Water Management Plan

Stage 3 – Rum Jungle Rehabilitation Project

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1	23 Nov 2019	G. Farrer	Draft WMP Submission
2	25.Nov.2019	J .Hartnett	Review of Draft
3	26.Nov.2019	P. Delaney	Independent Peer Review
4	27.Nov.2019	J. Hartnett	Incorporate Peer Review Comments

Acronyms	Full form
AEP	Annual Exceedance Probability
AMD	Acid Metalliferous Drainage
AS	Australian Standards
AS/NZ	Australian and New Zealand Standards
BoM	Bureau of Meteorology
CWQOs	Construction Water Quality Objectives
DPIR	Department of Primary Industry and Resources
EBFR	East Branch of the Finniss River
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EMU	Environmental Monitoring Unit (DPIR group)
ESCP	Erosion and Sediment Control Plan
GDE	Groundwater Dependant Ecosystem
GL	Gigalitre
ha	Hectare
IECA	International Erosion Control Association
IFD	Intensity-Frequency-Duration design rainfalls
K	Hydraulic Conductivity
kL	kilolitre
LDWQOs	Locally Derived Water Quality Objectives
mAHD	Meters above Australian Height Datum

mBGL	Meters below ground level
ML	megalitres
NT	Northern Territory
NT EPA	Northern Territory Environmental Protection Agency
pH	Power of hydrogen
Project	Rum Jungle Stage 3 Rehabilitation Project
Q	Design flood peak discharge
RFFE	Regional flood frequency estimate
SIS	Seepage Interception System – installed around Intermediate and Main WRDs
TDS	Total dissolved solids
ToR	*Terms of Reference for Preparation of an Environmental Impact Statement – Rehabilitation of the former Rum Jungle mine site.*
TSS	Total suspended solids
WMP	Water Management Plan
WRD	Waste Rock Dump (existing)
WSF	Waste Storage Facility (planned)

Contents

1. Introduction

The Northern Territory Government (NTG; the Proponent), represented by the Department of Primary Industry and Resources (DPIR), proposes the rehabilitation of the former Rum Jungle Mine site (the project), located 6 km north of Batchelor, Northern Territory (NT). The project location and regional setting are shown on Figure 1-1 The purpose of the project is to restore water quality objectives within the East Branch of the Finniss River (EBFR) and improve onsite environmental conditions to support future land use as described in the Land Use Plan.

The Rum Jungle mine operated between 1954 and 1971 and produced 3,530 tonnes of uranium oxide and 20,000 tonnes of copper concentrate, as well as some nickel and lead products. The former mining and processing operations resulted in legacy landform, groundwater and surface water contamination, including significant acid and metalliferous drainage (AMD) issues and pollution of the East Branch of the Finniss River (EBFR). The site and downstream environs have been the subject of numerous phases of investigation, remediation and rehabilitation since the late 1970's, with the most significant rehabilitation works implemented between 1983 and 1986.

This Water Management Plan (WMP) covers all water treatment processes required to achieve the proposed Stage 3 Rehabilitation project objectives including the abstraction and treatment of historically contaminated groundwater and the treatment of surface waters impacted by the Stage 3 rehabilitation scope of works. This WMP forms part of the draft Environmental Impact Statement (EIS) submitted to the Northern Territory Environmental Protection Agency (NT EPA) for assessment under the *Environmental Assessment Act 1982 (NT)*.This WMP will be improved and further developed as detailed engineering design is further developed for this project. It is unlikely that material changes will be made to this plan however in the event that improved methods or technologies arise, these will be incorporated into future drafts of this WMP.

This WMP will form a foundation document for the Waste Discharge Licence that is likely to be required by the project. This WMP is proposed to provide detail on the management of water throughout the full rehabilitation and is structured as follows:

- Project description: details the rehabilitation strategy including construction sequence and construction components;
- Current state: details of the regional and site-specific current conditions, specifically related to water;
- Construction (Stage 3): details the scope of water management components throughout the construction period. Includes monitoring and reporting of water management; and
- Post-Construction (Stage 4): details the scope of maintenance and monitoring activities associated with water management, in the period following construction.

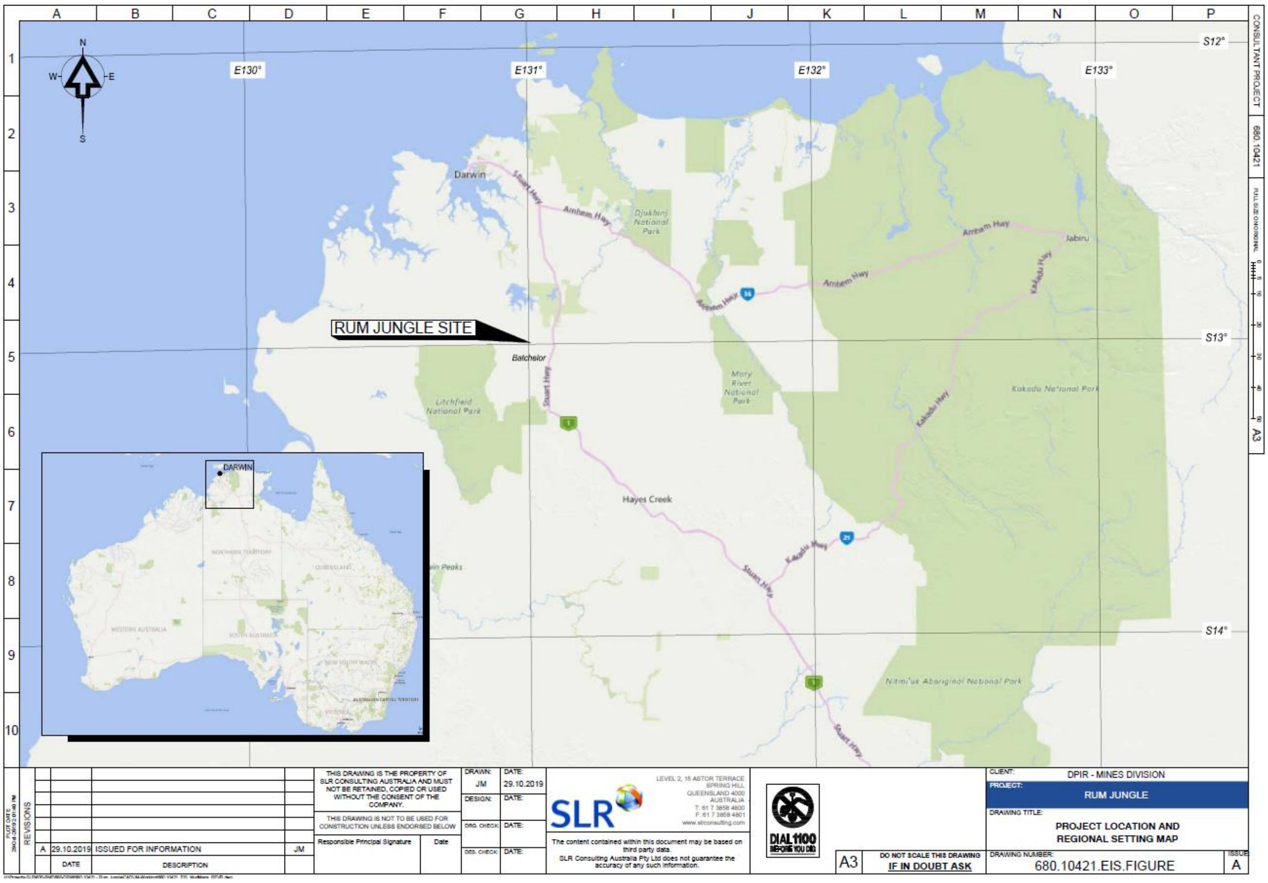


Figure 1-1 Rum Jungle Project Location

2. Proposal Description

The Project components were all formerly part of the Rum Jungle uranium field and consist of three land parcels as described here:

- Rum Jungle proper – Section 2968 Hundred of Goyder (vacant Crown land recommended for grant by the Aboriginal Land Commissioner Justice Toohey on 22 May 1981);
- Mt Burton – Section 998 Hundred of Goyder (estate in fee simple held privately); and
- Mt Fitch – within NT Portion 3283 (Crown Lease Perpetual 862 held by the Northern Territory Land Corporation).

Further, additional materials are required to undertake the Project. These materials are sources from two individual sites which are a component of the Project:

- Cover materials sourced from pre-disturbed land owned by CCGC; and
- Cover materials sourced from former sand mining areas which are located on FRALT.

The Overall Project Layout at Figure 2-1 shows each of the project components listed above.

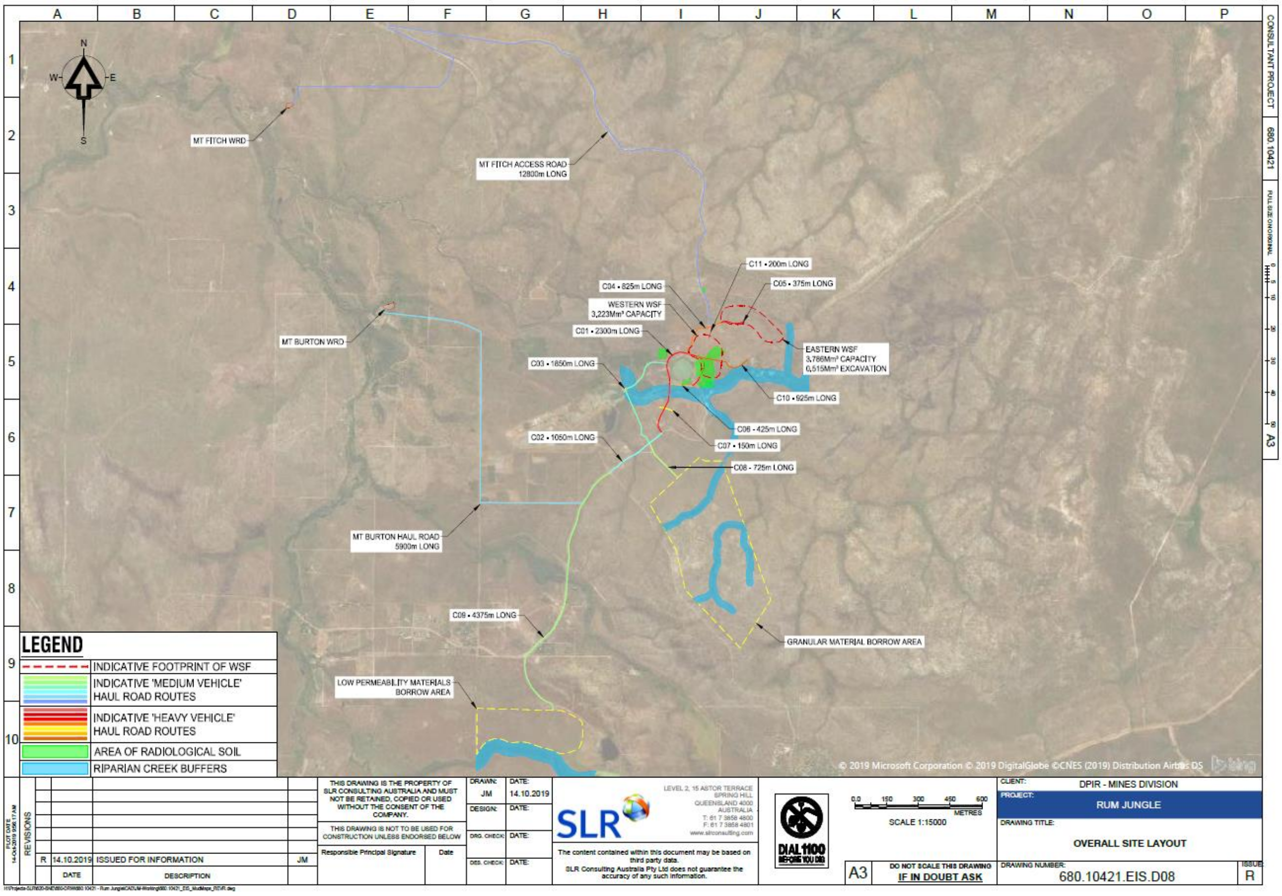


Figure 2-1 Overall Project Layout

Rehabilitation Objectives

Based on the over-arching intention to restore or remedy compromised environmental and cultural values, the Project's high-level objectives are two-fold and focus on environmental remediation and advancing the likelihood of resolution of the Land Claim as described below:

- Improve the environmental condition on site and downstream of site within the EBFR. This includes key outcomes:
  - Surface water quality conditions within EBFR in accordance with locally derived water quality objectives (LDWQOs)
  - Chemically and physically stable landforms.
  - Self-sustaining vegetation systems within rehabilitated landforms.
  - Physical environmental conditions supportive of intended land use plan.
- Improve site conditions to restore cultural values as far as possible and support potential future land use. This includes key outcomes:
  - Restore the flow of the EBFR to original course as far as possible.
  - Remove culturally insensitive landforms from adjacent to Sacred Sites and relocate ensuring a culturally safe distance from the Sacred Sites.
  - Return living systems including endemic species to the remaining landforms.
  - Preserve Aboriginal cultural heritage artefacts and places.
  - Isolate sources of contamination, including radiological hazards.
  - Maximise opportunities for Traditional Owners to work on site to aid reconnection to country.

Proposed Construction Sequence

The scope of this EIS is temporally constrained to the Stage 3 scope of works as described in this section and generally, this refers to the Construction and Post-Construction Stabilisation and Monitoring phases. The works associated with the Project Stage 2B, 4 and 5 deliverables are outside of the scope of the EIS however they are interdependent in achieving the overall project objectives over the short, medium and long term. The high-level cross-stage Project timeline is shown in Figure 2-2 where the EIS scope steps are shaded a darker blue than the out-of-scope works. Each of the Construction, Stabilisation and Monitoring steps are described below.

The estimated start date for this Project is difficult to determine as it must first be approved by Cabinet and is dependant variables outside of the Project control. Therefore, the Project Schedule at Figure 2-2 commences at year one rather than a specific year.

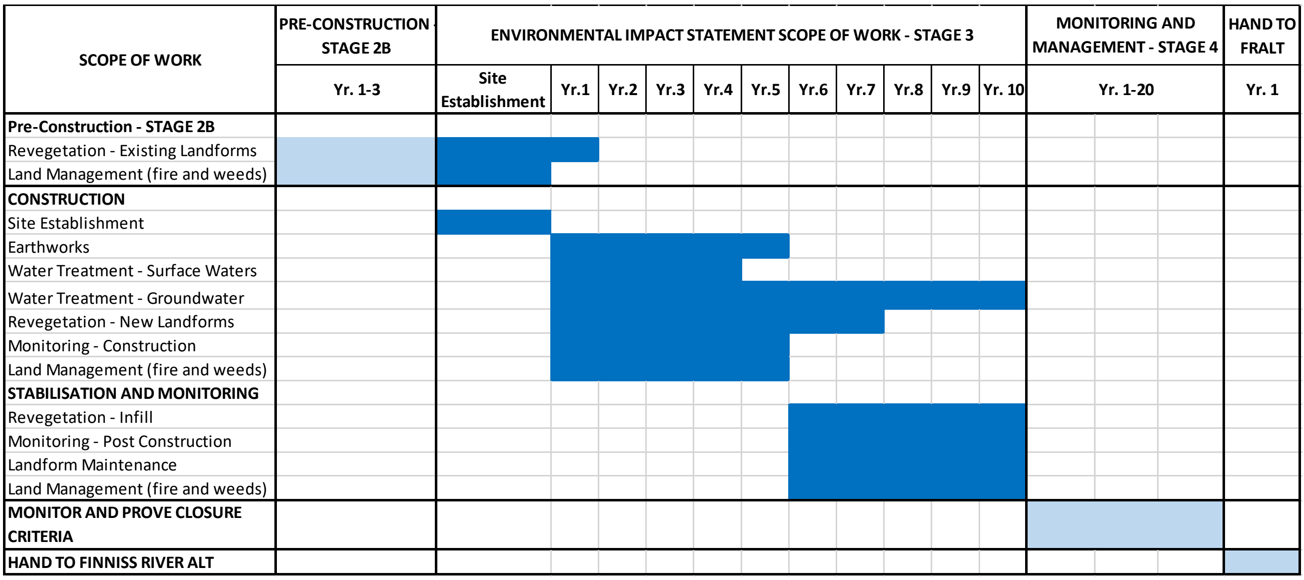


Figure 2-2 Rum Jungle Rehabilitation Project Schedule

2.1.1. Project Establishment

During the project establishment phase, focus will be on establishing project management systems and preliminary earthworks such as road upgrades, workshop facilities and haul road construction. Works to be carried out in Establishment include:

- New haul roads to be constructed to both avoid areas of importance (cultural, historical and environmental).The location of the haul roads are detailed on Figure 2-3.
- New or upgraded river crossings: several diversion channel, creek line and river crossings are required to facilitate site access during wetter months of the year. The location of river crossings has been selected to both avoid areas of importance (cultural, historical and environmental) and also reduce haul lengths to reduce greenhouse gas emissions and project costs. The location of the haul roads are detailed on Figure 2-3.
- Office compound facilities: The preference is to utilise existing office, ablution and laboratory facilities that are in place at the Brown's Oxide mine adjacent to site. If an agreement cannot be reached with the mine, it is proposed to locate office compound facilities adjacent to the workshop area.
- Other infrastructure: other infrastructure such as workshops and go-lines and the water treatment area are detailed on Figure 2-3. These locations have been selected primarily to avoid areas of importance (cultural, historical and environmental) but also to be practically located near to work areas.

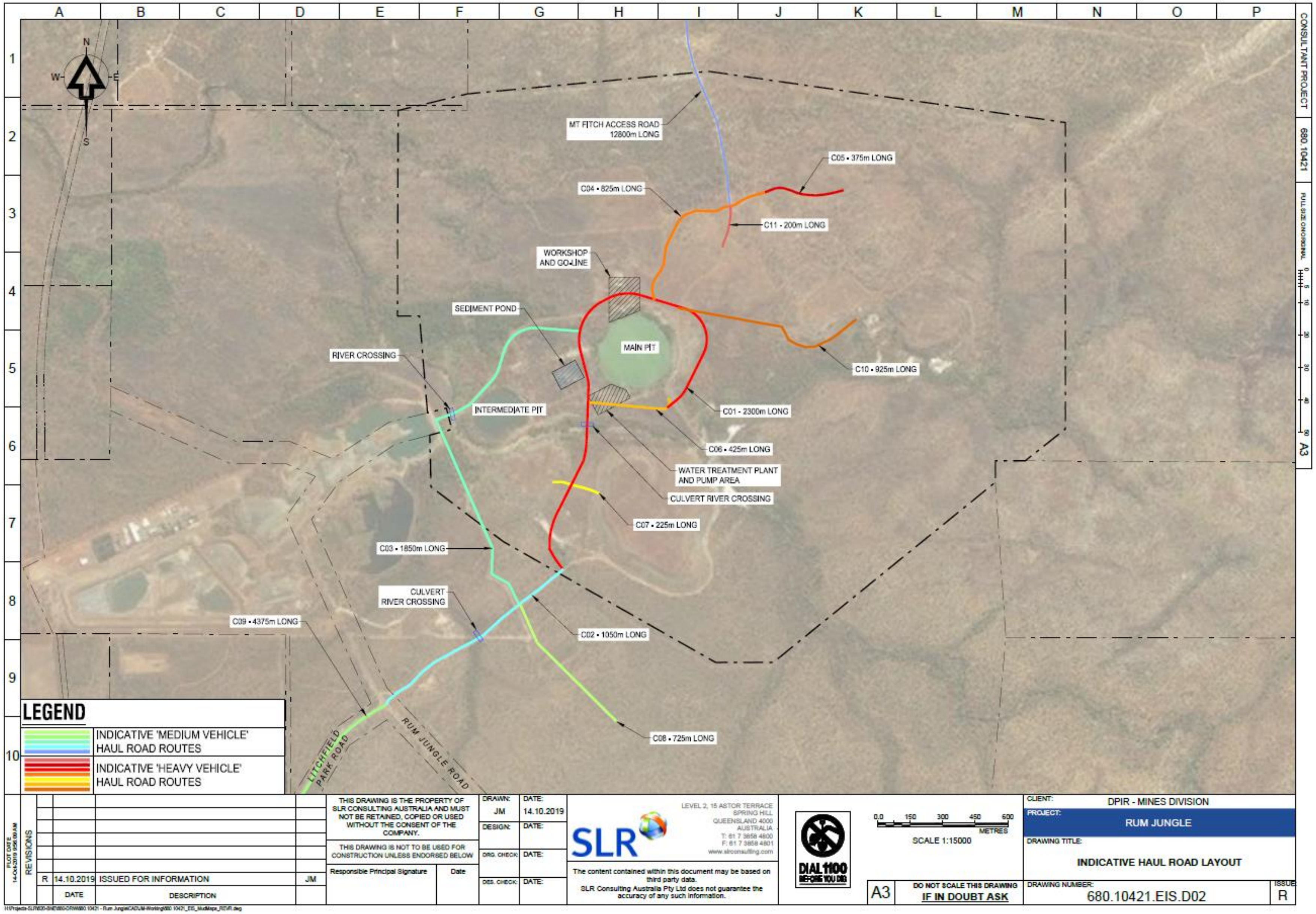


Figure 2-3 Indicative Haul Road Layout

2.1.2. Earthworks – New WSF Foundation Preparation

This project step is necessary to prepare for relocation of waste rock and will be undertaken progressively over years one to five. The approximate footprints of the two WSFs is detailed on Figure 2-4.

Foundation preparation will also include development of internal drainage structures for the purpose of managed natural attenuation of any seepage generated by the facility.

2.1.3. Earthworks – Relocation of Waste Rock and Contaminated Soils (including WSF construction)

The relocation of waste rock and contaminated soils will occur throughout all five years of the Construction phase. The purpose of relocating the waste rock and contaminated soil is to store these materials safely in a manner that isolates contaminants from the environment and future land users and stabilises the acid production reactions within the acid forming waste rock. Contaminated soils are to be stored within the WSFs. Waste rock is to be stored in one of three locations:

- Main Pit Backfill
- Eastern WSF
- Western WSF

The materials nominated for permanent storage within the Main Pit Backfill are those with the highest acid forming potential:

- Intermediate Waste Rock Dump
- Dysons Backfilled Pit – materials formerly from the Copper Extraction Pad
- Main Waste Rock Dump – the remaining volume that can be stored within the Main Pit.

All remaining contaminated soils and waste rock will be stored in the Eastern and Western WSF. The location of these WSFs is noted in Figure 2-4.

Detail on the construction methodology for both the Pit Backfill and WSFs can be found within the Draft EIS at Chapter 7 – Rehabilitation Strategy. Transportation of contaminated soils and waste rock will be carried out using internal haul road networks except in the case where Mt Burton waste rock is hauled to site for safe storage within the new WSFs. Project land disturbance areas are provided in Table 2-1.

The areas of contaminated soil and waste rock is provided on Figure 2-5.

Table 2-1 Estimated Project Land Disturbance

Project Component	Total Mapped Area (m^2)*	Planned Disturbance Area (m^2)	Estimated Previously Disturbed Land (%)	New Clearing (m^2)
WSF East and West	705,650	-	90%	71000
Contaminated soils	993,300	-	100%	-
Haul roads	9,435 m length	-	95%	-
Other infrastructure	50,000	-	100%	-
Cover Borrow	918,300	400,821	95%	20000
Granulated Borrow	2,529,600	400,821	40%	20000

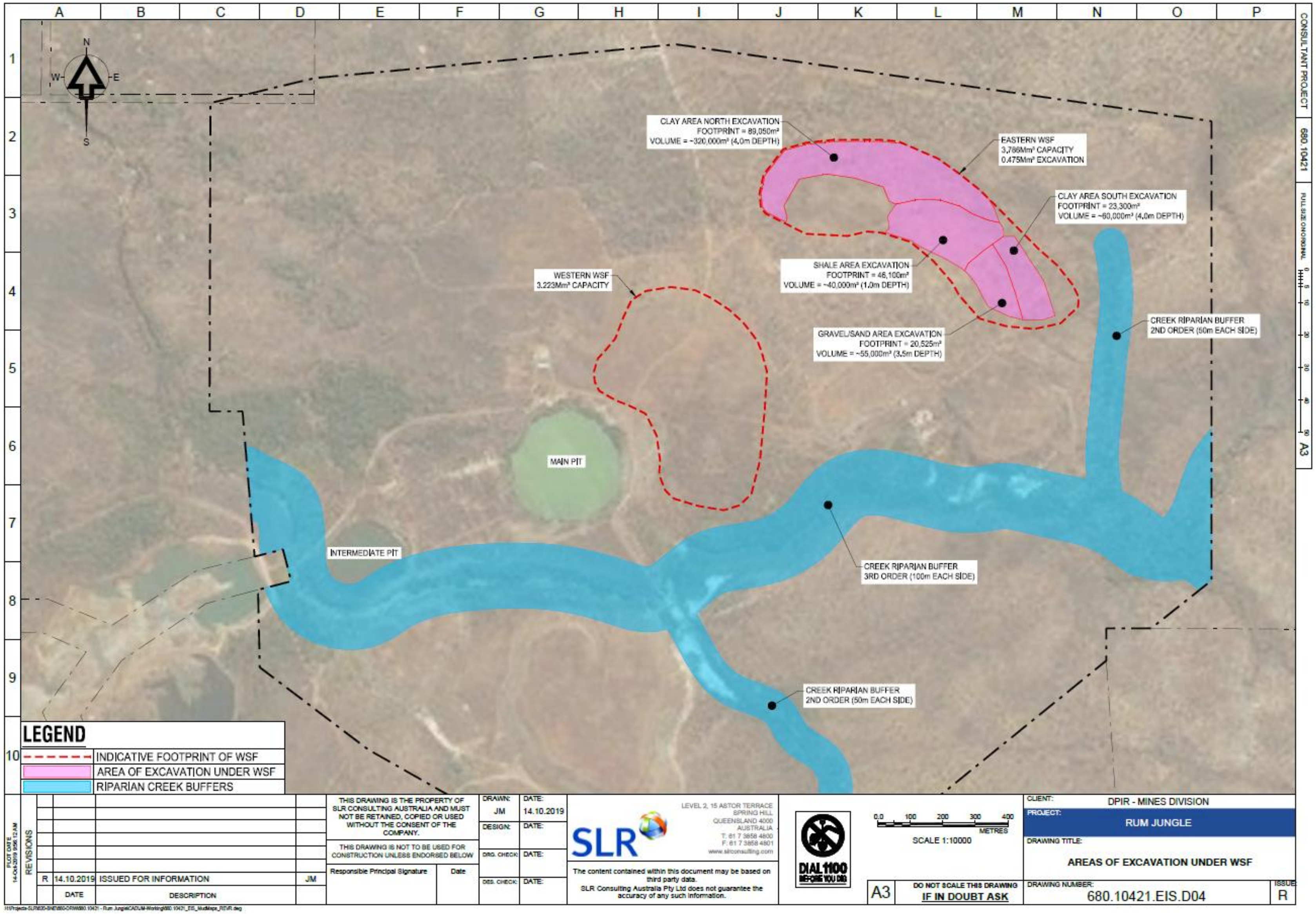


Figure 2-4 Areas of Excavation under WSFs

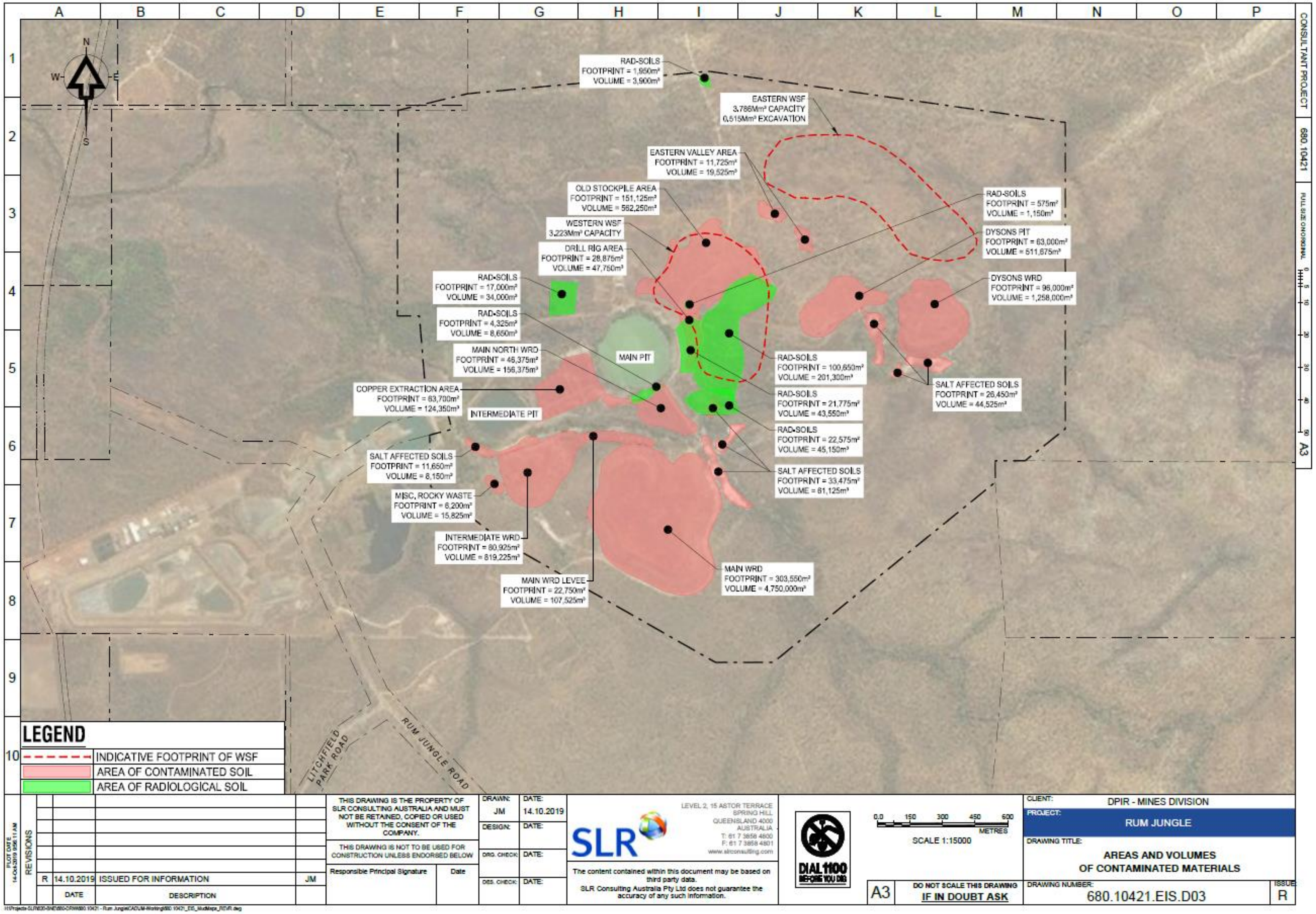


Figure 2-5 Areas and Volumes of Contaminated Soils

2.1.4. Earthworks – Cover Systems

The development of cover systems for the new WSFs and the residual WRD footprints will take place progressively over the life of the construction project. The purpose of the cover system for the residual WRD footprints is to develop a viable surface for vegetation establishment therefore must include:

- sufficient depth and drainage properties for root development (estimated as 3m) for local woodland species,
- sufficient quality and quantity topsoil to inoculate the area with symbiotic soil microbes, provide nutrients and seed bank and;
- sufficient erosion control structures to stabilise the newly formed surface.

The purpose of the new WSF cover system is to exclude as far as reasonably practicable the diffusion of oxygen into the waste rock mass, the net percolation of rainfall and to provide a sufficient matrix for development of shrubs and grasses. Therefore, the WSF cover system must include:

- low permeability barrier,
- store and release layer to improve available soil moisture,
- topsoil layers for inoculation of microbes, nutrients and seed bank,
- rock mulching to improve erosion protection, and
- surface water drainage systems to safely convey plateau area catchment down to natural surface.

Cover system installation will occur throughout all five years of the Construction phase. Cover materials are to be sourced from within the WSF footprint and from two potential borrow areas located on the adjacent Finniss River Aboriginal Land Trust and a freehold parcel held by the Coomalie Community Government Council. These potential borrows are shown in Figure 2-1.

It is estimated that approximately 3.2 million m^3 of cover materials will be required for the Project. These materials will be transported to site using both public and private roads at approximately 58-65 truck movements per day for the five years. The proposed public haul route is provided on Figure 2-3.

2.1.5. Construction – Decommissioning and Demobilisation

The purpose of this stage is to remove all facilities from the site after the construction works are complete. The majority of the decommissioning will take place in the final year of the construction schedule however the groundwater SIS infrastructure and Water Treatment Plant will stay in place until decommissioned at the end of year 10. This scope of work includes:

- Removal of all haul roads and river crossings that are not required by the future land owners;
- Removal of all project related infrastructure that is not required by the future land owners.
- Removal of all project related equipment.

This stage could be expedited if an agreement can be made to lease facilities at Browns Oxide mine.

2.1.6. Construction – Land Management, Revegetation and Monitoring

The purpose of the construction phase monitoring plan is to ensure that the rehabilitation operations are not exacerbating impacts to the already impacted EBFR. This will also include monitoring impacts to community and neighbouring properties. Monitoring programs are recommended in each Chapter of this report. Monitoring will take place over the entire Stage 3.

The purpose of the construction phase land management activities are to ensure that appropriate measures are taken to reduce the risk of uncontrolled weed spread and uncontrolled bushfire. Both of these elements have potential to negatively impact on revegetation success on new land forms. These are discussed in detail within this EIS. Land Management activities will take place over the entire Stage 3.

The purpose of the construction phase revegetation program is tri-fold – to establish self-sustaining vegetation systems on new landforms, to physically stabilise new landforms and to develop vegetation systems that will form the foundation for ecosystem restoration. Revegetation activities will take place across the entire Stage 3 and will also be incorporated into the Stage 2B scope of work.

These activities may form the foundation for a future Traditional Owner ranger training program which would benefit all people and lands of the Finniss River ALT. Ideally, for successful site restoration that the skills and resources for site specific monitoring, land management and revegetation are developed during the Stage 2B scope of works.

2.1.7. Stabilisation and Monitoring

Following the Construction phase, a five-year stabilisation and monitoring phase (year 6-10 of the Project) is planned. The purpose of this phase is to provide a sufficient period of time for intensive site monitoring while the new landforms are settling. Over this period of time, vegetation systems should commence taking over the role of surface stabilisation whilst the engineering erosion controls are also performing their role. During this period, it is expected that landform settlement may cause minor erosion. The following practices are expected to take place:

- Active feral animal control.
- Minor erosion repairs.
- Infill planting of all revegetation areas. This may include succession planting.
- Active fire and weed management including first burns in revegetation areas once vegetation is at a sufficient growth stage.

The monitoring regime for this period will target the identification of issues arising that may require repair or mitigation works. Additionally, the program will phase into monitoring for trends for rehabilitation success metrics which are documented in the EIS Chapter 7 – Rehabilitation Strategy.

3. Current State

Groundwater and surface water quality at the former Rum Jungle Mine Site are degraded by Acid and Metalliferous Drainage (AMD). The primary AMD sources are sulphide-bearing waste rock in the historic Waste Rock Dumps (WRDs) and leached low-grade ore and contaminated soils placed in shallow zones of Dyson's Pit during rehabilitation in 1984/1985 (see Allen and Verhoeven, 1986). Groundwater quality in some areas of the site is further degraded by historic AMD sources that were eliminated by rehabilitation in the 1980s or by metalliferous liquor lost during an experimental heap leach operation from 1965 to 1971 in the Copper Extraction Pad area.

AMD impacts to groundwater and the East Branch of the Finniss River (EBFR) have been intensively characterized and monitored by the Department of Primary Industry and Resources (DPIR) since recent rehabilitation planning was initiated in 2010. Routine groundwater and surface water monitoring data collected by the DPIR and information gathered during geotechnical and hydrogeological field investigations in 2014, 2017, and 2018 are the basis for a conceptual hydrogeological model developed by Robertson GeoConsultants Inc. (RGC). The model has been developed iteratively since 2011 and was updated in 2019 to include additional information from hydrogeological field investigations in 2017 near the northern site boundary and in 2018 in the Copper Extraction Pad area.

3.1.1. Climate

The site is characterized by a tropical wet-dry monsoonal climate. Monthly climate data from the SILO climate database (Queensland Government, 2016) are summarized in Table 3-1. Rainfall data for the weather station established in 2010 near the Main WRD and at the Batchelor Airport are also provided. Rainfall data for the weather station near the Main WRD are used throughout this chapter unless otherwise specified. Any missing data for this station were patched using data from the Batchelor Airport. Mean annual precipitation (MAP) is 1459 mm, all of which occurs as rainfall. More than 90% of MAP occurs during a distinct wet season that lasts from November to April. Mean monthly maximum temperatures at the Batchelor Airport range from 31°C in June to 37°C in October (during the 'build up' to the wet season).

Table 3-1 Historical Monthly Rainfall Averages and Extremes for the Area (1889-2015 SILO Database)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	332.0	311.4	265.2	77.2	11.9	2.4	1.3	3.5	14.4	57.7	134.0	245.8	1459.1
Min	89.3	67.3	47.6	0.0	0.0	0.0	0.0	0.5	0.0	0.0	41.2	82.5	855.4
Max	778.4	669.0	701.2	474.6	269.9	78.9	61.6	64.9	216.9	217.3	329.5	601.9	2365.9
Count	128	128	128	128	128	127	127	127	127	127	127	127	127

Wet Season	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
Batchelor Airport (Station 014272)													
2007/2008	1	11	88	159	368	318	670	338	36	0	0	0	1989
2008/2009	0	8	40	130	361	224	430	50	0	16	0	0	1259
2009/2010	0	27	29	71	576	422	316	92	155	49	0	3	1740
2010/2011	7	29	162	93	288	555	608	296	354	0	0	0	2392
2011/2012	0	0	110	133	149	326	168	517	29	43	0	0	1475
2012/2013	0	12	59	208	179	274	259	364	67	150	1	0	1573
2013/2014	1	30	64	207	216	543	403	97	53	8	0	0	1622
2014/2015	0	0	11	101	211	377	220	44	-	-	-	-	964
Mean	1	15	70	138	294	380	384	225	108	38	0	0	1653
Gauge near the Main Waste Rock Dump													
2010/2011	0	36	138	84	322	578	697	382	165	0	0	0	2402
2011/2012	0	0	57	112	152	362	230	419	15	30	0	0	1377
2012/2013	0	5	30	138	144	257	237	331	51	185	1	0	1379
2013/2014	5	25	79	193	332	539	373	76	74	33	0	0	1729
2014/2015	0	0	16	72	-	316	255	162	-	-	-	-	821
Mean	1	13	64	120	238	410	358	274	76	62	0	0	1542

3.1.2. Surface Water

The project area exists within the Finniss River catchment. Watercourses are referred to as the Finniss River (main or trunk) until a confluence where it branches into the East and West Branches. As shown in Figure 3-2, the majority of the project footprint is within the catchment of the East Branch. The exceptions are Mt Fitch and Mt Burton, which are adjacent to the West Branch, and the low permeability material borrow area, which is adjacent to Meneling Creek (which flows into the West Branch).

The Finniss River is dynamic in terms of flow and sediment processes, the key elements of which include monsoonal/season rainfall, high rates of sediment delivery from an eroding mine landscape, a sand-bearing geology, and high groundwater connectivity (Hydrobiology 2013).

The following summary of the two branches has been constructed from information in Metcalfe (2002):

- The West Branch (and, indeed, the main Finniss River) is a large, permanent watercourse. It typically has steep banks (3 to 5 m high) that are terraced, a relatively extensive floodplain, and is characterised by sandy, heavily-vegetated levees. There are billabongs associated with the watercourse and floodplains, and downstream it flows through the Finniss River Coastal Floodplain Site of Conservation Significance, which supports several listed threatened species.

- The East Branch is a semi-permanent stream within a distinct channel that dries to a number of pools in the mid to late dry season depending on the amount of rainfall in the preceding wet season. The bed is typically broad with low, earthy banks 1 to 3 m high with many sandy to rocky mid-stream shoals. Although riparian vegetation on the East Branch shows obvious signs of degradation, it currently supports a reasonable density and diversity of riparian species. The East Branch riparian corridor typically merges rapidly with surrounding Eucalypt woodland areas; there is little to no surrounding floodplain areas.

Metcalfe (2002) conducted surveys along Rum Jungle South Creek (which lies between Meneling Creek and the East Branch), and described it as a small, permanent spring-fed stream that joins the West Branch River. The creek is characteristically an incised channel 0.5 to 1.5 m deep flowing within a relatively-narrow corridor of dense riparian vegetation. That description of structure and vegetation is also applicable to Meneling Creek which is adjacent to the low permeability material borrow area.

During operation, Rum Jungle Mine delivered substantial downstream contamination – primarily caused by copper derived from Acid Metalliferous Drainage (AMD) – into the East Branch, causing severe detriment to the water and sediment quality downstream, and appreciable detriment in the main Finniss River for 15 km downstream of the junction with the West Branch (based on measures made in 1973/4; cited in Jeffree *et al.* (1992) and Jeffree & Twining (1992). Remediation of the Rum Jungle mine site began in 1983, but post-remediation studies did not occur until the 1990's. Field and experimental studies conducted in the 1990's showed substantial reductions in the annual loads of metal delivered into the Finniss River via the East branch, as well as greater reductions in the water concentrations of the metals and acidity in the East Branch and main Finniss River (Jeffree & Twining 2000, Hydrobiology 2013).

In light of the knowledge gleaned by a technical panel during Stage 1 of the Rum Jungle Rehabilitation Project, a zone breakdown of the Finniss River system was developed to allow for the different environmental values and water quality objectives in different parts of the river system, based on natural geomorphological characteristics, major tributary junctions, and the declared Site of Conservation Significance (SOCS) in the lower Finniss River. The zones are described in Table 3-2. Those most relevant to the EIS are shown in Figure 3-2.

Table 3-2 Finniss River Zones

Zone	Condition
1. East Branch & tributaries: upstream of the mine (red)	Slightly-Moderately Disturbed
2. East Branch: within mine site to Old Tails Creek (purple)	Highly Disturbed
3. East Branch: Old Tails Creek to Hannah Spring (light green)	Highly Disturbed
4. East Branch: Hannah Spring to confluence with West Branch (brown)	Highly Disturbed
5. West Branch: upstream of confluence with East Branch (dark green)	Slightly-Moderately Disturbed
6. Finniss River: confluence to Florence Creek (dark blue)	Slightly-Moderately Disturbed
7. Finniss River: Florence Creek to SOCS inland boundary (not on map)	Slightly-Moderately Disturbed
8. Finniss River: SOCS upstream limit to freshwater / saltwater interface (not on map)	High Conservation Value
9. Finniss River: estuary (not on map)	High Conservation Value

The drainage lines in the area are shown in Figure 3-2. At present, the mine voids on the main site are water filled with the presence of backfilled tailings within the Main Pit and the existence of a diversion channel of the East Branch to the south of the Pits (East Finniss Diversion Channel – EFDC). It is a key component of the Stage 3 works to safely re-divert as much flow as possible back through the East Branch original alignment. This alignment is mapped in Figure 3-1.

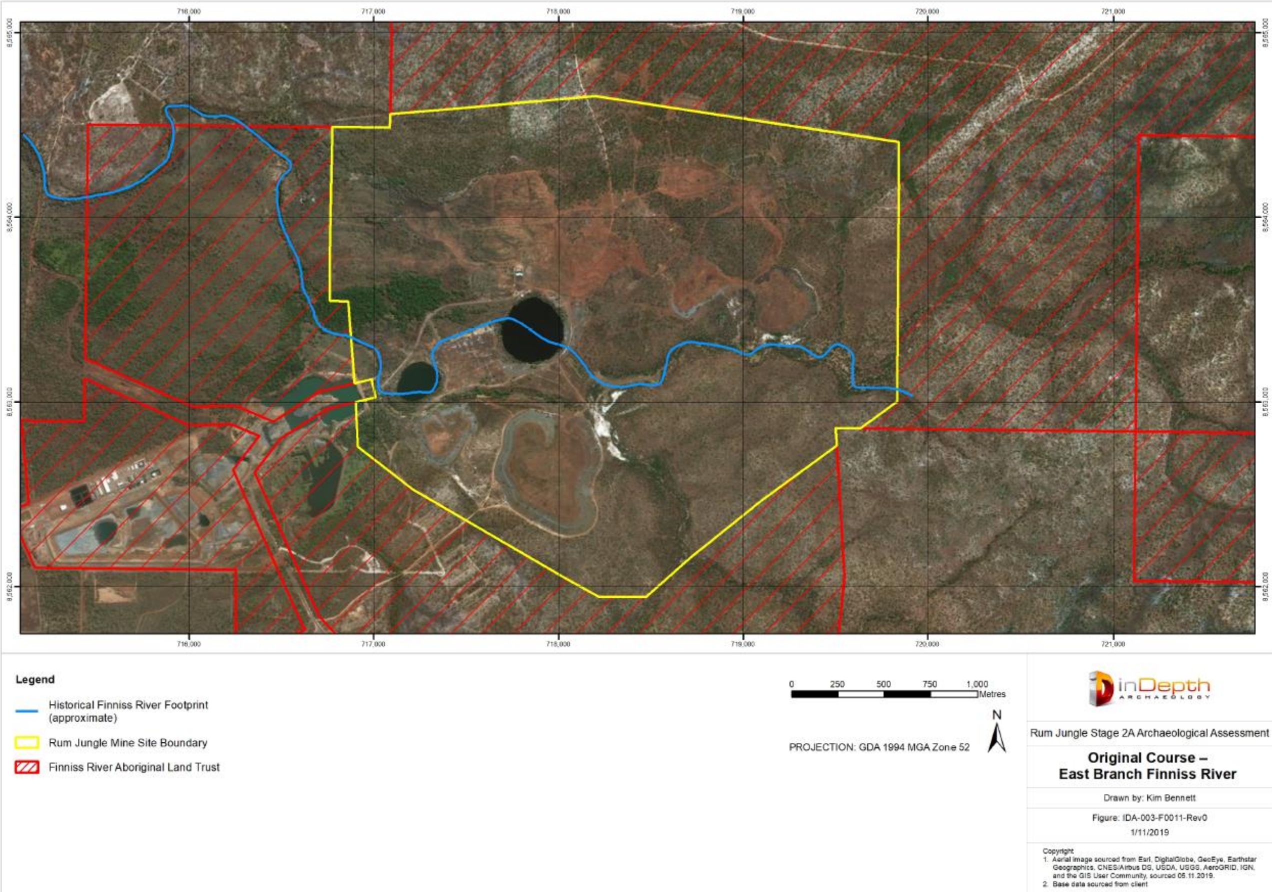


Figure 3-1 Original Course of the East Branch

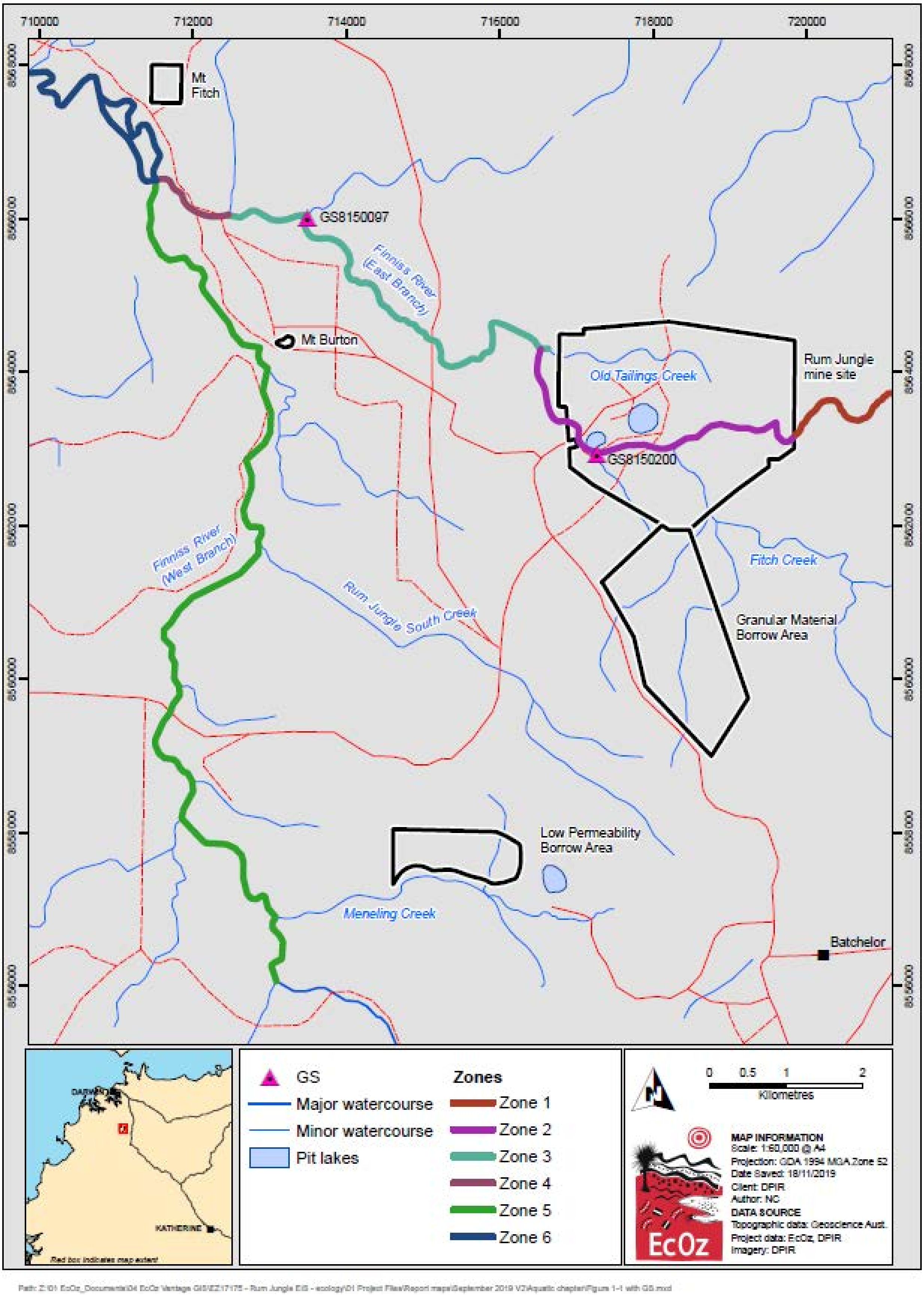


Figure 3-2 Map of surface water features and river zones. (EcOz, 2019)

Groundwater Beneficial Uses

The vine forest within the mine site to the north of the Intermediate Pit is, to some degree, a terrestrial groundwater-dependent ecosystem. There is the potential that changes (positive or negative) in groundwater levels of surrounding aquifers due to project activities could be detrimental to that ecosystem. This could occur because of the live storage and/or groundwater remediation programs proposed south of the Intermediate and Main pits.

Surface Water Beneficial Uses

The only beneficial users of the East Branch downstream of the mine site are Traditional Owners engaged in fishing, hunting and other traditional uses. Other people may also fish in the East Branch; however, access to the branch is limited and the West Branch contains far better fishing. Browns Oxide discharge treated water into the branch during times of high flow.

Downstream from the confluence, the Finniss River is used recreationally and by Traditional Owners only. There are vast areas of remnant bushland – with no pastoral properties, although some small blocks may be used for cattle grazing. There are no formal industries or communities that are known to extract water from the river for any beneficial use. Local landholders may do so on an ad hoc basis.

Meneling Creek and the West Branch downstream to the confluence have a handful of properties adjacent to them that undertake industries which may beneficially use the water from the river. There are some mango farms, rural residential blocks, and some hay and silage.

3.1.3. Environmental Values

Hydrobiology Pty Ltd. (2016) identifies environmental values in the EBFR and Finniss River based on wet season and dry season sampling in 2014 and 2015 for terrestrial vertebrates, riparian vegetation, aquatic Tetrapods, and aquatic biota. Aquatic biota, including macroinvertebrates, diatoms, mussels, and fishes, are identified as the environmental value that is most affected by elevated metal concentrations due to AMD. Other less-affected environmental values, e.g. irrigation water quality, etc., would therefore be adequately protected by achieving LDWQOs for the EBFR. Further details are provided in Hydrobiology Pty Ltd. (2016).

3.1.4. Locally-Derived Water Quality Objectives (LDWQOs)

Recommended LDWQOs for the EBFR and Finniss River from Hydrobiology Pty Ltd. (2016) are summarized in Table 3-3. Default trigger values from ANZG (2018) are provided for purposes of comparison. The locations of the river zones listed and the routine water quality monitoring points used to provide the data to support the LDWQOs are shown in Figure 3-3.

As detailed in Chapter 10 of the EIS, the Proponent intends to achieve the LDWQOs in **Table 3-3** during the construction phase and post rehabilitation. The LDWQOs will be adopted as trigger values in a WDL. The LDWQOs are applicable to the EBFR (in any zone) and apply to river flows and/or treated effluent that is present in the EBFR channel during the wet season or dry season unless other trigger values are agreed to in the WDL.

LDWQOs for the EBFR were developed in accordance with the methodology outlined in ANZECC/ARMCANZ (2000) and are consistent with ANZG (2018). The LDWQOs for Zone 2 (within the mine site) represent a 70% aquatic ecosystem protection level. This “relaxed” protection level, i.e. < 80%, reflects the limited value of aquatic ecosystems within Zone 2 and is pragmatic according to Hydrobiology Pty. Ltd. (2016) given severity of current water quality impacts due to AMD and the history of the site. Further details on these ecosystems and the rationale for the reduced protection level for Zone 2 is provided in Chapter 12 and references therein. LDWQOs for Zones 3 to

7, e.g. 27.5 µg/L Cu, represent approximately 80% protection levels for aquatic ecosystems (all taxa) (see Hydrobiology Pty. Ltd., 2015).

Table 3-3 LDWQOs Established by Hydrobiology, 2016

River Zone	Applicable Location	EC µS/cm	SO_4 mg/L	Mg mg/L	Al µg/L	Cu µg/L	Co µg/L	Fe µg/L	Mn µg/L	Ni µg/L	Zn µg/L
Default ANZECC/ARMCANZ trigger value - 80% protection level											
n/a	Any location if LDWQO not available	-	-	-	150	2.5	-	-	3,600	17	31
East Branch of the Finniss River											
1	Fitch Creek and EBFR upstream of mine site	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1
2	EBFR at gauge GS8150200	2,985	1,192	86.6	236	60.2	89	300	795	130.4	210.5
3	EBFR at gauge GS8150327	2,985	997	86.6	150	27.5	25.9	300	443	43.1	180
3	EBFR at gauge GS8150097	2,985	997	86.6	150	27.5	25.9	300	443	43.1	180
4	EBFR near confluence with Finniss River	427	761	33.2	117	7.9	3.6	300	228	32.5	180
Finniss River											
6	Finniss River at gauge GS8150204	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1
7	Finniss River	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1

See Hydrobiology (2016) for additional details on LDWQO development

Trigger values for EC, SO_4, Mg, Co, and Fe are not available from ANZECC/ARMCANZ (2000)

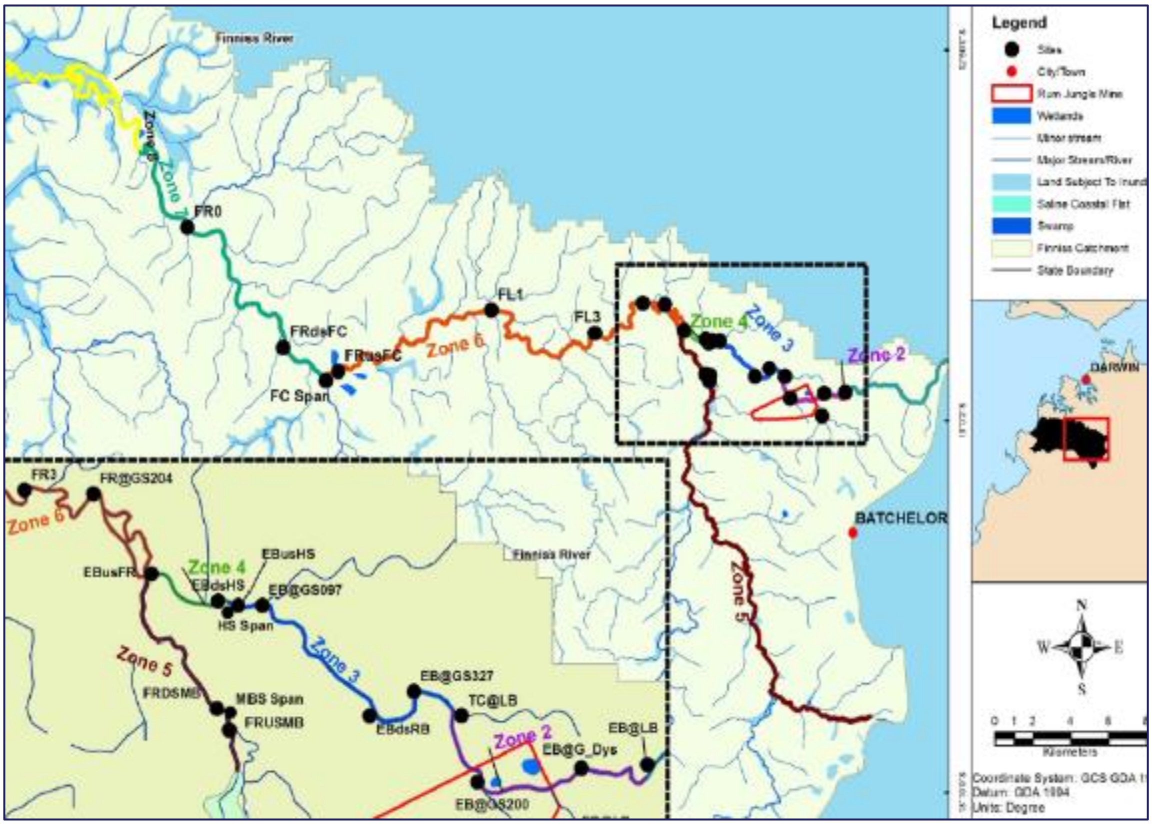


Figure 3-3 Surface Water Monitoring Locations and Zones (Hydrobiology, 2016)

Groundwater Monitoring Program

Groundwater monitoring bores are shown in Figure 3-4 with key site features and the mine lease boundary. The groundwater monitoring network consists of a series of historic bores referred to by their Registration Number (RN) and the MB10, MB12, MB14, MB17, and MB18 bore series. The MB prefix stands for “Monitoring Bore” and the integer denotes the year the bore was installed. Most of the bores were installed with 80 mm PVC casing and machine-slotted PVC screens. An “S” denotes a shallower bore at a particular location and a “D” denotes the deeper bore, e.g. MB10-08S and MB10-08D. Most of the S and D bores were installed as paired installations, meaning the shallower bore was installed in a second, separate borehole nearby after the deeper bore was completed. Bores MB10-9S and MB10-9D are an exception as these bores were installed as a nested installation with 50 mm PVC casing in a single open borehole (RN022108) that was drilled in the 1983. Several monitoring bores in the Copper Extraction Pad area were also installed in existing exploration holes (see RGC, 2016a).

Most of the RN bores were installed in the 1980s to support previous rehabilitation planning. Many of the RN bores are shallow (< 5 m deep) and therefore dry for part of the year when groundwater levels are below the bottom of the screen. The MB10 bores were installed in areas under-represented by the historic RN bores, either near the WRDs or down gradient to define the extent of groundwater quality impacts north of the central mining area towards the EBFR. The MB12 and MB18 bores were installed in the Copper Extraction Pad area to delineate the spatial extent and depth of groundwater quality impacts in this area. The MB14 (Old Tailings Dam area) and MB17 bores (near northern site boundary) were installed to characterize groundwater conditions near the WSF footprints proposed during previous project phases. Each of the MB bores was installed and developed under RGC supervision and further details are provided in RGC (2016) and references therein.

There is a single production bore (PB12-33) on site in the Copper Extraction Pad area. This bore was installed in 2012 to complete a one week pumping test in November 2012 to characterize the hydraulic properties of bedrock in this area and does not have a permanent pump installed. The 2012 pumping test has been interpreted to constrain the hydraulic properties of bedrock between the Main and Intermediate Pits. Additional information on the hydraulic properties near the Main Pit was provided by a geotechnical investigation of the pit rim in 2018 (see SRK, 2018). Monitoring bores were not installed during this investigation but airlift testing and other relevant testing was undertaken and the results were incorporated into RGC's updated conceptual hydrogeological model. Information from a geotechnical drilling program to assess tailings backfill in the Main Pit were also incorporated to confirm the depth to tailings below the pit lake surface.

The DPIR has routinely monitored groundwater levels in 43 RN bores and 66 additional MB bores installed in 2010, 2012, and 2014. EMU also measured groundwater levels in the MB17 and MB18 bores since they were installed. In 2018, a total of 160 bores were monitored monthly during the dry season and every two weeks during the wet season. This frequency was selected to characterize the substantial intra-annual (seasonal) variations in groundwater levels in some areas of the site and to infer the site-wide groundwater flow field at different times of the year. Depth-to-water measurements are collected manually from each bore with a water level tape. Measurements are collected from the top of the PVC casing and subtracted from professionally-surveyed top-of-casing elevations to calculate the geodetic groundwater elevation relative to the Australian Height Datum (AHD), i.e. in m AHD.

Continuous groundwater level monitoring measurements collected by pressure transducers are also available for selected monitoring bores, including bore RN022081 (which has recorded since 1991) and bores MB14-02S/D, MB14-17S/D, and MB14-20S/D. Transducer data for selected MB bores were interpreted to monitor the rapid response of groundwater levels in some area due to rainfall infiltration and to derive recharge rates that were incorporated into the groundwater model.

Groundwater quality sampling is routinely undertaken by the DPIR's Environmental Monitoring Unit (EMU). From 2010 to 2018, EMU collected water samples once per year in the dry season and once per year in the wet season from each of the bores most of the bores on site. Seepage from the WRDs and Dyson's (backfilled) Pit is also sampled opportunistically by EMU or DPIR staff. In 2018, the scope of routine water quality monitoring was reduced to an annual sampling campaign in the dry season. This change was recommended by RGC because baseline conditions are well-established from previous monitoring and there have been no changes on site that would necessitate continued monitoring. Dry season sampling is normally planned for August or September. Monthly routine groundwater level and pit water level monitoring continues.

Groundwater is sampled according to a "low flow" procedure and processed in the field in a lab truck to ensure a representative sample is collected. Prior to groundwater sampling, EMU collects manual depth-to-water measurements with a water level tape and records the pH, temperature, and electrical conductivity (EC). Water samples are sent to an accredited laboratory in Darwin for analysis. Groundwater samples are analysed for SO_4, Ca, Mg, Na, K, Al-f, Fe-f, Cu-f, Co-f, Mn-f, Ni-f, U-f, and Zn-f, where 'f' stands for filtered samples (<0.45 μm) that are acidified. EMU routinely collects duplicate samples and runs routine checks for EC, temperature, and pH measurements in the field and provides a charge (ionic) balance for each sample as part of QA/QC protocols.

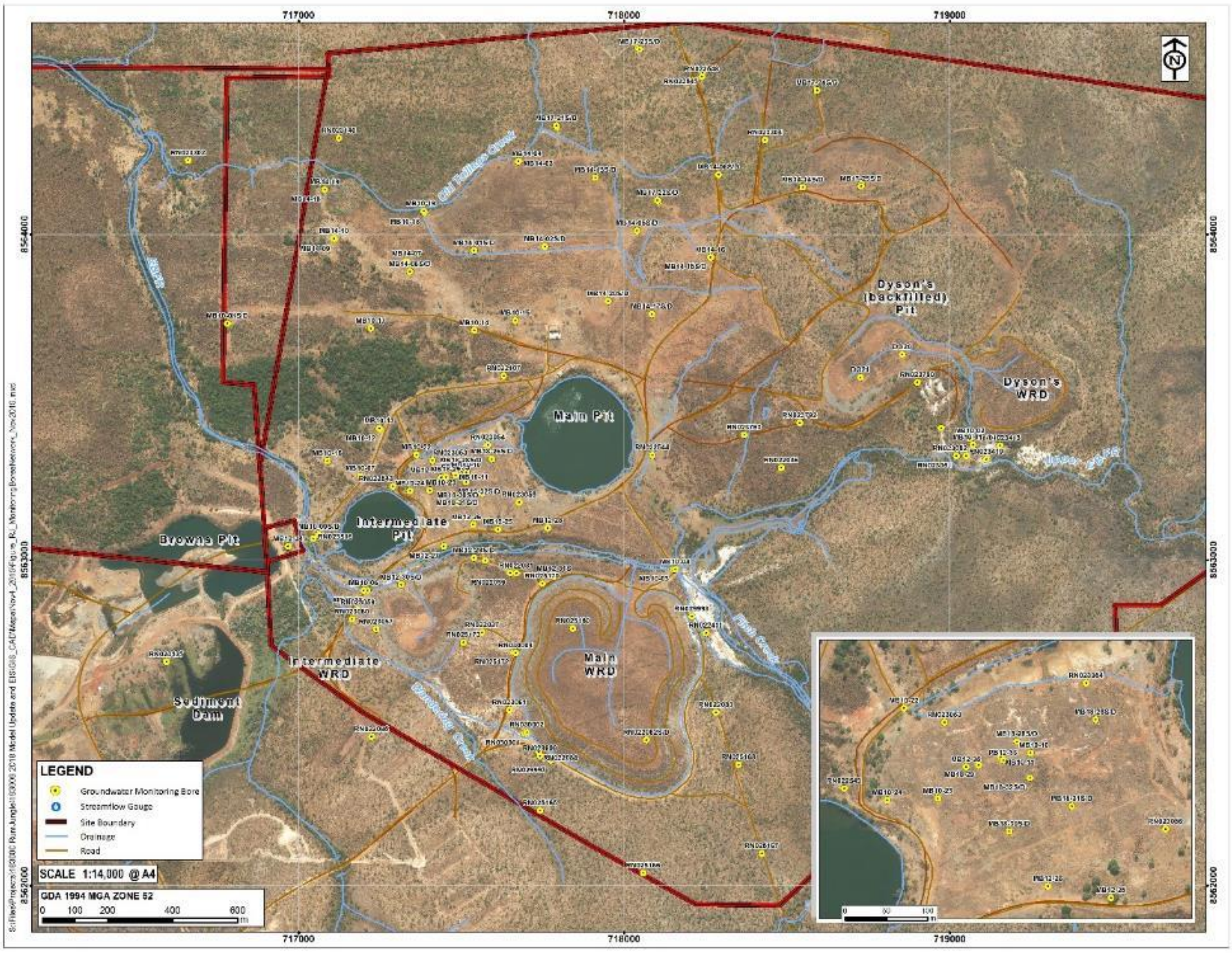


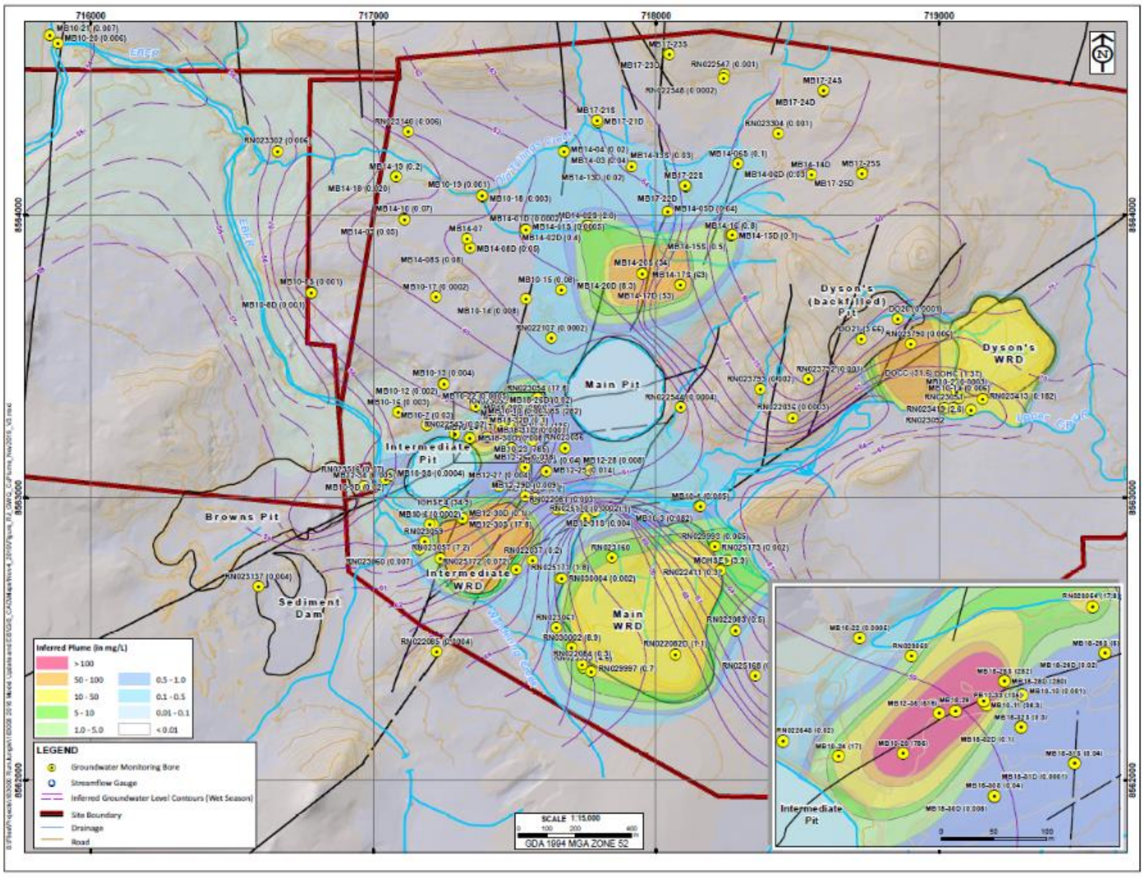
Figure 3-4 Groundwater Monitoring Network

3.1.4.1. Background Water Quality

Groundwater not impacted by AMD within the former Rum Jungle mine site is typically circum-neutral to slightly alkaline and characterized by alkalinity values up to 200 mg/L as $CaCO_3$, depending on the screened lithology. SO_4 concentrations in unimpacted groundwater typically range from 1 to 5 mg/L SO_4 and Cu-t concentrations are typically 0.001 to 0.006 mg/L. Elevated Mn concentrations are observed in groundwater from the Coomalie Dolostone, e.g. at bore RN022085.

3.1.5. Existing Groundwater Quality Impacts

Observed SO_4 and Cu concentrations in groundwater (and inferred plumes) are shown in Figure 3-5. Further details on the derivation of these plumes is provided in RGC (2019). Groundwater quality impacts in key areas of the site are discussed in Chapter 10 of the EIS Representative water quality results are discussed and additional water quality observations are provided in RGC (2016) and RGC (2019).



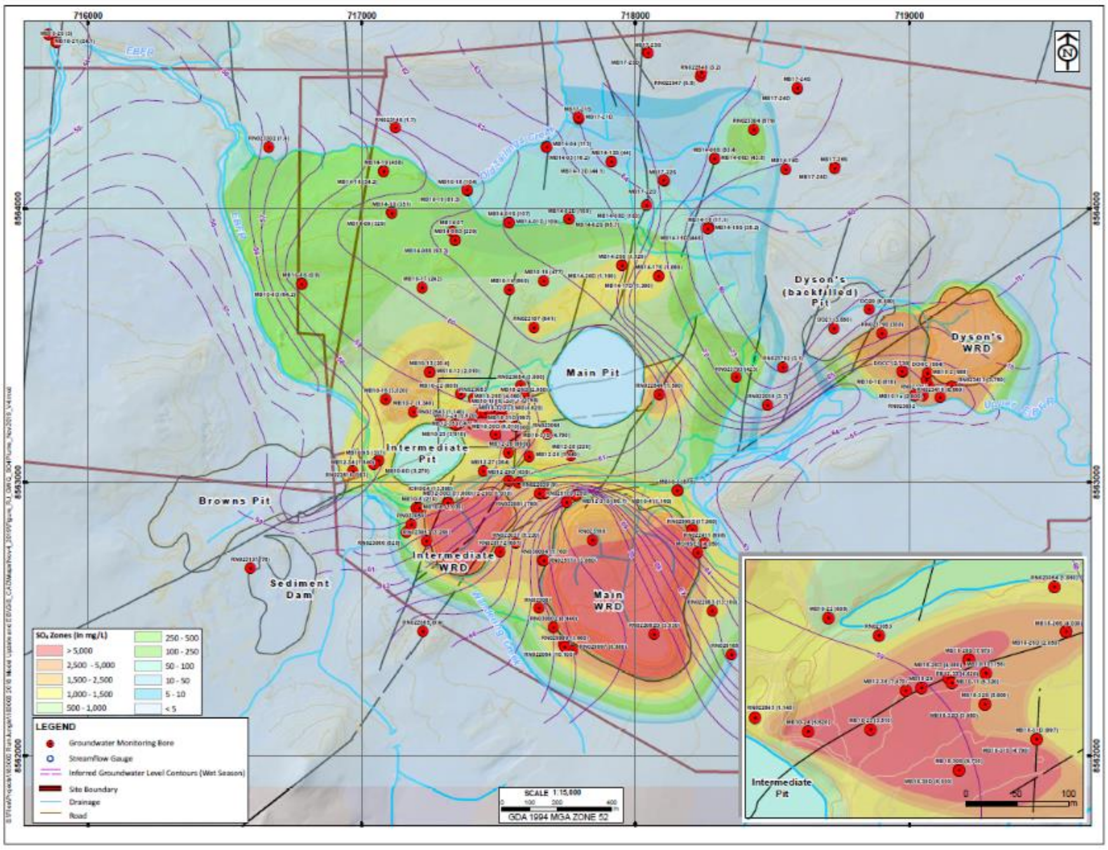


Figure 3-5 Observed copper (a) and sulphate (b) in groundwater with inferred plumes

3.1.6. Contaminant Transport in Groundwater

RGC assumes that SO_4 behaves conservatively in groundwater. This implies that SO_4 is not removed or retarded in groundwater by geochemical reactions or adsorption and is therefore transported at a rate that is nearly equivalent to the linear velocity of groundwater. Locally, this assumption may not be valid due to the precipitation of secondary minerals, such as Fe- and/or Al hydroxide sulphates. However, at the regional scale of the model, these changes in SO_4 concentrations are likely small, and would not affect the overall conclusions drawn from the solute transport modelling.

Dissolved metals, such as Cu, cannot be assumed to behave conservatively in groundwater because their mobility is often hindered by geochemical reactions along a flow path. Reduced mobility (and hence slower rate of transport) that is caused by metals adsorbing to aquifer materials or precipitating to form secondary minerals. These mechanisms are often pH dependent, and not only retard the movement of metals in groundwater, but also provide a future source of metals to groundwater if the metals are eventually released by desorption or they begin to dissolve.

For Cu, groundwater and soil chemistry strongly influence the speciation of Cu (and, in turn, how it behaves along a flowpath). For instance, in aerobic, alkaline systems, $CuCO_3$ is the dominant, soluble copper species. The cupric ion (Cu^{2+}), and hydroxide complexes, i.e. $CuOH^+$ and $Cu(OH)_2$, are also common under these conditions. Each of these copper species can form strong complexes with humic acids, and the affinity of Cu for these acids increases as pH increases. Moreover, Cu adsorption to hydrous iron oxides that precipitate from groundwater also increases at higher pH. Together, these factors explain the high retardation factors that are often assigned to Cu under near-neutral-to-alkaline conditions.

According to RGC and DJEE (2019), the concentrations of metals in leachate from waste rock samples from the WRDs at the Rum Jungle Mine Site are likely controlled by the solubilities of hydroxide and carbonate phases in waste rock, and by the adsorption of metal ions to both the primary bulk solid phases (e.g. chlorite, muscovite) and to secondary, precipitated Fe and Al hydroxide phases. These controlling processes (solubility and adsorption) are a function of pH, with the extent of metal precipitation and metal adsorption typically increasing as the pH increases from an acidic initial condition, to near-neutral or alkaline pH conditions (i.e. along a 'pH adsorption edge').

Adsorption is likely to be the more important process at lower metal concentrations, i.e. in groundwater, as opposed to seepage, and when the pH of pore water initially increases from a more acidic starting value near AMD sources. The latter typically occurs over a 1 to 2 unit pH range for the types of alumino-silicate phases that dominate the mineralogy of the wastes at the Rum Jungle Mine Site (see RGC, 2019). The exact range of pH values that defines the 'pH adsorption edge', which reflects range of processes that act to remove metals from pore water at a site or in a WRD. Regardless, the key finding is that Cu will be removed from groundwater and would reside on aquifer materials until it desorbs or becomes irreversibly adsorbed by ageing. This is consistent with observed groundwater quality impacts at the Rum Jungle Mine Site, which show that Cu concentrations are very high in groundwater near the WRDs but are much lower (if not absent) from groundwater downgradient (see below).

Surface Water Monitoring Programs

The EBFR is an intermittent river that flows approximately west and northwest through the former Rum Jungle mine site. Before mining, the EBFR flowed through the area now occupied by the Main Pit and the Intermediate Pit. The EBFR was partially dammed by the Sweetwater Dam and Acid Dam and diverted through the East Finniss Diversion Channel during mining operations in the 1950s and 1960s. These dams were removed during rehabilitation in 1984 and 1985 and a system of inlets and outlets was installed to convey a portion of flows in the EBFR through the Main Pit and, in turn, the Intermediate Pit. Flows between the pits occur only during high flow periods in the wet season. Flows between the pits occur in a channel near the northern perimeter of the former Copper Extraction Pad area. The EBFR returns to its natural channel near the road bridge near the western lease boundary (towards the Browns site) and flows northwest beyond the mine lease boundary.

Surface Water Flows

Combined flows from the Intermediate Pit and through the EFDC are measured at gauge GS8150200. Gauge GS8150200, and downstream gauges GS8150327 and GS8150097, are shown in Figure 3-6 with catchment areas for each gauge. Each of these gauges is operated by the NT Government as part of regional monitoring. Other gauges have been operated by the DPIR in the past to monitor flows in and out of the pits (GS8150212 and GS8150213) but these gauges are not currently operated. Further details on the streamflow gauges currently operated are summarized below:

- **Gauge GS8150200**. This gauge is in the natural (pre-mining) EBFR channel downstream of the road bridge near the western lease boundary. It was installed in 1981 and records the combined flows of the EBFR through the EFDC and outflows from the Intermediate Pit. This gauge has operated continuously since 1981 and has a catchment area of 53 km^2 that includes most of lease boundary, except for the Old Tailings Dam area and Old Tailings Creek.
- **Gauge GS8150327**. This gauge is about 1.5 km downstream of gauge GS8150200 on private property. It was installed in 2010 at RGC's request to measure streamflows (and water quality) in the EBFR downstream of the entire lease domain, including flows from Old Tailings Creek and groundwater discharge to the EBFR downstream of GS8150200. This gauge has a catchment area of 59 km^2, including a 6 km^2 that is not part of the catchment area of GS8150200.
- **Gauge GS8150097**. Gauge GS8150097 is about 5 km downstream of GS8150327 and has been operated near-continuously since 1965. Several creeks discharge to the EBFR between gauges GS8150327 and GS8150097. This gauge has a catchment area of 65 km^2. This is slightly lower than previous catchment area estimates as RGC understands that the catchment area does not include a right-bank tributary that has been included in previous area estimates (A. Brandis, personal communication).

Gauges GS8150200, GS8150327, and GS8150097 record water level heights (in metres, m) at an irregular time step, with the highest monitoring frequency occurring in flood conditions when the water level is changing rapidly. The measured water levels are converted to equivalent discharge rates using a rating curve. Discharge is reported in cubic meters per second (m^3/s). Streamflow data for each station seem to be reasonably reliable and no major issues with data quality were identified by RGC while developing the WLBM for the site. Peak discharges at gauge GS8150097 do, however, appear to be over-estimated as unit daily discharges can exceed daily rainfall amounts during high flow periods. Also, gauges GS8150200 and GS8150097 sometimes show flows in the dry season when true flows are zero. There are no practical implications to the over-estimation of peak flows in the EBFR as metal concentrations are often lowest during these periods. Moreover, the WLBM that RGC has developed does not predict loads or concentrations in the EBFR during periods when there is not sustained discharge, so erroneous flow measurements during the dry season are irrelevant.

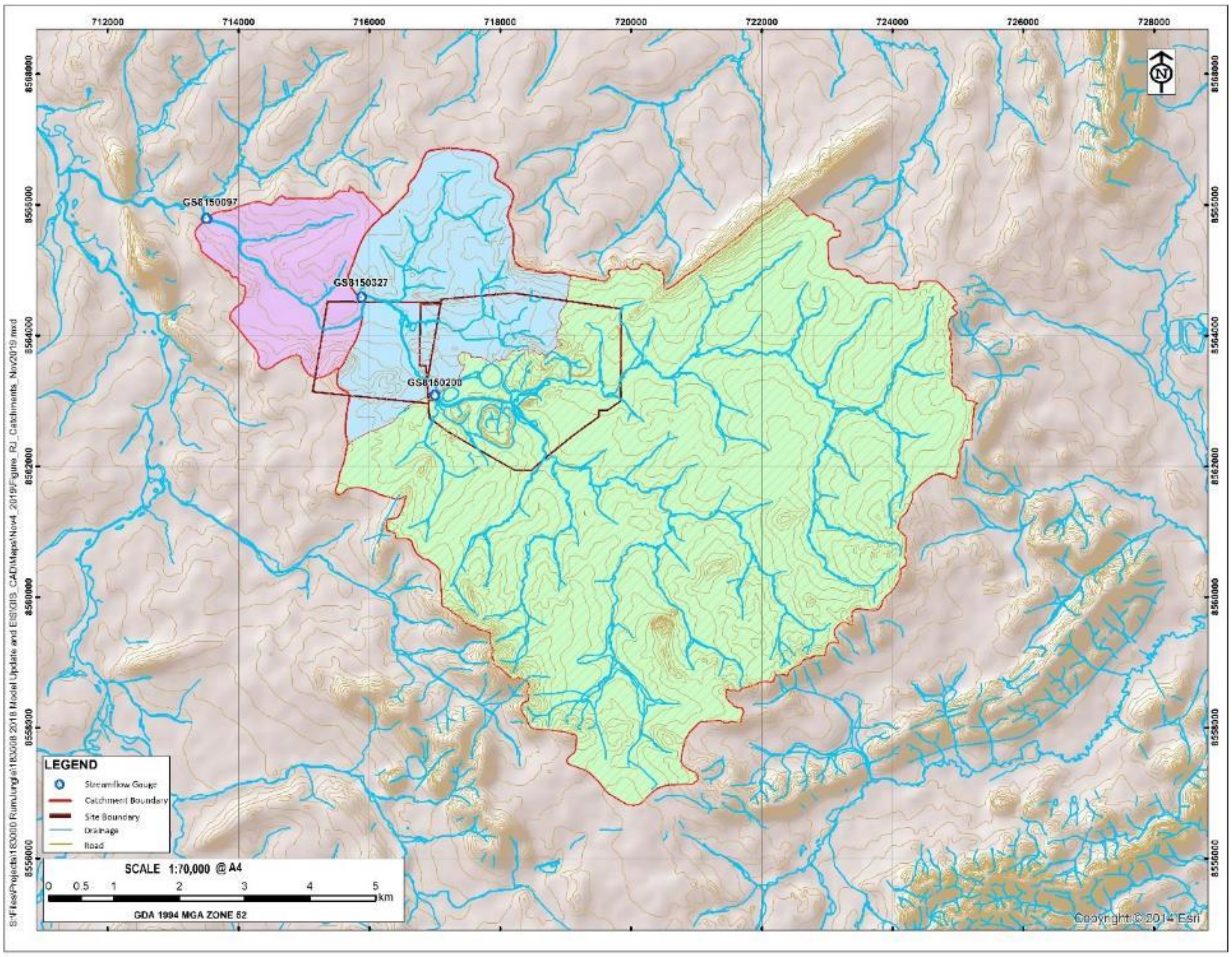


Figure 3-6 Streamflow Gauge Locations and Catchment Areas

Surface Water Quality

Water quality in the EBFR is routinely monitored at gauges GS8150200, GS8150327, and GS8150097. Gauge GS8150327 was installed because the EBFR appears to be inadequately mixed at GS8150200 and hence collecting a representative sample can be problematic (Lawton and Overall, 2002). Gauge GS8150327 was installed in 2010 in part to avoid the mixing issues at GS8150200 and to provide a record of the total streamflow through the lease boundary, including flows from Old Tailings Creek and groundwater discharge to the EBFR downstream of gauge GS8150200. Grab samples from each gauge have been collected several times per month by EMU during the wet season since 2010. Field pH, field EC, and water temperature are measured during sampling.

Surface water samples are analysed for SO_4, Ca, Mg, Na, K, Al-f, Al-t, Fe-f, Fe-t, Cu-f, Cu-t, Co-f, Co-t, Mn-f, Mn-t, Ni-f, Ni-t, U-f, U-t, Zn-f, and Zn-t, where ‘f’ denotes a filtered (<0.45 μm) sample that is acidified and ‘t’ denotes a total concentration, i.e. the concentration in an unfiltered and acidified sample. Total and bicarbonate alkalinity, in mg/L as $CaCO_3$, are determined by titration in the field. EMU also routinely collects duplicate samples and runs routine checks for EC, temperature, and pH measurements in the field and provides a charge (ionic) balance for each sample as part of QA/QC protocols. Hourly measurements of water temperature, EC, pH, and turbidity are collected at each gauge with a transducer.

Pit water quality profiling has been undertaken periodically since rehabilitation in the 1980s to characterize the degree of stratification and mixing in the Main Pit and Intermediate Pit due to inflows from the EBFR (see Lawton and Overall, 2002a,b). Additional profiling was done in 2008 (see Tropical Water Solutions, 2008) and by EMU in 2014. Pit water at surface and flowing from the Intermediate Pit are also routinely collected by the DPIR and/or EMU. Samples from the pits are also collected as part of routine monitoring undertaken by the operators of the adjacent Browns site for their Waste Discharge License (WDL). Pit water levels in the Main Pit and Intermediate Pit are monitored monthly or every two weeks by the DPIR as part of routine groundwater monitoring. Pit water levels in the Browns Pits are not routinely monitored but some data from 2008 to 2011 are available (see RGC, 2012a).

3.1.7. Existing Pit Water Quality Impacts

Pit water quality data for the **Main Pit** are summarized in Table 3-4. The Main Pit was originally mined to about 111 m below ground surface (bgs). It was subsequently partially backfilled with 900,000 m^3 of tailings, largely originating from Rum Jungle Creek South, in the final years of ore processing on the site.

The Main Pit was used for to store process water during mining operations and was later flooded with impacted groundwater when mining ceased and the pit was no longer de-watered. The top 20 m of highly-contaminated pit water was treated in 1985 by pumping water to a water treatment plant A layer of untreated pit water was left at the bottom of the Main Pit.

The thickness of the layer of untreated water (or “bottom lens) has since been progressively reduced by annual flushing and mixing by upper catchment water via the EBFR, and its possible that the thickness of this untreated water is now less than 5m .

Table 3-4 Pit Water Quality Profiling Results, Main Pit

Depth m	Date	pH	EC, µS/cm	SO_4, mg/L	Al, mg/L	Cu, mg/L	Fe, mg/L	Mn, mg/L	Ni, mg/L	Zn, mg/L
*Pit water quality for the first 15 years after mining operations ceased (Davey, 1975)**										
0	1969	2.7	-	4,750	-	52	-	86	-	-
0	1970	2.8	-	6,000	-	53	-	115	-	-
0	1974	2.4	-	5,700	-	56	-	150	-	-
50	1974	2.2	-	9,200	-	60	-	220	-	-
Typical water quality immediately prior to rehabilitation (from Mining and Processing Engineering Services report)										
15	Aug-85	2.5	-	8,200	230	55	430	230	14	6
Pit water quality in 1990 (from Henkel, 1991b)										
0	Oct-90	4.6	640	300	-	0.8	-	4.4	-	0.2
2	Oct-90	4.8	630	300	-	0.8	-	4.2	-	0.2
12	Oct-90	4.7	630	310	-	0.8	-	4.2	-	0.2
14	Oct-90	4.6	640	300	-	0.9	-	4.3	-	0.2
20	Oct-90	4.6	640	310	-	0.9	-	4.3	-	0.2
22	Oct-90	3.0	6,600	4,900	-	22	-	120	-	4.1
24	Oct-90	3.0	7,900	6,400	-	44	-	180	-	6.1
26	Oct-90	2.9	8,500	7,600	-	54	-	200	-	6.4
28	Oct-90	2.9	8,600	7,700	-	55	-	210	-	6.9
30	Oct-90	2.9	8,600	8,200	-	56	-	210	-	6.9
Pit water quality in 1991 (from Henkel, 1991b)										
0	May-91	6.5	170	63	-	0.1	-	0.6	-	0.0
2	May-91	6.0	170	66	-	0.2	-	0.6	-	0.1
12	May-91	6.5	170	65	-	0.2	-	0.6	-	0.0
14	May-91	6.5	170	66	-	0.1	-	0.6	-	0.0
20	May-91	6.0	220	94	-	0.3	-	1.1	-	0.0
22	May-91	5.7	240	100	-	0.5	-	1.3	-	0.1
24	May-91	4.7	380	260	-	1.0	-	3.0	-	0.2
26	May-91	2.9	8,000	6,500	-	46	-	184	-	6.4
28	May-91	2.9	8,300	7,500	-	57	-	220	-	6.9
30	May-91	2.9	8,200	7,700	-	59	-	240	-	6.6
36	May-91	2.9	8,300	7,700	-	61	-	230	-	7.0
Pit water quality in April 1998 (from Lawton and Overall, 2002)										
0	Apr-98	6.8	157	61	0.1	0.1	0.5	0.3	0.1	0.04
5	Apr-98	6.5	172	-	0.1	0.1	0.4	0.3	0.1	0.1
10	Apr-98	6.1	110	41	0.2	0.1	0.4	0.3	0.1	0.03
15	Apr-98	5.7	115	-	0.1	0.1	0.2	0.5	0.1	0.04
20	Apr-98	5.4	151	64	0.1	0.2	0.1	0.7	0.1	0.04
25	Apr-98	5.4	171	-	0.1	0.2	0.1	0.8	0.1	0.1
30	Apr-98	4.4	274	137	1.9	0.8	0.1	2.5	0.2	0.1
31	Apr-98	4.1	458	-	5.2	1.3	0.2	4.4	0.4	0.2
32	Apr-98	3.7	993	-	15	3.1	0.9	18	1.0	0.4
33	Apr-98	3.8	7,168	-	215	54	378	244	19	5.5
34	Apr-98	3.8	7,478	-	226	60	404	269	17	7.4
35	Apr-98	3.8	7,558	8,270	236	62	420	254	19	7.8
Depth profiling in May 2008 (by Tropical Water Solutions Pty Ltd.)										
0	May-08	-	-	60	0.1	0.1	0.4	0.1	0.1	0.02
5	May-08	-	-	60	0.2	0.1	0.7	0.1	0.1	0.02
30	May-08	-	-	60	0.2	0.1	0.7	0.1	0.1	0.02
36	May-08	-	-	63	0.2	0.1	1.0	0.1	0.1	0.03
41	May-08	-	-	7,710	170	38	851	219	12	6.2
43	May-08	-	-	7,810	107	26	1,160	220	10	5.2
Depth profiling by EMU in July 2014										
0	Jul-14	-	193	75	0.005	0.03	0.04	0.9	0.1	0.02
5	Jul-14	-	192	75	0.004	0.03	0.04	0.9	0.1	0.02
10	Jul-14	-	193	73	0.005	0.03	0.04	0.9	0.1	0.02
15	Jul-14	-	193	74	0.005	0.03	0.05	0.9	0.1	0.02
20	Jul-14	-	193	72	0.005	0.03	0.04	0.9	0.1	0.02
25	Jul-14	-	193	76	0.005	0.03	0.04	0.9	0.1	0.02
30	Jul-14	-	193	83	0.01	0.03	0.05	0.9	0.1	0.02
35	Jul-14	-	193	82	0.01	0.03	0.1	0.9	0.1	0.02
40	Jul-14	-	193	80	0.01	0.03	0.1	0.9	0.1	0.02
43.5	Jul-14	-	8,797	7,930	4.7	2.9	1,370	189	5.0	1.7

Note: Red numbers indicate that the concentration was below the indicated detection limit and hyphens indicate the parameter was not measured
* Total metal concentrations

Pit water quality data for the **Intermediate Pit** are summarized in Table 3-5.The Intermediate Pit was mined to about 57 m bgs. The Intermediate Pit was not used to store process water during mining operations but was characterized by elevated SO_4 and metals, in part due to flows from the Main Pit and runoff from the former heap leach pad.

Pit water from the Intermediate Pit was treated in 1985 *in situ* by bulk dosing of lime to pH 7, in contrast to the *ex situ* treatment used for the Main Pit. Vertical mixing of the water column was induced by aerating (with air compressors) from the bottom of the pit instead of pumping water to the water treatment system as was done for the Main Pit. The EBFR was later directed through the Intermediate Pit in series with the Main Pit to flush pit water each year (see Allen and Verhoeven, 1986).

In 2014, most pit water was characterized by low concentrations of SO_4 and most metals. In contrast to the Main Pit, water near the bottom of the Intermediate Pit was characterized by much lower concentrations of SO_4, Fe, and Mn, with Cu concentrations being very low.

Table 3-5 Pit Water Quality Profiling Results, Intermediate Pit

Depth m	Date	pH	EC, µS/cm	SO_4, mg/L	Al, mg/L	Cu, mg/L	Fe, mg/L	Mn, mg/L	Ni, mg/L	Zn, mg/L
*Pit water quality before treatment (Davey, 1975)**										
15	Aug-85	3.5	-	3100	60	60	2	60	14	7
Pit water quality in 1990 (from Henkel, 1991b)										
0	Oct-90	4.9	900	460	-	1.2	-	2.1	-	0.3
1	Oct-90	4.5	900	460	-	1.1	-	2.1	-	0.3
15	Oct-90	4.7	890	450	-	1.1	-	2.0	-	0.3
17	Oct-90	4.7	890	460	-	1.1	-	2.0	-	0.3
21	Oct-90	4.7	890	460	-	1.1	-	2.1	-	0.3
23	Oct-90	4.7	890	460	-	1.1	-	2.1	-	0.3
25	Oct-90	4.7	3,600	2500	-	0.7	-	1.7	-	0.6
27	Oct-90	4.8	3,800	2700	-	0.6	-	1.9	-	0.6
29	Oct-90	5.2	4,000	2800	-	0.4	-	1.5	-	0.4
Pit water quality in 1991 (from Henkel, 1991b)										
0	May-91	6.6	180	71	-	0.4	-	0.8	-	0.1
2	May-91	4.6	190	76	-	0.4	-	0.8	-	0.1
12	May-91	5.9	180	73	-	0.2	-	0.8	-	0.1
14	May-91	6.3	180	73	-	0.4	-	0.8	-	0.0
20	May-91	6.1	190	76	-	0.4	-	0.9	-	0.0
22	May-91	5.5	250	110	-	0.5	-	1.2	-	0.1
24	May-91	5.2	380	220	-	0.5	-	1.5	-	0.2
26	May-91	5.4	3,600	2800	-	0.6	-	3.6	-	0.5
28	May-91	6.1	3,700	3100	-	0.2	-	4.4	-	0.3
30	May-91	6.4	3,700	3100	-	0.2	-	4.3	-	0.4
Pit water quality in April 1998 (from Lawton and Overall, 2002)										
0	Apr-98	6.9	143	53	0.2	0.2	0.4	0.4	0.1	0.03
5	Apr-98	6.7	141	-	0.2	0.1	0.4	0.4	0.1	0.03
10	Apr-98	6.5	130	48	0.2	0.1	0.3	0.4	0.1	0.02
15	Apr-98	5.6	124	-	0.2	0.2	0.03	0.7	0.1	0.04
20	Apr-98	5.5	125	51	0.2	0.2	0.02	0.7	0.1	0.04
25	Apr-98	5.4	137	-	0.2	0.2	0.03	0.7	0.1	0.04
30	Apr-98	5.3	161	71	0.2	0.3	0.1	0.9	0.2	0.1
31	Apr-98	5.0	240	-	0.3	0.4	0.1	1.2	0.2	0.1
32	Apr-98	4.7	418	-	0.5	0.6	0.1	1.7	0.3	0.2
33	Apr-98	4.5	1,104	-	1.1	1.1	0.1	3.5	1.0	1.0
34	Apr-98	4.8	2,278	-	1.6	1.1	16	10	1.8	2.0
35	Apr-98	4.7	3,478	2410	0.4	0.1	25	10	1.1	0.7
Depth profiling in May 2008 (by Tropical Water Solutions Pty Ltd.)										
0	May-08	-	-	45	0.1	0.1	0.16	0.32	0.06	0.02
15	May-08	-	-	45	0.1	0.1	0.22	0.31	0.06	0.02
31	May-08	-	-	101	0.0	0.1	0.06	0.64	0.09	0.05
Depth profiling by EMU in July 2014										
0	Jul-14	-	224	61	0.01	0.1	0.01	0.30	0.05	0.02
5	Jul-14	-	178	62	0.01	0.1	0.01	0.31	0.05	0.02
10	Jul-14	-	178	62	0.01	0.1	0.01	0.30	0.05	0.02
15	Jul-14	-	178	62	0.01	0.1	0.01	0.30	0.05	0.02
20	Jul-14	-	178	62	0.01	0.1	0.01	0.29	0.05	0.02
25	Jul-14	-	179	62	0.01	0.1	0.01	0.30	0.05	0.02
30	Jul-14	-	180	62	0.01	0.1	0.01	0.29	0.05	0.02
35	Jul-14	-	182	64	0.01	0.1	0.01	0.31	0.05	0.02
40	Jul-14	-	186	65	0.01	0.1	0.01	0.32	0.05	0.02
45	Jul-14	-	1,167	537	0.002	0.003	2.80	3.29	0.13	0.05
50	Jul-14	-	4,738	2,840	0.02	**0.00005**	14	11	0.24	0.003

Note: Red numbers indicate that the concentration was below the indicated detection limit and hyphens indicate the parameter was not measured
* Total metal concentrations

3.1.8. EBFR Water Quality Impacts

Observed streamflows in the EBFR vary predictably in response to intra-annual variability in rainfall and typically vary by several orders-of-magnitude over the course of a year. Sustained flows in the EBFR typically start in December or January and persist until May when flows begin to substantially recede. No appreciable flows are observed from July to October. For the purposes of deriving annual flows the water year is defined as July 1st to June 30th. Daily average discharges at monitoring locations on the EBFR are shown in Chapter 10 of the EIS, and exhibit considerable variation in wet season flow rates.

3.1.8.1. EBFR Water Quality Upstream of Mine Site

Upstream of the mine site (in the upper EBFR and Fitch Creek), the EBFR is typically circum-neutral in pH and characterized by less than 5 mg/L SO_4, 10 to 20 mg/L Mg, and very low concentrations of most metals, e.g. 0.001 to 0.002 mg/L Cu-t. Al-t and Fe-t concentrations in the EBFR upstream commonly exceed the LDWQOs for Zone 2 (0.236 mg/L Al and 0.300 mg/L Fe) due to high concentrations of naturally-occurring iron and aluminium in soils. Some of the natural loads are related to particulate matter and/or suspended sediments that are included in total metal concentrations.

3.1.8.2. Water Quality in Dyson's Area and EFDC

Elevated SO_4 and metal concentrations are initially observed in the upper EBFR in Dyson's Area and in Fitch Creek near the Main WRD and Zone 2 LDWQOs can be exceeded at both locations. This is consistent with streamflow surveys from April 2012 and May 2012 that show elevated SO_4 and metal concentrations due to AMD in the upper EBFR in Dyson's Area, in Fitch Creek, and in the EFDC (Figure 3-7). Those surveys also suggest a major load contribution to the EFDC from the Intermediate WRD, as metal concentrations in the EBFR often double or triple along the reach of the EFDC adjacent to the Intermediate WRD. Streamflows in Fitch Creek and the upper EBFR, or in the EFDC, are not routinely monitored so it is difficult to provide a rigorous assessment of when exceedances occur. However, it is evident from available water quality observations that Zone 2 LDWQOs are consistently exceeded in the EBFR throughout the site.

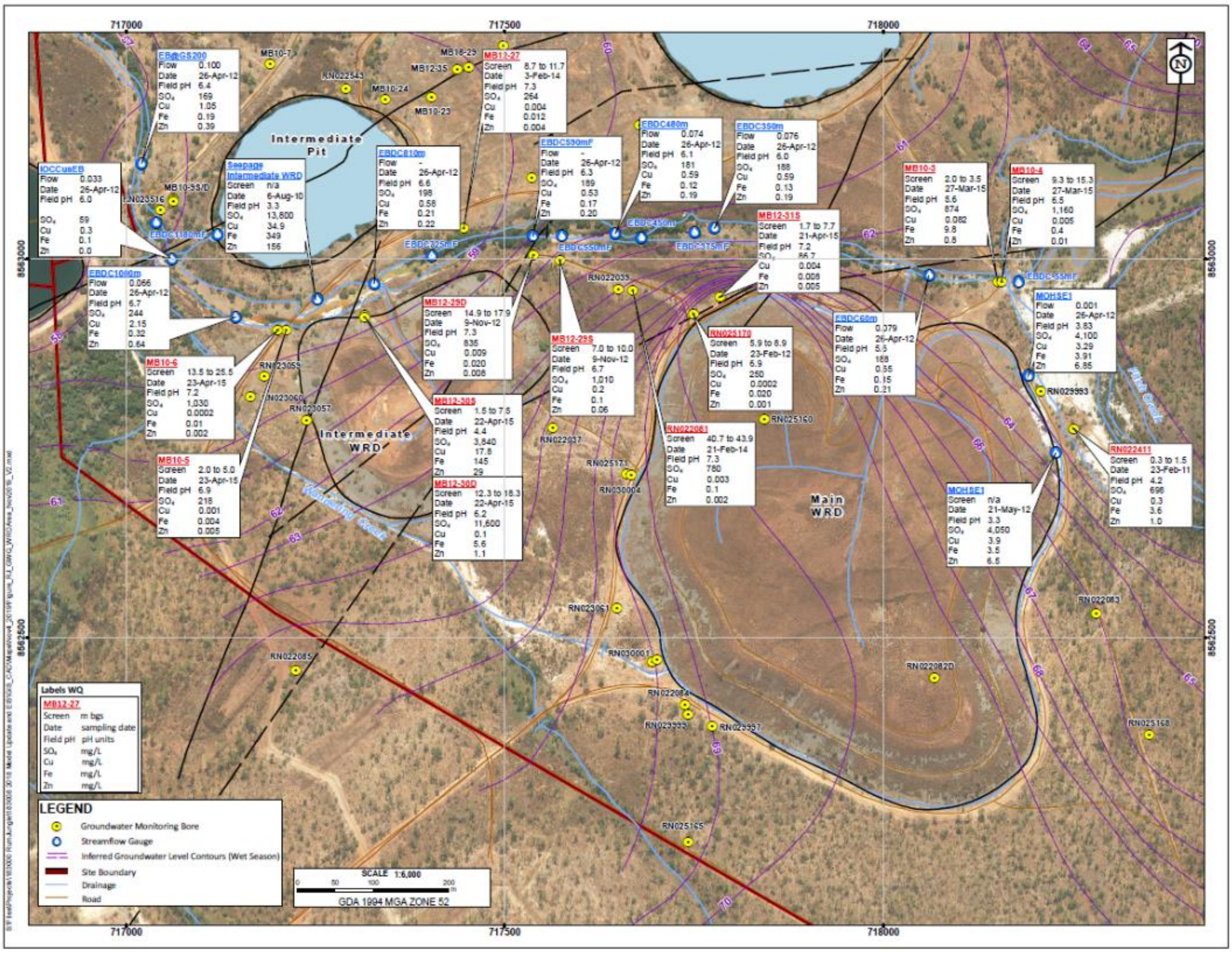


Figure 3-7 Groundwater and Surface Water Quality Observations near EFDC

3.1.8.3. EBFR Water Quality

EBFR water quality from 2010 to 2018 is discussed in the sub-sections below. Observed metal concentrations in the EBFR and LDWQOs from Hydrobiology Pty. Ltd. (2016) are expressed in milligrams per litre (mg/L) in this section and the remainder of this chapter for consistency. The discussion below highlights intra-annual variations in water quality to illustrate how direct inputs of AMD to the EBFR and inputs of AMD-impacted groundwater vary and to describe how concentrations of parameters from AMD inputs compare to LDWQOs. Further details are provided in RGC (2019) and Hydrobiology Pty. Ltd. (2016).

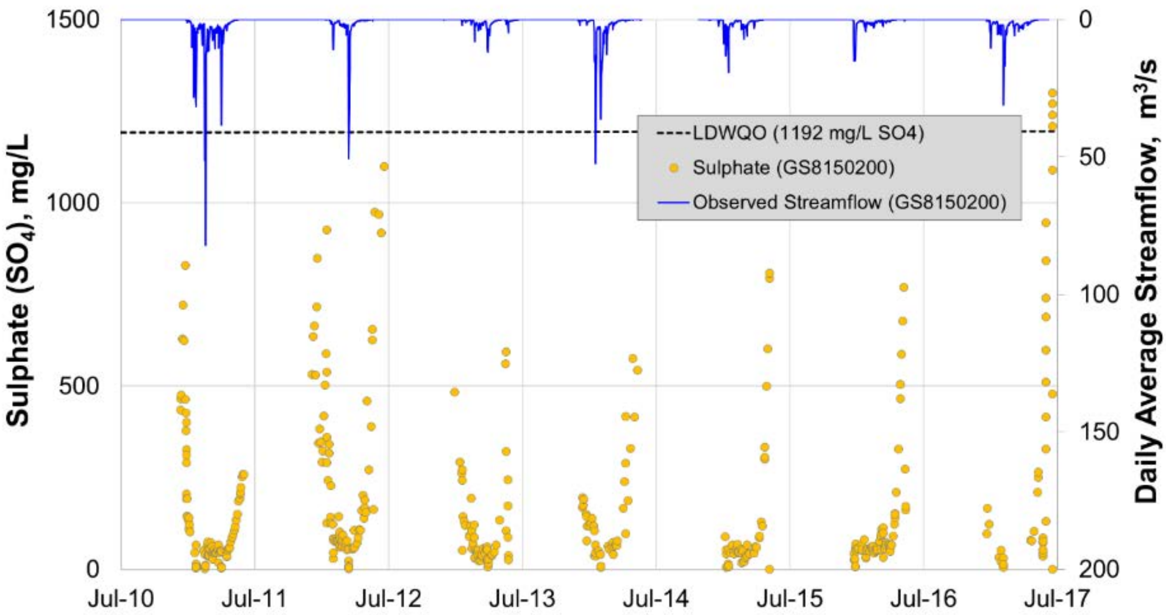
Observed SO_4 and Cu concentrations in the EBFR at gauges GS8150200, GS8150327, and GS8150097 from 2009 to 2018 are shown in Figure 3-8, Figure 3-9 and Figure 3-10, respectively.

LDWQOs for Al, Cu, Co, and Fe are commonly exceeded in the EBFR at GS8150200, GS8150327, and GS8150097, regardless of the flow in the EBFR. LDWQOs for SO_4 and Mg, and Zn are rarely exceeded if there is appreciable flows in the EBFR. The greatest impact from the site therefore occurs during the start of the wet season when pools of highly contaminated (by metals and acid) water that have accumulated in the site drainage lines during the dry are flushed out into the EBFR.

First flows at each gauge are observed in early December 2017 and peak flows occur in January and February before gradually receding in the subsequent months. At stations GS8150200, first flush pH values of around 4 and EC values higher than 1000 µS/cm are initially observed. Abrupt increases in flow in December 2017 are associated with higher pH values (to pH 5) and higher EC values, suggesting higher concentrations of SO_4, Mg, and some metals and acidic water is being flushed from the EFDC towards gauge GS8150200 by cleaner water following high flows from the EBFR upstream. Later in the wet season, short-term increases in flow cause lower pH and higher EC values, suggesting inputs of AMD-impacted groundwater from the site to the EBFR occurring between these flow periods. The trends at GS8150200 are generally consistent with the dilution of AMD inputs by EBFR flows from upstream, which explains the gradual increase in EC (and decrease in pH) during the late wet season.

In the EBFR downstream at stations GS8150327 and GS8150097, first flows also occurred in December 2017 and peaks flows occurred in January and February 2019. Unlike at GS8150200, the pH of the EBFR is initially circum-neutral during the early wet season, most likely due to the discharge of relatively unimpacted groundwater to the EBFR between gauges GS8150200 and GS8150097 during the dry season. This is consistent with pools in the EBFR that are sustained by higher pH groundwater discharge throughout the dry season.

EC values increased abruptly in early 2018 as higher flows occurred. pH values decreased to less than pH 6, suggesting a pulse of acidic water was moving downstream. pH values recover to near circum-neutral values in February and circum-neutral, if not slightly alkaline pH values, are typical in the late wet season. EC values are typically less than 500 µS/cm at GS8150200 and GS8150097 throughout the wet season, before values at both locations gradually increase as flows recede. Turbidity at the downstream gauges is generally higher than at GS8150200 due to the higher proportion of particulate metals that result from the precipitation of metal hydroxides within the creek. This is consistent with the observations of total and filtered metal concentrations at these gauges (see below).



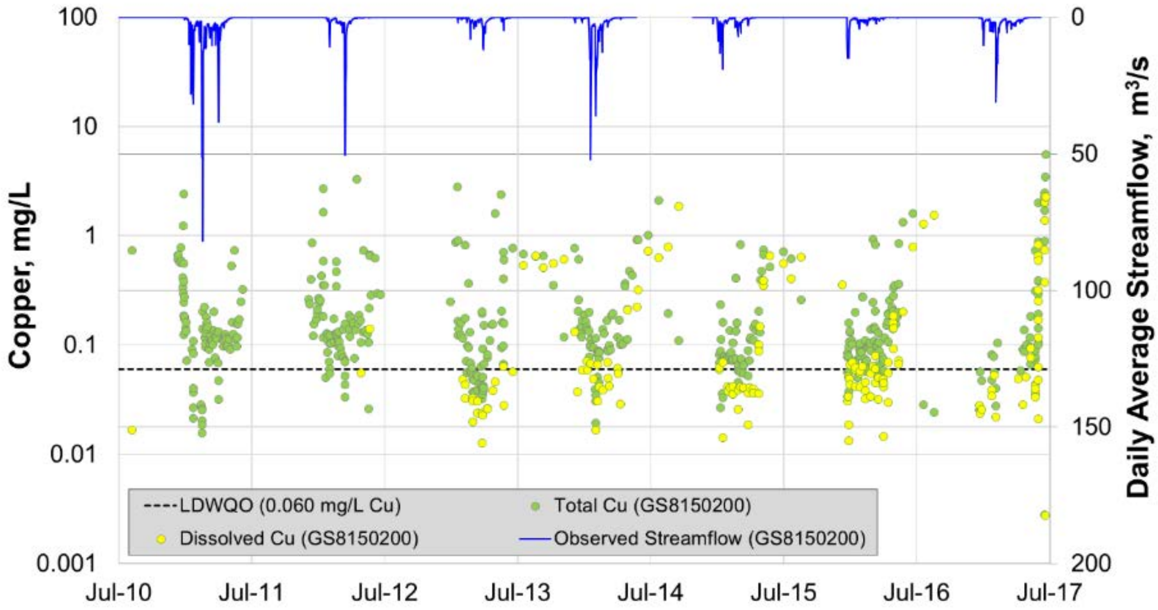
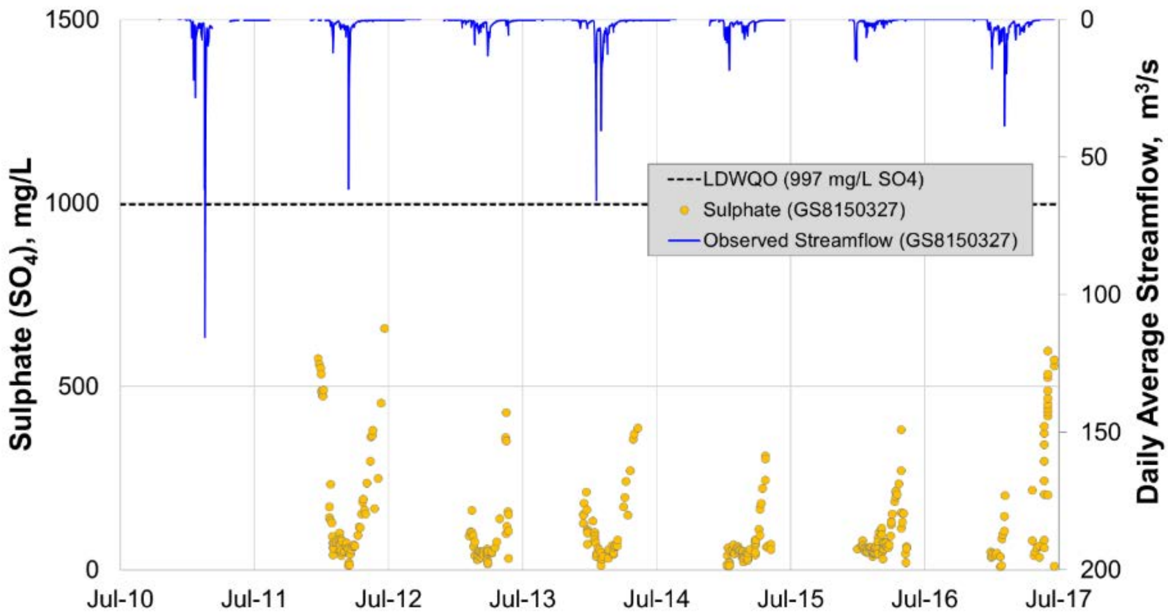


Figure 3-8 Observed Copper and Sulphate Concentrations in the EBFR at Gauge GS8150200, July 2010 to July 2017



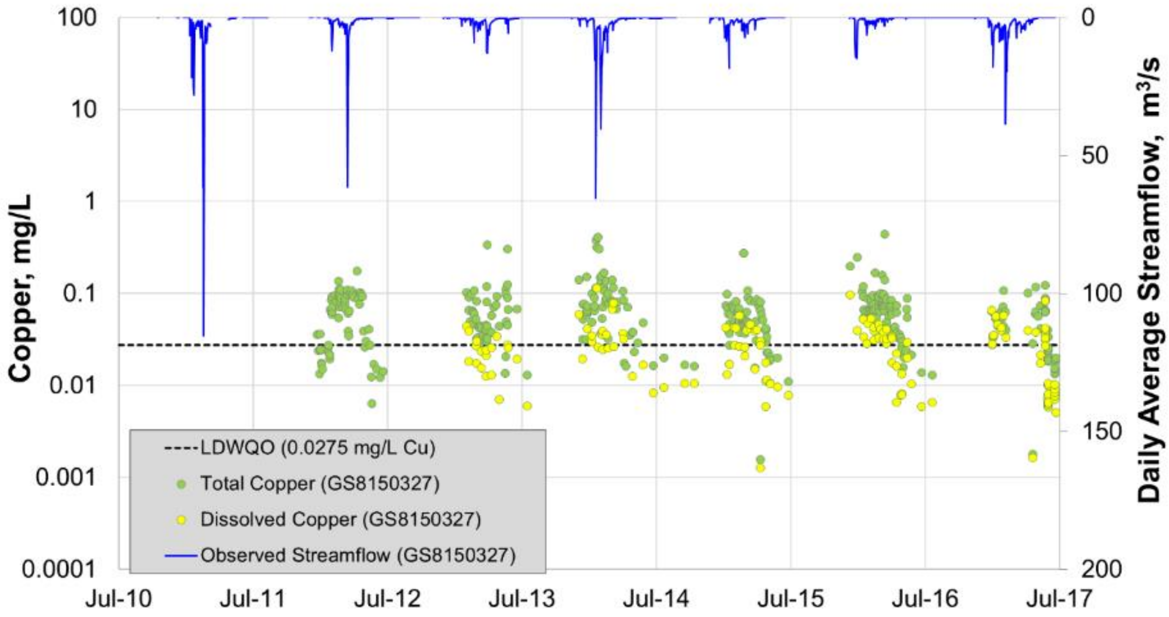
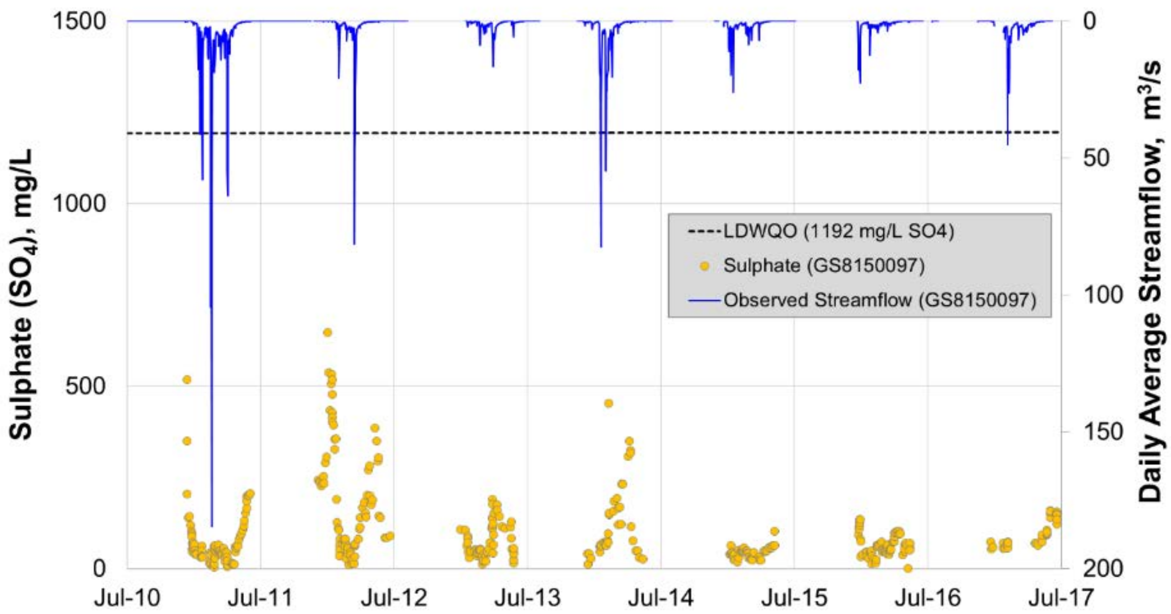


Figure 3-9 Observed Copper and Sulphate Concentrations in the EBFR at Gauge GS8150327, July 2010 to July 2017



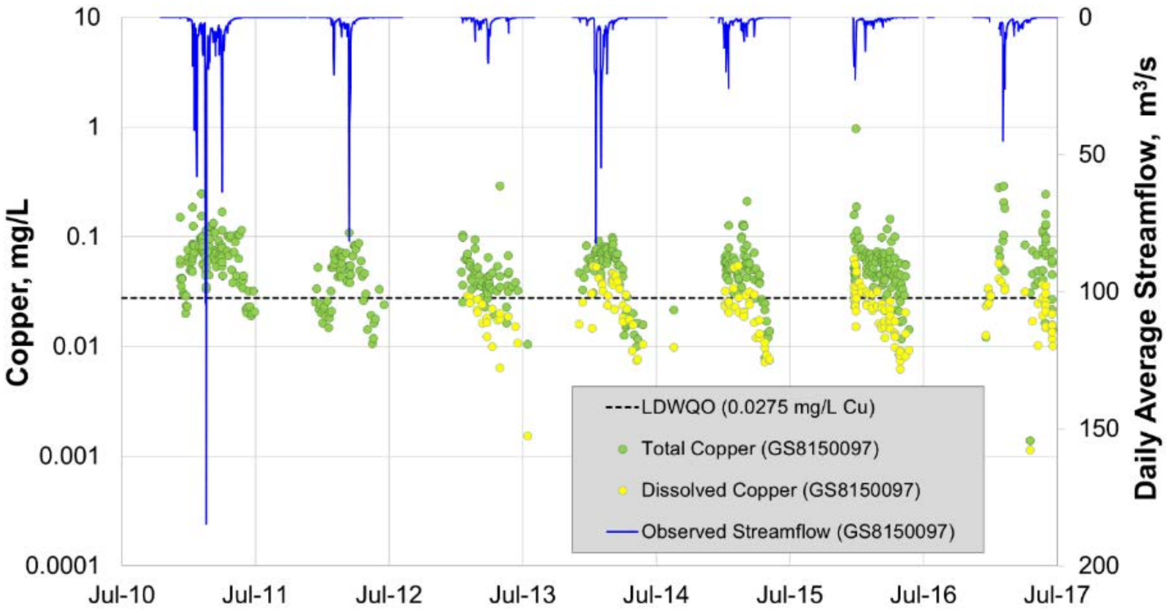


Figure 3-10 Observed Copper and Sulphate Concentrations in the EBFR at Gauge GS8150097, July 2010 to July 2017

LDWQO Exceedances

Figure 3-11 and Figure 3-12 show percentage exceedances for SO_4, Mg, and total metals in the EBFR at GS8150200 (Zone 2) and GS8150327 (Zone 3) since 2010. At GS8150200, only samples collected when flows in the EBFR exceed 0.05 m^3/s are included and only samples collected when flows in the EBFR exceed 0.1 m^3/s are included for GS8150327. This excludes samples of stagnant water collected when the creek is not flowing. LDWQOs from Hydrobiology are compared to total metal concentrations. This table shows that SO_4 and Mg concentrations rarely exceed the LDWQOs from Hydrobiology Pty. Ltd. (2016) under current conditions, whereas LDWQOs for Al, Cu, Co, Ni, and Fe are consistently exceeded.

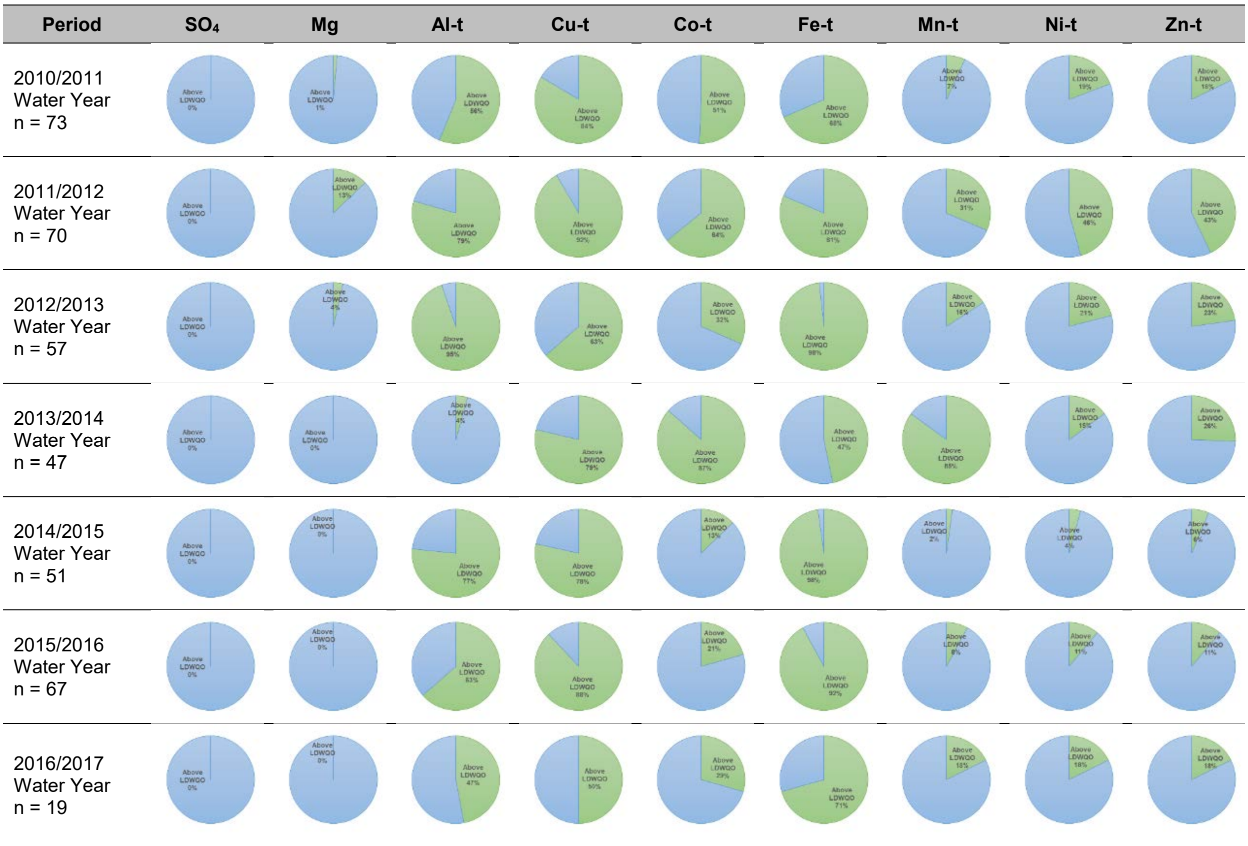


Figure 3-11 LDWQO Exceedances at Station GS8150200

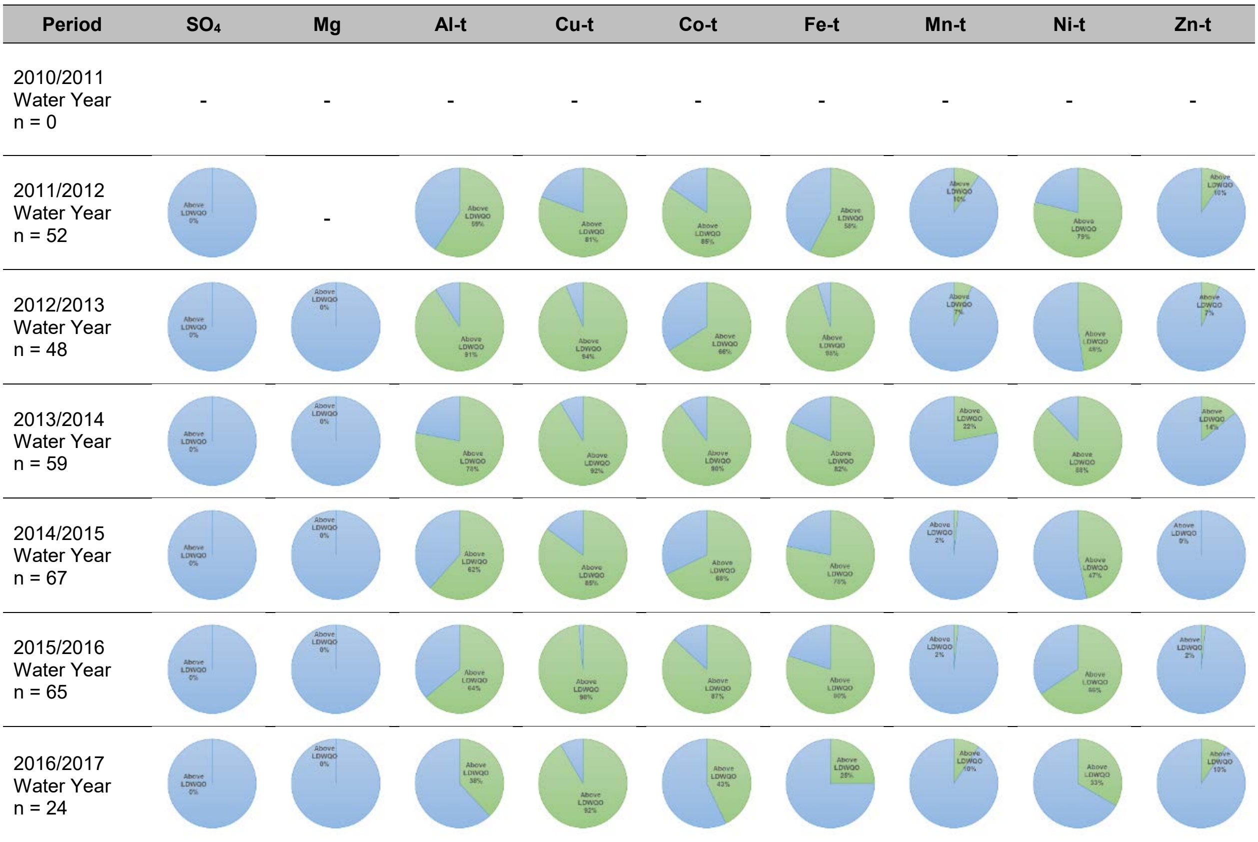


Figure 3-12 LDWQO Exceedances at Station GS8150327

Contaminant Loads in EBFR, 2010 to 2018

Observed SO_4 and Cu loads in the EBFR for the seven water years since 2010 are summarized in Table 3-6 and Table 3-7 respectively. Average rainfall and discharge volume in the EBFR for each water year (July 1st to June 30th) are also provided. SO_4 and Cu loads in the EBFR were calculated by "patching" the historic concentration records for stations GS8150200, GS8150327, and GS8150097. Patching, which is shorthand for the process by which sensible estimates are made for data gaps in a record, requires an examination of the concentration-discharge relationship at a given station. This is particularly important for the EBFR because the range of SO_4 and Cu concentrations decreases substantially downstream and the slopes of the concentration-discharge relationships varies between the monitoring stations. Further details on these relationships and the patching of historic concentrations records are provided in RGC (2019).

Key observations regarding observed SO_4 and Cu loads in the EBFR are summarized below:

- Annual SO_4 loads in the EBFR at GS81503200 range from 821 to 2086 t/year. The highest SO_4 load was for the 2010/2011 water year, which was the wettest water year during the calibration period. The average annual SO_4 load in the EBFR at station GS8150200 is 1270 t/year, or about 40% lower than the load for the 2010/2011 water year. Annual SO_4 loads are typically around 800 to 1000 t/year for water years with rainfall amounts near the long-term average for the site, i.e. 1438 mm.
- Annual SO_4 loads in the EBFR at station GS8150327 are higher than the loads at station GS8150200, suggesting a SO_4 load to the EBFR between these stations, most likely due to AMD-impacted pH neutral groundwater that discharges from the Old Tailings Dam area. The annual SO_4 loads in the EBFR at stations GS8150327 and GS8150097 are often within 10 to 20% of one another, suggesting no additional SO_4 load to the EBFR between these stations.
- Loads in the EBFR at station GS8150097 were the primary calibration target for the surface water modelling in Section 10.6, as it has the longest record of discharge and water quality and the EBFR is thoroughly mixed at that location. The rating curve for station GS8150097 does substantially over-estimate high flows but this over-estimation has few implications for the load calculations provided in this chapter and RGC (2019).
- Cu loads in the EBFR (for complete years) range from 1.4 t/year Cu to 5.7 t/year Cu, with the average annual Cu load being 2.6 to 2.8 t/year. Approximately two-thirds of the total Cu load in the EBFR at station GS8150097 is particulate Cu, either related to suspended sediments or precipitates. The proportion of particulate Cu at the other stations is slightly less. In contrast for SO_4 there is no evidence of any further inputs of Cu downstream of gauge GS8150200.

Further details on the derivation of annual SO_4 and Cu loads and patching historic concentrations is provided in RGC (2019).

Table 3-6 Observed Annual Sulphate Loads in the EBFR, 2010 to 2017

Water Year	Rainfall,	Annual Discharge Volume (at GS8150327)	Sulphate Loads at GS8150200,	Sulphate Loads at GS8150327,	Sulphate Loads at GS8150097,
	mm/year	m^3	t/year SO_4	t/year SO_4	t/year SO_4
2010/2011	2,460	74,095,587	2,086	-	3,354
2011/2012	1,492	29,591,751	1,100	1,886	1,707
2012/2013	1,432	23,490,086	821	1,233	973
2013/2014	1,649	43,976,995	1,960	2,992	2,244
2014/2015	1,146	28,287,014	914	1,010	1,196
2015/2016	1,291	13,274,331	893	1,112	1,074
2016/2017	1,529	38,867,128	1,119	1,759	1,648
Average:	**1,571**	**35,940,413**	**1,270**	**1,665**	**1,742**

Table 3-7 Observed Annual Copper Loads in the EBFR, 2010 to 2017

Water Year	Rainfall	Average Annual Streamflow (at GS8150097)	Copper Loads in EBFR at GS8150200		Copper Loads in EBFR at GS8150327		Copper Loads in EBFR at GS8150097	
			Cu-t	Cu-d	Cu-t	Cu-d	Cu-t	Cu-d
	mm	m^3	t/year	t/year	t/year	t/year	t/year	t/year
2010/2011	2,460	74,095,587	5.1	-	-	-	7.1	-
2011/2012	1,492	29,591,751	2.4	-	2.2	-	2.0	-
2012/2013	1,432	23,490,086	1.9	-	1.5	0.5	0.8	0.3
2013/2014	1,649	43,976,995	3.7	1.0	5.7	2.6	3.5	2.1
2014/2015	1,146	28,287,014	2.4	1.0	1.4	0.6	1.6	0.6
2015/2016	1,291	13,274,331	1.9	0.7	2.6	0.7	1.7	0.6
2016/2017	1,529	38,867,128	1.7	0.9	2.4	1.7	3.2	1.4
Average:	**1,571**	**35,940,413**	**2.7**	**0.9**	**2.6**	**1.2**	**2.8**	**1.0**

Notes:

Red numbers indicate an incomplete year, as data for first 2 to 3 months of the wet season are missing

4. Stage 3 Rehabilitation Project

4.1.1. Summary Erosion and Sediment Control Plan

The ESCP is applicable to all activities associated with the Project and will be used by all personnel (including contractors) involved in rehabilitation activities.

- The specific objectives of the ESCP are:
- To implement a management system to safeguard against soil loss and in turn, minimise the risk of water quality impacts;
- Assist in providing a self-sustaining and stable landform post rehabilitation;
- To meet the requirements of 'Best Practice Erosion and Sediment Control' guideline (IECA, 2008);
- Assist in preventing adverse impacts to the surrounding environment and the general public;
- To identify activities that could cause soil erosion and/or sedimentation; and
- To describe the proposed ESC measures to minimise soil erosion and the mitigation of sediment to downstream waters.

The following activities have been identified as activities that could cause soil erosion and generate sediment unless controlled:

- Stripping of vegetation, subsoil and topsoil;
- Stockpiling of subsoil and topsoil;
- Earthworks activities;
- Construction of water management structures (i.e. clean water diversions, dirty water channels and sediment dams);
- Construction / upgrades of river crossings;
- Construction/maintenance of roads and surface facilities (i.e. surface compound, cultural centre etc); and
- Vehicle and machinery movements.

The transport of sediment off site and into natural drainage systems can have a wide range of detrimental effects including safety, social, economic and environmental impacts. Pollution can occur in the form of finer sediment fractions such as silts and clays that create turbid water, and also in the form of coarse sediments such as sand particles that travel off-site.

Erosion and sediment controls are to be implemented across the site during the construction and rehabilitation works to mitigate the impacts on watercourses and the surrounding environment. Standard ESC techniques and management principles will be used in accordance with the requirements of *Best Practice Erosion and Sediment Control (IECA, 2008).*

The main runoff classifications to be managed by the site include:

- Clean water – surface water runoff from undisturbed areas of the site
- Dirty water – surface water runoff from disturbed areas of the site
- Contaminated water – water containing contaminants other than sediment (e.g. heavy metals, radioactive, hydrocarbons etc.).

The proposed water management and ESC measures will be designed to minimise the potential impact on downstream water quality. Wind and water erosion of disturbance areas cannot be eliminated completely however, measures will be taken to minimise the impact by:

- Conducting best practice land clearing procedures for all proposed disturbance areas;

- Undertake disturbance works, as much as is practically possible, during the dry season (May to November) and during periods when good weather is forecast;
- Stabilised rock pads (vibration grid) and/or wash down facilities will be installed at all site entry / exit points during the construction and rehabilitation works (refer to the ESCP for drawings);
- Appropriate storage of soil stockpiles in areas away from roadways and other drainage lines. Suitable sediment control measures will be installed downslope of soil stockpiles and upslope clean water runoff diverted (where possible). Refer to ESCP for the standard drawings;
- Minimising the disturbance footprint;
- Coordinating works to minimise the exposure duration of disturbed soils;
- Separation/diversion of ‘clean’ water catchment runoff from disturbed areas (where practical) to minimise sediment-laden runoff volumes requiring treatment;
- Containment of all contaminated water on-site prior to treatment or disposal of in a suitable manner;
- Minimising soil erosion (i.e. rehabilitation, drainage and erosion control measures including rock mulching) at the source, rather than trapping resultant sediment;
- Ensuring sediment-laden runoff is treated via designated sediment control devices;
- Clearly identifying/communicating no-go areas to maintain disturbance areas and traffic movement to the designated areas;
- Conducting bank stabilisation works for vegetation clearing required at creek crossings;
- Revegetation of disturbed areas as soon as possible following the completion of ground disturbance activities;
- Effective dust suppression measures;
- As per Australian Standards, any liquid wastes, fuels and oils stored on-site will be sufficiently bunded to contain any potential spills. Accidental spillage or poor management of fuels, oils, lubricants, hydraulic fluids, solvents and other chemicals during the construction phase will be controlled through spill management actions (including the availability of spill kits) to prevent water quality and ecological impacts and no further mitigation measures are considered necessary. Captured liquid wastes, fuels and oils should be pumped out by a liquid waste contractor and disposed of at an appropriately licenced facility; and
- Implementing an effective monitoring and maintenance program for the site.

Wherever possible, the Project has attempted to avoid disturbing areas of quality vegetation and has preferred to use areas which have previously been disturbed. Land disturbance would be minimised by clearing the smallest practical area of land required for the rehabilitation works and leaving this disturbed for the shortest possible time where practical. This will be achieved by:

- Restricting the areas to be cleared of existing vegetation to the areas being actively worked as well as no closer than 50 m from all existing second order watercourses and 100 m from all existing third order watercourses (except for the creek crossing and creek diversion remediation works);
- Clearly identifying and delineating areas in the field required to be disturbed and ensuring that disturbance is limited to those areas;
- Clearing vegetation only as required to achieve the works and minimising machinery disturbance outside of these areas; and
- Limiting the number of roads and tracks established.

The total areas to be disturbed and an estimate of the percentage of previously disturbed land is summarised below within Table 4-1.

Table 4-1 Estimated Disturbance Areas

Project Component	Total Mapped Area (m^2)*	Planned Disturbance Area (m^2)	Estimated Previously Disturbed Land (%)	New Clearing (m^2)
WSF East and West	705,650	-	90%	71,000
Contaminated soils	993,300	-	100%	-
Haul roads	9,435 m length	-	95%	-
Other infrastructure	50,000	-	100%	-
Cover Borrow	918,300	400,821	95%	20,000
Granulated Borrow	2,529,600	400,821	40%	20,000

Topsoil is a valuable resource for erosion control as it provides the basis for successful land stabilisation once earthworks have been completed. Topsoil can greatly increase the chances of groundcover germination and survival, and in many cases the topsoil will contain a viable seed bank that will germinate and survive well if appropriate conditions are maintained. This means that the correct management of topsoil can provide significant environmental and economic returns, as it is a cost-effective method of achieving land stabilisation without the need to import additional materials.

Best practice (IECA 2008) soil management are implemented where appropriate:

- Topsoil should be preserved for reuse on the site wherever possible;
- Wherever reasonable and practicable, strip and stockpile topsoil immediately before bulk earthworks, and confine any soil disturbance to the immediate construction stage;
- Topsoil should be stripped only while in a light moisture condition. If the soil is too dry, stripping it will pulverise the soil, if too wet it may lead to clodding or hardsetting – particularly if the soil has a high silt or clay content;
- To the maximum degree practicable, topsoils should not be mixed with subsoils during the stripping and stockpiling procedure, especially if the subsoils are dispersive;
- If it is desirable to retain the seed content of the soil, then the stockpiling should consist of long low mounds no greater than 1 to 1.5 m in height, otherwise topsoils stockpiles should not exceed 3m in height. Long term stockpiles (i.e. >12 months) may need to be mulched or temporarily vegetated to prevent weed infestation;
- Stripped topsoil should be used as soon as possible, and preferably not stockpiled for more than 12 months. Long term stockpiling can degrade its biological and chemical qualities;
- Maintain all stockpiles in a free draining condition to avoid long-term soil saturation;
- All topsoil should be tested for fertility and adjusted (where necessary), even if the soil originated from the site;
- Soil should be removed from stockpiles in a manner that avoids vehicles travelling over the stockpiles if possible;
- Exposed sub-soils should be covered as soon as practicable, especially if dispersive;
- After spreading topsoil, ensure the surface is left in a scarified (roughened) condition to assist moisture infiltration and inhibit soil erosion;
- When working adjacent to waterway vegetation, avoid spreading topsoil at a significantly different elevation form where it originated;
- Ensure all exposed sub-soils are covered, especially if dispersive; and
- Soil stockpile areas should be rehabilitated as soon as reasonable and practicable after the material has been removed.

Soil management and clearing works shall also comply with recommendations detailed within the Rehabilitation Plan, Weed Management Plan and Biodiversity Management Plan.

Erosion and Sediment Control Measures

All information pertaining to erosion and sediment control has been abstracted from SLR (2019) Erosion and Sediment Control Plan. The Rum Jungle site is located such that runoff from only a small upslope clean water catchment reports to the new WSF disturbance areas during rainfall events. Proposed ESC measures for the Project are described in the sections below. Minimising soil erosion (i.e. rehabilitation, drainage and erosion control measures including rock mulching) at the source is preferred over downslope sediment control measures. However, due to the extent of the proposed disturbance works some downslope sediment control measures such as sediment dams will be required to manage dirty water runoff.

Specific ESCP drawings will be prepared for the proposed works, by a suitably qualified person in accordance with the IECA guidelines, prior to any ground disturbance.

4.1.2. WSF Batter Erosion Control Measures

To minimise erosion risks and to maximise visual assimilation, the WSF batters will have a maximum gradient of 4(H):1(V), which is equivalent to 25%. The store and release cover system will consist of a compacted clay liner separating waste rock from a growth medium of two metres thickness. Rock mulching of batters will be carried out where required. Additional erosion control drainage measures will also be considered during the ESC design of the WRD following finalisation of the landform design.

A number of erosion control techniques are available for implementation at the site, as detailed in Table 4-2 below which is in accordance with the 'Best Practice Erosion and Sediment Control' guideline (IECA, 2008).

Table 4-2 Summary of Potential Erosion Control Measures

Erosion Control Measure	**Typical Use**
Bonded fibre matrix	Grass establishment and protection of newly seeded areas.
Cellular confinement system	• Containment of topsoil or rock mulch on medium to steep slopes. • Control erosion on non-vegetated medium to steep slopes such as bridge abutments and heavily shaded areas.
Compost blanket	• Used during the revegetation of steep slopes either incorporating grasses or other plants. • Particularly useful when the slope is too steep for the placement of topsoil, or when sufficient topsoil is absent from the slope.
Erosion control blanket	• Temporary erosion control on exposed soils not subjected to concentrated flow. • Temporary control of rain drop impact erosion on earth embankments before and during the revegetation phase.

Erosion Control Measure	Typical Use
Gravelling	• Protection of non-vegetated soils from raindrop impact erosion. • Stabilisation of site office area, temporary car parks and access roads.
Heavy mulching	• Stabilisation of soil surfaces that are expected to remain non-vegetated for medium to long periods. • Suppression of weed growth on non-grassed areas. • Stabilisation of existing and proposed garden beds.
Light mulching	• Control of raindrop impact erosion on flat and mild slopes. May be placed on steeper slopes with appropriate anchoring. • Control water loss and assist seed germination on newly seeded soil.
Revegetation	• Temporary and permanent stabilisation of soil. • Stabilisation of long-term stockpiles. • Includes turfing and temporary seeding.
Rock mulching	• Stabilisation of long-term, non-vegetated banks and minor drainage channels. • Stabilisation of those areas of a garden bed subject to concentrated overland flow.
Soil binder	• Dust control. • Stabilisation of unsealed roads.

To reduce erosion risks, the WSFs will be progressively rehabilitated over the construction phase.

4.1.3. Sediment Dams

Due to the extent of the proposed disturbance areas it is likely that a number of sediment dams will be required to manage dirty water runoff in accordance with the IECA guideline (IECA, 2008). The location and capacity of the dams will be determined following finalisation of the final landform designs and once the specific staging of works has been determined. Where practical, sediment dams will be located above the 5-year Average Recurrence Interval (ARI) flood level. Where this is not practical then all reasonable efforts will be undertaken to maximise the flood immunity of the dam.

Dam storage calculations will be undertaken in accordance with the 'Best Practice Erosion and Sediment Control' guideline (IECA, 2008) and include the following design criteria and assumptions:

- Capacity calculations based on a 5 day, 85th percentile rainfall depth of 46.7 mm derived from Equation B8 of the IECA guideline;
- Type F/D dams;
- Disturbed runoff coefficient of 0.69 in accordance with Table B7 of the IECA guideline for a type D hydrological group with rainfall between 40 – 50 mm;
- 'Clean' water runoff coefficient from undisturbed areas of 0.3; and

- The sediment storage zone determined based on a management period of 12 months (i.e. the sediment dam would be desilted once a year).

Sediment dams will be constructed with suitably designed spillways to manage overflows during significant storm events. The dams will also be constructed such that they are safe to people, vehicles and wildlife during their operation.

4.1.4. Works within the Existing Finniss River Diversion

Unless adequately managed, in-stream disturbance activities can represent a significant environmental hazard. These works can cause an increase to both turbidity and bed load sediment. These impacts have the potential to directly affect downstream ecological processes.

Works are proposed within the Finniss River Diversion including:

- A new culvert crossing;
- Upgrade works to the existing crossing;
- Remediation and rehabilitation works.

Suitable ESC measures will be implemented prior to the proposed works within the Finniss River Diversion. These measures will be determined once the final details of the works have been determined. Specific ESC measures that may be applicable to the in-stream works include the following:

- Only undertaking works during the dry season (May to November) and when good weather has been forecast;
- Staging of works to minimise risk at any given time;
- Downslope temporary sediment control measures (i.e. coir logs, sediment fences, check dams etc.);
- Bank stabilisation with rip rap material;
- Upslope coffer dams; and
- Bank rehabilitation works as soon as practically possible including:
    - Regrading to a maximum slope of 3(H):1(V);
    - The use of suitable topsoil to 100mm;
    - Amelioration with gypsum at a rate of 1kg/m^2;
    - Backfilling eroded areas, as required; and
    - Revegetation using suitable riparian seed mixes.

The importance of maintaining a natural vegetation buffer, of at least 25 m between waterways and any disturbed areas, is also recognised and adhered to as far as practicable.

4.1.5. Clean Water Diversions

Clean water diversions direct ‘clean’ water runoff from upstream catchments around the potentially disturbed and/or contaminated areas of the site. The local topographical conditions at the Rum Jungle site is such that the use of clean water diversions is likely to only be required for relatively small catchments upslope of small disturbance areas.

The need for clean water diversions will be identified following finalisation of the final landform designs and once the specific staging of works has been determined. Any clean water diversion structures will be designed to convey the 10-year ARI design discharge in accordance with Table 4.3.1 of the IECA guideline and will include suitable channel lining measures, as required.

4.1.6. Conveyance Channels

Runoff from areas exposed during the works (including the WSFs batters) will be controlled by construction of temporary conveyance channels and bunds/back push banks that will direct sediment laden runoff to suitably designed and constructed ESC devices. Proposed conveyance channels will be designed following finalisation of the final landform designs and once the specific staging of works has been determined.

Conveyance channels will be designed to convey runoff from a 10-year ARI rainfall event in accordance with Table 4.3.1 of the IECA guideline. Energy dissipation and sediment trapping structures (i.e. check dams) may be required (at regular intervals to limit erosion, however this will be determined during the design of the conveyance channels.

4.1.7. Check Dams

Check dams are used in channels to trap sediment and reduce the potential for scouring to occur. They can be made from a number of different materials including rock, sandbags, coir logs, hay bales etc. Check dams are typically installed at regular intervals which are typically closer together on steeper slopes.

It is important that check dams are installed such that flows cannot pass around the sides and that they overflow over the check dams themselves. The use of sandbags and hay bales are limited to temporary erosion and sediment control in channels during construction, as these devices tend to deteriorate over time. Where sandbags are used, it is important not to overfill them as this can cause gaps when the sandbags are wedged together. Three quarters to two thirds full is generally the right amount of material within each sandbag.

4.1.8. Sediment Fences

Sediment fences act as minor sediment dams. They temporarily detain runoff, trapping sediment and allowing filtered water to pass. Sediment fences should be constructed around the base of any small areas of exposed land that are not subject to concentrated overland flows and that are not adequately protected by existing structures. Sediment fencing should be installed around the extent of the disturbance area where sediment-laden water could potentially enter clean downstream receiving waters. They are placed on the contour or slightly convex to the contour and each end of the fence should be turned to create a stilling pond up slope of the fence. Sediment fences require regular maintenance. Trapped sediments should be removed, pickets straightened, filter cloth re-secured and tightened as required.

4.1.9. Vegetation Filters

Vegetative filters are used as a supplementary treatment device for sheet flow dirty water runoff. They provide a simple method of trapping coarse sediment in the majority of storms other than extreme storm events. This assumes that, where this vegetation is to be retained, it will have sufficient time to ‘recover’ before the next load of dirty water enters the vegetative filter. The amount of sediment that might be stored in the area above the filter and the width of the filter should both be considered in the design. Native vegetation in riparian zones should not be used as vegetative filters. The best vegetation cover is one that provides a relatively uniform dense ground cover (e.g. sward-forming grasses about 150mm high).

4.1.10. Roads / Access Tracks

ESC planning and construction of roads and access tracks is undertaken in accordance with the guidelines presented in Appendices J and K of the ‘Best Practice Erosion and Sediment Control’ guideline (IECA, 2008) or guidance material as supplied by the NT Rural Fire Service. Surface drainage is optimised and stabilised, thereby reducing roadside erosion and sedimentation.

To ensure any potential surface water impacts associated with the site access tracks and haul roads are minimised, the following measures will be undertaken:

- Provide cross fall drainage at 3% either side of the road crown (or from infall and outfall cross falls) to shed runoff from the road surface;
- Table drains, mitre drains, culverts and cross drains are to be used where required to safely convey the water from the haul road and access track surfaces so to prevent runoff from eroding them or adjacent land. Mitre drain spacing should not exceed 50 m even on soils with low erodibility. Cross Drains are placed every 20 to 90 m depending on the road grade and soil erodibility as required;
- Sediment fencing, sand bags or vegetation filters are used to control the sediment at the end of mitre drains, and controls are periodically inspected to maintain their performance; and
- Cut and fill batters associated with service tracks are formed to a safe slope and stabilised by vegetation. Where cut batters are greater than 1.5m, stabilisation methods are to be applied to these areas such as laying back, revegetation and drainage. Stabilisation is assisted by spreading topsoil and/or by applying chemical or organic mulch over the exposed batter surface. Fill batters are constructed with grades no steeper than greater than 2(H):1(V).

4.1.11. Dust Suppression

A number of controls are proposed to minimise the potential impacts of dust during the construction and rehabilitation works. These are described within the Air and Dust Management Plan and include:

- The use of water sprays on haul roads and unsealed surfaces;
- Implementation of road speed limits including lower speeds during high wind events;
- Limiting the amount and frequency of material transported; and
- Dust minimisation treatment of external haul roads (e.g. primer sealing on dirt roads).

In order to minimise water use, water for dust suppression can be sourced from sediment dams (if available), groundwater bores and the adjacent Brown's Oxide site (subject to a suitable water use agreement). Water from potable water sources (i.e. trucked-in) would only be used as a last resort. Both the Main and Intermediate Pit quality is not suitable for use as dust suppression or construction water.

4.1.12. Water Quality Trigger Values

The Proponent intends to achieve the LDWQOs during the construction phase of rehabilitation. The LDWQOs will be adopted as trigger values in a WDL and any exceedances will be reported upon in accordance with the requirements of the WDL. Reporting will involve a notification to the NT EPA and all exceedances will be documented in an annual Monitoring Report. The LDWQOs are applicable to the EBFR (in any zone) and apply to river flows and/or treated effluent that is present in the EBFR channel during the wet season or dry season unless other trigger values are agreed to in the WDL.

LDWQOs will be achieved during construction by operating the SIS and collecting surface runoff from each of the working areas in sediment trap ponds to reduce turbidity and total suspended sediment (TSS) loads prior to discharge to the EBFR. The pH of runoff collected in these ponds may also be modified to improve water quality prior to its release or the water could be directed to the water treatment system, if necessary. There are, however, no established LDWQOs for turbidity or TSS provided in Hydrobiology Pty. Ltd. (2016) so these decisions will depend on the conditions of a WDL.

4.1.13. Stage 3 Water Management

Water management planning will be further developed as Stage 3 detailed design work is progressed. The Main Pit will be backfilled during Years 1 to 4. Water management during the backfilling process will entail managing the pit water displaced during backfilling and the groundwater flows from the SIS and the recovery bores in the Copper Extraction Pad area and former ore stockpile area. The groundwater recovery bores will operate from Year 1 to 10 and recovered groundwater will be delivered to a water treatment plant (WTP). Currently, the dedicated water management facilities proposed include:

- the Groundwater SIS
- the Water Treatment Plant for treatment of both ground and surface water streams
- Sediment Control ponds as mentioned in the ESCP and
- the Intermediate Pit, which will be partly de-watered to provide live storage during pit backfilling.

There are no other water retaining dams or other facilities aside from the small storage ponds that may be needed to collect runoff from the borrow pit working faces.

A key element of the Stage 3 construction works is the backfilling of the Main Pit. This is currently scheduled to take approximately 4 years (3 wet seasons) and is planned to run through both the wet and dry seasons. It is currently proposed that waste rock will be deposited in the Main Pit by a conveyor system that will extend onto the surface of the pit lake via a system of articulated pontoons. The rock to which neutralant has been added will be discharged at the surface of the pond and drop through the water column to the bottom of the pit. Before this occurs a bridging layer of sand will be deposited over the tailings present in the pit to minimise the possibility of waste rock from penetrating the tailings and displacing this material upwards.

Rock will continue to be placed until it is approximately 1.5 m below the predicted minimum post-groundwater level. The system of articulated pontoons will allow this configuration to be achieved by moving the discharge point of the conveyor around the pond in a systematic manner, allowing for an even distribution of waste rock. The deposited waste rock will ultimately be capped with a layer of clean material (rock and sand) to physically separate it from the overlying water column. In order to do this task, surface water flows onsite will have to be well managed to avoid impacts to worker safety, to backfilling equipment and to protect offsite water quality during the backfilling process. WTP sludge will be co-disposed with the waste rock during backfilling operations. Sludge generated after the cessation of waste rock movement will be filtered and landfilled in a dedicated facility onsite.

The key objectives of the proposed water management strategy are to:

- Protect EBFR water quality by reducing the likelihood of spillage (uncontrolled discharge) of untreated water from the Intermediate Pit.
- Maintain the pond level in the Main Pit within a narrow range to facilitate operation of the floating conveyor system.

These objectives will be achieved using the following strategy:

- The inlet culvert to the Main Pit will be blocked at the outset of the rehabilitation phase to direct the full flow of the EBFR down the existing diversion channel, thereby substantially reducing the effective catchment areas of the Main Pit and Intermediate Pit and reducing the possibility of overflows from these pits to the environment during the construction period.
- All excess flows generated on the incremental catchments of the open pits, plus groundwater from recovery bores, are assumed to report to a water treatment system. The hydraulic capacity of the WTP will be sized to prevent spillage of untreated water from the Intermediate Pit to the EBFR, except during extremely wet years. For the purpose of the EIS, rainfall conditions that occurred during the 2010/2011 water year were adopted as the design event for selecting a suitable capacity. This water year was the wettest year of the 129-year SILO rainfall record and included Tropical Cyclone Carlos.
- Storage will be required to regulate the inflows to the water treatment system. The groundwater system will effectively act as the storage for the SIS, allowing for the temporary interruption of bore extractions during upset conditions at the WTP or during extreme flooding events. Additional storage (400,000 m^3) will be provided by maintaining minimum operating levels in the Main Pit and Intermediate Pit at 58 m AHD and 49 m AHD, respectively. These levels are roughly 2 m and 8 m below the spill elevations of the respective pit's outlet culvert. With the pit ponds drawn down to these target levels, the Main Pit would provide a live storage of about 160,000 m^3 while the Intermediate Pit would provide a larger storage of 240,000 m^3.
- The Intermediate Pit will be initially partially de-watered by pumping pit water directly to the EBFR during the wet season to reduce the water level and create temporary storage. Once the initial dewatering is completed, subsequent de-watering flows will be directed to the WTP. The pond level in the Main Pit will be maintained within a tight range to facilitate operation of the conveyor. To minimize interruptions of the pit backfilling operations, flows from the Main Pit may also be directed to the Intermediate Pit, meaning the pit backfilling operation will effectively become independent of the operation of the WTP.
- Some spillage may occur to the EBFR during rainfall events such as Tropical Cyclone Carlos in February 2011, which generated the single largest daily discharge ever recorded on the EBFR at gauge GS8150097. During Tropical Cyclone Carlos, the model (see RGC, 2019) simulated the complete filling of the live storage in the system resulting in a small spill of water from the Intermediate Pit, i.e. about 60 L/s for two days.
- When an extreme rainfall event such as Tropical Cyclone Carlos is predicted, the operation of the SIS and the conveyor system will be suspended to manage the Intermediate Pit level to avoid over-topping (spillage) to the EBFR. Overall, however, it seems unlikely that there will be any spillage from the pits to the EBFR unless an event comparable to Tropical Cyclone Carlos occurs while the Main Pit is being backfilled. Further details on how to reduce the likelihood of spillage, including the construction of diversion ditches around the Main Pit and operating rules to exploit live storage of the Main Pit, are provided in RGC (2019).

The Intermediate Pit will be de-watered during backfilling to provide "live storage" if required for displaced pit water and groundwater flows from the SIS and other recovery bores. Flows from the SIS bores, Main Pit, and Intermediate Pit will report to a water treatment system. Treated effluent from the water treatment system will be discharged to the EBFR. Discharge of treated water to the EBFR during the dry season may be necessary. Average flows of 10 to 17 L/s (peaking at 100 L/s) of treated water to the EBFR during the dry season are predicted while the pit is being backfilled. However, water demands for dust suppression, vehicle washing, nursery supply, and waste rock compaction during WSF construction, amongst other water demands, were not accounted for in the WLBM due to lack of information on the timing and intensity of these demands. Each of these demands could be substantial during the dry season so it is conceivable that there may be much less than 10 to 17 L/s of discharge, if any at all. Flows are then simulated to decrease so further reducing the likelihood of dry season discharge.

An Emergency Management Plan for the operation of this process will be required to protect workers, equipment and property in the event of extreme rainfall events (for example cyclones).

The operational water levels for the Pits are considered conservative for the 3 year operational phase and have been selected based on the following considerations:

1. The Intermediate Pit acts as a sink for some contaminated groundwater flows from the Intermediate and Main Waste Rock Dumps. Draw down of the Intermediate Pit will draw an increased flow of AMD-impacted groundwater into the Intermediate Pit thus deteriorating the water quality in that Pit. Excessive draw down of the Intermediate Pit is likely to cause significant deterioration to the Intermediate Pit water quality.
2. The Intermediate Pit is connected by groundwater to the East Branch and water quality of the Intermediate Pit itself can cause impact to the East Branch via groundwater drawdown and movement.
3. The Intermediate Pit is connected by groundwater to the groundwater dependant ecosystem to the north of the Intermediate Pit. This vine forest would be adversely impacted by excessive drawdown of the Intermediate Pit.
4. The Main Pit is to be backfilled by an overwater conveyor and barge setup. This requires a minimum freeboard in which to operate. Additionally, geotechnical stability of the Main Pit crest is at risk under excessive pit water draw down. This would present an unacceptable safety risk.
5. The nominated operational water levels were modelled against rainfall events that have occurred within the 45 year dataset of events captured at GS150097. This configuration of pit water elevations would allow for capture of all high rainfall events within the dataset except for Tropical Cyclone Carlos.

It is likely that the Main Pit water quality will deteriorate during backfilling operations because the existing chemocline is likely to be disturbed and vertical water column mixing may occur. Additionally, the placement of waste rock materials that have been on surface for up to 70 years into the water filled void is likely to cause solutes within the waste rock to dissolve. It is imperative that pH control of the Main Pit lake is maintained to precipitate high risk heavy metals and to reduce further acidification. However, soluble salts such as calcium, magnesium, potassium and sodium sulphate are likely to readily dissolve into solution. The water quality during backfilling is difficult to predict; therefore, the most critical controls for environmental protection are the Water Treatment Plant and the maintenance of a ‘live storage’ volume as described above.

The riparian and aquatic habitats associated with the river have evolved to such conditions, and any substantial change to flow regimes because of project works could have an impact on those habitats. Such changes could be as result of temporary or permanent diversions of watercourses, and/or changes due to earthworks to the surface hydrology in the sub-catchments that supply them. There are currently no planned works that would result in reduced wet season flow regimes in the East Branch.

However, in order to safely manage surface waters within the site Pits, and to backfill the Main Pit in the most efficient manner possible, it is proposed that surface water discharge from site would be required during the Cease to Flow period (dry season). The volume of this discharge is estimated at a maximum of 10-17 L/sec (totalling approximately 0.2 GL) for the dry season period. This is the volume of water predicted to exit the Water Treatment Plant during the dry season and it is important to note that a significant proportion of this volume (approximately half) would be consumed in onsite earthworks processes for dust suppression and Waste Storage Facility construction. The volume of dry season treated water is equivalent to the pumped groundwater for treatment from the existing Waste Rock Dumps. This is proposed for the three-year pit backfilling operation. Although it would be helpful to also discharge to the EBFR during the dry season for the post-backfill period of six years, this additional period of time may be considered to pose an unacceptable risk to the downstream ephemeral systems. An efficient alternative storage arrangement for the post-backfilling period can be found in the Intermediate Pit.

The discharge point for this water to the EBFR is yet to be finalised and will be complete and will be done so within the timeframe of the detailed engineering design package.

In order to gain perspective on this proposed WTP discharge regime, the available data for current flow conditions for the downstream flow gauging station GS15097 and GS150204 were compared to conditions predicted with the addition of the WTP discharge. The station GS150097 is downstream of the Rum Jungle project boundary by approximately 5.6 km, whilst GS150204 is located approximately 3 km downstream of GS150097 beyond the confluence of the East Branch and West Branch.

A summary of the potential impacts to the hydrological regime are presented here in Table 4-3.

Table 4-3 Impact of Proposed WTP Discharge Regime During Pit Backfilling (3 yrs)

Station:	**GS150097**		**GS150204****	
Parameter	**Current Condition**	**Predicted Change**	**Current Condition**	**Predicted**
Flow Period	Early Dec to early Jun	Year round	Dec to mid-Oct	Unchanged
Peak Flow	Feb-Mar	Unchanged	Jan-Mar	Unchanged
Annual Volume	10-65 GL	Increase by 0.6 GL	90-310 GL	Increase <0.6 GL
Wet Season Flow Rate	0.6-4 m^3/s	Increase by 0.034 m^3/s*	7-18 m^3/s	Increase < 0.034 m^3/s

**Averaged groundwater contribution for a year*

Alternatives to the dry season discharge include the construction of a substantial water storage facility onsite, or the further drawdown of the Intermediate Pit during the East Branch flow period. Both alternatives are not considered a sound investment of Project (public) funds, as the potential risk to aquatic ecosystem health is considered to be Moderate due to:

- The short term nature of this activity (3 seasons);
- The current impacted aquatic ecosystem health of the downstream East Branch due to historic water quality impacts from Rum Jungle AMD; and
- The Finniss River proper is a large permanent watercourse, therefore impacts to it can be absorbed.

Therefore, at worst, any detrimental impact would be felt at the East Branch section from site to 8 km downstream of site as this is the point of confluence with the permanent watercourse. This is the section of the river that is most heavily impacted by historic and ongoing AMD contamination.

The impact to hydrological processes due to altered surface water flow regimes during the Pit backfilling operations will be moderated by maximumising the use of treated water in the dust suppression and construction processes onsite. The dry time of year correlates to the highest water demand period for dust suppression and construction, because all work areas will be subject to low humidity, warm conditions and high equipment movement rates. The availability of this treated water offsets the need to abstract from clean water sources for the purpose of dust suppression and construction.

4.1.14. Stage 3 East Branch Finniss River re-instatement

A cornerstone of the cultural restoration of the Rum Jungle site is to restore, as far as possible, the original flow path of the East Branch Finniss River. This has been explicitly requested by senior Traditional Owners and Custodians of the site. This will involve the reconstruction of a flow path that safely conveys water through the Main Pit lake, the original river bed, the Intermediate Pt Lake and then out to the main channel of the East Branch. This is expected to have a positive impact on restoration of site cultural values, on seasonal passage of aquatic fauna, on aquatic fauna colonisation of onsite features such as the Main Pit Lake, and on control of site AMD contamination processes.

The reinstatement of the EBFR flow path will not significantly alter downstream hydrology. There may be a slight delay in ‘wetting up’ of this section of the watercourse as the Main and Intermediate Pit landforms fill to the point of overflow.

The reinstated channel will be designed in accordance with leading practice guidelines for channel restoration and reinstatement and include the following considerations:

- Replicating, as far as practicable, the morphological and hydraulic characteristics of the natural East Branch channel. These might include factors such as width, depth, instream bars and benches, bed material and substrate, roughness elements, slope, length and vegetation.
- Incorporate natural features present in the landscape and in local watercourses.
- Maintain equilibrium, functionality and stability.
- Consider longer term sediment supply, transport and fate within the context of the local conditions.
- Ensuring that there is no increase in flood levels at sacred sites upstream of the Main Pit.
- Design to the 1% AEP flood event and not alter current upstream flooding regine.

Key site specific considerations for the reinstatement will include:

- The need to ensure passage for aquatic fauna through the pits and the reinstated channel. This will require flow velocities to accord to appropriate limits, and the inclusion of areas of temporary refuge for migrating aquatic fauna using roughness elements, backwaters and the like.
- Establishment of a resilient vegetation community using appropriate and acceptable species to enhance natural values and provide erosion protection, particularly given the seasonal rainfall characteristics and potentially high flow rates. This will require establishment of a stable soil surface, and establishing both fast growing ground cover and slower growing shrubs and trees via seeding and the use of tube stock.
- Low weirs and diversion structures as appropriate to ensure the required flow split between the Existing Diversion and the Reinstated Channel is achieved.

Key considerations for the backfilled Main Pit are expected to include:

- Engineered entry and exit transition zones between the reinstated channel and both the Main and Intermediate pits to ensure that erosion does not occur at these flow transition points.
- Covers over waste rock in the Main Pit, including rip rap rock armour.
- Re-profiling of the Pit rim edge area to allow vegetation to establish.
- Overland drainage management to prevent uncontrolled runoff into the Main Pit from overland flow, and any associated erosion and gullying.

Detailed design of the EBFR reinstatement will be prepared by appropriately qualified professional.

The EBFR will not be connected into the Main Pit until the Main Pit is backfilled, cover material placed over the backfill, and the water inside the Main Pit meets environmental criteria for discharge to the EBFR. During most of the construction phase flows in the EBFR will continue to flow into the existing diversion of the EBFR, located south of the Main Pit.

4.1.15. Predictive Groundwater Modelling Stage 3

Groundwater recovery and treatment is a key component of the Stage 3 rehabilitation works and the recovery system has been designed to address significant sources of AMD contamination to the EBFR. Additionally, recovery of impacted groundwater that does not contribute significant loads to the EBFR is also planned to improve the groundwater values within the main Rum Jungle site. Groundwater conditions during the construction phase of rehabilitation were predicted by adapting the calibrated groundwater model. Key adaptations were to:

- Represent the effect of thirteen groundwater recovery bores (SIS bores – see Figure 4-1) that are intended to reduce loads to the EBFR during the construction phase of rehabilitation and reduce the extent of impacted groundwater (plumes) that may discharge to the EBFR post-rehabilitation. The bores would be constructed in the Year 1 Dry Season and are assumed to operate throughout the construction phase of rehabilitation and for five years after construction earthworks are completed. Seepage may also be collected from (i) the existing ditch along the western toe of the Main WRD (via a sump near the head of the EFDC) and/or (ii) an interceptor trench along the northern "toe" of the Intermediate WRD.
- Progressively reduce the extents of the WRD footprints and the footprint of Dyson's (backfilled) Pit each year as material is hauled to either the WSF or the Main Pit (see Figure 4-2). This was done by assuming any changes in the residual footprint areas at the end of a Dry Season are represented in the subsequent Wet Season, based on footprint areas provided by SLR.
- Represent the effect of four groundwater recovery bores in the Copper Extraction Pad area and one recovery bore in the former ore stockpile area that are intended to improve local groundwater quality in these areas.
- Maintain a fixed pit water level (58 m AHD) in the Main Pit during pit backfilling in Years 1 to 4 to allow the conveyor proposed by SLR to operate safely and efficiently during a range of rainfall (runoff) conditions (see WMP for further details).
- Maintain a fixed pit water level for the Intermediate Pit approximately 8 m (49 m AHD) below the invert elevation of the outlet to provide adequate live storage to prevent spillage from the Main Pit during backfilling for most rainfall events (see WMP for further details).
- Assume seepage to groundwater from the new WSF at a rate of 21 mm/y through the horizontal top and 17 mm/y for the side-slopes, as per infiltration rates for the "Cover #3 Low NP" cover alternative from O'Kane Consultants (2013). This rate represents infiltration through the closure cover proposed for the WSF and may represent a lower bound for effective amount of water introduced during the construction period, either by rainfall or dust suppression or to compact waste rock. The above numbers were assumed here for simplicity and to estimate the initiation of seepage from the WSF during the construction phase of rehabilitation. Seepage to groundwater is assigned 10,000 mg/L SO_4 and 0.2 mg/L Cu as per RGC and DJEE (2019).

- Assume seepage from backfill materials in the Main Pit to groundwater downgradient in Year 5 and onwards. The seepage rate is proportional to constant head boundary that is assumed to maintain at least 2 m of water over the sand backfill in the Main Pit. Seepage from backfill materials is assigned 2,000 mg/L SO_4 and 0.2 mg/L Cu, based on batch testing results provided in RGC and DJEE (2019).
- Cease operating the recovery bores after the Year 10 Wet Season.

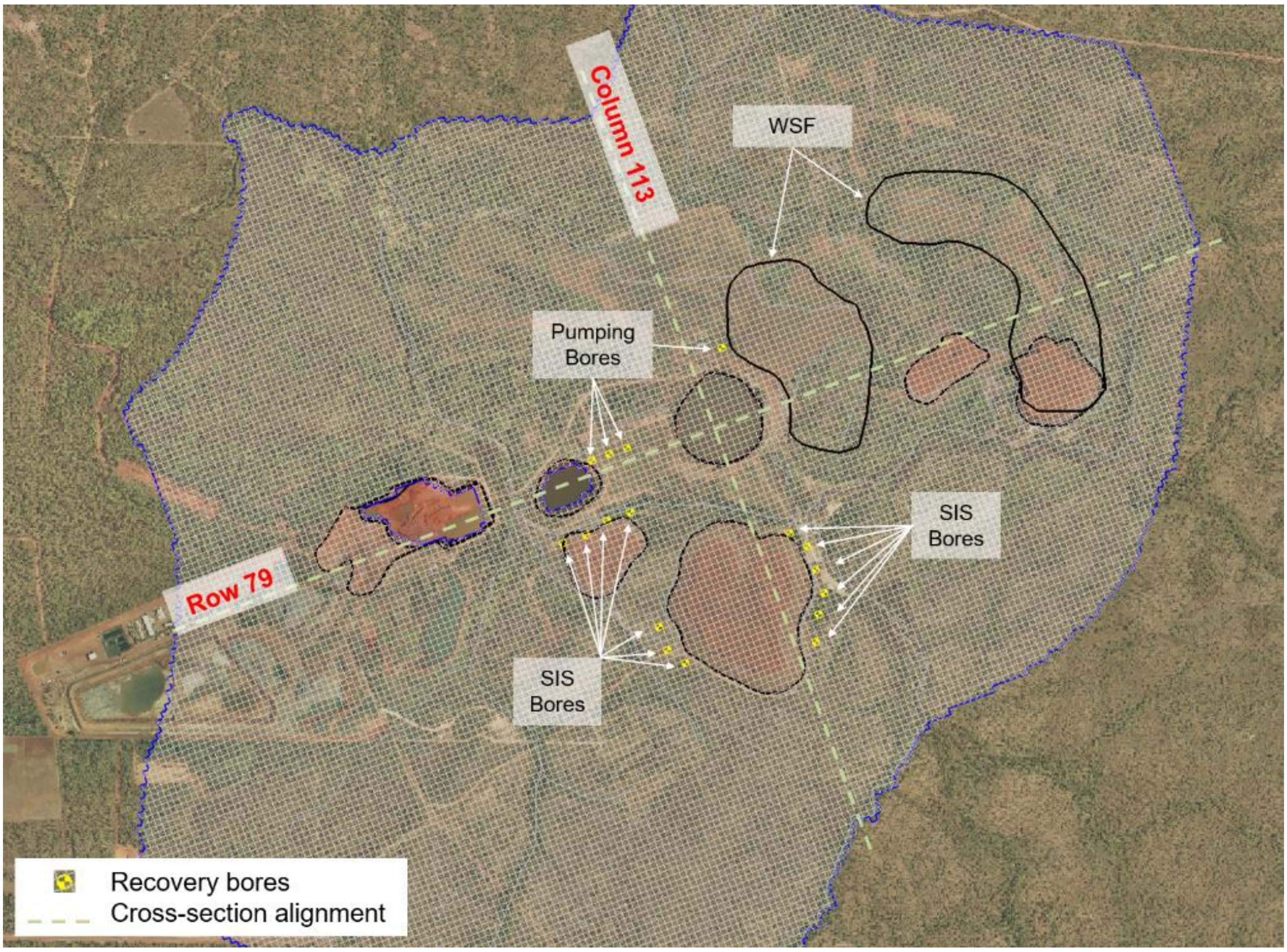


Figure 4-1 Recovery Bore Locations and Cross-Section Alignments

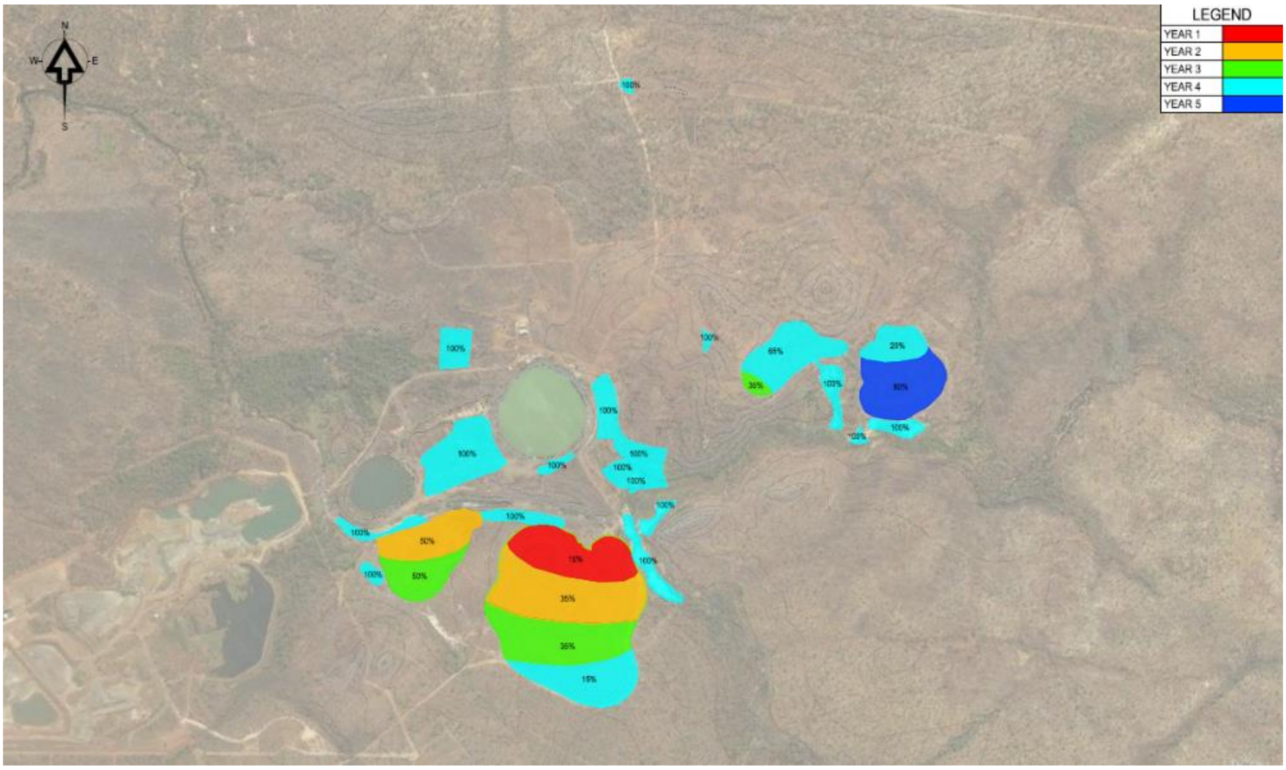


Figure 4-2 Waste Re-Location Sequence and Residual WRD Footprints

4.1.15.1. Predicted Groundwater Conditions – Construction Phase

Simulated SO_4 and Cu plumes for Years 1 to 10 are shown in Figure 4-3, Figure 4-4 and Figure 4-5**.** Predicted loads to the EBFR and the pits during the construction period are summarized in Table 4-4 and Table 4-5. Key observations from these figures and tables are summarized below:

- The SIS bores and the recovery bores in the Copper Extraction Pad area are simulated to extract a combined 17 L/s during the dry season and 34 L/s during the wet season, or about 1 to 2 L/s per bore. These flows are the maximum able to be sustained by pump extraction based on the calibrated hydraulic properties for bedrock, i.e. Rum Jungle Complex near the Main WRD and Whites Formation near the Intermediate WRD.
- The SIS bores are predicted to recover more than 1000 t/year SO_4 in Years 1, 2, and 3. Annual loads are then predicted to decrease as the extent of the SO_4 plumes is reduced by pumping, particularly after the Main and Intermediate WRDs have been re-located. The SIS bores recover 6 to 8 t/year Cu in Years 1 to 8 and slightly less in Years 9 and 10. The average annual Cu-t load recovered during the construction period is 6.6 t/year. This load is approximately twice the observed Cu load in the EBFR for current conditions, as the Cu load recovered in the Copper Extraction Pad area is predicted to be substantial.
- A substantial reduction during the construction period in the extent of the AMD-impacted groundwater is predicted by the model due to operating the SIS and recovery bores in the Copper Extraction Pad area and former ore stockpile area. The extent of the simulated SO_4 and Cu plumes is reduced to a greater extent after the active AMD sources on site, (the WRDs and shallow backfill materials in Dyson's Pit) have been removed. This is particularly evident for SO_4 because it is assumed to be transported conservatively in groundwater. Cu plumes are slower to reduce in extent because the SIS relies on Cu-impacted groundwater near and within the WRD footprints reaching the SIS bores near the EBFR. The rate of reduction of Cu loads in the system

will much slower than for SO_4, since as discussed previously it is dependent on the rate of desorption/dissolution of Cu from the rock matrix.

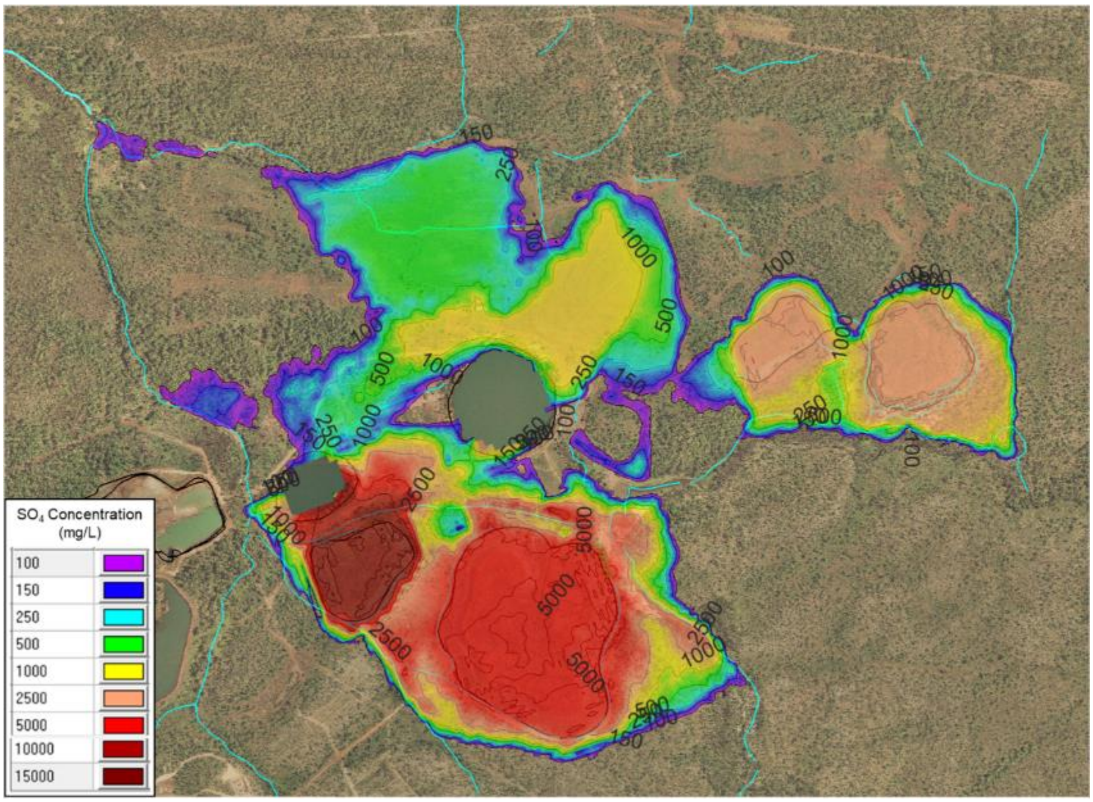
- There are no SIS bores proposed to be installed in the Dyson's Area because the Cu load to the EBFR was considered small enough that LDWQOs could be achieved during construction without recovering this load. Hence groundwater quality in Dyson's Area is not predicted to start to improve until waste rock from Dyson's WRD and shallow backfill materials from Dyson's pit are re-located and groundwater in this area begins to be flushed by rainfall without an AMD source present.
- In Year 5, a SO_4 plume is predicted to start emanating from the backfilled Main Pit and SO_4 plumes emanating from the WSF footprints are predicted to develop. This assumes seepage starts to occur almost immediately, as per O'Kane Consultants Inc. (2016). The predicted SO_4 plume from the northern WSF footprint migrates north and then west towards Old Tailings Creek. The SO_4 plume from the other WSF footprint is simulated to move west until it reaches the Main Pit. A Cu plume is also predicted to develop from the Main Pit backfill but is characterized by concentrations that are too small to differentiate from residual impacted groundwater in the Copper Extraction Pad area. A low-strength Cu plume from the WSF is restricted in extent and difficult to discern at the regional scale of the groundwater model.
- In Year 9, the groundwater model predicts that SO_4 and Cu loads to the EBFR will be reduced to 66 t/year and 0.24 t/year, respectively. These loads are both an order-of-magnitude lower than the simulated SO_4 and Cu loads for current conditions, suggesting SO_4 and Cu concentrations in the EBFR will likely be much lower than LDWQOs while the SIS is operating.
- In Year 10, the groundwater model predicts residual Cu plumes near the northern toe of the Intermediate WRD (where it meets the EFDC) and near the northeast corner of the Main WRD. These residual plumes account for most of the post-rehabilitation Cu load to the EBFR and could affect whether LDWQOs for Zone 2 are achieved. More detailed modelling will be done during the detailed design phase of the project to help determine if these residual plumes may be problematic or if the current predictions of the groundwater model are over-estimating the extent and strength of the Cu plumes in these areas (see RGC, 2019).

Table 4-4 Predicted Sulphate Loads During Stage 3

Reach	Description	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Average (Years 5 to 10)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	118	146	147	150	124	59	37	32	27	25	50	56%
B	Main WRD (east)	21	4	1	1	0	0	0	0	0	0	0	0%
C	Main WRD (west) and Int. WRD	22	13	9	6	3	3	2	2	1	1	2	2%
D	Middlebrook Creek	0	0	0	0	0	0	0	0	0	0	0	0%
E	EFDC near Main and Int. WRDs	9	10	8	6	5	5	4	4	3	3	4	5%
F	Former stockpile area	9	6	5	5	4	7	7	7	7	7	6	7%
G	EBFR downstream of GS8150200	2	0	0	0	5	13	13	13	13	13	12	13%
H	EBFR in Old Tailings Dam area	5	2	1	1	2	7	8	8	8	8	7	8%
I	EBFR near GS8150327	5	2	1	1	2	6	8	9	9	10	7	8%
	Simulated Load to EBFR:	**192**	**183**	**172**	**169**	**146**	**100**	**80**	**75**	**69**	**66**	**89**	**100%**
-	To Main Pit	42	47	46	48	37	37	26	25	25	25	29	86%
-	To Int. Pit	235	276	225	195	3	4	3	3	3	3	3	9%
-	To Browns Pit	0	0	0	0	1	2	2	2	2	2	2	5%
-	To Model Flooding Drains	1	1	1	0	0	0	0	0	0	0	0	0%
	Simulated Load to Pits:	**277**	**324**	**271**	**243**	**40**	**43**	**31**	**30**	**30**	**29**	**34**	**100%**
-	Load to recovery bores	1112	1398	1004	703	446	381	325	295	282	266	332	-

Table 4-5 Predicted Copper Loads During Stage 3

Reach	Description	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Average (Years 5 to 10)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	0.24	0.29	0.29	0.31	0.28	0.25	0.22	0.21	0.20	0.19	0.23	84%
B	Main WRD (east)	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	3%
C	Main WRD (west) and Int. WRD	0.06	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	9%
D	Middlebrook Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
E	EFDC near Main and Int. WRDs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4%
F	Former stockpile area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
G	EBFR downstream of GS8150200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
H	EBFR in Old Tailings Dam area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
I	EBFR near GS8150327	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	Simulated Load to EBFR:	**0.35**	**0.36**	**0.35**	**0.36**	**0.33**	**0.30**	**0.26**	**0.25**	**0.24**	**0.23**	**0.27**	**100%**
-	To Main Pit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	12%
-	To Int. Pit	0.7	1.2	1.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.02	86%
-	To Browns Pit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	2%
-	To Model Flooding Drains	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0%
	Simulated Load to Pits:	**0.7**	**1.3**	**1.3**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.02**	**100%**
-	Load to recovery bores	4.8	7.8	6.9	6.5	7.9	7.4	6.7	6.3	5.8	5.4	6.6	-



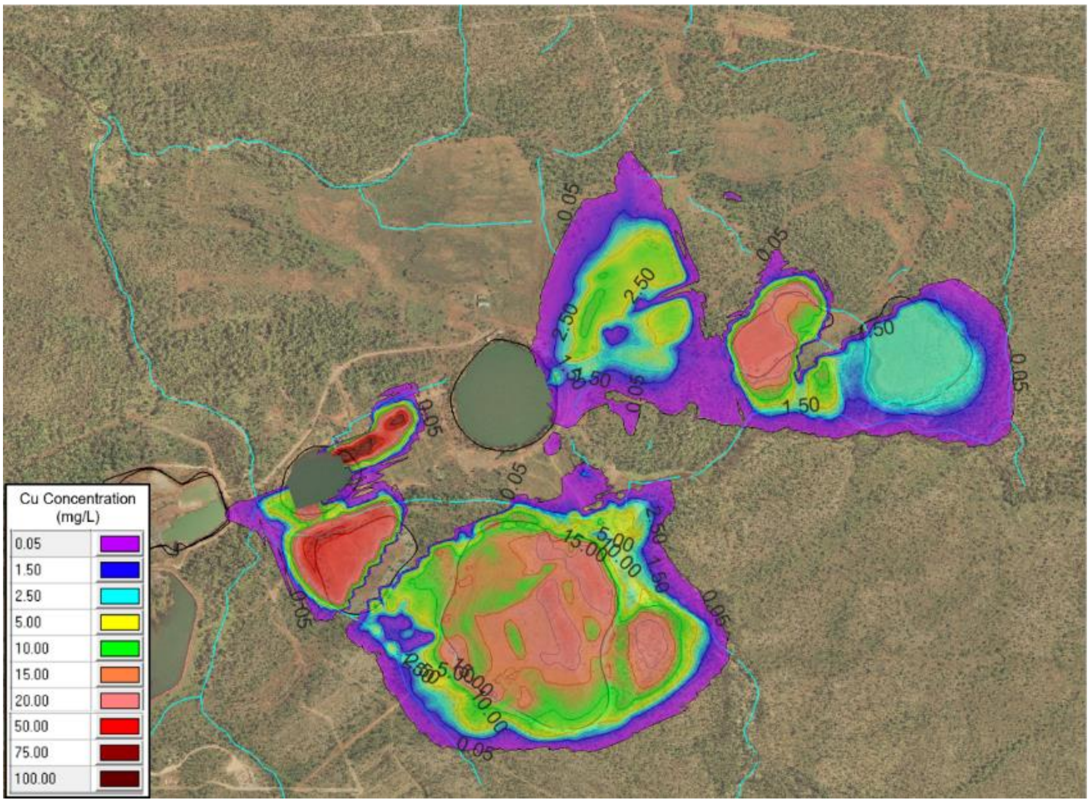
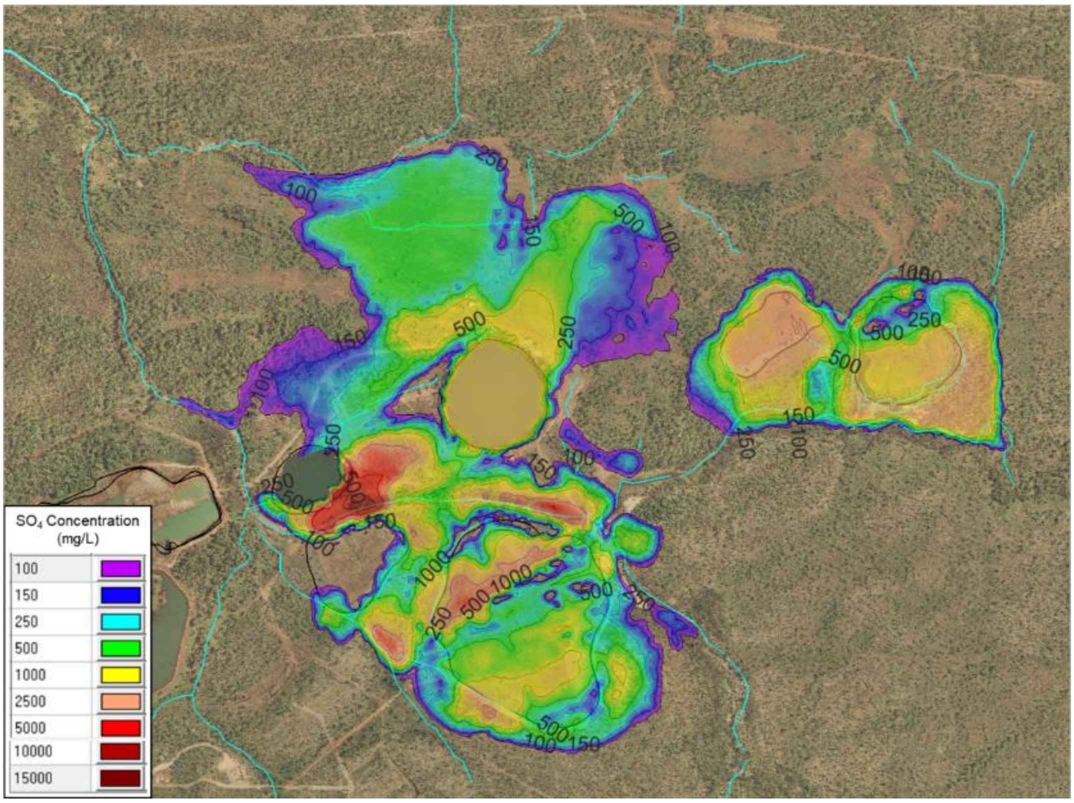


Figure 4-3 (a) Simulated Sulphate Plume, (b) Simulated Copper Plume. Year 1



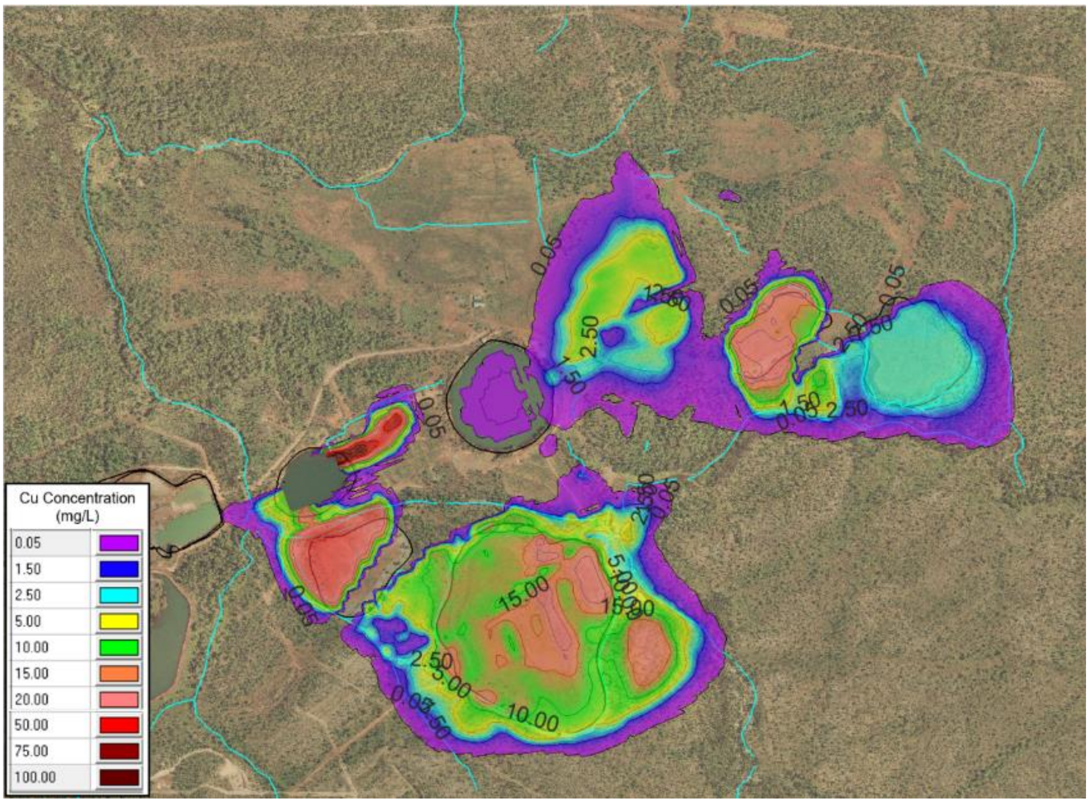
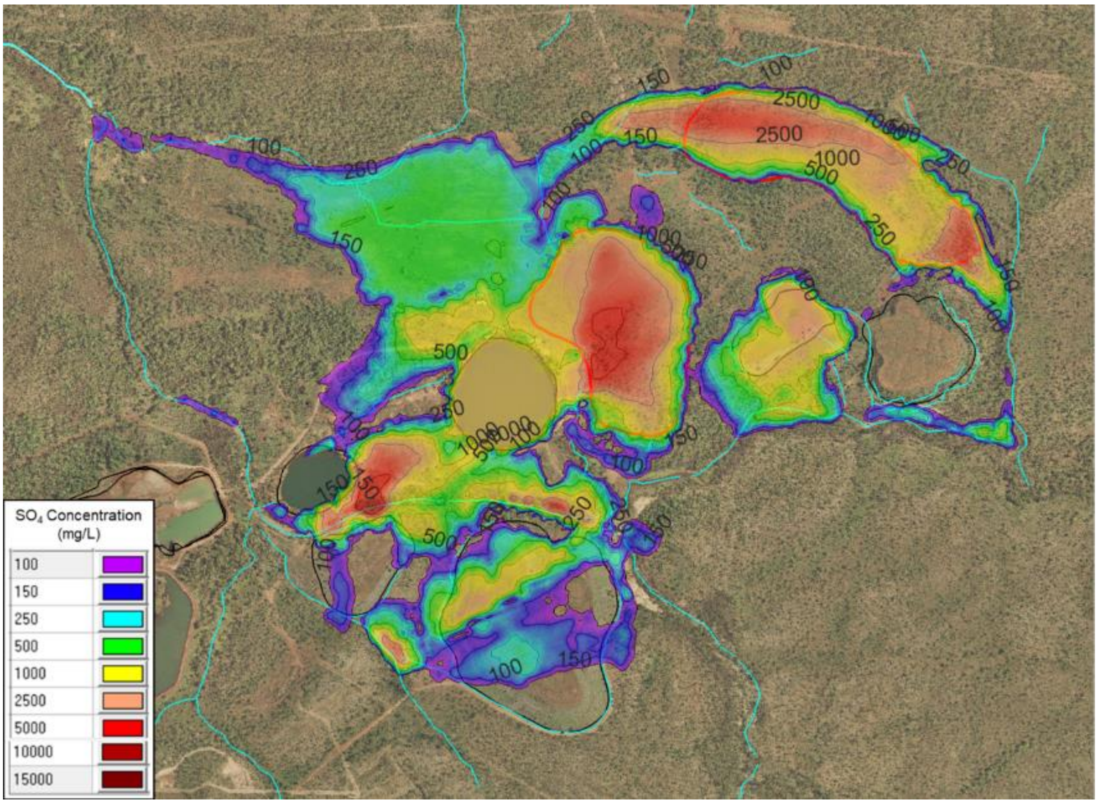


Figure 4-4 (a) Simulated Sulphate Plume, (b) Simulated Copper Plume. Year 5



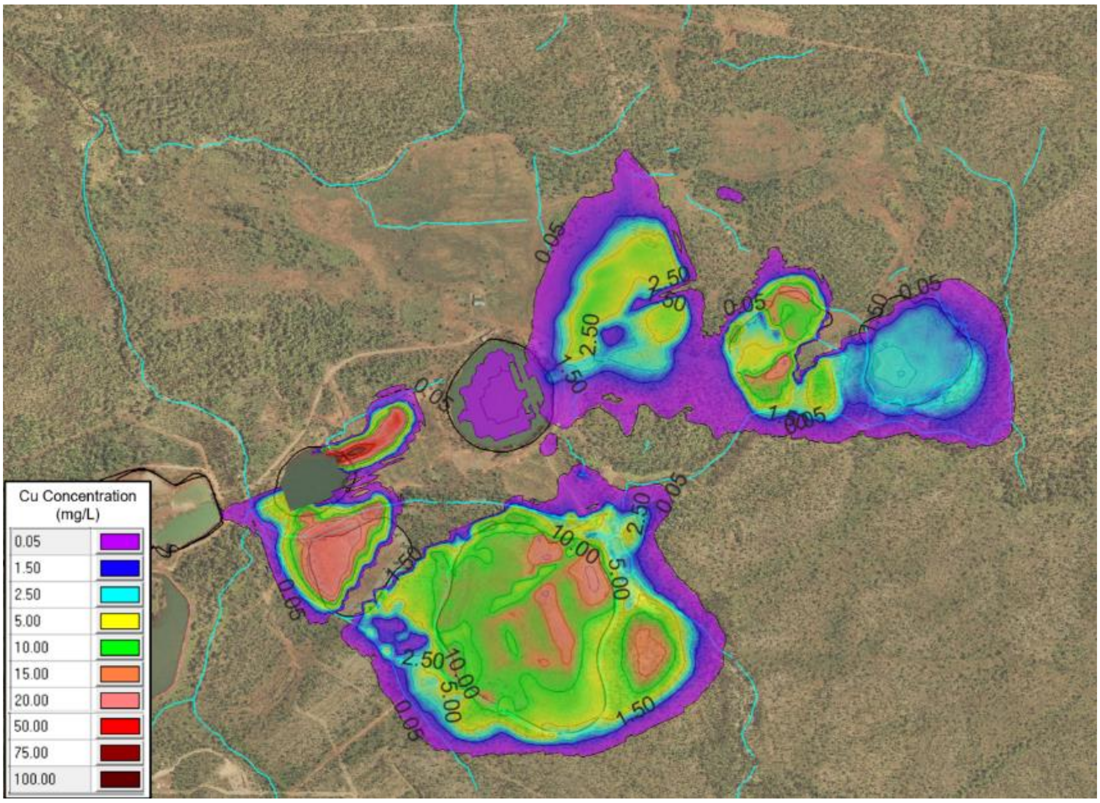


Figure 4-5 (a) Simulated Sulphate Plume, (b) Simulated Copper Plume. Year 10

4.1.15.2. WSF seepage management

Natural Attenuation –s described by the NT EPA (2017) – includes the utilisation of naturally occurring processes to reduce the load, flux or toxicity of polluting substances. The WSF storage methodology is a clear example of utilisation of a pH-controlled environment to attenuate copper and other metals. The remaining mobile copper load is predicted to be negligible / very low from the newly-formed WSFs. Copper loads reporting from the new facilities are predicted to be at levels well below that which would cause impact to flora, fauna and human health. Throughout this process, secondary reaction minerals may be produced and it is likely that calcium, sodium and magnesium sulphates will be produced as a result of the acid neutralisation and metals attenuation process.

In order to reduce future management burden as far as possible, potential seepage generation from the WSFs will be managed via natural attenuation processes. The primary Contaminants of Concern (copper and other heavy metals) are predicted to remain attenuated within the waste rock mass; however, saline drainage may form from within the new WSFs. It is proposed to direct seepage internally to the WSF to encourage vertical migration of seepage into the underlying rock mass. The volume of saline drainage will be reduced as far as possible through the methodologies of surface capping and stored rock mass density increase by compaction. The seepage quality is expected to contain magnesium and calcium sulphates with very low metals concentrations. A monitoring program for this approach is described below.

4.1.15.3. Inferred EBFR Water Quality during Stage 3

Stage 3 rehabilitation works are expected to cause a perturbation to the current quality and hydrology of the EBFR due to groundwater recovery and treatment and the operations required for Main Pit Backfilling. Modelling of the Stage 3 hydrological changes onsite and groundwater quality changes has been carried out in order to investigate what inferred EBFR water quality impacts can be expected during the Stage 3 works. Table 4-6 shows model set up.

Table 4-6 Model Setup for Simulating Construction Phase

Item	Value	Units	Description
Simulation period	1 Sep 2019 to 31 Aug 2025	Datetime	Simulation includes warm-up period so simulation results become nearly independent of initial conditions. Selected period assumes rehabilitation plan will commence in late 2020.
Climate sequence	1 Sep 2008 to 1 Sep 2014	Datetime	This historical sequence of daily rainfall and evaporation data includes the occurrence of Tropical Cyclone Carlos.
Production rates			
Sand for bridging layer	2780	tonne/d	Rate sand delivered by conveyor during construction of bridging layer.
Waste rock	3880	tonne/d	Rate waste rock is deposited in Main Pit.
Clean fill	2780	tonne/d	Rate sand delivered by conveyor during construction of capping layer.
Void ratio			
Legacy tailings	0.9		V_{voids} / V_{solids}
Bridging layer	0.43		Assumed void ratio of sand placed by subaqueous deposition.
Waste rock	0.6		Assumed void ratio of waste rock placed by subaqueous deposition.
Clean fill	0.65		Assumed void ratio of clean fill placed by subaqueous deposition.
Window for pit backfilling	Jan 18 to Dec 21	Datetime	Assumed operated year-round except for four-week Christmas break
Ultimate surface elevation			
Legacy tailings	15.5	m AHD	Estimated average elevation of existing tailings deposit in Main Pit
Bridging layer	20.5	m AHD	Assumed surface is struck level
Waste rock	54.7	m AHD	Assumed surface is struck level
Clean fill	57	m AHD	Assumed surface is struck level
Dead band			Pumps turn on at low elevation and turn off at high elevation
Main Pit	58 to 59	m AHD	Narrow target range of pit lake during subaqueous deposition
Intermediate Pit	49 to 50	m AHD	Range for maintaining live storage during subaqueous deposition
WTP hydraulic capacity	100	L/s	Selected capacity of water treatment plant
Pump capacities			
Main Pit to EBFR	150	L/s	Maximum pumping rate during initial pit dewatering
Intermediate Pit to EBFR	150	L/s	Maximum pumping rate during initial pit dewatering
Main Pit to WTP	100	L/s	Dictated by capacity of WTP
Main Pit to Inter Pit	130	L/s	
Intermediate Pit to WTP	100	L/s	Dictated by capacity of WTP
Milestone date			
Main Pit culvert blocked	1 Nov 2020	Datetime	Date inlet culvert to Main Pit is blocked to force all EBFR flow down the diversion channel.
Start pit dewatering	1 Dec 2020	Datetime	Date the initial dewatering of the two open pits commences
Start pit backfilling	1 May 2021	Datetime	Date the construction of the bridging layer commences
Days to dismantle conveyor	60	days	Minimum time from completing sand cap to restoring flow of EBFR
Outlet crest elevation			
Main Pit	59.95	m AHD	Surveyed elevation at downstream end of existing outlet culvert
Intermediate Pit	57.82	m AHD	Surveyed elevation at downstream end of existing outlet culvert

Cu loads are predicted to be reduced by 75% by Year 2 due to operating the seepage interception system/recovery bores near the WRDs, and by an order of magnitude by Year 10 following removal of the WRDs. SO_4 and Cu concentrations during construction were not simulated with the WLBM. Their concentrations are, however, expected to be substantially reduced during the wet season due to the major reduction in loads to the EBFR by operation of the SIS, implying concentrations could be much lower than observed from 2010 to 2018.

It has been assumed for the operation of the WBM that controlled discharge will be authorized year-round. The DPIR will commit to limiting dry season discharge to the extent practical and achievable. Dry season discharge to the EBFR during the construction period will be restricted to treated effluent from the WTP. LDWQOs will apply to the

EBFR throughout the year, regardless of what the composition of water in the EBFR is, i.e. river flows, treated effluent, or a mixture of each, meaning the LDWQOs will be design criteria for the water treatment system unless other criteria are specified in a WDL.

Dry season flows in the EBFR will be limited to Zone 2, to the extent practical. This will be achieved by discharging treated effluent near the current inlet to the Main Pit. Treated effluent may pool near Fitch Creek and then flow down the EFDC towards GS8150200, where it could be "stored" along the EFDC (or lost, to some extent) along the EFDC. Evaporative losses would also be increased, so it is plausible that there is very little flow into Zone 3 during the dry season considering the site demands for water listed above and evaporative losses.

Rehabilitation is predicted to greatly improve groundwater and surface water quality. However, the ultimate extent and time to achieve these future improvements is intrinsically uncertain. It is, however, likely that groundwater quality and the water quality of the EBFR would improve due to the operation of a SIS and a series of recovery bores in the Copper Extraction Pad area and the former ore stockpile area. The annual average Cu load in the EBFR are, for instance, is predicted to be reduced by about 90% while the SIS is operating. Loads of other metals, including Al, Fe, and Co will likely be reduced by a similar margin, meaning each of the LDWQOs for the EBFR would be achieved.

Post-rehabilitation, when the SIS is not operating, the average annual Cu load in the EBFR is predicted to be approximately 1.0 t/year, or about 60% lower than the current load in the EBFR (from 2010 to 2018). The Cu load in the EBFR in Year 40 (30 years after construction is complete) is predicted to be 0.6 t/year, which is 75 to 80% lower than current conditions. In Year 40, residual AMD-impacted groundwater is predicted to be the primary source of Cu and other metals to the EBFR, as lime-amended waste rock in the WSF and backfilled Main Pit will likely be minor sources of Cu to groundwater and, in turn, the EBFR. The WSF is predicted to be considerable source of SO_4 to groundwater and new SO_4 plumes are predicted to develop downgradient of this facility however these are not predicted to adversely impact EBFR quality.

Future updates/refinements of the groundwater model and WLBM are needed to provide more certainty regarding the timing and degree of future improvements in groundwater and surface water quality on site. These models would warrant updating when additional calibration data are available and information is available on groundwater conditions near the proposed WSF. Pumping tests near the alignments along which SIS recover bores are proposed and in the Copper Extraction Pad area could provide the calibration data needed to update the transport component of the groundwater model whereas additional data from a hydrogeological field investigation near the proposed WSF footprints are needed to update the flow model. Further details on this recommended work is provided in RGC (2019). Field mixing trials to assess the effectiveness of neutralant addition and mixing methods (to refine source terms) and prove up field sampling and testing method(s) to provide a robust QA/QC validation during construction are also recommended (see RGC and DJEE, 2019).

5. Monitoring and Reporting

5.1.1. Stage 3 Monitoring Plan

As the completion of detailed design draws closer, the Main Pit water quality depth profile should be updated in order to inform the completion of detailed design .This profiling would verify the thickness (and volume) of and remaining untreated pit water at the bottom of the pit. On completion of detailed design, this Water Management Plan may be updated at the completion of detailed design if conditions are materially different to those presently known.

The objectives of the Stage 3 monitoring program are to ensure worker safety, protection of equipment, and protection of environment by:

- Establishing a dataset of actual discharged water volumes and quality over time in which to compare downstream monitored ecosystem changes during the 3 year Main Pit Backfilling program.
- Ensuring that the reinstated channel remains stable and fulfils its design objectives by construction and operations monitoring for (1) channel stability, (2) ecosystem processes and (3) vegetation establishment.
- Ensuring that the Intermediate and Main Pit water levels are maintained at the proposed operational elevations to ensure that high rainfall event storage is adequate.
- Ensuring that operations management and staff are aware of forecast high rainfall events well in advance in order to prepare workers and equipment for that event.
- Understanding input volume and quality into the WTP to maximise treatment efficiency.
- Understanding the quality of water being extracted from the SIS and recovery bores to maximise WTP treatment efficiency.
- Ensuring that Groundwater abstraction does not impact GDEs.
- Confirm groundwater remediation progress.
- Confirm surface water quality remediation progress.
- Confirm discharge quality to EBFR, monitoring down-stream to confirm minimal impact on downstream receiving environments.

Monitoring and reporting during construction will be conducted as per the conditions of a WDL. The monitoring and reporting program will include, but will not be limited to, the following:

- Groundwater monitoring to assess remediation performance, including flow rate monitoring for the recovery bores, water level monitoring, and monthly and quarterly water quality sampling.
- Monthly surface water quality monitoring in the EBFR from Dyson's Area to GS5150200 to assess water quality improvements during the wet season and monthly monitoring at GS8150200 and GS8150327 during the wet season.
- Continuous monitoring of pH, EC, and turbidity levels at stations GS8150200, GS8150327, and GS8150097, as currently undertaken.
- Monthly monitoring at GS8150327 during the Dry Season when only treated effluent flows will be present in the EBFR.
- Monitoring inflows to the water treatment system during pit backfilling, including flows of displaced pit water and groundwater pumped from recovery bores.
- Treated effluent monitoring (flows and water quality) where controlled discharge to the EBFR is authorized.

The groundwater monitoring locations to be used for performance assessment and frequencies of sampling are to be finailsed after installation of additional monitoring bores at the new WSFs and recovery SIS bores. Additional monitoring bores are to be installed between the Main Pit and the former ore stockpile area. A hydrogeological field investigation of the WSF area is also recommended in addition to any geotechnical investigations of foundation conditions. Further details on recommended work to be completed in Stage 3 are provided in RGC (2019).

Monitoring commitments during pit backfilling and monitoring of treated effluent will be defined during the process of applying for a WDL.

Performance monitoring should be conducted by a Qualified Person(s) who is familiar with the site and the operation of the recovery bores. The possible need for Additional recovery bores or extension of the SIS should be assessed based on the meeting of trigger values in the WDL and/or exceedances of WQOs defined for the construction phase of rehabilitation.

Additionally, the following datasets are recommended for capture in order recalibrate existing site ground and surface water models and provide a real data set to test parameters established by sensitivity analysis:

- Recovery bore installation and extended pumping tests near the Intermediate WRD and in the Copper Extraction Pad area to assess potential capture zone areas and groundwater quality improvements and metal desorption rates from sub-surface materials.

Both groundwater and surface water monitoring programs will be designed to provide adequate spatial distribution across the site and also the receiving environment. The Summary Stage 3 water monitoring plan is detailed in Table 5-1.

Table 5-1 Summary Stage 3 water monitoring plan

Location	Parameters	Target	Frequency	Internal Management Reporting
Main Pit Water Level	Level	58-59 mRL	Continuous	Daily
Intermediate Pit Water Level	Level	49-50 mRL	Continuous	Daily
***WTP Discharge to East Branch**	Flow Rate	NA	Continuous	Daily
	Discharge Criteria	LDWQTV	Daily	Weekly
Sed. Control Ponds Mud Level	% full	NA	Daily	Daily
Sed. Control Ponds – wet season	TSS, pH, EC	TSS: 110% of baseline, pH/EC: LDWQTV	Daily	Daily
EBFR Operational Monitoring Sites (within project work area)	TSS, pH, EC	TSS: 110% of baseline, pH/EC: LDWQTV	Daily	Daily
***Groundwater Points – Pits**	Level	NA	Weekly during Pit Backfill	Weekly
SIS Locations	Level	NA	Daily	Weekly
	Discharge Criteria	LDWQTV	Weekly	Monthly
Recovery Bores (copper extraction area)	Level	NA	Daily	Weekly
	Discharge Criteria	LDWQTV	Weekly	Monthly

***Groundwater Quality**	Level	NA	Monthly	Monthly
	Discharge Criteria	NA	Quarterly	Quarterly
***Surface Water Quality**	Discharge Criteria	NA	Quarterly	Quarterly

Notes:

*To be monitored for WDL

Where possible and practical, monitoring is to be automated

Pre-Wet Season and ESCP

A Wet Season Plan will be developed for the Stage 3 works and include pre-wet season earthworks such as sediment trap and diversion channel inspections and maintenance, monitoring frequency for Main and Intermediate Pit water levels and frequency of monitoring and reporting forecast weather events to all personnel.

The performance of ESC devices will decline if they are not maintained. All ESC devices (including sediment dams) will be inspected regularly as part of the site's environmental inspection program. Regular visual inspections of rehabilitated areas will be undertaken to ensure water is safely conveyed from the areas and that a stable landform is being created. The inspections will also include assessing vegetation cover to ensure that erosion potential is minimised.

Table 5-2 contains the inspection schedule used to ensure the ESC's are functioning effectively at the site. The inspections will also determine the scheduling of maintenance required for the ESC structures. Further detail is available in the ESCP.

Table 5-2 ESCP Inspection Schedule

To Be Inspected	Frequency
All ESC Structures and Stockpiles	Weekly (December to April), monthly (May to November) or following significant rainfall events (i.e. > 15mm in 24hr period)
Rehabilitated Areas (Water Management Structures and Vegetation Cover)	Monthly or following heavy rainfall events (i.e. > 15mm in 24hr period)
Road Drainage works	Quarterly or following heavy rainfall events (i.e. > 15mm in 24hr period)
Equipment That Utilise Hydrocarbons	Daily for spills and leaks

5.1.1.1. Summary Stage 3 Reporting

Reporting of monitoring results during Stage 3 is likely to be for four purposes, as described below:

1. Regulatory: to comply with the WDL or any other licences. Likely to consist of an Annual Monitoring Report as detailed below;;

2. Confirmation of modelling assumptions: significant resources have been committed to developing robust models which have predicted how the site should behave both during and after construction. Reporting against these assumptions to confirm trajectory will be important. This is likely to be undertaken in conjunction with regulatory reporting;

3. Comparison against LDWQO: During monitoring works completed as a component of Stage 3, results will be compared and reported against LDWQOs to assess design performance; and

4. Operational: it will be important to understand and communicate operational water requirements. This is to support the two reporting requirements above but also to maximise operational efficiency and appropriately manage safety risks associated with hydrological processes. Operational reporting is likely to consist of raw data transfer and dashboards or summary reports.

Should monitored results be outside of WDL parameters and/or exceed LDWQO trigger values , an incident reporting and investigation procedure will be implemented.

An Annual Monitoring Report will be prepared as required by the WDL. It is anticipated that the Annual Monitoring Report will:

- Report on compliance with trigger values in WDL and/or exceedances of WQOs as defined for the construction phase.
- Reviews and interpret flow and water quality monitoring data, and include a performance assessment for the SIS and recovery bores on site and detail.
- Recommend any changes in routine monitoring for the subsequent year.
- Recommend as necessary any additional recovery bores.
- Recommend any corrective actions warranted by exceedances or trends in the monitored data

5.2. Stage 4

Although Stage 4 is currently outside of the temporally constrained EIS, the Stage 4 monitoring plan is documented here for purpose of continuity. The EIS has been developed for Stage 3 works as it is the primary rehabilitation construction, stabilisation and monitoring phase. The purpose of Stage 4 water monitoring is to confirm that water quality is improving on the trajectory that the model indicates, and as a result, meets water quality performance criteria.

Similar to the Stage 3 proposed monitoring program, Stage 4 monitoring will ensure that both groundwater and surface water monitoring programs are designed to provide adequate spatial distribution across the site and also the receiving environment. This will consist of monitoring locations within known source zones, immediately down gradient, and within the receiving environment. Summary Stage 4 water monitoring plan is detailed in Table 5-3.

Table 5-3 Summary Stage 4 water monitoring plan

Location	Parameters	Target	Frequency	Regulatory Reporting
Main Pit Water Quality	Discharge Criteria	LDWQTV	Quarterly	Annual
Intermediate Pit Water Quality	Discharge Criteria	LDWQTV	Quarterly	Annual
Groundwater Quality	Level	NA	Quarterly	Annual
	Discharge Criteria	NA	Quarterly	Annual
Surface Water Quality	Discharge Criteria	NA	Quarterly	Annual

Notes:

Where possible and practical, monitoring is to be automated

5.2.1. Summary Stage 4 Reporting

Post-rehabilitation monitoring and reporting will likely be comparable to construction phase commitments for a multi-year transition period during which monitoring frequencies will decrease based on annual recommendations in a Monitoring Report for the WDL.

Reporting of monitoring results during Stage 4 is likely to be for two purposes, as described below:

1. Confirmation of modelling assumptions: significant resources have been committed to developing robust models which have predicted how the site should behave both during and after construction. Reporting against these assumptions to confirm trajectory will be important; and

2. Comparison against LDWQOs: the LDWQOs have been developed by Hydrobiology (2016).Should reported results be outside of the LDWQOs, investigation and reporting will be implemented.

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7. Independent Reviewer Biography

Paul Delaney is a Civil Engineer with over 35 years' experience, with a strong focus on flooding and water management. He presently manages SLR's Civil Engineering practice in Australia. Paul has expertise in mine site water management, water quality, and erosion and sediment controls. He has been responsible for the review or update of numerous water management plans, and has prepared several surface water assessments for major developments.

14 January 2020

680.10421 Independent Peer Review of WMP L01-v1.0.docx

Department of Primary Industry and Resources
Rum Jungle Stage 2A, Mines Division
Northern Territory Government
GPO Box 4550, Darwin, NT, 0801

Attention: Jackie Hartnett

Dear Jackie,

Rum Jungle Draft EIS
Independent Review of Water Management Plan in Draft EIS

This letter provides a summary of comments arising from an independent expert peer review of the Water Management Plan (WMP) included within the draft EIS intended for submission by DPIR. This final review in January 2020 applies to the WMP document dated 26 November 2019, which includes some refinement following the earlier comments from an initial review in mid-November 2019. It is assumed that the draft WMP will be read in the context of the broader EIS, and in particular Chapter 10 which provides substantial information on baseline conditions.

The review considers water management aspects of the Terms of Reference (TOR) issued by the Northern Territory Environment Protection Authority in November 2019, and specifically the requirements outlined in the following tables:

- Table 1 – relating to description of existing environmental condition.
- Table 2 – Water - proposal description.
- Table 3 – Water - proposal specific environmental objectives.
- Table 6 – Hydrological processes.
- Table 7 – Inland Water Quality including specific requirements for WMP.

Comments from this review are structured as per the tables above.

Existing environmental conditions

Existing surface and groundwater conditions are adequately described in Chapter 10 of the EIS and the draft WMP, and a reduced level of detail is satisfactory in the WMP.

Proposal description

The draft WMP describes the groundwater treatment strategy in adequate detail. Aspects which will need to be refined during the detailed design for Stage 3 works and included into an updated WMP include:

- More information on the Water Treatment Plant (WTP) relating to fate of sludges;
- Nominate location for discharge from WTP;

- Estimated water demand and water source. Dust suppression across disturbed areas is likely to use a significant amount of water during the dry season; and
- Predicted flood behaviour associated with restoring the alignment of the EBFR.

Proposal specific environmental objectives

The locally derived water quality objectives were developed in 2016 and adopt a zoned approach with lower levels of protection applicable to the mine site which is highly disturbed. This approach is valid during the construction phase and recognises the history of the site.

It is noted that additional information on the currently predicted improvements to long term (post construction) water quality in the EBFR has been added into the end of Section 4 of the WMP.

Hydrological processes

The WMP does not provide much information on existing flooding behaviour at the site, or predicted flood levels, and in particular any upstream increase in flood levels or alteration of peak flows. While the diversion works may not have been fully designed yet, the WMP does specify design for a 1% AEP flood event and no alteration to the upstream flood regime.

Inland Water Quality including specific requirements for Water Management

The TOR mention the possibility of saline discharges from lime treated waste rock. The WMP adequately describes a strategy for managing the possibility of saline discharges. Saline discharges will be reduced by capping of the WSF surfaces, and densification of waste rock. It is also noted that the WSF designs will direct seepage to the underlying rock mass for natural attenuation rather than allowing seepage to the ground surface. The monitoring regime described in Section 5 of the WMP includes monitoring salinity of groundwater and surface water locations.

The WMP adequately describes the currently predicted water quality impacts on the EBFR including perturbations during the construction of rehabilitation works, and the predicted improvement in water quality when the completion criteria are met. It is also noted that the WMP recommends future updates and refinements to the groundwater model and WLBM to improve certainty regarding the timing and degree of future improvements in both groundwater and surface water quality.

Bio of Author

Paul Delaney is a Civil Engineer with over 35 years' experience, with a strong focus on flooding and water management. He presently manages SLR's Civil Engineering practice in Australia. Paul has expertise in mine site water management, water quality, and erosion and sediment controls. He has been responsible for the review or update of numerous water management plans, and has prepared several surface water assessments for major projects.

Yours sincerely,

PAUL DELANEY
Technical Discipline Manager - Civil Engineering