GRANTS LITHIUM PROJECT

Environmental Impact Statement

Appendix C

Water Management Plan

Prepared by EcOz

October 2018

GRANTS LITHIUM PROJECT

Environmental Impact Statement

Water Management Plan

Prepared by EcOz Environmental Consultants for Core Exploration
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ABBREVIATIONS AND DEFINITIONS

AEP	annual exceedance probability
AMD	acid, saline or metalliferous drainage
AS	Australian Standards
AS/NZ	Australian and New Zealand Standards
ASS	acid sulfate soils
BoM	Bureau of Meteorology
BTEXN	Benzene, Toluene, Ethylbenzene, Xylene, Naphthalene
DMS	dense medium separation
DO	dissolved oxygen
DPIR	Department of Primary Industry and Resources (Northern Territory)
DSO	direct shipping ore
EC	electrical conductivity
EMP	Environmental Management Plan
EIS	Environmental Impact Statement
ESCP	Erosion and Sediment Control Plan
EY	exceedance per year
GDE	groundwater dependent ecosystem
GL	gigalitre (10^9 litres)
ha	hectare
IECA	International Erosion Control Association
IFD	Intensity-Frequency-Duration design rainfalls
K	Hydraulic conductivity
kL	kilolitre (10^3 litres)
LOR	limit of reporting for laboratory analysis
mAHD	metres above Australian Height Datum
mBGL	metres below ground level
MCA	Minerals Council of Australia
MCP	Mine Closure Plan
ML	megalitre (10^6 litres)
ML/a	megalitre per year
ML	Mineral Lease (granted)
MMP	Mining Management Plan
Mt	million tonnes
NATA	National Association of Testing Authorities Australia
NOI	Notice of Intent
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
ORP	oxidation reduction potential
pH	power of Hydrogen
Project/ Proposal	Core Exploration Limited's Grants Lithium Project

Q	design flood peak discharge
RFFE	Regional Flood Frequency Estimate: method developed by Engineers Australia to estimate design flood peak discharge (Q)
TDS	total dissolved solids
TPH/TRH	Total Petroleum Hydrocarbons NEPM 1999 suite / Total Recoverable Hydrocarbons NEPM 2013 suite
TSS	total suspended solids
ToR	*Terms of Reference for the Preparation of and Environmental Impact Statement, Grants Lithium Project*
TSF	tailings storage facility
SSTV's	Site Specific Trigger Values: contaminant concentrations derived using the ANZECC 2000a Guidelines methodology above-which water quality impacts may be occurring and investigation of the cause is recommended.
SWL	standing water level
RoM	Run of Mine pad
RWD	raw water dam
WDL	Waste Discharge Licence
WMP	Water Management Plan
WQMP	Water Quality Monitoring Plan
WRD	waste rock dump

1 INTRODUCTION

Core Exploration Limited (Core) propose to develop the Grants Lithium Project (the project) mining operation located approximately 24 km south of Darwin, and 22 km north-west of Berry Springs (Figure 1-1). The targeted ore body is a near-vertical pegmatite intrusion, rich in the lithium-bearing mineral spodumene. The ore body will be mined via an open-cut pit using drill and blast methods, and processed on site by crushing, screening and water-based dense medium separation (DMS), to produce a concentrate for transport via road to Darwin Port for export. Waste rock from the pit will placed in an onsite waste rock dump (WRD), and waste from processing will be placed in a tailings storage facility (TSF) contained within the WRD. Mine life is expected to be two to three years. Figure 1-2 shows the general mine site layout.

This Water Management Plan (WMP) covers all water usage, and surface and groundwater interactions of the proposed mining operations. It currently forms part of the Environmental Impact Statement (EIS) submitted to the Northern Territory Environment Protection Authority (NT EPA) for project assessment under the *Environmental Assessment Act*. Once operations commence, it will be updated to incorporate any water-related recommendations issued by the NT EPA resulting from the EIS process, and become part of the Project's *Mining Management Plan* (MMP), as required under the NT *Mining Management Act*. This WMP will be updated regularly throughout operations to reflect on-ground activities as mining progresses.

1.1 Purpose and Scope

1.1.1 EIS Terms of Reference requirements

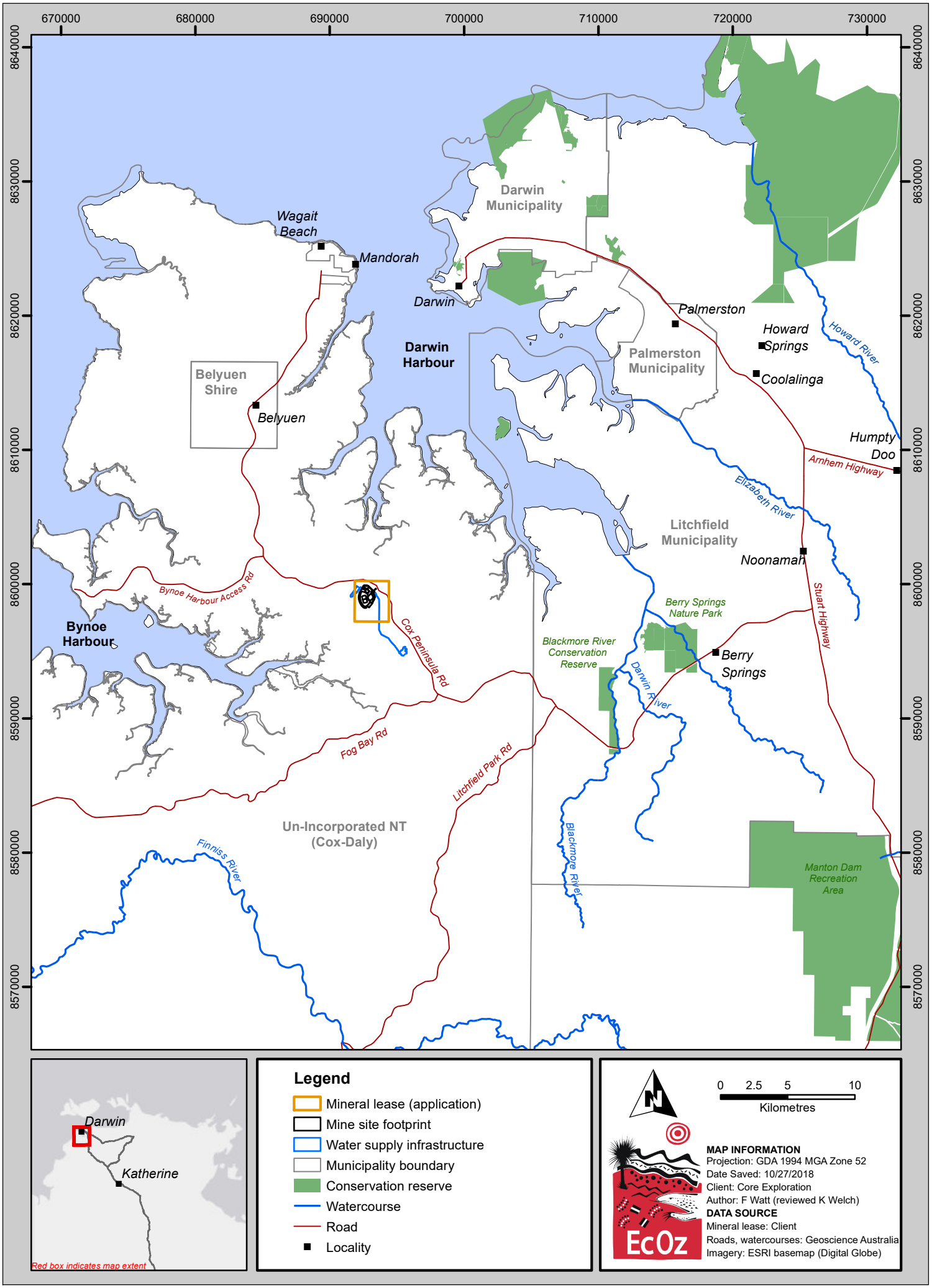
Information required in the EIS by the NT EPA is set out in the *Terms of Reference for the Preparation of an Environmental Impact Statement* (ToR) issued to Core for the Grants Lithium Project in August 2018. As requested in the ToR, and required for the MMP, this WMP is presented in accordance with the NT Department of Primary Industry and Resources *Template for the Preparation of a Mining Management Plan, Section 6 Water Management* (DPIR 2017), and covers the water-related information requested in ToR sections:

- ***2 Description of the Proposal***, Section 2.3.6 *Water*
- ***4 Preliminary key environmental factors***, Section 4.2 *Water*, which includes the identified key environmental factors: 4.2.1 *Inland water environmental quality* and 4.2.2 *Hydrological processes*

The NT EPA's objectives for the two key environmental factors listed above are respectively:

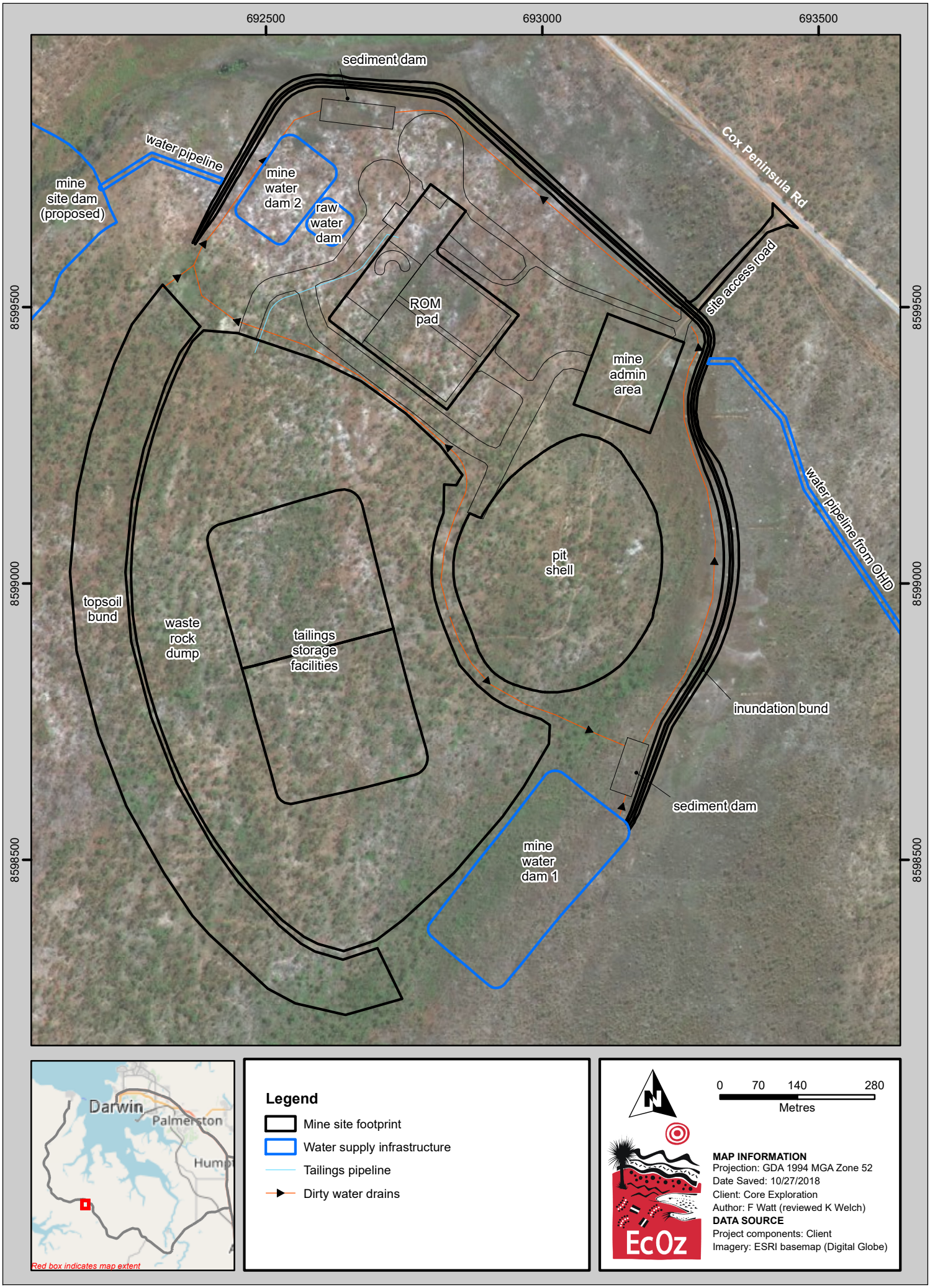
1. *Maintain the quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected.*
2. *Maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.*

This WMP aims to assist in achieving these objectives for the project.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 1-1. Grants Lithium Project location.mxd

Figure 1-1. Map of Grants Lithium Project location



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 1-2. Mine site layout.mxd

Figure 1-3. Map of mine site layout

1.1.2 WMP Scope

The scope of this WMP includes all:

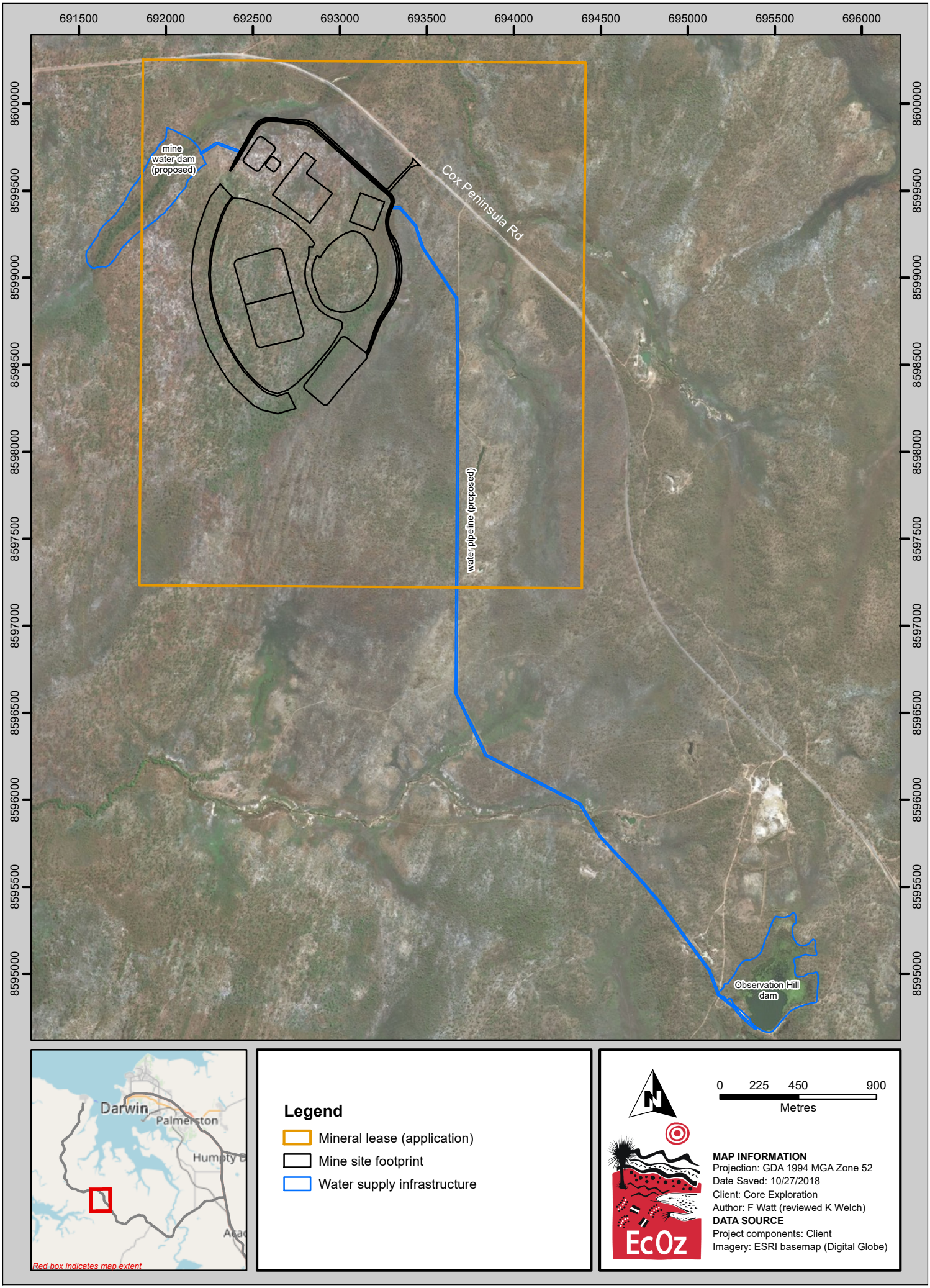
- Water aspects of mining operations within Mineral Lease ML31726 (referred to as mine site / mine area / mine footprint); i.e. that associated with the open pit, WRD, TSF, Run of Mine (RoM) pad, processing plant, access/haul roads, water storages and holding dams, stormwater drains and sediment basins, ablutions and office facilities (Figure 1-2).
- Water stores and infrastructure located outside ML31726 within Ancillary Mineral Leases (to be applied for and issued prior to commencement of mining); i.e. Mine Site Dam (MSD), Observation Hill Dam and pipeline linking Observation Hill Dam to the mine site (Figure 1-3).
- Surface and groundwater systems influenced by mining operations, including those up-gradient and down-gradient of the mine area, and down-gradient of Observation Hill Dam and MSD.

This WMP does not cover the transport route (i.e. Cox Peninsula Road and Stuart Highway) for product trucked to Darwin's East Arm Port or Core's lease area within the Port. The stockpiling and ship loading of product will be managed in accordance with Darwin Port requirements.

In order to cover all relevant ToR and MMP requirements, this WMP includes:

- Project details relevant to water management
- A description of existing surface water and groundwater systems
- Baseline surface and groundwater water quality results
- Identified potential impacts of the project on surface and groundwater quality and flows, and on receiving ecosystems and water users
- A risk assessment identifying hazards, ranking risks, and outlining management and mitigation measures
- Details of surface and groundwater monitoring programs to be undertaken before, during and after operations
- Proposed water quality objectives for assessing surface and groundwater quality monitoring results and detecting any impacts
- Proposed assessment/performance criteria for detecting any impacts on flows/levels or downstream ecosystems or water users
- Management actions/contingency measures to stop/reduce any impacts when detected
- Residual impact detailing the extent to which mitigation and management measures will address potential impacts.
- A water balance for the proposed mining operations in accordance with the Minerals Council of Australia *Water Accounting Framework* (MCA 2014); provided in Appendix A.

As required in the ToR Section 4.2.1.4 *Mitigation and monitoring*, this WMP has been submitted for peer review by an "independent, third party, recognised by industry as a senior practitioner and is independent from the Proponent/principal consultant and the proposal". This review is being undertaken by Rohan Ash (Out-Task Environmental Pty Ltd), Environmental Auditor (Industrial Facilities), appointed pursuant to the *Environment Protection Act* (Victoria). In addition, Bill Howcroft (Principal Hydrogeologist) will review the groundwater hydrology aspects. Independent reviewer biographies are provided in Appendix B. All reviewer comments and recommendations will be addressed in an updated WMP to be submitted as part of the Supplementary EIS.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 1-3. Proposed surface water storages.mxd

Figure 1-3. Map of proposed surface water storages

2 PROJECT DETAILS RELEVANT TO WATER MANAGEMENT

2.1 Project overview

The project proposes to mine a near-vertical pegmatite ore body that contains the lithium-bearing mineral spodumene. The ore body is approximately 400 m long, by 32 m wide, and will be mined via an open-cut pit (470 m long x 375 m wide) using drill and blast methods down to approximately 180 m depth (Figure 2-1). Around 1.8 million tonnes (Mt) of ore is planned for extraction over the two to three-year mine life.

The pegmatite ore body has intruded into Proterozoic Burrell Creek Formation (BCF) comprising shales, siltstones, and strongly foliated phyllite. The weathering profile extends to depths of 30 to 50 m before reaching fresh, un-weathered BCF. Weathered and fresh BCF comprise the bulk of waste rock requiring excavation to access the ore body. A thin surface layer (less than 5 m thick) of Cenozoic sediments, mainly laterite gravel, sand and clay, lies over most of the proposed mine area.

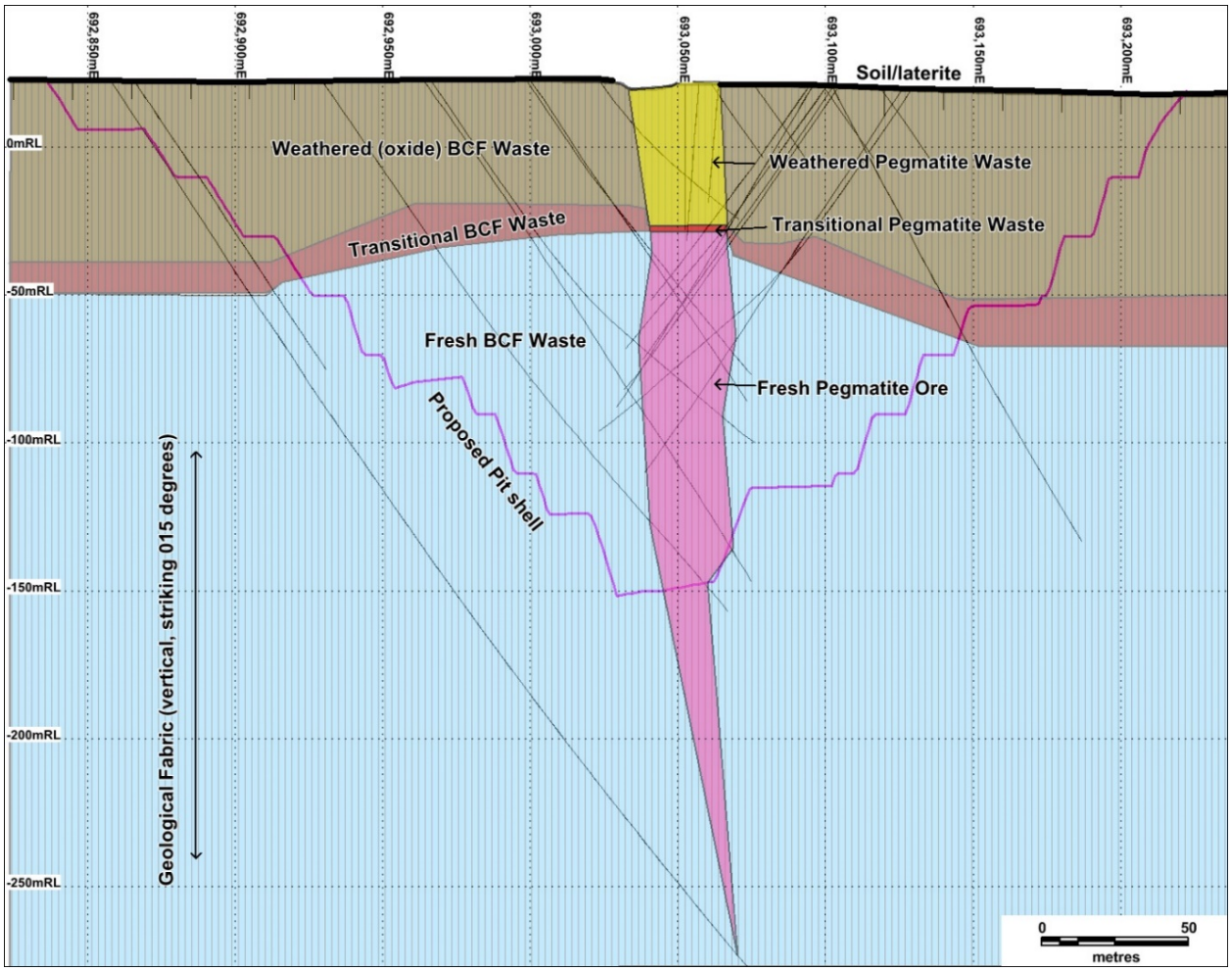


Figure 2-1. Cross section of ore body within the Burrell Creek Formation (BCF) and open pit shell.

2.2 Project components

Project components are shown in Figure 1-2 and Figure 1-3, and listed in Table 2-1. Components relating to water management or with implications for hydrological process or water quality are outlined in Sections 2.4 to 2.8.

The mine site area (mine footprint) covers approximately 147 ha, encompassed by the wider Mineral Lease ML31726 (total 750 ha). Areas outside the mine footprint but within ML31726 will remain largely undeveloped.

Project components outside ML31726 include the existing Observation Hill Dam, located around 5 km south-east of the mine, and a 6 km-long underground water pipeline linking this dam to the mine (Figure 1-3). A possible new dam, referred to as Mine Site Dam (MSD) to be constructed, if required, is designed on an ephemeral drainage line immediately west of the mine. The dam wall is within ML31726; however, some of the inundation area would be outside ML31726 (Figure 1-3).

Table 2-1. Project components.

Components within the mine footprint and ML31726
Open pit and associated heavy vehicle access ramps and haul roads
Waste rock dump (WRD) and integrated tailings storage facility (TSF); two TSF cells within WRD
Crushing and screening plant and dense medium separation (DMS) processing plant
Run of Mine (RoM) stockpile pad for stockpiling unprocessed ore for feeding the crushing plant, and crushed ore for feeding the DMS plant. Rejects stockpile of low-grade ore from DMS plant for transfer to WRD. Concentrated product stockpile from DMS plant adjacent to the road train load-out loop.
Mine operations centre incorporating site offices, equipment laydown, LV car parking and wash-down, emergency facilities, HV workshop and wash-down, and refuelling.
Bund (referred to as 'inundation bund') around northern and eastern side of mine site to prevent ingress of water from natural drainage lines on either side mine, if these drainage lines were to flood. The inside of this bund also acts to direct run-off within the mine site towards the sediment basins.
Bund (referred to as 'topsoil bund') around western side of WRD to prevent ingress of run-off from upslope areas into WRD, and to prevent this 'clean' water from running on to mine site. Instead, this water is directed around WRD into natural drainage lines. The inside of this bund also acts to direct run-off from the WRD outer walls into drains that lead to the sediment basins.
Drains and erosion and sediment controls within mine site to prevent stormwater run-off into open pit and other operational areas, and to direct run-off into drains, through erosion and sediment controls (e.g. rock check dams), and into sediment basins for treatment and testing prior to release off-site.
Mine Water Dam 1 (MWD1) to hold water from pit dewatering (groundwater inflows and incident rainfall) for use in dust suppression and ore processing
Mine Water Dam 2 (MWD2) as contingency for holding TSF decant water in excess of that stored in the tank supplying water to ore processing plant, or excess water dewatered from pit to avoid Dry season release from MWD1.
Raw water dam (RWD) to hold water from Observation Hill Dam and/or Mine Site Dam (see below) for supplying potable/non-potable water to mine operations centre, and additional water for ore processing and dust suppression when pit dewatering and TSF decant is insufficient.
On-site septic for treating wastewater from ablutions
Components outside ML31726
Observation Hill Dam (existing), located approximately 5 km south-east of mine to supply water to RWD.
Underground pipeline (6-km long) to transport water from Observation Hill Dam to mine site.
Mine Site Dam (MSD) to be constructed (if required) as additional supply to RWD; dam wall within ML31726, portion of inundation area is outside western boundary of ML31726.

2.3 Mining schedule

The extraction of ore from the open-cut pit will occur over 25-months, followed by mine rehabilitation and closure, as outlined in Table 2-2.

Table 2-2. Mining schedule.

Year/Month	Months 1-7	Months 8-25	Months 26-30	Months 31 onward
Phase	**Pre-strip & construction**	**Operation**	**Rehabilitation & Closure**	**Post-closure**
Activities	Removal of oxide waste and oxidised pegmatite waste. Construction of site infrastructure and processing facilities.	Mining of the pegmatite ore body and adjacent 'fresh' waste, and processing/ transport of product to Darwin Port	Rehabilitation and mine closure activities undertaken in accordance with Mine Closure Plan	On-going monitoring of the mine site until rehabilitation completion criteria are achieved and the site is relinquished.

2.4 Water requirements, sources and storages

The greatest anticipated daily water demand at the peak of mining is 2,018 kL/day. Of this, 1060 kL is for dust suppression (Dry season maximum), and 950 kL for ore processing; the remainder (8 kL) is for the mine operations centre (offices, potable, ablutions, vehicle wash-down, workshops etc). Figure 2-2 shows a flow diagram of water inputs, outputs and uses across the mining project.

The project water balance (Appendix A) indicates that pit dewatering (comprising direct rainfall and groundwater inflows) can provide the bulk of ore processing and dust suppression requirements. Combined with reuse of decant water recovered from the TSF (for ore processing only), around 95% of these requirements will be met. Surface water storages will make up the remainder. Potable and non-potable supply to the mine operations centre will also come from surface water storages.

The project plans to utilise the existing Observation Hill Dam as the primary surface water storage. This dam was constructed to supply water for tin and tantalite mining and ore processing that occurred in the 1980's and 1990's (Frater 2005). The estimated dam volume when full is around 364 ML (EnviroConsult 2018a). To ensure water security for the project in the event of lower than average rainfall, the project is considering raising the dam wall by approximately 1.5 m to increase storage capacity to around 628 ML (increases inundation area by 9 ha to a total 40 ha).

There are also tentative plans to construct a second surface water storage referred to as the Mine Site Dam (MSD) on an ephemeral drainage line immediately west of the mine (Figure 1-3). This dam may be required to further ensure there is sufficient water for mining operations during a drier than average year and/or unanticipated increases in water requirements.

Current design of the MSD (maximum capacity 387 ML, areal extent 19 ha) is based on topographic and engineering/construction constraints, and the proximity of mine infrastructure such as the WRD, that must remain above the maximum inundation level. It also assumes a worst-case scenario where the Observation Hill Dam wall is not raised, and pumping from the MSD is constant throughout the year without any offsets from reuse of water on-site (pit dewatering, TSF decant), or reduced water demand for dust suppression during the Wet season. This was done in order to model the worst-case scenario for potential flow-reduction impacts on downstream natural waterways (see Chapter 4).

The current project water balance indicates that water from pit dewatering, TSF decant reuse, and the Observation Hill Dam can most likely meet all water requirements over the mine life. Refinement of the water balance as project components are finalised will inform Core's final decision whether to proceed with construction of the MSD and if so, its required capacity.

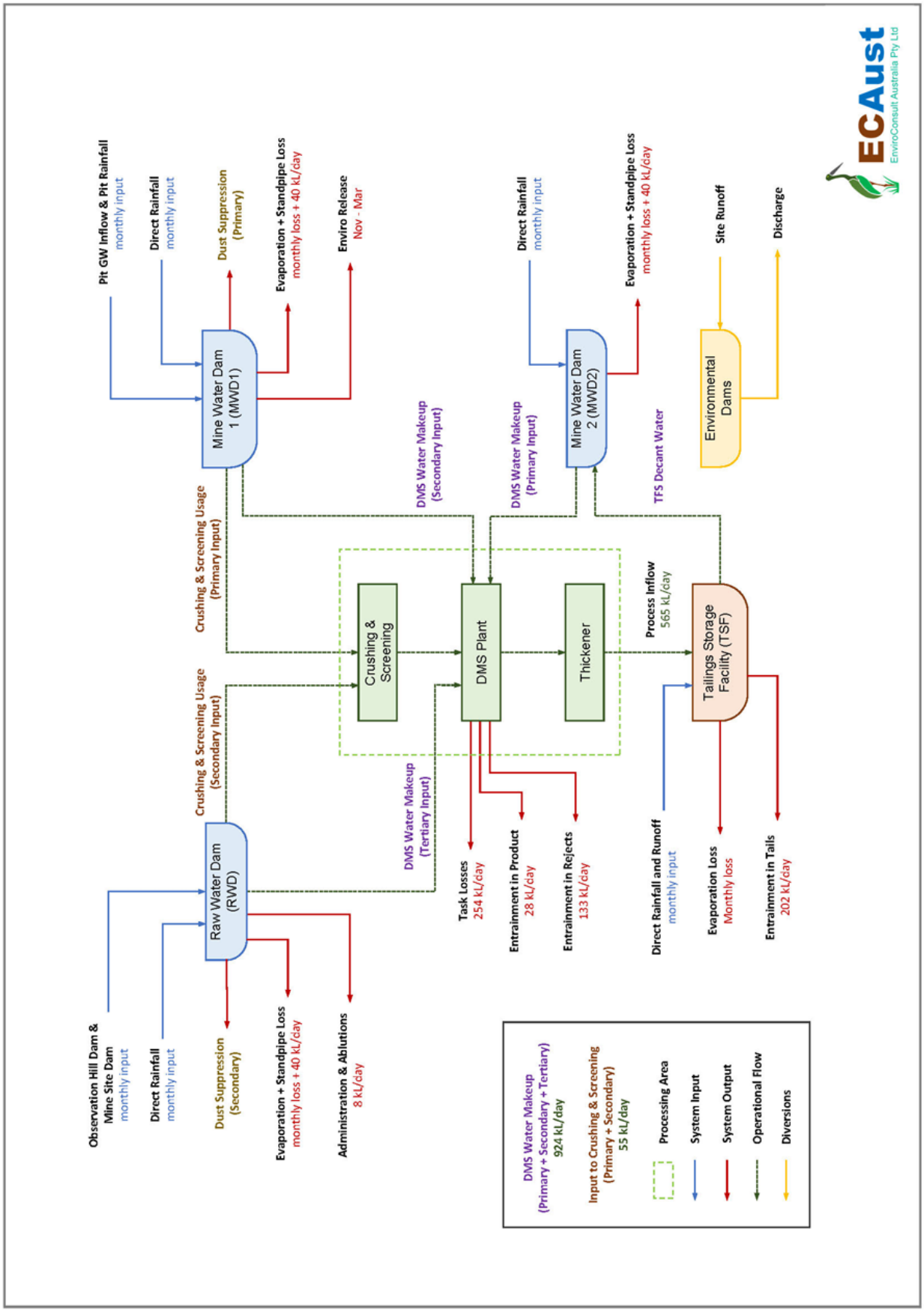


Figure 2-2. Flow diagram of project water inputs, outputs, tasks and storages.

2.4.1 Internal mine site water holding dams

Internal mine site holding dams for the management and use of water include a raw water dam (RWD), and Mine Water Dams 1 and 2 (MWD1 and MWD2); locations shown in Figure 1-2. These dams will ensure water from different sources i.e. pit dewatering, TSF decant, and surface water storages, remains separate (see Figure 2-2), and is used in accordance with its water quality.

The RWD will hold water pumped from Observation Hill Dam (and/or MSD if required) for use in ore processing, dust suppression and the mine operations centre (offices, potable, ablutions, vehicle wash-down, workshops etc). It's size (4.6 ML) aims to contain around 48 hours' operational supply, topped-up as needed. The project water balance indicates the RWD will be the primary source of water during the first two months of mining, supplying around 30 ML per month. As groundwater inflows into the pit increase with mining depth, the RWD will become a supplementary water supply and MWD1 (containing water dewatered from the pit) will become the primary supply. An average 1.5 ML per month will be required from the RWD after the second month.

MWD1 (capacity 240 ML) will hold water dewatered from the pit (see Section 0) for use in ore processing and dust suppression. Its size is based on having no Dry season overflow accounting for the rate of pit dewatering inputs, and ore processing and dust suppression outputs. It is expected release of water from this dam to the environment will be required during the Wet season when volumes of water removed from the pit will be higher, and dust suppression requirements lower (see water balance Appendix A). Table 2-3 provides modelled discharge volumes for the 2019 and 2020 Wet seasons based on average rainfall, and the expected depth of mining during each Wet season. The greatest discharge volumes will occur in January and February of each year and will be slightly higher in 2019 compared to 2020. The maximum rate of release will be 50 L/s. During mining operations, a flow gauge will be installed at the outlet of MWD1 to record the amount of discharge.

MWD2 (capacity 60 ML) is designed as a contingency storage for excess TSF decant, or excess pit dewatering volumes. Under normal operations, TSF decant is transferred to a holding tank adjacent to the processing plant for feeding direct into ore processing. If pit dewatering volumes are higher than modelled scenarios, and MWD1 capacity is exceeded, the excess water sent to this dam will avoid the need to discharge during the Dry season.

MWD1 discharge water quality overview

MWD1 is expected to contain overall good water quality for most parameters, with the final dam water quality influenced by the relative proportions of groundwater to rainwater flowing into the pit, and amount of direct rainfall into MWD1 (see Table 2-3). Baseline groundwater quality results indicate the groundwater has a neutral pH, low dissolved metal concentrations below the guideline levels for Darwin Harbour (NRETAS 2010), and levels of the nutrient nitrogen, predominantly in the form of nitrate, within the same range as that of surface waters. Aluminium concentrations are elevated but remain below levels in receiving surface waters. Parameters with relatively high concentrations compared to the receiving surface waters include EC (which is actually relatively low for groundwater), arsenic and phosphorus (which are above the guideline level), and iron and lithium (which are elevated compared to surface waters).

Dilution with rainwater into the pit, and into MWD1, will reduce concentrations (see Table 2-3). Rainwater generally makes-up more than 50% of the water in MWD1, with the highest dilution occurring during the mid-Wet season (up to 69% in January 2020) and lowest during the early-Dry season (44% in November 2020). Rainwater makes-up a greater proportion of water in MWD1 during the second year of mining compared to the first because groundwater inflows are greatest during the early phase of mining as the weathered BCF has a higher groundwater specific yield and hydraulic conductivity than the underlying fresh BCF and ore (see Section 2.4.2). Once the fresh BCF is intersected, pit inflow rates decline.

The naturally occurring process of oxidation and co-precipitation of arsenic and phosphorus with iron whilst the water is held within MWD1 may also assist in reducing levels of dissolved arsenic and phosphorus. Although the extent of this is not yet verified. In the event that arsenic and phosphorus levels remain high,

there are a number of commonly-used treatment options available. Removal technologies and treatments have been developed to remove arsenic from groundwater to make it suitable for drinking and removal of phosphorus from wastewater is commonly undertaken to make it suitable for discharge.

Regular testing of MWD1 water quality, as well as that within the mining pit sump itself, is included in the Water Quality Monitoring Plan (Chapter 10). Measures will be implemented to ensure discharge from MWD1 meets the water quality criteria prescribed in the Water Quality Monitoring Plan prior to release. Detailed discussion of predicted MWD1 water quality is provided in Section 7.4.

Surface water turbidity in the receiving drainage line is always low, even after significant rainfall. The turbidity of groundwater inflows into the pit and rainwater would also be low, however may become elevated on contact with fine sediments within the pit. Measures for minimising turbidity in water dewatered from the pit, such as filtering water as it is pumped from the pit sump and using flocculants in MWD1 will be undertaken to ensure turbidity levels of discharged water are below the water quality criteria prescribed in the Water Quality Monitoring Plan (Chapter 10).

Prior to any release from MWD1, this discharge point will require approval under the NT *Waste Management and Pollution Control Act*, and issue of a Waste Discharge Licence (WDL). Core will submit a WDL application to the NT EPA for assessment and approval in the coming months. As mentioned above, water quality monitoring of releases from this point, and also monitoring of the receiving sites downstream, is included in the project's Water Quality Monitoring Plan (Chapter 10). This Plan will be updated to align with all conditions in the WDL once issued.

Table 2-3. Modelled discharges from MWD1 for average rainfall years over life of mine, and % rainfall making up water dewatered from pit and water in MWD1.

Month	Discharge volume (ML/month)	%Rainfall in pit water	Vol. direct rainfall into pit (ML/month)	% Rainfall in MWD1
2019 Dry season	No discharge	-	-	-
January 2020	61.72	49	19.58	57
February 2020	85.50	43	16.62	51
March 2020	66.18	39	13.06	46
2019 Wet season Total	**213.40**	**44**	**49.26**	**52**
2020 Dry season	No discharge	-	-	-
November 2020	3.07	28	18.01	44
December 2020	46.18	37	28.47	54
January 2021	79.99	53	53.67	69
February 2021	74.45	48	45.57	65
March 2021	58.62	42	35.80	59
2020 Wet season Total	**262.31**	**43**	**181.52**	**60**

2.4.2 Pit dewatering

Figure 2-3 shows the results of modelling undertaken by Knapton and Fulton (2018) of groundwater flows into the pit over the life of mining operations. The model predicts that inflows will increase rapidly from commencement of mining, reaching a peak at about 2,000 kL/d in month nine. Inflows are greatest during this early phase of mining as the weathered BCF has a higher groundwater specific yield and hydraulic conductivity than the underlying fresh BCF and ore. Once the fresh BCF is intersected, pit inflows decline to around 1,600 kL/d for the rest of the mine life.

The total volume of pit dewatering required will be a combination of groundwater inflows and incident rainfall directly into the pit (stormwater drains will prevent any surface water run-off into the pit). Table 2-4 shows the predicted volume of groundwater inflows and incident rainfall, and combined total monthly volumes of water requiring removal from the pit assuming a July 2019 start date. Potential variations in groundwater inflows and incident rainfall over low, average and high Wet season rainfall conditions are captured in the model (see Knapton and Fulton 2018); Figure 2-3 and Table 2-4 show volumes for an average Wet season.

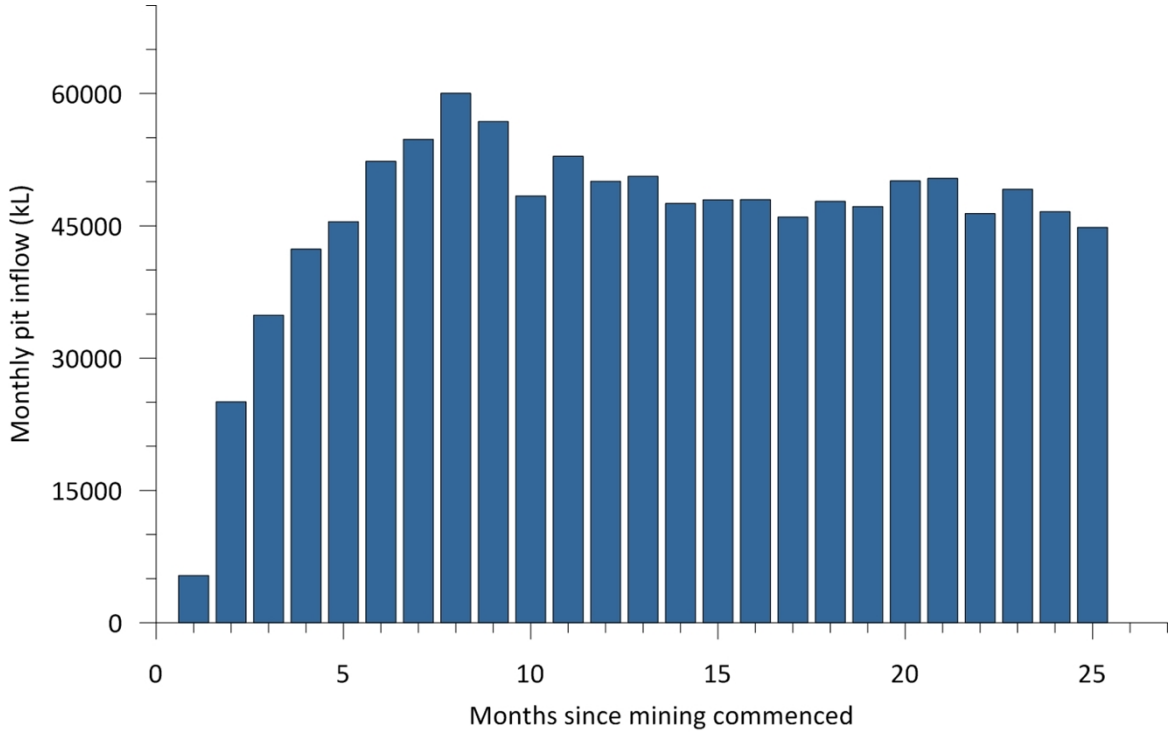


Figure 2-3. Modelled pit inflows (kL/month) during life of mine.

Table 2-4. Modelled volumes of pit water to be removed (dewatered) per month over the life of mine assuming July 2019 start date and average rainfall conditions.

Month	Mining stage	Groundwater inflow (ML/mth)	Rainfall (ML/mth)	Total pit inflows
Jul 2019	Waste	5.35	0.00	5.35
Aug 2019	Waste	25.05	0.00	25.05
Sep 2019	Waste	34.87	0.73	35.60
Oct 2019	Waste	42.36	6.77	49.13
Nov 2019	Waste / Ore	45.48	18.01	63.49
Dec 2019	Waste / Ore	52.32	28.47	80.80
Jan 2020	Waste / Ore	54.82	53.67	108.49
Feb 2020	Waste / Ore	60.03	45.57	105.60
Mar 2020	Waste / Ore	56.83	35.80	92.63
Apr 2020	Waste / Ore	48.39	9.34	57.74
May 2020	Waste / Ore	52.89	0.61	53.50
Jun 2020	Waste / Ore	50.06	0.00	50.06
Jul 2020	Waste / Ore	50.62	0.00	50.62
Aug 2020	Waste / Ore	47.54	0.00	47.54
Sep 2020	Waste / Ore	47.95	0.73	48.68
Oct 2020	Waste / Ore	47.98	6.77	54.75
Nov 2020	Waste / Ore	45.99	18.01	64.00
Dec 2020	Waste / Ore	47.78	28.47	76.26
Jan 2021	Waste / Ore	47.20	53.67	100.87
Feb 2021	Waste / Ore	50.10	45.57	95.67
Mar 2021	Waste / Ore	50.38	35.80	86.18
Apr 2021	Nothing	46.40	9.34	55.74
May 2021	Nothing	49.16	0.61	49.76
Jun 2021	Nothing	46.61	0.00	46.61
Jul 2021	Nothing	44.84	0.00	44.84
TOTALS:		**1150.99**	**397.96**	**1548.95**

2.5 Erosion and sediment control and flood prevention

The *Erosion and Sediment Control Plan* (ESCP) details the controls implemented across the site to minimise erosion and sedimentation, and prevent contamination of stormwater by directing it around operational areas. This plan has been developed by a Certified Practitioner in Erosion and Sediment Control and is consistent with the International Erosion Control Association, *Best Practice Erosion and Sediment Control* (IECA 2008).

Figure 2-4 shows the internal mine site drainage, erosion and sediment controls, and surrounding bunding. The bund (referred to as 'topsoil bund') around western side of WRD is to prevent ingress of run-off from upslope areas into the WRD, and to prevent this 'clean' water from running on to the mine site. Instead, this water is directed around the WRD into natural drainage lines. The inside of this bund also acts to direct run-off from the WRD outer walls into drains that lead to the Sediment Basins 1 and 2 via erosion and sediment controls e.g. rock check dams.

The bund (referred to as 'inundation bund') around northern and eastern side of mine site is to prevent ingress of water from natural drainage lines on either side the mine, if these drainage lines were to flood (see flood inundation modelling in Section 4.3). The inside of this bund also acts to direct run-off within the mine site towards the sediment basins.

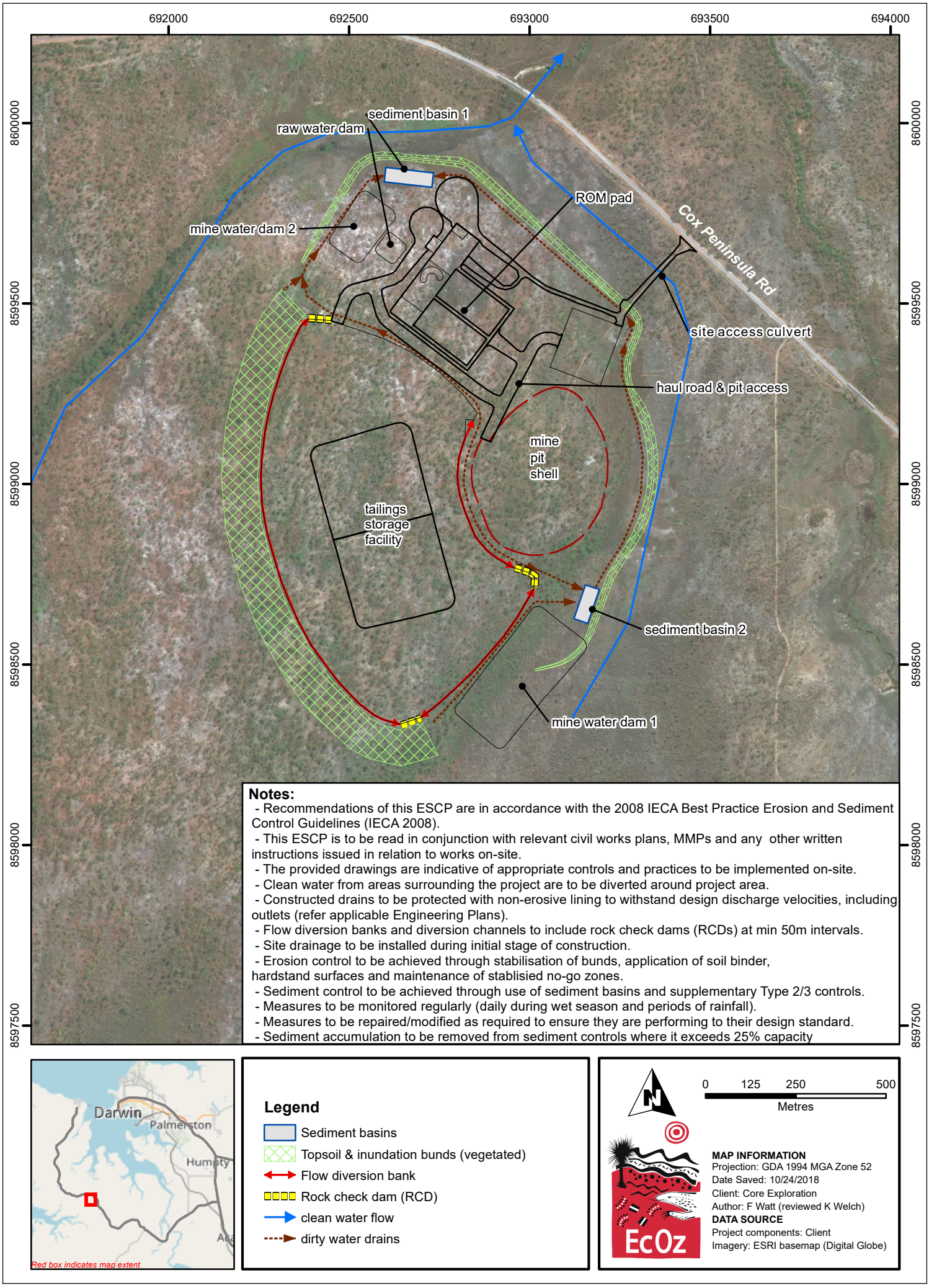
Internal drains within the mine site act to prevent stormwater run-off flowing into the open pit or other operational areas where is may become contaminated. Instead, this water is directed into drains, via erosion and sediment control measures (e.g. rock check dams), and into the sediment basins for treatment and testing prior to release off-site.

As will all erosion and sediment controls across the site, the design of sediment basins and method of release of water from these basins will be in accordance with IECA (2008).

The water quality of sediment basins will be monitored and tested weekly during discharge as part of the Water Quality Monitoring Plan (see Chapter 10). The results of this testing will guide how this water is treated with flocculants etc, and also identify any issues requiring action such as sources of contamination or improving erosion and sediment control measures.

See the ESCP for the design specifications of all erosion and sediment control measures (sediment basins, diversion banks rock check dams, catch drains etc).

In order to prevent stormwater contamination, all operational areas such as the DMS plant, workshops, fuel tanks, refuelling areas, heavy and light vehicle wash-down areas etc that store or use potentially contaminating materials such as fuels, chemicals, DMS processing additives etc are designed to the relevant Australian Standards for hazardous materials storage, and are covered and bunded where appropriate (see Section).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 2-4. Map of erosion and sediment controls.mxd

Figure 2-4. Map of erosion and sediment controls

2.6 Ore processing

The 1.8 Mt of fresh pegmatite ore contains approximately 1.5% concentration by weight of lithium oxide (Li_2O). Crushing, screening and DMS processing will increase the Li_2O concentration in the product to around 5.5%.

Crushing and screening will reduce the ore material to less than 6.3 mm. This material then goes through a wet screen to remove 'fines' (material less than 0.5 mm). Fines are sent to the thickener for dewatering, then to the TSF. The remaining material (0.5 to 6.3 mm) is mixed with a water-based heavy medium (ferrosilicon FeSi) to make a slurry, and then fed to the DMS cyclone. The specific density of the FeSi medium (2.7-2.9) separates the beneficiated product containing concentrated Li_2O, which sinks, from the lighter less concentrated material, which floats. The beneficiated product is stockpiled for road train transport to Darwin Port, whereas the 'floats' are sent to the rejects stockpile area and then to the TSF. The FeSi medium is recovered and reused.

Water reuse and recovery will minimise the need to source water from surface water storages. Water for processing will be sourced firstly from recovery from the tailings thickener, TSF decant, recovery from dewatering of product and rejects, and from pit dewatering prior to using water from surface water storages (Observation Hill Dam and/or MSD). A statement of operational efficiencies is included in the water balance (Appendix A). This statement indicates a re-use efficiency of 39 % (i.e. 39 % of water requirements comes from water reuse).

2.6.1 Additives

Additives used in ore processing include the FeSi heavy medium to achieve separation of the product and flocculant in the tailings thickener. Minor residues of these additives will end up in the WRD along with the coarse rejects (FeSi) and TSF with the fines (flocculent), however neither of these present a significant risk to the environment. Iron and silicon are naturally present in the laterite overlying the site, and dissolved iron is already present in surface and groundwaters (see background surface and groundwater water quality in Chapters 6 and 7). The Water Quality Monitoring Plan (Chapter 10) includes on-going monitoring of dissolved iron levels in surface and groundwater in order to detect any increase above background levels of dissolved metals.

The flocculant product is yet to be chosen. Only a product assessed as having low environment risk will used. Once known, the ingredients of this flocculant will be included in the Water Quality Monitoring Plan, if not already included.

2.7 Waste rock dump and tailings storage facility

2.7.1 Waste rock dump

The strip ratio for the Grants deposit is 13.8:1. Over the mine's life, an estimated total 8,920,762 bank cubic metres[1] of waste rock, i.e. weathered, transitional and fresh BCF host rock, will be excavated in order to access the ore body. A WRD will be constructed to accept all waste rock material removed from the pit and coarse rejects from the crushing/screening process. Waste characterisation studies (see Section 2.7.3 below) indicate limited potential for production of acid, saline or metalliferous drainage (AMD) from the waste rock and therefore no requirement for construction of containment cells. The processing rejects are coarse and also do not pose an AMD risk, and therefore will be co-disposed in the WRD. Some waste material has dispersive

[1] A bank cubic metre is a solid measure of the volume of earth "in situ", i.e. moved from a bank (before excavation or blasting).

characteristics and may need to be managed by selective placement and storage towards the centre of the WRD, so as not to affect the stability of the annulus.

2.7.2 Tailings storage facility

The DMS wet screening process will produce fine rejects (tailings). Initial tailings classifications are a silty sand, that should drain successfully. Geochemical characterisation results for the fresh pegmatite ore indicate AMD is not expected to be an issue; see Section 2.7.3 below. No chemical processing is required in the DMS plant. Therefore, tailings solids are expected to be geochemically stable and not contain any contaminants. Further tailings characterisation work will be undertaken as part of processing plant trials, to confirm the tailings characteristics moving into the TSF detailed design phase.

The TSF will be integrated within the WRD. This design concept has the benefit of minimising the mine site footprint and allows for the WRD to entirely encircle the TSF on closure, therefore avoiding ongoing issues associated with water management and revegetation of an exposed tailings dam.

The TSF will be developed in conjunction with the first stage of the WRD construction. The facility will consist of retaining embankments constructed from pit overburden / waste rock. It will comprise two cells (Cell 1 to the north and Cell 2 to the south), with centrally located decant water return structures.

Initial waste classification works indicate the waste from the proposed open cut mine will have a very low risk of AMD. The design has therefore been structured to maximise drainage, without a need for preventative measures for oxidation of the material. The base of the structure will be appropriately treated to provide a low permeability barrier, which, along with the underdrainage system, would allow effective management of any risk of groundwater mounding.

The containment embankments will feature an upstream zone (Zone 1) of low permeability, primarily fine-grained materials sourced from residual soils from pit overburden excavations. This zone will allow the TSF to be a water retaining structure. The majority of the embankment will consist of weathered earth fill / rock fill won from the pit overburden (Zone 3).

Each cell will contain a centrally located decant water return structure, and associated access causeway constructed out of Zone 3 material. Directly around the decant return structure will be a zone of clean, durable filter rock. The decant structures will consist of precast concrete, vertical slotted pipe, with a submersible return pump within the structure.

The embankment batter slopes have been conservatively designed at 2.5 Horizontal: 1 Vertical (2.5H:1V). This will be further refined upon completion of site investigations and testing of the foundations and embankment materials.

The Dam Failure Consequence Category has been assessed as ‘Significant’, in accordance with the Australian National Committee on Large Dams (ANCOLD) “Guidelines on Tailings Dams” (ANCOLD, 2012). The classification was primarily driven by the impact on the business as well as the environment, in the event of a dam failure. The spillway has therefore been sized to accommodate a 0.1 % AEP flood event.

The Environmental Spill Consequence Category has been assessed as ‘Low’, due to the benign nature of tailings and low environmental risk of processing additives. The Design Storage Allowance (DSA) prior to spilling has therefore been set at a nominal 1 % AEP, 72-hour flood event.

Tailings thickening

Tailings are pumped to a thickener where flocculant is added to separate the slurry into an underflow component (tailings approximately 50% solids) and overflow component of process water that is returned back to the processing circuit. The thickened tailings slurry is then pumped to the TSF.

Tailings deposition

Tailings will be pumped approximately 950 m from the plant to the TSF through the main delivery pipeline. At the TSF, the tailings will be sent to either of the two cells, where the slurry will be deposited sub-aerially, through pipelines running around the perimeter of each cell, with spigot offtakes at 50 m centres. This system has been selected in order to minimise the rate of rise and provide an even distribution of tailings deposition, thereby improving consolidation, density and strength properties of the material.

TSF staging

Due to the relatively short mine life, the TSF will be constructed to the full height in a single construction campaign. Cell 1 (to the north) may be constructed first, allowing for tailings deposition to commence during construction of Cell 2.

Water management

The TSF will feature centrally located decant water return structures, along with a system of underdrains, in order to facilitate drainage of the tailings and further promote consolidation of the material. The TSF decant water will be returned directly to the process plant for re-use, or stored in MWD2. Wet season run-off will either be stored in the TSF, or pumped to MWD2 for future process / evaporation.

2.7.3 Waste rock characterisation

Table 2-5 summarises the waste rock characteristics for the project determined through testing and analysis reported in EcOz (2018a).

Table 2-5. Summary of waste rock characteristics

Acid Sulphate Soils
None of the soil samples collected at the site are indicative of ASS. This result concurs with the land unit mapping, which shows the project area has a Nil (class 1) risk of ASS conditions.
Acid drainage potential
The majority of sub-surface material collected (156 samples) at the site have a sulfur concentration less than 0.05 %, which indicates a low risk of PAF material. 17 of 164 samples had an elevated sulfur concentration; only 1 of these within the pit shell is classified as potentially acid forming material. The sulfur concentrations in samples are low; total sulfur concentrations vary between <0.01 %S and 1.88 %S. 148 samples (or 90% of all samples) have total sulfur concentrations <0.05 %S indicating non- PAF material. Approximately 10% of samples have concentrations ≥ 0.05 %S. All of the samples were from depths > 50 m below surface level with the majority coming from deeper than 100 m below surface. All samples with a sulfur concentration > 0.10 %S (7 samples) were from greater than 100 m deep. Subsequent classification of samples based on NAPP and NAGpH (pHOX) results found only two samples classified as PAF. These samples are fresh hard rock phyllite located 125 m deep or deeper from the surface. One sample is from the south east section of the pit shell and the other from the central western half. Overall the waste rocks are considered materials with no AMD potential primarily due to the absence/scarcity of sulfur, which is typical of the sedimentary environment in which it was deposited. Waste rocks that classify as PAF will be limited in volume; they are not confined to a specific area and will be excavated with NAF materials and placed in the waste rock dump surrounded and underlain by materials that have sufficient ANC to offset any potential acid generation.
Metalliferous drainage potential
126 samples were analysed for soluble metal concentrations. Some samples have detectable but very low concentrations of As, Mn, Se and Zn whilst Cd, Cr, Co, Cu, Pb, Ni, V and Hg. All below their limits of reporting.

Ten of these samples with Total Sulfur concentrations >0.04 %S was submitted for determination of leachable metals. The leachates contained As (1 sample at 0.2 mg/L), Ba (ten samples at between 0.2 mg/L and 0.3 mg/L), Cu (one sample at 0.1 mg/L), Zn (ten samples at between 0.1 mg/L and 0.4 mg/L) and Mn (ten samples at between 0.2 mg/L and 11.9 mg/L averaging 2.4 mg/L). Be, B, Cd, Cr, Co, Pb, Ni, Se, V and Hg were absent in leachates. Waste rocks may leach metals; however, concentrations will be low. This finding is corroborated by baseline surface and ground water monitoring which indicates: • Groundwater contains elevated concentrations of As (0.009 mg/L and 0.166mg/L) and Fe. Most other metals i.e. Al, Cd, Cr, Cu, Pb, Ni, Se, Zn and Hg are generally absent except for a few minor detections at very low concentrations. • Surface water contains Al (between 0.01 mg/L and 0.08 mg/L) and As (between <0.001 mg/L and 0.007 mg/L) whilst metals such as Cd, Cr, Cu, Pb, Ni, Se, Zn, Sn and Hg are below their limits of reporting.
Saline drainage potential
All had very low electrical conductivity (0.004 dS/m - 0.280 dS/m) and are considered low saline and highly unlikely to produce saline drainage.
Sodic or dispersive potential
33% of samples spread across the pit shell and at varying depths, were classified non-sodic but potentially dispersive. These samples have an Emerson Class Number 3 which indicates that remoulding (at moisture content near optimum for compaction) may cause dispersion. A high portion of the samples were from the highly to moderately weathered phyllite, with the highest occurrences in the eastern portion of the pit shell from surface to 5m depth and from 8-54m depth across the whole pit shell. Where this material occurs in the shallow parts of the pit it is a potential source of construction materials and therefore further detailed geotechnical testing and assessment is required to characterise physical characteristics stability. Material from the deeper parts of the pit shell will be placed in the centre of the WRD and therefore dispersive characteristics in these materials is not of management concern.
Naturally Occurring Radioactive Material
Background and materials to be extracted from the pit shell as waste rocks have low concentrations of NORM which do not warrant further investigation and assessment and/or management measures.

2.8 Non-mineral waste and hazardous materials

The project involves activities that produce domestic and industrial wastes, and storage/handling of hazardous materials. Sources of waste and methods proposed for storage and disposal are described in the sections below.

2.8.1 Predicted waste streams

The industrial and domestic wastes expected during mining activities are:

- General domestic putrescible waste
- Construction and demolition waste
- Recyclable wastes (packaging, metals, wood, tyres)
- Waste oils, lubricants, coolants and filters
- Wash-down facility wastewater
- Sewage.

All industrial and domestic waste will be segregated for removal from site by a licenced waste contractor. Domestic waste will be stored in lidded receptacles and removed from site regularly to prevent odour and flies,

and access by vermin. Receptacles for recyclable waste will be lidded comingle receptacles. Construction waste, scrap metal and tyres will be placed in open-top skipped bins. Waste oils will be stored in bulk containers and other workshop wastes such as used chemical containers and batteries, will be segregated and stored undercover to prevent ingress of rainfall and subsequent release of contaminated water from storage areas.

General domestic waste, construction wastes and recyclables would be taken either to the nearest Litchfield Shire Waste Transfer Station that accepts commercial waste (i.e. Humpty Doo) or directly to the Shoal Bay Landfill. Hazardous wastes would need to be taken directly to Shoal Bay Landfill as they are not accepted at Humpty Doo. The ultimate approach used for waste segregation, storage, collection and disposal, will be determined by the waste management contractor engaged to manage this aspect of the site operations.

Wastewater produced at the wash-down facility will enter a sump fitted with an oil/water separator for removal of hydrocarbon contaminants. Solid waste (sediments) accumulating in the sump will be removed as required and disposed of to the WRD.

Analysis of hydrocarbons in surface and groundwater is included in the Water Quality Monitoring Plan (Chapter 10). The objective for these is for concentrations to remain below laboratory detection limits.

2.8.2 Hazardous materials

Diesel fuel will be used to power the on-site generators. Approximately 330,000 litres of diesel will be stored at the mine site in three 110,000 litre above-ground tanks. Additional remote storage will be as follows:

- TSF – 1 x 15,000 litre
- Observation Hill – 1 x 5,000 litre
- Mine Water Dam – 1 x 5,000 litre.

The remote storage is proposed to be small tanks for security and/or theft mitigation. Smaller tanks will be filled by service trucks as required.

Diesel will be stored in above-ground tanks that comply with Australian Standard *AS1940 Storage and handling of flammable and combustible liquid*s. Diesel fuels will be supplied by a licenced contractor as required and all plant and equipment will be refuelled on site in the refuelling area located within the MOC. Diesel spill response measures are incorporated in the project's Environmental Management Plan.

Processing additives will be stored in designated undercover storage areas. The additives (in their powdered form) pose limited risk to the environment; however, they are classified as hazardous chemicals under Workplace Health and Safety Regulations and therefore their storage and handling will be regulated by Worksafe NT.

2.8.3 Sewage treatment

Sewage and wastewater will be managed by connection to an on-site wastewater management system. The system type and design is yet to be finalised but will comply with the requirements of the *Code of Practice for On-site Wastewater Management* (Department of Health, 2014).

2.8.4 Product storage and handling

The concentrate product from the DMS plant will be stockpiled on the product pad. A front-end loader will be used to load the product into quad road trains. Each carriage of the road train will be covered to minimise release of dust during transport. There will be ten trucks loaded per day during operations.

3 CURRENT CONDITIONS

3.1 Rainfall and evaporation

The project is in the wet-dry tropics. The Wet season is typically November to April, and the Dry season May to October. The closest Bureau of Meteorology (BoM) rain gauges to the project with consistent long-term data (at least 20 years) are:

- Darwin River Dam (Station No. 14183); 24 km south-east of project site
- Territory Wildlife Park (14264); 22 km east
- Wagait Beach (14238); 22 km north
- Dum in Mirrie (14277); 32 km west

Given these BoM stations surround the project site in three directions, and monthly rainfall averages at all four are very similar (Figure 3-1), they are considered representative of project site rainfall. Typically, January and February are the wettest months with monthly average rainfall totals between 335 and 448 mm. June, July and August are the driest months when usually no rain falls. Average annual rainfall for these sites ranges between 1,622 mm (Darwin River Dam) and 1,827 mm (Territory Wildlife Park).

Mean monthly pan evaporation data available for Darwin Airport BoM station (No. 14015) shows maximum evaporation occurs in October, and minimum in February (Figure 3-1; BoM pan evaporation data accessed through World Meteorological Organisation website http://data.un.org/). Average annual pan evaporation is 2,688 mm, which exceeds average annual rainfall by at least 860 mm. Over the year at any one time, either rainfall or evaporation significantly dominates. Average monthly rainfall significantly exceeds evaporation for only four months of the year; during the Wet season (December to March).

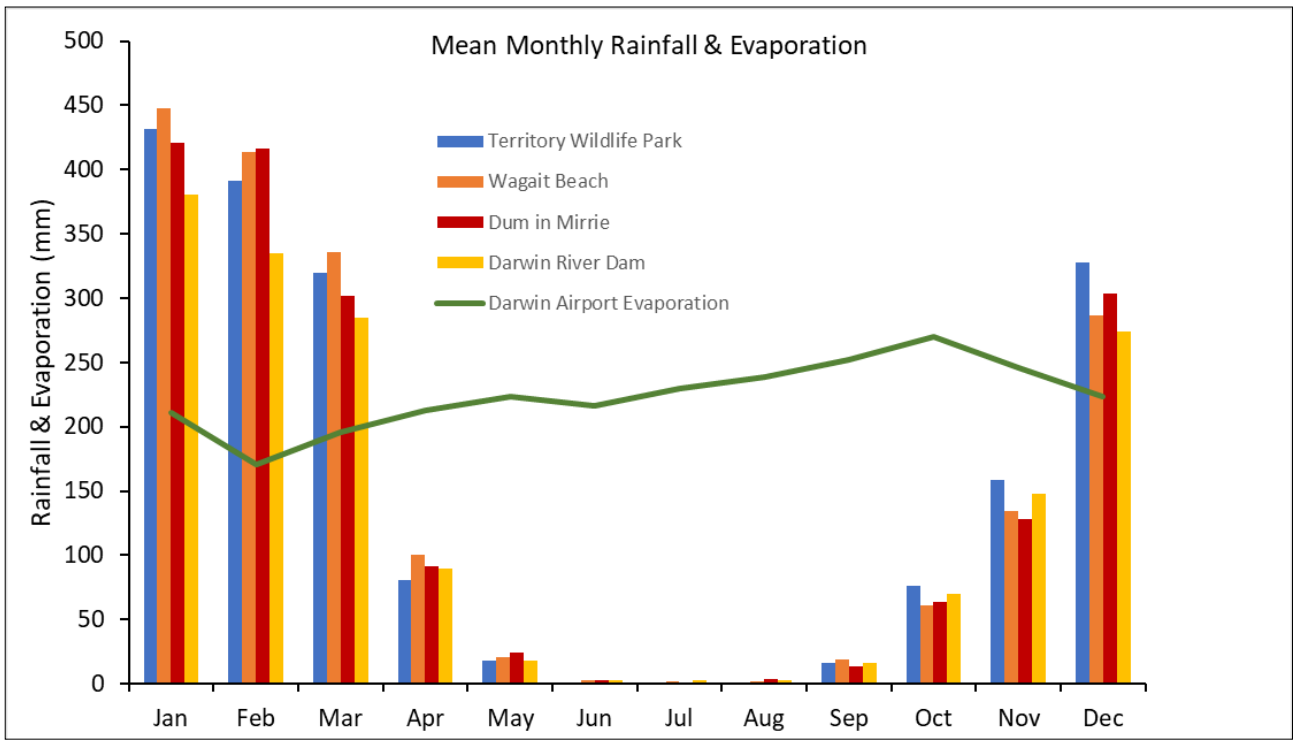


Figure 3-1. Mean monthly rainfall and pan evaporation for closest BoM sites with reliable data.

3.2 Surface water

3.2.1 Catchments and drainage

The Darwin Harbour / Bynoe Harbour catchment boundary cuts across the south-west corner of ML31726 (Figure 3-2). A majority of the lease, and all proposed mining infrastructure lies north of this catchment boundary, where surface water drains north into the West Arm of Darwin Harbour estuary. The small drainage lines starting in the south-west corner of ML31726 flow south-west into a tidal inlet of Bynoe Harbour. These drainage lines flowing to Bynoe Harbour are not subject to any proposed mining impacts and are not discussed further in this WMP.

The existing Observation Hill Dam, proposed to supply a portion of mining water requirements, is located around 5 km south-east of the mine footprint within the Bynoe Harbour catchment (Figure 3-2). It is situated at the headwaters of a drainage line that flows into the lower reaches of the Charlotte River, where it is tidal and becomes part of Bynoe Harbour.

There is no existing stream flow data for the drainage lines or streams relating to the project area. Based on aerial imagery and site visits at various times during the year, it is known there are no permanent watercourses within ML31726 or immediately downstream of Observation Hill Dam. The drainage lines around the mine footprint down to where they flow north under the Cox Peninsula road are very shallow, and lack a well-defined channel or riparian vegetation (see photos of monitoring sites GPUS SW3 and GPDS SW1 in Figure 6-1). They cease to flow early in the Dry season and are difficult to locate when not flowing.

These ephemeral watercourses, meet prior to crossing under the Cox Peninsula Road through a culvert. Around 1 km north of the mine, they meet another watercourse (Figure 3-3). Downstream of this confluence, the watercourse maintains pools into the Dry season, and a further 1 km downstream, the watercourse flows into a mangrove-lined tidal inlet of Darwin Harbour, West Arm.

Immediately downstream of Observation Hill Dam there is a wet area with poorly defined drainage and some pools near the foot of the dam wall, which appear to remain wet as a result of seepage (see survey undertaken for threatened wetland plant *Stylidium ensatum* by EcOz 2018). These areas support sedges and herbs in the ground layer during the Wet and early Dry season, but mostly dry out later in the Dry season.

The ephemeral drainage further downstream has a well-defined channel starting from a point around 1 km downstream of the dam wall (i.e. surface water monitoring site BPUS SW1; see photo in Figure 6-2). A late-Dry season (October 2017) site inspection of this watercourse observed pools but no visible flows starting from a point around 2 km downstream of the dam wall. The watercourse at this point has well-developed riparian vegetation (i.e. surface water monitoring site BPDS SW2; see photo in Figure 6-2).

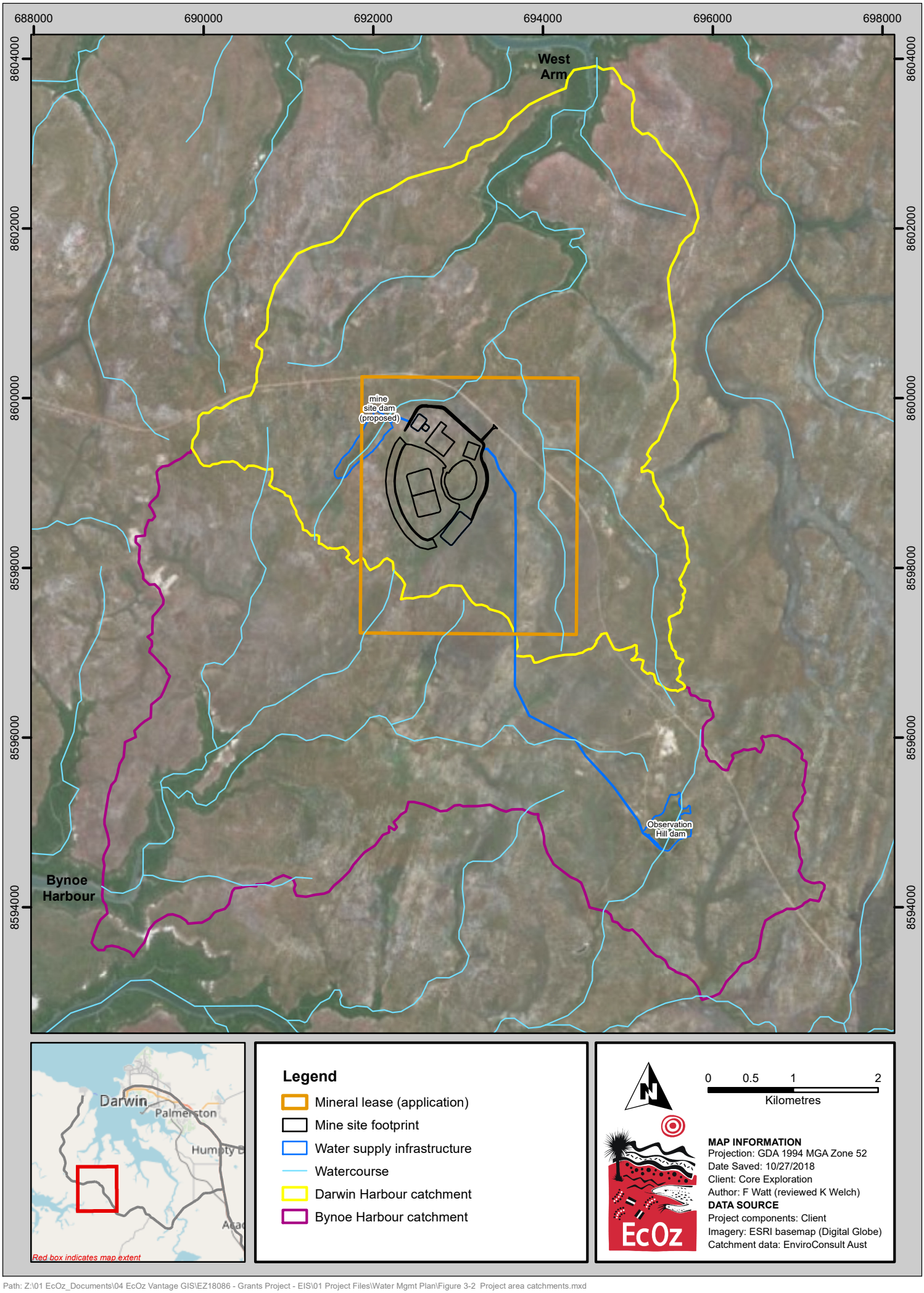
Delineated catchments and sub-catchments

Figure 3-3 shows the sub-catchments for the mine footprint area delineated by EnviroConsult (2018a and 2018b) using available topographic information, aerial imagery, and a 2 m digital elevation model. The catchment referred to as catchment 5 includes the mine footprint, and is divided into sub-catchments 5a and 5b. Catchment 2 lies directly east of the mine, and is divided into sub-catchments 2a and 2b.

Sub-catchments 5a and 5b drain to a culvert under the Cox Peninsula Road located directly north of the mine. Sub-catchment 2b drains to a culvert under the Cox Peninsula Road directly east of the mine. Sub-catchment 2a is on the other (north) side of Cox Peninsula Road and drains into sub-catchment 2b just downstream of the culvert. All four sub-catchments drain to a common outlet, around 1 km north of the project area. As mentioned in the section above, the watercourse at this point maintains pools into the Dry season, and a further 1 km downstream, flows into a tidal inlet of Darwin Harbour. Table 3-1 provides sub-catchment areas and slopes.

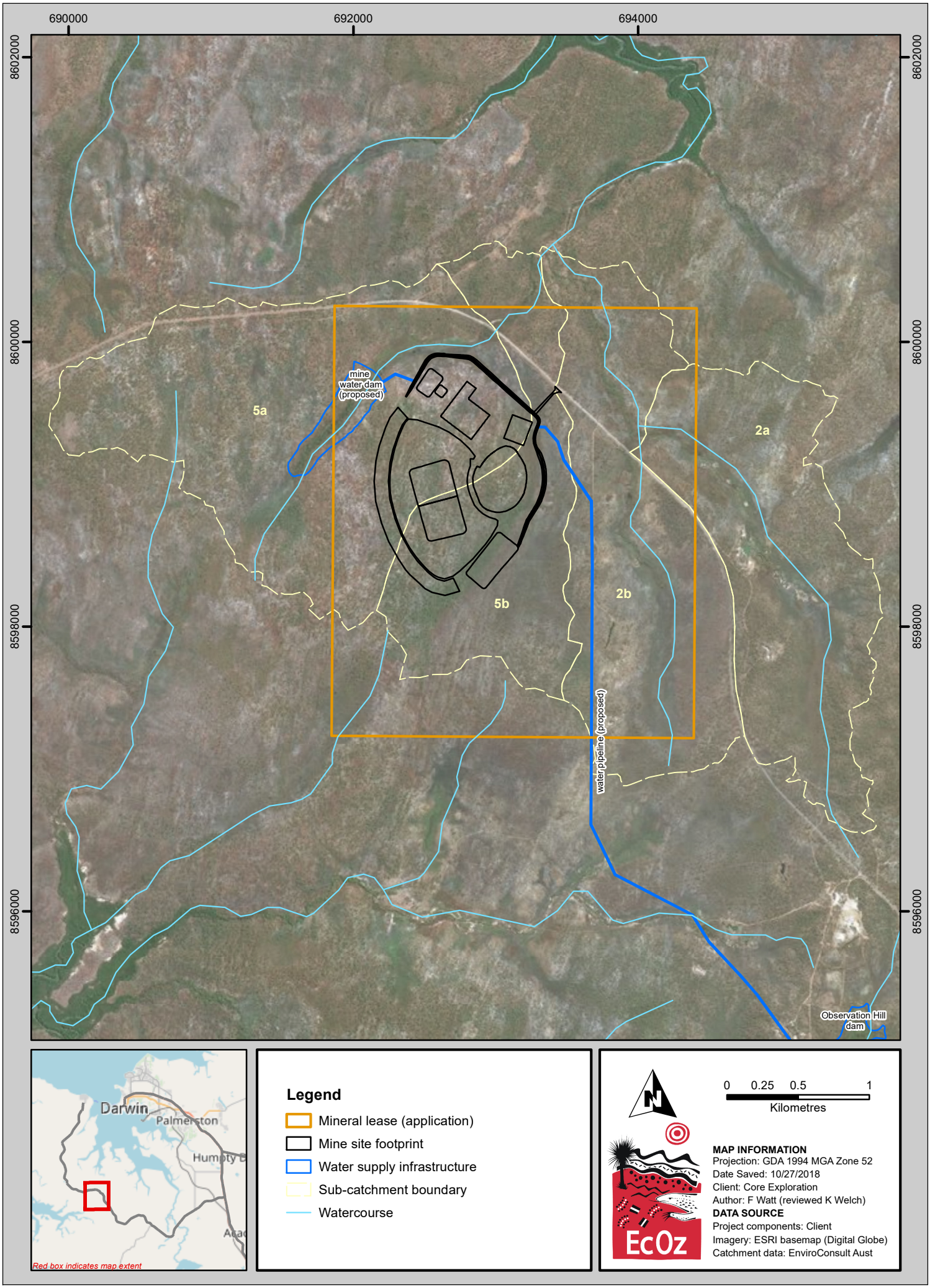
Table 3-1. Sub-catchment areas and slope.

Sub-catchment	Area (km^2)	Stream slope %
5a	4.8	0.5
5b	2.4	
2a	3.4	0.6
2b	3.0	
Total	13.6	0.5



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 3-2 Project area catchments.mxd

Figure 3-2 Map of surface water catchments of the project area



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 3-3 Mine footprint subcatchments.mxd

Figure 3-3. Map of mine footprint sub-catchments

3.2.2 Topography and soils

The topography within ML31726 is relatively flat and stream slope gradients are less than 1% (EnviroConsult 2018a). The highest elevation is 35 mAHD in the south, along the Darwin Harbour / Bynoe Harbour watershed, and the lowest is 10 mAHD, where the drainage lines flow under the Cox Peninsula Road (derived from *National Digital Elevation Model 1 Second Shuttle Radar Topography Mission*: http://www.ga.gov.au/elvis/).

The mine footprint is on a slight rise within an area mapped as land unit 2a1, comprising rudosol type soil's, and described as "Low Rises, gradient to 4%; shallow gravelly lithosols: *Eucalypt* Open Woodland, minor Woodland" (DLRM 2015).

The drainage lines on either side of the mine footprint have seasonally inundated hydrosol soils and are mapped as Land Units 5a and 6b; described as:

Land Unit 5a: "Narrow upland alluvial plains; gradient <1%; hard-setting apedal mottled yellow duplex soils: Grassland with scattered trees"

Land Unit 6b: "Broad lowland plains; gradient <1.5%; shallow to moderately deep siliceous sands: *Grevillea/Melaleuca* Tall Shrubland to Low Open Woodland, minor Open Woodland"

The drainage line upstream and downstream of Observation Hill Dam is mapped as land unit 5a.

Some areas along the drainage lines either side of the mine footprint, and also downstream of Observation Hill Dam, can retain saturated soils and/or pools into the early Dry season. A survey targeting the threatened wetland plant *Stylidium ensatum* undertaken by EcOz Environmental Consultants in June 2018 (EcOz 2018b) recorded shallow pools remaining in the drainage lines either side of the mine footprint, and also wet areas downstream of Observation Hill Dam; as mentioned in the section above.

The project area, including both ML31726 and Observation Hill Dam, are mapped as having no acid sulfate soil risk; see the *Acid Sulfate Risk Categories of the Greater Darwin Area* Map (DIPE 2004). There are no areas mapped as "High" risk within 10 km of the project area. The closest risk of acid sulfate soils ("Moderate") is the Darwin Harbour intertidal area, which is greater than 2 km north of the mine footprint, and the Bynoe Harbour intertidal area, which is greater than 4 km downstream of Observation Hill Dam.

3.2.3 Surface water environmental and social values

Land-use and surface water use

There are no national parks or conservation areas within the catchment upstream or immediately downstream of the proposed mine or Observation Hill Dam. The closest is Channel Island Conservation Reserve, 16 km to the northeast in Darwin Harbour, and Blackmore River Conservation Reserve, which is 20 km to the southeast, and well outside the project area catchment.

There are no residences, farms or industry within the catchment areas upstream or immediately downstream, and no uses for which surface water is currently being extracted. Berry Springs, a small township and rural residential area 22 km southeast of the project, is the closest area of intensive land-use; mainly horticulture and some cattle grazing.

Biodiversity values and Beneficial Uses

The project area including both the mine footprint and Observation Hill Dam catchments as well as surrounding catchment areas are largely undeveloped vacant crown land with only minor disturbances including the sealed Cox Peninsula Road, unsealed access tracks, historic mining pits and dams (see Frater 2005), and mineral exploration activities. Given this, waterways in the project area are largely intact (close to reference condition) and would be considered under the ANZECC 2000a protection level classification as 'slightly disturbed'.

The NT Government identifies Darwin Harbour as *a Site of Conservation Significance* with important biodiversity values (see Factsheet NRETAS 2009). The Harbour supports a range of estuarine, freshwater and terrestrial environments including extensive areas of tidal mudflats and mangroves. Fifteen threatened species are reported from within the Site, although none within the catchment upstream or downstream of the project. A survey targeting the threatened wetland plant *Stylidium ensatum*, undertaken in the project area in June 2018 (EcOz 2018b), found no evidence of this plant. Also, despite the freshwater stream downstream of the mine footprint (between Cox Peninsula Road and Darwin Harbour upper tidal limit) being assessed as in reference or 'good' ecological condition (see *Baseline aquatic ecology* section below), it is not an example of a rare, highly diverse, or significant habitat in the region. Similarly, the ephemeral drainage lines either side of the mine footprint prior to flowing under the Cox Peninsula Road do not maintain flows into the Dry season, and do not have a well-defined channel or riparian vegetation (see photos of monitoring sites GPUS SW3 and GPDS SW1 in Figure 6-1).

The watercourse downstream of Observation Hill Dam, starting from a point around 2 km downstream of the dam wall has a well-developed channel and riparian vegetation (i.e. surface water monitoring site BPDS SW2; see photo in Figure 6-2). This section of watercourse may hold some ecological values; although the habitat itself is not rare in the region or the specific habitat of a threatened species.

Darwin Harbour is listed as a wetland of national significance in the *Directory of Important Wetlands in Australia* (DIWA: NT029 Port Darwin). The drainage lines within the project area and waterways immediately downstream of the mine footprint and Observation Hill Dam do not have any specifically identified important wetlands; only the habitats fringing the Harbour itself e.g. mangroves, saltmarsh, tidal mudflats.

The project area lies within the *Darwin Harbour Region* declaration of surface water beneficial uses under the NT *Water Act* (NT Government Gazette No. G27, 7 July 2010). This declaration states that in relation to waterways within the Darwin Harbour Region:

> *The protection of environment, cultural (aesthetic, recreational and cultural), agriculture and rural stock and domestic to be the beneficial uses of water that apply to all natural waterways in the Darwin Harbour catchment, including all named and unnamed springs, creeks, rivers, lakes, lagoons, swamps or marshes.*

The water quality objectives that apply to these waterways under this declaration are the *Water Quality Objectives for the Darwin Harbour Region Background Document* (NRETAS 2010). For parameters such as

metals and other toxicants, where no objective is specified, the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a) apply.

Each year, the NT Government releases a *Darwin Harbour Region Report Card*, which summarises the results of water quality monitoring undertaken by the Aquatic Health Unit. The Report Card specific to West Arm, the where the waterways from the project area drain into, has received an "A" grading, indicating excellent water quality, for all years since the report cards started in 2009 (except for 2015 where it received a "B"). The Aquatic Health Unit considers West Arm to be relatively undisturbed with stream inflows limited to Wet season run-off from a largely intact undisturbed catchment.

In relation to management and control of surface and groundwater extraction, the project area lies within the *Darwin Rural Water Control District* declared under the NT *Water Act*. Pursuant to Section 41 of the Act, a permit is required to construct a dam and pursuant to section 45, a licence is required to take surface water. At the time of writing, mining activities were exempt from this requirement; however, an amendment to the Act to encompass mining is expected in early 2019. Core is anticipating having to apply for these permits in order to construct and extract water from the Mine Site Dam and Observation Hill Dam.

Baseline aquatic ecology

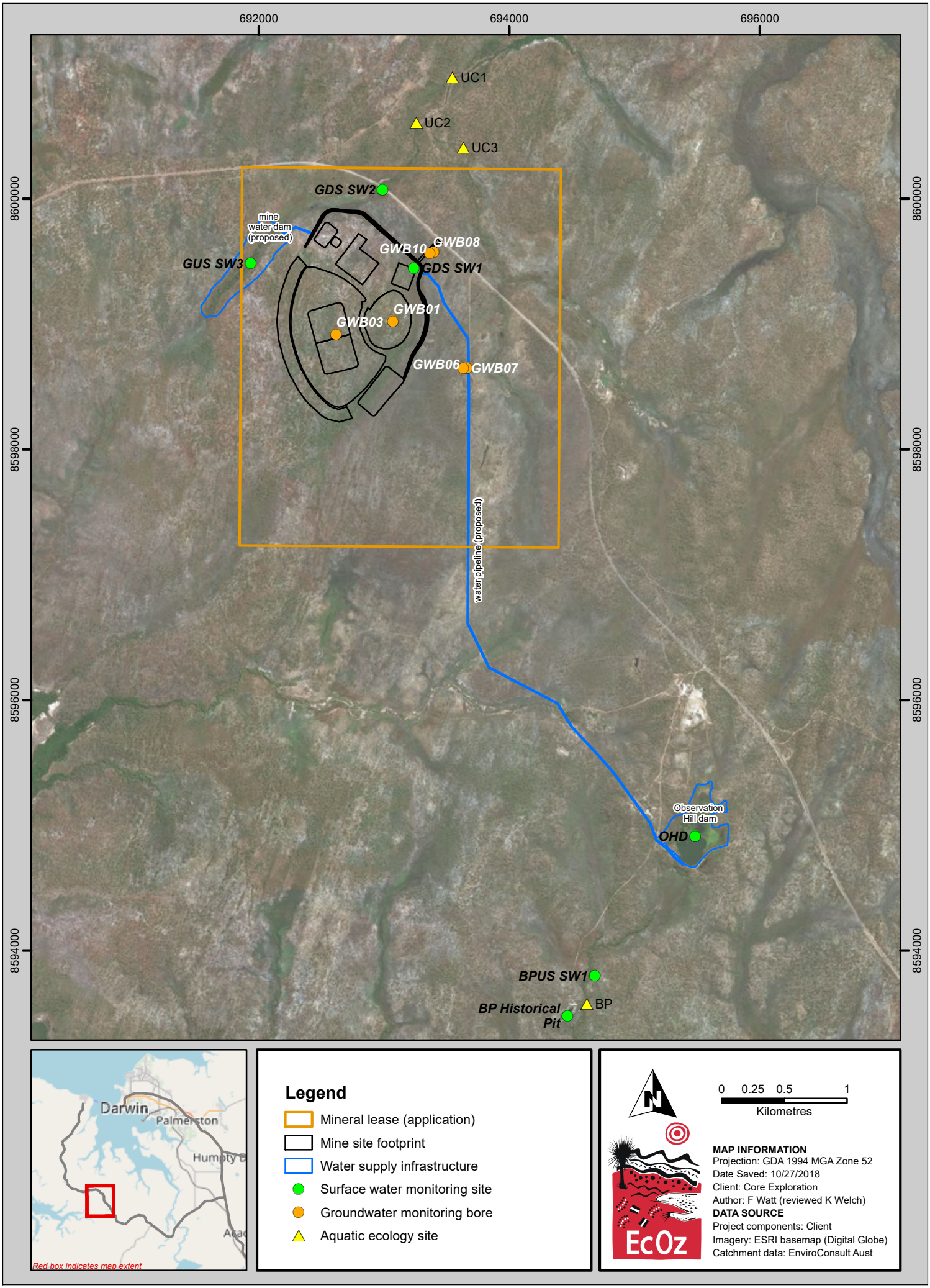
GHD (2017a) completed a baseline aquatic survey for the project in May 2017. This is the only known aquatic ecology survey specific to the project area. The survey sampled for macroinvertebrates and fish species at three sites downstream of the mine footprint; all north of the Cox Peninsula Road (Figure 3-4). Site UC2 is on an ephemeral stream receiving drainage from sub-catchments 5a and 5b, and UC3 is on an ephemeral stream receiving drainage from sub-catchments 2a and 2b. Site UC1 is downstream of the confluence of the streams from these sub-catchments, and is less than 1 km from the mangrove-lined tidal reaches of Darwin Harbour West Arm, where a distinct major increase in electrical conductivity (EC) was measured marking the change to tidal waters.

A forth site, BP, is located outside the catchment area encompassing the mine footprint. This site is in an adjacent catchment, just upstream of the historic BP mine pit. It is intended as a control site for future repeat aquatic ecology surveys (if required) during or post mining.

All sites appeared in a natural undisturbed condition with riparian vegetation, pools and woody debris. The only impact noted was elevated turbidity at UC1 (33 NTU) from an upstream ford constructed where an unsealed vehicle track crosses. Upstream of this ford, at site UC3, turbidity was recorded as very low (2.4 NTU). Sites UC2 and BP also recorded very low turbidity (0.6 and 2.7 NTU respectively).

All sites are freshwater, although the influence of seawater was detected at site UC1, where EC was comparatively higher (162 µS/cm) than the sites upstream UC2 and UC3 (both 19 µS/cm) and BP (24 µS/cm).

The results of macroinvertebrate sampling indicated that sites UC2, UC3 and BP had similar species composition and are un-impacted by pollution and in reference condition. Of the four sites, BP had the highest taxa richness and presence of pollution-sensitive species. Site UC1 differed significantly in its species composition and appeared slightly impacted; although this may be more to do with the species used in the AUSRIVAS Model; where many species recorded at this site are not included in the model used for indicating level of impact. UC1 also recorded an estuarine fish species (out of a total 4 species recorded at this site). Whereas all fish species recorded at the other sites were freshwater (total 7 species; each site having 5 of these). The closer proximity of UC1 to estuarine waters means it has differing aquatic species to the other three sites.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 3-4 Surface water, groundwater and aquatic ecology monitoring sites.mxd

Figure 3-4 Location of baseline surface water, groundwater and aquatic ecology monitoring sites

3.3 Groundwater

3.3.1 Groundwater aquifers and flows

Knapton and Fulton (2018) have described and modelled the groundwater aquifers of the project area. Their report is used in the summary below for existing background information relevant to groundwater of the area, and in Chapter 5 for modelled results of groundwater flows for assessing potential impacts of the proposed mine.

Data is also taken directly and used in the summary below from the groundwater monitoring database established through regular sampling by EcOz of six bores installed on site in May/June 2017 (bore installation by GHD 2017b). Originally, 10 bores were planned, however, only six of these were installed:

- **GWB01** is a deep bore located close to the centre of the proposed mining pit
- **GWB08** and **GWB10** are a nest of two bores, one deep and one shallow located down-gradient of the pit
- **GWB03** is a deep bore located at the centre of the proposed WRD site and up-gradient of the pit
- **GWB06** and **GWB07** are a nest of two bores, one shallow and one deep, located up-gradient of the mine footprint

Unfortunately, GWB06 was contaminated with cement during drilling and cannot be used for water quality monitoring, only groundwater level measurements.

Bore locations are shown in Figure 3-4 and bore details provided in Table 3-2.

Table 3-2. Groundwater monitoring bore details.

Bore ID	RN	Depth (m)	Screened Interval (m)	Screened Formation	Purpose
GWB01	040093	160	88-154	Fresh BCF	Deep bore in proposed pit shell, representative of groundwater into the pit.
GWB03	040096	63	50-62	Fresh BCF	Deep bore located on site of proposed WRD, up-gradient of proposed pit (W side).
GWB06	040097	18	6-12	Clay-highly weathered shale	Shallow bore in surface aquifer; paired with deep bore GWB07; both up-gradient of mine footprint (SE side). NOTE – this bore is contaminated with cement and cannot be used for water quality; only groundwater levels.
GWB07	040098	63	49-61	Fresh BCF	Deep bore in BCF fractured rock aquifer; paired with shallow bore GWB06; both up-gradient of mine footprint (SE side).
GWB08	040095	60	47-59	Slightly weathered to fresh BCF	Deep bore in BCF; both down-gradient of mine footprint (N side).
GWB10	040094	12	0.5-6	Laterite	Shallow bore in surface aquifer; paired with deep bore GWB08; both down-gradient of mine footprint (N side).

Aquifer geology

The substrate and underlying geology of the area around the proposed mine footprint comprises a thin surface layer (less than 5 m thick) of Cenozoic sediments, mainly laterite gravel, sand and clay, underlain by Proterozoic Burrell Creek Formation (BCF) comprising shales, siltstones, and strongly foliated phyllite. The weathering profile goes to depths of 30 to 50 m before reaching fresh, un-weathered BCF (see mine pit profile in Figure 2-1).

The weathered and fractured rock BCF aquifer is a poor groundwater resource with a lack of primary porosity and open fracturing, and bore yields typically less than 0.5 L/s. Localised higher yields can occur where drilling intersects fracture zones or quartz veining; also at the base of the weathered zone. The weathered zone is more permeable than the un-weathered fresh BCF, with the highest permeability's most likely in the overlying Cenozoic sediments and upper-most weathered (laterised) BCF. The potential of these zones to store and transmit groundwater however is not significant, due to their limited saturated thickness. Minor aquifers may occur in the surface Cenozoic sediments in areas with thicker alluvial cover, such as along drainage lines.

Hydraulic conductivity

Hydraulic conductivity (K) is the ease with which groundwater can move through the geological formation which hosts the aquifer. Where K is high, water will flow through the aquifer easily, and the converse when K is low. Testing to derive Ks for the shallow and deep aquifers under the project area i.e. slug tests and recovery tests (GHD 2017b) found the:

- Thin surface laterite aquifer has a moderately high K ranging between 0.068 and 1.7 m/day
- Weathered zone has a moderate K ranging between 0.022 and 0.16 m/day
- Fresh BCF has the lowest K ranging between 0.003 and 0.024 m/day.

Groundwater levels

Groundwater levels, measured in metres below ground level (mBGL), i.e. standing water levels (SWLs), have been recorded continuously by loggers installed in each bore since June 2017. SWL's are also measured manually during water quality sampling rounds. Figure 3-5 shows how SWL's varied from the peak of the Wet season in late January/early February 2018 into the Dry season until August 2018.

SWLs in the BCF aquifer ranged from 0.3 to 2.0 mBGL in the Wet season, and 4.0 to 6.5 mBGL in the Dry season. This equates to a seasonal fluctuation in the BCF aquifer of between 3.3 and 4.5 m, with the largest change in the deep mine pit bore GWB01.

Levels in the shallow laterite aquifer ranged from artesian (flowing at the surface) during the Wet season, to around 2.7 mBGL in the Dry season. The continuous groundwater levels measured in the shallow laterite bore GWB10 (Figure 3-6) show that levels are highly responsive to rainfall, with spikes following individual rainfall events in the early Wet season, sustained levels close to ground level during the wettest months of the Wet season, and a steep drop in levels once Wet season rains finish. Water quality in this bore also reflects the close connection between surface and groundwater in the shallow laterite aquifer (see Chapter 7).

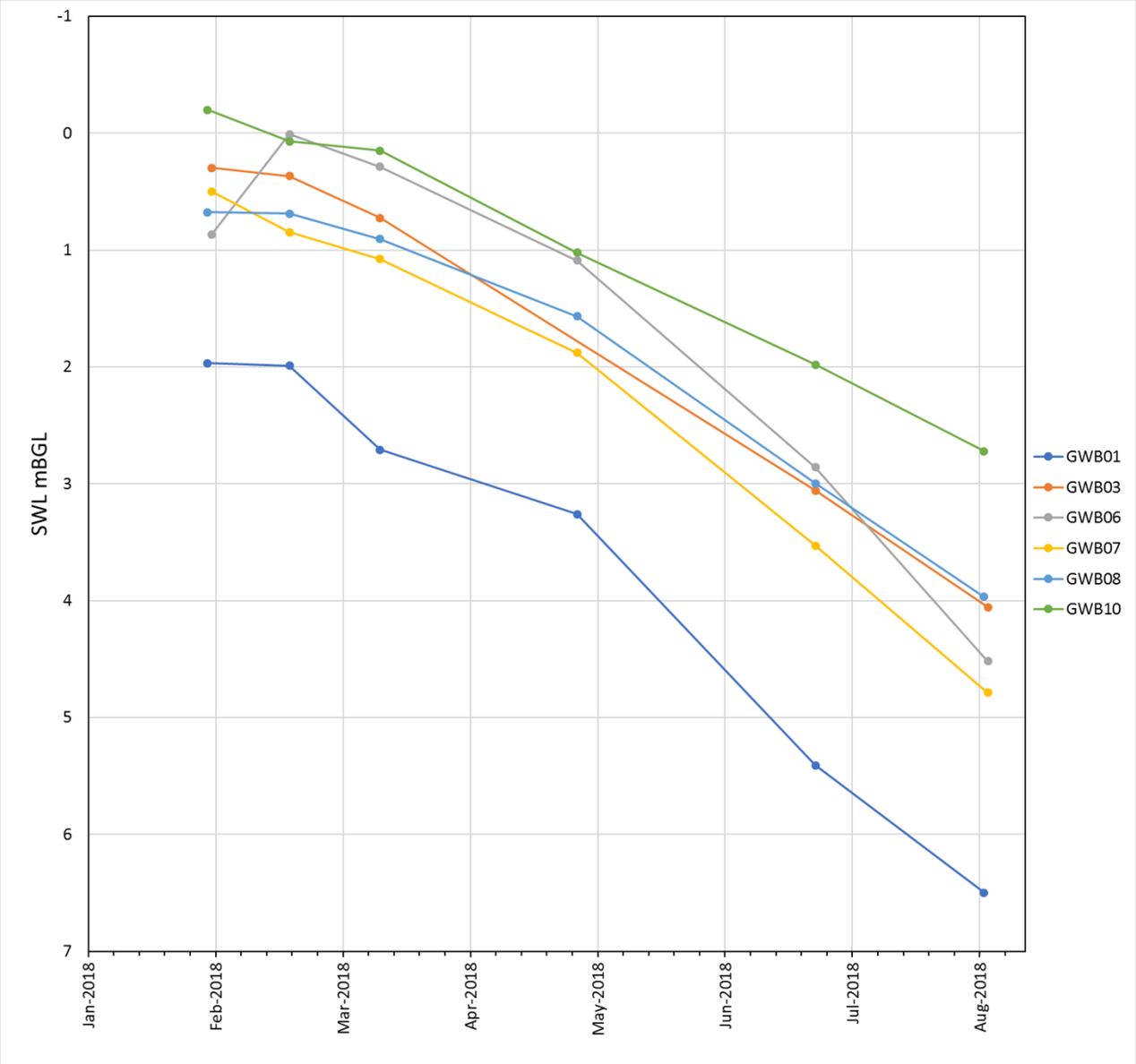


Figure 3-5. Standing water levels (metres below ground level) measured in the six groundwater monitoring bores.

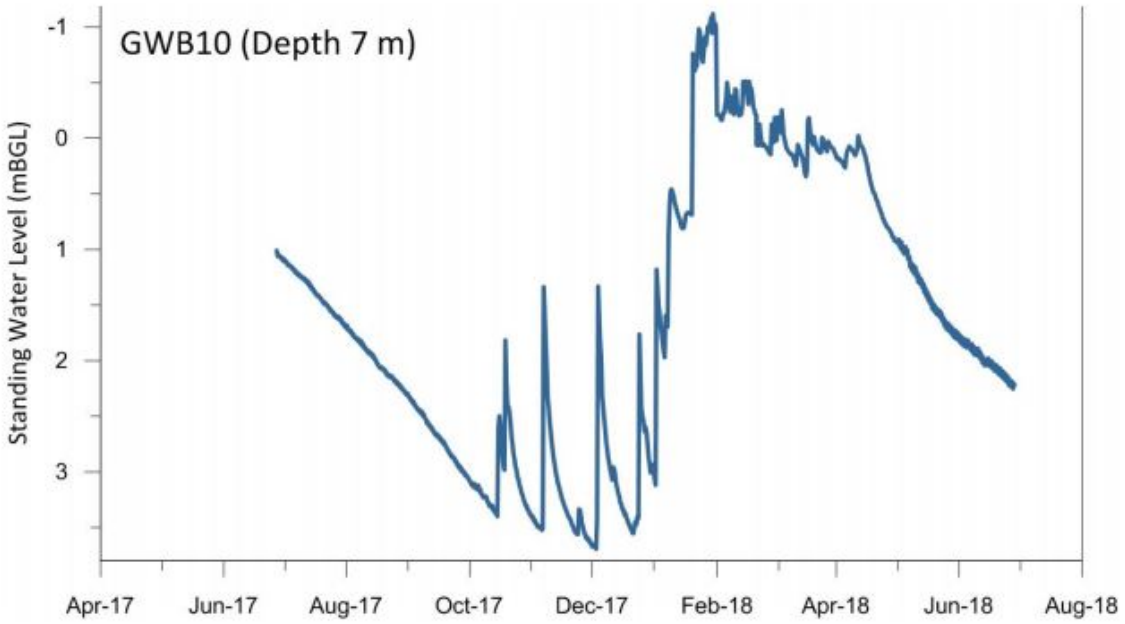


Figure 3-6. Hydrograph for shallow laterite aquifer from logger installed in Bore GWB10.

Groundwater flows and recharge

Based on the conversion of standing water levels across the site to metres Australian Height Datum (mAHD), groundwater flows were found to be in a north to north-east direction. Levels fluctuate seasonally by up to 4.5 m however, the general flow direction remains the same. Regionally, it is expected the groundwater table is a subdued reflection of the topography, flowing from areas of higher topography to areas of lower topography, and that groundwater from the site flows north towards Darwin Harbour.

Diffuse recharge is expected to be the dominant recharge mechanism, where water is added to the aquifer from percolation of rainfall over a wide area. Evapotranspiration and diffuse discharge are likely the dominant groundwater discharge mechanisms. Discharge to ephemeral drainage lines will also occur but volumes are expected to be small due to the low K of the aquifer. Comparisons of baseline surface water quality with groundwater quality confirm this for the drainage lines upstream and downstream of the mine footprint (see Chapter 7). Surface water quality downstream of Observation Hill Dam indicates a degree of groundwater inputs.

3.3.2 Groundwater environmental and social values

The BCF fractured and weathered rock aquifer beneath the project area is a poor groundwater resource, with bore yields typically less than 0.5 L/s. Given this, there is limited use of this aquifer for domestic, stock, or agricultural water supply. The closest registered bore currently in use is located on the Cox Peninsula Road, approximately 13 km east of the proposed mining pit (Knapton and Fulton 2018). This is well outside the modelled groundwater drawdown cone at the end of the two years of mining, which extends approximately 1 km from the pit and will remain within the mining lease boundary. It also does not intersect any of the ephemeral drainage lines around the mine footprint.

The Berry Springs Dolostone aquifer is located around 22 km east of the project area. There are current concerns regarding over-extraction from this aquifer and water allocation is closely managed and subject to the *Berry Springs Water Allocation Plan 2016-2026* (DLRM 2016). The BCF fractured rock aquifer beneath the project area has no connection to the Berry Springs Dolostone aquifer. The BCF aquifer has very poor hydraulic conductivity, and would have very poor connectivity over a distance of 22 km. Further, groundwater

underneath the project area flows from the higher ground to the south, not the east where the dolostone aquifer is located, similarly, groundwater leaving the mine footprint area flows north towards Darwin Harbour, not east.

Groundwater dependent ecosystems (GDEs) are "ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services" Richardson et al (2011). Types of potential GDEs found in areas around the project area could include vegetation associated with springs or seeps, wetlands that persist throughout the Dry season, riparian vegetation or monsoon rainforest patches reliant on groundwater remaining within the root zone for much of the year.

Given the low hydraulic conductivity of the aquifer, groundwater discharge to surface features in the region around the project area is likely minimal. Surface and groundwater quality results for the area around the mine footprint indicate this (see Chapters 6 and 7). Therefore, the occurrence of GDE's dependant on such discharge is unlikely.

Knapton and Fulton (2018) reviewed *The Groundwater Dependent Ecosystems Atlas* available through the BoM website (http://www.bom.gov.au/water/groundwater/gde/map.shtml). Figure 3-7 reproduced from Knapton and Fulton (2018) shows the low, medium and high potential terrestrial GDEs mapped at a national scale. There are no medium potential terrestrial GDEs located within 2 km of the mine footprint and therefore none within the predicted 1 km drawdown cone from pit dewatering. There is a medium potential GDE located around 2 to 3 km north of the mine, however this is on the northern side of the tidal inlet, which would form a no-flow boundary, preventing connection to groundwater moving north from the project area. Groundwater supply to this GDE would be from the higher ground immediately to the north-east.

In relation to Observation Hill Dam, medium potential GDEs are located up-gradient (west and north-west) and down-gradient along the drainage line that receives overflows from the dam (Figure 3-7). Baseline groundwater quality monitoring undertaken for the project (Chapter 7) indicates groundwater is contributing to flows in the drainage line downstream of Observation Hill Dam during the Wet season. There is however, no evidence of spring-fed surface water flows during the Dry season.

Observation Hill Dam is likely a source of recharge to the groundwater aquifer. Prior to construction of the dam, the area now occupied by the dam would also have been a source of recharge; albeit diffuse recharge. The presence of the dam potentially contributes to extended recharge of the aquifer into the Dry season. The degree of importance of this recharge and subsequent groundwater supply for maintaining riparian vegetation and ecosystems in the waterway downstream are not known. Late-Dry season (October 2017) site inspections of the watercourse found pools but no visible flows at a point starting around 2 km downstream of the dam wall. The well-developed riparian vegetation at this point indicates some level of sub-surface input from groundwater is supporting this vegetation community throughout the Dry season.

As discussed in Chapter 4 below, raising the Observation Hill Dam wall extends the time it takes for the dam to fill and spill once Wet season rains start in November/December. Once full, the dam is modelled to remain above its previous capacity of 364 ML until at least the mid-Dry season in July/August (see Figure 15 in EnviroConsult 2018b), and therefore, will be supplying the same amount of seepage and groundwater aquifer recharge until this time.

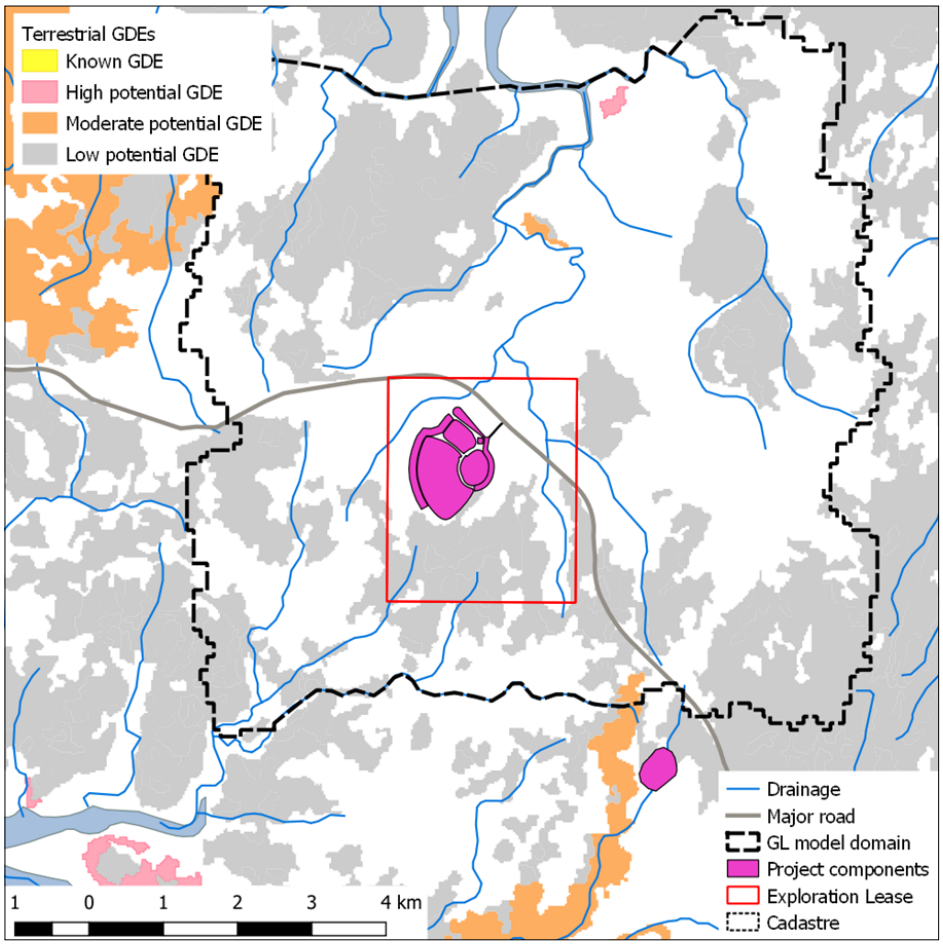


Figure 3-7. GDEs mapped for the project area and surrounds (from national-scale dataset available through BoM website *The Groundwater Dependent Ecosystems Atlas*).

4 HYDROLOGICAL POTENTIAL IMPACTS

Hydrological modelling was undertaken for the project area and proposed water storages (Observation Hill Dam and MSD) by EnviroConsult Australia Pty Ltd (EnviroConsult 2018a, 2018b and 2018c). Tasks included delineating the catchments and sub-catchments relevant to the project, sourcing required model input data (rainfall, streamflow, landform, run-off, evaporation etc), and building, calibrating and testing the hydrological model (EnviroConsult 2018a). This model was then used to derive a pre- and post-mining water balance for low, average and high rainfall scenarios to investigate potential impacts to downstream flows (EnviroConsult 2018b).

EnviroConsult (2018b) also determined the existing available water storage (Observation Hill Dam) and different scenarios for increasing water storage for the project i.e. raising Observation Hill Dam wall and building a new dam adjacent to the mine (Mine Site Dam).

Modelling was used in EnviroConsult (2018c) to assess how mine infrastructure will change flooding extent for a 1 in 100-year storm event i.e. 1% AEP (Annual Exceedance Probability).

4.1 Surface water storage requirements

EnviroConsult (2018a) estimated the current storage capacity of Observation Hill Dam to be 364 ML. This is not considered sufficient to ensure a secure mine water supply in the event of a drier than average year, or if the volume of groundwater inflows to the pit are less than predicted. The use of water from pit dewatering is expected to provide the bulk of water for dust suppression and ore processing (see Section 2.4 above, and Water Balance in Appendix A). The project water balance includes an operational efficiencies statement. This statement indicates a re-use efficiency of 39 % (i.e. 39 % of water requirements comes from water reuse).

EnviroConsult (2018b) modelled the increase in storage capacity for different wall lift scenarios. If a wall lift is undertaken, it is likely the dam wall will be raised by 1.5 m; increasing the storage capacity to 628 ML. This sizing is based on a worst-case scenario where offsets from reuse of water on-site (pit dewatering, TSF decant), or reduced water demand for dust suppression during the Wet season are not included.

Additionally, as previously outlined in Section 2.4, in order to ensure sufficient water supply as contingency in the event of a drier than average year, and/or unexpected water needs, an extra dam referred to as the Mine Site Dam (MSD) is being considered for construction on a drainage line immediately north-west of the mine within sub-catchment 5a (Figure 3-3). Based on modelling undertaken by EnviroConsult (2018b), the estimated capacity required for the MSD is around 387 ML. The water surface area for a dam with this capacity (19 ha) is shown in Figure 3-3. This sizing is based on a worst-case scenario where the Observation Hill Dam wall is not raised, and pumping from the MSD is constant throughout the year without any offsets from reuse of water on-site (pit dewatering, TSF decant), or reduced water demand for dust suppression during the Wet season.

4.2 Potential impacts from surface water extraction

In order to assess the potential effect on downstream flows, EnviroConsult (2018b) modelled the effect of constructing the MSD, and also raising the Observation Hill Dam wall by 1.5 m to increase its capacity. All hydrological modelling results are an overestimation given they are based on the worst-case scenario where surface water storages need to supply all water requirements without inputs from pit dewatering or TSF decant return, and a maximum pumping rate from the dams of 2.02 ML/day throughout the whole year.

Table 4-1 presents the total annual and monthly reductions in streamflow volume at three sequential points downstream of the MSD corresponding to the sub-catchment outlets shown in Figure 3-3. Modelling assumes the MSD is empty at the start of each Wet season. Changes to surface water drainage caused by mine site

infrastructure was also taken into account, such as the diversion of drainage around the outer mine site bunds. Capture of direct rainfall within the mine site bunds and within the pit, was treated as being retained on-site and not discharged. As such, discharges from the sediment basins and from MWD1 are not included; which further mean the modelled reductions are an overestimation.

Table 4-1. Modelled annual and monthly percentage (%) reduction in streamflows downstream of MSD and mine footprint.

Note these are maximum reductions based on worst-case scenario where surface water storages need to supply all water requirements without inputs from pit dewatering or TSF decant return, and the maximum pumping rate of 2.02 ML/day from the dam throughout the whole year. Additionally, direct rainfall within the bunds surrounding the mine is counted as a reduction and discharge from sediment basins and MWD1 are not included, which mean this is even more an overestimation.

Outflow location	Total Annual	July-Oct	Nov	Dec	Jan	Feb	Mar	Apr	May-Jun
End of sub-catchment 5, prior to confluence with sub-catchment 2.	37.0	0.0	75.6	74.2	70.8	33.1	28.7	50.5	0.0
Immediately downstream of confluence sub-catchments 5 and 2.	7.5	0.0	43.7	36.1	27.5	5.0	2.5	14.5	0.0
Upper tidal extent of Darwin Harbour where mangroves start.	5.5	0.0	24.1	21.6	19.2	3.7	1.8	9.9	0.0

Table 4-2 presents the monthly reduction in streamflow volume determined at the watershed outlet downstream of Observation Hill Dam where it meets the tidal reaches of Bynoe Harbour. Reductions of raising the dam wall combined with the maximum worst-case water extraction of 2.02 ML/day are compared to the existing catchment (present dam wall height and no pumping) and a natural system (no dam).

Table 4-2. Modelled monthly percentage (%) reduction in streamflow downstream of Observation Hill Dam at watershed outlet point.

Note these are maximum reductions based on worst-case scenario where surface water storages need to supply all water requirements without inputs from pit dewatering or TSF decant return, and the maximum pumping rate of 2.02 ML/day from the dam throughout the whole year.

Comparison	Total Annual	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May-Sep
Compared to current flows (OHD present)	1.8	0.0	0.0	0.0	0.0	1.6	1.5	1.1	0.0
Compared to natural catchment (pre-OHD)	Not modelled	0.0	3.3	3.3	3.2	3.2	2.5	2.8	0.0

The *NT Water Allocation Planning Framework* guideline (DENR 2018) indicates that at least 80 % of flows at any time be maintained as water for environmental and other public benefit i.e. no more than 20% reduction. This guideline has been used in the discussion below as the basis for assessing the impact from flow reduction in the waterways downstream of the mine footprint (Darwin Harbour, West Arm catchment) and downstream of Observation Hill Dam (Bynoe Harbour catchment).

4.2.1 Darwin Harbour, West Arm catchment

The maximum total annual reduction in flows immediately downstream of the mine footprint is 37 % (Table 4-1). Where flows from catchment 2 enter the drainage, the reduction in annual flow volume decreases to 7.5%. This is because a proportion of the flow reduction experienced immediately downstream of the mine

footprint is due to diversion around the mine site, where some stream flows that would normally flow to the catchment 5 outlet are instead diverted into catchment 2.

The maximum reduction in flows occurs during the early Wet season (November), when modelled flows immediately below the mine footprint are reduced by 75.6%. This is primarily because the MSD is retaining water as it fills. This decreases downstream to 24.1%, where the waterway meets the tidal waters of Darwin Harbour, West Arm. The lowest reduction in flows occurs during the late Wet season (28.7% in March), with a corresponding reduction downstream where the waterway meets Darwin Harbour of 1.8%. In regards to the guideline of maintaining at least 80% of natural flows, this is breached during all Wet season months immediately downstream of the mine footprint, and breached (slightly) during December and January where the waterway meets Darwin Harbour.

These reductions in flows would result in the ephemeral drainage lines downstream of the mine footprint remaining drier for longer during the early Wet season. Whilst the habitats along these drainage lines would be adapted to low/no-flow conditions, it is possible that the modelled reduction in early Wet season flow could alter the quality and/or species composition of the riparian zone. This is of lesser concern for the ephemeral drainage line immediately downstream of the MSD prior to where it flows under the Cox Peninsula Road as this drainage line does not have a well-defined channel or riparian vegetation (see photos of monitoring sites GPUS SW3 and GPDS SW1 in Figure 6 1).

In regards to the habitats along the section of waterway between Cox Peninsula Road and Darwin Harbour, these have been assessed using macroinvertebrate assemblages as in reference or 'good' ecological condition (see Section 3.2.3). Despite this, the riparian habitat along this waterway is relatively sparse and not an example of a rare, highly diverse, or significant habitat for threatened species in the region. The change in flows is unlikely to result in the loss of riparian vegetation along this section of stream, as it will continue to receive surface water flows through the peak of the Wet season, which will fill the temporary waterholes around which riparian species occur.

The nearest mangroves are approximately 1.7 km downstream of the mine site, at the upper tidal limit of West Arm. The first freshwater flushes are important for mangrove community health and any alteration to the quality and/or species composition would be greatest on the hinterland margin, which has the greatest diversity of freshwater-dependent species (Kristen Metcalfe, Eco Science NT, pers. comm. Sept 2018). It is possible that the modelled reduction in early Wet season flow could alter the quality and/or species composition of the hinterland mangrove zone. Any impact is expected to be very localised as the community will continue to receive some early freshwater inputs from stream flows (60-70% of natural flow) and also from overland flows within the larger part of the catchment that is not affected by the mine site. The reduction in total Wet season freshwater input to the upper mangroves has been modelled at 7.5% for an average Wet season. Impacts are not expected to be significant because natural flushing of the system will still occur over the Wet season, and the system is likely to have some resilience to changes in flow timing due to its reliance on ephemeral flows with a high level of natural variability.

In regards to cumulative impacts on the environment when the project's extraction is combined with that of existing users and/or potential impacts on other consumptive users of surface water within the catchment of the mine footprint, there are no other commercial or domestic uses for which surface water is currently being extracted. There are no residences, farms or industry within the catchment, and no aquaculture activities downstream in West Arm. There are also no known planned consumptive uses, other than that of the project in the short term.

4.2.2 Bynoe Harbour catchment

Raising the dam wall of Observation Hill Dam wall by 1.5 m, combined with water extraction of 2.02 ML/day, would reduce the total annual spillway outflow volume by 69 % when compared to the existing catchment with the current dam wall height. The reduction in flows compared to an undisturbed catchment prior to dam construction would be even greater.

Comparative flow reductions (compared to the catchment with dam wall at current height) only occur during the mid- to late-Wet season months of February, March and April. There is no change in flow regime for the early to mid-Wet season because the existing dam wall would have reduced flows during this time anyway. Raising the dam wall extends the time it takes for the dam to fill and spill. Once full, the dam is modelled to remain above its previous capacity of 364 ML until at least the mid-Dry season in July/August (see Figure 15 in EnviroConsult 2018b), and therefore, will be supplying the same amount of seepage and groundwater aquifer recharge until this time.

Immediately downstream of Observation Hill Dam there is a wet area with poorly defined drainage and some deep pools near the foot of the dam wall, which appear to remain wet as a result of seepage (see survey undertaken for threatened wetland plant *Stylidium ensatum* by EcOz 2018). These areas support sedges and herbs in the ground layer during the Wet and early Dry season, but mostly dry out later in the Dry season. The area does not support a particularly rare, diverse or important wetland for threatened or migratory species in the region and is also to a degree adapted to annual rainfall variability and periods of dryness. As mentioned above, the rate and timing of seepage from the dam to this area is not expected to change significantly with raising the dam wall and pumping from the dam.

The watercourse further downstream of Observation Hill Dam, starting from a point around 2 km downstream of the dam wall has a well-developed channel and riparian vegetation (i.e. surface water monitoring site BPDS SW2; see photo in Figure 6 2). This section of watercourse may hold some ecological values; although the habitat itself is not rare in the region or the specific habitat of a threatened species. The level of flow reduction to this section of waterway has not been modelled but would be significantly less than 69% given this location receives run-off from an additional 234 ha of catchment. The total catchment area above this section of watercourse is approximately 344 ha, and the catchment above Observation Hill Dam takes up approximately 110 ha of this. Therefore, the amount of catchment area feeding this part of the watercourse has been reduced by about 32%.

Further downstream at the watershed outlet, where the catchment meets the tidal waters of Bynoe Harbour, the total annual reduction in flow is 1.8%. This is well below the guideline of no more than 20% flow reduction. When compared to a natural catchment without any dams, the maximum monthly flows reduction at the watershed outlet is 3.3%, which occurs in early-Dry season months November and December (Table 4-2). This is still well below the 20% flow reduction guideline and as such is unlikely to affect mangrove communities in this area.

4.3 Mine site flood inundation modelling

EnviroConsult (2018s) modelled how mine infrastructure may affect flooding in the area resulting from a 1% Annual Exceedance Probability (AEP) rainfall event. AEP is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year, i.e. a 1% AEP is a 1 in 100-year rainfall event. The modelling found a critical rainfall duration of 6 hours is required to produce such an event at a point located around 2 km downstream of the mine, where the waterway meets the tidal reaches of Darwin Harbour. The probable maximum peak discharge (Q) without mining infrastructure at this point was 118.9 m^3/s, and with mining infrastructure 115.0 m^3/s (a drop of 3%). For total Q, there is a drop of 6% caused by the retention of water within the pit and water holding dams within the mine site.

The presence of mine site infrastructure also resulted in a smaller flood inundation area compared to without mining infrastructure. The modelling indicates the Cox Peninsula Road at the culvert directly north of the mine site would be flooded for a shorter period due to the presence of the mine (6.1 hours) compared to without the mine (7 hours). Apart from this small change, the modelling found little difference between areas of inundation before and after construction of the mine.

The modelling also ran scenarios that included the occurrence of storm surge at the same time as flooding. It was found that storm surge has no effect on inundation levels. The mine site is too far out of the storm surge zone.

4.4 Potential impacts from increased flows from discharge

Discharge of excess water from the MSD is another aspect of the project that could alter surface water flows. Estimates of pit dewatering and subsequent discharge requirements are provided in Sections 2.4.1 and 2.4.2. Discharge of excess water from the MSD will be required during the Wet season. In the first year of mining, discharges are predicted from January to March, and in the second year, discharges will be required from November to March (Table 4-3). The release of excess water will always be a relatively small percentage of the overall natural streamflow (less than 8%), apart from in November 2020 (88%) and December 2020 (40%), where the current modelled discharge requirements represent a significant portion of the natural streamflow. Note however, that this does not include potential reduced flows from construction of the MSD (see Section 4.2.1), which would reduce these increased flow percentages. Impacts from reduced flows from surface water extraction from the MSD, are assessed in isolation from the assessment of impacts from increased flows from MWD1 discharge. This represents the worst-case scenario.

It is reasonable to say that these increases in streamflow during the early-Wet season (for only two months during the whole mine life) would remain within the range of natural variability. These increased volumes would easily replicate the occurrence of early-Wet season storms. Given this, it is proposed that early-Wet season releases of water from MWD1 be undertaken in pulses rather than as a slow continuous realise, which could encourage the growth of algae and eutrophication along the drainage lines, and does not replicate natural storm activity at this time of year.

The Water Quality Monitoring Plan (Chapter 10) addresses discharge requirements and monitoring, and plans for further baseline monitoring required to increase the certainty around early Wet season discharge requirements and appropriate management strategies. Subject to the project gaining approval, discharges from the mine site require separate authorisation by a Waste Discharge Licence under the *Waste Management Pollution Control Act*, a process which provides an additional layer of regulatory scrutiny and oversight by the NT EPA beyond the EIS process. As a result of these measures it is unlikely that discharge of excess water will significantly alter downstream surface water flows.

Table 4-3. Percent increase in streamflows downstream of MWD1 from discharge.
Streamflow and %increase values are for the sub-catchment 5 discharge point in Figure 3-3.

Month	Discharge volume (ML/month)	Streamflow without discharge (ML/month)	Increase
January 2020	41	1009	4%
February 2020	86	2747	3%
March 2020	66	5044	1%
November 2020	24	27	88%
December 2020	46	115	40%
January 2021	80	1009	8%
February 2021	74	2747	3%
March 2021	59	5044	1%

5 GROUNDWATER POTENTIAL IMPACTS

5.1 Modelled pit inflows and impacts to existing groundwater aquifers from mining

Modelled groundwater inflows into the mining pit and predicted dewatering volumes were outlined in Section 0. At the end of mining, dewatering from the base of the pit will result in a drawdown cone extending approximately 1 km from the pit (Knapton and Fulton 2018). This is not predicted to affect groundwater levels beneath ephemeral drainage lines or impact groundwater levels outside the mining lease boundary. Furthermore, the (pre-mining) water quality of ephemeral drainage lines around the mine footprint, and downstream of the mine footprint, indicate that groundwater doesn't presently contribute to baseflows (see Chapters 6 and 7).

Numerical modelling undertaken by Knapton and Fulton (2018) predicts that post closure, the mine pit will gradually fill with water over a 50-year period before stabilising at a level around 7 to 8 m below the surrounding land surface. At this time, the water table is expected to be lower than pre-mining levels by 5 m at the pit edge, reducing to 0.5 m at 500 m from the pit edge.

Post-mining, the pit lake will act as a groundwater sink, meaning that groundwater in the immediate vicinity of the pit (within around 500 m) will flow towards the pit. This is because the total annual water loss from the pit from evaporation is greater than total annual groundwater and rainwater inputs. Given this, water quality in the pit lake is not expected to influence water quality in the surrounding aquifer.

Water quality in the final pit lake is expected to be good, with relatively low EC (for groundwater), neutral pH, and low concentrations of dissolved metals and nutrients except for arsenic, phosphorus, iron and lithium in comparison to surface water levels (see Section 7.4). Water quality is good in the nearby inundated BP33 historic mining pit, which has a similar geology to the Grants Project mine pit. EC is lower, and arsenic and phosphorus levels are very low possibly from dilution with rainwater and/or the precipitation and settlement of insoluble arsenic and phosphorus compounds due to oxidation and co-precipitation with dissolved iron.

The closest groundwater bores are more than 13 km from the mine site and will not be impacted. As the drawdown cone will be predominately within Core's ML31726, and entirely within the areas of Core's exploration tenements, the proposal is very unlikely to constrain future consumptive land-uses.

5.2 Localised mounding of groundwater

Seepage from the TSF and/or encompassing WRD material, could result in localised recharge of groundwater, and associated mounding of groundwater (where groundwater levels are locally higher than the surrounding aquifer). The majority of water from the TSF will be recovered through the under-drainage system and reused in operations. The TSF will be constructed of low permeable material, limiting infiltration and subsequent groundwater recharge. Seepage is estimated to be 0.1 ML per month. During operations, the flow of groundwater is towards the pit, and the WRD / TSF sit above the groundwater drawdown cone, indicating any seepage will flow towards the pit (with a small proportion possibly flowing towards the north, see Section 5.3 below).

Post-closure, the TSF will be capped with low permeable material, limiting retention of rainwater that could seep into the groundwater. The volume of water seeping from the final closed TSF to the groundwater is expected to be similar, or less than during operations, as the TSF will not be receiving water from pumped tailings. The final pit lake has been modelled as a groundwater sink (see Section 5.1 above), meaning that groundwater in the immediate vicinity, including under the WRD, will predominantly flow towards the pit.

Given the small volume of water, the low hydraulic conductivity of the aquifer, and the location of the WRD within the drawdown cone, it is not expected there will be significant mounding of groundwater during operations or after closure, and regional groundwater flows would be unaffected.

The groundwater quality monitoring program (Chapter 10) includes the installation of additional bores up-gradient and down-gradient of the WRD/TSF for monitoring any changes in groundwater levels, and testing water quality parameters designed to detect any contaminants of concern from TSF/WRD seepage.

5.3 Particle tracking

Knapton and Fulton (2018) modelled the predicted direction and spread of seepage from the WRD through the aquifer. The modelling uses forward particle tracks, or streamlines, to simulate the advective transport of solutes. The particles move along the hydraulic gradient (down-gradient) until exiting the model at an outflowing boundary (or ending up in a zone without significant flow velocity). The use of streamlines assumes steady-state flow conditions. Random-Walk Particle-Tracking solutions can be obtained by incorporating dispersive processes to the standard advective particle tracking. These solutions are theoretically consistent with advection - dispersion equation solutions.

The fate of particles seeded beneath the WRD at the end of the mine's life are presented below in Figure 5-1. The majority of particles terminate at the pit to the east of the WRD as the groundwater gradient is towards the pit. A small proportion of particles beneath the northern portion of the WRD are not captured and terminate to the north of the proposed mine footprint. Reducing the size of the WRD or shifting the location of the WRD further south will result in a greater proportion of leakage being captured by the pit.

Note the analysis assumes that no additional recharge (associated with leakage from the waste rock) is assigned within the footprint of the WRD. Including recharge may result in a mound developing beneath the WRD and a greater proportion of the particles terminating to the north and northeast.

Random walk particle tracking is also used to investigate the fate of seepage from the WRD following mine closure. The particle tracks are similar to those for the end mine life, with the majority of seepage captured by the pit. However, filling of the pit with water has reduced the gradient towards the pit-lake resulting in a greater proportion of seepage from the northern portion of the WRD not being captured by the pit-lake and terminating north toward the drainage line.

As mentioned in the section above, the groundwater quality monitoring program (Chapter 10) includes the installation of additional bores up-gradient and down-gradient of the WRD/TSF for monitoring any changes in groundwater levels, and testing water quality parameters designed to detect any contaminants of concern from TSF/WRD seepage.

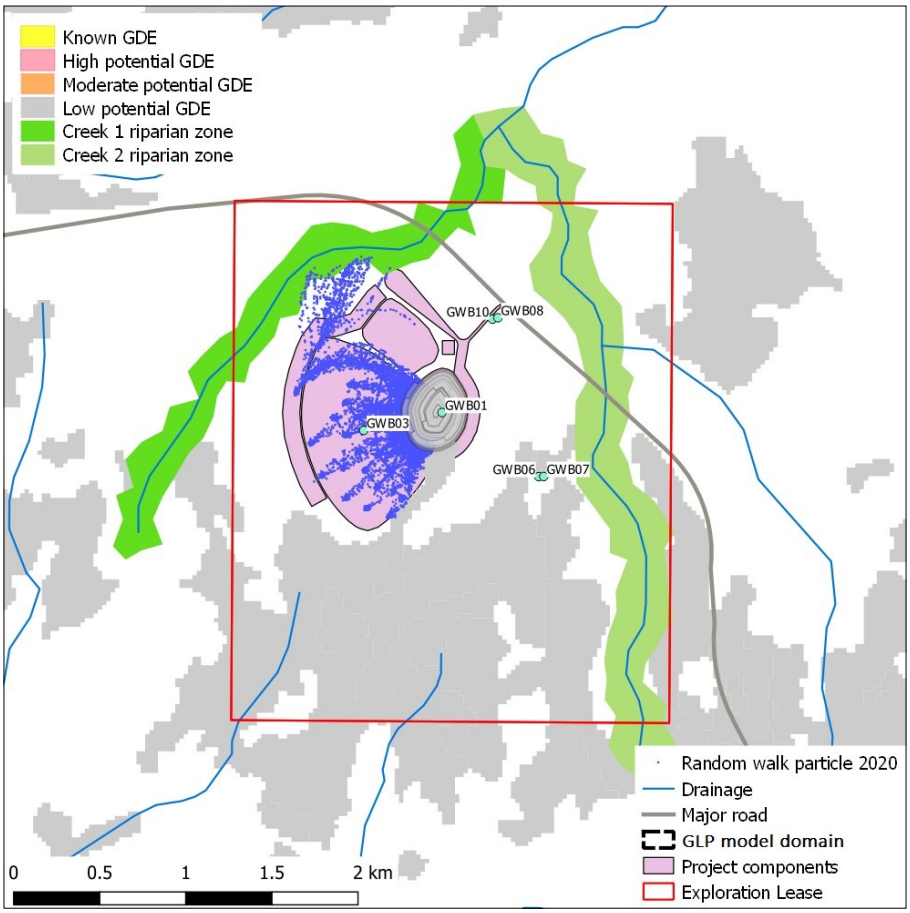


Figure 5-1. Results of modelling showing the direction and spread of seepage from the WRD.

6 BASELINE SURFACE WATER QUALITY

6.1 Baseline surface water quality monitoring

6.1.1 Monitoring sites

Baseline surface water quality monitoring has been undertaken for the project since February 2017. Figure 6-1 shows the location of surface water monitoring sites. Sites relating to the proposed mine footprint are:

- **GDS SW1** (Grants Down Stream Surface Water 1) on an ephemeral drainage line downstream of the proposed mine footprint (eastern side in sub-catchment 5b).
- **GDS SW2** (Grants Down Stream Surface Water 2) downstream of GUS SW3 and GDS SW1, where the ephemeral drainage lines on either side of the mine footprint join and flow through the culvert under Cox Peninsula Road.
- **GUS SW3** (Grants Up Stream Surface Water 3) on an ephemeral drainage line upstream of the proposed mine footprint (western side in sub-catchment 5a). During and after mining, this site will remain an upstream reference site not subject to mining impacts.

Surface water monitoring site selection was limited around the project area as drainage lines are very shallow and poorly defined (see photos in Figure 6-1). GDS SW1 and GUS SW3 do not have a distinct channel or riparian vegetation. During the Wet season, these sites are identified by where the water flows through the tall grass. Also at GDS SW1, the water flows through a culvert under an unsealed access track. It is difficult to locate these drainage lines when they are dry.

GDS SW2 is on a well-defined channel with riparian vegetation that goes through a culvert under Cox Peninsula Road (see photos in Figure 6-1). Water typically flows at this site throughout the Wet season and into the early Dry season. Water also flows for much of the Wet season and early Dry season in the shallow drainages of GDS SW1 and GUS SW3; although cease to flow earlier than GDS SW2.

A further three sites are located in the Bynoe Harbour catchment downstream of Observation Hill Dam (Figure 6-2). The purpose of these sites is to investigate if mining of the BP 33 open cut pit (now filled with water), has resulted in any water quality impacts. This pit was mined between 1997 and 1999 to recover tin and tantalum ore from a pegmatite very similar to that targeted for the Grants Project (Frater 2005). Water quality in the BP33 pit may also indicate groundwater quality flowing into the Grants Project open cut pit. These sites are also downstream of the existing Observation Hill Dam, proposed as a possible water source for mining operations. Furthermore, if Core was to expand mining operations to the BP 33 area in the future, these sites could be used as monitoring sites for these operations. The three sites are:

- **BP Historic Pit** inundated BP 33 open cut mining pit located directly adjacent, 70-80 m west, of the ephemeral drainage line flowing from Observation Hill Dam.
- **BPUS SW1** (BP 33 Up Stream Surface Water 1) on ephemeral drainage line upstream of BP33 pit and downstream of Observation Hill Dam.
- **BPDS SW2** (BP 33 Downs Stream Surface Water 2) on ephemeral drainage line downstream of BP33 pit and downstream of BPUS SW1 and Observation Hill Dam.

The ephemeral drainage line of these sites is well-defined by a channel and riparian vegetation, and typically flows throughout the Wet season and early Dry season (Figure 6-2).

Observation Hill Dam (OHD) was added to the monitoring program in October 2017 following the decision to possibly use this dam as a water source for the project.



Figure 6-1. Photos of surface water monitoring sites around mine footprint taken 15 February 2017.



Figure 6-2. Photos of surface water monitoring sites relating to BP 33 historic open cut mining pit taken 15 February 2017.

6.1.2 Monitoring undertaken

Sampling was undertaken between February 2017 and August 2018 as outlined in Table 6-1 below.

Table 6-1. Baseline surface water quality monitoring undertaken.

Date	Season	Sites Sampled
15 Feb 2017	Mid Wet	All sites except OHD
19 Apr 2017	Late Wet	All sites except OHD
12 Oct 2017	Late Dry	OHD and BP Historic Pit only. All other sites dry.
31 Jan / 1 Feb 2018	Mid Wet	All sites except OHD
14 Mar 2018	Late Wet	All sites except OHD
3 May 2018	Early Dry	All sites except OHD and GDS SW1 (dry)
8 / 9 Aug 2018	Mid Dry	OHD and BP Historic Pit only. All other sites dry.

Rainfall over the 2016/17 and 2017/18 Wet seasons was above average. In particular, record high rainfalls were recorded across the Darwin region during January 2018, with total monthly rainfalls greater than 900 mm recorded by the BoM stations closest to the project area (see Section 3.1). This is more than double the average January rainfall for these BoM stations.

Stream flows continued at all sites into the early Dry season. Flows began to stop in May (2017 and 2018), starting with GDS SW1, which was not flowing during the 3 May 2018 monitoring round. All sites had stopped flowing by the mid Dry season (2017 and 2018) and only sites OHD and BP Historic Pit could be sampled mid to late Dry season.

6.2 Baseline surface water quality results

Water quality results are compared to the *Water Quality Objectives for the Darwin Harbour Region* (NRETAS 2010). These objectives aim to protect the beneficial uses identified for waterways in the Darwin Harbour region as outlined in Section 3.2.3 above. The specific objectives relating to the beneficial use of environment (aquatic ecosystems) are applied given these are the most conservative, and adherence to these would in most cases also protect the other beneficial uses of cultural (aesthetic, recreational and cultural), agriculture and rural stock and domestic water supply.

The NRETAS (2010) water quality objectives developed specifically for “freshwater rivers and streams” are the most appropriate for the types of waterways receiving water from the project area, such as that released from sediment dams, or the MWD1 containing water dewatered from the pit.

Table 6-2 presents the field parameter results, and Table 6-3, Table 6-4 and Table 6-5 present the laboratory results.

6.2.1 Field parameters

Field parameters for the sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2) are discussed separately to the sites relating to Observation Hill Dam and BP33 pit (BPUS SW1, BPDS SW2, BP33 Historic Pit and OHD).

Field parameters measured at the sites upstream and downstream of the mine footprint show the water is:

- Fresh, with low EC concentrations generally between 9 and 15 µS/cm, and always well below the water quality objective of 200 µS/cm.
- For the three sites, pH varies widely between 5.41 and 8.14 with no apparent seasonal pattern or trends. Within-site variability is also very large with each of the three sites recording both acidic and alkaline pH's at various times; often above and below the water quality objective range (i.e. is outside the range 50% of the time). The reason for this is that pH in these drainage lines is highly responsive to the effect of photosynthesising/respiring plants and algae within the water causing pH to vary widely over the course of each day. The degree of plant photosynthesis versus respiration removes or adds carbon dioxide to the water depending on the time of day, cloud-cover and shading i.e. removing carbon dioxide when sunlight is available and photosynthesising, and producing carbon dioxide when sunlight is less available and respiring. Carbon dioxide produces carbonic acid when dissolved in water, lowering the pH. Fresh inputs of rainwater (which is naturally acidic in the tropical Darwin region) can also lower pH, whereas stagnating water with an algal bloom can have a high pH during the day. Additionally, these waters have low total alkalinity (all <2 mg/L; see laboratory results below), which means the water has little buffering capacity to neutralise acids and stabilise pH.
- Dissolved oxygen (DO) at all three sites is generally between 60 and 100% (median 80%saturation) and remains within the water quality objective range. There was no seasonal pattern or identifiable trends, and within-site variability was large for the same reasons explaining pH variability (i.e. variation from the effect of plant photosynthesis/respiration producing and removing oxygen from the water). Organic matter breakdown also has an influence, removing oxygen from the water. The low DO of 41%saturation measured at GUS SW3 in May 2018 is likely due to low flow conditions as the stream dries up in the absence of rainfall and fresh oxygenated run-off. There is also a high oxygen demand placed on the remaining small volume of water from organic matter breakdown combined with plant respiration (this measurement was taken during the early morning following the night time period where plants are respiring and not photosynthesising).
- Turbidity levels are generally always low, even during high rainfall periods; remaining below 12 NTU and well below the water quality objective of 20 NTU. This is because the drainage lines flow through thick groundcover vegetation and their small catchments have minimal exposed soil.

Field parameters measured at the sites relating to Observation Hill Dam and BP33 pit show the water is:

- Fresh, with low EC concentrations generally between 14 and 35 µS/cm, and always well below the water quality objective of 200 µS/cm.
- Similarly to the mine footprint sites described above, pH varies widely at all four sites between 5.06 and 9.31 with no apparent seasonal pattern or trends. Within-site variability is also very large, with each of the sites recording both acidic and alkaline pH's at various times; often above and below the guideline range (i.e. is outside the range 50% of the time). The reasons for this pH variability are the same as those explained above for the mine footprint sites.
- Dissolved oxygen (DO) is generally between 60 and 100% (median 80%saturation; same as sites around mine footprint) and remains within the guideline range. There was no seasonal pattern or trends, and within-site variability was large for the same reasons explaining pH variability. The low DO of 34, 35 and 41%saturation measured at the three sites sampled in May 2018 is likely due to organic matter breakdown and the absence of fresh oxygenated rainwater inputs.

- Turbidity levels are generally always low, even during high rainfall periods; remaining below 9 NTU and well below the water quality objective of 20 NTU. This is because the catchment areas of these sites are well vegetated with minimal exposed soil.

6.2.2 Laboratory parameters

Anion, cation and total alkalinity concentrations are:

- All very low at all seven sites. The concentrations at the three sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2) are all below 2 mg/L. Concentrations in the OHD, BP Historic pit and upstream and downstream of BP33 pit are slightly higher (between 2 and 8 mg/L comprising 100% bicarbonate alkalinity). This is because these sites receive some input from groundwater, which is relatively higher in anion and cation concentrations (see Section 7.2.2).

Dissolved metal concentrations are:

- All below laboratory detection limits and below the water quality objectives at all seven sites for cadmium, chromium, copper, lead, nickel, selenium, zinc, tin and mercury.
- Above the water quality objectives for aluminium most of the time at all three sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2). Concentrations up to 0.08 mg/L.
- Sometimes above the water quality objective for aluminium at the BPUS SW1 and BPDS SW2 sites.
- Always below the water quality objective for aluminium at the OHD and BP Historic Pit sites.
- Always below laboratory detection limits and the water quality objective for arsenic at the three sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2).
- Above laboratory detection limits but remain below the water quality objective for arsenic at OHD and sites upstream and downstream of the BP33 pit. The BP Historic Pit site has the highest arsenic concentrations, however these remain below the water quality objective except for one instance where the concentration was slightly above the objective. The source of arsenic in the BP33 pit, and also OHD and sites upstream and downstream of the BP33 pit is from groundwater inflows (see Section 7.2.2).
- All below 0.002 mg/L for lithium at the three sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2), and at OHD. Concentrations are slightly higher (up to 0.008 mg/L) in the BP Historic Pit and also the upstream and downstream BP 33 sites. The source of lithium to these sites is from groundwater inflows (see Section 7.2.2).
- All below 0.1 mg/L for iron at the three sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2), and at OHD and BP Historic Pit. Of note, is that concentrations are generally always higher (up to 0.38 mg/L) at the upstream and downstream BP 33 sites. The source of this is not known but possibly from groundwater inputs from the shallow laterite aquifer (see Section 7.2.2).

Nutrient concentrations are:

- Generally always above the water quality objective for nitrate+nitrite (NO_x) at all seven sites; typically up to 0.03 mg/L and sometimes up to 0.06 mg/L. Nitrate makes up 100% of the measured NO_x concentrations i.e. no nitrite.
- Always below the water quality objective for total nitrogen (TN) at the BP Historic Pit site, and upstream and downstream BP33 pit sites.
- Generally always below the water quality objective for TN at the sites upstream and downstream of the mine footprint (GUS SW3, GDS SW1 and GDS SW2) and at OHD; except for some isolated spikes.

- Generally always below detection limits for total phosphorus (TP) except for a few isolated spikes in the BP Historic Pit, and the upstream and downstream BP33 pit sites. Note laboratory limit of reporting (LOR) for NO_x and reactive phosphorus is greater than water quality objective. As such, unless concentration is above LOR, it is not known if objective is exceeded.
- Always below the reactive phosphorus water quality objective except for two isolated instances slightly above the objective at GUS SW3 and BP Historic Pit.

The consistent pre-existing baseline exceedances of the water quality objective for aluminium and NO_x, and occasional spikes in TN, TP and reactive phosphorus must be taken into consideration when assessing impacts on water quality during and after mining. The ANZECC (2000a) *Guidelines for Fresh and Marine Water Quality* recommend under these circumstances to calculate site-specific trigger values based on the 80th percentile of baseline (or reference site) data. It is not however possible at this stage to calculate site-specific trigger values given the ANZECC (2000a) methodology requires at least two years' worth of monthly data. It is recommended that assessment be based on comparing the baseline range of concentrations with those measured during and after mining, for example NO_x ranges between <0.01 and 0.06 mg/L, if concentrations were to become consistently above this range then impacts on water quality can be implicated. Similarly, the occasional spike in TN, TP and reactive phosphorus would be considered background, whereas consistent concentrations above the objective would indicate an impact.

Total Petroleum Hydrocarbons / Total Recoverable Hydrocarbons (TPH/TRH) were analysed for all carbon fractions between C_6 and C_{40}, and also Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene (BTEXN) at all sites during all monitoring rounds. Results are provided in Appendix C.

All concentrations were below detection limits except for one isolated instance at site BPUS SW1 in April 2017, where concentrations of TPH C_{10}-C_{14} and C_{15}-C_{28} (TRH >C_{10}-C_{16} and >C_{16}-C_{34}) up to 1450 µg/L were detected. The cause is unknown. The samples were rerun by the laboratory using the silica-gel clean-up method, which removes any naturally occurring organic material such as algae that might give a false reading unrelated to petrochemical hydrocarbons. The silica-gel clean-up results were no different to the original results, therefore the concentrations are from fuel or oil contamination. No evidence of a hydrocarbon spill, or sheen or odours were observed during sampling. The site is remote and there are no known current activities or sources in the catchment. Possibly it came from a small fuel spill by unknown people fishing or hunting in the area. No further hydrocarbon detections occurred at this site during the subsequent three monitoring rounds.

6.3 Baseline surface water quality summary and potential impacts

6.3.1 Mine footprint sites

When flowing, water quality of the ephemeral drainage lines upstream and downstream of the mine footprint is very fresh, with low EC concentrations generally less than 15 µS/cm, and always well below the water quality objective of 200 µS/cm.

Natural background pH varies widely between 5.41 and 8.14, and is often above or below the objective range. Similarly, DO varies widely, but remains within the objective range of 60 to 100%, with a median DO of 80%saturation. There is no apparent seasonal pattern or trend in the widely varying pH and DO readings. This is because these parameters are highly changeable depending on sunlight levels, the time of day, rainfall, streamflow, and aquatic plant biomass. Variability over the short term is far larger than any seasonal variability. Additionally, in regards to pH, total alkalinity measured at all sites is very low (<2 mg/L), which means the water has little buffering capacity to neutralise acids and stabilise pH.

Low DO levels below 60% can occur during low flow conditions as the stream dries up in the absence of rainfall and fresh oxygenated run-off, and the high oxygen demand placed on the remaining small volume of water from organic matter breakdown combined with plant respiration.

Turbidity levels are generally always low, even during high rainfall periods; remaining below 12 NTU and well below the water quality objective of 20 NTU.

All dissolved metal concentrations are below laboratory detection limits, and as such, below the water quality objectives for arsenic, cadmium, chromium, copper, lead, nickel, selenium, zinc, tin and mercury. Aluminium is above the water quality objective most of the time, with concentrations up to 0.08 mg/L. All lithium concentrations remain below 0.002 mg/L, and iron concentrations below 0.1 mg/L. There are no water quality objectives defined for lithium and iron.

NO_x concentrations (made up of 100% nitrate) are generally always above the water quality objective; often up to 0.06 mg/L. Whereas TN, TP and reactive phosphorus are generally always below the water quality objective with the exception of some isolated TN and reactive phosphorus spikes. Note that for the first two monitoring rounds the laboratory limit of reporting (LOR) was higher than the water quality objective for reactive phosphorus, and as such, unless the concentration was above the LOR, it could not be determined whether the objective was exceeded or not. This was rectified in subsequent monitoring rounds, confirming that most of the time reactive phosphorus remains below the objective.

TPH/TRH and BTEXN concentrations are always below detection limits.

Potential impacts

In regards to potential impacts during mining, the following is highlighted:

- EC, turbidity and dissolved metals (except aluminium) are very low and well below their respective water quality objectives. Sediment and erosion controls across the site must be highly effective, and the release of stormwater from the sediment dams, and release of water from MWD1, must ensure EC, turbidity and dissolved metals are not increased above the water quality objectives at surface water monitoring sites downstream.
- For lithium and iron, which don't have water quality objectives, downstream levels must remain below the natural background range; i.e. less than 0.002 mg/L and 0.1 mg/L respectively.
- pH and DO are naturally highly variable and it will be difficult to distinguish impacts on these parameters from the mine unless pH becomes consistently more acidic (less than 5.4) or highly alkaline (greater than 8.1), or DO becomes consistently above or below the objective range; noting that DO can become naturally low during low flow conditions.

- TPH/TRH and BTEXN concentrations are always below detection limits and must remain so during mining operations.
- The consistent pre-existing baseline exceedances of the water quality objectives for aluminium and NO_x, and occasional spikes in TN and reactive phosphorus, must be taken into consideration. The ANZECC (2000a) Guidelines recommend under these circumstances to calculate site-specific trigger values based on the 80th percentile of baseline (or reference site) data. It is not however possible at this stage to calculate site-specific trigger values given the ANZECC (2000a) methodology requires at least two years' worth of monthly data. It is recommended that assessment be based on comparing the baseline range of concentrations with those measured during and after mining, for example NO_x ranges between <0.01 and 0.06 mg/L, if concentrations were to become consistently above this range then impacts on water quality can be implicated. Similarly, the occasional spike in TN and reactive phosphorus would be considered background, whereas consistent concentrations above the objective would indicate an impact.

6.3.2 Observation Hill Dam and BP33 sites

Water in the Observation Hill Dam, BP33 pit and in the ephemeral drainage line upstream and downstream of the BP33 (also downstream of Observation Hill Dam) is always fresh, with low EC concentrations generally lower than 35 µS/cm, and always well below the water quality objective of 200 µS/cm.

Similarly to the mine footprint sites described above, natural background pH varies widely at all four sites ranging between 5.06 and 9.31 and often outside the objective range. DO also varies widely but remains within the objective range with a median DO of 80%saturation. This is because these parameters are highly changeable depending on sunlight levels, the time of day, rainfall, streamflow, and aquatic plant biomass. Variability over the short term is far larger than any seasonal variability. Additionally, in regards to pH, total alkalinity is low (<8 mg/L) which means the water has little buffering capacity to neutralise acids and stabilise pH. Although notably, anion, cation and alkalinity levels are higher at these sites compared to the mine footprint sites. This is because these sites receive some input from groundwater (see Section 7.2.2).

Low DO levels can occur during low flow conditions due to organic matter breakdown and the absence of fresh oxygenated rainwater inputs.

Turbidity levels are generally always low, even during high rainfall periods; remaining below 9 NTU and well below the water quality objective of 20 NTU.

All cadmium, chromium, copper, lead, nickel, selenium, zinc, tin and mercury concentrations are below laboratory detection limits, and as such, below the water quality objectives. Aluminium is sometimes above the water quality objective at the drainage line sites (BPUS SW1 and BPDS SW2), and always below the water quality objective at the impounded water sites (OHD and BP Historic Pit).

Arsenic is higher at these four sites compared to the mine footprint sites. The drainage line sites and OHD site are above laboratory detection limits (up to 0.002 mg/L) but remain below the water quality objective. The BP33 pit has higher concentrations (0.007 to 0.15 mg/L), with the highest being slightly above the objective. Lithium concentrations for all sites is up to 0.008 mg/L; which is also higher than the mine footprint sites. Likewise in regards to higher anion and cation concentrations compared to the mine footprint sites, the source of arsenic and lithium is from groundwater inflows (see Section 7.2.2).

Iron concentrations are always below the detection limit at the impounded water sites (OHD and BP Historic Pit) and relatively high (up to 0.38 mg/L) at the drainage line sites. The source of this is not known, but possibly from groundwater inputs from the shallow laterite aquifer (see Section 7.2.2).

NO_x concentrations (made up of 100% nitrate) are generally always above the water quality objective; often up to 0.04 mg/L. Whereas TN, TP and reactive phosphorus are generally always below the water quality objective with the exception of some isolated TN, TP and reactive phosphorus spikes.

TPH/TRH and BTEXN concentrations are generally always below detection limits.

Potential impacts

In regards to potential impacts during mining, the following is highlighted:

- Given the only project-related activity in the catchment of these sites will be the extraction of water from Observation Hill Dam, physical (field parameters) and laboratory-measured parameters are not expected to change significantly from baseline levels.
- Any water quality impacts resulting from reduced surface water flows and/or reduced groundwater aquifer recharge from extraction of water from Observation Hill Dam, will likely be very subtle and not detectable over the two to three-year mine life.
- Continuation of water quality monitoring of these sites will provide further background water quality data for the region for comparison with sites downstream of the mine footprint; also background reference data if Core were to extend mining operations to within this catchment e.g. BP33 pit.

Table 6-2. Baseline surface water quality monitoring results, field parameters.

Site	Date Sampled	Field Parameters					
		pH	Temp	ORP	EC	DO	Turbidity
		pH unit	°C	mV	µS/cm	%sat	NTU
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)		6.0-7.5			200	50-100	20
GUS SW3	15-02-17	6.59	28.3	248	18.0	61	3.10
GUS SW3	19-04-17	6.04	26.2	303	11.4	80	0.60
GUS SW3	01-02-18	5.90	28.0	279	11.1	80	2.30
GUS SW3	14-03-18	6.54	25.3	178	10.5	72	1.33
GUS SW3	03-05-18	8.14	26.8	58	15.3	41	12.10
GDS SW1	15-02-17	6.71	28.0	336	14.0	86	4.54
GDS SW1	19-04-17	5.66	26.3	300	13.8	76	2.10
GDS SW1	31-01-18	7.04	35.6	208	13.1	95	2.80
GDS SW1	14-03-18	6.37	29.6	171	11.9	89	5.07
GDS SW2	15-02-17	8.07	26.8	178	51.0	81	2.53
GDS SW2	19-04-17	5.41	26.3	305	12.1	63	0.80
GDS SW2	31-01-18	5.74	30.5	238	10.7	86	1.70
GDS SW2	14-03-18	6.20	29.4	152	9.0	92	1.27
GDS SW2	03-05-18	5.83	27.6	157	13.1	73	2.80
OHD	12-10-17	6.59	31.7	80	19.1	80	3.70
OHD	09-08-18	9.31	26.5	-10	34.7	79	8.90
BP HISTORIC PIT	15-02-17	6.91	31.2	288	23.9	96	3.35
BP HISTORIC PIT	19-04-17	6.65	30.7	272	18.8	98	0.60
BP HISTORIC PIT	12-10-17	7.33	32.3	210	22.6	82	3.18
BP HISTORIC PIT	01-02-18	8.90	29.9	131	26.2	100	8.40
BP HISTORIC PIT	14-03-18	8.27	32.7	159	17.1	69	1.82
BP HISTORIC PIT	03-05-18	7.64	30.8	117	20.7	35	1.94
BP HISTORIC PIT	08-08-18	8.18	26.5	-15	22.1	94	1.90
BPUS SW1	15-02-17	6.46	27.7	324	14.6	84	3.31
BPUS SW1	19-04-17	5.45	27.5	308	18.2	72	2.00
BPUS SW1	01-02-18	7.78	27.6	270	14.0	85	4.60
BPUS SW1	14-03-18	7.24	25.1	173	15.7	73	3.86
BPUS SW1	03-05-18	7.42	26.4	118	26.4	34	4.98
BPDS SW2	15-02-17	5.06	27.9	437	15.3	82	3.16
BPDS SW2	19-04-17	5.49	27.5	306	17.7	70	2.20
BPDS SW2	01-02-18	7.84	28.0	243	16.6	85	5.60
BPDS SW2	14-03-18	7.26	25.0	169	16.6	54	3.68
BPDS SW2	03-05-18	6.67	26.6	145	24.4	41	2.10

Table 6-3. Baseline surface water quality monitoring results, major anions and cations.

Site	Date Sampled	Major Anions							Major Cations			
		Total hardness as $CaCO_3$	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Sulfate as SO_4	Chloride	Calcium	Magnesium	Sodium	Potassium
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
GUS SW3	15-02-17	<1	<1	<1	<1	<1	<1	1	<1	<1	2	<1
GUS SW3	19-04-17	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
GUS SW3	01-02-18	<1	<1	<1	2	2	<1	1	<1	<1	1	<1
GUS SW3	14-03-18	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1
GUS SW3	03-05-18	<1	<1	<1	2	2	<1	<1	<1	<1	1	<1
GDS SW1	15-02-17	<1	<1	<1	<1	<1	<1	2	<1	<1	2	<1
GDS SW1	19-04-17	<1	<1	<1	1	1	<1	2	<1	<1	1	<1
GDS SW1	31-01-18	<1	<1	<1	1	1	<1	2	<1	<1	2	<1
GDS SW1	14-03-18	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1
GDS SW2	15-02-17	<1	<1	<1	2	2	<1	1	<1	<1	2	<1
GDS SW2	19-04-17	<1	<1	<1	2	2	<1	1	<1	<1	1	<1
GDS SW2	31-01-18	<1	<1	<1	1	1	<1	2	<1	<1	1	<1
GDS SW2	14-03-18	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1
GDS SW2	03-05-18	<1	<1	<1	2	2	<1	<1	<1	<1	2	<1
OHD	12-10-17	<1	<2	<3	4	4	<1	3	<1	<1	2	<1
OHD	09-08-18	<1	<1	<1	5	5	<1	2	<1	<1	1	<1
BP HISTORIC PIT	15-02-17	<1	<1	<1	3	3	<1	3	<1	<1	2	<1
BP HISTORIC PIT	19-04-17	<1	<1	<1	4	4	<1	2	<1	<1	2	<1
BP HISTORIC PIT	12-10-17	<1	<1	<1	8	8	<1	3	<1	<1	3	<1
BP HISTORIC PIT	01-02-18	<1	<1	<1	6	6	<1	2	<1	<1	2	<1
BP HISTORIC PIT	14-03-18	<1	<1	<1	5	5	<1	<1	<1	<1	2	<1
BP HISTORIC PIT	03-05-18	<1	<1	<1	6	6	<1	1	<1	<1	2	<1
BP HISTORIC PIT	08-08-18	<1	<1	<1	4	4	<1	2	<1	<1	2	<1
BPUS SW1	15-02-17	<1	<1	<1	2	2	<1	1	<1	<1	2	<1
BPUS SW1	19-04-17	<1	<1	<1	2	2	<1	2	<1	<1	2	<1
BPUS SW1	01-02-18	<1	<1	<1	2	2	<1	1	<1	<1	1	<1
BPUS SW1	14-03-18	<1	<1	<1	4	4	<1	<1	<1	<1	1	<1
BPUS SW1	03-05-18	<1	<1	<1	5	5	<1	3	<1	<1	2	<1
BPDS SW2	15-02-17	<1	<1	<1	2	2	<1	1	<1	<1	2	<1
BPDS SW2	19-04-17	<1	<1	<1	2	2	<1	2	<1	<1	2	<1
BPDS SW2	01-02-18	<1	<1	<1	2	2	<1	2	<1	<1	1	<1
BPDS SW2	14-03-18	<1	<1	<1	4	4	<1	<1	<1	<1	2	<1
BPDS SW2	03-05-18	<1	<1	<1	4	4	<1	3	<1	<1	2	<1

Table 6-4. Baseline surface water quality monitoring results, dissolved metals.

Site	Date Sampled	Dissolved Metals												
		Aluminium	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Zinc	Lithium	Iron	Tin	Mercury
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)		pH >6.5 0.055 pH <6.5 0.0008	0.013	0.0002	0.004	0.0014	0.0034	0.011	0.011	0.008				0.0006
GUS SW3	15-02-17	0.07	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	<0.05	<0.001	<0.0001
GUS SW3	19-04-17	0.02	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	<0.05	<0.001	<0.0001
GUS SW3	01-02-18	0.07	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.001	0.05	<0.001	<0.0001
GUS SW3	14-03-18	0.02	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	<0.001	<0.05	<0.001	<0.0001
GUS SW3	03-05-18	0.01	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.001	<0.05	<0.001	<0.0001
GDS SW1	15-02-17	0.08	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.08	<0.001	<0.0001
GDS SW1	19-04-17	0.04	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.05	<0.001	<0.0001
GDS SW1	31-01-18	0.08	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.002	0.10	<0.001	<0.0001
GDS SW1	14-03-18	0.08	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	<0.001	0.06	<0.001	<0.0001
GDS SW2	15-02-17	0.05	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.05	<0.001	<0.0001
GDS SW2	19-04-17	0.02	<0.001	<0.0001	<0.001	0.001	<0.001	<0.001	<0.01	<0.005	-	0.06	<0.001	<0.0001
GDS SW2	31-01-18	0.04	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.001	<0.05	<0.001	<0.0001
GDS SW2	14-03-18	0.02	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	<0.001	0.06	<0.001	<0.0001
GDS SW2	03-05-18	<0.01	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	<0.001	<0.05	<0.001	<0.0001
OHD	12-10-17	<0.01	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	<0.001	<0.05	<0.001	<0.0001
OHD	09-08-18	<0.01	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.001	0.06	<0.001	<0.0001
BP HISTORIC PIT	15-02-17	0.02	0.008	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	<0.05	<0.001	<0.0001
BP HISTORIC PIT	19-04-17	<0.01	0.007	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	<0.05	<0.001	<0.0001
BP HISTORIC PIT	12-10-17	<0.01	0.015	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.006	<0.05	<0.001	<0.0001
BP HISTORIC PIT	01-02-18	0.05	0.006	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.006	<0.05	<0.001	<0.0001
BP HISTORIC PIT	14-03-18	0.01	0.007	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.006	<0.05	<0.001	<0.0001
BP HISTORIC PIT	03-05-18	<0.01	0.010	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.008	<0.05	<0.001	<0.0001
BP HISTORIC PIT	08-08-18	<0.01	0.008	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.008	<0.05	<0.001	<0.0001
BPUS SW1	15-02-17	0.04	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.17	<0.001	<0.0001
BPUS SW1	19-04-17	0.01	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.09	<0.001	<0.0001
BPUS SW1	01-02-18	0.04	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.002	0.09	<0.001	<0.0001
BPUS SW1	14-03-18	0.02	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.003	0.06	<0.001	<0.0001
BPUS SW1	03-05-18	0.02	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.007	0.25	<0.001	<0.0001
BPDS SW2	15-02-17	0.03	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.16	<0.001	<0.0001
BPDS SW2	19-04-17	0.02	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	-	0.10	<0.001	<0.0001
BPDS SW2	01-02-18	0.04	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.002	0.07	<0.001	<0.0001
BPDS SW2	14-03-18	0.01	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.003	0.06	<0.001	<0.0001
BPDS SW2	03-05-18	0.02	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.006	0.38	<0.001	<0.0001

Table 6-5. Baseline surface water quality monitoring results, nutrients.

Note laboratory limit of reporting (LOR) for NO_x and reactive phosphorus is sometimes greater than water quality objective. As such, unless concentration is above LOR, it is not known if objective is exceeded.

Site	Date Sampled	Nutrients							
		Ammonia as N	Nitrite as N	Nitrate as N	Nitrite + Nitrate as N	TKN as N	Total Nitrogen as N	Total Phosphorus as P	Reactive Phosphorus as P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)					0.008		0.23	0.01	0.005
GUS SW3	15-02-17	0.11	<0.01	0.04	0.04	0.8	0.8	0.01	<0.01
GUS SW3	19-04-17	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
GUS SW3	01-02-18	<0.01	<0.01	0.02	0.02	0.2	0.2	<0.01	0.006
GUS SW3	14-03-18	0.05	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.001
GUS SW3	03-05-18	0.08	<0.01	0.03	0.03	0.4	0.4	<0.01	<0.001
GDS SW1	15-02-17	0.06	<0.01	0.06	0.06	0.1	0.2	<0.01	<0.01
GDS SW1	19-04-17	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
GDS SW1	31-01-18	0.08	<0.01	0.02	0.02	0.2	0.2	<0.01	0.003
GDS SW1	14-03-18	<0.01	<0.01	<0.01	<0.01	0.2	0.2	<0.01	0.003
GDS SW2	15-02-17	0.05	<0.01	0.03	0.03	<0.1	<0.1	<0.01	<0.01
GDS SW2	19-04-17	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
GDS SW2	31-01-18	0.12	<0.01	0.06	0.06	0.2	0.3	<0.01	0.004
GDS SW2	14-03-18	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.001
GDS SW2	03-05-18	0.01	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.001
OHD	12-10-17	0.03	<0.01	0.03	0.03	0.2	0.2	<0.01	<0.01
OHD	09-08-18	0.01	<0.01	<0.01	<0.01	0.3	0.3	<0.01	0.002
BP HISTORIC PIT	15-02-17	0.08	<0.01	0.02	0.02	<0.1	<0.1	<0.01	<0.01
BP HISTORIC PIT	19-04-17	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
BP HISTORIC PIT	12-10-17	<0.01	<0.01	0.03	0.03	0.2	0.2	<0.01	<0.01
BP HISTORIC PIT	01-02-18	<0.01	<0.01	0.03	0.03	0.1	0.1	<0.01	0.006
BP HISTORIC PIT	14-03-18	0.06	<0.01	<0.01	<0.01	0.2	0.2	<0.01	<0.001
BP HISTORIC PIT	03-05-18	<0.01	<0.01	0.01	0.01	0.2	0.2	1.18	<0.001
BP HISTORIC PIT	08-08-18	0.06	<0.01	<0.01	<0.01	0.1	0.1	<0.01	0.002
BPUS SW1	15-02-17	0.04	<0.01	0.04	0.04	0.1	0.1	<0.01	<0.01
BPUS SW1	19-04-17	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
BPUS SW1	01-02-18	<0.01	<0.01	0.02	0.02	0.2	0.2	0.72	0.003
BPUS SW1	14-03-18	0.07	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.001
BPUS SW1	03-05-18	0.12	<0.01	0.03	0.03	0.2	0.2	<0.01	<0.001
BPDS SW2	15-02-17	0.12	<0.01	0.03	0.03	0.2	0.2	<0.01	<0.01
BPDS SW2	19-04-17	0.06	<0.01	<0.01	<0.01	<0.1	<0.1	0.02	<0.01
BPDS SW2	01-02-18	<0.01	<0.01	0.02	0.02	0.1	0.1	<0.01	0.004
BPDS SW2	14-03-18	<0.01	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.001
BPDS SW2	03-05-18	0.02	<0.01	0.03	0.03	0.2	0.2	<0.01	<0.001

7 BASELINE GROUNDWATER QUALITY

7.1 Baseline groundwater quality monitoring

7.1.1 Monitoring bores

The context of the six monitoring bores installed on site in and around the proposed mine pit were outlined in Section 3.3.1. Bore locations are shown in Figure 3-4 and bore details provided in Table 3-2. Monitoring of water quality was undertaken in Bore GWB06, however results clearly show this bore is contaminated with cement and not suitable for including in the groundwater quality analysis. This bore can only be used for SWL measurements.

7.1.2 Monitoring undertaken

Sampling was undertaken between June 2017 and August 2018 as outlined in Table 7-1 below. All six bores were sampled each monitoring round. The first round in June 2017 was undertaken by GHD (2017b) around two to three weeks after the bores were installed. All subsequent monitoring rounds were undertaken by EcOz.

Table 7-1. Baseline groundwater quality monitoring undertaken.

Date	Season
27 June 2017	Early Dry
31 Jan / 1 Feb 2018	Mid Wet
1 May 2018	Late Wet
8/9 August 2018	Mid Dry

Rainfall over the 2017/18 Wet season was above average, and groundwater levels in all bores except the deepest bore GWB01 were within 1 m of the ground surface in January and February 2018. At times, after intense rainfall periods, bores GWB03, GWB06, GWB07 and GWB10 were artesian i.e. would have been flowing if not for the bore casing above ground level. Especially after the intense rainfall period that occurred in January 2018, when total monthly rainfall in the project region was over 900 mm, which is more than double the average January monthly total (based on data from nearest BoM stations; listed in Section 3.1 above).

7.2 Baseline groundwater quality results

Water quality results are compared to the *Water Quality Objectives for the Darwin Harbour Region* (NRETAS 2010). These objectives aim to protect the beneficial uses identified for waterways in the Darwin Harbour region as outlined in Section 3.2.3 above. The specific objectives relating to the beneficial use of environment (aquatic ecosystems) are applied given these are the most conservative, and adherence to these would in most cases also protect the other beneficial uses of cultural (aesthetic, recreational and cultural), agriculture and rural stock and domestic water supply.

The NRETAS (2010) water quality objectives developed specifically for “freshwater rivers and streams” are used. These are the most appropriate given the project includes provision to discharge water dewatered from the pit (comprising groundwater inflows and direct rainfall) during the Wet season when this water will be in excess to that required for ore-processing and dust suppression. The water will be discharged into a natural drainage line adjacent to the mine.

Table 7-2 presents the field parameter results, and Table 7-3, Table 7-4 and Table 7-5 present the laboratory results.

Groundwater quality in the four bores installed in the weathered and un-weathered BCF aquifer (i.e. GWB01, GWB03, GWB07 and GWB08) is distinctly different to that of the bore installed in the shallow laterite surface aquifer (i.e. GWB10). Results for field parameters and laboratory parameters are discussed separately for each of the two different aquifers.

7.2.1 Field parameters

Field parameters measured in the weathered and un-weathered BCF aquifer show the groundwater:

- Is moderately fresh, with relatively low EC concentrations for groundwater ranging between 137 and 281 μS/cm. In relation to the surface water quality objectives however, all concentrations measured in the deep mine pit bore (GWB01) were above the objective (200 μS/cm), and most concentrations in GBW03 were above the objective. Concentrations in GWB07 varied with the first two sampling rounds above the objective in June 2017 and February 2018, and the final two sampling rounds in May and August 2018, below the objective. GWB08 was always below the objective. Notably, GWB08 is screened within the weathered BCF, whereas the others are in the fresh BCF. EC concentrations appear to increase with depth into the aquifer away from the weathered zone.
- Has a relatively neutral pH ranging between 6.41 and 7.52, and remaining within the water quality objective range, except for one slightly high pH of 7.52 in GWB01.
- As expected for water that has been out of contact with the atmosphere for a period of time, DO was always low and oxidation reduction potential (ORP) always reduced (i.e. negative).

Field parameters measured in the laterite surface aquifer (GWB10) show the groundwater:

- Largely reflects the water chemistry expected of rainwater and stream water showing this aquifer is closely connected to surface water.
- EC is low (all below 26 μS/cm) and reflective of the surface water and well within the water quality objective.
- pH is relatively acidic and below the water quality objective range. This pH is reflective of rainwater, which is naturally acidic in the warm tropical Darwin region, where carbon dioxide in the air readily dissolves in rainwater forming carbonic acid. Notably, pH increases (becomes less acidic) in the absence of rainfall (August 2018 sampling round). The pH of water in the soil can also be lowered through carbon dioxide from respiration by plants and soil organisms, and from the breakdown of organic matter.
- DO is higher than that of the deeper BCF aquifer and more oxidised (positive ORP) indicating the water has more recently been in contact with the atmosphere i.e. aquifer is readily recharged with surface water.

7.2.2 Laboratory parameters

Major anion and cations measured in the weathered and un-weathered BCF aquifer show the groundwater:

- Has moderate alkalinity (comprising 100% bicarbonate alkalinity) with concentrations increasing with depth into the aquifer i.e. GWB01 has higher concentrations (between 97 and 143 mg/L) than the shallower bores GWB03, GWB07 and GWB08 (between 67 and 107 mg/L).
- Hardness is relatively low in all bores; all less than 42 mg/L, which is considered “soft”, and low in dissolved ions such as calcium and magnesium.

Major anion and cations measured in the laterite surface aquifer (GWB10) show the groundwater:

- Has negligible alkalinity, hardness and dissolved major cations; similar to those measured in the surface water around the mine footprint (see Section 6.2.2).

Dissolved metal concentrations measured in the weathered and un-weathered BCF aquifer show the groundwater:

- Has very low metal concentrations below laboratory detection limits for all metals except aluminium, arsenic, zinc, lithium and iron (which are discussed below). Nickel levels were mostly very low and below the detection limit, and always well below the objective.
- Aluminium concentrations are below the water quality objective except for three instances where it was slightly above the objective; all of which occurred during the first monitoring round (June 2017). All subsequent rounds, the aluminium concentrations were below the objective, and this metal is considered in low concentrations in the BCF aquifer.
- Arsenic concentrations are above the water quality objective in all bores, with the highest concentrations in bore GWB07; ranging between 0.131 to 0.290 mg/L. The median concentration for all four bores is 0.060 mg/L, which is more than 4.5 times higher than the water quality objective (0.013 mg/L). Also, if the *Australian Drinking Water Quality Guidelines* (NHMRC 2011) are considered, these levels are more than 6 times the guideline limit (0.01 mg/L).

  Arsenic concentrations in groundwater of the Darwin region were investigated by Karp (2008). The resulting map from this study shows areas of low, medium and high risk of bores producing water with arsenic concentrations above the drinking water guideline. The BCF aquifer as mapped as "high" risk. It is concluded that arsenic present in minerals of the BCF in the project area are being mobilised into the groundwater through natural processes such as oxidation, weathering reactions, and/or biological activity. Significantly, given arsenic levels in surface water sampling undertaken around the mine footprint were all below detection limits (see Section 6.2.2), these drainage lines must receive very little groundwater inflows. Conversely for the drainage lines downstream of OHD, it appears that groundwater inflows do contribute to stream flows, and arsenic is detectable up to concentrations of 0.002 mg/L.
- Zinc was slightly elevated above the objective in GWB08 during the January 2018 sampling round (0.010 mg/L). All other monitoring rounds this bore was below the 0.008 mg/L objective. Also, given zinc levels in all other bores during almost all other monitoring rounds was below detection, zinc is not considered elevated in the BCF aquifer. The zinc detection in GWB08 may be from the percolation of water down from the surface laterite aquifer, given zinc is elevated in the shallow laterite aquifer bore GWB10, which is co-located (nested) with GWB08.
- Lithium has no water quality objective. As expected, concentrations were highest in the deep mine pit bore (GWB01), where the lithium-bearing mineral spodumene is present. Levels ranged up to 1.730 mg/L. GWB08 had the next highest concentrations, ranging up to 0.279 mg/L, followed by GWB03 (up to 0.189 mg/L). Levels in the BCF aquifer are certainly elevated compared to areas without lithium-bearing mineralisation, and also compared to the surface water in the mine site area, which is below 0.002 mg/L (further evidence the BCF aquifer is not contributing significant groundwater inflows to the drainage lines around the mine site; see arsenic discussion above). Similarly to arsenic, groundwater is contributing to detections of lithium up to 0.007 mg/L in the drainage lines downstream of OHD (see Section 6.2.2).
- Iron has no water quality objective. Concentrations were a lot higher in GWB08 (up to 0.77 mg/L) compared to the other three bores (up to 0.33 mg/L). This is higher than the surface water levels, which were up to 0.10 mg/L. GWB08 is screened within the weathered BCF, whereas the other three bores are screened within the fresh BCF. Possibly, these higher dissolved iron concentrations are associated with the weathered zone. Notably, the iron concentrations are similar to those in the highly weathered laterite surface aquifer (GWB10).

Dissolved metal concentrations measured in the laterite surface aquifer (GWB10) show the groundwater:

- Has higher concentrations than the BCF aquifer for copper, lead, and zinc (discussed further below), and lower concentrations for arsenic and lithium (largely remaining below the objective for arsenic).

Aluminium levels are comparable to the BCF aquifer however, exceed the objective more frequently because of the lower pH. Iron levels are comparable to the weathered zone BCF aquifer and above levels measured in the surface water around the mine footprint.

- Similarly, to the BCF aquifer, all other metal concentrations are below detection limits (i.e. cadmium, chromium, selenium, tin and mercury). Nickel levels are mostly very low and always below the objective.
- Copper and zinc concentrations are always above the respective water quality objective, and significantly higher than both the BCF aquifer and surface water, which are mostly below detection limits. Lead was above the objective on one occasion. Concentrations of copper, lead and zinc appear to increase in the absence of rainfall, with the Dry season concentrations higher than the Wet season concentrations.
- The higher copper, lead, and zinc levels in GWB10 compared to the bores in the BCF aquifer is possibly related to the weathered laterite host rock. It is not possible however, to determine the reason without more data collected from other bores screened in this same aquifer. Iron and zinc certainly appear to be associated with the weathered rock, given GWB08 also has some elevated concentrations. It is possible the elevated copper and lead concentrations (and a proportion of the zinc concentrations) are associated with poor bore construction.

Nutrient concentrations in the BCF aquifer are:

- Above the water quality objective for NO_x (made up of 100% nitrate) at least 50% of the time; typically up to 0.03 mg/L. These levels remain well within the baseline surface water range of NO_x concentrations (see Section 6.2.2), which are frequently up to 0.03 mg/L, and sometimes up to 0.06 mg/L.
- Always below the water quality objective for TN except for one isolated spike in GWB03.
- Always above the water quality objective for TP and reactive phosphorus and also well above levels measured in surface waters, which are predominantly below the objectives. Concentrations are particularly high in bores GWB07 and GWB08 (ranging between 0.32 and 0.50 mg/L for TP, and 0.269 and 0.78 mg/L for reactive phosphorus). GWB01 had the lowest concentrations; less than 0.15 mg/L for TP, and less than 0.105 mg/L for reactive phosphorus; but still significantly above the objective. The high phosphorus concentrations appear associated with the mineralogy of the BCF; in particular, that of the more weathered zones; reducing in concentration with depth.

Nutrient concentrations in the laterite surface aquifer (GWB10) are:

- Predominantly below the water quality objective for TN, and generally above the water quality objective for NO_x (made up of 100% nitrate) with an unexplained spike in concentration (0.21 mg/L) during the August 2018 monitoring round. Disregarding this spike, levels remain within the baseline surface water range of NO_x concentrations. More data is required from this bore (and other bores to be installed in this shallow aquifer) to determine the pattern of NO_x and TN concentrations.
- Generally above the objective for TP and reactive phosphorus, and above the baseline surface water concentrations; although much lower than in the BCF aquifer, presumably from the oxidation and precipitation of phosphorus on reaction with iron and aluminium in the groundwater.

All TPH/TRH and BTEXN concentrations measured in all bores are below detection limits. Results are provided in Appendix C.

7.3 Baseline groundwater quality summary and potential impacts

7.3.1 BCF aquifer

The BCF aquifer is moderately fresh, with EC concentrations ranging between 137 and 281 μS/cm. In relation to the water quality objective applying to surface water however (200 μS/cm), this EC range extends above the objective. Groundwater from the deeper fresh BCF has higher EC usually above the objective, whereas groundwater from the shallower weathered BCF zone has lower EC below the objective.

Groundwater pH is generally close to neutral ranging between 6.41 and 7.52 and remaining within the water quality objective range.

As expected for water that has been out of contact with the atmosphere for a period, DO is low and oxidation reduction potential (ORP) always reduced (i.e. negative). DO would increase rapidity to within the objective range when exposed to the atmosphere in the pit and pumped to the holding dam. Likewise, ORP would become positive.

Bicarbonate alkalinity is moderate, with concentrations increasing with depth into the aquifer i.e. deeper groundwater below 88 m is between 97 and 143 mg/L, and shallower groundwater between 67 and 107 mg/L.

Hardness is relatively low throughout the BCF aquifer (less than 42 mg/L), which is considered “soft”, and low in dissolved ions such as calcium and magnesium.

Dissolved metal concentrations are below laboratory detection limits for all metals except aluminium, arsenic, zinc, lithium and iron. Nickel levels were mostly very low and below the detection limit, and always well below the objective. Similarly, aluminium and zinc concentrations are predominantly below the water quality objective and not considered elevated in the BCF aquifer.

Lithium has no water quality objective. In relative terms, lithium concentrations are much higher in the BCF aquifer compared to surface water concentrations around the mine footprint. Levels in groundwater are up to 1.730 mg/L, recorded in the mine pit bore, whereas surface waters are below 0.002 mg/L.

Iron has no water quality objective. Concentrations are up to 0.77 mg/L in the weathered BCF compared to up to 0.33 mg/L in the fresh BCF; both of which are significantly higher than surface water levels around the mine footprint (up to 0.10 mg/L).

Arsenic concentrations in the BCF aquifer are significantly elevated above the water quality objective. The median concentration for all four bores is 0.060 mg/L, which is more than 4.5 times higher than the water quality objective (0.013 mg/L). If the *Australian Drinking Water Quality Guidelines* (NHMRC 2011) are considered, these levels are more than 6 times the guideline limit (0.01 mg/L). The BCF aquifer is a known “high” risk aquifer for arsenic (see Karp 2008). The arsenic is from minerals of the BCF being mobilised into the groundwater through natural processes such as oxidation, weathering reactions, and/or biological activity.

TN concentrations in the BCF aquifer are predominantly below the water quality objective. NO_x concentrations (made up of 100% nitrate) are above the water quality objective most of the time however, levels remain well within the baseline surface water range of NO_x concentrations. In contrast, TP and reactive phosphorus concentrations are always above the respective water quality objective, and also well above levels measured in surface waters, which are predominantly below the objectives. The high phosphorus concentrations appear associated with the mineralogy of the BCF; in particular, that of the more weathered zones; reducing in concentration with depth.

TPH/TRH and BTEXN concentrations are always below detection limits.

Potential impacts

In regards to potential impacts during mining, the following is highlighted:

- EC, TP, reactive phosphorus, and arsenic are elevated in the BCF aquifer above the water quality objectives, and above the baseline surface water quality of the mine footprint area. Release of water from MWD1 (which contains a proportion of groundwater dewatered from the mine pit), must ensure the

concentration of these parameters is not increased above the water quality objectives at surface water monitoring sites downstream.

- Lithium and iron, which don't have water quality objectives, are also elevated in the BCF aquifer compared to the natural background surface water levels at the mine footprint site. Release of water from MWD1 must ensure the concentration of these parameters in downstream surface water monitoring sites is not increased above the natural background range; i.e. above 0.002 mg/L for lithium and 0.1 mg/L for iron.
- All other metals aluminium, cadmium, chromium, copper, lead, nickel, selenium, tin, zinc, mercury are below the water quality objectives and do not pose a hazard to surface waters.
- pH in the BCF aquifer is close to neutral and does not pose a hazard to surface waters. Similarly, DO levels are low in the groundwater but will increase rapidly with exposure to the atmosphere and pumping from the pit prior to any release to surface waters.
- TPH/TRH and BTEXN concentrations in groundwater are always below detection limits and must remain so during mining operations i.e. no contamination of the groundwater aquifer from hydrocarbon spills or leaks on site.
- TN concentrations are mostly below the objective, and NO_x concentrations are within the same range as that of that baseline surface water of the mine footprint and do not pose a hazard if released to surface waters.

7.3.2 Laterite surface aquifer

Water quality of the shallow laterite aquifer largely reflects the water chemistry expected of rainwater and stream water, showing this aquifer is closely connected to surface water. EC is low (below 26 μS/cm), and pH is relatively acidic and reflective of rainwater, which is naturally acidic in the tropical Darwin region.

DO and ORP are higher than in the BCF aquifer; and indicative of an aquifer recently recharged with fresh oxygenated rainwater. Further, the negligible alkalinity, hardness and dissolved major cation concentrations in this aquifer are similar to that measured in the surface water around the mine footprint.

The laterite surface aquifer has higher concentrations of copper, lead and zinc than the BCF aquifer, and lower concentrations of arsenic and lithium (largely remaining below the objective for arsenic). Aluminium levels are comparable to the BCF aquifer however, exceed the objective more frequently because of the lower pH. Iron levels are comparable to the weathered zone BCF aquifer and higher than in the surface water around the mine footprint.

Similarly, to the BCF aquifer, all other metal concentrations are below detection limits (i.e. cadmium, chromium, selenium, tin and mercury). Nickel levels are mostly very low and always below the objective.

Copper and zinc concentrations are always above the respective water quality objective, and significantly higher than in both the BCF aquifer and surface water, which are mostly below detection limits. Lead was above the objective on one occasion.

The higher copper, lead, and zinc levels in GWB10 compared to the bores in the BCF aquifer is possibly related to the weathered laterite host rock. It is not possible to determine the reason without more data collected from other bores screened in this same aquifer. It is possible the elevated copper and lead concentrations (and a proportion of the zinc concentrations) are associated with poor bore construction.

TN concentrations are predominantly below the water quality objective, and NO_x, concentrations are generally above the water quality objective but within the baseline surface water range of NO_x concentrations. More data is required from this bore (and other bores to be installed in this shallow aquifer) to determine the pattern of NO_x and TN concentrations.

TP and reactive phosphorus concentrations are generally above the water quality objectives and also above the baseline surface water concentrations; although much lower than in the BCF aquifer, presumably from the oxidation and precipitation of phosphorus on reaction with iron and aluminium in the groundwater.

TPH/TRH and BTEXN concentrations are always below detection limits.

Potential impacts

In regards to potential impacts during mining, the following is highlighted:

- Copper, zinc, lead, TP, and reactive phosphorus are elevated in the laterite aquifer above the water quality objectives, and above the baseline surface water quality of the mine footprint area. Release of water from MWD1 (which contains a proportion of groundwater dewatered from the mine pit), must ensure the concentration of these parameters is not increased above the water quality objectives at surface water monitoring sites downstream.
- Lithium and iron, which don't have water quality objectives, are elevated (albeit to a lesser extent than the BCF aquifer) compared to the natural background surface water levels at the mine footprint site. Release of water from MWD1 must ensure the concentration of these parameters in downstream surface water monitoring sites is not increased above the natural background range; i.e. above 0.002 mg/L for lithium and 0.1 mg/L for iron.
- All other metals aluminium, cadmium, chromium, nickel, selenium, tin, zinc, mercury are below the water quality objectives or within the range of natural surface water background levels and do not pose a hazard to surface waters.
- pH in the laterite aquifer is relatively acidic but no more so than the natural acidity of rainwater in the Darwin region. DO levels are relatively low but will increase rapidly with exposure to the atmosphere and pumping from the pit prior to any release to surface waters.
- TPH/TRH and BTEXN concentrations in groundwater are always below detection limits and must remain so during mining operations i.e. no contamination of the groundwater aquifer from hydrocarbon spills or leaks on site.
- TN concentrations are mostly below the objective, and NO_x concentrations are within the same range as that of that baseline surface water of the mine footprint and do not pose a hazard if released to surface waters.

Table 7-2. Baseline groundwater quality monitoring results, field parameters.

Site	Date Sampled	Field Parameters								
		SWL	pH	Temp	ORP	EC	TDS	Salinity	DO	Turbidity
		mBGL	pH unit	°C	mV	µS/cm	mg/L	ppt	%sat	NTU
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)			6.0-7.5			200				
GWB01	27-06-17	4.49	6.80	30.0	-64.0	255.0	156.0	-	24	-
GWB01	31-01-18	1.97	7.14	31.5	-53.4	247.4	160.4	0.12	2	4.6
GWB01	01-05-18	3.26	7.23	31.4	-133.8	280.7	162.5	0.12	2	15.0
GWB01	08-08-18	6.50	7.52	31.4	-167.9	236.5	153.7	0.11	4	11.1
GWB03	27-06-17	2.16	6.60	28.0	-109.0	238.0	146.0	-	2	-
GWB03	01-02-18	0.30	6.77	30.8	-39.1	225.1	146.3	0.10	2	0.9
GWB03	01-05-18	-0.54	6.96	31.4	-27.0	250.0	144.0	0.10	23	21.0
GWB03	09-08-18	4.06	7.42	30.2	-102.0	185.9	120.9	0.09	27	2.7
GWB07	27-06-17	3.64	6.80	28.0	-144.0	213.0	186.0	-	2	-
GWB07	01-02-18	-0.81	6.72	30.9	-56.5	204.8	133.4	0.10	2	12.3
GWB07	01-05-18	1.88	6.74	31.5	-48.8	168.0	96.9	0.07	12	65.0
GWB07	09-08-18	4.79	7.32	30.3	-89.1	137.0	88.9	0.06	13	6.5
GWB08	27-06-17	3.00	6.50	29.0	-140.0	187.0	130.0	-	4	-
GWB08	31-01-18	0.68	6.41	31.3	-6.5	172.0	111.0	0.08	2	1.2
GWB08	01-05-18	1.57	6.57	32.2	-4.3	188.7	107.9	0.08	29	18.0
GWB08	08-08-18	3.97	7.23	31.3	-97.7	142.5	92.6	0.07	4	2.8
GWB10	27-06-17	1.99	4.60	31.0	1.6	37.0	72.0	-	38	-
GWB10	31-01-18	-0.20	4.97	31.0	254.6	21.3	13.8	0.01	57	5.6
GWB10	01-05-18	1.02	5.16	33.2	148.1	25.2	14.3	0.01	13	45.0
GWB10	08-08-18	2.72	6.39	33.9	62.5	26.2	15.1	0.01	35	195.0

Table 7-3. Baseline groundwater quality monitoring results, major anions and cations.

Site	Date Sampled	Major Anions							Major Cations			
		Total hardness as $CaCO_3$	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Sulfate as SO_4	Chloride	Calcium	Magnesium	Sodium	Potassium
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
GWB01	27-06-17	-	<1	<1	97	97	2	3	7	2	34	2
GWB01	31-01-18	31	<1	<1	126	126	2	4	9	2	36	2
GWB01	01-05-18	28	<1	<1	143	143	<1	3	8	2	36	2
GWB01	08-08-18	37	<1	<1	126	126	<1	3	10	3	34	2
GWB03	27-06-17	-	<1	<1	91	91	<1	6	8	6	26	4
GWB03	01-02-18	38	<1	<1	105	105	<1	5	7	5	25	4
GWB03	01-05-18	42	<1	<1	107	107	<1	5	7	6	27	4
GWB03	09-08-18	36	<1	<1	92	92	<1	5	6	5	25	4
GWB07	27-06-17	-	<1	<1	70	70	8	8	4	1	33	3
GWB07	01-02-18	16	<1	<1	88	88	<1	7	3	2	34	2
GWB07	01-05-18	9	<1	<1	67	67	<1	5	2	1	26	3
GWB07	09-08-18	9	<1	<1	68	68	<1	6	2	1	23	2
GWB08	27-06-17	-	<1	<1	74	74	<1	4	7	4	17	3
GWB08	31-01-18	34	<1	<1	79	79	<1	4	7	4	18	3
GWB08	01-05-18	31	<1	<1	80	80	<1	2	6	4	18	3
GWB08	08-08-18	31	<1	<1	72	72	<1	4	6	4	18	3
GWB10	27-06-17	-	<1	<1	6	6	<1	3	<1	<1	4	<1
GWB10	31-01-18	<1	<1	<1	7	7	<1	2	<1	<1	2	<1
GWB10	01-05-18	<1	<1	<1	3	3	<1	2	<1	<1	2	<1
GWB10	08-08-18	2	<1	<1	4	4	<1	2	1	<1	2	<1

Table 7-4. Baseline groundwater quality monitoring results, dissolved metals.

Site	Date Sampled	Dissolved Metals												
		Aluminium	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Zinc	Lithium	Iron	Tin	Mercury
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)		pH >6.5 0.055 pH <6.5 0.0008	0.013	0.0002	0.004	0.0014	0.0034	0.011	0.011	0.008				0.0006
GWB01	27-06-17	0.08	0.069	<0.0001	<0.001	<0.001	<0.001	0.001	<0.01	<0.005	1.730	<0.05	<0.001	<0.0001
GWB01	31-01-18	0.04	0.062	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	1.640	<0.05	<0.001	<0.0001
GWB01	01-05-18	<0.01	0.056	<0.0001	0.001	0.001	<0.001	<0.001	<0.01	<0.005	1.540	0.11	<0.001	<0.0001
GWB01	08-08-18	<0.01	0.067	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	1.680	0.19	<0.001	<0.0001
GWB03	27-06-17	0.08	0.006	<0.0001	<0.001	<0.001	<0.001	0.002	<0.01	0.006	0.189	0.33	<0.001	<0.0001
GWB03	01-02-18	<0.01	0.016	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.153	0.16	<0.001	<0.0001
GWB03	01-05-18	<0.01	0.015	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.166	0.13	<0.001	<0.0001
GWB03	09-08-18	<0.01	0.014	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.145	0.09	<0.001	<0.0001
GWB07	27-06-17	0.06	0.131	<0.0001	<0.001	<0.001	<0.001	0.001	<0.01	<0.005	0.099	0.08	<0.001	<0.0001
GWB07	01-02-18	0.03	0.290	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.076	0.30	<0.001	<0.0001
GWB07	01-05-18	<0.01	0.167	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.080	0.17	<0.001	<0.0001
GWB07	09-08-18	<0.01	0.166	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.063	0.11	<0.001	<0.0001
GWB08	27-06-17	0.01	0.065	<0.0001	<0.001	<0.001	<0.001	0.001	<0.01	<0.005	0.279	0.77	<0.001	<0.0001
GWB08	31-01-18	<0.01	0.067	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	0.010	0.248	0.38	<0.001	<0.0001
GWB08	01-05-18	<0.01	0.059	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.005	0.226	0.44	<0.001	<0.0001
GWB08	08-08-18	<0.01	0.061	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	0.008	0.268	0.43	<0.001	<0.0001
GWB10	27-06-17	0.05	0.005	<0.0001	<0.001	<0.001	<0.001	0.008	<0.01	0.012	0.018	0.47	<0.001	<0.0001
GWB10	31-01-18	0.03	0.016	<0.0001	<0.001	0.002	<0.001	<0.001	<0.01	0.071	0.007	0.38	<0.001	<0.0001
GWB10	01-05-18	<0.01	0.008	<0.0001	<0.001	0.002	<0.001	<0.001	<0.01	0.027	0.003	0.44	<0.001	<0.0001
GWB10	08-08-18	0.13	0.009	<0.0001	<0.001	0.019	0.005	0.002	<0.01	0.099	0.044	0.12	<0.001	<0.0001

Table 7-5. Baseline groundwater quality monitoring results, nutrients.

Note laboratory limit of reporting (LOR) for NO_x is sometimes greater than water quality objective. As such, unless concentration is above LOR, it is not known if objective is exceeded.

Site	Date Sampled	Nutrients							
		Ammonia as N	Nitrite as N	Nitrate as N	Nitrite + Nitrate as N	TKN as N	Total Nitrogen as N	Total Phosphorus as P	Reactive Phosphorus as P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Objectives Darwin Harbour Region (freshwater rivers & streams)					0.008		0.23	0.01	0.005
GWB01	27-06-17	0.02	-	-	0.03	<0.1	<0.1	-	-
GWB01	31-01-18	0.07	<0.01	0.02	0.02	<0.1	<0.1	0.15	0.105
GWB01	01-05-18	0.06	<0.01	<0.01	<0.01	<0.1	<0.1	0.10	0.079
GWB01	08-08-18	0.21	<0.01	<0.01	<0.01	0.2	0.2	0.13	0.087
GWB03	27-06-17	<0.01	-	-	0.02	<0.1	<0.1	-	-
GWB03	01-02-18	0.20	<0.01	0.02	0.02	0.4	0.4	0.24	0.278
GWB03	01-05-18	0.19	<0.01	<0.01	<0.01	0.2	0.2	0.23	0.219
GWB03	09-08-18	0.10	<0.01	<0.01	<0.01	0.2	0.2	0.23	0.277
GWB07	27-06-17	0.01	-	-	0.03	<0.1	<0.1	-	-
GWB07	01-02-18	0.03	<0.01	0.03	0.03	<0.1	<0.1	0.50	0.343
GWB07	01-05-18	0.03	<0.01	0.01	0.01	<0.1	<0.1	0.46	0.378
GWB07	09-08-18	0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.34	0.375
GWB08	27-06-17	<0.01	-	-	<0.01	<0.1	<0.1	-	-
GWB08	31-01-18	0.04	<0.01	0.03	0.03	0.1	0.1	0.37	0.301
GWB08	01-05-18	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	0.37	0.309
GWB08	08-08-18	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	0.32	0.269
GWB10	27-06-17	0.02	-	-	0.03	0.1	0.1	-	-
GWB10	31-01-18	0.17	<0.01	0.06	0.06	0.1	0.2	0.04	0.009
GWB10	01-05-18	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	0.03	0.005
GWB10	08-08-18	0.10	<0.01	0.21	0.21	0.1	0.3	0.08	0.048

7.4 Predicted pit water quality and discharge water quality

The project intends to pump water dewatered from the pit (comprising groundwater inflows and direct rainfall) to MWD1, from where it will be reused in dust suppression and ore processing. There will be no discharge from this dam during the Dry season when volumes dewatered from the pit are lower and dust suppression requirements higher. Discharge will be required during the Wet season months December to March when pit dewatering volumes are highest and dust suppression requirements lowest (Table 2-3). This discharge represents a potential impact to surface water quality depending on the final concentration of parameters in MWD1 compared to existing baseline concentrations in surface water.

Groundwater quality is compared to baseline surface water quality of the drainage lines receiving discharge in Section 0 above, and summarised in Table 7-6. Parameters elevated in the groundwater include EC, arsenic, TP, reactive phosphorus, lithium, and iron. Copper, lead and zinc are elevated in the surface laterite aquifer but not the BCF aquifer.

The final MWD1 water quality will be influenced by the relative proportions of groundwater to rainwater flowing into the pit, and the contribution of direct rainfall into MWD1 (see Table 2-3). Rainwater generally always makes-up more than 50% of the water in MWD1, with the highest dilution occurring during the mid- Wet season (up to 69% in January 2020) and lowest during the early-Dry season (44% in November 2020). Rainwater makes-up a greater proportion of water in MWD1 during the second year of mining compared to the first, this is because groundwater inflows are greatest during the early phase of mining as the weathered BCF has a higher groundwater specific yield and hydraulic conductivity than the underlying fresh BCF and ore (see Section 0). Once the fresh BCF is intersected, pit inflows decline.

Water quality in the inundated BP33 pit may give an indication of groundwater quality into the Grants Project pit, and also water quality of the final pit lake in the years following the end of mining. Water quality measured in the BP33 pit waters during 2017 and 2018 was generally good. ECs were low (less than 26.2 µS/cm), pH was not acidic (lowest pH was 6.65), dissolved metal concentrations were all below the water quality objectives (except for one isolated instance of arsenic) and nutrient concentrations were not elevated when compared to surface water concentrations. Dilution with rainwater would have contributed to this. Also possibly absorption / co-precipitation and settlement of insoluble arsenic and phosphorus compounds due to oxidation and reaction with iron (see Baken et al. 2015).

Copper, lead and zinc are also not elevated in the BP33 pit, likely because these are only above the water quality objectives in the lateritic surface aquifer, and not the BCF aquifer, which will make up the bulk of groundwater inflows into the pit.

In regards to turbidity, surface water turbidity in the drainage line receiving MWD1 discharge is always low, even after significant rainfall. The turbidity of groundwater inflows into the pit and rainwater would also be low, however may become elevated on contact with fine sediments within the pit. Measures for minimising turbidity in water dewatered from the pit, such as filtering water as it is pumped from the pit sump and using flocculants in MWD1 will be undertaken to ensure turbidity levels of discharged water are below the water quality criteria prescribed in the Water Quality Monitoring Plan (Chapter 10).

Similarly, if the naturally occurring process of oxidation and co-precipitation of arsenic and phosphorus with iron whilst the water is held within MWD1 is not effective in reducing levels of these metals, there are a number of commonly-used treatment options available. Removal technologies and treatments have been developed to remove arsenic from groundwater to make it suitable for drinking, and removal of phosphorus from wastewater is commonly undertaken to make it suitable for discharge.

Management of discharge from MWD1 will be subject to the provisions in a WDL; yet to be applied for and issued. Presently, water quality testing of MWD1 is planned to be weekly during discharge, and monthly when not discharging (see Water Quality Monitoring Plan Chapter 10). Discharge water quality will aim to meet the *Water Quality Objectives for the Darwin Harbour Region* (NRETAS 2010) for most parameters, except for

where the background surface water concentrations are already exceeding the objective (i.e. NO_x and aluminium) or when there is no objective (i.e. lithium and iron), when the aim will be to remain within the background range.

Table 7-6. Comparison of groundwater quality with surface water quality (mine footprint sites).

Parameter	Baseline levels in Surface Water: Mine Footprint Sites	Levels in BCF Aquifer	Levels in Laterite Aquifer	Comment
pH	Highly variable above and below objective range	Close to neutral	Acidic similar to rainfall	No risk
DO	Highly variable but remains within objective range	Low but will increase rapidly on exposure to atmosphere and pumping to holding dam	Low but will increase rapidly on exposure to atmosphere and pumping to holding dam	No risk
EC	Very low, well below water quality objective	Relatively low for groundwater but high in comparison to surface water and often above objective	Very low and below objective	High in BCF aquifer but likely reduced below objective with dilution in pit by rainwater
Cadmium Chromium Nickel Selenium Tin Mercury	Always below detection limits	Always below detection limits or objective	Always below detection limits or objective	No risk
Aluminium	Frequently elevated above objective	Elevated but generally lower concentrations than in surface water	Elevated but generally lower concentrations than in surface water	No risk
Lithium	Up to 0.002 mg/L	Elevated above surface water levels (up to 1.730 mg/L	Elevated but to a lesser extent than BCF aquifer	High in both aquifers but likely reduced below surface water background levels with dilution in pit by rainwater
Iron	Up to 0.1 mg/L	Elevated above surface water levels (up to 0.77 mg/L)	Elevated but to a lesser extent than BCF aquifer	High in both aquifers but likely reduced below surface water background levels with dilution in pit by rainwater
Arsenic	Always below detection limit	Elevated with median concentration 0.060 mg/L, which is more than 4.5 times higher than objective (0.013 mg/L).	Mostly below objective	High in BCF aquifer but likely reduced below objective with dilution in pit by rainwater. May also reduce with absorption/co-precipitation with iron in surface water.
Copper	Always below detection limit	Always below detection limit	Mostly above objective	Elevated in laterite aquifer but likely reduced below objective with dilution in pit by rainwater and also BCF water
Zinc	Always below detection limit	Always below detection limit	Always above objective	Elevated in laterite aquifer but likely reduced below objective with dilution in pit by rainwater and also BCF water
Lead	Always below detection limit	Always below detection limit	Occasionally above objective	Elevated in laterite aquifer but likely reduced below objective with dilution in pit by rainwater and also BCF water

Parameter	Baseline levels in Surface Water: Mine Footprint Sites	Levels in BCF Aquifer	Levels in Laterite Aquifer	Comment
NO_x	Frequently elevated above objective	Elevated above objective but generally lower than in surface waters	Elevated above objective but generally lower than in surface waters	No risk
TN	Mostly below objective	Mostly below objective	Mostly below objective	No risk
TP	Always below detection limit	Always above objective	Always above objective	High in both aquifers but likely reduced below objective with dilution in pit by rainwater. May also reduce with absorption/co-precipitation with iron in surface water.
Reactive P	Mostly below objective	Always above objective	Always above objective	High in both aquifers but likely reduced below objective with dilution in pit by rainwater. May also reduce with absorption/co-precipitation with iron in surface water.

8 RISK ASSESSMENT

Risks to hydrological processes and water quality were assessed as part of the whole-of-proposal impact analysis and risk assessment prepared to support the EIS. The principles of qualitative risk management described in *AS/NZS 31000:2009 Risk Management – Principles and Guidelines* were used to set-up a framework for assessing the risk that the project poses to the NT EPA environmental objectives for 'Hydrological Processes' and 'Inland Water Environmental Quality', as listed below.

NT EPA objective for 'Hydrological Processes':

Maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.

NT EPA objective for 'Inland Water Environmental Quality':

Maintain the quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected.

8.1 Identify hazards and rank risks

Each project component that could be a source of environmental impact during the construction/operations phase was identified using the project details provided in Chapter 2 of the EIS. For each project component, events/incidents that could cause impacts to environmental values (receptors) were identified. Potential direct and indirect impacts were then identified by considering cause and effect pathways for impacts.

For each potential environmental impact identified by the project team, the risk assessment considered both the likelihood of the impact occurring and the worst-possible consequence in relation to the NT EPA environmental objectives. The likelihood and consequence categories adopted in the environmental risk assessment are provided in Table 8-1 and Table 8-2. The likelihood and consequence ratings were combined to derive an overall risk rating using the matrix in Table 8-3.

Table 8-1. Likelihood categories adopted in risk assessment

Likelihood category	Description
Almost certain	The event/impact will occur or is expected to occur. The impact occurs regularly in association with similar projects and/or in similar environments.
Likely	The impact will probably occur in most circumstance but there is some uncertainty about the likelihood. The impact has occurred on more than one occasion in association with similar projects and/or in similar environments.
Possible	The impact could occur in some circumstances. The impact has occurred infrequently on similar projects and/or in similar environments.
Unlikely	The impact is not expected to occur. The impact occurs very infrequently on similar projects and/or in similar environments.
Rare	The impact is very unlikely to occur. The impact has not occurred on similar projects and/or in similar environments.

Table 8-2. Consequence categories adopted in risk assessment

Consequence or severity of Impacts	Score	Inland Water Environmental Quality	Hydrological processes (Surface water)	Hydrological processes (Groundwater)
Severe	5	Permanent major exceedance of water quality criteria for beneficial uses in the marine receiving waters of West Arm or Bynoe Harbour.	Catchment wide reduction in surface water flow volumes and/or timing of flows/discharges that permanently alters the ecological health, land-uses and/or amenity.	Drawdown of groundwater in a regional scale aquifer that permanently alters ecological health, land-uses and/or amenity.
Major	4	Major exceedance of water quality criteria for beneficial uses at the catchment outlets to West Arm or Charlotte River, that continues for many years post-closure.	Reduction in surface water flow volumes, groundwater levels and/or timing of flows/discharges that compromises ecological health, land-uses and/or amenity for many years post-closure.	Drawdown of groundwater in a regional scale aquifer that compromises ecological health, land-uses and/or amenity for many years post-closure.
Moderate	3	Minor sustained exceedances of water quality criteria for beneficial uses in the ephemeral water courses downstream, that occurs throughout operations but ceases within months' post-closure.	Localised reduction in surface water flow volumes, and/or timing of flows/discharges with no impact on ecological health, land-uses and/or amenity.	Localised drawdown of groundwater throughout operations that recovers rapidly post-closure.
Minor	2	Minor temporary exceedances of water quality criteria for beneficial uses at the mine site discharge points and immediate sub-catchment area.	Limited reduction in surface water flow volumes, groundwater levels and/or timing of flows/discharges in the immediate sub-catchment area with no impact on ecological health, land-uses and/or amenity.	Limited drawdown of groundwater throughout operations that recovers rapidly once operations cease.
Insignificant	1	No measurable exceedance of pre-development water quality conditions.	No measurable change to hydrological regimes	No measurable change to hydrological regimes

Table 8-3. Risk matrix adopted in risk assessment

			CONSEQUENCE				
			1	2	3	4	5
			Insignificant	Minor	Moderate	Major	Severe
LIKELIHOOD	5	Almost Certain	2 Medium	2 Medium	3 High	4 Very High	4 Very High
	4	Likely	2 Medium	2 Medium	3 High	4 Very High	4 Very High
	3	Possible	1 Low	2 Medium	2 Medium	3 High	4 Very High
	2	Unlikely	1 Low	1 Low	2 Medium	2 Medium	3 High
	1	Rare	1 Low	1 Low	1 Low	2 Medium	3 High

Risks were identified and assessed separately for the construction/operations phase and the rehabilitation/closure phase of the project. The current version of the Water Management Plan addresses only construction/operations phase risks. The requirement for water quality monitoring and management post-closure is specified in the Mine Closure Plan. Future updates of the Water Management Plan will address post-closure requirements.

8.2 Mitigation and management

Measures to avoid, mitigate and manage impacts were identified, focussing on impacts with an inherent risk level of Moderate or above. Suitable controls were generally identified with reference to mining best-practice guidelines and past experience of the mining engineers and other technical experts engaged to work on the proposal. Measures were identified with the goal of reducing all risks to 'As Low As Reasonably Practicable' (ALARP). For a risk to be ALARP, the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained. Mitigation and management measures for reducing risks to water quality and hydrological processes are provided in Section 9.

8.3 Residual risk

Residual risk ratings were assigned assuming effective implementation of the mitigation and management measures prescribed in this plan. All risks to hydrological processes were reduced to low or moderate. A summary of the risk assessment is provided in Table 8-4.

Impacts assigned a low residual risk rating, with a moderate to high level of certainty, are expected to have limited to no effect on the NT EPA's environmental objectives. Impacts assigned a residual risk rating of medium or above have some potential for residual impact either because the mitigation and management measures require further work in order to demonstrate they will be effective, or because it is not practicable to avoid some level of impact.

Table 8-4. Summary of risk assessment for Hydrological Process and Inland Water Environmental Quality factors

Hazard/Aspect	Incident/event	Description of Impact	Assumptions	Inherent Risk	Residual Risk
Inland Water Environmental Quality					
Site clearing and preparation	Erosion (wind/water) due to disturbance and exposure of ground surface	Increased turbidity in watercourses that flow into West Arm affects environmental values and/or other users	• Clearing will occur during the dry season. • Exposed surfaces of the inundation bund and WRD annulus will be susceptible to erosion during first rains. • Minor ephemeral drainage lines are the receiving waters. • Baseline water quality monitoring indicates wet season flows have low levels of turbidity.	**3 - High**	**2 - Medium**
Water supply and use	Overflow of Raw Water or Process Water Dams	Increased turbidity in watercourses that flow into West Arm affects environmental values and/or other users	• Raw Water Dam designed to be continuously pumped to processing circuit and dust suppression. • Process Water Dam designed to receive pit dewatering and TSF decant and be continuously pumped to processing circuit. • Dam overflows would be contained within the mine site by drainage channels and the diversion bund.	**1 - Low**	**1 - Low**
Water supply and use	Erosion of stream banks downstream of dam walls/spillways	Increased turbidity in receiving waters downstream of dams affects environmental values and/or other users	• Spillway modelled to overflow during January of an average wet season. • Hydrographs show event based overflows in Jan/Feb and continuous overflow in Feb/Mar and event based again through late Mar into early Apr. • Dam wall and spillway design yet to be completed but will be in accordance with ANCOLD guidelines. • Watercourses are ephemeral - no significant aquatic or riparian habitats downstream.	**2 - Medium**	**1 - Low**
Water supply and use	Discharge of excess water in wet season	Poor water quality in watercourses discharging to West Arm affects environmental values	• Discharge water is groundwater dewatered from pit and therefore water quality is expected to be similar to the groundwater aquifer. • Arsenic and phosphorous is naturally elevated in the groundwater, but not in surface water. • Discharge required in wet season months of Dec to May i.e. peak flows - maximum dilution. • Water will be stored in separate storage to process water. • Sediments are key contaminant of concern.	**3 - High**	**2 - Medium**
Mining and ore processing	Contamination of pit in-flows due to exposure to PAF and/or other contaminants in pit walls	Poor water quality in groundwater aquifer affects environmental values and/or other users	• Waste characterisation (EcOz/Pendragon 2018) does not identify any significant PAF material occurrences within the pit shell. • Process water could be redirected to the pit in the event of extreme flood events but will not contain contaminants of concern. • Groundwater flows will be towards the pit and therefore water quality in the pit will not influence groundwater in the surrounding aquifer.	**1 - Low**	**1 - Low**
Mining and ore processing	Rainfall onto mine site produces contaminated runoff that is released off-site	Poor water quality downstream of mine site affects environmental values and/or other users	• Ore and rejects characterisation indicates material is inert and gravel like and therefore will not leach contaminants of concern. Fine sediments key contaminant of concern. • Stockpile areas are located within the area enclosed by the inundation bund and WRD, so no direct flow path to the environment. • Run-off directed to stormwater drains and sediment dams, for treatment prior to release off-site.	**2 - Medium**	**1 - Low**

Hazard/Aspect	Incident/event	Description of Impact	Assumptions	Inherent Risk	Residual Risk
Waste rock, rejects and tailings disposal	Seepage of water from WRD/TSF to groundwater aquifer	Poor water quality in groundwater aquifer affects environmental values and/or other users	• Waste characterisation (EcOz/Pendragon 2018) does not identify any AMD potential. • Tailings characterisation indicates the material is inert with no chemical contaminants. Fine sediments is the only contaminant of concern. • Groundwater flow direction under TSF is towards the pit. • Pit void is classified as a groundwater sink, so movement of contaminants into groundwater not expected to occur. • No groundwater users within 12km of site.	**2 - Medium**	**1 - Low**
Waste rock, rejects and tailings disposal	Release of contaminated water/tailings from WRD/TSF into surface water	Poor water quality in surface watercourses that flow into West Arm affects environmental values	• Tailings characterisation indicates the material is inert with no chemical contaminants. Fine sediments is the only contaminant of concern. • Tailings to be placed in TSF constructed in centre of the WRD and will be surrounded by competent waste rock. • Dam failure and environmental spill consequence categories assessed according to ANCOLD guidelines. Spillway sized to accommodate 0.1%AEP flood event. Design Storage Allowance prior to spilling set at 1%AEP, 72hours flood event. • In the event of TSF failure/overtopping, the WRD annulus provides for secondary containment. • Run-off from landform is intercepted by stormwater drains and directed to sediment dams.	**2 - Medium**	**2 - Medium**
Waste rock, rejects and tailings disposal	Erosion of WRD annulus	Increased turbidity in surface watercourses that flow into West Arm affects environmental values	• Run-off from landform is intercepted by stormwater drains and directed to sediment dams. • WRD annulus will be exposed to a single wet season, with rehabilitation planned around end of year 1 mining activities.	**3 - High**	**2 - Medium**
Storage and handling of hazardous materials	Leaks and spills from diesel fuel storage areas entering groundwater	Hydrocarbon contamination of aquifer affects environmental values and/or other users	• Above-ground fuel storage tanks used over short life of mine - lowers risk associated with diffuse pollution over time. • Fuel storage and handling in designated areas and accordance with AS1940. • Groundwater aquifer is shallow but transmissivity is low. • During mining, groundwater beneath the mine site will flow towards the pit. • No GDE's or other users in proximity to site.	**1 - Low**	**1 - Low**
Storage and handling of hazardous materials	Leaks and spills from diesel fuel storage areas entering surface water	Hydrocarbon contamination of downstream ephemeral watercourses that flow into West Arm	• Above-ground fuel storage tanks used over short life of mine - lowers risk associated with diffuse pollution over time. • Fuel storage and handling in designated areas and accordance with AS1940. • Diversion bund around site provides added barrier to movement of spills off site by surface water flows.	**2 - Medium**	**1 - Low**

Hazard/Aspect	Incident/event	Description of Impact	Assumptions	Inherent Risk	Residual Risk
Non-ore waste management	Leaks from septic system into groundwater	Bacterial contamination of groundwater beneath the site affects environmental values and/or other users	• Capacity based on max 64 staff onsite will be less than 2,000l/day. • On-site waste water system will be installed by a licensed plumber in accordance with NT Code of Practice for onsite wastewater management. • Groundwater aquifer is shallow but transmissivity is low. During mining, groundwater beneath the mine site will flow towards the pit.	**1 - Low**	**1 - Low**
Non-ore waste management	Leaks from septic system into surface water	Bacterial contamination of surface water flows affects environmental values	• Capacity based on max 64 staff onsite will be less than 2,000l/day. • On-site waste water system will be installed by a licensed plumber in accordance with NT Code of Practice for onsite wastewater management. • Diversion bund around site provides added barrier to movement of spills off site by surface water flows.	**1 - Low**	**1 - Low**
009 Non-ore waste management	Hazardous waste storage areas do not have adequate containment	Contamination of surface water and/or groundwater affects environmental values and/or other users	•Waste produced on site will comprise waste oils/lubricants, batteries, tyres. • Any release of contaminants to ground would either seep to groundwater, which flows towards the pit, or enter the on-site stormwater management system that is direct to the sediment dams.	**2 - Medium**	**1 - Low**
Hydrological processes					
Construction of mine site infrastructure	Alteration of surface water flows and discharges	Reduced flows affects environmental values	• Mine site infrastructure will change stream lines in the upper catchment. • No significant or sensitive water dependent environmental values in ephemeral drainages upstream of saltwater influence, where modelled flow reduction is up to 46% during the early wet season. • Combined impact of the mine site and dam could reduce flows into the upper mangroves of West Arm by 16-20 % in the early wet season months Nov-early Jan, dropping to between 1% and 7% for the remainder of the wet season.	**2 - Medium**	**2 - Medium**
Water supply and use	Dam wall failure Mine Site Dam	Downstream flooding in West Arm catchment	• Due to the proximity of the dam to the Cox Peninsula Road, the Population At Risk (PAR) has been assessed as 1 – 10. • Consequence Category as 'Significant'. • Spillway has been designed to pass a 0.1% AEP flood event.	**3 - High**	**1 - Low**
Water supply and use	Dam wall failure Observation Hill Dam	Downstream flooding in Bynoe catchment	• Population At Risk (PAR) has been assessed as 1 – 10. • Consequence Category as 'Significant'. • Spillway has been designed to pass a 0.1% AEP flood event.	**3 - High**	**1 - Low**
Water supply and use	Harvesting of surface water flows to fill OHD	Reduced flows downstream to Charlotte River affects environmental values	• NT Water Allocation Planning Framework contingent allocation for environmental and public benefit is 80%. • No public benefit water uses in catchment. • Riparian rainforest along drainages downstream of dam may be sensitive to reduced flows. • The modelled reduction in flows at the outlet to Charlotte River is up to 2.6% in February.	**1 - Low**	**1 - Low**

Hazard/Aspect	Incident/event	Description of Impact	Assumptions	Inherent Risk	Residual Risk
Water supply and use	Operational efficiencies not achieved resulting in increased project water requirements	Additional extraction of water from dams decreases downstream flows more than predicted	• Conservative approach applied to modelling with pump rate based on entire mine site supply coming from a single source. • Site water balance prepared for feasibility stage design indicates pit dewatering expected to supply most of the site water requirements. Obs Hill Dam could provide all of the projects make-up water needs; however, mine site dam proposed as a contingency supply option. • Any additional supply requirement is not likely to be of a magnitude that would increase the modelled reduction of flows.	**1 - Low**	**1 - Low**
Water supply and use	Discharge of excess water in wet season	Increased flows downstream into West Arm affects environmental values	• The site water account predicts discharge requirement during Dec to Mar each year. • Discharge is driven by groundwater inflows to pit. • Model parameter estimation was undertaken in accordance with best practice guidelines (Barnett et al, 2008). The model is deemed to meet the requirements of a Class 2 model and is suitable for providing estimates of dewatering requirements for mines and the associated impacts.	**2 - Medium**	**1 - Low**
Water supply and use	Harvesting of surface water flows to fill Mine Site Dam	Reduced flows downstream into West Arm affects environmental values	• NT Water Allocation Planning Framework contingent allocation for environmental and public benefit is 80%. • No significant or sensitive water dependent environmental values in ephemeral drainages upstream of saltwater influence, where modelled flow reduction is <45% during the early wet season. • Hinterland mangroves 1.7km downstream closest sensitive receptor. • Combined impact of the mine site and dam could reduce flows into the upper mangroves of West Arm by 16-20 % in the early wet season months Nov-early Jan, dropping to between 1% and 7% for the remainder of the wet season.	**2 - Medium**	**2 - Medium**
Mining and ore processing	Groundwater inflows to pit	Drawdown of groundwater levels in aquifer affects environmental values and/or other users	• Groundwater inflows to pit modelled over life of mine. Model deemed to meet the requirements of a Class 2 model (Barnett et al 2008) and is suitable for providing estimates of mine dewatering requirements. • End of mining drawdown cone modelled to extend 1 km from the pit. • No GDE's present in area. Drawdown modelling indicates impact will not affect discharge to ephemeral watercourses. • No other users within 12km of site.	**1 - Low**	**1 - Low**
Waste rock, rejects and tailings disposal	Aquifer recharge from TSF cells	Localised mounding of groundwater	• Groundwater flow direction in area of TSF will be towards the pit void. • Modelled drawdown cone covers area beneath WRD/TSF landform.	**1 - Low**	**1 - Low**

9 MANAGEMENT MEASURES

This section documents the management measures that will be implemented to reduce construction/operations phase risks to hydrological processes and water quality to ALARP. For each potential impact identified through the environmental risk assessment process Table 9-1 documents:

- Environmental objectives
- Management actions required to achieve those objectives
- Monitoring that will be undertaken to measure performance
- Performance indicators
- Corrective actions to be applied if performance indicators are not being met
- Reporting requirements.

Table 9-1. Water management framework for construction/operations phase

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
Hydrological processes								
1.	West Arm & Charlotte River catchments	Downstream flooding due to dam wall failure of Mine Site Dam and/or of Observation Hill Dam	No dam wall failure of Mine Site Dam or Observation Hill Dam	• Design dam in accordance with ANCOLD Guidelines	Dam walls maintain their structural integrity	Regular inspection and testing of dam wall integrity	• Repair wall immediately • Report flooding to DPIR and NT EPA • Investigate cause of failure	Include incident report in annual MMP report
2.	West Arm & Charlotte River catchments	Altered environmental flows due to harvesting of surface water to fill Mine Site Dam and Observation Hill Dam	Minimise reduction of surface water flow volumes downstream of the dams	• Design dams based on the minimum requirement to achieve a sustainable water supply for the project • Design mine site to incorporate additional storages (MWD 1 & 2) so that TSF decant and pit dewatering can be used as the primary project water supply	No significant increase from water extraction volumes used in modelling of flow reductions	Recording of water extraction volumes from Observation Hill Dam and Mine Site Dam	As per management provisions	Water usage volumes and water balance updates as required for annual MMP reporting
3.	West Arm & Charlotte River catchments	Lower than predicted environmental flows due to increased surface water harvesting because of increased project water requirements	No reduction in surface water flow volumes below those predicted	• Include water efficiency and recycling in the design of processing facility • Adopt a conservative approach when modelling potential impacts and estimating returns through recycling of water				
4.	West Arm catchment	Altered environmental flows due to a release from Mine Site Dam of	Minimise increase of surface water flow volumes	• Design mine site to incorporate additional storage (MWD2) for dewatering of pit inflows	• No non-conformances of Waste Discharge Licence conditions	• Recording of discharge volumes from MWD1	As per management provisions	• Water usage volumes and water balance updates

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
		water excess to requirements	downstream of the dams	so that discharge required in Wet season only • If early-Wet season discharges are required, release the water in pulses rather than slow continuous release to simulate early Wet season storms and avoid stream eutrophication that can occur under low-flow conditions • Adhere to the discharge timing and volumes that are authorised by the project Waste Discharge Licence	• No significant impacts on downstream water quality based on assessment using criteria in Water Quality Monitoring Plan	• Monitoring downstream impacts in accordance with Water Quality Monitoring Plan and Waste Discharge Licence conditions		required for annual MMP reporting • Annual Waste Discharge Licence reporting requirements and non-conformance reporting requirements
5.	Local aquifers	Localised mounding of groundwater seepage from TSF cells	Minimise seepage from the TSF cells to local aquifer	• Construct TSF foundation from low permeability material that has been rolled and compacted • Cap TSF at closure and encase within WRD • Incorporate an underdrainage system in the TSF design	• No unseasonal (Dry-season) increases in standing water levels in monitoring bores • No significant increases in contaminant concentrations in groundwater due to TSF seepage	Groundwater level and water quality monitoring as per Water Quality Monitoring Plan	As per management provisions	Water quality results assessment as required for annual MMP reporting
Inland water environmental quality								
6.	West Arm catchment	Turbidity due to rainfall run-off from the mine site	No release of turbid water draining from the mine site	• Undertake construction in the Dry season • Implement the ESCP to ensure stabilisation cleared areas and establishment of sediment controls • Design mine site such that all run-off is	Water released from sediment basins meets the 75 NTU criteria and downstream surface water monitoring sites meet the 20 NTU criteria	Water Quality Monitoring Plan – surface water monitoring	Review all on-site erosion and sediment controls and make improvements	Water quality results assessment as required for annual MMP reporting

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
				intercepted by stormwater drains and directed to sediment dams • Design and operate sediment dams in accordance with the ESCP • Treat the water in sediment dams with a flocculent and tested whether water quality criteria have been achieved prior to release				
7.	West Arm & Charlotte River catchments	Turbidity due to erosion of WRD annulus	No release of turbid water draining from the mine site	• Construct the WRD annulus from competent waste material • Place dispersive waste in the centre of the WRD • Stabilise and rehabilitate the WRD annulus as per the Mine Closure Plan • Design mine site such that all run-off is intercepted by stormwater drains and directed to sediment dams				
8.	West Arm & Charlotte River catchments	Turbidity due to erosion of downstream stream banks when dams overflow	Minimise erosion of stream banks downstream of dam walls and spillways	• Implement the erosion and sediment controls that accompany the construction engineering drawings for the dam walls and spillways • Design dam walls and spillways to ANCOLD guidelines	Downstream turbidity does not consistently exceed 20 NTU criteria	Water Quality Monitoring Plan – surface water monitoring	• Increase stream bank protections • Slow down release of water from dams	Water quality results assessment as required for annual MMP reporting

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
9.	West Arm catchment	Turbidity due to an overflow of the Raw Water and/or Process Water Dam	No overflow of the Raw Water and/or Process Water Dam	• Design dams such that, as a contingency during extreme wet weather events, excess water can be directed to the pit and/or TSF	Water levels in the Raw Water and Process Water Dams do not encroach within 0.8 m of the dam wall tops.	Monitor dam water levels daily	Direct excess water to the pit and/or TSF	Water quality results assessment and water balance updates as required for annual MMP reporting
10.	West Arm catchment	Turbidity and/or contamination due to a release from MWD1 of water excess to requirements	Adhere to the discharge timing and volumes authorised by the Waste Discharge Licence	• Discharge excess water as per the timing and volumes authorised by the Waste Discharge Licence	• Downstream turbidity does not exceed 20 NTU objective • No significant exceedance of water quality objectives in relation to potential contaminants	• Downstream turbidity monitoring as per Water Quality Monitoring Plan • Surface water monitoring for contaminants as per Water Quality Monitoring Plan	• Make improvements to treatment of water pumped from the pit to minimise turbidity • Treat water in MWD1 with flocculants to reduce suspended sediments and contaminants – i.e. this may also assist in reducing arsenic and P concentrations	• All Waste Discharge Licence non-conformances must be reported immediately followed by an investigation of potential environmental impacts • Water quality results reported for annual MMP report • Water quality results reported for annual Waste Discharge Licence report
11.	West Arm catchment	Turbidity due to water released from the WRD/TSF	No release of water from the WRD/TSF into the catchment	• Construct the WRD annulus from competent waste material • Place dispersive waste in the centre of the WRD	Downstream turbidity does not significantly exceed 20 NTU criteria.	Downstream turbidity monitoring as Water Quality Monitoring Plan	Review all on-site erosion and sediment controls and make improvements	Water quality results assessment as required for annual MMP reporting

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
				• Stabilise and rehabilitate the WRD annulus as per the Mine Closure Plan • Design mine site such that all run-off is intercepted by stormwater drains and directed to sediment dams				
12.	Local aquifers	Contamination caused by seepage of water from the WRD/TSF	No seepage of contaminated water from the WRD/TSF into groundwater	• Construct TSF foundation from low permeability material that has been rolled and compacted • Cap TSF at closure and encase within WRD • Incorporate an underdrainage system in the TSF design	No exceedance of water quality objectives in relation to potential contaminants	Groundwater monitoring for contaminants as per Water Quality Monitoring Plan	As per management provisions	• Water quality results assessment as required for annual MMP reporting • Reporting of pollution incident to NT EPA followed by investigation into potential environmental impacts
13.	West Arm & Charlotte River catchments Local aquifers	Contamination caused by mishandling and/or inappropriate storage of fuels	No contamination of groundwater or surface water by fuels	• Surround storage areas for fuels and oils with an impervious bund that contains 120% of the largest container stored in the bund – as per AS1940 • Refuel vehicles within bunded areas • Make available spill containment equipment kits at the works area that are adequately-sized	No detection of hydrocarbons	Surface water and groundwater monitoring for hydrocarbons as per Water MP	Investigate cause of spill and update procedures as necessary	• Reporting of pollution incident to NT EPA followed by investigation into potential environmental impacts • Include incident report in annual MMP

No.	Value	Potential impact	Objective / outcome	Management provisions	Targets / performance indicators	Monitoring	Response	Reporting
				to manage the volume of fuels that could be spilled				report
14.	West Arm & Charlotte River catchments Local aquifers	Contamination caused by mishandling and/or inappropriate storage of hazardous waste	No contamination of groundwater or surface water by hazardous waste	• Use, handle, store and dispose of all hazardous materials in accordance with the *Dangerous Goods Act* and the *Waste Management and Pollution Control Act* • Locate chemical and hazardous goods storage areas no less than 50 m from any areas of concentrated water flow, flood and poorly-drained areas • Make available spill containment equipment kits at the works area that are adequately-sized to manage the volume of hazardous materials stored within the works areas	No exceedance of water quality objectives in relation to potential contaminants (see Water MP for detail)	Surface water and groundwater monitoring for contaminants as per Water Quality Monitoring Plan	Investigate cause of spill and update procedures as necessary	
15.	West Arm & Charlotte River catchments Local aquifers	Contamination caused by a leak from the septic system	No contamination of groundwater or surface water due to septic system	• Locate and construct the septic system based on the *NT Code of Practice for Onsite Wastewater Management*	No exceedance of water quality objectives in relation to nutrients	Surface and water groundwater monitoring for nutrients as per Water Quality Monitoring Plan	Investigate cause of leak and update procedures as necessary	

10 WATER QUALITY MONITORING PLAN

This Water Quality Monitoring Plan (WQMP) outlines the surface and groundwater quality monitoring to be undertaken during:

- The 2018/2019 Wet season and 2019 Dry season representing a continuation of pre-mining baseline monitoring for informing further development of assessment criteria and identifying potential impacts.
- Mining operations (planned to start late 2019 Dry season) to provide early warning and trigger management actions for preventing impacts to surface waters and/or groundwater aquifers.

Chapters 6 and 7 present the results of baseline (pre-mining) surface and groundwater monitoring undertaken since February 2017 for surface water, and June 2017 for groundwater. This WQMP uses the results of this monitoring to design the surface and groundwater monitoring programs. The selection of monitoring sites, sampling frequency, analytical parameters, and assessment criteria is also designed to assist in monitoring and minimising the potential impacts and risks discussed in the earlier chapters of this WMP.

This WQMP will become part of the project's *Mining Management Plan* (MMP), as required under the NT *Mining Management Act*, and be updated regularly throughout operations to reflect on-ground activities as mining progresses. It will also support the project's *Waste Discharge Licence* (WDL) issued under the NT *Waste Management and Pollution Control Act* to allow discharge from MWD1. Once issued, this WQMP will be updated to reflect all WDL monitoring and reporting requirements.

The monitoring program design, sampling methods, data assessment criteria and reporting are in accordance with:

- ANZECC (2000a), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy Paper No 4*, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.
- ANZECC (2000b), *Australian Guidelines for Water Quality Monitoring and Reporting, National Water Quality Management Strategy Paper No 7*, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.
- AS/NZ Standards 5667:1998 - *Water Quality Sampling Parts 1, 4, 6, 10 and 11.*

All surface water and groundwater quality monitoring must be undertaken by a qualified professional in accordance with the standards listed above. All hand-held field parameter meters must be calibrated immediately prior to commencing sampling, and all sample collection for laboratory analysis must be into the appropriate laboratory-supplied bottles and handled in accordance with the standards listed above e.g. samples kept cool in esky until delivered to laboratory, and all samples delivered to laboratory within required holding times. All laboratory samples will be analysed by a NATA accredited laboratory.

10.1 Surface water quality monitoring program

10.1.1 Surface water quality monitoring sites

Proposed surface water monitoring site locations are shown in Figure 10-1 and detailed in Table 10-1. All existing surface water monitoring sites used in baseline monitoring are retained except for BP Historic Pit, as on-going water quality monitoring of this pit will not provide any further information for detecting or assessing impacts from the mine.

Site GUS SW3 is located within the proposed MSD inundation area. The final location of this site will require review following completion of mine site infrastructure. The site will continue to be sampled until infrastructure is in place in order to extend the existing baseline dataset for this site. The longer-term location of this site needs to ensure it is not receiving any run-off or potential impacts from the mine as its purpose is as an upstream reference site.

An extra reference site (GUS SW4) has been added in order to provide on-going background data for comparing to potentially impacted sites. This site receives water from the sub-catchment 2b, which has a similar size and very similar characteristics to the 5a and 5b catchments subject to mine impacts (see Section 3.2.1 for sub-catchment details). Monitoring of this site will commence immediately.

An extra downstream site (GDS SW5) has been added located further downstream of the mine between Cox Peninsula Road and the upper tidal limit of West Arm, Darwin Harbour. The aim of this site is to monitor any impacts from mining in this stretch of waterway further downstream of where water leaves the mining lease at GDS SW2. Monitoring of this site will commence immediately.

The existing sites GDS SW1 and GDS SW2 will continue to be monitored prior to mine construction to extend the baseline dataset for these sites. Then, following construction of the mine, these sites will be used for monitoring impacts immediately downstream in the drainage lines receiving run-off from the mine footprint, and discharge from the Sediment Basins and MWD1; as outlined in Table 10-1.

Sites that will be added to the monitoring program following the construction of mine site infrastructure include Sediment Basins 1 and 2, and MWD1. Monitoring of these basins and dams aims to ensure that water quality meets the required assessment criteria prior to release. Regular sampling of these dams and basins, even when not discharging, will also guide implementation of any treatment measures or management actions needed to improve input water quality or contained water quality. If water is stored in MWD1 for a long period without inputs, pumping out for dust suppression or discharge it may also become stagnant with low DO, algal bloom and high nutrients. Such conditions would be detected through the water quality monitoring program and management options for treating this prior to release would include oxygenation, removal of organic matter, or using the water for dust suppression rather than in discharging it (during Dry season only).

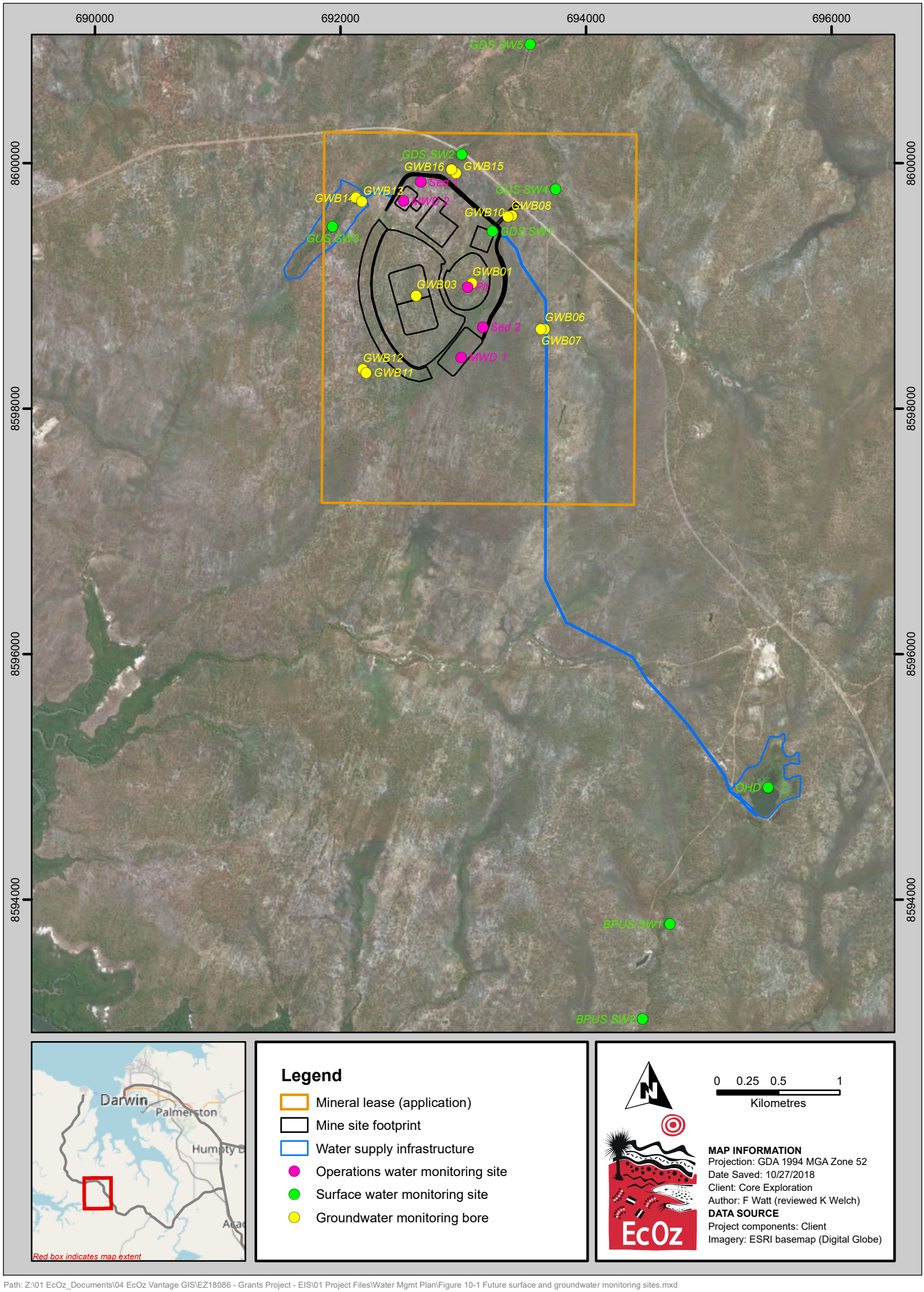
Following the commencement of mining and establishment of the open cut pit, water from the pit sump will be sampled in order to monitor the quality of groundwater entering the pit and being pumped to MWD1 for use in dust suppression and ore processing. This will provide early warning of any unusually high levels of contaminants entering the pit or acid mine drainage (which is not expected refer Section 2.7).

Sampling of MWD2 will be undertaken when this dam is receiving TSF decant water. Obtaining better data on TSF decant water quality will assist in determining the potential contaminants to monitor closely in groundwater and surface water monitoring results for detecting any seepage from the TSF.

Monitoring of Observation Hill Dam and the two sites located downstream will continue. The water quality of Observation Hill Dam is required to establish the incoming water quality of water supplied to the mine. Continued monitoring of BPUS SW1 and BPD SW2 aims to detect any downstream impacts from Observation Hill Dam water extraction and data from these sites can also be used as a regional reference for monitoring larger-scale changes to background water quality, enabling distinction of water quality changes caused from mine impacts as opposed to natural seasonal / climatic changes.

Table 10-1. Surface water quality monitoring site details.

Catchment	Site ID	Site Name	New/ Existing Site	Location	Purpose	Sampling Frequency
Darwin Harbour, West Arm	**GDS SW1**	*Grants Downstream Surface Water 1*	Existing	Ephemeral drainage line downstream of mine footprint, eastern side in sub-catchment 5b	Monitor impacts immediately downstream of eastern side of mine footprint including MWD1 discharge and Sediment Basin 2 discharge.	Monthly when flowing i.e throughout Wet-season until flows stop in Dry season. Weekly when discharging from either MWD1 and/or Sediment Basins.
	GDS SW2	*Grants Downstream Surface Water 2*	Existing	Downstream of GUS SW3 and GDS SW1, where ephemeral drainage lines on either side of mine footprint join and flow through culvert under Cox Peninsula Road.	Monitor impacts immediately downstream of northern side of mine footprint including Sediment Basin 2 discharge and MSD releases. Also, receives any impacts detected at GDS SW1 from MWD1 and Sediment Basin 2. Represents water quality leaving the Mining Lease.	
	GUS SW3	*Grants Upstream Surface Water 3*	Existing	Ephemeral drainage line upstream of mine footprint, western side in sub-catchment 5a.	Reference site upstream of mine footprint. Note site location may need review depending on inundation area of MSD and so it remains upstream of any run-off from mine footprint.	
	GUS SW4	*Grants Upstream Surface Water 4*	New	Ephemeral drainage line in adjacent sub-catchment 2b not subject to mine impacts.	Reference site in adjacent catchment not subject to mine impacts with similar size and characteristics as impacted catchments.	
	GDS SW5	*Grants Downstream Surface Water 5*	New	Waterway downstream of all other sites between Cox Peninsula Road and where the waterway meets Darwin Harbour tidal waters.	Monitor extent of impacts (if any) on waterways further downstream of mine.	
Mine Footprint	**Sed1**	*Sediment Basin 1*	New	Sediment Basin 1, which receives run-off from WRD and all operational areas in northern half of mine site.	Monitor water quality in Sediment Basin/Dam to ensure it meets assessment criteria prior to release. For guiding any water quality treatment measures required prior to release or management actions to improve input water quality.	
	Sed2	*Sediment Basin 2*	New	Sediment Basin 2, which receives run-off from southern half of WRD and areas south of pit.		
	MWD1	*Mine Water Dam 1*	New	Dam receives water dewatered from the pit.		
	MWD2	*Mine Water Dam 2*	New	This dam receives excess TSF decant water.	Monitor quality of TSF decant to inform detection of any TSF seepage in groundwater or surface water monitoring results.	Monthly when dam is receiving water.
	Pit	*Mine Pit Sump*	New	Mine pit sump collects groundwater inflows and incident rainfall for pumping to MWD1.	Monitor quality of groundwater inflows and provide early warning of any unusually high levels of contamination or AMD risk.	Monthly lab parameters Weekly field parameters
Bynoe Harbour	**OHD**	*Observation Hill Dam*	Existing	Surface water storage	Monitor incoming quality of water being used on site.	Monthly
	BPUS SW1	*BP33 Pit Upstream Surface Water 1*	Existing	Downstream of OHD but upstream BP33 pit	Monitor impacts from OHD water extraction on downstream waterways. Can also be used as a regional reference site for monitoring larger-scale changes to background water quality to enable distinction of water quality changes caused from mine impacts as opposed to natural seasonal / climatic changes.	
	BPDS SW2	*BP33 Pit Downstream Surface Water 2*	Existing	Downstream of OHD, BPUS SW1, and BP33 pit		



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18086 - Grants Project - EIS\01 Project Files\Water Mgmt Plan\Figure 10-1 Future surface and groundwater monitoring sites.mxd

Figure 10-1. Map of future surface and groundwater monitoring sites

10.1.2 Sampling frequency

Sampling frequency of all sites will be at least monthly when flowing (sites located along drainage lines) or when containing water (Sed1, Sed2, MWD1, MWD2, Pit, OHD); see Table 10-1.

The continued collection of baseline (pre-mining) data on a monthly basis at all existing sites, and the new sites GUS SW4 and GDS SW5, will commence as soon as these drainage lines start flowing this coming Wet season (November/December 2018).

Monthly sampling of the internal mine footprint sites Sed1, Sed2, MWD1, MWD2 and Pit will commence as soon as these basins/dams/pit have finished construction and are receiving water.

Weekly sampling of Sed1, Sed2, and MWD1 will occur whilst these basins/dams are discharging. Additionally, whilst any of these basins/dams are discharging, all upstream and downstream sites must also be monitored weekly i.e. GDS SW1, GDS SW2, GUS SW3, GUS SW4 and GDS SW5.

MWD2 will be monitored monthly when receiving inputs.

For the Pit site, in addition to the monthly sampling, weekly field parameters will be measured to ensure a rapid response if pH levels were to become very acidic, EC very high, or turbidity very high.

The BPUS SW1 and BPDS SW2 sites will be monitored monthly when flowing. The OHD site will have water available for monthly sampling throughout the year.

Sampling will be undertaken throughout operations and post-closure until the rehabilitation criteria specified in the *Mine Closure Plan* are achieved.

10.1.3 Parameters measured

The field and laboratory parameters measured at all sites during all sampling rounds will always be the same (Table 10-2). These are the same parameters measured for baseline surface water monitoring completed so far. The parameters aim to allow the detection of all identified surface water quality-related impacts discussed in the preceding chapters of this WMP, such as causing the elevation of:

- Dissolved metals and nutrients in waterways receiving discharge from MWD1, in particular, EC, arsenic, lithium, iron and phosphorus, which are potentially elevated in groundwater dewatered from the pit and transferred to MWD1.
- Turbidity in waterways receiving discharge from MWD1, where turbidity may become elevated in water pumped to MWD1 when groundwater and direct rainwater come into contact with fine sediments within the pit.
- Turbidity in waterways receiving discharge from Sediment Basins 1 and 2, where turbidity may become elevated above the allowable discharge criteria in run-off entering the basins indicating more effective flocculent treatment may be required within the basins or improvements to mine site erosion and sediment controls.
- Hydrocarbons in waterways receiving run-off from the mine and discharge from Sediment Basins 1 and 2 and MWD1 due to spills or leaks of fuels, oils, lubricants etc from operational areas of the mine.
- Dissolved metals and nutrients in waterways receiving run-off from the WRD or seepage from the TSF.

Whilst at the site, field conditions must also be noted as listed in Table 10-2, and photos taken.

Table 10-2. Surface water and groundwater quality field and laboratory parameters and field notes.

Field Parameters	Laboratory Parameters
• pH (pH units) • Electrical Conductivity (µS/cm) • Total Dissolved Solids (mg/L) • Turbidity (NTU) • Temperature (ºC) • Oxidation Reduction Potential (mV) • Dissolved Oxygen (%) • Standing water level (mBGL) for groundwater	• Nutrients (ammonia, NOx (nitrate+nitrite), total nitrogen, total phosphorus, reactive phosphorus) • Dissolved metals (Al, As, Cd, Cr, Cu, Fe, Li, Hg, Pb, Ni, Zn) • Major anions (sulfate, chloride, alkalinity), Major cations (calcium, magnesium, sodium, potassium) • Hydrocarbons (TPH/TRH, BTEXN)
Field Notes	
• Sampler Name/s • Date and Time • Weather conditions • Flow conditions, spillway flowing etc, note pumping rate for groundwater • Any visible pollutants, algae, water plants, fish, other biota • Water clarity • Any odour • Take photos	

10.1.4 Assessment criteria

The water quality objectives that apply to waterways downstream of the mine footprint are those listed in the *Water Quality Objectives for the Darwin Harbour Region Background Document* (NRETAS 2010). For parameters such as metals and other toxicants, where no objective is specified, the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a) apply.

These objectives aim to protect the beneficial uses identified for waterways in the Darwin Harbour region as outlined in Section 3.2.3. The specific objectives relating to the beneficial use of environment (aquatic ecosystems) are applied here given these are the most conservative, and adherence to these would in most cases also protect the other beneficial uses of cultural (aesthetic, recreational and cultural), agriculture and rural stock and domestic water supply.

The NRETAS (2010) water quality objectives developed specifically for 'freshwater rivers and streams' are the most appropriate for the types of waterways receiving water from the project area. These objectives include values for physical parameters (pH, EC, turbidity, and DO) and nutrients (NO_x, TN, TP, and reactive phosphorus). For toxicants (dissolved metals and hydrocarbons) the ANZECC (2000a) 'trigger values for freshwater; 95% species protection' are the most appropriate.

Baseline surface water quality results found aluminium and NO_x consistently exceeded of the water quality objectives, and pH was often above and below the objective range. The ANZECC (2000a) Guidelines recommend under these circumstances to calculate site-specific trigger values based on the 80th percentile of baseline (or reference site) data. It is not however possible at this stage to calculate site-specific trigger values given the ANZECC (2000a) methodology requires at least two years' worth of monthly data. It is recommended that assessment be based on comparing the baseline range of concentrations with those measured during and after mining. That is, NO_x ranges between <0.01 and 0.06 mg/L, aluminium between <0.01 and 0.08 mg/L and pH between 5.06 and 8.14 (not including the alkaline spikes measured in the OHD and BP Historic Pit sites). If concentrations were to become consistently outside these ranges, then impacts on water quality can be implicated.

In regards to the dissolved metals lithium and iron, which don't have ANZECC (2000a) trigger values, the natural background range is used as the assessment criteria i.e. 0.002 mg/L for lithium and 0.1 mg/L for iron.

In regards to turbidity in discharge directly from Sediment Basins 1 and 2, and MWD1, a higher assessment criteria than the NRETAS (2010) objective of 20 NTU is proposed. This is because it is unlikely that water requiring discharge from these basins/dam will meet this objective at times of high rainfall and run-off. This is the typical situation for construction and mine sites across the NT during the Wet season. The Inpex Ichthys LNG Project constructed at the nearby Blayden Point within Darwin Harbour adopted a 75 NTU criteria for allowing discharge of water offsite from sediment basins (see Appendix D). This criterion is adopted initially and will be reviewed following consideration of sediment basin water quality monitoring data collected over the 2019/2020 Wet season. The 20 NTU objective will apply to all other surface water quality monitoring sites.

For hydrocarbons, which were undetectable in all baseline surface water and groundwater results, the assessment criteria are set at remaining below laboratory detection limits.

The water quality assessment criteria for the project applying to both surface and groundwater is presented in Table 10-3.

It is highlighted in regards to all future monitoring, that laboratory analytical detection limits must be low enough to allow assessment using the objectives/trigger values. This was the case for all parameters during baseline surface and groundwater quality monitoring except for NO_x and reactive phosphorus. The analytical limit of reporting (LOR) for both NO_x and reactive phosphorus was <0.01 mg/L, whereas the objectives are 0.008 mg/L and 0.005 mg/L respectively.

Table 10-3. Water quality objectives / trigger values (assessment criteria) for both surface and groundwater quality.

**Note the turbidity and DO values don't apply to groundwater. Also, baseline groundwater concentrations of EC, arsenic, iron, lithium and reactive P are often already above these values. Groundwater results will still be compared with these guidelines for assessment purposes but the background range will also be taken into account for detecting any groundwater contamination. Standing water levels only apply to groundwater monitoring.*

Parameter	Objective/Triger Value
pH	Remain within 5.06 and 8.14
EC*	200 µS/cm
Turbidity*	20 NTU all sites except Sed1, Sed2, MWD1 which are 75 NTU
DO*	Remain within 50-100 %saturation
NOx	0.06 mg/L
TN	0.23 mg/L
TP	0.01 mg/L
Reactive P*	0.005 mg/L
Aluminium	0.08 mg/L
Arsenic*	0.013 mg/L
Cadmium	0.0002 mg/L
Chromium	0.004 mg/L
Copper	0.0014 mg/L
Iron*	0.1 mg/L
Lead	0.0034 mg/L
Lithium*	0.002 mg/L
Mercury	0.0006 mg/L
Nickel	0.011 mg/L

Parameter	Objective/Triger Value
Zinc	0.008 mg/L
Hydrocarbons	Remain below detection limits
Standing Water Levels*	Remain within background range as per Section 3.3.1 and do not indicate groundwater mounding.

10.2 Groundwater quality monitoring program

10.2.1 Groundwater monitoring bores

Proposed groundwater monitoring site locations are shown in Figure 10-1 and detailed in Table 10-4. All existing monitoring bores used in baseline monitoring are retained except for GWB01, which is located within the mine pit and will be destroyed, and GWB03, which will be decommissioned prior to establishment of WRD over the top. GWB01 and GWB03 will continue to be sampled until infrastructure is in place, in order to extend the existing baseline dataset for these sites.

Seven additional bores are proposed (Table 10-4). GWB17 will be a shallow bore screened in the shallow laterite aquifer to replace GWB06, which is contaminated with cement and cannot be used for water quality monitoring. The existing paired deep bore at this site, GWB07 will continue to be sampled prior to mine construction to extend the baseline dataset. Then, following mine construction, will be used along with GWB17 as an up-gradient reference site on the south-eastern side of the mine footprint.

Existing paired bores GWB08 (screened in BCF aquifer) and GWB10 (screened in surface laterite aquifer) located down-gradient of the mine on the northern side, will continue to be sampled prior to mine construction to extend the baseline dataset for this site. Then, following construction of the mine, this site will be used for monitoring impacts immediately downstream of the mine footprint.

New paired bores GWB11 (screened in BCF aquifer) and GWB12 (screened in surface laterite aquifer) to be installed up-gradient of the WRD/TSF, will used as reference bores for monitoring the un-impacted water quality of groundwater flowing underneath the WRD and then underneath the mine site. Unseasonal increases in standing water levels (SWLs) in these bores during the Dry season may indicate groundwater mounding under the WRD. If this was to occur, then these bore would no longer be ‘up-gradient’ as groundwater would start flowing from the WRD/TSF towards these bores.

New paired bores GWB13 (screened in BCF aquifer) and GWB14 (screened in surface laterite aquifer) to be installed down-gradient of the WRD/TSF, will used to detect any impacts on groundwater from TSF seepage, and could also indicate groundwater mounding if SWLs increased during the Dry-season.

New paired bores GWB15 (screened in BCF aquifer) and GWB16 (screened in surface laterite aquifer) to be installed down-gradient of the mine site, will be used to detect any impacts on groundwater from TSF seepage and any other potential contamination sources such as hydrocarbon leakage.

Final bore locations and depths will be decided by a qualified hydrogeologist, who will also manage and supervise the bore drilling program.

Table 10-4. Groundwater quality monitoring bore details.

Bore ID	New/ Existing Site	Screened Aquifer	Location and Purpose
GWB01	Existing	BCF	Baseline data indicating quality of groundwater flowing into mine pit. Note this bore will be destroyed once mining of pit begins.
GWB03	Existing	BCF	Baseline data beneath WRD. Note this bore will no longer exist following establishment of WRD.
GWB07	Existing	BCF	Paired bores; both reference bores up-gradient of mine footprint (SE side).
GWB17	Replacement for GWB06	Shallow	
GWB08	Existing	BCF	Paired bores; both down-gradient of mine footprint (N side) for detecting any groundwater contamination from entire mine site operations.
GWB10	Existing	Shallow	
GWB11	New	BCF	Paired bores; both reference bores up-gradient of WRD/TSF for determining original groundwater quality flowing underneath WRD; may also indicate groundwater mounding if unseasonal rise in SWLs – hence no longer a reference site at that time as would become down-gradient of WRD/TSF.
GWB12	New	Shallow	
GWB13	New	BCF	Paired bores; both down-gradient of WRD/TSF for monitoring seepage from TSF and groundwater mounding.
GWB14	New	Shallow	
GWB15	New	BCF	Paired bores; both down-gradient of whole mine site for detecting any groundwater contamination from entire mine site operations
GWB16	New	Shallow	

10.2.2 Sampling frequency

All bores will be sampled quarterly. This will commence immediately for the existing bores and will commence for the new bores once they are installed. This is expected to occur early 2019. Sampling will be undertaken throughout operations and post-closure until the rehabilitation criteria specified in the *Mine Closure Plan* are achieved.

10.2.3 Parameters measured

Table 10-2 lists the parameters to be measured.

10.2.4 Assessment criteria

Table 10-3. lists the assessment criteria for comparing with groundwater monitoring results. Note the turbidity and DO values do not apply to groundwater. A high turbidity reading in groundwater would indicate an issue with sampling methods or bore construction/development rather than an impact of mining on water quality. DO is low in groundwater because it has been out of contact with the atmosphere for a period of time and not a result of mining impacts on water quality. DO would be expected to increase rapidly on exposure to the atmosphere and pumping to MWD1.

In regards to EC, arsenic, iron, lithium and reactive phosphorus, these parameters are already often above the assessment criteria (which is based on surface water quality objectives). Groundwater results will still be compared with these values for assessment purposes but the background range will also be taken into account for detecting any groundwater contamination from the TSF or other sources of contamination from mining operations.

10.3 Recording and reporting

All results from surface water and groundwater quality monitoring will be entered into the database (Excel spreadsheet) already established and populated with the baseline monitoring results.

Reporting requirements will align with those required for annual MMP reporting and the reporting required for the WDL.

11 INFORMATION/KNOWLEDGE GAPS

11.1 Identification of information/knowledge gaps

Identified information and knowledge gaps are:

- **Discharge volumes from MWD1**. Predicted volumes have been modelled based on the best available data (see Water Balance Appendix A). However, there is a level of uncertainly that could mean that discharge is greater or less than the predicted volumes. The amount of discharge will depend on the:
    - 1. Rate of groundwater inflows into the pit, which should be relatively constant and predictable, only changing progressively as mining progresses to deeper levels, and
    - 2. Amount of direct rainfall into the pit and MWD1, which will change from year to year.

  It will not be possible to determine exact volumes until mining commences.
- **MWD1 water quality**. The predicted water quality contained within MWD1 and potentially discharged to the environment has been predicted using baseline groundwater data collected since the instalment of monitoring bores on site in July 2017. Final water quality discharged to the environment will depend on the level of dilution from direct rainfall into the pit and into MWD1. It may also depend on the naturally occurring oxidation reactions and precipitation of chemical constituents in the water on exposure to the surface, pumping to, and retention in MWD2.
- **Water extraction from surface water storages**. Predicted volumes have been modelled based on the best available data (see Water Balance Appendix A). However, there is a level of uncertainly that could mean that extraction is greater or less than the predicted volumes. It will not be possible to determine exact volumes until mining commences.
- **Turbidity levels in Sediment Basins**. Baseline surface water turbidity levels are very low in the drainage lines receiving discharge from the sediment basins. Levels remain below 12 NTU (well below the water quality objective of 20 NTU) even during heavy rainfall events. The assessment criteria for allowing release of water from the basins is 75 NTU with levels decreasing downstream with dilution from catchment run-off to below the water quality objective of 20 NTU. Sediment basins have been designed and sized in accordance with IECA (2008) *Best Practice Erosion and Sediment Control*, by a Certified Practitioner in Erosion and Sediment Control, however there is still uncertainty in the final levels of turbidity that will be contained within the basins. It will not be possible to know this until the basins are receiving run-off from the site.
- **AMD risk**. The risk of AMD materials in waste rock and tailings has been tested and assessed as low. There is a small risk that during mining AMD materials are encountered and groundwater entering the pit and seepage from the WRD/TSF becomes highly acidic and metalliferous.

11.2 Filling information/knowledge gaps

The following will be undertaken to address the above knowledge gaps:

- **Discharge volumes from MWD1**. A flow gauge will be fitted to the outlet of MWD1 to record discharge volumes. Also, from the outset of mining, the volumes of groundwater inflows into the pit will be recorded and the Water Balance updated accordingly. Similarly, a rainfall gauge will be installed onsite for improving water balance calculations.
- **MWD1 water quality**. The water quality of groundwater inflows into the pit will be monitored weekly for field parameters and monthly for laboratory parameters. This monitoring will occur immediately as soon

as dewatering of the pit becomes necessary. A rainfall gauge installed onsite will assist in calculating dilution factors. Monitoring of water quality in MWD1 will commence as soon as this dam contains water pumped from the pit. The results of monitoring will inform the level of treatment or management actions required, whether this be to reduce turbidity through better pit sump pumping practices and/or flocculant application, or to reduce contaminant levels through treatment.

If water is stored in MWD1 for a long period without inputs, pumping out for dust suppression or discharge it may also become stagnant with low DO, algal bloom and high nutrients. Such conditions would be detected through the water quality monitoring program and management options for treating this prior to release would include oxygenation, removal of organic matter, or using the water for dust suppression rather than in discharging it (during Dry season only).

- **Water extraction from surface water storages**. Water volumes extracted from surface water storages will be recorded and water balance calculations updated accordingly. Similarly, data from the rain gauge installed on site will be used to update the water balance.
- **Turbidity levels in Sediment Basins**. Turbidity levels in sediment basins, and in surface water sites downstream, will be monitored weekly whilst discharging. If levels are found to be consistently exceeding the assessment criteria, the ESCP will be reviewed and improved accordingly.
- **AMD risk**. On site geologists will be assessing the pit walls daily for any AMD materials, and the pH of water entering the pit will be tested at least weekly. The water quality of TSF decant water will also be tested regularly from MWD2. Quarterly groundwater monitoring will detect any acidic seepage from the TSF.

12 REFERENCES

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APPENDIX A WATER BALANCE

Please refer to Appendix J of the Grants Lithium Project EIS

APPENDIX B INDEPENDENT REVIEWER BIOGRAPHIES

Rohan Ash

Principal environmental engineer with 30 years' experience as an environmental manager, regulator, consultant and expert advisor to industry and government. Rohan is an Environmental Auditor (Industrial Facilities) appointed by EPA Victoria. He is also a Qualified Person pursuant to the *Waste Management and Pollution Control Act* to perform environmental audits in the NT.

He specialises in:

- Statutory approvals, licensing, compliance strategies, regulator/stakeholder liaison
- Environmental impact and risk assessments
- EMS and environmental management and monitoring plans
- Environmental audits including for landfills, industrial facilities and water recycling schemes
- Wastewater treatment and water quality management
- Water use efficiency, water balances and recycling strategies
- Soil/land capability and catchment management.

He is regularly sought after to provide these services by a wide range of industries including water, power, landfills, construction, ports, food and other manufacturing businesses, agriculture, industry associations, research bodies and government agencies (federal, state, territory and local). Rohan has conducted a number of audits and independent OEMP and WMP reviews in the NT including for INPEX LNG plant at Bladin Point, Port Melville and AACo abattoir.

Dr Bill Howcroft

Principal hydrogeologist with more than 20 years' experience conducting hydrogeologic and environmental investigations across Australia. Within the Northern Territory, Dr Howcroft has been involved in numerous mining-related projects, including the development of a new TSF for BHP Billiton on Groote Eylandt, investigation of caustic impacts to groundwater at Rio Tinto's facility in Alcan Gove, geochemical and groundwater transport modelling for Crocodile Gold at its facilities near Pine Creek, and the preparation of a Water Management Plan (WMP) for HNC (Australia) at its Brown's Oxide Mine near Bachelor. Dr Howcroft holds Bachelor's, Master's and PhD degrees in the Geology, Geography and Hydrogeology, respectively and has published scientific articles in internationally recognized, peer-reviewed journals examining groundwater-surface water interaction using aqueous geochemistry and stable and radioactive isotopes.

APPENDIX C TPH/TRH AND BTEXN BASELINE SURFACE WATER AND GROUNDWATER QUALITY RESULTS

Baseline surface water hydrocarbon results

Site	Date Sampled	Total Petroleum Hydrocarbons - NEPM 1999					Total Recoverable Hydrocarbons - NEPM 2013							BTEXN							
		C6 - C9 Fraction	C10 - C14 Fraction	C15 - C28 Fraction	C29 - C36 Fraction	C10 - C36 Fraction (sum)	C6 - C10 Fraction	C6 - C10 Fraction minus BTEX (F1)	>C10 - C16 Fraction	>C16 - C34 Fraction	>C34 - C40 Fraction	>C10 - C40 Fraction (sum)	>C10 - C16 Fraction minus Naphthalene (F2)	Benzene	Toluene	Ethylbenzene	meta- & para-Xylene	ortho-Xylene	Total Xylenes	Sum of BTEX	Naphthalene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
GUS SW3	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GUS SW3	19-04-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GUS SW3	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GUS SW3	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GUS SW3	03-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW1	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW1	19-04-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW1	31-01-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW1	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW2	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW2	19-04-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW2	31-01-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW2	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GDS SW2	03-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
OHD	12-10-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
OHD	09-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	19-04-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	12-10-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	03-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BP HISTORIC PIT	08-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPUS SW1	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPUS SW1	19-04-17	<20	320	1450	<50	1770	<20	<20	800	840	<100	1640	800	<1	<2	<2	<2	<2	<2	<1	<5
BPUS SW1	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPUS SW1	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPUS SW1	03-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPDS SW2	15-02-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPDS SW2	19-04-17	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPDS SW2	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPDS SW2	14-03-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
BPDS SW2	03-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5

Baseline groundwater hydrocarbon results

Site	Date Sampled	Total Petroleum Hydrocarbons - NEPM 1999					Total Recoverable Hydrocarbons - NEPM 2013							BTEXN							
		C6 - C9 Fraction	C10 - C14 Fraction	C15 - C28 Fraction	C29 - C36 Fraction	C10 - C36 Fraction (sum)	C6 - C10 Fraction	C6 - C10 Fraction minus BTEX (F1)	>C10 - C16 Fraction	>C16 - C34 Fraction	>C34 - C40 Fraction	>C10 - C40 Fraction (sum)	>C10 - C16 Fraction minus Naphthalene (F2)	Benzene	Toluene	Ethylbenzene	meta- & para-Xylene	ortho-Xylene	Total Xylenes	Sum of BTEX	Naphthalene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
GWB01	27-06-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GWB01	31-01-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB01	01-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB01	08-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB03	27-06-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GWB03	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB03	01-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB03	09-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB07	27-06-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GWB07	01-02-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB07	01-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB07	09-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB08	27-06-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GWB08	31-01-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB08	01-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB08	08-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB10	27-06-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GWB10	31-01-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB10	01-05-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5
GWB10	08-08-18	<20	<50	<100	<50	<50	<20	<20	<100	<100	<100	<100	<100	<1	<2	<2	<2	<2	<2	<1	<5

APPENDIX D TURBIDITY WATER QUALITY ASSESSMENT CRITERIA

APPENDIX C SURFACE WATER QUALITY CRITERIA

Parameter	Detection method	Discharge criteria	Reference
pH	Calibrated field equipment	Between 6 and 8.5	*Water quality objectives for the Darwin Harbour region—background document* (NRETAS 2010)
Turbidity	Calibrated field equipment	• No greater than 75 NTU up to design (major) storm event. • Turbidity criteria to be reviewed and revised in accordance with background data as it becomes available	See Note below
Oil and grease	Visual	• No visible sheen • No detectable odour	Good International Industry Practice (GIIP)
Iron floc and scum	Visual	None visible	GIIP
Floating matter/litter	Visual	None visible	GIIP

Note: The guidelines in Best practice erosion and sediment control *(IECA 2008) specify a discharge criteria of 50 mg/L Total Suspended Solids (TSS). Given the need for a real-time measurement of suspended sediment for site management the adopted figure of 75 NTU has been used. A number of correlations have been attempted between TSS and NTU across the site and in the receiving environment with no clear correlation evident. Therefore, for site management the adopted figure of 75NTU will continue to be used as best practice guideline.*


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