Fortescue
The New Force in Iron Ore

Report

Western Hub Stage 1 - Eliwana and Flying Fish

Conceptual Site Model and Operational Risk Assessment

16 February 2018

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	Western Hub - Stage 1 Eliwana and Flying Fish – Conceptual Site Model and Operational Risk Assessment		
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Units of Measure

° .... Degrees
a .... Annum / year
cm .... Centimetre
Ga .... Giga annum / billion years
GL/a .... Giga litres per annum
kg H_2SO_4/t .... Kilograms sulfuric acid per tonne
ha .... hectares (10,000 m²)

L .... Litre
m AHD .... Metres above Australian Height Datum (sea level)
mg .... Milligram
mg $CaCO_3$/L .... Milligram calcium carbonate per litre
mm/yr .... millimetres per year
Mt .... Mega / Million tonnes
µg .... Microgram
µS .... Micro-Siemens
t .... Metric tonne (1 000 kg)
wt. % .... Weight per cent

Abbreviations and Acronyms

95% of ANZECC SLP .... 95% of Species limit of protection
ADWG .... Australian Drinking Water Guidelines
AHD .... Australian Height Datum
AMD .... Acid and/or metalliferous drainage
ANZECC .... Australian and New Zealand Environmental and Conservation Council
ARMCANZ .... Agriculture and Resources Management Council of Australia and New Zealand
BD .... Dales George Member
BJ .... Joffre Member
BW .... Whaleback Shale Member
BY .... Yandicoogina Shale Member
CID .... Channel Iron Deposit
DA .... West Angela Member
DER .... Department of Environmental Regulation
DIIS .... Department of Industry, Innovation and Science
DITR .... Department of Industry, Tourism and Resources
DMP .... Department of Mines and Petroleum
DWER .... Department of Water and Environmental Regulation
EC .... Electrical conductivity
HB .... Brockman Iron Formation
HD .... Wittenoom Formation
HG .... Bee Gorge Member
HM .... Marra Mamba Iron Formation
HR .... Mount McRae Shale Formation
JR .... Roy Hill Shale Member
Mbgl .... Metres below ground level
MM .... McLeod Member
MN .... Mount Newman Member
MPA .... Maximum potential acidity
Mtpa .... Million tonnes per annum
MU .... Nammuldi Member
NAF .... Non-acid forming
NAG .... Net acid generating
NEPM .... National Environmental Protection Measures
NMD .... Neutral Mine Drainage
PD/S .... Dolerite dyke / sill
PT .... Turee Creek Formation
TSF .... Tailings storage facility
WRL .... Waste rock landform

1. INTRODUCTION

Fortescue Metals Group Ltd (Fortescue) is proposing to develop the Western Hub Stage 1 Iron Ore Mine Project (the Project) comprising the Eliwana and Flying Fish deposits in the Pilbara region of Western Australia.

1.1 Project

The project area has been defined through the use of a development envelope and the estimated mine life is 24 years. The project includes the development of above and below water table mine pits, along with associated infrastructure, processing facilities, water management infrastructure for groundwater abstraction and surplus water disposal, temporary and permanent waste landforms and tailings storage facilities. The Western Hub Mine Project is associated with Fortescue's existing approved Port, Railway and the Solomon Iron Ore Mine, and the proposed Eliwana Railway.

The mining method will be conventional open cut. Ore from the Eliwana Mine will be transported via the proposed Eliwana Railway (the subject of separate referrals under both the Environmental Protection Act and Environmental Protection Biodiversity Conservation Act), before being transported along the existing Fortescue Rail network for export.

1.2 Objectives

The main aim of the *Conceptual Site Model and Operational Risk Assessment* is to outline and describe the contaminant-transport-receptor (CTR) model based on the National Environmental Protection Measures (NEPM) guidelines for assessing contamination (NEPM, 2013).

1.3 Reference documents

This document the *Western Hub Stage 1 Conceptual Site Model and Risk Assessment* document number 750WH-5700-RP-HY-0008 was prepared using the following resources:

- *Acid and/or Metalliferous Drainage Management Plan*, Report Ref.: 100-PL-EN-1016_Rev1 (Fortescue, 2014)
- *Western Hub Stage 1 – Geological Summary Report* (Fortescue, 2015)
- *Western Hub - Hydrogeological Conceptual Model Report*, Report Ref.: 1671484-002-R-Rev0; Golder Associates (Golder, 2017);
- *Western Hub Stage 1 – Eliwana and Flying Fish Subsurface Material Characterisation Assessment,* Report Ref.: 750WH-5700-RP-HY-0007 (Fortescue, 2017a);
- *Western Hub Stage 1 Closure Risk Assessment*, Report Ref.: 750WH-5700-RP-HY-0009 (Fortescue, 2017b);
- *Western Hub Stage 1 Conceptual Mine Void Water Assessment*, Report Ref.: 750WH-5700-RP-HY-0010 (Fortescue, 2017c).

2. SUMMARY OF PHYSICAL ENVIRONMENT

The project is located in the Pilbara biogeographic region of Western Australia (WA), where the climate is semi-arid to arid. The climate of the Pilbara Region is characterised by two distinct seasons with seasonal periodic rainfall mainly during the summer months and high evaporation rates. The gradient varies from open, flat topography to areas of steep hills, gorges, and gullies. The study area is located in a valley extending east to west between the main Hamersley Range to the north and Brockman Ridge to the south reaching elevations of up to 1,020 m AHD. The project area is a constrained fluvial valley system, with central surface drainage and an underlying palaeovalley groundwater system.

The project is situated within the greater Ashburton River catchment with the most significant drainage line within the mine being the Duck Creek subcatchment (which encompasses Caves Creek and Boolgeeda Creek), a tributary of the Ashburton River, which crosses the central section of the study area and flows northwest. Several unnamed minor to mid-order tributaries of Duck Creek also intersect the study area. With the main central channel named Pinarra Creek. Surface drainage is ephemeral, with a few persistent (possibly permanent) pools along the main channel of Duck Creek (Johnson & Wright, 2001). Surface water flow direction from the mine area is predominantly southerly in the eastern catchments and westerly on the eastern catchments Figure 1.

Large portions of the project area are used for pastoral grazing and substantial mineral exploration has been undertaken in localised areas. The condition of vegetation within the Project Area ranges from Completely Degraded/Cleared to Excellent, with the majority falling within the Very Good to Excellent categories.

2.1 Operations

The planned mine voids are given in Figure 2. Operational elements of the Project include:

- Mining in the Eliwana Area includes below water table mining, operational temporary standing water and permanent and ephemeral post closure pit lakes in mine voids;
- Mining in the Flying Fish Area includes above water table mining and ephemeral, surface water-driven, pit lakes in mine voids;
- Ore processing with waste disposal in tailing storage facilities (TSF) and waste rock dumps (WRDs);
- Water supply from a combination of mine dewatering and water supply borefields;
- Surplus water resulting from mine dewatering will be managed through a combination of surface discharge and controlled aquifer reinjection.

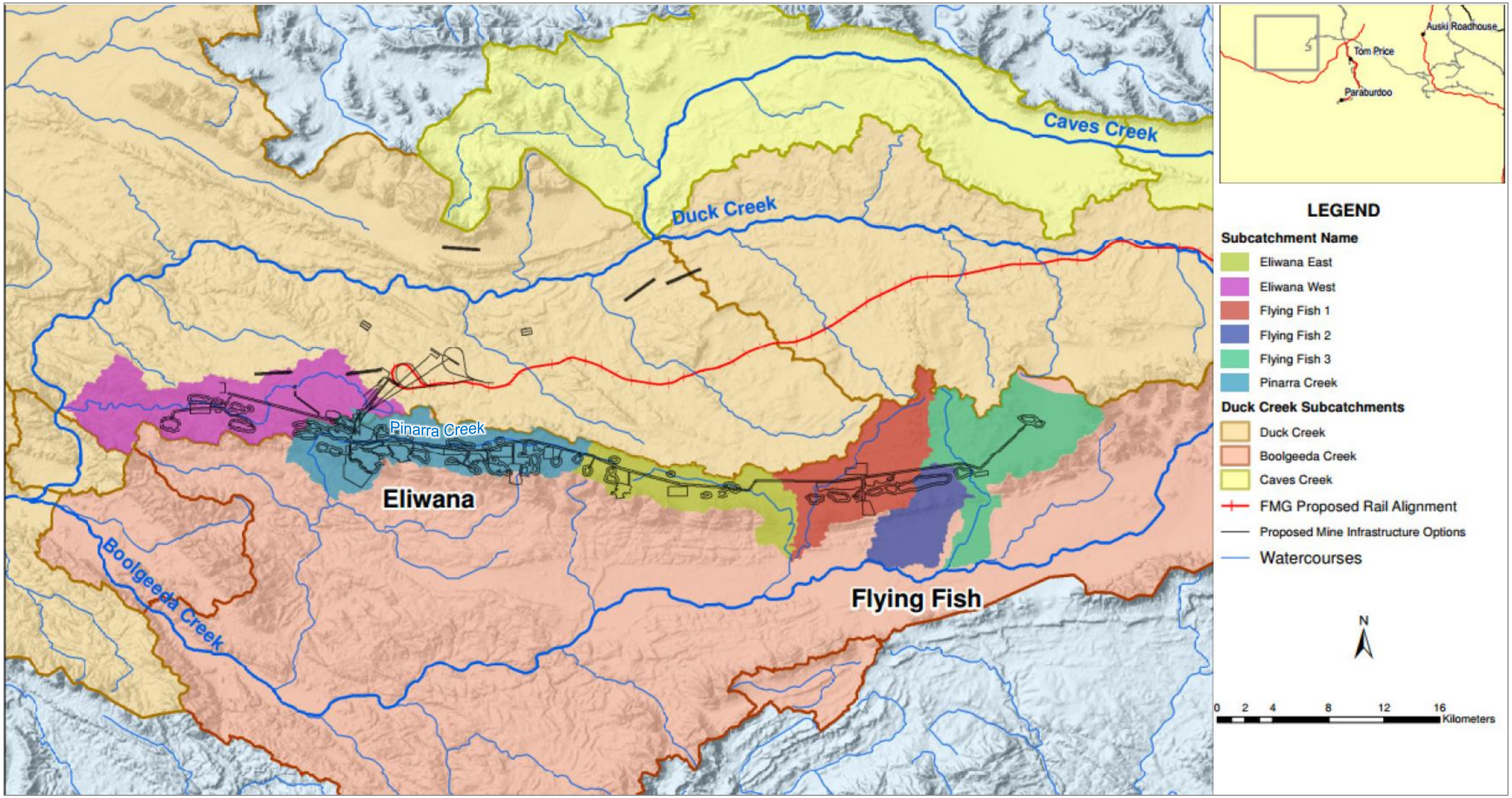

Figure 1: Surface water features and catchments of the mine area

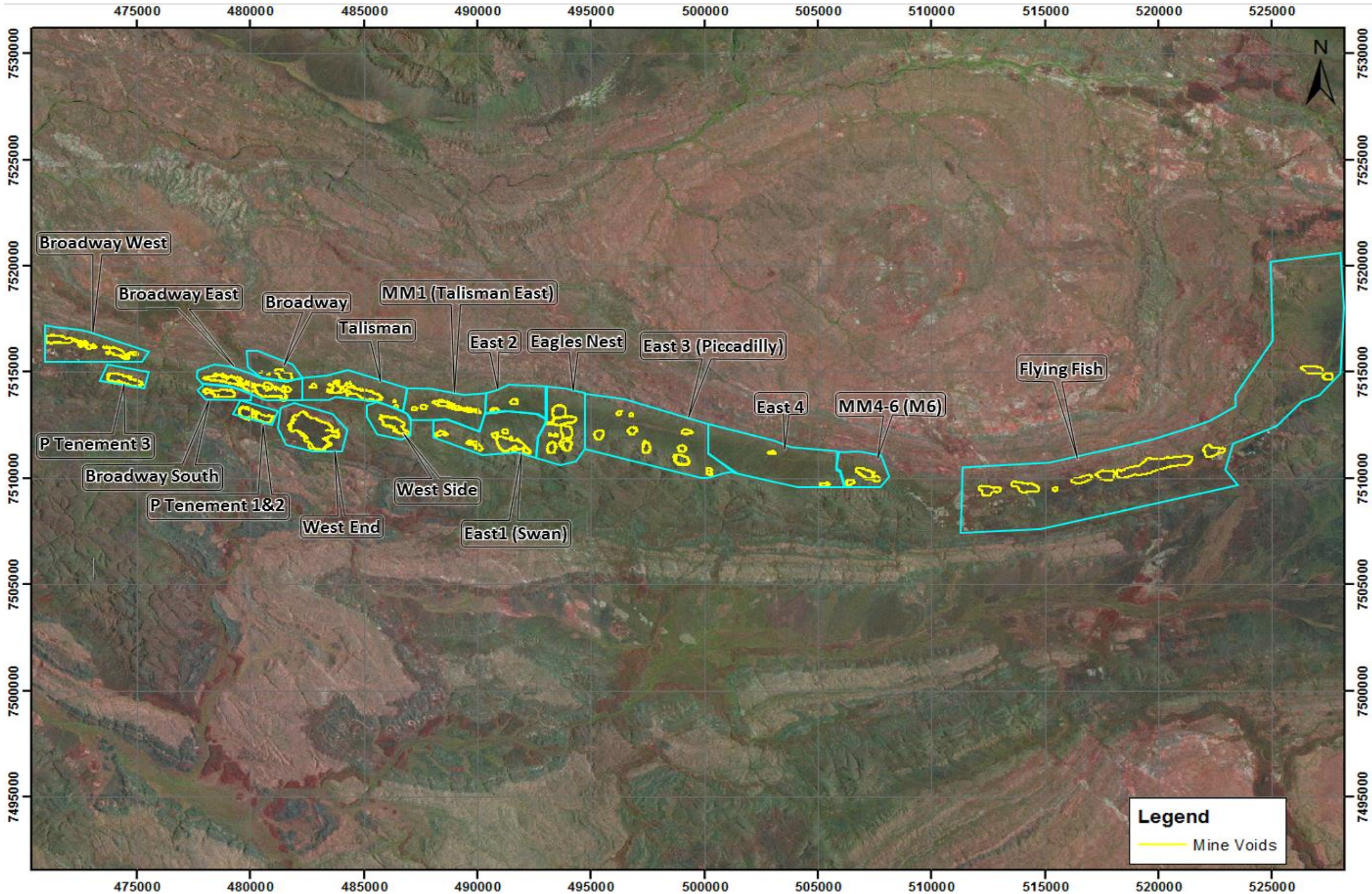

Figure 2: **Location and name of Western Hub mine voids considered in this assessment (geometry is subject to change over the project)**

2.2 Geology

The generalised stratigraphy of the Hamersley Basin, as interpreted by Johnson & Wright (2001), is shown in Table 1. The bedded stratigraphy dips to the south with the oldest units to the north, progressing through overlying younger material to the south (Figure 3).

Table 1: Stratigraphy of mine area

Unit			Description
Tertiary Detritals (Qa/Ta/Td)			Overlying the calcrete and silcrete are mainly poorly sorted, unconsolidated gravels, comprising banded iron, ironstone or dolerite in a clay matrix. Calcrete (or dolomite) and silcrete is commonly found.
Channel Iron Deposits (CID)			Robe Pisolite unaltered hematite-goethite pisoliths.
Dolerite dykes (PD)			Near vertical trend NW-SE, NNW-SSE and NE-SW
Dolerite sill (PS)			Intrudes into the J3 units
Hamersley Group			
Brockman Iron Formation (HB)	Yandicoogina Shale Member (BY)		Alternating chert and shale up to 60 m thick, does not occur in waste
Brockman Iron Formation (HB)	Joffre Member (BJ)	Unit 6 (J6) Unit 5 (J5) Unit 4 (J4) Unit 3 (J3) Unit 2 (J2) Unit 1 (J1)	Brockman Iron Formations consist of the highest grade bedded iron deposits. Homogeneous with approximately 330 m of alternating banded iron formation and shale bands. The banded iron comprises interbedded chert and iron rich material.
Brockman Iron Formation (HB)	Whaleback Shale Member (BW)		Approximately 50 m thick, this member consists of thinly bedded shales with thicker chert or BIF bands, weathered with supergene enrichment of BIF bands
Brockman Iron Formation (HB)	Dales George Member (BD)	Unit 4 (D4) Unit 3 (D3) Unit 2 (D2) Unit 1 (D1)	An alternating sequence of BIF and shale macro-bands. The BIF bands comprise of centimetre thick bands of chert and iron rich material in a chert matrix. The shale bands comprise primarily volcanogenic and carbonate turbidite. Member is ~ 142 m thick
Mount McRae Shale Formation (HR)			Comprises thinly laminated, fissile shale with minor subordinate amounts of chert, dolomite and BIF. Unweathered unit occurs as black graphitic and chloritic shale with significant **pyrite** that represents a potential spontaneous combustion and acid forming material risk when exposed through mining
Mount Silvia Formation (HS)	(Bruno's Band)		Three prominent banded iron formation (BIF) bands, separated by laminated mudstone and minor chert and dolomite with the upper a recognisable regional marker known as Bruno's band. Thickness is varies from 30 to 45 m
Wittenoom Formation (HD)	Bee Gorge Member (HG)		A thinly laminated fissile argillite also contains subordinate thickness of carbonate, chert, volcaniclastics and iron formation with distinct marker bed: the Main Tuff Interval, Member ranges in thickness from 100 to 227 m
Wittenoom Formation (HD)	Paraburdoo Member (HP)		Comprises a majority of dolomite with minor amounts of chert and argillite (clay, mudstone, shale), thickness between 260 and 420 m.
Wittenoom Formation (HD)	West Angela Member (DA)		Predominantly massive to laminated dolomite interbedded with shaley dolomite with **pyrite** and chert, between 30 and 50 m thick.
Marra Mamba Iron Formation (HM)	Mount Newman Member (MN)		Banded iron interbedded with carbonate and shale, between 45 and 60 m thick containing eight identified shale bands
Marra Mamba Iron Formation (HM)	McLeod Member (MM)		Banded iron, chert and carbonate along with interbedded shales, 25 to 45 m. The upper most beds contain the most shale units, closely spaced together.
Marra Mamba Iron Formation (HM)	Nammuldi Member (MU)		Cherty, banded iron formation interbedded with thin shales. The un-mineralised Nammuldi Member is between 75 and 100 m thick
Fortescue Group			
Jeerinah Formation (FJ)			Dark grey to black shale, commonly with spheroidal pyrite concretions.
Roy Hill Shale Member (JR)			

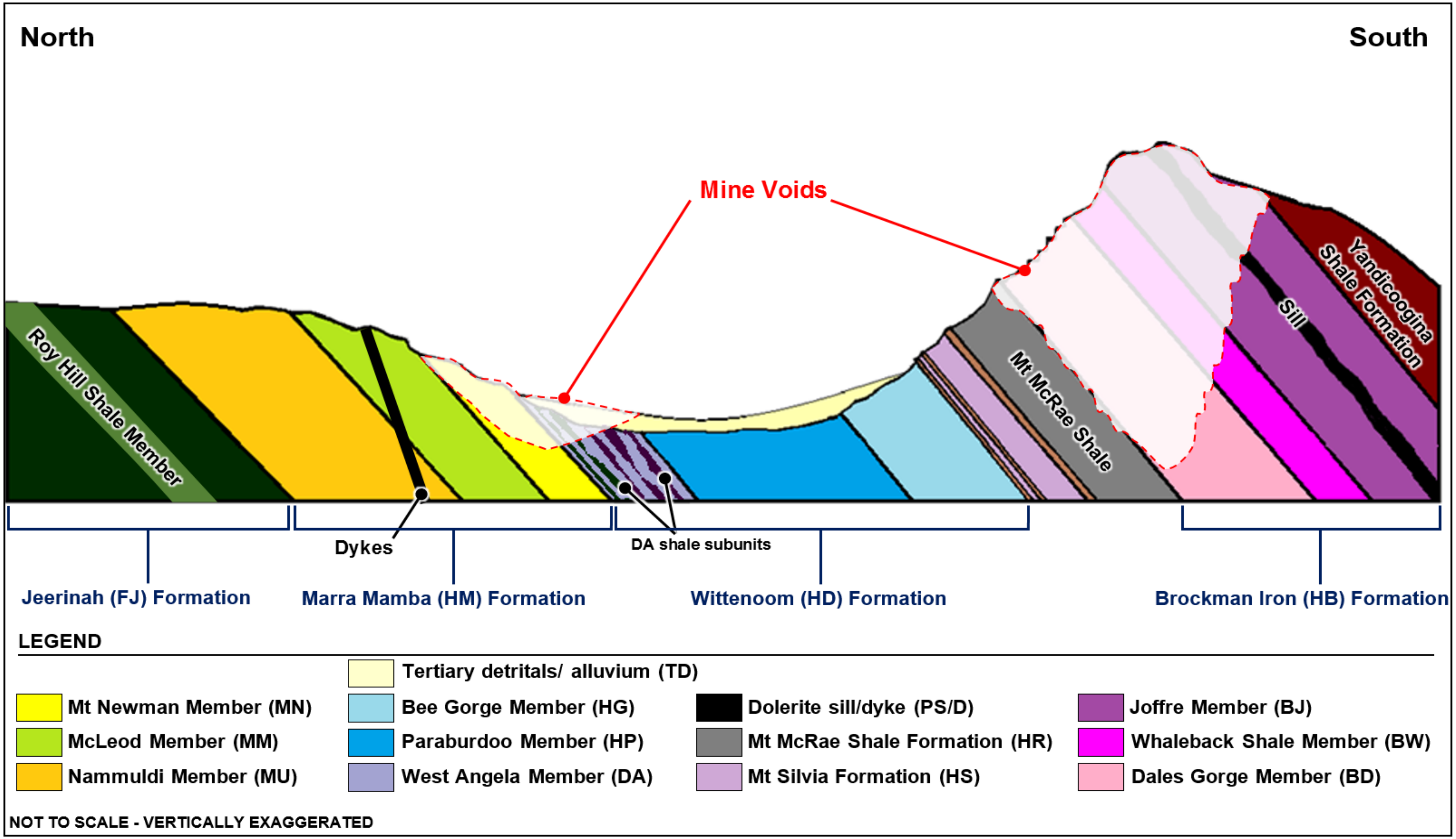

Figure 3: Conceptual geological profile of the Western Hub valley (vertically exaggerated, not to scale)

2.3 Mine voids

The below table lists the planned mine voids indicating geology of waste and ore units. Where ore units are not mineralised these will also be sent to waste.

Table 2: Mine voids and geology of waste

Planned mine void name	Ore units	Waste material
Broadway West 1, 2 & 3 Broadway East 1 & 2 Broadway	McLeod (MM) Member Mount Newman (MN) Member	Tertiary Detritals (Td) Channel Iron Deposits (CID) Bedded Iron Deposits (BID) West Angela (DA) Member
Broadway South	Dales Gorge (BD)	Bedded Iron Deposits (BID) Mount McRae Shale (HR)
Eagles Nest East 1 (also called Swan)	Joffre (BJ) Member Whaleback Shale (BW) Member Dales Gorge (BD) Member	Tertiary Detritals (Td) Mount McRae Shale (HR) Wittenoom (HD) Formation
East 2, 3 & 4	Mount Newman (MN) Member	Tertiary Detritals (Td) West Angela (DA) Member
MM1 (now called Talisman East MM4-6 (also called M6)	McLeod (MM) Member Mount Newman (MN) Member	Tertiary Detritals (Td) West Angela (DA) Member
P Tenement 1 (P1) P Tenement 2 (P2)	Joffre (BJ) Member Whaleback Shale (BW) Member	Joffre (BJ) Member
P Tenement 3 (P3)	Joffre (BJ) Member Whaleback Shale (BW) Member	Joffre (BJ) Member Whaleback Shale (BW) Member Dolerite dykes (PD)
P Tenement 4 (P4)	Dales Gorge (BD) Member	Dales Gorge (BD) Member
Talisman 1 & 2	McLeod (MM) Member Mount Newman (MN) Member	Tertiary Detritals (Td) West Angela (DA) Member
West End	Joffre (BJ) Member Whaleback Shale (BW) Member Dales Gorge (BD) Member	Tertiary Detritals (Td) Dolerite Sill (PS) Mount McRae Shale (HR) Wittenoom (HD) Formation
West Side	Joffre (BJ) Member Whaleback Shale (BW) Member Dales Gorge (BD) Member	Mount McRae Shale (HR) Wittenoom (HD) Formation
Flying Fish	McLeod (MM) Member Mount Newman (MN) Member	Tertiary Detritals (Td) Channel Iron Deposits (CID) West Angela (DA) Member

2.4 Hydrogeology

The hydrogeological environment is based on the geological model, airborne total magnetic intensity interpretation, hydrogeological and resource bores (Golder, 2017).

2.4.1 Tertiary detrital aquifer

Shallow Tertiary Detrital material comprising alluvial/colluvial valley infill and calcrete deposits does not strictly function as an aquifer as it is unsaturated, however flow through this material will occur during high rainfall events. It is for the most part unconfined and as such may function as a flow pathway, however, Tertiary clays in the valley may act as a local aquiclude preventing connection with the Wittenoom Aquifer below. Channel Iron Deposits (CID) of unknown and limited extent occur within the project area, but are generally confined to the Flying Fish area.

2.4.2 Mineralised Brockman aquifer

The mineralised Brockman Iron Formation (comprising Joffre, Whaleback Shale and Dales Gorge Members) is formed by the same hypergene enrichment that formed the bedded mineralisation in the Hamersley Basin. The replacement by groundwater of silicate and carbonate minerals with goethite results in stratigraphic thinning and associated increases in porosity and permeability. The Whaleback Shale Member is assumed to be part of the aquifer where it is weathered/mineralised.

2.4.3 Marra Mamba and Wittenoom aquifer

The Wittenoom Aquifer includes all weathered Members of the Wittenoom Formation as well as the mineralised upper Newman Member of the underlying Marra Mamba Iron Formation which is connected. The West Angela Member comprises shaley dolomite and interbedded banded iron formation, while the Bee Gorge and Paraburdoo Members tend to contain mostly dolomite with the highest permeability.

The upper Mount Newman Member is sometimes separated from the lower Mount Newman Member by an impermeable shale band. To account for this the Newman Member will be tested separately to determine the connectivity. Where the overlying Tertiary Detritals materials are saturated and in hydraulic connection with the groundwater contained in the Wittenoom Formation these sediments will be included in the Wittenoom Aquifer.

2.4.4 Aquitards

Aquitards slow the flow of groundwater from one aquifer to another. The unmineralised Brockman Iron (HB) Formation, Yandicoogina Shale (BY) Member, Marra Mamba Iron (HM) Formation, Mount Sylvia (HS) Formation and Roy Hill Shale Member (Jr) as well as unweathered members of the Wittenoom Formation are considered aquitards. Dolerite dykes and sills are also considered aquitards. The Mount McRae Shale (HR) is also considered an aquitard and acts as a boundary that partitions the Mineralised Brockman Aquifer from the Wittenoom Aquifer. A prominent dolerite sill occurs in the J3 unit of the Joffre (BJ) Member on the southern limb of the Brockman Syncline. These aquitards act to bound the mining area to the south by the Yandicoogina Shale (BY) Member of the Brockman Iron Formation and to the north by Roy Hill Shale (JR) Member of the Jeerinah Formation (FJ), resulting in little to no movement of groundwater and effective groundwater compartmentalisation.

3. CONCEPTUAL SITE MODEL

The conceptual site model (CSM) describes the potential sources of geochemical contamination in the mining area and assesses the transport pathways to any local or regional receptors. As the major transport pathways relate to water movement and receiving environments the risk assessment has focussed on them. This is a qualitative risk assessment designed to highlight areas of high risk and potential uncertainty that require management to mitigate, or further study to quantify more fully.

3.1 Introduction

In the context of a geochemical risk assessment, contamination is defined as an increase or decrease in any chemical parameter compared to the natural conditions that are present in the environment, so that such a decrease or increase may result in a significant impact to any human or environmental factor or value. In order that the final landform is geochemically safe, stable, non-polluting and capable of sustaining an ecosystem, the reactivity and weathering potential of all potential sources is required to be assessed so that any risks can be managed. Potential sources are discussed in the general case with all *potential* risks highlighted, not certainties.

The risk assessment follows the contaminant-transport-receptor (CTR) model where risk is only present if these three factors are all present *and* connected (Figure 4). If there is no source, there is no risk, if there is no pathway to connect source and receptor there is no risk, and if there is a source and a pathway but no receptor, there is no risk. The risk assessment following will evaluate the likelihood of risks prior to and after mitigation methods.

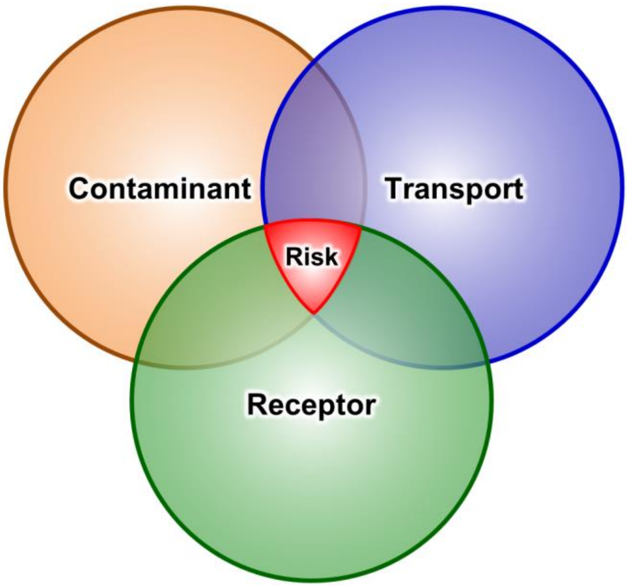

Figure 4: Contaminant-Transport-Receptor model

While the *Subsurface Materials Characterisation Assessment* (750WH-5700-RP-HY-0007) has identified the material that is likely to pose the greatest risk, ore bodies and geological formations are heterogeneous and continuous characterisation with continued investigation of the ore body is required in a phased approach coinciding with the increasing level of knowledge of the area and resource geology (Fortescue, 2017a).

The development of the CSM closely follows the *Acid and Metalliferous Drainage Management Plan* (100-PL-EN-1016_Rev1) details a high level method of investigation to be conducted during each phase of mining to answer specific informational requirements (Fortescue, 2014). The AMD Management Plan was designed to deal with a general case and to be applicable to all sites. In addition to this model of ascertaining risk, the closure principle requirement that the final landforms are geochemically safe, stable, non-polluting and capable of sustaining an ecosystem is also taken into consideration as rock weathering and the potential for contamination to the environment continues for millennia after mining has ceased.

In terms of the AMD management plan this assessment satisfies the knowledge requirements for the Exploration, Prefeasibility, and Feasibility stages. Sufficient testing has been conducted at this stage to identify the major risks and materials that require specific material handling consideration. This information will then inform the mine planning and waste rock landform designs. It is clear that the potential deleterious material comprises a minor volume which is easily encapsulated in the bulk of the benign surplus rock and that careful scheduling and design will mitigate most risks posed by excavated, potentially-AMD generating material. The conclusions from the *Subsurface Characterisation Assessment* (750WH-5700-RP-HY-0007) directly affect landform planning and construction during operations, as well as closure strategies (Fortescue, 2017a). As more information is gathered in the successive stages of the project the AMD management methods and assumptions may change to address changing mine conditions, community expectations, stakeholder inputs and the emergence of new, more cost-effective AMD management methods as the mine proceeds (DIIS, 2016c).

3.2 Sources of potential contamination

A source of contamination is considered to be any material, either ore, rock, soil or water that has undergone disturbance as a result of mining processes such that the geochemical composition may be affected or degraded. Airborne particulates are not considered in this contamination assessment as air quality and dust is addressed separately. In addition, physical sources of contamination, such as: sediment loads, suspended matter, breathable fibres or gases, are not considered here. Other potential sources of contamination associated with the operation such as hydrocarbons, pesticides or sewerage have not been assessed at this stage but may be included as part of this process once construction has been completed.

Table 3 summarises the potential sources of contamination detailed in this section and in which stage they pose a risk.

Table 3: Summary of potential sources in operations and post closure

Potential Sources	Operations	Closure	Comment
Acid sulfate soils	No	NO	No permanent surface water or near-surface groundwater will be dewatered
Construction material	YES	NO	Only present during operations.
Aboveground waste rock landforms	YES	YES	In construction during operations and rehabilitated on closure
Ore stockpiles	YES	NO	Not remaining following operations
Sub-grade ore stockpiles	YES	YES	May be remaining following operations, based on economic variability
Tailings storage facilities	YES	YES	In construction during operations and rehabilitated on closure
Mine void wall rock	YES	YES	Exposed during operations and stabilised on closure
Backfill/ below surface overburden storage	YES	YES	In construction during operations and rehabilitated on closure
In situ dewatered rock	YES	NO	Dewatered during operations, groundwater rebound after closure
Episodic, ephemeral or semi-permanent mine void water	NO	YES	Intercepted surfaces water controlled and discharged during operations
Permanent mine void water	NO	YES	Groundwater dewatered during operations only rebounding on closure into below water table mine voids

3.2.1 Acid sulfate soils

No known unconsolidated sediments, peat or lignite, below the water table, are expected to be excavated. Soils are considered to be Not Acid Sulfate Soils (NASS) and are not considered as a source of potential contamination.

3.2.2 Construction material

Geological material used for the construction of roads, embankments diversions, plant and building pads may pose a risk if it has not been adequately sourced and characterised. It is important that construction planning take into account which material has been identified as potentially deleterious and avoids excavation of or into such units. Construction material will only be evaluated separately from waste rock during operations as it is not expected that additional rock material will be excavated on closure.

3.2.3 Aboveground waste rock landforms

Excavation, storage and disposal practices combine the overburden units, internal non-mineralised rock and other geological material, resulting in a heterogeneous composition in landforms. The primary contributing factor to the generation of AMD is the exposure of reactive, acid generating minerals in this excavated waste rock to oxygen and water. As a basic principle the generation of AMD can be avoided by excluding oxygen and/or water from contact with problematic rock units.

Rock landforms are present from the start of operations and will continue to constitute a potential following closure. Classification and analysis of rock samples at the Western Hub has determined that;

- The majority of material is non-acid forming but the Mount McRae Shale Formation has the potential to generate acid and neutral or alkaline metalliferous drainage;
- Mount McRae Shale occurs in the wall of the West End, West Side and in minor amounts in the Eagles Nest mine voids;
- There is an unlikely chance (3-30%) that chromium, copper, selenium, thallium and vanadium will occur above the ANZECC 95% of species limit of protection in any drainage from waste rock;
- There is a rare chance (0-3%) that arsenic, cadmium, cobalt and nickel will occur above the ANZECC 95% of species limit of protection in any drainage from waste rock.
- Aluminium, iron, manganese and zinc are highly soluble in this environment with large reservoirs for long-term weathering. These metals are locally, naturally elevated but may exceed background concentrations and impact fauna and flora;
- Elements of specific concern are arsenic and selenium which occur in samples from Mount McRae Shale and Wittenoom Formation. There is minor concern that cobalt, chromium, copper and nickel may also be present at elevated concentrations;
- The West Angela Member shale subunits are pyritic at the base of the unit, just above the Mount Newman ore is likely to result in acidic and metalliferous drainage;
- Weathering testing indicates that aluminium, cobalt, manganese and zinc, with minor concern that beryllium and thallium, may pose a long-term risk;

While the occurrence of some elements indicates the possibility of trace element leaching from unsegregated material, the frequency and magnitude of the occurrences results in a low potential impact and as a result they are not included in the risk assessment. Surface and groundwater hardness is elevated and environmental tolerance for cadmium, copper, chromium, nickel and lead is higher, so they are not considered to be of concern.

For the purposes of this CSM **aluminium**, **arsenic**, **cobalt**, **manganese**, **selenium** and **zinc** with minor **cobalt**, **beryllium** and **thallium** are considered potential contaminants of concern from rock material at the Western Hub during operations and post-closure.

3.2.4 Ore stockpiles

Ore stockpiles are present during operations only and will be exhausted once mining is complete. An estimation of whether stockpiles may have an impact was based on the water leach results of only the ore units Dales Gorge (BD) and Joffre (BJ) Members and samples from the Marra Mamba Iron Formation (HM). Should any contamination occur this will be addressed during decommissioning and will not be a risk post-closure. Classification and analysis of ore units at the Western Hub has determined that:

- Ore units comprise Brockman Iron and Marra Mamba Formations;
- Most samples were non-acid forming. Only stockpiled basal Dales Gorge Member ore, unit D1 poses a risk for acid generation but it is unlikely to be mineralised;
- There is a possible chance (30-70%) that aluminium, boron, barium, manganese and lead will be present in any stockpile drainage;
- There is an unlikely chance (3-30%) that cadmium, chromium, copper, iron, cadmium, copper, selenium, tin and zinc will be present in any stockpile drainage;
- There is a rare chance (0-3%) that molybdenum, nickel, thallium and uranium will be present in any stockpile drainage.

Of these elements that occur frequently in water leach samples, only **aluminium**, **iron**, **manganese**, **selenium**, **thallium** and **zinc** have any concentrations above the ANZECC 95% of SLP. There are two to three individual instances of cadmium, chromium and copper that marginally exceed the HMTV. These occurrences are rare and not considered to be a concern.

3.2.5 Sub-grade ore stockpiles

Sub-grade stockpiles are differentiated from run-of-mine (ROM) ore stockpiles as there is a risk they may be stored for much longer periods of time depending on the ore price and mine product strategy or never used at all. As a result they may be subjected to much longer periods of weathering and oxidation than normal ROM piles. They are potentially long-term sources of AMD, and may still be present on closure if economic factors do not result in use as resource. As such, they may pose a higher risk than well-designed surplus rock storage areas with little to no planning as to their location and construction.

The same elements that occur frequently in ore leaches are a risk for sub-grade ore: **aluminium**, **iron**, **manganese**, **selenium**, **thallium** and **zinc** with the added risk of acid generation from basal Dales Gorge Member unit, D1.

3.2.6 Tailings storage facilities

Minimal beneficiation is planned and less than 100 million tonnes is estimated for tailings generation over the life of the mine. Tailings material will be generated during operations and may be stored above or below the water table. Tailings comprises milled, ground ore residue, largely aluminium-oxyhydroxides and ferrosilicates, that has been gravity separated and extracted groundwater as the slurry fluid. Of these the water is more likely to be transported while the consolidated solids will be present post-closure.

Preliminary classification and analysis of tailings material has determined that, in general, tailings material is not considered a risk for acid generation, saline or metalliferous drainage, however there is an indicated risk of **minor chromium** drainage. The regional groundwater generally has elevated hardness and as a result the risk from chromium in drainage is not likely to be high.

3.2.7 Mine void wall rock

It is likely that Mount McRae Shale (HR) Formation and basal Dales Gorge (BD) Member units will be exposed in the West End and West Side mine voids.

It is likely that the West Angela (DA) Member shale unit of the Wittenoom Formation (HD) will be exposed in the northern mine voids and may influence the quality of mine void water both ephemeral and permanent.

For the purposes of this CSM **aluminium**, **arsenic**, **cobalt**, **manganese**, **selenium** and **zinc** with minor **cobalt**, **beryllium** and **thallium** are considered potential contaminants of concern from waste rock and mine void walls at the Western Hub during operations and post-closure.

3.2.8 Backfill material/ belowground waste rock storage

In some instances mine voids may be completely or partially backfilled either to make the mine void safe and stable or as a preferred option for the disposal of waste material. Backfill may include waste rock or tailings and may be placed below or above the water table in the mine void. If backfill is not well planned and characterised it may be a cause of AMD in contact with either groundwater and/or surface flow.

The best environmental outcome may, however, conversely, include backfilling deleterious waste such Mount McRae shale either above or below the water table to reduce weathering, exclude oxygen or capture unavoidable drainage in a terminal sink. If a mine void situated in a floodplain contains backfill material the risk to surface water is also required to be assessed.

For the purposes of this CSM **aluminium**, **arsenic**, **cobalt**, **manganese**, **selenium** and **zinc** with minor **cobalt**, **beryllium** and **thallium** are considered potential contaminants of concern from waste material at the Western Hub during operations and post-closure.

3.2.9 *In situ* dewatered and depressurised rock units

Pyritic shale units that are either situated in the footwalls, or near to the edges of the pits present a risk that dewatering activities may influence the water levels in these units. However, pump testing of the mine void areas have indicated that the water levels in shale units adjacent to mine voids are disconnected and do not respond during pumping. The impermeability of the shale units indicate they will not be effected by dewatering and are unlikely to cause AMD. Groundwater appears to be highly compartmentalised with no or very low flow through the shale units from north to south and is further segregated from east to west by dolerite intrusions, which also act as flow boundaries. The risk of *in situ* dewatering of pyritic shale is therefore low.

However, in order that the stability of the mine void walls is not compromised during mining by high pressure differentials between the void and the shale unit, it is possible that bores will be installed to depressurise these units, which may result in AMD during operations. Any AMD caused by the installation of depressurisation bores will be required to be pumped out to facilitate operations and treated or diluted so as not to damage infrastructure, so it is not expected to have an environmental impact and volumes will be very low and will be captured in the mine void.

3.2.10 Dewatering discharge

The groundwater extracted from ore units to facilitate mining is expected to be discharged to surface water drainage lines. The preliminary baseline groundwater and surface water quality is given in the *Subsurface Material Characterisation Assessment*, Section 3.5.3 (Fortescue, 2017a). Groundwater is described as a pathway in the following section, however in this case, it is removed from the natural environment of the aquifer and discharged to the surface where there may be an impact on the ecology. The main difference in water quality is the higher salinity of groundwater as compared to surface water, and consequently all major ions, alkalinity and minor elements affected by salinity e.g. boron, barium. In terms of metals: copper and manganese are marginally higher in groundwater while aluminium and zinc are higher in surface water.

While it is possible that the increased salinity may have an impact, flora and fauna communities of the Pilbara are usually salt tolerant, and the increased nutrients from calcium and magnesium and moisture, are likely to offset any negative effects. Dewatering discharge will be present during the operational stage and will not occur following closure.

3.2.11 Mine void water

It has been determined through modelling that following cessation of operations, remaining mine voids will be in contact with both surface and groundwater environments and will result in both the permanent and temporary presence of water. Mine void water is not considered a contamination risk during operations unless an extremely large and rare event results in egress. This type of event is unlikely to be a contamination risk however as it will comprise highly diluted rainwater. A brief outline of mine void water risk is given as follows but the *Conceptual Mine Void Water Assessment* is outlined in report number 750WH-5700-RP-HY-0010 (Fortescue, 2017c).

3.2.11.1 Ephemeral, episodic and semi-permanent water

Ephemeral and episodic water in mine voids is likely to comprise only direct precipitation and small volumes of wall runoff. This water will infiltrate and evaporate quickly and be fresh in quality, resulting in a minimal build-up of salts (evaporites) at the base of the mine void. For voids mined above the water table, and not in connection to a creek system, precipitation and runoff will be the sole source of temporary water and are not considered to pose a high risk of potential contamination.

Semi-permanent water may result from a seasonal increase in groundwater levels that result in a minor ingress into mine voids or where a mine void is in connection with a creek system during periods of high flow such that captured surface water takes a longer amount of time to evaporate than incidental rainfall. The duration of semi-permanent mine water is likely to be on the order of several months. The quality of this type of water body will also be highly influenced by whether the source of water is precipitation and minor wall rock runoff or more saline groundwater, and as such the amount of evaporative salts will likely be higher than ephemeral and episodic water but still low, and is unlikely to pose a high risk as a result of flow terminating at the lowest point of the mine void and becoming a sink.

3.2.11.2 Permanent water – not connected

Voids mined below the water table will recover to have permanent groundwater inflow once dewatering ceases into the mine void. During operations no permanent mine void water will be present as active operations will be dewatered. The pit lakes will only form and constitute a potential source of contaminants on closure. These mine voids are not connected to surface water and are reliant on groundwater almost entirely. These mine voids are likely to be terminal sinks as a result of high evaporation as well as the low permeability shale units, and dolerite dykes that bound the mine area to the north and south, and the east and west, respectively, preventing outflow. Mine void water in West Side, West End and Eagles Nest may be in contact with Mount McRae Shale in the wall rock, while M6 (also called MM4-6) mine void water may be in contact with West Angela Member Shale in the wall rock. This water will be groundwater inflow, initially of similar quality to background observations, diluted marginally with fresher quality precipitation and runoff but will deteriorate over time as a result of evapoconcentration and exposed shale units that leach metals. However, because of the very low likelihood that these sources will be in contact with any transport pathway, the risk of contamination posed to the environment is low.

3.2.11.3 Permanent water –connected

Some mine voids may be in contact with the environment as a result of their position in the floodplain. These mine voids may have groundwater and surface water ingress or only surface water inflows. The majority of these mine voids will be terminal sinks as a result of the high evaporation. Some of the voids with only surface water inflows may be shallow enough to resume creek flow but accumulated salts from evaporation of smaller surface water inflows will be low and the impact of any outflow will be negligible.

There is higher surface water ingress (than from just precipitation and runoff) from creek flow into the Talisman and Broadway East mine voids. Both Talisman and Broadway East have a less than 1% chance of outflow which would only occur in very large, rare flood events of a volume greater than 1:100, when the creek intersected by this mine void may resume flow. It is likely that such a large volume of water would dilute any evapoconcentrated water to such an extent that contamination is unlikely to pose a risk.

The Broadway West mine void however, has a high likelihood of outflow from surface and groundwater ingress. Outflow is likely to occur on a yearly basis with seasonal rainfall events as the catchment to which Broadway West is connected is large. Frequent outflow and large volumes of surface water inflow, will result in a much lower likelihood of poor quality water by evapoconcentration. However, some West Angela (DA) Member shale occurs in the wall rock and may contribute to metal leaching. Surface water flow from these mine voids will travel west to Duck Creek.

At this stage of the project planned mine void designs are subject to a high degree of variability. The water balance can only be estimated at this stage, as a result of the large number of variables required to be included in modelling, namely operational dewatering, climate change, infiltration, flood events, rainfall intensity, aquifer recharge and potential interaction between closed mine voids. When the amount of salt and metals contributed to the environment can be accurately modelled, mine voids may be redesigned in order to reduce any unacceptable risks.

Contaminants of concern combine elements naturally occurring in groundwater with dissolved metals from leaching and long-term weathering tests of rock material representing wall rock, waste rock and potential backfill. For the purposes of this CSM acid generation and neutral/ alkaline drainage containing **aluminium, arsenic, manganese, selenium** and **zinc** with minor **beryllium, cobalt** and **thallium** are considered potential contaminants of concern. The risks for predicted permanent water bodies are assessed separately as the ingress and egress regimes are different, and distinct wall rock stratigraphies result in different potential contaminants.

3.2.11.4 Summary of hydrology and hydrogeology

A summary of the predicted surface and groundwater regimes is given in Table 4. This table collates the planned depth of mining for each pit, with the surface and groundwater models to detail which mine void will intersect groundwater and have inflow in the current plan, and which mine voids are situated within a floodplain. With a large enough rainfall event any mine void in the floodplain could intercept surface water flow, even if just for a few hours. The table indicates whether mine void water will be permanent enough to form a pit lake and whether outflow may occur during rain events. The compilation of these scenarios has allowed the risk of contamination to be assessed.

Table 4: List of mine voids showing planned depth and water regime

Pit name	Planned Depth (mAHD)	Groundwater Inflow	Position in Floodplain	Pit Lake	Surface water outflow
Broadway West 3	363	**Likely**	**Within**	**Likely**	**Almost certain - yearly**
Broadway West 2	411	Remote	**Within**	Remote	N/A
Broadway West 1	408	Remote	**Within**	Remote	N/A
Broadway East 2	435	**Likely**	**Within**	**Likely**	Very Rare – Extreme
Broadway East 1	453	**Likely**	**Within**	**Likely**	
Broadway	483	Remote	Above	Remote	Very Rare – Extreme
Broadway South	444	Remote	Above	Remote	Very Rare – Extreme
Eagles Nest	492	**Likely**	Above	**Likely**	N/A
East 1 (now called Swan)	543	Remote	Above	Remote	N/A
East 2	510	Remote	Above	Remote	N/A
East 3 (now called Piccadilly)	543	Remote	Above	Remote	N/A
East 4	546	Remote	Above	Remote	N/A
MM1 (now called Talisman East)	489	Remote	Above	Remote	N/A
MM4-6 (now called M6)	450	**Likely**	Above	**Likely**	N/A
P Tenement 1 (P1)	486	Remote	Above	Remote	N/A
P Tenement 2 (P2)	570	Remote	Above	Remote	N/A
P Tenement 3 (P3)	423	Remote	Above	Remote	N/A
P Tenement 4 (P4)	417	Remote	Above	Remote	N/A
Talisman 1	480	Remote	**Within**	Remote	N/A
Talisman 2	426	**Likely**	**Within**	**Likely**	Very Rare – Extreme
West End	310	**Likely**	Above	**Likely**	N/A
West Side	456	**Likely**	Above	**Likely**	N/A
Flying Fish 1	-	Remote	**Within**	Remote	Rare
Flying Fish 2	-	Remote	Above	Remote	N/A

3.3 Transport pathways and other exposure routes

The following sections discuss each of the potential migration pathways or exposure routes that have been identified as part of this CSM, both during operation and post closure.

3.3.1 Direct

Direct exposure of receptors to contaminants may occur in the form of dust inhalation/ingestion, ingestion of contaminated water or dermal contact with contaminated material or water. Dust and air quality factors are managed separately on site and are not considered as part of this CSM.

Other direct exposure is the ingestion of potentially contaminated fauna or flora (bushtucker). As a result of health and safety management during construction and operations this not likely to a route of exposure for site workers, but may be a pathway after closure if members of the community gain access to the site.

3.3.2 Seepage and leaching

Leaching refers to the incidental movement (seepage) of water through disturbed material, either rock or tailings in constructed landforms or backfill, such that dissolved constituents are transported away from the material to another pathway or receptor. Seepage is distinct from runoff in that runoff is more of a temporary, surface water flow during or just after rain events, while leaching and seepage may have a different water source e.g. tailings slurry or groundwater, and maintains residence in the source material for a longer period of time than runoff, in the pores where oxidation and hydrolysis is taking place, and is thus the quality potentially changed more than runoff. Runoff is thus considered as part of surface water flow. Leached parameters could include, but are not limited to: acidity generated by oxidised sulfide minerals, soluble major ions and minor or trace metals or non-metals. Suspended material is not considered to be leached, but rather eroded. Leaching may occur during operations and post-closure.

3.3.3 Groundwater flow

The flow of groundwater through the sub-surface environment under both natural gradients (pre-mining), induced, pumped gradient (operations) or recovering gradients (post-closure) presents a potential pathway for the migration of leached parameters and constituents not *naturally* present, or elevated at concentrations above those naturally occurring.

3.3.4 Surface water and runoff

Surface water is a pathway to transport any leachate, or dissolved material on or above the surface / final post-closure landscape downstream to potential receptors. Seepage may interact with surface water, which in turn may interact with groundwater under gravity horizontal flow. As a result of the ephemeral nature of surface water in the Pilbara, the majority is not permanent water but is lost to either evaporation or deeper groundwater.

3.4 Receptors and other risks

The following sections discuss each of the potential receptors that have been identified as part of this CSM, both during operation and post closure. A receptor may be any factor that is negatively affected by contamination caused by the mining operation. Of the potential receptors identified, Table 5 summarises those that are to be considered further as part of this CSM during operations and post-closure.

Table 5: Summary of potential receptors for operations and post-closure

Potential Receptor	Operations	Closure	Comment
Site Workers	YES	NO	Only present during operations, only direct contact considered (e.g. ingestion of contaminated material).
Pastoralists/Other	NO	YES	Access to mine site restricted during operations only direct contact considered (e.g. ingestion of contaminated material)
Tertiary Detrital Aquifer	YES	YES	Potential receptor during operations and post closure
Mineralised Brockman Aquifer	YES	YES	
Wittenoom Aquifer	YES	YES	
Surface Water	YES	YES	Potential source and receptor during operations and post closure
Soil	NO	NO	Soil onsite is safe guarded by stockpiling while soil impacts offsite are represented by surface water impacts
Native Vegetation	YES	YES	These potential receptors are listed and described here for the sake of a complete assessment of all potential sources but are outside of the scope of this CSM
Terrestrial Fauna	YES	YES	
Subterranean Fauna	YES	YES	
Heritage sites	YES	YES	
Ecological degradation	YES	YES	
Regulatory risk	YES	YES	
Reputation risk	YES	YES	
Financial risk	YES	YES	

3.4.1 Site workers

Although management practices and site procedures during operations aim to limit the exposure of site workers to harm and potential contaminants there remains a possibility that contact may occur with the sources identified previously. Post-closure, site workers will not be present and as such this receptor shall only be considered for the operational scenario in this CSM.

3.4.2 Environmental value

The environmental value of an area is defined as the beneficial use of the land and the health of the ecosystem. An area that has a highly degraded ecosystem or has no particular beneficial use, in this case with respect to water quality, has a lower environmental value. Preservation of environmental values requires assessment of natural background variability, prior to disturbance of water resources and an assessment of current use impacts. Environmental values for water are values that define the end use of the water resource (EPA, 2016). Proposed activities should not lead to degradation of surface water or groundwater quality that would impact on future and current users.

The current beneficial use of the area is for agriculture - pastoral grazing, mining and Aboriginal cultural observance.

Existing mining operations located in close proximity (including Fortescue's Solomon Mine, Rio Tinto's Silvergrass and Brockman/Nammuldi operations) are likely to have had some negative impact to the environmental value of the water quality. There are no known significant water bodies or ecosystems on or near the site or in the area, which has already been impacted by farming and mining. There is no known water that is used for drinking purposes, commercial activity, recreation, of cultural or aesthetic value downstream of the proposed project. Potential future landuse would likely revert to stock farming. As such the environmental value of this area is not considered to be highly significant.

3.4.3 Pastoralists, public, Shire of Ashburton, indigenous and future land users and other stakeholders

During operations, access to the site by pastoralists and other site users is managed and restricted, particularly in the active mining areas. Post-closure these restrictions will not be maintained and contact with the sources identified previously may occur. For the purposes of this CSM these receptors shall only be considered for the post-closure scenario. Only potential contamination issues from direct contact with rock materials are addressed here and the safety of the public from other hazards is not considered in this CSM.

Unauthorised access to the site is controlled during site operations and as a result pastoralists, the indigenous and local community are not considered to be direct receptors during operations, only in the post-closure scenario.

3.4.4 Other downgradient land/tenement and water users

Downgradient tenements and water users may be potential receptors of any rock or tailings material or water contamination offsite. The most likely vector of potential contamination would be surface or groundwater and as a result, downgradient users are not considered as a separate receptor in the risk assessment. Water quality is at present assessed on more ecologically stringent limits than any human or livestock receptors would require.

3.4.5 Aquifers

The geological and hydrogeological models have identified three discrete aquifers which could be considered receptors;

- Shallow unsaturated Tertiary Detrital Aquifer/palaeochannel, may not recover following closure, may provide connection between compartments in times of high precipitation and infiltration;
- Mineralised Brockman Formation Aquifer; and
- Wittenoom Formation Aquifer.

For the purposes of this CSM all three aquifers highlighted above are considered potential receptors for the both the operational and post-closure scenarios of this CSM.

3.4.6 Drainage channels

Surface waters and groundwaters of catchments containing mineral resources often show elevated baseline solute concentrations due to their geologic provenance. Since aquatic ecosystems are likely to represent the highest use value for waters affected by AMD water quality guidelines and targets should take into account the conservative measures based on toxicology as well as the site specific environment. In arid environments tolerance for high salt and metals loads by ecological receptors is also a factor for consideration.

The existent water quality guidelines provide protection for sustained (chronic) exposures to toxicants, as well as opportunity and access to potential sources has to be considered, as well as evapoconcentration resulting in concentrations that may reach acute toxicity.

The risk assessment has considered rainfall events of at least a 1:100 annual return interval during the operating life of the mine and the following surface water scenarios:

- the immediate flushing by precipitation events of evapoconcentrated salts and metals and waste materials stored on site by direct runoff and contact with flowing surface water;
- the production of leachate and seepage after a rain event; and
- The percolation of infiltrated rainfall through waste containing soluble oxidation products, as well as to the shallow surface water dependent aquifer.

Specific surface water receptors considered in this risk assessment are:

- The ephemeral Pinarra Creek: a minor tributary to the Boolgeeda Creek which is situated in the central Eliwana valley, as well as other unnamed minor tributaries that occur onsite;
- The ephemeral Boolgeeda Creek: to which most minor tributaries present on site eventually connect; and
- The ephemeral Duck Creek which flows past the western boundary of the site and into which upstream mines discharge excess water.

3.4.7 Soil

Soil is a potential receptor of any rock or tailings material or water contamination on and offsite. In marginal arid environments a decrease in soil quality either by erosion, salinisation or metal contamination could severely impact ecosystems.

On site, soil quality is preserved by stripping off topsoil in impacted areas and stockpiling for use as a growth medium when rehabilitation is conducted. Off site, the most likely vector of potential contamination would be surface or groundwater and as a result, soil is not considered as a separate receptor in the risk assessment.

3.4.8 Native flora

Large portions of the project area are used for pastoral grazing and substantial mineral exploration has been undertaken in localised areas. The condition of vegetation within the ranges from Completely Degraded/Cleared to Excellent, with the majority falling within the Very Good – Excellent categories. No Priority 1 flora or declared rare species have been observed.

Native Vegetation may be impacted as a consequence of leaching, seepage, weathering of waste material, contamination of water resources and dewatering or excavation activities during operations. Consideration of native vegetation as a receptor of contamination has been conducted as part of the environmental impact assessment and is not included in this risk assessment, but considered here as a potential receptor for rigour.

3.4.9 Terrestrial fauna

Terrestrial Fauna may be impacted as a consequence of leaching, seepage, weathering of waste material, contamination of water resources and dewatering or excavation activities during operations. Some threatened fauna that may occur in the area are the Northern Quoll, Night Parrot, Pilbara Olive Python and the Leaf-Nosed and Ghost Bats

Other impacts to fauna may be an increase in avian species as a result of additional surface pools, as well as an increase in predation and feral alien species. Terrestrial animals need to be considered as receptors as they can bioaccumulate and/or biomagnify certain elements (for example, cadmium, mercury and selenium) by consuming water, aquatic animals and plants. Consideration of terrestrial fauna as a receptor of contamination has been conducted as part of the environmental impact assessment and is not included in this risk assessment, considered here listed as a potential receptor for rigour.

3.4.10 Subterranean fauna

Subterranean fauna may be impacted as a consequence of leaching, seepage, weathering of waste material, contamination of water resources and dewatering or excavation activities during operations. Consideration of subterranean fauna as a receptor of contamination has been conducted as part of the environmental impact assessment and is not included in this risk assessment, but considered here as a potential receptor for rigour.

3.4.11 Heritage sites

Heritage site may be impacted as a consequence of leaching, seepage, weathering of waste material, contamination of water resources and dewatering or excavation activities during operations. The potential of heritage sites to be disturbed has been conducted as part of the environmental impact assessment and is not included in this risk assessment, but considered here as a potential receptor for rigour.

3.4.12 Ecological degradation

Ecological degradation refers to the accumulated impact of several different land uses and users all contributing minor or major impacts that contribute collectively to the environment becoming unable to sustain a viable ecology. The potential for cumulative ecological degradation is addressed in the environmental impact assessment and is not included in this risk assessment, but considered here for rigour.

3.4.13 Regulatory risk

The regulations that must be adhered to by law are given in the Environmental Protection and Biodiversity Conservation Act (1999) but provide general direction as to preventing environmental harm. Specific guidelines are followed in the risk assessment with reference to the *Preventing AMD* handbook (DIIS, 2016a), the *National Environmental Protection Measures for the Assessment of Site Contamination* (NEPM, 2013) and the general closure principals that final landforms must be safe, stable, non-polluting and capable of sustaining an ecosystem. In addition the author of this risk assessment is qualified and certified in site contamination investigation (EIANZ CEnvP. Site Contamination Specialist).

While there is a risk that prior to mine closure regulations may change, receptors may be deemed more significant, or some other unforseen risk arises, the assessment has been conducted on the precautionary principle and is intended to safeguard against such possibilities. As such the potential for regulatory changes to impact the successful closure of the project is low and not included in the risk assessment but considered here for rigour.

3.4.14 Financial risk

The closure liability for each mine site is included in any assessment of the viability and cost of each project, and accounted for prior to operation. In addition progressive rehabilitation is conducted on site when the disturbance of individual, smaller areas has ceased. As such the potential for reduced finances is not included in the risk assessment but considered here for rigour.

3.4.15 Reputational risk

There is the potential for a poorly or incorrectly assessed project to damage the reputation of the mining industry, the scientific community and government oversight bodies, in general, and the Fortescue corporate commitment to responsibility for the land and community, specifically, such that public trust in environmental impact assessment to mitigate the harmful effects of industrial development is eroded, and the process is opposed. While full scientific certainty and prediction can never be achieved in a complicated and highly heterogeneous environment, this lack is not used as a reason to conduct an activity or postpone the implementation of adequate control measures. As such the potential damage to reputation is not included in the risk assessment but considered here for rigour.

4. RISK ASSESSMENT

In order to minimise AMD risk the results from the geochemical testwork, geological distribution of ore, geotechnical data as well as surface and groundwater considerations have been incorporated into the mine planning design. This integrated approach is required to be conducted with the knowledge and expertise of geochemical and contamination issues as strict compliance with regulatory guidelines does not necessarily reduce risk. No legislation can adequately account for all potential geological and mining scenarios or risks to the environment, and guidelines only provide a strategic outline for how to address general concepts. While Australian and international references have been heavily relied on for this assessment, the conclusions, risks, recommendations and management options are entirely site specific.

4.1.1 Purpose

The purpose of a geochemical risk assessment is to highlight all potential risks to internal and external stakeholders such that the mitigation of risks is a collaborative effort where the best strategies are utilised to reduce harm and the most efficient use of resources is implemented. Mining operations are capital intensive and inherently hazardous and operational failures can be costly with significant impacts on the environment, if geochemical risk is not affectively assessed and managed (DIIS, 2016b). The goal of any risk management strategy is the sustainability of the environment while operating a successful business and being responsible for social and ecological aspects.

4.1.2 Method

The geochemical study was conducted in a phased approach whereby characterisation increased in detail. The preliminary assessment highlighted key issues and provided detail on other factors such as the ore deposit geology, climate, topography, surface and groundwater regimes and hydrogeology as well as pertinent mining detail, such as waste rock volumes and method of production and beneficiation. The detailed characterisation provided further information concerning where deleterious material is located, whether it remains in the wall rock, or will be excavated to waste, along with what potential for acid drainage exists, likely soluble metals, potential transport pathways and risk to water resources. Based on these considerations the risk of specific material located in the landscape and the likely connection to pathways has been assessed.

The risk matrix is given below in Table 6 with each category given a rating out of seven for severity has been adapted from *Preventing Acid and Metalliferous Drainage* (DIIS, 2016c). A detailed description of the consequence, likelihood, duration and extent categories used for this assessment is given, with terminology definitions, in Tables 7, 8, 9, 10 and 11. The maximum possible risk rating would be a value of 2,401 which is the maximum severity of seven for all four categories multiplied i.e. 7 x 7 x 7 x 7.

The maximum risk rating for each risk level is the value when two of the four factors are in the next category (i.e. 1 x 2 x 2 x 1 = 4, 5 x 4 x 5 x 4 = 400 etc.). As a result of the multiplication of categorisation factors, not every number in the range of risk ratings is possible (i.e. prime numbers greater than 11 do not occur).

Table 6: Risk rating matrix

Lvl	Consequence	Likelihood	Duration	Extent	Risk Rating	Risk Level Description
1	Insignificant	Extremely Remote	Hours	Immediate	1 to 4	Very Low
2	Slight	Remote	Days	Confined	5 to 36	Low
3	Intermediate	Rare	Weeks	Limited	37 to 144	Minor
4	Medium	Unlikely	Months	Internal	145 to 400	Moderate
5	Significant	Possible	Years	Local	401 to 900	High
6	Very Significant	Likely	Decades	Catchment	901 to 1764	Serious
7	Severe	Almost Certain	Centuries	Regional	1765 to 2401	Extreme

Table 7: Consequence Categories

Rating Level	Health and Safety	Social and Natural Environment	Reputation and Brand	Compliance
1	No medical treatment required.	Insignificant damage of low significance.	Public concern restricted to local complaints about Fortescue brand.	Low level legal issues.
2	No medical treatment required.	Slight effects on biological or physical or social environment.	Minor, adverse local public or media attention and complaints about Fortescue brand.	Multiple minor breaches of laws or regulations and potential complaints.
3	Minor first aid – no disabling.	Intermediate effects but not affecting ecosystem function or ongoing social issues.	Attention from local media and/or heightened concern by local community complaints.	Minor breach of laws or regulations could result in civil litigation. Closure delayed
4	Disabling incident requiring medical treatment with no permanent impact.	Medium environmental effects or ongoing serious social issues.	Independent review of outcomes required. Significant adverse national media and public attention impacting on Fortescue brand and shareholder brand.	Single significant breach of laws or regulations resulting in litigation and potential class actions. Relinquishment delayed
5	Serious (permanent) disabling injury that was life threatening – “near miss”.	Significant environmental impairment of ecosystem function or ongoing widespread social impacts.	Serious public or media outcry International coverage with significant impact on Fortescue brand and shareholder brand	Multiple significant breaches of laws resulting in major civil litigation, fines and penalties.
6	A fatality or very serious irreversible injury to a small number of people in localised area.	Very significant impact on highly valued species, habitat, or eco system or breakdown in social order.	International media condemnation with major impact on Fortescue brand and shareholder brand.	Major breach of laws or regulations. Potential fines and criminal prosecutions. Temporary closure of operating sites.
7	Multiple fatalities or very serious irreversible injury to multiple persons in localised area.	Severe impact on highly valued species, habitat or eco system or complete breakdown in social order.	Prolonged international condemnation with permanent damage to Fortescue brand and shareholder brand.	Objective impossible to achieve. Multiple major breaches of laws resulting in imprisonment of executives/directors. Loss of licence to operate.

Table 8: Likelihood

Rating		Qualitative Description	Probability
1	Extremely Remote	Not expected in most circumstances: Less than once in 100 years	<1%
2	Remote	Not expected to occur: Once in 100 years	1%-10%
3	Rare	May occur in exceptional circumstances: Once in 50 years	10%-25%
4	Unlikely	Could occur at some time: Once in 25 years	25%-50%
5	Possible	Should occur at some time: Once in 10 years	50%-75%
6	Likely	Probably occur in most circumstances: At least once in 2 years	75%-90%
7	Almost certain	Occurs in most circumstances: At least once per year	>90%

Table 10: Duration

Timeframe		Description
1	Hours	Negligible issue such as a spill, clean up/ resolved immediately
2	Days	Brief issue will attenuate naturally within days or require minimal attention
3	Weeks	Minor occurrence - can be resolved with a few weeks of action
4	Months	Moderate action required
5	Years	High consequence - large and sustained response required to resolve
6	Decades	Serious occurrence - management strategy and mine plan response required
7	Centuries	Severe action - rehabilitation and relinquishment impacted, liability not able to be ended

Table 11: Extent of disturbance

Distance		Description
1	Immediate	Several metres
2	Confined	Small area affected
3	Limited	Minor area, up to half of footprint
4	Internal	Will not exceed disturbance footprint
5	Local	Travel off disturbance footprint for some distance <10-20 km
6	Regional sub-catchment	Extended area of up to 100 km
7	Regional Basin	Large extent affected >100 km

Table 9: Key Definitions

Term	Definition
Action	Defined tasks and/or plans required to further mitigate the risk in addition to the existing risk mitigation strategies
Cause	Contributing internal or external factors which lead to a risk event occurring.
Consequence	The cumulative impact that is expected to arise should the risk event occur within the defined timeframe. This should consider both positive opportunities and negative impacts
Control	An activity that reduces or prevents (preventative controls) the likelihood of risk event or eliminates or reduces the impact on the business (mitigating controls) if the risk event occurs.
Control Owner	Person responsible for ensuring that a control is operating and / or further action is implemented
Hazard	Maximum reasonable outcome (consequence) given the current level of knowledge and effectiveness of implemented controls.
Inherent Risk Rating	Measure of the current risk given what has been implemented / constructed on site, the current level of knowledge and effectiveness of implemented controls.
Likelihood	Assessment of the probability and/or frequency of the event occurring with the expected consequence within the defined timeframe.
Residual Risk Rating	Measure of the risk remaining taking into consideration planned and/or implemented controls and other risk management strategies. The calculation of residual risk should assume that identified risk mitigation strategies (including controls) are operating effectively.
Risk	Negative effects from an uncertain future event or circumstance where Fortescue has limited ability to control the occurrence of the risk with the consequential impact to the business being mitigated by appropriate risk management strategies
Risk Owner	Person or function with the accountability and authority to manage a risk
Risk Response Plan	A defined set of activities or processes to manage the risk to an acceptable level. This would normally include the critical preventative and mitigating controls related to the risk
Status	State of whether an action or control is open/planned, completed/implemented or rejected/expired respectively

Table 12 gives the results of the risk assessment for operations, while Figure 5 shows the connections between source, pathways and receptors in operations.

All relevant potential sources of contamination are assessed for each likely transport pathway and each likely potential receptor. The unmitigated (inherent) risk is rated based on the severity of the consequence that specific geochemical contaminants identified in the characterisation program would pose, the likelihood that such contaminants or transport pathway would occur, the duration a potential source or pathway may exist and the extent of distance that a pathway might affect.

The risk is then described and options for mitigations are described when the risks are moderate or higher. The risk was then reassessed assuming the described mitigation scenario was successful, to provide an indication of the potential to manage the risk. Further work is recommended where risk mitigation strategies have the potential to reduce risks to an acceptable level.

All risks that are rated as minor to serious have been indicated to require management (there are no extreme risks).

Table 12: Summary of conceptual site model during operations (A3 size page)

Source	Specific concern	Transport	Potential Receptors	Consequence	Likelihood	Duration	Extent	Unmitigated Risk Rating	Description of risk and mitigation measures to reduce risk during operations	Mitigated Risk Rating
Construction material	Acid generation and neutral/ alkaline drainage containing aluminium, arsenic, selenium and zinc with minor chromium, copper, manganese and nickel	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to construction material will occur during the construction phase and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	1	2	3	2	12	***Low Risk*** that leaching of contaminants from construction material could reach the aquifer. The potential area of impact is limited to the immediate vicinity of the source by a low likely volume of seepage, and capture by nearby dewatering.	-
			Mineralised Brockman Aquifer	1	1	3	1	3	***Very Low Risk*** that leaching of contaminants from construction material could reach the aquifer. The potential area of impact is limited to the immediate vicinity of the source by a low likely volume of seepage, and capture by nearby dewatering.	-
			Wittenoom Aquifer	1	1	3	1	3	***Very Low Risk:*** Very low risk that leaching of contaminants from construction material could reach the aquifer. The potential area of impact is limited to the immediate vicinity of the source by a low likely volume of seepage, and capture by nearby dewatering.	-
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	3	2	6	2	72	**Minor Risk** that construction material runoff will come into contact with creeks and surface water channels. They will be diverted around constructed landforms to avoid damage, however the duration of the presence of construction material will last for the life of mine. The consequence of this risk can be **reduced to *Low Risk*** by avoiding the use of any deleterious shale material as construction rock	**24**
			Boolgeeda Creek	1	1	6	1	6	***Very Low to Low Risk*** that construction material will come into contact with creeks and surface water channels. They will be diverted around constructed landforms to avoid damage, however the duration of the presence of construction material will last for the life of mine. Mitigation not required	-
			Duck Creek	1	1	1	1	1		-
Aboveground waste rock landforms	Acid generation and neutral/ alkaline metalliferous drainage containing aluminium, arsenic, manganese, selenium and zinc with minor beryllium, cobalt and thallium	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to waste rock will occur during operations and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	5	7	7	5	1050	***Serious Risk*** that deleterious waste rock can oxidise and cause AMD if not properly disposed of in the waste rock landform. The consequence, likelihood and extent can be **mitigated to *Low Risk*** if WRL design and waste scheduling is carefully managed and maintained to prevent the ingress of oxygen and water as the duration of WRL will remain centuries	**28**
			Mineralised Brockman Aquifer	2	3	1	2	12	***Low Risk*** that leaching of contaminants from waste rock material could reach the aquifer. The potential area of impact is limited to the immediate vicinity of the source by a low likely volume of seepage, and capture by nearby dewatering or only reaching the shallow groundwater aquifers.	-
			Wittenoom Aquifer	2	3	1	1	6		-
		Surface water and runoff	Runoff	6	6	7	3	756	***High Risk*** that runoff from waste rock will cause AMD if not properly disposed of in the landform. The consequences, likelihood and extent can be mitigated if the WRL is properly designed with only benign, water shedding, material as cover but the duration of WRL will remain centuries and as a result the risk can be **mitigated to *Low Risk***	**28**
			Pinarra Creek and other minor onsite tributaries	5	6	7	3	630	***High Risk*** that the Pinarra Creek, which is situated in the centre of the mining footprint, will be heavily impacted by either runoff or flow interruption. The consequence of this impact can be reduced to insignificant with properly managed WRLs and because the Pinarra Creek is not of specific ecological importance. The risk can be **reduced to *Minor Risk***	**126**
			Boolgeeda Creek	4	3	7	3	252	***Moderate Risk*** that the Boolgeeda Creek, downgradient of the mining footprint will be impacted either by runoff or interruption of flow. It is likely that significant runoff will only result after large rainfall events in which any metal or salt load is likely to be diluted, however planned WRLs are situated in tributaries and material locations and compactions must be carefully planned to reduce the consequence and likelihood to insignificant and remote, respectively, in order for the risk to be **reduced to *Low Risk***	**42**
			Duck Creek	3	2	7	2	84	***Minor Risk*** that the Duck Creek, further downgradient of the mining footprint will be impacted either by runoff or interruption of flow. It is likely that significant runoff will only result after large rainfall events in which any metal or salt load is likely to be diluted as a result the consequence can be reduced to insignificant and the risk **reduced to *Low Risk***	**28**
Ore stockpiles	Aluminium, iron, manganese, selenium, thallium and zinc	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to waste rock will occur during operations and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	1	6	2	1	12	***Low Risk*** that seepage of contaminants from ore stockpiles could reach the aquifer. The potential area of impact is limited to the immediate vicinity of the source by a low likely volume of seepage, and capture by nearby dewatering or only reaching the shallow groundwater aquifers.	-
		Surface water & runoff	Pinarra Creek & tributaries	1	4	2	1	8	***Low Risk*** that ore runoff will come into contact with creeks and surface water channels. These will be diverted around stockpiles to avoid product loss and mitigation is not required	-
			Boolgeeda Creek	1	2	2	3	12		-
			Duck Creek	1	1	2	5	10		-
Sub-grade ore stockpiles	Acid generation and aluminium, iron, manganese, selenium, thallium and zinc	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to sub-grade ore will occur during operations and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	3	5	7	2	210	***Moderate Risk*** that deleterious sub-grade ore can oxidise and cause AMD seepage if not properly stored. The consequence, likelihood and extent can be **mitigated to *Low Risk*** if sub-grade ore (specifically basal Dales Gorge Member unit D1) is assessed for AMD drainage potential prior to storage or sent to waste disposal instead, if the risk is high, and the stockpiles are capped with benign material on closure, as the duration of ore stockpiles my remain for centuries	**28**
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	2	5	7	2	140	***Minor Risk*** that deleterious sub-grade ore can oxidise and cause AMD runoff if not properly stored. The consequence, likelihood and extent can be **mitigated to *Low Risk*** if sub-grade ore (specifically basal Dales Gorge Member unit D1) is assessed for AMD drainage potential prior to storage or sent to waste disposal instead if the risk is high, and the stockpiles are capped with benign material on closure, as the duration of ore stockpiles my remain for centuries	**14**
			Boolgeeda Creek	2	1	2	4	16	***Low Risk*** that the Boolgeeda and Duck Creeks, downgradient of the mining footprint will be impacted by runoff. A significant volume of runoff could only reach these creeks during a very large event which would result in any metal or salt load being highly diluted.	-
			Duck Creek	1	1	2	5	10		

Tailings storage facilities	Early stage uncertainty and minor chromium drainage	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to tailings ore will occur during operations and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	1	6	5	2	60	***Minor Risk*** from tailings seepage into the Tertiary Aquifer. The water quality is unlikely to be poor and thus the consequence is low, however the likelihood and duration cannot be mitigated, the extent could be reduced by slurry return and dewatering operations to **mitigate to Low Risk**.	30
			Mineralised Brockman Aquifer	1	6	1	1	6	***Low Risk*** from tailings seepage to this aquifer: while the likelihood of seepage occurring is high, the quality is unlikely to adversely impact the aquifer and the consequence of any seepage is low.	-
			Wittenoom Aquifer	4	6	5	3	360	***Moderate Risk*** from tailings seepage into the Wittenoom Aquifer. The seepage may cause AMD if coming into contact with pyritic shale material and thus the consequence is higher and the likelihood and duration cannot be mitigated. The only mitigation measure available is to avoid this scenario by siting the TSF away from any pyritic shale material and reducing seepage volume by dewatering operations and efficient water return to **reduce to Low Risk**.	30
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	1	5	5	1	25	***Low Risk*** from tailings seepage into the Pinarra Creek. While the likelihood of seepage occurring is high, the quality is unlikely to adversely impact the aquifer and the consequence of any seepage is low.	-
			Boolgeeda Creek	1	1	2	3	6	***Low Risk*** that the Boolgeeda and Duck Creeks, downgradient of the mining footprint will be impacted by tailings seepage as the distances are too great. A significant volume of seepage could only reach these creeks during a very large, rare event which would result in any metal or salt load being highly diluted.	-
			Duck Creek	1	1	2	5	10		-
Mine void wall rock	Acid generation and neutral/ alkaline drainage containing aluminium, arsenic, manganese, selenium and zinc with minor beryllium, cobalt, chromium, copper, thallium and nickel	Seepage	Shallow Tertiary Detrital Aquifer	3	2	6	1	36	***Low Risk*** from wall rock seepage into the aquifers during operations as any runoff will be captured in the mine void and dewatered.	-
			Mineralised Brockman Aquifer	3	2	6	1	36		-
			Wittenoom Aquifer	3	1	6	1	18		-
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	4	5	2	3	120	***Moderate Risk*** from wall rock seepage into the Pinarra Creek. There is a risk to water quality if West Angela Member shale is exposed in the walls of mine voids that are in connection with surface water. The consequence, likelihood and duration can be reduced if exposure is reduced and risk can be ***mitigated* to Low Risk**.	12
			Boolgeeda Creek	2	3	2	3	36	***Low Risk*** that the Boolgeeda and Duck Creeks, downgradient of the mining footprint will be impacted by wall rock runoff as the distances are too great. A significant volume of runoff could only reach these creeks during a very large, rare event which would result in any metal or salt load being highly diluted.	-
			Duck Creek	1	2	2	5	20		-
Backfill material: above or below water table waste rock or tailings storage	Acid generation and neutral/ alkaline metalliferous drainage containing aluminium, arsenic, manganese, selenium and zinc with minor beryllium, cobalt and thallium	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to backfill material will occur during operations and is managed through health and safety practices but has a very low risk of workers being effected by chemical contamination and does not require mitigation	-
		Seepage	Shallow Tertiary Detrital Aquifer	4	4	2	2	64	**Minor Risk** that deleterious backfill material can oxidise and cause AMD if not properly disposed of in backfill. The consequence, likelihood and extent can be **mitigated to Low Risk** if backfill design and waste scheduling is carefully managed and maintained to prevent the ingress of oxygen and water as the duration of backfill will remain centuries	16
			Mineralised Brockman Aquifer	4	4	2	2	64		
			Wittenoom Aquifer	2	2	2	1	8	***Low Risk*** that deleterious backfill can oxidise and cause AMD if not properly disposed of in backfill as interbedded shale units will reduce the permeability into the Wittenoom Aquifer.	-
		Groundwater Flow	Shallow Tertiary Detrital Aquifer	4	5	6	1	120	***Minor Risk*** that groundwater in contact with backfill can cause AMD if deleterious material is not properly disposed of in backfill. The consequence can be reduced if only benign material is used and **mitigated to *Low Risk***.	30
			Mineralised Brockman Aquifer	4	5	6	1	120		
			Wittenoom Aquifer	1	1	1	1	1	***Very Low Risk*** from groundwater in contact with backfill impacting the aquifer as interbedded shale units will reduce the permeability into the Wittenoom Aquifer.	-
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	4	6	2	3	144	***Minor Risk*** that backfill runoff into the Pinarra and Boolgeeda Creeks can cause AMD if deleterious material is not properly disposed of in backfill. The consequence can be reduced if only benign material is used and mitigated to Low Risk.	36
			Boolgeeda Creek	3	2	2	5	60		20
			Duck Creek	1	2	2	5	20	***Low Risk*** that Duck Creek downgradient of the mining footprint will be impacted by backfill runoff as the distance is too great. A significant volume of runoff could only reach these creeks during a very large, rare event which would result in any metal or salt load being highly diluted.	-
Dewatering discharge	Salinity	Direct	Site Workers	1	1	1	1	1	***Very Low Risk*** that direct exposure to dewatering discharge will impact site workers	-
		Surface water and runoff	Pinarra Creek and other minor onsite tributaries	2	2	5	2	40	***Minor Risk*** that dewatering discharge into the Pinarra Creeks will cause salinisation of creek system	-
			Boolgeeda Creek	1	2	5	2	20	***Low Risk*** that dewatering discharge into Duck and Boolgeeda Creek downgradient of the mining footprint will be impacted by increased salinity as the distance is too great.	-
			Duck Creek	1	2	5	2	20		

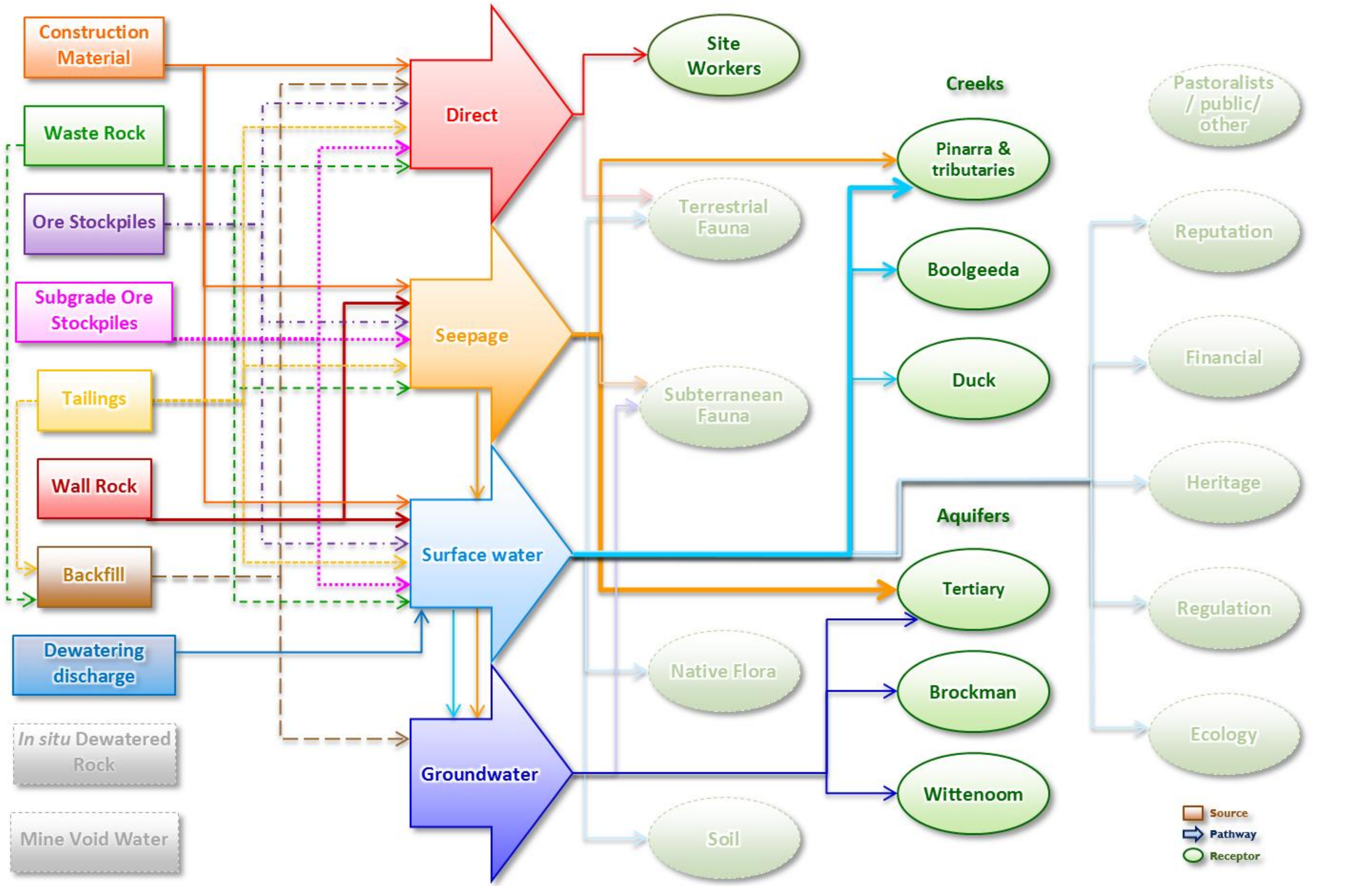

Figure 5: **Source-Pathway-Receptor connections during operations** (A3 size page)

4.1.3 Findings

The conceptual site model showing geology, mine voids and key transport pathways, is given in Figure 6. The compartmentalised nature of the pre-mining groundwater levels is shown along with the likely surface and groundwater movement for different scenarios. The northern mine void is representative of the Talisman and Broadway risks while the southern mine void represents the West End risks. This conceptual model is a general case and specific detail, such as mine void volumes and exact extents, is likely to change. The key factors that require management to mitigate risks are as follows:

- Mount McRae Shale and West Angela units should not be used as construction material.
- When aboveground waste rock landforms are constructed and designed, care should be taken to place Mount McRae Shale and West Angela Member shale material, so as to exclude oxygen and water.
- WRL should in general, not be situated in a floodplain. Where contact between surface drainage and WRLs is unavoidable, water should be excluded from contact with high risk material.
- Sub-grade ore stockpiles will be managed so that any ore material that may be acid generating such as basal Dales Gorge unit D1 will be assessed prior to storage.
- Tailings storage facilities should not be sited directly above pyritic shale units, as potential percolation of seepage into such units may cause acid and saline drainage.
- Dewatered or depressurised units as a potential source are not considered to pose a risk to the environment in the assessment.
- Waste rock landforms require planning and management to ensure that material that may generate acid or leach metals is excluded from contact with air and water. These materials include but may not be limited to Mount McRae Shale and West Angela Member shale.
- All mine voids will temporarily contain water from direct precipitation and runoff. This water is likely to be episodic, ephemeral or semi-permanent and will quickly infiltrate and evaporate. Salt build-up as a result is not expected to be high or to pose a risk of contamination in the event of a flushing episode.
- Permanent water will occur where mining is conducted below the pre-disturbance water level.
- Hydrological and hydrogeological modelling has indicated that groundwater-only dependent pit lakes will form in the West Side, West End, Eagles Nest and M6 (also called MM4-6) mine voids. The water quality is likely to deteriorate as a result of evaporation and runoff from Mount McRae and West Angela shale exposed in the wall rock and, over time, will contain high salinity and dissolved metals. These pit lakes will be terminal, evaporative sinks and are unconnected to any transport pathways or receptors. As such they are not considered to pose a risk to the environment, surface water or groundwater.
- There is no known transport pathway for potentially evapoconcentrated saline, acid and/or alkaline/neutral metalliferous pit lake water from the West Side, West End, Eagles Nest and M6 (also called MM4-6) mine voids to enter the environment and these sources are not considered to be a significant risk to the regional environment.

- The Talisman and Broadway East mine voids are likely to be in connection with both groundwater as well as ingress of creek flow but the risk of outflow is very low.
- The Talisman and Broadway East mine voids are highly likely to have inflows from both fresher surface water and more saline groundwater but will likely be evaporative sinks. Water quality will deteriorate over time as a result of evapoconcentration and potential exposure of West Angela Member shale in the footwall rock. There is a remote likelihood that very large, rare events of a 1:100-year's volume of rainfall will allow flushing and resumption of creek flow to occur. These events are unlikely to pose a risk of contamination from evapoconcentrated salts and metals as a result of the large dilution factor and high infiltration reducing the consequence and extent.
- The Broadway West mine voids are likely to be in connection with groundwater and creek flow and are almost certain to resume creek flow yearly, during seasonal rainfall events. This poses the greatest risk for the transport of potentially poor quality water.
- The highest risk for surface and groundwater contamination is posed by Broadway West mine voids. The risk of outflow is almost certain as a result of the larger rainfall catchment to which Broadway West is connected. This water may not undergo significant evapoconcentration as a result of significant dilution volumes but groundwater inflow is more saline naturally, there is some West Angela shale in the wall rock that may leach and impact the downstream environment.

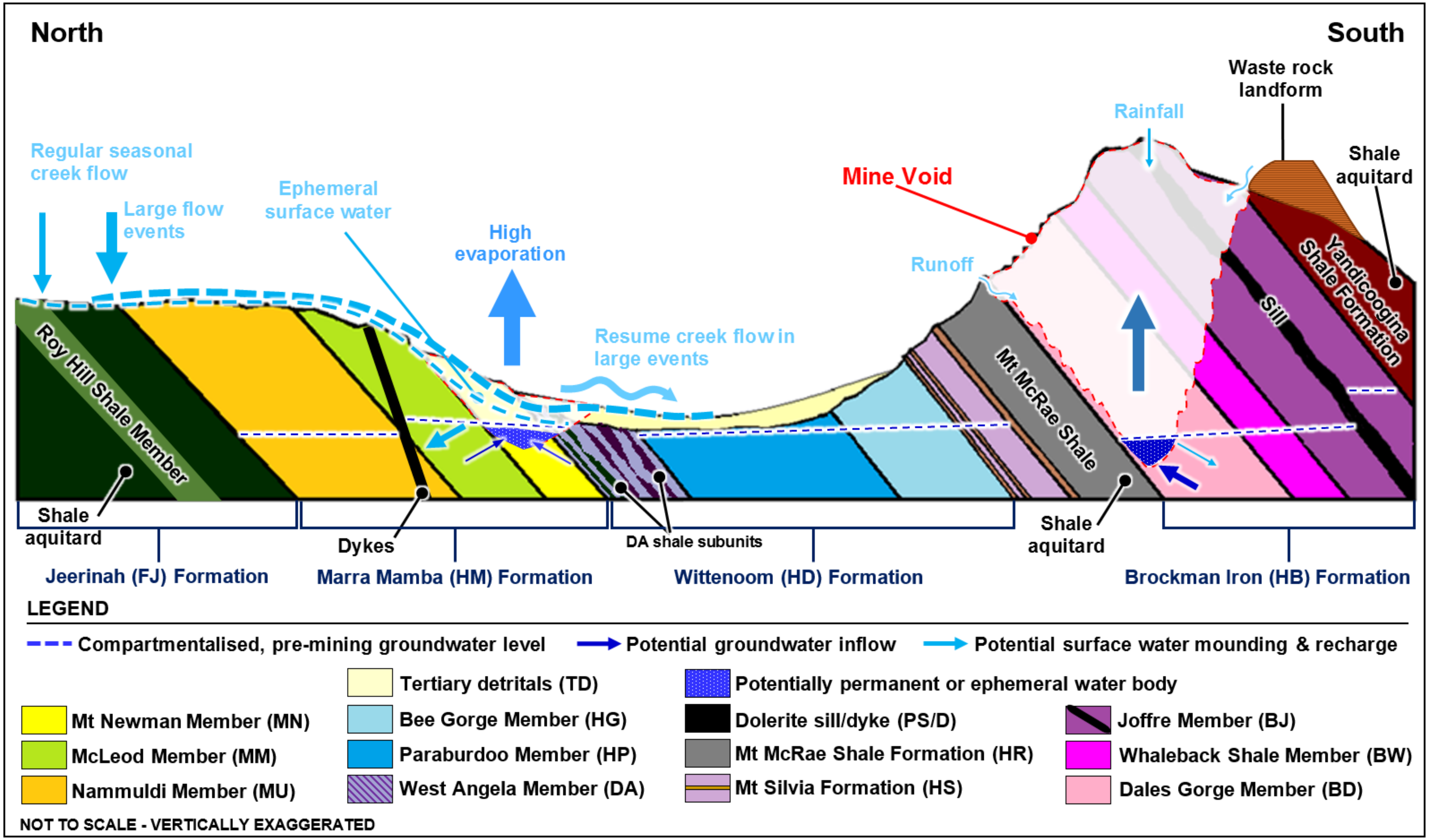

Figure 6: Conceptual Site Model

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