

BHP Iron Ore Pty Ltd (BHP)

# Conceptual Exposure Model

Definition Phase Study, Jimblebar  
Beneficiation Project  
7731-A-85248-VD-00020

January 2025



# Question today *Imagine tomorrow* Create for the future

Conceptual Exposure Model  
Definition Phase Study, Jimblebar  
Beneficiation Project  
7731-A-85248-VD-00020

BHP Iron Ore Pty Ltd (BHP)

WSP

wsp.com

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5	10 January 2025	Issued for approval

We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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# Executive summary

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## Introduction

BHP Iron Ore Pty Ltd (BHP) is progressing the Definition Phase Study (DPS) design of the Orebody 17 (OB17) Swan and Orebody 18 (OB18) De Grey in-pit tailings storage facilities (IPTSFs) as part of the Jimblebar Beneficiation (JBB) Project.

This report presents a DPS Conceptual Exposure Model (DPS CEM), which is updated from the Selection Phase Study (SPS) CEM, and utilises information from geotechnical, hydrological, hydrogeological, geochemical and closure studies undertaken by WSP Australia Pty Ltd (WSP).

### *Objective and scope*

The objective of the DPS CEM is the conduct of a risk assessment to assist BHP with management actions during the IPTSF operations and closure phases and to comply with legislative obligations. The DPS CEM risk assessment focuses on the source-pathway-receptor (SPR) linkages for emissions associated with the Swan and De Grey pits and potential human and ecological receptors for the operations phase (expected to be Financial Year (FY) 29 – FY 49) and closure phase (post 2050).

Operations comprises active tailings deposition from FY29 to FY31 as part of the first fill, and subsequent fill phases (“topping up” cycles) through to FY48 prior to closure implementation. The land use during operations is assumed to be an operational mine site.

The closure phase is expected to occur from FY51 once tailings deposition has ceased. A range of closure options were assessed in previous parts of the project, incorporating a number of factors including assessment of human health and environmental risks. The preferred closure option was assessed as Closure with Partial Backfill, which has been adopted in the CEM. The final land use at closure has not yet been confirmed but based on current information and for the purpose of the CEM, it is assumed to be native ecosystems and potentially some limited grazing<sup>1</sup>.

The scope of the DPS CEM is limited to predicted conditions and emissions, particularly related to water quality, as presented in the reports of the various associated studies and does not consider current environmental conditions. The risk assessment focuses on ecological and human receptors, excluding occupational and safety risk<sup>2</sup>. This is consistent with the Western Australian Department of Water and Environmental Regulation (DWER) *Guideline: Risk Assessments*.

### *Risk assessment approach*

The risk assessment component has been carried out according to the DWER *Guideline: Risk Assessments*, as the relevant regulatory risk framework. Risk ratings are calculated as a function of likelihood and consequence. The general method outlined in DWER guidelines is as follows:

- Identify the risk events through SPR analysis.
- Establish the consequence of each risk event.
- Establish the likelihood of each risk event.

---

<sup>1</sup> The stability of any pit voids and post-closure rehabilitation measures such as revegetation over tailings would need to be considered and assessed to ascertain suitability for grazing; however grazing has been included for completeness.

<sup>2</sup> It is expected that health and safety risks to workers during operations or physical safety risk to the community during closure will be assessed and managed via other mechanisms.



- Apply a risk rating using consequence criteria and likelihood criteria.
  - Determine the risk rating via the risk rating matrix.
- 

## Uncertainties

The key uncertainties that impact on the CEM assessment are summarised below.

- The reliability of the water balance, hydrogeological, and geochemical modelling used to inform the CEM, including their inputs, assumptions, and outputs. In particular, the results of the high-level studies conducted for the closure phase, which were based on an alternative closure option, should be considered indicative and refinement may allow a more definitive risk assessment.
- Derivation of Hazard Quotients (HQ) based on national or international guidelines and screening criteria which may not reflect local ecosystems in the area, including their type, habitats and exposure durations; this likely overestimates the risk, which could be refined with more site-specific data on ecosystems likely to be present.

Further discussion on these and other uncertainties is provided in Section 7.

---

## Conclusions

The CEM assessed potential risks to ecological and human receptors posed by chemical stressors associated with the Swan and De Grey IPTSFs using the DWER guideline methodology. The risk ratings of complete SPR linkages associated with operational and closure phases are summarised below.

### *Operations*

No high-risk ratings were identified for Operations. Two medium risks were identified and are summarised below. The remaining risk ratings were low.

#### **Medium Risk**

- Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems (subterranean fauna and riparian vegetation), and the migration of seepage-impacted groundwater from the IPTSFs to the OB31 dewatering system and subsequent disposal of surplus water to the receiving environment resulting in impacts to surface water aquatic ecosystems and native terrestrial flora and fauna.
- Entry to IPTSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water by native terrestrial fauna.

Operations Risk Ratings are outlined in **Section 5.7** and Table 5.20.

#### **Downstream water quality during operations**

Downstream water quality modelling was also conducted to assess water quality parameters at OB31 during operations. It considered a mixture of pond seepage and natural groundwater in proportions indicated by the groundwater modelling as a time series (on a monthly basis). The screening assessment of downstream water quality indicates that TDS and barium exceed the screening criteria (see Section 5.6.4).

Of the exceedances, one high seepage scenario (during sustained seepage in the late stages of the operational period) showed Barium with a HQ >5. In summary, downstream water quality (at entry into the groundwater system) may have concentrations of PSOIs exceeding adopted screening levels. However, barium is noted to be naturally elevated in the groundwater, so the risk from JBB may be lower than indicated.

It's also important to note that - for barium as well as for other risks - hazard quotients are based on inherently conservative guidelines that generally assume long-term exposure, which is not necessarily the case in the JBB context (as discussed in **Section 4.2**) and a more detailed assessment may show a lower risk than indicated.

### *Closure with Partial Backfill*

No high-risk ratings were identified for the partial backfill closure strategy. The medium risks for Closure are similar to those for Operations and are summarised below; the remaining risk ratings were low.

#### **Medium Risk**

- Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems (subterranean fauna and riparian vegetation communities).
- Entry to IPTSF containment and subsequent direct contact with or ingestion of waste fines and/or intermittent pond water by native terrestrial fauna within in-pit ponds.

The assessment of water quality at the receptors was not in the scope of this assessment and modelling has been conducted for operational downstream modelling at OB31 only. As such, medium risk is warranted which also considers incomplete understanding of the water quality at the receptors.

Closure Risk Ratings are outlined in **Section 6.7** and Table 6.2.

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## Recommendations

### *Reducing uncertainties*

Additional assessment and modelling works are recommended to reduce uncertainties in the CEM risk ratings and refine the outcome, including:

#### **Operations and Closure**

- Collecting and/or assessing additional background environmental data to increase understanding of naturally elevated constituents in the area, and to increase confidence of the use of derived Site-Specific Trigger Values or modify where relevant.

It may also establish baseline conditions to assist with understanding any significant impacts on the environment (such as pipeline spills) and the requirement for cleanup.

#### **Closure**

- Updating the geochemical studies and water balance and water quality modelling, to be more specific to Closure Option without Backfill. This could allow the seepage risk to groundwater to be refined, and the identification of potential receptors that may be impacted.
- The preferred Closure Option (original Option 2, with partial backfill) incorporates the tailings material being capped after the period of consolidation with a benign material (indicated to be waste rock covered by locally sourced surface soils). Assessment of the cover material is outside of the scope of this CEM. However, it is recommended that the suitability of the cover material in relation to chemical exposure risks of humans and wildlife is assessed prior to use.

### *Risk control and mitigation measures*

A number of engineering and management measures are recommended to protect the local environment and ecosystems, including human health. These include protection of air quality and soil, groundwater and surface water (from tailings delivery systems, decant water and tailings slurry deposition) and are outlined in the Risk Assessment tables for Operation (Appendix D) and Closure (Appendix E).

The recommended control measures for the two highest-risk scenarios identified for Operation and Closure (both classified as medium risks) are:

- a Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems and to aquatic ecosystems and native terrestrial flora and fauna from migration of seepage-impacted groundwater to surface water.

Risk controls could include:

- Monitoring of groundwater and surface water quality and quantity (water level, flow).
- Continued operation of dewatering system to manage seepage.

- b Entry to IPTSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water by native terrestrial fauna and aquatic ecosystems within in-pit ponds.

Risk controls could include:

- Exclusion bunding around pit to discourage access.
- Routine surveillance program, including regular fauna checks.

These recommendations are in addition to the management measures outlined in the IPTSF Closure Strategy (WSP, 2024j).

# 1 Introduction

BHP Iron Ore Pty Ltd (BHP) has commissioned WSP Australia Pty Ltd (WSP) to conduct geotechnical, hydrological, hydrogeological, geochemical, and closure studies for the Definition Phase Study (DPS) for the Jimblebar Beneficiation (JBB) De Grey and Swan In-pit storage facilities (IPTSFs). The existing pits are currently referred as orebody (OB)18 De Grey and OB17 Swan. The key purpose of the DPS is to pre-emptively secure a deposition location for tailings processed at a proposed beneficiation plant at Jimblebar.

As part of the DPS, this report presents the Conceptual Exposure Model (DPS CEM), an update to the SPS CEM (WSP, 2023a). At the direction of BHP, the DPS CEM incorporates a high level risk identification summary that considers the potential risks of the project on water resources and ecological and human receptors within the surrounding environment at a regional scale.

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## 1.1 Purpose

This report presents the updated DPS CEM that includes a revised risk assessment of chronic exposures and effects to human and ecological receptors, using based on the outcomes of the associated studies listed below.

The following studies have been used to inform the development of the DPS CEM.

- Conceptual Exposure Model (Selection Phase Study) (WSP, 2023a).
- Slope stability assessment (WSP, 2024a).
- Water balance model (WSP, 2024b).
- Tailings deposition (WSP, 2024c).
- Consolidation modelling (WSP, 2024d).
- Water quality modelling (WSP, 2024e).
- Groundwater assessment (WSP, 2024f).

Specifically, the DPS CEM focuses on the complete source-pathway-receptor (SPR) linkages for exposures associated with the Swan and De Grey IPTSFs<sup>3</sup> and human and ecological receptors for both operations (pre-2051) and closure (post-2051). The DPS CEM incorporates the selection and design of a Preferred Investment Alternative (PIA) for closure which is understood to be partial backfill, as described in Section 7.1.1 (WSP, 2024g).

This work has been performed in accordance with the CEM objectives outlined in Section 3.2.3 of Proposal for Jimblebar In-Pit Tailings Storage Facility Definition Phase Study (reference number: PP135736-001-R-Rev2, dated 24 November 2022).

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<sup>3</sup> Via air (dust), surface water and groundwater pathways.

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## 1.2 Background

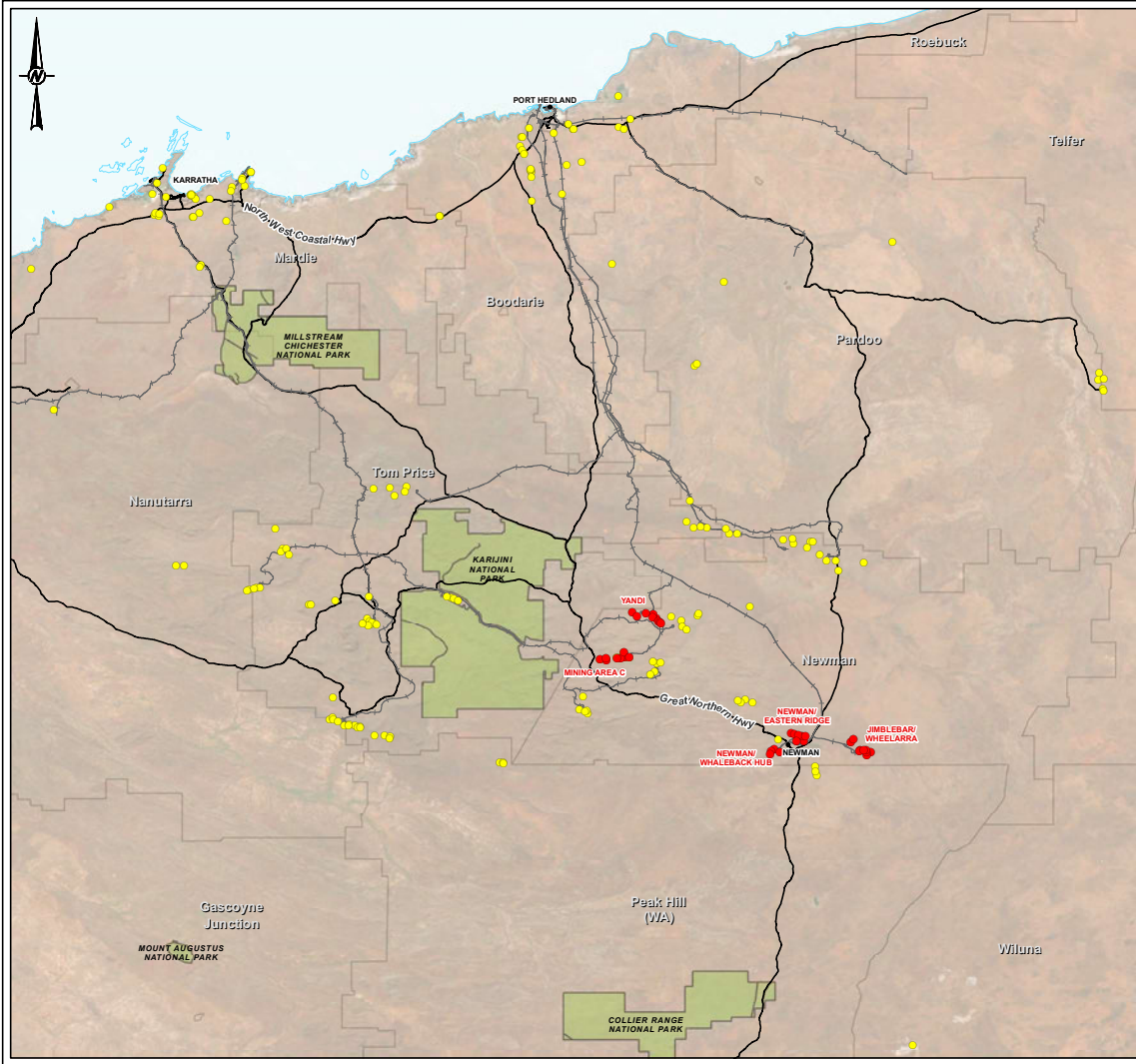
### 1.2.1 *Extractive mining operations*

BHP Western Australian Iron Ore (WAIO) currently operates iron ore mining in the Pilbara region of northern Western Australia and processes the ore in four processing hubs (i.e., Newman, Jimblebar, Mining Area C, and Yandi). The Jimblebar Hub, located approximately 35 km east of the town of Newman, includes the following orebodies:

- Orebody 17 (Swan OB17) and Orebody 18 (De Grey OB18) – Extractive mining operations, concluded in 2020.
- Orebody 31 (OB31) – still operating.

The activities conducted at the Jimblebar orebodies consisted of above and below water table open pit mining, with dewatering infrastructure utilised to abstract groundwater for access to below water table ore.

The locality of the project site is presented on Figure 1.1 on the following page.



**LEGEND**

- CURRENT OPERATING MINE PIT (BHP)
- CURRENT OPERATING MINE PIT (OTHER)
- ▬ FORTESCUE MARSH
- ▬ RAILWAY
- ▬ NATIONAL PARK / STATE FOREST
- ▭ POSTCODE BOUNDARY

**KEY MAP**

0 50 100  
Kilometers

1:2,000,000  
KILOMETRES

**NOTE**  
1. COORDINATE SYSTEM: GCS GDA 1994

**REFERENCES:**  
1. AERIAL IMAGE (DEC 2016) PROVIDED BY CLIENT.  
2. ROADS AND SUPPLEMENTARY AERIAL IMAGERY (2013) © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2016)

**CLIENT**  
BHP

**PROJECT**  
JIMBLEBAR PIT TAILINGS

**TITLE**  
LOCATION OF PROJECT SITE

CONSULTANT	YYYYMMDD	2024-11-27
	DESIGNED	MJ
	PREPARED	AM / JE
	REVIEWED	CA
	APPROVED	KB

PROJECT NO: PS134791    CONTROL: 020 R    REV: 2    FIGURE: 1.1

## 1.2.2 Context of the IPTSF

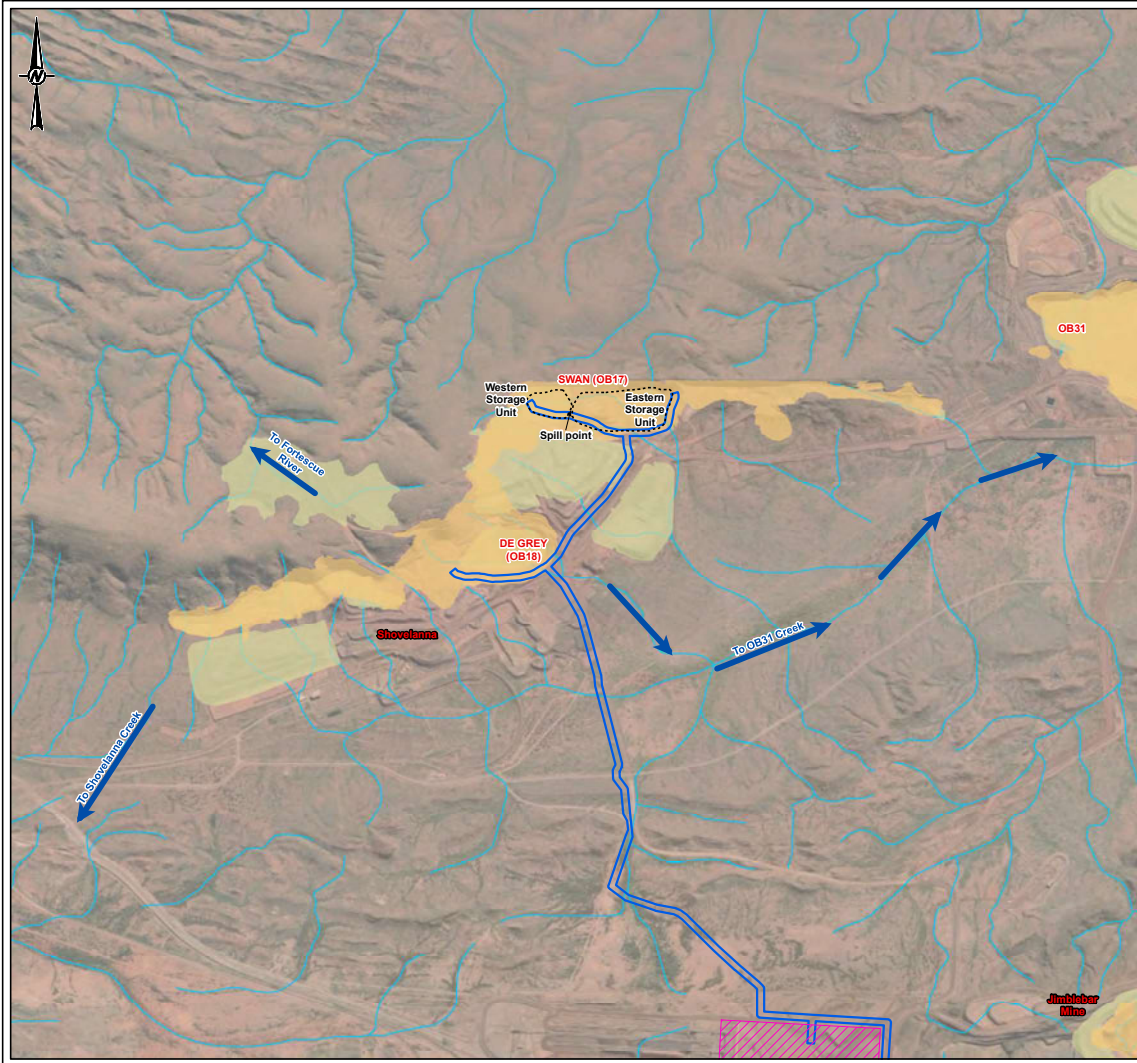
An Identification Phase Study (IPS) was undertaken in 2020 to consider the development of an in-pit strategy for the disposal of tailings produced at the Jimblebar operation (SKR, 2020). The IPS considered numerous pit options for the IPTSFs but recommended the De Grey Pit. The IPS presented the findings of the conceptual tailings deposition, hydrogeological, geochemical and environmental assessments. BHP undertook a trade-off study based on technical, safety, environmental, and economic risks, to compare several options for tailings disposal solutions. In-pit storage of short- and medium-term tailings was deemed the most appropriate option at the time, based on these considerations with the De Grey and Avon Pits considered as the most beneficial for this option. An SPS was therefore required to better understand the potential execution of this endeavour.

Previously, BHP commissioned Golder Associates (now WSP) to undertake the SPS tailings design, geotechnical, hydrological, hydrogeological, geochemical, CEM, and closure studies for the De Grey and Avon Pits. A decision was made to replace the Avon Pit with the Swan Pit primarily due to low capacity and high rate of rise in the Avon Pit. The SPS was completed by Golder Associates in 2021.

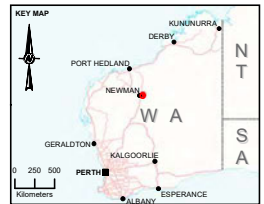
The operations phase of the IPTSF is projected to occur from Financial Year 2028 (FY28) to Financial Year 2051 (FY51). Operations comprises active tailings deposition from FY28 to FY31 as part of the first fill, and subsequent fill cycles through to FY47 prior to closure implementation (FY51) (WSP, 2024b). The tailings deposition process includes deposition cycling between De Grey and Swan IPTSFs (i.e., 2-week on and off rotations). Once maximum tailings elevation is achieved as part of the initial fill (FY28 to FY31), the in-pit TFSs will remain dormant to allow tailings to consolidate, upon which subsequent filling phases will commence again until FY47 (WSP, 2024b). Closure implementation (post FY51) will involve a period of tailings consolidation (consolidation rate <1m/yr for the tallest tailing column will be reached in 2086 for De Grey and 2072 for Swan), until the final landform can be achieved.

The available capacity in the pits is 13.78 Mm<sup>3</sup> at maximum tailings elevation for De Grey and 10.80 Mm<sup>3</sup> at maximum tailings elevation for Swan. The Swan Pit consists of two (east and west) individual storage units separated by an internal high point (also referred to as an internal spill point) (Figure 1.2). Above this high point, the pit acts as a single storage unit (WSP, 2024b). The Swan tailings deposition plan reflects this configuration whereby the east storage unit is filled initially until it reaches the internal spill point, after which the western storage unit is filled.

The De Grey Pit consists of a single uniform storage unit for tailings deposition, starting at 474 m RL (WSP, 2024b). Deposition within the Swan Pit has been considered into a dry pit whilst De Grey tailings deposition will be into an existing pond. Decant pumping in both De Grey and Swan IPTSFs is proposed to commence at the start of tailings deposition and maintains the pond within a specified operating range (1 m deep pond) (WSP, 2024b).



- LEGEND**
- PIT
  - OVERBURDEN STORAGE AREA
  - PROPOSED BENEFICIATION PLANT
  - APPROXIMATE DELIVERY AND DECANT PIPELINE CORRIDOR
  - SURFACE WATER FLOW DIRECTION IN CATCHMENT
- BHP MINE (CURRENT)**  
**BHP MINE PIT (CURRENT)**




1:30,000  
**NOTE**  
 1. COORDINATE SYSTEM: GCS GDA 1994  
**REFERENCES:**  
 1. AERIAL IMAGE SERVICE LAYER CREDITS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY  
 2. ROADS, RAILWAY, MINES FROM WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANGGATE (2016)  
 3. RIVERS FROM DOW

**CLIENT**  
 BHP

**PROJECT**  
 JIMBLEBAR PIT TAILINGS

**TITLE**  
 SITE OVERVIEW AND SURFACE WATER FLOW DIRECTION

CONSULTANT	YYYYMMDD	2024-11-27
	DESIGNED	MJ
	PREPARED	AM / JE
	REVIEWED	CA
	APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
PS134791	020 R	2	1.2



## 2 Environmental Setting

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### 2.1 Geology, Hydrology and hydrogeology

The Jimblebar operations are situated within three adjacent bioregions, consisting of the eastern portion of the Hamersley and Fortescue subregions of the Pilbara, and the Augustus subregion of the Gascoyne.

The Hamersley Range and Fortescue Plains subregions (where Swan Pit and De Grey Pit are located) are typified by an arid and tropical climate, with hot wet summers and cool dry winters. Rainfall is intense, seasonal, and variable (DPIRD, 2021). Average annual rainfall is typically 300 mm, most of which falls during the summer as a result of rain depressions and cyclones (BOM, 2021). These intense weather events tend to cause high flow ephemeral creeks, which rapidly connect through drainage networks. Hot, dry, and sunny conditions in the Pilbara lead to very high evaporation rates. As a result of these high temperatures and seasonal rainfall events, surface flow in creek systems within the Pilbara region is generally brief and temporary, as a result of rainfall events. Recharge to the aquifers is typically via infiltration following rainfall events where the host rocks are exposed, or via intermediary alluvial systems associated with surface drainage.

The Swan and De Grey Pits are located on the south flank of Shovelanna Hill (Figure 2.1). The surface water catchment divide borders the north and southwest sides of the Swan and De Grey Pits. Runoff from the ridge flows mainly to the south and east towards OB31 Creek, an east flowing tributary of Jimblebar Creek. Runoff from the ridge also flows towards the western side of the catchment divide, draining into the Shovelanna creek catchment, and runoff towards the north, flows into the Fortescue River, catchment, and floodplain in the direction of Fortescue Marsh located approximately 100 km to the northwest of the IPTSFs.

The aquifers at Shovelanna area comprise **local orebody aquifers** and a **regional aquifer system**.

The **local orebody aquifers** are found within the Marra Mamba Iron Formation and the Brockman Iron Formation and are characterised by secondary permeability and porosity that have developed coeval with mineralisation. As is typical for aquifers defined by secondary permeability and porosity, they tend to be less continuous which limits both total aquifer storage and interconnectivity along strike. The spatial extents (and associated aquifer storage) are variable and correlate with the size and interconnectivity of fractures.

The **regional aquifer system**, made up of Wittenoom Formation dolomites (Paraburdoo Member) and Tertiary Detritals where present and saturated, extends from Ethel Gorge in the west (located about 18 km west of OB18) to OB31 in the east.

Tertiary valley-fill sediments are developed along an east–west trending valley to the south of OB18, these are approximately 50 m thick in this area and consist of an alternating sequence of alluvial, colluvial, aeolian sediments and calcrete. Where saturated, the valley-fill aquifer is expected to have a higher specific yield than the surrounding bedrock aquifers. However, the monitoring data indicates, in general, unsaturated detritals occur around the OB18 pits.

The regional aquifers are the major pathways for groundwater flow in the region and under natural conditions groundwater flow is westerly. No discharge areas or associated groundwater dependent ecosystems (GDE) have been directly associated with orebody aquifers in the Shovelanna area.

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## 2.2 Environmental receptors

The key environmental receptors identified are listed below followed by a summary of related details.

- The Ethel Gorge Threatened Ecological Community (TEC) with respect to groundwater.
- The ecological systems of the surface water bodies in the vicinity of the pits, including riparian vegetation.

The dominant land uses in the region are grazing, native pastures, ecological conservation, mining and urban. Unallocated Crown Land (UCL) and the Sylvania Pastoral Lease are the underlying land tenures occupying the Swan and De Grey areas. Table 2.1 presents an overview of the surrounding land uses based on a 30 km search radius for ecological receptors and wider for human receptors, including their location and relation to the proposed Swan and De Grey IPTSF.

With respect to groundwater, the key environmental receptor is the Ethel Gorge TEC. While OB31 dewatering is occurring, the seepage from the De Grey and Swan IPTSFs is not predicted to flow towards the TEC. However, seepage from the IPTSFs is expected to flow towards the OB31 dewatering system and surplus abstracted groundwater from this system is discharged to the Ophthalmia Dam Managed Aquifer Recharge (MAR) facility, which is adjacent to the Ethel Gorge TEC.

The MAR facility consists of the dam, four recharge ponds, two infiltration basins, and an open earth canal. Excess water from dewatering can be returned to the Ethel Gorge aquifer system via the Ophthalmia Dam MAR. The MAR maintains groundwater levels within the Ethel Gorge aquifer system, which hosts the stygofauna TEC, maintaining water levels on the TEC and the downstream Newman town potable water supply.

In addition, abstracted groundwater will also be injected into the Ninga MAR, which is approx. 1 km from the Warrawandu water supply and mining camp.

Other environmental receptors include the ecological systems, including riparian vegetation, of the surface water bodies in the vicinity of the pits, including creeks and minor drainage lines to the east downstream of OB31.

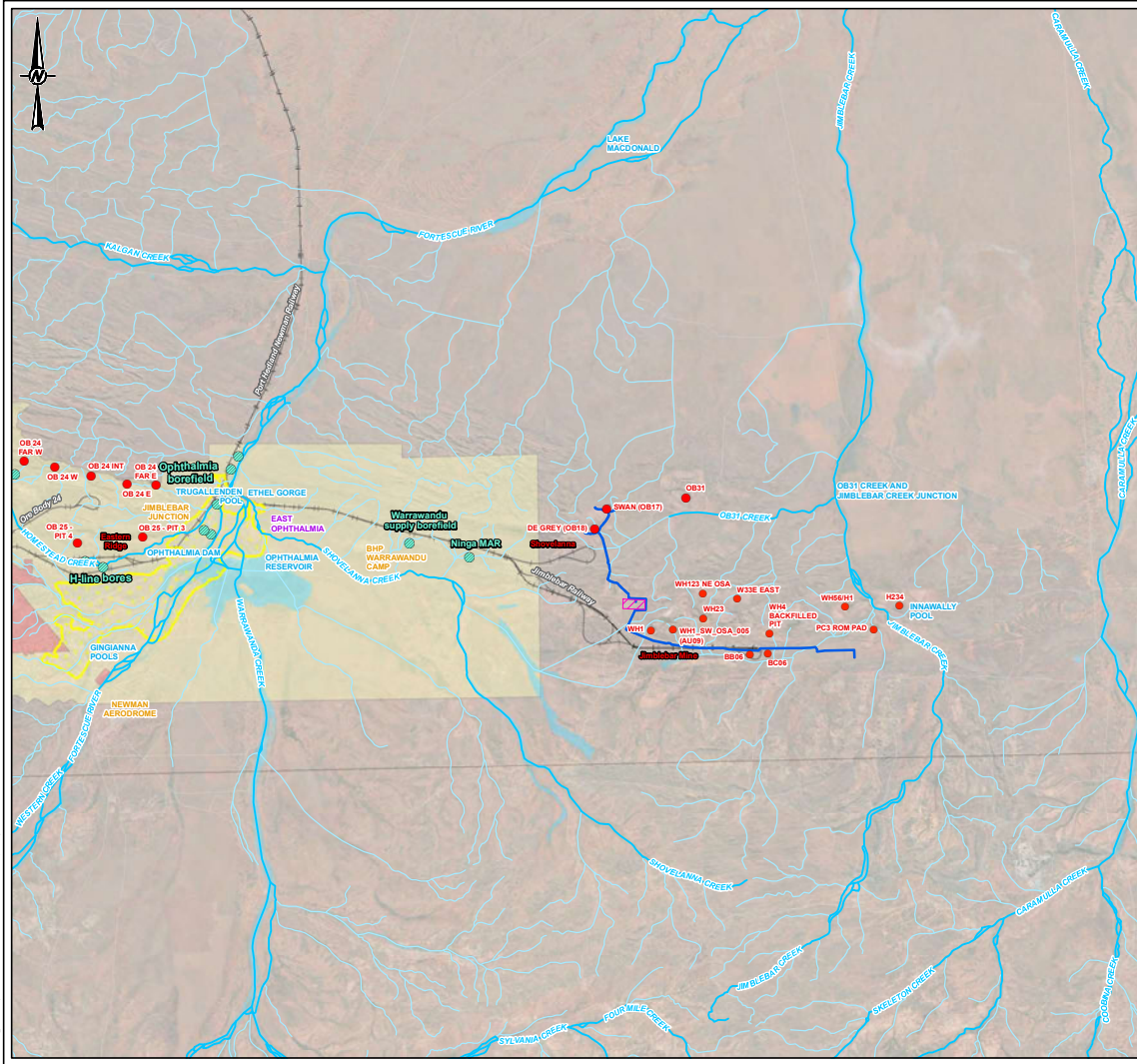
For the purposes of the CEM, it is assumed that the current land uses will persist beyond the life of the Swan or De Grey IPTSF.

Table 2.1 Surrounding land Uses

Direction from site	Land Use Activity/Features <sup>1</sup>
North	<ul style="list-style-type: none"> <li>— Lake Macdonald (19 km north)</li> <li>— Kalgan Creek (19.5 km northwest)</li> <li>— Sandy Creek (21 km northwest)</li> </ul>
East	<ul style="list-style-type: none"> <li>— Jimblebar Creek (13 km downgradient)</li> <li>— Jigalong Aboriginal Community<sup>2</sup> (60 km east)</li> <li>— Carramulla Creek (23 km east)</li> <li>— Coobina Chromite Mine (28 km southeast)</li> </ul>
South	<ul style="list-style-type: none"> <li>— <b>OB31 Creek (&lt;1km south)</b></li> <li>— Innawally Pool (16 km southeast)</li> <li>— Sylvania Creek (22 km southwest)</li> </ul>
West	<ul style="list-style-type: none"> <li>— Shovelanna Creek (&lt;7 km downgradient)</li> <li>— BHP Warrawandu Mining Camp (11.5 km west)</li> <li>— BHP Warrawandu Water Supply Borefield (as above)</li> <li>— <b>Newman Water Reserve<sup>3</sup> (~1 to 2 km west)</b></li> <li>— Ninga MAR (~10 km west)</li> <li>— Town of Newman and associated facilities and infrastructure<sup>4</sup> (31 km west)</li> <li>— Parnpajinya Aboriginal Community<sup>5</sup> (31.5 km west)</li> <li>— Major roads, such as Marble Bar Road (~18 km west)</li> <li>— Ethel Gorge TEC (17 km west)</li> <li>— Ophthalmia Dam (17 km west)</li> <li>— Ashburton River (18 km west)</li> <li>— Upper Fortescue River<sup>6</sup> (23.5 km northwest)</li> <li>— Newman Airport (29 km southwest)</li> <li>— Sylvania Station (28 km southwest)</li> <li>— Southern reaches of the Fortescue River<sup>6</sup> (22 km southwest)</li> <li>— Trugallenden Pool (18 km southwest)</li> </ul>

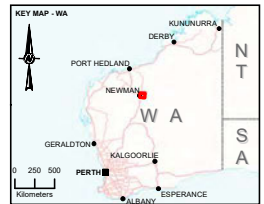
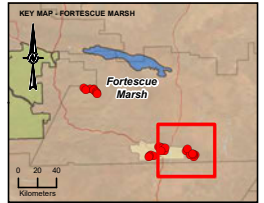
Notes:

- 1) Sensitive human health and ecological receptors down hydraulic gradient and within 10 km of Swan (OB17) and De Grey (OB18) are bold.
- 2) Jigalong is an Aboriginal community of approximately 300 people, situated approximately 60 km to the east of Jimblebar.
- 3) The boundary of the Newman Water Reserve encompasses the groundwater bores that supply the public drinking water for the town of Newman. The IPTSFs are not located within the Newman Water Reserve, but it is adjacent to the eastern boundary of the reserve and has been included in the receptor identification process for completeness.
- 4) Facilities and infrastructure associated with the town of Newman include a wastewater treatment plant, cemetery, residential, commercial and light industrial areas, and various recreational facilities (e.g., golf course, horse racing track, gun club and shooting range).
- 5) Parnpajinya is an Aboriginal community of approximately 60 residents and 13 houses that is situated in the northern part of the town of Newman.
- 6) For the purposes of this report, the Fortescue River has been divided into the upper and lower reaches based on proximity above and below the Ophthalmia Dam. The lower Fortescue River is outside of the scope of this investigation, due to its distance from the IPTSF.



**LEGEND**

- RAILWAY
- ROAD
- PROPOSED BENEFICIATION PLANT
- APPROXIMATE DELIVERY AND DECANT PIPELINE CORRIDOR
- APPROXIMATE ETHEL GORGE TEC
- NEWMAN WATER RESERVE
- PRIORITY AREA 1
- PRIORITY AREA 3
- NEWMAN WATER RESERVE DRINKING WATER BOREFIELDS
- BHP MINE (CURRENT)**
- BHP MINE PIT (CURRENT)**
- OTHER MINE (CURRENT)**
- ANTHROPOGENIC FEATURE**
- ECOLOGICAL FEATURE**



1:200,000

**NOTE**  
 1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 51

**REFERENCES:**  
 1. AERIAL IMAGE SERVICE LAYER CREDITS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY  
 2. ROADS, RAILWAY, MINES FROM WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRAILING AS LANGGATE (2016)  
 3. RIVERS FROM DOW

**CLIENT**  
 BHP

**PROJECT**  
 JIMBLEBAR PIT TAILINGS

**TITLE**  
 SURROUNDING LAND USES AND KEY ANTHROPOGENIC AND ECOLOGICAL FEATURES

**CONSULTANT**

	YYYYMMDD	2024-11-27
	DESIGNED	MJ
	PREPARED	AMUE
	REVIEWED	CA
APPROVED	KB	

**PROJECT NO.** PS134791    **CONTROL** 020 R    **REV.** 2    **FIGURE** 2.1

# 3 Scope of the DPS CEM

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## 3.1 Overview

The DPS CEM described in this report builds upon the initial SPS CEM and is augmented by the updated hydrogeological and geochemical studies and information received from BHP. To summarise, the following are the key factors and elements considered in the development of the DPS CEM.

- Assessment of the potential risk of adverse effects to ecological and human receptors (excluding Occupational Health and Safety risk<sup>4</sup>) in accordance with the Western Australian Department of Water and Environmental Regulation (DWER) *Guideline: Risk Assessments* (DWER, 2020). Section 4 provides detail on the risk assessment approach.
- Identification of water being the main pathway by which contamination may be conveyed away from the IPTSFs to receiving environments. The focus of this report is on water resources and the associated modelling studies (surface, groundwater, geochemical) conducted to inform water quality and quantity. Other transport pathways and exposure scenarios were considered including exposure to fugitive dust and direct exposure to waste fines and/or ponded water if receptors enter the TSF containment.
- Consideration of both operations and closure phases, expected to be from 2028 to 2050 (operations) and post-2051 (closure). Summaries of the operations and closure phases are provided in Section 3.1.
- Revision of the SPS CEM based on the updated understanding of the IPTSFs developed through the wider DPS, the closure design and other related studies, which are summarised in Section 3.3.

The scope of the DPS CEM does not consider, with any specificity, the quality of the current surface and groundwater quality and attributes. The state of the current water quality has been used in the identification of chemicals that may be at elevated concentrations due to natural processes or existing mining activities. Prior work by BHP to develop groundwater Site Specific Trigger Values (SSTV) (for a range of physical-chemical properties) and surface water SSTV (for Total Dissolved Solids (TDS) and pH) for the region implicitly consider natural elevation in baseline surface water and groundwater quality.

The DPS CEM does not consider current monitoring or modelling of future air quality (dust). WSP understands that BHP monitors and manages current dust issues as a part of the wider Jimblebar Precinct. The DPS CEM assessment of dust is based on a qualitative assessment and provides a discussion on likely dust management measures.

The approach taken to assigning risk ratings to each of the SPR linkages is described in Section 4.

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<sup>4</sup> The DWER (2020) risk assessment guidelines excludes employees, visitors, and contractors of the licence holder, and therefore assessment of occupational health and safety related risk has not been included. Occupational health and safety risks to workers during operations or physical safety risk to the community during closure will be assessed and managed elsewhere via other mechanisms.

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## 3.2 Operations and Closure Phases CEM

The operations phase of the IPTSF is considered to occur from FY28 to FY51 (BHP, 2023b). Operations comprises active tailings deposition from FY28 to FY31 as part of the first fill, and subsequent fill phases (“topping up” cycles) through to FY47 prior to closure implementation (FY51). The operations CEM considered SPR linkages while tailings are being deposited into the IPTSF during the first fill and subsequent fills, and the periods of consolidation between the subsequent fills (up to FY51). The land use during operations is considered to be an operational mine site.

The closure phase of the IPTSF is considered to occur from FY51, once tailings deposition has ceased. The closure CEM considers SPR linkages post-FY51, including a period of tailings consolidation before the final landform has been achieved. The preferred closure option is partial backfill (discussed further in Section 6), with the final land use expected to be native ecosystems and potentially some limited grazing. Note that the stability of any pit voids and post-closure rehabilitation measures such as revegetation over tailings would need to be considered and assessed to ascertain suitability for grazing.

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## 3.3 DPS CEM Inputs

Key information used in the DPS CEM assessment has been sourced from the following documents and studies that were prepared to support the DPS and Closure Design:

- Tailings Deposition Model - (WSP Ref: PS134791-WSP-ADL-MNG-MEM-017 Rev3 DPS Tailings Deposition Update at De Grey and Swan pits) BHP Document Number 7731-A85248-VD-00004 Dated 30 September 2024.
- Tailings Consolidation Model - (WSP Ref: PS134791-WSP-ADL-MNG-REP-033 Rev2 DPS Consolidation Modelling Update) BHP Document Number 7731-A85248-VD-00004. Dated 8 October 2024.
- Water Balance Model - (WSP Ref: PS134791-WSP-ADL-MNG-REP-026 Rev1) BHP Document Number 7731-A85248-VD-00018. Dated 29 October 2024.
- Groundwater Assessment - (WSP Ref: PS134791-WSP-PER-MNG-REP-065-Rev2 Groundwater Assessment) BHP Document Number 7731-A85248-VD-00042. Dated 25 September 2024.
- Water Quality Model - (WSP Ref: PS134791-WSP-PER-MNG-REP-058 Rev3) BHP Document Number 7731-A85248-VD-00019. Dated 8 January 2025.

### 3.3.1 *Links between water related components of DPS*

WSP has completed a number of water-related assessments as part of the DPS design of the Swan and De Grey IPTSFs. These water components each have separate objectives as well as interdependencies to other water related components on the project. Figure 3.1 summarises the objectives of each component and its links to other water related components. Ultimately all these components inform and are summarised in the detailed design reporting. Key studies informing the CEM are discussed in the following sections.

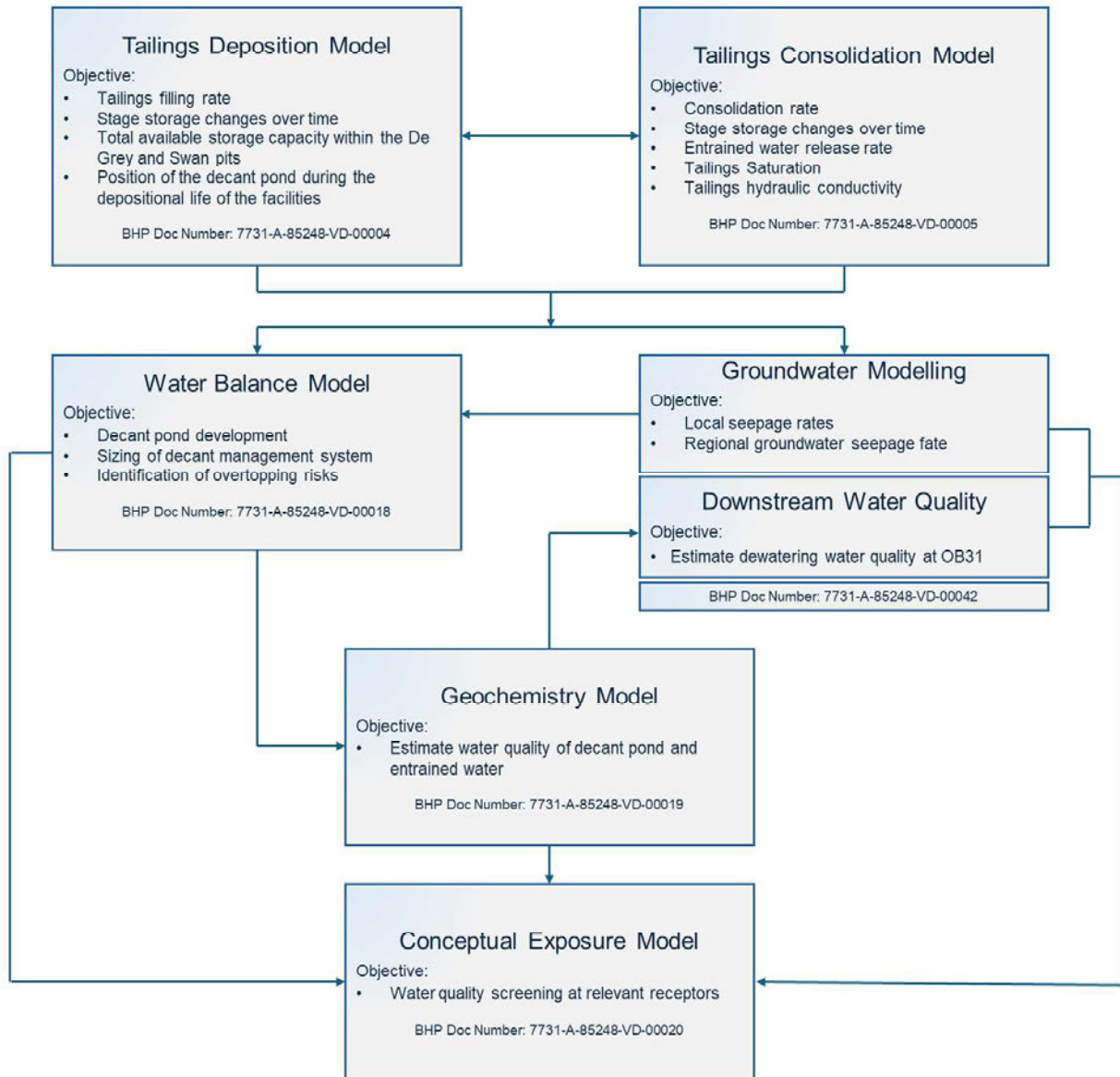


Figure 3.1 Links between water related components of the DPS

### 3.3.2 Project design elements

Information on known project design elements for the DPS was provided to BHP by Calibre<sup>5</sup> consultants. The information included delivery and decant water pipeline routes and proposed measures to manage a failure of a pipeline (BHP, 2024c).

### 3.3.3 Geochemical testwork of tailings samples

WSP Golder assessed the geotechnical and geochemical characteristics of five composite tailings samples, understood to be representative of the tailings likely to be generated at the Jimblebar Beneficiation Plant (WSP Golder, 2022). The tailings composite samples supplied by BHP have a ‘P2 Blend’ base with varying proportions of Joffre and Marra Mamba tailings. The compositions of the tailings samples are presented in Table 3.1.

<sup>5</sup> CalibreQuadR, now part of WSP.

Table 3.1 Jimblebar tailings composites samples

Sample ID	P2 Blend (%)	Joffre (%)	Marra Mamba (%)
P2 Blend	100	0	0
High Joffre	40	60	0
High Marra Mamba	50	25	25
SPS Average Tailings Blend	52.5	40	7.5
High P2	82.5	10	7.5
Low P2^	-	-	-

BHP has indicated that SPS Average Tailings Blend and High P2 tailings are likely to be generated during the first five years of Beneficiation plant operation. High P2 has also been assumed to be the representative sample for tailings produced following the first five years of production as mining operations continue. Note that SPS Average Tailings Blend and High P2 were previously named Average Blend and High Dales respectively in the tailings testwork report and corresponding laboratory test reports. Further detail on the analysis is provided in “Jimblebar VD12 Variation: Results of geotechnical and geochemical testwork on tailings composite samples” (WSP Golder, 2022).

WSP understand that two of the tailings blends, “SPS Average Tailings Blend” (formerly Average Blend) and “High P2” (formerly High Dales), will be the predominant blends present in the IPTSFs (BHP, 2023c). Therefore, geochemical analysis of these two blends has been considered in the CEM. The analysis results data for tailing solids and tailings supernatant (slurry) water has been used in the development of the DPS CEM including the associated risk assessment (Section 4).

### 3.3.4 Water balance

WSP developed an operations water balance model for the DPS using the Goldsim software (WSP, 2024b). The water balance model estimated water surpluses and deficits of the IPTSFs during the operational phases. The mean water quantity estimates provide a basis for the geochemical assessment (discussed in Section 3.3.5). In addition, the water balances assisted with understanding pond behaviour during and in-between tailings filling phases to assess decanting requirements to prevent overtopping during these periods. The water balance model presented the following sensitivity scenarios:

- Climate scenario base case and two climate change scenarios using the Willis Towers Watson (WTW) dataset for rainfall and evaporation mean monthly and annual projections provided by BHP. For the water quality model and assessment in the CEM, only the shared socio-economic pathway (SSP) SSP5-8.5 scenario is simulated, as it represents the worst-case wet scenario.
- Two seepage outflow scenarios have been assessed which reflect the outcomes of the groundwater study component (WSP, 2024c). This includes base case and highest case seepage outflow scenarios.

A simplified water balance was also developed to represent the original Closure Option 1 conditions – Optimised Without, OWO (WSP, 2023) - using the 90 percent tailings consolidated surface to represent the IPTSF closure landform elevations. Note that the preferred closure option is now Partial Backfill (original Option 2), but additional modelling was not seen as essential to provide sufficient indicative information to allow screening risk assessment.

The key inflow is rainfall-runoff, as decommissioning of the beneficiation plant removes the peak inflow of supernatant water from tailings deposition. Two reporting catchment scenarios were assessed looking at the fate of the adjacent Overburden Storage Area (OSA) final landform. One scenario assumes runoff from the final OSA landform crest reports to the IPTSF closure pond (if the crest grading and/or diversions are not maintained during closure), and the other assumes runoff is permanently diverted away from the IPTSF closure pond. The mean water quantity estimates for the conceptual closure condition were also provided as a basis for the geochemical assessment (discussed in Section 3.3.5).



### 3.3.5 Water Quality

WSP developed an updated operational water quality model (WSP, 2024e). The model is developed from the mean water inflow/outflow results of the water balance assessment (discussed in Section 3.3.4), tailings deposition modelling and pit wall exposure mapping (WSP, 2024c), and laboratory testing (Golder, 2021a) and (WSP Golder, 2022)). The water quality model output represents the potential water quality within the IPTSF decant pond and the ‘at-source’ seepage composition from the decant pond. The model considered two sensitivity scenarios in addition to the base case:

- Base Case – comprising a mixture of scenarios with and without geochemical controls (such as equilibrium with atmospheric CO<sub>2</sub>, precipitation of mineral phases and sorption onto precipitated ferrihydrite surfaces). The base case scenario considers a mix between sensitive scenarios combining 80% geochemically controlled conditions and 20% non-geochemically controlled conditions.
- Highest Case (also referred to as High Seepage) – considering tailings hydraulic conductance is assumed to be 2 times higher than those used in the Base Case.
- Climate Change – comprising scaling of the stochastic climate by the mean projected rainfall and evaporation data for SSP5-8.5 scenarios from the WTW dataset provided by BHP.

Further information on the sensitivity tests is provided in the water quality modelling report (WSP, 2024e). The base case scenario (in both the water balance and water quality modelling) forms the models most expected outcomes based on the information considered in the respective studies.

The water quality model outputs represent the potential water quality of the combined surface runoff going into the pit catchment, including direct rainfall/precipitation and subsequent evaporation. Water quality was modelled for two scenarios for the Swan pit and four scenarios for De Grey pit. The differences between scenarios are the inclusion of OSA runoff and re-exposure of pit wall rock following erosion of consolidated tailings.

### 3.3.6 Groundwater Assessment

WSP undertook hydrogeological modelling to develop an understanding on how contaminants, present in the proposed IPTSFs, would potentially impact upon groundwater conditions and environmental receptors (WSP, 2024f). The analysis included predicting the potential seepage rates that may occur during the operational period of tailings deposition (including top up events) and the subsequent consolidation phase until the end of the dewatering operation at OB31 in 2055. The analysis evaluated the potential dilution of concentrations of likely contaminants present in the tailings at the OB31 dewatering system. Dilution factors were calculated with time, and dilution factors were calculated considering three periods; initial condition, first filling seepage and sustained seepage. The average dilution factors have been qualitatively discussed in relation to the pond water quality screening assessment, refer to Section 5.6.

### 3.3.7 Site investigation of PFAS in groundwater

Two targeted site investigations were undertaken, by ERM in 2022 and 2023, as part of a broader regional assessment to understand the nature and extent of per- and poly-fluoroalkyl substances (PFAS) in soil and groundwater at the Jimblebar Mine Site (ERM, 2023). Six groundwater monitoring wells (JBCSGW0001 – JBCSGW0006) were installed and sampled in the vicinity of OB18 Pit and OB31 Pit. Analytical results for PFAS compounds were generally reported as less than the limit of reporting (LOR) or below the adopted assessment criteria for ecological protection and human health, with the exception of monitoring well location JBCSGW0006. In the first monitoring round (May 2022) Perfluorooctane sulfonic acid (PFOS) at monitoring well location JBCSGW0006 (concentration 0.0012 µg/L) was reported to exceed the PFAS NEPM Ecological water quality guideline value for freshwater 99% species protection (high conservation value system) (criteria of 0.00023 µg/L). However, in the second monitoring round (November 2022) PFAS analytical results were below the LOR, including PFOS which was reported as <0.0002 µg/L.

Therefore, PFAS compounds have not been included as a potential stressor of interest (PSOI) in the DPS CEM because PFAS compounds were observed to be non-detect or at relatively low concentrations in groundwater in the vicinity of OB18 Pit and OB31 Pit. WSP understands that BHP will continue to assess and manage PFAS in the wider Jimblebar Precinct as a separate scope of works.

# 4 Risk Assessment Approach

The risk assessment component has been carried out according to the DWER *Guideline: Risk Assessments* (DWER, 2020), as the regulatory risk framework. Risk ratings are calculated as a function of likelihood and consequence. The general method outlined in DWER (2020) is as follows:

- Identify the risk events through SPR analysis.
- Establish the consequence of each risk event and apply consequence rating (Table 4.1).
- Establish the likelihood of each risk event and apply a likelihood rating (Table 4.4).
- Apply a risk rating using consequence criteria and likelihood criteria.
- Determine the risk rating via the risk rating matrix (Table 4.5).

## 4.1 Identifying risk events

Risk events have been identified, as per DWER (DWER, 2020) by the process of identifying potential contamination (emission); a receptor which may be exposed to that hazard through an identified actual or likely pathway; and the potential adverse effect to the receptor from exposure to that hazard. In summary, establishing potential SPR linkages.

## 4.2 Establishing the consequence - screening assessment

The DWER (DWER, 2020) guidelines recommend the use of specific criteria for consequences to the environment or public health to determine the consequence rating for each identified potential risk event. The specific criteria are applied at the receptor identified as most affected by the emission and considering the nature, value and sensitivity of the receptor. This has been undertaken via a screening assessment process described below. Each risk event is assessed and given a consequence criteria as per Table 4.1.

Table 4.1 Consequence criteria (DWER, 2020)

Consequence	Consequence Description	
	Environment	Public Health and Amenity <sup>1</sup>
<b>Severe</b>	On-site impacts: catastrophic. Off-site impacts local scale: high level or above. Off-site impacts wider scale: mid-level or above. Mid to long term or permanent impact to an area of high conservation value. Specific Consequence Criteria are significantly exceeded.	Loss of life. Severe adverse health effects or ongoing medical treatment. Specific Consequence Criteria <sup>2</sup> are significantly exceeded. Local scale impacts: permanent loss of amenity.
<b>Major</b>	On-site impacts: high level. Off-site impacts local scale: mid-level. Off-site impacts wider scale: low level. Short term impact to an area of high conservation value. Specific Consequence Criteria are exceeded.	Adverse health effects or frequent medical treatment. Specific Consequence Criteria exceeded. High level impact to amenity.
<b>Moderate</b>	On-site impacts: mid-level Off-site impacts local scale: low level Off-site impacts wider scale: minimal. Specific Consequence Criteria are not likely met.	Adverse health effects or occasional medical treatment. Specific Consequence Criteria are not likely met. Mid-level impact to amenity.

Consequence	Consequence Description	
	Environment	Public Health and Amenity <sup>1</sup>
<b>Minor</b>	On-site impacts: low level. Off-site impacts local scale: minimal. Off-site impacts wider scale: not detectable. Specific Consequence Criteria are likely met.	Specific Consequence Criteria are likely met. Low level impact to amenity
<b>Slight</b>	On-site impacts: minimal. Specific Consequence Criteria met	Specific Consequence Criteria met Minimal impacts to amenity

Notes:

1) Such as air and water quality, noise, and odour.

2) In this assessment, Specific Consequence Criteria are the screening criteria presented in Section 4.2.1).

It is common practice in human health and ecological risk assessment to undertake a screening assessment to establish if any of the identified chemical hazards warrant further investigation. This involves a comparison of the available known concentration of chemical hazard within the media under scrutiny (exposure concentrations) with published and established risk-based guidance levels or SSTV (screening criteria). Risk-based guidance levels are generally derived using the following factors:

- Toxicity of the agent – dose-response information to understand how much will cause an adverse effect.
- Generic exposure scenarios and assumptions – so the criteria can be applied broadly across a range of situations.
- Application of uncertainty and safety factors – to account for variation and uncertainty.

Screening assessments are inherently conservative, and it should be noted that an exceedance of a screening criteria does not mean an adverse effect is imminent or even likely but is simply a trigger for further investigation.

- Firstly, screening criteria have several layers of conservatism or safety applied in their derivation and are set at levels well below concentrations that may cause adverse effects, often by orders of magnitude. That is, they err well on the side of caution and are deliberately overly-protective of different environments (e.g., groundwater/groundwater dependent ecosystems, surface water and/or terrestrial environments) and receptors (e.g., ecological fauna, livestock or human health).
- Secondly, the environmental data used will often involve use of upper 90th percentile (P90) or maximum concentrations that are unlikely to present most of the time in likely exposure situations. Note that in this assessment, both the P90 and average chemical concentrations identified within the associated media have been used as the exposure concentrations for screening purposes.
- Screening criteria are also usually derived using general exposure assumptions that are based on worst-case scenarios to cover a wide range of situations and sensitive sub-populations. For example, the NHMRC Recreational Water guideline values are based on the assumption that a person will consume 200 mL of water (approximately half a soft drink can, or nearly a standard cupful) whilst swimming every day for a lifetime. In reality, these types of generic scenarios do not generally occur and the screening criteria likely overestimate the exposure as a precautionary tactic.

The screening process against hazard-based guideline values typically results in a ratio known as the hazard quotient (HQ). The HQ is calculated using the equation below.

$$\text{Hazard Quotient: } HQ = \frac{\text{Exposure concentration}}{\text{Screening criteria}}$$

The HQ is a measure of the margin of safety rather than a line identifying definite adverse effects. The margin of safety is reflected in the size of the HQ. The smaller the HQ the larger the margin of safety.

<sup>6</sup> P90 is the 90<sup>th</sup> percentile in the data set. That is 90% of the analysed sample concentrations will be lower than the P90 value.

- If the HQ is less than or equal to one, the exposure concentration is less than or equal to the screening criteria, indicating that the chemical is highly unlikely to cause adverse effects and generally no further assessment is required.
- If the HQ value is greater than one, the exposure concentration is greater than the screening level. Given the screening criteria are overly conservative in relation to risk of adverse effects, this assessment has adopted a HQ of five (5) to be used as the trigger for further evaluation of the potential for risk to a specific receptor or receptors in the site-specific setting.

This assessment has used the lowest screening criterion (i.e. most protective) in instances where multiple guideline values were available for the one exposure scenario (e.g., where two groundwater SSTVs were available for one chemical). Where the use of the alternative SSTVs results in a different outcome, this is included in the discussion.

#### 4.2.1 Adopted screening criteria

The following provides the screening criteria that have been adopted for identified risk event and each media type. Note that due to an absence of more site-specific criteria, many of the ecosystem screening criteria are derived from international studies of plants, animals and ecosystems that don't generally apply to Australian flora and fauna, due to differences in soil types, climate, species types and other factors. Regardless, these criteria are not completely unrelated and provide some basis to assess the consequence.

##### 4.2.1.1 Tailings solids screening criteria

In the absence of tailings-specific screening criteria, the tailings solids data has been screened against the following soil quality guidelines grouped by potential receptors and listed in order of preference.

Table 4.2 Summary of tailings solids screening criteria.

Screening Criteria	Guideline
Ecological	National Environment Protection Measures (NEPM, National Environment Protection Council, 2013) Ecological Investigation Levels (EILs) for Areas of Ecological Significance <sup>1</sup> .
	Canadian Council of Ministers of the Environment (CCME, 2023) Soil Quality Guidelines (SQG) for land use of Residential/Parkland.
	United States Environmental Protection Agency (US EPA, 2005) ecological soil screening levels (EcoSSLs).
Livestock Health	CCME (2023) SQG for land use of Agriculture.
Human Health	NEPM (NEPC, 2013) Health Investigation Levels (HILs) for Land Use Category C (Recreational).
	US EPA (2023) Regional Screening Levels (RSLs) – Residential Soil adjusted for recreational exposure <sup>2</sup> .

Notes:

- 1) As site-specific soil data for cation exchange capacity, pH, organic carbon and % clay is not currently available, estimated EILs have been developed using generic soil parameters intended to be representative of the Jimblebar Hub.
- 2) US EPA RSLs for Residential settings have been increased by a factor of 4 (to account for differences in soil ingestion rates) to be more representative of likely recreational exposure.

##### 4.2.1.2 Water Screening criteria

The available water data, including tailings supernatant (dissolved and total), pond water quality modelling data, and OB31 dewatering water quality outcomes, has been screened against the following receptor-specific water quality guidelines.

Table 4.3 Summary of receptor-specific water screening criteria.

Screening Criteria		Guideline
Ecological	Groundwater	Jimblebar Groundwater SSTV SSTVs (Golder, 2015) <sup>3</sup> .
		BHP Shovelanna SSTVs (HGG,2023) <sup>4</sup> .
	Surface water	Jimblebar Creek Surface water SSTV (BHP, 2018a)
		Ophthalmia Dam Surface water SSTV (BHP, 2018a)
For parameters without surface water SSTVs, the following were used:		ANZG (2018) 95% species protection Default Guideline Values (DGVs) for Freshwater <sup>5</sup> toxicants (i.e., for slightly to moderately disturbed systems) <sup>5</sup>
		ANZECC and ARMCANZ (2000) physical chemical stressor DGV for tropical wetlands <sup>7</sup>
Livestock		Livestock Drinking Water Trigger Value (low risk) (ANZECC,2000)
Human Health		NHMRC and NRMCC (2011, updated in 2022) Australian Drinking Water Quality Guidelines (ADWG) <sup>1</sup>
		NHMRC (2008) recreational water guidelines (which refer to the ADWGs <sup>2</sup> ).

Notes:

- 1) Applies to total, not filtered (dissolved) concentrations.
- 2) NHMRC (2008) suggest a 10× increase in the guideline value can be applied when considering incidental ingestion of recreational water during activities such as swimming, wading, fishing, and entry into water bodies. Due to the ephemeral nature of the creeks in the vicinity of Swan and De Grey, the ingestion of waters is likely to be conservative apart from recreation in Ophthalmia Dam, but recreational activities in and on Ophthalmia Dam are prohibited
- 3) These SSTVs were part of GWL Operating Strategy for Jimblebar (Document number 0019543, Version 4.0, dated 15 February 2018) which forms part of the licence conditions for Licence to Take Water GWL158795(8). The Jimblebar SSTV are used in the first instance given their regional relevance and approval by WA Department of Water and Environmental Regulation (DWER).
- 4) Groundwater SSTVs for Shovelanna Operations (“Shovelanna Groundwater SSTVs (2023)”) in Hydro Geochem Group (2023) Revision of Site Specific Trigger Values for Groundwater Quality Monitoring (document number J-H-AU0062-001-R-Rev0, dated 23 June 2023). While these SSTVs are more recent and specific for the Shovelanna area, they are yet to be approved by DWER. Therefore, in the interim, both the Jimblebar SSTVs (Golder , 2015) and the Shovelanna SSTVs will be used in the screening processes.
- 5) In the absence of available water quality data (i.e., total dissolved solids, electrical conductivity) for OB31 Creek, it is assumed that the Creek is a freshwater system.
- 6) In the absence of site specific information on the ecosystem description of OB31 Creek (e.g., water quality data) and considering the historical and ongoing mining practices in the area, OB31 Creek is considered likely to be representative of a highly disturbed ecosystem (and to which the 90% species protection levels may be applied). However, given the uncertainties in the CEM including the designation of water quality of OB31 Creek and the limitations of the model outputs available to inform the assessment of risk, screening of water quality against the 95% species protection levels (for a slightly to moderately disturbed ecosystem) has been used as a conservative assessment.
- 7) In the absence of site-specific criteria for phosphorous and total nitrogen based on West Australian River pools provided in ANZECC & ARMCANZ 2000, Vol 2 (Section 8.2.2, Table 8.2.3).

## 4.3 Establishing the likelihood – exposure evaluation

The likelihood of a risk event has been rated using the likelihood criteria in Table 4.4 as per the DWER (2020) risk assessment process. Rating likelihood has been informed by the outcomes of the associated studies listed in Section 3.3 combined with specialist evaluation of the risk event exposure scenarios and the factors associated with screening criteria exposure assumptions.

Table 4.4 Likelihood criteria (DWER, 2020)

Likelihood	Likelihood Description
<b>Almost Certain</b>	The risk event is expected to occur in most circumstances.
<b>Likely</b>	The risk event will probably occur in most circumstances.
<b>Possible</b>	The risk event could occur at some time.
<b>Unlikely</b>	The risk event will probably not occur in most circumstances.
<b>Rare</b>	The risk event may only occur in exceptional circumstances.

As discussed in Section 4.2, the screening criteria values are established using generic exposure scenario assumptions that over-estimate exposure as a protective measure. These generic exposure factors include certain population characteristics, behaviours, and exposure frequencies and durations in order to be valid for a broad range of applications. For example, the Australian drinking water guidelines assume people drink 2 L of water per day; and the recreational water guidelines are based on the ADWG values include the assumption that 200 mL of water is ingested during recreational activities in the water 365 days per year. Swimming every day of the year and incidentally ingesting 200 mL of water is highly unlikely for most of the Australian population. These types of assumptions are applied to both human health and ecological guideline values.

With this in mind, the likelihood of an actual site-specific exposure occurring (at the scale assumed for the derivation of the screening criteria) for each risk event is considered when applying a likelihood criterion (as per Table 4.4) for each risk event. Where the risk event exposure is decidedly different than that assumed in deriving the applicable screening criterion, it is reflected in the likelihood criterion applied.

The rationale for decisions regarding likelihood are provided in the risk assessment tables in Section 5.7 and Section 6.7.

## 4.4 Risk ratings

Risk ratings for each risk event have been assessed in accordance with DWER (DWER, 2020) guidance. This involves the assessment of each identified emission or hazard source and consideration of potential SPR linkages. Where linkages are incomplete they have not been considered further in the risk assessment.

Consequence and likelihood criteria are rated for each applicable risk event based on specialist assessment of the fundamental factors and assumptions, considering site-specific information and the various levels of conservatism applied throughout the process. It should be noted that conservatism also exists within the modelling processes used to estimate contamination concentrations within the water and tailings solids.

Table 4.5 Risk rating matrix (DWER, 2020)

Likelihood	Consequence				
	Slight	Minor	Moderate	Major	Severe
Almost Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Medium	Medium	Medium	High
Rare	Low	Low	Medium	Medium	High

Operations and Closure risk ratings are present in Section 5.7 and Section 6.7 respectively. The rationale used to reach the risk ratings are presented in Appendix D for Operations and Appendix E for Closure.

# 5 Operations Conceptual Exposure Model

## 5.1 Overview

A conceptual site model (CSM) diagram has been generated to visually represent the possible complete SPR linkages associated with operations of the Swan and De Grey IPTSFs (Figure 1.2). The sources (Section 5.2), pathways (Section 5.3), and receptors (Section 5.4) are described in greater detail in the following subsections. This is followed by Table 5.1 (Section 5.6), which presents the SPR linkages associated with operational phase of the Swan and De Grey Jumblebar IPTSF. Table 5.1 also includes the risk ratings assigned to each SPR linkage, including the rationale for these ratings considering mitigation and controls that may be put in place.

A key consideration for the Operations CEM is the hydrogeological understanding, which is discussed in Section 5.1.1.

### 5.1.1 Hydrogeology

The pre-mining conceptualisation (BHP, 2022) of the hydrogeological setting between Ethel Gorge TEC and OB31 has the groundwater flow direction from Swan and De Grey Pits, from east to west (Figure 5.1) driven by low groundwater gradients of the order of a few metres over approximately 20 km. At least two partial flow barriers (dykes) are thought to exist between OB31 and the Ethel Gorge TEC aquifer (Figure 5.1). One is located south of the De Grey and Swan pit, whilst the other is located between the Ninga MAR borefield and OB18. These produce three quite distinct aquifer compartments. It is important to note that a number of planned mines, borefields and MAR schemes are located downgradient (west) of the Swan and De Grey Pits. The pre-mining conceptualisation does not account for these existing and future facilities that will modify the future groundwater flow paths towards Ethel Gorge.

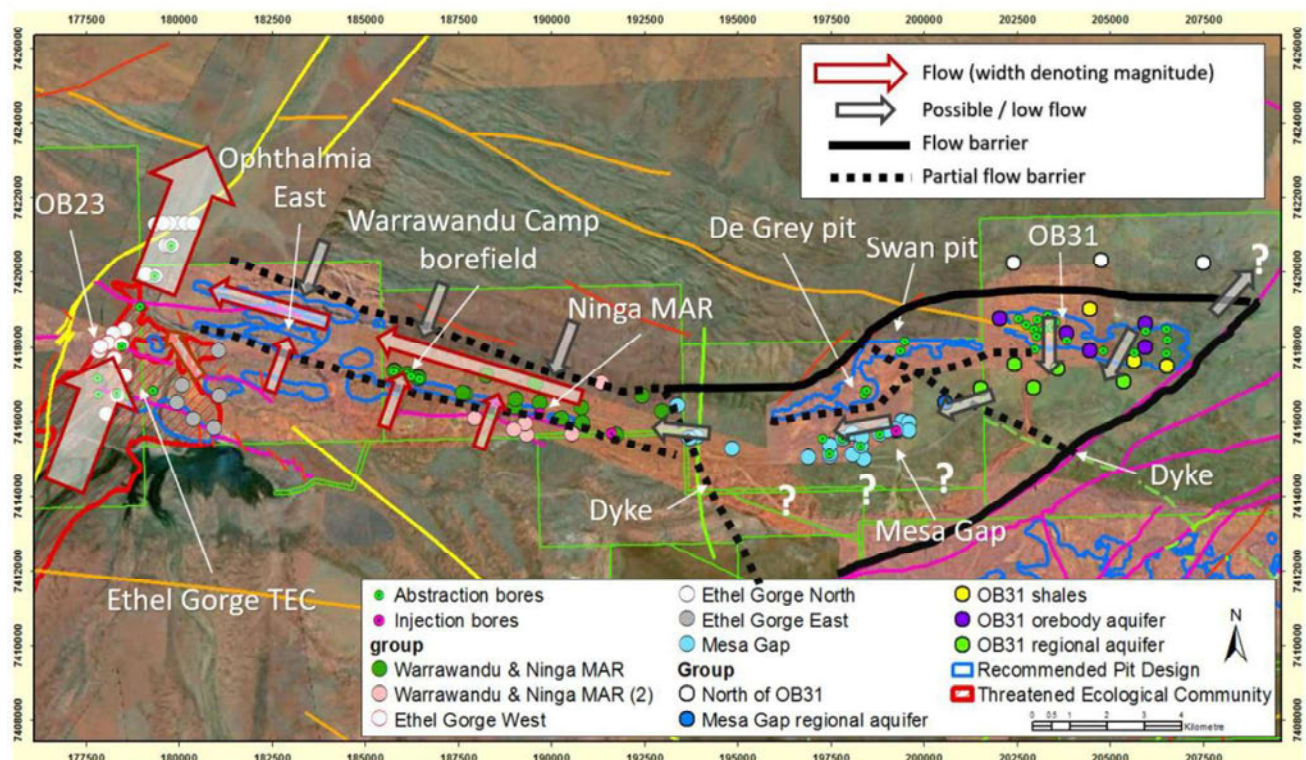


Figure 5.1 Regional conceptual model (pre-mining) (BHP, 2022)

Dewatering operations at OB31 will maintain groundwater levels at Swan Pit below the pit floor and draw groundwater at the Swan Pit to the east. This situation is likely to continue until sometime after dewatering at OB31 ceases, currently scheduled for 2055. The De Grey Pit, however, is not hydraulically connected to OB31 and is not responding to dewatering at OB31.

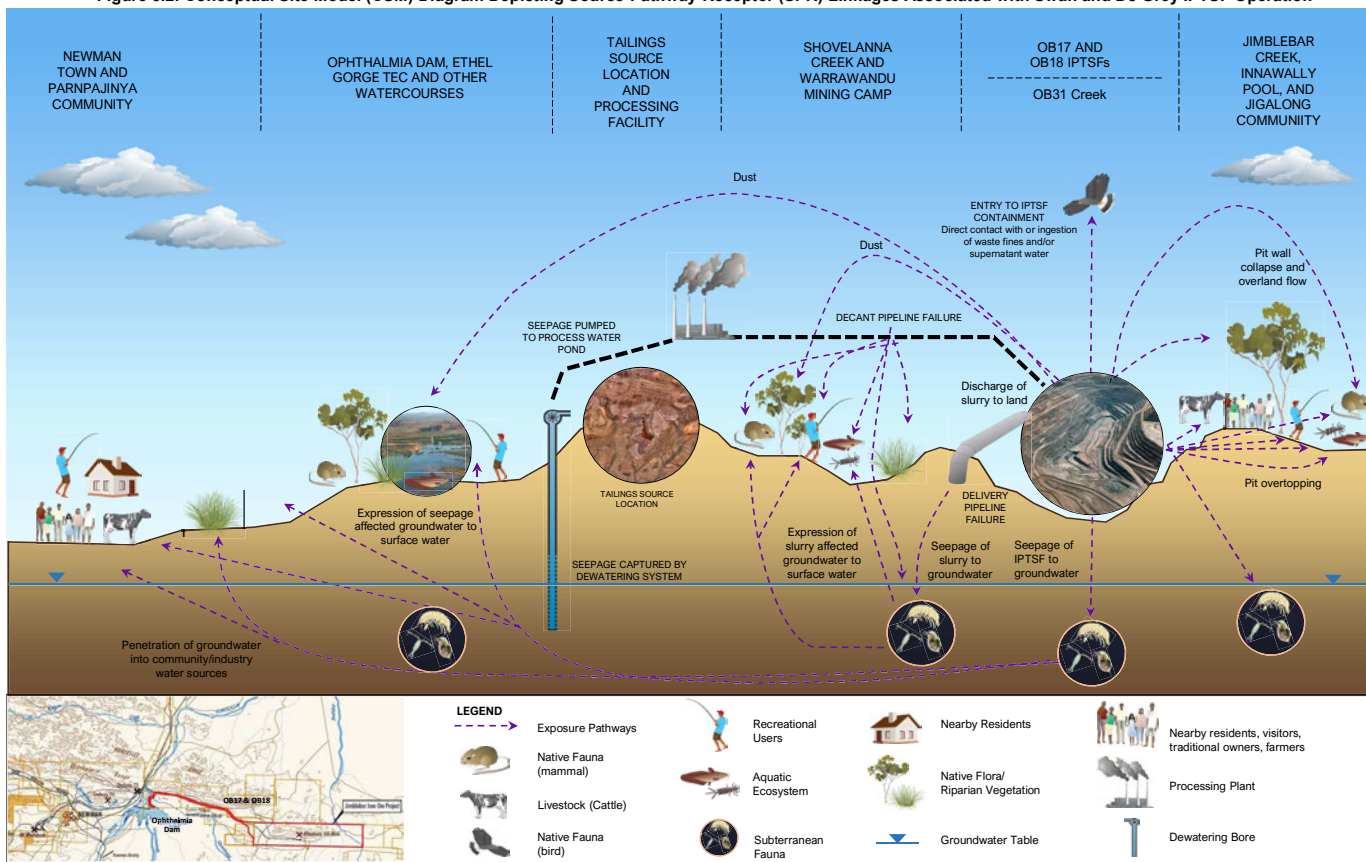
Hydrogeological modelling has confirmed that there will be some seepage losses from Swan and De Grey IPTSF during the operational phase (WSP, 2024i). The highest seepage rates from the pit occur during the tailings deposition when the tailings are in a slurry form or have not yet undergone significant consolidation. As the saturated tailings are deposited, the hydraulic pressure increases, which results in a gradual increase in infiltration rates until the deposition process is complete. The areas with the highest seepage rates are expected to be where the decant pond directly contacts the pit floor/wall or where the settling tailings come into direct contact with zones of high hydraulic conductivity. During fallow periods, there are minimal water inputs compared to the deposition phase and the tailings will progressively become unsaturated over time and the pressure head diminishes. The tailings also consolidate under their own weight which results in a reduction in hydraulic conductivity. Consequently, it is likely that the rate of tailings seepage will decrease over time.

Surface expressions of seepage are unlikely due to the considerable depth of the water table. Flow is expected to predominantly move downward through the unsaturated zone under gravity, recharging the deeper aquifer rather than moving laterally or toward the surface.

Groundwater modelling (WSP, 2024f) provided insights into the risk of groundwater level rise during IPTSF operations. While Swan Pit shows higher seepage rates than De Grey Pit, groundwater levels are predicted to remain below the Swan Pit floor due to ongoing dewatering at OB31. The majority of seepage from Swan during operations is expected to be captured by the OB31 dewatering system (WSP, 2024i) and the combined water from Swan seepage mixed with OB31 dewatering will be directed to Ophthalmia Dam reinjection facilities. In contrast, the De Grey Pit, which is not hydraulically connected to OB31, revealed localised effects of groundwater mounding. This is due to the pit being bounded by the lower permeability Mount McRae Shale and Mt Sylvia Formations, and due to the inferred hydraulic barrier (dyke) between Swan and De Grey. The model predicts that groundwater mounding will not be high enough to result in seepage to ground surface.



Figure 5.2: Conceptual Site Model (CSM) Diagram Depicting Source-Pathway-Receptor (SPR) Linkages Associated with Swan and De Grey IPTSF Operation



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## 5.2 Potential Contamination Sources and Stressors

### 5.2.1 Potential contamination sources

The main sources of potential contamination, associated with operation of the Swan and De Grey IPTSF are:

- Waste fines/tailings slurry, including tailings solids and tailings supernatant/process water.
- Decant water.
- Poned water, comprising supernatant water from the tailings, and runoff from pit wall materials.

The contaminants associated with the above identified sources are dependent on the chemistry of the:

- Feed water quality<sup>7</sup>.
- Composition of the ore.
- Process chemicals (e.g., flocculants).
- Contribution from blast residues (i.e., nitrogen compounds).

### 5.2.2 Environmental data

The following data is available for assessment of PSOI for the operation of the Swan and De Grey IPTSF:

- Analytical data for the tailings solids and supernatant water.
- Water quality model outputs from the geochemical assessment for the ponded water in-pit for Swan and De Grey IPTSF.
- Water quality predictions at the OB31 dewatering site (based on dilution factors established in the hydrogeological and water quality assessments for the seepage of water from the Swan and De Grey IPTSF to the OB31 dewatering system (WSP, 2024e)).

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## 5.3 Potential Contaminant Pathways

The following transport pathways have the potential to expose receptors to risk, from PSOI associated with the operations of the Swan and De Grey IPTSF:

- Airborne dust.
- Seepage of IPTSF waters through base and/or pit walls to groundwater.
- Expression of groundwater contaminated with IPTSF waters to surface water.
- Surface water migration downstream along natural waterways/watercourses.
- Spillage from failure of delivery/discharge or decant water pipelines.
- Pit overtopping<sup>8</sup> and/or Collapse of pit wall. (Both events are generally related to localised instability or asymmetry in tailings discharge and could lead to similar outcomes, i.e. tailings release).

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<sup>7</sup> Feed water is the input/source water used to process the iron ore.

<sup>8</sup> Tailings can “squeeze” causing overtopping on the opposite side to the point of discharge when freeboard is low (towards termination of filling the pit). This occurs due to weight of the tailings around the discharge point causing localised slumping that can create a surge of tailings to flow and produce overtopping of the ponded water (or tailings) at one side of the pit.

Potential receptors may become exposed to PSOI associated with the operations of the IPTSFs via the following exposure pathways:

- Inhalation of dust by humans.
- Dermal contact by humans or direct contact by native terrestrial fauna<sup>9</sup> with waste fines and/or supernatant water.
- Dermal contact by humans of the seepage water (e.g., during wading, fishing, or other recreational water activities).
- Direct contact/uptake of PSOI from water or other affected media (i.e., soil, sediment, groundwater) by aquatic or terrestrial flora and fauna.
- Ingestion of seepage water (e.g., by livestock or native fauna), including incidental ingestion by human recreational users of natural watercourses or waterbodies.

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## 5.4 Potential Receptors

Based on site knowledge and a review of surrounding land uses (Section 2.2) and readily available information, the following were identified as potential receptors of interest (ROI) that may be exposed (either directly or indirectly as indicated in Table 5.1) by PSOI identified as associated with the IPTSF Operations (Swan and De Grey):

- Ecological Receptors:
  - Surface water aquatic ecosystems (Innawally Pool, OB31 Creek, Jimblebar Creek<sup>10</sup>, Shovelanna Creek and Ophthalmia Dam), including aquatic fauna and riparian vegetation.
  - Groundwater Dependent Ecosystems (GDE) as listed in the Australian Government Bureau of Meteorology, Groundwater Dependent Ecosystems Atlas (Appendix B of the SPS CEM):
    - Ethel Gorge aquifer stygobiont Threatened Ecological Community (TEC).
    - Subterranean fauna.
  - Native and terrestrial flora and fauna, including Commonwealth and State listed species of conservation significance (described in Appendix B of the SPS CEM for the full detailed Environment Protection and Biodiversity Conservation [EPBC] Act Protected Matters Reports and NatureMap Species Reports).
  - Livestock (cattle)<sup>11</sup>.
- Human Receptors:
  - Recreational users of nearby watercourses and waterbodies for wading, swimming, and fishing.
  - Newman Water Reserve<sup>12</sup> public drinking water source protection zones (Priority Areas 1 and 3) and associated borefields.
  - Nearby residents and visitors to the town of Newman.

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<sup>9</sup> Native terrestrial fauna includes migratory birds.

<sup>10</sup> The Jimblebar Creek regional surface water catchment is depicted in Figure 1 of the BHP (2018) Surface Water Management Plan Jimblebar report.

<sup>11</sup> The nearest pastoral leases to the Swan and De Grey ISTSF are the Prairie Downs Station to the west and the Sylvania Station to the southeast, both of which operate as cattle stations. The Sylvania Station pastoral lease is jointly owned by BHP and Pilbara Pastoral Co Pty Ltd and is operated by a private pastoral lessee. Ownership of the Prairie Downs Station is unknown.

<sup>12</sup> Swan and De Grey are located ~1 km outside of the boundaries of the Newman Water Reserve, the area encompassing the borefields responsible for Newman's public drinking water supply (DOW 2014). Source water from the Newman Water Reserve is extracted and/or treated by BHP and the Water Corporation, prior to potable use.

- Warrawandu potable water borefield.
- Aboriginal residents and visitors of the Parnpajinya and Jigalong Communities.
- Traditional owners (Niyiyaparli people) and custodians (Martu people) of the land.
- Farmers associated with the Prairie Downs and Sylvania Stations.

Further information on the receptor identification process is provided in Appendix A.

It is acknowledged that the Newman town water supply source water is treated by BHP and the Water Corporation to meet the Australian Drinking Water Guidelines (NHMRC and NRMCC, (2011, updated 2021).), as required by WA Health (BHP, 2021). Based on this, exposure of humans to hazards via drinking water that has indirectly been affected by the OB31 dewatering system is not likely a complete pathway (i.e., the hazard (emission) has been removed from the SPR linkage). However, to ensure completeness, and to protect the Warrawandu source, all town drinking water is being treated as an exposure pathway and assessed in the CEM.

In addition, some of the other exposure pathways are unlikely to be realised to major extents but have been included for completeness.

Assessment of impact to receptors exposed to water piped to Ophthalmia Dam assumes the pathway of exposure is complete and appropriate water quality and quantity data are available. Cumulative impacts from other operations to receptors using water from Ophthalmia Dam are excluded from this assessment.

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## 5.5 Operations - Risk events (SPR linkages)

Table 5.1 presents the identified operations-related risk events as a summary of the exposure pathways that relate to each of the SPR linkages.

Table 5.1 Summary of Operations SPR linkages for IPTSF (Risk events)

Primary and Secondary Sources (Environmental Media)	Transport Pathway	Receptors	Exposure Pathways				
			Ingestion	Inhalation	Dermal Contact	Direct Contact / Uptake	Food Chain <sup>3</sup>
Deposition of tailings slurry in Swan / De Grey IPTSF  Dry waste fines  (Air quality)	Airborne fugitive dust generated from TSF landform	Native terrestrial flora	-	-	-	✓	-
		Recreational users, nearby residents <sup>1</sup> , traditional owners, and/or farmers	-	✓	-	-	-
Failure of delivery pipeline carrying tailings slurry to Swan / De Grey IPTSF  (Soil, groundwater, and surface water)	Direct discharge of tailings slurry to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	-	-	-	✓	-
		Groundwater dependent ecosystems including subterranean fauna	✓	-	-	✓	-
	Expression of contaminated groundwater to surface water and subsequent migration further downgradient; overland flow to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Jimblebar Creek or Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	-	-	-	✓	✓
		Native terrestrial fauna <sup>3</sup>	✓	-	-	-	✓
		Recreational users	✓	-	✓	-	-
Livestock (cattle)	✓	-	-	-	✓		
Decanting supernatant water from tailings in Jimblebar IPTSF  Failure of decant water pipeline carrying supernatant water to process water pond  (Soil, groundwater, and surface water)	Direct discharge of supernatant water to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	-	-	-	✓	-
		Groundwater dependent ecosystems including subterranean fauna	✓	-	-	✓	-
	Expression of contaminated groundwater to surface water and subsequent migration further downgradient; overland flow to surrounding creeks (OB31 Creek) and downstream receiving waters including Jimblebar Creek or Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	-	-	-	✓	✓
		Native terrestrial fauna <sup>3</sup>	✓	-	-	-	✓
		Recreational users	✓	-	✓	-	-
Livestock (cattle)	✓	-	-	-	✓		

Primary and Secondary Sources (Environmental Media)	Transport Pathway	Receptors	Exposure Pathways				
			Ingestion	Inhalation	Dermal Contact	Direct Contact / Uptake	Food Chain <sup>3</sup>
Deposition of tailings slurry in Swan / De Grey IPTSF	Seepage of IPTSF waters through base and/or pit walls to groundwater	Groundwater dependent ecosystems including subterranean fauna	✓	-	-	✓	-
		Consolidation of tailings slurry and resulting supernatant water (Groundwater and surface water)	Expression of groundwater contaminated with IPTSF waters to surface water and subsequent surface water migration downstream along natural waterways/ watercourses	Native terrestrial flora	-	-	-
Piping of tailings affected (via seepage of IPTSF waters) surplus dewatering volumes to Ophthalmia Dam <sup>2</sup>	Direct discharge of dewatering volumes to Ophthalmia Dam	Aquatic ecosystems <sup>2</sup>	-	-	-	✓	✓
		Native terrestrial fauna <sup>3</sup>	✓	-	-	-	✓
		Livestock (cattle)	✓	-	-	-	✓
		Recreational users	✓	-	✓	-	-
		Groundwater dependent ecosystems including subterranean fauna	✓	-	✓	✓	-
Deposition of tailings slurry in Swan / De Grey IPTSF  Collapse of pit wall / Pit overtopping (Soil / rock, groundwater, and surface water)	Flow of supernatant water, and/or tailings over the pit rim	Aquatic ecosystems <sup>2</sup>	✓	-	-	✓	-
		Groundwater dependent ecosystems including subterranean fauna	-	-	-	✓	-
	Contact with falling debris (soil/rock) following collapse of pit wall	Aquatic ecosystems <sup>2</sup>	-	-	-	✓	✓
		Native terrestrial fauna <sup>3</sup>	✓	-	-	-	✓
		Livestock (cattle)	✓	-	-	-	✓
		Recreational users	✓	-	✓	-	-

Primary and Secondary Sources (Environmental Media)	Transport Pathway	Receptors	Exposure Pathways				
			Ingestion	Inhalation	Dermal Contact	Direct Contact / Uptake	Food Chain <sup>3</sup>
Deposition of tailings slurry in Swan / De Grey IPTSF  Consolidation of tailings slurry and resulting supernatant water  (Waste fines and supernatant water inside Swan / De Grey IPTSF containment)	Entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water	Native terrestrial fauna <sup>3</sup>	✓	-	-	✓	-

- Notes:
- 1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pampajinya and Jigalong Communities.
  - 2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
  - 3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.
  - 4) The 'food chain' exposure pathway refers to indirect dietary exposure to PSOI taken up in food items/prey consumed by fauna.
  - 5) Seepage water collected by the dewatering system will be managed as part of BHP's overall water management system and re-used or disposed of (options for management to be considered in the next stage of the study). Seepage-affected groundwater must meet all applicable water quality guidelines and licence discharge criteria prior to being discharged to the receiving environment

## 5.6 Operations – Consequence analysis (Screening)

The following presents a summary of the screening assessment in relation to operations-related SPR linkages as per Section 4.

### 5.6.1 Tailings Samples

The results of the geochemical testwork of tailings samples, including supernatant water (slurry) samples as described in Section 3.3.3, were assessed. Where detectable concentrations of PSOI were reported, they have been compared to the adopted criteria in the following tables included in Appendix B:

Tailings solids:

- Table B.1 – Ecological.
- Table B.2 – Livestock.
- Table B.3 – Human health (recreational).

The tailings supernatant water (dissolved concentrations):

- Table B.4 – Ecological.

The tailings supernatant water (total concentrations):

- Table B.5 – Livestock.
- Table B.6 – Human health (recreational).

### 5.6.2 Exceedances

Exceedances of adopted criteria are detailed below. The concentrations reported for the tailings supernatant water were below the adopted livestock and human health screening criteria.

#### 5.6.2.1 Ecological receptors – screening criteria exceedances

Exceedances of the ecological adopted screening criteria for the tailings solids and supernatant water data and the respective HQs are presented in the following in-text tables.

Table 5.2 Concentrations exceeding adopted screening criteria and calculated Hazard Quotients – Tailings Solids (mg/kg) & Supernatant Water Data (mg/L) – Ecological Receptors

Analyte	Guideline	Guideline Reference	Tailings Blend – Average Blend		Tailings Blend – High Dales	
			Conc.	HQ	Conc.	HQ
Tailings Solids (mg/kg)						
Arsenic	20	NEPM (2013) Area of Ecological Significance	17	<1	21.4	1.1
Copper	25	NEPM (2013) Area of Ecological Significance	32	1.3	39	1.6
Manganese	220	US EPA EcoSSL	918	4.2	1185	<b>5.4</b>
Antimony	0.27	US EPA EcoSSL	1	3.7	1	3.7
Zinc	50	NEPM (2013) Area of Ecological Significance	61.9	1.2	69.3	1.4



Analyte	Guideline	Guideline Reference	Tailings Blend – Average Blend		Tailings Blend – High Dales	
			Conc.	HQ	Conc.	HQ
Tailings Supernatant Water (Dissolved) – Groundwater screening criteria (mg/L)						
Barium	0.01	Jimblebar Groundwater SSTV (Golder , 2015)	0.0897	9.0	0.0937	9.4
Copper	0.0014	Jimblebar Groundwater SSTV (Golder , 2015)	<0.0005	N/A	0.0045	3.2
Tailings Supernatant Water (Dissolved) - Surface water screening criteria (mg/L)						
Copper	0.0014	(ANZG, 2018) Freshwater 95% toxicant DGV	<0.0005	N/A	0.0045	3.2
Zinc	0.008	(ANZG, 2018) Freshwater 95% toxicant DGV	0.002	<1	0.015	1.9

Notes:

Shading is applied to the HQ based on the following scale: HQ >5 - 10 = light blue; HQ >10 = dark blue.

N/A – HQ not able to be calculated.

### 5.6.2.2 Livestock – screening criteria exceedances

Exceedances of the adopted livestock screening criteria for the tailings solids and the respective HQs are presented in the following table:

Table 5.3 Concentrations exceeding adopted screening criteria and calculated Hazard Quotients – Tailings Solids (mg/kg) – Livestock

Analyte	Guideline	Guideline Reference	Average Blend		High Dales	
			Conc.	HQ	Conc.	HQ
Tailings Solids (mg/kg)						
Arsenic	17	CCME SQG	17	<1	21.4	1.3

### 5.6.2.3 Human Health – screening criteria exceedances

Exceedances of the adopted human health screening criteria for the tailings solids and the respective HQs are presented in the following table:

Table 5.4 Concentrations exceeding adopted screening criteria and calculated Hazard Quotients – Tailings Solids (%) – Human Health

Analyte	Guideline	Guideline Reference	Average Blend		High Dales	
			Conc.	HQ	Conc.	HQ
Tailings Solids (%)						
Iron	22	US EPA Regional Screening Levels for Residential soil	48.4	2.2	48.6	2.2

#### 5.6.2.4 Pond water quality model outputs

The estimated median and 90<sup>th</sup> percentile (P90) concentrations from the pond water quality modelling for operations (including sensitivity scenarios detailed in Section 3.3.5) are compared to the adopted screening criteria in the following tables included in Appendix B:

- Table B.7 – Ecological.
- Table B.8 – Livestock.
- Table B.9 – Human health (recreational).

For pH the screening criteria are a range, and therefore, minimum results may also be relevant for assessment. An initial acidic pulse is expected in the De Grey (Base Case), resulting from run off from exposed potentially acid forming (PAF) Mt McRae Shale and is predicted to be present for approximately the first few months (until the PAF material is covered by tailings). The pH is predicted to stabilise for mildly alkaline conditions during subsequent fills. No initial acidic pulse is expected from Swan.

Median and 90<sup>th</sup> percentile results (and predictions post the initial year of tailing deposition) for pH are within the adopted screening criteria.

Calculations for the below HQs are presented in Appendix C:

- Table C.1 – Ecological – Groundwater screening criteria.
- Table C.2 – Ecological – Surface water screening criteria.
- Table C.3 – Livestock.
- Table C.4 – Human Health.

A summary of HQs greater than 5 are presented in the below in-text tables. As noted in **Section 4.2** a HQ value greater than one indicates the exposure concentration for that chemical or stressor is greater than the screening level; however this screening assessment against a screening guideline allows for maximum exposure time in the reported concentration, i.e., it does not account for shorter exposure times than used when deriving the screening levels. In many of the scenarios, the exposure durations will be low and intermittent, in many cases expected to be <20% of the possible exposure duration and hence there would be a 20% lower exposure concentration.

Given the screening criteria are overly conservative in relation to risk of adverse effects, as well as assuming high exposure durations (e.g., exposure every day for a lifetime), this assessment has adopted a HQ of five (5) to be used as the trigger for further evaluation of the potential for risk to a specific receptor or receptors in the site-specific setting.

Table 5.5 De Grey Filling Periods: Ecological Hazard Quotients Greater than 5 with Regards to the Adopted Groundwater GDEs.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods				High Seepage - Filling periods				Climate Change - Filling periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
Al	Jimblebar Groundwater SSTV (Golder , 2015)	0.055	-	-	0.858	16	-	-	0.520	9	-	-	1.167	21
Ba	Jimblebar Groundwater SSTV (Golder , 2015)	0.01	0.15	15	0.28	28	0.15	15	0.24	24	0.15	15	0.25	25
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.029	-	-	0.28	10	-	-	0.24	8	-	-	0.25	9
Co	Jimblebar Groundwater SSTV (Golder , 2015)	0.001	-	-	-	-	-	-	-	-	-	-	0.006	7
Cu	Jimblebar Groundwater (Golder , 2015)	0.0014	-	-	0.0079	6	-	-	-	-	-	-	0.009	7

Notes: <sup>1</sup>Not Formally adopted

Shading is applied to the HQ based on the following scale: HQ >5 - 10 = light blue; HQ >10 = dark blue

N/A – HQ not able to be calculated.

Table 5.6 De Grey Fallow Periods: Ecological Hazard Quotients Greater than 5 with Regards to the Adopted Groundwater GDEs.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods				High Seepage - Fallow periods				Climate Change - Fallow periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	Jimblebar Groundwater SSTV (Golder , 2015)	430	-	-	19,565	45	8,585	20	28,009	65	5,514	13	16,420	38
Al	Jimblebar Groundwater SSTV (Golder , 2015)	0.055	-	-	1.074	19	0.481	9	1.302	24	0.430	8	0.835	15
B	Jimblebar Groundwater SSTV (Golder , 2015)	0.37	-	-	2.85	8	-	-	3.6	10	-	-	2.40	6
Ba	Jimblebar Groundwater SSTV (Golder , 2015)	0.01	0.12	11	4.84	484	1.94	194	6.19	619	1.23	123	4.08	408
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.029	-	-	4.84	167	1.94	67	6.19	213	1.23	42	4.08	140
Mo	Jimblebar Groundwater SSTV (Golder , 2015)	0.001	-	-	0.055	55	0.020	20	0.061	61	0.014	14	0.045	45
Zn	Jimblebar Groundwater SSTV (Golder , 2015)	0.024	-	-	0.518	21	0.262	10	0.717	29	0.151	7	0.424	18
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.054	-	-	0.518	9	0.262	18	0.717	13	-	-	0.424	8

Notes: <sup>1</sup>Not Formally adopted

In addition, sulphate (SO4) exceeded the adopted trigger value of 88 mg/L, which was adopted based on the measured P90 value for SO4 in groundwater data from OB31. There is no formal screening level for sulphate. The HQ was greater than 5 for average and P90 values for all scenarios in De Grey Fallow Periods, with HQ >10 for P90, with a maximum of HQ=30 in the High Seepage scenario. These exceedances were not considered a significant risk and were not included in Table 5.6.

Table 5.7 Swan Filling Periods: Ecological Hazard Quotients Greater than 5 with Regards to the Adopted Groundwater GDEs.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods				High Seepage - Filling periods				Climate Change - Filling periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
Ba	Jimblebar Groundwater SSTV (Golder , 2015)	0.01	0.22	22	0.32	32	0.21	21	0.31	31	0.21	21	0.31	31
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.029	0.22	7	0.32	11	0.21	7	0.31	11	0.21	7	0.31	11

Table 5.8 Swan Fallow Periods: Ecological Hazard Quotients Greater than 5 with Regards to the Adopted Groundwater GDEs.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods				High Seepage - Fallow periods				Climate Change - Fallow periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	Jimblebar Groundwater SSTV (Golder , 2015)	430	3704	9	9683	23	4551	11	10768	25	3521	8	9831	23
Ba	Jimblebar Groundwater SSTV (Golder , 2015)	0.01	0.80	80	2.10	210	0.99	100	2.38	238	0.76	76	2.13	213
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.029	0.80	28	2.10	72	0.99	34	2.38	82	0.76	28	2.13	72
Mo	Jimblebar Groundwater SSTV (Golder , 2015)	0.001	0.007	7	0.016	16	0.008	8	0.019	19	0.006	6	0.017	16
Zn	Jimblebar Groundwater SSTV (Golder , 2015)	0.024	0.141	6	0.322	13	0.170	7	0.380	16	0.134	6	0.310	13
	BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) <sup>1</sup>	0.054	-	-	0.322	6	-	-	0.380	7	-	-	0.310	6

Note: Sulphate (SO<sub>4</sub>) exceeded the adopted trigger value of 88 mg/L (based on the measured P90 value for SO<sub>4</sub> in groundwater data from OB31, as there is no formal screening level for sulphate). The HQ was greater than 5 for P90 values only, for all scenarios in Swan Fallow Periods, with HQ = 10-11 (maximum in the High Seepage scenario). These exceedances were not considered a significant risk and were not included in Table 5.8.

Table 5.9 De Grey Filling Periods: Ecological Hazard Quotients Results Greater than 5 with Regards to the Adopted Surface Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods				High Seepage - Filling periods				Climate Change - Filling periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	60	1011	17	1802	30	1012	17	1798	30	1006	17	1584	26
Al	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	0.055	-	-	0.858	16	-	-	0.520	9	-	-	1.168	21
Cu	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	0.0014	-	-	0.008	6	-	-	-	-	-	-	0.009	7
Zn	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	0.008	-	-	0.060	7	-	-	0.060	8	-	-	0.063	8

Table 5.10 De Grey Fallow Periods: Ecological Hazard Quotients Results Greater than 5 with Regards to the Adopted Surface Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods				High Seepage - Fallow periods				Climate Change - Fallow periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	60	763	<b>13</b>	19565	<b>326</b>	8585	<b>143</b>	28009	<b>467</b>	5514	<b>92</b>	16420	<b>274</b>
Al	95% species protection - freshwater ecosystems (ANZG, 2018)	0.055	-	-	1.074	<b>19</b>	0.481	8	1.302	<b>24</b>	0.430	8	0.835	<b>15</b>
Total Nitrogen	(ARMCANZ and ANZECC, 2000) Default trigger values for Wetlands	1.15	-	-	-	-	-	-	6.33	5	-	-	-	-
TI	95% species protection - freshwater ecosystems (ANZG, 2018)	0.00003	-	-	0.00017	6	-	-	0.00020	7	-	-	0.00015	5
U	95% species protection - freshwater ecosystems (ANZG, 2018)	0.0005	-	-	0.0067	<b>13</b>	0.0025	5	0.0071	<b>14</b>	-	-	0.0054	<b>11</b>
Zn	95% species protection - freshwater ecosystems (ANZG, 2018)	0.008	-	-	0.52	<b>65</b>	0.26	<b>33</b>	0.72	<b>90</b>	0.16	<b>20</b>	0.42	<b>53</b>

Table 5.11 Swan Filling Periods: Ecological Hazard Quotients Results Greater than 5 with Regards to the Adopted Surface Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods				High Seepage - Filling periods				Climate Change - Filling periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	95% species protection - freshwater ecosystems (ANZG, 2018)	60	1209	20	1588	26	1228	20	1698	28	1172	20	1568	26
Zn	95% species protection - freshwater ecosystems (ANZG, 2018)	0.008	-	-	0.054	7	-	-	0.057	7	-	-	0.05	6

Table 5.12 Swan Fallow Periods: Ecological Hazard Quotients Results Greater than 5 with Regards to the Adopted Surface Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods				High Seepage - Fallow periods				Climate Change - Fallow periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	95% species protection - freshwater ecosystems (ANZG, 2018)	60	4,419	74	11,330	189	4,461	74	10,800	180	3704	62	9,692	162
Zn	95% species protection guideline values for freshwater ecosystems (ANZG, 2018)	0.008	0.141	17	0.322	40	0.170	21	0.380	47	0.134	17	0.310	39



Table 5.13 De Grey: Livestock Hazard Quotients Greater than 5 with Regards to the Adopted Livestock Drinking Water Trigger Values.

Analyte	Guideline Reference	Guideline (mg/L)	Filling periods - Base Case		Filling periods - High Seepage		Filling periods - Climate Change		Fallow periods - Base Case		Fallow periods - High Seepage				Fallow periods - Climate Change				
			90th %ile	HQ	90th %ile	HQ	90th %ile	HQ	90th %ile	HQ	Average	HQ	90th %ile	HQ	Average	HQ	90th %ile	HQ	
TDS	ANZECC 2000 Livestock Drinking Water Trigger Value (low risk)	4,000	-	-	-	-	-	-	-	-	-	-	-	28,009	7	-	-	-	-
F	ANZECC 2000 Livestock Drinking Water Trigger Value (low risk)	2	-	-	11	5	-	-	11	5	-	-	11	5	-	-	15	8	

Table 5.14 Swan: Livestock Hazard Quotients Greater than 5 with Regards to the Adopted Livestock Drinking Water Trigger Values.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods		High Seepage – Fallow periods	Climate Change - Fallow periods		
			90th Percentile	HQ	90th Percentile	HQ	90th Percentile	HQ
F	ANZECC 2000 Livestock Drinking Water Trigger Value (low risk)	2	13	7	13	7	13	7

Table 5.15 De Grey- Filling Periods: Human Health Hazard Quotients Greater than 5 with Regards to the Drinking Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods		High Seepage – Filling periods		Climate Change - Filling periods	
			90th Percentile	HQ	90th Percentile	HQ	90th Percentile	HQ
Al	ADWG Aesthetics (2011, updated 2022)	0.2	-	-	-	-	1.167	6
F	ADWG Health (2011, updated 2022)	1.5	10.6	7	10.6	7	10.5	7

Table 5.16 De Grey- Fallow Periods: Human Health Hazard Quotients Greater than 5 with Regards to the Drinking Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods		High Seepage – Fallow periods				Climate Change - Fallow periods			
			90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	ADWG Health (2011, updated 2022)	600	19,565	33	8,392	14	28,002	47	5,515	9	16,415	27
Na	ADWG Health (2011, updated 2022)	180	6,188	34	2,532	14	8,561	48	1,609	9	5,192	29
Cl	ADWG Aesthetics (2011, updated 2022)	250	9,600	38	3,936	16	13,323	53	2,499	10	8,049	32
SO4	ADWG Aesthetics (2011, updated 2022)	250	1,919	8	-	-	2709	11	-	-	1618	6
Al	ADWG Aesthetics (2011, updated 2022)	-	1.07	5	-	-	1.3	6	-	-	-	-
F	ADWG Health (2011, updated 2022)	1.5	15.4	10	13.4	9	17.1	11	12.1	8	14.6	10
Mn	ADWG Aesthetics (2011, updated 2022)	0.1	0.5	6	-	-	0.7	7	-	-	-	-
Se	ADWG Health (2011, updated 2022)	0.01	-	-	-	-	0.05	5	-	-	-	-

Table 5.17 Swan- Filling Periods: Human Health Hazard Quotients Greater than 5 with Regards to the Drinking Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Filling periods		High Seepage – Filling periods	
			90th Percentile	HQ	90th Percentile	HQ
F	ADWG Health (2011, updated 2022)	1.5	8.0	5	9.9	7

Table 5.18 Swan- Fallow Periods: Human Health Hazard Quotients Greater than 5 with Regards to the Drinking Water Guidelines.

Analyte	Guideline Reference	Guideline (mg/L)	Base Case - Fallow periods				High Seepage – Fallow periods				Climate Change - Fallow periods			
			Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ	Average	HQ	90th Percentile	HQ
TDS	ADWG Health (2011, updated 2022)	600	3704	6	9683	16	4551	8	10768	18	3521	6	9831	16
Na	ADWG Health (2011, updated 2022)	180	1063	6	2958	16	1333	7	3306	18	1005	6	3005	17
Cl	ADWG Aesthetics (2011, updated 2022)	250	1653	7	4606	18	2074	8	5145	21	1562	6	4680	19
F	ADWG Health (2011, updated 2022)	1.5	8.05	5	13.14	9	8.36	5	13.46	9	7.95	5	13.11	9

Screening the Swan and De Grey IPTSF water quality is a conservative assessment of PSOI for several of the release scenarios where attenuation along the flow path is expected (except for the exposure pathways of a leak in pipelines used for tailings placement, dewatering, or decanting or direct contact of receptors with pond water).

Note that screening the groundwater concentrations against the BHP SSTVs for groundwater (from Hydro Geochem 2023) indicates a lower HQ and hence lower risk, compared with the Golder 2015 SSTVs. The BHP SSTVs are based on more recent background groundwater monitoring data showing higher background levels of some analytes, assumed to be naturally occurring; these SSTVs have not yet been formally approved for use.

Modelling to estimate concentrations in downgradient groundwater receiving environments is discussed in Section 5.6.3 assumptions made.

### 5.6.3 Downstream Seepage Water Quality Assessment

A downstream seepage water quality assessment was conducted to predict, at a high level, the composition of seepage-impacted dewatering water abstracted from OB31 (WSP, 2024h). The water quality modelling concept is tailored based on the regional flow and dilution assessment, which estimated the proportion of seepage from the De Grey and Swan IPTSFs that would reach the OB31 dewatering borefield (i.e. the dilution estimate).

For the downstream water quality assessment, the following were considered:

- ‘At-source’ seepage compositions for De Grey and Swan pits were developed, mixing the ‘pond water’ and ‘entrained tailings water’ in the proportion they outflow each pit. This proportion was determined by the combination of water balance and groundwater models outputs:
  - Overall seepage rates at the De Grey and Swan IPTSFs were estimated using three-dimensional (3D) FEFLOW models (WSP, 2024f) (Aconex: 7731-A-85248-VD-00042).
  - Decant pond seepage was estimated using the water balance model (WBM) generated in GoldSim Version 14 (WSP, 2024b) (Aconex: 7731-A-85248-VD-00018).
  - Retained water within the underlying tailing material that gradually seeps out of the De Grey and Swan pits were obtained subtracting the decant pond seepage from the overall seepage rates (on a monthly basis)
- ‘At-source’ seepage and natural groundwater are then mixed in the proportion indicated by the dilution assessment (i.e., dilution factors). This approach assumes that the entire seepage volume and solutes concentrations reach OB31 without any changes. Processes like dispersion, diffusion, or attenuation within the aquifer are not accounted for.
- The source terms representing inflow water quality at OB31 were defined as follows:
  - Natural groundwater reaching OB31 is represented by average quality monitoring data from bores screened around the pit.
  - Seepage outflow from the De Grey and Swan decant ponds is represented by the results of the water quality model, considering the mixed control scenario for the base case, high seepage, and climate change scenarios (WSP, 2024e) (Aconex: 7731-A-85248-VD-00019).
  - Entrained (saturated) water was derived from tailings composite samples selected by BHP (‘High P2,’ ‘Plant Blend,’ and ‘High Joffre’), based on geochemical testwork, and aligned with the tailings deposition plan (WSP, 2024c) (Aconex: 7731-A-85248-VD-00004).

It is important to mention, that despite the use of the term 'dilution,' this concept may be misleading, as natural groundwater already contains a base case chemical load. Therefore, the 'dilution factors' should be interpreted as mixing coefficients. Note that no proper transport modelling was conducted in this assessment.

In line with the pond water quality modelling, three sensitivity scenarios were modelled including the base case, highest seepage and climate change scenarios. Downstream water quality modelling data is presented in Table B.10 in Appendix B.

Overall results show that two PSOIs exceeded one or more of the adopted screening levels - Barium and Total Dissolved Solids (TDS). Barium exceeded both the Jimblebar Groundwater SSTVs (Golder , 2015) and BHP Shovelanna SSTVs (Hydro Geochem Group, 2023) (not formally adopted). Natural groundwater has been found to have elevated dissolved Ba concentrations present (WSP, 2024f) and as such these exceedances are likely be more representative of the natural conditions and do not indicate significant additional risk.

Total dissolved solids (TDS) are modelled below both SSTVs for all scenarios and indicate no additional risk to ecological receptors.

In terms of human health, no health effects are directly attributable to TDS and the Australian Drinking Water Guidelines are based on aesthetics and palatability; the TDS exceedances in each modelled scenario are generally in the range of 'fair' drinking water quality in relation to the guidelines.

In addition, alkalinity was slightly above the ADWG level (maximum of 211 mg/L CaCO<sub>3</sub>, compared with ADWG of 200 mg/L); this is not related to health effects<sup>13</sup> and the exceedance is not considered significant (being <1% of the guideline value).

Hazard quotients (HQ) were calculated for each PSOI and are detailed in Table C.5 in Appendix C. One HQ > 5 was calculated for Barium based on the Non-Climate Change Scenario (NCCS) highest seepage, during later stages (i.e. sustained seepage period). As described above, this is considered to be a product of naturally elevated dissolved Barium within groundwater.

#### 5.6.4 Summary of Operations PSOI

Based on the screening process, the analytes presented in Table 5.19 have been identified as PSOI associated with operation of the Swan and De Grey IPTSF (i.e., the P90 concentration exceeded at least one of the adopted screening levels).

The PSOIs have been identified through screening of available analytical data or modelled/predicted concentrations against generic screening criteria for several receptor scenarios. The next section of the report outlines the transport and exposure pathways by which contamination could potentially reach humans and/or ecological receptors. The risk assessment then describes the likelihood of contamination reaching humans and/or ecological receptors.

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<sup>13</sup> Total hardness above 200 mg/L may lead to excessive scaling of pipes and fittings, and cause blockage of safety relief valves in hot water systems. Soft water may lead to greater corrosion of pipes, depending on other factors such as pH and dissolved oxygen content. Total hardness in major Australian reticulated supplies ranges between ~5 mg/L - 380 mg/L.

Table 5.19 Summary of PSOs identified for different receptor scenarios during Operations

Data available	Receptor Scenarios	PSOs Identified
Tailings solids analytical results	Native terrestrial flora and fauna	— Potential for direct toxicity effects to native flora and fauna from antimony, arsenic, copper, manganese, and zinc.
	Recreational users <sup>3</sup>	— Potential for direct toxicity effects to recreational users from iron.
	Livestock (cattle) <sup>3</sup>	— Potential for direct toxicity effects to livestock from arsenic (minor exceedance).
Tailings supernatant analytical results	Groundwater dependent ecosystems, including subterranean fauna	— Potential for direct toxicity effects to groundwater ecosystems from barium and copper.
	Aquatic ecosystems <sup>1</sup>	— Potential for direct toxicity effects to surface water ecosystems from copper and zinc.
	Recreational users <sup>3</sup>	— Concentrations below the adopted screening criteria.
	Livestock (cattle) <sup>3</sup>	— Concentrations below the adopted screening criteria.
Pond water quality predictions	Groundwater dependent ecosystems including subterranean fauna	De Grey — Potential for direct toxicity effects to groundwater ecosystems from TDS, aluminium, antimony, arsenic, boron, barium, molybdenum, lead, selenium, and zinc. It is noted that water quality modelling during fallow periods show the majority of exceedances. — Potential for direct toxicity effects from nutrients (nitrate) and indirect effects from increased nutrient inputs (i.e., nitrogen) such as oxygen depletion. Swan — Potential for direct toxicity effects to groundwater ecosystems from TDS, arsenic, boron, barium, molybdenum and zinc. It is noted that water quality modelling during fallow periods show the majority of exceedances. — Potential for direct toxicity effects from nutrients (nitrate) and indirect effects from increased nutrient inputs (i.e., nitrogen) such as oxygen depletion
	Aquatic ecosystems <sup>1</sup> and native terrestrial flora and fauna <sup>2</sup>	De Grey — Potential for direct toxicity effects to surface water ecosystems from TDS, Aluminium, Arsenic, Boron, Selenium Thallium, Uranium and Zinc. It is noted that water quality modelling during fallow periods show the majority of exceedances. — Potential for direct toxicity effects from nutrients (total nitrogen and nitrate) and indirect effects from increased nutrient inputs (i.e., nitrogen) to watercourses such as harmful algal blooms (HAB) Swan — Potential for direct toxicity effects to surface water ecosystems from TDS, Arsenic and Zinc.
	Livestock (cattle) <sup>3</sup>	De Grey — Potential for direct toxicity effects to livestock from TDS and Fluoride. Swan — Potential for direct toxicity effects to livestock from Fluoride.

Data available	Receptor Scenarios	PSOs Identified
	Recreational users <sup>3</sup>	De Grey <ul style="list-style-type: none"> <li>— Potential for direct toxicity from fluoride and nickel.</li> <li>— Potential for aesthetic taste or discolouration (chloride, iron, manganese, sodium, sulphate and TDS).</li> </ul> Swan <ul style="list-style-type: none"> <li>— Potential for direct toxicity from antimony, arsenic, fluoride, lead, nickel and selenium.</li> <li>— Potential for aesthetic taste or discolouration (chloride, iron, manganese, sodium, sulphate and TDS).</li> </ul>
	Drinking water <sup>3</sup>	De Grey <ul style="list-style-type: none"> <li>— Potential for direct toxicity from Sodium, Arsenic, Fluoride, Manganese and Selenium. It is noted that water quality modelling during fallow periods show the majority of exceedances.</li> <li>— Potential for aesthetic taste or discolouration (chloride, sulphate and TDS), scaling problems (alkalinity).</li> </ul> Swan <ul style="list-style-type: none"> <li>— Potential for direct toxicity from, Arsenic, Sodium and TDS. Its noted that only Fluoride shows direct toxicity effects during filling periods.</li> <li>— Potential for aesthetic taste or discolouration (chloride and Sulphate)</li> </ul>
Downstream and dilution predictions at OB31 dewatering	Groundwater dependent ecosystems including subterranean fauna Aquatic ecosystems <sup>1</sup> Native terrestrial flora and fauna <sup>2</sup>	<ul style="list-style-type: none"> <li>— Downstream water quality modelling results suggest that concentrations of PSOs in groundwater are <i>likely</i> to attenuate resulting in reduced concentrations. Barium and TDS exceed the adopted ecological screening criteria at the OB31 dewatering system</li> </ul>

Notes:

- 1) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
- 2) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.
- 3) No direct exposure pathway between receptors and the pond water, but this data is considered in the context of a potential failure of the tailings delivery pipeline or decant water pipeline (refer Table 5.1).

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## 5.7 Operations – Likelihood & Risk Assessment

An assessment of risk for the complete SPR linkages associated with the operational phase of the Swan and De Grey IPTSF (Figure 5.1) are presented in Appendix F. The SPR linkages identified along with proposed mitigation strategies and controls, are based on the sources described in Section 5.2, the pathways described in Section 5.3, and the receptors considered in Section 5.4. The risk ratings, assigned to each SPR linkage are based on the DWER guidelines (DWER, 2020) presented in Section 4. Appendix F provides the rationale for these ratings considering mitigation and controls that may be put in place, as well as making recommendations for additional work that may be required.



Table 5.20 Summary Operational Phase Risk Ratings for Jimblebar In-pit Tailings Storage Facilities

Risk Event				Risk Assessment		
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Consequence	Likelihood	Risk Rating
Deposition of tailings slurry in Swan / De Grey IPTSF <b>Dry waste fines</b> (Air quality)	Fugitive dust generated from TSF landform	Native terrestrial flora	Reduction in photosynthesis, respiration, and transpiration due to dust deposition	Slight	Possible	Low
		Nearby residents, traditional owners, and/or farmers. Recreational users of Ophthalmia Dam (limited exposure) <sup>1</sup>	Acute and chronic adverse health effects and amenity.	Minor	Rare	Low
Failure of delivery pipeline carrying tailings slurry to Swan, De Grey IPTSF (Soil, groundwater, and surface water)	Direct discharge of tailings slurry to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline including riparian vegetation communities	Reduced soil and/or groundwater quality resulting in localised, short-term decline in floristic health	Slight	Unlikely	Low
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	Minor	Rare	Low
	Expression of contaminated groundwater to surface water and subsequent migration further downgradient; overland flow to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low
	Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna	Minor	Rare	Low	
	Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low	

Risk Event				Risk Assessment		
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Consequence	Likelihood	Risk Rating
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and downgradient receiving waters	Slight	Rare	Low
Decanting supernatant water from tailings in Swan, De Grey IPTSF Failure of decant water pipeline carrying supernatant water to process water pond (Soil, groundwater, and surface water)	Direct discharge of supernatant water to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	Soil and/or groundwater contamination resulting in localised, short-term decline in floristic health	Slight	Possible	Low
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	Minor	Rare	Low
	Expression of contaminated groundwater to surface water and subsequent migration further downgradient; overland flow to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna	Minor	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and associated creeks	Minor	Rare	Low
		Drinking water	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low

Risk Event				Risk Assessment		
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Consequence	Likelihood	Risk Rating
Deposition of tailings slurry in Swan / De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Groundwater and surface water)	Seepage of IPTSF waters through base and/or pit walls to groundwater	Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Degradation of groundwater near Swan / De Grey IPTSF	Minor	Unlikely	Medium
	Expression of groundwater contaminated with IPTSF waters to surface water and subsequent surface water migration downstream along natural waterways/ watercourses Expression of groundwater contaminated with IPTSF waters to OB31 dewatering system	Native terrestrial flora including riparian vegetation communities	Localised, short-term decline in floristic health due to raised water tables, uptake of contaminated shallow groundwater or surface water, and/or increased salts in surface soils due to evapo-concentration	Minor	Rare	Low
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and quantity and associated effects to aquatic ecosystems and the hydro cycle	Minor	Rare	Low
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek other nearby watercourses and waterbodies	Slight	Rare	Low
		Drinking water	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
Deposition of tailings slurry Swan / De Grey IPTSF Pit overtopping (Soil, groundwater, and surface water)	Flow of supernatant water over the pit rim <sup>4</sup>	Native terrestrial flora including riparian vegetation communities	Potential soil erosion and physical damage to vegetation from overland flow and/or flooding Soil and/or groundwater contamination resulting in decline in floristic health	Minor	Rare	Low
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	Minor	Rare	Low
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low

Risk Event				Risk Assessment		
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Consequence	Likelihood	Risk Rating
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
		Recreational users	Adverse impacts to human health from recreational use of Ophthalmia Dam, or other nearby watercourses	Minor	Rare	Low
Deposition of tailings slurry in Swan and De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Waste fines and supernatant water inside Swan and De Grey IPTSF containment)	Entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water	Native terrestrial fauna <sup>3</sup>	Acute or chronic effects on health Entrapment in soft fines	Minor	Possible	Medium
Deposition of tailings slurry in Swan and De Grey IPTSF Collapse of pit wall (Soil/rock)	Overland flow of debris and subsequent displacement of tailings and subsequent overland flow to downgradient receiving environments following pit wall collapse	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems Destruction of habitat	Minor	Rare	Low
		Native terrestrial flora and fauna <sup>3</sup>	Smothering and/or entrapment of receptors Destruction of habitat	Minor	Rare	Low

Notes:

- 1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pampajinya and Jigalong Communities.
- 2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
- 3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.
- 4) Pit overtopping may occur as a result of an extreme storm event, collapse of pit wall (if a supernatant pond is present in the TSF), or human failure.

AEP = annual exceedance probability; DMIRS = Department of Mines, Industry Regulation and Safety; ANCOLD = Australian National Committee on Large Dams.

# 6 Closure Conceptual Exposure Model

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## 6.1 Overview

The DPS is intended to refine the assessments completed in the SPS to support various environmental and economic aspects. In addition, the DPS scope involves the selection and design of the closure Preferred Investment Alternative (PIA) with a set of design elements. Within the DPS scope, WSP prepared and issued the DPS — IPTSF Closure Strategy (WSP, 2024j) report that consolidates the assessment, selection, and design of the PIA. The process encompassed the development of closure concepts with sufficient engineering detail supporting the risk-based Multicriteria Assessment (MCA). The closure strategies assessed for validation of the PIA during the DPS phase were as follows:

- Option 1 Optimised Without (OWO) – No closure activities implemented other than monitoring of the IPTSF as left follow the completion of operations.
- Option 2 Partial Backfill – Tailings surface covered follow the completion of operations resulting in only Partial Backfill of the IPTSF (not water shedding).
- Option 3 Full Backfill - Refinement and updates required for the strategy defined as part of the SPS phase.

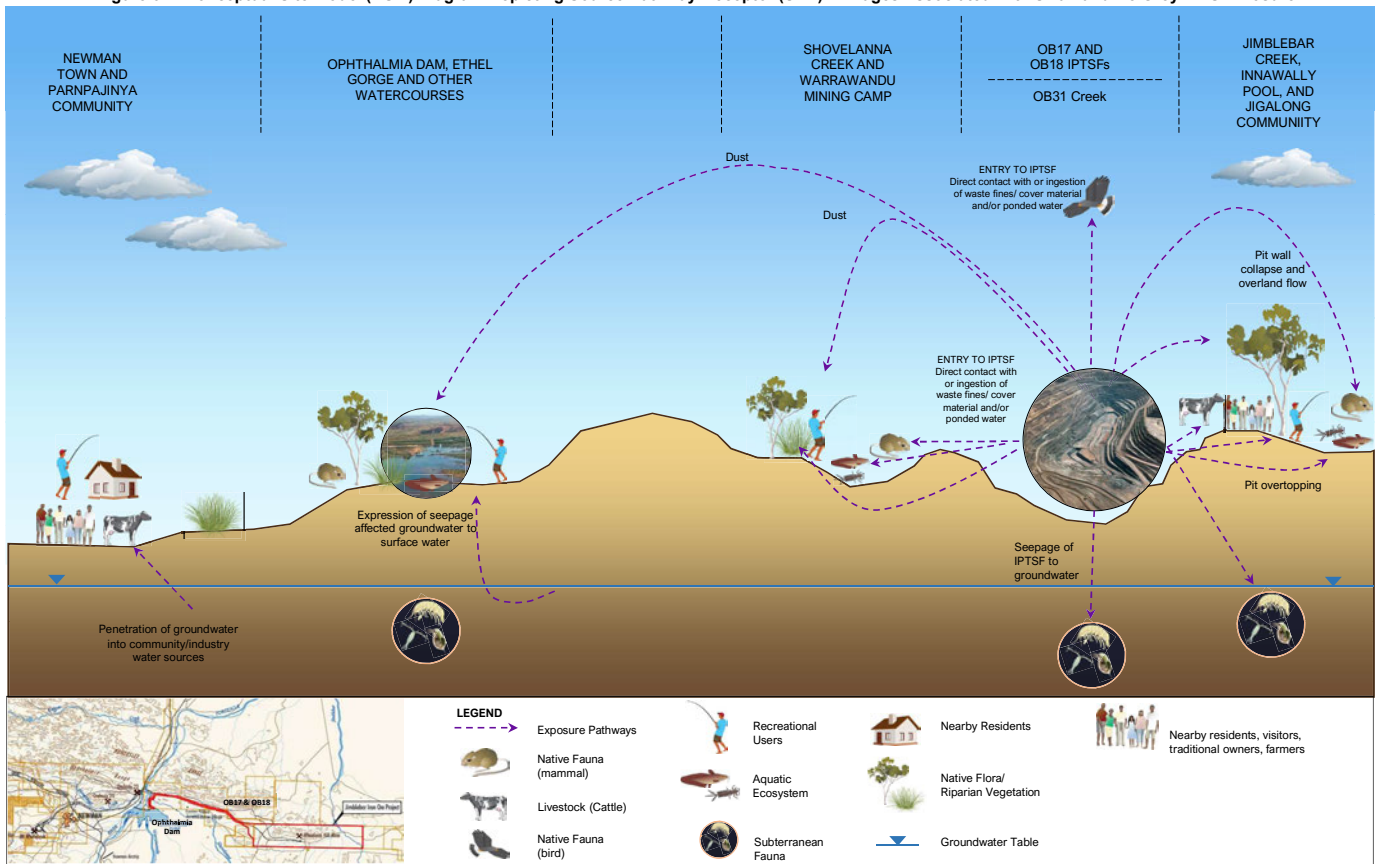
Option 2 Partial Backfill was identified as the PIA for the IPTSF Closure Strategy via the MCA process. As such, the Partial Backfill closure option and associated information has been used to undertake this Closure CEM. The Partial Backfill closure characteristics is summarised in Section 6.1.1.

A CSM diagram has been generated to visually represent the potential SPR linkages associated with closure of the Swan and De Grey IPTSFs (Figure 6.1). The Closure CEM has drawn on the Operations CEM, while considering key differences in the environmental setting and characteristics of the IPTSFs at closure compared to operations.

While the final land use at closure has not been confirmed, based on current information and for the purpose of the CEM, it is considered to be native ecosystems and potentially some limited grazing. Note that the stability of any pit voids and post-closure rehabilitation measures such as revegetation over tailings would need to be considered and assessed to ascertain suitability for grazing.

The sources (Section 6.1.2), pathways (Section 6.3), and receptors (Section 6.4) are described in the following subsections. This is followed by Table 6.2 which presents the SPR linkages associated with closure phase of the IPTSF. Table 6.2 also includes the risk ratings assigned to each SPR linkage, including the rationale for these ratings considering mitigation and controls that may be put in place, as well as making recommendations for additional work that may be required.

Figure 6.1: Conceptual Site Model (CSM) Diagram Depicting Source-Pathway-Receptor (SPR) Linkages Associated with Swan and De Grey IPTSF Closure



### 6.1.1 Closure Option - Partial Backfill

Partial Backfill closure considers that the tailings surface would be covered after the end of operations resulting in only partial backfill of the IPTSF (not complete backfill and not water shedding). In addition, a cover would be placed over exposed PAF material in the pit walls. Final cover will result in a backfilled surface at a minimum level of 5 m above the post-mining recovered water table, as currently committed in the Mine Closure Plan. This includes:

- Consolidation rate <1m/yr for the tallest tailing column will be reached in 2086 for De Grey and 2072 for Swan.
- A minimum of 5m thick at the perimeter, falling to the centre of the pit at a 12% uniform gradient. This will result in a maximum cover thickness of 26m in De Grey and 20m in Swan.
- A cover constructed of material sourced from within a 5 – 10 km haul, potentially within 2 km from the East OSA, will be placed across the tailings surface (assumes benign backfill).
- Adjacent catchments as per landforms at the end of operations.
- In-pit ponding conditions could be very oscillating post-consolidation, with intermittent shallow ponding potentially occurring after rainfall events.

### 6.1.2 Hydrogeology

The pre-mining conceptualisation (BHP, 2022) of the hydrogeological setting between Ethel Gorge and OB31 is described in Section 5.

The current groundwater scenario has dewatering operations at OB31 maintaining groundwater levels at Swan Pit below the pit floor and drawing groundwater at the Swan Pit to the east. This situation is likely to continue until some time after dewatering at OB31 ceases, currently scheduled for 2055. The De Grey Pit, however, is not hydraulically connected to OB31 and is not currently responding to dewatering at OB31; if any future seepage does leave De Grey and flow into the regional aquifer system, it too is expected to flow towards OB31 during this time.

At the Swan Pit, the rate of groundwater recovery following dewatering cessation is uncertain and will rely on post-IPTSF-closure water management in the groundwater catchment as well as short and long term rainfall events and recharge conditions. The time taken to reach equilibrium will be measured in hundreds of years. At this stage, the closure strategy for OB31 is unknown and whether the pit is left to form a pit lake (i.e., a regional groundwater sink) or partially or fully backfilled, will affect the rate and magnitude of groundwater level recovery at OB31.

At this stage it is assumed that groundwater level at the Swan Pit following cessation of dewatering at OB31 will return to the pre-mining level of approximately 500 m AHD, and predominantly westerly groundwater flow directions will re-establish (Figure 6.1). No known Groundwater Dependant Ecosystems (GDE's) are located along the westerly pre-mining flow path from Swan and De Grey Pits. The groundwater flow path will swing to the north at Ethel Gorge and likely bypass the Ethel Gorge TEC due to higher groundwater levels in the TEC. Available information indicates that there is little potential for seepage water from Swan or OB31 to enter Ethel Gorge TEC (BHP, 2022).

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## 6.2 Potential Contamination Sources and Stressors

There will be different stages during closure – including consolidation, landform management/reinstatement such as capping and vegetation, post-consolidation and on-going management – which will all have some differences in the environmental fate and transport activities and hence contamination sources. There will be different hazards during the different closure timeframes, for example, supernatant water may be a source hazard during consolidation, but not during long-term closure, i.e., after final landform has been developed.

However the exact nature and duration of these stages and associated environmental fate & transport is unknown, based on available data, so they have not been differentiated in the risk assessment at this stage.



Based on the available environmental data, the main sources of potential contamination associated with closure of the Swan and De Grey IPTSF are:

- Waste fines/tailings (more likely to be generated during dry periods and if no vegetation established).
- In-pit ponded water, comprising runoff from pit wall materials, and basal seepage from waste rock dump into IPTSF (extent will depend on consolidation process and backfilling processes and timing).

The contaminants associated with the above identified sources are dependent on the chemistry of the:

- Residual feed water quality (the input/source water used to process the iron ore).
- Composition of the ore.
- Residual process chemicals (e.g., flocculants).
- Contribution from blast residues (i.e., nitrogen compounds).

The following data is available for assessment of potential PSOI for the closure of the Swan and De Grey IPTSF:

- Analytical data for the tailings solids.
- Interpretation of the operations quality model outputs for the ponded water. (High-level water quality model outputs for the ponded water in-pit for Swan and De Grey IPTSF was considered in the SPS CEM however data is not considered relevant for the current closure strategy)

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## 6.3 Potential Contaminant Pathways

The following transport pathways have the potential to expose receptors to risk from PSOI associated with the closure phase of the Swan and De Grey IPTSF:

- Airborne dust, primarily during consolidation period when dry, without vegetation or other capping.
- Seepage of IPTSF waters through base and/or pit walls to groundwater.
- Spillage from failure of decant water pipelines – Contaminant transport due to failure of a decant water pipeline has been retained in the Closure CEM. The decant system will likely be decommissioned post-operations, because the risk of overtopping is reduced at closure and therefore it is unlikely that the pond will need to be maintained (i.e., regularly decanted/pumped down) to keep it within a defined operating range. Mitigation for reducing runoff volumes from reporting to the pond (thereby keeping the pond volumes as low as reasonably practicable) includes constructing upstream diversions to direct runoff elsewhere downstream. However, noting the above, there is still the potential that at some stage during closure there will be a need to decant water from ponds within the pits and therefore, this exposure pathway has been retained in the Closure CEM. Decanting at closure will be at a significantly reduced rate to that of operations.
- Pit overtopping and/or Collapse of pit wall. (Both events could lead to similar outcomes, i.e. tailings release.)

As tailings deposition will have ceased at closure, spillage from the failure of delivery pipeline is no longer relevant, therefore this contaminant transport pathway has been removed from the Closure CEM.

In addition, migration of in-pit water from groundwater to surface water has been removed, based on advice from the IPTSF Closure Strategy (WSP, 2024j) that any water that accumulates in the pit will remain in the pit and/or be managed so that there is minimal likelihood of expression to surface water or other media outside the pit (e.g., soil or sediment). Therefore there is minimal likelihood of direct contact or ingestion of PSOI from seepage or surface water by aquatic or terrestrial flora and fauna or livestock or native fauna, including incidental ingestion by recreational users of natural watercourses or waterbodies.

Potential receptors may become exposed to PSOI associated with the closure phase of the IPTSFs via the following exposure pathways:

- Inhalation of dust by humans.
- Direct contact /uptake of PSOI by terrestrial or aquatic flora and fauna<sup>14</sup> from waste fines and/or supernatant water within Swan or De Grey pits: – While exclusion bunding is expected to discourage access of humans, livestock and wildlife to the pits, the effectiveness of exclusion bunding is unknown. In addition, at closure there will no longer be active machinery onsite to deter wildlife access. There may be intermittent water collection within the pits, with some potential for ephemeral aquatic habitats to establish; however, permanent ponding is unlikely. Any ecosystems that may establish are considered to be highly modified and likely not representative of local native surface waters, and any contact with pond water by humans or other terrestrial fauna is unlikely to be significant.
- Direct contact with surface water impacted by tailings release through overtopping or pit wall collapse, in the event of emergency. The potential of this scenario occurring is likely to decrease significantly as consolidation progresses.

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## 6.4 Potential Receptors

Based on site knowledge, a review of surrounding land uses (Section 2.2), readily available information and the identified closure option, the potential receptors at Closure are essentially the same as during Operations, except that most will be at a lower likelihood of exposure provided the proposed management measure are in place, as included in the IPTSF Closure Strategy (WSP 2024c).

The following were identified as potential receptors of interest (ROI) that may be exposed (either directly or indirectly as indicated in Table 6.1) by PSOI identified as associated with the IPTSF (Swan and De Grey) at Closure:

- Ecological Receptors:
  - Surface water aquatic ecosystems (Innawally Pool, OB31 Creek, Jimplebar Creek<sup>15</sup>, Shovelanna Creek and Ophthalmia Dam), including aquatic fauna and riparian vegetation.
  - Groundwater Dependent Ecosystems (GDE) as listed in the Australian Government Bureau of Meteorology, Groundwater Dependent Ecosystems Atlas (Appendix B of the SPS CEM):
    - Ethel Gorge aquifer stygobiont Threatened Ecological Community (TEC).
    - Subterranean fauna.
  - Native and terrestrial flora and fauna, including Commonwealth and State listed species of conservation significance (described in Appendix B of the SPS CEM for the full detailed Environment Protection and Biodiversity Conservation [EPBC] Act Protected Matters Reports and NatureMap Species Reports).
  - Livestock (cattle)<sup>16</sup>.
- Human Receptors:
  - Recreational users (e.g., campers) and Traditional owners<sup>17</sup> visiting the IPTSFs landforms at Closure.
  - Recreational users of nearby watercourses and waterbodies for wading, swimming, and fishing.

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<sup>14</sup> Native terrestrial fauna includes migratory birds.

<sup>15</sup> The Jimplebar Creek regional surface water catchment is depicted in Figure 1 of the (BHP, 2018) Surface Water Management Plan Jimplebar report.

<sup>16</sup> A potential future use of the IPTSFs at closure is pastoral land, including cattle grazing.

<sup>17</sup> The IPTSF project area itself has no registered aboriginal heritage sites. Therefore, exposure of Traditional Owners to the IPTSFs at Closure is considered to be represented by recreational exposure.

- Newman Water Reserve<sup>18</sup> public drinking water source protection zones (Priority Areas 1 and 3) and associated borefields.
- Nearby residents and visitors to the town of Newman.
- Aboriginal residents and visitors of the Parnpajinya and Jigalong Communities.
- Traditional owners (Niyiyaparli people) and custodians (Martu people) of the land.
- Farmers associated with the Prairie Downs and Sylvania Stations.

Further information on the receptor identification process is provided in Appendix A.

It is acknowledged that drinking water (Newman town water supply) source water is treated by BHP and the Water Corporation to meet the Australian Drinking Water Guidelines (NHMRC and NRMMC, (2011, updated 2021).), as required by WA Health (BHP 2012). Therefore, there is likely an incomplete pathway for exposure of humans via drinking water that has indirectly been affected by water sourced from the OB31 dewatering system. However, for completeness, drinking water has still been considered as an exposure pathway in the CEM.

In addition, some of the other exposure pathways are unlikely to be realised to major extents but have been included for completeness.

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## 6.5 Closure – Risk events (SPR linkages)

Table 6.1 presents the identified closure-related risk events as a summary of the exposure pathways that relate to each of the SPR linkages for closure.

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<sup>18</sup> Swan and De Grey are located ~1 km outside of the boundaries of the Newman Water Reserve, the area encompassing the borefields responsible for Newman’s public drinking water supply (DOW 2014). Source water from the Newman Water Reserve is extracted and/or treated by BHP and the Water Corporation, prior to potable use.

Table 6.1 Summary of Closure SPR linkages for IPTSF (Risk events)

Primary and Secondary Sources (Environmental Media)	Transport Pathway	Receptors	Exposure Pathways				
			Ingestion	Inhalation	Dermal Contact	Direct Contact / Uptake	Food Chain <sup>4</sup>
Post-Deposition activities in Swan / De Grey IPTSF  Dry waste fines  (Air quality)	Airborne fugitive dust generated from TSF landform, prior to complete vegetation and during any in-pit mechanical activities.  (Expected to be mainly in consolidation phase.)	Native terrestrial flora	-	-	-	✓	-
		Recreational users, nearby residents <sup>1</sup> , traditional owners, and/or farmers	-	✓	-	-	-
Post-Deposition in Swan / De Grey IPTSF  Consolidation of tailings slurry and resulting supernatant water  (Groundwater)	Seepage of IPTSF waters through base and/or pit walls to groundwater	Groundwater dependent ecosystems including subterranean fauna	✓	-	-	✓	-
Post-Deposition in Swan / De Grey IPTSF	Flow of ponded and/or tailings over the pit rim, Contact with falling debris (soil/rock) following collapse of pit wall	Native terrestrial flora	-	-	-	✓	-
		Groundwater dependent ecosystems including subterranean fauna	✓	-	-	✓	-
		Aquatic ecosystems <sup>2</sup>	-	-	-	✓	✓

Primary and Secondary Sources (Environmental Media)	Transport Pathway	Receptors	Exposure Pathways				
			Ingestion	Inhalation	Dermal Contact	Direct Contact / Uptake	Food Chain <sup>4</sup>
Collapse of pit wall / Pit overtopping  (Soil / rock, groundwater, and surface water)		Native terrestrial fauna <sup>3</sup>	✓	-	-	-	✓
Post-Deposition in Swan / De Grey IPTSF  Consolidation of tailings slurry and resulting supernatant water  (Waste fines and supernatant water inside Swan / De Grey IPTSF containment)	Entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water	Native terrestrial fauna <sup>3</sup>  Aquatic ecosystem within in-pit ponds	✓  -	-  -	-  -	✓  ✓	-  ✓

Notes:

- 1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pampajinya and Jigalong Communities.
- 2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
- 3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.

The 'food chain' exposure pathway refers to indirect dietary exposure to PSOI taken up in food items/prey consumed by fauna

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## 6.6 Closure – Consequence analysis (Screening)

The following presents a summary of the screening assessment for closure related SPR linkages as per Section 4.

### 6.6.1 Tailings data

The tailings solids data is compared to the adopted screening criteria in Section 4.1.

### 6.6.2 Pond water quality predictions

The Partial Backfill closure option (Option 2) was the preferred selected option for closure, which resulted in an improved outcome with respect to Option 1 (OWO option). The compounded/weighted residual risk score during the MCA was almost in the zone of “well within the risk appetite”. Only one risk scenario was assessed to be outside of appetite, i.e., direct exposure of fauna to ponded surface water (seepage management was not considered to be required for the closure landform). However, the following engineering controls were recommended to be applied to reduce the likelihood and/or duration of ponded surface water within the IPTSF:

- Development of a partial backfill geometry that increases surface evaporation (flat surface, large evaporation area, and shallow water ponding); and
- Surface water diversions to reduce runoff into the IPTSFs.

Assuming the recommended engineering controls are implemented, the access of fauna to permanent or temporary ponded surface water at closure will be minimized. Therefore, water quality for the Partial Backfill closure option is not considered in the CEM at this level of study. Future closure study phases should incorporate more detailed water quality assessments to the target study level and be supplementary to other studies (e.g., hydrology, hydrogeology, CEM, etc.).

### 6.6.3 Summary of Closure PSOI

In the absence of water quality modelling specific to the proposed closure strategy, the screening processes analytes presented in Section 5.2 have been identified as potential PSOI's associated with closure of the Swan and De Grey IPTSF.

It is acknowledged that the closure concentrations are expected to be as a result of secondary seepage of tailings water post-deposition and consolidation and therefore the PSOIs are predicted to be at reduced concentrations. As such, reduction of concentrations will remove analytes from being identified as a stressor. Water quality modelling considering the proposed closure design and conditions should be undertaken to confirm these assumptions.

### 6.6.4 Downstream Water Quality at Closure

Downstream water quality has been assessed in the context of the Operation Conceptual Exposure Model (Section 5.6.3). No downstream modelling has been undertaken within the context of the Closure strategy and further assessment is recommended. However, screening results for the operational downstream water quality indicated elevated concentrations of TDS and Barium are present. It can be assumed that conditions at closure are likely to be similar, however as noted further assessment is recommended.

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## 6.7 Closure – Likelihood & Risk Assessment

An assessment of risk for the complete SPR linkages associated with the closure phase of the Swan and De Grey IPTSF (Figure 6.1) are presented in Table 6.2. The SPR linkages identified in Table 6.2 along with proposed mitigation strategies and controls, are based on the sources described in Section 6.1.2, the pathways described in Section 6.3, and the receptors considered in Section 6.4.

The risk ratings, assigned to each SPR linkage are based on the DWER (DWER, 2020) guidelines presented in Section 4. Appendix G also provides the rationale for these ratings considering mitigation and controls that may be put in place.

Table 6.2 Summary Closure Phase Risk Ratings for Jimblebar In-pit Tailings Storage Facilities

Risk Event				Risk Assessment		
Primary and Secondary Sources  (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Closure Strategy - Partial Backfill		
				Consequence	Likelihood	Risk Rating
Post-Deposition of tailings slurry in Swan / De Grey IPTSF Dry waste fines (Air quality)	Fugitive dust generated from TSF landform	Native terrestrial flora	Reduction in photosynthesis, respiration, and transpiration due to dust deposition	Slight	Rare	Low
		Recreational users, nearby residents <sup>1</sup> , traditional owners, and/or farmers	Acute and chronic effects on human respiratory system and general health and amenity	Minor	Rare	Low
	Direct discharge of supernatant water to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	Soil and/or groundwater contamination resulting in localised, short-term decline in floristic health	Minor	Rare	Low
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	Minor	Rare	Low
	Expression of contaminated groundwater to surface water and subsequent migration further downgradient; overland flow to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna	Minor	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and associated creeks	Slight	Rare	Low
Post Deposition of tailings slurry in Swan / De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water  (Groundwater and surface water)	Seepage of IPTSF waters through base and/or pit walls to groundwater	Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Degradation of groundwater near Swan / De Grey IPTSF	Minor	Unlikely	Medium
		Native terrestrial flora including riparian vegetation communities	Localised, short-term decline in floristic health due to raised water tables, uptake of contaminated shallow groundwater or surface water, and/or increased salts in surface soils due to evapo-concentration	Minor	Rare	Low
	Expression of groundwater contaminated with IPTSF waters to surface water and subsequent surface water migration downstream along natural waterways/ watercourses	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and quantity and associated effects to aquatic ecosystems and the hydro cycle	Minor	Rare	Low
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low



Risk Event				Risk Assessment		
Primary and Secondary Sources  (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Closure Strategy - Partial Backfill		
				Consequence	Likelihood	Risk Rating
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek other nearby watercourses and waterbodies	Slight	Rare	Low
		Drinking water	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
Post Deposition of tailings slurry Swan / De Grey IPTSF Pit overtopping (Soil, groundwater, and surface water)	Flow of supernatant water over the pit rim <sup>4</sup>	Native terrestrial flora including riparian vegetation communities	Potential soil erosion and physical damage to vegetation from overland flow and/or flooding Soil and/or groundwater contamination resulting in decline in floristic health	Minor	Rare	Low
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	Minor	Rare	Low
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low
		Recreational users	Adverse impacts to human health from recreational use of Ophthalimia Dam, or other nearby watercourses	Slight	Rare	Low
Post Deposition of tailings slurry in Swan and De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Waste fines and supernatant water inside Swan and De Grey IPTSF)	Entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or intermittent pond water	Native terrestrial fauna <sup>3</sup>	Acute or chronic effects on health  Entrapment in soft fines	Minor	Possible	Medium
		Aquatic ecosystem within in-pit ponds	Acute or chronic effects on health	Slight	Rare	Low

Risk Event				Risk Assessment		
Primary and Secondary Sources  (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Closure Strategy - Partial Backfill		
				Consequence	Likelihood	Risk Rating
		Livestock (cattle)	Acute or chronic effects on health	Slight	Rare	Low
		Recreational users	Acute or chronic effects on health	Minor	Rare	Low
Post Deposition of tailings slurry in Swan and De Grey IPTSF Collapse of pit wall (Soil/rock)	Overland flow of debris and subsequent displacement of tailings and subsequent overland flow to downgradient receiving environments following pit wall collapse	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	Minor	Rare	Low
		Native terrestrial flora and fauna <sup>3</sup>	Smothering and/or entrapment of receptors Destruction of habitat	Minor	Rare	Low
		Livestock (cattle)	Destruction of grazing land	Minor	Rare	Low
		Recreational users	Destruction of recreational areas/ significant sites	Minor	Rare	Low

- Notes:
- 1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pampajinya and Jigalong Communities.
  - 2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
  - 3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.

Pit overtopping may occur as a result of an extreme storm event, collapse of pit wall (if a supernatant pond is present in the TSF), or human failure.

AEP = annual exceedance probability; DMIRS = Department of Mines, Industry Regulation and Safety; ANCOLD = Australian National Committee on Large Dams

# 7 Uncertainties

Table 7.1 provides the uncertainties identified as potentially impacting the CEM.

Table 7.1 Uncertainty analysis

Area of uncertainty	Detail	Impact on CEM
Design and associated factors	The CEM relies on the accuracy of the design parameters and criteria outlined in the Basis of Design (WSP, 2024) and other supporting studies.	Modification to the design and/or inaccuracy may result in changes to CEM and the risk assessment.  May result in over- or under-estimate of risk ratings.
Supporting studies	The risk ratings presented in the CEM are informed by the outputs of the water balance, hydrogeological, and geochemical modelling which includes the assumption that the Swan, De Grey, and adjacent pits (OB31) dewatering system are operational	Conservatism of modelling in the supporting studies will result in over-estimation of risk ratings
		Inaccuracies in support study modelling may result in over- or -under estimation of risk ratings
Supporting studies	The water balance and geochemical studies undertaken to support the closure assessment are considered high-level. Therefore, these results should be considered preliminary and may be subject to change, as more refined modelling is completed at later stages of the closure assessment.	High-level, less refined modelling results may over- or -under estimate risk ratings
Supporting studies	There are uncertainties associated with the groundwater conditions at closure creating uncertainties regarding the potential receptors that might be exposed to PSOs in seepage that migrate in groundwater from the IPTSF. Based on the current understanding and available information, for this CEM it has been assumed that dewatering at OB31 will cease and westerly groundwater flow directions will re-establish.	Uncertainty in groundwater conditions may result in over- or -under estimation of risk ratings
Consequence assessment criteria, guideline values, screening criteria	The adopted screening criteria are derived with uncertainty and safety factors and are set at levels well below concentrations that may cause adverse effects, often by orders of magnitude.	Can result in over-estimation of consequence and risk rating.
Consequence assessment criteria, guideline values, screening criteria.	Screening criteria are also usually derived using general exposure assumptions that are based on worst-case scenarios to cover a wide range of situations and sensitive sub-populations.	Can result in over-estimation of consequence, likelihood and risk rating
Environmental data	Use of 90th percentile (P90) concentrations that are not likely present at all times in all exposure situations.	Can result in over-estimation of likelihood and risk rating

Area of uncertainty	Detail	Impact on CEM
Environmental data	Air quality data was not available to inform the chemical composition and particle size distribution of the fugitive dust generated by the TSF landform. CEM assessment authors assumed that any windblown dust generated would be dominated by the coarse sized particulate matter fraction.	If finer respirable dust is generated, risk ratings possible under-estimated.
Environmental data and screening	Additional conservatism may be included for some aquatic ecosystems by use of 95% species protection levels, when some of the receiving surface waters appear likely to be highly disturbed ecosystems and may allow the use of 90% protection levels	Can result in over-estimation of consequence and risk rating.
Operations and controls	The rating of risk due to pipeline failure has been conducted on the basis that the delivery pipeline system will be equipped with pressure sensors and an automatic line shut off designed to trigger in event of a pressure drop	If pipeline controls are not utilised, risk ratings may likely be under-estimated.
Closure	The preferred Partial Backfill Closure Option involves the tailings material being capped after the period of consolidation with a benign material (indicated to be waste rock covered by locally sourced surface soils). Assessment of the cover material is outside of the scope of this CEM. However, it is recommended that the suitability of the cover material in relation to chemical exposure risks of humans and wildlife is assessed prior to use.	Type of closure material can impact exposure and may result in over- or - under estimation of risk ratings.

# 8 Conclusions

The CEM describes complete source-pathway-receptor (SPR) linkages (i.e., potential interactions between the IPTSF, air [dust], surface water and groundwater, and receptors [humans and ecology]) associated with the Swan and De Grey IPTSF. The DPS CEM considers both operations and closure phases. The preferred closure option has been assessed as Option 2 – Partial backfill.

The Operations and Closure CEMs assess potential risks to ecological and human receptors posed by chemical stressors associated with the Swan and De Grey IPTSFs. The CEMs exclude occupational and safety risk. Health and safety risks to workers during operations or physical safety risk to the community during closure will be assessed and managed separately.

The risk ratings of the complete source-pathway-receptor (SPR) linkages associated with operation and closure of the De Grey and Swan IPTSF are summarised as follows:

## 8.1 Operations

No high-risk ratings were identified for Operations. The medium risks are summarised below. The remaining risk ratings were low, and therefore, have not been discussed in this summary.

Medium Risk:

- Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems (subterranean fauna), and the migration of seepage-impacted groundwater from the IPTSFs to the OB31 dewatering system and subsequent disposal of surplus water to the receiving environment (including Ophthalmia Dam) resulting in impacts to surface water aquatic ecosystems and native terrestrial flora (including riparian vegetation communities) and fauna.
  - Groundwater modelling (WSP 2023e) predicts that groundwater mounding will not be high enough to result in seepage to ground surface. Groundwater impacted by seepage from the IPTSFs through OB31 dewatering and disposal of surplus water to the receiving environment may provide a potential exposure pathway for surface water aquatic ecosystems, native terrestrial fauna and flora (including riparian vegetation), livestock and humans (recreational users and drinking water).
  - Modelling of the chemistry of the seepage impacted OB31 dewatering water (i.e., downstream) indicates that TDS and Barium exceed the screening criteria, with one high seepage scenario during sustained seepage (late stages of the operational period) resulting in a HQ > 5.
  - Further monitoring of the groundwater is recommended to determine if the water quality is suitable to be discharged to a sensitive receiving environment<sup>20</sup> or if further management measures are needed.
  - The pathway for exposure to humans via drinking water is likely to be incomplete. Any impact is likely to be due to water sourced from the OB31 dewatering system and to be diluted and treated before any drinking water exposure. The concentrations of PSOs in seepage- impacted groundwater present a low risk to livestock and drinking water, with low Hazard Quotients<sup>21</sup>.

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<sup>20</sup> It is assumed that seepage water collected by the OB31 dewatering system will be managed as part of BHP's overall water management system and re-used or dispose. Seepage affected groundwater must meet applicable water quality guidelines and licence discharge criteria (e.g., SSTVs) prior to being discharged to the receiving environment (including Ophthalmia Dam).

<sup>21</sup> For livestock and drinking water, it is assumed that water in Ophthalmia Dam would be required to seep into the underlying groundwater and then migrate to an abstraction bore before it is used for livestock feeding or drinking water. It is likely that some further dilution of the PSOs would occur during migration in groundwater and this would reduce the risks posed to human health from drinking water or livestock. In addition, it is acknowledged that drinking water (Newman town water supply) source water is treated by

Entry to IPTSF containment and subsequent direct contact with, or ingestion of, waste fines and/or supernatant water by native terrestrial fauna.

- There were minor exceedances of some screening criteria, which would require assessment of the likelihood of terrestrial fauna coming in direct contact with the surface water or waste fines. The screening criteria for both apply more to a chronic (i.e., long-term) exposure scenario, rather than sporadic exposures for short durations. If there are only short-term intermittent exposures, the risk is likely to be low.
- However, due to the unknown potential for exposure, a likelihood rank of possible is applied which derives a medium risk to native terrestrial fauna from entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water<sup>22</sup>.

## 8.2 Closure – Option 2, Partial Backfill

No high-risk ratings were identified for Closure Option 2. The medium risks are virtually the same as those identified for the Operations phase and are summarised below, with the remaining risk ratings being low.

Medium Risk:

- Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems (subterranean fauna and riparian vegetation communities).
- Entry to IPTSF containment and subsequent direct contact with or ingestion of waste fines and/or intermittent pond water by native terrestrial fauna within in-pit ponds.

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BHP and the Water Corporation to meet the Australian Drinking Water Guidelines (NHMRC and NRMCC 2011), as required by WA Health (BHP 2012).

<sup>22</sup> WSP anticipates that BHP will manage the potential risks to the environment from the rare event of a pit wall collapse through implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure). As a result, the risk to aquatic ecosystems and native terrestrial flora and fauna is assessed to be low on the assumption that minor consequences are only expected under exceptional circumstances.

# 9 Recommendations

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## 9.1 Reducing uncertainties

Where uncertainties are impacting on the outcome, additional assessment and modelling works may reduce uncertainties in the CEM risk ratings and fill information gaps to help decide on the final outcome.

### 9.1.1 *Operations and Closure CEM*

Assessing background environmental data further (in addition to the groundwater data already collected e.g. OB31 Groundwater Quality) would increase understanding of the potential for naturally elevated metal concentrations in the area surrounding the IPTSFs. Understanding background conditions may be used to refine the risk ratings by assessing whether PSOI concentrations in environmental media are elevated above the natural background conditions and whether the derived Site-Specific Trigger Values are relevant.

It may also be used to establish baseline conditions to assist with understanding the magnitude of potential discharges to the environment (such as pipeline spills) and the requirement for cleanup; for this purpose, background environmental data should be collected before deposition of tailings commences.

This additional data could include the collection of soil data, surface water quality data (e.g., OB31 Creek, Shovelanna Creek, Jimlebar Creek) and sediment/soil quality data along drainage and creek lines (OB31 Creek, Shovelanna Creek, Jimlebar Creek).

### 9.1.2 *Closure CEM*

The seepage risk from the IPTSFs to groundwater may be refined through hydrogeological modelling for closure to understand changes in groundwater levels and flow direction once OB31 dewatering has ceased and once the closure strategy for OB31 Pit is known. The rate of recovery of groundwater levels following the cessation of dewatering operations at OB31 is unknown; it has not been numerically modelled and may take hundreds of years.

In addition, as the water balance and geochemical studies that have been undertaken to support the closure assessment are considered high-level and focused on Closure Option 1, the results can be considered preliminary; additional hydrogeological modelling focused on Closure Option 2 may assist in reducing uncertainties associated with seepage migration at closure and the identification of potential receptors.

- Note: Water balance models or water quality models were not developed for the Closure Option 2, and updating those for Option 2, potentially incorporating updated design elements as relevant and the final landform and land use/s to confirm the ecological and human receptors that may be exposed, would assist with refining the risk rankings.

The preferred Closure Option (Option 2, with partial backfill) incorporates the tailings material being capped after the consolidation period with a benign material (indicated to be waste rock). Assessment of the cover material is outside of the scope of this CEM, however, it is recommended that the suitability of the cover material is assessed prior to use to minimise chemical exposure risks of humans and wildlife.

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## 9.2 Risk control and mitigation measures

A number of engineering and management measures are recommended to protect the local environment and ecosystems, including human health. These include protection of air quality and soil, groundwater and surface water (from tailings delivery systems, decant water and tailings slurry deposition) and are outlined in the Risk Assessment tables for Operation (Appendix D) and Closure (Appendix E).

This section discusses the recommendations for the two medium risk scenarios identified for both Operation and Closure:

- Seepage of IPTSF waters through base and/or pit walls to groundwater resulting in impacts to groundwater dependent ecosystems (subterranean fauna and riparian vegetation); and to aquatic ecosystems and native terrestrial flora (including riparian vegetation) and fauna from expression of seepage impacted groundwater to surface water.

Risk controls could include:

- Monitoring of groundwater and surface water quality and quantity (water level, flow).
- Continued operation of dewatering system to manage seepage.
- Entry to IPTSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water by native terrestrial fauna and aquatic ecosystems within in-pit ponds.

Risk controls could include:

- Exclusion bunding around pit to discourage access.
- Routine surveillance program, including regular fauna checks.

These recommendations are in addition to the management measures outlined in IPTSF Closure Strategy (WSP 2024C).

Other resources that may assist in mitigating hazards and risks include:

WA Department of Energy, Mines, Industry Regulation and Safety (2022) - [Guidance about tailings storage](#).

*This includes guidance and a Code of Practice on siting, designing, constructing, operating and decommissioning a Tailings Storage facility (TSF).*

Global Tailings Review, 2020 (partnering with International Council on Mining & Metals, ICMM; UN Environment Program, UNEP; and Principles for Responsible Investment, PRI) - Global Industry Standard on Tailings management [global-industry-standard\\_EN.pdf](#).

*To be compliant with the Standard, Operators must ... “implement best practices in planning, design, construction, operation, maintenance, monitoring, closure and post closure activities”.*



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# Appendix A

Receptors of Interest



# 1 Ecological Receptors

The Pilbara is characterised by a much higher evaporation rate than precipitation rate, and approximately 70% of the precipitation occurs between the months of November and April. This causes several extremely dry months so that the creeks and river systems in the Pilbara are ephemeral and often groundwater-dependent. The catchments and the associated groundwater within the Jimblebar and Wheelarra Hill areas, are habitat for approximately 20 stygofauna species (Bennelongia 2013a, 2014a, 2014b).

Mining activities in the region have resulted in drawdown of water table and consequently these surface water systems, which are naturally groundwater fed, are currently receiving reduced groundwater inputs. It is understood that BHP manage aquifer recharge of the local aquifer, to counteract effects of dewatering in the system.

## 1.1 Aquatic Ecosystems

The aquatic communities of ephemeral waters, such as Jimblebar Creek, are characterised by receptors that typically have short reproductive life cycles that are triggered by, and completed within, periods of inundation. Inundation is followed by drought during which time these receptors enter a period of dormancy (e.g., production of eggs that are desiccation-resistant) where life processes are halted until inundation occurs, or find refuges (such as springs, or permanent standing water).

Innawally Pool is a permanent waterbody formed by the erosion by high water flows from the incised gorge of Jimblebar Creek. The pool is approximately 700 m long and 30 m wide and retains water throughout the year (BHP 2021). Limited information is available on the aquatic communities of the local waterways (BHP 2019). The exception being Innawally Pool, which has been found to support a freshwater turtle (Steindachner's turtle), native frogs, and invertebrates (BHP 2021).

Other receptors such as fish and macroinvertebrates may find refuges during periods of drought in groundwater-fed springs or permanent pools. Fish may colonise the local ephemeral waters after transport from upstream locations during periods of inundation. Examples of invertebrates that are adapted for extended periods of desiccation and may be found within local creeks and receiving waters include aquatic molluscs (e.g., snails [Gastropoda]), water mites, and crustaceans (copepods [Copepoda], water fleas [Cladocera], seed shrimp [Ostracoda], and side swimmers [Amphipoda]).

The ephemeral creeks and pools within the Jimblebar area also support riparian vegetation communities along their main drainage channels and adjacent floodplains. These communities include the facultative tree species *Eucalyptus camaldulensis subsp. refulgens* and *Eucalyptus victrix* found on the flood plains (BHP 2019). A survey of riparian and aquatic flora and vegetation in Jimblebar Creek and Innawally Pool by Onshore Environmental (2016<sup>1</sup> cited in Onshore Environmental 2018) identified the following significant flora species: *Rhagodia sp* and *Goodenia nuda*.

## 1.2 Groundwater Dependent Ecosystems

Groundwater plays an important role in sustaining aquatic and terrestrial ecosystems, such as springs, wetlands, rivers, and vegetation in arid settings. Understanding these groundwater-dependent ecosystems (GDE) is essential for groundwater management and planning.

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<sup>1</sup> Not sighted

A search of the GDE Atlas was undertaken to assess the presence of aquatic, terrestrial, and subterranean GDEs proximate to the Swan and De Grey pits. Further information on the search of the GDE Atlas database is found in Appendix B. The lower and upper reaches of the Fortescue River, the Warrawanda Creek and Shovelanna Creek were identified to be moderate and high potential aquatic GDEs (national assessment), respectively. The areas surrounding the upper Fortescue River and Warrawanda Creek were identified as having moderate and low potential for terrestrial GDE. The areas surrounding Shovelanna Creek and Jimblebar Creek also displayed low potential for terrestrial GDE. No data was available for subterranean GDEs, as no analysed ecosystems were present within a 2 km radius of the Jimblebar Mine. As stated in SRK (2020), Ethel Gorge is designated as a Threatened Ecological Community (TEC) whereas Fortescue Marsh (Marsh located approximately 100 km to the northwest of OB17 and OB18) is designated as a Priority Ecological Community (PEC). The depth to groundwater in the vicinity of Jimblebar Creek and Innawally Pool is approximately 40-50 m bgl indicating these waterbodies are not GDE (SRK 2020).

### 1.2.1 Subterranean Fauna

Subterranean fauna includes stygofauna and troglofauna. Troglofauna are air-breathing animals that live in caves and voids in the sub-surface. Stygofauna are aquatic subterranean species (including micro and macroinvertebrates) that live below the earth's surface in aquifers, cave lakes, and groundwater systems. Stygofauna generally inhabit groundwater habitats with substantial fissures or voids, which in the vicinity of the area of study includes saturated Tertiary alluvium, along with orebody, dolomite, and fractured rock aquifers (SRK 2013). Subterranean fauna are predominantly invertebrates with a small number of vertebrates also having been identified to date (such as fish and a reptile).

The preservation and protection of subterranean ecosystem is a priority due to the unique biology, and function this fauna perform in groundwater systems. Stygofauna maintain the pore spaces in aquifers and remove organic material and nutrients in groundwater thereby providing an important ecosystem service of bio-remediating groundwater contaminants and maintaining groundwater quality. The Pilbara region is reported to have high diversity subterranean fauna (EPA 2016). It is conservatively estimated that the region supports between 500 and 550 species of stygofauna (Bennelongia 2015). As of 2015, more than 650 morphospecies of troglofauna had been recorded in the Pilbara to date, with the total number of species present likely to be much higher (Bennelongia 2015).

Stygofauna and other subterranean species are a focus of environmental assessment because a high proportion of them have localised distributions (Gibert and Deharveng 2002). According to Eberhard et al (2009), around 70% of Pilbara stygofauna species are likely to be short range endemics due to the limited physical connections between groundwater systems (Bennelongia 2013).

Limited research has been conducted on the effects of toxicant stressors on stygofauna. The physiology of stygofauna can differ from surface species and as such they may be expected to respond differently to toxicants compared to populations of surface taxa (Hose 2005, 2007 cited in Hose et al. 2015). It is considered likely that stygofauna communities may be more sensitive to some toxicants compared to surface water communities (Hose 2005 cited in Hose et al. 2015) and because of this, groundwater ecosystems are recommended to be protected (ANZG 2018).

Although no subterranean GDE were identified by the Atlas search, the Ethel Gorge/Ophthalmia Basin alluvium calcrete aquifer on the Fortescue River supports the Ethel Gorge Aquifer Stygobiont Community. This community is classified as a Threatened Ecological Community (TEC) B (ii) community based on it being of "limited distribution, with few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes" (DBCA 2020).

Several stygofauna assessments have been conducted in the study area in 2013 and 2014 to assess risks posed to stygofauna from proposed dewatering at OB17 (Swan), OB18 (De Grey), and OB31. Sampling yielded a total of 78 stygofauna species in Newman and surrounds, 59 of which occur in the Ethel Gorge TEC. Specific investigations at Jimblebar found only one species near the OB17 (Swan) and OB18 (De Grey) pits, 11 species in the OB31 footprint, 15 species in the vicinity of the Wheelarra Hill/Jimblebar mine area, and nine species surrounding the Sylvania Station (Bennelongia 2013a, 2014a, 2014b).

Several troglofauna studies have also been undertaken within the Jimblebar footprint, revealing approximately 38 species present at Jimblebar/Wheelarra Hill. Investigations indicate that these species are likely to be constrained to the clay rich habitat of the tertiary detritals and all species found in the area are likely to have widespread dispersals expanding outside of the area.



## 1.3 Terrestrial Ecosystems

### 1.3.1 General Description

The Pilbara region supports high species richness and many endemic species of plants and animals, including one of the richest reptile assemblages in the world, more than 125 species of acacia, and more than 1,000 species of aquatic invertebrates (DPAW 2017).

Jimblebar is located on the plains and low hills between three bioregions, with ephemeral creeks occurring in the eastern portion of the project area. Jimblebar is located between the eastern portion of the Hamersley and Fortescue subregions of the Pilbara, and the Augustus subregion of the Gascoyne. The surrounding vegetation is classified by BHP (2019) as follows:

- *Triodia* hummock/open hummock grass on hill slopes and low undulating hills
- *Acacia* high open shrubland (Mulga) and *Triodia* hummock grassland on floodplains
- *Triodia* hummock grasslands.

The gorges and summits of the highest peaks of the Hamersley Range protect isolated populations of land snails, skinks, and plants (DPAW 2017). Many endemic plant species, including the Threatened flora species *Aluta quadrata* and rare ecosystems are also found in the Hamersley subregion. Additional information pertaining to the conservation significant flora and fauna found in the study area is presented in subsequent sections.

Environment Protection and Biodiversity Conservation (EPBC) and NatureMap database searches were conducted to identify Commonwealth and State listed species of conservation significance that may be present within a 25 km radius of the study areas. Database search results are presented in Appendix B, with a summary of the flora and fauna species of conservation significance identified by the database searches provided in Tables B1 and B2, respectively. Additional details are provided in subsequent sections.

### 1.3.2 Flora and Vegetation of Conservation Significance

The NatureMap database search identified 15 priority flora species that may occur within a 25 km radius of the Swan and De Grey pits. The EPBC database searches also identified one threatened flora species that may occur within the 25 km radius. Mt Augustus Foxglove (*Pityrodia augustensis*) is listed as Vulnerable under the EPBC Act 1999 (Commonwealth) and as a Declared Rare Flora under the Wildlife Conservation Action 1950 (Western Australia). Mt Augustus Foxglove is a small flowering shrub endemic to a small area of Western Australia, spanning the rocky hillsides in the Mt Augustus area, north-east of Carnarvon, and Mt Fraser in the Robinson Range, north of Meekatharra in the Geraldton district of Western Australia (Brown et al. 1998)

### 1.3.3 Vertebrate Fauna of Conservation Significance

Together, the EPBC and NatureMap database searches identified species of birds, mammals and reptiles of conservation significance that may be present within a 25 km radius of Swan and De Grey, including:

- 11 Commonwealth listed threatened<sup>2</sup> species
- 15 listed migratory<sup>3</sup> and/or protected under an international agreement bird species
- 12 listed marine bird species

<sup>2</sup> Threatened fauna and flora may be listed in any one of the following categories pursuant to Section 179 of the *EPBC Act 1999*: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, or Conservation Dependent.

<sup>3</sup> Many migratory species are listed under international conventions and agreements to which Australia is party. The list of migratory species is established under Section 209 of the *EPBC Act 1999* and relates to the following conventions and agreements: Bonn Convention, JAMBA, CAMBA, and ROKAMBA.

- Three Priority 4 mammals<sup>4</sup>
- One Priority 1 and two Vulnerable reptiles
- One other specially protected fauna (Schedule 7).

### 1.3.4 Short Range Endemic Species

Fauna surveys conducted in 2013 and 2014 revealed six potential short range endemic (SRE) species. Two mygalomorph spiders (*Karaops* ‘ARA003-DNA’, and ‘ARA004-DNA’), a pseudoscorpion (*Xenolpium* ‘PSE079’), and three isopods (*Buddelundia* ‘10NM’, ‘49’, and *Buddelundiinae* ‘WN’) (Biologic 2013, 2014). These SREs are minorly impacted by habitat fragmentation, but are not expected to be further impacted by the proposed IPTSFs at Jumblebar Mine.

## 2 Livestock

The dominant land uses in the region are grazing, native pastures, ecological conservation, mining and urban. Unallocated Crown Land (UCL) and the Sylvania Pastoral Lease are the underlying land tenures occupying the Swan and De Grey areas. Sylvania Station is located approximately 28 km to the southwest of OB17 and OB18.

## 3 Humans

The human receptors considered in the conceptual exposure model (CEM) that were identified at the site and surrounds include:

- Nearby residents and visitors to the town of Newman and Aboriginal residents of Parnpajinya Community and traditional owners (Niyiyaparli people) and custodians (Martu people) of the land that:
- Consume drinking water sourced from the Newman Water Reserve<sup>5</sup> public drinking water source protection zones (Priority Areas 1 and 3) and associated borefields; and
- Undertake recreational activities in Ophthalmia Dam, OB31 Creek, Fortescue River, Jumblebar Creek, Ethel Gorge, or other nearby watercourses and waterbodies for wading, swimming, and fishing.

Drinking water (Newman town water supply) will not be considered further, as source water is treated by BHP and the Water Corporation to meet the Australian Drinking Water Guidelines (NHMRC and NRMCC 2011), as required by WA Health (BHP 2012). Incidental ingestion of creek water is considered in the CEM according to the recreational guidelines for managing risks in recreational water (NHMRC 2008).

Cultural heritage sites are listed in Appendix B for completeness, given their cultural and spiritual value and potential to be impacted by current and ongoing mining activities (refer to Section 3.1). With respect to Swan and De Grey IPTSFs, these sites may be affected where they are situated in the path of unmanaged releases. However, cultural heritage sites have not been explicitly considered in the CEM.

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<sup>4</sup> Priority species are still considered to be of conservation significance (i.e., they may be rare or threatened) but cannot be considered for listing under the Western Australian Wildlife Conservation Act 1950 (WC Act) until there is adequate understanding of threat levels imposed on them.

<sup>5</sup> Jumblebar mining activities are not located within the boundaries of the Newman Water Reserve, the area encompassing the borefields responsible for Newman’s public drinking water supply (DOW 2014); therefore, they have not been explicitly considered further in this CEM.

### 3.1 Cultural Heritage Sites

According to the Aboriginal Heritage Inquiry System database, which is maintained by the Department of Planning, Lands and Heritage (DPLH 2021), there are 18 registered Aboriginal sites and 19 other indigenous heritage sites within an approximate 5 km radius surrounding the proposed Swan and De Grey IPTSF pits. It is noted that there are no registered Aboriginal site within the IPTSF project area. Items or areas of significance that may be present within a 5 km radius of the proposed Swan and De Grey IPTSF include:

- Quarry
- Modified trees
- Artefacts/scatter
- Rock shelters
- Arch deposits
- Ceremonial man-made structures.

The crown lease for the OB17 and OB18 area falls within the boundary of Nyiyaparli Native Title Claim. BHP has a comprehensive agreement with the Nyiyaparli people, the objective of which is to minimise impacts, engage with the Nyiyaparli people, and provide an opportunity to influence the management of environmental issues (NNTT 2021). For example, recognition of the Innawally Pool (located on Jimblebar Creek) as having historical significance to the Nyiyaparli people.

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# Appendix B

Comparison of Environmental Data and  
Modelling Predictions to Adopted Screening  
Criteria





Table 82: Tailings Solids - Lowveld

Sample	Ag	Al	As	Ba	B	Bi	Ca	Co	Cu	Cr	Fe	Ga	Ge	Hf	In	K	La	Mn	Mg	Mo	Nb	Ni	P	Pb	Rb	S	Se	Si	Sr	Ta	Tb	Ti	Tl	V	W	Y	Zn	Zr		
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		
Sample 10001	11	46.35	49	222	6228	8.94	1222	408	2.40	21.3	41	12	46.4	11	48	1.41	1228	428	26.4	14	428	148	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	
Sample 10002	11	46.35	49	222	6228	8.94	1222	408	2.40	21.3	41	12	46.4	11	48	1.41	1228	428	26.4	14	428	148	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	428	1.48	1228	428

Notes:  
FCC values based on total chromium





Table B.3 – Comparison of Tailings Solids Data to Human Health (Recreational) Screening Criteria

Sample	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Be mg/kg	Bi mg/kg	Ca mg/kg	Cd mg/kg	Ce mg/kg	Co mg/kg	Cr mg/kg	Cs mg/kg	Cu mg/kg	Fe %	Ga mg/kg	Ge mg/kg	Hf mg/kg	In mg/kg	K %	La mg/kg	Li mg/kg	Mg %	Mn mg/kg	Mo mg/kg
NEPM HILa Recreational C			300		90			90		300	300		17000										19000	
US EPA Regional Screening Levels - Resident Soil Adjusted*	1560	31		60000										22								640		1560
Total Elemental Composition Results																								
Tailings Blend - SPS Average Tailings Blend	0.007	3.8	17.0	89	2.28	0.226	0.04	0.025	106	5.61	41.3	0.1	32	48.4	7.1	0.8	1.81	0.038	0.01	56.4	5.4	0.05	918	1.47
Tailings Blend - High P2	0.011	3.8	21.4	81	2.11	0.265	0.04	0.029	106	6.29	47.3	0.09	39	48.6	7.8	0.6	2	0.051	0.02	58.7	5.4	0.06	1185	1.64

Sample	Na %	Nb mg/kg	Ni mg/kg	P %	Pb mg/kg	Rb mg/kg	Re mg/kg	S %	Sb mg/kg	Se mg/kg	Sn mg/kg	Sr mg/kg	Ta mg/kg	Tc mg/kg	Th mg/kg	Ti %	Tl mg/kg	U mg/kg	V mg/kg	W mg/kg	Y mg/kg	Zn mg/kg	Zr mg/kg	
NEPM HILa Recreational C			1200		600						700											30000		
US EPA Regional Screening Levels - Resident Soil Adjusted*								124			188000	188000					3	64	1560					
Total Elemental Composition Results																								
Tailings Blend - SPS Average Tailings Blend	0.013	4.35	21	0.146	9.49	1.09	<0.0004	0.02	1	6.52	0.701	0.92	40.8	0.35	0.09	5.85	0.103	0.046	2.22	31.3	1.74	17.65	61.9	74.9
Tailings Blend - High P2	0.013	4.33	23.3	0.15	9.25	1.21	<0.0004	0.02	1	7.39	0.529	0.98	42.9	0.36	0.113	6.22	0.109	0.058	2.54	34.2	1.82	18.85	69.3	78.2

Notes:  
\* US EPA RSLs for Residential settings have been adjusted by a factor of 4 (to account for differences in soil ingestion rates) to be representative of recreational exposure.  
Criteria for Al and Fe have been converted to %



Table B.4 Comparison of Tailings Supernatant Water Data to Ecological Screening Criteria

Tailings Supernatant (Dissolved)

Sample ID	pH (1-5)	EC (1-5)	Redox Potential	Cl	SO <sub>4</sub>	F	OH Alkalinity	CO <sub>3</sub> Alkalinity	HCO <sub>3</sub> Alkalinity	Total Alkalinity	Ca	K	P	Mg	Na	Si	NH <sub>4</sub>	NO <sub>2</sub>	NO <sub>3</sub>	NO <sub>2</sub> -NO <sub>3</sub>	TKN As N	Total N as N	Total P as P	Reactive P as P				
	pH Units	µS/cm	mV		mg/L			mg/L CaCO <sub>3</sub>			mg/L						mg-NH <sub>4</sub> -L	mg-NO <sub>2</sub> -L	mg-NO <sub>3</sub> -L	mg-NO <sub>2</sub> -NO <sub>3</sub> -L								
Groundwater	BHP Shevkhana SSTV (Hydro Geoschem Group, 2023)	6.8-8.5	1200																									
Surface water	Dudhichar Groundwater SSTV (Goldex, 2015)	6.8-8.5	670-1800										0.05											0.05				
	Dudhichar Creek Surface water SSTV (BHP, 2018a)	6.8-9.0																										
	Dudhichar Dam Surface water SSTV (BHP, 2018a)																											
	ANZG (2018) Freshwater 95% instream DGV*	6.8-8.0																										
	ANZECC (2000) Default trigger values for Wetland	7-8.5												0.08									1.15	0.08				
SPS Average Tailings Blend	8.04	760	208	194	39	1	<-1	<-1	72	72	24	10	<-1	8	107	4.65	<-0.01	<-0.01	0.14	0.14	<-0.1	0.1	<-0.01	<-0.01				
High P2	8.03	772	210	215	40	1	<-1	<-1	66	66	25	10	<-1	8	105	5.31	<-0.01	<-0.01	0.09	0.09	0.1	0.2	<-0.01	<-0.01				
Sample ID	Ag	Al	As	B	Ba	Be	Bi	Cd	Cu	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Sb	Se	Sr	Tl	Tb	Te	Ti	V	W	Zn	Zr
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Groundwater	BHP Shevkhana SSTV (Hydro Geoschem Group, 2023)	0.00005	0.05	0.013*	0.37	0.029		0.001	0.006	0.0014	0.03	0.0006	1.9	0.001	0.074	0.059	0.011											0.054
Surface water	Dudhichar Groundwater SSTV (Goldex, 2015)							0.0002	0.001	0.01	0.1	0.0006	1.9	0.01	0.011	0.0024	0.001	0.011										0.001
	Dudhichar Creek Surface water SSTV (BHP, 2018a)																											
	Dudhichar Dam Surface water SSTV (BHP, 2018a)																											
	ANZG (2018) Freshwater 95% instream DGV*	0.0005	0.05*	0.013	0.94			0.0002		0.001*		0.0014		0.0006	1.9		0.011	0.0014	0.009	0.011		0.0001				0.0005	0.006	0.008
	ANZECC (2000) Default trigger values for Wetland	<0.0001	<0.005	<0.0002	0.05	0.0007	<0.0001	<0.00005	<0.00005	<0.0001	<0.0002	<0.00004	<0.0005	0.0007	<0.0005	<0.0001	<0.0002	0.0009	0.15	0.00001	<0.0001	<0.0002	0.00007	<0.0002	<0.001	0.002	<0.005	
SPS Average Tailings Blend	<0.0001	<0.005	0.0003	0.054	0.0017	<0.0001	<0.00005	<0.00005	<0.0001	<0.0002	0.00045	<0.002	<0.00004	<0.0005	0.0007	0.0006	0.0002	<0.0002	0.001	0.152	0.00004	<0.0001	<0.0002	0.00008	<0.0002	<0.001	0.015	<0.005
High P2	<0.0001	<0.005	0.0003	0.054	0.0017	<0.0001	<0.00005	<0.00005	<0.0001	<0.0002	0.00045	<0.002	<0.00004	<0.0005	0.0007	0.0006	0.0002	<0.0002	0.001	0.152	0.00004	<0.0001	<0.0002	0.00008	<0.0002	<0.001	0.015	<0.005

\*NO<sub>2</sub> value from ANZECC and ANMACANZ (2000) was erroneous (ANZG, 2018). Therefore has not been adopted in this screening assessment.



Table B.5 - Comparison of Tailings Supernatant Water to Livestock Screening Criteria

Tailings Supernatant (Total)

Sample	pH (1-5)	EC (1-5)	Redox Potential	Cl	SO <sub>4</sub>	F	OH Alkalinity	CO <sub>3</sub> Alkalinity	HCO <sub>3</sub> Alkalinity	Total Alkalinity	Ca	K	P	Mg	Na	NO <sub>3</sub> as N	NO <sub>2</sub> as N	NO <sub>3</sub> as N	TKN as N	Total N as N	Total P as P	Reactivity						
		µS/cm	mV	mg/L	mg/L		mg/L CaCO <sub>3</sub>				mg/L		mg/L															
ANZECC 2000 Livestock Drinking Water Trigger Value (low risk)					1000	2					1000						9.1	92										
SPS Average Tailings Blend											27	10	-1	6	97													
High P2											28	10	-1	6	97													
Sample	As	Al	Ac	B	Ba	Bb	Bc	Cl	Cc	Co	Cr	Fe	Hg	Mn	Mo	Ni	Pb	Sb	Se	Sr	Tl	Tb	Sr	U	V	W	Zn	Zr
ANZECC 2000 Livestock Drinking Water Trigger Value (low risk)		5	0.5	5				0.01	1	1	0.4	0.002		0.15	1	0.1		0.02						0.2			20	
SPS Average Tailings Blend	-0.0001	0.007	0.0008	0.05	0.0003	0.001	0.00014	0.00056	0.0002	-0.0002	0.001	-0.002	-0.00004	0.0006	0.0005	-0.0005	0.0006	0.0006	0.0005	0.154	0.00033	0.0002	-0.0002	0.00033	-0.0002	-0.0001	0.003	-0.005
High P2	-0.0001	0.008	0.0004	0.054	0.0072	-0.0001	-0.00005	-0.00005	-0.0001	-0.0002	0.0055	0.003	-0.00004	-0.0005	0.0005	0.0005	0.0004	-0.0002	0.0006	0.153	0.00002	-0.0001	-0.0002	0.00013	-0.0002	-0.0001	0.016	-0.005

A - Al value based on pH=6.5  
B - As value based on As<sup>3+</sup> criteria  
C - Cr value based on Cr<sup>6+</sup> criteria



Table B.6 Comparison of Tailings Supernatant Water Data to Human Health Screening Criteria

Tailings Supernatant (Total)		pH (1-5)	EC (±5)	Revised Potential	Cl	SO <sub>4</sub>	F	OH Alkalinity	CO <sub>3</sub> Alkalinity	HCO <sub>3</sub> Alkalinity	Total Alkalinity	Ca	K	P	Mg	Na	NH <sub>3</sub>	NO <sub>2</sub>	NO <sub>3</sub>	NO <sub>2</sub> -NO <sub>3</sub> as N	TKN as N	Total N as N	Total P as P	Reactive P as P								
Sample ID		pH Units	uS/cm	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L								
Drinking Water	ADWG Health (2011, updated 2022)						1.5																									
	ADWG Aesthetics (2011, updated 2022)	6.5-8.5			250	250										180	0.5															
Recreation	ADWG Health (2011, updated 2022) x 10 for inorganics	6.5-8.5			250	250	15									180	0.5	30	500													
	SPS Average Tailings Blend											27	10	<1	8	97																
	High P2											26	10	<1	9	97																
Sample ID		Ag	Al	As	B	Be	Ba	Bi	Cd	Cr	Cu	Cu	Cr	Cr	Fe	Hg	Mn	Mn	Ni	Pb	Sb	Se	Sr	Tl	Tb	Sc	U	V	W	Zn	Zr	
Drinking Water	ADWG Health (2011, updated 2022)	0.1			4	2	0.06		0.002		0.05 <sup>A</sup>	2			0.001	0.5	0.05	0.02	0.01	0.003	0.01											
	ADWG Aesthetics (2011, updated 2022)	1			40	20	0.6		0.02		0.5	20	0.3	0.01	5	0.2	0.1	0.03	0.1													
Recreation	ADWG Health (2011, updated 2022) x 10 for inorganics			0.1	40	20	0.6		0.02		0.5	20	0.3	0.01	5	0.2	0.1	0.03	0.1													
	SPS Average Tailings Blend	<0.0001	0.007	0.0008	0.05	0.0803	0.001	0.00014	0.00056	0.0002	<0.0002	0.001	<0.002	<0.00004	0.0006	0.0005	<0.0005	0.0006	0.0005	0.154	0.00033	0.0002	<0.0002	0.00033	<0.0002	0.00013	<0.0002	<0.001	0.003	<0.005		
	High P2	<0.0001	0.008	0.0004	0.054	0.0872	<0.0001	<0.00005	<0.00005	<0.0001	<0.0002	0.0058	0.003	<0.00004	<0.0005	0.0005	0.0005	0.0004	<0.0002	0.0006	0.153	0.00006	<0.0001	<0.0002	0.00013	<0.0002	<0.001	0.016	<0.005			

A = Al value based on pH<6.5  
B = As value based on As<5- criteria  
C = Cr value based on Cr<6+ criteria









Table B.10 - Comparison of Downstream Water Quality Modeled Data to Screening Criteria

Table with columns for Parameter, Unit, pH, Fe, TDS, Alkalinity, Ca, Mg, K, Na, Cl, SO4, Al, Sb, As, B, Br, Cu, Cr, Co, Ni, Pb, Mn, Mo, Total Nitrogen, N, P, Se, Si, Sr, Tl, U, V, Zn. Rows include Shreemata SSTV (BOD5, 2023), Shreemata SSTV (NH4-N, 2023), Working water guidelines health (ADWA, 2017), NCCS - Base Soapage, NCCS - High Soapage, and CCS - Base Soapage. Each row contains multiple data points for various parameters and conditions like Initial Condition, First Filling Soapage, and Sanitized Soapage.

A - TDS SSTV is calculated. EC is converted to TDS using an approximate conversion factor of 0.67  
B - Alkalinity concentrations are listed but are not significant, being less than 1% of the guideline value (based on potential scaling of pipes)  
C - As values based on pH=6.5  
D - As values based on As<sup>5+</sup> criteria  
E - Cr values based on Cr<sup>6+</sup> criteria  
F - Mn value from ANZECC and ARMCANZ (2000) was erroneous (ANZU, 2014). Therefore, this value has not been adopted in this screening assessment.  
G - SON TV based on 90th Percentile from monitoring data from O&M

# Appendix C

## Hazard Quotient Calculations















# Appendix D

Operations – Risk Assessment





Risk Event				Risk Assessment				
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Proposed Controls/ Mitigation Strategies	Consequence	Likelihood	Risk Rating	Rationale and Recommendations
Deposition of tailings slurry in Swan / De Grey IPTSF Dry waste fines (Air quality)	Fugitive dust generated from TSP washdown	Native terrestrial flora	Reduction in photosynthesis, respiration, and transpiration due to dust deposition	<ul style="list-style-type: none"> <li>Engineering and management controls (e.g. vegetation windbreaks, dust suppression, as required)</li> <li>Waste fines surface is below the pit crest, reducing resuspension, wind exposure, and dust generation</li> <li>Air quality and dust deposition monitoring will be undertaken</li> </ul>	Slight	Possible	Low	<p>The risk to native terrestrial flora from airborne fugitive dust is considered low. In general, dust associated with iron ore mining (i.e., dust generated from mining activities in totality and not necessarily considering the dust generated from tailings alone) in the Pilbara is generally chemically inert (Bauer 2009, Turner 2013). Effects on vegetation tend to be physical (e.g., dust loading/blocking stomata of leaves and interfering with photosynthetic processes and transpiration loss) (Gleeson 2015).</p> <p>Long-term studies of vegetation in other iron ore mining areas surrounding areas have demonstrated the resilience of vegetation to dust exposure (Onshore Environmental, 2017). Additionally, monitored dust levels on vegetation at another iron ore related site in the Pilbara was not noted to cause significant stress or death to the vegetation monitored (Woodman Environmental, 2017). This is in part attributed to the fact that plant growth in arid environments is typically limited by rainfall with the growth period confined to the wet season when dust generation and loading are at their least and rainfall has dampened the landscape and washed leaves free of dust. Dust control measures will be implemented at various stages of tailings deposition and upon completion, surface dust levels are expected to be comparable to those from surrounding landforms.</p>
		Nearby residents, traditional owners, and/or farmers. Recreational users of Ophthimia Dam (limited exposure) <sup>2</sup>	Acute and chronic adverse health effects and amenity.		Minor	Rare	Low	<p>Despite ongoing deposition of iron waste fines slurry, tailings beaches have the potential to dry out. If left undisturbed, these types of surfaces tend to form crusts and hence, their susceptibility to wind erosion is low. If the surfaces are frequently disturbed, or the materials do not form a physical crust, then these tailings beaches can be subject to wind erosion and long-term deflation. Fugitive particulate matter or dust generated by wind from crustal sources are generally found in the &lt;10 µm diameter range (PM10) and require a threshold wind speed velocity in the range of 5-10 m/s to become dislodged and airborne. Long-term wind erosion potential of tailing storage has been identified as very low to negligible, and the magnitude of emissions is lower than emissions from other local and regional sources (McNaughton, et al. 2024). Additionally, the surface area available for dust generation of the tailings beaches is a small proportion of the local area.</p> <p>Initially, in-filling of Swan and De Grey with tailings has very low potential to produce wind-blown fugitive dust. There is an approximate 50% reduction of coarse dust (PM10) emissions from these types of sources due to "in-pit retention". Tailings will be deposited to within the minimum allowable freeboard limits (WSP, 2024b). Therefore, near the end of the Swan and De Grey fill, there is the potential for tailings fines to be subject to greater wind erosion. These emissions are episodic and may become more frequent near the end-of-life for Swan and De Grey. These emissions can be reduced by implementing engineering and management controls (e.g. wind speed reduction via vegetation wind breaks, surface stabilisation, dust suppression). The effectiveness of the dust emissions controls will be assessed using ambient air quality and dust deposition monitoring.</p> <p>Placement of tailings slurry in the IPTSF has the potential to generate dust, some of which - depending on its grain size and quantity - may potentially reach the town of Newman (25 km west), and the Aboriginal communities of Pampajima or Ngilpin, located approximately 23 km west and 60 km east of the IPTSF, respectively. Coarse dust (PM10) generated from mining activities typically settles within 10% to 50% of metres from the source. Iron ore tailings also generates fine dust (PM10) however, the proportion of generated PM10 is likely to be low, i.e., much lower than dust PM10. The potential exists for the dust to contain a proportion of crystalline silica, however, the dust needs to be within the respirable size range (PM10) in significant proportions to exert noticeable adverse effects. It is generally understood that airborne particulate matter from crustal sources is less hazardous than that from combustion sources. Fine dust (PM10) has the potential to travel 100's of metres to a few kilometres. Given that nearest communities are located further than 20 km from the IPTSF and they reside in a mining district, potential exposure to dust is a cumulative effects issue, rather than a risk attributed exclusively to the use of Swan and De Grey as IPTSF. If necessary, potential exposure of residents or sensitive environmental receptors to dust generated from the Swan / De Grey IPTSF, and/or other sources, can be assessed through air quality monitoring and modeling.</p> <p>Overall, based on the rare potential for inhalation exposure (required for health effects) and therefore minor outcomes, this pathway is assigned a low risk rating.</p>
Failure of delivery pipeline carrying tailings slurry to Swan, De Grey IPTSF (Soil, groundwater, and surface water)	Direct discharge of tailings slurry to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline including riparian vegetation communities	Reduced oak and/or groundcover quality resulting in localised short-term decline in floristic health	<ul style="list-style-type: none"> <li>Pipelines are specifically engineered for the material (i.e., tailings) being transported</li> <li>Use of pipeline containment bunds</li> <li>Regular (i.e., daily) visual inspections of pipelines</li> </ul>	Slight	Unlikely	Low	<p>The risk to receptors from failure of the delivery pipeline ranges is ranked as low. Firstly, the proposed controls and mitigation strategies are expected to minimise the release of tailing slurry in the unlikely event of delivery pipeline failure. The system will be equipped with flow and pressure sensors and a time variable set point is included in the control system, with the intent to initiate a shut-down as quickly as practical. This will effectively minimise the release of tailings slurry to the ground surface, and together with the containment bunds, will limit the distance that tailings slurry is able to travel as overland flow. Any impacts from direct discharge of tailings slurry to the ground surface are expected to be localised, with the option of removing and discarding contaminated soil, if deemed necessary.</p> <p>Groundwater in the vicinity of the Swan and De Grey area has been significantly drawn down to permit mining operations. Swan and OB31 have a hydraulic connection, therefore impacts to groundwater quality in the vicinity of Swan have the potential to impact the broader regional aquifer.</p>
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems		Minor	Rare	Low	<p>The delivery pipeline route is expected to travel northwest from the proposed new beneficiation plant to the Swan / De Grey IPTSF locations along a bounded corridor (Figure 1.2).</p>
		Aquatic ecosystems <sup>3</sup>	Adverse impacts to surface water quality and associated ecosystems	<ul style="list-style-type: none"> <li>Pipeline integrity</li> <li>Periodic pipeline wear assessments</li> <li>Flow and pressure monitoring of pipelines for leaks</li> </ul>	Minor	Rare	Low	<p>To understand the consequence resulting from exposure of identified receptors to the tailings slurry (solids and supernatant water), the tailings slurry was screened against adopted assessment criteria (Section Error! Reference source not found.1. Firstly, tailings slurry was below adopted trigger criteria for human health (recreational) and livestock exposure scenarios. Additionally, the likely realistic exposure situations for humans and livestock would be much less frequent and for shorter durations than the scenarios assumed in the screening criteria therefore, the slurry is considered to present a low to negligible risk to these human and livestock receptors.</p>
		Native terrestrial fauna <sup>4</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna		Minor	Rare	Low	<p>The tailings solids material and the tailings supernatant water reported concentrations of PSDI predominantly below the adopted ecological screening levels. Low level exceedances of screening criteria were identified in tailing solids, groundwater, and surface (refer to HQ presented in Section 5.5). As discussed in the report, an exceedance of screening criteria doesn't mean an adverse effect but triggers investigation. In regard to native terrestrial flora the following have been considered in assigning a low risk rating:</p> <ul style="list-style-type: none"> <li>Surface water screening criteria apply to aquatic ecosystems not terrestrial</li> <li>Adopted tailings solids screening criteria are for long term exposure not acute short term scenarios such as a pipe failure</li> <li>The proposed management and controls splits from a pipe failure will be localised</li> <li>The likelihood of a failure is unlikely.</li> </ul>
Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low			
Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and downstream receiving waters				Slight	Rare	Low	<p>In regard to aquatic ecosystems, and other receptors drinking or having direct contact with surface waters, the following factors were considered in the event that OB31 Creek, as the nearest surface water receptor, is impacted due to a delivery pipeline failure:</p> <ul style="list-style-type: none"> <li>At its closest point, the pipeline corridor is located within approximately 3.8 km of OB31 Creek</li> <li>The proposed new beneficiation plant will be located within approximately 4.7 km of OB31 Creek</li> <li>At its closest point, Swan/De Grey is located within approximately 400 m of OB31 Creek</li> <li>The close proximity of small tributaries of OB31 Creek to the pipeline corridor (Figure 1.2), which have the potential to direct/channel the flow of tailings slurry to OB31 Creek.</li> </ul> <p>However, given the proposed management controls outlined above, the likelihood of tailings slurry material reaching OB31 Creek in the event of a pipeline failure is considered rare. OB31 Creek, an east flowing tributary of Amblabar Creek, is an ephemeral waterway, experiencing only occasional short-lived flows in response to rainfall (RPS, 2013). As such, the presence of aquatic receptors (which are naturally adapted to completing their life cycle when water is present) and use of the watercourse by terrestrial fauna would be confined to a relatively short period of time during the year. This would limit receptor exposure to contamination in the event of a pipeline failure. Should a delivery pipeline failure occur, provided there is limited to minimal to no residual contamination in the creek bed after clean up, adverse effects for aquatic receptors are likely to be limited to one season, with any legacy contaminants likely to be dispersed downstream by the next high rainfall event. Therefore, the risk to receptors associated with OB31 creek are considered low.</p>



Risk Event				Risk Assessment							
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Proposed Controls/ Mitigation Strategies	Consequence	Likelihood	Risk Rating	Rationale and Recommendations			
Decanting supernatant water from tailings in Swan, De Grey IPTSF Failure of decant water pipeline carrying supernatant water to process water pond (Soil, groundwater, and surface water)	Direct discharge of supernatant water to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	Soil and/or groundwater contamination resulting in localised, short-term decline in floristic health	— Pipelines are specifically engineered for the material (i.e., supernatant water) being transported	Slight	Possible	Low	Supernatant water, unlike tailings slurry, is a less viscous liquid, which, in the event of a decant pipe failure, may travel greater distances as overland flow if unimpeded and/or unmonitored. However, proposed controls and management of the decant pipeline (including bunding and flow/pressure monitoring) will reduce the risk of excess release.			
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	— Use of pipeline containment bunds	Minor	Rare	Low	Supernatant water will be piped back to the beneficiation plant for reuse in processing. However, excess decant water will need to be stored in a process water pond, the location of which is yet to be confirmed.			
		Expression of contaminated groundwater to surface water and subsequent migration further down gradient; overland flows to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Shoebanna Creek	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	— Flow and pressure monitoring of pipelines for leaks	Minor	Rare	Low	Geochemical modelling results indicate that a majority of the PSDI in ponded water from Swan / De Grey IPTSF will be at concentrations below the adopted ecological screening levels for surface waters and groundwater (refer to HQ presented in Section 5.5.3). Some low level exceedances of metals were identified in the surface water (Copper and Zinc) and groundwater (Barium and Copper) were identified during the screening process. Barium was the only PSDI with HQ greater than 5, resulting in a consequence rating of minor. Additionally, there is a lack of evidence that a pipeline spill will result in direct contact of ecological receptors in surface waters and groundwater. So there are several factors to consider in terms of likelihood.		
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna	Minor	Rare	Low	— the likelihood of a decant pipe failure	— the supernatant water from a spill reaching surrounding creeks or watercourses	— the short period that the supernatant water will be released in the event of a decant pipe failure	— the exposure durations of ecosystems within impacted surface water areas (which are expected to be limited and low)	As the location of the process water ponds is unconfined, there is uncertainty in the assessment of likelihood that supernatant water will reach the surrounding creeks (OB31 Creek) or other nearby watercourses in the event of a decant pipeline failure.
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low	The concentrations of PSDIs in the ponded water from the IPTSFs were all below adopted screening levels for livestock, indicating the limited potential for direct impacts to livestock (cattle). Additionally, livestock direct exposure (ingestion) to supernatant water as a result of a pipeline spill is deemed to be rare. Pipeline spill water pooling in surface water systems is likely to be for a short period and dilution of the PSDIs from the ponded water would occur once it reached groundwater which may be used for consumption. Therefore, the risk to livestock from the failure of the decant water pipeline is considered low.				
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and associated creeks	Minor	Rare	Low	The concentrations of PSDIs in the ponded water from the IPTSFs were below the screening levels for human health (recreational exposure and drinking water). In terms of likelihood for humans, exposure may occur where a pipeline spill was to result in water pooling in surface water systems or where it migrates into groundwater and is captured by a groundwater bore used for drinking water. Ponded water pooling in surface water systems is likely to be for a short period and therefore, not going to expose people undertaking recreational activities (such as swimming, wading and fishing) in the water is considered unlikely. It is likely that some dilution of the PSDIs from the ponded water would occur once it reached groundwater and this would further reduce the risks posed to human health from drinking water. Therefore, the risk to human health (recreational exposure and drinking water) from the failure of the decant water pipeline is considered low.				
Deposition of tailings slurry in Swan / De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Groundwater and surface water)	Seepage of IPTSF waters through base and/or pit walls to groundwater	Native terrestrial flora including riparian vegetation communities	Localised, short-term decline in floristic health due to raised water tables, uptake of contaminated shallow groundwater or surface water, and/or increased salts in surface soils due to evapo-concentration	— Groundwater and surface water quality and quantity (water level, flow) monitoring	Minor	Unlikely	Medium	Downstream water quality modelling has been conducted to assess water quality parameters at OB31 during operational periods which consider a mixture of pond seepage and natural groundwater in the proportions indicated by the groundwater modelling, as a time series (monthly basis). Screening results of the downstream water quality predictions indicate TDS and Barium exceed the screening criteria (See Section 5.4.4). Of the exceedances, one scenario detailing high seepage scenario during sustained seepage (late stages of the operational period) resulted in a HQ > 5. In summary, downstream water quality (upon entry into the groundwater system) may have concentrations of PSDI with some exceedances of the adopted screening levels.			
		Surface expressions of seepage is unlikely, as the relative permeability between hydrogeological units is more likely to promote flows towards the deep aquifer rather than towards the surface.	Groundwater modelling (WSP 2023a) provided insights into the risk of groundwater level rise during IPTSF operations. While Swan Pit shows higher seepage rates than De Grey Pit, groundwater levels are predicted to remain below the Swan Pit floor due to ongoing dewatering at OB31. Furthermore, the majority of seepage of IPTSF waters from Swan during operations is expected to be captured by the OB31 dewatering system (WSP, 2022b). In contrast, the De Grey Pit, which is not hydraulically connected to OB31, revealed localised effects of groundwater mounding. This is due to the pit being bounded by the lower permeability Mount McRae Shale and Mt Sylvia Formations, and due to the preferential hydraulic barrier (pale) between Swan and De Grey. The model predicts that groundwater mound will not be high enough to result in seepage to ground surface.								
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and quantity and associated effects to aquatic ecosystems and the hydro cycle	Minor	Rare	Low	There is a potential pathway of exposure for surface water aquatic ecosystems, native terrestrial flora (including riparian vegetation communities) and fauna, livestock and humans (recreational users and drinking water) to groundwater impacted by seepage from the IPTSFs through the OB31 dewatering system, and the disposal of surplus water from this system to the receiving environment (including Ophthalma Dam). Downstream water quality modelling has been conducted to assess water quality parameters at OB31 during operational periods which consider a mixture of pond seepage and natural groundwater in the proportions indicated by the groundwater modelling, as a time series (monthly basis). Screening results of the downstream water quality predictions indicate TDS and Barium exceed the screening criteria (See Section 5.4.4). Of the exceedances, one scenario detailing high seepage scenario during sustained seepage (late stages of the operational period) resulted in a HQ > 5. In summary, downstream water quality (upon entry into the groundwater system) after closure may have concentrations of PSDI with some exceedances of the adopted screening levels.				
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source	Minor	Rare	Low	It is assumed that seepage water collected by the OB31 dewatering system will be managed as part of BHP's overall water management system and re-used or disposed. Seepage affected groundwater must meet applicable water quality guidelines and licence discharge criteria (e.g., SSTVs) prior to being discharged to the receiving environment (including Ophthalma Dam). Based on the potential exceedance of adopted screening criteria (including the SSTVs) for aquatic environments, livestock and human drink water at the OB31 dewatering system may require treatment prior to re-use or disposal.				
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low	Without treatment prior to disposal to receiving environments (including Ophthalma Dam), the concentrations of PSDIs in groundwater impacted by seepage at the OB31 dewatering system present a medium risk to surface water aquatic ecosystems and native terrestrial flora (including riparian vegetation communities) and fauna.				
		Recreational users	Adverse impacts to human health from recreational use of OB31 Creek and other nearby watercourses and waterbodies	Slight	Rare	Low	For livestock and drinking water, it is assumed that water in Ophthalma Dam would be required to seep into the underlying groundwater and then migrate to an abstraction bore from this system used for livestock feeding or drinking water. It is likely that some further dilution of the PSDIs would occur during migration in groundwater and this would reduce the risks posed to human health from drinking water or livestock. In addition, it is acknowledged that drinking water (Newman town water supply) source water is treated by BHP and the Water Corporation to meet the Australian Drinking Water Guidelines (NHMRC and NHMRC 2011), as required by WA Health (BHP 2012). Therefore, there is likely an complete pathway for exposure of humans via drinking water that has indirectly been affected by water sourced from the OB31 dewatering system. Therefore, the concentrations of PSDIs in groundwater impacted by seepage at the OB31 dewatering system present a low risk to livestock and drinking water.				
Drinking water	Adverse health impacts resulting from ingestion of contaminated drinking water source	Slight	Rare	Low	Based on the available information, a medium risk ranking is warranted for aquatic ecosystems. A low risk rating is assigned to native terrestrial flora and fauna, and a low risk to livestock, and recreational users of creeks and the groundwater receiving waters such as Ophthalma Dam from seepage losses.						





Risk Event				Risk Assessment				
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Proposed Controls/ Mitigation Strategies	Consequence	Likelihood	Risk Rating	Rationale and Recommendations
Deposition of tailings slurry Swan / De Grey IPTSF Pit overtopping (Soil, groundwater, and surface water)	Flow of superatant water over the pit <sup>1</sup>	Native terrestrial flora including riparian vegetation communities	Potential soil erosion and physical damage to vegetation from overland flow and/or flooding	<ul style="list-style-type: none"> <li>Engineering assessment of factor balance and capacity to contain significant flood events</li> <li>Contingency freeboard within relevant regulatory (i.e., DMIRS and ANCCOLD) guidelines</li> </ul>	Minor	Rare	Low	<p>As detailed in the water balance model (WSP, 2023b), De Grey and Swan in-pit IPTSFs are located on Shovelanna Hill; therefore, flood risks from extreme storm events for these pits are minimal as they are not adjacent to any major watercourses. The reporting catchments are relatively small and would not cause excessive runoff inflow volumes during extreme storm events. Critical surface water management structures (i.e., diversions such as channels, dikes, and/or bunds) are not planned under future flood management strategies for these oerbodies.</p> <p>In addition:</p> <ul style="list-style-type: none"> <li>the final tailings elevation of the in-pit TSP is such that the 1 in 1,000 AEP, 72-hour extreme storm event can be stored which complies with Global Industry Standard on Tailings Management (GISTM) requirements for a consequence category of 'Significant' and aligns with BHP's key risk indicators (KRIs) for TSPs; and</li> <li>the contingency freeboard on top of the extreme storm event is the largest vertical distance of either 0.5 m above the stored event according to DMIRS requirements, or an additional 0.3 m plus freeboard for 1 in 10 AEP wind according to ANCCOLD requirements.</li> </ul> <p>The most likely cause of a pit overtopping is an extreme storm event (and if there is overtopping of the diversion drains), beyond what the Swan / De Grey IPTSF have been designed for. Overtopping above the stored 1 in 1,000 AEP, 72-hour event may occur if another event occurs right after; however, the likelihood of consecutive independent events is extremely rare. In the rare event that the containment area overtops, the escaping superatant water is likely to be diluted by heavy rainfall and thus, the risk to potential receptors from water quality and quantity in the receiving environment is considered low.</p>
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems		Minor	Rare	Low	
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems		Minor	Rare	Low	
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low	
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low	
		Recreational users	Adverse impacts to human health from recreational use of Ophthamia Dam, or other nearby watercourses		Minor	Rare	Low	
Deposition of tailings slurry in Swan and De Grey IPTSF Consolidation of tailings slurry and resulting superatant water Waste fines and superatant water inside Swan and De Grey IPTSF containment	Entry to TSP containment and subsequent direct contact with or ingestion of waste fines and/or superatant water	Native terrestrial fauna <sup>3</sup>	Acute or chronic effects on health Entrapment in soft fines	<ul style="list-style-type: none"> <li>Exclusion bunding around pit to discharge access</li> <li>Routine surveillance program, including daily fauna checks</li> </ul>	Minor	Possible	Medium	<p>To gauge the consequence to ecological receptors if exposed to tailings solids, the tailings solids data were screened against available assessment criteria (Section 5.5). Concentrations of manganese and antimony concentrations had minor exceedances of the adopted ecological tailings screening values which triggered further investigation as to the likelihood of direct contact by terrestrial fauna.</p> <p>In terms of the consequent ecological receptors from exposure to superatant water, modelling predictions for the in-pit ponded water were screened against available assessment criteria (Section 5.5). Low level exceedances of copper and zinc were identified. This triggered further investigation as to the likelihood of direct contact to the surface water by terrestrial fauna.</p> <p>Note that the screening criteria for both tailings solid and superatant water apply to more of a chronic exposure scenario, rather than an sporadic or intermittent exposures for short durations. The logic therefore leads to a minor consequence.</p> <p>In addition, there may be potential for direct or indirect effects from nutrients, such as harmful algal blooms (HAB) based on the nitrogen concentrations.</p> <p>In terms of likelihood of direct contact to tailings solid and superatant water, the presence of a superatant pond with beaches of tailings solids, may attract terrestrial fauna, particularly birds. However, the presence of moving plant and equipment in and around the TSP may deter some wildlife. Furthermore, the presence of nearby water storage dams which fauna may favour rather than accessing the superatant pond.</p> <p>Regardless of the minor consequence, due to the unknown potential exposure, a likelihood rank of possible is applied which derives a medium risk to native terrestrial fauna from entry to TSP containment and a subsequent direct contact with or ingestion of waste fines and/or superatant water.</p> <p>WSP anticipates that BHP will manage the potential risks to the environment from the rare event of a pit wall collapse through implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure). As a result, the risk to aquatic ecosystems and native terrestrial flora and fauna is assessed to be low on the assumption that minor consequences are only expected under exceptional circumstances.</p> <p>WSP anticipates that BHP will manage the potential risks to the environment from the rare event of a pit wall collapse through implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure). As a result, the risk to aquatic ecosystems and native terrestrial flora and fauna is assessed to be low on the assumption that minor consequences are only expected under exceptional circumstances.</p>
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems Destruction of habitat		Minor	Rare	Low	
Deposition of tailings slurry in Swan and De Grey IPTSF Collapse of pit wall (Sloppy)	Overland flow of debris and subsequent displacement of tailings and subsequent overland flow to downgradient receiving environments following pit wall collapse	Native terrestrial flora and fauna <sup>3</sup>	Smothering and/or entrapment of receptors Destruction of habitat	<ul style="list-style-type: none"> <li>Implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure)</li> </ul>	Minor	Rare	Low	
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems Destruction of habitat		Minor	Rare	Low	

Notes:  
1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pumpajinya and Agiling Communities.  
2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.  
3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.  
4) Pit overtopping may occur as a result of an extreme storm event, collapse of pit wall (if a superatant pond is present in the TSP), or human failure.  
5) Ophthamia Dam is currently subject to limited recreational use which prohibits entry and activities associated with contact of the dam waters (BHP and East Pilbara Share 2021).  
AEP = annual exceedance probability; DMIRS = Department of Mines, Industry Regulation and Safety; ANCCOLD = Australian National Committee on Large Dams.

# Appendix E

Closure – Risk Assessment





Risk Event				Risk Assessment				
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Proposed Controls/ Mitigation Strategies	Closure Strategy - Partial Backfill			Rationale and Recommendations
					Consequence	Likelihood	Risk Rating	
Post Deposition of tailings slurry in Swan / De Grey IPTSF Dry waste fines (Air quality)	Fugitive dust generated from TSF landform	Native terrestrial flora	Reduction in photosynthesis, respiration, and transpiration due to dust deposition	<ul style="list-style-type: none"> <li>Engineering and management controls</li> <li>Waste fines surface is below the pit crest, reducing evaporation, wind exposure, and dust generation</li> <li>Air quality (i.e., dust) monitoring will be undertaken</li> <li>Proposed closure strategy create separation barrier to source</li> </ul>	Slight	Rare	Low	The risk to native terrestrial flora from airborne fugitive dust is considered low. In general, dust associated with iron ore mining (i.e., dust generated from mining activities in totality and not necessarily considering the dust generated from tailings alone) in the Pilbara is generally chemically inert (Butler 2009, Turner 2013). Effects on vegetation tend to be physical (e.g., dust loading blocking stomata of leaves and interfering with photosynthetic processes and transpiration loss) (Kierssen 2015). Long-term studies of vegetation in other iron ore mining areas in surrounding areas have demonstrated the resilience of vegetation to dust exposure (Onshore Environmental 2017). This is in part attributed to the fact that plant growth in arid environments is typically limited by rainfall with the growth period confined to the wet season when dust generation and loading are at their least and rainfall has dampened the landscape and washed leaves free of dust.
		Recreational users, nearby residents', traditional owners, and/or farmers	Acute and chronic effects on human respiratory system and general health and amenity	<ul style="list-style-type: none"> <li>Pipelines are specifically engineered for the material (i.e., supernatant water) being transported</li> <li>Use of pipeline containment bunds</li> <li>Flow and pressure monitoring of pipelines for leaks</li> <li>Proposed closure strategy decommission pipeline infrastructure therefore removing potential source/pathway</li> </ul>	Minor	Rare	Low	The partial backfill strategy option incorporates a cover layer with revegetation, which is considered to minimise dust generation. However, revegetation can only commence post the tailings consolidation period. During tailings consolidation (approximately 20 years post-2051), the dust generation potential would be similar to the operational period. These emissions can be reduced by implementing engineering and management controls. The effectiveness of the dust emission controls can be assessed using ambient air quality and dust deposition monitoring. In addition, progressive remediation of the tailings surface, as consolidation allows, will reduce the area of tailings exposed and unvegetated overtime, further reducing the risk of dust. Overall, this pathway is assigned a low risk rating based on the final revegetated landform and the management of dust prior to revegetation being completed.
	Direct discharge of supernatant water to land and seepage to groundwater	Native terrestrial flora within the vicinity of the pipeline	Soil and/or groundwater contamination resulting in localised, short-term decline in floristic health	<ul style="list-style-type: none"> <li>Pipelines are specifically engineered for the material (i.e., supernatant water) being transported</li> <li>Use of pipeline containment bunds</li> <li>Flow and pressure monitoring of pipelines for leaks</li> <li>Proposed closure strategy decommission pipeline infrastructure therefore removing potential source/pathway</li> </ul>	Minor	Rare	Low	The decant system will likely be decommissioned post-operations. The risk of overtopping is reduced at closure and therefore, it is unlikely that the pond will need to be maintained (i.e., regularly decanted/pumped down) to keep it within a defined operating range. Furthermore, the closure design assumes that no permanent pond will exist however intermittent ponding from rain events may occur. Mitigation for reducing runoff volumes from the pit (thereby keeping any ponding volumes as low as reasonably practicable) includes constructing upstream diversions to direct runoff elsewhere downstream. However, noting the above, there is still the potential that at some stage during closure there will be a need to decant water from ponds within the pits and therefore, this exposure pathway has been retained in the Closure CEM. Decanting at closure will be at a significantly reduced rate to that of operations. Therefore, the risk of a pipe carrying decanting water is reduced at closure because water will be decanted at a significantly reduced frequency.
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems	<ul style="list-style-type: none"> <li>The water quality of ponds for Partial backfill closure has not been modelled. In the absence of predicted water quality modelling for Partial Backfill Closure, it has been assumed that the water quality of the ponds will have no concentrations greater than the modelling results from the Operations water quality. Given the discussion above on the reduced frequency of decanting, the likelihood of exposure has been assessed as rare, resulting in a risk rating of low. However further studies are recommended to increase the understanding of the geochemical conditions and influence to the regional hydrogeology at closure.</li> </ul>	Minor	Rare	Low	
	Expression of contaminated groundwater to surface water and subsequent migration further downstream, overland flow to surrounding creeks (OB31 Creek and other tributaries) and downstream receiving waters including Shovelanna Creek	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems		Minor	Rare	Low	
		Native terrestrial fauna <sup>1</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source by fauna		Minor	Rare	Low	
Livestock (cattle)		Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low		
Recreational users		Adverse impacts to human health from recreational use of OB31 Creek and associated creeks		Slight	Rare	Low		
Deposition of tailings slurry in Swan / De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Groundwater and surface water)		Seepage of IPTSF waters through base and/or pit walls to groundwater	Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Degradation of groundwater near Swan / De Grey IPTSF	<ul style="list-style-type: none"> <li>Groundwater and surface water quality and quantity (water level, flow) monitoring</li> </ul>	Minor	Unlikely	Medium
Expression of groundwater contaminated with IPTSF waters to surface water and subsequent surface water migration downstream along natural waterways/ watercourses	Native terrestrial flora including riparian vegetation communities	Localised, short-term decline in floristic health due to raised water tables, uptake of contaminated shallow groundwater or surface water, and/or increased salts in surface soils due to evapo-concentration		<ul style="list-style-type: none"> <li>Hydrogeological modelling was undertaken for operations but not for closure (post-2051). Informed by the operations hydrogeological modelling outcomes, it is assumed that seepage from the in-pit ponded water to underlying groundwater will continue at closure.</li> <li>Downstream water quality modelling has been conducted to assess water quality parameters at OB31 during operational periods which consider a mixture of pond seepage and natural groundwater in the proportions indicated by the groundwater modelling, as a time series (monthly basis). Screening results of the downstream water quality predictions indicate TDS and Barium exceed the screening criteria (See Section 5.5.4). Of the exceedances, one scenario denoting high seepage scenario during sustained seepage (late stages of the operational period) resulted in a HQ<sub>5</sub>. In summary, downstream water quality (upon entry into the groundwater system) after closure may have concentrations of PSOI with some exceedances of the adopted screening levels which are likely to be reduced, further.</li> </ul>	Minor	Rare	Low	
	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and quantity and associated effects to aquatic ecosystems and the biotic cycle		Minor	Rare	Low	Based on the adopted results from the in-pit ponded water modelling during closure and downstream modelling results during operations, a risk rating of Low to Medium has been assigned in relation to groundwater dependent ecosystems (primarily subterranean fauna) to groundwater contaminated with IPTSF waters.	
	Native terrestrial fauna <sup>1</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source		Minor	Rare	Low	High-level water quality modelling undertaken for Closure Option 1 for the in-pit ponded water for the IPTSFs indicates that PSOI concentrations in the ponded water will be below the adopted screening criteria for livestock and human health (with the exception of minor exceedances of taste thresholds for iron and manganese). Therefore, a risk rating of low has been assigned to exposure of livestock and humans to groundwater contaminated with IPTSF waters.	
	Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low		
	Recreational users	Adverse impacts to human health from recreational use of OB31 Creek other nearby watercourses and waterbodies		Slight	Rare	Low		
Drinking water	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low			



Risk Event				Risk Assessment				
Primary and Secondary Sources (and Affected or Impacted Environmental Media)	Transport Pathway	Receptors	Potential Impacts	Proposed Controls/ Mitigation Strategies	Closure Strategy - Partial Backfill			Rationale and Recommendations
					Consequence	Likelihood	Risk Rating	
Deposition of tailings slurry in Swan and De Grey IPTSF Pit overtopping (Soil, groundwater, and surface water)	Flow of supernatant water over the pit rim <sup>1</sup>	Native terrestrial flora including riparian vegetation communities	Potential soil erosion and physical damage to vegetation from overland flow and/or flooding Soil and/or groundwater contamination resulting in decline in floristic health	— Engineering assessment of water balance and capacity to contain significant flood events — Contingency freeboard within relevant regulatory (i.e., DMIRS and ANCOLD) guidelines — Proposed closure strategy design for no-permanent pond and management intermittent ponding	Minor	Rare	Low	The risks associated with pit overtopping at closure are the same or less than the risks identified for operations. GISTM requirements for facilities in passive closure require the management of the 1 in 10,000 AEP event to be managed (or stored) as a minimum, which is already a rare event. Whereas other relevant guidance documents require the management of the probable maximum flood (PMF) event. The closure design criteria for managing extreme flood events will consider these requirements which are more conservative compared to operational flood design criteria. In addition, with the consolidated tailings surface and partial backfill, more runoff inflow volumes can be stored compared to the final design tailings surface during operations (i.e., more storage capacity). As supernatant water is the dominant inflow during operations, the dominant inflow during closure would be from the external catchments (assuming beneficiation plant is decommissioned). Proposed mitigation for reducing runoff volumes from reporting to the pond (thereby keeping the pond volumes as low as reasonably practicable) is constructing upstream diversions to direct runoff elsewhere downstream. In the rare event that the containment area overtops, the escaping ponded water is likely to be diluted by heavy rainfall and thus, the risk to potential receptors from water quality and quantity in the receiving environment is considered <b>low</b> .
		Groundwater dependent ecosystems including subterranean fauna and riparian vegetation communities	Adverse impacts to groundwater quality and associated ecosystems		Minor	Rare	Low	
		Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems		Minor	Rare	Low	
		Native terrestrial fauna <sup>3</sup>	Adverse health impacts resulting from ingestion of contaminated drinking water source		Minor	Rare	Low	
		Livestock (cattle)	Adverse health impacts resulting from ingestion of contaminated drinking water source		Slight	Rare	Low	
		Recreational users	Adverse impacts to human health from recreational use of Ophahalmis Dam, or other nearby watercourses		Slight	Rare	Low	
Deposition of tailings slurry in Swan and De Grey IPTSF Consolidation of tailings slurry and resulting supernatant water (Waste fines and supernatant water inside Swan and De Grey IPTSF)	Entry to TSF containment and subsequent direct contact with or ingestion of waste fines and/or supernatant water ponded water	Native terrestrial fauna <sup>3</sup>	Acute or chronic effects on health Entrapment in soft fines	— Exclusion bunding around pit to discourage access	Minor	Possible	Medium	While exclusion bunding to discourage access of humans, livestock and wildlife to the pits is proposed, the effectiveness of exclusion bunds in preventing access to the pits by these receptors is unknown. In addition, at closure there will not be moving and operating equipment deterring wildlife access. The Partial Backfill Closure Strategy incorporates the tailings material being capped after the period of consolidation with a benign material (indicated to be waste rock covered by locally sourced surface soils). Therefore, direct exposure to tailings is considered unlikely. Assessment of the cover material is outside of the scope of this CEM. However, it is recommended that the suitability of the cover material in relation to chemical exposure risks of humans and wildlife is assessed prior to use. The tailings solids data was screened against available screening criteria (see Section 6.5.1). The tailings solids were below adopted criteria for the protection of human health (recreational use) and livestock and the material is considered to present a low risk for direct contact to these receptors. The tailings solids had PSOI concentrations above the adopted ecological screening levels (refer to HQ presented in Section 6.5.1), indicating that there is the potential for direct toxicity effects to ecological receptors (wildlife) if direct contact with tailings solids occurs. However, contact is unlikely based on the incorporated capping material and likelihood is ranked as rare. This translates to a low risk to human health and livestock. Intermittent ponding may occur in both the IPTSFs for the Partial Backfill Closure Strategy. Therefore, there is the potential for an aquatic habitat to establish in the pond over time. However, these ecosystems are considered to be highly modified and likely not representative of native surface waters in the area. The water quality of these ponds has not been modelled as such further modelling is recommended. The potential exposure frequency and durations of terrestrial fauna is relatively unknown, and therefore a likelihood of possible has been allocated. This results in a risk rating of <b>medium</b> for native terrestrial fauna as a result of entry to TSF containment and subsequent direct contact with or ingestion of ponded water. Based on direct toxicity and likelihood, if in-pit aquatic ecosystems establish, the risk ranking for this scenario is <b>low</b> . If aquatic ecosystem do not establish, this scenario does not require assessment and exposure to in-pit water is non-existent.
		Aquatic ecosystem within in-pit ponds	Acute or chronic effects on health		Minor	Rare	Low	
		Livestock (cattle)	Acute or chronic effects on health		Slight	Rare	Low	
		Recreational users	Acute or chronic effects on health		Minor	Rare	Low	
Deposition of tailings slurry in Swan and De Grey IPTSF Collapse of pit wall (Soil/rock)	Overland flow of debris and subsequent displacement of tailings and subsequent overland flow to downstream receiving environments following pit wall collapse	Aquatic ecosystems <sup>2</sup>	Adverse impacts to surface water quality and associated ecosystems	— Implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure)	Minor	Rare	Low	Detailed assessment of the physical safety risks associated with slope stability is outside the scope of this CEM and will be considered as a part of the Closure scope (WSP, 2023b). WSP anticipates that BHP will manage the potential risks to the environment from the rare event of a pit wall collapse through implementation of engineering controls (e.g., regular inspections of pit wall stability/slope failure). As a result, the risk to aquatic ecosystems and native terrestrial flora and fauna is assessed to be low on the assumption that minor consequences are only expected under exceptional circumstances. The risk of potential destruction of grazing land and recreational areas is also considered <b>low</b> .
		Native terrestrial flora and fauna <sup>3</sup>	Smothering and/or entrapment of receptors Destruction of habitat		Minor	Rare	Low	
		Livestock (cattle)	Destruction of grazing land		Minor	Rare	Low	
		Recreational users	Destruction of recreational areas/ significant sites		Minor	Rare	Low	

- Notes:
- 1) Nearby residents refers to residents and visitors to the town of Newman, as well as Aboriginal residents and visitors to the Pampajinya and Jigalong Communities.
  - 2) Aquatic ecosystems includes surface waterbodies and watercourses, and their associated aquatic flora and fauna.
  - 3) Native terrestrial fauna includes ground-dwelling mammals, reptiles, and birds.
  - 4) Pit overtopping may occur as a result of an extreme storm event, collapse of pit wall (if a supernatant pond is present in the TSF), or human failure.

AEP = annual exceedance probability; DMIRS = Department of Mines, Industry Regulation and Safety; ANCOLD = Australian National Committee on Large Dams.

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