2024b):

- Pit backfill surfaces - native grasslands with shrubs at low to medium density.
- Perimeter benches - native tree species in low density.
- Seasonal ponds - native grasslands with scattered trees, occasional shrubs and grasses in understory with seasonal wetland species. If there is permanent standing water, more native reeds and sedges will (naturally) establish.
- Alluvial bars - native grasslands with scattered trees and some shrubs on alluvial bars.
- Energy dissipation apron - rocky outcrop possibly with standing dead wood and some native trees.
- Embankments - grasslands, scattered trees, and rocky outcrops.

*Pit walls*

While some trees have naturally established on pit walls where groundwater seepage is occurring (Section 5.15.5.2), specific rehabilitation / revegetation for pit walls (other than laybacks and buttresses) is not considered to be safe or practical based on-site observations.

Vegetation strategies for pit laybacks and buttresses require further investigation.

#### Ex-pit (including OSA, ROM, stockpile, infrastructure and camp footprints, roads / tracks, rail, landfill)

Ex-pit areas will be revegetated to grass and shrub steppes based on topographical zones (Okane, 2024b) refer to Appendix M.4.2 and Appendix I.1.

## 9.4 Implementation schedule

The schedules outlined in this section relate to areas that have not yet been rehabilitated. Map 2-2 (Section 2.3) shows areas that have been disturbed to date, and those that have been rehabilitated.

### 9.4.1 Development of detailed closure design

As discussed in Section 1.4, the Yandi SPS has been put on hold at the request of BNTAC / Banjima. The remainder of the study will be re-scoped and scheduled pending the outcomes of consultation with BNTAC / Banjima and finalisation of future mining options.

The intent of the SPS is to optimise the preferred closure alternative to enable the alternative to progress to detailed design. BHP has a rigorous process for reviewing the outcomes of each project study phase before allowing it to progress to the next stage. This process includes an Independent Peer Review (IPR) conducted by technical specialists relevant to each key discipline considered by the study.

Once the reviewers are satisfied that the SPS adequately addresses all key factors relevant to the closure of Yandi, the study will progress to DPS which will fully define the selected closure option to an executable design.

### 9.4.2 Life of asset overview

Table 9-8 provides an overview of the proposed schedule of closure works, including progressive closure over the remaining life of mine. The implementation schedule will be further refined as closure planning progresses.

**Table 9-8 Yandi mining operations closure implementation schedule**

| Domain | Feature | Completion timing[65] |
|---|---|---|
| OSAs / mine voids | Progressive backfill / buttressing within selected mine voids through to mining completion in FY32. | 2032 |
| | Closure backfill / buttress rehandle from OSA to mine voids | 2037 |
| | Rehabilitation | 2040 |
| | Safety bunds | 2041 |
| Infrastructure | Stage 1 decommissioning, demolition & rehabilitation | 2023 - 2026 |
| | Stage 2 decommissioning, demolition & rehabilitation | 2028 - 2032 |
| | Final decommissioning, demolition & rehabilitation | >2042 |
| Surface water infrastructure | Flood channels | 2041 |
| | Creek diversion and flood bund upgrades | 2037 |
| Infrastructure jointly owned with RTIO | Airport and road to the airport. | Subject to consultation with RTIO |

### 9.4.3 5-year plan

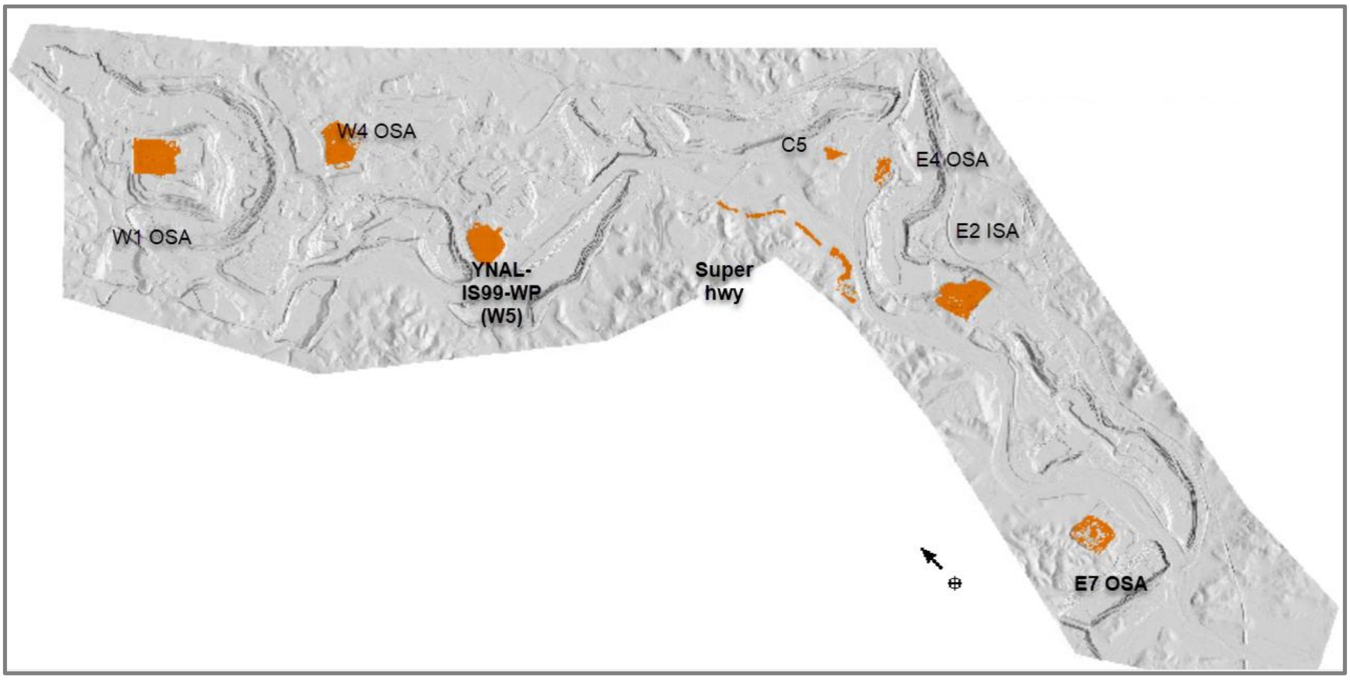
The Yandi five-year rehabilitation plan is updated annually as part of the CAP process (BHP, 2023b) outlined in Section 1.5. It is developed to align with the five-year mine plans and identifies no-regret areas available for final landform earthworks and rehabilitation within the five-year period.

The Yandi five-year plan mostly focuses on infrastructure removal and backfilling of the pits as this needs to precede the rehabilitation of most ex-pit areas (Table 9-9).

**Table 9-9 Yandi five-year plan summary**

| Activity | FY24 / FY25 | FY26 | FY27 | FY28 | FY29 |
|---|---|---|---|---|---|
| OSA reclaim for backfill / buttressing (see Map 9-6 for locations) | W1, W4, W5, Super Hwy, C5, E2, E7 | W5, E2 | W5, E2, W1 | W5, C5, E2, E4, W1, W4 | E4, W1, E7 |
| Stage 1 infrastructure demolition & rehabilitation | Demolition of Fire Training Area<br>OHP 1 - non-process infrastructure (complete)<br>Yandi Village (complete)<br>Eastern Workshop (partial removal)<br>Old Admin | Demolition of IOWA crusher, Central Administration.<br>Demolition of OHP 1, OHP 2 & workshops is also under consideration.<br>Progressive rehabilitation of W0 laydown, W1 landfill, W5 LGBG, W2 OSA | Progressive rehabilitation of OHP 1, KFC, W4, E1 perimeter, BGC laydown | Progressive rehabilitation of Yandi Village golf course & firebreak, W1NE topsoil footprint, E356 SE corner, OHP 1 belt yard, E4 creek diversion remediation | Progressive rehabilitation of TLO 1 loop road, Tango 56 base |
| Construct rehabilitation trial | Okane topsoil trial<br>CRC TiME Project 4.6 on climate adapted seed | | | | |

65 Timing reviewed annually with directional mine plans




**Map 9-6** **Five-year plan locations of material to be reclaimed for backfill**

## 9.5 Unplanned or unexpected closure

BHP is required to review a range of risks associated with the closure of its facilities annually, as assessed using the risk processes described in the Risk Management Global Standard (BHP, 2023f). One of these risks is unexpected or unplanned closure. In the event that unplanned or unexpected closure occurs:

- The closure designs will be finalised, based on the forward work program outlined in Section 13.3 which includes consultation with BNTAC and the Banjima people.
- The site will be decommissioned and rehabilitated in line with the objectives outlined in this document and with consideration of BHP's commitments under the Marillana State Agreement and the broader BHP Iron Ore operations across the Pilbara.

Annual cost provisioning for closure in line with the closure cost estimating methodology outlined in Section 11 provides an understanding of the current closure liability, with present closure obligation costs representing an unplanned or unexpected closure scenario.

# 10 Closure monitoring and maintenance

## 10.1 Monitoring program overview

Across its Pilbara mining operations, BHP has implemented monitoring programs to evaluate the performance of rehabilitated mine landforms and to assess whether they have met the site completion criteria or are showing satisfactory progress towards meeting these criteria. These programs will be expanded as new areas of the mine are rehabilitated and will be refined based on monitoring results and rehabilitation success.

Monitoring events will be undertaken in line with the processes outlined in this section, with the outcomes informing rehabilitation strategies, facilitating refinement of completion criteria, and directing maintenance and remedial action plans consistent with the adaptive management approach (Section 7.1), and demonstrating performance against completion criteria in preparation for rehabilitation sign-off.

In some instances, achievement of completion criteria would be verified by audit or inspection rather than by monitoring over a period of time. Section 10.1.1 provides further details of the means to verify achievement of these criteria.

### 10.1.1 Closure completion audit and inspection

Table 10-1 outlines those completion criteria (Table 8-2) that would be verified through a completion audit and inspection rather from the monitoring processes discussed in Sections 10.1.2 to 10.1.12. This section focuses only on completion criteria. Other interim audits and inspections will be conducted to confirm that planning and execution criteria are met.

**Table 10-1 Completion audits and inspections**

| Category | Completion Criteria | Means of Verification |
|---|---|---|
| C1.1 Post-closure land use | Monitoring, inspection and / or survey reports that the rehabilitation objectives have been substantially met. These are the measures that the post-mining land use has been met. | Completion audit of:<br>• Post-closure monitoring and survey reports.<br>• Post-closure land user / owner's written acknowledgement that rehabilitation objectives and completion criteria have been met. |
| | The current assumed land use is related to underlying tenure (pastoral) and achievement of the criteria for land management (C1.3), stability (C3.2 - C3.4), revegetation (C4 and water (C5) will indicate that this criterion has been met. | |
| C1.2 Infrastructure | Stakeholders agree to the transfer of infrastructure ownership and accept ongoing responsibility for maintenance of the infrastructure. | Completion audit of documented transfer of infrastructure to stakeholders. |
| | In-ground infrastructure has been removed to 0.6 mbgl unless (C):<br>• An alternate standard has been agreed with the post-mining landowner / manager.<br>• Risk assessment indicates that a different specification is required. | Completion audit of:<br>• Demolition contractor's report against agreed standard.<br>• Site inspection report following demolition. |
| C1.3 Land management | At the time mine closure is considered complete, site land management requirements are aligned to the post completion land use and / or approved closure strategy. | Completion audit of:<br>• Post-relinquishment land management plan.<br>• Closure strategy achieved as demonstrated by achievement of post-mining land use criterion C1.1 |
| | If additional management actions are required post-completion, these will have been agreed with the landowner / manager. | Completion audit of the documented agreement of additional active management measures required post-completion. |
| C2.1 Safety | Residual safety and health hazards have been identified and controlled in accordance with regulatory requirements and consideration of industry guidance and are acceptable to the District Mines Inspector (C). | Completion audit of the:<br>• Site inspection by the District Mines Inspector following execution confirming that all sites are assessed as acceptable. |
| | The geotechnical and geochemical stability criteria (C3.2 and C3.3) have been met (C). | Completion audit of the achievement of the geotechnical and geochemical stability criteria (C3.2 and C3.3). |
| C3.1 Visual amenity | Landforms meet visual design criteria. | Rehabilitation inspections / surveys confirm final landform has substantially met landform visual design criteria. |

| Category | Completion Criteria | Means of Verification |
|---|---|---|
| C3.2 Geotechnical stability | OSAs conform to DEMIRS guidelines for structural stability (DMIRS, 2019) and achieve design FoS criteria. | Completion audit of report on performance in relation to design criteria and DEMIRS guidelines (DMIRS, 2019). |
| | Mine voids conform to DEMIRS guidelines for structural stability (DMIRS, 2019) and achieve design FoS criteria. | |
| | Surface water infrastructure achieves design FoS criteria. | |
| C5.7 Contaminated sites | Contaminated sites classification issued by DWER is consistent with the post-mining land use. | Completion audit of DWER contaminated sites classification relative to agreed post-mining land use. |
| C5.8 Cultural values | Mine closure execution is substantially in accordance with designs for the protection of cultural values. | Completion audit of as constructed report relative to designs to protect cultural values. |
| | Cultural artefacts have been repatriated in accordance with stakeholder requirements. | Completion audit of confirmation by Banjima People representative that artifacts have been repatriated |

## 10.1.2 Rehabilitation monitoring

This section discusses the rehabilitation monitoring methodologies relevant to backfilled pits and ex-pit areas, excluding the E1 and E4 creek diversions, which are monitored according to the methodology outlined in the Marillana Creek Diversion Management Plan (BHP Billiton, 2016) summarised in Section 10.1.5.

### 10.1.2.1 Monitoring objective

Monitoring will be used to assess whether initial vegetation establishment has been successful, rehabilitation is developing satisfactorily and is ready for signoff. Monitoring of tree health and riparian vegetation is discussed in Section 10.1.6 as this monitoring pertains to monitoring of natural riparian vegetation communities rather than communities re-established through rehabilitation.

The completion criteria against which the results of the monitoring program outlined in this section will be assessed are outlined in Table 10-2.

**Table 10-2 Completion criteria relevant to rehabilitation performance assessment monitoring**

| Category | Domain | Completion criteria |
|---|---|---|
| C4.1 Growth media.<br>C4.2 Vegetation development.<br>C4.5 Fauna | Ex-pit areas (OSAs & OSA, ROM, stockpile, infrastructure footprints) | **Land use: Relatively natural environments for pastoral grazing purposes**<br>• % bare ground (Q):<br>- Hills, slopes, dry plains ≤50%.<br>- Drainage lines and floodplains (excluding channel bed) ≤20%.<br>• Perennial native species richness recorded in aggregated 50 x 50 m plot achieves target % for each target vegetation type (Appendix M.4.2) (Q).<br>• At least one dominant species from each stratum present (see Appendix M.4.2) (Q).<br>• >50% common species for the target vegetation type present (Appendix M.4.2) (Q).<br>• Plant cover achieves target % for each stratum and vegetation type (Appendix M.4.2) (Q) |
| | Backfilled pits | Rehabilitation of in-pit areas falls within the acceptable ranges defined for the novel ecosystems targeted for each area. Further work is required to investigate and define these criteria. |
| | Floodplains, minor & intermediate creek diversions | Rehabilitation of floodplains and minor and intermediate creek diversions falls within the acceptable ranges defined for the ecosystems targeted for each area. Further work is required to investigate and define these criteria and determine appropriate monitoring programs. |
| C4.3 Resilience (Reproductive Capacity) | All where revegetation is planned | Flowering and seed production observed in more than one native lifeform (Q).<br>Different aged plants observed for more than one native species and for all lifeforms (Q). |

### 10.1.2.2 Monitoring method and frequency

To maintain quality control at all stages of the rehabilitation processes (e.g. execution of rehabilitation works, maintenance and monitoring), activities will be completed in line with WAIO's suite of procedures (WAIO, 2024a; 2023b; 2022b) which provide guidance on aspects such as:

- Rehabilitation audit and inspection during execution;
- Rehabilitation data capture; and
- Rehabilitation monitoring.

Rehabilitation monitoring is conducted generally in accordance with WAIO's Rehabilitation Monitoring Technical Process Instruction (WAIO, 2024a) (Appendix H.2). This procedure was updated in March 2024 to incorporate the remote sensing techniques that BHP has been trialling since 2020.

Remote sensing is conducted every two years. Plot based ground sampling is also conducted biennially to collect data that cannot be captured by remote sensing. A brief description of each method is provided below.

**Remote sensing**

Four band (RGBI) aerial imagery is captured at the end of the Pilbara wet season at 0.1 m ground sample distance. An orthorectified, mosaiced, and colour balanced image is then produced and assessed using machine learning algorithms. Following classification of the data via the machine learning algorithms, a thorough, visual quality assessment is carried out to identify any classification errors. Identified errors are manually corrected and used to retrain and improve the machine learning algorithms. Remote sensing currently captures the following data:

- Bare ground.
- *Triodia* cover.
- Shrub cover.
- Tree cover.
- Herb cover.
- Tussock grass cover.
- *Cenchrus* cover (*C. ciliaris* and *C. setiger*).
- *Aerva javanica* cover.
- *Calotropis procera* cover.
- *Acacia aneura* complex cover.
- Total area of weeds identified.
- Total area of vegetation cover.

**Plot based sampling**

Plot based sampling is aligned with the guidelines set out by the EPA for Level 2 Flora and Vegetation Surveys (EPA, 2016), and comprises assessment of the following attributes within a 50 m x 50 m plot:

- Species richness.
- Evidence of flowering and seed production and variable aged plants.

Photographs are also taken from the corner of each plot.

Permanent plots are sampled every two years, generally six to eight weeks after the wet season (during April to June).

The location of quadrats is decided by random stratified sampling, and plots are placed at representative locations throughout the survey area to cover a mixture of landforms, geology, elevation, slope, aspect, surface or groundwater expressions, and soil types. The number of 50 m x 50 m quadrats is determined by the area of rehabilitation (Table 10-3). The total quadrat area (1 quadrat = 0.25 ha) must be equal or greater than 1 % of the sum total of all rehabilitated areas.

**Table 10-3 Number of plots required for each rehabilitated area**

| Size of rehabilitated area | Number of quadrats required |
|---|---|
| < 10 ha | 0 plots |
| 10-25 ha | 1 plot |
| 25-50 ha | 2 plots |
| 50-75 ha | 3 plots |
| >75 ha | 4 plots |

#### 10.1.2.3 Corrective action

Should ongoing monitoring indicate that completion criteria cannot be met, the appropriate maintenance and / or remedial work will be undertaken. Depending on the cause of the deficiency, remedial actions could include, but not be limited to, reseeding, application of ameliorants / fertiliser and / or rework of an area. Further monitoring would be subsequently undertaken on repaired areas to demonstrate achievement of relevant criteria.

### 10.1.3 Weed monitoring

#### 10.1.3.1 Monitoring objective

To assess weed populations in relation to completion criteria targets (Table 10-4) and the effectiveness of weed control measures.

**Table 10-4 Weed completion criteria**

| Category | Domain | Completion criteria |
|---|---|---|
| C4.4 Weeds | Ex-pit areas except E1 & E4 creek diversions (OSAs, OSA, ROM, stockpile, infrastructure footprints, surface water infrastructure) | Priority alert weed species are not present (C), or if present, cover is less than or equal to the surrounding areas (regional baseline) (Q).<br>No new priority alert weed species introduced (C) |
| | Ex-pit areas except E1 & E4 creek diversions (OSAs, OSA, ROM, stockpile, infrastructure footprints & surface water infrastructure) | Total weed cover:<br>• Drainage lines, floodplains <20%.<br>• Upland hills, slopes and flats <10%.<br>Buffel grass cover:<br>• Drainage lines, floodplains <10%.<br>• Upland hills, slopes and flats <10%. |
| | Backfilled pits | Weed cover is within the acceptable ranges defined for in-pit environments. Note criteria have yet to be developed. |
| | E1 & E4 creek diversions | New weed species are absent |

#### 10.1.3.2 Monitoring method and frequency

BHP's weed management procedures (WAIO, 2022g) describe the weed monitoring to be conducted and the measures used to prevent the introduction and spread of weeds, including weed control requirements. Site inspections are conducted annually and weed monitoring via quadrats and relevé transects is conducted during rehabilitation monitoring described in Section 10.1.2.

#### 10.1.3.3 Corrective action

Where weed cover is not meeting objectives, weed control measures will be implemented in accordance with the Weed Management Procedure (WAIO, 2020c). Post-mining weed control measures will be refined in consultation with the relevant authorities. Approved changes to the monitoring programs and control measures will be documented in the AER and revisions of the Weed Management Procedure (WAIO, 2020c).

### 10.1.4 Fauna inspection of rehabilitation areas

#### 10.1.4.1 Monitoring objectives

We recognise that fauna have an intrinsic value to key stakeholders and natural processes within rehabilitation, however, the transient nature of fauna makes it difficult to consistently capture data that can be compared to a quantitative target. The objectives of fauna monitoring are, therefore, to:

- Provide information to key stakeholders on observed use of rehabilitation areas by fauna; and
- Inform management of the impacts of feral animals and pests on rehabilitation.

#### 10.1.4.2 Monitoring method and frequency

Damage to rehabilitation from feral animals / pests is currently recorded during on-ground rehabilitation monitoring and inspections. BHP is in the process of reviewing its rehabilitation monitoring procedures to determine how fauna use of rehabilitated areas can be integrated into the monitoring program.

#### 10.1.4.3 Corrective action

Implement feral animal and pest controls, if required.

### 10.1.5 Marillana Creek E1 & E4 diversion monitoring

#### 10.1.5.1 Monitoring objectives

The objectives of the Marillana Creek E1 and E4 diversion monitoring program are to assess diversion performance and confirm that it is on trajectory towards equilibrium. The completion criteria for the diversion are outlined in the monitoring methodology table (Table 10-5, Section 10.1.5.2).

#### 10.1.5.2 Monitoring method and frequency

The Marillana Creek Diversion Management Plan (BHP Billiton, 2016) outlines the monitoring program that will be used to assess the performance of the E1 and E4 creek diversions. It outlines a tiered program based on the results of the previous monitoring program and level of risk associated with each diversion based on the outcomes of this monitoring (Figure 10-1). Table 10-5 summarises the different levels of monitoring within this program[66].

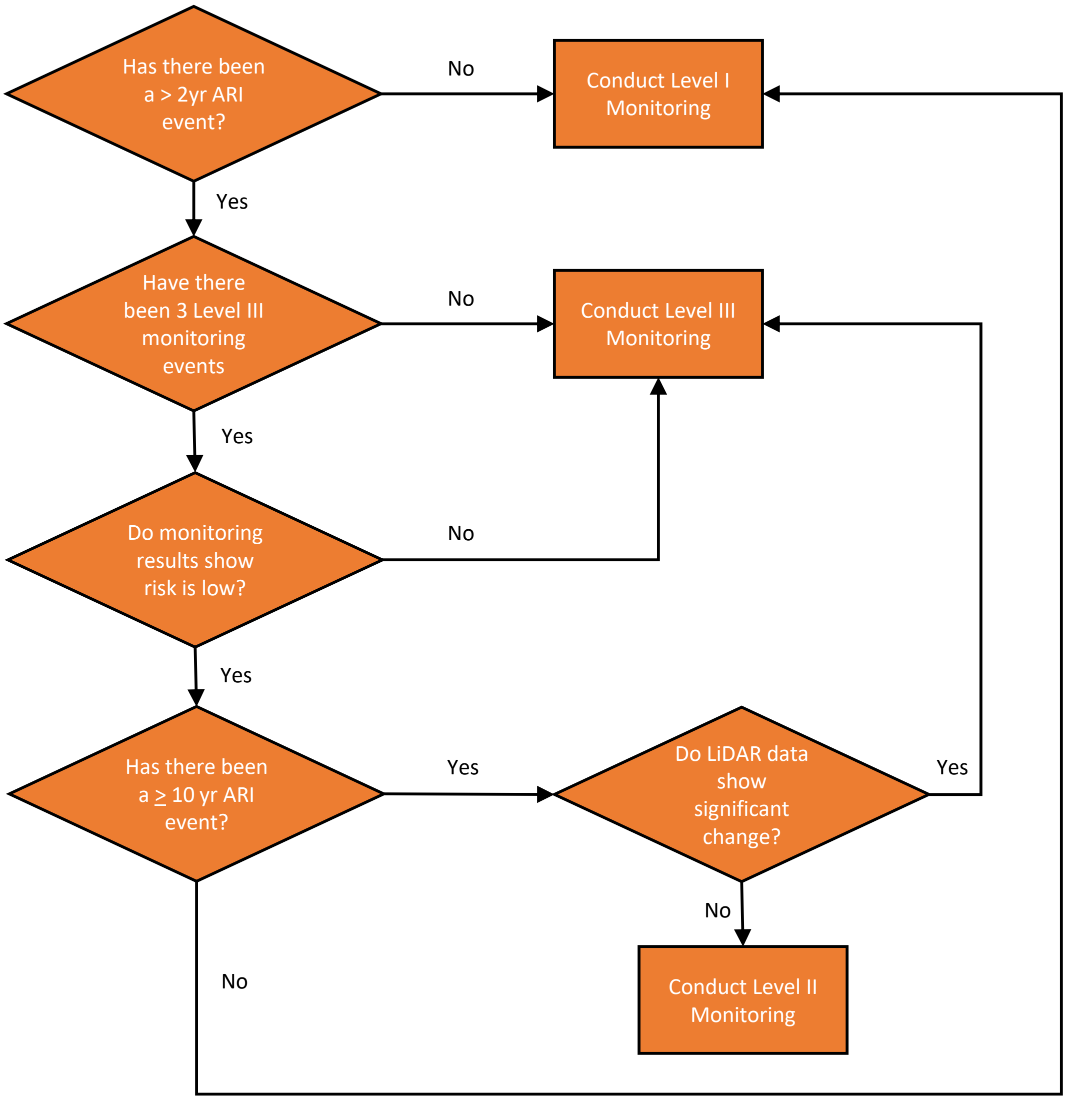



**Figure 10-1 Chart for determining the level of monitoring to be applied to Marillana Creek diversions**

**Table 10-5 Marillana Creek diversion monitoring program**

| Monitoring method | Frequency | Relevant completion criteria |
|---|---|---|
| **Level I, Level II & Level III Monitoring**<br>A full walk-through of the diversion, plus upstream and downstream reaches to get an overview of the diversion performance and to understand whether natural features are developing throughout. This will include photographs with GPS coordinates. | Annually until three Level III monitoring events have been undertaken post flood channel construction (refer to Figure 10-1). | The channel incorporates, and has the capacity to develop, geomorphic features that are similar to those seen through existing channel reaches. |

66 Where there are discrepancies between the monitoring program outlined in this plan and the Marillana Creek Diversion Management Plan (including revisions), the program in the Marillana Creek Diversion Management Plan takes precedence.

| Monitoring method | Frequency | Relevant completion criteria |
|---|---|---|
| **Level II & Level III Monitoring**<br>IDC monitoring | Refer to Figure 10-1 for frequency. | Marillana Creek diversions to achieve a total IDC score in diversion reaches that is comparable (>70%) with the total IDC score for the upstream control reach during the establishment phase of diversion morphological development. IDC indicators are:<br>• Width of high flow channel, active channel and low flow channel.<br>• Bank condition and piping of banks.<br>• Bed condition.<br>• Spoil piles.<br>• Recovery.<br>• In-stream structures. |
| **Level II & Level III Monitoring**<br>Comparative LiDAR assessment to determine changes in elevation since the previous monitoring effort to approximate sediment transport based on digital elevation models of difference. | Refer to Figure 10-1 for frequency. | The volume of sediment exiting diversions is similar to that entering. |
| **Level II Monitoring**<br>Photographs taken at established points | Refer to Figure 10-1 for frequency. | Channel stability and erosion is within acceptable ranges consistent with the Marillana Creek Diversion Management Plan (BHP Billiton, 2016). |
| **Level II & Level III Monitoring**<br>Identification and assessment of operational risk where necessary | Refer to Figure 10-1 for frequency. | |
| **Level III Monitoring**<br>Photographs taken at established photo points and analysis of historical photographs undertaken to determine changes over time.<br>Aerial photograph analysis to identify lateral shifts in channel position.<br>Flow event overview / analysis to identify events since the previous monitoring effort.<br>An assessment of the condition of any rectification or rehabilitation measures (e.g. bank stabilisation works, structures) that have been installed within the diversion based on an informed visual assessment of whether the measure is operating as it was designed. | Refer to Figure 10-1 for frequency. | |
| **Level III Monitoring**<br>Evaluation of key ecological indicators. | Refer to Figure 10-1 for frequency. | • Structural intactness for vegetation is comparable to natural channel reaches.<br>• There is evidence of recruitment in diversions.<br>• The longitudinal connectivity of vegetation cover in diversions is comparable to natural channel reaches.<br>• There is a variety of ages evident in vegetation.<br>• Key species are present (refer to Appendix M.4.1):<br>  - Trees - 1 out of 4 species present.<br>  - Lower trees 2 out of 5 species present.<br>  - Shrubs 3 out of 9 species present.<br>  - Low shrubs 1 out of 1 species present.<br>  - Grasses 2 out of 5 species present.<br>• New weed species are absent.<br>• There is evidence of pool formation.<br>• Persistence of pools is comparable to that in natural channel reaches.<br>• There is evidence of organic matter in or adjacent to pools<br>• There is evidence of macrophytes or algal covers in pools. |

Source: BHP Billiton (2016)

#### 10.1.5.3 Corrective action

Creeks are dynamic environments, and the creek diversions have been designed to account for the morphological changes that may occur in natural creek systems. While the nature and rate of morphological change in the diversions will be subject to the magnitude and frequency of flood events that occur, nominal timeframes for the evolution of channel form are as follows (BHP Billiton, 2016):

- Adjustment phase (in the order of 5 years) where there may be significant changes and a substantial redistribution of sediment through scour and aggradation.
- Establishment phase (from about 3 to +15 years) where the basic features of the channel start to form ((benches, anabranch, ridges).
- Equilibrium phase (from about 8 to +15 years).

As creek diversions are expected to undergo morphological change, particularly during the initial adjustment phase, intervention may not be required unless there is an unacceptable operational or environmental risk, or an undesirable trend in diversion behaviour. The nature of any rectification actions will depend on the type and scale of changes observed, and an understanding of the drivers of such change. Potential actions could include:

- Revetment of banks using rip-rap;
- Replacement of, or addition to existing rip-rap with larger clast-size material;
- Placement or removal of boulders and / or large woody debris;
- Targeted seeding of vegetation;
- Adjusting batter angles of channel banks; or
- Replacement or removal of alluvial material.

### 10.1.6 Riparian vegetation & tree health monitoring

#### 10.1.6.1 Objective

Monitoring of natural riparian vegetation communities (i.e., those that are not part of a rehabilitation program) is conducted in accordance with the Marillana Creek Water Resource Management Plan. The purpose of this program is to monitor impacts to riparian vegetation arising from groundwater dewatering and surplus water discharge during operations.

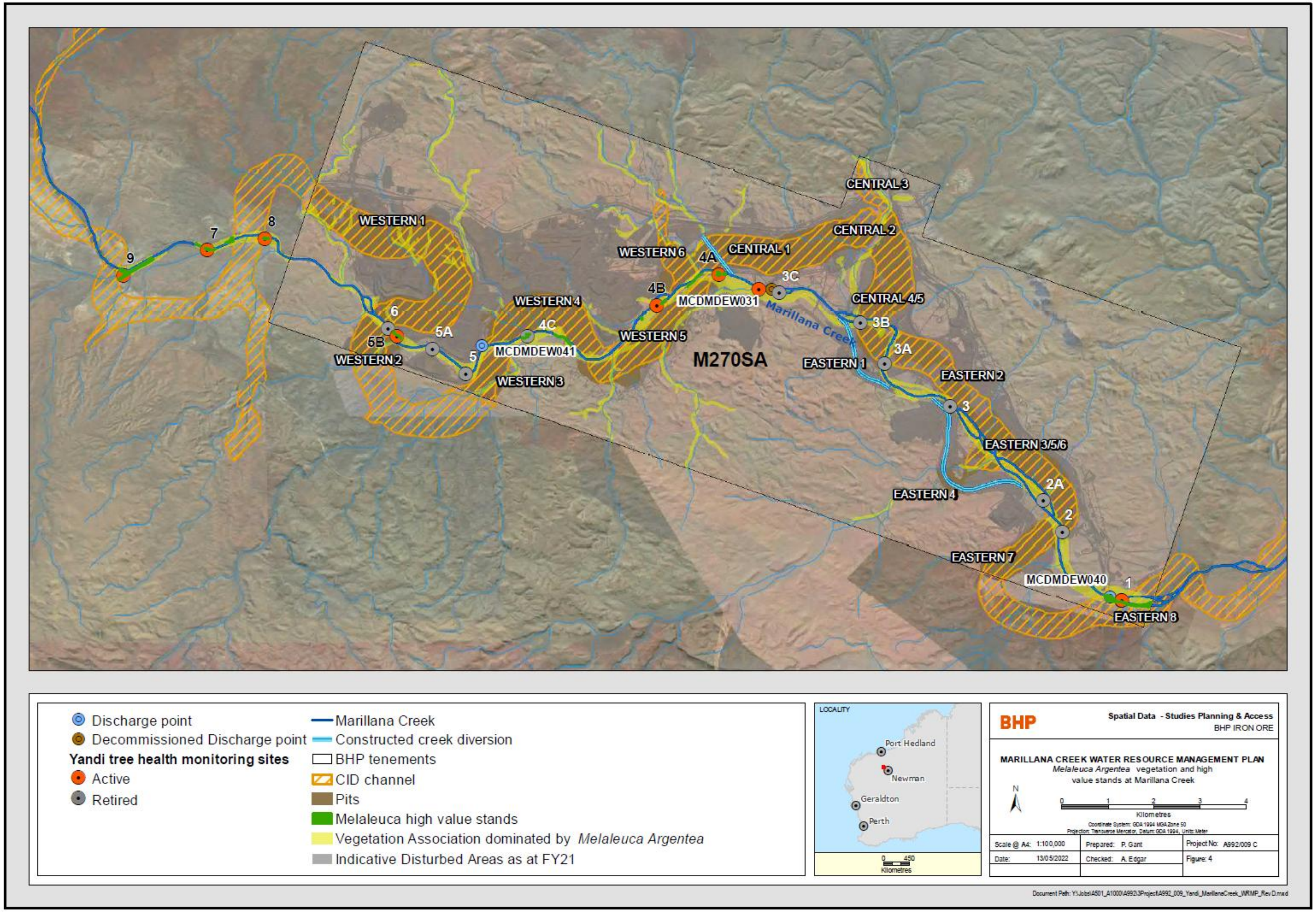
This program will also contribute to measuring achievement of surface water and groundwater completion criteria post-closure (refer to Sections 10.1.8 and 10.1.10 for further details).

#### 10.1.6.2 Monitoring method and frequency

The Marillana Creek Water Resource Management Plan describes the methodology and frequency of monitoring, however, a brief summary is provided below[67]. This monitoring plan will be updated and adjusted, as required, over the life of the mine.

The current riparian vegetation monitoring locations are shown in Map 10-1, and the key monitoring variables are outlined in Table 10-6.

[67] The monitoring program presented in this MCP reflects that described in the current (BHP, 2022b) version of the Marillana Creek Water Resource Management Plan and will be periodically updated as revisions to the plan are approved. Where there are discrepancies between the monitoring program outlined in this plan and the Marillana Creek Water Resources Management Plan (including revisions), the program in the Marillana Creek Water Resources Management Plan takes precedence.




Source: BHP (2022b)

**Map 10-1 Current riparian vegetation monitoring locations**

**Table 10-6 Monitoring variables used in the riparian vegetation monitoring program**

| Parameter | Monitoring method | Description | Frequency |
|---|---|---|---|
| Predawn leaf water potential (ΨPD)[1] | Pressure chamber (Scholander *et al.* 1965) | *Melaleuca argentea* shoots are collected before dawn and tested in a pressure chamber (n = 3 to 8 trees / site depending on abundance). Lower readings indicate greater water stress. | Biannual[2] |
| Crown condition score[3] | Visual ratings (Souter *et al.* 2009) | Percentage estimate of crown extent and crown density of live trees (n = up to 22 trees / site, with roughly even numbers of *Melaleuca argentea*, *Eucalyptus victrix* and *E. camaldulensis*). | Biannual |
| Understorey condition (cover) | Visual estimates | Percentage cover of all vegetation, separated into native cover and weed cover measured in permanent 10 m by 10 m quadrats (n = 3 quadrats / site). | Biannual |
| Site condition (general) | Photographs and visual observations | Observational notes and visual rating (0 - 3) of abundance of tree mortality, regeneration, pests / diseases, grazing, fire, flood. | Biannual |
| Vegetation and tree condition (remote sensing)[4] | Satellite remote sensing (WorldView and Landsat) | Modified Soil Adjusted Vegetation Index is used to quantify vegetation condition. | Biannual |
| Recent canopy loss (ground-truthing) | Visual estimation | Areas of change detected in remote sensing analysis prior to on-ground monitoring are inspected if data available. | Biannual |

Source: BHP (2022b)

Notes: [1] Pre-dawn leaf water potential (ψPD) approximates the matric potential in the water source used by the tree. It assumes that the hydraulic gradient across the tree equilibrates over night when there is negligible transpiration demand.

[2] Biannual refers to end of the dry season and the end of the wet season.

[3] Crown condition refers to the physical status of the leaves and branches. Visual assessments of canopy condition based on qualitative scoring systems can provide cost effective, informative data on tree condition.

[4] Collection and analysis of remote sensing data for Marillana Creek water management area is used to maintain a site-scale overview of changes in vegetation condition.

#### 10.1.6.3 Corrective action

The Marillana Creek Water Resource Management Plan outlines monitoring thresholds and actions to be taken if these thresholds are exceeded. Any actions requiring long-term management via the closure strategy will be reviewed and appropriate closure measures will be incorporated into this MCP as appropriate.

### 10.1.7 Regional water monitoring network

From a closure perspective, it is necessary to have an understanding of:

- Pre-mining conditions and acceptable levels of change so that appropriate completion criteria can be developed;
- The changes that occur during mining so that conceptual and numerical models can be refined to facilitate:
  - Prediction of impacts at closure; and
  - The development of a post-closure monitoring regime that will enable model predictions to be calibrated and validated over time.
- The changes that occur post-closure to enable models to be calibrated and provide an acceptable level of certainty in model predictions.

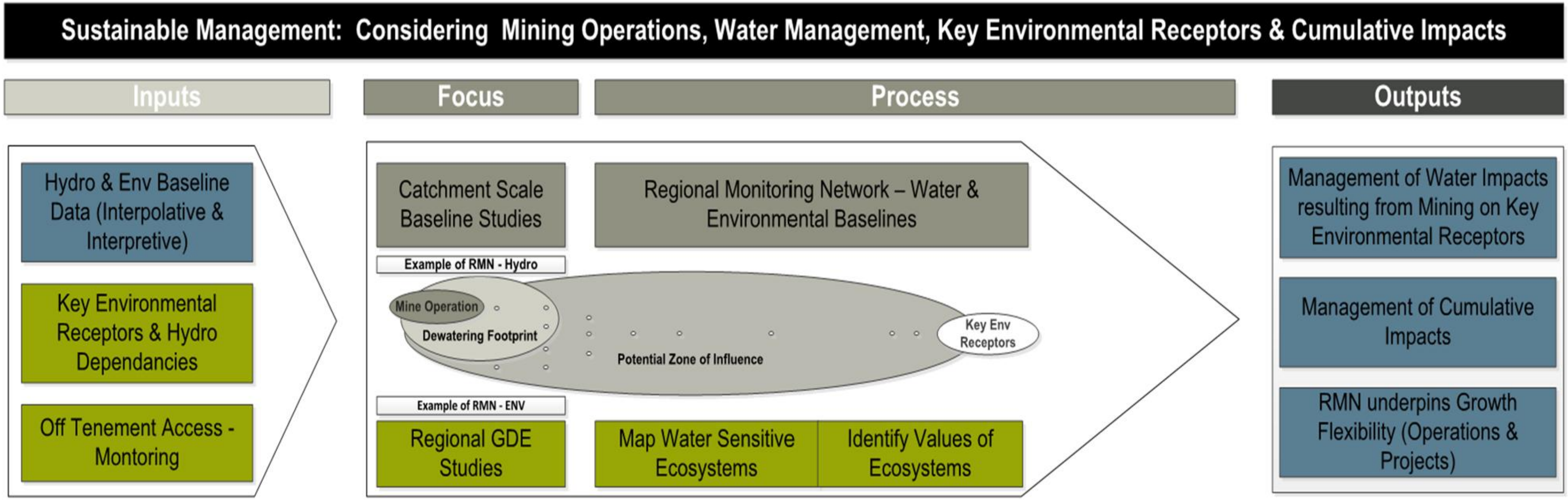
A regional monitoring network has been installed at an operational and catchment scale and a monitoring program collects important information for compliance reporting and to improve the capacity to estimate receptor response to changing hydrological conditions and natural climatic variations and stresses (Figure 10-2). The data from the program are used to develop an understanding of the baseline conditions (prior to BHP operations) and current conditions (with BHP operations), to:

- Define the natural variance in hydrological conditions;
- Underpin adaptive management and modelling processes; and
- Be consistent with the threshold variables being used to assess significance of impacts to receiving receptors.

The regional monitoring network will continue to be used to support and inform closure assessments, enabling progressive improvement in understanding, and confidence in the achievement of the stated closure objectives related to the hydrological regime.

The regional monitoring network - hydrological enables time-variant data collection from various hydrological systems, including:

- Groundwater aquifer water levels and quality;
- Surface water drainage features and creek flow volumes;
- Spring discharges, seepages, waterholes and marsh zones; and
- Weather and climatic conditions.




Note: GDE - Groundwater Dependent Ecosystems

**Figure 10-2 Regional monitoring network overview**

The data from the regional hydrological monitoring network will be supplemented by ecological data collected on:

- Vegetation assemblages;
- Significant biodiversity, flora and fauna values;
- Tree health monitoring, including lead indicators such as leaf moisture, sap flow and trunk / stem growth gauges or satellite / aerial photography-based vegetation condition; and
- Hydrological dependence of receiving receptors on surface water, groundwater or soil moisture.

## 10.1.8 Surface water monitoring

Current pre-closure hydrological monitoring at Yandi is focussed on meeting operational requirements and establishing a data set which can be used as the basis for determining numerical completion criteria. Ongoing monitoring during operations will provide a foundation for distinguishing between natural and mining-related changes in the Marillana Creek system at the end of operations. Closure monitoring will focus on the performance of surface water management structures, particularly in relation to sustaining the flow regime and water quality of Marillana Creek post-mining.

### 10.1.8.1 Monitoring objectives

The objectives of surface water monitoring program are to enable calibration of surface water models and assess the achievement of the completion criteria outlined in Table 10-7.

**Table 10-7 Surface water completion criteria**

| Category | Domain | Completion criteria |
|---|---|---|
| C5.2 Surface water flows | Flood bunds, floodplains and intermediate and minor creek diversions | Flows will be acceptable at downstream environmental receptors as evidenced by:<br>• The physical condition of surface water infrastructure which should perform as designed (e.g. no significant head cutting or erosion beyond design parameters) (P).<br>• Riparian vegetation monitoring which should be within the ranges accepted via project approvals (Q). |
| C5.3 Surface water quality | OSAs, flood channels & diversions | Surface water quality is within limits:<br>• Defined, through the detailed analysis of pre-closure monitoring data from appropriate reference sites, to represent no significant impact to downstream ecohydrological receptors; and / or<br>• Accepted via project approvals or other regulatory processes |
| | Mine voids | Monitoring shows that pit lake quality aligns with hydrogeochemical modelling trajectory and risk assessment assumptions. |

### 10.1.8.2 Monitoring method and frequency

#### Surface water flows

Direct flow monitoring of Marillana Creek is not a reliable method of demonstrating whether the closure objective of "*impacts on natural surface water flows are acceptable at key receptors"* as there are many variables associated with the flows in the creek due to the spatial distribution of rainfall (e.g., there may be flows in Marillana Creek from rainfall upstream in the catchment, but no contributing flows from tributaries such as Lamb, Iowa or Herbert's creeks). Monitoring of the condition of surface water infrastructure is, therefore, proposed as a proxy to assess whether the infrastructure is performing as designed (see Section 10.1.11), and therefore, whether flows have been maintained as designed.

The objective of maintaining flows is to maintain riparian vegetation along Marillana Creek. It is, therefore, proposed that this criterion be measured via the riparian vegetation monitoring program outlined in Section 10.1.6. A complexity associated with demonstrating that surface flows have been maintained to support riparian vegetation is the interaction between groundwater levels in the CID, pits and the alluvium. Some impacts to riparian vegetation are expected in these areas as outlined in Section 7.3.2.6, and have been highlighted and accepted via approval submissions (BHP Iron Ore, 1995; EPA, 2005). Streamflow data from the Flat Rocks Gauging Station and groundwater monitoring in the alluvium (Section 10.1.10) are, therefore, used to assist in the interpretation of vegetation data, in general accordance with the Marillana Creek Water Resource Management Plan (BHP, 2022b).

#### Surface water quality

A review of the surface water quality monitoring program at Yandi was conducted by Hydro Geochem Group (2022) and several recommendations were made for improvements in the monitoring program to facilitate the establishment of numerical completion criteria. This section outlines the current operational surface water monitoring program and the proposed improvements to the program based on the recommendations made by Hydro Geochem Group.

*Operational monitoring program*

**Environmental licence monitoring**

Surface water quality monitoring is currently being conducted in accordance with Yandi's environmental licence as outlined in Table 10-8.

**Table 10-8 Operational ambient surface water quality monitoring program**

| Monitoring Location | Parameter | Units | Averaging Period | Frequency |
|---|---|---|---|---|
| Marillana Creek surface water monitoring sites YNSWPC001 YNSWPC002 (Map 10-2) | pH[1] | - | Spot sample | Following rain events |
| | Electrical Conductivity | (µS/cm) | | |
| | TDS, Total Suspended Solids (TSS), Total Recoverable Hydrocarbons (TRH); Na, K, Ca, Mg, Cl, Carbonate, Bicarbonate, $SO_4$, $NO_3$, Al, B, Fe, Cu, Zn, Ag, As, Cr, Cd, Hg, Ni, Se, Mn | mg/L | | |

[1]Note: in-field non-NATA accredited analysis permitted

**Rising stage samplers**

There are three rising stage sampling locations along Marillana Creek (Map 10-2) with sondes that measure turbidity, temperature, conductivity, total dissolved solids, and salinity. Samples are also collected during flow events for laboratory analysis.

*Proposed improvements to monitoring program*

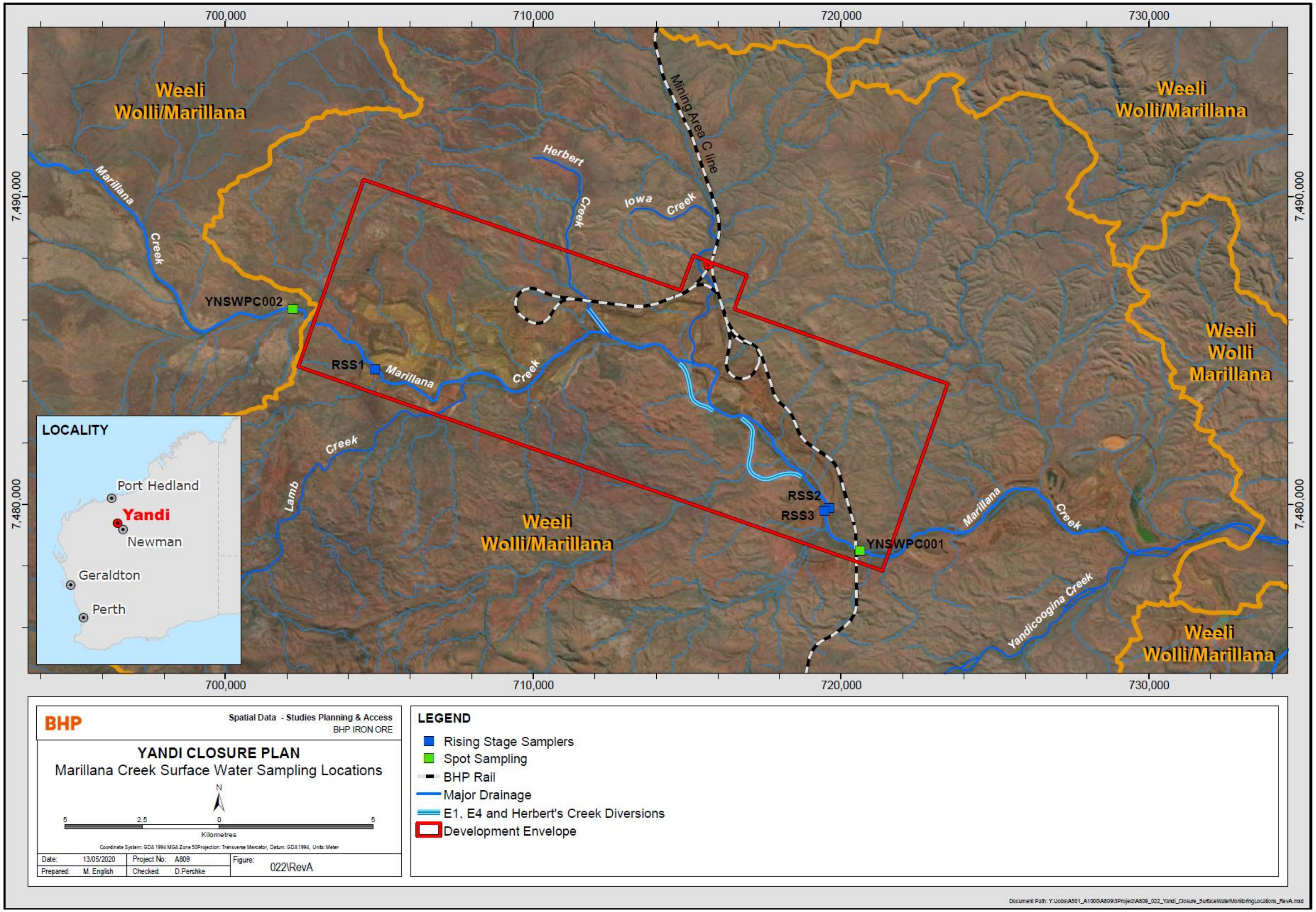
Monitoring locations will be expanded to target key sources of impact. Continuous samplers will be installed to optimise the probability of viable surface water samples given the episodic nature of creek flow.

Samples will be analysed for, at a minimum, pH, EC TDS, suspended solids, cations (Ca, Mg, Na, K), anions (Cl, $SO_4$, alkalinity), nitrate, total N and P, and dissolved metal(loid)s (Al, As, B, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn). Dissolved metal(loid) samples will be filtered during sample collection. In accordance with Hydro Geochem Group's (2022) recommendations, this list of analytes may be rationalised over time to more closely reflect the potential sources of constituents of potential concern at Yandi.

It is proposed that the expanded monitoring program will operate for a period of five years with rationalisation occurring thereafter based on monitoring data collected.

#### 10.1.8.3 Corrective action

Post-mining monitoring programs will be developed and / or refined during the mine life in consultation with the relevant authorities. Approved changes to the monitoring programs and control measures will be documented in the AER and this MCP. If monitoring indicates that completion criteria will not be achieved, an investigation into the cause of the exceedance will be conducted, and remedial measures defined in consultation with appropriate regulatory authorities.




See Appendix Q for a pdf version of this map

**Map 10-2 Marillana Creek surface water sampling locations**

### 10.1.9 Pit lake monitoring

#### 10.1.9.1 Monitoring objectives

The pit lake monitoring objectives are to validate pit lake modelling for water levels and water quality and assess achievement of the completion criteria outlined in Table 10-9.

**Table 10-9 Pit lake completion criteria**

| Category | Domain | Completion criteria |
|---|---|---|
| C5.4 Pit lakes | Mine voids | The pit lake risk assessment shows no significant impact to human health or native fauna. |
| | | Monitoring shows that pit lake quality aligns with hydrogeochemical modelling trajectory and risk assessment assumptions. |
| | | Groundwater level data show that permanent pit lakes will act as sinks. |
| C5.3 Surface water quality | | Monitoring shows that pit lake quality aligns with hydrogeochemical modelling trajectory and risk assessment assumptions. |
| C5.6 Groundwater quality | | Pit lake water quality aligns with hydrogeochemical modelling trajectory and demonstrates that the potential for density driven impacts is low. |

#### 10.1.9.2 Monitoring method and frequency

Table 10-10 outlines the monitoring methods to be implemented to demonstrate achievement of completion criteria for pit lakes.

**Table 10-10 Pit lake monitoring program**

| Monitoring method | Frequency |
|---|---|
| Groundwater level monitoring of in-pit bores or near-pit bores and surveys of pit lake levels. | Quarterly (initial 5 years) in monitoring bores, then decreased frequency (i.e., twice per year after 5 years) until groundwater models can be validated. |
| Sampling of permanent pit lakes and in-pit or near-pit bores in backfilled pits, and, at a minimum, analysis for pH, EC, TDS, Cations (Ca, Mg, Na, K), Anions (Cl, $SO_4$, Alkalinity), Nitrate, TSS, Total N & P, Al, As, B, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn), Acidity. | Annually for permanent pit lakes.<br>In-pit or near pit bores - quarterly (initial 5 years), then decreased frequency (i.e., twice per year after 5 years) until it can be shown that water quality aligns with the hydrogeochemical modelling trajectory. |
| Sampling of seasonal expressions of water in backfilled pits and, at a minimum, analysis for pH, EC, TDS, Cations (Ca, Mg, Na, K), Anions (Cl, $SO_4$, Alkalinity), Nitrate, TSS, Total N & P, Al, As, B, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn), Acidity. | Spot samples when present, until it can be shown that water quality aligns with the hydrogeochemical modelling trajectory. |

#### 10.1.9.3 Corrective actions

If pit lake monitoring shows significant departures from modelling results or risk assessment assumptions, an investigation will be conducted, and modelling / risk assessments revised. If revised modelling / assessments indicate that remedial actions are required, these will be defined in consultation with relevant regulators.

### 10.1.10 Groundwater monitoring

The existing Yandi groundwater monitoring program supports and informs operational water management and closure groundwater assessments. An extensive monitoring bore network has been developed that spans the CID aquifers, ex-pit Weeli Wolli Formation and the alluvial aquifer. The program is designed to enable progressive improvement in the understanding of groundwater behaviour and confidence in the achievement of the stated closure objectives for groundwater. This includes a framework for testing and validating groundwater modelling predictions at closure.

#### 10.1.10.1 Monitoring objectives

The monitoring objectives are to confirm groundwater and pit lake modelling assumptions and assess the achievement of completion criteria[68] (Table 10-11).

**Table 10-11 Groundwater completion criteria**

| Category | Domain | Completion criteria |
|---|---|---|
| C5.5 Groundwater levels | Mine voids | Groundwater levels at key environmental receptors are within model predictions and the parameters accepted via project approvals and informed by stakeholder consultation. |
| C5.6 Groundwater quality | Mine voids, OSAs, ex-pit areas including OSA, ROM, stockpile footprints | Groundwater quality is within limits:<br>• Defined, through the detailed analysis of pre-closure monitoring data from appropriate reference sites, to represent no significant impact to downgradient ecohydrological receptors; and / or<br>• Accepted via project approvals or other regulatory processes. |

#### 10.1.10.2 Monitoring method and frequency

Groundwater is currently monitored in accordance with the Groundwater Operating Strategy (WAIO, 2022d) for Yandi and the Marillana Creek Water Resource Management Plan (BHP, 2022b). Together, these monitoring programs provide context to the riparian tree health monitoring program outlined in Section 10.1.6, and provide data to enable hydrogeological models to be updated.

A review of the groundwater quality monitoring program at Yandi was conducted by Hydro Geochem Group (2022) and several recommendations were made for improvements in the monitoring program to facilitate the establishment of numerical completion criteria.

This section outlines the current operational groundwater monitoring program and the proposed improvements to the program based on the recommendations made by Hydro Geochem Group (2022). It also defines a preliminary post-closure monitoring program (Table 10-13).

**Current groundwater monitoring**

The current groundwater monitoring program is summarised in Table 10-12. Following closure, the monitoring program will be refined to focus on demonstrating achievement of completion criteria.

**Table 10-12 Current groundwater monitoring program**

| Monitoring Type | Location | Sample Sites | Monitoring Parameters | Minimum Frequency[1] |
|---|---|---|---|---|
| Regional water levels | Upgradient | Representative monitoring bores up gradient of W1 deposit:<br>• HYW0002M.<br>• MB16YSN0001M.<br>• MB16YSN0003M.<br>• MB16YSN0004M. | Water level | Monthly |
| | Downgradient | Representative monitoring bores down gradient of E6 deposit:<br>• YM0121M<br>• HYE1508M,<br>• HYE1515M<br>• HYM0011M | | |

68 Monitoring data is collected during operations to enable groundwater models to be calibrated (i.e., adjust various parameters in the groundwater model until the model outputs reflect data observed over time). Following calibration, monitoring data will be used to validate groundwater models by comparing model predictions of groundwater recovery to observed data (i.e., checking that groundwater is behaving as predicted following mining).

| Monitoring Type | Location | Sample Sites | Monitoring Parameters | Minimum Frequency[1] |
|---|---|---|---|---|
| Dewatering | Active pits (W1, W2, W3, W4, W5, C1, C2, C3, C4 C5, E1, E2, E3/5/6, E4, E7 | All active production bores and active sumps | Cumulative volume | Monthly |
| | | 1 representative dewatering bore[2] per deposit, all active sumps | Field EC and pH | Monthly |
| | | | Al, Alkalinity, As, B, Ba, Cd, Ca, Cl, Cr, Cu, EC, F, Fe, $HCO_3$, Hg, Pb, Mg, Mn, Mo, Na, Ni, $NO_3$, pH, K, $SiO_2$, Se, $SO_4$, TSS, TDS, Hardness as $CaCo_3$, Zn. | Biannually |
| | New bores | New bores | As above and turbidity, sulphide, total CN, radionuclides, Ag, Total Petroleum Hydrocarbons (TPH), Benzene, Toluene, Ethylbenzene, Xylene (BTEX), | First sample |
| In-pit monitoring bores | Active pits (W1, W2, W3, W4, W5, C1, C2, C3, C4 C5, E1, E2, E3/5/6, E4, E7 | 1 representative monitoring bore per deposit | Water level | Monthly |

Notes: [1]Frequency may be increased to support operational planning

[2]Individual bore may change depending on access or bore being mined out

*Proposed improvements*

Biannual monitoring (nominally during the wet and dry seasons) will be undertaken at:

- Established reference bores screened in all three main aquifers (alluvial, CID, Weeli Wolli).
- Nominated bores (to be monitored in the long-term) screened in a single aquifer along the source-pathway-receptor alignment to facilitate the validation of various modelling studies conducted to inform closure planning for Yandi.

Groundwater will be analysed for a standard suite of analytes that allow geochemical water-typing and include constituents of potential concern from sources identified in the conceptual site model. Initially, the analyses will include at a minimum, analysis for pH, EC, TDS, cations (Ca, Mg, Na, K), anions (Cl, $SO_4$, alkalinity), nitrate, total N and P, and dissolved metal(loid)s (Al, As, B, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn). Dissolved metal(loid) samples will be filtered during sample collection. This list of analytes may be rationalised over time to more closely reflect the potential sources of constituents of potential concern at Yandi.

**Preliminary post-closure monitoring program**

**Table 10-13 Preliminary post-closure groundwater monitoring program**

| Monitoring method | Frequency |
|---|---|
| Water level monitoring in existing monitoring bore network (shallow and deep) and new monitoring wells placed appropriately to monitor water levels representative of mine voids and upstream of mine voids. | Quarterly (initial 5 years) then decreased frequency (i.e., twice per year after 5 years) until groundwater modelling can be validated. |
| Refer to in-pit and near-pit groundwater quality monitoring outlined in Section 10.1.9. | Refer to in-pit and near-pit groundwater quality monitoring outlined in Section 10.1.9. |

#### 10.1.10.3 Corrective actions

If monitoring indicates that completion criteria will not be achieved, an investigation into the cause of the exceedance will be conducted, and remedial measures defined in consultation with appropriate regulatory authorities.

### 10.1.11 Landform and erosion monitoring

#### 10.1.11.1 Monitoring objectives

The monitoring objectives are to:

- Assess landform geotechnical and surface erosion stability against the completion criteria outlined in Table 10-15.
- Assess the performance of creek diversions and flood bunds relative to expected design performance.
- Identify any obvious sources of off-site impact.

**Table 10-14 Surface and geotechnical stability completion criteria**

| Category | Domain | Completion criteria |
|---|---|---|
| C3.2 Geotechnical stability | OSAs | • No significant slumping or failure of accessible ex-pit constructed slopes or berms |
| C3.4 Surface stability | OSAs | • Slope surfaces do not show significant erosion which may be defined as having:<br>- Channelised flow resulting in extensive active gullies;<br>- Failure of banks, berms or bunds; and<br>- Evidence of ongoing significant sheet erosion (including large accumulation of silt at base of slope, exposed subsoil, poor seedling establishment).<br>• The average rate of erosion of slopes, flats and crests of OSAs measured at completion is <6t/ha/yr.<br>• The erosion rate at any point on a slope does not exceed the target threshold average rate by more than 100%. |
| | Surface water infrastructure | • Surface water infrastructure is performing as designed. |
| | Backfill / floodplains | • Backfill / floodplain settlement is within design tolerances. |
| | | • Erosion does not compromise the design objectives for the backfill / floodplain surface. |

#### 10.1.11.2 Monitoring method and frequency

Table 10-15 outlines the monitoring methods to be implemented to demonstrate achievement of completion criteria for landforms and erosion.

**Table 10-15 Landform and erosion monitoring program**

| Domain | Monitoring method | Frequency |
|---|---|---|
| OSAs | Visual inspections and / or photographic review to identify:<br>• Absence / presence of rilling or sheet erosion.<br>• Whether the erosion is active or inactive (i.e., will the erosion likely get worse, or self-heal).<br>• Failed frontal / inter-bunds.<br>• Evidence of slumping | During on-ground rehabilitation monitoring events (Section 10.1.2). |
| OSAs, flood bunds, diversions, floodplains, backfilled pits | LiDAR, INSAR data, photogrammetry surveys and / or comparative assessment of erosion / scour / deposition at established survey points.<br>Post-execution LiDAR / INSAR or photogrammetry survey data may also be used to identify areas of differential settlement that may pose a risk to the hydraulic functionality of landform designs.<br>Physical inspections may be conducted if remote sensing data indicate these are required. | Annually (initial 10 years) then decreased frequency if a trend toward surface stability has been demonstrated by year 10. Monitoring will be conducted until a review of results indicates that landforms meet completion criteria. |

#### 10.1.11.3 Corrective action

Where unacceptable erosion or threats to geotechnical stability have occurred, maintenance works will be undertaken to improve performance.

### 10.1.12 Public safety monitoring

#### 10.1.12.1 Monitoring objective

To confirm the integrity of public safety measures.

#### 10.1.12.2 Monitoring method and frequency

Monitoring will be conducted during the post-closure monitoring and maintenance period and will include:

- Periodic visual inspection of safety bunds and other safety measures including fencing and signage. Records will be kept of these inspections.
- Inspection and audit by District Mines Inspector to confirm the site is acceptable with respect to safety at completion.

#### 10.1.12.3 Corrective action

Maintenance will be conducted where:

- The integrity of the bunds or other safety measure has been compromised to the extent that inadvertent public access could occur.
- Methods of egress during an emergency may become obstructed.

## 10.2 Reporting

The following information will be reported in the AER which covers all of BHP's operations:

- Progress and performance of rehabilitation including a summary of the rehabilitation monitoring results for the reporting period, maintenance / remedial actions completed or planned;
- New rehabilitation activities conducted including the area and nature of the rehabilitation;
- Research and development activities; and
- Rehabilitation activities planned for the future reporting period which will continue to be reported as environmental initiatives on an annual basis.

Reporting results will be made available to the relevant authorities on request.

## 10.3 Maintenance

The monitoring program will provide feedback on the performance of the site rehabilitation to identify any issues and inform maintenance activities. Examples of remedial maintenance activities that may occur during the post-closure phase include:

- Minor earthworks
  - Repair erosion or stability issues identified during landform monitoring (including OSAs, creek diversions, flood bunds, flood channels and floodplains).
- Maintenance and repair
  - Fences, signage etc.
  - Monitoring networks.
  - Any retained infrastructure assets.
- Infill planting or reseeding
  - Based on failing to maintain development trajectory, additional tube stock may be planted, or reseeding undertaken to improve density or species diversity.
- Weed control
  - Weed control may be required to manage weed species that may compete with planted rehabilitation species, increase fire risk or as required under regulation.
- Fire management
  - Fire is part of traditional land management practices but is a risk to initial development of rehabilitation, and therefore, will be controlled.
  - Fire will be excluded from rehabilitation areas for a nominal period until framework species have achieved the required parameters (to be determined from research). Following this establishment phase, season cool burns will be promoted to build resilience in the rehabilitation landscape.
- Application of fertiliser
  - Some growth media used in rehabilitation may require fertiliser to create optimal growing conditions, however due to losses from volatilisation (from heat) and leaching (from rainfall) much of the fertiliser is unavailable to plants. Based on monitoring results for plant health and nutrient cycling, reapplication of fertilisers may be required.
- Pest control
  - Insect damage and grazing by native and feral vertebrate fauna can impact rehabilitation success. Monitoring results will be used to determine impact vectors and appropriate management actions.
- Water management
  - Irrigation established to support rehabilitation growth, if required, will be removed when no longer required.
  - If passive water / sediment structures are established for closure, these structures will be removed when no longer required.

Triggers for maintenance activities will be developed via the adaptive management process and will be based on measured deviation away from the completion criteria.

## 10.4 Completion and relinquishment

As discussed in Section 8.3 the DEMIRS (2021) guideline provides for progressive completion. Given the continued use of the Yandi site beyond cessation of mining at Yandi, there may be some time between completion of some areas, and completion and relinquishment of the whole site. During the time between completion and relinquishment, completed areas may still be managed by BHP, but differently to areas that are still subject to the post-closure monitoring and maintenance phase. This section outlines key steps in completion reporting, post-completion management and relinquishment.

### 10.4.1 Completion reporting

As areas of Yandi approach completion, BHP will prepare completion reports in accordance with the Mine Closure Completion Guideline (DMIRS, 2021). With reference to the guideline requirements, BHP will consult with DEMIRS and DJTSI regarding the eligibility of the area for evaluation prior to submission of a completion report.

Completion reports will collate evidence that the completion criteria, outlined in Section 8.3, have been achieved using the data collected from the monitoring programs outlined in Section 10. The reports will also include:

- Details of how the closure risks identified in the MCP have been managed, and an assessment of any residual post-closure risks requiring management by the post-mining land manager.
- A post-completion land management plan where there are residual post-closure risks that require management.
- Relevant information on consultation with stakeholders including:
  - Documented acknowledgement of landowners / managers that rehabilitation objectives and completion criteria have been met.
  - Documented infrastructure transfer agreements where infrastructure has been transferred.
  - Documented agreements with post-mining land managers on implementation of any post-closure management activities (including the post-relinquishment land management plan).

### 10.4.2 Post-completion management

Following completion and prior to relinquishment, BHP will maintain tenure over the Yandi site. During this period, the land will be managed in accordance with the post-completion land management plan, either by BHP, or by arrangement with the landowner / manager. As detailed in the completion criteria in Section 8.3, land management requirements will be typical for the agreed post-completion land use unless otherwise specified in the post-completion land management plan agreed with the landowner / manager.

### 10.4.3 Relinquishment

At relinquishment, land management responsibilities will be transferred to the landowner / manager, with adequate provisions for management requirements beyond those normally associated with the agreed post-completion land use.

# 11 Financial provisioning for closure

BHP considers the specifics of the closure cost estimate (provision) to be commercially sensitive information. This section outlines the general process used to develop the closure cost estimate.

## 11.1 BHP principles for closure cost estimation

The financial provision preparation is undertaken in accordance with the Closure and Legacy Management Global Standard (BHP, 2023c), and the associated BHP accounting and cost estimation standards. Closure cost estimates are updated annually.

BHP ensures costs included in the provision encompass all closure and rehabilitation activities (for areas disturbed as at balance sheet reporting date) expected to occur progressively over the life of the operation, at the time of closure and during the post-closure period (e.g., monitoring). This includes all expected indirect costs, such as project management costs, statutory reporting fees and technical support costs.

In some cases, substantial judgements and estimates are involved in forming expectations of future activities and the amount and timing of the associated cash flows. These expectations are formed based on existing environmental and regulatory requirements and / or company standards or policies as outlined in this MCP.

Adjustments to the estimated amount and timing of future closure and rehabilitation cash flows are a normal occurrence in light of the substantial judgements and estimates involved. Factors influencing those changes include:

- Revisions to the estimated mine life;
- Developments in technology;
- Regulatory requirements and environmental management strategies;
- Changes in the estimated extent and costs of anticipated activities; and
- Movement in economic input assumptions (interest rates, inflation).

BHP maintains sufficient closure input assumption documentation to support the closure model financial provision outcomes. The provision process and outcomes are subject to internal and external audit on an annual basis.

For Yandi mining operations the provision is made up of:

- Three phases of closure studies.
- Contaminated sites monitoring and management requirements.
- Landform earthworks and general land disturbance rehabilitation including:
  - Rehandling OSAs to the pits as backfill and reprofiling the backfill surface (based on closure engineering design reports).
  - Constructing upgrading surface water management infrastructure (based on closure engineering design reports).
  - Implementing pit wall stability measures and constructing safety bunds (based on mine planning designs).
  - Reprofiling of OSA, ROM, stockpile and infrastructure footprints.
  - Topsoil / growth media haulage and spreading
  - Ripping / scarifying (as required) and seeding
- Remaining infrastructure removal and disposal including (based on independent contractor estimate):
  - Building demolition and removal.
  - Removal of concrete footings, services and linear infrastructure to a minimum of 0.6 mbgl, or greater depth determined by a risk assessment or stakeholder agreements.
  - Waste management.
- Post-closure monitoring and maintenance costs for up to 20 years.
- Stakeholder engagement.
- Allowance for failed rehabilitation.
- A contingency factor.
- Manning forecasting requirements.
- Human resources allowances.

## 11.2 Closure cost estimation methods

The closure cost estimation process is conducted in accordance with BHP's Closure and Legacy Management Global Standard (BHP, 2023c) and the associated BHP accounting and cost estimation standards. The level of accuracy increases as the site approaches closure. The closure cost estimate is:

- An expected cost, based on best available information at a point in time;
- Reflective of the class of estimates appropriate for the proximity in time to the commencement of closure activities; and

- Inclusive of uncertainty and reflective of the maturity of the estimate using methods such as sensitivity analysis, weighted scenarios, range analysis, risk events and / or contingency.

Closure cost estimates are developed within the BHP business and include input from specialists in closure planning, rehabilitation, contamination, risk, finance, engineering (mining, civil, mechanical), water planning, and, where necessary, external consultants. The closure cost estimate is developed from the activities required to close each domain and uses internal BHP costs and / or external third-party rates, as appropriate for the activity. Selected costs are benchmarked against third party rates to provide confidence in the quantum of the estimate. The cost estimate for each activity is developed using the method that is considered by BHP to provide the most reasonable estimate. Methods include cost estimates built up by BHP from first principles, factorisation based on BHP's experience at its Pilbara sites, or cost estimates provided by specialist third-party consultants for specific studies such as engineering studies, demolition studies and / or detailed execution planning. BHP maintains sufficient closure input assumption documentation to support the closure model financial provision outcomes. The closure cost estimate is updated annually to take account of incremental changes to disturbance during the year and to capture changes to the cost basis for execution activities. The provision process and outcomes are subject to internal and external audit on an annual basis.

For commercial reasons BHP does not document the actual estimate in this Closure Plan.

# 12 Data management

BHP will collect, store and manage closure data in line with its existing data management procedures, including the WAIO-wide Rehabilitation Data Capture Work Instruction (001006) (WAIO, 2022b).

The MCP and related information will be managed by BHP. All data will be stored in a central and readily accessible location in accordance with existing BHP standards and procedures. After lease relinquishment, BHP will transfer the MCP and all associated completion relevant information to the DEMIRS for its files.

BHP will progressively update this MCP over time to capture and summarise current closure planning information associated with:

- Closure planning prior to cessation of operations;
- Implementation of the closure program of works; and
- The post-closure monitoring and reporting period.

BHP will communicate closure planning progress to the regulators via existing AER channels and will update the MCP as knowledge gaps are filled and closure plans are refined.

# 13 Reviewed mine closure plans

This section outlines the key changes to this MCP from the previous revision submitted to government in 2020:

- Section 13.1 provides a summary of the key changes between this revision of the plan and the last;
- Section 13.2 summarises regulator comments provided on the 2020 plan and how these have been addressed in this update; and
- Section 13.3 outlines progress made to address knowledge gaps and implement improvement activities. It also summarises the new knowledge gaps identified during the development of this MCP.

## 13.1 Changes to this revision of the MCP

This revision of the MCP (Revision 6) represents a major update to the 2020 MCP (Revision 5) and incorporates the outcomes of a range of studies conducted to support the Closure IPS and SPS, noting that the designs presented in this plan are subject to change following further consultation with BNTAC and the Banjima people, and additional design studies. The key changes between this revision of the MCP and the 2020 plan are summarised below and in Table 13-1:

- The plan has been restructured to address comments from regulators on other plans. The forward work program has been moved to Section 13.3, and information on risk management measures that was previously in Section 7, has been moved to Section 9 to reduce duplication.
- The expected completion date for mining at Yandi has changed from 2028 to around 2032 including mining at E8, with options currently under internal consideration for mining remnant ore, and utilising Yandi infrastructure as a regional processing hub for satellite ore bodies beyond cessation of current mining activities.
- The stakeholder section has been updated to amend the consultation program and include a summary of consultation that has occurred since the last closure plan (Section 4).
- The knowledge base section has been updated to include the outcomes of technical studies conducted since the submission of the last closure plan including:
  - Analysis of rainfall variability (Section 5.1.1).
  - Geochemical characterisation of overburden including static and multi-stage leach testing (Section 5.2.3).
  - Update to the characterisation of backfill hydraulic properties (Section 5.2.4.3) and settlement assessment (Section 5.2.4.4).
  - Summary of fibrous materials detected during drilling in the W1-SP0 flood channel alignment (Section 5.2.4.5).
  - Updates to the volumes of materials available for backfill (Section 5.2.5).
  - Landform evolution modelling of the potential for pit wall erosion post-closure (Section 5.4.3).
  - Updates to information on vegetation, flora and fauna based on studies conducted for the *Marillana Creek (Yandi) Life of Mine Proposal Significant Amendment* ERD (Sections 5.6 to 5.7).
  - Updated flood modelling for existing conditions (Section 5.9.1.2).
  - Updates to conceptual and numerical groundwater modelling (Section 5.9.2).
  - A review of groundwater and surface water quality monitoring results, with a view to developing a monitoring program that will inform the development of numerical completion criteria (Section 5.9.3).
  - Revision to the status of contaminated sites (Section 5.10).
  - Update to knowledge of the cultural values of Banjima people, obtained through consultation and a review of publicly available information (Section 5.12).
  - Additional water balance modelling to account for updated information on the permeability of backfill, test different backfill configurations and include:
    - C6 Pit (which was previously excluded from modelling).
    - Revised pit shells based on updated mine planning data.
    - A revised assumption for the downstream water levels in the RTIO Mungadoo Pit based on the joint BHP / RTIO modelling
  - Information on the approach taken to the backfill designs presented in Section 9 (Section 5.14.2).
  - Pit lake water quality modelling (Section 5.14.3).
  - An assessment of the potential impacts of a release of water captured by W4 Pit to Marillana Creek (Section 5.14.4).
  - An initial pit lake risk assessment (Section 5.14.6).
  - Design studies for infrastructure to manage surface water flows post-closure (Sections 5.14.7 to 5.14.10).
  - Update to the materials balance for closure (Section 5.14.12).
  - Updated information on the performance of rehabilitated areas including the C1 and E2 OSAs that will remain in the landscape post-closure, and E1 and E4 Marillana Creek diversions (Sections 5.15.2 to 5.15.4). Section 5.15.4 also includes a summary of landform evolution modelling conducted for the C1 and E2 OSAs.
  -

  - A summary of the research conducted to develop vegetation completion criteria (Section 5.15.5) and the scope of a rehabilitation trial proposed for FY25 (Section 5.15.7).
- The assumed post-mining land use remains *relatively natural environments for pastoral grazing purposes*, however, Section 6 has been updated to provide a brief summary of the status of post-mining land use planning, with further information provided in Appendix J.1.
- Section 7 (identification and management of closure issues) has been updated to:
  - Simplify the change assessment (Section 7.3) so that the section focuses on the cumulative change to the post-mining environment, compared to the pre-mining environment, following implementation on the proposed closure designs outlined in Section 9. Most of the information for this section has been drawn from the studies summarised in Section 5, but the section includes the outcomes of surface water modelling for closure conditions (including a climate change scenario) (Section 7.3.2.1).
  - Include a more detailed assessment of risks reflecting the stage of the Yandi mine life and associated design studies (Section 7.4 and Appendix L.2).
- There have been some minor updates to completion criteria (Section 8) to reflect BHP's contemporary practice and information arising from the design studies outlined in Section 5.
- The closure implementation section has been revised to include:
  - A new visualisation reflecting amendments to mine closure designs (Section 9.2.1).
  - The closure designs developed as part of the Closure IPS and SPS for:
    - Mine voids (Section 9.2.3)
    - Surface water management infrastructure (Section 9.2.4)
  - Additional information on demolition and asset retention and maintenance programs (Section 9.2.5).
  - Updates to the revegetation strategy (Section 9.3).
  - A revised implementation schedule (Section 9.4).
- Details of pre-closure and post-closure monitoring programs have been updated to reflect:
  - Recommended improvements to the surface water and groundwater monitoring programs (Sections 10.1.8 and 10.1.10) arising from the review of monitoring data in Section 5.9.3.
  - A summary of riparian vegetation monitoring conducted under the Marillana Creek Water Resource Management Plan (BHP, 2022b) (Section 10.1.6).
- Further details on BHP's processes for financial provisioning for closure (Section 11).

**Table 13-1 Summary of key changes between the 2020 MCP (Revision 5) and this revision (Revision 6)**

| Mine Closure Plan checklist | Y / N / NA | Section No. | Changes from previous revision (Y / N) | Section No. | Summary |
|---|---|---|---|---|---|
| Has the Checklist been endorsed by a senior representative within the tenement holder/operating company? | N/A | No longer a requirement. | | | |
| **Public Availability** | | | | | |
| Are you aware that all approved MCPs will be made publicly available? | Y | N/A | | | |
| Is there any information in this MCP that should not be made publicly available? | Y | Y | | | Commercially sensitive |
| If 'Yes' to Q3, has confidential information been submitted in a separate document/section? | Y | Appendix H<br>Appendix J<br>Appendix K<br>Appendix L.1.1<br>Appendix R | | | Commercially sensitive |
| **Cover Page, Table of Contents** | | | | | |
| Does the cover page include;<br>• title;<br>• site name and code (environmental group site name and code from EARS2 system or note if this is a greenfields or new site);<br>• version number;<br>• date;<br>• tenement(s); and<br>• tenement holder or authorised company/person. | Y | Cover, Page ii | | | |
| **Project Summary** | | | | | |
| Does the project summary include;<br>• Description of the mining operation<br>• Map of the location of the mining operation showing all relevant mine activities, land disturbances, tenements and other land tenure.<br>• Estimated project completion date. | Y | Section 2 | Y | Section 2 | Minor amendments have been made to features included within the scope of the plan (C6 and proposed E8 Pit). The disturbance table has been updated. The closure domains and completion date have also been updated. |
| **Legal Obligations and Commitments** | | | | | |
| Does the MCP detail all legal obligations for rehabilitation and closure that will affect the post-mining land use and closure outcomes? | Y | Section 3 | Y | Section 3 | Minor update to include the CS Act, *Rail Safety National Law WA Act 2015 (WA)* and revised management plans. |

| Mine Closure Plan checklist | Y / N / NA | Section No. | Changes from previous revision (Y / N) | Section No. | Summary |
|---|---|---|---|---|---|
| **Stakeholder Consultation** | | | | | |
| Does the MCP include:<br>• Information on the engagement that has been undertaken with stakeholders relevant to rehabilitation and mine closure<br>• A record of the engagement undertaken to date<br>• A strategy for ongoing engagement. | Y | Section 4 | Y | Section 4 | The consultation program has been updated to reflect the current stage of the Yandi mine life, and details have been provided of consultation conducted since the 2020 MCP. |
| **Collection and Analysis of Closure Data** | | | | | |
| Does the MCP include:<br>• baseline data that:<br>- informs successful rehabilitation and closure;<br>- identifies the issues to be managed through the mine closure process and the environmental closure risks;<br>- informs the development of criteria or indicators for closure monitoring and performance;<br>- informs the establishment of achievable closure outcomes and goals in a local and regional context; and<br>- establishes baseline conditions for closure monitoring programs.<br>• an analysis of the baseline data that describes how the wider receiving environment, receptors and exposure pathways have been considered;<br>• an analysis of the baseline data that identifies the knowledge gaps and the risk of not having that information; and<br>• details of the methodology of analysing the baseline data. | Y | Section 5 | Y | Section 5 | Information has been updated to include new / additional information on:<br>• Rainfall variability.<br>• Geochemical characterisation of overburden including static and multi-stage leach testing.<br>• Backfill hydraulic properties and settlement assessment.<br>• Fibrous materials.<br>• Landform evolution modelling of the potential for pit wall erosion.<br>• Vegetation, flora and fauna.<br>• Flood modelling for existing conditions.<br>• Conceptual and numerical groundwater modelling.<br>• Groundwater and surface water quality.<br>• Contaminated sites.<br>• Cultural values of the Banjima people.<br>• Water balance modelling and backfill configurations.<br>• Pit lake water quality modelling and an assessment of the potential impacts of a release of water captured by W4 Pit to Marillana Creek.<br>• Pit lake risk assessment.<br>• Design studies for infrastructure to manage surface water flows post-closure.<br>• Update of the materials balance for closure.<br>• Performance of rehabilitated areas.<br>• Landform evolution modelling conducted for the C1 and E2 OSAs.<br>• Research conducted to develop vegetation completion criteria, and the scope of a rehabilitation trial proposed for FY25. |

| Mine Closure Plan checklist | Y / N / NA | Section No. | Changes from previous revision (Y / N) | Section No. | Summary |
|---|---|---|---|---|---|
| Have all relevant technical reports been attached as appendices? | Y | Appendix R | Y | Appendix R | New reports have been provided to reflect the new studies summarised in Section 5. |
| **Post Mining Land Use(s) and Closure Objectives** | | | | | |
| Does the MCP include the post-mining land use(s) that has been proposed or agreed with key stakeholders, including regulators. | Y | Section 6 & Appendix J.1 | Y | Section 6 & Appendix J.1 | While the assumed post-mining land use remains the same, Section 6 has been updated to provide a brief summary of the status of post-mining land use planning, with further information provided in Appendix J.1. |
| Does the MCP describe how the post-mining land use(s) is:<br>• relevant to the environment in which the mine will operate or is operating;<br>• achievable in the context of post-mining land capability;<br>• acceptable to the key stakeholders; and<br>• ecologically sustainable in the context of the local and regional environment. | Y | Section 6 | N | | |
| **Identification of Management of Closure Issues** | | | | | |
| Does the MCP include an environmental closure risk assessment that:<br>• identifies all the environmental closure risk pathways;<br>• evaluates these risks to derive an inherent risk rating, prior to the application of treatments;<br>• identifies appropriate risk treatments, using the hierarchy of control; and<br>• re-evaluates the risk pathways to derive a residual risk rating; and<br>• demonstrates that all residual risks are as low as reasonably practicable (ALARP). | Y | Section 7.4 and Appendix L.2 | Y | Section 7.4 and Appendix L.2 | A more detailed risk assessment has been conducted to reflect the current stage of the Yandi mine life. Appendix L.2 provides detail on the approach taken to framing each of the risks outlined in Table 7-2 (Section 7.4). Where an inherent risk has been assessed as very low, it is outlined in Appendix L.2, but has not been carried through to Table 7-2, to maintain a focus on the key risk issues of importance to Yandi. |
| Does the MCP include information on the processes and methodologies undertaken to identify the closure risks and their potential environmental impacts post-mining, including a description of the risk assessment criteria and risk evaluation techniques. | Y | Section 7.4 and Appendix L | Y | Section 7.4 and Appendix L | Section 7.4 outlines the approach taken to the Yandi closure risk assessment, and Appendix L includes the risk matrices used for prioritising risks and the approach taken to framing the risks provided in Table 7-2 (Section 7.4). |

| Mine Closure Plan checklist | Y / N / NA | Section No. | Changes from previous revision (Y / N) | Section No. | Summary |
|---|---|---|---|---|---|
| **Development of Closure Criteria** | | | | | |
| Does the MCP include:<br>• Site-specific closure outcomes consistent with the post-mining land use(s) that are realistic and achievable based on the closure risk assessment.<br>• Completion criteria that are specific, measurable, achievable, relevant and time-bound, and will demonstrate the achievement of the closure outcomes and monitoring. | Y | Section 8 | Y | Section 8 | There have been some minor updates to completion criteria (Section 8) to reflect BHP's contemporary practice and information arising from the design studies outlined in Section 5. |
| **Closure Implementation** | | | | | |
| Does the MCP include:<br>• a closure work program for achieving the closure outcomes, with implementation strategies and timeframes for each domain and / or feature of the mining operations;<br>• closure designs for landforms; and<br>• contingencies for premature or early closure or suspension of operations. | Y | Sections 9.2, 9.4, 9.5 and 13.3 | Y | Sections 9.2, 9.4, 9.5 and 13.3 | Following comments from regulators, the forward work program has been moved from Section 7 to Section 13.3 and has been updated to reflect the progress made on the program outlined in the 2020 MCP and the new studies arising from the work conducted to develop this MCP.<br>Section 9.2 includes updated closure designs for mine voids and surface water management infrastructure based on the design studies conducted since the 2020 MCP. It also includes a section on asset retention and maintenance.<br>Section 9.4 has been revised to reflect the current understanding of the program for implementation of closure at Yandi.<br>Section 9.5 has been updated to reflect the maturity of the closure planning for Yandi and the approach that will be taken to finalising designs for execution. |
| **Closure Monitoring and Maintenance** | | | | | |
| Does the MCP include:<br>• a monitoring framework to monitor the progress of the closure implementation strategies for achieving closure outcomes and completion criteria;<br>• description of proposed post-closure monitoring; and<br>• a description of the monitoring methodology. | Y | Section 10 | Y | Section 10 | Details of pre-closure and post-closure monitoring programs have been updated to reflect:<br>• Recommended improvements to the surface water and groundwater monitoring programs arising from the review of monitoring data in Section 5.9.3.<br>• A summary of riparian vegetation monitoring conducted under the Marillana Creek Water Resource Management Plan (BHP, 2022b) |
| **Closure Financial Provisioning** | | | | | |
| Does the MCP include details of closure costing methodology, including clearly documented assumptions and uncertainties? | Y | Section 11 | Y | Section 11 | Section 11 has been updated to provide further details on BHP's processes for financial provisioning for closure |

| Mine Closure Plan checklist | Y / N / NA | Section No. | Changes from previous revision (Y / N) | Section No. | Summary |
|---|---|---|---|---|---|
| **Management of Information and Data** | | | | | |
| Does the mine closure plan include a description of data management strategies, including systems and processes for the retention of mine records and all information and data relevant to mine closure? | Y | Section 12 | N | | |
| **Reviewed Mine Closure Plans** | | | | | |
| If the mine closure plan is reviewed under s84AA of the Mining Act or included in a revision to an approved mining proposal, has the reviewed MCP included:<br>• A revision summary table that clearly outlines all changes made in the reviewed mine closure plan.<br>• A summary table documenting how the aspects identified by the department for improvement in the prior revision of the mine closure plan have been addressed.<br>• A table documenting how the knowledge gaps identified in the prior revision of the mine closure plan have been addressed, as well as any new gaps identified. | Y | This section (Section 13) | Y | This section (Section 13) | Refer to remainder of table for a summary of changes. Tables detailing responses to regulator comments and progress against knowledge gaps are detailed in Sections 13.2 and 13.3 respectively. |

## 13.2 Feedback on 2020 closure plan & response in this MCP

Table 13-2 summarises the feedback provided by regulators on the 2020 version of the MCP and how this MCP has responded to the feedback.

**Table 13-2 Feedback on 2020 MCP**

| Item No. | Section No. | Regulator Comments | Closure Plan Response |
|---|---|---|---|
| **DMIRS (now DEMIRS) closure comments** | | | |
| 1. | Maps | It is requested that in the next Mine Closure Plan (MCP) iteration maps are provided in a larger scale using satellite imagery to allow the Department of Mines, Industry Regulation and Safety (DMIRS) to review the extent of the disturbance and location of permanent features. This will enable DMIRS to obtain a better understanding and to assess closure risks. | Original pdfs of maps have been provided in Appendix Q to provide greater clarity. |
| 2. | Stakeholder consultation | Stakeholder engagement is a key component of mine closure planning. Early and continuous engagement with stakeholders enables operators to better understand and manage stakeholder expectations. DMIRS expects that further engagement with key stakeholders will occur prior to submission of the next iteration of the MCP, particularly regarding post-mining land use and closure outcomes / criteria. | There have been several engagements with BNTAC and the Banjima people since the 2020 MCP which have included high level discussions of closure outcomes and sharing of information on post-mining land use (Section 4.3). The consultation process is ongoing. At the time of writing, BNTAC and the Banjima people had requested that the SPS be put on hold and a summary be provided of the decision-making process leading to the current proposed closure approach, and post-mining land use investigations conducted to date. These summaries were provided in March 2025 and BNTAC and the Banjima people were considering the information at the time of writing. |
| 3. | Collection and analysis of closure data | Limited information regarding potential for generation of Neutral Metalliferous Drainage (NMD) is provided in the MCP. It is unclear whether any waste or exposed surfaces contain metals / metalloids at concentrations that exceed environmental investigation levels, and what analysis has been undertaken to determine that NMD is not a risk. The occurrence of only low concentrations of sulphide minerals, or indeed the absence of sulphides, does not mean that mined materials will not produce drainage, such as NMD that could present a risk to the receiving environment. It is understood that further Acid Mine Drainage (AMD) assessments will be undertaken by the proponent. The results of these assessments are expected to be provided in the next iteration of the MCP.<br>With regards to material characterisation undertaken to date, it is expected that in the next iteration of the MCP this section provides details of spatial representation of samples analysed to date. | Further overburden characterisation has been conducted including multi-stage and saturated column leach testing (Section 5.2.3).<br>The number of samples taken from each deposit and lithology during various studies are provided in Appendix B.<br>A review of the sampling program by Mine Waste Management (2022a) concluded that together the available geochemistry data from the studies conducted at Yandi are sufficient for the purposes of AMD source hazard assessment and closure planning. As a minimum, ABA data are available for the stratigraphies that represent 93% of the total estimated overburden volume, and leachate testing has been completed for the key stratigraphies representing the bulk of the total overburden volume (66%) and pit wall surface exposures (estimated to be 90% or greater). This information is supplemented by a more extensive BHP assay dataset of around 9 million total sulphur data as well as estimated ANC and total elemental concentrations (Section 5.2.3.1). |

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| 4. | Identification and management of closure issues | • The risk assessment section provides a risk assessment based on the standard BHP risk process. The description / definition of consequences and likelihood considered relevant to the project are provided as an attachment to the MCP. The consequence description is generic and not specific to each environmental factor / receptor at risk at closure.<br>• Risk rating / levels have not been provided in table 7-6.<br>• Risk pathways have been combined into 5 key risk events, and it is unclear if all risks identified throughout the document are listed / described and addressed in table 7-6. DMIRS recommends that individual risk pathways are provided for each activity / source, as risks posed to the environment are different. Risk Category and pathways for revegetation should be provided separately (currently combined into a completion criteria category).<br>• The environmental risk assessment will determine which risk pathway require development of closure criteria and outcomes, thus table 7-6 is required to be more specific and clearly inform criterion objectives in table 8-2.<br>• Failure to achieve the agreed completion criteria and consequently closure outcomes needs to be considered as a higher consequence than it currently is. Failure to meet agreed closure outcomes is likely to result in failure to achieve relinquishment of site, ongoing closure costs, poor stakeholder opinion / reputational impacts and from that, impacts to future projects and approvals. | The risk assessment has been updated to the contemporary format used by BHP and includes the consequence, likelihood and risk ratings within Table 7-2.<br>The severity table that BHP uses to assess consequences has been provided as a confidential appendix (Appendix L.1.1). This provides further guidance on how to rank consequences.<br>The information in Table 7-2 provides links to locations within the MCP where risks are discussed. Justification for the risk pathways selected is provided in Appendix L.2.<br>The risks in Table 7-2 have been broken down to a greater level of granularity, however, a degree of aggregation is appropriate as breaking down risks to individual causes may underestimate the cumulative risk associated with a particular landform or area. The key purpose of the risk assessment is to systematically identify issues that need to be managed in closure and prioritise high risks that require close scrutiny or additional resources to manage. The systematic consideration of risk can also identify areas where further information is required. The risk register in this document achieves these objectives.<br>Table 7-2 references the completion criteria relevant to each risk, and likewise the completion criteria table (Table 8-2) references relevant risks in Table 7-2. |
| 5. | Closure outcomes and completion criteria | There is limited consideration of performance of permanent landforms or rehabilitated land in the long-term. For example, DMIRS expects that Landform evolution modelling is undertaken to demonstrate that landforms will perform as expected not only at the time of closure and relinquishment, but also in the long-term (~300 years or longer). Hydrogeochemical modelling also needs to demonstrate that final landforms are non-polluting / non-contaminating in the long-term post-closure. | Since the 2020 MCP, SIBERIA landform evolution modelling has been conducted for the W1 Pit walls (which can be used as a proxy for other pits, which share similar benched profiles (Section 5.4.3) and the C1 and E2 OSAs that have been rehabilitated and will be retained post-closure (Section 5.15.4.3).<br>The design of the Marillana Creek diversion included geomorphic assessment and sediment transport modelling over the long-term to assess the implications for closure. The creek is designed to replicate natural conditions and, therefore, would be expected to change over time (Appendix N.1).<br>Allowance has been made for meander in the Herbert's Creek land bridge design to accommodate natural creek dynamics (Appendix G.6) and SIBERIA modelling has been conducted to estimate the potential hillslope erosion and crest recession that could result from the development of gullies over 1,000 years (Section 5.14.10). The forward work program (Section 13.3) includes an action to review the Herbert's Creek land bridge design for closure.<br>While the erosion of pit buttresses has not been specifically considered, lessons learnt from pit wall and Herbert's Creek land bridge erosion modelling have been captured in Section 9.2.3.3.<br>Hydrogeochemical modelling of pit lakes has been conducted for this MCP and is summarised in Section 5.14.3. Multi-stage leach testing (Section 5.2.3) shows that the potential for acid, neutral metalliferous and / or saline drainage from overburden and pit wall exposures at Yandi is low. |

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| *5.* | *Closure outcomes and completion criteria cont'd* | Some criteria are in a S.M.A.R.T format, however refinement is required to ensure they are all measurable and time bound. The rationale behind criteria should also be provided (e.g. revegetation and ecological criteria) and it should be demonstrated that they are based on, and continuously informed by scientific studies and / or trials. Domains where revegetation is planned, should also be specified in table 8-2. This should be addressed in the next iteration of the MCP. | BHP concurs with the assertion that there should be a basis for completion criteria and notes that criteria do not necessarily need to be numerical to be measurable. The framework in Section 8.3 aligns with the WABSI completion criteria guidance provided in Young et al. (2019). This MCP includes an analysis of surface water and groundwater quality with a view to the development of numerical completion criteria (Section 5.9.3). The review recommended a monitoring program to inform the development of appropriate completion criteria. This has been included in Section 10 and 13.3.<br>Section 5.15.5 incorporates a summary of the work conducted to research vegetation completion criteria and determine the criteria outlined in Section 8.3.2. However, vegetation and growth media trials are also planned to be established in FY25 (Section 5.15.7) which will enable completion criteria to be refined, if required. Sections 5.6.3.1, 5.15.5, 5.9.4.1 and Appendix N.1 discuss the work that has been conducted to inform the vegetation criteria for the Marillana Creek diversion. This was also provided in the 2020 MCP.<br>Table 8-2 in Section 8.3 has been amended to include more detail on the domains where revegetation is planned, but we also note that the areas to which the various the vegetation development completion criteria applies were outlined in the 2020 MCP and further discussed in in Section 9.1.3 (Section 9.3 of this MCP). |
| | | There are a number of knowledge gaps that are required to be addressed to refine and inform completion criteria. Backfilling scenarios and acceptable levels for water quality for example are still to be determined. This is requested to be addressed in the next iteration of the MCP. | There has been significant work to develop the backfill strategy for Yandi outlined in Section 9.2.3.1, however, as outlined in Section 4, the strategy may be subject to change pending further consultation with BNTAC and the Banjima people.<br>Work to inform the future development of completion criteria for pit lakes includes hydrogeochemical modelling and an initial pit lake risk assessment, noting that this assessment will need to be refined as designs progress (Sections 5.14.3 to 5.14.6). |
| | | Refinement of the following Criterion Objective is recommended. Criterion objective: *Materials with poor chemical properties do not compromise rehabilitation (landform stability and revegetation) or water quality.* DMIRS expects that all final landforms and rehabilitated land are non-polluting / non-contaminating post-closure and do not compromise rehabilitation, or negatively impact any downstream receptors. This is required to be addressed in the next iteration of the MCP. | It is not clear why DEMIRS considers the objective '*materials with poor chemical properties do not compromise rehabilitation (landform stability and revegetation) or water quality'* to be different to the wording '*all final landforms and rehabilitated land are non-polluting / non-contaminating post-closure and do not compromise rehabilitation, or negatively impact any downstream receptors'.* The objective is specifically focused on the aspect 'geochemical stability' and hence is focused on the chemical properties of materials, rather than general contamination which is addressed by the water quality and contaminated sites criteria. The objective picks up the key aspects of not compromising:<br>• Rehabilitation; and<br>• Water quality.<br>Given that this objective is standard across out Pilbara sites and that it meets the key aspects required by DEMIRS, we have not changed it. |
| | | Consultation with key stakeholders regarding proposed criteria is critical at this stage of mine life. Further engagement is required prior to next iteration of the MCP. | There has been a significant amount of engagement with key stakeholders since the 2020 MCP and this is recorded in Section 4.3. Engagement is ongoing. |

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| 6. | Closure implementation | Buried infrastructure is proposed to be removed to a depth of 600 millimetres (mm) below ground surface. DMIRS believe that the acceptable minimum depth pipelines, and other underground services, need to be buried to remain in-situ post-decommissioning is 1,500 mm (sealing of pipelines might also be required). The issue with leaving shallow buried infrastructure in-situ is the possibility of exposure of infrastructure to the surface during rehabilitation works and post-closure. There is usually also no indicator for any future land user that a buried infrastructure exists, which could be unearthed during future activities on the land. | BHP recently engaged DEMIRS (19/12/24) in relation to buried infrastructure removal depth (Section 4.3) and made the case that in general, removal depth for below ground infrastructure to 600 mm is a reasonable approach that presents a low risk for post-mining land uses such as the interim post-mining land uses for Yandi (Section 6.3), and aligns to BHP processes on rehabilitation.<br>Under BHP procedures deep ripping (up to 1000 mm) only occurs in heavily compacted areas like haul roads. In infrastructure areas, the BHP procedures state a maximum ripping depth of 600 mm. Test ripping commonly forms part of rehabilitation execution scope and ensures ripping depths are fit for purpose. Experience demonstrates that ripping depths required during execution are typically less than maximums stated in the procedure.<br>During this engagement, DEMIRS expressed an openness to consider alternate infrastructure removal depths, including removal to 600 mm, if it presents low risk to post-mining land uses, accounts for rehabilitation practices (ripping depths) and considers external stakeholder feedback.<br>As outlined in Section 9.2.5, buried infrastructure will generally be removed to a minimum depth of 600 mm below ground surface although final depths of infrastructure removal may be greater if required due to site specific conditions or risks, or agreements with stakeholders. BHP notes that updates to post-mining land uses in future MCPs may require a review of the risks associated with buried infrastructure to determine whether an alternate standard is required. |
| | | DMIRS expects that in the next iteration of the MCP that the following is provided for each domain:<br>• Indicative final footprint and updated closure designs (relevant technical reports attached).<br>• Domain specific knowledge gaps and proposed timeframe to address these.<br>• Domain specific rehabilitation timeframes.<br>• Domain specific rehabilitation materials volume requirements. | Updated closure designs are provided in Section 9 by domain and associated technical studies summarised in Section 5 and attached as Appendix R.<br>Domain-specific knowledge gaps are outlined in Section 13.3 along with proposed timeframes for completing relevant technical studies.<br>Domain-specific rehabilitation timeframes are provided in Section 9.4.<br>Material balances are provided in Section 5.2.5. |
| | | Detailed information regarding strategies for suspended operations under care and maintenance should be provided in the next iteration of the MCP. | Section 9.2.5.4 outlines the asset retention and maintenance plan for Yandi infrastructure that is not in use for operations. |

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| *6.* | *Closure implementation cont'd* | Pits (e.g. E7, W2, W3) are located within close proximity to tenement boundaries (due to the scale of figures provided, distance to boundaries cannot be determined), demonstration that zones of instability and bunds are within tenement boundaries is required in the next iteration of the MCP. | BHP and RTIO are planning to mine the pillar of CID between the Mungadoo and E7 pits which will include planning for safety bunds on both tenements.<br>At the time of writing, pit wall stabilisation measures and safety bund locations were being studied, but the outcomes of this work were not available for incorporation in this MCP. One of the factors associated with this study is consideration of tenement boundaries. Any changes to the backfill strategy following consultation with BNTAC and the Banjima people are likely to impact pit wall stabilisation measures required. Updated information will be included in future updates of this MCP.<br>Tenement boundaries have been considered as part of surface water management design studies, where relevant (Section 5.14.9). |
| | | Backfilling of pits: it is unclear if BHP has consulted with DMIRS Geological Survey and Resource Strategy Division to determine that the State is satisfied that no future resources will be sterilised through backfilling. It is recommended that BHP do this prior to next iteration of the MCP. | BHP contacted DEMIRS regarding the submission of sterilisation reports in September 2021 (Section 4.3). The reports will be submitted progressively as the backfill strategy for Yandi evolves in line with stakeholder consultation, and backfill operations are progressively implemented (Section 9.2.3.1). This activity has been captured in the forward work program in Section 13.3. |
| 7. | Financial provisioning for closure | Statutory Guidelines for Mine Closure Plans requires the MCP to include the details of closure costing methodology, including clearly documented assumptions and uncertainties. This has not been provided in this iteration of the MCP. Please include this information in the next iteration of the MCP. | Section 11 has been updated to include additional information. |
| 8. | Closure monitoring and maintenance | • Monitoring framework to monitor progress of the closure implementation strategies for achieving closure outcomes and completion criteria is generally provided. This will need to be refined in the next iteration of the MCP with the detailed methodology provided.<br>• Details of any analogue or reference sites used for monitoring should also be provided. | Section 10 has been updated to include improvements to BHP's water quality monitoring program and to provide further details of BHP's rehabilitation monitoring procedure. Appendix H.2 includes the current version of the procedure. Section 5.15.5 summarises the research conducted to define the completion criteria in Section 8.3.2. |
| **DMIRS (now DEMIRS) geotechnical comments** | | | |
| 1. | Pit wall stability | When mining has been completed, pit wall stability should be re-analysed based on as-excavated pit wall geometries, particularly for the wall sections currently not meeting the selected criterion for long-term stability. When the re-analysis has been completed, the details should be provided to DMIRS. | Noted. An action has been included in the forward work program to provide this information in future updates of the MCP. |
| 2. | Overburden storage areas (OSA): | Upper surface of the OSA has been designed to contain water from a 72-hour 200-year ARI (0.5% Annual Exceedance Probability) rainfall event. The events exceeding the design rainfall are to be managed without allowing excessive erosional damage and compromising structural integrity of the landform. The design recommends rock armouring of some areas of the OSA to prevent scouring from runoff. The concept designs presented are acceptable. The finalised design details should be provided to DMIRS for review before accepting the final closure strategy. | SIBERIA modelling has been conducted for the OSA landforms (which were largely rehabilitated between 1998 and 2011, although an area of C1 OSA was remediated in 2021) and concludes that the landforms will be erosionally stable in the long-term. Design information is provided in Section 5.15.4 and Appendix N. |
| 3. | Mine void backfilling | Some areas of the mined-out pits will be backfilled to improve long term stability of pit walls. The backfilling design concept with a 3:1 (horizontal: vertical) slope angle should be appropriate subject to the use of competent backfill materials, and water management in and around the pits. Further analyses of pit wall stability are to be conducted to confirm the exact locations for the backfilling strategy. These are required to be provided for DMIRS assessment. | The backfill design has been refined and is described in Section 9.2.3.1. This does not include potential pit wall buttresses or laybacks. At the time of writing, pit wall stabilisation measures were being studied, but the outcomes of this work were not available for incorporation in this MCP. Any changes to the backfill strategy following consultation with BNTAC and the Banjima people are likely to impact pit wall stabilisation measures required. Updated information will be included in future updates of this MCP. |

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| 4. | Access restriction to the mined out open pits (safety bunds): | The exact location of the bunds will have to be decided based on the as-mined pit conditions. | The final position of safety bunds will be dependent on the final pit shells and backfill designs. Updated information will be provided in future iterations of the MCP. |
| | | In recent years, pit lakes at decommissioned open pit mines have become places of tourist attraction due to publicity given through social media. This in turn has become an emerging public safety concern at open pit mines after closure. Since some areas of the mine void will be converted to pit lakes, the next iteration of the MCP should include consideration of the emerging public safety concerns from a long-term point of view. | An initial pit lake risk assessment has been conducted to assess the risks of pit lake water quality to human health (Section 5.14.6). This will be updated as the backfill strategy is finalised and closure designs progress.<br>Where pit lakes meet backfilled surfaces, these have been designed with a shallow drop-off to mitigate against drowning (Section 9.2.3.1). Further assessments of risk will be conducted an incorporated into future iterations of this MCP. |
| 5. | Marillana Creek diversion | • Additional information regarding the proposed design of the diversion of the Marillana creek has been provided within the document. A good summary of studies undertaken to date and interpretation of the results are provided and considered appropriate; however, technical geotechnical reports were not attached to the MCP, which is a requirement of the *2020 Statutory Guidelines for Mine Closure Plans* and essential for DMIRS assessment. Please include the relevant geotechnical reports in the next iteration of the MCP.<br>• In regard to the information contained within the document the following needs to be addressed:<br>- To prevent 'large scale' slope failures, the cut slopes of the Marillana Creek diversion channels are designed to achieve a factor of safety (FOS) of 1.5 for static conditions. Clarification is required on whether the cut slopes will be stable under seismic loading conditions applicable to the project area. Please include this information in the next iteration of the MCP.<br>- The cut slopes were also designed to be sufficiently steep with a FOS of 1.0 to 1.2 to allow localised small scale (not large scale) instability, which is considered to be beneficial to the fluvial system in the long-term. However, the localised instability, combined with subsequent erosion, could contribute to 'large scale' instability, which may cause partial blockage of the channel. From the information provided in the MCP, it is not clear whether this possibility has been assessed. The possibility that the localised instability, combined with subsequent erosion, could contribute to 'large scale' instability requires further discussion within the next iteration of the MCP. | The geotechnical stability analysis for the Marillana Creek diversion (Advisian, 2017d) is summarised in Appendix N.1.11 and provided in Appendix R. However, it should be noted that the creek has a large transport capacity (the width of the creek is in the order of 100 m) compared to the volume of material that could be deposited from a slip failure of an embankment (maximum height 35 m). Deposition in creeks is generally carried downstream by the next significant flow event. Localised slumping is an important source of sediment for the creek and adds to geomorphic diversity. |
| 6. | Flood channel stability assessment: | • Final location for W1-SP0 should be confirmed when the ongoing investigations for alternative locations or alignments are completed.<br>• The W4 SP3 flood channel design should ensure that Marillana Creek does not flow back into the W4 Pit along the flood channel during high flow events.<br>• The selected alignment of H-SP2 flood channel should be confirmed when the relevant studies are completed.<br>• The MCP has identified knowledge gaps and listed additional studies required to finalise flood channel designs. DMIRS endorse the additional studies listed in the MCP and expect the results to be provided in the next iteration of the MCP. | Updated information on flood channels has been incorporated into this iteration of the MCP, including the outcomes of geotechnical investigations and several optimisation studies (Section 5.14.7). |

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| **DWER comments** | | | |
| 1. | General | BHP has identified the requirement for ongoing investigations to inform a preferred closure strategy to be conducted on pit salinities for Yandi operations to address Condition 9 of MS 679. Condition 9 addresses mine closure requirements specifically addressing pit lake salinity at relinquishment of the leases by the Proponent with the preparation of a Hypersaline Waters Diversion Management Plan. The Hypersaline Waters Diversion Management Plan has not been provided as part of the MCP.<br>DWER recommend that the Hypersaline Waters Diversion Management Plan as required by condition 9 of MS 679 is submitted as part of the mine closure review as it correlates with Condition 5 of MS 1039 mine closure requirements. | Condition 9 of MS 679 is triggered when monitoring shows that pit lakes exceed a concentration of 6,500 mg/L TDS on one or more occasion in each of two consecutive years. At this time, a Salinity Contingency Plan must be developed which includes corrective actions. If this plan includes diversion of surface flow into a pit lake to reduce salinity, a hypersaline diversion management plan is required.<br>At this stage of the mine, there are no pit lakes and consequently Condition 9 of MS679 has not been triggered. BHP is still working through the backfill strategy with BNTAC and the Banjima people and, following completion of this consultation (noting that it will take several consultation sessions to work through the closure strategy), will review Condition 9 and may seek to update it to align with the final mine void closure strategy.<br>The current closure strategy involves diversion of surface water to W1 and W4 pits in extreme rainfall conditions, but these pits are not predicted to be permanent pit lakes. Studies progressed to date have identified that the risks of discharging saline water to Marillana Creek are low (Section 5.14.4) (very low likelihood / low consequence). |
| 2. | Knowledge Gaps | DWER advises the MCP is required to address the following knowledge gaps:<br>• The evaluation framework established to determine different backfill configurations.<br>• Discussion of AQ2 modelling updates on GoldSIM modelling undertaken in 2016.<br>• Discussion of pit closure priorities within Yandi operations.<br>• Correlation and alignment of studies and investigations associated with Condition 9 of MS 679 and input into mine closure requirements of Condition 5 of MS 1039.<br>• Review outcomes of discussions with Traditional Owners on expectations on final land use options.<br>DWER would welcome the opportunity to discuss knowledge gaps and in particular the closure approaches defined in this version of the MCP, including explore closure scenarios and the knowledge gaps outlined in Section 5.13.1.5. DWER recommends consultation be held early 2022 coinciding with the timing of scheduled studies and investigations outlined in Table 7-12 of the MCP for Yandi closure improvement activities for 2022. | The modelling to support backfill designs has been updated by AQ2 (Section 5.14.1) and further studies have been conducted to support backfill option selection and residual risk analysis, including:<br>• An initial pit lake risk assessment by Mine Lakes Consulting on whether there would be benefits to backfilling certain pits compared to others (Section 5.14.6).<br>• Hydrogeochemical modelling (Section 5.14.3).<br>• Release of pit lake water to Marillana Creek (Section 5.14.4).<br>• Groundwater modelling (Section 5.9.2.7).<br>Condition 9 of MC679 is discussed above.<br>Several consultations have been undertaken with Traditional Owners since the 2020 MCP (Section 4.3) and are ongoing (Section 4.2 and 13.3). |

## 13.3 Forward work program & progress to address knowledge gaps

Table 13-3 outlines:

- The data gaps and improvement activities incorporated into the 2020 MCP and provides commentary on the current status of those activities.
- New knowledge gaps identified in the completion of this plan.

The table is structured as follows:

- Column 1 identifies the technical area to which a knowledge gap and improvement pertains.
- Column 2 identifies the closure domains relevant to each knowledge gap and improvement activity.
- Column 3 outlines the knowledge gap that needs to be filled.
- Columns 4 to 6 (shaded grey) reproduce the forward work program in the 2020 MCP and provide commentary on the progress made against each activity in the 2020 program.
- Columns 7 to 9 outline the forward work program identified for this MCP following work completed since 2020. Column 7 identifies whether:
  - An action has been carried forward from the 2020 MCP. In some instances, activities have been carried forward as they were scheduled for completion at a later date or require further work.
  - An action has been carried forward from the 2020 MCP but has been reworded. In these cases, an activity may be broadly similar to one in the 2020 MCP but needs to be refocused based on work done since the 2020 MCP.
  - An action is new and has arisen as a result of the investigations conducted since 2020.
  - An action was completed in 2020.

Note the timings in Table 13-3 are subject to the timeframe for consultation with the Banjima people and recommencement of the study program.

**Table 13-3 2025 forward work program and progress against forward work plan in the 2020 Yandi closure plan**

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| **CONSULTATION** | | | | | | | | | |
| Government and stakeholder consultation | Ex-pit areas, mine voids, surface water infrastructure | Traditional Owner values, visual amenity and requirements for repatriation of cultural artefacts and safe access post-closure. | Consultation with Banjima people to:<br>• Validate values guiding closure designs and decision-making (i.e. the ecohydrological evaluation framework).<br>• Assess visual amenity impacts.<br>• Identify requirements for repatriation of cultural artefacts and safe access post-closure. | Ongoing | There have been several engagements with BNTAC and the Banjima people since the last MCP (Section 4.3), however, further engagement is required and this action has been carried through to the 2024 forward work program, but has been made more general to encompass all aspects relevant to closure of Yandi discussed with BNTAC and Banjima. | FWP 1 | **REWORDED**<br>Consultation with the Banjima people regarding the closure designs for Yandi and requirements for repatriation of cultural artefacts, songlines and safe access post-closure.<br>*Note: consultation on post-mining land use is captured by FWP 45.* | Ongoing | At the request of BNTAC, BHP has provided a summary of the option evaluation process to select the currently proposed closure option outlined in Section 9. However, the Banjima people have expressed opposition to saline pit lakes and further consultation is required. This timing is, therefore, appropriate. |
| | Infrastructure | Stakeholder requirements for infrastructure post-closure | Undertake government and stakeholder consultation to identify requirements for infrastructure as part of the post-mining land use consultation. | Prior to decommissioning | There has been communication with both government and other stakeholders regarding infrastructure arising from the Stage 1 decommissioning program at Yandi (Sections 4.3 and 9.2.5.1). However, this action will be carried forward to capture this requirement for future decommissioning projects. | FWP 2 | **REWORDED**<br>Undertake government and stakeholder consultation to identify requirements for infrastructure prior to Stage 2 demolition. | 2028 | Consultation has already been conducted for Stage 1 demolition. This timing is appropriate as it aligns with the next stage of demolition. |
| **LANDFORMS** | | | | | | | | | |
| Materials characterisation | Mine voids | Permeability of backfill materials | Conduct permeability testing of backfill materials. | 2022 | Initial testing program completed (Section 5.2.4.3). | FWP 3 | **REWORDED**<br>Complete further permeability testing of backfill materials that increases the spatial distribution of test locations. | Next statutory update (2028) | The GoldSim water balance model is sensitive to the assumption used for permeability of backfill material. The outputs of the model influence pit lake modelling outcomes and backfill designs. It is, therefore, appropriate that a high priority be put on this forward work program. |
| | OSAs | Characteristics of OSAs remaining post-backfill | Characterisation of remaining ex-pit materials to inform OSA landform design, if required. | 2022 | Only C1 and E2 OSAs will remain in the landscape post-closure. SIBERIA landform evolution modelling has been conducted for a range material types and has predicted that the landforms will be stable in the long term (Section 5.15.4.3). No further action is required. | - | **COMPLETE** | N/A | N/A |
| | Mine voids | Ability to selectively recover materials of different permeabilities | Investigate OSA construction to determine if there is adequate segregation of overburden with different permeabilities to enable them to be selectively recovered and placed within pits. Revise estimates of different overburden types available for use. | 2022 | Permeability testing (Section 5.2.4.3) has indicated that stockpiled material is mixed and unlikely to have a significant range of hydraulic conductivity. Therefore, segregation of different materials and selective placement of backfill is unlikely to be make a difference to how groundwater moves within the backfilled material. Segregation of materials for use in backfill has, therefore, been discounted and no further action is required. | - | **COMPLETE** | N/A | N/A |
| | Backfilled mine voids / floodplains | Settlement rates | N/A | N/A | N/A | FWP 4 | **NEW**<br>Conduct further assessment of overburden settlement rates to inform backfill and floodplain designs. | Next statutory update (2028) | Overburden settlement rates have a potentially significant influence over mine void closure outcomes (e.g., presence and salinity of seasonal expressions of water) and the effectiveness of floodplain surfaces. A high priority has, therefore, been assigned to this task. |
| | Flood channels | Fibrous material exposure risks in flood channels | N/A | N/A | N/A | FWP 5 | **NEW**<br>Further risk assessment of the potential fibrous material exposures in the W1-SP0 flood channel in comparison to natural analogues and review of mitigation options, if required. | Next statutory update (2028) | While it is expected that the risk of fibrous material exposures is low, the timing of this program is appropriate, as the risk needs to be further investigated prior to progressing to detailed closure design. |

[69] Note: the timing of programs may be influenced by the BNTAC and Banjima people consultation program.

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Materials characterisation cont'd* | *Flood channels continued* | *Fibrous material exposure risks in flood channels continued* | N/A | N/A | N/A | FWP 6 | **NEW**<br>Where there is safe access, map fibrous materials exposures in flood channels following construction to enable confirmation (or otherwise) that the assumptions used in risk assessments are valid. | Following construction of flood channels | Given the random and unpredictable occurrence of fibrous materials in drill core. The extent of exposures can only be estimated following construction. |
| | Mine voids | Influence of backfill materials on pit lake quality including metals and salt mobilisation from AMD0 overburden | Further leach testing of key lithologies comprising backfill materials to inform pit lake water quality predictions. | 2022 | Leach testing has been conducted on key backfill lithologies representing the bulk of the overburden volume (Section 5.2.3). | - | **COMPLETE** | N/A | N/A |
| | Mine voids | Pit wall exposures of PAF material | N/A | N/A | N/A | FWP 7 | **NEW**<br>Once pit shell designs have been finalised, including consideration of any pit wall stabilisation measures (e.g., buttressing, pit wall re-profiling), the geochemical characteristics of pit wall exposures will be reassessed. | TBA following consultation with Banjima | Final pit designs will be influenced by the final backfill strategy and consequently, this action is influenced by the completion of this work which is, in turn, influenced by the outcomes of ongoing consultation with BNTAC and the Banjima people. |
| | Surface water infrastructure | Potential for PAF within flood channel alignments | Conduct drilling and characterisation of materials prior to flood channel construction to assess the potential for exposing PAF materials. | Prior to construction | Drill core from the flood channel geotechnical drilling program is available for analysis and a sampling and analysis plan has been developed. Geochemical analyses have been carried forward to the 2024 forward work program. | FWP 8 | **2020 ACTION CARRIED FORWARD**<br>Conduct drilling and characterisation of materials prior to flood channel construction to assess the potential for exposing PAF materials. | Next statutory update (2028) | While it is expected that the risk of PAF material exposures is low, the timing of this program is appropriate, as the risk needs to be further investigated prior to progressing to detailed closure design. |
| Geotechnical stability | Mine voids | Pit wall stability for closure | Once the backfill strategy has been confirmed:<br>• Re-analyse pit wall stability where:<br>- Initial assessments of a pit without backfill indicated a FoS <1.5.<br>- Pit walls lie adjacent to Marillana Creek.<br>• Identify areas where additional pit wall stability controls are required.<br>• Conduct a review of the stability of bunds over unconsolidated material and confirm the location of safety bunds taking into account interactions with surface water flows and management systems. | 2023 | Pit wall stabilities and stabilisation measures were under review at the time of writing and are likely to be impacted by any changes to the backfill strategy. This activity has been carried forward to the 2024 forward work program.<br>Geotechnical analyses have been progressed for significant bunds (Section 5.14.8.4), but further work is required as captured in FWP 12 below.<br>FWP 9 has been reworded to reflect the work conducted to date and to avoid duplication with other activities in the 2024 forward work program. | FWP 9 | **REWORDED**<br>Complete pit wall stability analyses and design of safety bunds and pit wall stabilisation measures as pit wall and closure designs evolve and incorporate updated information into the next revision of the MCP. | Next statutory update (2028) | Updated information on pit wall stability analyses and designs for pit wall stabilisation measures can be provided in the next statutory MCP update based on work currently in progress. However, further work may be required following consultation with the Banjima people on backfill designs for closure. The timing of this additional work will be dependent on the timing and outcomes of consultation. |
| | | | N/A | N/A | N/A | FWP 10 | **NEW**<br>Following cessation of mining conduct a final check of pit wall stabilities to confirm stability assessments based on as constructed pit geometries, where required. | Following cessation of mining | This work has been prioritised in accordance with DEMIRS geotechnical comments outlined in Table 13-2. |
| | Surface water management infrastructure | Flood channel stability | Collect additional geological and geotechnical data to inform the next phase of flood channel design, and as part of the design, conduct:<br>• Slope stability analysis of the flood channel cuts, including kinematic analysis of final walls on slightly weathered to fresh rock where the geological structures will control the stability of the mass;<br>• Erodibility analysis of flood channel designs;<br>• Assessment of the potential sources of materials for rock armouring (for possible use on a range of engineered structures required for closure at Yandi); and<br>• Constructability assessment. | 2022 | Additional geotechnical data have been collected, and stability / erodibility assessments completed along with several studies to optimise flood channel alignments and designs (Section 5.14.7).<br>Further data is required to progress towards detailed design, and this has been captured in the 2024 forward work program. | FWP 11 | **REWORDED**<br>Conduct further geotechnical investigations and analyses at the W1-SP3, W4-SP4 and eastern part of the W1-SP0 flood channel locations. | Next statutory update (2028) | The inherent risk of creek capture in the absence of surface water management controls is high and consequently a high priority has been placed on conducting work that will enable designs to be finalised. |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Geotechnical stability cont'd* | Surface water management infrastructure | Flood bund stability | N/A | N/A | N/A | FWP 12 | **NEW**<br>Conduct further geotechnical inspections / investigations and analysis of new or existing flood bund locations where additional data is required, including assessment of:<br>• The impact of seepage through the alluvium where it intersects the pit wall.<br>• The potential for dissolution of the calcareous materials of the Oakover Formation.<br>• The condition of the CID where flood bunds are proposed to be constructed on this material. | Next statutory update (2028) | The inherent risk of creek capture in the absence of surface water management controls is high and consequently a high priority has been placed on conducting work that will enable designs to be finalised. |
| | | Floodplain stability | N/A | N/A | N/A | FWP 13 | **NEW**<br>Inspect remnant CID in floodplain locations and conduct further geotechnical stability assessments. | Next statutory update (2028) | |
| | | Minor and intermediate diversion stability | N/A | N/A | N/A | FWP 14 | **NEW**<br>Conduct geotechnical assessments of intermediate and minor diversions, including collection of additional geotechnical information, as required. | Next statutory update (2028) | While failure of intermediate and minor operational diversions have moderate and low inherent risks respectively, a high priority has been placed on this work to enable designs to be finalised while other work is on hold, pending the outcomes of consultation with BNTAC and the Banjima people. |
| | | | N/A | N/A | N/A | FWP 15 | **NEW**<br>Conduct a geotechnical analysis of Herbert's Creek land bridge taking into account the proposed floodplain and backfill design.<br>Assess the need for a geosynthetic liner and the risks associated with tree growth and long-term stability. | Next statutory update (2028) | |
| Safety | Mine voids | Safe access and egress | Following confirmation of the backfill strategy, consider options for incorporating measures for safe access and egress into designs. | 2023 | As discussed in Section 1.4, the backfill strategy has not yet been confirmed and the SPS has been put on hold at the request of BNTAC and the Banjima people. This action has been carried forward to the 2024 forward work program. | FWP 16 | **2020 ACTION CARRIED FORWARD**<br>Following confirmation of the backfill strategy, consider options for incorporating measures for safe access and egress into designs. | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's availability. |
| Landform designs | OSAs | Designs for ex-pit landforms | Following the optimisation of the Yandi backfill strategy, develop landform designs for remaining ex-pit OSAs, conduct a review of the long-term stability of W4 and E2 OSAs and develop remedial action plans, if required. | 2023 | Only C1 and E2 OSAs will remain in the landscape post-closure. SIBERIA landform evolution modelling has been conducted for a range material types and has predicted that the landforms will be stable in the long term (Section 5.15.4.3). No further action is required. | - | **COMPLETE** | N/A | N/A |
| | Mine voids | Preferred backfill strategy | Refinement of preferred backfill strategy based on the outcomes of material characterisation and quantification, backfill material permeability testing and stakeholder engagement. Strategy may include consideration of:<br>• The selective placement of different overburden types with varying physical characteristics and permeabilities (if possible, based on OSA investigation into material segregation) to optimise groundwater level and pit lake outcomes, if necessary to achieve closure objectives.<br>• Selectively contouring overburden within pits to minimise risks to safety and optimise pit lake outcomes and the development of riparian vegetation.<br>• Backfill settlement rates if further investigation is warranted. | 2022 | The backfill strategy has been refined (Sections 5.14.2 and 9.2.3.1) based on permeability testing and revised modelling (Sections 5.2.4.3 and 5.14.1), however, as discussed in Section 1.4, the Banjima people have expressed their opposition to saline pit lakes and further consultation is required before a final strategy can be defined. | FWP 17 | **REWORDED**<br>Review and, if necessary, revise or refine the backfill strategy based on the outcomes of:<br>• Further consultation with BNTAC and the Banjima people.<br>• Data sharing with RTIO.<br>• Settlement studies.<br>• Pit wall stability and floodplain designs.<br>• Updated modelling including any revisions to permeability assumptions.<br>• Updated material balance. | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's calendars.<br>Note that the following forward work programs scheduled for completion prior to the next statutory update will provide supporting information for progressing this action once consultation with BNTAC and the Banjima people has concluded:<br>• Permeability testing (FWP 3).<br>• Assessment of settlement rates (FWP 4).<br>• Completion of current pit stability study (FWP 9). |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Landform designs cont'd* | Mine voids | Sterilisation reports | N/A | N/A | N/A | FWP 18 | **NEW**<br>Provide backfill sterilisation reports to DEMIRS in line with the progressive backfill schedule, commencing with reports for E2 and W5. | Progressive, commencing 2024 | Progressive submission of backfill sterilisation reports in line with the backfill schedule will enable any changes to plans for mining remnant ore to be captured. |
| **CLIMATE CHANGE** | | | | | | | | | |
| Climate change | General | Climate change projections | N/A | N/A | N/A | FWP 19 | **NEW**<br>Incorporate relevant data from updated climate change projections into the next MCP update | Next statutory update (2028) | This timeframe is consistent with the process currently underway to update climate projections to 2090 (Section 5.1.3). |
| **WATER** | | | | | | | | | |
| Groundwater | Mine voids | Impact to groundwater levels surrounding the mine Refinements to pit lake modelling | Conduct investigations to validate the rates used in the GoldSim modelling for seepage from the Weeli Wolli Formation and alluvium following creek flow events. | 2023 | This action has been carried forward to the 2024 forward work program but has been reworded to reflect recommendations made by AQ2 in the most recent backfill modelling study (Section 5.14.1). | FWP 20 | **REWORDED**<br>Incorporate modelling of closure conditions into the regional groundwater model described in Section 5.9.2.7 and align GoldSim and regional groundwater model inputs and outputs. | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's calendars. |
| | Mine voids | Long-term mitigation measures for Flat Rocks riparian vegetation decline | N/A | N/A | N/A | FWP 21 | **NEW**<br>Following the study into long-term mitigation measures for groundwater decline at Flat Rocks conducted in accordance with the Marillana Creek Water Resource Management Plan, incorporate relevant measures into the MCP, if required. | Next statutory update (2028) | The timing is dependent on the timing of the studies conducted in accordance with the Marillana Water Resource Management Plan. |
| | Mine voids | Cause of water level decline in the Ministers North aquifer | N/A | N/A | N/A | FWP 22 | **NEW**<br>Complete investigations to assess the potential for a connection between dewatering in the CID and Ministers North aquifer to the south. | Ongoing with an update to be provided at the next statutory update | This timing is appropriate as additional data needs to be collected over a period of time to enable conclusions about the connection to be drawn. |
| | Mine voids | Impact to groundwater | Conduct additional groundwater and pit lake modelling with revised input parameters on seepage and backfill permeability to investigate:<br>• The influence of pit backfill strategies on groundwater levels and quality surrounding the mine, including a more detailed assessment of:<br>  - The risks associated with selecting either W1 or W5 as an additional sink in a multi-sink option.<br>  - The impact of lower permeability material stored in E1 and E2 pits on water levels and quality.<br>  - The effects of different backfill designs on water levels upstream and downstream of the mine.<br>  - The effects of pit lake stratification and fresh / saline water interfaces.<br>• In more detail, the potential water quality impacts of pit lake releases to Marillana Creek taking into account the results of leach testing of backfill materials. | 2022 | Further backfill modelling has been conducted (Section 5.14.1) with revised permeability estimates based on the work outlined in Section 5.2.4.3.<br>A review has been conducted of whether backfill of any pits would be preferable over other pits (Section 5.14.6.4) and the backfill option has been refined based on the outcomes of this assessment and the need for the W5 Pit to be backfilled to provide stability to a land bridge through the pit.<br>Sinks have been selected for W2, W3, C4/5 and E7. This configuration was selected based, *inter alia*, on consideration of the benefits of backfilling W1 compared to leaving as a sink (Section 5.14.1.1).<br>The effects of pit lake stratification have been considered in sensitivity testing conducted during pit lake hydrogeochemical modelling (Section 5.14.3), and an initial assessment of the potential for density driven flow has been conducted (Section 5.14.5) although further work is required to confirm that the risk of density driven flow is low.<br>The action to assess potential water quality impacts of a pit lake release to Marillana Creek has been completed (Section 5.14.4).<br>The 2024 forward work program has been amended to reflect the work completed to date and that which is still outstanding. | FWP 23 | **REWORDED**<br>Further investigate the potential for the Yandi pit lakes to stratify and result in density driven flow. | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's calendars. |
| | | | | | | FWP 24 | **REWORDED**<br>Update water balance modelling, as required, to inform the refinement of the backfill strategy | TBA following consultation with Banjima | |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| Permanent pit lakes | Mine voids | Permanent pit lake outcomes & risks | N/A | N/A | N/A | FWP 25 | **NEW**<br>• Update the pit lake hydrogeochemical modelling, if required following update of backfill designs.<br>• Should changes to closure designs or associated knowledge base warrant, review the implications for pit lake water release to Marillana Creek and update modelling, if required.<br>• Refine the pit lake risk assessment based on the outcomes of modelling | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's calendars. |
| Seasonal expressions of water | Backfilled mine voids | Potential for salt accumulation | N/A | N/A | N/A | FWP 26 | **NEW**<br>Investigate the significance of backfill permeability and surface topography to salt accumulation as backfill designs are refined. | TBA following consultation with Banjima | |
| Surface water | Surface water management infrastructure | Flood channel detailed design | Identify alternative locations / alignment for flood channel W1-SP0 to address heritage constraints. | 2022 | Complete (Section 5.14.7.5) | - | **COMPLETE** | N/A | N/A |
| | | | Following confirmation of the backfill strategy, update hydraulic modelling to assess the impact on flood hydraulics and closure flood channel and bund requirements. This should incorporate consideration of the impact of longer duration flood events on flood channel flows. | 2022 | A significant amount of work has been conducted to optimise flood channel designs, including geotechnical investigations and additional hydraulic modelling (Section 5.14.8). This has modified the flood channel configuration and selected energy dissipator types. A 1.5 m cut has been selected as the option to deter access into the W1-SP0 flood channel. Further modelling is required to progress the flood channels towards detailed design. | FWP 27 | **REWORDED**<br>Optimise flood channel designs (including considerations of safety measures) based on additional geotechnical data and hydraulic modelling. | 2028 - 2030 | This work can only be completed following collection of additional geotechnical data (FWP 11). Design optimisation work may commence prior to submission of the next statutory update but may not be completed for inclusion in that plan. |
| | | | Review and revise flood channel designs based on the outcomes of geotechnical investigations and hydraulic modelling. During detailed design of flood channels:<br>• Assess the impacts of turbulence, air entrainment and pit lake levels.<br>• Assess the benefits / costs of stilling basins or plunge pools.<br>• Optimise energy dissipator type (single drop, steps, ramp).<br>• Refine the W1-SP0 and H-SP2 flood channel designs to prevent flows during the 20-year ARI event entering the flood channels.<br>• Incorporate measures into flood channel designs for preventing public access | 2024 | | | | | |
| | | Peak flow rates for Herbert's and Iowa creeks | Review and, if necessary, revise 10,000-year ARI event peak flow rates for Herbert's Creek and Iowa Creek to inform detailed designs for surface water management infrastructure. | 2022 | Baseline flood modelling has been updated along with design flows for Herbert's Creek and Iowa Creeks (Section 5.9.1.2). | - | **COMPLETE** | N/A | N/A |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Surface water Cont'd* | Surface water management infrastructure | Flood bund design | Review and revise closure requirements for flood bunds based on the outcome of hydraulic modelling conducted following confirmation of the backfill strategy. | 2023 | Hydraulic modelling has been updated to inform flood bund upgrades (Sections 5.14.8). | FWP 28 | **REWORDED**<br>Conduct further hydraulic analysis and scour modelling, including a sensitivity analysis for design flows and consideration of scour from more frequent events in tributaries without backwater impacts from Marillana Creek and use the outputs to:<br>• Confirm, or otherwise, the suitability of in-situ material along pit crests to retain a 1:10,000 AEP event without the need for additional flood bunds.<br>• Optimise the tie in of flood bunds with existing creek and floodplain surfaces to minimise local scour and erosion and avoid impacts to heritage features during construction. | Next statutory update (2028) | The inherent risk of creek capture in the absence of surface water management controls is high and consequently a high priority has been placed on conducting work that will enable designs to be finalised. |
| | | | N/A | N/A | N/A | FWP 29 | **NEW**<br>Assess the need for erosion protection for the backslope (downstream slope) of bunds. | Next statutory update (2028) | |
| | | | N/A | N/A | N/A | FWP 30 | **NEW**<br>Conduct a detailed investigation and assessment of existing minor flood bunds. | Next statutory update (2028) | While failure of minor flood bunds as a low inherent risk, a high priority has been placed on this work to enable designs to be finalised while other work is on hold, pending the outcomes of consultation with BNTAC and the Banjima people. |
| | | Floodplain design | N/A | N/A | N/A | FWP 31 | **NEW**<br>Conduct further hydraulic modelling and design optimisation to:<br>• Manage the risk of scour and erosion of floodplains.<br>• Manage the interaction of the W6 floodplain landform with Herbert's Creek land bridge design for closure.<br>• Consider the implications to Traditional Owner heritage sites and values. | Next statutory update (2028) | The inherent risk of creek capture in the absence of surface water management controls is high and consequently a high priority has been placed on conducting work that will enable designs to be finalised. |
| | | Diversion designs | N/A | N/A | N/A | FWP 32 | **NEW**<br>Complete modelling (hydrological, hydraulic, geomorphological) to optimise diversion designs including consideration of:<br>• The risk of lateral channel migration.<br>• The potential to achieve more natural looking systems, erosion and deposition processes and establishment of riparian vegetation.<br>• Diversions that require additional measures to manage erosion and increase capacity (e.g., W3, W2, W5 East, C5).<br>• The tie in of the W4 diversion with the W4-SP4 flood channel.<br>• The W1 diversion (south of W1) tie-in with the W1-SP0 following optimisation of flood channel design.<br>• The configuration of C1/2 diversion as the backfill designs for C6 are progressed.<br>• Upgrades required to E1 and E4 diversions to accommodate a climate change scenario. | 2028 - 2030 | Optimisation of intermediate and minor diversion designs requires geotechnical investigations (FWP 14) to be completed. Design optimisation work may commence prior to submission of the next statutory update but may not be completed for inclusion in that plan. |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Surface water Cont'd* | Surface water management infrastructure | *Diversion designs continued* | N/A | N/A | N/A | FWP 33 | **NEW**<br>Conduct hydraulic modelling and geomorphic assessments to inform the upgrade of the Herbert's Creek land bridge for closure. | Next statutory update (2028) | While failure of Herbert's Creek land bridge has a moderate inherent risk, a high priority has been placed on this work to enable designs to be finalised while other work is on hold, pending the outcomes of consultation with BNTAC and the Banjima people. |
| | | Performance of E1 PAF exposure management | Monitor the E1 PAF exposure to determine whether any further action is required. | Ongoing | An assessment of surface water and groundwater quality at Yandi has concluded that data reviewed show no impact due to AMD and that acid, neutral metalliferous and / or saline drainage are unlikely to be processes affecting water quality at Yandi (Section 5.9.3). However, an inspection of the E1 diversion PAF exposure has been carried over to the 2024 forward work program to confirm this. | FWP 34 | **2020 ACTION CARRIED FORWARD**<br>Inspect the E1 diversion PAF exposure determine whether any further action is required. | Next statutory update (2028) | While the exposure of PAF material in the E1 diversion is a low risk, the results of an inspection of the exposure will be included in the next statutory MCP update. |
| **COMPLETION CRERIA** | | | | | | | | | |
| Completion criteria | Mine voids, surface water infrastructure, ex-pit areas | Refinement of completion criteria. | Refine completion criteria based on the outcomes of:<br>• The agreed backfill strategy and associated modelling.<br>• Ongoing surface water monitoring.<br>• Consultation with stakeholders to inform post-mining land use performance objectives.<br>• Research to support the likely revegetation outcomes of backfilled areas. | 2022 | Work has been undertaken to enable the refinement of completion criteria (Sections 4.3, 5.9.3, and 5.14.1 to 5.14.4), but further monitoring (Sections 10.1.8 and 10.1.10), trials (Section 5.15.7) and consultation with BNTAC and the Banjima people (Section 4) are required to enable completion criteria to be refined. | FWP 35 | **REWORDED**<br>Define domain-specific vegetation and other land use completion criteria on the basis of<br>• Post-mining land use discussions with BNTAC and the Banjima people.<br>• Refinements to closure designs and confirmation of the vegetation communities and species mix to be assigned to each domain.<br>• Data from trials and progressive rehabilitation monitoring.<br>• An updated assessment / mapping of the influence of post-mining groundwater levels in the CID on riparian vegetation within the Yandi lease. | TBA following consultation with Banjima | While the completion of domain-specific criteria is dependent on the outcomes of consultation with BNTAC and the Banjima people (FWP 1 and FWP 45), trials will be progressed as outlined in FWP 38 and progress reported in the next statutory MCP update. |
| | | | | | | FWP 36 | **NEW**<br>Implement revised surface water and groundwater monitoring programs as an input to refinement of completion criteria including:<br>• Confirming reference bores in all three aquifers for groundwater.<br>• Identifying a set of bores for long-term routine groundwater monitoring.<br>• Establishing additional surface water monitoring locations.<br>• Updating the analytical suite | Next statutory update (2028) | In recognition of the need to collect data to support the development of quantitative completion criteria, this program has been scheduled for completion prior to the next statutory update. |
| **REHABILITATION** | | | | | | | | | |
| Revegetation | Backfilled pits, ex-pit areas | Topsoil and growth media suitability | Assess the viability of existing topsoil stockpiles and whether any amelioration will be required during rehabilitation. | 2026 | A topsoil testing program is planned as part of the proposed growth media trials (Section 5.15.7). | FWP 37 | **REWORDED**<br>Test topsoil stockpiles for a range of physical and chemical parameters that influence plant growth. | Next statutory update (2028) | This work program is required to inform the rehabilitation trials (FWP 38) and hence will be completed prior to the implementation of the trials and the information included in the next statutory update of the MCP. |
| | | | Quantify alternate growth media sources and conduct rehabilitation trials to identify the best sources to use in rehabilitation and appropriate amelioration strategies. | 2026 | Growth media trials are planned for FY25 (Section 5.15.7). | FWP 38 | **REWORDED**<br>Incorporate details of growth media trial outcomes in future iterations of the MCP and refine revegetation strategies accordingly. | Update to be provided in the next statutory update (2028) | The trial is expected to be implemented in FY25, but data is required to be collected over a period of time, so while not expected to be complete, an update will be provided in the next statutory update of the MCP. |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| *Revegetation continued* | Backfilled pits | Revegetation strategy for novel ecosystems. | Conduct further research and trials to inform the revegetation strategy for backfilled pits and Herbert's Creek land bridge, taking into account the influence of water quality in backfilled pits on vegetation communities. This will include potential for further delineation of vegetation types / zones (e.g., flood tolerant vegetation, emergent macrophytes) and inclusion of conservation or bush tucker species. | 2026 | Okane (2024b) conducted additional research on the target ecosystems that may be applicable to the Yandi post-mining landscape (Section 5.15.5.3). Further work is required to define appropriate vegetation strategies for backfilled pits, floodplains, buttresses and pit laybacks. | FWP 39 | **REWORDED** Conduct further research and trials to inform the revegetation strategy for backfilled pits including floodplains, buttresses and pit laybacks. | TBA following consultation with Banjima | The timing of these trials is influenced by the outcomes of consultation with the Banjima people on the final pit designs. Once designs have been finalised, a schedule of appropriate trials will be developed which takes advantage of areas that can be completed early to enable trials to be established. |
| | Backfilled pits, ex-pit areas | Optimising revegetation establishment | N/A | N/A | N/A | FWP 40 | **NEW** Maintain a watching brief on emerging research associated with the use of out of provenance seed sources to increase genetic diversity to provide resilience to climate change. | Update to be provided in the next statutory update (2028) | The timing is appropriate given the emerging nature of the research. |
| Fauna | Backfilled pits | Suitability of mine void closure strategy to recreate habitats for fauna. | Investigate the extent to which stygofauna and troglofauna might recolonise backfilled pits, and the influence of water quality on these communities. | Following recovery of groundwater | Not yet commenced. This task can only commence following backfill and recovery of groundwater. | FWP 41 | **2020 ACTION CARRIED FORWARD** Investigate the extent to which stygofauna and troglofauna might recolonise backfilled pits, and the influence of water quality on these communities. | Following recovery of groundwater | The timing of this program is appropriate since it can only commence following backfill and recovery of groundwater. |
| | Pit lakes | | Investigate the influence of pit lakes at Yandi on fauna assemblages. | * | An initial pit lake risk assessment has been conducted to assess potential impacts of pit lakes on fauna (Section 5.14.6). | FWP 42 | **REWORDED** Revise pit lake risk assessment as closure designs progress. | TBA following consultation with Banjima | This action can only be completed once consultation on the backfill strategy has been concluded with BNTAC and the Banjima people (FWP 1 and FWP 45) and, as noted in Section 4.2, is subject to the constraints of the BNTAC / Banjima people's calendars. |
| | Ex-pit, surface water infrastructure, backfilled pits | Fauna return to rehabilitated areas | N/A | N/A | N/A | FWP 43 | **NEW** Research program to investigate fauna habitat and the return of fauna to rehabilitated areas, including consideration of key species of significance to Traditional Owners. | Update to be provided in the next statutory update (2028) | The research program is currently being developed, and the timing is driven by the completion of the planning and implementation of the program. Updates will be provided as elements of the program are completed. |
| **CONTAMINATED SITES** | | | | | | | | | |
| Contaminated sites | Infrastructure | Extent and severity of contamination on site. | Conduct PSIs and DSIs to assess contamination, and develop remediation action plans, if required. | Investigations planned for 2021 - 2029 as outlined in Section 5.10 | Contaminated sites investigations have progressed as outlined in Section 5.10. Further investigations and remediation activities are scheduled according to the risk-based approach agreed with DWER. | FWP 44 | **2020 ACTION CARRIED FORWARD** Conduct PSIs and DSIs to assess contamination, and develop remediation action plans, if required. | According to the schedule outlined in Section 5.10 | This timing reflects BHP's risk-based approach agreed with DWER. |
| **POST-CLOSURE LAND USE & DECOMMISSIONING** | | | | | | | | | |
| Land use planning | Ex-pit areas, infrastructure, mine voids, surface water infrastructure | Post-mining land use is not yet confirmed (interim use is currently *relatively natural environment for pastoral grazing purposes*). | Consultation with post-mining land managers to confirm post-mining land uses and requirements for safe access. | Ongoing | Post-mining land use investigations have progressed (Section 6 and Appendix J.1), but post-mining land uses have yet to be fully defined in consultation with key stakeholders. To reduce duplication, these two actions have been amalgamated (reworded to encompass both purposes) and carried forward to the 2024 forward work program. | FWP 45 | **REWORDED** Consult with key stakeholders regarding post-mining land uses at Yandi. | Ongoing | At the request of BNTAC, BHP has provided a summary of post-mining land use investigations conducted to date and seeks to collaborate with BNTAC as well as other stakeholders to gain alignment on a post-mining future at Yandi. This work is ongoing and is likely to be iterative. This timing is, therefore, appropriate. |
| | | | Gain input from Banjima people, decision making authorities and other key stakeholders relevant to post-mining land use consultation and planning. | Ongoing | | | | | |
| | | Post-closure maintenance requirements | N/A | N/A | N/A | FWP 46 | **NEW** Identify post-completion land management requirements through the post-closure monitoring and maintenance program and conduct an assessment of post-completion residual risks and costs for management. Develop a post-completion land management plan and agreements for implementing the plan with landowners / managers. | 2050 | The timing of this study is appropriate as post-completion land management requirements and risks can only be determined following monitoring of closed landforms. |

| Technical Area | Relevant Domains | Knowledge gap / improvement | 2020 proposed activities & progress | | | 2024 revised forward work program | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Proposed improvement activity | Indicative timing | Progress | ID | Revised / new activity | Indicative timing[69] | Priority / justification for timing |
| Decommissioning & demolition | Infrastructure | Post 2026 decommissioning & demolition plans | N/A | N/A | N/A | FWP 47 | **NEW**<br>Develop decommissioning and demolition plans for Stage 2 demolition. | 2028 | This timing reflects the program for Stage 2 demolition. |

*Notes: no date provided in 2020

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# Appendices

Supplied as separate volumes:

- A to G, I, L to O
- H, J, K, L1.1 - Commercially sensitive and not publicly available
- Appendix P
- Appendix Q
- Appendix R (6 Volumes) - Commercially sensitive and not publicly available